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SIXTH

AEC AIR CLEANING CONFERENCE

July 7–9, 1959

United States Atomic Energy Commission
Office of Technical Information

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July 7–9, 1959

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U. S. ATOMIC ENERGY COMMISSION

Division of Reactor Development
Washington, D. C.
and
Harvard Air Cleaning Laboratory
and
Health and Safety Division
Idaho Operations Office

PREFACE

This Sixth Air Cleaning Conference report was compiled from technical papers, notes and tape recordings taken during this continuing series of meetings in connection with the Atomic Energy Commission air cleaning activities. The seminar furnished the Committee and its contractors an opportunity to hold technical discussions and evaluate air cleaning operations and appraise new developments in this field.

During the three-day Conference, the practical field experiences in the decontamination of gaseous effluents from reactor operations, fuel fabrication facilities and other Atomic Energy Commission laboratories and contractor operations, were reviewed.

The Environmental and Sanitary Engineering Branch of the Division of Reactor Development, U. S. Atomic Energy Commission, sponsored this Conference in cooperation with the Harvard Air Cleaning Laboratory and the Health and Safety Division, Idaho Operations Office of the Atomic Energy Commission.

In conjunction with the Conference there was also a meeting of the AEC Stack Gas Problem Working Group. Members of the group attended and participated in conference sessions. The group advises the Commission and its contractors in the treatment and control of gaseous effluents and in this capacity assisted in guiding the technical discussions and other activities of the meeting.

CONTENTS*

Tuesday Morning, July 7—Joseph A. Lieberman, Chairman

Tuesday Afternoon, July 7—Leslie Silverman, Chairman

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*Technical papers were published as received in Headquarters, AEC, Washington, D. C., and no further review for technical accuracy was made. Therefore, any errors noted should be reported directly to the authors.

Tuesday Evening, July 7—M. D. Thaxter, Chairman

Wednesday Morning, July 8—Abel Wolman, Chairman

Wednesday Afternoon, July 8—J. R. Horan, Chairman

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*This paper is not included in this compilation because it has already been published as BNL-542(T-140). However, the discussion which followed the presentation of the paper is included.

Wednesday Evening, July 8 — Leslie Silverman, Chairman

RADIOACTIVE PARTICULATE FALLOUT PROBLEMS AT THE ICPP

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ABSTRACT

The Site Survey Branch of the Health and Safety Division routinely conducts a monitoring program for determining levels of airborne radioactivity at the National Reactor Testing Station and its environs. Among methods utilized for the detection of particulates are horizontal collection plates of gummed-paper which are located outside plant areas. During the summer of 1958 routine autoradiographic analysis of these samples indicated a particulate problem connected with the Idaho Chemical Processing Plant. The follow-up program is discussed, including particle distribution, size, isotopic content, and health hazard calculations. A special attachment to the microscope to facilitate location and identification of radioactive particles is also discussed.

* * * * *

The use of gummed-paper collectors for monitoring fallout from nuclear operations was started in 1951 by the Atomic Energy Commission (Eisenbud and Harley, 1953, 1955, 1956 and Holland, 1959). The extreme simplicity of placing, collecting, and of measuring the gummed paper for radioactivity was a strong inducement to employ this technique at a number of locations at the National Reactor Testing Station (NRTS) and its environs. As a result, the Site Survey Branch of the Health and Safety Division adopted this method as a routine means of monitoring radioactive particulate fallout. Stations have been located outside several of the plant areas in the prevailing down-wind direction (southwesterly during the day and northeasterly at night).

At each station a horizontal plate has been attached to the top of a steel fence post approximately four feet above the ground. The gummed-paper is mounted on a thin aluminum frame and the frame attached to the plate with binder type clips. The effective surface area of the gummed-paper presently in use is 12 square inches. The samples are collected bi-weekly from all stations. Each sample is scanned with a G. M. instrument to determine if a detectable amount of activity has been collected, following which the samples are covered with a thin polyester film and exposed to X-ray film for seven days and then developed in the normal manner. The presence of particulate radioactivity on the sample is indicated by dark images on the film. In a study undertaken to determine the efficiency of this monitoring procedure, Rosinski (1957) found that it does not provide a precise or quantitative means of determining radioactivity. However, when carried out routinely, it serves as an economical means for detecting changes in the rate of fallout.

As a result of this monitoring program an increase in the amount of radioactivite particulate fallout was noted at stations surrounding the Idaho Chemical Processing Station (ICPP) during the summer of 1958. (The location of stations relevant to the MTR-ETR and ICPP are shown in Figure 1.) The increase started about the last week in July and reached a peak during the first week in September. At station "E" which is located approximately 100 feet east of the 250 foot stack, only three small particles were detected during the months of May and June. For the period of July 25th through September 5th an average of one particle per day was detected at this station. If it is assumed that the size of the image on the X-ray film is proportional to the amount of activity the particle contains, then there was an indication that the amount of activity per particle had also increased. However, this was not borne out statistically and particle size could be the controlling factor.

A check of gummed-paper samples from other areas on the NRTS did not reveal any increase in particle deposition. Therefore, it was assumed that the most logical place to check was the ICPP. As a follow-up of the gummed-paper program, a field survey of the area was conducted. Four plots, each approximately three-feet square, chosen at random within a 50-foot radius of the gummed-paper stations were surveyed with a G.M. instrument and a record maintained of the number of particles detected. (Figure 2 shows the results of this survey.)

Because of the size of the particles the position of maximum deposition is believed to have been predominately controlled by the terminal settling velocity of the particle and not from vertical atmospheric turbulence. The terminal settling velocity of a 300 micron size particle with a specific gravity of 1.0 settling in air at 70°F is approximately 3 feet per second. Then, neglecting the effect of vertical turbulence, this particle falling from a height of 250 feet in a 10 mph wind would likely be deposited approximately 1,200 feet downwind from its release point. This agrees with the distance of maximum deposition found from the survey. During the field survey, samples of soil containing particles were collected for laboratory analysis. At the laboratory the soil samples were divided and sub-divided and a thin end-window probe used to locate the radioactive particle. To finally isolate the radioactive particle from the nonradioactive particles considerable time was required until the microscope was fitted with a special attachment. This attachment was modeled after one discussed by Mr. F. E. Adley in the April 1958 issue of the Industrial Hygiene Journal. Primarily it consists of a "collimating attachment," mounting plate, and a thin end-window probe which have replaced the microscope sub-stage condenser. (Figure 3 shows the special attachment.) Two "collimating attachments" were made; one with a hole .125 inch in diameter and the other with a hole .024 inch in diameter. The probe, which is usually flush with the bottom of the "collimating attachment", is connected through an amplifier to provide an audible signal. The speciman slide is moved over the hole until the signal indicated that the radioactive particle is over the hole. Usually the attachment with the .125 inch diameter hole is used. Once the radio-

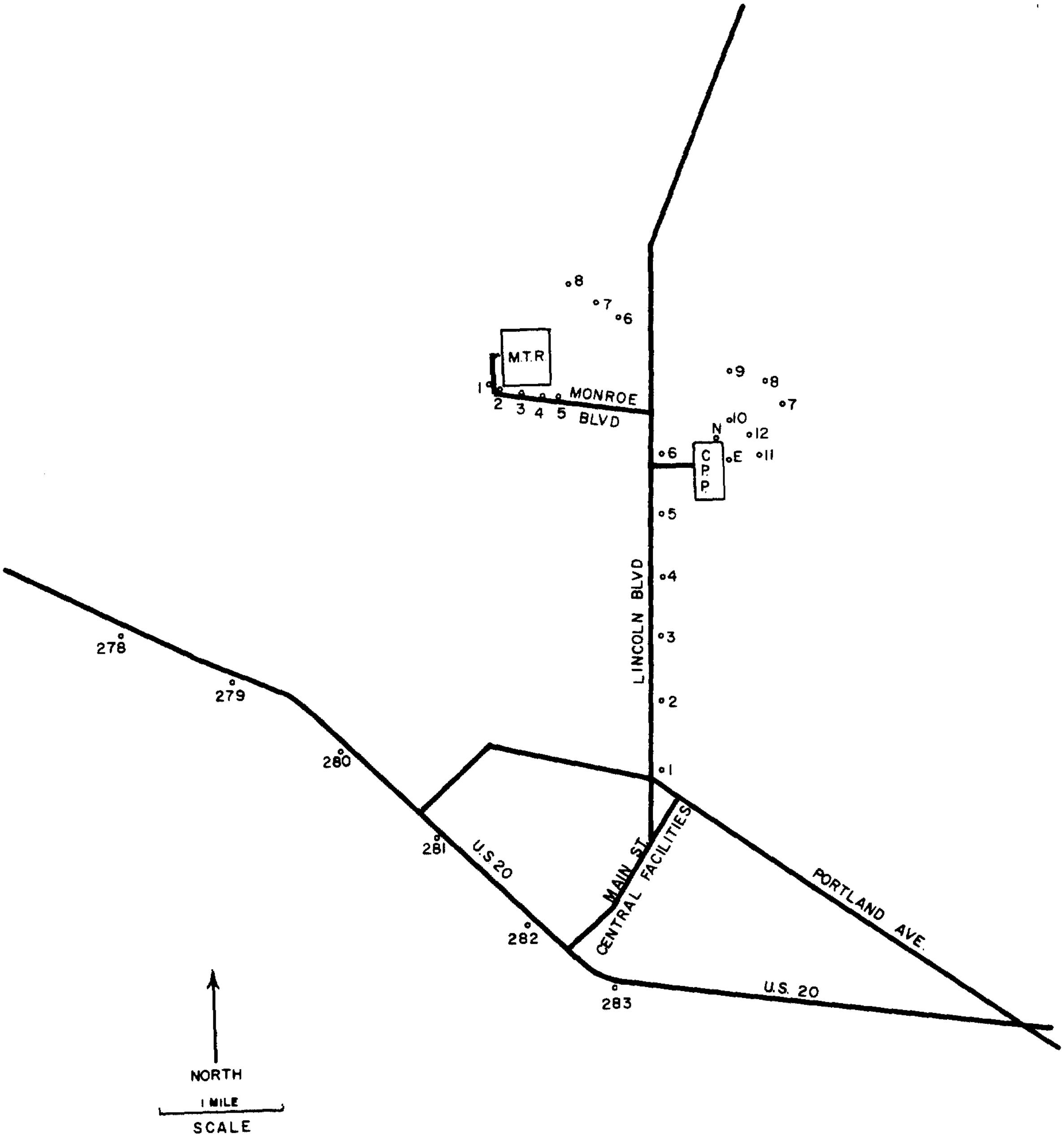

Fig. 1 — Fallout stations around MTR, ETR, and ICPP.

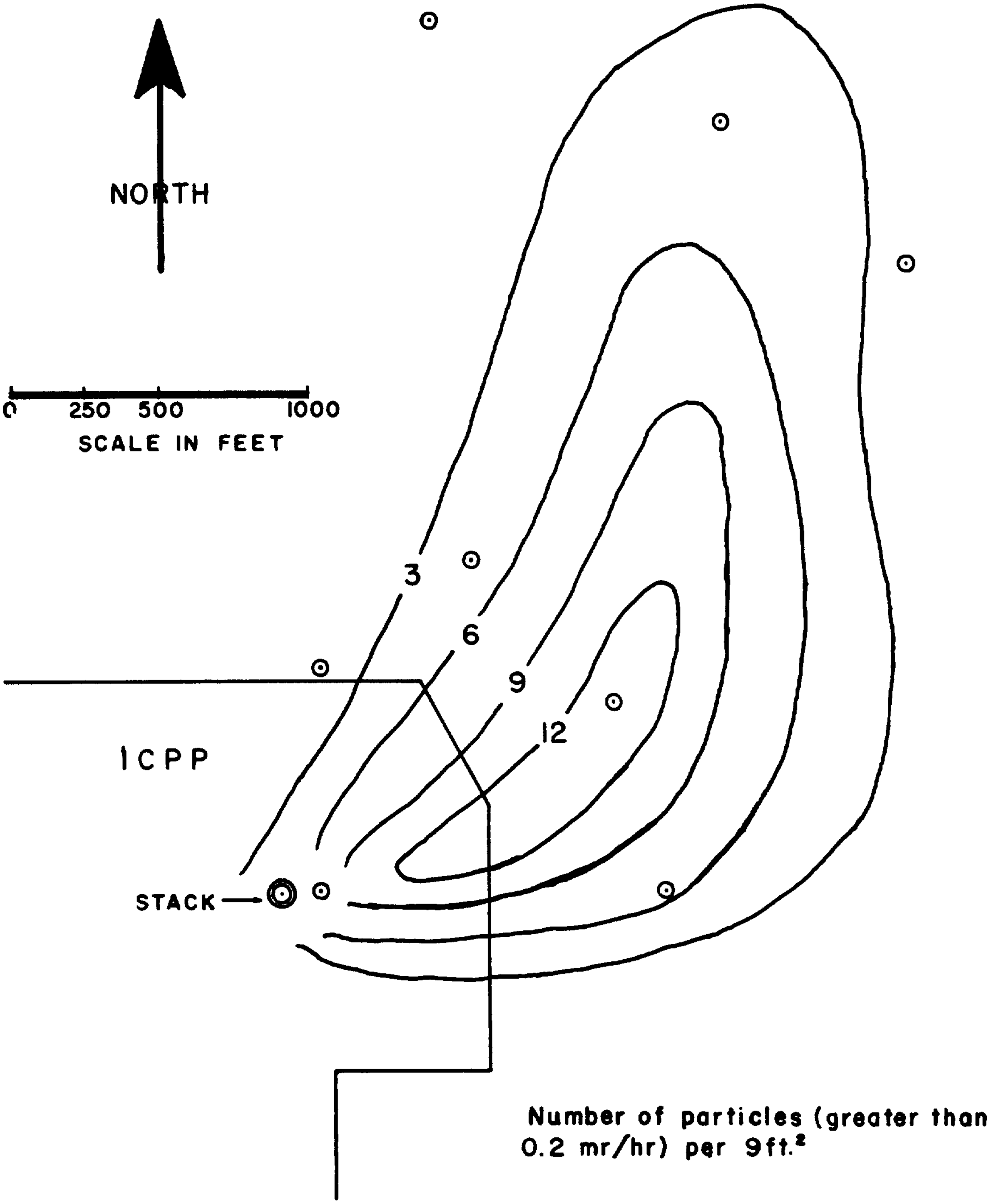

Fig. 2—Concentration of particles on the ground downwind of the ICPP stack.

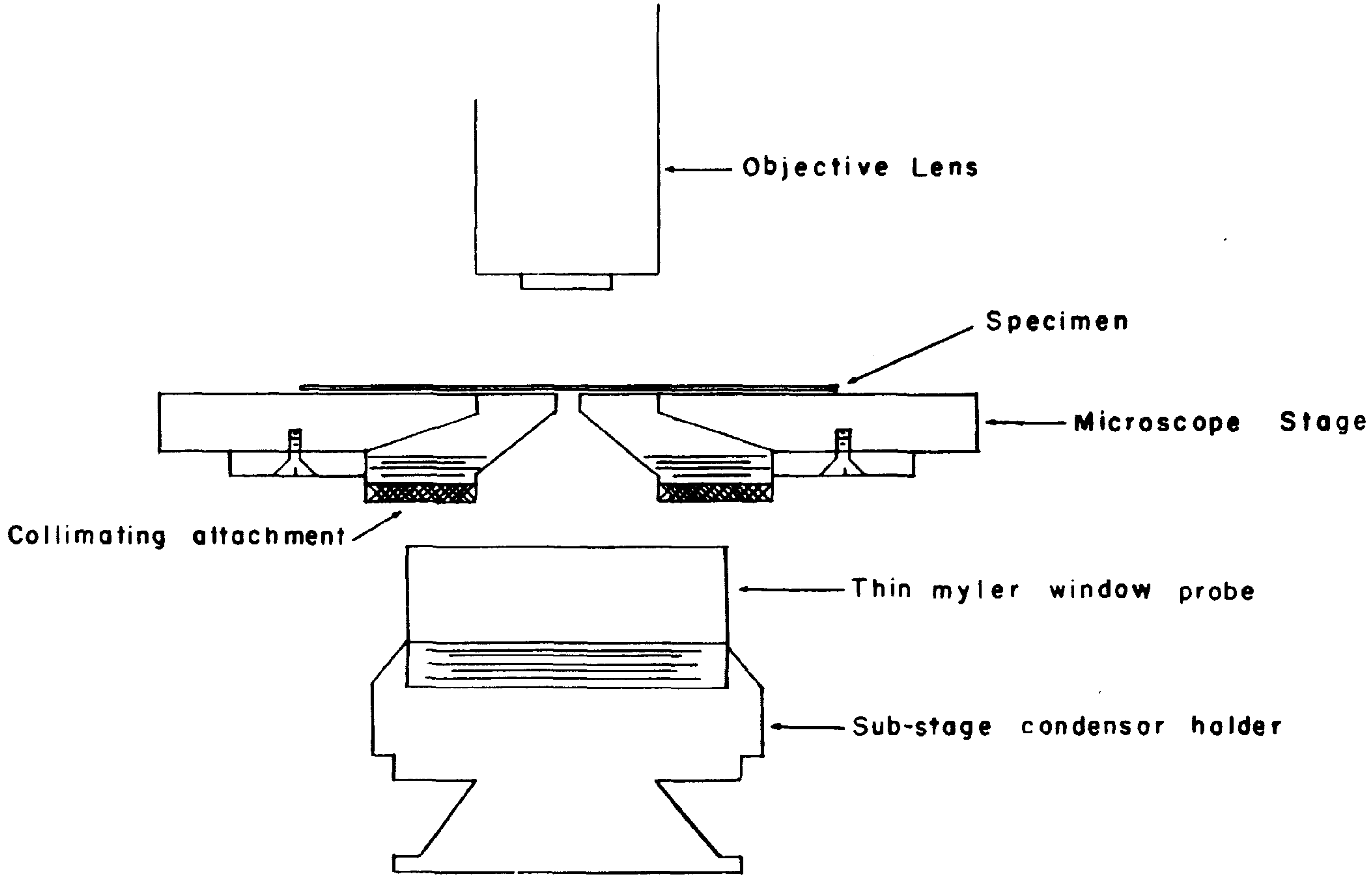

Fig. 3—Special microscope attachment used to facilitate isolation of radioactive particles.

active particle is located the attachment with the smaller holes is used to finally locate the particle. By successively moving the speciman slide in several directions it is possible to locate the radioactive particle. With this attachment considerable time is saved in isolating particles. After isolation the size of the particles is determined. The particle sized varied over a wide range, from 70 to 350 microns. However, this does not exclude the existance of smaller particles. The activity eminating from the smaller particles is not detectable with the G.M. survey instruments. Tiny images on the X-ray film definately indicate that small particles were involved, but the small amounts of activity present did not permit any evaluation of these particles.

Calculations of absorbed dose for two critical organs were made from gamma ray spectrographic analysis of particles collected downwind from the 250' stack at the Chemical Processing Plant. These were the "hottest" particles noted on fallout plates in the area. It was found that the particle indicating the most cerium-144 contained 0.1 microcurie of this isotope. The particle containing the highest amount of zirconium-95, niobium-95 contained 0.01 microcurie of these isotopes.

For dose calculations the zirconium-95, niobium-95 activity was assumed to be all niobium-95, since this isotope presents a greater biological hazard than does zirconium-95. Evaluations were made to determine what dose to the bone could be expected if such a particle were inhaled and were completely solublized even though the latter is remote. For calculations of dose from soluble constituents, 100% solubility was assumed. In addition to the above, the following assumptions were made:

1. For the case where the bone is the critical organ, the isotope is eliminated from the body exponentially.
2. All NBS Handbook 52 values apply.

Table I presents the maximum dose in millirads from a singe particle calculated as Cerium-144 and Niobium-95, with both the bone and the G.I. tract as being the critical organs.

TABLE I

DOSE DUE TO INHALATION

Isotope	Critical Organ	Soluble	Insoluble
Cerium-144	Bone	25. mrad	--
Niobium-95	Bone	0.05 mrad	--

DOSE DUE TO INGESTION

Isotope	Critical Organ	Soluble	Insoluble
Cerium-144	Bone	0.05 mrad	--
Cerium-144	G.I. Tract	17. "	17. mrad
Niobium-95	Bone	0.05 "	--
Niobium-95	G.I. Tract	0.02 "	0.02 mrad

It must be emphasized that the values given in the above table represent the maximum doses and may make the problem appear greater than it is in actuality. All assumptions were necessarily made to maximize any hazard. The fallout is not considered to be an inhalation hazard since all of the particles isolated have been far above the respirable range of 0.1

to 5 microns. The hazard due to the smaller particles was not considered since these particles contained only a small fraction of the total radioactivity.

Since construction workers were often within the fallout area, it was necessary to consider the probability of transferring a particle from the ground to the face area where inhalation or ingestion might take place. Schwendiman (1956) has estimated that in an area where surveys show one particle per square foot, a man may walk on the average of 2,000 hours before a particle will be deposited in the face area. In Schwendiman's study the mean particle diameter was 2 microns and the probability of inhaling larger particles should be even smaller. Therefore, no restrictions were placed on the area surrounding the ICPP and no restrictions were imposed upon construction workers in the area. Surveilance of the area continued while ICPP Operations sought a solution by locating and correcting the leak.

In conclusion, it should be pointed out that the use of a network of gummed-paper stations does provide an economical means of monitoring for fallout in the vicinity of a plant utilizing radioactive material. Once fallout is detected the assistance of plant operations is needed to pinpoint the source of the activity. Throughout the entire time that this problem existed, liason was maintained with ICPP Operations. The results of their findings are reported in paper by Cederberg and Bower (1959).

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Cederberg, G., and J. Bower, Minimizing Gaseous and Particulate Activity and Particulate Activity in Idaho Chemical Processing Plant Off-gas, (To be published.)

Discussion *

Q. Any α activity measured in this matter?

A. None

Q. It wasn't measured or wasn't found?

A. (?)

Q. Could you not get a small particulate added by turbulance bringing it down to 1200 feet?

A. Yes, etc.

Q. Did you actually measure the size of the particulate?

A. Were measured.

Q. Haven't you found that it did not -- however, when carried out routinely it does serve as a means of detecting - in cleaning the amount of radioactive particulates was noted in the - while in some instances it might have indicated the dose quite high, - minimize any hazard.

A. No restrictions were placed on the area surrounding the CPP. The monitor program continued through the problem and we maintained consistent contact with the CPP operations group to assist them in determining the source of the problem - the results of their findings will be reported in the next paper by Mr. Cederberg and Mr. Bower.

*** NOTE:**
All the questions, answers and comments were recorded on tapes. Later, when the tapes were transcribed it was noted that some of the material was incomplete and in several cases it may have been improperly interpreted. Due to the time involved, no attempt has been made to change this material.

MINIMIZING GASEOUS AND PARTICULATE ACTIVITY IN IDAHO CHEMICAL PROCESSING PLANT OFF-GAS

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ABSTRACT

Bench-scale tests on iodine removal from RaLa process off-gas, reported at the last Air Cleaning Conference, were continued and evaluation tests of the Plant charcoal beds have been completed. About 97 percent iodine-removal efficiency was demonstrated. Iodine-containing particles possibly formed by the gas-liquid contactor preceding the charcoal beds, limit the efficiency of the bed in removing iodine.

Radioactive particles are formed in the Fuel Element Cutting Facility by cutting, carrying, and charging techniques. Cyclones and filters are used for collection.

Studies of particles originating in the vessel off-gas system and the waste solvent incinerator are directed towards minimizing their frequency and activity level.

* * * * *

This discussion of Idaho Chemical Processing Plant off-gas cleaning problems involves the removal of iodine from off-gas formed by the RaLa process and the diminution of particulate activity from other ICPP equipment off-gas.

Iodine Removal

The RaLa process produces barium-140 from a 2-day cooled MTR element by digesting the aluminum in the element in sodium hydroxide and by chemically separating the barium from the uranium-gross fission product residue. Because of the two days cooling, compared to 120 days cooling normally given to other fuel elements, this process contributes large quantities of fission product iodine to the process off-gas. The majority of the iodine dissolves in the caustic-aluminate and gaseous iodine is removed in a packed scrubber.

The objective of the iodine studies was to lower the iodine concentration in the off-gas by preventing it from volatilizing from solutions and by more effectively scrubbing it from the off-gas. The RaLa caustic scrubber, containing $\underline{1M}$ NaOH and $0.1\underline{M}$ $Na_2S_2O_3$ as the scrub solution, gave a decontamination factor of 100 to 500 on the gaseous iodine but this was not consistent and not completely adequate. Numerous tests scoped and evaluated a variety of materials for removing more of the gaseous iodine which passed through the RaLa scrubber. Some of these tests were reported at the last air cleaning conference.(1) Activated charcoal was concluded to be the most efficient and practical of the materials tested because of its high efficiency at room temperature and ease of handling. Development tests showed a 1-inch diameter by 12-inch long bed of 8 to 14 mesh activated charcoal gave a decontamination factor of 33 at a superficial flow velocity of about 0.2 feet per second.

Based on the development work, two 7-cubic foot beds of activated charcoal, containing extruded pellets of 2.8 mm diameter, were installed to treat from 15 to 20 cfm of RaLa off-gas. The RaLa equipment is illustrated by Figure 1. Normally this off-gas is treated separately from other plant off-gas streams although it can be valved to go directly to the plant vessel off-gas system. The charcoal beds can be operated individually or in parallel with the exit gas from the charcoal bed passing through a sintered stainless steel filter to prevent charcoal fines from passing to the stack.

Evaluation tests of the plant charcoal beds showed they give decontamination factors between 10 and 30. This was determined by the use of small filter-adsorber cartridges constructed of a filter medium and activated charcoal in a polyethylene tube. Identical cartridges were used to sample equal flows of the inlet and outlet gas of the charcoal bed.

Although the literature(2) cites activated charcoal as giving a decontamination factor of 1000 or better for elemental iodine, I_2, the lower efficiency observed in the tests is attributed to small particles entrained from the scrubber. Apparently small droplets containing $NaOH$-Na_2CO_3-$Na_2S_2O_3$-NaI are formed at the surface of the scrubber and entrained, dried, and carried through the charcoal bed. Disassembly of the outlet sample cartridge showed that the filter contained a considerable proportion of the total activity on the cartridge with no indication that the retained particles were radioactive carbon fines.

Comparison of the parts in the inlet and outlet cartridge after one test showed that the filter medium preceding the charcoal cartridge was 8.5 times more radioactive than the filter in the outlet cartridge. The charcoal in the inlet sample cartridge was 2800 times more radioactive than the charcoal in the outlet sample cartridge. Cartridges used in other tests showed smaller ratios of the total activity on the inlet and outlet cartridges, but the activity on the filters of the cartridge was still indicative of particles.

Victoreen radiation monitor heads on the sides of the beds indicated that the inlet surface of the bed was from 500 to 5000 times more radioactive than the outlet of the bed. Decay rates of the activity on the inlet surface indicated it was predominantly iodine-132.

The peak radiation at the inlet surface of the bed varied from 60 Roentgens per hour to greater than 1000 Roentgens per hour.

At the last conference no applicable chemical additive had been found which was compatible with the caustic-aluminate waste solution,

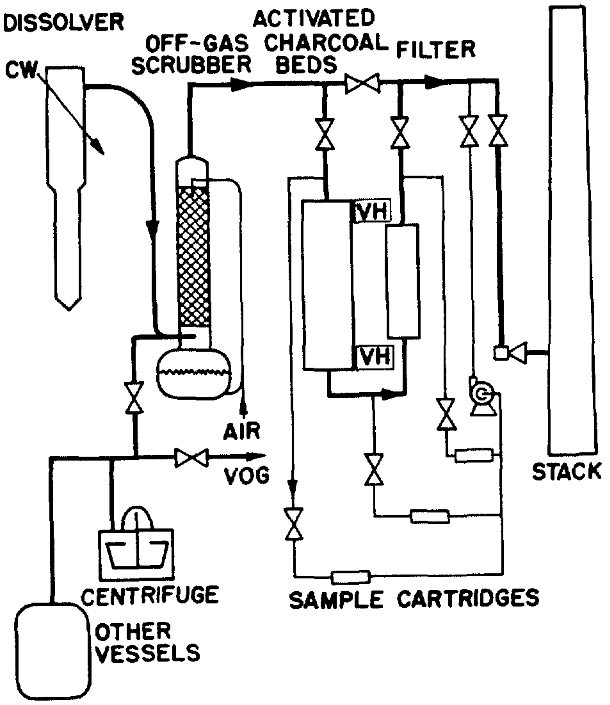

Fig. 1—RaLa iodine removal system.

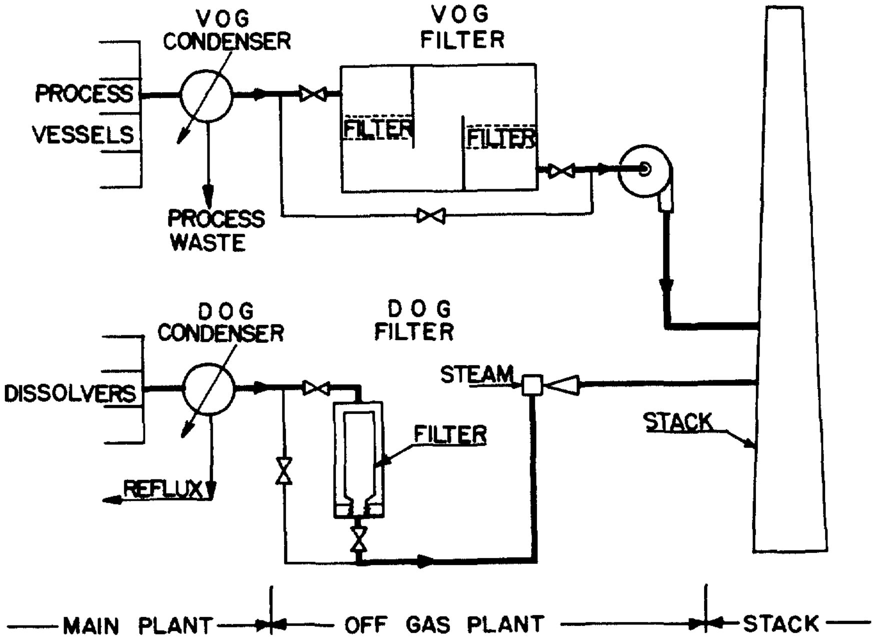

Fig. 2—Plant off-gas systems.

containing about 90 percent of the iodine, and which could more effectively hold the iodine in solution during acidification. Mercuric nitrate in the caustic would be precipitated and the use of mercuric nitrate in the uranium-fission product mixture prior to the barium separation was ruled out because of potential product contamination. However, mercuric nitrate has recently been added to the 60 percent nitric acid used to neutralize and acidify the waste caustic-aluminate solution and to the water used to dilute the uranyl nitrate-fission product nitrate solution remaining after the barium separation. In these solutions from 0.001M to 0.005M mercuric nitrate has effectively limited the volatilization of iodine during later transfers and samplings.

In another recent process change, suggested by work done at HAPO,(3) five percent nitric acid containing 0.001M mercuric nitrate and 0.001M mercurous nitrate has replaced the 1M NaOH-0.1M $Na_2S_2O_3$ previously used as the RaLa off-gas scrubber solution. Although the $NaOH-Na_2S_2O_3$ effectively scrubbed the iodine (I_2) from the off-gas, it contributed entrained solids, predominantly NaOH and Na_2CO_3, into the outlet pipe. This plugged the rotameter and partially plugged the scrubber column. Subsequent runs showed that the $HNO_3-Hg(NO_3)_2-HgNO_3$ scrub solution eliminated the plugging and provided adequate scrubbing.

After mercuric and mercurous ions were added to the waste solutions and to the acid scrub solution, the peak activity at the inlet surface of the carbon bed during several runs was between 10 and 20 Roentgens per hour compared to the 60 to 1000 Roentgens per hour observed previously. This demonstrated that a smaller amount of iodine was volatilized from the process solutions.

Results from the stack gas monitor have confirmed the effectiveness of mercuric and mercurous ion in suppressing iodine release. When the waste streams are transferred from the RaLa cell to other cells the RaLa scrubber can no longer be used and any iodine released into the off-gas passes directly to the stack. Since the addition of mercury to the waste streams, the amount of iodine released from the stack to the atmosphere has been significantly reduced.

Particles in Regular Plant Off-Gas

The problem of radioactive particles in other ICPP equipment off-gas came into focus when hot particles were observed on gummed-paper fall-out plates stationed around the ICPP. The Site Survey Branch of the IDO Health and Safety Division routinely monitors the NRTS area with gummed-paper fall-out plates. Beginning about July, 1958, plates from the stations on the northeast perimeter of the CPP collected an unusually large number of particles.

Part of our investigation involved taking samples from all of the possible sources. The samples were used to determine if the material taken from any potential source was similar in physical and radiochemical properties to the particles on the fall-out plates. The data from these samples provided a basis for remedial action to minimize the dispersion of particles into the effluent off-gas from the CPP process buildings.

Some of the observed particles were about 70 microns (barely visible) although many were much smaller. The activity varied from 16 milliroentgens per hour to barely detectable. Some particles which had a very low activity and which were not detectable with an open window beta counter were detected by the small dark spot they made on X-ray film during autoradiographing. The fall-out plates were autoradiographed by a week-long exposure to an X-ray film.

In all possible cases the particles were examined, either with or without magnification, to determine the color and physical characteristics of the material. Gamma pulse height analyses of particles and samples by CPP and AEC analysts helped identify some of the particles as having come from specific sources. Some of the particles were yellowish-colored crystals showing a high percentage of cerium-144 in the gamma spectrum as well as other long-lived fission products. This indicated this was very old material which had probably been formed with essentially no selectivity.

Solid material found around the discharge of the vessel off-gas (VOG) system blower was very similar in color and gamma spectrum to the observed particles. It was concluded that the vessel off-gas and the dissolver off-gas (DOG) system could be emitting particles as a result of corrosion in the filters. These systems are shown schematically in Figure 2.

Although no substantial increase in the number of particles had been detected by Site Survey before July, 1958, a study of the DOG and VOG systems showed no positive reason that particles were not emitted prior to this. The high levels of radiation near the VOG and DOG systems leaves little doubt that these systems have accumulated radioactive contamination from entrained liquids and solids from plant vessels since the plant began operation in 1953. Although both systems have filters to remove this material, observation of the outside of the VOG filter showed it to be corroding.

According to the VOG filter drawing details the filter medium is Fiberglas but the containment box is carbon steel. The carbon steel box has been repaired in times past by welding metal patches over some of the corroded holes and by putting patches of masking tape over other holes. Even though the corroded condition could allow particles to pass unfiltered to the stack, the important aspect is that corrosion products, which have collected in the plenum chamber on the outlet side of the filter medium, could be stirred by air turbulence and carried into the off-gas.

The vessel off-gas has traces of oxides of nitrogen and small concentrations of water vapor. Although the off-gas condenser cools the gas to between 15 and 25°C, small changes of temperature in the VOG system could allow water to condense and dissolve some of the corrosion products. Migration of the solution with the off-gas and later increases in temperature could redeposit the solids at a different location in the system. The solid crust forming on the outside of the outlet flange of the VOG blower, possibly the crystallization of the corrosion products, indicates there are liquids and solids in the VOG system between the filter and the stack. The gamma ray spectrum, showing a predominance of cerium-144, and the yellow color of a sample of the crust were similar to the spectrum and color of some of the particles found on the fall-out plates and on the ground around the CPP area. This proves that the VOG system can be a source of particles.

The gas flow through the VOG filter has been continuous, but sometime in the history of the VOG system the VOG filter bypass was opened. About July of 1958, several attempts were made to decrease the absolute pressure in the VOG headers in the main process building for the purpose of eliminating intermittent pressurizations which occurred in dissolving cell. These changes were made by adjustment of the air bleed rate in the VOG blower room and adjustments of the filter bypass valve. The adjustments could have stirred up some of the particles of corrosion products in the filter and some of the fission product-corrosion product particles lying dormant in the bypass line.

The DOG filter vessel is fabricated of stainless steel but the filter insert is a carbon steel shell containing the filter medium. Since the dissolver off-gas normally contains some nitrogen dioxide and waste vapor, it is almost certain that the filter cartridge is highly corroded. Samples of debris from the DOG system were unavailable because of its all-welded construction.

Coincident with the appearance of particles the ICPP was being operated at a high rate. Off-gas rates varied considerably and very likely could have stirred up solids existing in the lines and related equipment.

In order to minimize the dispersion of particles, the VOG filter was completely bypassed and it was recommended that a drum should be installed to provide de-entrainment of liquid droplets and particles. It was also recommended that the DOG filter element should be replaced with a new all-stainless steel element as soon as operating conditions would permit. These recommendations have not yet been carried out.

During the recent operating interval from November, 1958, to May, 1959, the frequency of occurrence of radioactive particles was much lower than during the July to September interval in 1958. Although the plant was at times operating at a somewhat reduced rate, this should have been a minor factor in the number of VOG particles which were released. Apparently, the action taken to bypass the VOG filter helped reduce the number of dispersable particles.

Solvent Burner Particles

The possibilities of particles being formed by the waste solvent burner were also considered in connection with the above problem. Waste Amsco, a kerosene-type hydrocarbon, and waste Amsco containing tributyl phosphate (TBP) are accumulated from the first cycle extraction columns and burned at the stack in a specially designed burner, illustrated in Figure 3. Although the operation of the solvent burner and the appearance of the particles suggested a relationship of the burner to the particles, the dissimilarity of the gamma spectrum of the larger particles found on the field and of the sample particles taken from the burner duct indicates that the solvent burner is not the major contributor. A lack of correlation between the appearance of particles on the Site Survey plates from week to week and the intervals of operation of the burner also indicates the burner is not the major contributor.

Since Amsco containing traces of TBP absorbs zirconium better than it absorbs ruthenium and other fission product, zirconium and niobium and only traces of other fission products will appear in the burner effluents. Some of the activity eventually deposits on the walls of the fire box and exit ducts with the soot. Apparently, during normal operation this residue of soot and fission products is continuously eroded from the surfaces and carried into the effluent gases. The majority of the gas, carrying these eroded particles is mixed with all the plant ventilation air and is discharged from the 250-foot stack to the atmosphere. It is possible that these particles were too small to be detected individually and only caused a pin-point of exposure on the radioautograph. However, some of the burner effluent gas puffs out the bottom openings of the duct venturi and, possibly, some larger particles are scattered in the immediate vicinity of the burner building and the base of the stack. Larger particles, appearing black and, sometimes glassy and having a high zirconium-95 concentration, have been found in the vicinity of the stack although they were not observed on the fall-out plates. These particles resembled the sample taken from the burner duct.

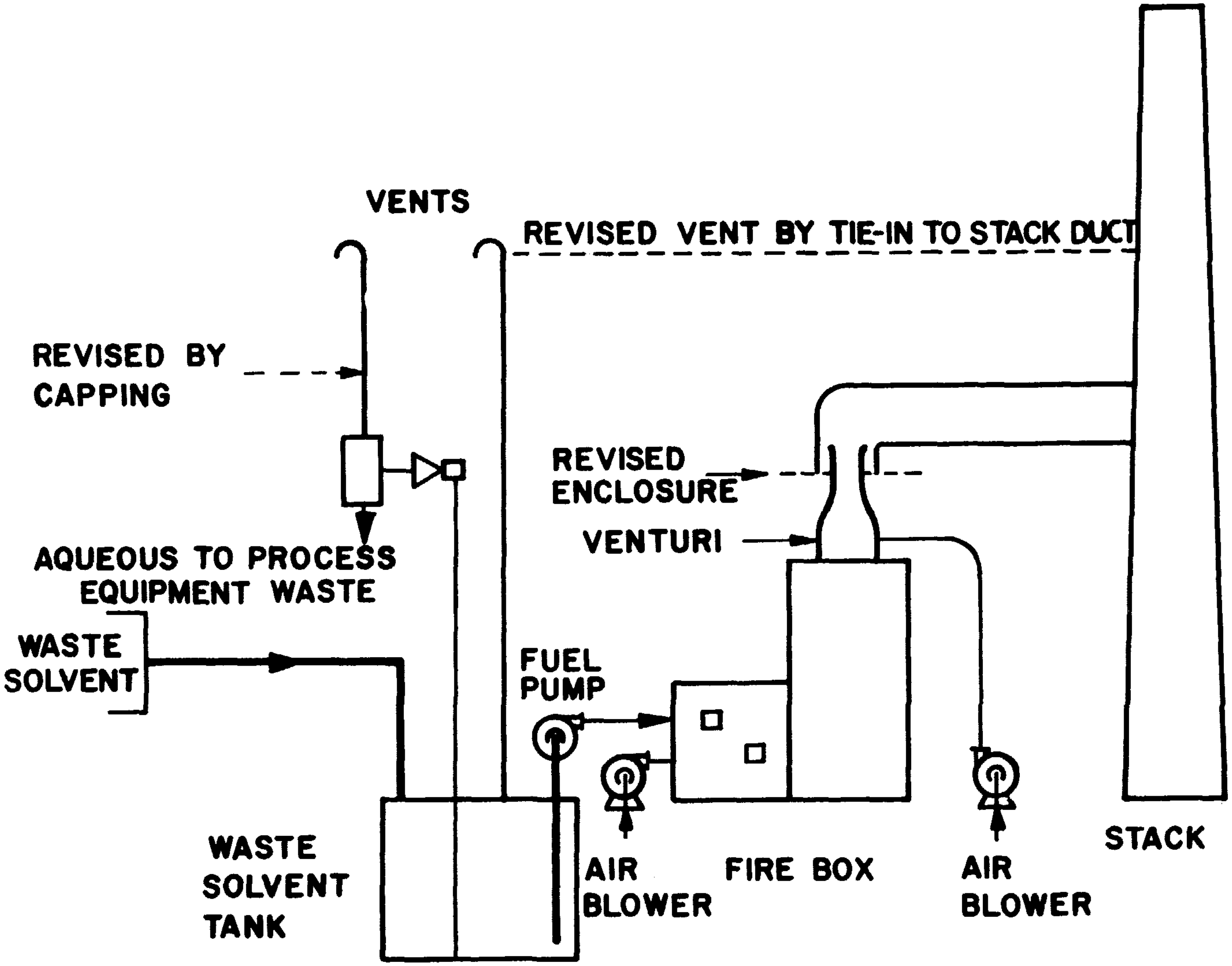

Fig. 3—Waste solvent burner system.

Although the organic waste generally has a low activity level, it is possible for small volumes of aqueous-organic mixtures to be sent to the waste solvent collection tanks. Recently, in an attempt to minimize the activity, the solvent has been washed with an aqueous sodium carbonate solution which is decanted to the aqueous waste facilities. Prior to the introduction of the washing procedure some highly radioactive column interface crud, probably an aqueous-organic emulsion, was sent to the burners. This caused the radiation levels of the burners and ducts to increase from 0.1 Roentgen per hour to 1.5 Roentgen per hour with maximum radiation levels up to 4 Roentgen per hour.

The decanting jet on the solvent collection tank was also a source of particles. After decanting the aqueous layer from the tank, the Amsco in the organic-aqueous interface vaporized in the jet. This vapor rose in the vent to the roof of the solvent burner building and came out of the vent as a mist. Some of this mist coalesced on the top of the building and some settled randomly down-wind from the burner building. This was remedied by repiping the decanter equipment directly to the process equipment waste system and piping the vessel vent to the plant vent duct. The interim remedy was to control the jetting and, if possible, stop the jetting before the organic-aqueous interface reached the jet intake.

Radioactive carbon particles which have escaped from the openings in the burner equipment have been detected on the flat surfaces around the burner facility. These have been minimized by sealing the opening of the exit duct venturi. The exit duct venturi was designed to admit ambient air to help cool the burner exhaust gases. The burner has been operated continuously at lower rates to prevent gas from puffing out of the burner during stop and starts. This lower rate has helped keep the exit duct from over heating although some other cool dilution air is provided by a compressor.

The flat equipment surfaces and the ground around the burner building have been cleaned to prevent the wind from carrying previously deposited loose particles from the solvent burner area.

Other Particle Sources

Other particles are formed in the Fuel Element Cutting Facility (FECF) during the cutting of aluminum-uranium fuels, but these particles were not similar to the other hot particles seen on the plates. Some of these particles, though adhering to the cut pieces, sift from the transfer cask but are collected in a pan under the cask. Other particles in the FECF are air-borne and are collected in cyclones and AEC-type air filters built into the FECF. One of these air filters ruptured during a cell decontamination procedure and caused some contamination of the environs. Although some of the contamination was scattered by the winds, the majority of it was isolated into the drains by water flushing. Other areas which were contaminated by this activity were isolated as limited access areas.

Other possible sources were also investigated but were found to be insignificant.

Although the RaLa off-gas system contains some particles of activated charcoal as well as the previously mentioned residual from the scrubber, this system was not deemed to be a significant source of particles because short half-lived isotopes such as iodine-131 were not detected on the fall-out plates. The activated charcoal is closely confined by perforated support plates and filters.

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Discussion

Q. At this stage of the game the Rala system does not require meteorological control? Is this correct?

a. Still provide forecast but not under control it used to be. Primarily for site survey monitoring system. Forecast for site survey for Rala system.

Q. Is one to get the impression from that,that the site survey problems associated with it are less than they have been in the past?

A. Yes, I believe it is considerably reduced. It has now been reduced - we do routine monitoring, but not nearly as extensively as previously.

Q. (John Hall, United Kingdom) What sort of filter do you have in your rala - in the charcoal beds?

A. Stainless steel filter.

Q. (C. E. Lapple - Stanford Research Lab.) Do you have any data on how long they did last or how often you need to replace them?

A. No, we do not. We feel it will have a very long life - equipment - and material can be removed later in the life.

Q. (R. C. Walker, GE - HAPO) I would like to know two things - what is the velocity through the charcoal beds, is this in df in the two stages or in each stage?

A. They are not in series - they are either individual or parallel. Velocity through the bed 7 cu. ft. Bed can handle 7 cu. ft. of material off-gas.

A METHOD FOR THE COLLECTION AND IDENTIFICATION OF RADIOACTIVE XENON AND KRYPTON

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Abstract

The Health and Safety Division is responsible for radioactive monitoring of out-plant areas of the National Reactor Testing Station. In order to determine if a leak existed in the RALA off-gas system a sampler capable of collecting radioactive xenon and krypton was required so that identification could be made. A sampler consisting of a "U"-shaped copper tube filled with activated carbon and cooled in liquid nitrogen has proved very effective. Two sizes have been made using 3/4" and 1-1/2" tubing. The collection efficiency for xenon and krypton was essentially 100% at flow rates of 1 cfm even with the smaller sampler. Several such samplers were used at strategic locations and disclosed some leaks in the process system. Retention of xenon and krypton in activated carbon at room temperature is also discussed.

* * * * *

The Health and Safety Division is responsible for radioactive monitoring of out-plant areas of the National Reactor Testing Station. During a RALA operation for the recovery of barium-140 from short-cooled fuel elements (1), activity was detected in the field at a time when all off-gas was supposed to have gone to storage. The activity could be detected with portable survey instruments but could not be collected on either filter paper or activated carbon. Shortly before the activity was discovered, multi-curie quantities of radioactive xenon and krypton had been released into the off-gas line from the caustic dissolution of the aluminum cladding of the fuel element. Rare-gas fission products were suspected, apparently from a leak in the RALA off-gas system. Such a leak would be difficult to detect because of the high general radiation background in the plant. A sampler capable of collecting the inert gases was required so that the activity could be identified.

Since the melting points of xenon and krypton are -112° C. and -156.5° C., respectively, liquid nitrogen with a boiling point of

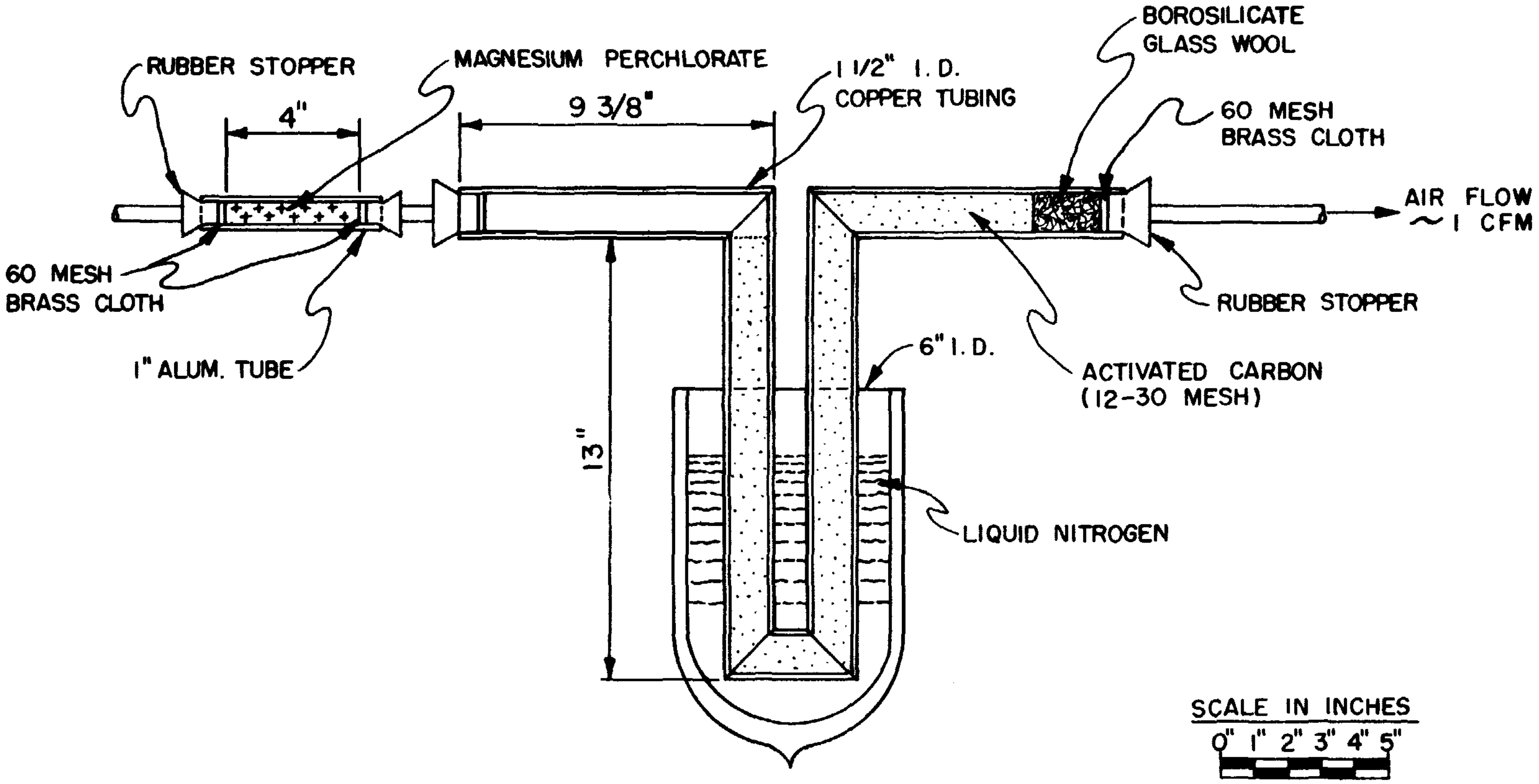

Fig. 1—Large sampler system.

-195.8° C. (2) should be adequate to freeze xenon and krypton out of the air stream efficiently. Browning and Bolta (3) determined the holdup time of krypton on charcoal down to -110° C. and reported that retention increases with decreasing temperature. Activated carbon was used to obtain a large surface for adsorption and to provide large heat capacity for cooling the gas stream.

The sampler is shown in Figure 1 and contained 450 grams of 12 to 30 mesh activated carbon when filled as shown. The borosilicate glass wool was used to prevent the carbon from packing against the brass screen. The air stream was passed through a column of 10 to 20 mesh anhydrous magnesium perchlorate to remove moisture to prevent the cold trap from freezing shut. The samplers were operated for periods up to one hour without the drier becoming saturated. The rate of flow of air was dependent upon the drier and not the carbon trap. A 3" piece of 1/2" copper tubing connected the drying unit to the sampler. The drier also served as a filter for any particulate matter that might be in the air.

The copper tube filled with carbon was set 9" deep in a 4300 ml. Dewar flask and clamped to the steel arms of the frame holding the flask. During operation the level of liquid nitrogen was maintained at 2" to 4" below the top of the flask. The rate of evaporation was a function of the depth of the liquid nitrogen in the Dewar flask. A sampler in operation lost one liter in about twenty minutes with a total loss of approximately 2600 ml. in one hour. The 1600 ml. left in the flask was about the minimum amount required for satisfactory operation.

Six sampling units were constructed and placed at strategic locations both in the field and inside the Idaho Chemical Processing Plant during a RALA operation. The average rate of flow of the air through the samplers was 1 cfm. Radioactive xenon and krypton were found in quantities up to 3 r/hr at contact in all but one of the samplers with the intake side containing essentially all of the activity. Two samplers were placed in series as shown in Figure 2 to determine the collection efficiency. The collection efficiency of

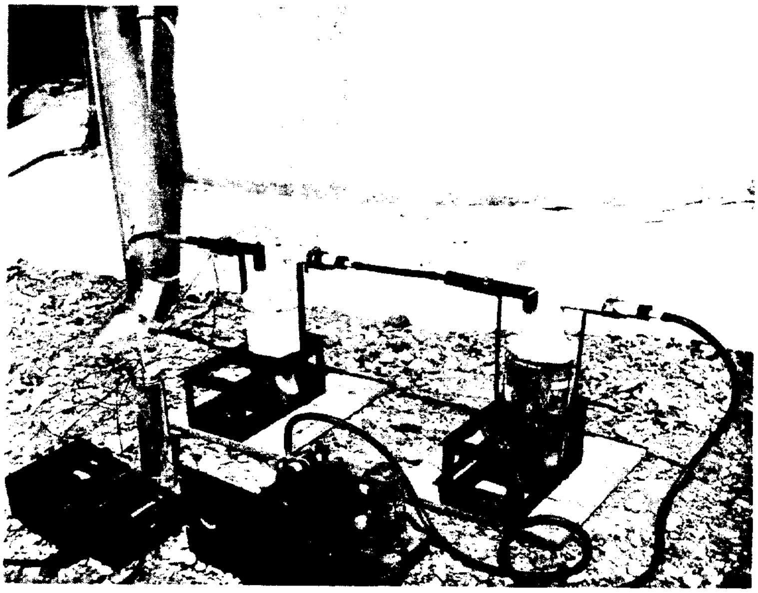

Fig. 2—Two large samplers in series.

the sampler was very nearly 100% and dropped as low as 99% in only one instance. Xenon-133 and krypton-85 were the only isotopes found in concentrations of any significance. Traces of xenon-135 and krypton-85m were detected. Identification was made by gamma ray spectroscopy using a multichannel analyzer with a 3" x 3" sodium iodide (thallium-activated) crystal as the detector.

Because the efficiency of the sampler was so high, it was apparent that its size was too large for the sampling flow rate used and that a smaller one could be used without impairment of the collection efficiency. The smaller sampler was made from a "U"-shaped piece of 3/4" I.D. copper tubing. The overall dimensions were 1-3/4" wide and 10-3/4" long. A total of 75 gms. of 12 to 30 mesh activated carbon was held in the sampler with 60 mesh brass screens and two #3 rubber stoppers. Connection to the suction line was provided by 1/2" copper tubing inserted into pre-cut holes in the rubber stoppers. A laboratory clamp on a ring stand held the sampler about 7" deep in a 665 ml. Dewar flask. The liquid nitrogen level was maintained at 1" to 3" below the top of the flask during operation.

To determine the distribution of the xenon and krypton through the small sampler, the carbon was divided into 5 equal sections. Each section was separated with a sixty-mesh brass screen. The small sampler was placed in the liquid nitrogen and connected between two large samplers at liquid nitrogen temperature. The air stream was drawn consecutively through the drying unit, the first large sampler containing radioactive xenon and krypton from RALA, the smaller sampler, the second large sampler with no activity, a flow rate meter, and the suction pump. The flow rate was adjusted to 0.5 cfm. A shielded sodium iodide crystal was directed at the inlet of the small sampler. The output from the detector was connected in parallel to the multichannel analyzer and a scaler. The scaler was set to run continuously throughout the experiment.

The first large sampler was removed from the liquid nitrogen and allowed to warm up to room temperature. A few minutes after the temperature of the air coming out of the first sampler reached zero degrees centigrade the scaler showed an increase in activity. A gamma spectrum showed that only radiokrypton was coming off. A few minutes later the radioxenon started coming over and continued for about 20 minutes. The small sampler was removed from the liquid nitrogen, and the sections were quickly and carefully poured out into 5 separate bottles. The bottles were then tightly capped to prevent the escape of xenon and krypton. Gamma spectra of the five sections were made. The first and second sections contained all of the radioxenon with no radiokrypton showing on the spectra. The second section had slightly more activity than the first section. The third and fourth sections contained only radiokrypton with the fourth section containing less than 0.1% of what was in the third section. The fifth section contained a trace of radiokrypton. A gamma spectrum of the second large sampler showed a trace of both radioxenon and radiokrypton. The concentration of radioactive xenon and krypton found in the fifth section and the second large sampler was insignificant. The collection efficiency of the small sampler was essentially 100% for both radioactive xenon and krypton.

One of the large samplers was modified for temperature studies. Copper-constantan thermocouples extending 5" through 00 stoppers were inserted into the activated carbon through two 1/2" holes drilled over the center of the vertical tubes of the sampler. The other ends of the thermocouples were kept in a water-ice equilibrium mixture. A potentiometer bridge was connected to the thermocouples to measure the emf. Figure 2 shows this modified sampler and the other equipment while a sample was being taken. The temperature of the air coming out of the first sampler was -150° C. when the first activity reached the sampler. Seven minutes later when sampling was stopped the temperature had dropped to -170° C. The flow rate was approximately 0.7 cfm. The first sampler measured about 500 mr/hr at contact. There was no activity in the second sampler in the series. The carbon in the outlet arm of the first sampler was carefully poured out and examined. No activity was found, indicating that when the samplers are cooled to about -160° C. radioactive xenon and krypton are collected completely.

To determine the length of time activated carbon retains xenon and krypton at room temperature a 30" piece of 25 mm pyrex glass tubing was filled with 12 to 30 mesh activated carbon. Two sixty mesh brass screens and two rubber stoppers were used to hold the carbon in place. The air stream was drawn consecutively through the drying unit, the modified sampler containing radioactive xenon and krypton from the previous run, a continuous carbon cartridge (4) in a shielded sodium iodide (thallium-activated) well crystal, the glass tube filled with carbon, a second continuous carbon cartridge in a second shielded well crystal, a flow rate meter, and the suction pump. The multichannel analyzer and a scaler were connected in parallel to the first well crystal. A scaler was connected to the second well crystal and both scalers were set to run continuously during the experiment. Any increase in activity could be readily observed. The pump was turned on while the sampler was still immersed in the liquid nitrogen. The flow rate was maintained at approximately 0.2 cfm.

Figure 3 shows the temperature vs. time curve with time zero being the time the sampler was removed from the liquid nitrogen. The temperature continued to drop for a few minutes because the sampler had not run long enough to completely cool the carbon around the thermocouples. Curve #1 is the temperature of the inlet side and curve #2 is the outlet side.

As shown by the line marked Kr in Figure 3, the radiokrypton was detected 30 minutes later in the first carbon cartridge. The carbon cartridge is a 5/8" x 2½" plastic vial filled with 3 gms. of 12 to 30 mesh activated carbon. At room temperature the holdup time of radioxenon and radiokrypton on the carbon cartridge is sufficient to allow detection of the activity but is short enough not to interfere with the experiment. At the end of 32 minutes a gamma spectrum of the radiokrypton was made and is shown in Figure 4. The radiokrypton was detected in the second carbon cartridge two minutes after the isotope appeared in the first carbon cartridge. In approximately 36 minutes the radiokrypton had disappeared and both counters returned to background, represented by the small circles in Figure 4. As shown in Figure 3 the radioxenon started coming off 52 minutes from time zero. Figure 4 shows the gamma spectrum of the radioxenon at the end of 55 minutes. The radioxenon reached the second carbon cartridge in about 14 minutes. At 18° C. the 30" glass tube filled with carbon retained the radiokrypton for 2 minutes and the radioxenon for 14 minutes. A survey of the distribution of the activity along the large sampler was made and a peak identified as radioxenon was found. The peak of the xenon activity moved 7" through the carbon in about 12 minutes. The increased holdup time on the carbon in the sampler over

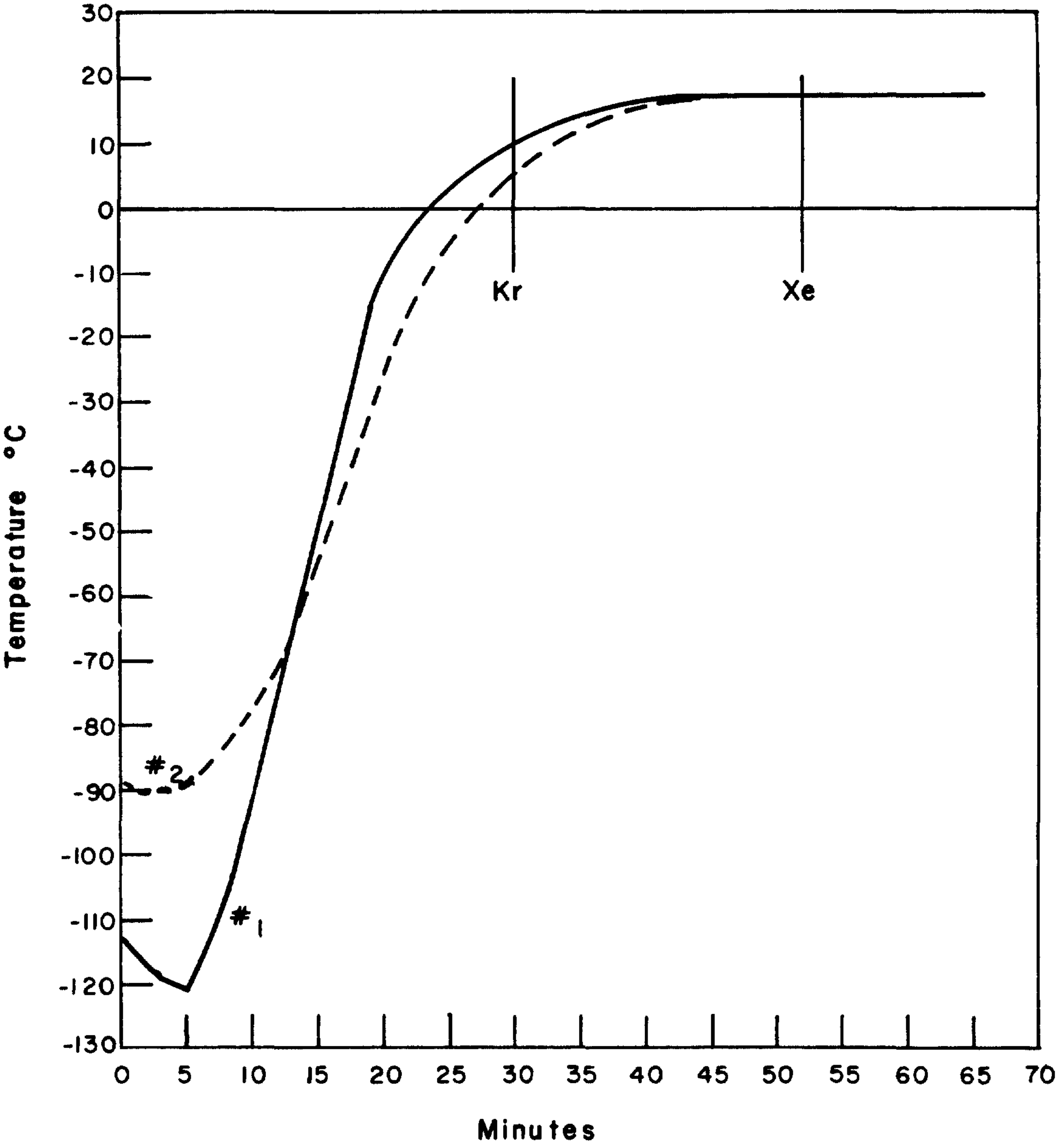

Fig. 3—Evolution of xenon and krypton.

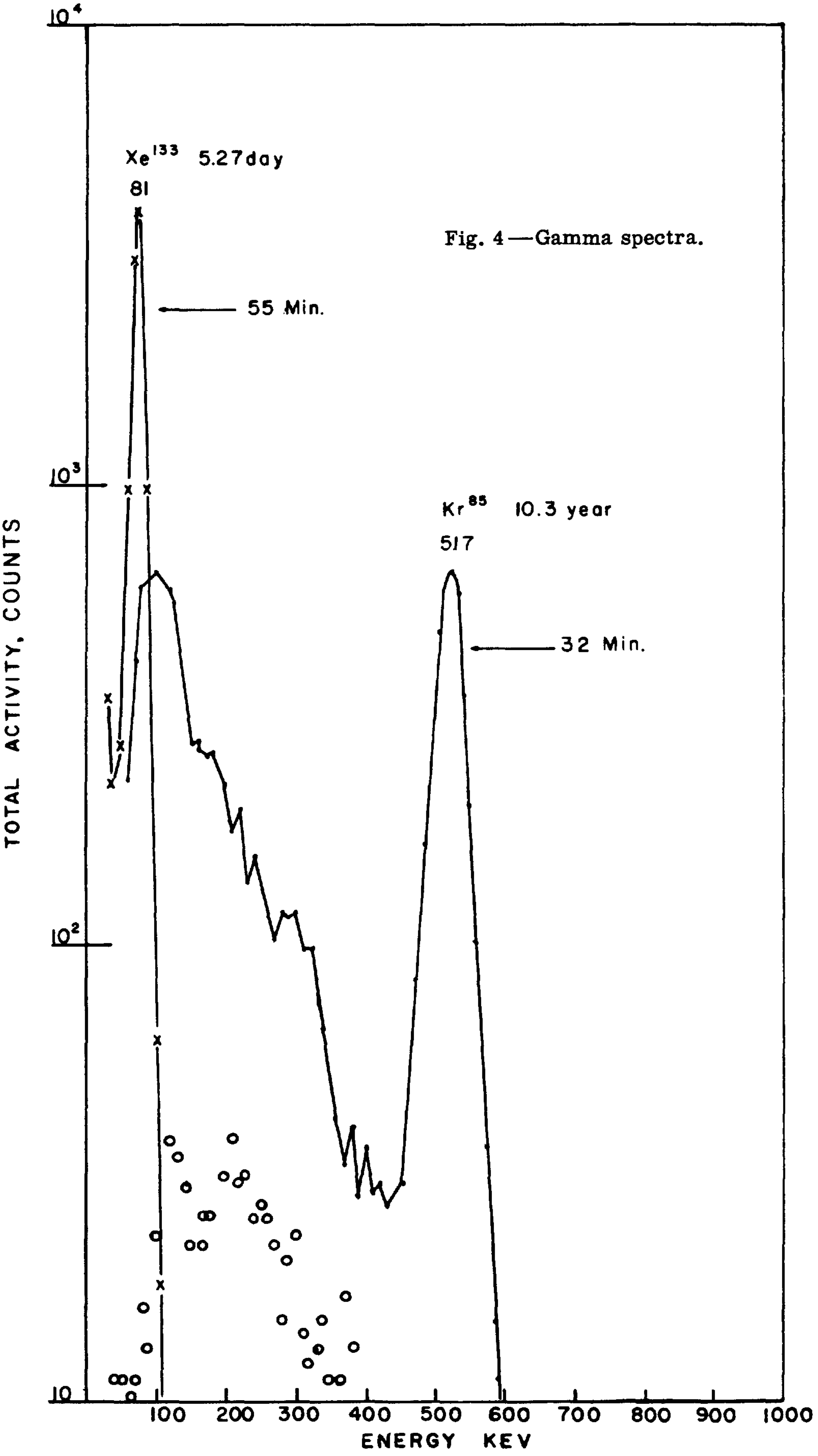

Fig. 4—Gamma spectra.

the carbon in the glass tube was probably due to the larger diameter of the sampler tube. It was evident from the position and movement of the xenon activity in the large sampler that the radioactive xenon and krypton evaporated at approximately the same time. The 22 minute delay in the appearance of radioxenon after the radiokrypton as shown in Figure 3 was caused by the longer holdup time of the radioxenon on activated carbon.

CONCLUSIONS

Krypton as well as xenon can be collected completely if the temperature is below -160° C. and the surface area for heat transfer is large. The large sampler had more than enough capacity and with the proper drying unit the flow rate of air could be increased many times above 1 cfm. without any loss in efficiency. The small sampler contained sufficient activated carbon to do an adequate job of collection at 1 cfm. At room temperature the holdup time of radioxenon on activated carbon is longer than that of radiokrypton. Previously unsuspected leaks in the RALA off-gas system were found which would have been almost impossible to detect using conventional methods.

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WASTE CALCINATION OFF-GAS STUDIES

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ABSTRACT

Development studies concerned with treatment of off-gas from the waste calcination facilities currently being installed at the Idaho Chemical Processing Plant are described. Fission products contained in dust from the calciner make an essentially 100 per cent gas-solid separation mandatory.

Calcination conditions determine the size and concentration of solids in the off-gas. Data from the evaluation of venturi scrubbers on a pilot plant calciner show that all but 1.6×10^{-3} grains of solids per cubic foot of gas can be removed. Tests with a venturi scrubber and electrostatic precipitator independent of the cold calciner indicate that a gas containing only 1.5×10^{-6} grains of solids per cubic foot of gas may be attained at the expense of 10 to 15 inches Hg pressure drop across the venturi scrubber.

INTRODUCTION:

The current construction of a demonstrational fluidized bed calciner is the Idaho Chemical Processing Plant's (ICPP) attempt to dispose of radioactive waste in a safe economical manner and evaluate the method as an ultimate means of disposal. A fluidized bed calciner is, of course, an excellent aerosol generator and presents some complex air cleaning problems. Unlike most industries which are satisfied with an off-gas cleaning efficiency of 95 to 98 per cent, the ICPP can only be satisfied with essentially 100 per cent gas-solids separations because of the radioactive nature of the solids. The ICPP is limited to the maximum permissible concentration of strontium 90, the controlling isotope, at the perimeter fence as given by NBS Handbook 52. Absolute quantities are dependent upon the prevailing atmospheric conditions and the physical dimensions and operating characteristics of the ICPP stack and are beyond the scope of this paper.

The fluidized calciner will convert the corrosive radioactive liquid aluminum nitrate, currently stored in stainless steel tanks into a solid aluminum oxide product. Conversion to the aluminum oxide form eliminates the corrosive nature of the radioactive waste and reduces the volume nominally by eightfold. The process is very simple: liquid aluminum nitrate is sprayed into a bed of fluidized aluminum oxide which is at a temperature of 400°C - 500°C. Upon contact nitrates and water vapor are driven off leaving behind the alumina and radioactive oxides. NaK circulated through a bundle of heat exchange tubes transfers the heat from an oil fired furnace to the calciner bed. The fluidizing media is air, and of course, it entrains solids which must be separated before the air plus other waste gases are discharged to the atmosphere.

Calcination studies have shown that product size and solids concentration in the off-gas are primarily dependent upon the quantity of air used to atomize the feed in the spray nozzle. Space velocity of the fluidizing air in the calciner also affects the quantity of solids entrained in the off-gas. Control of calciner variables plus the off-gas cleansing apparatus will permit sufficient gas-solids, separations. Off-gas cleansing apparatus includes (1) a primary cyclone, (2) venturi scrubber plus knockout cyclone, (3) ruthenium adsorbers, and (4) AEC filters. Our pilot plant studies also encompass evaluation of an electrostatic precipitator. The balance of this paper will be primarily concerned with off-gas studies and equipment used only in the pilot plant calciner.

EQUIPMENT:

Figure 1 shows the calciner pilot units on which the variables affecting calcination are studied. Fluidizing air under pressure is introduced to a jet which in turn feeds the fluidizing gas to bubble cap air distributors in the bottom of the calciner. The fluidizing air entrains solids as it passes through the aluminum oxide bed. The solids laden off-gas enters the primary cyclone after leaving the calciner where about 95 per cent of the solids are removed. The separated solids in the cyclone plus about 30 per cent of the off-gas are returned via the jet to the bottom of the calciner along with make-up fluidizing air.

TABLE I

Calciner Sizes	Off-Gas Rates SCFM	Diameter Venturi Scrubber Throat	Type Cyclone
6" Diameter	12 - 15	5/16"	US Hoffman
2 ft. sq.	130 - 150	1"	Ter Linden

The off-gas leaving the primary cyclone is then introduced into a venturi scrubber where it is contacted by water. Scrub solution on the pilot calciners can be either fresh water or recycle solution. Conditions permitting recycle are used to simulate proposed plant operation. A cyclone downstream of the scrubber then separates the liquid-solids from the gas. In our pilot plant calciners a condenser follows the venturi cyclone to reduce the volume of water in the off-gas. Sample taps exist to permit evaluation of the off-gas equipment and determine how calcination variables are affecting the off-gas. There are two

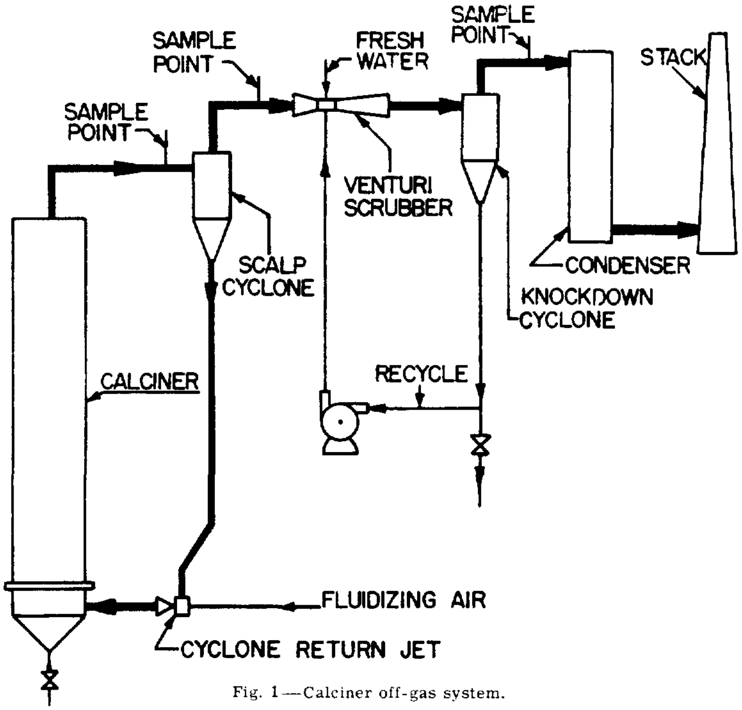

Fig. 1—Calciner off-gas system.

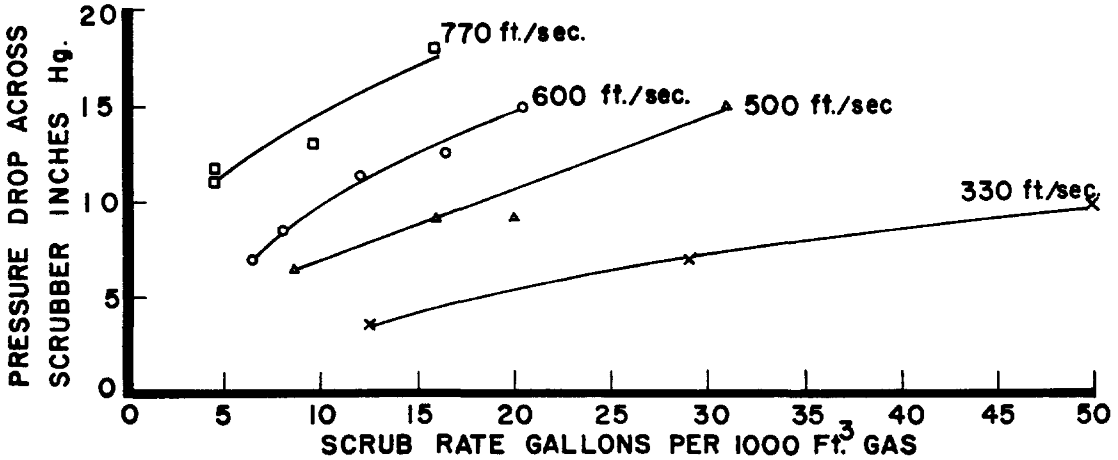

Fig. 2—Effect of scrub rate and air velocity on pressure drop across venturi scrubber.

calciner pilot units on which studies are being made: (1) a 6" diameter unit and (2) a two-foot square model. Table I tabulates the average off-gas flows as well as scrubber dimensions.

Scrubber equipment also included a short section of Yorkmesh Demister between the venturi scrubber and knock out cyclone during the early evaluation period. Occasional clogging of the Yorkmesh necessitated its later removal, however. The clogging was caused from entrained solids in air continuously bled to the spray nozzles to prevent their plugging when the calciner was down. The Yorkmesh did appear to increase scrubber efficiency somewhat.

Present equipment on the calciner includes an enlarged section downstream of the scrubber cyclone. All cyclones thus far used have permitted a film of liquid to be carried over at high gas velocities. Naturally a venturi scrubber can be no more efficient than the knock out cyclone. Re-entrainment of this film has been eliminated by using the enlarged section.

The independent venturi scrubber equipment consists of (1) bubble cap column one foot in diameter, (2) a venturi scrubber with a 1/4 inch diameter throat, (3) a US Hoffman type cyclone, and (4) a packed column downstream of the cyclone to eliminate water carry over film at high air rates.

The bubble cap column was used as the aerosol generator and was chosen to simulate the fluidized bed of the calciner. Aluminum oxide product from the calciner was pulverized in a ball mill for 10-16 hours and then put into the bubble cap column. Average particle size of this ground Al_2O_3 as determined by a Fischer Sub Sieve Sizer was less than 2 microns. Microscope examination showed the material ranged from 0.01 to 3 microns in size. Some agglomeration into larger particles was apparent, however. Metered air entering the bottom of the column generated an aerosol which was diluted 60 to 90 per cent with additional air before it was forced into the venturi scrubber at throat velocities of 300 to 800 feet per second.

Water was injected into a 1/16" hole bored perpendicular to the venturi scrubber throat at rates between 5 and 55 gallons per 1000 cubic foot of gas.

An electrostatic precipitator to separate Al_2O_3 particles from air is also being evaluated independently of the pilot plant calciner. The precipitator consists of 1.76" ID-12" long, wetted wall, column with a twisted stainless steel rod as a discharge electrode. A power pack capable of supplying 20,000 volts completes the precipitator.

The electrostatic precipitator has not been operated to date at voltages exceeding 10,000, however, because of a tendency to arc as the voltage builds up. Once this arcing starts, the voltage drops off. The original straight electrode was replaced by a twisted rod with 1/16" barb projections. This electrode has made it possible to increase ionizing voltages from 7-8000 to 9-10000 volts.

The wetted wall column section of the precipitator is usually operated with film of water 0.003 inches thick flowing continuously over the walls. The water film removes deposited solids thereby increasing overall efficiency. Splashing occurs when the water film is too thick causing excessive current discharge from the center electrode. Space velocities exceeding three feet per second tend to cause splashing also, which results in current discharge.

Aerosol for the precipitator is generated in a manner similar to that for the independent venturi scrubber. The solids concentration of the gas is then reduced to about 1.5×10^{-3} grains per cubic foot with a venturi scrubber prior to entering the electrostatic precipitator.

All gas samples are taken with a cascade impactor backed up with a millipore filter. The impactor is one designed by J. A. Brink(1) of Monsanto based on work of Ranz & Wong(5). Ordinarily the impactor is operated such that the particles caught on the plates are the characteristic particle sizes listed in Table II. The millipore filter catches those particles escaping the final plate of the impactor. Work performed at KAPL(3) indicates the millipore filter removes more than 90 per cent of those particles exceeding 0.01 microns.

TABLE II

Impactor Stage	Characteristic Size Microns
1	2.40
2	1.72
3	1.15
4	0.57
5	0.28

Samples of gas taken upstream of the venturi scrubbers were isokinetic because of the possible existence of large particles. Downstream samples were not necessarily isokinetic because the particles were primarily submicron in size.

EXPERIMENTAL:

Most of the data for the venturi scrubber evaluation were taken on the scrubber which was independent of the pilot plant calciner. Lack of flexibility of the calciner off-gas system necessitated this. The calciner for the most part was operated to determine what variables affected the process rather than for venturi scrubber evaluation. Thence, the very control of primary calcination variables severely limited the scrubbing conditions for any one venturi scrubber design. The independent venturi scrubber permitted exploration of a wide range of scrubber conditions on an Al_2O_3 aerosol. After optimum precipitator conditions have been established a precipitator will be designed and installed on the calciner.

Inlet loadings on the independent venturi scrubber were all considerably lower than those at a similar point on the calciner; that is, 0.7 to 1.5 grains per cubic foot as compared to 0.07 to 0.2 grains per cubic foot. This situation, of course, was undesirable but was necessitated by the gradual coating of the walls of the scrubber with Al_2O_3 upstream of the water injection point at higher aerosol concentrations. Water injected into the venturi throat apparently splashes somewhat, thereby wetting the upstream walls. The dry Al_2O_3 particles tend to stick to the wetted surface over a period of 8 to 10 hours, and build up the overall pressure drop. This phenomenon was also observed on the calciner venturi scrubbers when they were operated without feed injection. When feed is being sprayed into the calciner the off-gas is composed of vapor as well as nitrates and air. The presence of the vapor in the off-gas apparently prevents the solids from sticking to the venturi scrubber walls.

Gradual build up of pressure drop on the independent venturi scrubber was eliminated by keeping the solids concentration in the gas low and by inserting a 1/16" tube upstream of the venturi scrubber throat. The tube outlet was facing the throat and about 10 per cent of the scrub water was bled continuously through this tube and parallel to the venturi throat walls to wash the solids away.

DATA PRESENTATION:

The data are presented as a series of graphs. Data on the experimental venturi scrubber were collected under two sets of conditions: (1) with a section of Yorkmesh between the venturi scrubber and knock out cyclone to act as a coalescence surface and (2) without the Yorkmesh.

Figure 2 is a plot of the pressure drop data across the venturi scrubber and knock out cyclone without the Yorkmesh section. This figure shows that pressure drop is a function of both the aerosol velocity in the throat of the venturi scrubber and liquid scrub rate. Increasing velocities and scrub rates both increase overall pressure drop; however, the aerosol velocity contributes to the greater power loss. Data collected when the Yorkmesh was used reflect a somewhat higher pressure loss for corresponding aerosol velocities and scrub rates. The data points in Figure 2 represent pressure drop information collected during air cleaning periods. No definite attempt was made to obtain data primarily for pressure drop versus scrub rates and velocities.

Several investigators(2)(4)(6) have correlated venturi scrubber efficiency as a function of power loss. Figure 3 represents a similar correlation for our data. This study utilized higher aerosol velocities and scrub rates, resulting in much higher pressure losses across the venturi scrubber than did the previous investigations.

Penetration rather than efficiency has been plotted to convey the data more vividly. All data collected on the venturi scrubber set up is plotted in Figure 3 with no consideration given to gas velocity or scrub rate. Considerable data scatter is evident; however, there is a definite trend showing that the venturi scrubber efficiency is a function of the pressure drop or power utilized.

These data show that for the Al_2O_3 aerosol specific gas velocities or scrub rates are relatively unimportant. A combination of scrub rate and gas velocity will set a corresponding pressure drop which will result in a particular scrubber efficiency. Any extrapolation, of course, can be carried too far. It is erroneous to pick a high gas velocity with essentially no scrub rate and expect the same cleaning that a low gas velocity plus high scrub rate would produce even though the corresponding pressure drops were similar.

Other workers(2)(4)(6) have achieved excellent efficiencies on venturi scrubbers at lower power requirements; however, the concentration of solids was higher and/or the particle size was larger.

Figure 4 is similar to Figure 3 in that it shows how power consumption affects venturi scrubber cleaning. Off-gas loading downstream of the venturi scrubber as a function of the power requirements again follows a straight line variation on semi-log paper. The power requirements here for the scrubber are much more pronounced; i.e., the data are not scattered as much as in Figure 3.

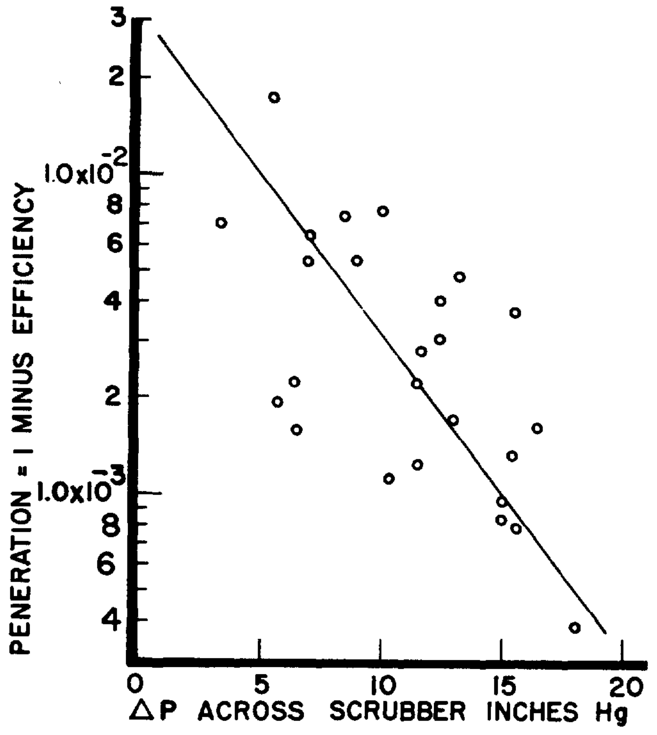

Fig. 3—Experimental scrubber efficiency for particles in the 3.0 to 0.01 μ range.

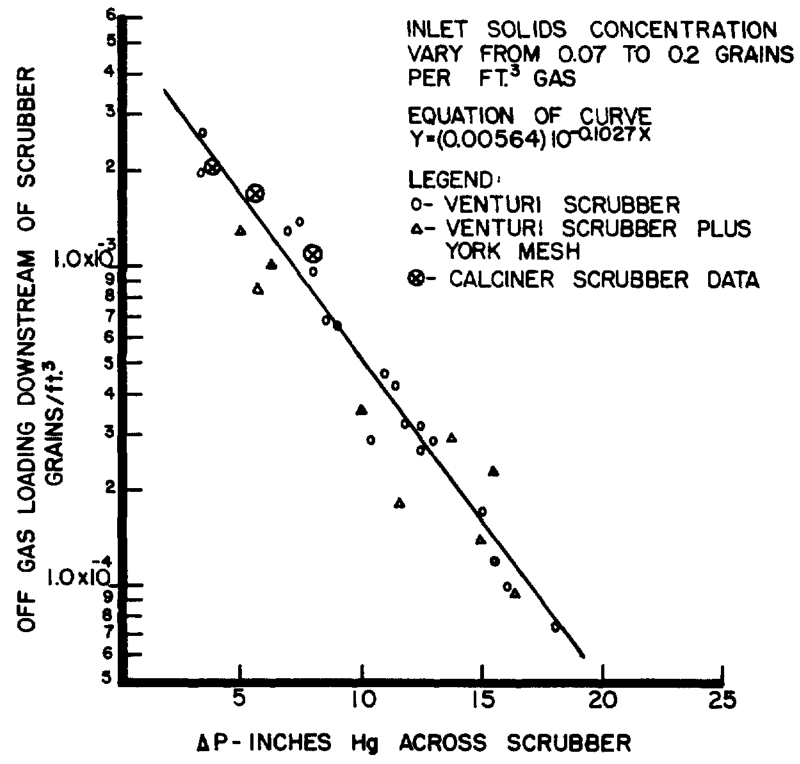

Fig. 4—Concentration of solids in gas downstream of venturi scrubber.

The empirical equation:

$$y = 0.00564(10^{-0.1027x})$$

describes the data in Figure 4.

Where: y = grains of solid per ft^3 of off-gas downstream of venturi scrubber

x = pressure drop across scrubber inches of Hg.

It may be assumed that if the upstream gas-solids concentration were the same for all data points the scatter in both graphs, Figures 3 and 4 would be identical. (The slope of the data is the same for both graphs.) Since the upstream loading varies by as much as threefold for different points, while the outlet loadings for similar pressure drops are essentially the same, it is evident that efficiencies must have more scatter. The data indicate that the importance of the upstream solids loadings on the venturi scrubber efficiency is nil in comparison to the power requirements. It is evident that the pressure drop is the most important of the variables examined in this study; i.e., scrub rate, aerosol velocity, and solids concentrations.

Figure 4 points up that extremely good gas cleaning may be performed on particles smaller than 3.0 microns if a large power loss can be expended.

Figure 5 illustrates how various aerosol velocities and scrub rate affect the off-gas loading downstream of the venturi scrubber. With the exception of the runs which had the Yorkmesh demister in the venturi scrubber it is the same data previously plotted as a function of pressure drop. The off-gas cleaning is somewhat better with the demister; i.e., the velocity parameters would be shifted downward. Slightly higher pressure drops were encountered though for similar velocities and scrub rates; hence the reason for better cleaning. This further indicates that the power requirements reflect the scrubber efficiency more than the other variables do. The Yorkmesh data were not included in Fugure 5 because the parameters are shifted slightly and tend to distort the picture.

Figure 5 clearly shows that the best off-gas cleaning occurs at high aerosol velocities and high scrub rates. These conditions both give the higher pressure drop.

TABLE III

% Scrub Recycled on Calciner	Off-Gas Loading - Grain/ft^3	
Scrubber	Calciner Scrubber	Independent Scrubber (% Recycle)
100	6.0×10^{-3}	7.0×10^{-5}
92	3.0×10^{-3}	1.0×10^{-4}
70	6.0×10^{-4}	1.0×10^{-4}
0	1.6×10^{-3}	1.3×10^{-3}

NOTE: Like pressure drop data are being compared

The major portion of the data collected downstream of the venturi scrubber on the calciner off-gas system was collected at a time when the scrub solution was being recycled. As might be expected the recycle of the scrub solution reduces scrubber cleaning ability by a considerable amount. Table III gives some comparative data collected for like

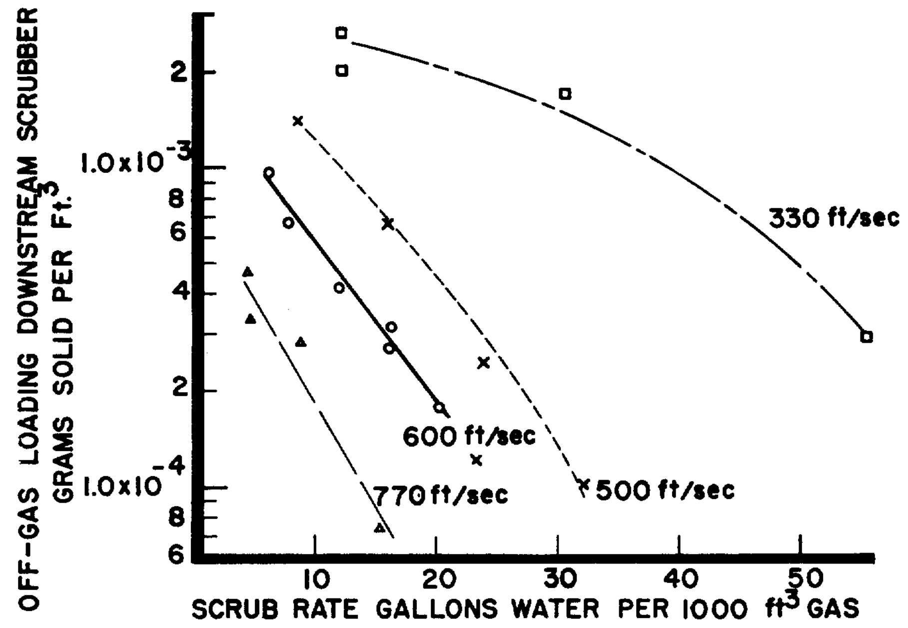

Fig. 5—Concentration of solids in gas downstream of experimental venturi scrubber.

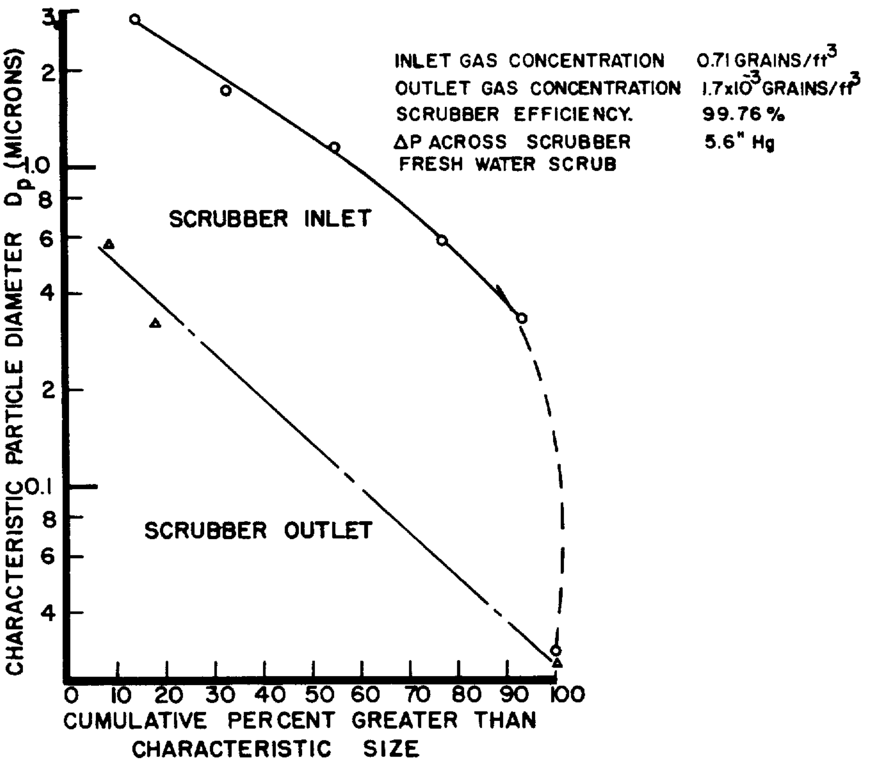

Fig. 6—Particle size distribution of off-gas entering and leaving the calciner venturi scrubber.

pressure drops across the calciner scrubber and independent scrubber. It is important to note that even at 100 per cent scrub recycle that portion of the liquid condensed in the calciner venturi scrubber was continuously bled off to insure equilibrium of (1) liquid volume and (2) solids concentration in the liquid. Solids concentration in liquid was dependent on the per cent of the scrub recycled as well as calcination conditions. Insufficient data prevent a comparison of liquid solids concentration instead of the scrubber recycle comparison in the table.

The table shows that venturi scrubber data for pilot plant and independent scrubbers are nearly the same when fresh water is used as scrub solution. As the per cent of recycle is increased the difference between the scrubbers becomes larger. At 100 per cent recycle the scrubber difference in downstream off-gas loading varies one hundredfold. (A portion of this may be due to the higher upstream gas-solids loading, tenfold higher. The zero per cent recycle data disqualifies this, however.)

Figure 6 represents the particle size distribution before and after the venturi scrubber on the two-foot square pilot calciner. For the particular day these data were taken, scrubber efficiency was 99.76 per cent with fresh water scrub. Naturally the scrubber was most efficient (100%) on particles greater than one micron. The scrubber efficiency decreased (97.2%) as the particle size decreased to those retained on the millipore filter.

Figures 7 and 8 pertain to data collected with the electrostatic precipitator. Off-gas loadings to the precipitator were in the range of 1.5×10^{-3} grains of solid per cubic foot of gas. Figure 7 shows that the wetted wall electrostatic precipitator efficiency drops from 90 per cent to 52 per cent for space velocities varying from 1 to 3½ feet per second. The data were for particulate matter smaller than 1.17 microns average size and 8000 volts. Several points on Figure 7 also indicate that higher voltages give better efficiencies.

At the first glance it appears that the venturi scrubber is a better off-gas cleaning device than is the precipitator. The difference in inlet loadings account for the wide differences in efficiencies. The loading to the calciner scrubber for data in Figure 6 exceeded the loading to the electrostatic precipitator more than two hundred times.

Surprisingly, however, the venturi scrubber is capable of giving almost the same type of gas cleaning as that from the precipitator, 1.5×10^{-6} grains of solid per cubic foot of gas as compared to 1.5×10^{-5} grains per cubic foot. Both numbers represent off-gas loadings downstream of the apparatus. The major difference, however, is that the pressure drop across the precipitator is about one-inch of water while that across the scrubber is about two hundred fifty inches of water.

The effect of voltage on efficiency and particle size is shown in Figure 8. Higher voltages and particles above 2 micron produce 100 per cent efficiency for this study. Once again off-gas loading is very small for Figure 8 data (1.5×10^{-3} grains per cubic foot.)

CONCLUSIONS:

(1) The major contributing factor to a venturi scrubber efficiency for particles smaller than 3.0 microns is amount of pressure drop taken.

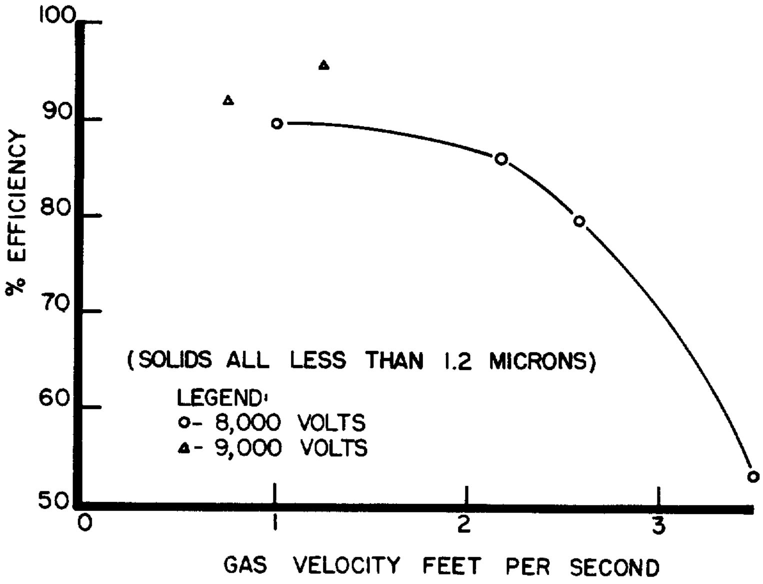

Fig. 7—Effect of air velocity on electrostatic precipitator efficiency.

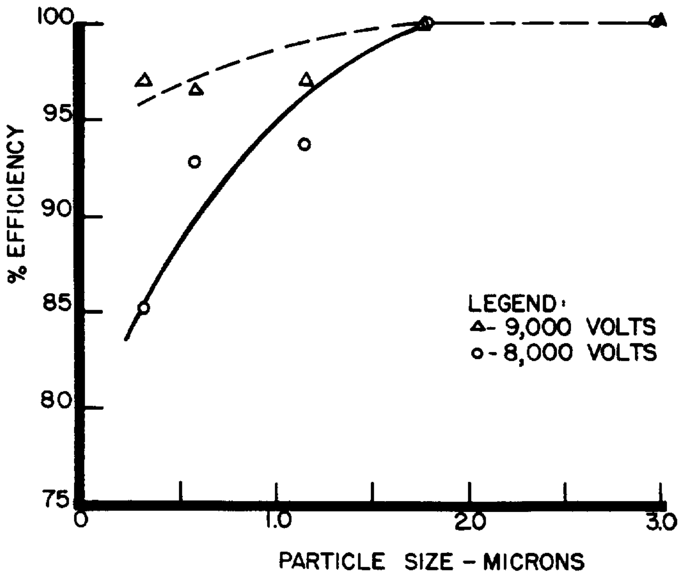

Fig. 8—Voltage effect on electrostatic precipitator efficiency.

Once the decision is made of what concentration of solids in off-gas can be tolerated data in this paper will indicate the power requirements in the form of pressure drop. For the area studied it matters very little whether high gas velocity plus low scrub rates or low gas velocity plus high scrub rates are used in the venturi scrubber.

(2) Variation in upstream solids concentration will not contribute to the gas cleaning ability of a venturi scrubber in the range 0.07 to 0.2 grains per cubic foot of gas.

(3) Electrostatic precipitator efficiency is best at high voltages and low gas space velocities. Higher voltages may be obtained with a barbed center electrode.

(4) The venturi scrubbers clean-up ability can approach that of the electrostatic precipitator. A pressure drop of two hundred fifty inches of water across the scrubber is expended, however, in comparison to one-inch of water across the electrostatic precipitator.

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Discussion

Q. I wonder why he didn't use higher voltage than 9,000 as this is pretty low for control type.

A. Reason is that we are using a little model. Not able to get high voltage without arcing or shorting out.

THE SIGNIFICANCE OF THE AIR CLEANING PROBLEM IN AIRCRAFT NUCLEAR PROPULSION

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Most of you are familiar with the effort being made by General Electric to produce a direct cycle nuclear power plant for aircraft propulsion. Figure 1 is a picture of the Heat Transfer Reactor Experiment (HTRE #1) as it is being moved by a shielded locomotive in the Idaho Test Station. The reactor and shield assembly is carried in the center of the Core Test Facility (CTF) which is literally a laboratory on wheels. This apparatus was the first to demonstrate that jet engines could indeed be operated by nuclear power. The apparatus obviously was not intended to fly.

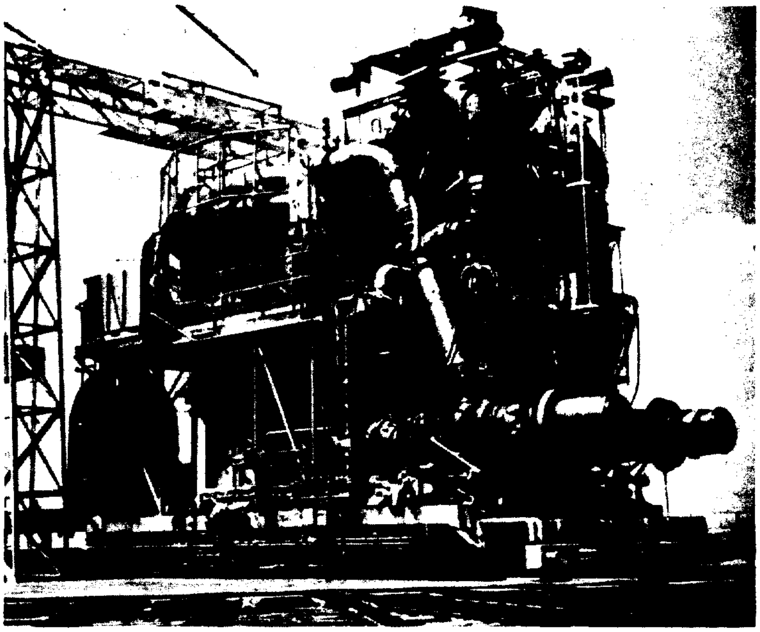

Fig. 1—Heat transfer reactor experiment (HTRE) power plant.

The mode of operation of the HTRE is shown schematically in Figure 2. Air is taken in through the compressors and routed through ducting and a torus to the reactor. After passing through the reactor, air again passes through ducting and a chemical burner can before passing out through the turbine and being exhausted to the atmosphere through a 150 foot stack.

Routine operation of the direct cycle reactors releases a negligible amount of radioactivity. This activity is carried out of the stack and dispersed without a problem. However, aircraft reactors require high power densities in order to minimize shielding requirements and therefore have rather stringent coolant requirements. Loss of coolant during operation at power or shortly after shutdown can cause considerable damage to the fuel elements and release significant amounts of activity in the form of fission products. Testing fuel elements in early development stages might also reasonably be expected to release activity. While it is not practical to clean the exhaust air of a flying jet bomber, the problem of cleaning the effluent from a stationary power plant during testing might be possible.

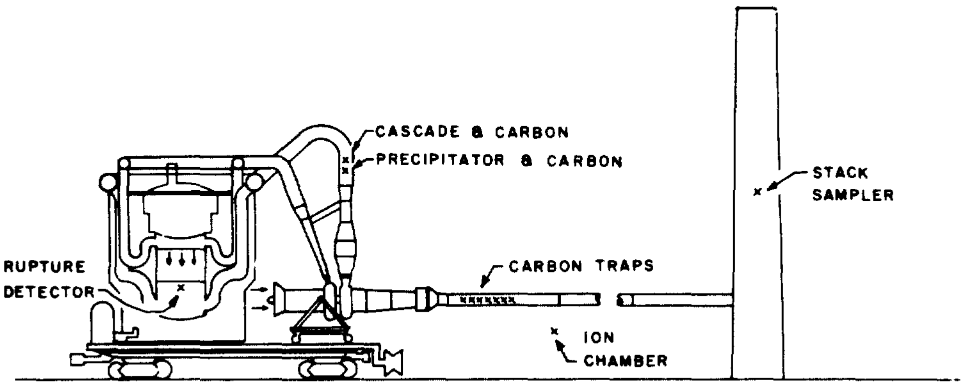

Fig. 2—In-facility sampling locations.

In order to get some idea of the degree of difficulty of air cleaning problems involved. Let us look at some typical numbers which might be expected when we are dealing with the testing of an operational power package. Consider the requirements for a conventional B-36 bomber. This plane is powered by six piston engines of about 3500 horsepower each and four J-47 turbojets of about 5000# thrust each. Each plane then requires somewhere around 25 MW. of power and if we consider that all power is to be supplied by a reactor which is relatively inefficient (and to generate nice round figures) a 100 MW. (thermal) reactor is reasonable. Typically, a J-47 operates on an air flow of about 50 pounds per second and exhausts air at about 900°F. If the six piston engines of the B-36 were replaced by J-47 jet engines, the total effluent would then be expected to be about 500 pounds of air per second at about 900°F which is a lot of air to clean!

Before one can determine specifications for a cleaning system, it is necessary to determine the physical characteristics of the contaminant-in this case fission products. Laboratory scale experiments have been performed to learn what fractional release can be expected in the event of overtemperatures to fuel elements. These studies will continue. However, it is difficult to mock-up a reactor malfunction in a laboratory, therefore a reactor was modified to provide in-situ experiments on fuel element damage studies. Figure 3 is a schematic of such an experimental arrangement. A valve has been installed to limit the coolant air to a fuel element of a reactor while the reactor is operating at power. One such experiment has been done at the Idaho Test Station to study fractional release and reactor damage. Figures 4 through 6 are pictures of some of the typical residue resulting from this experiment. From such tests

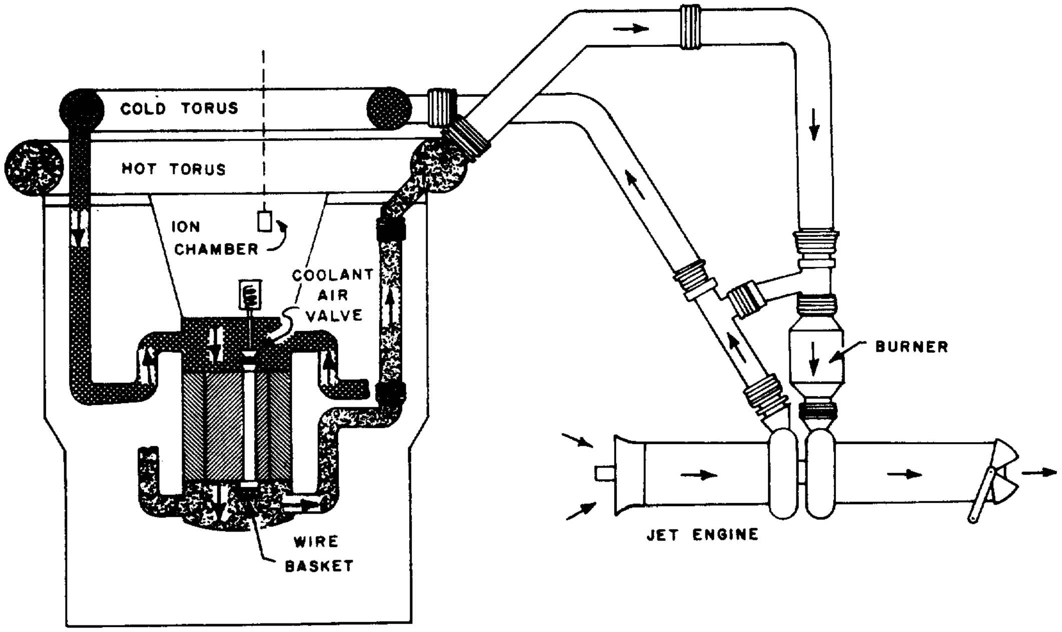

Fig. 3 — Schematic of HTRE with insert.

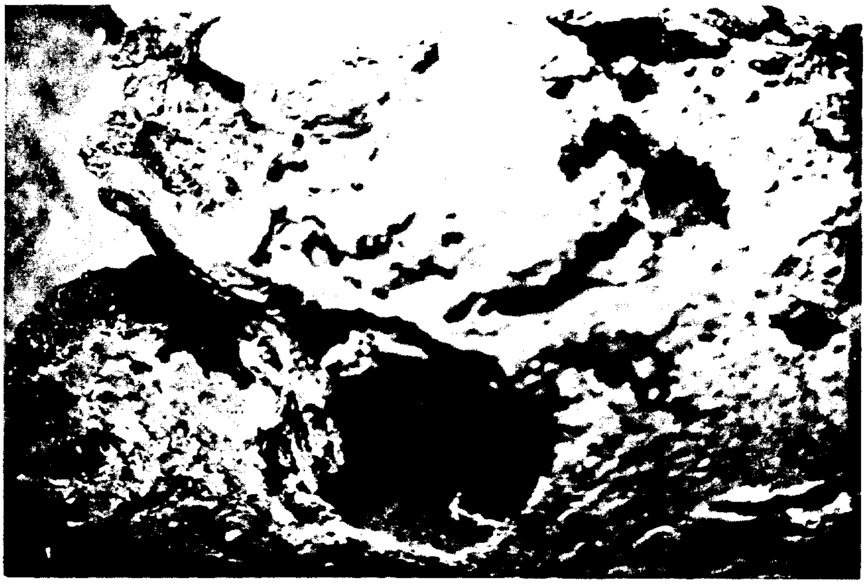

Fig. 4 — Fuel element residue.

we hope to learn mechanisms of reactor damage, the fraction of specific isotopes released, physical characteristics of the contaminants, and prediction of dispersion patterns for fission products once it is released.

Meteorological control, which has been used to date, has proven to be a workable method but it does impose some restrictions on operating time. The following papers will provide more detailed information on both meteorological control of operations in lieu of air cleaning and operations in which air cleaning has been used successfully.

Fig. 5 — Fuel element residue.

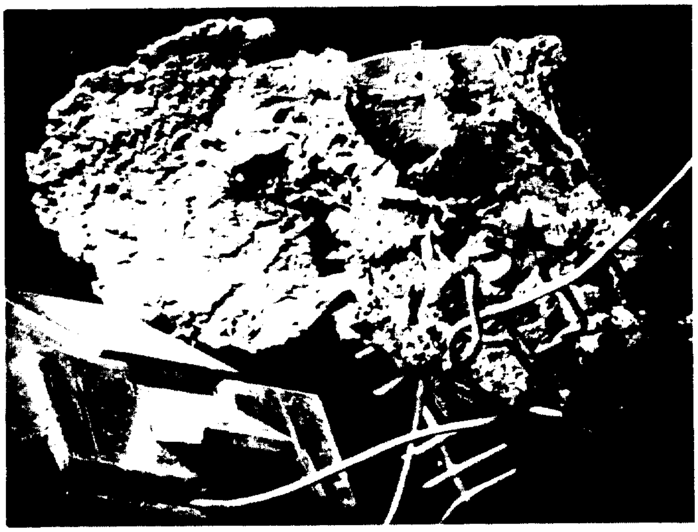

Fig. 6 — Fuel element residue.

Discussion

(C.) Reactor heat assembly - the heat transfer experiment, is it intended to fly? - routine operations produce only negative amounts of radioactivity. The radioactivity is carried out of the stack and therefore, they have very strict collecting requirements.

EXPERIENCE WITH NON-FILTERED AIR SYSTEMS AT THE IDAHO TEST STATION

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Abstract

Experimental direct cycle aircraft nuclear power plants are ground tested at the ANP Area, National Reactor Testing Station, without air cleaning. Effluent hazards are minimized by a system of meteorological control. To date, this system has proved to be successful in controlling the doses to humans and may prove to be adequate for full scale aircraft powerplant tests. Even if air cleaning of the effluent proves to be necessary in the future, a meteorological control program will serve to reduce the requirements of the air cleaning system, thereby reducing its cost.

* * * * *

The ground testing of experimental aircraft nuclear power plants of the direct cycle type presents a significant challenge in the field of air pollution control. Since the air which cools the reactor makes a single pass through the power plant system and is exhausted to atmosphere, any radioactive materials released within the reactor core can be carried by the winds to some point where human beings might be exposed.

Radioactive materials may be present in this coolant stream for several reasons. First, some experimental fuel elements are not designed for complete retention of the radioactive fission products. Secondly, some tests may be deliberately operated at conditions designed to induce failures in fuel cladding. Third, minor cladding defects may appear even in non-destructive testing. Fourth, activation products may be released. And, of course, there is always the possibility of an accident of some kind.

Ordinarily one would immediately suggest that an air cleaning system be installed to remove all or part of the offending materials. Unfortunately this approach is a difficult and expensive one due to the extremely large volumes of high temperature air pumped by the turbo-jet engines and the fact that high back pressures cannot be tolerated.

Various air cleaning systems are under consideration, but some of the more conventional systems have already been proved impractical.

Since the beginning of the ANP testing program at the National Reactor Testing Station, in early 1956, these power plants have been operated without any attempt at air cleaning. To minimize the effects of the radioactive materials released to the atmosphere, a system of meteorological control is utilized. This control system has been under continuous development and will, of course, continue to be developed in order to keep pace with the increasing demands of the ground test program. To date, the meteorological control system has been highly successful in limiting the dose to humans to very low levels, but, in the early stages especially, the extremely conservative approach to the problem has not always permitted the most expeditious progress of the test program.

In its present form, the ANP meteorological control program is operated as follows:

> The possible releases of radioactive materials are divided into two cases; the Accident Case and the Continuous Release Case. This is done because the permissible limits as well as the dose calculations are different for the two cases.
>
> In any nuclear system there are a number of different types of accidents which could occur, even though elaborate precautions are taken to prevent them. For each different ANP reactor, a hazards report is prepared for evaluation and approval by the AEC. These hazards reports contain discussions of the causes and effects of the various possible accidents. For a given reactor, then, controlling accident is selected for each phase of the planned test program by weighing the assumed probability of occurrence and the magnitude of the hazard which would be created. This is done by evaluating such factors as; fission product inventory, degree of reliability of various components of the system, probable effect upon the system should a given component fail and the state of knowledge concerning the operating characteristics of the power plant.
>
> Each time the reactor is operated, a series of calculations are made of the significant doses to the various critical organs at occupied areas downwind should this controlling accident occur. If the controlling dose, which is dependent on the atmospheric diffusion conditions, were calculated to be higher than accepted permissible limits, we would not operate the reactor until the meteorological conditions improve to the point that the accident dose is again within acceptable bounds.
>
> During the periods in which radioactivity is released continuously, the applicable critical organ doses to a given receptor area, per hour of reactor operation, are calculated based upon current atmospheric diffusion conditions and measured activity release rates. The meteorological portions of these calculations are then verified by means of measurement in the field. The accumulation of dose at a given location may then be controlled by selecting desirable meteorological conditions and by controlling reactor operating time.

It is obvious that the calculation of dose at some point remote from the test facility is an essential part of this control system. These calculations are made using a modified form of Sutton's diffusion equation. This modified equation may be thought of as containing three terms: one describing the effluent materials at the source; one describing the diffusion, transport, and deposition of these materials in the environment; and the third describing the biological factors which enter into the conversion of a concentration of material in a given media to a critical organ dose in the human body.

Indications are that these calculations can be made with reasonable accuracy provided the correct input data is used.

The Source Term. The source term must, of course, be derived differently for the two different cases. For the accident this is done by computing the current fission product inventory in the reactor for the particular isotopes of interest and then multiplying by a release fraction which varies from isotope to isotope and is also dependent upon the type of accident under consideration. Some experimental evidence is available on the release fractions for a limited number of accident cases, but this type of information is by no means complete.

In the case of the continuous release of fission products, more complete data is available because the materials can be monitored on their way through the ducting and stack system before they escape to the atmosphere. Since all sampling and monitoring devices for airborne fission products have inherent limitations, several different types of devices having different characteristics are used so that there are as few unknowns as possible.

A rupture detector, which utilizes a wet cyclone to remove a fraction of the particulate from the air, is closely coupled to the hot ducting of the power plant. The liquid from this system is passed over a shielded scintillation counter. This system, while not quantitative, has a response time in the order of a few seconds and serves to warn of sudden increases in the discharge activity. This device will actuate the reactor scram system in the event of a sudden increase above pre-set limits.

Two external radiation monitoring devices are located adjacent to the discharge ducting at some distance from the power plant. One of these is a gamma sensitive ionization chamber and the other is a fission chamber which measures delayed neutrons.

As the air passes up the exhaust stack, a sample is continuously drawn from the 80' level to a stack monitoring device which is located in a shielded vault underground. Here it is passed through a continuously moving filter tape which is scanned by two beta-sensitive scintillation counters - one immediately beneath the collection point and one at a point corresponding to a 30 minute decay time. After passing through the filter, the air then goes into a shielded tank which is scanned by a gamma ray spectrometer. This gas chamber has provisions for holding up a portion of the gas for decay counting.

In addition to these continuous monitoring devices, samples are collected at many different locations for later analysis in the laboratory. Extensive use is made of deep bed charcoal traps for the collection of radioactive iodine. Other sampling devices utilize aerosol filters, electrostatic precipitators and cascade impactors. These devices do not usually provide data which is immediately useful in the control of the current test run, but they are very useful for calibrating the various monitoring devices and they provide more detailed data on the characteristics and quantities of the various effluent materials.

The Meteorological Term. At present, the most useful meteorological data is obtained from a single 200 foot weather tower at the release point. A direct line to the U. S. Weather Bureau office at Central Facilities provides a means of effectively utilizing the services of this organization.

Four additional weather towers are currently being installed at radial distances of between 3.5 and five miles from the release point, thus forming a rough "box" around the ANP Area with the exhaust stack at the center. These stations will be equipped with radio-telemetering devices so that the resultant wind and temperature profile data can be transmitted to the control center on a continuous basis. The data from these outlying stations will be used to plot air flow stream lines across the ANP Area for a more accurate determination of plume trajectory, and will provide a more complete analysis of the micrometeorology of the test site and vicinity.

The important variables in the meteorological portion of the dose calculation are the diffusion coefficient "c", the stability parameter "n", and the effective stack height. At present, these are all determined by generalized methods. The effective stack height is estimated by using the Davidson Bryant equation. The stability parameter is defined by the temperature profile, and the diffusion coefficient is determined from a general method suggested by Barad and Hilst. These generalized methods do not provide the desired degree of accuracy for this type of program. Studies are being conducted to provide new or improved methods and meteorological instrumentation.

A group of 26 radiation monitoring stations are operated in a circle roughly ten miles in diameter around the area. These stations are also being equipped with radio-telemetering devices so that the airborne activity as well as the external gamma dose from the cloud are continuously printed out at the control point. These stations - supplemented by similarly equipped mobile units - serve as calibration points for the dose calculations. Another ring of 16 continuously recording gamma sensitive ion chambers is operated at a distance of about one mile from the stack to assist in the initial trajectory determination.

In addition to these automated monitoring stations a number of manually operated air sampling and fallout stations are operated on grids at various distances from the stack to obtain more detailed data, and a comprehensive vegetation sampling and analysis program is also conducted. Supplementary monitoring and data collection programs are also operated by the AEC-IDO Health and Safety Branch.

The results of the meteorological control program to date may be summarized by stating that, to our knowledge, off site doses resulting from ANP testing have been less than 1% of the annual non-occupational limits each year. Actually, the full effectiveness of the system has not been fully demonstrated, since the actual fission product release rates have not been high enough to approach the permissible dose limits in any occupied area. In fact, the nuclear weapons tests conducted in Nevada and elsewhere in the world have added more radioactivity to the environment of the ANP site than have the ANP tests themselves.

Beyond a certain point the actual reduction of hazards by meteorological control can only be accomplished by delaying the test program. Another important benefit of this type of program, however, is that it allows the recognition and use of the permissible limits which have been established for non-occupational exposure. Without this type of program there is no means of determining the extent of the hazard created by the release of airborne radioactive materials until after the damage is done. There are still important gains to be made by refining the present system. For example, the results of field verifications, to date, indicate that for typical daytime operating conditions the atmospheric diffusion calculations are conservative by a factor of 3 on the average. If, by learning more about atmospheric diffusion, this over-conservatism can be reduced a net gain in operating flexibility will be realized.

Extrapolations have been made to determine whether a meteorological control program will be adequate to cope with the releases expected from the full scale flight-type power plants to be ground tested in the future. This, of course, depends to a great extent upon the amount of time available in which to perform each test, but indications are that it will be a marginal situation. In other words, the operation of these future power plants, within the non-occupational dose limits may be possible without filtration of the exhaust air. Even if air cleaning is found to be necessary this type of control will certainly reduce the requirements of the cleaning system thus saving the taxpayers considerable expense. For this reason, the methods and techniques of meteorological control will continue to be developed, even as filtration systems for ANP ground testing are developed on a parallel path.

AIR CLEANING IN ANP EXPERIMENTS AT THE ETR AND MTR

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The accomplishment of ANP test objectives at the Idaho Test Station often results in an expected release of radioactive effluent. These releases can occur for several reasons:

1. Testing of fuel element types not designed for complete retention of fission products
2. Destruction testing to determine feasible operating parameter limits and life expectancy
3. Destruction testing to study kind of failure and effect.

It should be pointed out that the degree of effluent contamination we have experienced to date would not constitute a serious problem as a flying source. As a continuous source of radioactive effluent being released from a testing facility stack such as those at Materials Test Reactor or Engineering Test Reactor, the problem is somewhat more acute, and during adverse meteorological conditions, the conducting of such tests would have to be suspended if the effluent could not be at least partly decontaminated.

The effluents from tests conducted at ETR or MTR consist of hot air with a variable moisture content, some activation materials, and fission products. Of these, the latter is the most significant as a problem. Some of the fission product activity is associated with particulate matter in the air stream and some - noteably the iodines, bromines, xenons, and kryptons - are present in a gaseous state.

In reducing the stack release of radioactive material, it is desirable to reduce the gross activity released as much as possible and to remove in particular those constituents which are most harmful from a biological point of view.

To accomplish this reduction in stack release of radioactive material under the conditions that exist at the MTR (and which will exist at the ETR), the effluent undergoes three phases of treatment before being ducted to the stack for release:

1. Removal of particulate material

2. Treatment to reduce the iodine content

3. Reduction of the inert component and their daughters by decay and subsequent filtering.

The accompanying illustration (Figure 1) is a schematic diagram of a prototype filter system designed and built at the Idaho Test Station to test the effectiveness of a system designed to apply this three-phase treatment to effluents from ANP tests at MTR.

This particular test filter system was designed and sized to handle the coolant flow from a series of tests at the MTR which were expected to provide a suitable source of fission product contaminated effluent. Two of this series of tests were successfully completed earlier this year providing a total of approximately 400 hours of contaminated effluent.

The schematic diagram shows a test sample in a flux region in the MTR as the fission product source. Filtered coolant air flows through the source, through the exhaust ducting (shielded), through the filter system components in series, and then is released, via the MTR stack, to the atmosphere.

The filter system, as indicated, consists of three major components - two filters and a tank system.

The two filters are identical and each is composed of three elements or beds which are six inches in depth and twelve inches in diameter. The first element is silver plated fiber frax. Support and protection is provided by a Regimesh screen on the upstream face.

The second element is an absolute filter rated by the manufacturers as being capable of removing 99.95% of a test aerosol having an average particle size of .3 microns in diameter.

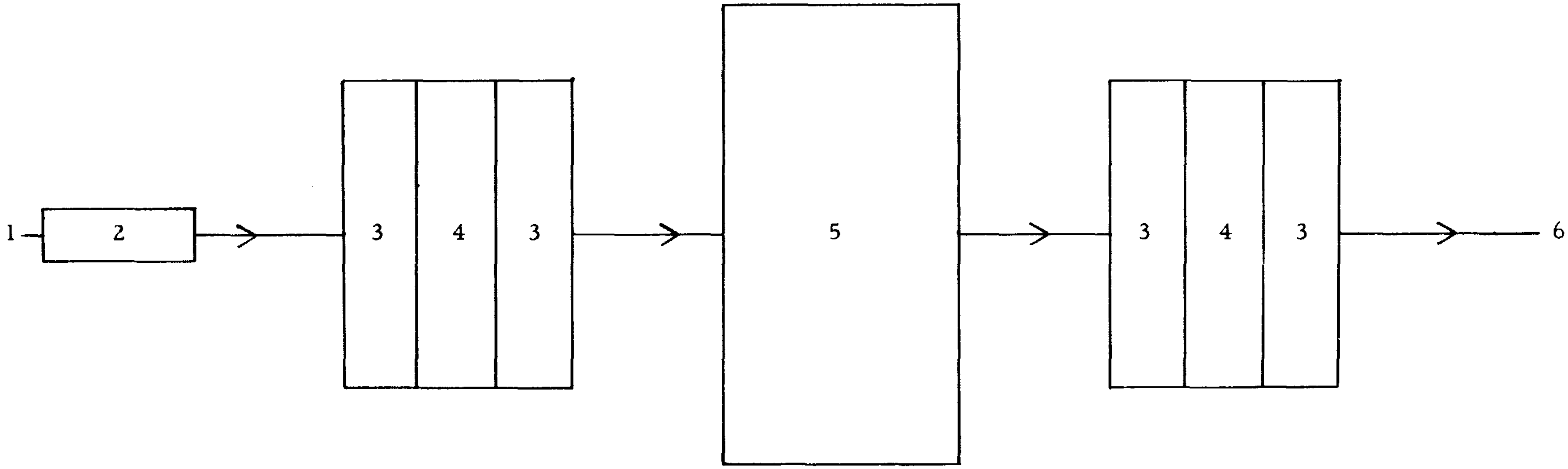
The third element is another six inch deep silver plated fiber frax bed similar to the first and having a Regimesh screen on the downstream face. Special high temperature glass fiber gaskets are employed between the flanges of adjacent elements and the three are bolted together to form a single unit when installed.

The first filter is designed to accomplish two of the treatment phases:

1. Removal of particulate material and the associated activity

2. Reduction of the radioactive iodine content by chemically combining it with the silver on the filter fibers

Quite a few of the fission products that are objectionable biologically have inert Xe or Kr precursors having short half lives. The second of the three-filter system components was so designed that the transit time of the effluent was about two minutes at the design flow conditions. This time is sufficient to permit the decay of many of the inert precursors to their more filterable Cs or Ba daughters which either plate out in the system or are removed by the second filter. In the test set-up, the two-minute transit time was provided by incorporating two appropriately-sized tanks in series with the filters. The tanks were constructed of carbon steel, baffled to insure a non-channeling flow, and designed to withstand a working pressure of 150 psig.



1. Air supply (filtered)
2. Fission product source
3. Silver plated fiber frax bed
4. Absolute filter bed
5. Delay tanks
6. To stack

Fig. 1—Schematic diagram of a prototype filter system.

The second filter, downstream of the delay tanks, is identical to the first filter. It has silver-plated beds also for two reasons: first, to take advantage of the series setup for removing that iodine which is in the gaseous form due to being formed as a fission product directly or decaying to iodine during the two minutes in transit, and second, to react with that component which may be held up as Te or Sb in the first filter, decay to iodine, and proceed through the system.

At design flow the pressure drop across the entire filter system (including a heat exchanger not shown in the schematic) is 4.9 psig. The pressure drop across each filter is 0.6 psig and across the delay tanks is 0.2 psig.

The two-minute transit time accomplishes one other desirable result. It reduces the total radioactivity of the effluent, disregarding any filtering action it enhances, by taking advantage of the fact that many of the major contributors to the activity of fresh fission products have extremely short half lives.

By comparing the gross effluent activity upstream and downstream of the filter system - and by determining the concentration of various fission product isotopes in samples of the effluent collected upstream and downstream of each component - it was determined that this design did accomplish the desired result. Stack releases of fission products were held well below acceptable limits enabling continued testing during weather conditions which normally would have suspended testing of this nature.

The data from isotopic analysis of samples of the effluent indicated a reduction in concentration of iodine (and iodine precursors) in the effluent by a factor of 10. Inlet concentrations to the system were quite low and there was some indication that had the concentration been higher the decontamination factor would have been greater. Laboratory tests using the same silver-plated filters with greater inlet concentrations of iodine (using I^{131} tracer) have shown a reduction by a factor of 100 across the filter.

The concentration of Xe and Kr daughters was reduced by a factor of 200 - 400 across the system. Most of this loss was across the combination of delay tank and secondary filter as was anticipated. The specific isotopes for which analyses were made were Ba^{139}, Ba^{140}, Sr^{91}, and Sr^{92}.

The gross activity of the effluent was monitored upstream and downstream of the system by shielded ion chambers adjacent to the effluent line. Data collected from these chambers indicated a reduction in total activity by a factor of 500 to 1000.

PROPOSED SIDE LOOP PROGRAM AT THE IET

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Idaho Test Station, Idaho Falls, Idaho

The two previous speakers have mentioned some of the air contamination problems associated with the Aircraft Nuclear Propulsion test program, and have described two methods which have been used successfully to cope with these problems. I should like to describe a third approach, now reaching the pilot plant stage.

Dependence upon meteorological control, in the manner described by Mr. O'Brien, becomes increasingly less attractive when reactors of higher power are to be tested, when test schedules become tighter, and when several test facilities may be operating simultaneously. We are looking ahead to a time when some form of air cleaning may be needed for the power plant effluent.

The methods described by Mr. Foster which are being successfully used for the MTR and ETR testing are inapplicable to cleaning the effluent from a nuclear aircraft engine because of the large pressure drop they require. What is needed is a filter capable of handling a large volume of air, on the order of 1000 pounds/second, with a pressure drop of no more than 6-12 inches of water. Since the air is initially hot, it is economically advantageous to avoid the expense of cooling it. Our engineering studies indicate that an electrostatic precipitator best meets these specifications. This device will, of course, remove only particulate contaminants from the air stream. Our data show, however, that radioactive gases will, under certain circumstances, adhere to solid particles in the air stream and will be removed with them. We propose, then, to add a material such as smoke after the reactor, and to remove it in the precipitator, along with at least some of the radioactive gases.

Before proceeding to a full scale filter, which would be an installation of considerable size and expense, we have thought it expedient to gain operating experience and to collect more data by constructing a pilot plant. Accordingly, we have designed and are now assembling the side filter loop at the Initial Engine Test Facility. This loop draws off a fraction, 5 to 10%, of the IET exhaust and passes it through an electrostatic precipitator. The precipitator is a commercially available, parallel plate, horizontal flow model. It is capable of handling 14,000 cfm of air at temperatures up to 900°F. It has two sections in series to permit studying the effect of changing the length of precipitator being used. It has provisions for rapping the plates and for a decontaminating wash down, and has a continuously flushed hopper to remove the contaminated material.

Fig. 1 shows the general layout, looking downstream from the IET test building. The IET stack and exhaust duct are on the right in the picture, and the precipitator on the left. A 20 inch diameter duct, not yet installed, will connect the precipitator to the main exhaust duct just downstream from the test building.

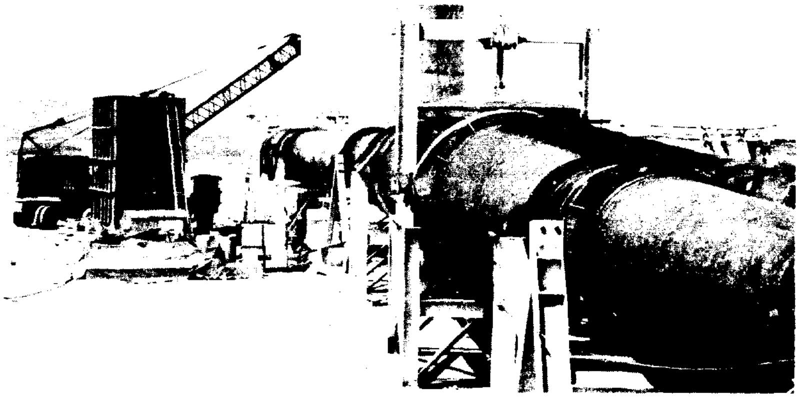

Fig. 1 — Side filter loop looking north from the Test Building.

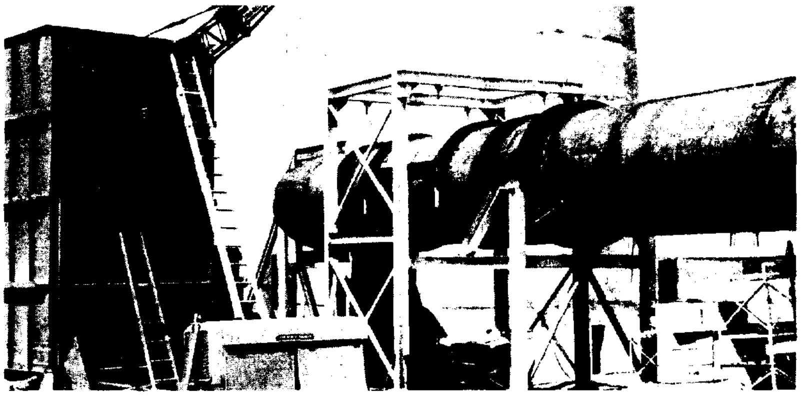

Fig. 2 — Closeup of electrostatic precipitator.

Fig. 2 shows the precipitator from a closer vantage point.

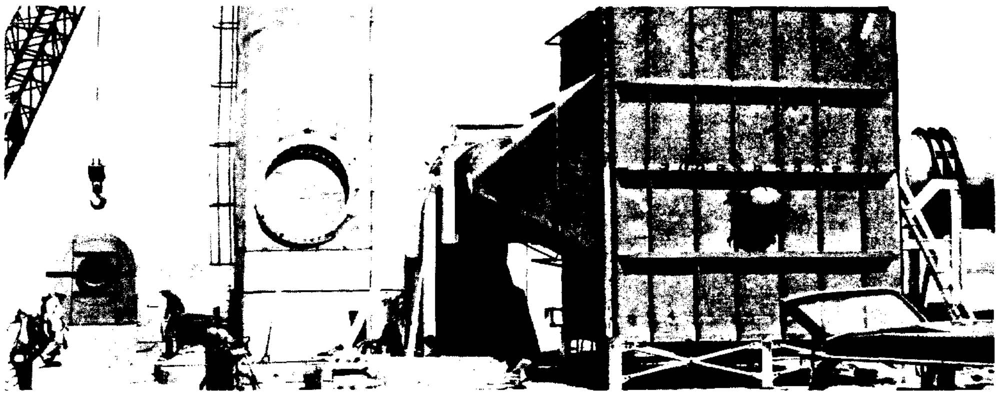

Fig. 3 — Side filter loop from the west.

Fig. 3, taken from the side, shows a blower, with a variable discharge valve, which will be used to control the air flow through the loop for experimental purposes. We do not plan to use any blowers on a full scale filter.

The loop will be provided with instrumentation for measuring pressure, temperature, and flow at several locations, and for removing samples of the effluent for analysis. There are provisions for adding materials such as smoke to aid in removing radioactive gases, for adding sources to permit testing of the loop when the main effluent is not contaminated, and for cooling the air with water if necessary.

The loop will be ready for checkout next month, and we expect to start collecting data shortly thereafter. Artificial sources will be used at first, and fission products from test power plants when these are available. The first question to be evaluated is, of course, whether the precipitator will do the job. Other investigations will concern the effects of temperature, flow, and additives, and the best methods for removal of trapped material. These data will permit us to design a full scale filter confidently, to predict its performance, and to determine whether its advantages are worth the cost.

Discussion

Q. Relative to MTR installation, I was wondering what the air velocity and pressure drop is plus the filter set up?

A. They are of the designs under conditions tested. Fast velocity - filters beds about 10' per minute.

Q. What type of smoke --- has there been any work done in generating smokes to trap fission products?

A. Our first experience with smoke was accidental. We were running power plant with relay of activity, smoke was released and got into the stack. A good deal of our testing involves particular chemical operations so we have smoke from the fuel and we can correlate readings from the stack monitor with the amount of fuel being burned during tests. We have released smoke consisting of burning old engine oil in engine exhausts, but we haven't really pinned the problem down. We don't have the data to know exactly what this machine will do.

Q. Can you give us some notion of the effectiveness of this smoke?

A. I am afraid I can't give you any really good answer. I think we are getting a factor 10- 100 increase in our tracing efficiency for radioactive materials (Iodine).

C. (L. Silverman, Harvard) We ran some experiments - passing the two gases (benzine smoke through iodine). -- In trying to collect I did not - indicating about 35% removal --- so rapidly that the pressure drop got out of line. Activated carbon would be the ideal aerosol.

A. (C. L. Storrs, ANP-GE) I think that is very interesting and I hope that I am not too optimistic and that it will work out. We really don't know what the thing will do.

Q (J. J. Sabo, U. S. Public Health) You gave a pressure drop of 20 psi, could you please break that down into components, was it 20 psi or 20 inches of water - seems like a high pressure drop for the system?

A. (D. C. Foster, ANP-GE) I believe the numbers are 20 psi. I have the tabulation of the breakdown here of 15 points in the system which I would be glad to let you check over, but under the designed test conditions for this particular system the inlet pressure was something of the order of - well it was exactly 100 psia and at the outlet the calculations indicated 81 or 82 psia. I believe the measurements made during the test indicated a somewhat smaller pressure drop but still considerably larger than a matter of inches. I think the test measurements were of the order of 10 to 12 pounds across the air system.

Q. (B. O. Shaver, GE HAPO) What consideration is given for, say - after the filter following the precipitator in the event of carry over?

A. (C. L. Storrs, ANP-GE) We won't have anything following the filter. Anything that comes through following precipitation will go up the stack and be diffused into the atmosphere - it undoubtedly will include meterological control - contact reduce particular elements - Iodine 131 - and if we can reduce this be a factor of 10 with meterological control - we can then proceed to operate with greater flexibility and without the filter.

A. (J. Lieberman - AEC, Wash) Matter of control and filtrations will still be working together.

Q. (Stevens) Have you tried any other dust collection equipment with a reasonable chance of success aside from the electrostatic precipitator?

A. We have considered other things but haven't really tried anything except on a laboratory scale. High pressure drops are unacceptable in our operations - blowers are prohibitively expensive - the precipitator is about the only one that will do us very much good and stay within reasonable amount of money.

C. (W. Boone, GE-ANP) The business of introducing carbon particulate smoke into the streams - to properly evaluate this requires a scale model - I tried loading filter papers with carbon in an attempt for better efficiency by burning engine fuel and drawing it through the filter papers - no effect whatsoever. From this I conclude it is essential that the carbon must be introduced beforehand - also in the use of a relative number with chemical fuel flow through generator engines with a factor of 2½ less my gross efficiency on glass fiber filter paper varied by a factor of 2. When we are running without - however, we get 80% efficiency with a piece of filter paper. - the efficiency drops to about 40% - many of the isotopes it is not influencing at all - our data is preliminary but we have some reasonably solid ground for suspecting that - will improve our efficiency all the way around. We need quite a bit more data, however.

WASTE CALCINER OFF-GAS SYSTEM

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ABSTRACT

Provisions for decontamination of the spent fluidizing air and other calciner off-gases presented major problems in the design of the pilot plant now being constructed at the National Reactor Testing Station for converting ICPP aluminum nitrate wastes to solids. In passing through the fluidized bed, the fluidizing air entrains radioactive particulate matter, a volatile radioactive fission product, and the oxides of nitrogen formed in the calcination reactions. This paper describes the off-gas cleaning system adopted for the Waste Calciner and gives some of the process considerations that entered into its design. Expected performance is given for the various types of air cleaning equipment employed. Particular emphasis is placed on the novel operations involved in the use of silica gel as a medium for adsorbing ruthenium and trapping dust. A new fixed bed cleaning method is described for removing the dust and ruthenium trapped in the silica gel. The operability of this and other ruthenium adsorber operations is substantiated by the results of a research program designed to test the mechanical performance of this equipment.

INTRODUCTION

Safe and economical long term storage of fission product bearing wastes is the goal of research now being conducted to develop processes for converting liquid wastes to highly inert solids. Existing aqueous processes for recovering fissionable materials from spent reactor fuels yield radioactive waste liquids which must be retained in expensive permanent storage. These liquid storage containers, and probably any type liquid storage which can be devised, are of questionable durability to withstand the earthquake, corrosion and other damage which might occur in the 300 to 400 year confinement period needed to reduce the radioactivity to levels generally acceptable for discharge to man's environment. The wastes are potentially more safely and economically stored in the solid rather than the liquid state due to the reduced mobility of the fission products, and the reduced volume of stored material. Argonne National Laboratory and Phillips Petroleum Company have performed the research work for a fluidized bed calcination process to convert to a solid the aluminum nitrate type waste liquid generated in the Idaho Chemical Processing plant. The Waste Calcination Facilities now being constructed at the ICPP will serve as the pilot plant for further development of this process and to obtain engineering data for future fluidized bed waste calcination plants.

Fluidized bed calcination is an excellent means of converting the ICPP aluminum nitrate type waste to a granular, pneumatically-transportable solid, but in this case, it is also the source of a severe gas cleaning problem. In this operation particles of the fission product bearing calcined product (Al_2O_3) are entrained in the fluidizing air and one of the radioactive fission products (ruthenium) is volatilized. Decontamination factors of 10^4 for the dust and 10^3 for the ruthenium are minimum requirements for discharge to the ICPP stack when calcining the 200 day out-of-reactor MTR wastes which serve as the design basis for the Waste Calcination Facilities. This gas cleaning problem is complicated by the presence of a high level of radioactivity. Simple dependable equipment is needed to minimize the frequency of the costly operations involved in the maintenance of such radiochemical plants and to facilitate the decontamination operations preparatory to direct maintenance.

OFF-GAS SYSTEM

Two major processing requirements governed the design of the calciner Off-Gas System. One was the need to reduce the calciner off-gas dust concentration by a factor of 10^4 and the other to reduce the ruthenium concentration by 10^3. Commercial equipment was available for most of the dust removal services. This was not so for ruthenium. The limited amount of published data on ruthenium succeeded only in confirming our belief that we were dealing with one of the most capricious elements known to man. Further, ruthenium is present only to the extent of 0.11 grains RuO_4/1000 CF of calciner off-gas. The very effective caustic scrubbing method was not applicable to this problem as large volumes of caustic would also react with the oxides of nitrogen present in the off-gas to give a neutralized waste having a volume larger than the acid waste originally fed to the plant. Water scrubbing would yield a mixture of ruthenium and nitric acid from which the ruthenium could be separated only by extreme and costly processing. These difficulties led to the search for a solid material to which ruthenium would adhere and preferentially separate from the water, oxides of nitrogen, and other components of the off-gas. This type separation was suggested by the well-known "plating-out" tendency of RuO_4 on many types of surfaces. Phillips Petroleum investigated a number of these substances as well as commercial adsorbents. As a result of their laboratory research, silica gel was selected for use in the Waste Calcination Facilities.

The off-gas system which was developed to remove both dust and ruthenium from the calciner off-gas is shown in Figure 1. Dust which is collected in the first two devices - calciner cyclone and venturi scrubber - is returned to the calciner fluidized bed. Most of the particles collected in this equipment agglomerate and pass out of the calciner with the calcined product to solids storage.

Water circulating to the venturi scrubber and quench tower absorbs oxides of nitrogen and ruthenium until equilibrium concentrations of these two gases build up in the water. Thus, there is no net recovery of ruthenium or oxides of nitrogen in this part of the plant. Oxides of nitrogen pass on through the system and out to the ICPP stack. Ruthenium is retained in the ruthenium adsorbers.

Process

Aluminum nitrate type ICPP waste enters the 4-foot diameter calciner and is sprayed into the hot fluidized bed through atomizing nozzles. The manner in which the atomizing nozzles are operated determines to a great extent the dust loading in the gas leaving the bed. Fluidizing air enters beneath the bed through a concave, perforated grid. The heat required to bring the feed to the 400°C calcination temperature and to support the reaction is furnished by heated

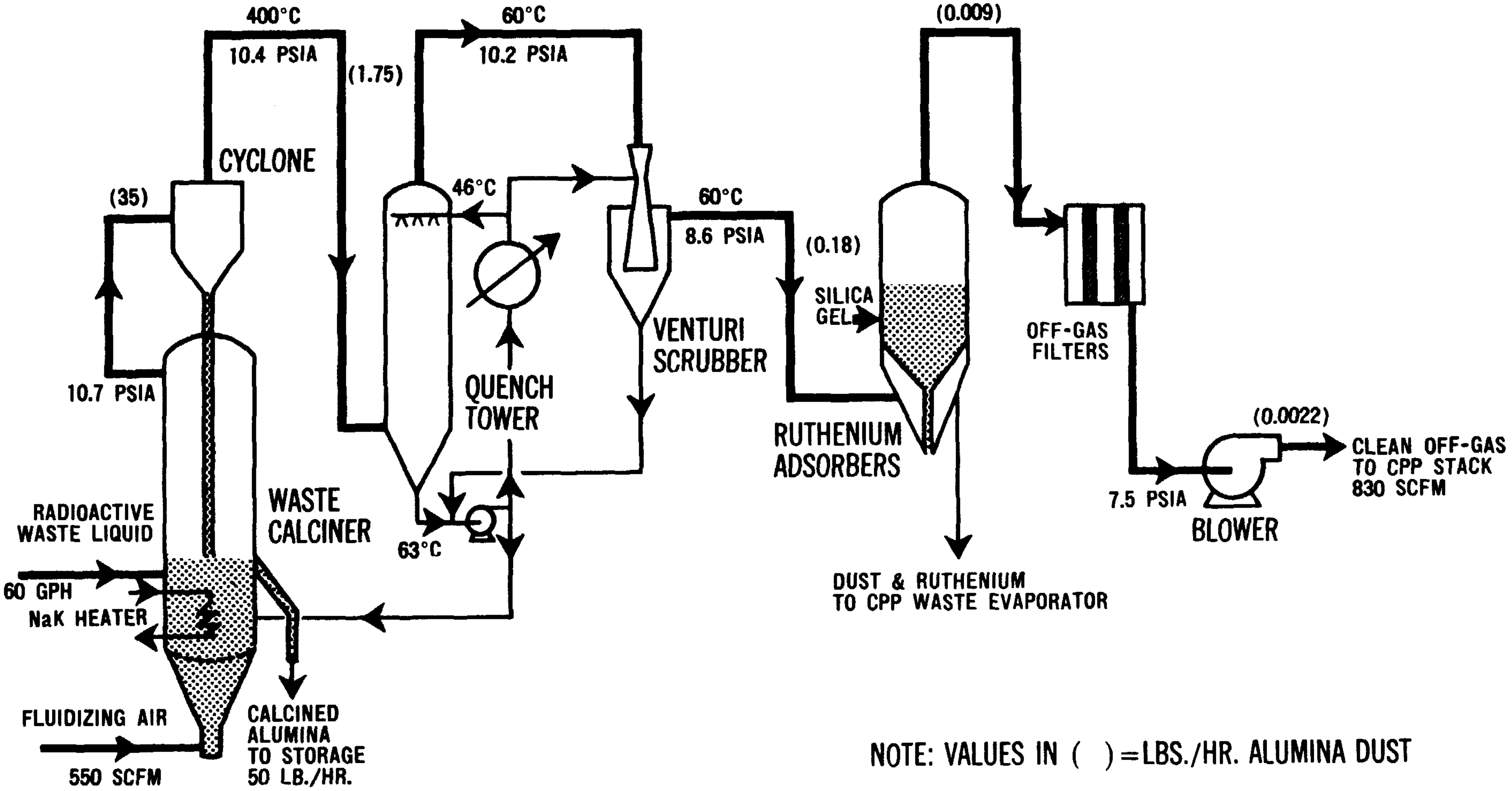


Fig. 1 —Waste calciner off-gas system.

NaK circulating through an exchanger located in the fluidized bed. Fluidizing air is preheated in the fired heater which is used to heat the circulating NaK to 760°C. The composition and quantity of the calciner off-gas are shown in Table I.

The calciner cyclone is a highly efficient unit consisting of 16 parallel cyclones of 4-inch diameter. Fines collected in this unit flow by gravity to the fluidized bed through a dip leg.

The second dust removal device in the off-gas train is a venturi scrubber. This is preceded by the quench tower which cools the calciner off-gas to the venturi scrubber operating temperature. The large temperature spread between the calciner and the venturi makes the quench tower necessary - for a smaller temperature difference, sufficient cooling could be effected in the venturi alone. No packing is provided in the quench tower, an empty 5½-foot diameter by 9-foot vessel with 4 spray nozzles for atomizing the quench water. A commercial venturi scrubber and disengaging vessel are used for the dust removal service. Water is pumped to the venturi throat at a rate of about 20 gal./1000 CFM of off-gas.

Equilibrium concentrations of nitric acid and ruthenium, and a controlled concentration of dust build up in the water circulating to the quench tower and venturi scrubber. The equilibrium nitric acid concentration is 40 weight per cent. Total Al_2O_3 content of the liquid is maintained at about 10 mg/ml by a purge of 20 GPH which is returned to the calciner. Water circulation to the quench tower is 3770 GPH and to the venturi 1680 GPH. Heat transferred to the quench water in cooling the off-gas is rejected to the plant cooling water system through a shell and tube exchanger.

TABLE I

CALCINER OFF-GAS COMPOSITION

Component	Vol. %
O_2	16.4
N_2	58.5
$NO-NO_2$	3.5
H_2O	21.6

CFM (@ 400°C and 10.7 PSIA) = 2840

Dust and ruthenium are trapped in the silica gel beds of the ruthenium adsorbers. These beds are periodically regenerated with water to remove the accumulated dust and adsorbed ruthenium.

Final cleaning of the off-gas is accomplished in three parallel units, each consisting of a Fiberglas prefilter followed by a glass-asbestos final filter. The prefilter has an NBS discoloration test efficiency of 30 - 35 per cent and the final filter a DOP efficiency of 99.97 per cent. The filter face velocities are 180 ft./min. during normal operation, 220 ft./min. during adsorber regeneration, and 270 ft./min. during filter replacement. Filter life is expected to be 600 to 1000 hours.

Filter replacement is carried out remotely due to the high radiation intensity of the accumulated dust. Two of the three parallel units are left on stream while the third is being replaced. A filter is shown in the on-stream position in Figure 2. The filter elements are contained in a disposable housing which is equipped with internal gas inlet and outlet valves (not shown in Figure 2). When a filter is to be removed these internal valves and the inlet and outlet valves in the piping are closed manually from the operating corridor by means of the valve operators and handles shown. The flanges are disconnected and the filter is lifted into the lead shielded (6-inch thick) transport cask. The cask is then lifted from the cell and removed to a burial ground where the filter container is deposited.

A 16 stage centrifugal blower provides the 6.9 PSIA pressure differential needed to pull the off-gas through the cleaning equipment and maintain all portions of the system under vacuum. It is driven by a 200 HP electric motor. The calciner and its off-gas system must be maintained at a negative pressure with respect to the cells so that any leakage will be fresh air into the processing equipment rather than contaminated air to the cell ventilation system.

Condensate formation in the off-gas leaving the venturi scrubber would cause damage in the silica gel (decrepitation), filters, and blower. A heater (not shown in Figure 1) raises the off-gas temperature to 66°C before it enters the silica gel. This temperature is maintained up to the filters by heating the cells housing the adsorber valve manifolds, adsorbers, and filter inlet piping manifolds.

Performance of Off-Gas Equipment

Expected performance of the off-gas equipment is difficult to predict due to uncertainties as to the quantity and size of particles which will be generated in the calciner and a lack of data for operation of the elements of the off-gas system as an integrated unit. Efficiencies and particle size distribution were assumed for the design basis, using data obtained by Phillips in a 6-inch diameter calciner equipped with a cyclone and venturi scrubber and operated on a synthetic, non-radioactive feed. The design performance of the various elements of the off-gas system is shown in Table II.

RUTHENIUM ADSORBERS

The results of the Phillips ruthenium decontamination studies suggested the use of a regenerable silica gel bed for removing ruthenium from the waste calciner off-gas. This work showed that silica gel would adsorb the ruthenium species generated in the laboratory under waste calcination conditions of temperature, pressure, and composition. When this synthetic calciner off-gas was cooled to around 60°C and passed through silica gel at a velocity of 1.0 ft./sec., or less, decontamination factors of 10^3 were obtained. The silica gel continued to remove ruthenium with this same efficiency after a total bed loading of 40 grams of ruthenium per cubic foot of silica gel. Fair desorption of the ruthenium from the bed could be obtained by washing with water.

Previous experimental work by the Bureau of Mines[1,4] and Sachsse[3] with moving coke bed filters, indicated that silica gel, when placed in the calciner off-gas system, would soon become clogged with dust. In fact, previous plant[5] and experimental experience with coke bed filters led to the consideration of using the ruthenium adsorbers as dust removal devices. In order to employ silica gel as a dust and ruthenium removal medium, it was first necessary to develop a simple, remote method for cleaning the bed of radioactive dust. The method of dust removal used in moving coke bed filters was considered much too complex

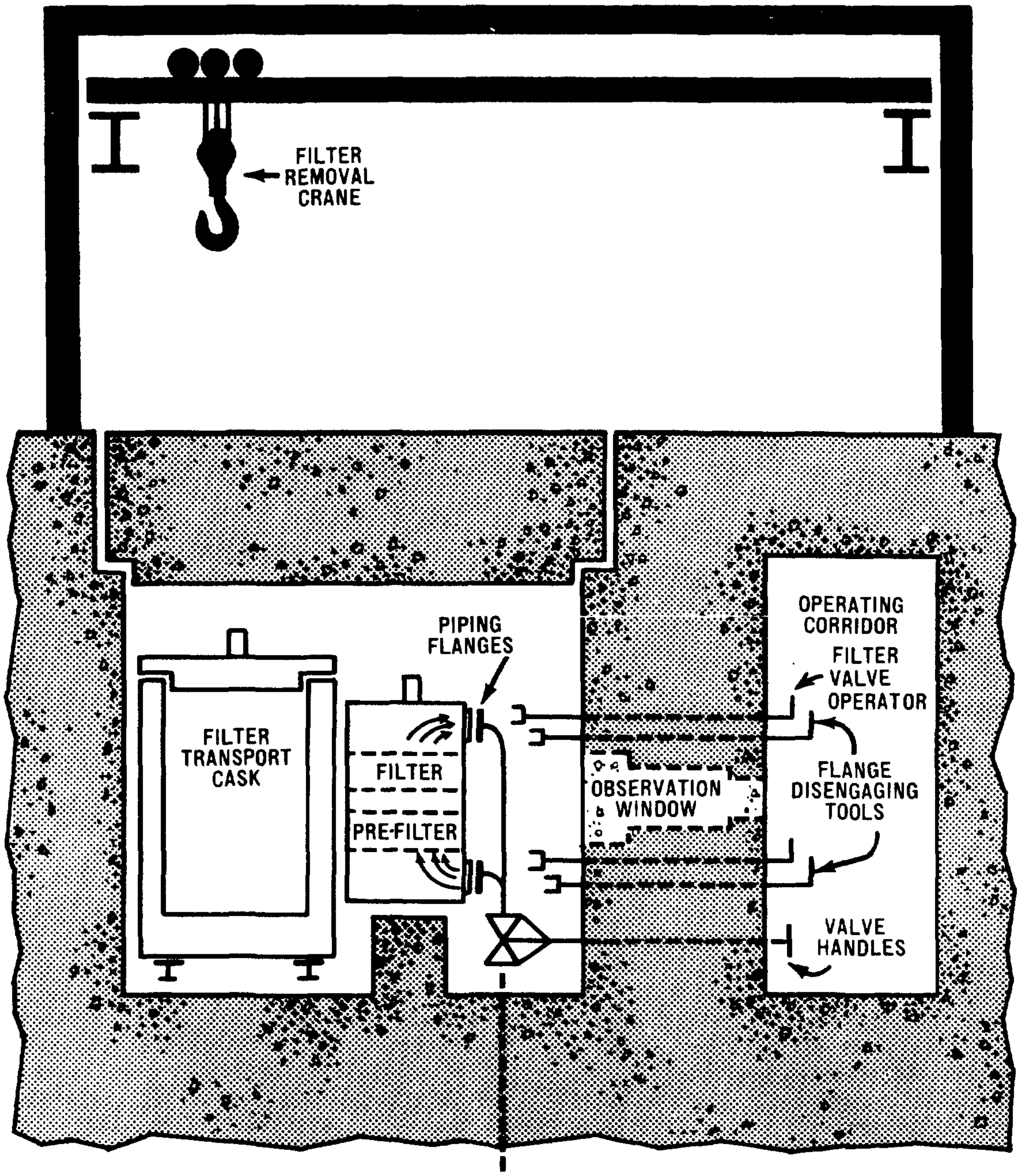


Fig. 2—Off-gas filter.

mechanically for use in a radiochemical plant. A ruthenium adsorber operating cycle was proposed and Fluor was asked to conduct a very specific research program[2] directed at determining the mechanical workability of the proposed scheme and developing alternative methods where needed.

TABLE II

DESIGN PERFORMANCE OF OFF-GAS EQUIPMENT

	Calciner Cyclone	Venturi Scrubber	Ruthenium Adsorbers	Off-Gas Filters
Inlet Dust Loading, Grains/1000 CF	1500	146	12	0.38
Design Dust Removal Efficiency, %	95	95	95	75
Pressure Drop, Inches H_2O	8	40	6 to 14	1 to 4

INLET PARTICLE SIZE DISTRIBUTION, WT. %

Size, Microns				
> 147	77.3			
20 - 147	6.0			
2.9 - 20	6.6	12.8	17 ($>1.2\mu$)	-
0.6 - 2.9	7.0	58.8	18 ($0.6-1.2\mu$)	
0.2 - 0.6	2.8	25.6	51	-
< 0.2	0.3	2.8	14	-

Operation of Ruthenium Adsorbers

Out of the Phillips and Fluor research, a method was evolved for operating the ruthenium adsorbers. This is shown schematically in Figure 3.

1. Adsorbing and Filtering

Four 7-foot diameter adsorbers are being installed in the Waste Calcination Facilities. The filtering/adsorbing bed consists of 6 to 12 mesh silica gel supported on a conical grating which is sloped at 30° from the horizontal to permit emptying the silica gel by gravity flow to the 8-inch diameter fluidizing leg. The bed varies in depth from 36 to 62 inches. Restrictive orifice distributors are placed below the bed to compensate for this difference in bed height.

Figure 3A shows one of the adsorbers in the on-stream position. Three of the four adsorbers are on stream at any one time, while the fourth is being regenerated, or held in standby. With three adsorbers on stream, the off-

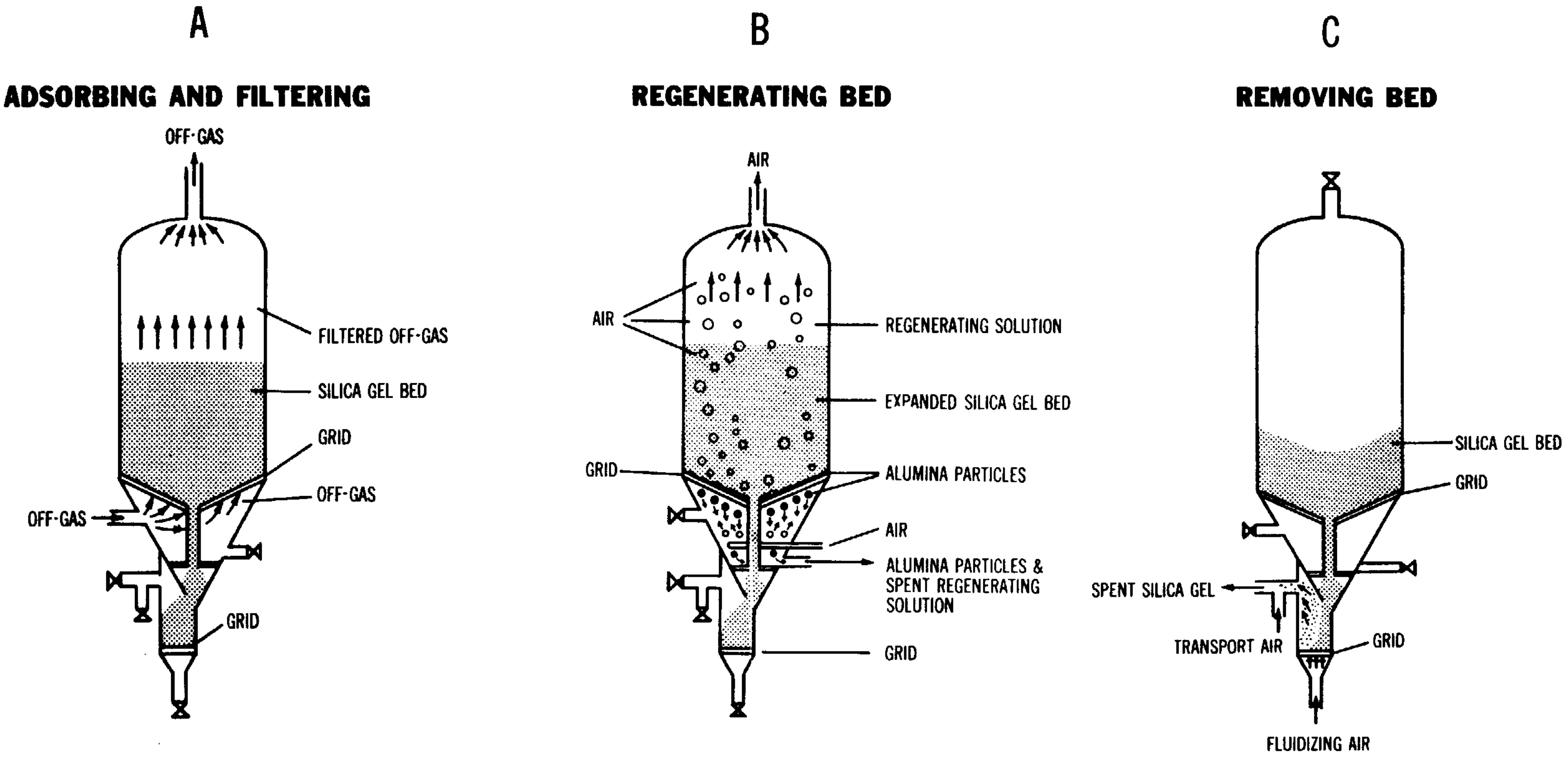


Fig. 3—Operation of ruthenium adsorbers.

gas superficial velocity through the bed is 0.33 feet per second. At this velocity, the pressure drop through the clean bed is 4-inches of water and through the distributing orifices 1.7-inches.

The laboratory work shows that ruthenium and dust both collect almost quantitatively in the lower 25 to 30 per cent of the bed. During plant operations, the build-up of dust on the bed rather than the degree of ruthenium adsorption will probably determine the length of time between regenerations, estimated to be 10 to 30 days.

2. Regenerating

The regenerating operation is shown in Figure 3B. Ruthenium removal is effected by washing the bed with three volumes of water. During the second wash, the water level is held above the silica gel bed and air is admitted below the grid through a sparger at a superficial velocity of 0.15 ft./sec. The air expands the silica gel, which has a specific gravity slightly above that of water, and causes a mild agitation of the granular particles. The smaller and heavier alumina particles become disengaged from the silica gel during this operation and fall to the bottom of the adsorber where they are swept out by the circulating water and are eventually pumped to the ICPP process waste evaporator. There is some indication that a small portion of the alumina particles adhere to the silica gel in a manner which is not detrimental to subsequent off-gas flow through the bed (i.e., pressure drop does not increase).

3. Drying

After regeneration, the silica gel bed is dried to 25 weight per cent contained water - the equilibrium water content of the bed when in contact with the calciner off-gas. Because of the possibility of contamination, the air used in drying is passed through the adsorbers which are on stream and into the off-gas filters.

4. Removing Bed

Should a silica gel bed become spent with respect to ruthenium removal or if it becomes necessary to perform maintenance in or on a contaminated adsorber, provisions are made for transporting the radioactive silica gel to the calciner product storage. As shown in Figure 3C, spent silica gel is pneumatically transported to the solids storage containers by a fluidizing leg at the bottom of the adsorber. The relative rates of the fluidizing and transporting air streams is determined by the pressure drop observed in the transport line.

Experiments to Evaluate Mechanical Performance

Evaluation of the mechanical performance of the ruthenium adsorbers was conducted in two parts. The first, bench scale tests, was undertaken to develop a simple method of removing accumulated dust from the silica gel. The second, one-third scale tests of the proposed adsorber, was undertaken to determine the effects on the silica gel of repeated saturation, washing, and drying operations, and to check the proposed schemes for replacing contaminated silica gel.

1. Bench Scale Tests

The bench scale tests were conducted in a 6-inch diameter metal cylinder containing a 23-inch bed of silica gel. The plant filtering operation was simulated in this apparatus by subjecting the bed to air containing fine alumina dust and water vapor in about the same concentrations as are expected for the plant ruthenium adsorber feed. The alumina dust, a fine cut from a laboratory cyclone, was made by grinding some of the product of the Phillips 6-inch calciner. A rough approximation of the particle size distribution of this dust was obtained by counting the various size particles observed under a microscope:

Particle Size Microns	Observed Particle Distribution %
> 10	10
5 - 10	30
1 - 5	50
< 1	10

The effectiveness of the new dust removal technique is illustrated by Table III which shows that only a short period of mild air agitation is needed to return the bed to its clean pressure drop. In this experiment emphasis was placed on using small quantities of air for agitation as all effluent regeneration air from the plant adsorbers is considered contaminated, and thus it must be handled by the off-gas filters and blower.

This procedure - whereby the bed is flooded with water and air is bubbled through the bed and the water - does not appear to result in carrying dust into the bed. Visual inspection of the bed did not reveal any significant dust penetration due to the cleaning procedure.

Although the bench scale test was intended primarily for developing a method of cleaning the silica gel, pressure drop buildup and efficiency data taken during this experiment give some idea of what might be expected when the plant goes into operation. These are shown in Table III and Figure 4. However, since the plant dust will probably contain a higher per cent of 1 micron and smaller particles, the ruthenium adsorbers are expected to be less efficient than the bench scale filters and the rate of pressure buildup will probably be greater than shown in Figure 4.

2. One-Third Scale Tests

These tests were conducted in a one-third scale model of the proposed ruthenium adsorbers. The plant regeneration operations were simulated in this apparatus by subjecting the silica gel bed to moist air (same concentration H_2O as plant off-gas, first, then slowly increasing to bring silica gel to its maximum water holding capacity), to liquid water, and to dry air. Each complete cycle required about 56 hours. A long saturation period (about 40 hours) was found necessary to insure against the tendency of silica gel to decrepitate when contacted with liquid water. We found that silica gel containing even as much as 39 weight per cent water (40% is saturation point) decrepitated when contacted with liquid water.

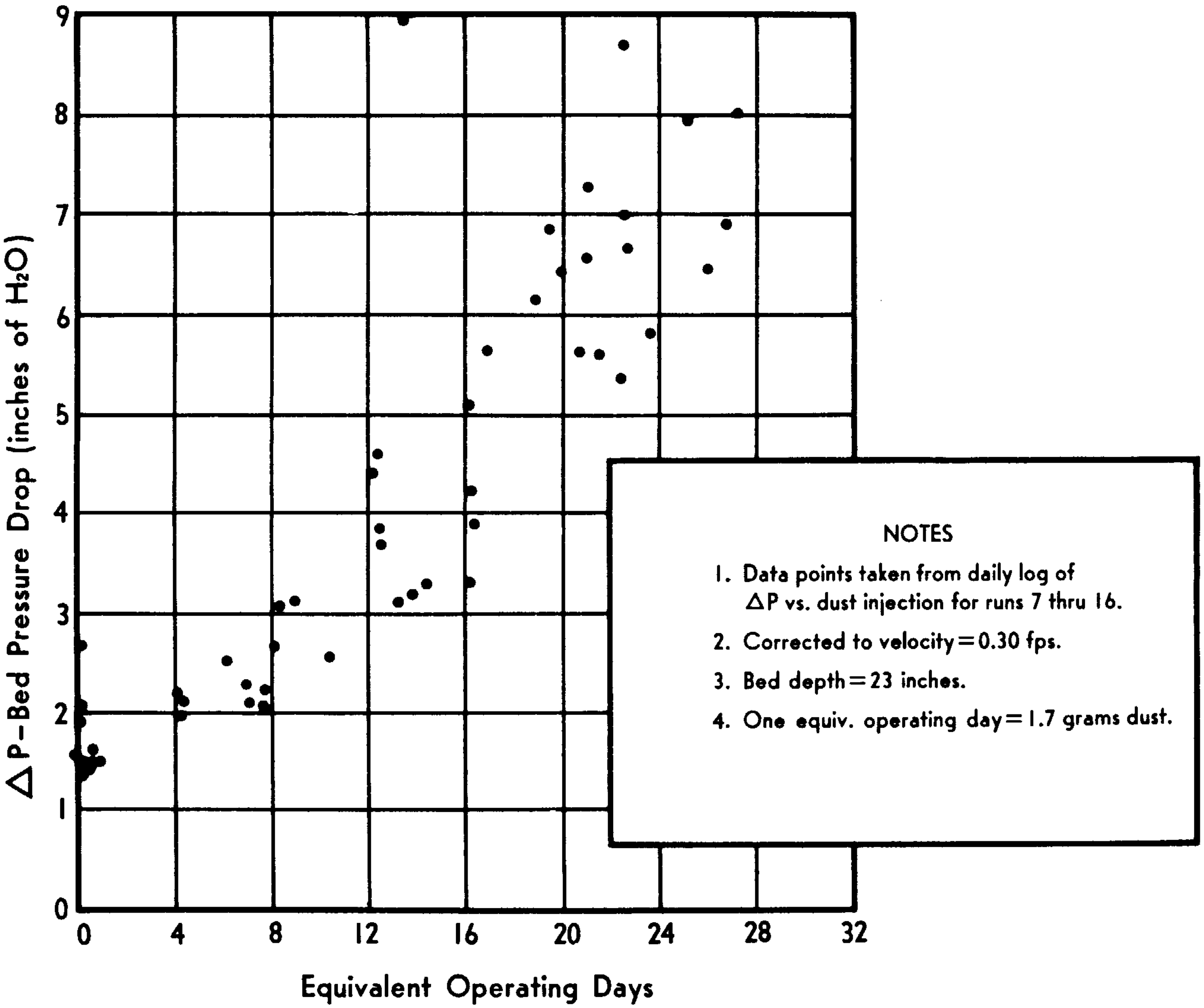
After 30 cycles of 56 hours each we found the silica gel to be free flowing and readily removable from the test vessel by the fluidizing leg. A small increase in silica gel fines was noted but the quantity generated was insignificant in its effect on pneumatic transport. The bed pressure drop increased from 1.5 inches of water for the first cycle, to 2.0 inches for the 30th cycle. This is a tolerable increase in view of the 8 to 25 regenerations per year expected for each plant adsorber. No attempt was made

TABLE III

TYPICAL RESULTS OF BENCH SCALE TESTS

SILICA GEL DUST FILTER

Run No.	10	11	12	13	14	15	16
Length of run in equivalent plant operating days	13.5	19.5	22.5	23.5	21	26.5	26
Pressure Drop, Inches H_2O							
Start of run	2.0	1.5	1.5	1.4	1.4	1.5	1.5
End of run	9.0	6.9	7.0	6.7	7.3	6.9	6.5
After regeneration	1.5	1.5	1.4	1.5	1.4	1.5	1.6
Regeneration							
Duration of Air Flow, Min.	180	90	45	22	11	6	6
Air Superficial Velocity, fps	0.15 to 0.20 →						0.15 to 0.20
Regen. Solution Volume, % Bed Vol.	300 →						300
Filtration Efficiency, %	99.2	99.0	99.2	99.5	99.5	99.8	99.5



NOTES

1. Data points taken from daily log of ΔP vs. dust injection for runs 7 thru 16.
2. Corrected to velocity = 0.30 fps.
3. Bed depth = 23 inches.
4. One equiv. operating day = 1.7 grams dust.

Fig. 4 — Effect of dust accumulation on pressure drop through silica gel bed.

in the one-third scale test to employ the dust removal technique developed in the bench scale test.

The decrepitation characteristics and water holding capacity of the silica gel changed markedly after repeated regeneration cycles. After 10 cycles, silica gel dried with air at room temperature and humidity did not decrepitate when subjected to liquid water. After 30 cycles the silica gel could not be made to decrepitate even after drying to 245°C. The water holding capacity changed from 40 weight per cent adsorbed new to 33 per cent at 10 cycles, 30 per cent at 20 cycles, and 27 per cent at 30 cycles.

Pneumatic conveying was shown to be an impractical method of filling the adsorbers due to attrition of the silica gel. The plant adsorber filling operation was changed to gravity flow as a result of this test.

CONCLUSION

The waste calcination pilot plant facilities described here should provide valuable information for improving the decontamination of radioactive aerosols encountered in many other operations as well as in the fluidized bed calcination of ICPP aluminum nitrate type waste. The research work performed by Argonne, Phillips, and Fluor provides a good basis for design of the pilot plant off-gas system. However, the data secured in operating the pilot plant will no doubt provide a firmer basis for the design of full scale plants and for improving the process.

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(4) Wainwright, H. W., Kane, L. J., Wilson, M. W., Shale, C. C., and Ratway, J., Ind. Eng. Chem. 46, 1123 (1956)

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THE ADSORPTION OF VOLATILE RUTHENIUM ON SILICA GEL

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ABSTRACT

The removal of volatile ruthenium by solid adsorbers from an air-nitric acid-water vapor phase was investigated. Silica gel was selected because it exhibited high affinity for ruthenium and the adsorbed ruthenium could be removed from the silica gel by washing with water. Decontamination factors obtained were in the range 100 to 1000 and total loadings as great as 58 grams of ruthenium per cubic foot of silica gel were experienced without obtaining a breakthrough of ruthenium.

INTRODUCTION

Since the beginning of the atomic energy industry, it has been recognized that under certain conditions radioactive ruthenium can become an environmental hazard due to the formation of volatile compounds, which are readily dispersed in the environs. A laboratory study of methods for removing volatile ruthenium from calciner off-gas was made at the Idaho Chemical Processing Plant (ICPP) concurrently with a study of the fluidized bed calcination of radioactive wastes.

The problem arose from laboratory data which indicated that at 400°C, the operation temperature proposed for the fluid bed calcination of radioactive aluminum nitrate wastes, the ruthenium in the waste was almost totally volatilized, presumably as ruthenium tetraoxide. This volatile ruthenium contains appreciable amounts of ruthenium-106, and in young wastes, ruthenium-103. Inasmuch as the off-gas from the calciner is to be released to the environment, it was necessary to provide some means of removing ruthenium from the off-gas stream.

The information reported here is a review of the study made at the ICPP by Hanson, Newby, and Rohde(2) and a summary of the most recent results obtained by Anderson and Rhodes(1).

Equipment

A simulated calciner off-gas was generated by continuously injecting a nitric acid solution containing ruthenium into a calciner maintained at 400°C as shown in Figure 1. In later models the U-tube adsorber was

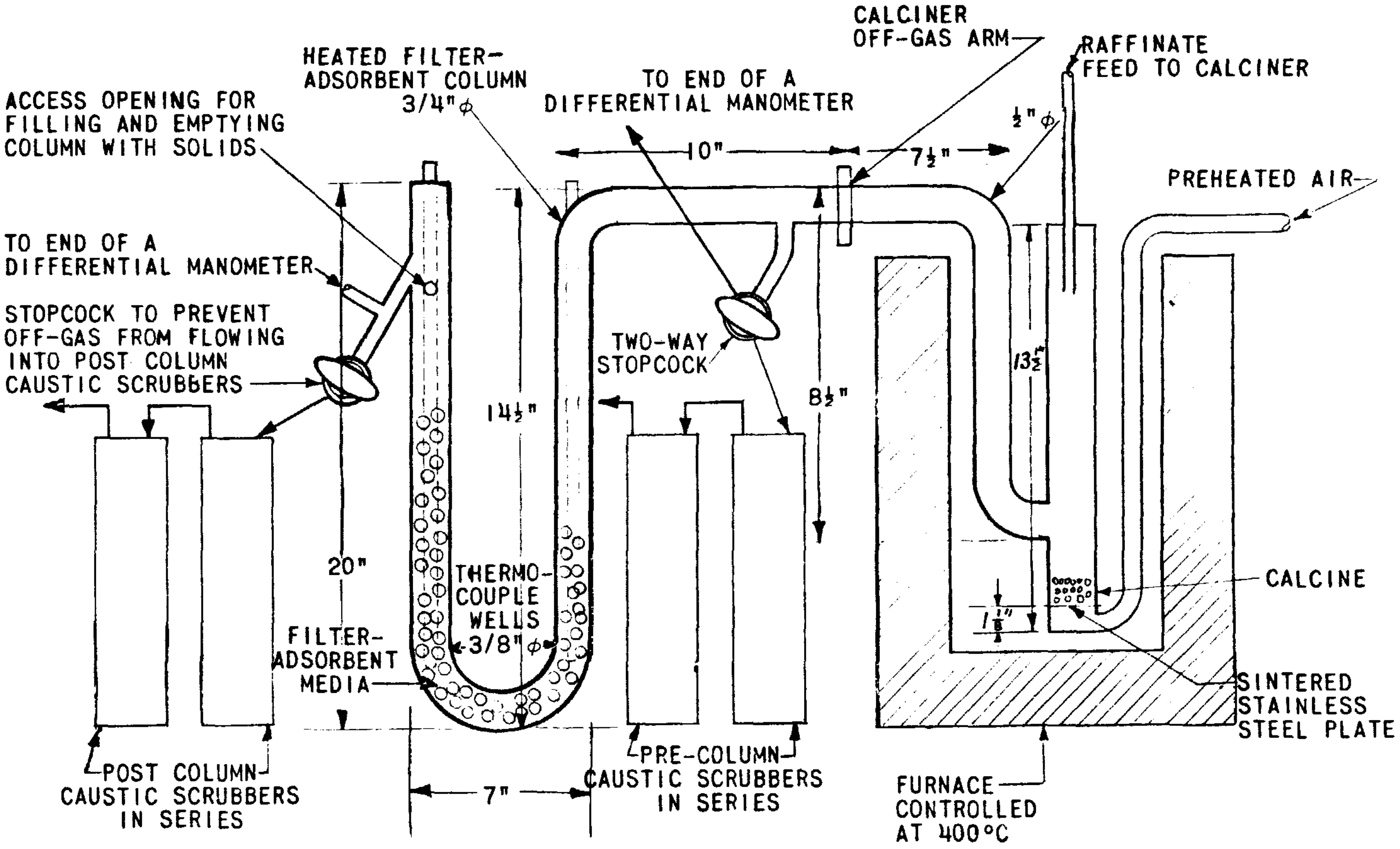

Fig. 1—Ruthenium calciner and adsorber equipment.

replaced by a straight tube. The feed solution contained only nitric acid and ruthenium traced with ruthenium-106. Aluminum nitrate was not included in the feed solution to avoid the formation of large amounts of solid with the subsequent problem of frequent cleanout of the calciner.

Selection of Adsorbent

The method of approach was simply to generate the volatile ruthenium species and attempt to remove it from the off-gas stream by adsorption on a variety of solid adsorbents. The results of several short term laboratory tests with solid adsorbents are shown in Table 1. From these tests, which show ruthenium decontamination across the adsorber column, it is evident that several materials have a reasonably high affinity for the volatile ruthenium. Some of the adsorbents (alumina and molecular sieves) were eliminated because of physical degradation by the components of the off-gas and others were rejected (marlex, stainless steel, alumina) because the ruthenium was held so tightly by the adsorbent that it was impossible to remove the adsorbed ruthenium by washing with water or acid.

TABLE 1

THE ADSORPTION OF RUTHENIUM ON SOLID ADSORBENTS

130 cc of adsorbent at approximately 100°C

Adsorbent	Mesh Size of Adsorbent	Ruthenium Decontamination Factor
None (blank)	--	1.3
Silica gel	6-16	1200
Activated Alumina (commercial)	8-14	2600
Marlex	1/4" x 1/4" x 1/16"	325
Alumina (calcined at 400°C)	28-65	100
Linde Molecular Sieve Type 4A	1/16" pellets	46
Kaolin Cracking Catalyst	3/16" pellets	50
Porous Glass No. 7930	12-25	2500
Carpenter-20 Yorkmesh	--	178

SILICA GEL STUDIES

Silica gel was chosen for further study because of its relatively high affinity for ruthenium, physical stability of the material under calciner operating conditions and ease with which the adsorbed ruthenium could be removed from the silica gel by washing. Figure 2 shows the elution of ruthenium from silica gel with various wash solutions. Water functioned equally as well as acids in removing the adsorbed ruthenium.

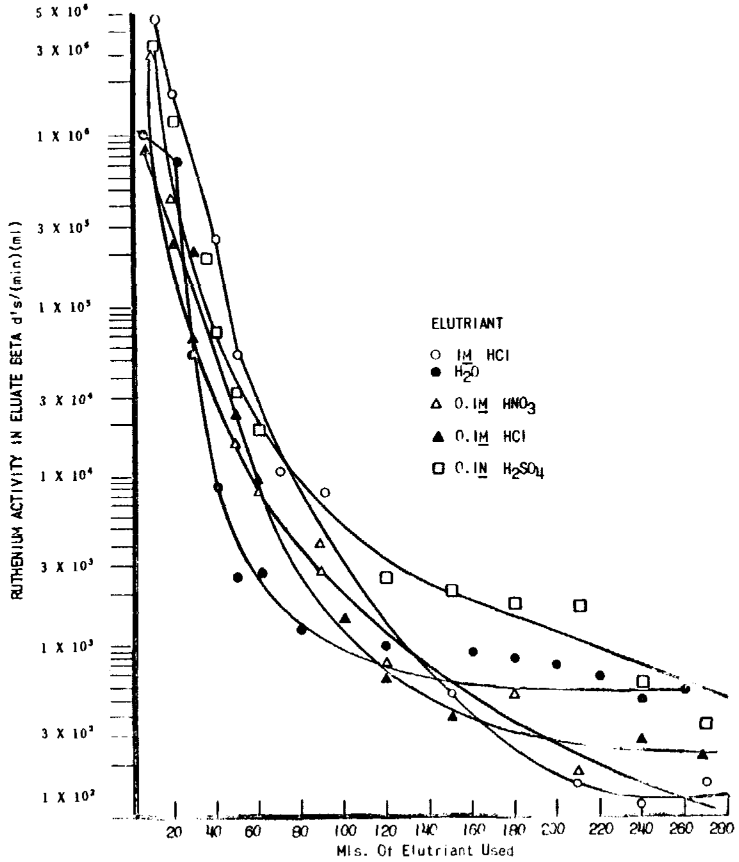

Fig. 2—Elution of ruthenium from silica gel (27 cc of silica gel at 60 C).

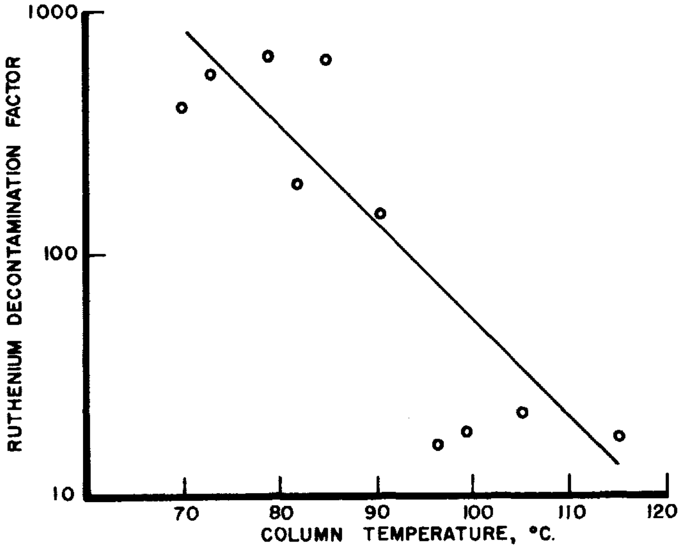

Fig. 3 --Ruthenium adsorption on silica gel.

Effect of Vapor Velocity

Laboratory studies indicated that the superficial vapor velocity within the range 0.6 to 1.2 ft/sec had no noticeable effect on the adsorption of ruthenium; however, the lower vapor velocities very likely produced a steeper concentration gradient within the column.

Effect of Column Length

Columns of 25 inches were of sufficient length to remove essentially all of the ruthenium under favorable operating conditions. When the length was reduced to 13 inches, the ruthenium DF was reduced to one tenth to one hundreth of the DF obtained with the longer column.

Effect of Temperature

The effect of temperature was found to be very critical in its effect on ruthenium DF. Some of the data from one run are shown in Figure 3. In general, it appeared that operation of the adsorbing column just above the dew point was the most favorable temperature for adsorbing ruthenium.

Determination of Loading Capacities

The determination of loading capacities during several adsorption-desorption cycles was attempted using a laboratory apparatus similar to that shown in Figure 1 with only minor modifications to permit continuous operation for several hundred hours. The results are shown in Table 2. A definite ruthenium breakthrough was not obtained in any of the runs. Run no. 1 was terminated due to inadequate temperature control of the silica gel column. This poor temperature control resulted in a relatively low average ruthenium DF. Run no. 2 was terminated due to lack of sufficient feed solution. During run no. 3, the fluidizing air supply was interrupted and volatile ruthenium was generated for about 24 hours in the absence of fluidizing air with poor temperature control on the column. This malfunction probably accounts for the low recovery of ruthenium during the wash cycle. Run no. 4 was terminated because it appeared that the loading capacity was so high that dust loading in the demonstration fluid bed calciner would necessitate

TABLE 2

RUTHENIUM ADSORPTION CAPACITY TESTS

110 cc of silica gel
approximately 100°C
Vapor Velocity 0.6 ft/sec

Run No.	Hours of Continuous Operation	Average Decontamination Factor	Loading Capacity grams Ru/cu.ft. of silica gel	Ru Eluted with Water at 60°C % of Total Adsorbed
1	140	23	22	55
2	233	326	40	75
3	209	394	24	11
4	621	1013	58	48

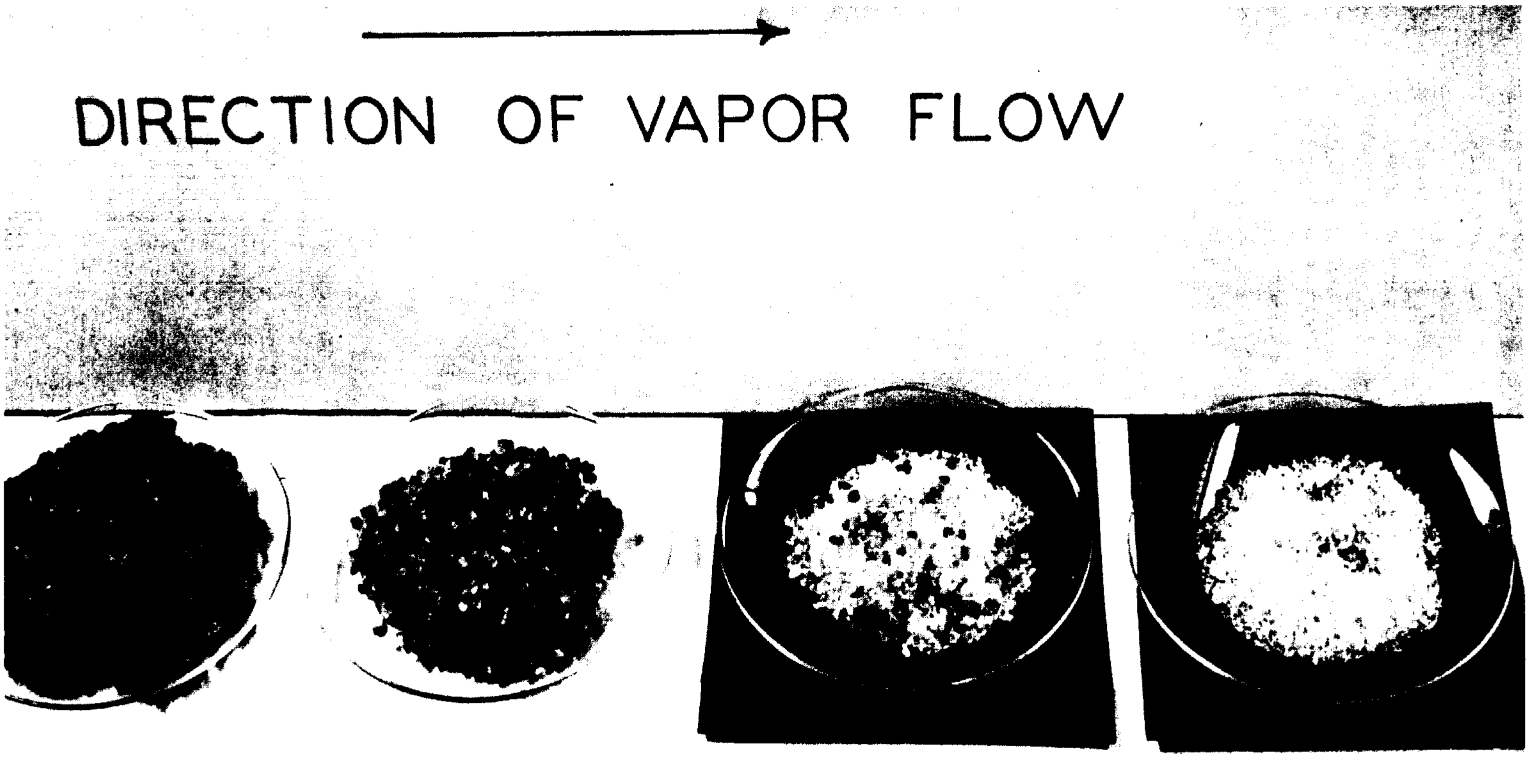

Fig. 4—Silica gel from ruthenium adsorber column.

washing the column long before the capacity of the silica gel for adsorbing ruthenium was exceeded.

Elution of the adsorbed ruthenium was moderately successful although an appreciable fraction of the ruthenium was retained by the silica gel as shown in Table 2.

The residual ruthenium in the column had no apparent detrimental effect on the adsorption of additional ruthenium. In fact, there appears to be a general trend of increasing ruthenium DF with continued use of the silica gel. Examination of the silica gel particles following the last run indicated a steep concentration gradient, Figure 4, with more than 98 per cent of the ruthenium being adsorbed in the first two-thirds of the column. Examination of the individual particles, which were blackened by the ruthenium, indicated that the ruthenium penetrated deeply into the particle, Figure 5. After sectioning an individual crystal, it was found that approximately 80 per cent of the total volume of the individual crystal was blackened by ruthenium.

Fig. 5—Silica gel from ruthenium adsorber column (Left, fragments of fractured particle; right, whole particle).

SUMMARY

Based on the laboratory data, it appears that silica gel can be used to remove ruthenium from a nitrogen oxide-air-water vapor off-gas stream sufficiently well under controlled conditions to warrant its use as a means for decontaminating the off-gas from a fluid bed calciner. Ruthenium adsorber units are included in the demonstration calciner(3), which is presently under construction at the ICPP, and a hot run using full activity level off-gas will be made as soon as possible.

REFERENCES

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3. MacQueen, D. K., and J. I. Stevens, Design Bases for ICPP Wash Calcination Facility, IDO-14462, 1959, (unclassified).

MEASUREMENTS OF ATMOSPHERIC DIFFUSION FROM AN ELEVATED SOURCE

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ABSTRACT

Diffusion from an elevated source under lapse conditions was measured utilizing uranine dye as a tracer. Comprehensive measurements of temperature and vertical and horizontal wind fluctuations were made at several levels on a 150-foot tower. The meteorological parameters are correlated with the ground-level air concentrations in an effort to establish predictors directly from Eulerian meteorological data. The effects of wind direction shear in the vertical on the maximum ground concentration is discussed. Techniques of dispersal, collection, analysis and the results of particle size counting are included. Diffusion parameters measured from the dye concentrations are included and compared with those presently used at the National Reactor Testing Station.

Introduction

In recent years atmospheric diffusion from ground-level point sources has been studied extensively at O'Neil, Nebraska through Project Prairie Grass in 1956 and the Great Plains Turbulence Project in 1953, sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center. The results of these comprehensive ground measurements have been extended to elevated sources by Cramer [1]. Other investigators, Moses [2], Stewart *et al* [3], Singer [4], and Smith *et al* [5] to mention a few, have studied diffusion from an elevated source, but their data have frequently been limited by the number of samples or they were concerned with a different aspect of the problem than the present discussion. It is believed that these experiments are the most comprehensive measurements of short range diffusion from an elevated source to date.

A total of 17 tests were performed from January to May 1959. The first test was discarded because of a slow wind shift during the period of the test resulting in three distinct concentration maxima. Uranine dye was used as a tracer for all tests as described by Robinson *et al* [6]. The characteristics of the dye are adequately described in the paper cited.

Instruments and Measuring Procedures

One hundred high volume Staplex air samplers were used at various arcs at the NRTS Grid No. 3. Initially arcs were set up at distances of 300, 400, 600, 1000, 1800, and 3400 meters from the release point. After the eighth test the arc at 3400 meters was discontinued and a new arc at 150 meters was added. The 300, 400 and 600 meter arcs were widened from 40 to 60 degrees at this time. After Test No. 8, arc spacing of samplers was 6° on the 150, 300 and 400 meter arcs, 2.7° on the 600 meter arc, 1.7° on the 1000 meter arc and 1.8° on the 1800 meter arc. The odd spacing arose from the fact that the grid was originally set up for a source 100 meters from the first arc rather than 300 meters where the meteorological tower was located.

Hurlburt X-934-AH glass fiber filter papers supported by MSA 2133 all dust filters were used to collect the samples of uranine dye. The glass filter papers were too fragile to be inserted in the Staplex high volume air samplers without some supporting medium. The air flow through the filter pairs was approximately 15 cfm, a rate rather low for the high-volume type sampler. According to Smith and Suprenant [7], the Hurlburt glass paper combines the best features of particle penetration, flow rate, pressure drop and dust loading for our purposes. Our own investigation revealed background characteristics superior to all filter media tested except Millipore AA filters. Other filters tested included SS 589, MSA 2133, and Whatman No. 42. The background blank of the filters (i.e. clean filter washed in distilled water) was five times that of pure distilled water in the first batch of filters used (Tests Nos. 1 to 6); after that the succeeding batches of filters used exhibited the same background blanks as distilled water. We attribute this reduction to some change in the fiber filler used in the Hurlburt paper. With the low background filters the lower detection limit, for 30-minute tests, of uranine dye was an air concentration of 1×10^{-9} g/m^3.

The dye solution was released at an elevation of 150 feet from the meteorological tower with an air flow of 500 cfm at 100 psi pressure. The dye solution was mixed at 3-1/2 pounds of dye per three gallons of water and was released over a 30 minute period. This resulted in a release rate of 0.88 g/sec of uranine dye. The writer is indebted to Dr. C. E. Lapple of the Stanford Research Institute for the design of the adjustable nozzle used to disseminate the dye solution. The droplet size was not determined, but it was assumed to be small. The dye solution was red while the plume was brown, the natural color of dried uranine dye stuff. Lack of fallout was evidenced by particle size studies included later and no appearance of dye on the snow-cover close to the tower. During the time when the correct solution of dye and nozzle adjustment were being determined fallout did occur and was readily visible on the snow-cover surrounding the tower.

Samples were collected for particle sizing during two tests. The first set were collected on the glass fiber papers but were unusable because the smaller particles were imbedded in the filter and not visible in sufficient number to give a good distribution. This phenomenon was also mentioned by Smith and Suprenant [7]. The second sample was collected on Millipore AA filter paper and examined under a microscope using the oil immersion technique. The results are presented in Table 1.

A third sample was attempted but the plume divided and missed the electrostatic precipitator employed for this test and insufficient particles were collected for sizing. The results listed in Table 1 are regarded as preliminary until more evidence is obtained. There is a tendency toward decreased particle size at greater distance but no significance is attached at this time pending more sampling of particle sizes.

The exposed filters were collected in covered plastic petri dishes and washed in 20 ml of distilled water. Four ml of one molar phosphate buffering solution were added to bring the solution to a constant Ph value. The concentration was read by measuring the fluorescence with a Photovolt Model 540 Fluorescence meter. Investigation indicated that the fluorescence was sensitive to Ph but not to temperature so the samples were analyzed at room temperature. One other departure from the method outlined by Robinson et al [6] was made in that a square quartz curvette was employed. There was evidence that scratches on round glass test tubes caused a change in the reading of the meter for the same solution.

TABLE 1

PARTICLE SIZE DISTRIBUTION

Arc Distance (meters)	Median Size (microns)	Standard Deviation (microns)
600	1.0	1.80
600	1.42	1.87
600	1.35	2.67
1000	1.20	1.50

Meteorological instrumentation included Beckman and Whitley anemometers at 20, 75 and 140 feet on the tower, bivanes at 20 and 140 feet, and temperature elements at 5, 75 and 150 feet. An Aerovane was placed at 3 meters on the 1800 meter arc.

Concentration Data

Figures 1, 2 and 3 illustrate the ground concentration data for three of the tests conducted. They are presented to illustrate the type of ground concentrations that occur with a release from an elevated source under unstable conditions.

Table 2 lists some of the pertinent data for the dye tests that are of particular interest to those using Sutton's [8] diffusion equations. An explanation of the method of determining the parameters seems in order. The stability parameter n was measured from wind speed profiles where available but rounded off to either 0.20 or 0.25, whichever was closer. The actual range of n values was 0.17 to 0.26. The values for distance to maximum concentration (d_{max}) and maximum concentration (χ_{max}) were obtained from a plot of the peak concentrations for each arc on log-log paper. The computed χ_{max} was obtained from

$$\chi_{max} = \frac{2Q}{e \pi \bar{u} h^2} \qquad (1)$$

The vertical diffusion coefficient C_z^2 was determined from the equation for d_{max}, i.e.

$$d_{max} = \left[\frac{h^2}{C_z^2}\right]^{\frac{1}{2-n}} \qquad (2)$$

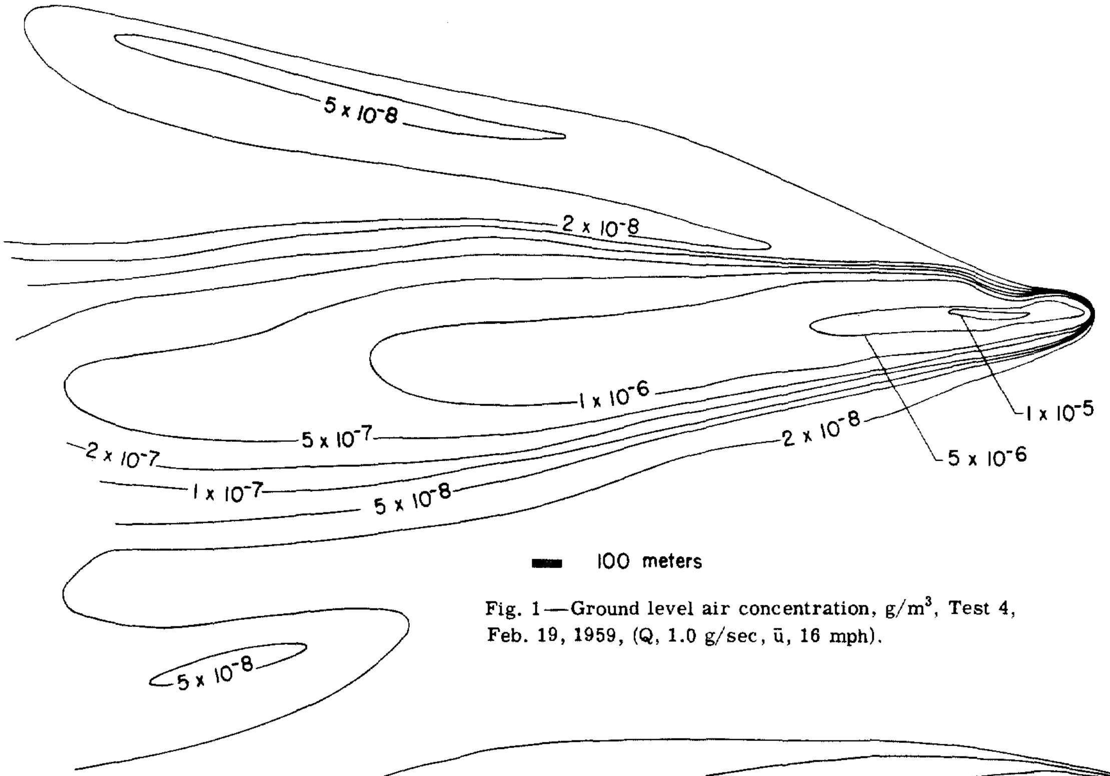

Fig. 1—Ground level air concentration, g/m^3, Test 4, Feb. 19, 1959, (Q, 1.0 g/sec, ū, 16 mph).

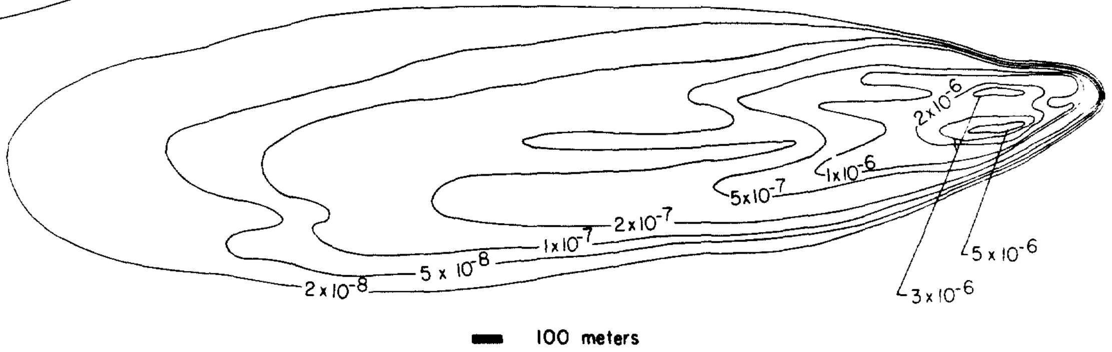

Fig. 2—Ground level air concentration, g/m^3, Test 6, Mar. 18, 1959, (Q, 0.79 g/sec, ū, 22 mpn).

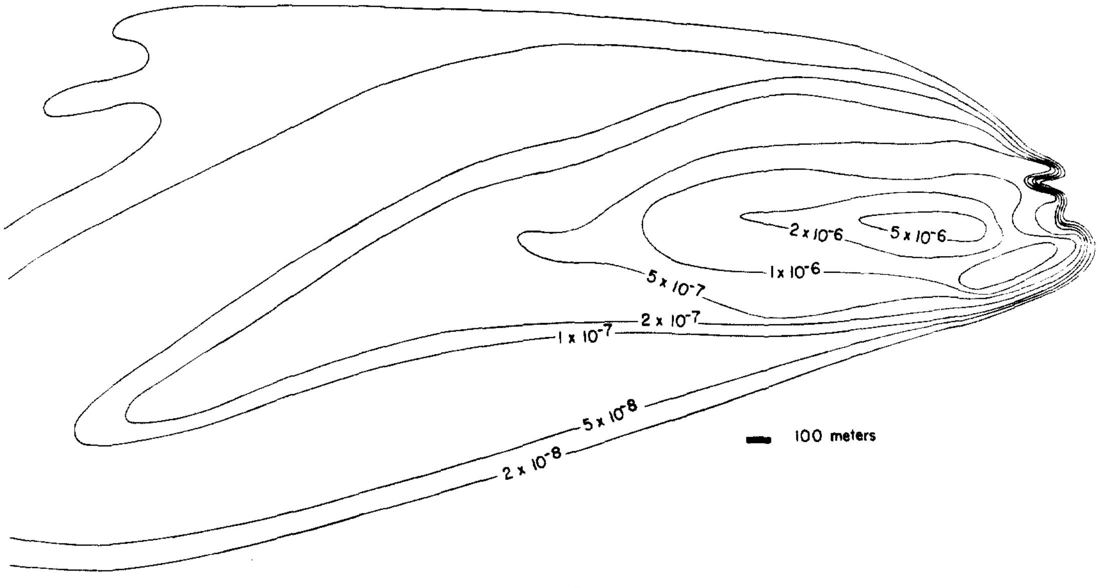

Fig. 3—Ground level air concentration, g/m^3, Test 15, May 4, 1959, (Q, 0.88 g/sec, ū, 15 mph).

TABLE 2

DATA FROM URANINE DYE TESTS

Run	Q (g/sec)	d_{max} (meters)	Assumed n	χ_{max} (g/m^3)	$\bar{u}_{140}$ (m/sec)	C_z^2 (m^n)	C_y^2 (m^n)	Computed χ_{max} (g/m^3)	$\chi(c)/\chi(m)$	$\sigma_\theta/\sigma_\epsilon$
2	0.77	700	0.25	5.0×10^{-6}	5.7	0.025	0.091	1.4×10^{-5}	2.8	M
3	1.39	300	0.20	7.9×10^{-6}	6.5	0.089	0.100	2.2×10^{-5}	2.8	1.1
4	1.00	400	0.20	1.8×10^{-5}	7.0	0.054	0.035	1.5×10^{-5}	0.8	M
5	3.20	530	0.20	2.6×10^{-6}	8.9	0.032	0.083	3.7×10^{-5}	14.2	1.3
6	0.79	650	0.25	4.0×10^{-6}	9.7	0.028	0.238	1.1×10^{-5}	2.8	1.5
7	0.88	600	0.25	4.0×10^{-6}	7.8	0.032	0.190	1.2×10^{-5}	3.0	1.4
8	1.00	560	0.20	2.2×10^{-6}	7.2	0.032	0.289	1.4×10^{-5}	6.4	1.9
9	0.88	470	0.20	2.8×10^{-6}	10.0	0.041	0.092	9.0×10^{-6}	3.2	1.9
10	0.88	940	0.25	2.2×10^{-6}	7.7	0.015	0.250	9.0×10^{-6}	4.1	M
11	0.88	315	0.20	3.4×10^{-6}	6.7	0.082	0.442	1.3×10^{-5}	3.8	2.5
12	1.32	940	0.25	6.7×10^{-6}	8.1	0.015	0.066	1.7×10^{-5}	2.5	1.0
13	0.88	460	0.20	1.2×10^{-6}	11.3	0.041	0.113	7.9×10^{-6}	6.6	1.6
14	0.88	480	0.20	6.1×10^{-6}	9.0	0.035	0.085	1.0×10^{-5}	1.6	1.4
15	0.88	300	0.20	7.4×10^{-6}	6.5	0.089	0.231	1.3×10^{-5}	1.8	1.7
16	0.88	730	0.25	2.6×10^{-6}	10.6	0.023	0.112	7.8×10^{-6}	3.0	1.5
17	0.88	250	0.20	3.0×10^{-6}	6.5	0.110	0.445	1.3×10^{-5}	4.3	2.3

σ_θ Standard deviations of lateral wind direction fluctuation
σ_ϵ Standard deviations of vertical wind direction fluctuation
(M indicates Missing)

The lateral diffusion coefficient C_y^2 was determined from the following definition:

$$\frac{\qquad}{Y^2} = \frac{1}{2} C_y^2 \; x^{(2-n)} \qquad (3)$$

It is valid only if we assume that the variance of the dye on the arc chosen (in this case the arc closest to d_{max}) is in fact the same variance as Sutton uses in his definition.

The values of C_z^2 range from 0.015 to 0.11 meters ^{n}. The values were somewhat lower than expected but still in the range of values generally accepted. The low values may have been caused by the relatively high wind speeds associated with most of the tests which probably reduced the looping that would have been expected with the lapse rates realized.

The values of C_y^2 range from 0.035 to 0.445 meters ^{n}. The values are somewhat larger than those used by many authors but it is felt that they are realistic when it is considered that no attempt was made, at this time, to remove bimodal tendencies or wind shear effect. The shear effect will be discussed later. These effects on the arcwise concentration distributions will obviously increase the lateral diffusion coefficient.

Sutton's diffusion model is based on a normal distribution, therefore, the normality of the concentration and wind data should be examined. Haugen [9] has set up criteria for values of skewness and kurtosis in the study of effects of sampler spacing on concentration data. The values for determining if the distribution is normal are: for skewness $B_1 \leq 0.10$, and for kurtosis $2.6 \leq B_2 \leq 3.4$: borderline cases are classified from $B_1 \leq 0.10$ and $1.70 \leq B_2 \leq 4.20$. Values for B_1 and B_2 for arcwise concentration distributions and the 140-foot level wind direction distribution are presented in Table 3. As indicated below in the table, only 17% of the cases of concentration data were normal. The addition of the borderline cases brings the total to 45% of all cases. The wind direction distribution at the height of the source is somewhat better, however, an inspection of the wind direction distribution at 10 feet indicates fewer cases of normal distribution than the concentration data. The kurtosis is about equally divided, in the concentration data, between platykurtic (curve too flat) and leptokurtic (curve too peaked). The leptokurtic cases were most frequently associated with skewed distributions.

The breakdown of the data at the end of the table indicates the number of normal cases of arcwise concentration distributions. There were 84 cases, of these 14 met the criteria mentioned above for normality and 24 additional cases were included under the definition of borderline normality. The remaining 46 cases did not meet the specified criteria for normality. The kurtosis of the curves is also indicated. The borderline cases are included since the interest here is only in whether the curve is platykurtic (flat) or leptokurtic (peaked). The curves were too flat in 28 cases and too peaked in 32 cases, therefore, only 24 cases were actually between the limits of kurtosis specified.

Figure 4 illustrates values for B_2 equal to 2, 3 and 4 so the reader may obtain a better understanding of the previous discussion. B_2 is equal to three for a normal distribution.

Figure 5 illustrates the variation of the cross plume standard deviation of concentration downwind from a continuous elevated point source. The tests were summarized according to the standard deviation of the 140-foot wind direction fluctuations. The range of the azimuth wind standard deviations is

TABLE 3

VALUES OF SKEWNESS (B_1) AND KURTOSIS (B_2)

TEST ARC		2	3	4	5	6	7	8	9
150	B_1								N
	B_2								N
300	B_1	0.13	0.84	0.003	0.92	0.06	0.94	0.08	0.95
	B_2	3.77	2.24	2.31	3.01	2.94	3.14	2.97	0.19
400	B_1	0.01	0.04	0.11	0.14	0.04	2.46	0.28	0.11
	B_2	2.90	2.05	4.52	2.24	5.07	6.59	4.15	0.33
600	B_1	0.00	0.01	0.67	0.08	0.04	0.28	0.09	0.01
	B_2	2.93	1.96	4.21	2.69	2.11	3.42	1.95	2.49
1000	B_1	0.00	0.11	0.00	0.34	0.02	0.00	0.48	0.15
	B_2	2.68	3.05	3.25	3.20	2.23	2.03	3.30	3.83
1800	B_1	0.13	0.19	0.17	0.44	0.20	0.25	0.02	0.09
	B_2	3.82	2.92	5.48	3.19	3.33	2.51	1.73	3.46
WIND	B_1	0.02	0.004	0.04	0.10	0.06	0.06	0.02	0.35
	B_2	2.98	2.40	5.46	3.99	3.27	3.60	2.65	3.15

TABLE 3 (Cont'd.)

VALUES OF SKEWNESS (B_1) AND KURTOSIS (B_2)

TEST ARC		10	11	12	13	14	15	16	17
150	B_1	0.038	1.51	N	0.13	N	0.95	N	2.18
	B_2	3.09	6.07	N	4.03	N	3.74	N	8.37
300	B_1	0.013	0.16	0.36	0.18	0.24	0.03	0.34	2.38
	B_2	2.47	2.38	1.56	3.67	4.56	4.24	4.60	5.46
400	B_1	0.05	0.46	0.19	0.69	4.34	0.32	0.03	4.17
	B_2	2.79	3.10	3.11	7.12	8.27	4.58	4.15	7.88
600	B_1	0.09	0.44	0.03	0.01	0.18	0.04	0.10	2.71
	B_2	1.94	4.45	1.89	1.84	3.65	2.63	3.88	6.38
1000	B_1	0.17	0.10	0.06	M	0.00	0.13	0.01	1.16
	B_2	2.41	2.17	2.48	M	2.76	10.4	2.30	5.65
1800	B_1	0.26	0.04	0.10	0.07	0.00	0.19	0.00	2.63
	B_2	2.85	1.96	3.21	2.59	2.01	4.98	2.25	8.60
WIND	B_1	0.17	0.09	0.09	0.00	0.011	0.01	0.09	0.44
	B_2	5.08	4.30	2.77	6.90	2.63	2.60	3.34	3.86

CONCENTRATION DATA

84 Cases 28 Platykurtic B_2 2.6
14 Normal 32 Leptokurtic B_2 3.4
24 Borderline

WIND DATA

16 Cases 1 Platykurtic B_2 2.6
7 Normal 7 Leptokurtic B_2 3.4
3 Borderline

(M indicates missing)

(N indicates no measurable concentration)

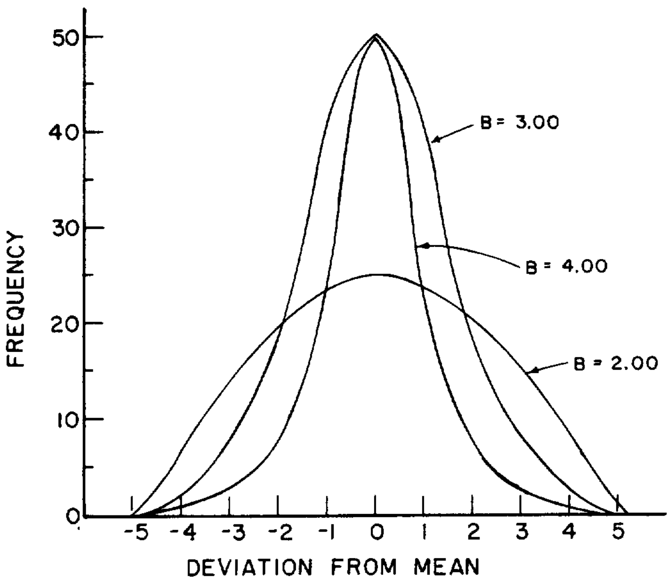

Fig. 4—Curves illustrating kurtosis for values of B_2 indicated (B_2 equal to three is a normal curve).

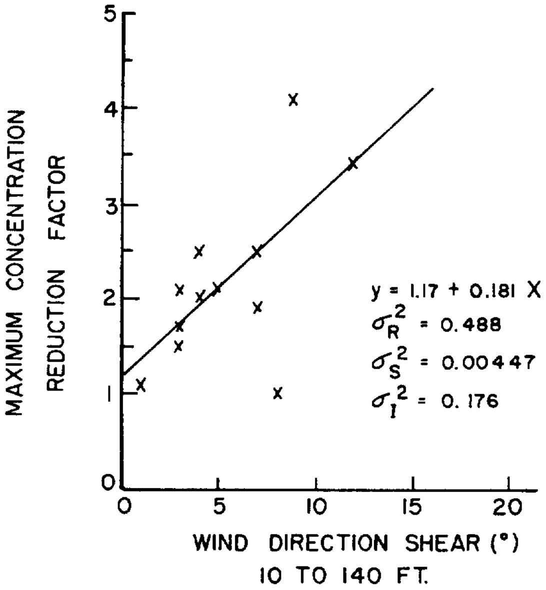

Fig. 6—Mean wind shear effect on maximum concentration.

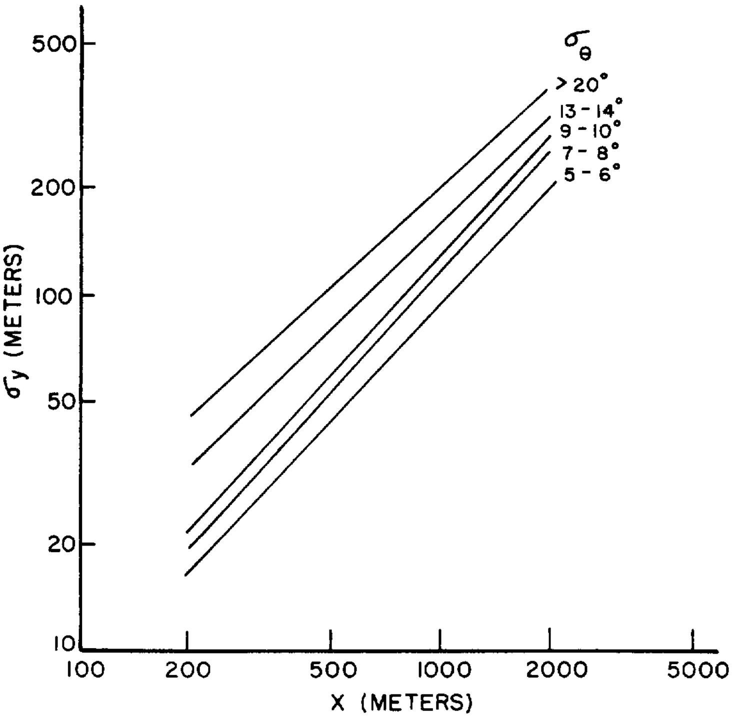

Fig. 5—Crossplume standard deviation of concentration downwind from a continuous elevated point source.

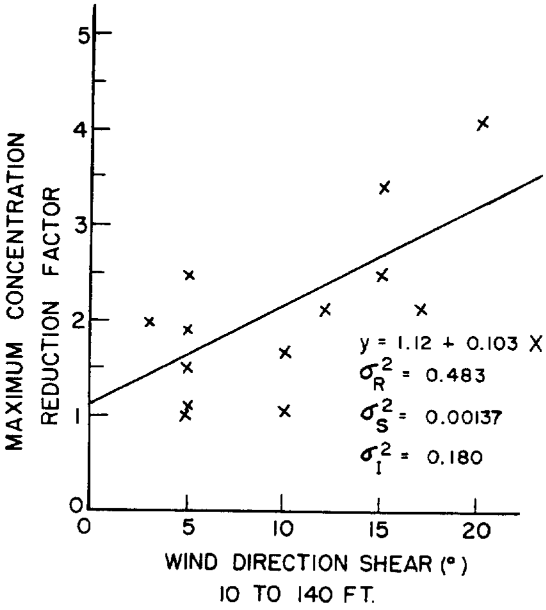

Fig. 7—Modal wind shear effect on maximum concentration.

indicated to the right of the lines in the figures. A recent paper by Cramer [10] using ground source data extrapolated to an elevated source indicates a slight convergence between near neutral and extremely unstable cases of crossplume standard deviation of concentration at distances beyond 2000 feet. There were insufficient data available to obtain any curvature to the lines in Figure 5 but there is an apparent tendency toward some convergence indicated at the extreme distances used in these tests. An analysis of the standard deviation in degrees of the arcwise concentration distribution indicates that the spread of the plume is not rectilinear, that is, the plume does not intercept the same number of degrees of arc at increasing distances. From this it is evident that the spread is a function of the distance frequently assumed to approximate some power law. This particular subject will be dealt with in another paper.

One of the most interesting results of these tests was the effect of vertical wind direction shear on the maximum ground level concentration. The computed maximum concentrations were consistently greater than those actually measured. Some of this may be attributed to the difference in sampling time between the three minute periods used to derive the equations by Sutton and the 30 minute sampling periods used in these tests and part of the difference may be attributed to the difference in the horizontal and vertical diffusion. For this study we have ignored the time difference factor and assumed that the vertical and horizontal diffusion are proportional to the vertical and horizontal deviations of a bivane. The maximum concentration equation was adjusted for the anisotropic turbulence in the following manner:

$$\chi_{max} = \frac{2Q}{e\pi\bar{u}h^2}\,\frac{\sigma_\epsilon}{\sigma_\theta} \tag{4}$$

where σ_ϵ and σ_θ are the standard deviations of the fluctuations of the vertical and horizontal wind direction traces. This factor was then removed from the ratio computed χ_{max}/measured χ_{max}. Both of these factors are listed in Table 2. The remaining reduction in the maximum concentration data was attributed to vertical wind direction shear causing the plume to be spread laterally more than would be expected in an atmosphere with a steady mean wind.

It was difficult to decide if the mean wind shear or the modal wind shear (i.e., the shear between peaks in the frequency distribution) were more important. Both cases were tested and are shown in Figures 6 and 7. The line of best fit was computed by the least squares method. The residual variances (σ_R^2) were computed to determine which represented the best method. Since the values were nearly identical the variances of the slope and intercept were then computed for each figure in a further effort to identify the best procedure. The variances of the intercepts (σ_I^2) are again nearly equal. The variances of the slopes (σ_S^2) indicate that the modal direction shear offers the best fit to the data. The differences are still so small that it would seem many more tests are required to determine which method should be used.

It should be noted that the samplers were at about three feet while the shear was only measured from 10 to 140 feet, so some error may have been introduced.

Conclusions and Recommendations for Future Studies

Uranine dye stuff has been an excellent tracer material for the tests conducted to date. The particle size is in the aerosol range and analysis is rapid and uncomplicated. The values of the stability parameter n were assigned but the values of diffusion coefficients have been calculated from the available data. These values were in accord with values generally used in atmospheric diffusion calculations. The values of the lateral diffusion coefficient (C_y^2) were somewhat larger than usually found and this may be attributed to two factors at least; 1) the meander of the plume becomes effective with sampling periods of thirty minutes creating wider plumes and 2) the vertical wind direction shear also creates a wider plume adding to the increase in lateral diffusion.

Future studies along this line should include samples in the vertical in order to obtain a complete budget of the dye. Even though particle size distributions have been determined and the aerosol range is realized, it would be best to determine the complete budget of material.

Plans for studies with the present data include testing various theoretical diffusion models and computing spectra of the horizontal and vertical wind fluctuations to determine the period and size of eddies most important to diffusion. The wind direction standard deviations are greater than those of the arcwise concentration distributions which indicates that a longer averaging period may be applicable rather than the five second means used.

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Discussion

C. I might give a few comments regarding the use of tracer techniques - since our original paper, we have had considerable more experience with fluorescent dyes - some of the problems you might get into - fluorescent dyes cost about $2 - $5 a pound. - economical for studies lasting a few days which can use about 100 pounds a day - if you have a study that goes on for weeks and months, chemical costs can be quite sizeable in long range diffusion studies. - now in those cases we have used - can use a few pounds a day and still get measurable quantities a few miles away - and still get unknown quantities - from the analyticalprocedure the filters experienced in our paper are not necessarily - also the light fuel may not be - pH control might be mentioned in trying to eliminate background. - changing from pH 5 to pH 7 - Filter leaching may be important. Reaction of background material dealing with extremely minute quantities - also multiple fluorescent dyes may be used.

Q. I would like to know whether the uranine or the other smokes or fumes can be used for predicting the concentrations of the bases the the noble gases. How confident are you?

A. We have the uranine dye particulate size down to aerosol size, but it is still a particulate. I think we can make a fair approximation, but would hesitate to say that that actually duplicated the diffusion of the noble gases, because we are dealing with particulates rather than gas, but they would come very close.

C. Lapple - Stanford Research

I would like to give a few comments regarding the uranine tracer type leak. Since our original paper, we have had considerable more experience with the use of fluorescent dyes and I would like to give a few comments, not any details, but just some of the problems you might get into. The fluorescent dyes generally cost about 2$ to 4$ a pound, so consequently if you have a study that lasts a few days you can afford to admit that at the rate of a couple of hundred pounds a day without incurring excessive chemical costs. If you have a study that may go for week or months then the chemical costs might become quite sizeable, as it might be in a long range diffusion tracer study. Now in most cases we have used ignition rates as low as a few pounds a day and still get measureable quantities several miles away from the admission point. However you do run into certain problems that have to be carefully considered. For example, in the analytical procedure the filters that are specified in our paper are not necessarily optimum, also the light source may not be optimum. These both may be influenced by the natural background of the materials. Ph control may be important in the analysis. For example, in the case of uraline you can get more than a ten-fold increase sensitivity by changing a Ph from Ph 5 to Ph of 7. The analysis right in that critical region can be used in distilled water. Also the Ph control may be important in trying to eliminate background as an item. Filter leaching may be important. It may be difficult to leach. We believe that this is associated with reaction with background materials where you are dealing with these extremely small quantities. Also multiple fluorescent dyes can be used and analyzed simultaneously where you may want to trace from the missions of different points at the same time.

Q. Newell - AEC Washington

I would like to ask a question as to whether the uranine or these other smokes are fumes can be used for predicting the concentrations of the gases - the noble gases, and how confident are you?

A. Bowne

We have the uranine dyed particles size down to the aerosol range but it is still a particle. I think we could make the fare approximation to the noble gases but I would hestitate to say that they actually duplicate the diffusion of the noble gases because we are dealing with a particle rather than a gas. They would come fairly close because they are a fairly small particle.

C. Silverman:

Not being inhibited by being a meteorologist I would go at that question to say that it would probably behave very much like it because the studies of Barren(?) and Johnstone indicated that under five microns you can consider the behavior practically as that of a gas - if you neglect depletion rates.

ESTIMATES OF ACCUMULATED EXPOSURES AND ENVIRONMENTAL BUILD-UP OF RADIOACTIVITY

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ABSTRACT

A simple method for estimating long-term effluent concentration and deposition values based on Sutton's and Chamberlain's equations is presented. Calculations of concentration and deposition are straight forward, and become especially convenient if averaged wind data are employed.

* * * * *

ESTIMATES OF ACCUMULATED EXPOSURES AND ENVIRONMENTAL BUILD-UP OF RADIOACTIVITY

An approach to long-range effluent concentrations, similar to that of Meade and Pasquill [1], was attempted at Oak Ridge. Hampered by bomb-test fallout and instrument variation, experimental verification as striking as Meade and Pasquill's results with SO_2 was not obtained. More elaborate and time consuming, the methods outlined below are, nevertheless, easily applied, and utilize existing wind information to the fullest extent practicable.

Meade and Pasquill, as well as earlier works by Holland [2], and Lowry [3], used the mean wind speed of each sector (direction) of interest. In our Oak Ridge studies we are going one step further by using the mean wind speed of each of six speed groups of every sector, giving a finer breakdown of wind behavior. We also are using the sixteen point direction scale, common to most wind rose publications in the U. S. Two sets of "Work Sheets" are prepared to facilitate computation, one for average air concentrations, the other for deposition calculations. Either can be used directly by untrained help, or can be modified to fit specific situations by anyone familiar with a slide rule and equations (4a), and(7a), below.

The Sutton formula for concentration at ground level from a steady, continuously emitting, elevated source is:

$$\chi = \frac{2Q_o}{\pi C^2 x^{2-n} \bar{u}} \exp\left[-\left(\frac{h^2+y^2}{c^2 x^{2-n}}\right)\right] \tag{1}$$

where χ = concentration (at ground level); parts/meter^3
Q_o = emission rate; parts/second
C = diffusion coefficients; meters$^{\frac{n}{2}}$
n = stability parameters; non-dimensional
x = distance downwind from source; meters
y = distance crosswind from plume centerline; meters
$\bar{u}$ = average wind speed; meters/second
h = height of source; meters

and isotropic dispersion is assumed [4].

The quantities in equation (1) that are assumed to vary significantly during a relatively long period are C, n, and $\bar{u}$. Q_o and h are assumed constant over a year's time. It is not unreasonable to assume that, on a seasonal or annual basis, the daytime n-value would approach the "neutral" stability level ($n = .25$), and the nighttime n-value would approach the "moderate inversion" value ($n = .33$). Wind speed values and the n-values then determine the remaining variable, C, as a function of a stack height. A nomogram convenient for determining C appears in reference [2].

Wind direction data are often based on 16 compass points, and this number will be assumed here. These 16 "points", however, are in reality 22.5° sectors. At five miles distance downwind, direct application of equation (1) might lead to an error of 5 orders of magnitude for any given point unless the average wind direction is known exactly. Over short distances and times, the error involved is not serious. Over a year's time, however, we cannot assign one direction to "north", for instance; "north" must rather be considered as an entire sector of 22.5°. This is achieved mathematically by integrating eq. (1) with respect to y and then distributing the result uniformly along the entire arc. Thus,

$$\frac{16}{2\pi x}\int_{-\infty}^{\infty} \chi\, dy = \frac{16}{2\pi x}\int_{-\infty}^{\infty} \frac{2Q_o}{\pi c^2 \bar{u} x^{2-n}} \exp\left[-\left(\frac{h^2+y^2}{c^2 x^{2-n}}\right)\right] dy \tag{2}$$

$$= \frac{16 Q_o}{\pi^{3/2} \bar{u} c\, x^{\frac{4-n}{2}}} \exp\left[\left(\frac{h^2}{c^2 x^{2-n}}\right)\right] \tag{3}$$

Equation (3) is modified to account for the annual wind speed and direction point frequency distribution (wind rose) in the following way. For a fixed n,

$$\overline{\chi}_D = \sum_{i=1}^{R} F_i \, \frac{16 Q_0}{\pi^{3/2} c_i \, x^{\frac{4-n}{2}} \, \overline{u}_i} \; \exp\left[-\left(\frac{h^2}{c_i^2 x^{2-n}}\right)\right] \tag{4}$$

where u_i = average speed for wind speed group "i"
F_i = fraction of total time wind is from direction D, and speed group i.
C = diffusion coefficient determined from n, $\overline{u}_i$, h.
$\overline{\chi}_D$ = annual average concentration along a 22.5° arc, at distance x, in direction D.
R = index denoting the number of wind speed groups in the annual distribution.

To facilitate hand compution, equation (4) may be written as,

$$\overline{\chi}_D = \sum_{i=1}^{R} F_i \, \beta$$

where B = $$\frac{16 Q_0}{\pi^{3/2} c_i \, x^{\frac{4-n}{2}} \, u_i} \; \exp\left[-\left(\frac{h^2}{c^2 x^{2-n}}\right)\right] \tag{4a}$$

Sixteen work sheets, one for each wind direction, are convenient, (32 work sheets if both night and day are computed). Figure (1) is a sample calculation sheet.

Figure (1) lists "Day" and "Night" conditions. When available, wind roses using "lapse" (for day) and "inversion" (for night) conditions are used in preference to merely daytime vs. nighttime wind roses. The number of hours of inversion varies with the location of the site. At Oak Ridge, we find the hours of inversion distributed as in Table I.

TABLE I
Average Daily Hours of Inversion by Season (1955-1958)

	Winter	Spring	Summer	Fall
TSF	10.1	10.1	12.7	12.7
MV	11.1	11.1	11.1	12.7
X-10	8.1	9.2	9.3	9.8

Where TSF = Tower Shielding Facility, 5-300 ft. above a wooded ridge top, (500 ft. from the valley "floor").

MV = Melton Valley, 5-60 ft. from the "floor" of a wooded valley.

X-10 = Oak Ridge National Laboratory site, 5-135 ft. atop a small ridge overlooking an industrial type valley, 90 ft. below.

Calculations for the Oak Ridge dispersion patterns are based on the TSF data, since the height of the stack plus plume rise through bouyancy would approximate the TSF height.

Direction ____ ±8

Plot as ____

$X = B \times Fi = \text{parts/meter}^3$

DAY n=.25

B

MILES u=	1–4 mph	5–9	10–14	15–19	20–24	25+
1	4.1×10^{-6}	1.0×10^{-6}	4.7×10^{-7}	3.0×10^{-7}	2.0×10^{-7}	1.3×10^{-7}
3	2.0 "	7.7×10^{-7}	4.6 "	3.3 "	2.6 "	2.1 "
5	9.2×10^{-7}	3.7 "	2.3 "	1.7 "	1.3 "	1.1 "
7	4.9 "	2.0 "	1.2 "	9.0×10^{-8}	7.1×10^{-8}	5.9×10^{-8}
10	2.6 "	1.0 "	6.5×10^{-8}	4.8 "	3.8 "	3.2 "
15	1.2 "	5.0×10^{-8}	3.1 "	2.3 "	1.8 "	1.5 "
20	7.2×10^{-8}	2.9 "	1.8 "	1.3 "	1.1 "	9.0×10^{-9}

NIGHT n=.33

B

MILES u=	1–4 mph	5–9	10–14	15–19	20–24	25+
1	1.4×10^{-10}	0	0	0	0	0
3	1.0×10^{-6}	1.3×10^{-7}	4.0×10^{-8}	2.9×10^{-8}	1.8×10^{-8}	8.6×10^{-9}
5	1.2 "	3.3 "	1.6×10^{-7}	1.2×10^{-7}	7.8 "	5.5×10^{-8}
7	9.9×10^{-7}	3.2 "	1.7 "	1.3 "	9.4 "	7.2 "
10	6.4 "	2.5 "	1.4 "	1.0 "	7.8 "	6.3 "
15	3.5 "	1.4 "	8.8×10^{-8}	6.3×10^{-8}	4.9 "	4.1 "
20	2.2 "	9.3×10^{-8}	5.8 "	4.2 "	3.3 "	2.7 "

B × Fi

MILES u=	1–4 mph	5–9	10–14	15–19	20–24	25+	Σ Day
1							
3							
5							
7							
10							
15							
20							

B × Fi

MILES u=	1–4 mph	5–9	10–14	15–19	20–24	25+	Σ Night	Σ 24 hr.
1								
3								
5								
7								
10								
15								
20								

Fig. 1—Sample work sheet for determining average annual effluent pattern, at surface; source height, h = 100 meters; source strength Q_0 = 1 part/sec.

Deposition

Once the average air concentrations are calculated, the average deposition (based on Chamberlain's method) [5], [6], may be computed. Deposition may be said to occur as,

$$\phi = \chi V_g \tag{5}$$

where ϕ = deposition, parts/meter^2 second
χ = concentration, parts/meter^3
V_g = Velocity of deposition, meters/second

χ has already been calculated from the effluent pattern worksheets for various distances downwind. As deposition occurs, however, the effective source is diminished, therefore χ should be multiplied by a "diminution factor", Q/Q_o, which is supplied in the deposition worksheet, figure 2.

Figure 2 could have been adjusted to read $(Q/Q_o)V_g$, instead of Q/Q_o, but Q/Q_o required adjustment when $V_g \neq .04$ meters/second. Should $V_g = K$ meters/second, the deposition worksheet may be modified by raising Q/Q_o to $K/.04$ power. Thus for any $V_g = K$,

$$\frac{Q'}{Q_o} = \frac{Q}{Q_o}^{\frac{K}{.04}} \tag{6}$$

Any change in effective source height, however, will alter Q/Q_o in a manner not easily calculated. To recalculate deposition values for $h \neq 100$ meters, the formula;

$$\ln \frac{Q_2}{Q_o} = \frac{C_{z1}\, u_1\, V_{g2}}{C_{z2}\, u_2\, V_{g1}} \ln \frac{Q_1}{Q_o} \tag{7}$$

and figures 3 and 4 may be used, [6].

$\frac{Q_2}{Q_o}$ = desired depletion factor

$\frac{Q_1}{Q_o}$ = depletion factor from figure 3 or 4

C_{z1} = diffusion coefficient from figure 3 or 4

u_1 = wind speed from figure 3 or 4

V_{g1} = deposition velocity from figure 3 or 4

C_{z2} = altered diffusion coefficient

u_1 = altered wind speed

V_{g1} = altered deposition velocity

Direction ±8

Plot as

$$\phi = Q/Q_o \times X \times V_g = \frac{\text{parts}}{\text{meter}^2 \times \text{sec.}}$$

DAY n=.25

Q/Qo

MILES u=	1–4mph	5–9	10–14	15–19	20–24	25+
1	.925	.98	1.00	1.00	1.00	1.00
3	.596	.83	.91	.93	.95	.95
5	.400	.70	.82	.87	.89	.90
7	.286	.65	.76	.82	.85	.87
10	.207	.54	.70	.77	.81	.83
15	.132	.457	.63	.71	.76	.79
20	.095	.34	.57	.66	.72	.74

NIGHT n=.33

Q/Qo

MILES u=	1–4mph	5–9	10–14	15–19	20–24	25+
1	1.00	1.00	1.00	1.00	1.00	1.00
3	.93	1.00	1.00	1.00	1.00	1.00
5	.61	.91	.96	.99	.99	1.00
7	.39	.79	.89	.94	.96	.46
10	.17	.60	.76	.84	.88	.90
15	.06	.38	.58	.68	.76	.80
20	.02	.26	.46	.58	.67	.72

$Q/Q_o \times X \times V_g$

MILES u=	1–4mph	5–9	10–14	15–19	20–24	25+	Σ Day
1							
3							
5							
7							
10							
15							
20							

$Q/Q_o \times X \times V_g$

MILES u=	1–4mph	5–9	10–14	15–19	20–24	25+	Σ Night	Σ 24hr.
1								
3								
5								
7								
10								
15								
20								

Fig. 2—Sample work sheet for determining average rate of deposition of material at surface; source height, h = 100 meters, and velocity of deposition, V_g = .04 meters/sec.

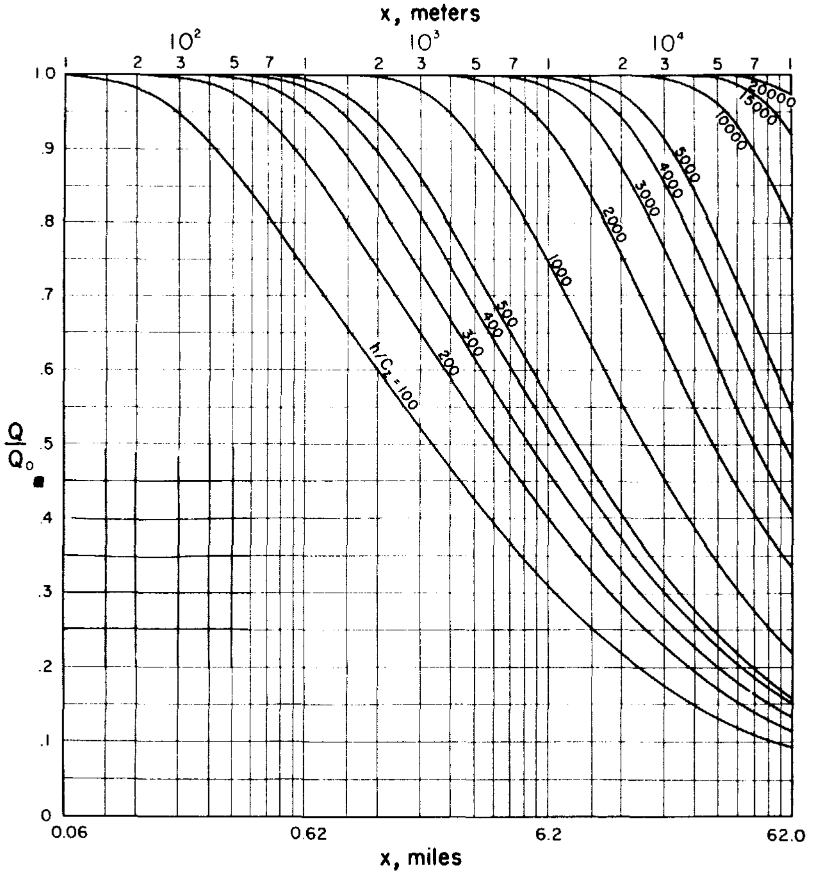

Fig. 3—Fraction of original source strength, Q/Q_0, remaining at a downwind distance x, as a function of h/C_z, with parameter values $n = .25$, $V_g = .04$ meters/sec, $u = 4.47$ meters/sec and $C_z = .100$ meters$^{n/2}$.

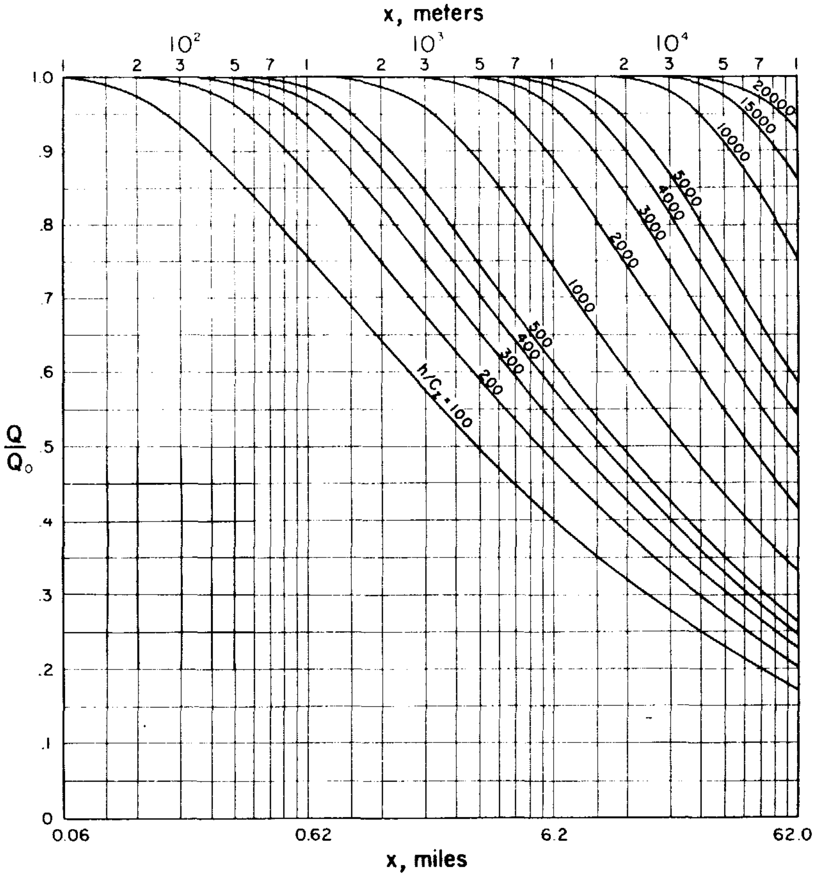

Fig. 4—Fraction of original source strength, Q/Q_0 remaining at a downwind distance x, as a function of h/C_z, for the parameter values $n = .33$, $V_g = .04$ meters/sec, $u = 4.47$ meters/sec and $C_z = .100$ meters$^{n/2}$.

Since C_{z1}, u_1 and V_{g1} are all constant, equation (7) becomes

$$\ln \frac{Q_2}{Q_0} = \frac{11.18\ V_{g2}}{C_{z2}\, u_2} \ln \frac{Q_1}{Q_0} \tag{7a}$$

The deposition work sheet may thereby be altered to fit any given set of parameters.

Plotting the Results

Figures 5 and 6 are representative plots of average daytime air concentrations (at the surface) and average daily deposition rates. Strictly speaking, the values should have been plotted as a series of discontinuous 22.5° arcs. For convenience, however, the calculated values were plotted at the center of each representative arc and isopleths smoothed to fit.

Deposition equations 5-7 are restricted to values of $V_g \ll u$. Thus, the deposition during "calm" cases, (or more to the point, at wind speeds less than detectable by the anemometer employed) must be treated in a different manner. An obvious method is;

$$\phi_c = \frac{F_c Q_0}{\pi G^2} \tag{8}$$

where ϕ_c = deposition during "calm" cases.

G = radius equal to the magnitude of the anemometer's starting speed. Equation 8 is not entirely satisfactory, but it serves as a basis for subjective analysis when the entire deposition pattern is drawn.

After plotting the average concentration and deposition values by use of figures 1 and 2, similar plots were made using the only mean wind speed of each direction multiplied by frequency of winds in the sector of interest. The results of both concentration and deposition values using the mean wind of each direction were very close to those obtained by using the entire wind distribution. It appears that computing effluent behavior by use of the mean wind is probably a very good approximation to the longer methods otulined above. Nevertheless, considering the applications of effluent predictions, one to two hours more effort seems worthwhile.

Further Considerations

An interesting and possibly quite useful extension to multiple point and area sources of the foregoing technique follows from a suggestion made by Gifford [7]. If there are, instead of a single point source, any number of arbitrarily located point (or small area) sources of arbitrary strength (but all at equal heights), the resultant annual concentration or deposition value at any ground-level point may be calculated easily by reversing the role of source and receptor in Figures 3 through 8. One would simply rotate the appropriate figure through 180° (i.e. turn it bottom side up), and orient the center point at the ground-level receptor location. If then the actual source locations be plotted on this figure, and for each such point the product of the concentration (or deposition) isopleth and the corres-

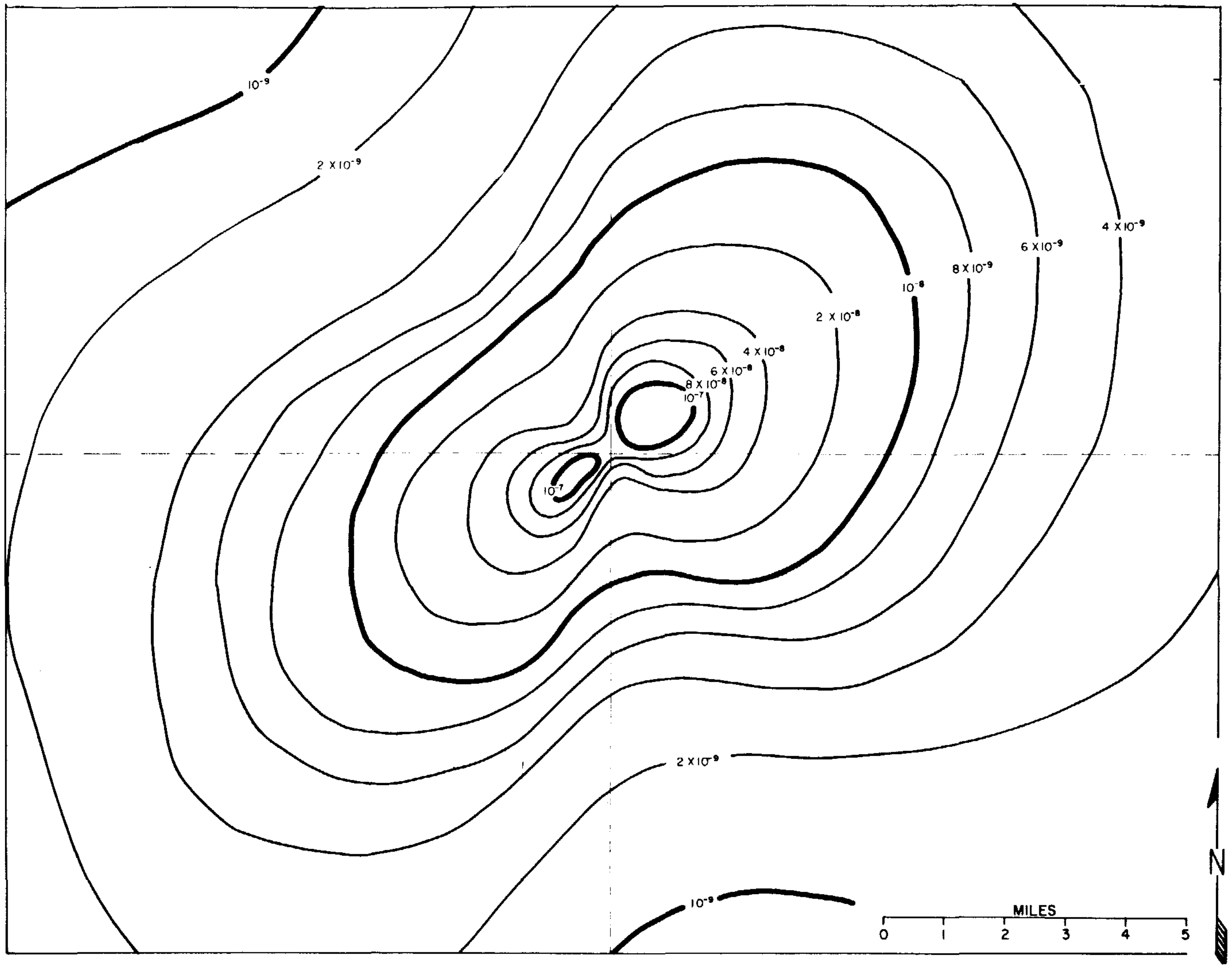

Fig. 5—Average daytime surface concentrations of effluent, based on yearly wind data; source height h = 100 meters; source strength, Q_0 = 1 part/sec, n = .25.

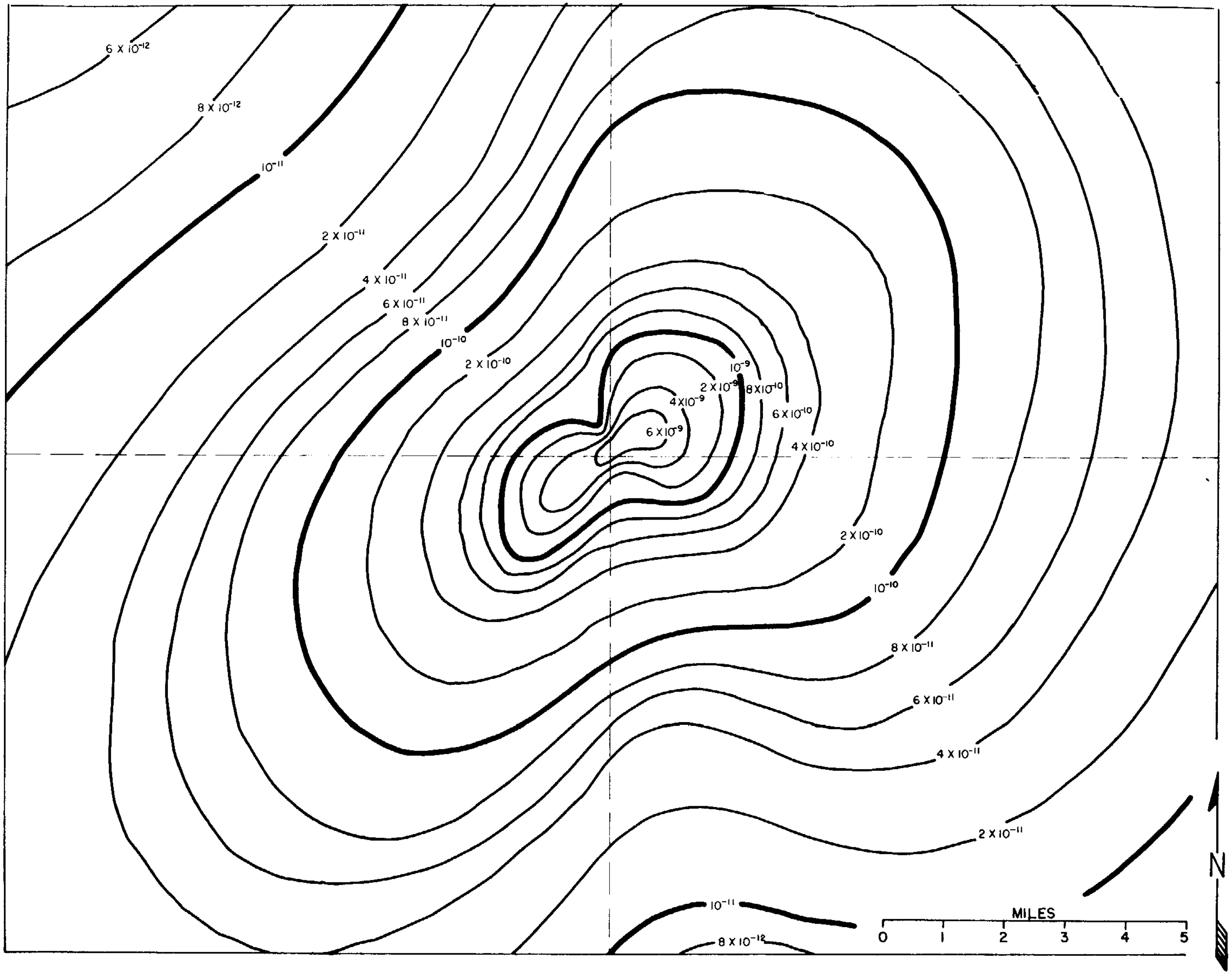

Fig. 6—Average daytime deposition rates, based on yearly wind data; source height, h = 100 meters, V_g = .04 meters/sec, Q_0 = 1 part/sec.

ponding source strength be formed, then the total annual concentration or deposition value at the receptor (center) point is given by the sum of these products. This process can be repeated for various receptor locations, thus providing annual distributions for multiple or area sources.

Acknowledgement

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ANL AIR CLEANING RESUME

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First, I will make a few comments on the various types of air cleaning equipment in use at Argonne, and then briefly discuss air cleaning plans for our new Fuels Technology Center.

High efficiency filters, in conjunction with prefilters, carry the major portion of the exhaust air cleaning load at the Laboratory. Generally, there are about six individually mounted filters per exhaust plenum. Most have fiberglass media and aluminum separators, although filters with asbestos media and some with asbestos separators are used for special requirements. Filters with paper separators have not been entirely replaced, but they are fading fast as all replacements are with the non-combustible separators. Recently, some filters with honeycomb construction have been purchased.

Our experience with high efficiency filters has been generally good, with a few exceptions that can be attributed to excessive insult to the filters.

In one case, glass media filters were installed in an exhaust system where there was the possibility of release of hydrogen fluoride. Evidently, hydrogen fluoride was released to two of the high efficiency filters as the filter media disappeared. This was easy to pick up on a check of the pressure drop across the aluminum separators.

In another instance, considerable laboratory acid fuming was carried out without an acid scrubber in the exhaust system. The media in the high efficiency final filter (with paper separators) dropped into the lower plenum.

A Millipore filter sample was run continuously at 1 cfm for 35 days on the exhaust side of a high efficiency filter serving a laboratory hood exhaust in our Chemistry Building. No detectable weight gain or reduction in flow rate was indicated. The Millipore filter had a gray discoloration, but there was no particulate loading that could be removed from it.

Prefilters are American Air Filter Company Type H and Type HX with fiberglass media. We find that the prefilters do a pretty good job of protecting the downstream ductwork against particulate contamination and in reducing the amount of particulates getting to the high efficiency filters.

The collectors used to clean the exhaust from operations in our Special Materials machine shop and foundry are a series combination of Type N Rotoclone, Electrocell Electrostatic Precipitator and Airmat paper filters. Efficiencies have ranged all the way from 60% to 98.8% for uranium and 96% to 99.9% for beryllium.

The cloth bag collector used for collection of considerable quantities of dust from our graphite machining room has proved satisfactory.

Building supply air filters are Type PL-24 with either Airmat paper or fiberglass media. Our tests have indicated average weight efficiencies for the two filter banks of 60-odd per cent against atmospheric dust.

The Venturi scrubbers for cleaning the exhaust from two sodium burn disposal booths do a good job. The problem is in limiting sodium fires to the burn booths.

Two large acid scrubber units with up to 6000 cubic feet per minute capacity for uranium fluoride pilot plant cell effluent have three stages of nozzles spraying potassium hydroxide solution into Schutte and Koerting throats. Early tests on our first scrubber indicated efficiencies of 98% to 100% against hydrogen fluoride. In operation, the highest fluoride concentrations found during discharge stack sampling has been 2.24 micrograms per cubic meter.

Type D Rotoclones are used for scrubbing the effluent from acid pickling tanks in our Special Materials foundry.

Our acid fume scrubbers for laboratory fume hoods are small (150 cfm) units utilizing a spray wetted fiberglass pad of 100 to 200 micron diameter fibers, and identical dry fiberglass pad, and a high efficiency final filter. The high efficiency particulate filter is needed as acid particles penetrate the scrubber stage. Collection efficiencies are greater than 99%.

Our new Fuels Technology Center, which is presently under construction, will have a variety of air cleaning problems. This facility will be devoted to carrying out research projects on reactor fuel element development, and the information gained will be used in production at the Fuels Fabrication Facility.

Some 456,000 cfm will be exhausted from the building, and this air will be replaced with high velocity supply air (3500 to 4000 fpm) filtered with American Air Filter rollomatic roughing filters, and secondary Type PL-24 fiberglass media filters. The general philosophy of the building is to keep each laboratory as a separate unit so that only one laboratory would have to be incapacitated in the event of a spill or other release of activity. Holes for utility pipes are to be caulked and doors and louvers could be taped to seal off the room. Recirculation duct connections will be installed in the corridor wall so that if future need arises a portable high efficiency filter unit could be attached to recirculate and clean the room air.

High efficiency filters for the room exhaust will be installed within the room near ceiling height. The plutonium gloveboxes will have a nitrogen atmosphere with 0.2 to 0.5% oxygen content in a recirculation system, with high efficiency filters at the glovebox entry and outlet and at the entry to the oxygen-hydrogen catalytic combiner units. Every part of the system, with up to 20 boxes per system, will be under 0.5 or more inches of water negative pressure with respect to the room.

A plastic pouch thermal seal filter change technique will be used to prevent the header filters from becoming open to the building atmosphere.

Work is now in progress to fabricate and test an acid fume scrubber to be used for some of the acid fuming in the chemical laboratories. The scrubber will be constructed of fiberglass impregnated with Hetron 92 plastic containing 5% antimony trioxide. The exhaust air from acid fuming beakers will pass through a sprayed fiberglass pad, then through a dry fiberglass pad mist eliminator, and finally through a cartridge packed successively with 200, 25, 1, and 0.5 micron glass fibers. This cartridge can be back-flushed to remove collected acid. Dr. L. Silverman, Harvard University, suggested design features of this unit.

Exhaust air from the Metallurgy machine shop, foundry, and ceramics operations will be filtered with reverse jet cloth bag collectors. In the case of the ceramics toxic materials laboratory, where fine beryllium powders will be used, these collectors will be backed up with high efficiency filters. Efficiency is specified at 99.95% vs. 1 micron spheres.

Gas absorbing units for pickling, plating and other operations in the shop and foundry area will have wet and dry stages of dynel fibers and the interior will be coated with a minimum of 50 mil thick polyvinyl chloride.

Preoperational efficiency tests will be run on the air cleaning equipment for this building, with occupancy scheduled to start after the first of the year.

SUMMARY OF AIR CLEANING ACTIVITIES AT ATOMICS INTERNATIONAL

E. C. HICKEY
Atomics International, Canoga Park, Calif.

At Atomics International, a Division of North American Aviation Company, activities are conducted primarily at two general site locations: (1) reactor, hot cell and critical assembly operations at the field site located in the Santa Susana Mountains and (2) research and development and fuel element fabrication operations at facilities located in Canoga Park section of the San Fernando Valley approximately 15 miles from the field site. Since a specific discussion of existing and proposed air cleaning installations relating to reactors, hot cells and critical facilities will be presented by A. R. Piccot of the Analytical Engineering Department at Atomics International, it would appear appropriate to confine these remarks to a brief discussion of current air cleaning activities as they relate to fuel element development and fabrication as well as basic research and development.

During the past year, considerable effort has been expended in the planning, design and construction of new facilities to meet the continually increasing demand for space to support R and D activities in the San Fernando Valley. Recently, construction was completed on a new building which will be devoted principally to fuel element development and fabrication. Construction is also underway at present on three (3) additional buildings which will complete a four (4) building complex. One of the latter buildings will be utilized exclusively for R and D laboratory work.

Due to the proximity and density of residential dwellings to the facilities in the San Fernando Valley, the basic criteria relating to the discharge of airborne radioactivity from these facilities can be summarized as follows:

> Operation or processes that produce, generate or disperse radioactive gases or particulates are provided with adequate means for the collection and removal of such contaminants from the air prior to discharge to the atmosphere. It is required that the most efficient and practical system of air cleaning be provided to reduce activity level to a minimum and

at all times sufficient to maintain
activity below prescribed tolerance
levels.

Collection of particulates is usually accomplished by the use of 2 inch thick non-combustible fiberglass prefilters and non-combustible high efficiency final filters. In many instances, however, pre-cleaning of the exhaust air prior to final cleaning is provided at the point of dust generation particularly in powder handling and machining operations. Reverse-jet filters are also being employed in this capacity for such operations as the machining of beryllium and contaminated graphite dies. Gas collection and removal is provided in all cases at the point of generation. In most instances the gas is collected in hold tanks for controlled discharge after decay. When direct discharge of gas to a hold tank is not possible, then methods such as freeze-out, adsorption and absorption are utilized depending upon the nature of the material.

The recently activated fuel element development and fabrication facility where SRE, OMRE and other special fuel elements are fabricated is provided with four (4) air handling systems and the general room and local exhaust air requiring cleaning amounts to approximately 90,000 cubic feet per minute. Operations carried on within this area include: vacuum casting operations, heat treating, slug loading, machining, assembly, testing and all phases of metallographic testing (hot grinding, hot polishing, microscopic examination, corrosion testing). Provisions will also be made at this facility to fabricate the fuel elements for the Hallam and Piqua Power Reactors. For the R & D laboratory building presently under construction, seven (7) air handling systems will be installed with a total general room and local exhaust air cleaning requirement of greater than 100,000 cubic feet per minute. Operations to be carried on within this facility include: High and low level analytical and separations chemistry, radiometric measurements and analysis, high temperature ceramic studies, organic reactor material studies, electronic and standards laboratories, R & D machine shops, a laboratory reactor and numerous other activities related to the various applications of nuclear materials. These air handlings and high efficiency air cleaning systems represent a sizeable capital investment and maintenance expenditure in order to satisfy the fundamental criteria relating to the discharge of airborne radioactivity from these facilities. The location, nature and extent of operations, however, justify the installation of adequate air cleaning systems.

In order to continually evaluate the effectiveness or integrity of any air cleaning program, stack sampling and environmental monitoring programs are utilized. Stack sampling is used on the present major exhaust systems and will be incorporated into the new systems as they become activated. Environmental monitoring which is considered an important adjunct to any air cleaning program is utilized to assay both airborne particulate activity as well as surface contamination or fall-out resulting from possible plant discharges or nuclear detonations. An extensive environmental monitoring program is in effect at Atomics International which includes constant air monitoring at all facility locations, the routine collection and analysis of soil and vegetation samples from forty-three (43) stations covering a 15 mile radius from the field site at Santa Susana. These results continue to show that no significant contamination has resulted in the environs due to the operations carried on within the area during the past 5 years. Meteorological data are also collected at Santa Susana which includes recorded wind speed and direction as well as temperature and relative humidity. These data supply necessary information which can be used for hazard evaluation studies as well as for emergency plans.

SUMMARY OF AIR-CLEANING ACTIVITIES*

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ABSTRACT

The air-cleaning policy of the Lawrence Radiation Laboratory includes studies for improvement of methods and equipment. Among new developments and applications are sampling equipment and scrubbing or decontamination assemblies; further investigations are needed.

General Statement

Our air cleaning policy is directed towards (a) improving the quality of air-cleaning equipment and practices, (b) reducing the contamination of air wherever processes and established routines permit, and (c) reducing the quantity of air exposed to contamination. The maintenance and enhancement of air-sampling equipment, methods, and data processing (including the interpretive reporting phase) continues as an essential portion of our air-cleaning program.

Improvements in Methods

1. Lawrence Radiation Laboratory, Berkeley, has substantially abandoned the use of fume-hood exhaust filters. Over many years the amounts of radioisotopes worked up in hoods had been decreased (as the use of total enclosures increased) to the point where hood filters were functioning as rather poor stack samplers. When adequate stack-sampling equipment became available the filters were abandoned. The sampling frequency is now weekly, and evaluation criteria shall be according to 10 CFR 20.

2. Heavy-element slug processing became 100% functional under our so-called "low leak" air-handling system. As a direct consequence, the stack samples for the first time were free of any detectable alpha activity.

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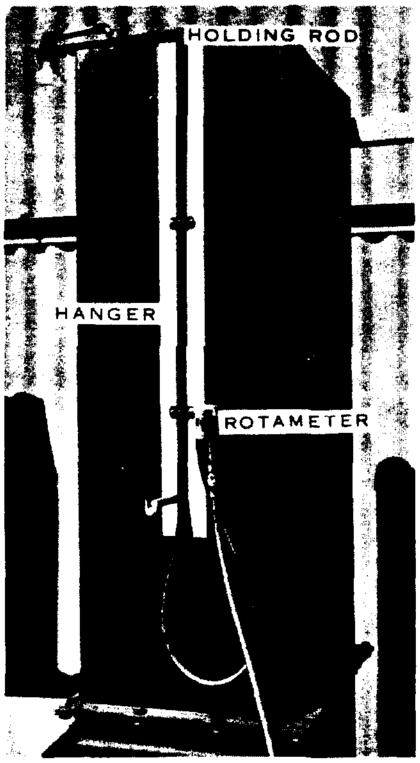
* Paper presented by H. Jorden

3. The so-called closed dissolver prototype, referred to at the 1957 seminar, has since been used on multicurie runs with quantitative capture of fission gases. No operating difficulties are experienced, and in the collection process the gases are automatically packaged and ready for burial.

Development of Air-Handling Equipment

1. A hood-exhaust sampling assembly (Figs. 1, 2) has been devised, tested, and installed. About 3 months' data are at hand. Replicate samples show about a 70% agreement with one another on samples of 1 week's duration. Relatively minor mechanical problems awaiting solution are (a) pump shutdown and (b) rubber deterioration, in a few instances, on the sampler head assembly.



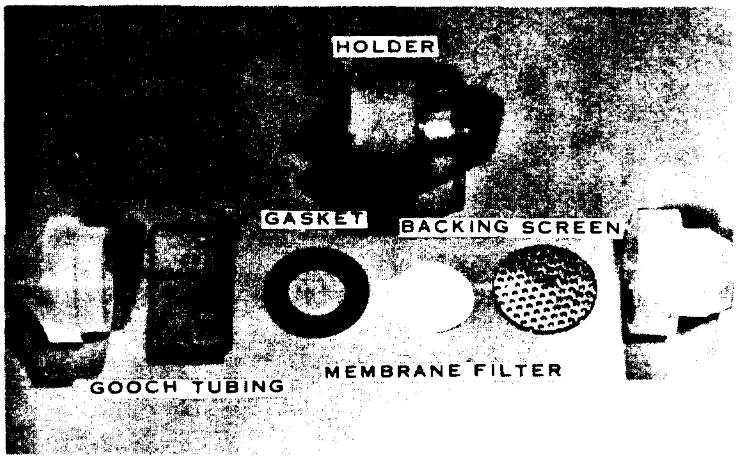


Fig. 2—Stack sampler (exploded view).

Fig. 1—Stack sampler assembly.

2. A general-purpose refrigerated scrubber and air-conditioning assembly for treating either recirculated or once-through process gases at a maximum rate of 18 cfm (Fig. 3) has been developed through a design study based on 8 years' experience at two sites. Several of these units have given successful service in high-level general radiochemistry. Experience shows that, through operator negligence, the Venturi throat may become plugged with crystalline deposits. A method is needed for removing these crystals from "hot" apparatus.

Exploratory data on aerosol and gas-removal efficiency during a recent high-level run indicated from 40% to 96% per pass, depending upon the isotope measured. This variation was not unexpected because of the wide range of solubilities, vapor pressures, etc., in a heterogeneous mixture of fission products and transplutonic compounds.

3. An air-sample alpha and beta-gamma counter with automatic-printout--for 4×9-inch filter paper samples--has been devised

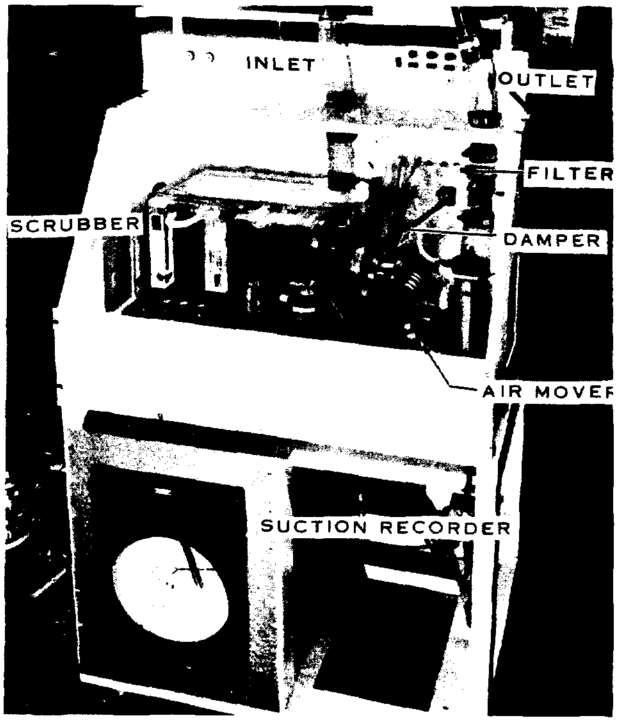


Fig. 3—Scrubber box assembly.

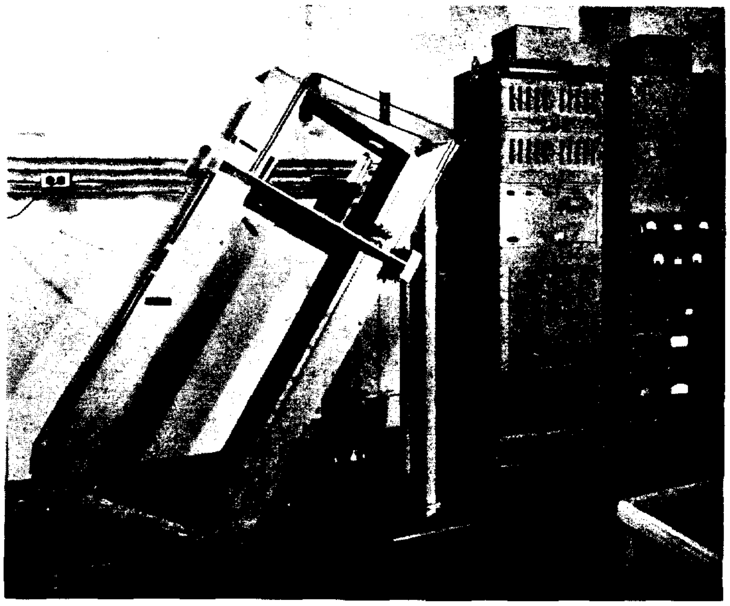


Fig. 4—Automatic filter-paper counter.

and substantially debugged, and is turning out routine data (Fig. 4). It can handle 85 samples per loading. A more detailed paper is in manuscript (M. D. Thaxter and T. G. Taussig, Automatic Filter Paper Reader, UCRL-8701, September 1959).

4. Modifications were made on a fail-safe self-checking circuit for box exhaust manifolds to employ commercially available components. We believe we now have a dependable assembly based on more than 2 years' use and development.

5. A prototype high-speed centrifugal evaporator or so-called "spin-dry" equipment shows promise; early runs indicate decontamination factors greater than 10^5. It is expected that development will proceed to both macro and semimicro hardware.

6. Safe equipment and methods for taking 15-ml process gas samples in 1/4-mil Mylar bags were developed and employed (Fig. 5). The technique permits detection of weak beta and alpha radiations and performance of pulse-height analyses on gamma emitters.

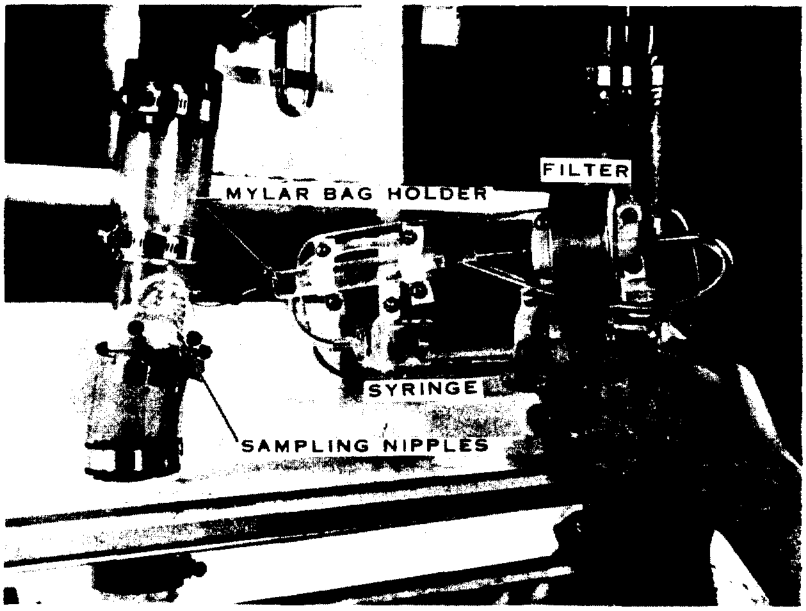


Fig. 5—Air-grab sampler assembly.

Investigations Needed or in Progress on Methods and Equipment

1. Radioactivity is found in the air near operating accelerators. A portion is airborne. The extent, nature, method of production, and evaluation of hazard (if any) of this airborne fraction is under investigation. At least a portion of the activity is collectable on dust filters and emits beta particles. Half lives ranging from $7\frac{1}{2}$ seconds to 40 hours have been observed.

2. Revelation of mechanical defects in high-efficiency filters (CWS 6 and AEC type) by visual inspection points up a need for technique and equipment to evaluate filter efficiency upon receipt. This is particularly important since only a very small part of the filter is visible to inspection.

3. Prompt detection in air of alpha emitters other than radon-thoron daughters is badly needed, and we continue to plead for research and development leading to a dependable and economical method.

4. Methods for safe, rapid evaporation of radioactive solutions, in addition to the "spin-dry" technique already mentioned, are the subjects of studies planned at this Laboratory.

Discussion

Q. (W. B. Harris, NYOO) About the hopper for collecting materials, I heard something about having a level indicator in the bin - is this adequate protection against a critical amount in the hopper?

A. It should never accumulate to that point at all. If it does, there is an alarm (which we hope will never go off).

SPEECH DELIVERED TO 6TH AEC AIR CLEANING SEMINAR AT IDAHO FALLS, IDAHO, ON JULY 7, 1959

R. J. WALKER
Dow Chemical Co., Rocky Flats Plant, Denver, Colo.

In reviewing the radioactive air filtration problems at the Rocky Flats Plant in Colorado for this group at Boston two years ago, I stressed the fact that we had experienced very commendable service (in both efficiency and cost) from our cellulose-asbestos final air filters. I expressed our concern over the danger of fire in these banks but I also expressed some misgivings we had concerning the new, all-glass, fire resistant filters being proposed by one of the filter manufacturers. Since we, as well as many of you, were living on "borrowed time", so to speak, with nearly 4000 of the old "firebug" filters in place, I was especially concerned that all due emphasis and effort be placed on getting a suitable "standard" evolved for the new fire resistant filters so that we could all proceed with our mass replacements without jumping from the frying pan into the fire. This is probably an unfortunate choice of words which could be better expressed by saying we surely didn't want to jump into such a major program and find we bet on the wrong horse. My sole point in the talk was to press for a solution to this problem and that if furthering this end were our only accomplishment at the meeting that all of our time would have indeed been well spent.

Very unfortunately, time ran out on us. As most of you are well aware, we lost one of our major banks of these filters in a fire just three months after that Boston meeting. Luck, nature, design, and super efforts on the part of personnel involved all helped to minimize what could have been catastrophic consequences. However, ready or not, there was no more time to wait for the solution to the problems of the new, all-glass, fire resistant filters. Hanford had just ordered the first major batch of these new units. By utilizing filters intended for them and by working all three manufacturers overtime, we were able to have this bank back in operation in about two weeks.

However, since then, some of our worst misgivings about the new units have been realized. First, our costs have been staggering for numerous reasons. This is not just sour grapes from an enemy of the "quality at any cost" school. The first cost of the first hurried units was nearly 50 percent over the old-type units. In the first four months, 10 percent of the filters in the bank had holes and had to be patched. In the first six months, we also had to completely replace another 10% of the bank. When the whole filter core is pulled out onto the floor, you have little choice. The man-hours needed to check, search for, and maintain such a bank become costly in dollars and rob important production functions. As a result, the whole bank was replaced with a new glass-asbestos type media filter in a year (up to being burned, the old bank had lasted five years). So far, the new units are doing a good job with much less effort on our part than the all-glass units. They do, however, require more attention (checking and patching) than the original bank.

The pressure of the crying need for the best in fire resistant final air filters has brought forth numerous variations and new designs. This, coupled with what seems to be a concentrated effort on the part of each of the filter manufacturers to put himself in a proprietary position, has led to considerable confusion in the specifying and using agencies. As a result of this changing design, a necessarily long lapse of time between order and use, and very poor marking of the shipped units, it is often almost impossible for the layman to tell what type a particular group of filters in the warehouse might be that are now ready for use in a particular area. With the very high cost of "hot changes" even in small (20 filters) systems, a wrong guess can surely be costly and again robs you of production time.

A further disturbing trend recently has been the high number of defective units received from the manufacturer. In prior years, 6 repairs out of 600 units installed was high and was usually due to accidental damage at installation. However, as recently as this past week almost 100 containers had to be opened and checked to get 20 usable units. Even then, half of the 20 had to be patched before they were installed. This is a lousy contingency to have to face on a tightly scheduled, hot maintenance job.

Therefore, gentlemen, once again I would like to exhort this group to put forth effort in all possible haste to reach a standardization in our specifications and to insist on any and all manufacturers meeting these specifications. It is essential that we restore the "final air filter field" to the position of integrity, dependability, and service it once held.

Discussion

Q. Is the life of glass filters appreciably less than asbestos type?

A. Haven't had glass ones in long enough to tell you. We think they will be somewhat less.

A. (L. Silverman - Harvard) Think life would be about the same.

Q. (G. J. Hurwitz - Army Chem. Center) Would like to know whether you attribute the damage in these filters to storage or deterioration in storage or did you receive them damaged from the manufacturer?

A. We are unable to say, we think we received them that way - had a prior shipment last year with no shipping damage. March damage was 96 out of 600. Later had to open up 100 to get 20 usable ones. Boxes were undamaged - think they left the plant that way.

Q. Have you any idea how long you had them in storage?

A. Some we have had as high as one year.

Q. Is it conceivable that they were damaged in storage?

A. It is possible, yes. In prior years we had no trouble, but were using a different type of filter material.

Q. To what do you attribute the experience of those which were destined for Hanford and reached Rocky Flat? Why did they fail so quickly? How do you go about the patching process?

A. Small holes were squirted with cement. When all else fails, you replace the unit - later asbestos glass not showing the proneness to damage.
We have some very minute amounts of Hf coming through - glass filters are not so prone to hf damage, but also we do have a small amount of hf damage.

A SUMMARY OF AIR CLEANING ACTIVITIES AT THE SAVANNAH RIVER PLANT

J. J. CROLEY, JR.
E. I. du Pont de Nemours & Company, Inc.,
Savannah River Laboratory, Augusta, Ga.

INTRODUCTION

Air cleaning activities at the Savannah River Plant involve extensive use of various types of air cleaning media ranging from liquid systems, such as caustic scrubbers, to sand filters. Like other AEC installations, the Savannah River Plant leans heavily on CWS-6 and all-glass fiber types of high efficiency filters.

DISCUSSION

Two groups of applications are considered in this discussion of air cleaning activities at the Savannah River Plant: (1) the cleaning of air for supply to indoor areas, and (2) the cleaning of exhaust air systems before discharge to the atmosphere.

1. Air Supply Cleaning Systems

All air supplied to production and laboratory facilities is filtered through "Airmat" type filters. These filters are fireproof. They consist of bonded glass fiber having an initial resistance not exceeding 0.10 inch water gage at a linear velocity of 35 feet per minute. Average dust arrestance shall not be less than 90% as determined by the Air Filter Institute Code Test Method. Filter frames are of heavy metal. It has been found necessary to change these filters on a frequency of only once per year in all installations. This media is exceptionally durable and has eliminated the problem of perforation under heavy load. Experience with this media at SRP has been very satisfactory to date.

Air supply to locations containing delicate instruments or sensitive laboratory procedures is often filtered through high efficiency filters of either the fireproof or fire-retardant type, depending upon the degree of fire hazard involved.

2. Air Exhaust Cleaning Systems

A. Reactor Installations

Air exhausted from reactor installations is not filtered, except to a minor degree for high level caves, but is discharged directly to the environment through a 250' stack. High level cave exhausts are filtered through high efficiency filters of the fire-retardant type. A constant monitoring program is utilized to measure the amount of radioactivity released to the atmosphere, particularly with regard to Argon^{41} which is produced when air is bled into the reactor systems during shutdowns, and tritium which is evolved from tritium-contaminated moderator.

B. Separations Installations

Air exhausted from separations systems may be cleaned in several different ways before final release to the atmosphere. These methods are discussed as follows:

1) Sandfilters

Sandfilters are utilized to clean air from several different canyon process streams. While efficiency data for this type of filter is somewhat controversial, Savannah River Plant experience has shown that such a filter can handle up to 300 curies of particulate contamination with an average decontamination factor of 99.95%. Pressure drop across the filter used for this example has increased only about 0.29 inch water gage or 6.52 to 6.81 inches water gage during a period of 4 to 5 years. Design specifications allow an increase of one inch water gage. The sandfilter is also used to back up other filtering systems utilizing fiberglas, caustic scrubbers, and dehumidifiers.

2) High Efficiency Filter Systems

This type of air cleaning media is used extensively throughout separations installations in all locations where toxic pyrophoric metals are handled. Prefilters are used extensively with this type of filter to increase its life expectancy. A review of all high-efficiency filter installations was completed recently resulting in a change from fire-retardant filters to fireproof filters in fire hazard locations.

Contamination released to these filters may vary enormously, depending upon leaks and spills in such process areas as the sample aisles and hot gang valve corridors. Experience has shown that filtering efficiency for CWS-6 type filters varies according to service from about 95% for mixed fission products to 99.9+% for plutonium. The Health Physics Section maintains a close check on the efficiency of these filters by constant monitoring both before and after final filtration.

High efficiency type filters are also used to clean exhaust air from recovery facilities. Uranium dust is the primary contaminant. Collection efficiencies approaching 100% are now obtained in these locations.

C. Metal Fabrication Facilities

Metal fabrication facilities employ local exhaust systems extensively for operations where uranium and its alloys are handled or processed. These local exhaust systems are then filtered through high-efficiency filter units of the CWS-6 fire-retardant or fiberglas fireproof type, depending upon the degree of fire hazard involved.

SUMMARY

In summary, current air cleaning practices at SRP utilize a variety of techniques directed at securing a maximum decontamination factor for radioactive gases and particulate matter. The most commonly used device is the high-efficiency package filter. All "critical" locations where a potential fire hazard exists employ fireproof type filters. Other filter installations utilize the fire-retardant, high-efficiency type filter as an economic factor, until the current inventory of these filters is exhausted. Future plans visualize the use of only the fireproof, high-efficiency filter at this Plant. Air cleaning experiences at the Savannah River Plant were good with no problems worthy of discussion.

Discussion

Q. (J. Murrow - U of Cal.) You mentioned fireproof filters, just what are they compared to fire type?

A. That is perhaps a term or nomenclature used specifically in SRA Divided filters into types - fire type to stand 250° continuously and fireproof to stand 800°F. continuously.

Q. Do you have any results on the silver plated tape tests at this time? Any other clues as to your activity bursts?

A. Not yet. - One of the largest ones we did have seemed to be about the time we had our largest fallout days and I would hesitate to even suggest that this was the cause. However, it would look a little bit in that direction.

C. (W. King, PPCo) These questions interest me - small increase about two times output similar to what you had. Have you removed the tape and analyzed it to see if it is fresh fission products or foreign fission pulled through the flush zone?

A. Unless you sit right with it, you can't do it. Sometimes happens at night - have tried to cut the tape and thought it was that very thing. Next time it was something else. We are completely at sea. The only reason we have noticed is that our old fuel oil background levels ran so high -- that weren't noticeable.

Q. What is the type of filter just before the Venturi that leads to the stack?

A. FG 100 after filters Dahlinger glass test type which should be getting better and better all the time because they've been in there about 9 years - high temperature filter - the after filters are doing a good job, we think.

Q. (L. Gemmell, BNL) Is it a general practice to test all filters before installing?

A. (H. Gilbert, AEC, Washington) Join the discussion on filters tonight and find out the answers.

FILTER EFFICIENCY STUDIES AT GOODYEAR ATOMIC CORPORATION

P. DIAMOND
Goodyear Atomic Corporation, Portsmouth, Ohio

ABSTRACT

Studies were conducted at Goodyear Atomic Corporation to evaluate the efficiencies of air filters and to gather data which could be used as bases in establishing effective filter cleaning and oiling schedules. Two types of filters were tested under various conditions and corresponding efficiencies were determined. A direct relationship was found to exist between the degree of louver opening and filter efficiency. The resistance across filter banks was found to increase over relatively long periods of time.

This paper presents the methods employed during the studies and the results obtained which were used to determine filter efficiencies and establish effective cleaning and oiling schedules.

INTRODUCTION

Despite the fact that the viscous impingement filter was the original filtration device, a review of the literature reveals very little on the collection efficiency of this filter for atmospheric dust. Studies were conducted at Goodyear Atomic Corporation of two types of impingement filters in an effort to evaluate efficiencies under various conditions and to establish effective cleaning and oiling schedules based on both filtration efficiency and resistance measurements. The magnitude of the studies may be illustrated by the fact that a total of over thirty million cubic feet of air is filtered each minute in three process buildings at Goodyear Atomic Corporation. Figure 1 shows one of these process buildings and its air-intake louvers. There are sixty-two filter rooms throughout the three buildings, representing a total of 64,500 square feet of filtration area. The average air flow through the filters is 500 linear feet per minute.

Figure 2 is a diagram of air circulation in a typical process building where the filtered air supply is used to cool compressor motors. Some typical ambient temperature readings are also shown on the diagram.

TEST PROCEDURES

Preweighed fiberglass filter papers were used in conjunction with Staplex hi-volume air samplers. Samples of the air were collected both prior to and following air passage

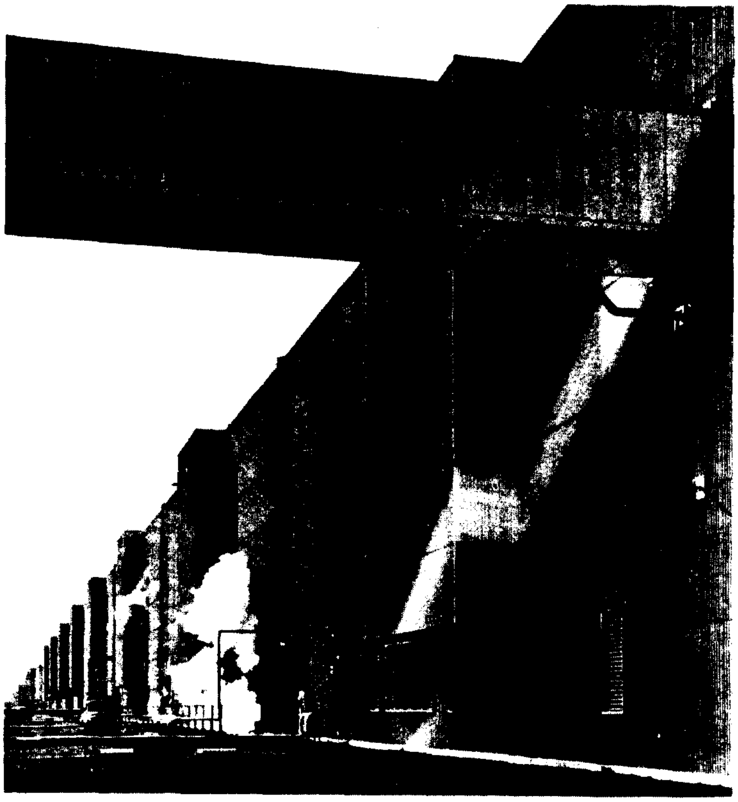


Fig. 1 — Typical process building showing air intake louvers.

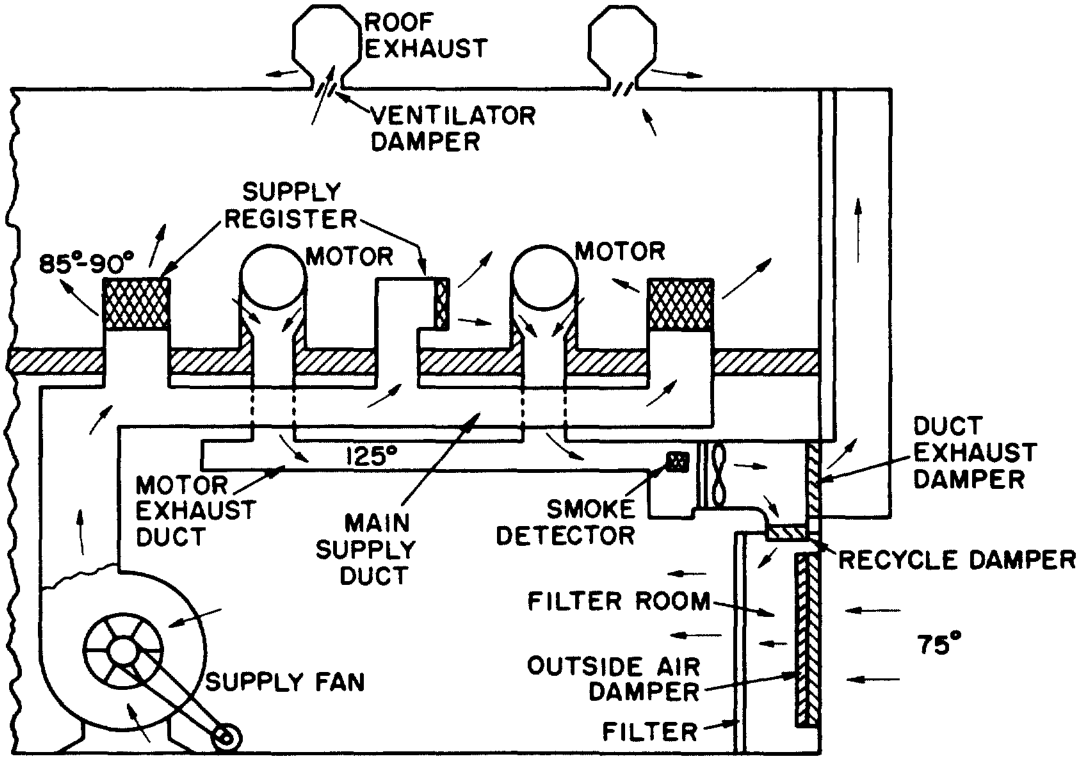


Fig. 2 — Typical ventilating system.

through the filter banks. The filter papers were dried at 110°F. for one-half hour and weighed immediately upon removal from the laboratory oven. The drying process was necessary in order to stabilize moisture content. The papers were then placed in the hi-volume samplers located on both intake and outlet sides of the air louvers and air was sampled at the rate of approximately 12 cu. ft. per minute. Following the collection of samples, the filter papers were again dried and reweighed. The increases in weights of both filters were used as bases for the determination of efficiency.

RESULTS

FAR-AIR FILTERS

Results of the tests of Far-Air filters indicated an over-all average efficiency of 42%. Twenty-eight pairs of samples were collected; each sample being collected for about seven hours. As previously stated, the increase in the weights of the filter papers, before and after the filter banks, was used in determining the efficiency by weight of the filters.

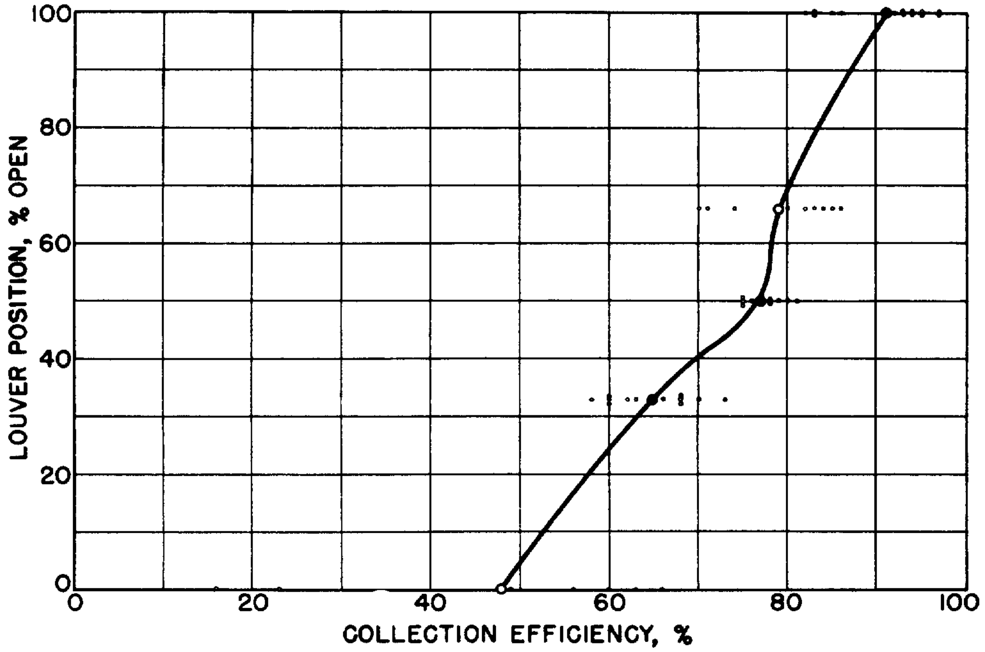


Fig. 3—Filter collection efficiency vs. louver position.

HV-2 FILTERS

Fifty-four pairs of samples were collected to determine the efficiencies of this type filter. Louver openings were adjusted during each of the tests in order to permit the entry of a predetermined amount of unfiltered air. The over-all results of these tests show the following efficiencies:

Louver Position	No. of Tests	Average Efficiency
Closed	7	48%
1/3 Open	13	65%
1/2 Open	10	77%
2/3 Open	9	79%
Completely Open	15	91%

The individual test results are graphically presented in Figure 3. It appears that a direct relationship exists between the degree of louver opening and dust collection efficiency. This may be explained by the fact that as the degree of louver opening increases, more air, containing larger foreign particles, is admitted from outside the buildings. The filtering of these larger particles results in the greater efficiency.

CONCLUSIONS

Experience to date has indicated that during an eight-month period the average resistance across the filter banks increased from 0.08 to 0.20 inch of water. Based on the manufacturers' specifications to clean the filters at the 0.25-inch level, a cleaning schedule has been established on an annual basis. An oiling schedule has been established at three times per year. The most economical method for cleaning and oiling the filters at Goodyear Atomic Corporation has been found to be the direct removal of the filters and immersion in an alkaline dip tank. The filters are subsequently cold water rinsed, hot water rinsed, replaced, and finally re-oiled using SAE 40 lubricating oil. The estimated cost is 16 cents per filter.

Sufficient evidence has not been accumulated to evaluate fully the optimum time interval between filter cleanings, but the necessary background material has been gathered to permit better evaluation of data to be collected in the future.

SUMMARY OF AIR CLEANING ACTIVITIES AT BROOKHAVEN

LEE GEMMELL
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ABSTRACT

A number of radioactive peaks have been seen on the dust monitor located in the cooling air of the BNL Research Reactor. These peaks are much more pronounced since the installation of the new enriched fuel in August 1958. Even though this radioactivity represents no health hazard to the environment, a study was made to determine the cause of these peaks. The results of this study were inconclusive and showed only that major changes in meteorological conditions bring changes in peaks but no specific correlations have been made.

A study is in progress to test the chemical combination of iodine and bromine on silverplated copper gauze at different temperatures. No results are available.

The Meteorology and Health Physics Divisions are studying the size, shape, concentration and height of the cooling air plume from the research reactor under various weather conditions using the radioargon in the air plume as the trace element. Preliminary results look satisfactory.

* * * * *

The largest and perhaps the most interesting and challenging air cleaning problem at Brookhaven is in connection with cleaning the cooling air of the Research Reactor. As you know, this reactor is air cooled, graphite moderated and, since last August, the original natural uranium has been replaced by an enriched fuel. To cool it requires approximately one million pounds of air an hour. This air is pulled with a pressure drop of about 50 inches of water through inlet filters, the reactor, and exit filters by five 1500-horsepower fans and exhausted from a stack 350 feet above the surrounding terrain.

The inlet air filters are deep pocket fiber glass (American Air Filter FG-100) and the exit air filters are woven glass fiber filters (Dollinger Glass Tex). The inlet filters are reasonably satisfactory for removing atmospheric dust. However, many particles in the sub-micron size pass through in the air stream. The Health Physics Division has installed a continuous dust collector for sampling the cooling air at the base of the stack. Figure 1 shows the cooling air system of the Brookhaven Reactor and Figure 2 shows instruments used in monitoring air for particulate activity.

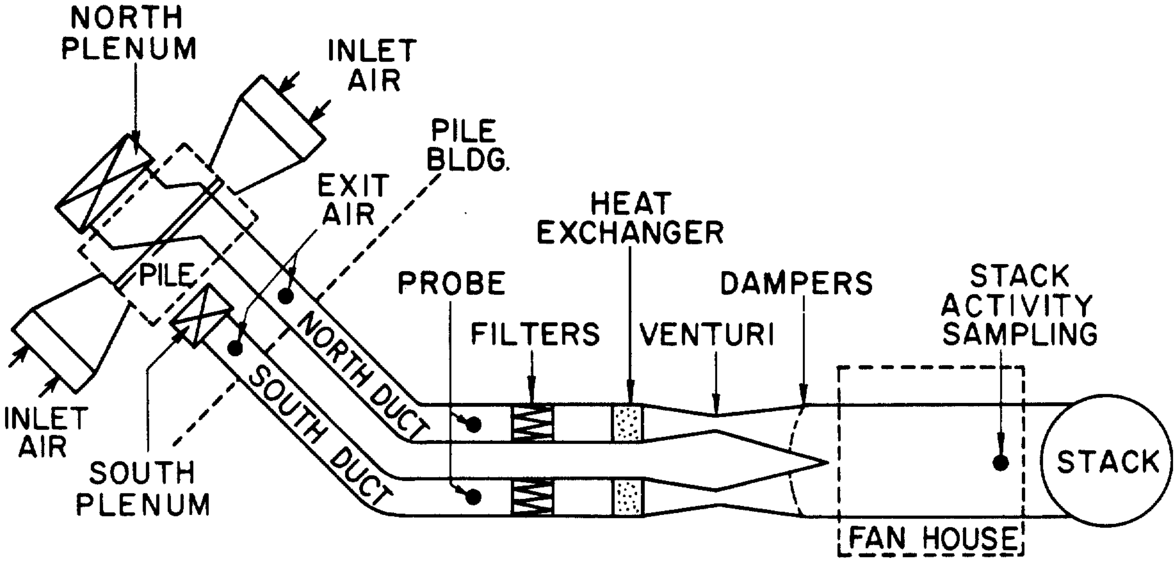

Fig. 1—Cooling air system, Brookhaven Reactor.

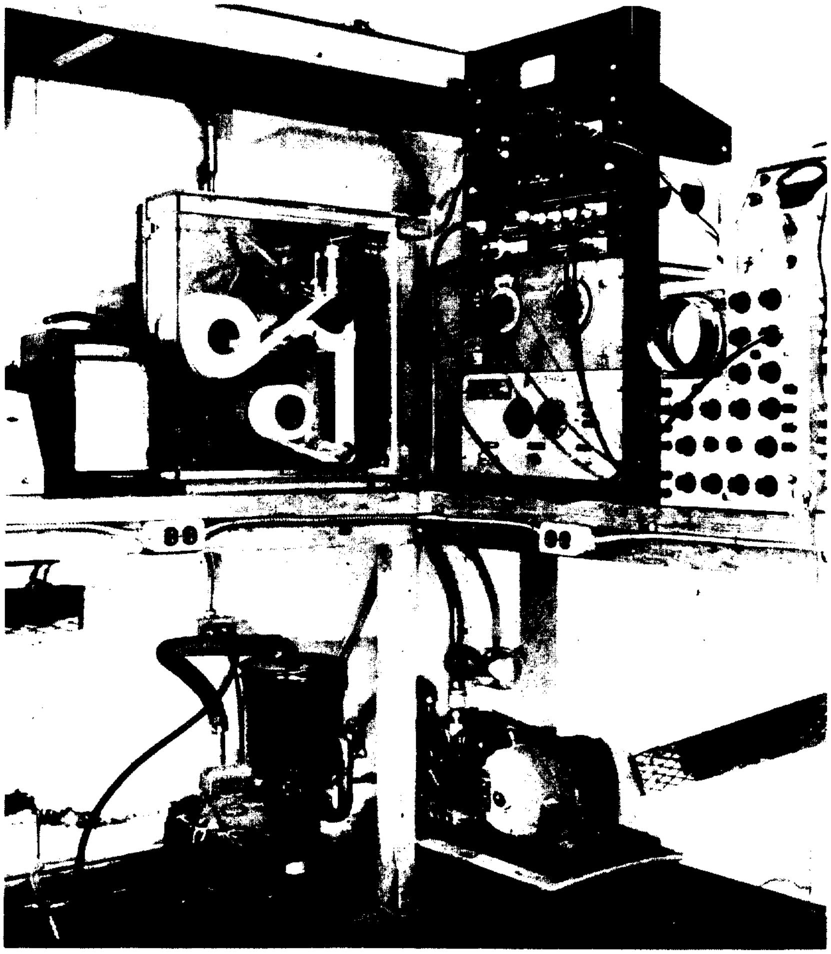

Fig. 2—Instruments used in monitoring air for particulate activity.

Of course, the principal radioactive contaminant in the cooling air stream is Argon-41. Even though there is very little Argon in air, approximately 15,000 curies of A^{41} are discharged up the stack each day. The height of the stack, the relatively short half-life of the radioargon (110 minutes) and the tremendous dilution by the atmosphere, causes no problem in disposing of it safely in this manner. The amount of A^{41} produced depends on reactor power level, amount of air moved and the length of time the air remains in the flux so tends to be fairly constant and predictable. The particulate problem, however, is more interesting because of certain natural and man made disturbances causing dust that affects the over-all radioactivity of the cooling air effluent.

Prior to the replacement of the natural uranium fuel last August, there was always a certain small amount of mixed fission product contamination from small fuel element leaks into the air stream. The dust monitor in the stack always detected a small "background" of this activity and tended to remain fairly constant. This amount of radioactive dust represented no hazard as far as the local environment was concerned.

After the change over to the new fuel, the same dust monitor displayed some rather sharp peaks that lasted for periods ranging from an hour or two to as much as three days. It was thought that these peaks were likely caused by possible uranium contamination on the outside of the new fuel, possibly by small blisters reaching through the cladding into the U^{235} alloy, or the scrubbing of fission product debris left over from the old fuel. The enriched fuel from one of the central holes was removed for routine replacement and it was then discovered that one of the elements was badly damaged. Following removal of the damaged element, there appeared to be less frequent peaks. This improvement may have been due to the removal of the damaged element or merely a coincidence.

Radioactive peaks still occurred although less frequently. A dust collector and monitor was installed in each exit air duct before the exit filters to see if the activity was coming from only one side of the Pile. Both monitors showed the same rises at the same time, indicating that something must be getting into the air stream before entering the Pile. It was at this point that automobile exhausts were linked to the rises in activities. If a truck or passenger car were left running in the general area of the inlet air intake, the activated exhaust would show on the dust monitor. This discovery looked promising as the answer. However, within a week, another peak appeared with no man made disturbance as far as could be ascertained.

A short time later, one of the Operations personnel noticed that a peak was coincidental with a shift of the wind to the south. The wind direction changed abruptly from the northwest about 15 minutes before the trace appeared. From windspeed data, the sea air from the south seemed to be perfectly timed for the peak. However, on later occasions, more peaks occurred without sea breezes.

Later, on a very humid foggy day, a large sharp peak appeared with nothing mentioned before as a possible contributing factor. The theory advanced this time suggested that moisture penetrating the inlet air filters was carrying dirt from the inside surface of the filter into the air stream. The next time this same atmospheric condition appeared, there was no peak. Since then, several cases have been examined and each time there seems to be less and less correlation.

If atmospheric polution is causing these abnormalities, then a sample of the atmosphere should be taken at the same time the peaks occur in the cooling air and analyzed spectrographically. This procedure was set up by providing an automatic triggering device that would turn on another air sampler for sampling the atmosphere when a peak showed in the Pile stack. These samples have shown nothing unusual to date. The dust monitor peaks are showing less frequently during the late spring and summer so it will probably be necessary to wait until fall for more data. The cause of these radioactive peaks at the moment is unknown. Major changes in meteorological conditions bring changes in peaks, but no specific correlations have been made.

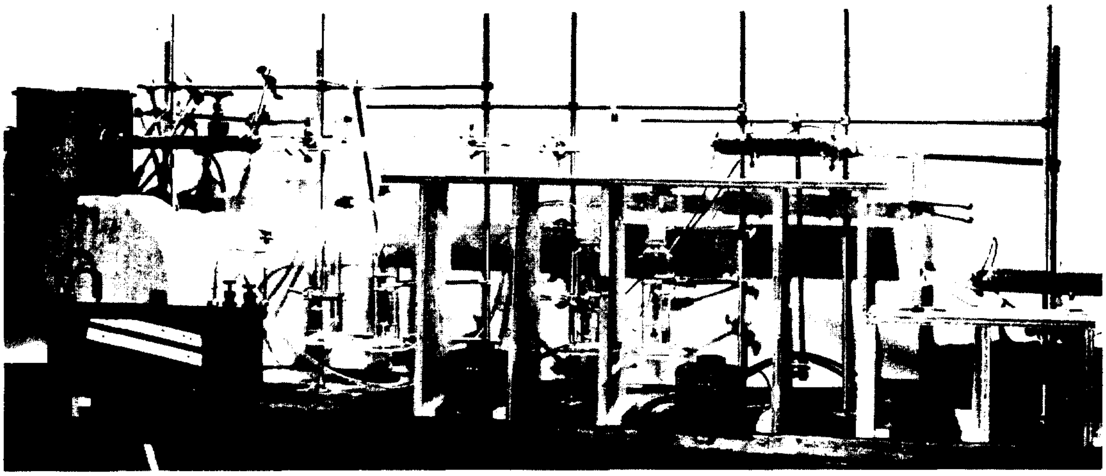

Fig. 3—Apparatus for the laboratory experiment.

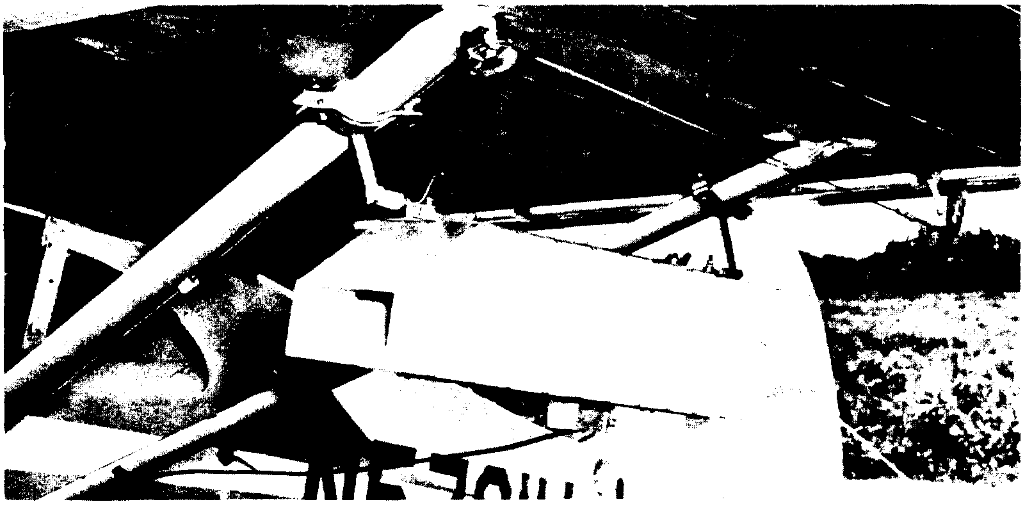

Fig. 4—Geiger counters mounted in aluminum box attached to underside of plane wing.

It is obvious that contaminants in the air, even though in very small concentrations, can be detected upon passing through the neutron flux in the reactor. The additional sensitivity of the reloaded Pile is due to the fact that since the new fuel reloading there is an area of considerably higher specific power, the flux is up by a factor of 3 or 4 and the air stays in the Pile longer.

The staff at the Harvard Air Cleaning Laboratory has been interested in testing the chemical combination of iodine and bromine on silver-plated copper gauze at different temperatures. Even though there are no routine problems or hazards connected with radioactive iodine or bromine at Brookhaven, our Reactor Operations Division is also interested in the project as an aid in cleaning up the cooling air effluent in case of a reactor accident. The test calls for the irradiation of a small piece of fuel plate, melt it quickly in an air stream and measure the amount of radioactive iodine and bromine on the silver-plated copper mesh in the stream. Figure 3 shows apparatus for the laboratory experiment.

The Meteorology and Health Physics Divisions are studying the size, shape, concentration and height of the cooling air plume from the research reactor under various weather conditions. To do this, an airplane flies a course back and forth through the cloud at varying distances and heights from the reactor stack. Geiger counters are used as detectors and are mounted in an aluminum box attached to the underside of the plane wing. (Fig. 4) The geiger tubes are sensitive to β particles and relatively insensitive to γ -rays. The air flows through the box at approximately the speed of the plane and the GM counters see primarily the activity in the box. The geiger pulses are recorded on a tape recorder and will be analyzed later on a multichannel type machine. It is hoped to get within 50 feet of the actual plume size. Preliminary results look satisfactory.

The Meteorology Group is also cooperating with the Health Physics Area Survey Group in an analysis of the effect of the use of the enriched reactor fuel on radiation in the local vicinity. The analytical procedure involves a careful separation of those hours in which a given monitoring station was unaffected by the reactor plume and those in which such an effect was certain or possible. This, coupled with appropriate radiological data from the Health Physics background monitoring stations and reactor operations data, should provide rather substantial detail on the problem after a study of about 6 months of data.

AIR CLEANING PRACTICE AT U.K.A.E.A., ALDERMASTON

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United Kingdom Atomic Energy Authority, Aldermaston, Berks, England

I. Air Cleaning Requirements

Air cleaning facilities are installed at Aldermaston in the ventilation systems of laboratories and workshops where radioactive and toxic hazards arise, in particular from experiments involving the handling of natural and enriched uranium plutonium and beryllium.

The Health Physics Branch has a dual responsibility, to limit the exposure of staff who work on toxic or radioactive materials to a safe level, and to limit, and record, the quantity of activity discharged to atmosphere from the site as a whole. In pursuance of these ends, they specify the standard of room ventilation and cleaning of extract air which is required for each particular operation. They also operate monitoring services to check that these ends are achieved.

Room ventilation requirements range from 5-20 air changes per hour for active and toxic laboratories, to 10 air changes per hour for semi-active areas such as change-rooms and stores. Air is usually supplied to these areas via a filtered plenum system which promotes cleanliness within the building and relieves the dust load on the extract filters.

Handling of exposed plutonium in all forms and of finely divided beryllium and uranium, is carried out in sealed glove boxes under a negative pressure with a recirculating inert atmosphere. Provision must be made for filtration of the High Pressure Extract discharge to stack which comes into operation in the event of a pressure rise in the boxes. High efficiency filters are installed on this H.P.E. extract, and also on the inert gas exit lines to confine contamination to the glove box installation.

Processing of beryllium and enriched uranium in massive forms is carried out in air hoods or fume cupboards which are extracted at such a rate as to provide a flow of at least 200 LFM through all openings. These are often equipped with a local low efficiency separator (coarse filter, cyclone or scrubber, according to circumstances) which facilitates the recovery of valuable materials and lightens the load in the main filter. For the average laboratory or workshop, the total extract from the installed machine boxes or fume cupboards is sufficient to supply the required number of room air changes per hour.

The combined extract air is required to be filtered before discharge to the stack, the policy being that contamination is reduced to a safe level by the cleaning system, plus the dilution achieved before reaching ground level by discharge from a stack of a certain height.

II. Design of Air Cleaning Systems

The specification and design of filtered extract systems is the responsibility of the Chemical Engineering Branch, whose work in this field falls into two main categories:

(a) design of air cleaning systems for spcified applications in new or existing buildings, and
(b) development and testing of new types of filters and other air cleaning devices.

1. Filters

The earliest installations at Aldermaston employed commercially available cylindrical filter units, about 5 ft. long x 8½ ins. dia., in which the filter medium was wrapped twice round a central perforated tube; the canister is welded up after packing (and disposed of with the filter after use). The medium employed is resin-coated wool, developed for removal of particulate smokes in respirators; these filters have a throughput of 180 cfm at a pressure drop of 0.5 - 0.8 ins. w.g., and a methylene blue penetration of 0.05%.

It was known that the filtration efficiency of resin-wool filters decreases during prolonged continuous operation, and to some extent during storage. Where continuous high efficiency was required, the resin-wool was replaced by a double-wound pad of asbestos-wool (mixture containing about 18% asbestos,) which gives a methylene blue penetration of 0.001%, but with a throughput of only 36 cfm at a pressure drop of 1.0 - 1.2 ins. w.g. In some instances an electrostatic precipitator was included.

This system, which is efficient but expensive in space and installation costs, has been replaced in later buildings by a pleated pad type filter, developed by the Chemical Defense Experimental Establishment, Porton, and supplied to U.K.A.E.A. specifications, employing a 50:50 cotton-asbestos filter medium, used either along or in conjunction with a pleated glass-wool prefilter made up from one layer of fine superimposed on one layer of superfine glass-wool, which extends the life between changes of the main filter. Throughput of these cotton-asbestos filters is 200 cfm for an 18" cube filter unit, at an initial pressure drop of 1.1 - 1.5 ins. w.g. and a methylene blue penetration of < 0.003%. These filters will withstand a temperature of 120°C before the cotton chars although at this temperature the asbestos would probably still remain as an effective filter.

A technique has been developed for replacing the prefilter medium in situ under highly active working conditions, (i.e., by working in "frog" suits); when the main filter is clogged, the whole canister is disposed of.

For the lower efficiencies required for work with uranium, a similar unit was developed, with one can 18" x 18" x 18" in which the main filter medium was a double layer of AA Grade with a prefilter of one layer of Fine Grade Fibreglass with pressure drop of 1.5 ins. w.g. at 330 cfm, and a methylene blue efficiency of 0.35%.

More recently pleated paper type filters have become available, which are still more compact. Originally the commercial units of this type employed asbestos paper, containing 5% of asbestos fibre, which is highly susceptible to the effect of moisture in the filtered gas and has only a very limited degree of fire resistance. Fireproofing of cotton-asbestos and asbestos paper has been tried with some success, but it is not considered by us to be a sufficient protection.

We are considering the adoption of pleated glass-paper units which are highly resistant to moisture and still effective after completely wetting and drying out again, and, with choice of suitable containers and cements, can be operated continuously at temperatures up to 500°C. A 24" x 24" x 12" unit has a throughput of 1000 cfm at 0.5 ins. w.g. pressure drop, but with a methylene blue penetration on only 0.01 - 0.03%. Two units can, however, be placed in series in a 24" cube canister to give penetration of $< 0.003\%$, and it is considered at present that this type of installation represents the most satisfactory solution to most filtration problems. It can also, at the expense of a slight loss in high temperature resistance, be made as an acid resistant unit.

The actual filter unit is pleated and sealed into a disposable metal frame, with separators between the folds made of pleated aluminum foil and, in the acid resistant one, resin impregnated fibreglass. This has been done by the firms concerned to our requirement. The units are pressed against the sealing faces of the canister by a wedge action.

2. Design of Installation

All main filters and fans are housed in a separate ventilated filter room within the building served, which, where high activity is involved, is a "purple" area, i.e., in which any operation such as filter changing must be carried out in "frog" suits with air line supply. Extract ducts are at present designed to give flow rates of about 1800 L.F.M. which has proved satisfactory in limiting deposition of particles within them, but we are not certain that this is the optimum in all cases, and should be interested to hear of U. S. practice.

3. Local air treatment prior to filtration

In many cases, the extract system from boxes and from hoods incorporates a local treatment which provides additional decontamination of highly active extract air, permits recovery of valuable materials, decreases the load on the main filters and lessens the danger of settling of larger particles in ducts. It may also act as a spark arrestor in certain cases, to decrease the danger of fire in the extract system.

Such installations vary according to the size of the airborne particles, and with the work being carried out in the enclosure. They may be simple, inexpensive and easily replaced glass-wool mats, high efficiency cyclones (wet or dry), bag filters, wet scrubbers or acid scrubbers.

4. Plenum Air Treatment

Most active buildings are provided with a plenum supply for temperature control. This is normally filtered for the reasons stated earlier, the local atmosphere dust loading is about 0.07 mgm/cu.m.).

Early installations were electrostatic precipitators followed by Vokes "Kompak" cotton fabric filters, a filter unit 12" x 24" x 18" giving a pressure drop of 0.2 ins. w.g. at 600 cfm. Efficiency on normal atmospheric dusts was about 90% in the precipitron and about 30% in the Kompak, giving an overall efficiency of 93%. Electrostatic precipitators however, are subject to occasional bursts with 100% penetration, or even to discharges in which the air loading is increased above input.

A later development was therefore the Kompak Composite filter in which a Kompak cotton fabric filter was preceded by a glass fibre prefilter. This gave a pressure drop of 0.5 ins. w.g. at 400 cfm with a methylene blue penetration of 2%.

Currently recommended systems consist of Vokes '44' pleated asbestos paper, 24" x 24" x 12" units preceded by glass fibre units which act as roughing filters and spark arrestors. This system has a pressure drop of 0.75 ins. w.g. at 1000 cfm and methylene blue penetration of $< 2.5\%$.

In all systems, the air is preheated to bring it below saturation with respect to moisture before passing to the filters.

III. The Work of the Filter Development Section

(a) Specification of filter systems for new or modified buildings

The building design engineer is supplied with a detailed chemical engineering specification with flowsheets, which satisfy all the requirements of User, Health Physics, Safety etc.

(b) Filter Testing

All filters are tested individually before installation in any active system in a test rig; the Filter Development Section uses one for experimental work. Pressure drop and filtration efficiency are determined at the designed flow rate. Filtration efficiency is normally tested by the methylene blue penetration test which is laid down in a British Standard Specification.

Where special filters are needed for local extract points, additional tests may be carried out with heavier loadings of standard test dusts - usually alumina or talc.

(c) Development of New Filters

This has gone on over many years and we think that at present the best available answer to our problems is the pleated glass paper filter, as a high capacity, fire-proof heat-resisting and moisture and acid-proof filter for all active and toxic extracts; where high efficiency filtration is necessary, two are used in series. The asbestos paper unit with glass fibre prefilter is accepted for plenum filtration as it is cheaper.

(d) Assessment of Filtration Costs

This has been carried out in detail for certain buildings in use, and provides data for assessment of costs of filtration in new buildings and provision of estimates for ventilation system.

(e) Investigation into airborne contamination

Determination of dust loading and particle size distribution under working conditions to determine filter loading rates and determination of efficiencies required.

(f) Review and replacement of older installations

Some systems installed during the last ten years are under review at present, and consideration is being given to the advantages in economics, efficiency and safety which can be achieved, together with release of building space, by replacing them with more modern types of filters. The work involved in making such changes under contaminated conditions is being looked into.

Discussion

Q. (G. J. Hurwitz, Army Chemical Center) In view of the fact that use of D.O.P. is pretty well standardized in this country for more than 10 years, I'm surprised you are still using methylene blue in Britain. If it is going to be used any length of time -- ?

A. We find methylene blue easier to handle and results more produceable ---

C. We understand and that's why we are interested in this. It doesn't take so long to get answers.

SUMMARY OF IMPORTANT AIR CLEANING ACTIVITIES AT FMPC, FERNALD, OHIO

C. H. STEVENS
National Lead Company of Ohio, Fernald, Ohio

Our criteria for industrial ventilation are similar to most other AEC installations; namely, (1) protection of the health of the worker by providing environment well below the M.A.C., (2) reduction of uranium losses through exhaust stacks to an absolute minimum and (3) keeping maintenance and downtime on ventilation equipment at the lowest possible levels.

This talk will briefly discuss some installations we have recently completed which I believe will be of interest to most of you. One job involved collection of very fine particles which caused us considerable difficulty in maintaining constant pressure drop across the dust collector bag. Another project involved the installation and operation of a prototype drumming station which has virtually eliminated dust leakage to the room while filling drums. A third installation dealt with a method of collecting dust from a booth where uranium ingots are separated from their molds. The last job I will mention will deal with the burning off of up to 5% enriched sludges in our Pilot Plant. We will also mention a few of the ventilation projects we are presently working on and expect to install within the next year or so.

In our Green Salt Plant we reduce UO_3 to UO_2 by passing hydrogen through UO_3 in a reactor. (Show Slide). The excess hydrogen used is burned, and the off-gas is passed through a bag collector where any fine material picked up by the hydrogen stream in its passage through the reactor is collected. We recently converted from screw reactors to fluid bed reactors, which resulted in higher loadings to the dust collector as well as finer dust particles. Our measurements indicated a loading of 2/10 of a grain per cubic foot of air. About 70% of the dust particles are finer than 5 microns and about 30% finer than 1 micron. Although this grain loading is by no means considered heavy in normal dust collection operations and we were only operating at an air to cloth ratio of about 12 to 1, we obtained pressure drops across the collector bags of 6 to 8 inches, with that pressure drop increasing by the hour. Periodic shutdown of the collector and hand-shaking of the bags was necessary to keep operating.

We have succeeded in remedying the situation by doing the following:

> Utilizing a small collector located nearby in parallel with our H_2 off-gas collector and thus dropping the air to cloth ratio to about 8 to 1. We also revised our hooding as much as feasible to reduce air volume requirement and still get adequate collection. We further installed truncated cones on top of the bags to prevent recirculation of the fines. In addition, we went over these collectors with a "bine tooth comb," checking proper blow ring center distances, carriage travel speeds, and other mechanical facets of collector operation. Pressure drop is now uniform somewhere around 4 to 5 inches across collector bags.

Another project was concerned with obtaining proper dust control at points where we are filling 55-gallon drums. We, therefore, decided to design and install a prototype drumming station which, if it works satisfactorily, will be used throughout this project. This slide shows this prototype drumming station just installed. As you can see, it is basically an enclosure with adequate windows and floodlights; we have also provided a semicircular ventilated hood around the drum. The station itself is also ventilated. We have allowed enough space in the drumming station so that the operator can move the drum away from the feed spout and lid the drum inside the enclosure. An air dust survey just completed shows excellent control at this drumming station; the counts taken at this station were practically the same as the general background level.

Another project just completed and now operating is a new ingot separation booth in our Metals Plant, where the ingot is separated from the mold. This booth is ventilated and the exhaust ducts are brought into an existing Mikro-pulverizer dust collector. There are existing ducts, brought in to the top of the collector by a specially sized manifold, as shown on the slide. To modify this manifold to provide for the additional air quantities required for the ingot separation booth ventilation would demand expensive duct changes. We, therefore, brought a new duct into the hoppers of this collector, as shown on this slide. Thus, in effect, most of the air enters the top of the collector, with about 25% of the air entering the bottom. No difficulties have been experienced as a result of this somewhat unusual method of air entry. The collector operates at an air to cloth ratio of approximately 13 to 1 and a bag pressure drop of 3 to 4 inches.

In our Pilot Plant, we have had the problem of burning off sludges of up to 5% enrichment. The fumes from this burning process are sticky and oily and generally difficult to collect. We tried some Cambridge "absolute" type filters preceded by a fiberglass prefilter, but found that the "absolute" filters plugged up rather rapidly. We have since replaced these filters with two banks of American Air Filter Company's PL-24 units of fiberglass media. Due to their larger dust holding ability, they have operated successfully for some time with no noticeable stack losses.

We are now working on a number of ventilation projects, such as a new off-gas system for the rotary kiln. As shown on this slide, the present system is a relatively complicated one and has a lot of ducts and equipment that not only could plug up but do plug up. We, therefore, propose a much simpler exhaust system, as shown on this slide, which basically involves only a few feet of ductwork with adequate cleanout doors, and a caustic scrubber with hopper bottom. Another project involves ventilation from our digestion tanks used to dissolve uranium scrap in the Scrap Plant. This ventilation is essential to vent hydrogen fumes generated by the digestion process. Unfortunately, the exhaust air also draws off hydrochloric acid fumes which we are planning to collect in a Chemical Construction Company Pease-Anthony Venturi Scrubber. This scrubber was picked for its inherent simplicity and consequent ease of operation and maintenance. Other installations being designed now involve additional ventilation for our green salt canning stations using a Wheelabrator Corporation Dust Collector, an off-gas scrubber for a sludge furnace in which grinder sludges are burned, ventilation for a Williams Crusher and allied equipment, general purpose bag collector for our Pilot Plant operations in which up to 5% enriched dusts will be collected, and a new continuous-automatic bag collector for our low enrichment metal remelt operations.

STACK SAMPLING PROCEDURE AT THE NATIONAL LEAD COMPANY OF OHIO

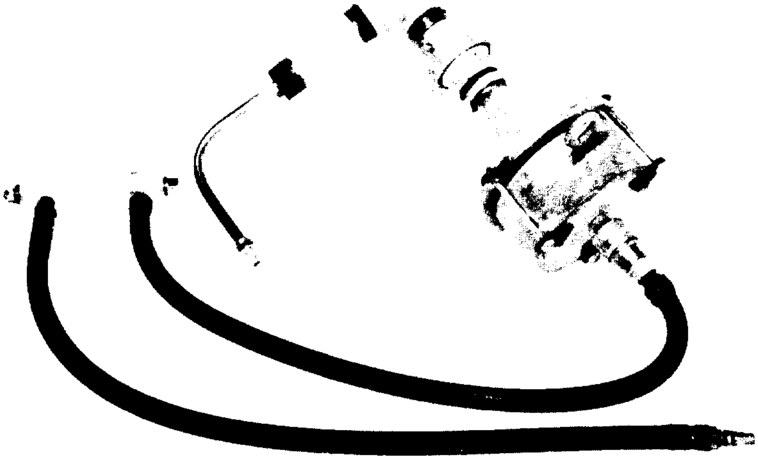
ROBERT H. STARKEY
Health and Safety Division, National Lead Company of Ohio, Cincinnati, Ohio

As at all AEC installations, all of us here are interested in the amounts of material being exhausted to the atmosphere. Ventilation equipment and dust collecting equipment represent an important investment at all AEC sites and we, as health and engineering people, are quite interested in seeing that this equipment is operating as efficiently as possible.

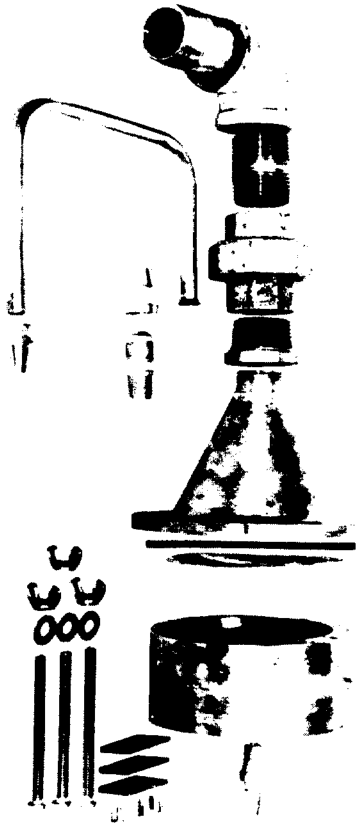
We decided to make a study to determine the efficiency of the dust collectors at the Feed Materials Production Center. As a result of this study, we developed a stack sampler and sampling procedure for the purpose of monitoring as many of our stacks as possible. The stack sampler is shown in Slide I, and I will describe the procedure we developed. It might possibly have a use at your site.

Presently we have approximately fifty of these samplers operating on a continuous basis. These cover all dry stacks. We have found that the results obtained from this program have been a very important tool in increasing the efficiency of the operation of the dust collecting systems in our plants. A preventative maintenance program on dust collectors was just getting under way at the time our stack sampling program was instituted. The stack losses which we reported, along with their accompanying monetary worth, were a valuable aid in speeding up the preventative maintenance program. The over-all dust collection inspection and maintenance program has improved to the point where we are now losing only 15% of the material that was being lost at the time of the original installation of the stack samplers. You can see, therefore, that the stack sampling program, in addition to greatly reducing the quantity of radioactive material released to the environs, has more than paid for itself in the intrinsic value of the material collected. Another indirect by-product has been the improvement of the ventilation provided on equipment as a result of the more efficient maintenance and operation of the dust collection equipment.

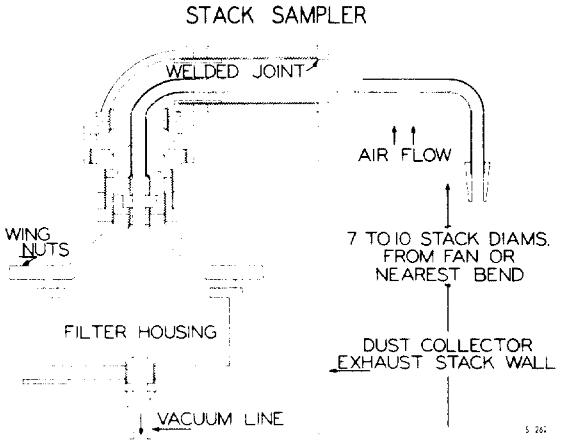
I would like to explain briefly the stack sampler developed, the procedure followed, and the use made of the results obtained. Slide I shows a picture of the stack sampler of the type presently being used. A number of changes have been made since the original design, all of which make the installation and sample changing easier. Notice the rotameter attached. I will explain more about its use later. Slide II is a disassembled view of the sampler and all of its integral parts. Slide III is a detailed sketch of the sampler showing the critical dimensions.



Slide I

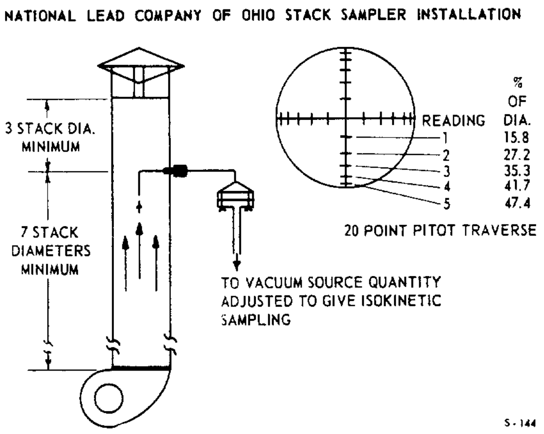


Slide II

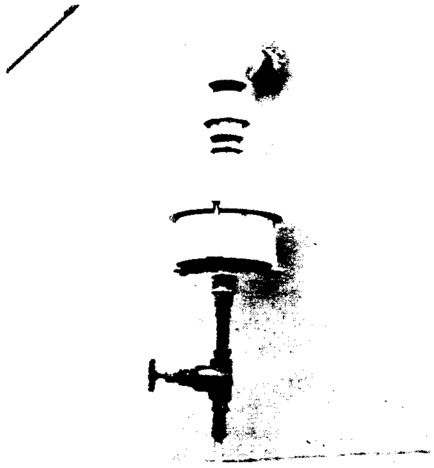


Slide III

Slide IV is a diagram of an ideal stack sampler installation, and Slide V is a picture of an actual installation. This is typical of the other installations with the one exception that it is one of the few installed on the roof of a building. Most of our samplers are installed inside the buildings, inasmuch as the type of roofs make sampling thereon impossible. Slide VI describes the procedure for installing the sampler in a stack.



Slide IV



Slide V

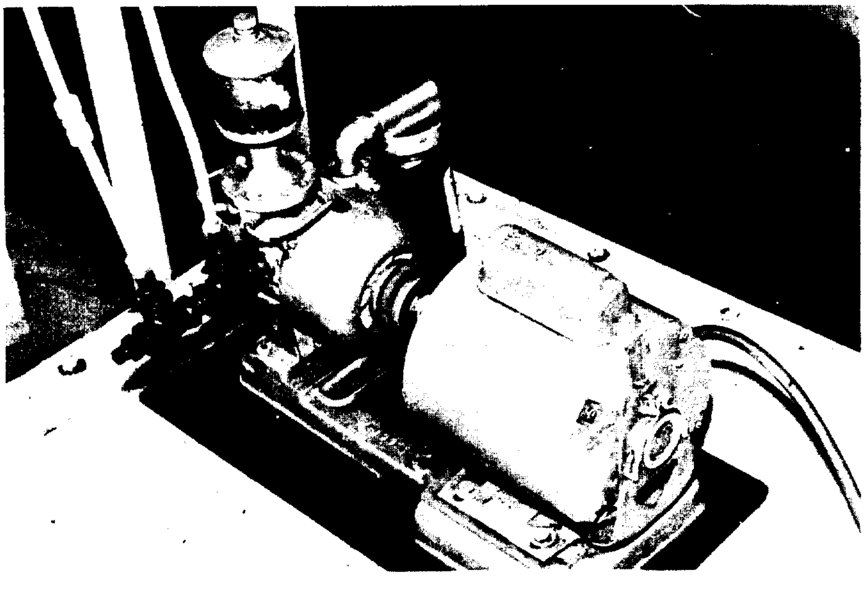
SLIDE VI

Procedure for Installation of Sampler in Stack

1. Drill hole in stack - best possible location inside building.
2. Traverse stack - determine average and centerline velocities. (This should be done bi-annually so appropriate corrections can be made.)
3. Have sampler constructed - for centerline sampling.
4. Determine best source of vacuum, either Hi-Vac unit (Slide VII) or Gast Pump (Slide VIII).
5. Install sampler - probe in center of duct and parallel to line of air flow.
6. Determine volume of air needed for isokinetic sample.
7. Adjust flow through gate valve with rotameter attachment.
8. Remove rotameter.

Slide IX shows the procedure followed for changing the sample. The samplers are visually checked a minimum of once each month and changed if sufficient material for weighing on a beam or platform balance (0.1 gram) is found on the pleated filter. If insufficient material is collected, the filter is allowed to remain in the stack until such time as enough material has been collected for analysis. When a sampler is not changed, the loss for the particular stack is recorded as non-detectable for the particular sampling period. In addition, samples are changed following the release of unusual amounts of material from the stack due to damaged dust collector bags or a malfunction of the collector. The production personnel notify us immediately following an incident and we install a new filter.

Slide VII



Slide VIII

SLIDE IX

Procedure for Changing Sample

1. Disconnect vacuum line from sampler.
2. Insert rotameter and check flow.
3. Loosen wing nuts and disassemble sampler.
4. Remove filter and place in pre-numbered plastic bag.
5. Insert new pre-numbered and pre-weighed type "S" filter.
6. Assemble sampler and tighten wing nuts.
7. Again check sampling rate and make necessary adjustments.
8. Remove rotameter and connect vacuum source to sampler.
9. Submit sample for analysis.

In the laboratory the following procedure is used:

Analytical Procedure

1. Pre-weigh and pre-number pleated filter and respective plastic bag prior to use.
2. Again weigh following use to determine gross weight of material collected.
3. Run wet chemical analysis of material collected to determine per cent of uranium.
4. Report both gross weight and per cent of uranium.

Slide X shows the calculation necessary for determining the pounds of uranium lost from each stack over <u>any</u> sampling period.

SLIDE X

$$\frac{V(ave)}{V(C_L)} \times \frac{R(s)^2}{R(p)^2} \times \frac{1}{454} \times Ug = U \text{ loss - lbs.}$$

$V(ave)$ - Average stack velocity (fpm)
$V(C_L)$ - Stack centerline velocity (fpm)
$R(s)$ - Radius of stack - inches
$R(p)$ - Radius of probe - inches
Ug - Uranium collected in grams

In summary, I have described the method that we use for estimating the material being exhausted from the stacks at our plant. It is fully realized that this is not an exact method in any sense of the word; however, we have conducted some preliminary tests which indicate the procedure is accurate within plus or minus 20%. We have found it a very worthwhile tool in checking the operation of our dust collectors and feel that possibly it has a use throughout industry. It can only be used where relatively large amounts of material (in the order of a pound) are being exhausted over a reasonable period of time; thus, it is probably of no use where absolute filters are used or on other types of systems exhausting only very small quantities of material. However, I do feel that where appreciable amounts of material--whether radioactive or non-radioactive--are exhausted, this method can be profitably used. Actually an adaptation of this stack sampler can very well be used for determining the loading on dust collectors by installing it on the inlet side of the collector. By using both the inlet and outlet sampler simultaneously, an efficiency study can also be carried out.

If any of you are interested, I would be only too glad to furnish the necessary drawings and equipment specifications for this sampler upon request.

AIR CLEANING AT THE KNOLLS ATOMIC POWER LABORATORY

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Abstract

The construction of a new $30,000 facility for the sole purpose of safeguarding against the spread of radioactive iodine has been started at the Knolls Atomic Power Laboratory. This facility is in addition to the many air cleaning facilities at KAPL which have been reported at previous AEC Air Cleaning Conferences.

Well over 475,000 cfm of laboratory air is cleaned at KAPL prior to discharging the air to the environs. The air is first introduced as 100% outside air thru air systems equipped to filter the air with self cleaning of throwaway filters. It is again filtered before it is discharged to the atmosphere. Over 350 CWS filters are employed in the exhaust systems. Multiclone and deep pack filters are also used.

A need for the control of radioactive iodine vapor in the Radioactive Materials Laboratory has created a new problem which has become unique to our operations and calls for a filter media which will retain gaseous matter as differentiated from particulate matter.

This report deals with the description of the newly designed activated carbon and stack system which will handle the radioactive iodine vapor and will be operated in conjunction with the existing systems in the Radioactive Materials Laboratory.

The new system will consist of a 17200 cfm fan and filtering facility and will employ 24 - 24" x 24" commercial activated carbon filters operating together with a 105 foot stack. The overall radioactive iodine concentration reduction factor will be in the order of 4×10^4.

In the event of a radiation incident or equipment failure back up features are included to safeguard against the spread of radioactive contamination.

Introduction - At KAPL there are 6 laboratory functions which call for the use of environmental air cleaning. The areas are shown on Sketch Y-A-1757 and are designated as follows:

1. Special Nuclear Materials Machine Shop
   Bldg. D-3, D-4. (Multiclone & deep pack filters)

2. Chemistry Physics and Metallurgy Labs
   Bldg. E-1, G-1, G-2, A-3. (CWS filters)

3. Radioactive Materials Laboratory
   Bldg. E-2, E-3, E-4. (CWS filters)

4. Nuclear Reactor Components
   Inspection & Quality Control
   Bldg. Q-4, Q-5. (CWS filters)

5. Waste Disposal Bldg. H. (CWS filters)

6. Zero Power Reactors
   Bldg. F, E-5. (CWS filters)

Because of the close proximity of the buildings and the location of KAPL in a suburban area positive control of effluent gases is essential.

The Radioactive Materials Laboratory has presented a radioactive iodine problem which has made it necessary for the design of the iodine vapor system. Specific reference will therefore be made to the control of radioactive iodine.

The new facility will allow immediate sectioning and chemical-and corrosion testing of irradiated samples which in the past could not be handled until the samples had sufficiently decayed and thus rendered safe to handle within the available facilities.

As stated above the new facilities will be added to the existing ventilation systems now serving the Radioactive Materials Laboratory. The purpose of the facility will be to fulfill the following needs, applicable to any radioactive materials processing laboratory.

1. Protect the laboratory personnel from any contact with contaminated materials whether such materials are in the particulate or vapor form.

2. Assure sufficient stack gas contaminant reduction to render the effluent gases harmless to the environs.

3. Provide safeguards which will assure continuity of operation and effective protection against the spread of contamination in the event of an incident.

In order to meet these needs the following critera are essential:

1. Introduce a tempered air supply into the building which will replace the air exhausted at the work areas.

2. Maintain uniform draft free air flow within the building in the direction of the contaminated areas. The building should be under a slightly negative pressure. The negative pressure

should become progressively greater in the direction of the hot work area until the highest negative pressure is attained where the hot work is performed.

3. Clean the air before it is discharged to the atmosphere.

4. Provide duplicate equipment if this is necessary to assure reliable operation. This is particularly applicable to fan equipment which is subject to breakdown.

The existing equipment at KAPL does not fully meet the requirements of items 2 and 3. Radioactive iodine might be discharged unless delays are imposed on the processing of radio iodine samples to allow them to cool off. There is also a chance of losing the continuity of air flow in the direction of the work within the cells in case of an incident. This latter inadequancy will be explained more fully after the existing facilities are described.

Description of Existing Facilities

The RML building measures approximately 72' x 140' x 24' high. Here several hot laboratory functions are performed all of which are primarily associated with the examination of irradiated samples.

Air is supplied to the building with two central plant air units on a once thru basis. Both units are equipped with 2" thick fibre glass filters and together the units have a capacity of approximately 12000 cfm. Air is discharged from duct openings high up under the roof in order to avoid air turbulence at the occupancy levels.

Air is exhausted from the work areas with several individual exhaust systems each of which is equipped with a fibre glass pre-filter followed by a CWS filter. From one (1) to six (6) such filters are installed ahead of each of the exhaust fans. The filters and fans are located on a 12' high balcony which runs along the length of the building. Discharge stacks rise straight up thru the roof from the fans to an elevation of 50 feet above ground level, approximately 25 feet above the roof.

A summary of the air flows is given:

1.	Autoclaves (in adjoining Cask Storage Bldg., fan in RML Bldg.)	400 cfm
2.	Localized Building Exhaust,	6,000
3.	Chemistry Hoods,	1,000
4.	Storage Vault,	200
5.	Decontamination Chamber & Room (in adjoining Bldg.)	2,800
6.	Cells 1 & 2,	3,000
7.	Isolation Boxes within Cells 1 & 2,	500
8.	Cells 3 & 4,	2,000
9.	Isolation Boxes within Cells 3 & 4,	300
10.	Cell 5 & 7,	600

11.	Cell 6,	300
12.	Cell 8 (in adjoining Bldg.)	100
	12 Stacks - Total Air Flow, cfm	17,200

Iodine work is primarily done in cells 1 thru 4, however it may be carried on to a degree in any of the other ventilated areas.

Since the optimum safety is required in cells 1 thru 4 the manner in which these cells are ventilated will be outlined in detail.

Figure No. 1 shows a diagrammatic view of the way in which the hazardous gases and dusts are contained within the work area. The work is performed within a isolation box consisting of an enclosure made of transparent polyethylene plastic sheets taped together nearly air tight. The boxes are about 3' x 3' x 3' in size and up to 3 or 4 isolation boxes are housed within a cell.

Proper operation of the ventilation depends on such factors as:

1. Assurance all isolation boxes are sealed up. Short circuiting of air due to an open box or branch duct may interrupt the adequate exhaust at other isolation boxes in use.

2. Proper equipment operation. Since two fan systems are virtually drawing air from the same space the flow direction in the isolation box system could be reversed under certain conditions, such as a fan failure. This means the "cold" to "hot" air flow concept would not be fulfilled. The hottest materials within the isolation boxes would be spread into the cell and into the balcony filters which by virture of their size are much more difficult to dispose of than the box filters within the cell.

3. Proper air balancing.
One central fan is used for 2 cells each of which contains 3 isolation boxes. Unless the air flows are adjusted proper static air pressure conditions may not be realized. The rate at which the box filters become dirty may affect the overall performance even after the system has been balanced.

4. Assurance the isolation boxes are under a negative pressure.
The plastic material gives a good indication where the net overall air pressure is, inside or outside the box, since there is some slack in the material.

Description of New Facilities

1. Improvement of In-Cell Ventilation

Figure No. 2 shows the new design for cells 1 thru 4.

This sketch shows one of the portable ventilators which will built to eliminate the deficiencies of the present systems serving the isolation boxes.

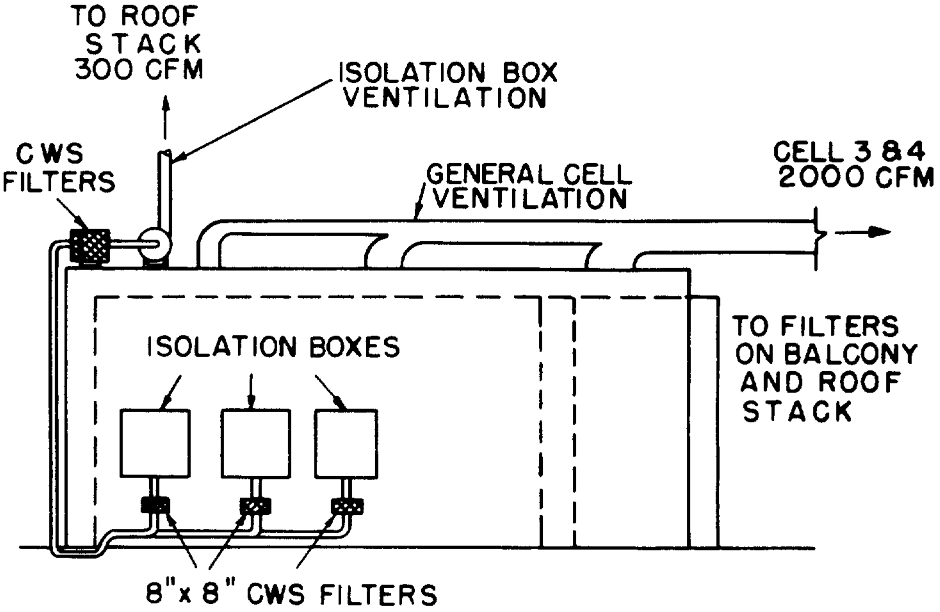


Fig. 1—Cell No. 3, ventilation systems (fan systems also exhaust adjoining Cell No. 4, duplicate of Cell No. 3).

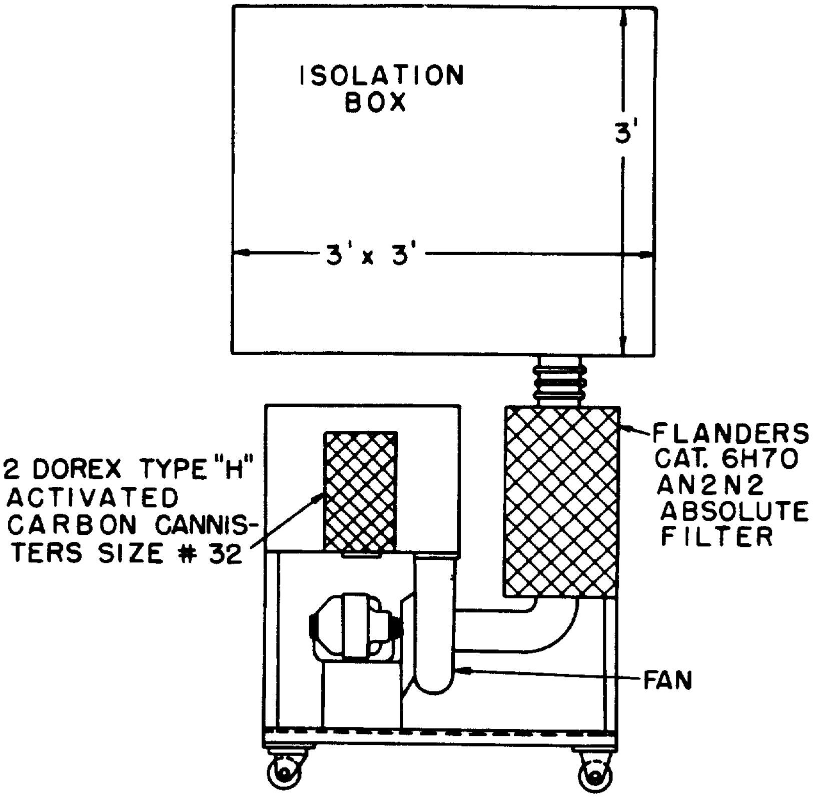


Fig. 2—Portable isolation box vent unit (for Cells 1 through 4).

Each isolation box will be equipped with its own fan and filter as shown. After the air is filtered it will be discharged directly into the cell. The air pressure within the box will always be lower than the cell. Fan failure will not greatly contribute to any spread of materials.

The old isolation box system will be dismantled up to the cell wall and will be for standby use only.

2. Central Activated Carbon Filtering System

A system of equipment was divised with a view to overcoming the difficiencies outlined.

The first decision related to the redesign of the present systems or to add to them. Except for the in cell isolation box ventilation it was decided to build on to the existing facilities. The reasons were:

a. We found inadequate in-building space to house additional carbon filters.

b. We wished to minimize downtime necessary to allow reconstruction of the unit exhaust systems.

c. It was felt a central system housing all of the carbon filters in a single enclosure will be much more satisfactory from a standpoint of:

   (1) Shielding, if ever necessary.

   (2) Dilution of radioactive gases generated at any one of the ventilated work areas as related to the performance of the carbon in filters.

   (3) A central system will also lend itself to future increased ventilation requirements.

   (4) Although all the air exhausted will pass thru the carbon filters provision has been made for the installation of a filter by-pass, if we ever desire to install one. Again it is much simpler to install such a by-pass in a central system than it would be with individual unit systems.

d. Aside from filtering out radioactive iodine discharged from any one of the existing systems, we also desired added protection afforded by a high stack. The stack alone justifies the added ductwork required to interconnect the existing stacks.

The new carbon filtering system is shown in Figure No. 3.

Twelve (12) of the existing ventilation stacks will be cut at the roof line and interconnected with ductwork into two (2) central headers from which air will be drawn by a booster fan thru a filter plenum located on the roof and housing twenty-four (24) "Dorex" Type C, size T-42 cells after which it will be discharged to atmosphere from a 38" diameter, 105 ft. high free standing stack. Except for the stack,

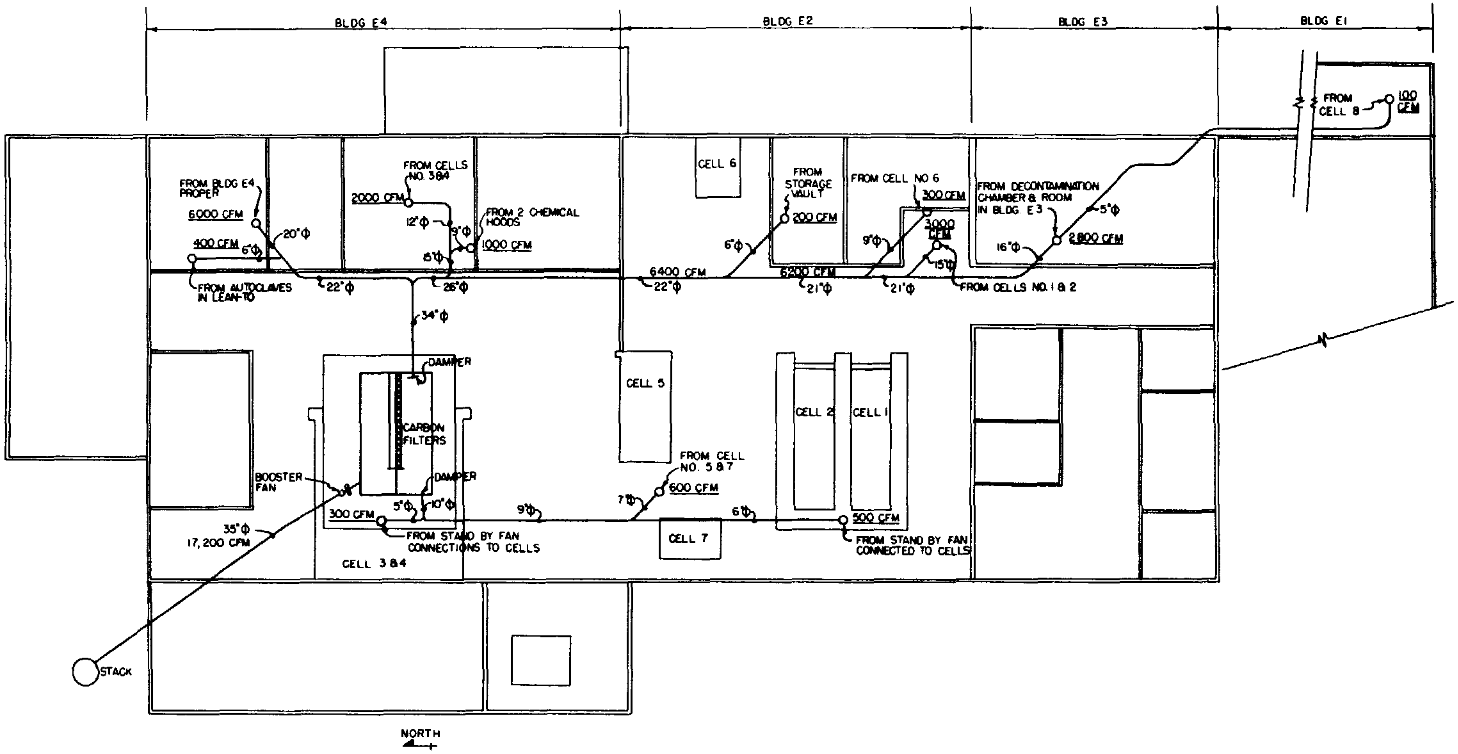


Fig. 3—Flow diagram.

which is to be relocated from the Separations Process Research Unit (no longer in use), all the equipment will be new.

3. Safeguard Measures

a. The individual unit systems equipped with CWS filters ventilate all of the cells and, in addition to this, will provide back-up protection for the portable in-cell CWS-activated carbon units in cells 1 thru 4 where the larger work is done.

b. Further backup protection will be provided by the central carbon system and stack.

c. A standby booster fan is to be added. This will start in response to an air flow switch from a separate power source.

d. Our Health Physics informs us that we can expect an overall radioactive iodine concentration reduction factor in the order of 4×10^4 as determined from the following reductions:

Concentration Reduction	Factor
Stack	100
Activated carbon filters (95% efficient filters will retain up to 18 lbs. radioactive iodine per 24" x 24" filter cell. Two filters in series)	400

overall factor: $100 \times 400 = 4 \times 10^4$

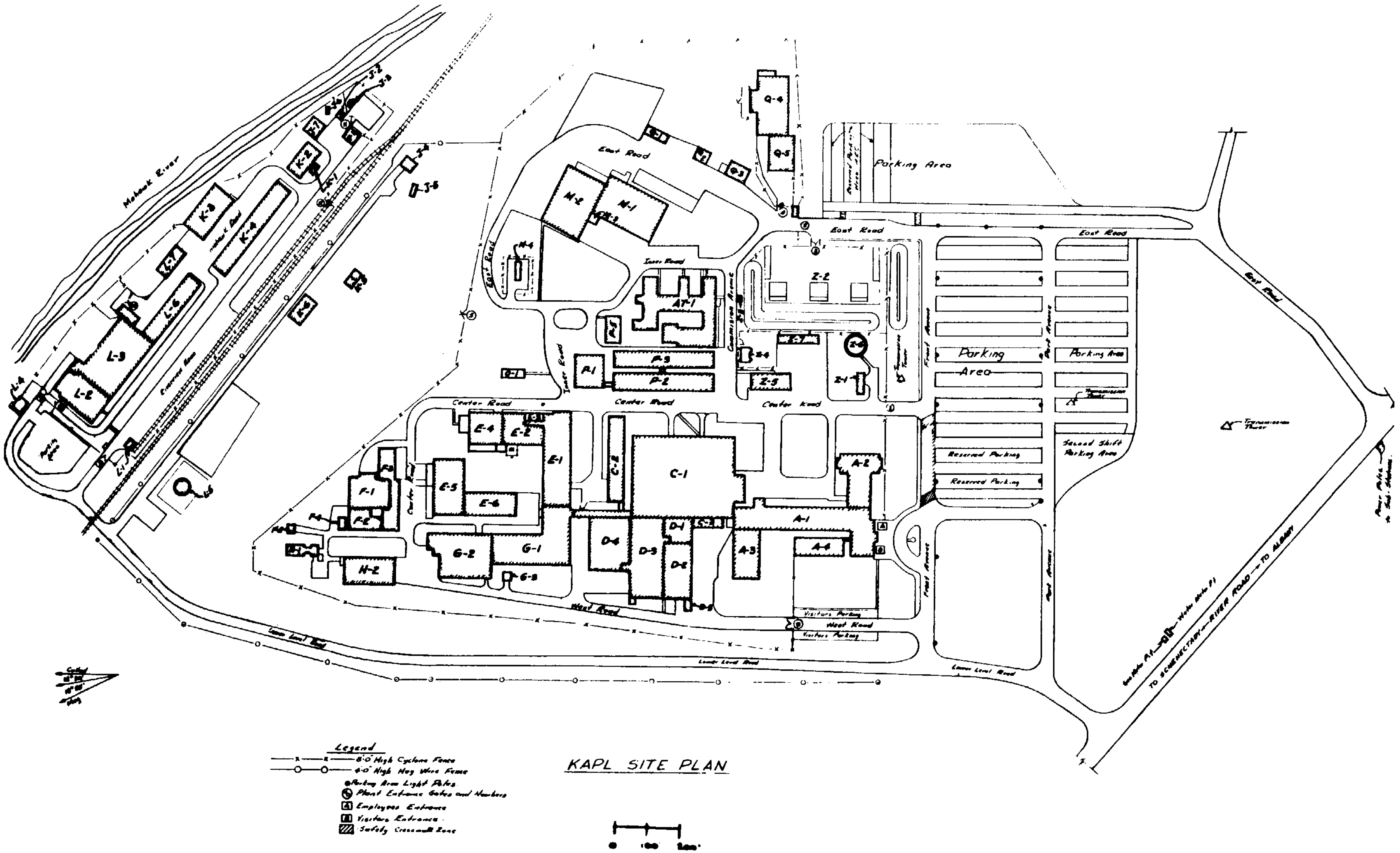
e. Provision has been made for the possible addition of a second bank of activated carbon filters in the filter plenum.

f. The carbon plenum is structurally adequate for future lead shielding up to a thickness of 1/2" along the four walls. The floor of the plenum is masked off by a cell block located immediately below.

g. Since the adsorption of radioactive xenon and krypton is greatly affected by temperature, the activated carbon will not be relied on for the removal of these gases. The 105-foot stack will provide adequate protection here, especially since xenon and krypton do not add to the environs as iodine does.

h. Highly oxidizing ruthenium tetroxide has been considered. The small amounts which might be given off will separate out in the particulate filters.

In conclusion, the system described should be very satisfactory for the containment of radioactive iodine effluents. Once



KAPL SITE PLAN

Building Designation	Description
A-1	Administration, Engineer. & Technical Offices
A-2	Cafeteria
A-3	Physics & Metallurgy Laboratories
A-4	Contracts & Purchasing & Employee Placement
C-1	General Shops and Offices
C-2	Engineering Offices & Dispensary
C-3	Finance Offices
D-1	Metallurgy Offices
D-2	Engineering Department
D-3	Special Materials Shop (Machining Operations)
D-4	Metallurgy Shops (Special Materials)
D-5	Liquid Metals Cleaning Area
E-1	Chemistry Laboratoires
E-2	Radioactive Materials Laboratory
E-3	Chemical Engineering Laboratory
E-4	Radioactive Materials Laboratory Addition
E-5	Critical Assemblies
E-6	Critical Assemblies, IBM Wing
F-1	Physics (Preliminary File Assembly)
F-2	Physics (SIR Proof Testing)
F-3	Physics (Advance Test Reactor)
F-4	Equipment Storage
F-5	Radioactive Waste Storage
G-1	Chemistry & Chemical Engineering Laboratories
G-2	Engineering & Technical Laboratories
G-3	Scrubber Pump House
H-1	Cooling Tower
H-2	Waste Disposal Facilities (Liquid)
J-1	Sludge Beds
J-2	Sewage Chlorination
J-3	Waste Incinerator
J-4	Filter Bed
J-5	Imhoff Tank
J-6	Parshall Flume
J-7	Utilities Storage

Building Designation	Description
K-1	Fuel Oil Pump House
K-2	Fuel Oil Tank Farm
K-3	Oil Storage Tank
K-4	Boiler House & Laundry
K-5	Retention Pits
K-6	Intermediate Radioactive Waste Storage
L-1	Helium Receiving Station
L-2	Coolant Test Building (Phase I)
L-3	Coolant Test Building (Phase II)
L-4	Pump House
L-5	Oil Storage Tank
L-6	Engineering Development
L-7	Radioactive Waste Handling
M-1	Warehouse
M-2	Warehouse
M-3	Stainless Steel Cutting
M-4	Test Specimen Storage
O-1	Engineering Offices
P-1	Engineering Offices
P-2	Engineering Offices
P-3	Engineering Offices
AT-1	AEC Offices
P-5	Records Storage
Q-1	Chemical Storage
Q-2	Liquid Metal Storage
Q-3	Site Maintenance Warehouse
Q-4	Development Shops
Q-5	Development Shops
Z-1	Water and Gas Pump House
Z-2	Gas Storage Trailer Stations & Canopies
Z-3	Laboratory (Physics)
Z-4	Power Sub-Station
Z-5	Fire House
Z-6	Water Tower & Valve House
Z-7	Storage Shed

Date: 5/10/57

the activated carbon system is placed in operation and its operation is observed for a period of time, other data will be made available.

Discussion

Q. Have you run any tests?

A. At present we have one installed as a trial filter - been in a matter of two months. - going to take measurements yet on this - there is only a quarter of an inch of carbon in the cell.

Q. (J. J. Sabo, U. S. P. H. S.) I am wondering why your filters are outside of your isolation box, the general tendency has been to put the filter inside the isolation box.

A. Actually located within seal anyway.

Q. (J. J. Sabo, U. S. P. H. S.) When you remove the filter from the isolation box, is there any danger of getting contamination in the cell?

A. Spread control pretty closely in a cell like this.

Q. (F. W. Schlapp, Atomics International) The scrubber he described, in it he mentioned that they use 5% solution of sodium hydroxide maintained in this concentration - why do they use this solution and how is it maintained, is it by adding water to the solution or some other?

A. Concentration didn't seem to make any great difference from 2-10% as far as keeping concentrations equal all the time, we don"t, but we do try to maintain it closely.

Q. (M. D. Thaxter, Lawrence Rad. Lab.) You mentioned your major problem was the dissolver fission in the off-gas handling. I was wondering how much volume was attributable to the process where requirements for dissolving led to the question of whether it would be possible to make a completely closed system dissolution to cut out the major problems?

A. We have had a maximum of 700 cfm flow - about .6 of this would be the normal flow through - new gas products of one sort or another is produced in the dissolving process - newly formed gases or parasitic air -

ADDITIONAL OFF-GAS FACILITY

A. B. FULLER
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The information contained in this article relays some considerations in the engineering design of additional radioactive off-gas cleaning and handling facilities at Oak Ridge National Laboratory. The new construction program and the goal for ever better decontamination of radioactive effluent has made the need for expanded facilities necessary in the immediate future.

* * * * *

For the past eight months the Engineering Department at Oak Ridge National Laboratory has been actively engaged in the design and the preparation of drawings and specifications for additional radioactive off-gas cleaning facilities. It is expected that these documents will be completed and out for contract bidding within a few weeks. This work will cost in the order of $230,000 (design costs approximately $20,000). These added facilities should triple the present gas handling capacity, from 2000 to 6000 cfm.

For the purpose of identification, off gas consists of the waste gases resulting from radioactive processes and from the ventilation of process vessels. Cell ventilation is essentially space ventilation of the over-all space enclosure where the processes are installed.

Present off-gas equipment provides a gas handling capacity of 2000 cfm with cleaning provided by a Cottrell electric precipitator followed by absolute filters with the effluent being released from a 250-foot brick stack along with other gaseous wastes. This system has operated satisfactorily for sometime with the exception of the past six months. During this latter period the gaseous wastes from two process buildings when mixed in the system caused dense smoke (ammonium nitrate) which partially passed the precipitator and quickly caused failure of the absolute filters. This problem has been minimized, but a full solution has not yet been found.

The present normal loading averages approximately 1200 cfm. This normal demand is expected to reach 3 times this level within less than 3 years.

A study of additional off-gas cleaning needs at Oak Ridge National Laboratory dates back over five years with subsequent studies up dating the needs to conform with the changes in the construction program. Oak Ridge National Laboratory is now involved in a construction program having costs in excess of $20 million, with FYs 60 and 61 planning that adds considerably more. The majority of these projects place an added demand upon the off-gas cleaning facilities.

A decision was made to centralize, as much as possible, all the off-gas cleaning facilities in the central X-10 area to better meet the needs for the service. This means several existing buildings will be served by the equipment planned, or now existing, at the 3039 stack area. The principal existing building to be added is the 3019 Pilot Plant, a chemical processing plant which is allotted as much as 700 cfm flow.

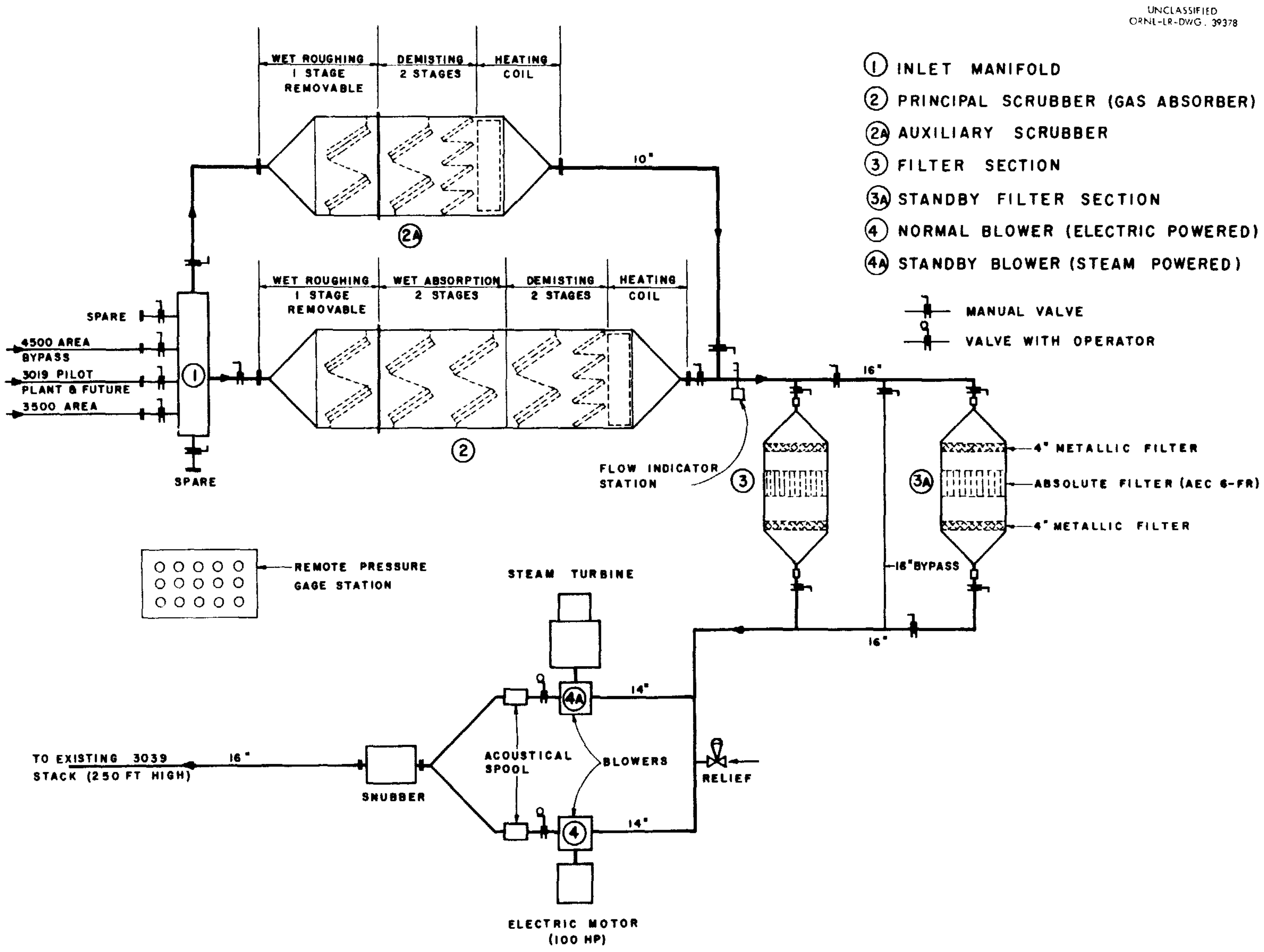
When design work of our new facilities was begun it was immediately evident we needed to know the analysis of the material we were expecting to clean up. A search was initiated to accummulate all the existing available data. For the purposes of design this information turned out to be wholly insufficient. It was not specific, and very little was written fact. To overcome this set-back, we initiated a survey; whereupon all contributors were asked "what gaseous matter do you release to the radioactive off-gas system, how much, at what frequency, what do you expect to do next year, even five years hence." We also sought the advice of the Harvard School of Public Health. In late January of this year, we discussed our problems with Dr. Silverman, Messrs. Dennis, Fitzgerald and others for two days. This visit was very fruitful. However, our survey at Oak Ridge National Laboratory was not successful. Our contributors could not give an accurate and complete analysis of their effluent. The labor, time and other complications in acquiring this information was beyond reason. The nature of operations at Oak Ridge National Laboratory do not include any continuous production where off gas is released. All operations are intermittent, not uniform and in most cases do not exist for long periods of time.

The immediate future will add several new customers to the system among which is the Power Reactor Fuel Reprocessing Facility that is now being designed. This then gives us a list of principal users that includes:

Facility	Max. Flow Allotted
Power Reactor Fuel Reprocessing (2527)	600 cfm
Multicurie Fission Products Pilot Plant (3517)	600 cfm
3019 Pilot Plant under Chemical Technology Div.	700 cfm
Metal Recovery under Chemical Technology Div.	600 cfm
OR Research Reactor	1000 or more

All uses, both now and within less than the next 3-year period, total over a 4800 cfm maximum flow with normal use expected to average from 60 to 70% of this maximum figure. Twenty-eight or more different buildings or facilities are to be served by the combined systems (old and new). The use of the service varies from a piped fume hood service to high level dissolver venting.

Our final analysis established that the off gas we expect to experience will be (1) quite corrosive, (2) will be radioactive in varying degrees, and (3) will contain only small quantities of particulate matter during normal periods. All particulate is expected to be normally less than 10 microns in size with the major portion less than 1 micron. Short periods of high fume concentrations will result from dissolver reactions.



Schematic routing of gas flow (maximum flow rate, 4,000 scfm.).

This is the worst period of operation believed to be encountered. From this it was decided neutralization must be accomplished before any filtration and, too, the features inherent with wet absorption would best give the required cleaning of both soluble gases and particulate. The selection of stages of absorption were based on trying to achieve 99.5% or better collection of all radioactive iodine for concentrations as low as 5 micrograms per cubic foot of gas. This form of cleaner is believed to be the type best suited to the combined problem of corrosiveness and radioactivity. With a remote underground sump it allows easier shielding of the absorbed activity.

All the principal items of equipment, except blowers, are enclosed with shielding walls with means of performing routine operation without entering the enclosures.

To provide continuous service a steam powered blower and solution pump are included with actuating controls making the changeover automatic. The system will be under the attention of an operator who will make a visual inspection of running equipment and pressure gages each hour. The operator's presence is not required to assist upon the occurrence of a changeover; however, an alarm will sound to indicate this, whereupon the operator can seek out the reason for the change and be aware of the condition.

After considerable investigation and consideration of costs versus life and operation it was decided to fabricate all the ductwork, scrubbers and filter housings of stainless steel. The blowers would be of conventional materials, probably cast iron. Rotary positive blowers were selected to give the more uniform flow over a wide range of pressure drop.

The design requirements for the extensive routing of underground ducts requires a relatively high suction. Up to 50" wg negative pressure is arranged for the inlet box manifold and an additional 30" wg maximum drop is possible through all the cleaning and filtering equipment. Equipment shall be tested airtight and structurally suitable for negative pressure up to 5 psi.

With reference to Drawing 39378 attached, the following will explain the routing of the gas flow.

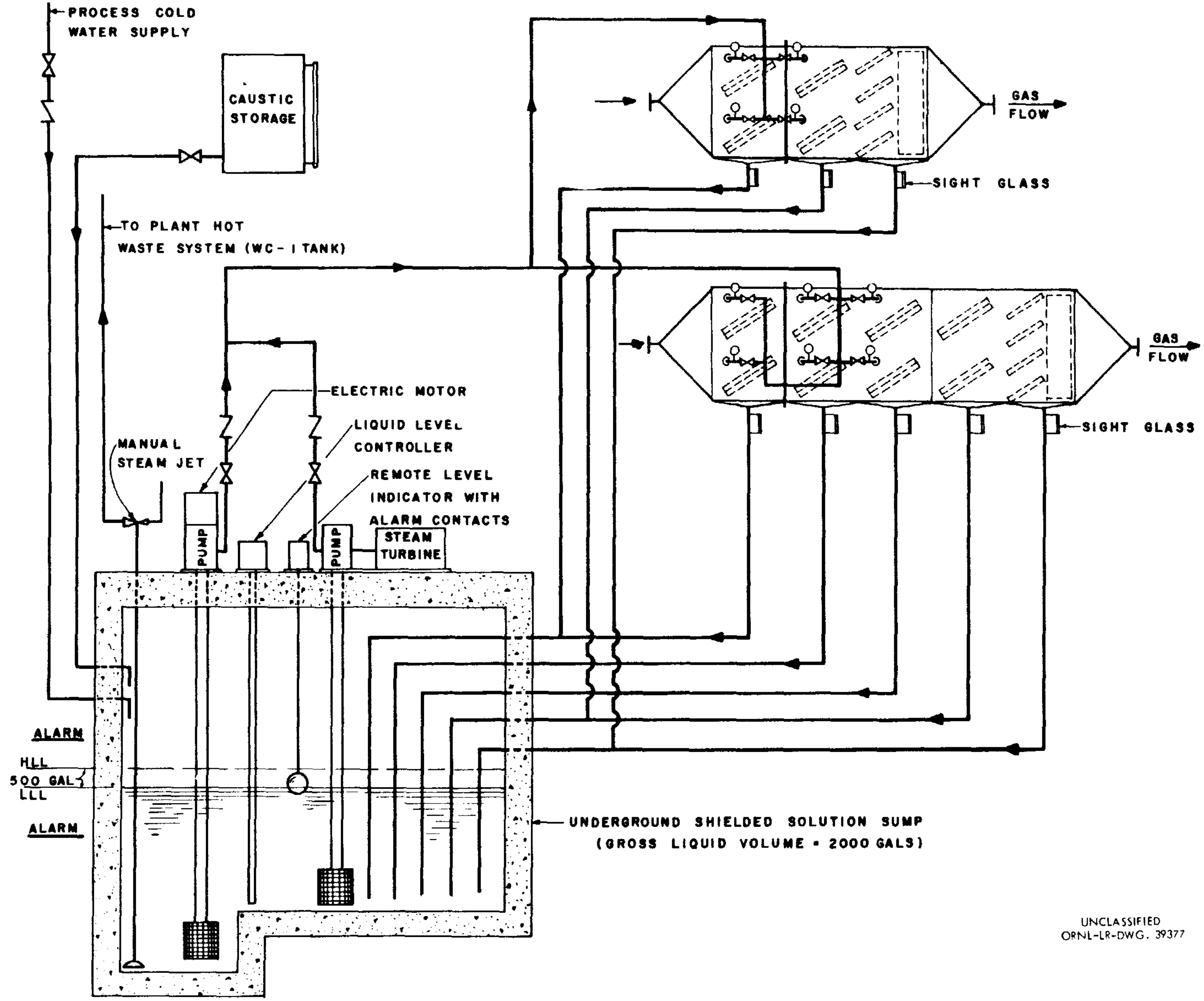
First, we enter the inlet manifold (item #1) on the upper left from the underground collecting duct; then enter the principal scrubber (item #2) which contains the 3 stages of absorption, 2 stages of demisting and finally a steam heating coil to eliminate condensation downstream.

Next, we advance to the dry filter section (item #3), a separate unit from the scrubber. This section contains the 4" metallic filter of silver coated copper, fire resistant absolute filters, and another section of 4" metallic filter, the same material as above.

Following this we pass through the blowers (item #4), through the acoustical spool, snubber and on to the existing 3039 stack. This stack is 250 feet high and is used for the release of cell ventilation effluent also. Normally over 120,000 cfm is discharged continuously.

The function of each stage is indicated by pressure differentials on the remote pressure gage station.

The auxiliary scrubber includes one wet roughing stage of absorption followed by two demisting stages and a heating coil. These com-



Schematic routing of scrubbing solution.

ponents are equal to the corresponding items in the principal scrubber and are interchangeable. The cell unit assembly is removable as a unit from the top allowing speedy replacement with the minimum of exposure. Spare cell assemblies are planned. The purpose of the two filter sections is to provide continuous service and allow radioactive decay of one section before it is refitted with clean filters. The two are shielded separately.

Effort was made to make possible the easy rearranging of the equipment components. Rather extensive tests are planned for this facility and this flexibility should allow a relative economical means of providing a more efficient system.

Initially the media in the various stages of the scrubber will be:

Wet Roughing:	175-200 micron dia. curled Saran or Dynel Fiber @ 6 to 7 #/cu.ft.
First Wet Absorption:	76-85 micron dia. curled Saran or Dynel Fiber @ 3.6 to 4 #/cu.ft.
Second Wet Absorption:	Same as first wet stage.
First Demisting:	Same material as the wet stages but @ 2.8 to 4 #/cu.ft.
Second Demisting:	18-30 micron dia. curled Saran or Dynel Fiber @ 2.5 to 3 #/cu.ft.

After some use we hope to determine if any plugging or holes occur and correct this by changing the media.

With reference to Drawing 39377 attached, the following will explain the flow of liquid from the underground shielded sump to the scrubber stages and return. The solution is to be 5% sodium hydroxide.

The sump has a gross liquid volume of 2000 gallons; a working volume variation of 500 gallons (or 25%).

Return lines were routed individually to minimize the solution above grade and to afford closer checks of the liquid flow. 3-gpm flow per sq. ft. of media face is set, making a flow to each stage of 66 gpm with a total flow of 198 gpm.

The solution will be periodically sampled, tested and when spent or too radioactive will be jetted manually to the plant hot waste system. Makeup to the sump will be made from the concentrated caustic storage and plant process water system.

The loss of pump discharge pressure initiates the emergency steam powered pump unit.

As mentioned previously extensive tests of this equipment are planned as soon as it is in operation. Perhaps at the next Air Cleaning Seminar a full report of the construction phase, and these tests, can be presented to give conclusive evidence.

CONDITION OF COMMERCIAL HIGH-EFFICIENCY FILTERS UPON RECEIPT OR INSTALLATION

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Berkeley, Calif.

ABSTRACT

AEC-type high-efficiency filters have recently been received with media breaks. A survey under AEC auspices at other sites shows that our experience is not unique.

Filter bypassing may also be due to other factors such as gasket failures or installation errors.

* * * * *

The quality of fabrication of commercial filters has come under study at Lawrence Radiation Laboratory, Berkeley, within the past year. One shipment was inspected visually; media rips necessitated 100% rejection. Two subsequent replacement shipments from the same supplier were 100% and 80% rejected, respectively. Similar rejections were noted at the Livermore site. Some of the defects observed are shown in Figs. 1 through 4.

Several features make it difficult to evaluate filters visually:
(a) less than 10% of the media of these filters is visible;
(b) some of the high-efficiency filters now being offered are assembled in such a manner that visual examination is impossible; (c) even if all the media could be inspected by eye, the efficiency specification of 99.96% is far more rigorous than can be perceived by eye.

These observations, though distressing, would not in the larger view be serious were they the troubles of but one user. The problem, however, was brought to the attention of the AEC, which conducted a survey of several other contractors (reported by another speaker), and in general it was found that the experience at Lawrence Radiation Laboratory is not unique. This problem, then, warrants further consideration.

Even if proper DOP testing equipment and personnel were available at users' sites we should not forget that testing upon receipt is expensive and an unwarranted duplication of the manufacturer's test procedure.

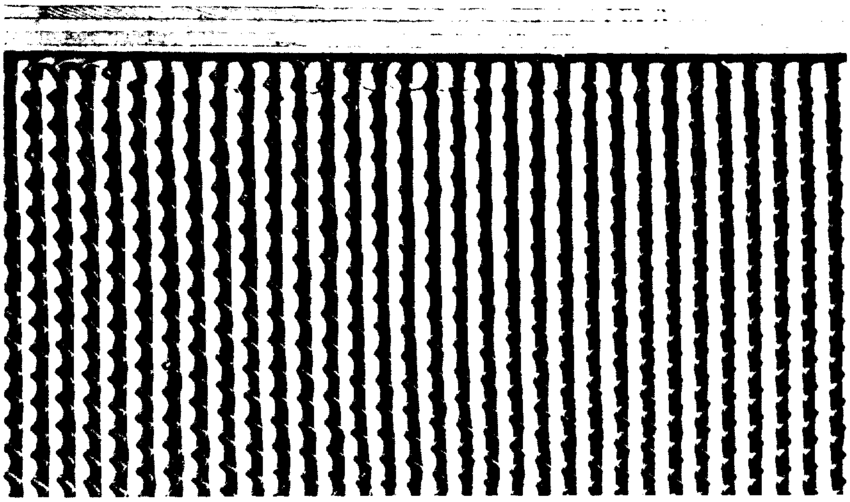


Fig. 1—Commercial high-efficiency filter with glass media and kraft separators, showing transverse media break.

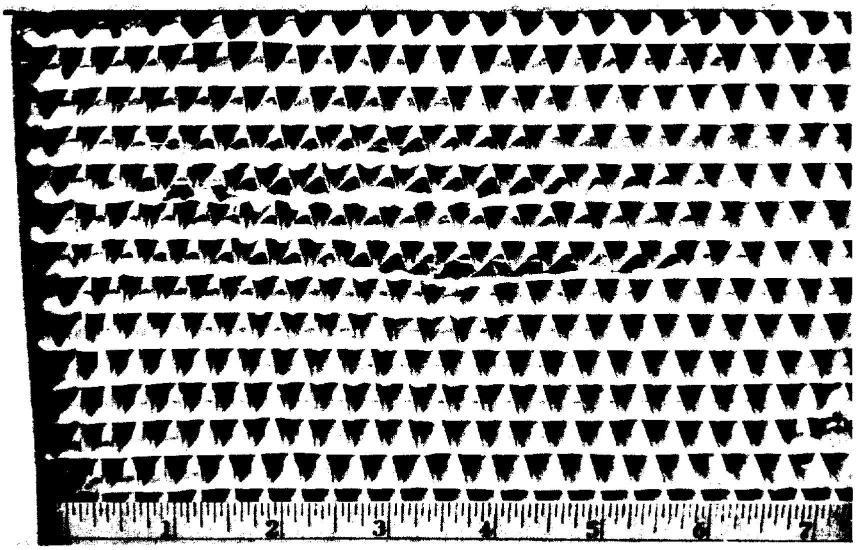


Fig. 2—Commercial high-efficiency filter with glass media and aluminum separators, showing pleat-edge media break.

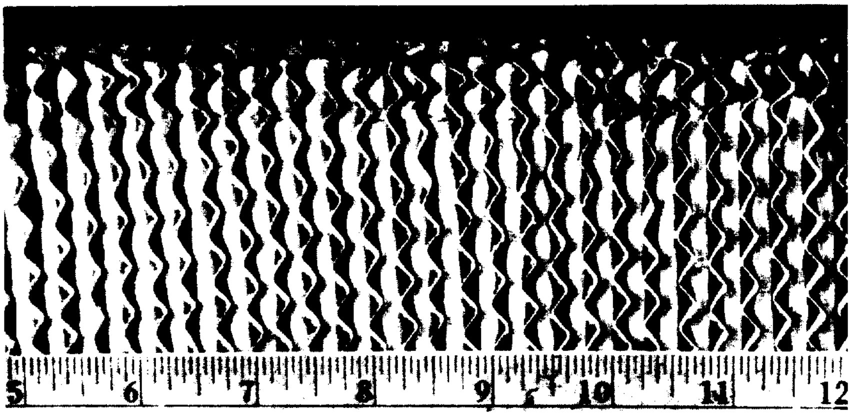


Fig. 3—Commercial high-efficiency filter with glass paper media and asbestos separators, showing transverse media breaks.

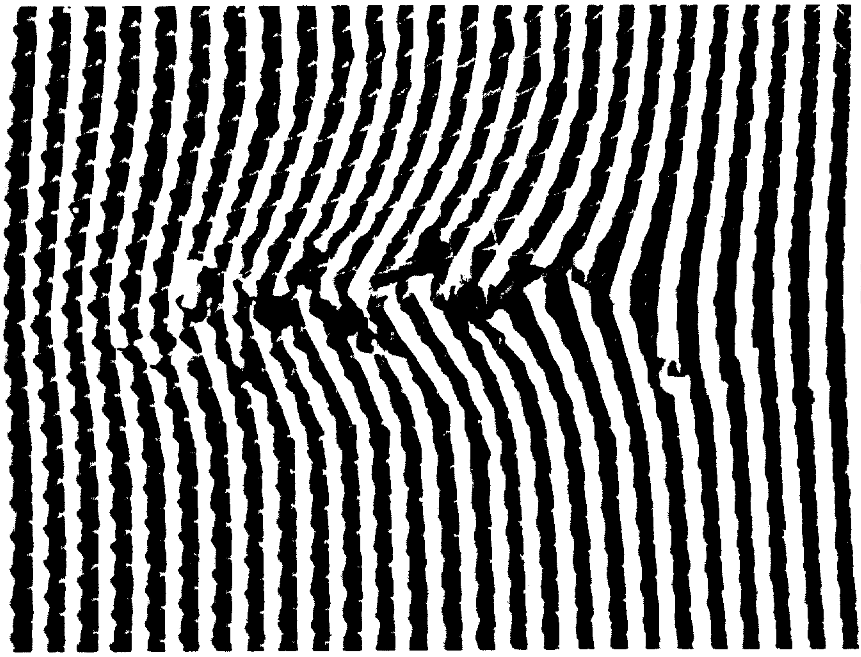


Fig. 4—Commercial high-efficiency filter with glass paper media and kraft separators, showing damage on receipt (external shipping carton undamaged).

Furthermore, acceptability tests on receipt do not assure the performance for which such filters are purchased--to wit, *as installed* in the duct system. It has been shown that inattention to details in fabrication and inspection of filterbank hardware, in assembly bolt pressures, and in other such minutiae can result in actual leakage around the filter and consequent pollution downstream. One weak item is the multipieced gasket on the filter face, frequently a butt-joint layup of low integrity.

A possible factor in as-installed performance--one which has not yet been evaluated--is the skill and care employed in installation. There is the possibility of substantial differences, at various laboratories, in the abilities of contractors' employees and in the local conditions of accessibility, radiation exposure, need for protective clothing, and dexterity required.

No solution is proposed here. Our purpose has been to state a real problem and invite further study leading to possible solutions. Meanwhile we had better sample our off-gas stacks continuously and carefully.

FILTER RATING AND TESTING PROGRAM

HUMPHREY GILBERT
United States Atomic Energy Commission, Washington, D. C.
and
GEORGE J. HURWITZ
Army Chemical Center, Maryland

Mr. George J. Hurwitz and I will present you some facts and some conclusions which are not necessarily the most palatable that could be talked about. Nevertheless, the atomic energy program has a problem, I should say, a real problem, affecting its air cleaning operations. We shall endeavor to be constructive.

Those of you who attended the last Air Cleaning Seminar at Harvard University in June 1957 may recall that one of the manufacturers of high efficiency particulate filters alleged that at least one of the other two manufacturers of these filters was using a DOP penetrometer which needed calibration. He inferred that, as a result, we were getting filters which did not meet the specifications for penetration and resistance, in other words, for true high efficiency.

After considering those remarks and having obtained information which seemed to bear out the allegation, we decided to verify sample filters of all three manufacturers. We also decided that the most impartial way to do this was to test random samples from filter stocks of atomic energy plants. Twelve 1000-cfm. filters were subsequently shipped to the Army Chemical Center at Edgewood, Maryland, to be tested on the Chemical Corps

DOP penetrometers, which are regarded as the most reliable to be found for this work. At the same time, each of the three filter manufacturers was invited to send samples of his own, and these were also tested and the results returned for their respective information.

When we opened the cartons containing these random samples from atomic energy stocks, and the cartons clearly had not been opened from the time the filters had been manufactured and packaged, we were appalled at what we found.

I would like Mr. George J. Hurwitz of the Quality Assurance Technical Agency, Army Chemical Center, to take over and describe the filters which were in these cartons. It was through Mr. Hurwitz' cooperation that we arranged the tests and he supervised the examinations from beginning to end. Mr. Hurwitz.

Mr. G. Hurwitz

Thank you Mr. Gilbert. Before going into the details of the testing program, let me say for the USA CmlC Quality Assurance Technical Agency that cooperating with the U. S. Atomic Energy Commission in this program has been a pleasant and instructive experience. It has been gratifying to be able to share with another Government service our capability in developing and fabricating test equipment and testing filters for both aerosols and toxic agents. As the sole source for this equipment we fully realize that the livss and health of many may rest on our ability to develop test equipment which can be depended upon for accuracy and reproducibility of results.

We have prepared a series of sixteen slides showing the damage observed when cartons containing the filters were opened at the Army Chemical Center. We did not inspect all the filters in detail; only those which gave erratic or high penetration readings. I believe that had these filters been subjected to the degree of inspection performed on Chemical Corps filters by one of our expert inspectors, several more filters would have been rejected for such defects as poor workmanship, missing or incorrectly applied adhesive, contamination or failure to meet the rough handling test.

We had been asked whether the damage observed could have been sustained during transportation so that a claim could properly be placed against the shipper. In all honesty we had to reply that there was no way of saying definitely that this was the case. Inspection of the cartons did not indicate rough handling or abuse. In fact, the cartons were in good enough condition to be used for returning the filters to their original sources. This we do know: three filters, received at a later date, had been inspected prior to shipment and these arrived in good condition.

The filters may bave been damaged during transportation or handling in the storage area; certainly, the shipping carton can stand redesign. However, damage can result from lack of proper control during the manufacturing process; filters which are cut too long and forced into the frame; aged or brittle cement, or one which has too high a coefficient of expansion, so that, on setting up it contracts and tears the filter. I have a photograph which illustrates such a case. Damage may also result from excessively tight packing of the pleats which causes the fluted separators to cut into the filter material. Excessively loose packing will allow undesirable movements of the separators.

I mentioned rough handling. It may be of interest to you to know that Chemical Corps filters are subjected to a rough handling test in the vertical position by being vibrated at a frequency of 200 cycles per minute with a 1 inch amplitude for fifteen minutes. If the filters pass this test, they should withstand normal transportation and handling.

Another point to be cleared up is the testing requirements. Whereas it is quite possible for a filter containing small punctures to meet resistance and penetration requirements, and this will be illustrated by a slide, this nevertheless is not an acceptable filter. All tests were conducted on a Chemical Corps E18 Penetrometer and Resistance Indicator at a flow rate of 1000 cfm and a DOP particle size of 0.3 microns.

The list of invitees to this seminar apparently did not include any of the manufacturers of the filters tested; nevertheless, test data must be considered proprietary information. Slides will be shown but test results will be cited without reference to the original source of the samples.

Slides 1 and 2 show a filter with pleats so badly broken that the penetration reading was 54%. Another filter containing similar breaks gave an even higher penetration reading.

Slides 3 and 4 illustrate another filter with damaged pleats. Penetration readings were .30% and .18%. The reason for the difference is that filters were tested from each side; on damaged filters, good reproducibility is the exception rather than the rule.

Slides 5 and 6 illustrate lesser damage; penetration readings were .072%, .094%, and.095%. Corresponding resistance readings were .87", .95", and .94".

Slides 7, 8, and 9 illustrate damage of the same magnitude with penetration readings .066% and .090%. Corresponding resistance readings were .81" and .96". The distortion of the pleats indicates that the filter was oversize and forced into the frameduring assembly.

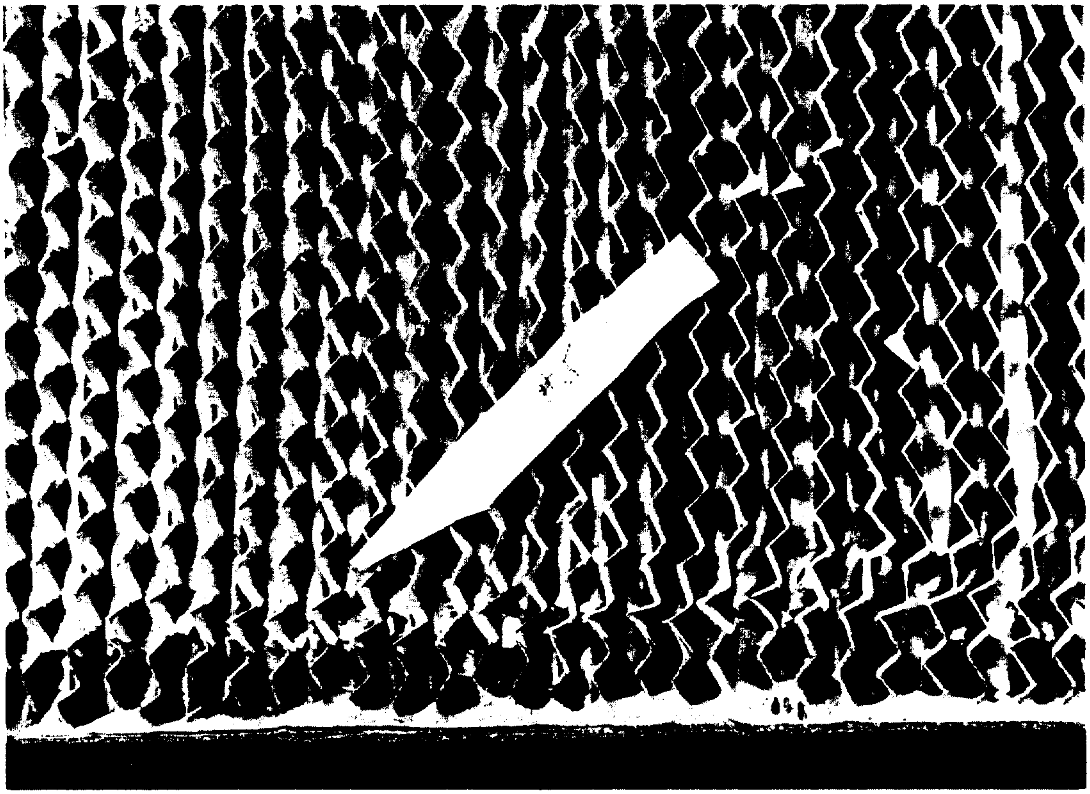
Slides 10 and 11 depict damage along the side of the filter and to a lesser degree on the bottom. Penetration readings were .32% and .40%. Resistance was .84" and .92".

Slides 12, 13, and 14 illustrate a series of breaks along the top and bottom. Penetration readings were .046%, .12%, and .083%. Corresponding resistance readings were .76", .94", and..84".

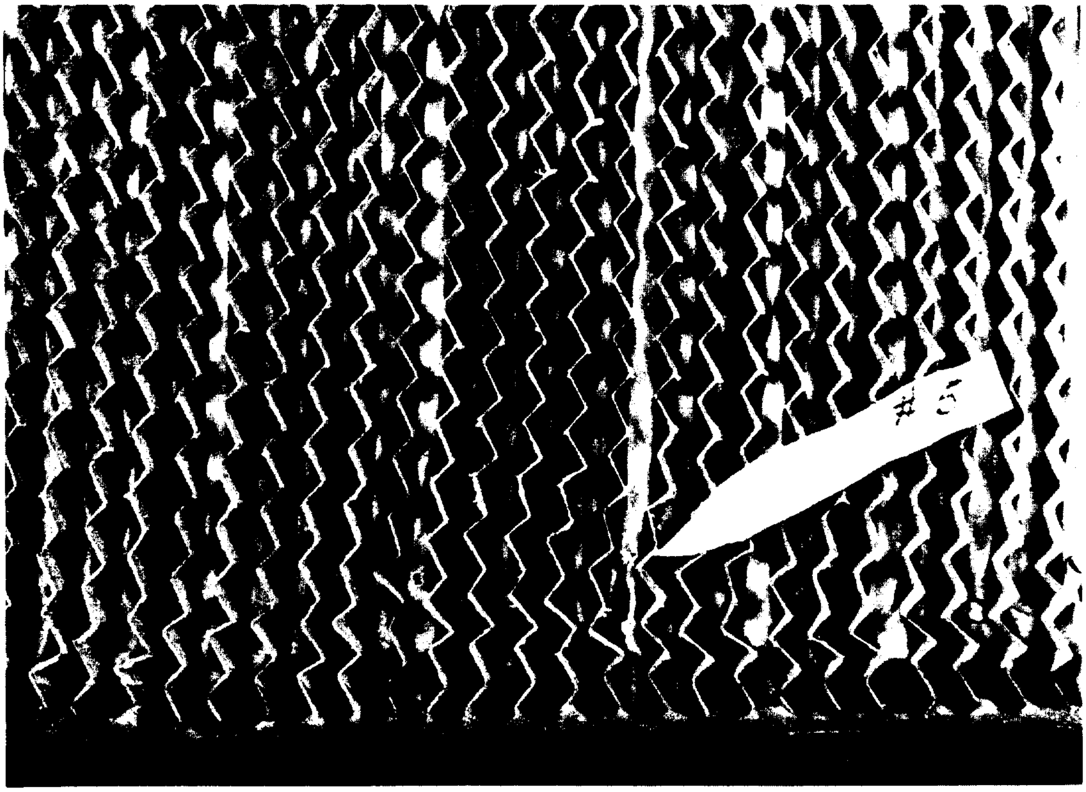
Slides 15 and 16 illustrate a damaged filter which did meet specification test requirements. Penetration readings were .048% and .039%. Corresponding resistance readings were .74" and .88".

Comparisons may not be in order since the items are not identical, however as a point of information permit me to cite some acceptance inspection results on filters produced for the Chemical Corps by one of its contractors. The filters were produced from a paper asbestos medium with corrugated paper liners instead of the glass fiber asbestos medium and separators of the same material which characterize AEC filters. Frames were aluminum instead of treated plywood. Each filter was inspected in accordance with specification requirements for visual defects as well as the penetration, resistance and rough handling tests.

(Text continued on p. 173)



Slide 1



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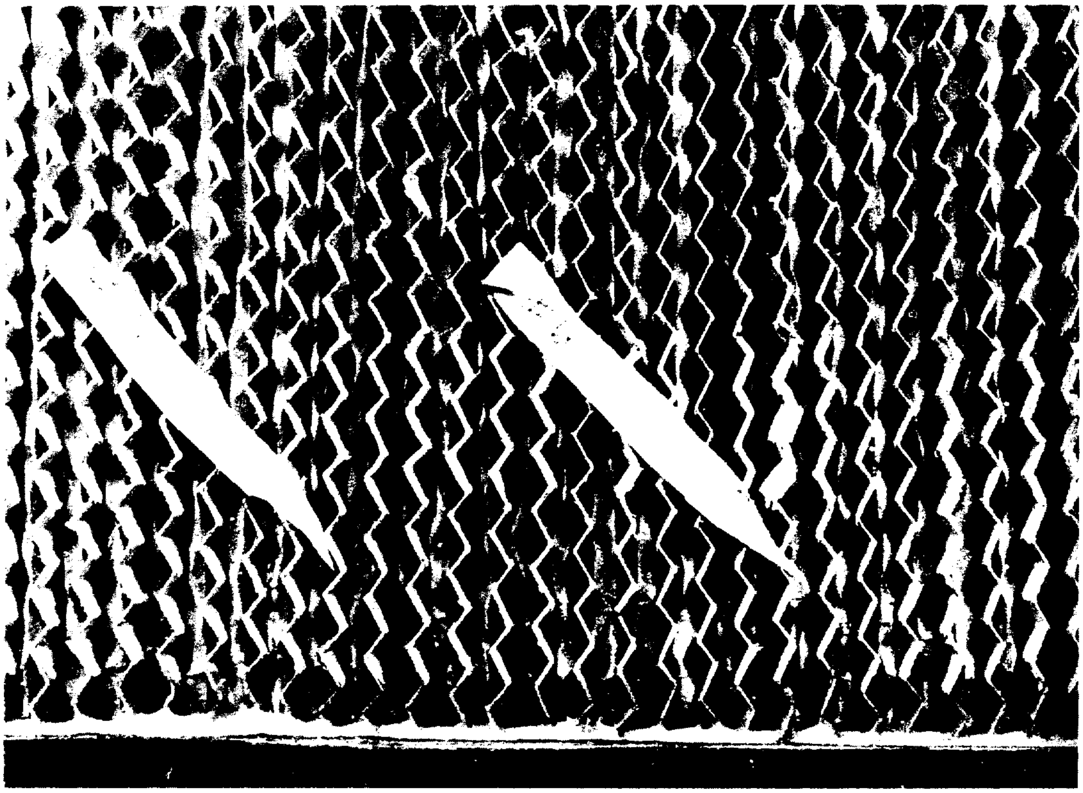

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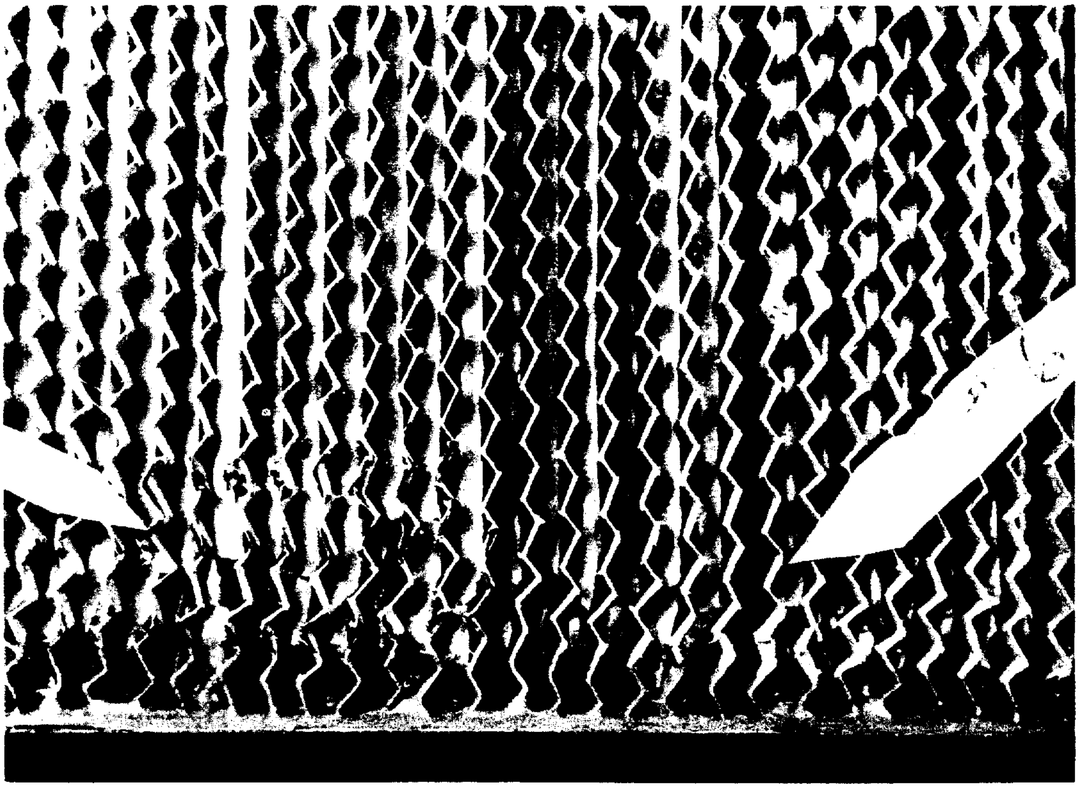

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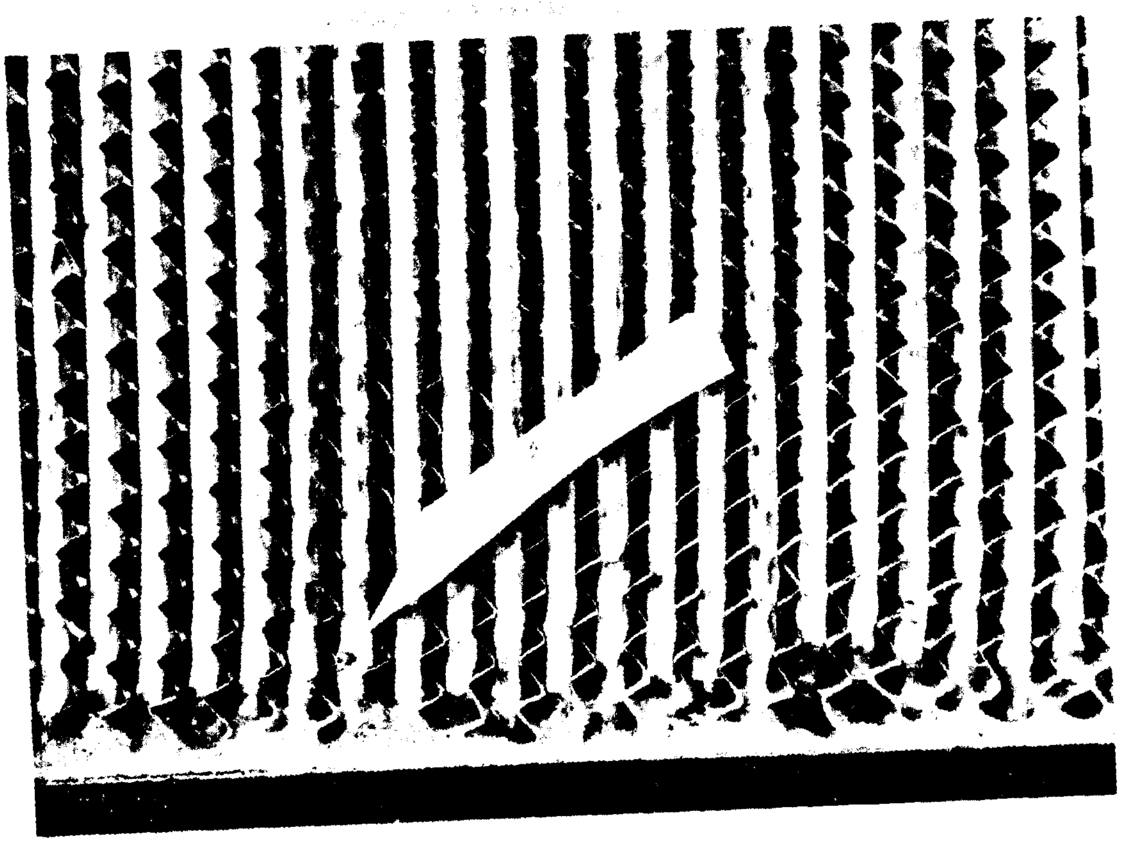

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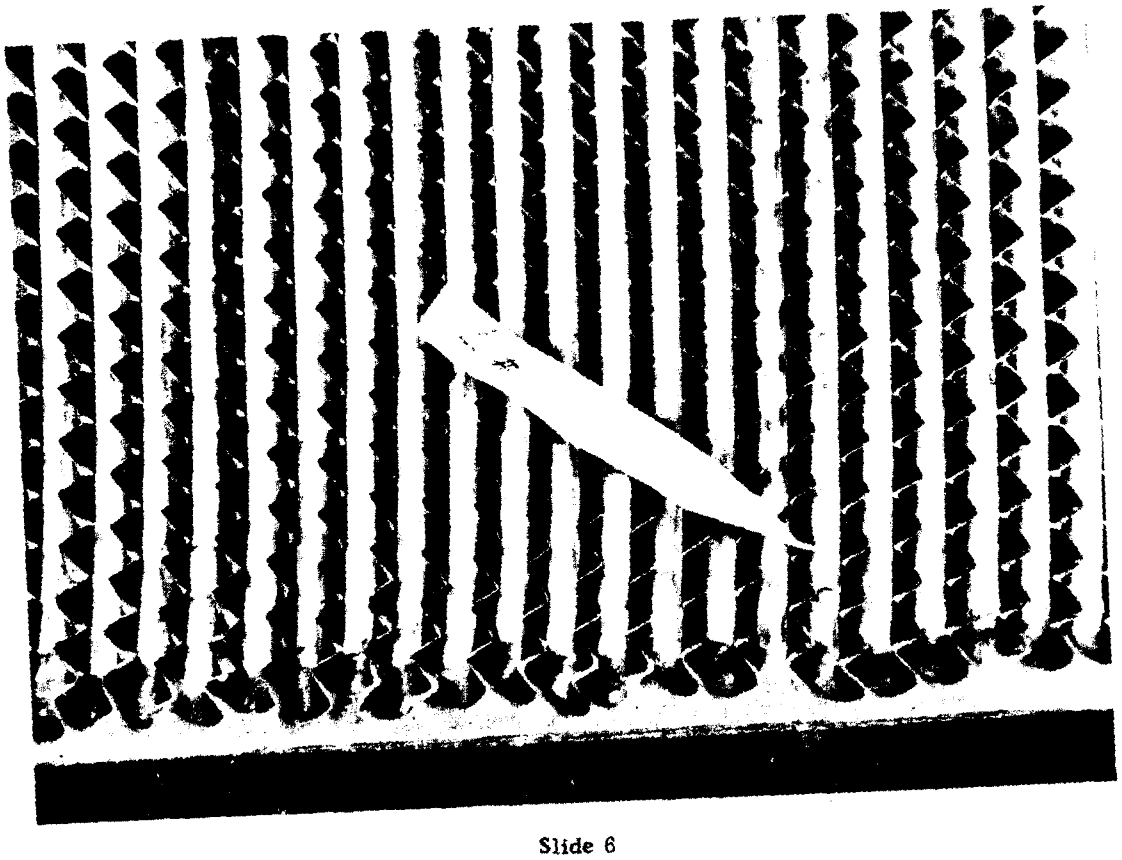

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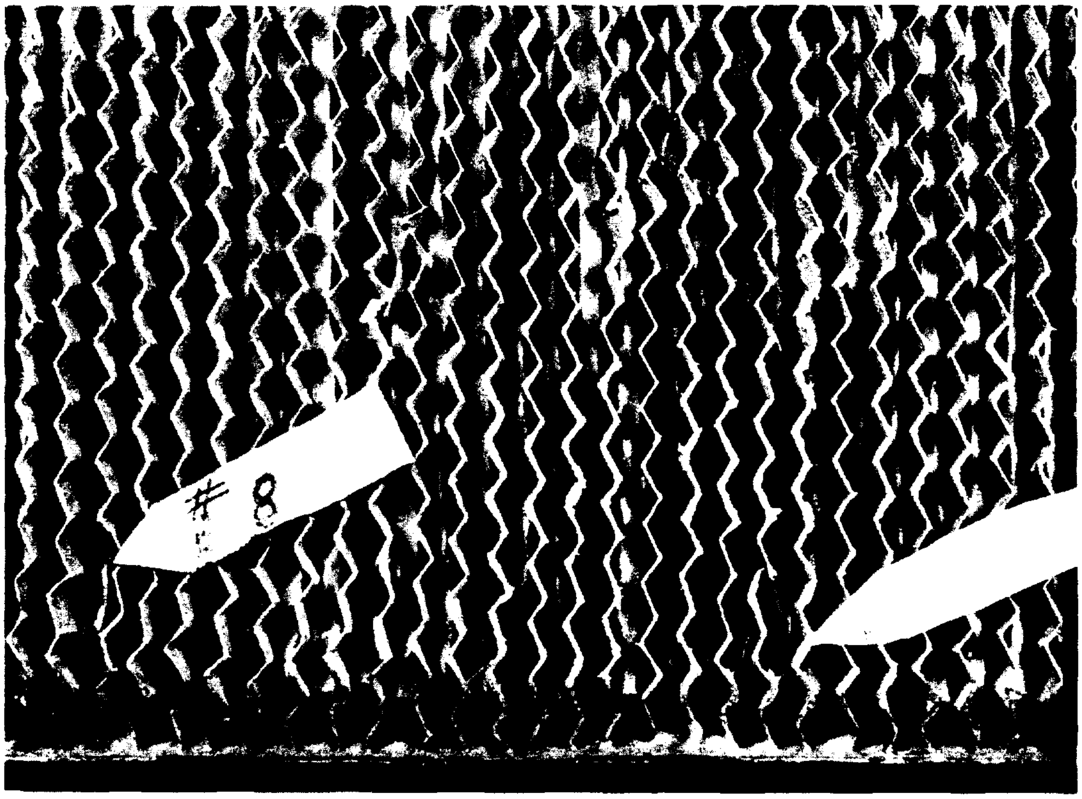

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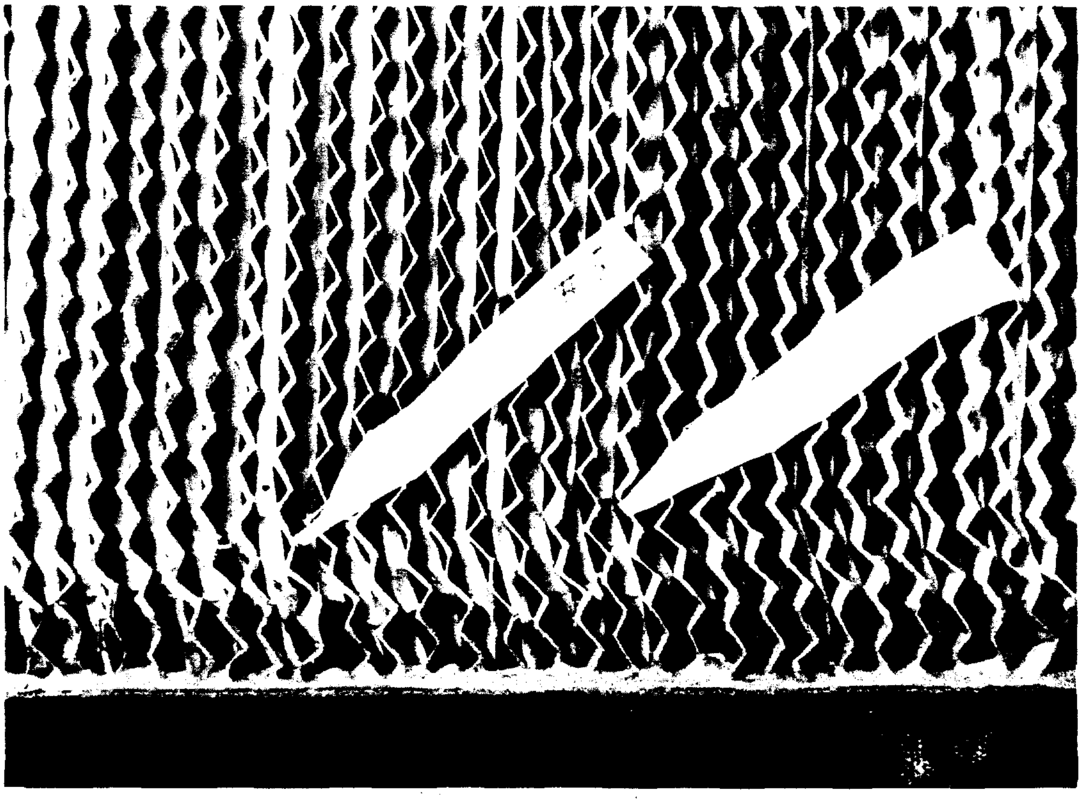

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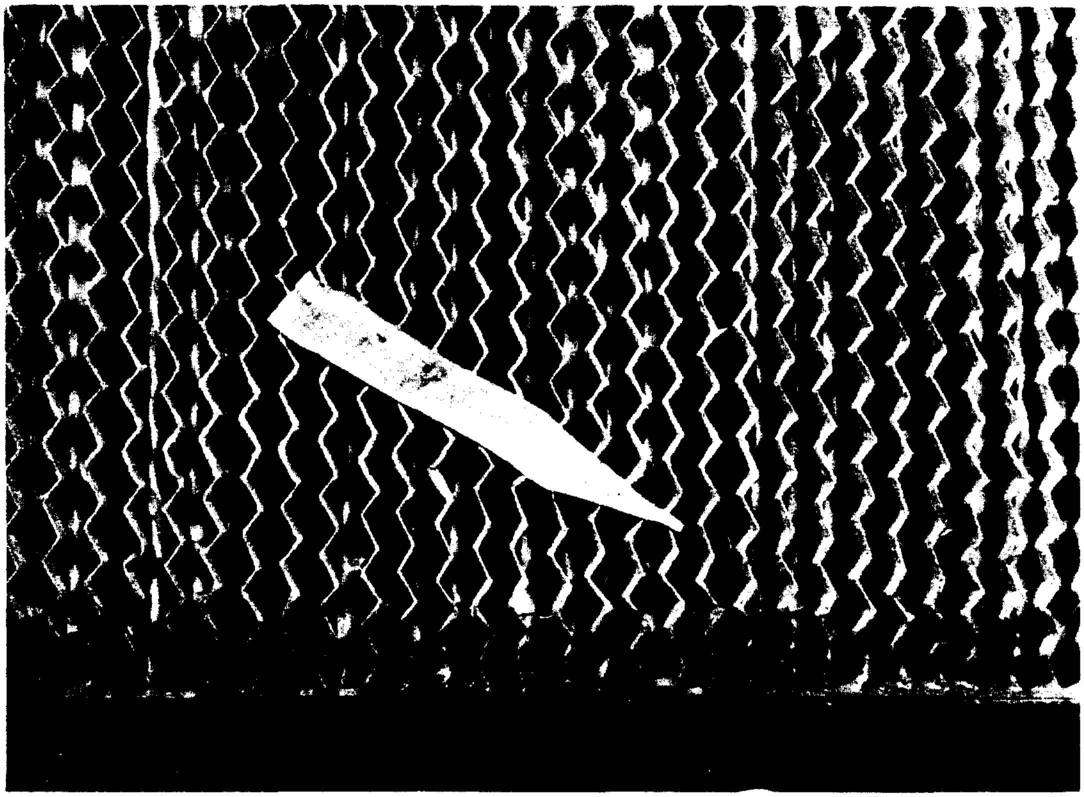

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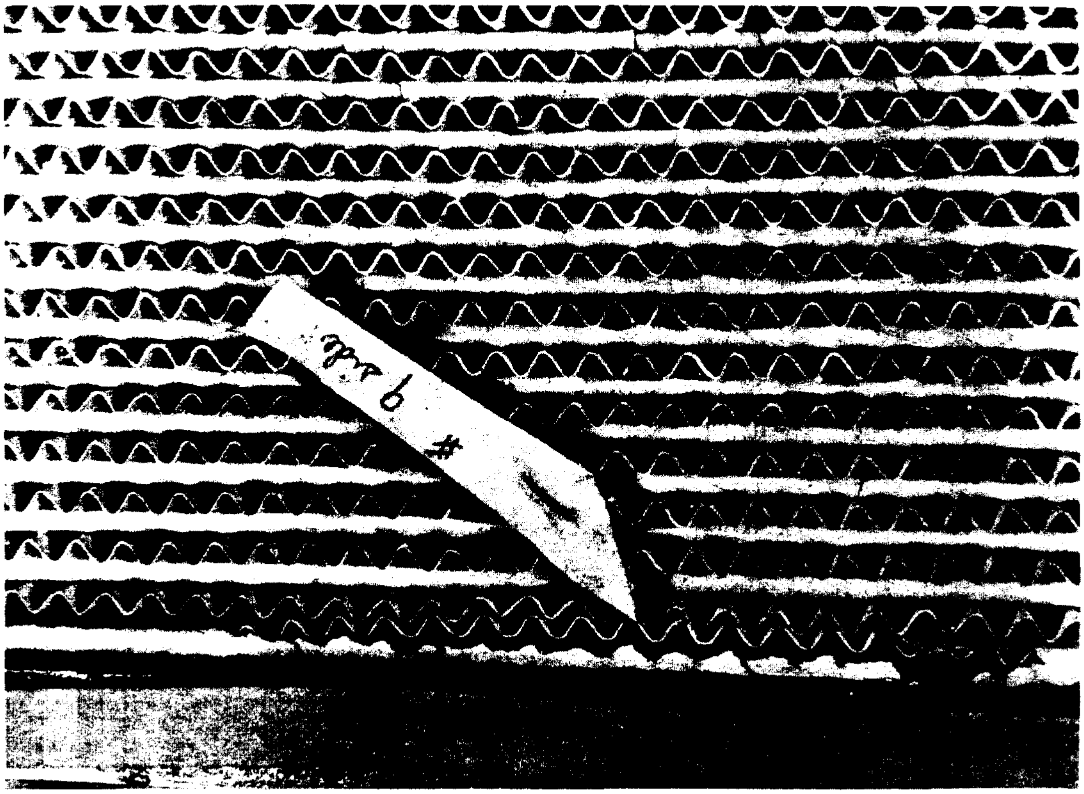
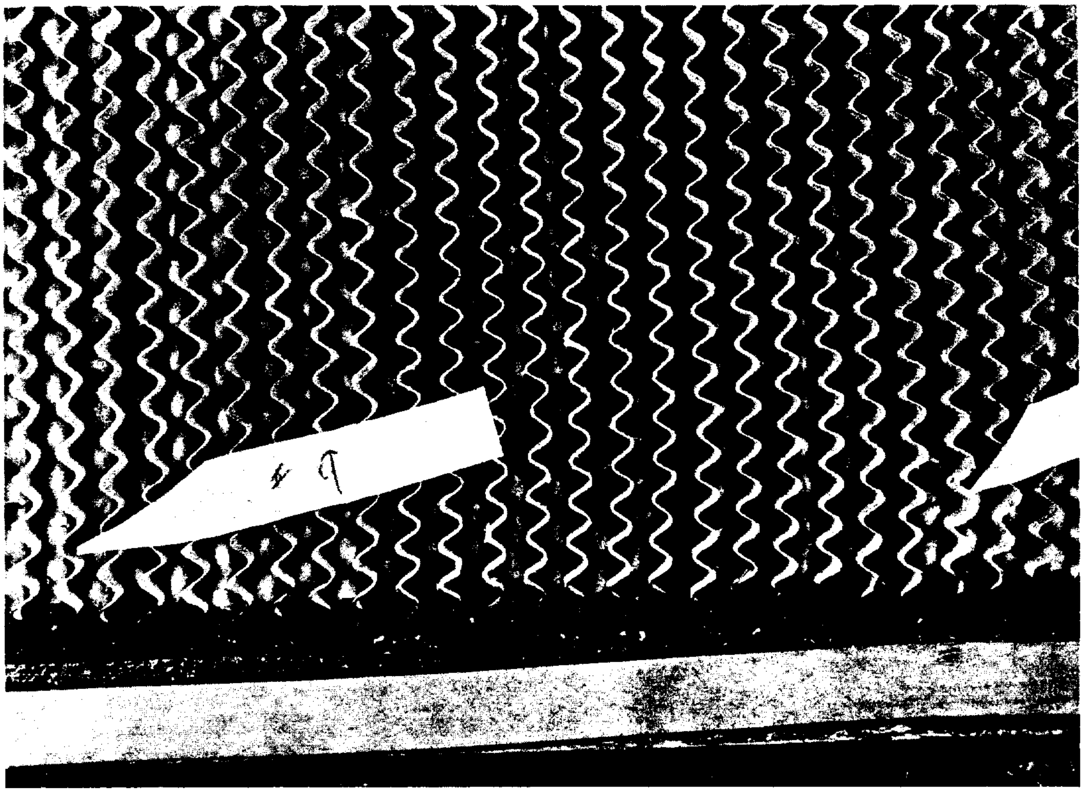


Slide 10



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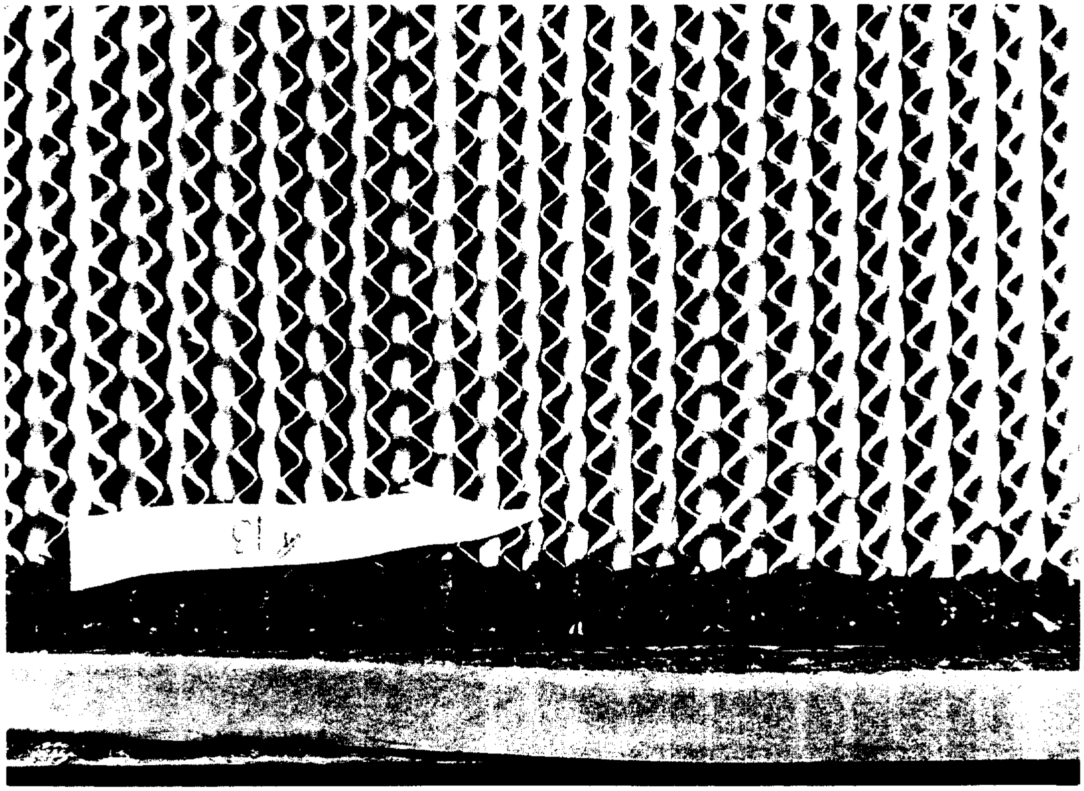

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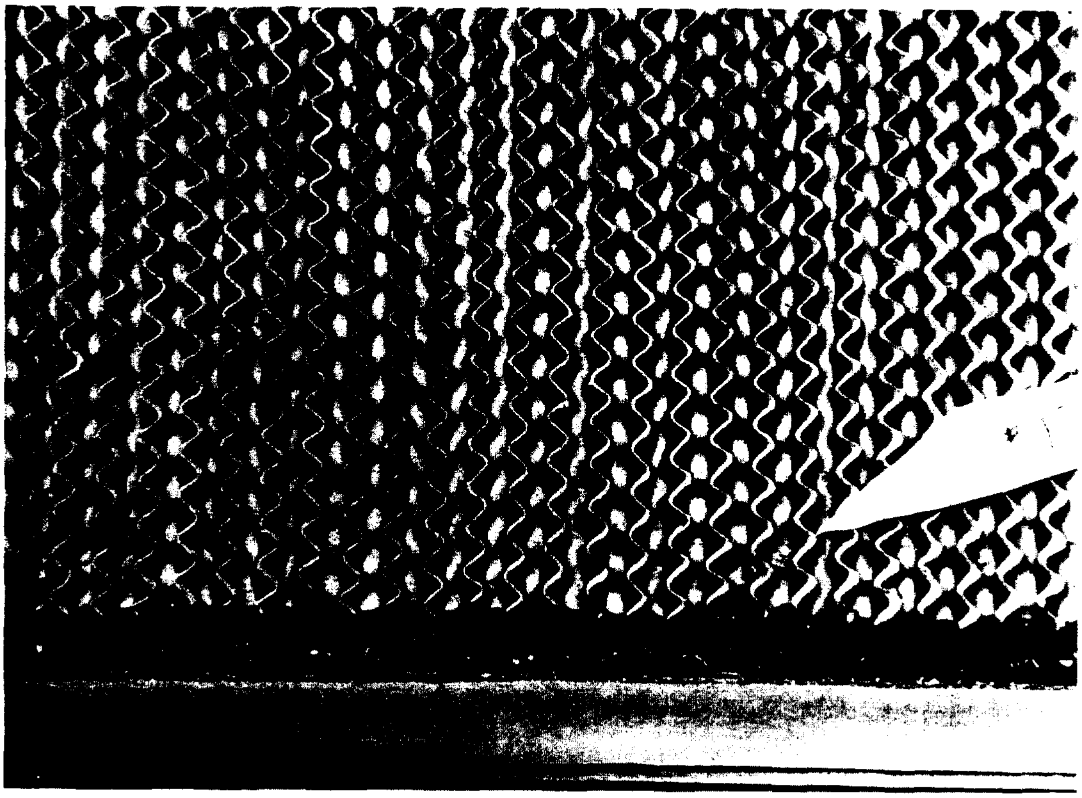

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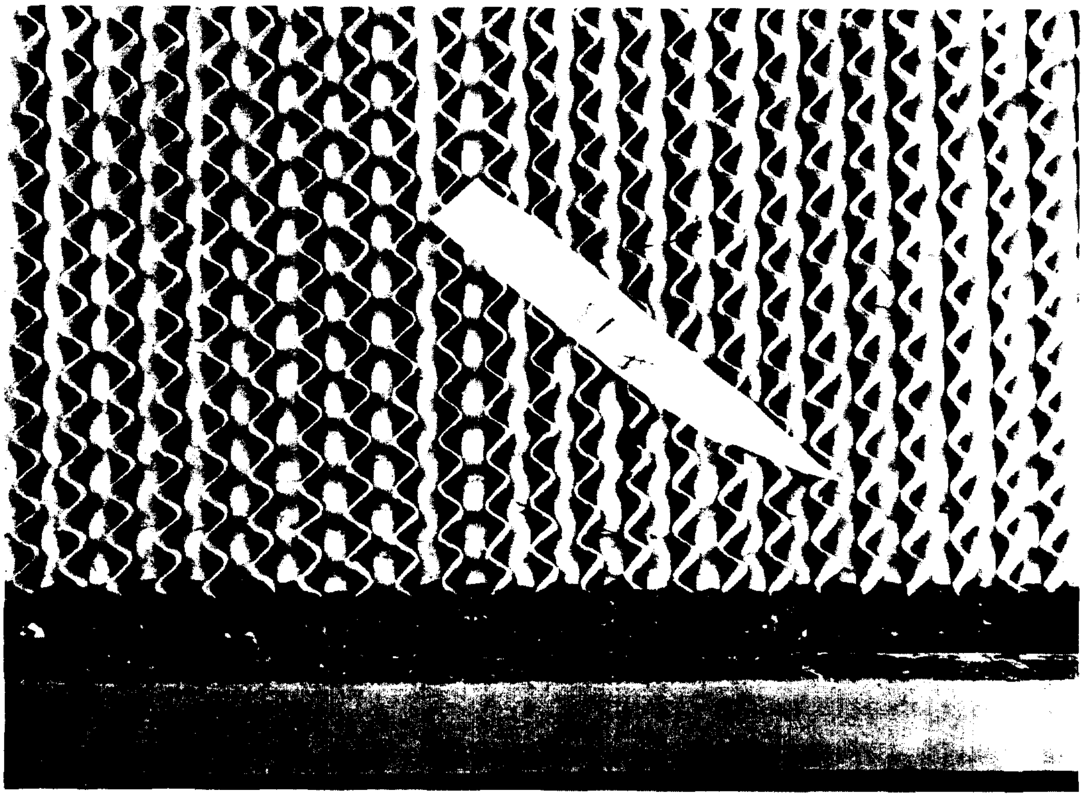

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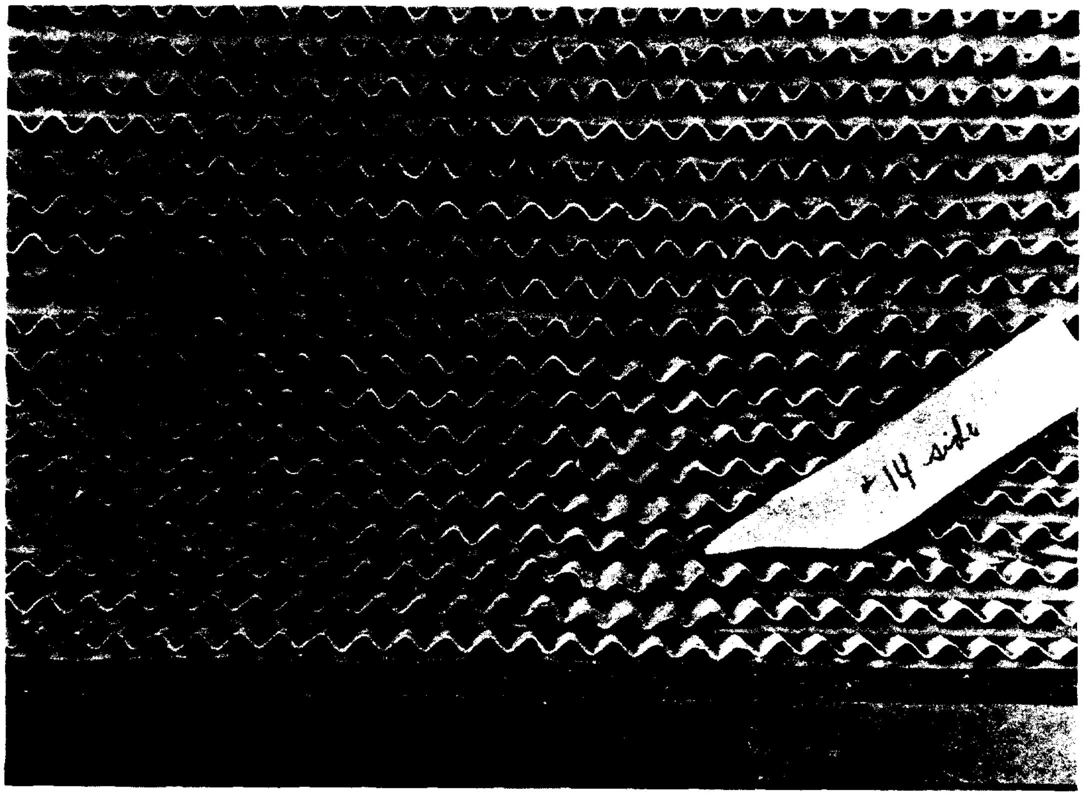
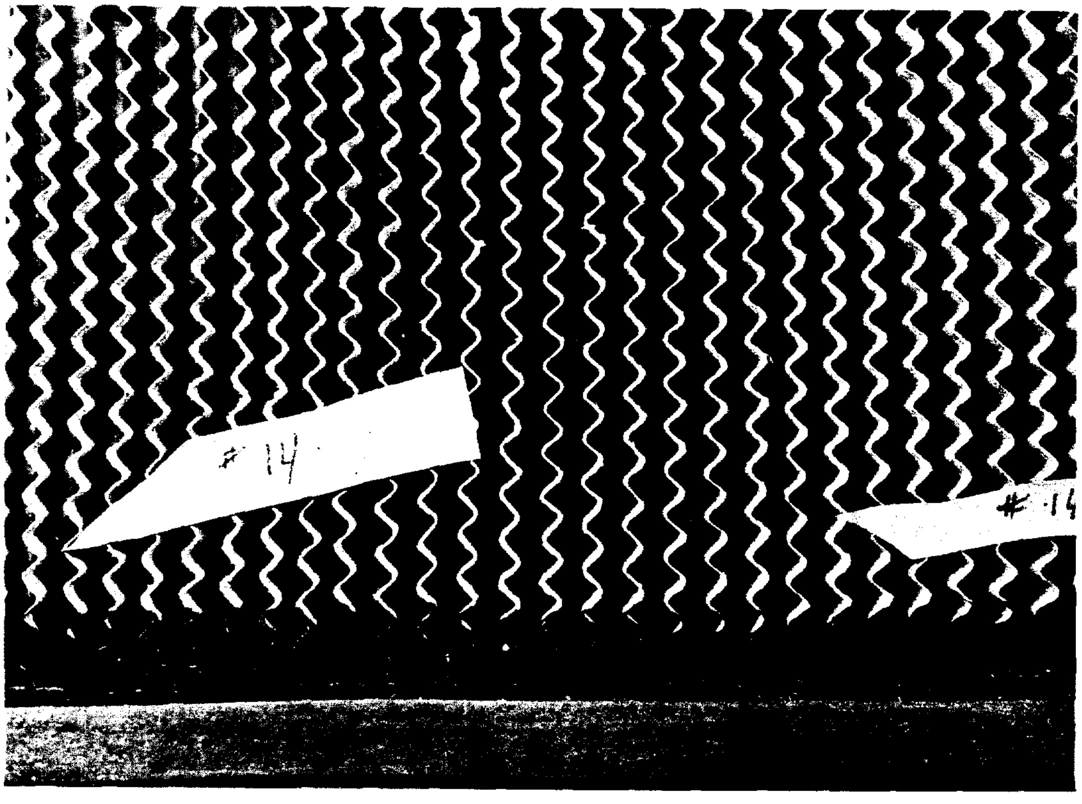


Slide 15



Slide 16

No. Samples	Penetration %		Resistance	
	Min	Max	Min	Max
240	.003	.024	.89	.97
222	.008	.024	.87	.98
118	.008	.024	.87	.97
120	.005	.023	.83	.98

These data were obtained from filters submitted for acceptance by the Chemical Corps inspector. The number of filters rejected by the contractor's own inspection and quality control activities is not known. From its experience with fabrication of filters, both in its arsenals and by contractors the Chemical Corps learned that, to obtain acceptable filters, we need definitive drawings and specifications, dependable test equipment, a good quality control program in the producing activity, and verification inspection by those having acceptance responsibility.

(Mr. Gilbert - continued)

Mr. Hurwitz has explained to you how seven of the twelve samples were defective. Needless to say, we reported to the plants from which we had obtained the defective filters and asked them to open all of their filters in stock to learn how many more were defective. Amusingly enough, one of the plants that had sent filters made by two different manufacturers contacted us and said, in effect: "We depend on stack monitoring to tell us when our filters are de~~e~~ffective. Please advise which manufacturer's filters were bad so we will not have to open all of the cartons of filters that we have in stock."

Somewhat later we obtained additional samples from atomic energy stocks for testing. This time the samples were inspected thoroughly before they were shipped to the Army Chemical Center to complete the tests. The second batch was tested June 4, 1959. This is how the filters compared so far as penetration and resistance are concerned:

Slide 1. This shows comparative penetration readings on sample filters made by Manufacturer "X". The yellow background indicates the maximum penetration allowable according to the specification of

5 one-hundredths of 1% for dioctyl phthalate aerosol particles approximating 3 tenths of one micron in diameter. The blue bar on the left is the penetration rating placed on the filter by the manufacturer and so stamped on the filter frame. The red bar alongside the blue one is the penetration found by the Army Chemical Center. Notice that none of these samples made by Manufacturer "X" was outside the specification for penetration.

Slide 2. Here are the comparative resistance ratings on these same three filters made by Manufacturer "X". Again the yellow background is the specification limit, 9 tenths of one inch of water resistance. Likewise, the blue bar on the left is the manufacturer's rating of the filter's resistance and the red bar is the Army Chemical Center test finding. These filters by Manufacturer "X" also met the specification for resistance.

Slide 3. These are the samples made by Manufacturer "Y". You note that the manufacturer rated penetration of the first filter, on the left, at .05%, which is the maximum acceptable under the specification. Chemical Corps test rated the penetration at .076%. The second filter had stamped on it the manufacturer's penetration of .40% and while the Chemical Corps found it .25%, the filter obviously does not meet the specification. Incidentally, all of these three samples carried a certification by an inspector representing the atomic energy plant that purchased the filters. Needless to say, the middle filter should have been rejected by the inspector. The third filter was acceptable for penetration.

Slide 4. These same three filters made by Manufacturer "Y" were within the limit of 9 tenths of one inch resistance.

Slide 5. Of these four filters made by Manufacturer "Z", the first, on the left, had a penetration rating of .012% by the manufacturer. Chemical Corps test showed it to be .23%, considerably outside the .05%

specification for penetration. The fourth filter, the one to the extreme right, had a manufacturer's rating of .008% and the Chemical Corps found it .056%, just outside the specification for penetration. The second and third filters, the two in the middle, met the specification.

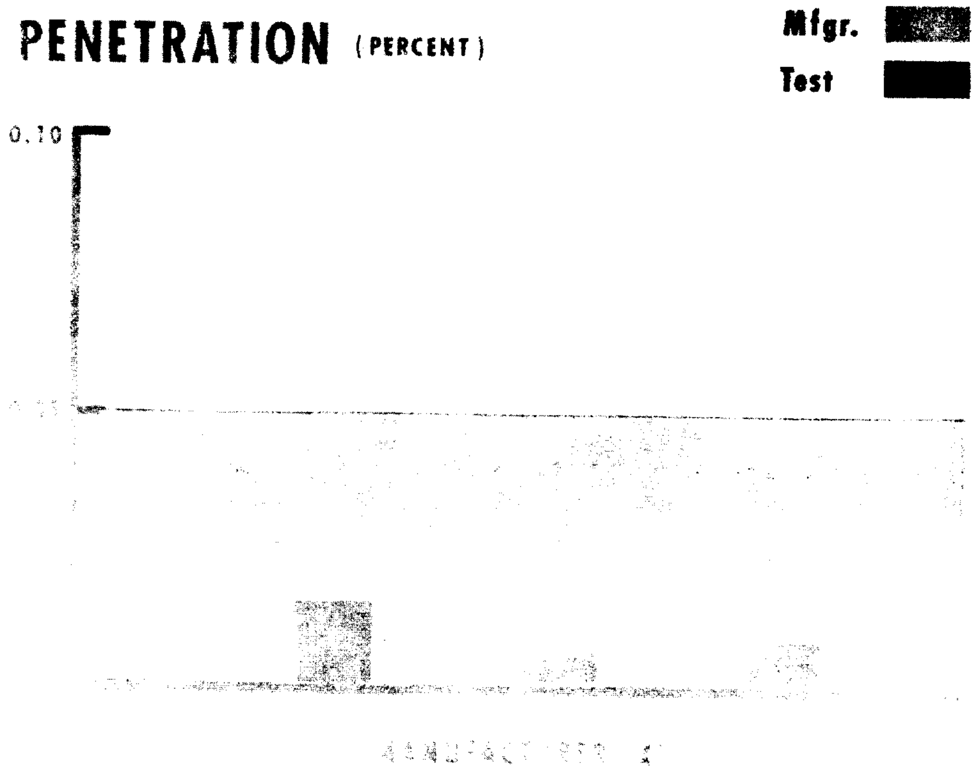
Slide 6. Now let's examine these samples of Manufacturer "Z" for resistance. The first two, from the left, had the manufacturer's ratings to show that they meet the specification for resistance. Both, as you can see, exceeded one inch of water in resistance. For the two at the right, the manufacturer rated them at 1.10 inches and 1.00 inch resistance, respectively. The third was found to have .92 and the fourth .97 inch resistance. All four were over the limit for resistance.

You have seen the defects that are being found in filters, which Mr. Hurwitz has described to you, and there is considerable evidence to indicate that these defects existed before the filters left the manufacturer's plant. Certainly filters can and have been damaged in shipment, however, these did not seem to be the case. Only two of a total of 18 filters sent by atomic energy plants to Army Chemical Center for testing had damage that could be attributed to handling or shipping after they were manufactured. You have also seen how these filters compared when verified on a DOP penetrometer other than the manufacturer's.

What course then shall we take?

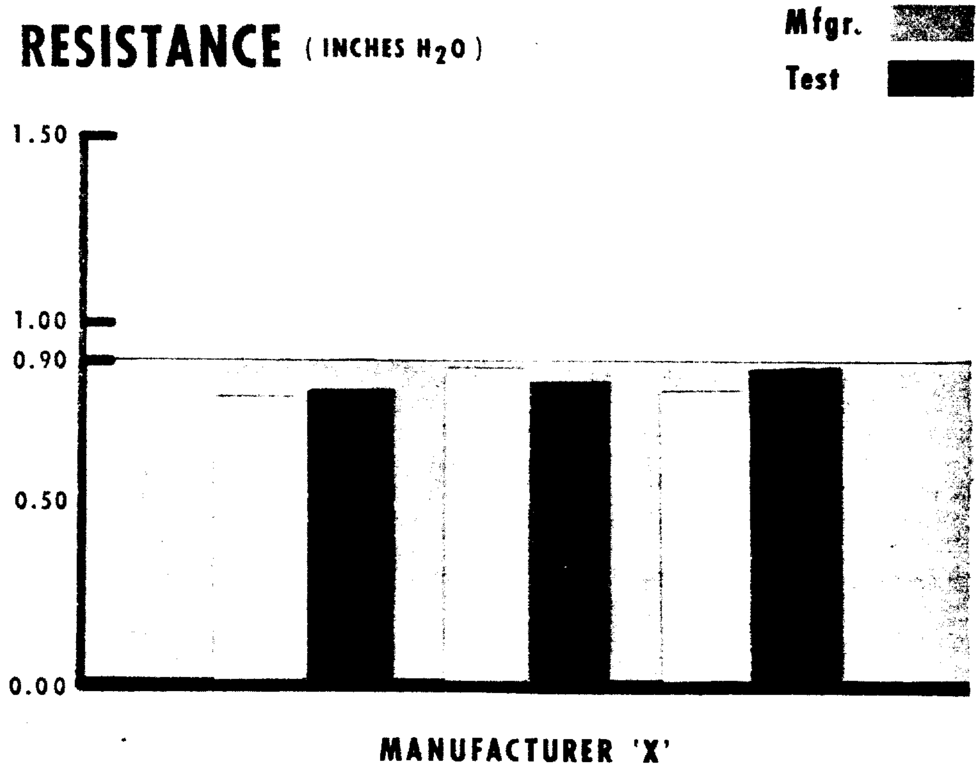
First, let's examine a basic point: Do we really need filters with the high degree of efficiency that is being specified? If we don't, then we are wasting money. We can buy filters with efficiencies of 70%, 80%, or 90%,on whatever particle size you select, at a price considerably less than we pay for these high efficiency filters Conversely, if we decide that we do need filters which are 99.95% efficient, then the time has come to make sure that we get what we are specifying. We have been negligent and, I suspect, a little naive, about the caliber of filters delivered to atomic energy installations. Just because we specify 5 one-hundredths of

PENETRATION (PERCENT)



Slide 1

RESISTANCE (INCHES H_2O)



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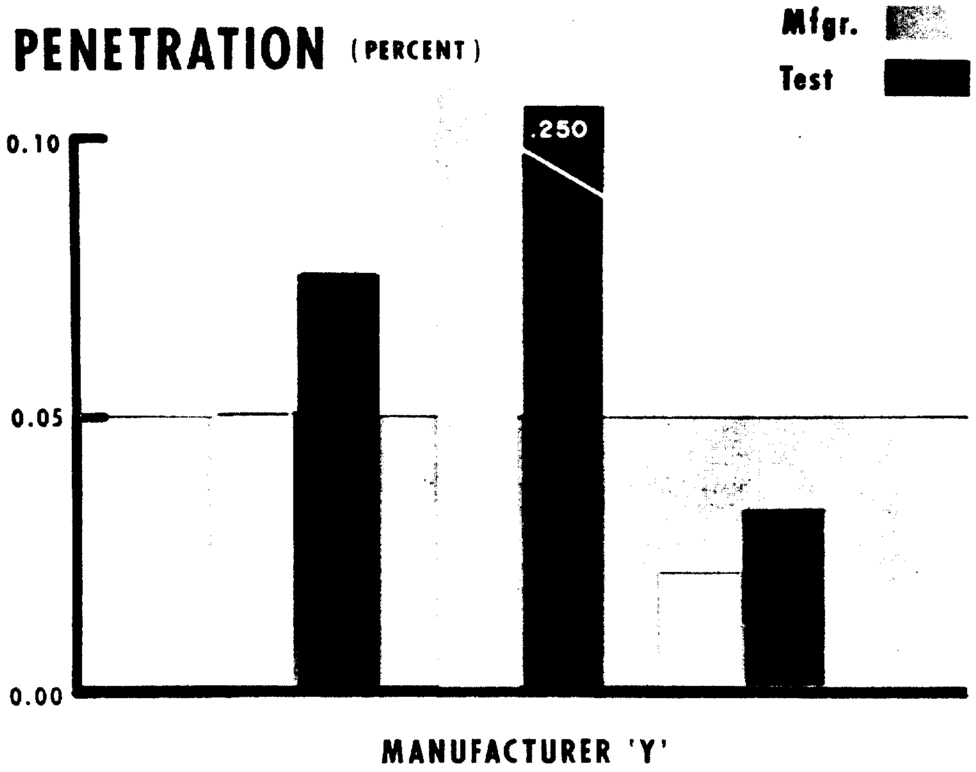

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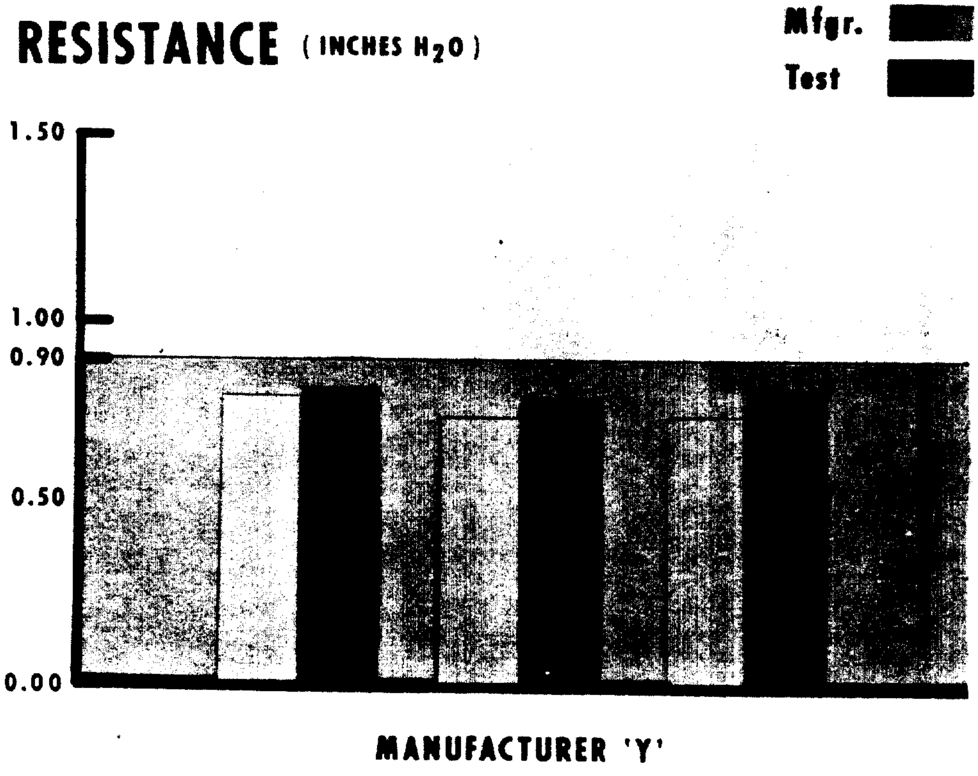

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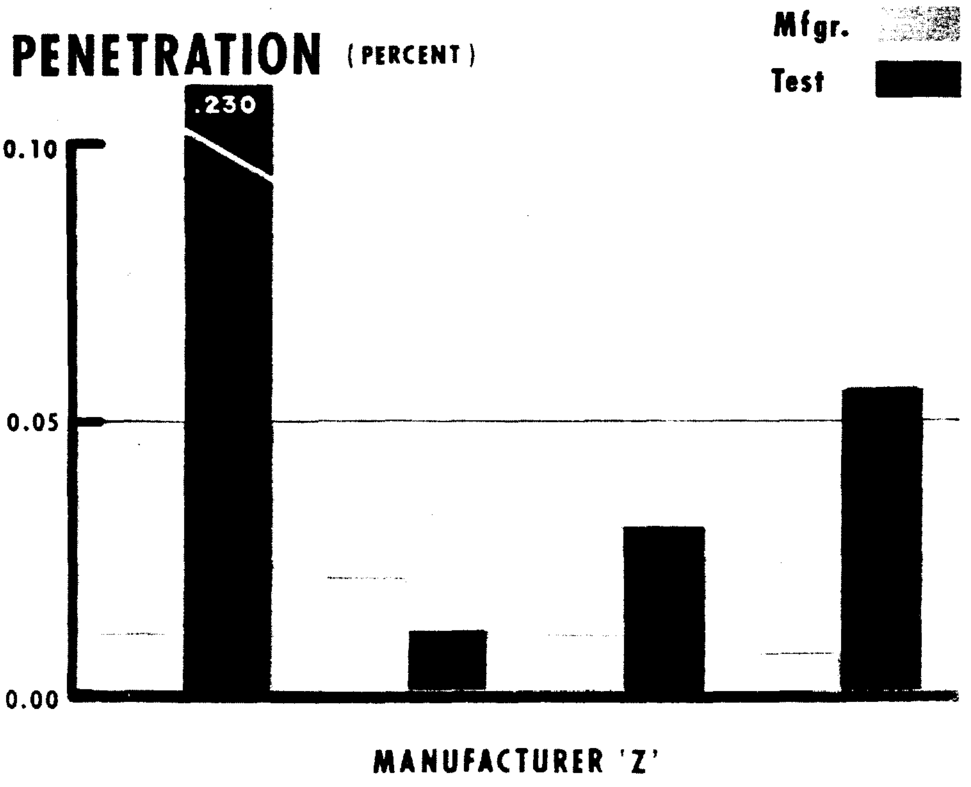

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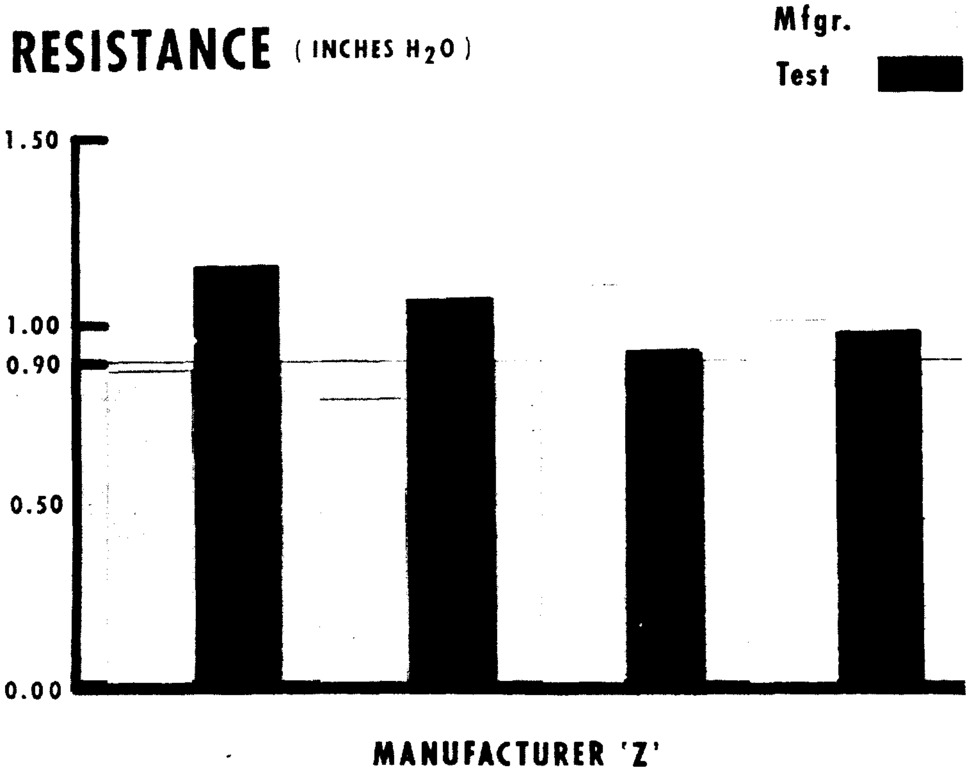


Slide 6

1% penetration and 9 tenths of an inch resistance is not automatic assurance that this is the quality of filter that will be delivered.

Now I recognize that you gentlemen representing the various establishments of the atomic energy program are not responsible for inspecting every filter delivered to your location. Nevertheless, I also recognize that you can be very influential in making certain that your plant accepts only those filters which meet the specification on which they are purchased.

Here are some suggestions: First, the purchase order for filters should specify that deliveries will be accepted subject to inspection and test. In this connection, we propose to revise the specification for fire resistive filters, contained in Issue No. 80 of AEC Accident and Fire Prevention Information, to include this suggestion. Copies of this issue are available here if, by chance, you have not received one.
Second, every filter received should be removed from its carton and inspected all over, including both faces, to assure that there are no holes or cracks in the media and no loss of seal or breaks in the adhesive. In addition, the filter should be true in shape, in dimension, and have good basic material in the frame.

Third, arrangements are now going on to install at Hanford two DOP penetrometers which will test filters of all sizes up to 1000 cfm. These machines will be available to check filters purchased by all atomic energy installations and the penetrometers will not be for Hanford's exclusive use. They are being installed at Hanford, rather than a more central geographical location, because there is every indication that Hanford will use many more filters than any other plant in the program. Consequently, it will be more economical to ship filters from other plants to Hanford, or from the manufacturer to Hanford for testing before delivery to you, rather than ship Hanford's filters to a more central point in the United States.
The AEC Safety Division at Richland, Washington, will be your point of contact for this testing service when arrangements are completed.

In addition to the penetrometers at Hanford, arrangements are being made with the Army Chemical Center to provide similar testing service. This will reduce transportation costs and expedite the testing for establishments nearer Edgewood, Maryland, than Hanford. When all of the details are worked out for penetrometer testing service at both places, the information will be circulated throughout the program.

Beyond the suggestions for inspecting and testing, the Underwriters' Laboratories is establishing an inspection and labeling procedure with the filter manufacturers to certify that high efficiency particulate filters which bear the UL label will be of fire resistive construction. This procedure also will help us to get filters of better quality, by discouraging the existence of holes and cracks such as Mr. Hurwitz showed you. The Underwriters' Laboratories'label, however, will not supersede each plant's responsibility to inspect the filter and to have it checked, independently of the manufacturer, for penetration and resistance. Mr. Leonard H. Horn of the Underwriters' Laboratories of Chicago is attending this Seminar. (Have Mr. Horn stand up and be identified). We have been working closely with Mr. Horn on this fire resistance problem and if any of you care to contact him outside these sessions, I am sure he will be willing to explain any aspect of the UL program. Whenever their program is put into effect, you probably will want to specify in your purchase orders that filters bear the UL label for fire resistive construction.

In conclusion, you must decide whether we need high efficiency filters or more economical filters with efficiences in the range of 70 to 90%. In some instances, these are what we are getting anyway although we are asking for high efficiency filters. If we do need high efficiency filters, then you must insist that filters, when delivered, be inspected visually
independently
and/tested for penetration and resistance to be sure that you are getting what you specify. We have notified all of the filter manufacturers

that we found defective filters in these tests and we have given each manufacturer the comparative penetration and resistance ratings on the samples which he manufactured. We have also put them on notice that, from here on in, we are going to inspect and test filters that come into the atomic energy program. I have had replies from all of them expressing their concern over the damaged filters we found, and it is difficult to believe that they would deliberately deliver defective and inefficient filters. Be that as it may, your efforts and the full impact of the influence of each and every one of you will be required at your plant or facility, if we are to keep bad filters out of the program. This is a condition that has existed too long in our air cleaning operations and you can help to correct it. Gentlemen, it is up to you.

THE INSTALLATION, HANDLING AND STORAGE OF HIGH EFFICIENCY FILTERS

W. J. RICHARDSON and J. H. PALMER
Chemical Processing Department, General Electric Company,
Hanford, Wash.

Part I

The highly efficient filters of today require equally efficient installation methods and care as much as does the manufacturing of the units.

The high efficiency developed by these filters can be seriously impaired by poor or careless installation methods and improper handling. Storage can also be an important factor.

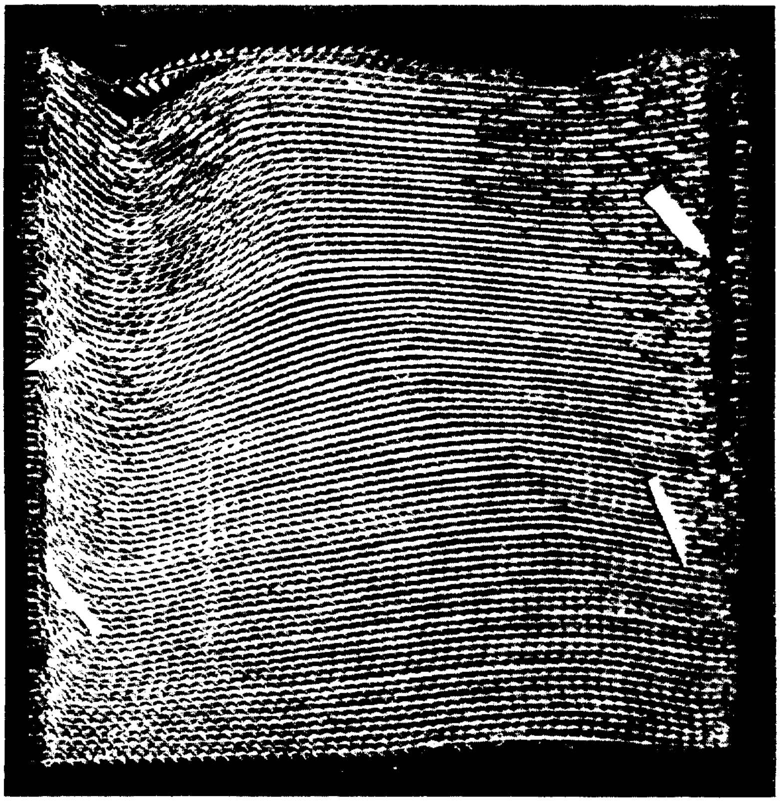
Thorough knowledge as to the construction of these filters should be acquired by all personnel involved in installation, handling, and storage. It has been found that many of the people who handle these filters have a misconception as to their construction. Some have the impression that the filter frame is packed with solid layers of media. With this impression, marred surfaces, split media, damaged separators, and holes in the filter face do not have any significance to them. The writer has often demonstrated the construction by means of cut-away models, usually followed by expressions of surprise by personnel, some of whom have been handling these filters for a considerable time.

The media, anywhere from 8 to 20 mils thick, is fragile and easily torn. When this is pointed out, the usual response is, "Why don't the manufacturers include perforated plates over the filter face?" This would be fine, except that it would be impossible to inspect the media for tears, or damage caused during shipment and/or handling at the factory.

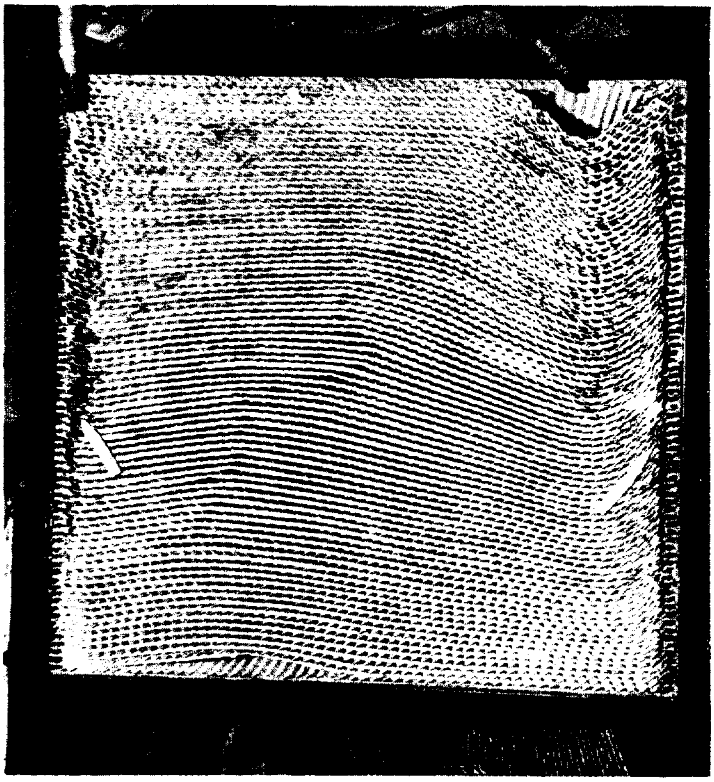
Perhaps the comment should be made at this time that damage, such as cracks in the media (especially along the sides of the frame), opening of the frame corners, and breaking away of the media from the adhesive does occur as a result of shipping and handling.

Pictures no's. 1, 2, 3, 4, 5, and 6.

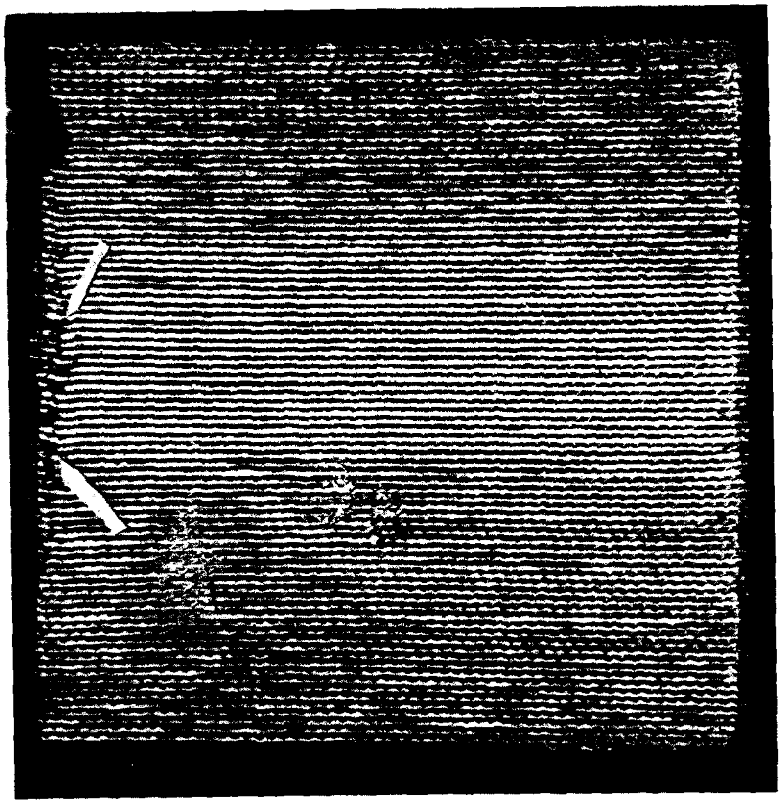
Sometimes the cause of damage can be determined by visible damage to the carton in which the filters are shipped, but not always. All filters should be inspected for the above mentioned faults as soon as received, so that they can be returned to the manufacturer, or so that shipping damage claims can be made.



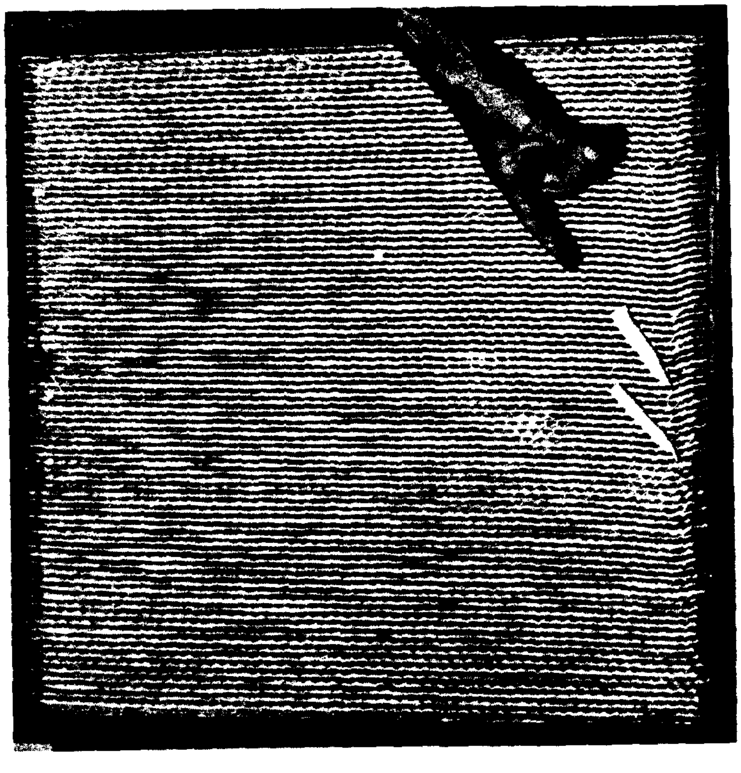
Picture No. 1—Filter damage. Note damage as a result of shipment. This is an unusual example.



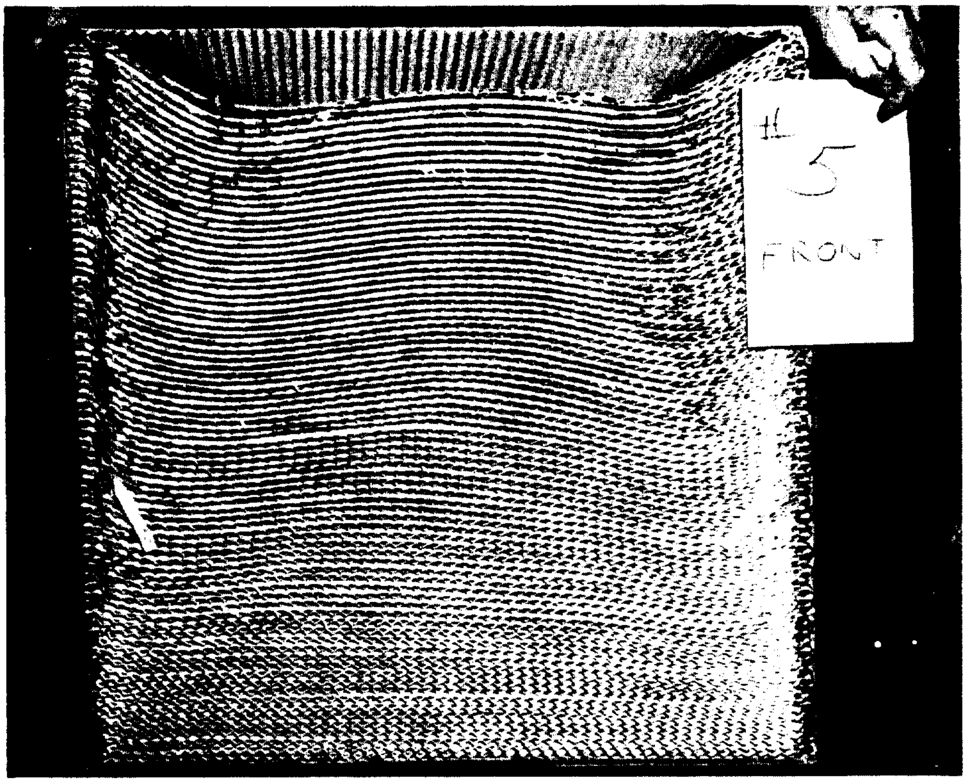
Picture No. 2—Filter damage. Opposite face of filter shown in Picture No. 1.



Picture No. 3—Filter damage. Filter media is cracked across top of filter. Separators are mashed. Mashed separators reduce capacity and life of the filter.



Picture No. 4—Filter damage. Filter media is broken in several places. Minor damage such as this is not too obvious to the uninformed and could be the cause of doubt as to efficiency of this type filter.



Picture No. 5—Filter damage. Another damaged filter. Container showed no external damage or corner bruises.

Picture No. 6—Gasket material. Note split in edge of gasket material.

INSTALLATION

Too much emphasis can not be placed on the importance of installation of the units. It is not too evident to the uninstructed mechanic, of the serious effect even a minor leak around the filter frame will have. Tests have been conducted at Hanford on the various methods of installation, in which the leakage rate was measured. Results were quite revealing and will be covered by my co-worker, Mr. W. J. Richardson, in a talk following this.

However, perhaps it should be pointed out at this time that even a one CFM leakage rate can be of serious concern when filtering highly contaminated air. For instance, it was found in one installation at Hanford, that a one CFM leak around a filter increased the down-stream count by a factor of two. This was on a new, clean filter. If the filter had been in service for some time with the consequent reduction of flow due to loading, the leakage could have been of greater significance.

The following instructions on installation of the space type high efficiency filters are, we believe, worthy of consideration:

1. The filter unit should be carefully removed from the carton, being careful not to drop the filter. (Jarring will sometimes cause the media and possibly the separators to crack at the place of contact with the adhesive.) Care should also be taken to not poke fingers through the media or damage the separators when removing the filter from the carton.

   If it is necessary to lay the filter with the back or face down when removed from the carton, care should be taken to be sure that bolts, nuts, stones, or uneven floor surfaces will not damage the media or separators. Remember - the filter is extremely susceptible to damage. Inspect the filter for cracks in the media and separators, and for separation from the frame.

2. See that the gasket is firmly cemented to the frame and that the gasket material is butted or meets at the joints and is itself undamaged. (Gaskets have been found with air-holes running through the sides of the material.)

3. If both gaskets are not needed for sealing purposes, the un-needed gasket should be removed and the edge of the filter frame cleaned at the points of clamp contact.

4. The surface to which the filter is applied must be true, clean, smooth, flat, and free of welds or weld spatter. It must be rigid enough to fully compress all the gasket surface, without warping or buckling the bearing surface.

5. The gasket should be firmly compressed, with the filter completely covering the opening.

6. The filters should be installed with the separators in the vertical position, to minimize sagging of media, when the filter is installed on edge.

7. In locations where the filter is subject to physical damage after installation, it should be protected by a wire mesh screen or expanded metal shield.

8. It will be noted that one face of the filter usually has a bead of adhesive on all four sides. The filter should be installed with this face towards the exhaust side of the ventilation system in order to minimize the possible

flow through the plywood joints of the frame of unfiltered air to the downstream. (These joints are usually tight, but when handling highly contaminated air, even a slight leak can be of significance.)

Various methods of filter installation will be described by Bill Richardson in his paper, following this.

FILTER REPLACEMENT

Filter units should be replaced under any one of the following conditions:

A. Pressure drop of 2" water gauge, or greater, across the filter.

B. Excessive build-up of lint, or product particles. (Fire and explosive hazard.)

C. Loss of efficiency as determined by air sampling measurements.

D. Visible damage or rupture of the filter media.

STORAGE

The filters should be stored where they will not be exposed to dampness, excessive heat or cold, or rapidly changing temperatures. They should be stacked no more than four high, with the separators in the vertical position as is usually indicated on the carton with a "This Side Up" sign or an arrow.

They should never be dropped, or thrown. The cartons should not be damaged in any way while handling. Hooks for handling cartons should never be used.

INSTALLATION, HANDLING, AND STORAGE OF HIGH EFFICIENCY FILTERS

Part II

I would like to take a few moments to explore just a little further into one of the several facets to which Mr. Palmer has referred in Part I of this discussion; this being the installation of high efficiency filters.

Those of you who are confronted daily with the problem of handling highly radio-active contaminants know that strict requirements are set by all AEC installations as to the amount of contaminants that can be safely emitted from any of the production or laboratory stacks.

You also know that in order to stay within these close tolerances you must obtain the most efficient filters on the market today.

Once the fact has been established as to the need of high efficiency filters for an installation, this would appear to alleviate all of our stack emission problems. However, as Mr. Palmer has stated, there are many pitfalls between the factory and the actual installation of these filters.

I would like to enumerate some of these pitfalls -

1. The filters must arrive at your plant site in good condition after being transported across the country.

2. All personnel handling the filters should be aware of the fact that these filters are actually delicate pieces of equipment.

3. Personnel responsible for the installation of the filters must provide a receiving framework that will permit maximum sealing of filters to the frame.

When you are certain that all of these conditions have been complied with, then, and only then, can you expect the optimum filtration for which these filters are designed.

I would like to relate a story concerning one of these pitfalls which occurred at one of our plants not long ago. Mr. Palmer offered his services to one of our production facilities to instruct their personnel on the proper methods of handling and installing high efficiency filters. The response received from this particular plant was, and I quote, "We have installed filters for years, we know all about them." It just so happened that Mr. Palmer and the writer had an opportunity to tour this plant a few weeks later. Being interested in filters, we naturally looked over their filter installations. Their primary filters are housed in stainless steel boxes with plexiglass ports for inspection and removal of filters. We were amazed to find numerous filters installed with the media on the front face torn or smashed in. Needless to say, these high efficiency filters were not performing as expected.

This attitude seems to be typical of plant operating people, who believe that the only thing that can happen to a filter is that it will "plug", or become loaded. They also seem to feel that as long as they replace the filters on a scheduled or predetermined basis, they will be assured of obtaining optimum filtration and that their responsibilities for clean atmospheric conditions end at installation.

They are of the opinion too, that small breaks or cracks, or leakage around gaskets is not of too much significance, as the leakage would be such a small percentage of the air being treated. This, of course, is entirely dependent upon the degree of contaminants held in the air being treated.

Our tests indicate that minor leaks are significant and that everyone responsible for installation of these units should be made aware of the consequence of such leakage.

How many of us can say we have personally, or at least have had qualified personnel, inspect these filters upon receipt at our plant site or just prior to actual installation? Also, have we inspected the construction of the rooms or boxes that are to house these filters?

We at HAPO asked ourselves these same questions and found that we were remiss in our responsibilities. As a result of this, we set up a test apparatus whereby we could simulate some of our actual methods of filter installation.

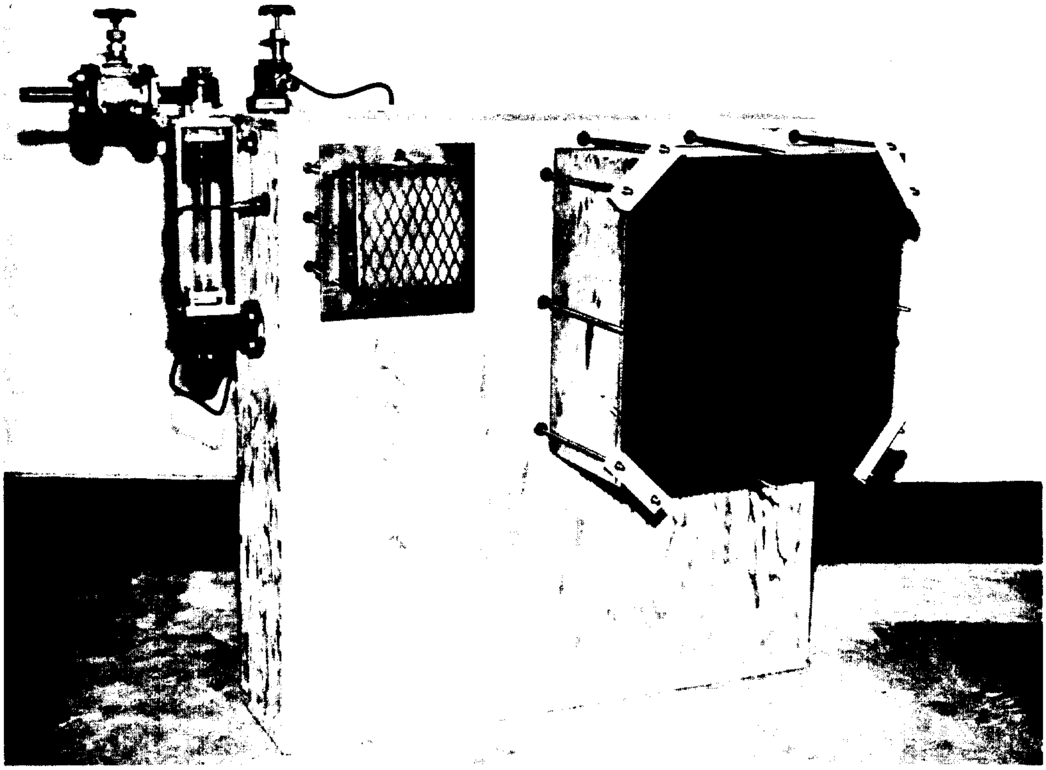
This merely consisted of a boxed chamber which would permit installation of both 8" x 8" and 24" x 24" filters.

The following slides will show some of the various methods of filter hold-down which are used in HAPO.

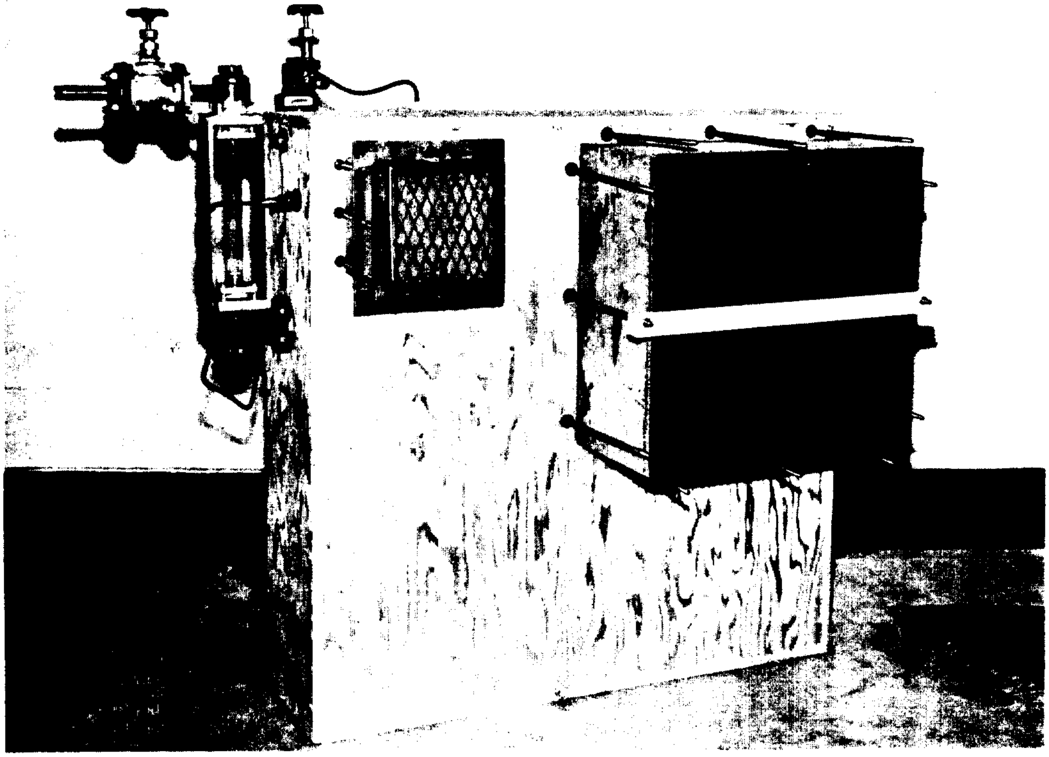
Picture 7 (Four corner hold down)
Picture 8 (One bar across middle)
Picture 9 (Two bars across filter)
Picture 10 (Three bars across filter)

Leak tests were conducted with these various hold-down methods on both the 8" x 8" and 24" x 24" filters to determine the amount of leakage around the filters.

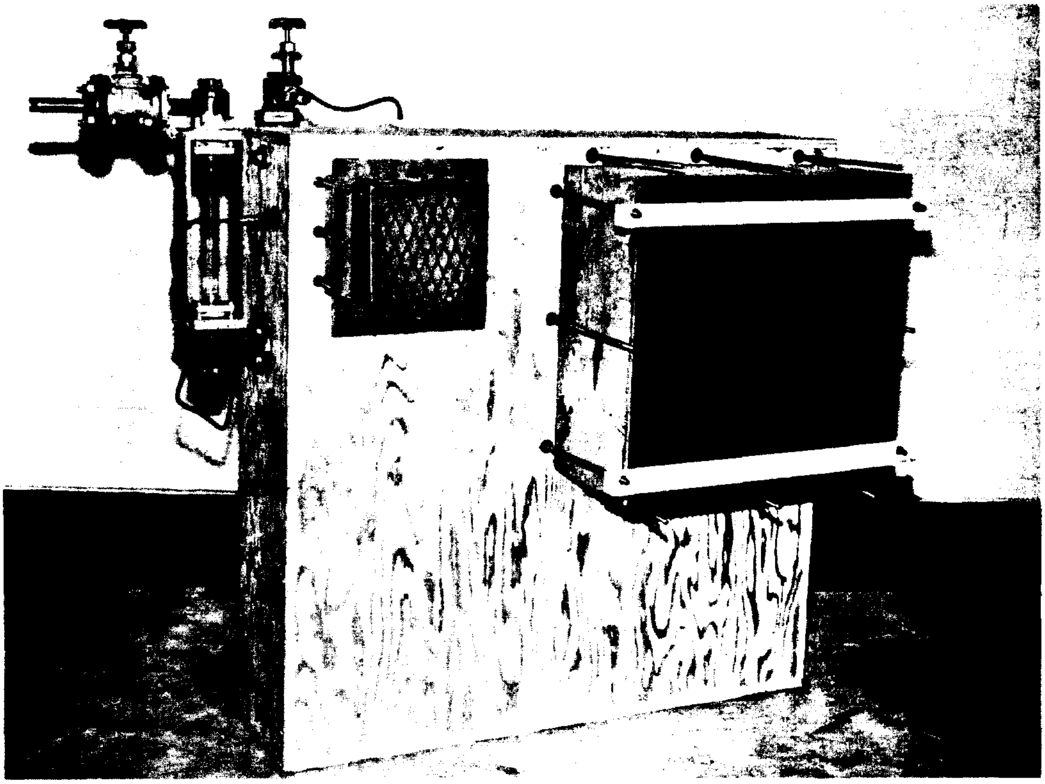
(Text continues on p. 195)



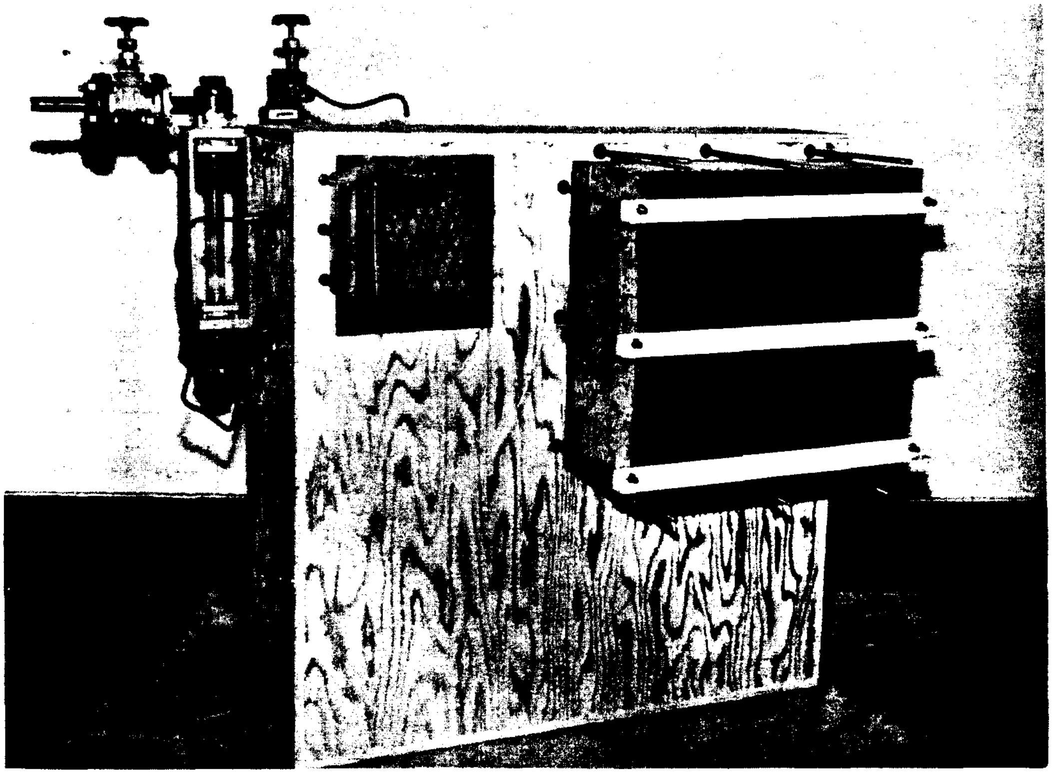
Picture No. 7—Gasket leak test. Four corner hold-down.



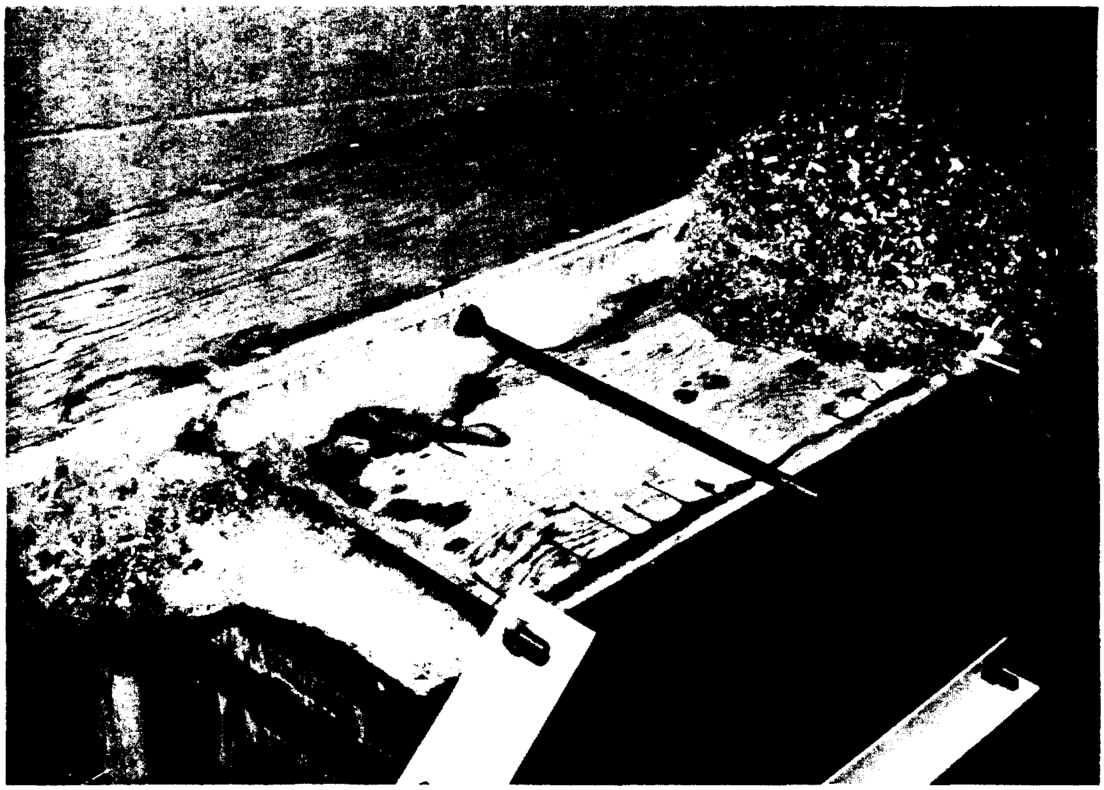
Picture No. 8—Gasket leak test. One bar across middle.



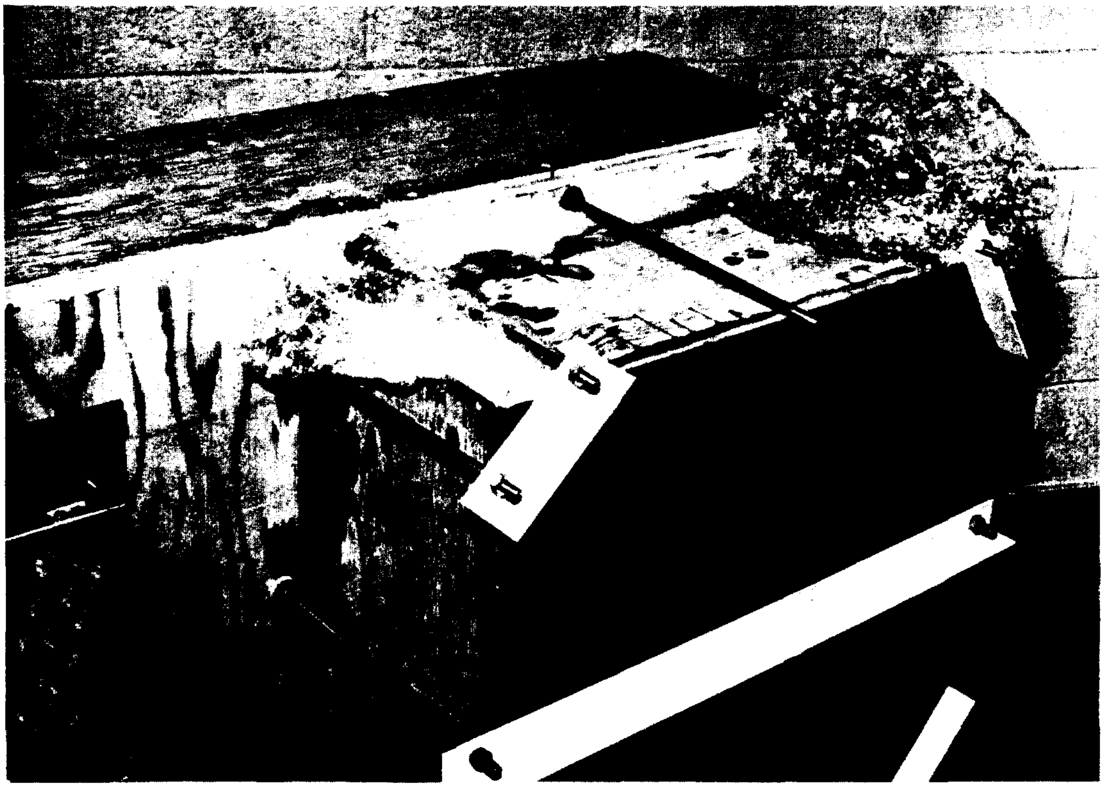
Picture No. 9—Gasket leak test. Two bars across filter.



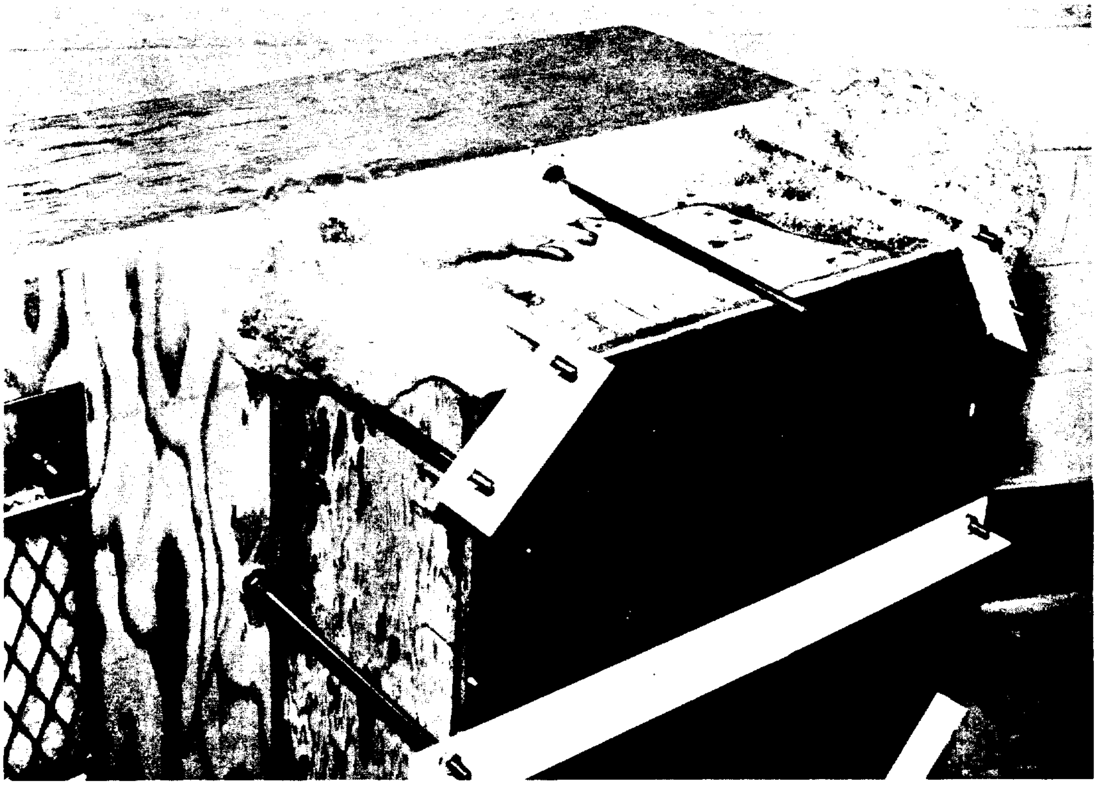
Picture No. 10—Gasket leak test. Three bars across filter.



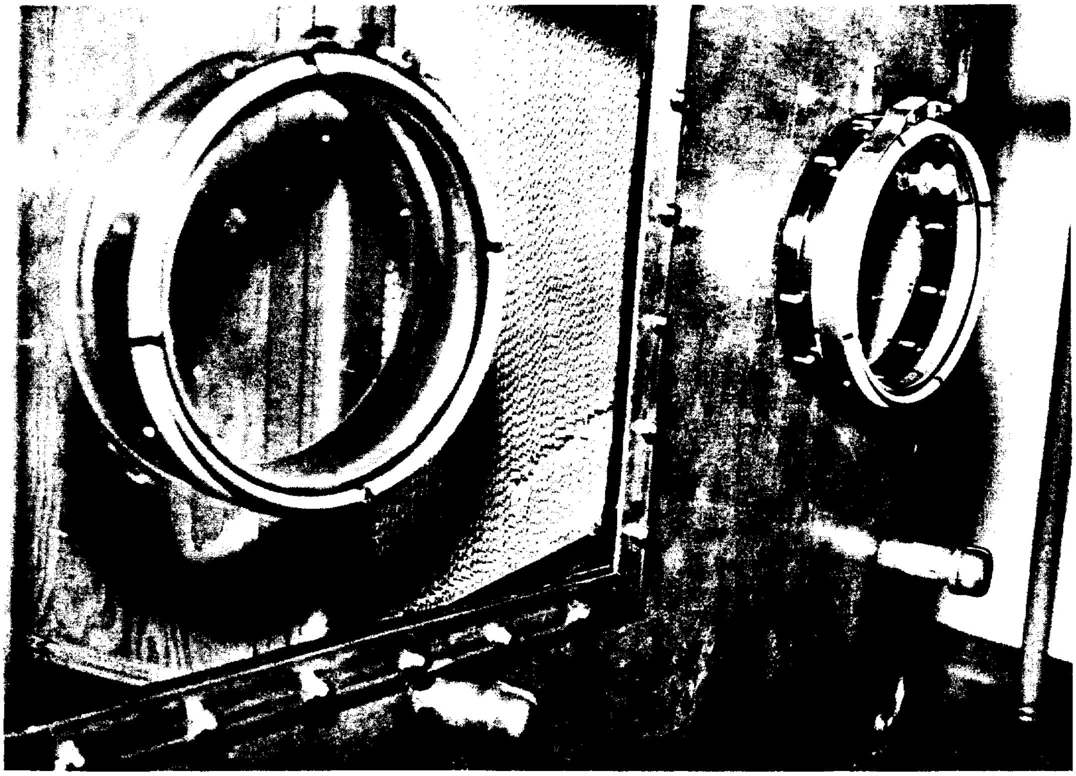
Picture No. 11—Gasket leak test. Test chamber under pressure. Soap solution used. Note leakage at frame joints.



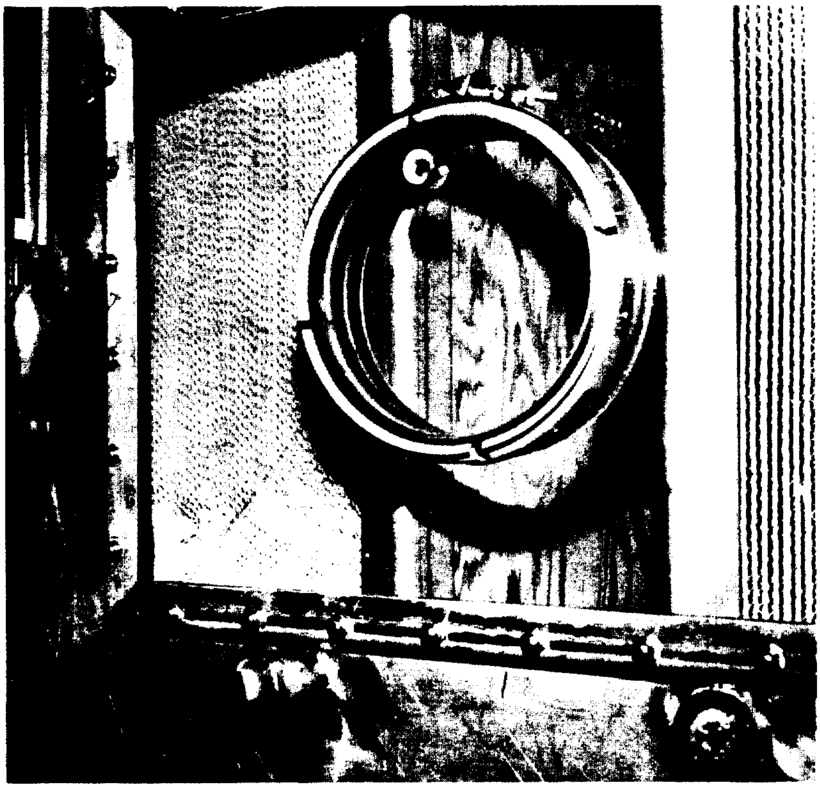
Picture No. 12—Gasket leak test. Note leakage at corners.



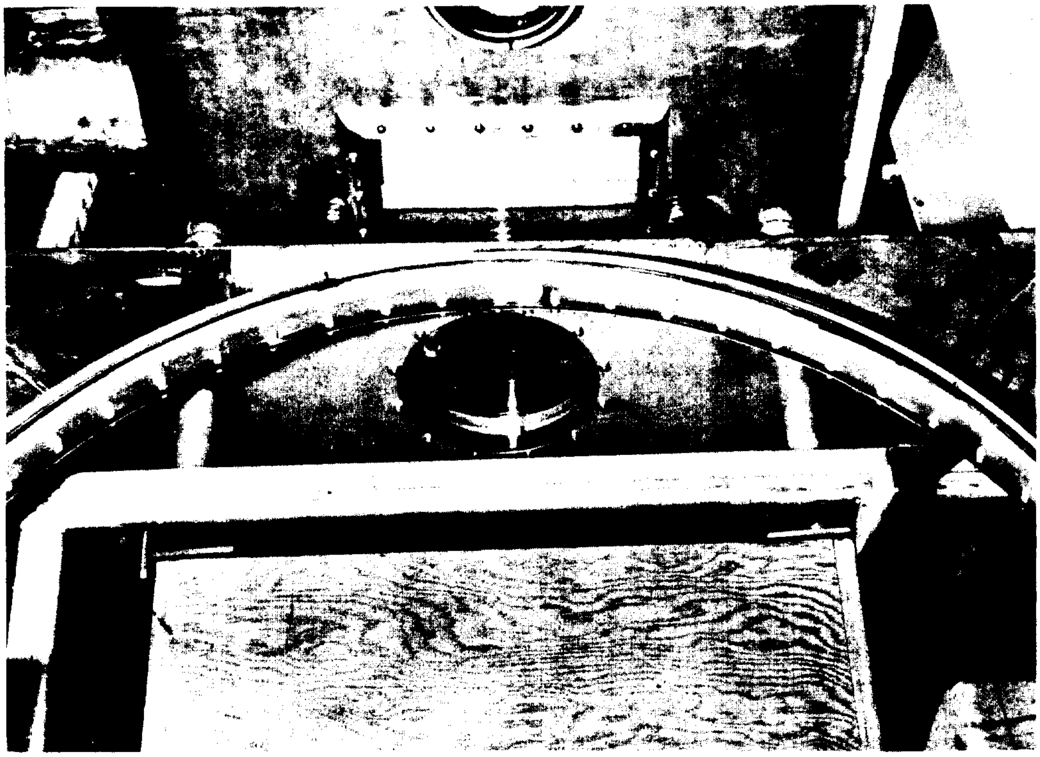
Picture No. 13—Gasket leak test. Note leakage at corners and at gasket. Gasket leakage is through pores of the gasket material.



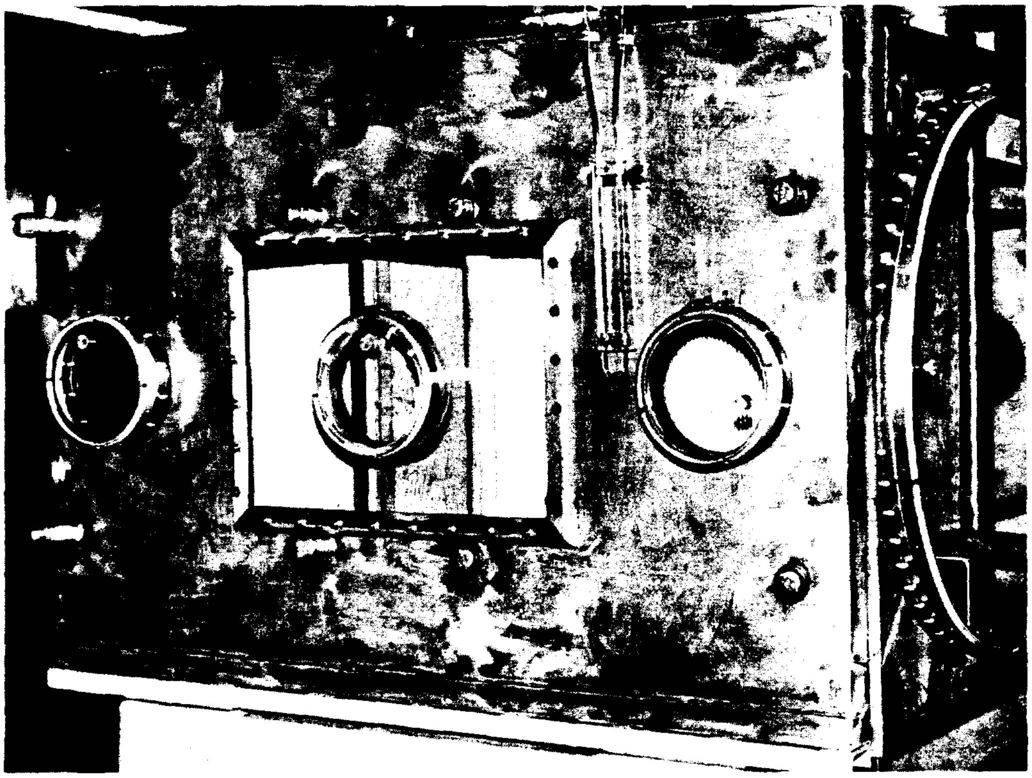
Picture No. 14—Filter installation. Actual installation. Note damaged filter. Media is broken through.



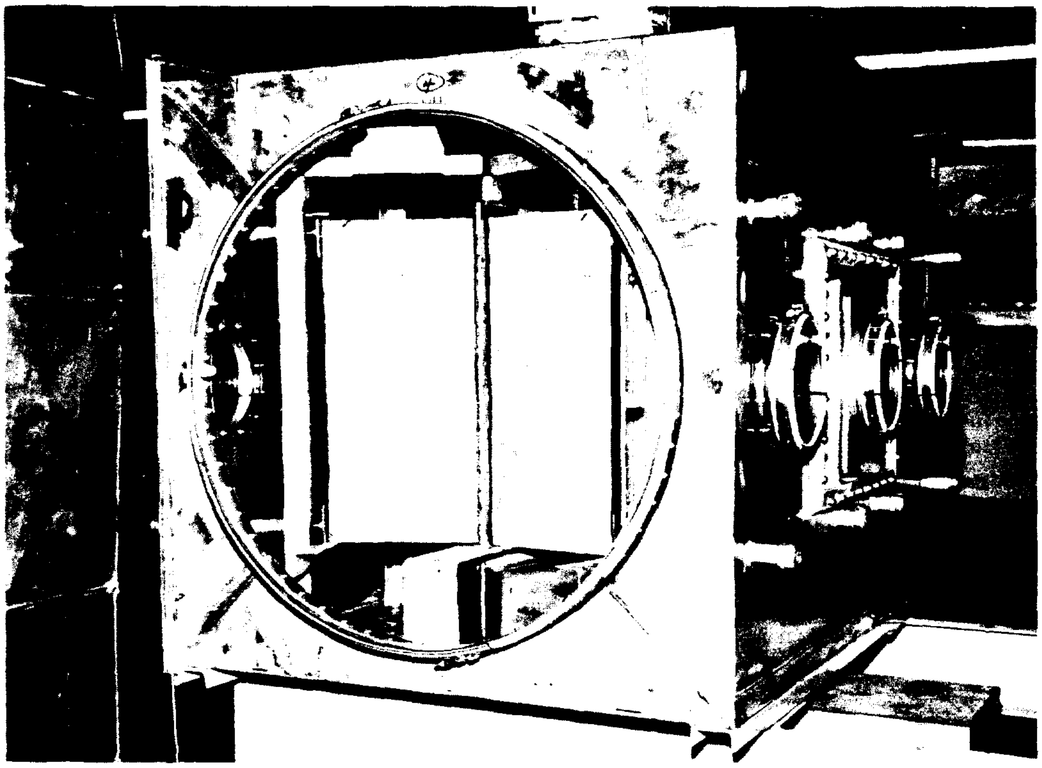
Picture No. 15—Filter installation. Same installation. Different filter. Note bruised separators. Media is punctured.



Picture No. 16—Filter installation. Note hold-down method. Hold-down bolts contact corner plates installed at filter frame corners and are manipulated from outside the filter box.



Picture No. 17—Filter installation. Filter box containing four filters. Heads of hold-down bolts are covered with pipe-caps.



Picture No. 18—Filter installation. Another view of the same filter box. Filters are installed at an angle, forming a diamond shaped center.

The 8" x 8" filter leakage was practically negligible with all methods of hold-down and from a 1" W.G. differential up to 6" W.G. differential.

The average leak rate on a 24" x 24" filter at normal differential pressure of 1" W.G. was ½ CFM. This increased to 1.5 CFM with a differential of 6" W.G. This leakage was primarily through the porous gasket material and especially where the strips of gasket material butted against each other. This leakage was constant with all types of hold-down as shown on slides, and made little difference whether hold-down bolts were finger tight or had a 5-pound torque applied. However, it must be pointed out that these tests were conducted with a perfectly smooth and aligned sealing surface for the filter.

Pictures no's. 11, 12, and 13 show results of soap tests. .

The application of 25-foot pounds torque pressure at each corner of the filter frame was necessary to completely stop leakage through the gasket edges. This torque however, did not stop leakage at the frame joints.

Additional tests have been made and are still in progress whereby we purposely have built-in frame mis-alignment and warpage. One of the tests with a built-in 1/16" warpage showed leakage rates of 6 CFM or greater at normal differential of 1" W.G. This was with hold-down bolts finger tight. Once a 5-pound torque was applied to hold-down bolts, the leakage rate dropped off at normal of ½CFM at 1" W.G. differential.

Pictures no's. 14, 15, 16, 17, and 18 show a new type of installation adopted at HAPO.

When leak tests have been completed, the information will be available to all interested parties.

Discussion

Q. Are the army specifications for filters available to all for vibration test, etc., and might it be practical for some of us who are far away from the manufacturer depend on such specifications for quality not inherent in the filters we buy?

A. Material available for the asking. Package problem - certainly your carton can stand redesign. However, the Chemical Corps specs, except for overseas shipment only call for commercial pack. Took some down to discuss problem with packaging experts and they said yes they could fix a package up and make it as good as you want. Could even be a returnable package. We did receive three filters prior to shipping. Received in excellent condition. They were returned and apparently took rough handling in good shape.

What do you really need? Proud of Chemical Corps filter - filters treated with reverence--second only to their gas mask. To them it symbolizes the difference between living and not living. It's that simple - some of this should rub off on the installations handling fissionable material.

What media do you need? Thinks your people haven't actually determined what type of filter media you need. Thinks you have a great big research program ahead of you.

Q. Assuming you need a .05 penetration, would it be possible or practicable to have an AEC man who is in the general vicinity of the manufacturer be present during the manufacture, fabrication, packaging, or whatever stage it might be to at least visually inspect the filters as they are manufactured to give some assurance that at least some with the large holes don't go into packaging.

A. (H. Gilbert - AEC, Washington) We run more of a staff than a service organization in Washington. Will arrange for what help we can get you. More contractors than able to cover adequately.

C. It is impractical for those on the West Coast to send representatives to the East Cost for inspection. It might be helpful to have an inspector.

C. (G. J. Hurwitz, Army Chemical Center) In the military we have inspection interchange whereby an inspector for the army can inspect material being purchased by the navy and vice versa. AEC would possibly come under the same regulation. There may be reimbursement in kind and there may not be. It is worthwhile looking into.

Q. (W. B. Harris - NYOO) When one has a job of air cleaning to do, it is reasonable to expect that the engineering department will look at the job and say how is it best to do it? Too many times we put in air cleaning which we think is reasonable for the job and then so we won't make a mistake, put more air cleaners behind it so if breakdown occurs we always have a high efficiency filter as a background. Thinks this is in many cases not necessary. Use of a space filter designed specifically as a space filter, either as a device to keep a command post clean or a tank has been applied to commercial air cleaning. Attempt to apply space filters to this type of application. Fire resistance in a filter is essential.

C. Another thing about the business of inspection - I think it is completely impractical to expect that any organization wants to order 6 filters; that these 6 will go from a manufacturer on the east coast to the laboratory in San Francisco and then be transshipped to Hanford, tested and shipped back again to Berkeley. It just doesn't make sense. If Hanford could be central purchasing agency and check filters, and if manufacturers understand their product was being spot-checked, quality would be improved considerably. Orders would go from this site to other sites. If no planned inspection is conceivable, this would certainly be an ideal situation.

Q. (J. F. Hall, United Kingdom) In connection with the licensees discussion on this - it will be interesting to see what our experience will be. We have the added safeguard on leaking gaskets and adjust - use canisters in all instances. Filter cartridge is put in and sealed up. It seems before you can have a common central inspection system you should have a common central specification. Much latitude exists. If people agree on things, why aren't they using them? I also heard you had a development on quartz paper.

A. (L. Silverman, Harvard) What you call quartz paper could be either - or fiber glass. Question of specs. is most important. Fibers based on insulation quality rather than filtration. Basic supply - who makes paper out of it may alter the supply. May have bad supply of paper for year and not know it. Differences show up due to manufacturers trying to cut costs. None of the suppliers are making money - marginal operation. If these things are controlled at the source and specs. written, then quality control rests on workmanship. Perhaps other materials might be applicable today. Look forward, and this situation may push us into a little more development.

C. (Silverman) First I'd like to say that you get what you pay for in efficiency and requirements for various operations will depend on what the upstream loading is and what it is you want downstream. So it is pretty hard to generalize and say that 70% will do and 90% is too much. I think we are now agreed that there is a safety factor in using.05% penetration and we apply it across the board. Part of our economic survey which Joe Fitzgerald will talk about tomorrow is aimed at finding out whether you are getting your money's worth efficiency wise, for your air cleaning dollar. There are many operations where low ratings would only require 70% filter. But there are many others where the activity of the material at low loading is so high that you have to use 99.95. So much then for requirement. It seems to me that a lot of this problem as it now exists has cropped up from the fire problem. We didn't have, as far as I know, this efficiency and filter rupture problem with the paper filters. I don't recall any of this and we at Harvard have done a lot of blasting of the paper filters under the shock wave test. We also tested under shock wave some of early glass ones but not of the more recent fire resisting construction. We also took both paper and glass filters out to Nevada for our shock test and we had, I think, two dozen filters out there at two points from the weapons tests we ran in Nevada. So I think that this problem has not been with us for the last ten years or if we are, Brookhaven has been filtering at a poor rate with their nine year old filters. I do think Lee Gemmell can confirm this. In fact, they have some that have been in operation at least five years and maybe longer, of the paper type. I knew of several that have been in for 4½ years. I guess Dow Chemical had the 4½ year ones, that went up in a hurry. So I think a lot of the problem is of recent origin and I think it is high time that we checked it now. The specifications that are required aren't so much for testing of filters. This is what concerns me. I think we may be trying to attack this Goliath with forks instead of with really good weapons. That is, to get back and find out if there is a material failure or whether it is the wrong material that is being used now or whether the cements are improper, and the specs used for the plywood are improper. It is true that the assembly and the Quality Control should be put into the specification but if they are going to have to test every one of these filters routinely it is going to run the cost of them way up and I think we have got to get back to the source of the defects. I cannot believe that it is all one of these random sort of things, and, that it will be in a given production, it might be the cement at one end and/or the other. I think there is something fundamental here that is faulty.

C. (Keigher, AEC Hanford) I think we should get back to the fire resistant aspect of this just a little bit. We are not going back to a combustible filter as far as I can see. We have had some fifty recorded fires in combustible filters in the Atomic Energy program already - like the one we had in the air cleaning lab that cost $10,000 - in Rocky Flats and in many other places. I feel that I should defend the fire resistant filter because I attended the air cleaning seminar at Argonne and they presented us with a challenge. We have always felt it should have the fire resistenceness or the non-combustibility and the same time the equivalent or better of the filtering media. I think that there has been a change, Mr. Silverman has referred to this, since they developed an A. D. Little paper in 1951, when they went towards the all glass and the glass asbestos media. This media apparently was an acceptable filtering media at the time it was made and I think those of us who are interested in the fire aspect of it expect the present media to be as good. Whether there were cracks in those days or not I don't know. I am convinced however, that just as we found there were never any fires in the CWS filters during the MED date, most of this was because of very poor reports. There were fires I found out but you can't find them recorded anywhere. I think breakthroughs could have occurred in those days but everyone was too busy winning a war to go into where this was happening and why and so forth. Now we have a chance to get into some of these finer aspects if you wish. The disposable and combustible filter has existed in industry. The New York Eastman Kodak had a $3½ million fire in November of 1950, in bag filters. The fact is that the fires in ventilation systems and filter banks are one of the major classifications of fire losses in American industry. I say all these things only to, let's not say it's impossible because it got into the fire resistant filters. This, I think, is a correlation here. But let's not go backward in this aspect. In manufacture of filters, we have to help manufacturer discover what is the matter. Find out what is wrong and fix it now. Someone should carry this matter to conclusion and AEC, Washington should be the one to do it.

C.- I'm afraid many of us have missed the major points. I feel that we don't want to go back to cellulose asbestos filters. But something in the manufacture of filters that are put out by all the people is wrong. I feel that we have to help these manufacturers find what is wrong. We have to find out what is wrong with these filters and fix it now.

C.-It would appear to my humble judgement that the Division of Reactor Development and the Harvard Air Cleaning Laboratory have been called upon to get their heads together - the move must come from them. The contractors as a group are almost helpless except for little things like visual inspection.

THE DISPOSAL OF RADIOACTIVE FISSION GASES BY ADSORPTION

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Abstract

In the operation of nuclear reactors, nuclear fuel reprocessing plants, and in-pile experiments, special provision must be made for disposal of gaseous fission products to prevent contamination of the atmosphere to an unacceptable degree. A disposal process is described in which the noble gas fission products, krypton and xenon, are delayed relative to the sweep gas by physical adsorption as they pass through an adsorbent such as activated charcoal. A theoretical expression describing this process has been developed, using a theoretical plate analysis, and has been verified experimentally. The retention time for a gas present in trace concentration is proportional to the amount of charcoal in the adsorber and to the adsorption coefficient which is evaluated experimentally for a particular combination of materials and conditions. The retention time is inversely proportional to the volume flow rate of the sweep gas. The retention times of experimental adsorbers have been measured by a radioactive tracer technique using krypton-85 and xenon-133 to typify fission gases. Retention times have been measured for various adsorbents including different grades of activated charcoal, silica gel, activated alumina, and molecular sieve materials. Activated charcoal was the most effective adsorbent. Retention times were measured using helium, hydrogen, argon, nitrogen, oxygen, air, CO_2, Freon-12 and krypton as sweep gases, individually. Retention time decreases logarithmically as temperature increases. Water vapor reduces the retention time for krypton on charcoal as does CO_2. Krypton interferes negligibly up to 1000 microns partial pressure. Provision must be made for the dissipation of heat from radioactive decay. Ignition temperatures for charcoal in oxygen were determined and methods of prevention and control of charcoal fires were investigated. Experimental results described have been used to design off-gas adsorber systems for in-pile experiments and to analyze the performance of an adsorber for a homogeneous circulating fuel reactor.

Introduction

In the operation of nuclear reactors, nuclear fuel reprocessing plants, and in-pile experiments, special provision must be made for the disposal of gaseous radioactive fission products to prevent contamination of the atmosphere. Figure 1 shows the important fission gas isotopes. Their half-lives range from a few minutes up to ten years. Among the krypton isotopes the longest-lived is krypton-85, approximately ten years, but the next longest is only four hours. The longest-lived xenon isotopes are Xe-131m and Xe-133, having half-lives of 12 days and 5.27 days, respectively; the shorter-lived one being more abundant. The longest-lived iodine isotope is I-131, having a half-life of eight days.

When a reactor accident occurs, all the radioactive isotopes shown in **Figure** 1 can appear in the gas system, even after removal of particulate matter. In reactors and in-pile experiments having circulating fuel, fission gases are released having the entire range of half-lives all the way down to a few seconds. By the time the off-gas reaches the disposal system, the age is such that only isotopes having half-lives greater than a few minutes are present to an appreciable extent. When solid fuels from reactors and in-pile experiments are dissolved after aging, only ten year Kr-85 and five and twelve day xenon and eight day iodine require consideration.

Various methods have been used to handle the noble gases, krypton and xenon. They have been vented to the atmosphere (1) or stored in large containers for decay. Solvent extraction has been applied successfully (2). This paper is concerned with the application of the process of dynamic adsorption of noble gas fission products.

Radioactive iodine vapor has been removed from air streams by caustic scrubbers or by hot silver reactors. Using I-131 tracer, we have found that it is removed at least 99.9% by charcoal adsorbers. This work, which is of a preliminary nature, is reported in ORNL-CF-58-5-59 (3), and more detailed studies are currently in progress.

Dynamic Adsorption

In the process of dynamic adsorption, the noble fission gases, krypton and xenon, are physically adsorbed from a moving sweep gas, by a material such as activated charcoal in a manner similar to that used in gas chromatography. Adsorption equilibrium exists at every point within the adsorber. Only a small fraction of the krypton and xenon remain in the moving gas phase, and as a result, they are delayed relative to the sweep gas. The delay times are characteristics of the adsorber and may be measured experimentally. In some applications the adsorber is regenerated continuously by radioactive decay of the adsorbed fission gases.

We have applied a radioactive tracer technique to measure retention times. A short pulse of radioactive krypton-85 and/or xenon-133 is injected into the flowing gas stream at the entrance of the adsorber. The concentration of radioactive gas is measured at the outlet of the adsorber as a function of time. Figure 2 shows a typical elution graph for a mixture of Kr and Xe. The ordinate is the relative concentration of radioactive gas and the abscissa is the time after injection. For each of the two elements, krypton and xenon, there is a characteristic breakthrough time, and a time to peak which for symmetrical elution curves is the average time for the passage of individual fission gas atoms through the adsorber. The breakthrough time is used for conservative design; however, the average retention time is easier to predict.

Theory

The transport of fission gases through an adsorber may be treated theoretically as shown in Figure 3 by considering a small element of length of the adsorber, dy. The rate of change of concentration of a fission gas, dP/dt, in the element dy is proportional to the concentration gradient, dP/dy, and to the volume flow rate, F, and is inversely proportional to

ISOTOPE	HALF-LIFE	ISOTOPE	HALF-LIFE
KRYPTON		XENON	
Kr^{83m}	114 MIN	Xe^{135}	9.13 HR
Kr^{85m}	4.36 HR	Xe^{137}	3.9 MIN
Kr^{85}	10.27 YR	Xe^{138}	17 MIN
Kr^{87}	78 MIN	IODINE	
Kr^{88}	2.77 HR	I^{130}	12.6 HR
Kr^{89}	3.18 MIN	I^{131}	8.05 DAYS
XENON		I^{132}	2.4 HR
Xe^{131m}	12 DAYS	I^{133}	20.8 HR
Xe^{133m}	2.3 DAYS	I^{134}	52.5 MIN
Xe^{133}	5.27 DAYS	I^{135}	6.68 HR
Xe^{135m}	15.6 MIN	I^{136}	1.43 MIN

Fig. 1—Fission products important in reactor off-gas streams.

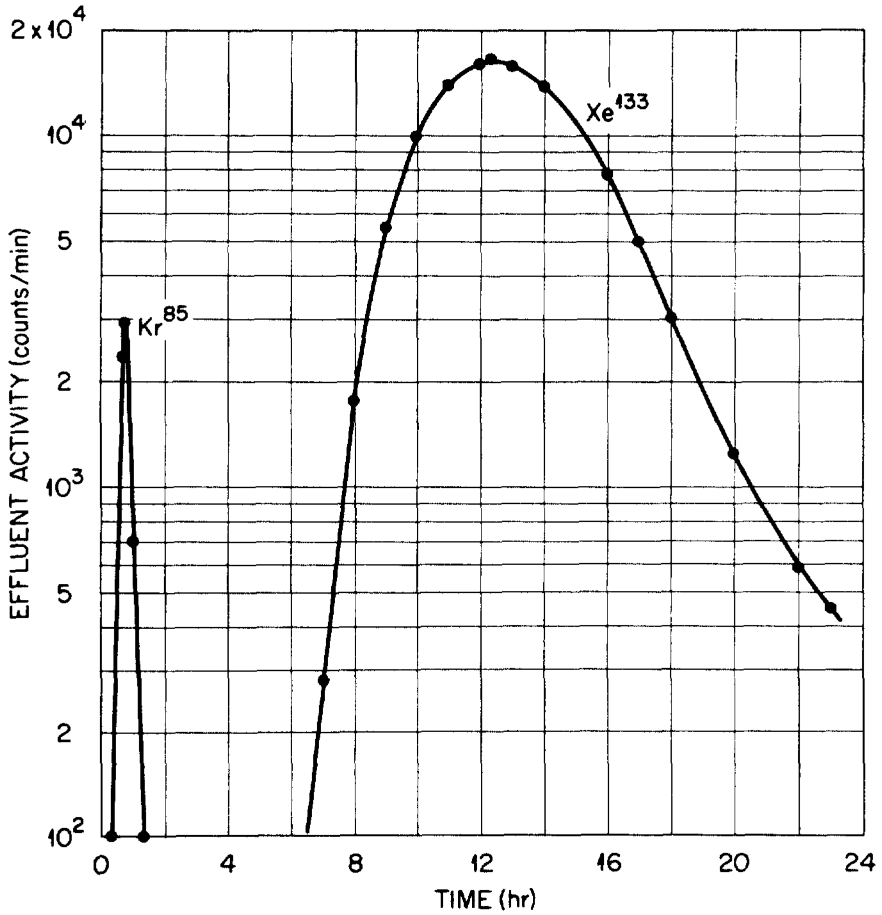

Fig. 2—Krypton-xenon elution curves.

$$\frac{\partial P}{\partial t} = - \frac{FL}{km} \frac{\partial P}{\partial y}$$

$$P = f_0(t - km/F)$$

Fig. 3—Theoretical equations for transport of fission gases through an adsorber.

$$\frac{dP}{dt} = - \frac{FN}{km} p$$

$$P = \frac{N^N A F^{(N-1)} t^{(N-1)}}{(N - 1)! (km)^N} e^{-NFt/km}$$

$$t_{max} = \frac{(N - 1)km}{NF}$$

Fig. 4—Theoretical plate equations for fission gas transport.

the equilibrium adsorption coefficient, k, and to the unit loading of the adsorber m/L.

P = concentration or partial pressure of fission gas in the gas phase (atm).

t = time at which P is observed (min).

F = flow rate of sweep gas (cc/min).

L = length of adsorber (cm).

m = amount of adsorbent in adsorber (gm).

k = either dynamic or equilibrium adsorption coefficient for fission gas on adsorbent (cc.atm/gm.atm or cc(STP)/gm.atm, respectively). Although these sets of units are somewhat dissimilar, the two coefficients, as employed herein, are theoretically equal numerically.

y = distance from entrance of adsorber at which P is observed (cm).

f_o = function which describes arbitrary variation of P at inlet of adsorber.

In the theoretical derivation k is the equilibrium adsorption coefficient relating the amount of fission gas adsorbed to the local partial pressure of fission gas. In the application of experimental results k is the dynamic adsorption coefficient which relates the average retention time to m/F. In the experimental test, f_o describes an instantaneous pulse of radioactive fission gas. t is the time after injection of the radioactive pulse. The solution in Figure 3 states that the pulse will emerge unchanged in shape, but delayed by a time, km/F. This simple treatment yields a useful value for the time to peak. However, it indicates erroneously that there will be no distortion of the pulse as it travels through the adsorber, because this mathematical treatment ignores pulse broadening processes.

We have used a theoretical plate model to treat dynamic adsorption while providing for the pulse broadening processes (4). In this analysis the adsorber is imagined to be divided into a number of theoretical chambers, N, with adsorption equilibrium in each one. The differential equation in Figure 4 describes the concentration of a fission gas as a function of time in the first one of these theoretical chambers, after injection of an instantaneous pulse of fission gas. The symbols have the same significance as in Figure 3. The quantity N is the number of theoretical chambers in an adsorber having an amount of adsorbent, m. The rate of change of fission gas concentration is proportional to the flow rate, F, and to the instantaneous concentration, P, and is inversely proportional to the adsorption coefficient, k, and to the weight of adsorbent in a theoretical chamber, m/N. The solution for the fission gas concentration at the outlet of the last chamber is given by the second expression in Figure 4. The time to peak concentration at the outlet is shown in the third expression and is similar to the last equation in Figure 3. The time to peak or average retention time is proportional to km/F, and is relatively insensitive to the number of theoretical chambers, N. The second equation in Figure 4 describes the shape of the elution curve and may be used to predict the breakthrough time.

Figure 5 compares the theoretical plate equation with experimental data. The theoretical curve has been fitted to the experimental curve by selecting values for k and N. The fit of the curves in the breakthrough region indicates the usefulness of the theoretical plate model. Using this analysis, experimental data may be reduced to two elementary parameters, k and N.

Experiments

The information on retention of fission gases under various conditions has been obtained experimentally using apparatus as shown in Figure 6. A constant flow of sweep gas, in this case oxygen, passes through an adsorber, a flow meter and past a Geiger-Muller tube. The radioactive tracer is injected at the krypton holder and the counting rate, which is proportional to concentration of tracer, is observed as a function of time by the G-M counter. Figure 7 shows the adsorbers on the right, the counters in the middle background, and instruments for registering counting rates on the left. Figure 8 shows an end-window Geiger-Muller counter tube equipped with a gas cell. Using apparatus of this type, elution curves shown in Figure 9 were obtained. Here the relative concentration of radioactive krypton in the effluent gas is plotted versus time after injection of the krypton pulse at the entrance of the adsorber. The adsorber contained 782 grams of charcoal and the sweep gas was oxygen at a flow of 250 cc/min. Elution curves are shown at four different temperatures. The lower the temperature, the longer is the retention time. Refrigerated beds would usually be more desirable except for possible failure of refrigeration. These data are analyzed to obtain the adsorption coefficient k as a function of temperature as shown in Figure 10, which also includes some other data.

The efficiency of various adsorbents has been investigated using this same technique. In Figure 11 activated charcoal is compared with silica gel, Driocel, activated alumina, and porous glass. Various grades of activated charcoal are compared in Figure 12. Columbia Grade G is slightly superior; however, the samples are all about the same with respect to k. Figure 13 shows that the performance of Linde Air Products Molecular Sieve materials is not as good as that of charcoal but where the combustibility of charcoal is a hazard, these materials are the best choice if moisture can be excluded. Sieve Material 5A is superior to the others. 4A has too small a pore size to admit krypton. Columbia Grade G activated charcoal has been used for most of the tests described below.

Figure 14 shows the effects of various sweep gases. Krypton is retained more efficiently in the presence of helium than with other gases, because helium is adsorbed to a lesser degree. Freon-12 is not suggested as a reactor sweep gas but it is used to illustrate the effect of a strongly adsorbed gas.

Figure 15 shows the effect of krypton partial pressure in oxygen with the total pressure constant at one atmosphere. In practical off-gas systems, the fission gas partial pressure does not ordinarily exceed 1 millimeter of mercury and the efficiency is not significantly affected. Figure 16 shows that small amounts of CO_2 cause a substantial reduction in the retention time. This effect can be quite important in the event of an accidental fire. One of our charcoal adsorbers serving a 5 MW reactor was ignited by an explosion of radiolytic deuterium in oxygen. Although the fire was put out without interrupting reactor operation, the combustion product, CO_2, reduced the retention time by approximately a factor of two, temporarily, and resulted in a measurable but not hazardous release of radioactive gases. The adsorber was restored to normal service after the CO_2 had been displaced.

(Text continues on p. 211)

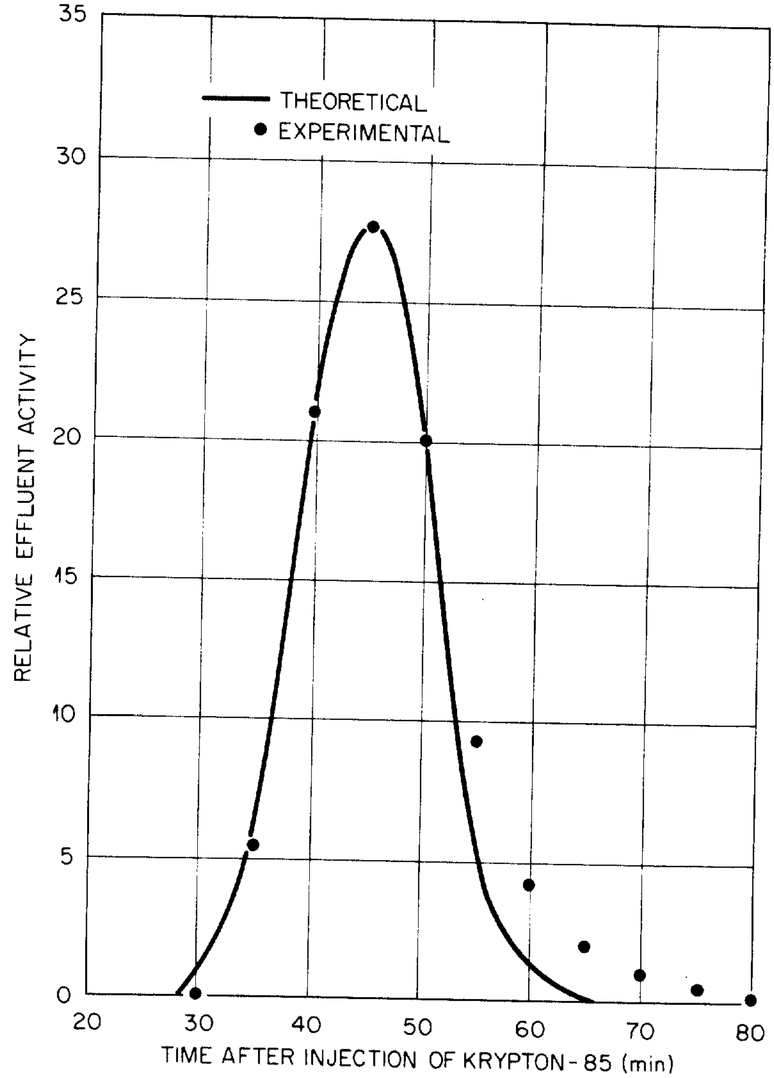

Fig. 5—Typical distribution of fission gas activity in experimental effluent gas stream.

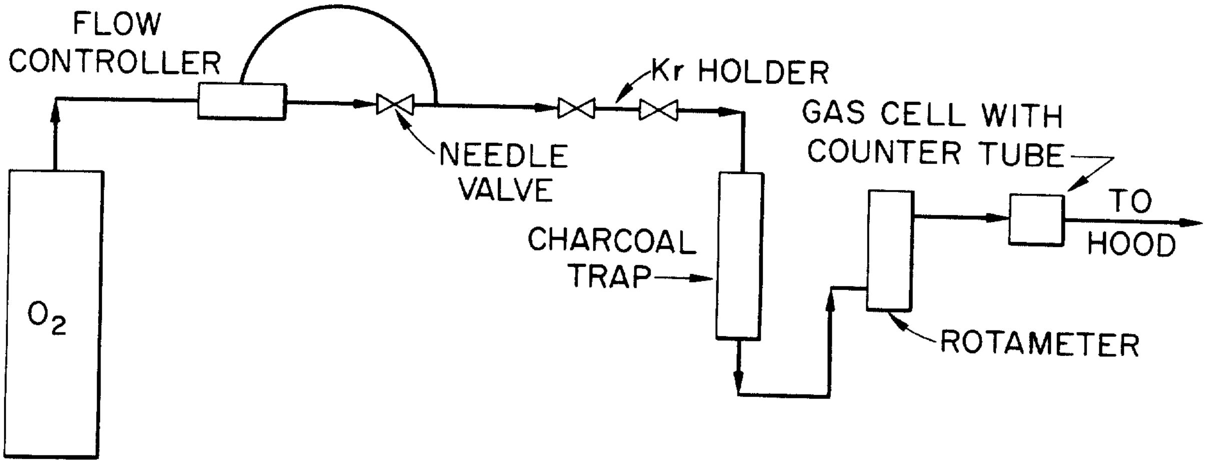

Fig. 6—Schematic diagram of equipment for measuring retention times.

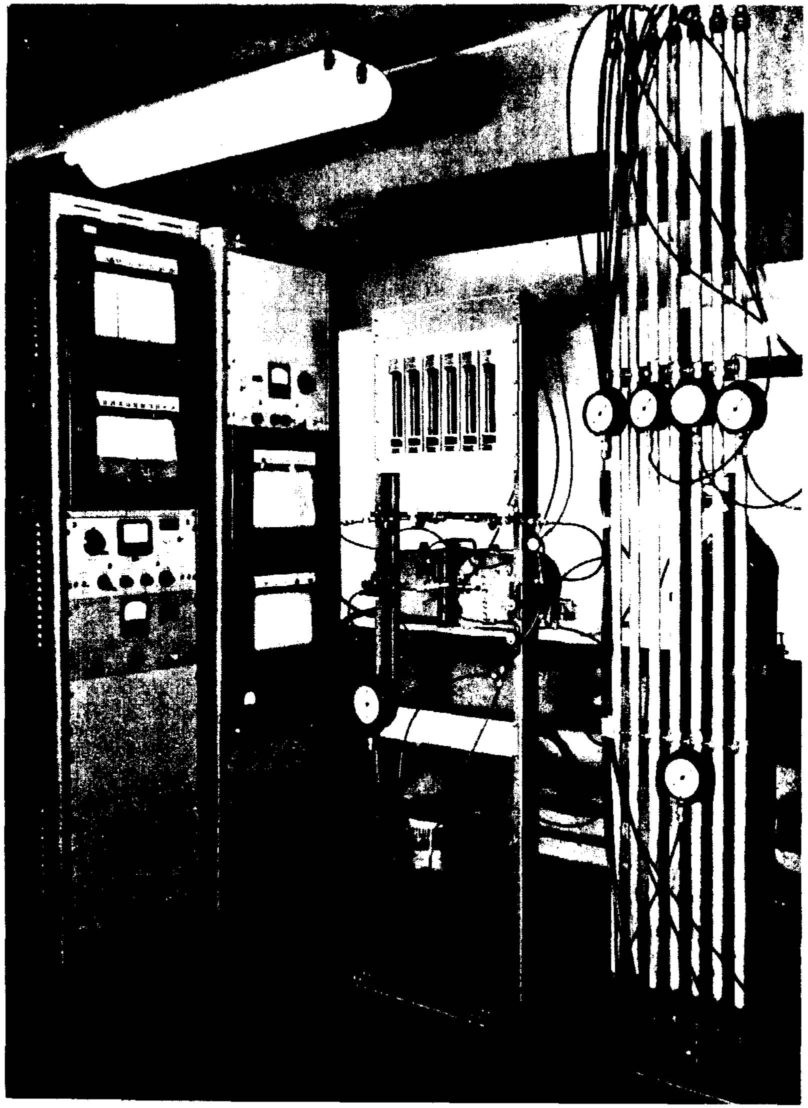

Fig. 7—Photograph of equipment for measuring retention times.

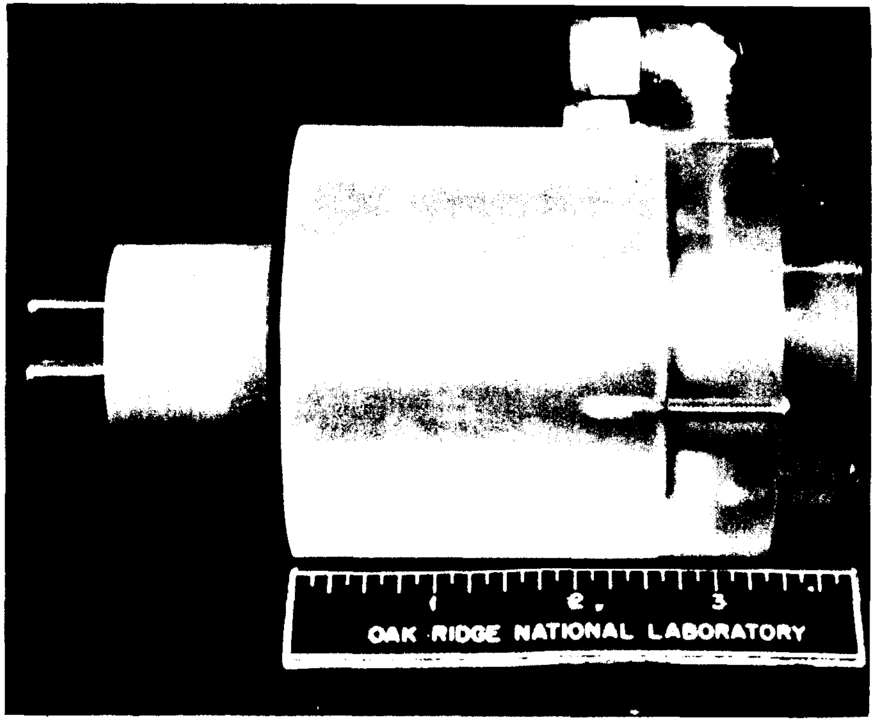

Fig. 8—End window GM tube, equipped with gas cell, for measuring Kr^{85} and Xe^{133}.

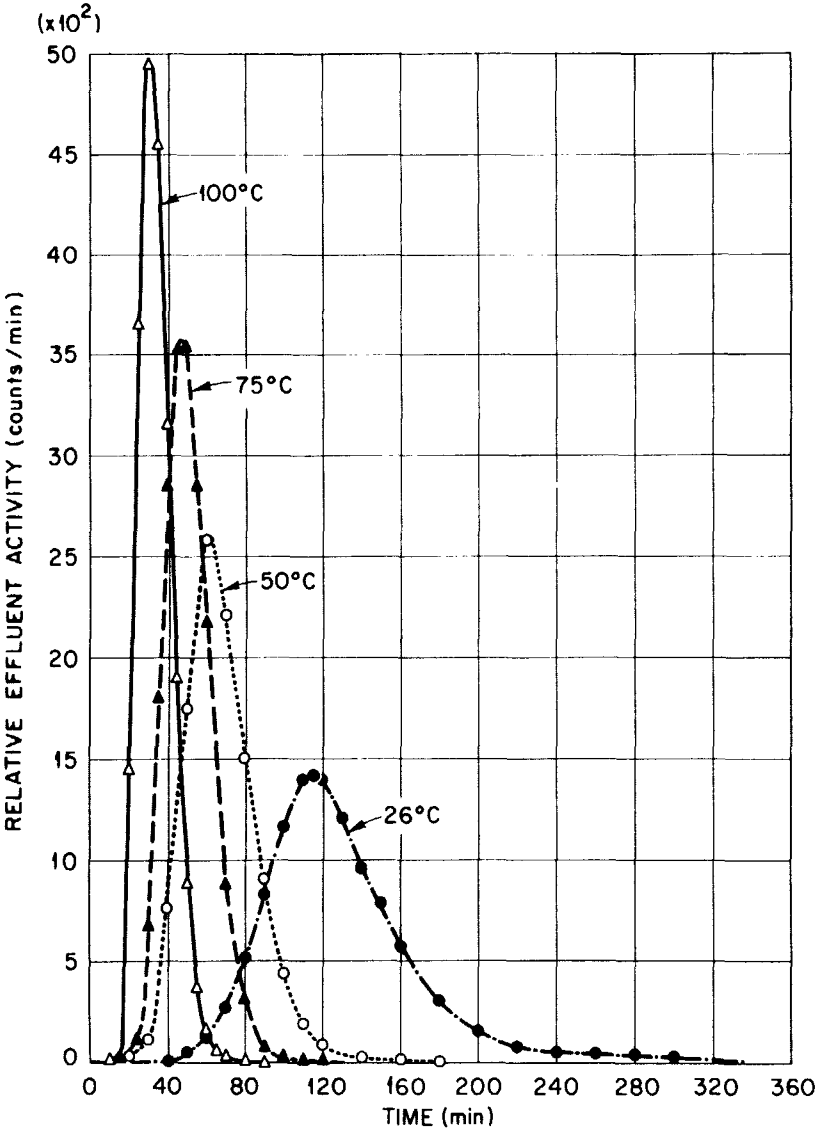

Fig. 9—Effect of charcoal temperature on elution curves.

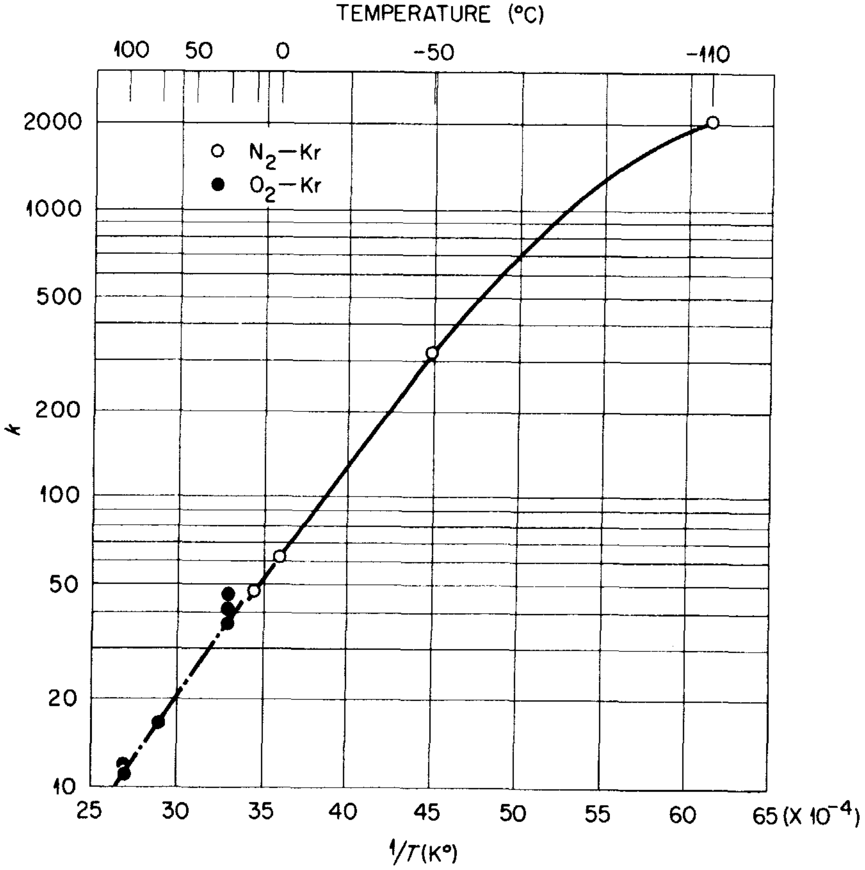

Fig. 10—Effect of temperature on dynamic adsorption coefficient for charcoal.

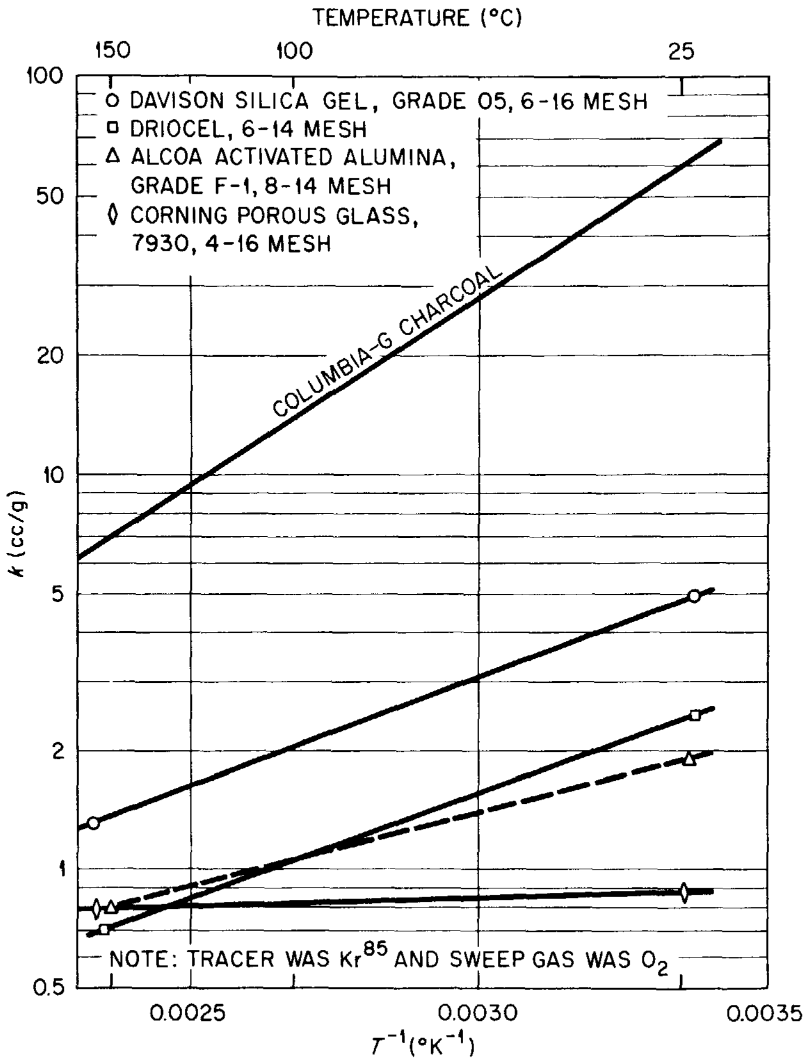

Fig. 11—Dynamic adsorption coefficients for miscellaneous adsorbents.

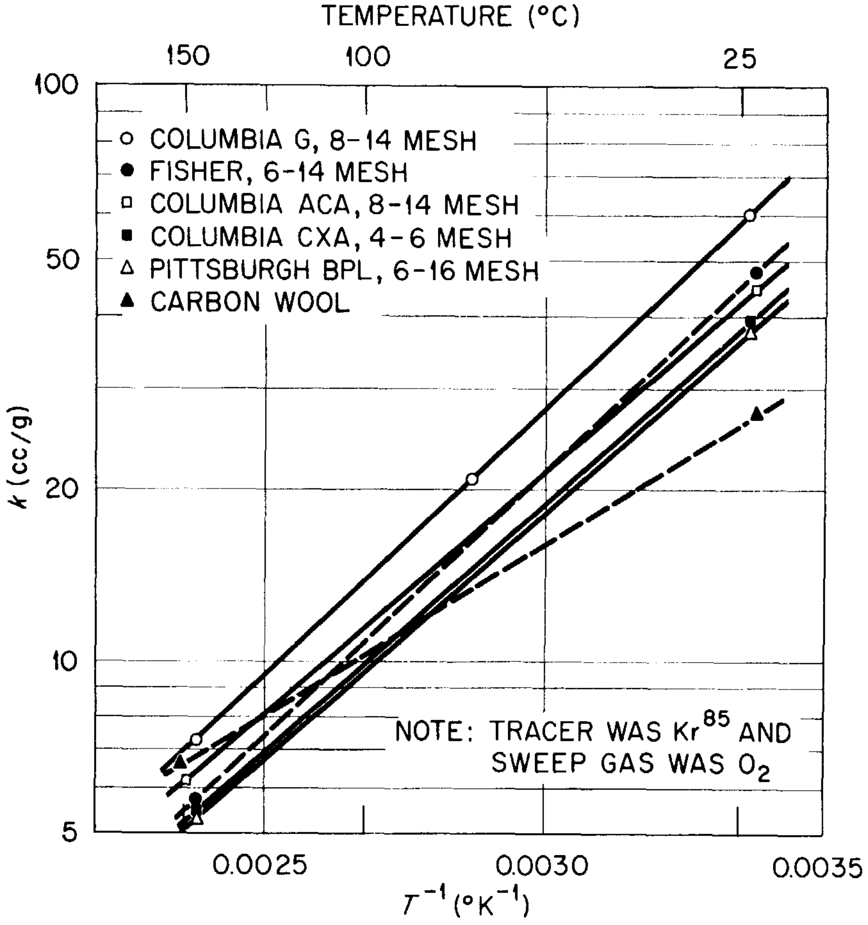

Fig. 12—Dynamic adsorption coefficients for various activated charcoals.

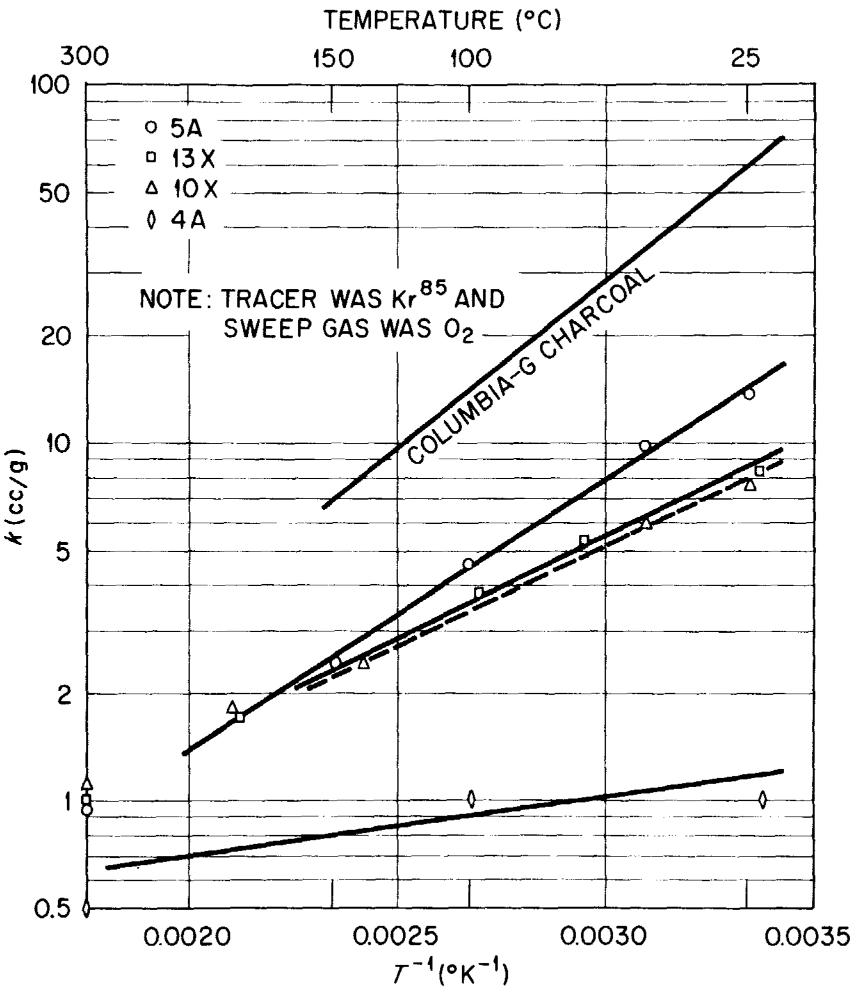

Fig. 13—Dynamic adsorption coefficients for Linde molecular sieves.

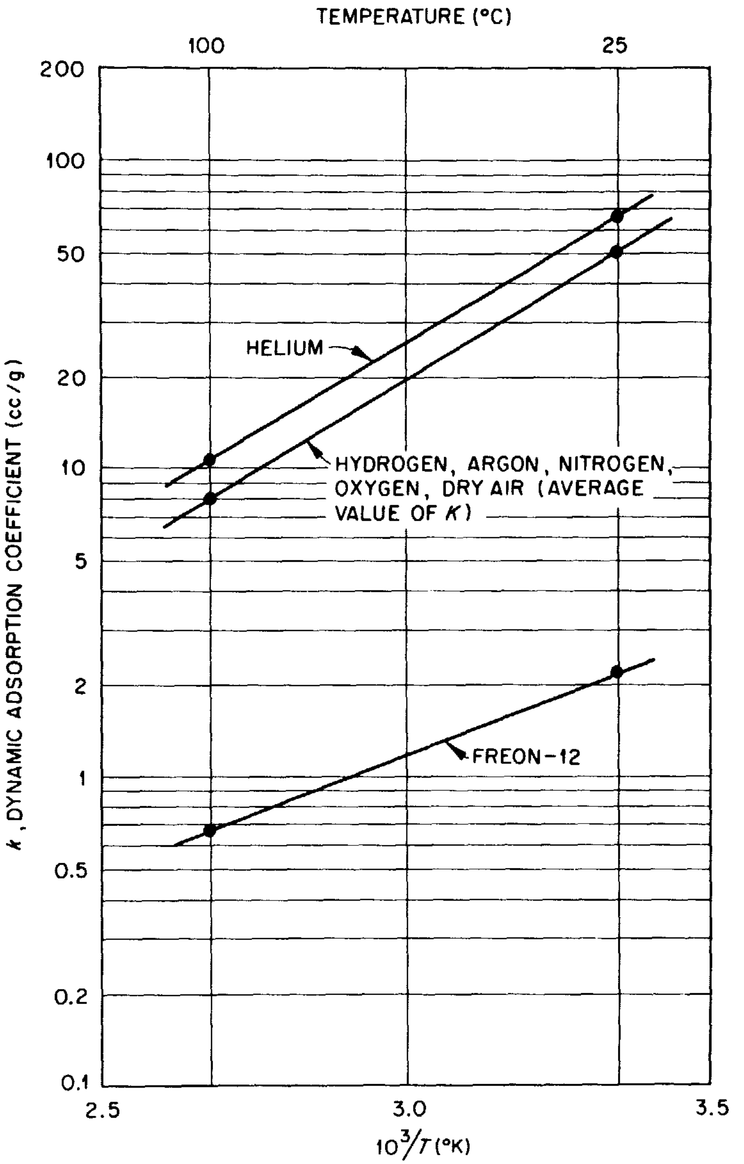

Fig. 14—Dynamic adsorption coefficients for columbia G activated carbon with various sweep gases.

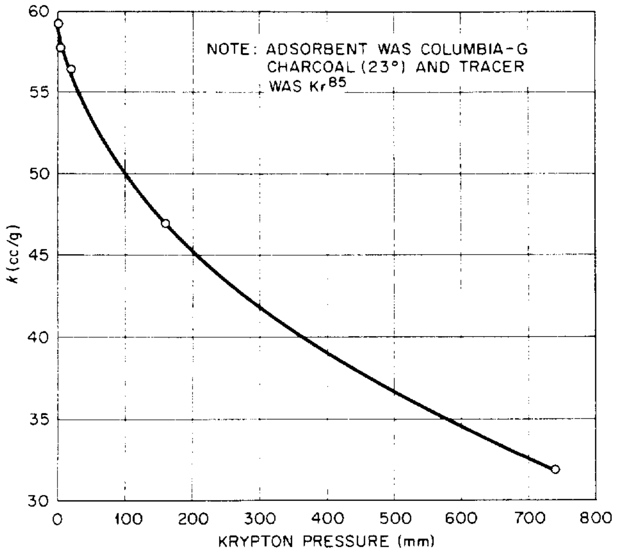

Fig. 15—Effect of krypton partial pressure on dynamic adsorption coefficient.

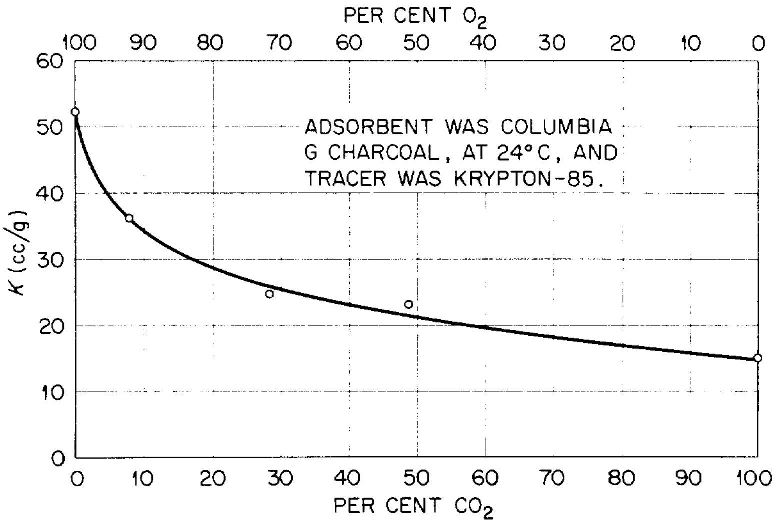

Fig. 16—Effect of CO_2 in the sweep gas on dynamic adsorption coefficient.

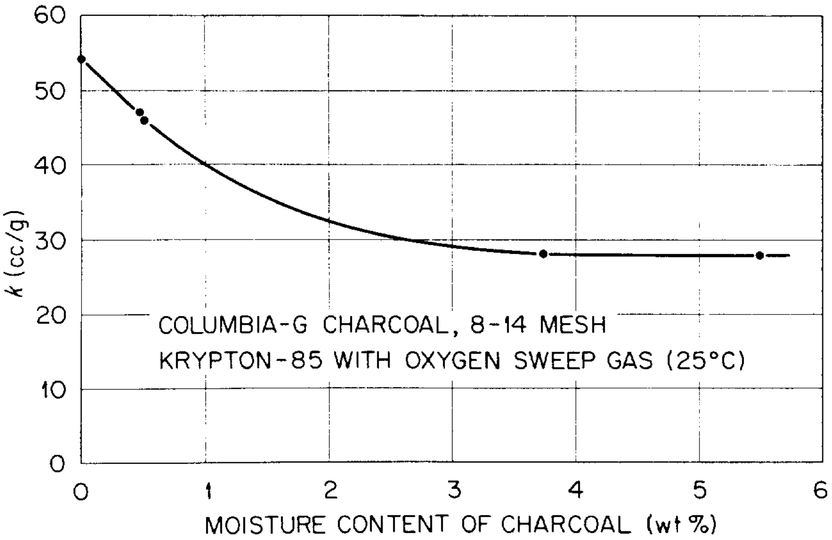

Fig. 17—Effect of moisture on dynamic adsorption coefficient.

Water vapor has an effect similar to that of CO_2. Figure 17 shows that the efficiency of charcoal may be reduced to one-half by adsorbed moisture. Charcoal in equilibrium with air at 50% relative humidity contains 5% water by weight.

The adsorption coefficient, k, shown in the preceding figures, is used for evaluating the average retention time, t_{max}. This quantity may be converted to the more useful breakthrough time, t_b, by the data contained in Figure 18, which applies to a 0.75 inch diameter charcoal adsorber with O_2 at 250 cc/min. The ratio of t_b to t_{max} approaches 90% for very long adsorbers. At 10 or 20 feet this ratio runs from 75 to 80%. For less than 5 feet ratios are less than 50%.

The adsorber must be fully packed. Figure 19 shows the performance of a horizontal adsorber which has only 3% of void space. The resulting tunnel provides a "short circuit" for the gas and the breakthrough time was only one-tenth of that ordinarily expected. It is desirable to install adsorbers vertically.

The adsorption coefficients for xenon have been determined for only a few conditions because only short-lived tracers are available. Xenon is retained about 10 to 30 times longer than krypton, depending upon temperature, as shown in Figure 20.

Design of Practical Adsorbers

With the theoretical results previously described and with the experimental data, we are now prepared to design a practical adsorber for krypton and xenon fission gases. In some applications it is useful to stop the flow of gas as soon as radioactivity is detected; and the retention time required is the time necessary to stop the flow of gas. In other cases it is necessary to remove fission gases from a continuously flowing gas stream. The adsorber delays the passage of radioactive krypton and xenon until they have decayed sufficiently except for Kr-85. The retention time required depends upon the concentration of fission gases entering the adsorber and upon the allowable concentration in the exit gases. The production of the various isotopes of krypton and xenon may be evaluated using ORNL-2127 (5) by Blomeke and Todd. The allowable emission of fission gas isotopes depends upon the location of the plant and the environmental conditions. It may be limited by the permissible external or internal doses to personnel in the plant or in the surrounding community. Interference with sensitive radiation detection instruments may be the limiting factor. The report ORNL-CF-58-12-10 (6) will assist in evaluating the allowable and initial emission rates.

From the ratio of input concentration to allowable output concentration and the half-life we calculate the decay time needed for each isotope and select the longest decay time required. From the last expression in Figure 4, using the approximation $(N - 1)/N = 1$, which is valid for large N, we obtain the amount of adsorbent required.

$$m = \frac{Ft_b}{kt_b/t_{max}}$$

m = amount of adsorbent needed to provide the required breakthrough time (gm).

F = flow rate of sweep gas (cc/min).

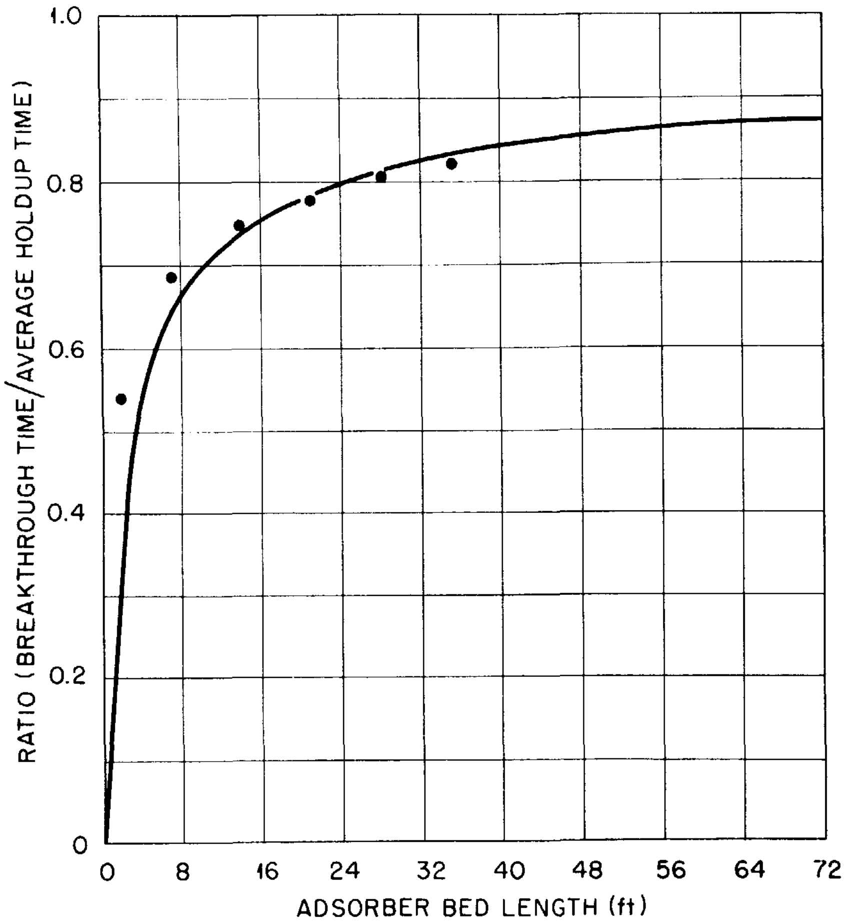

Fig. 18—Ratio of breakthrough time to average holdup time as a function of adsorber length.

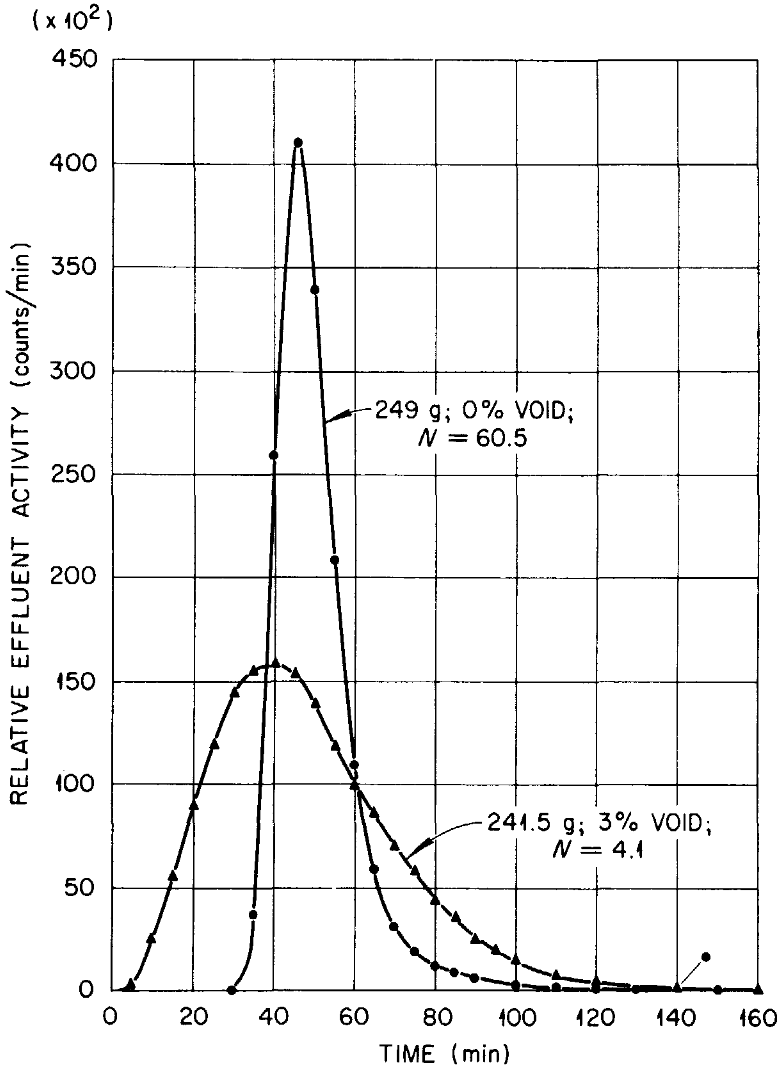

Fig. 19—Effect of void space in horizontal charcoal adsorber.

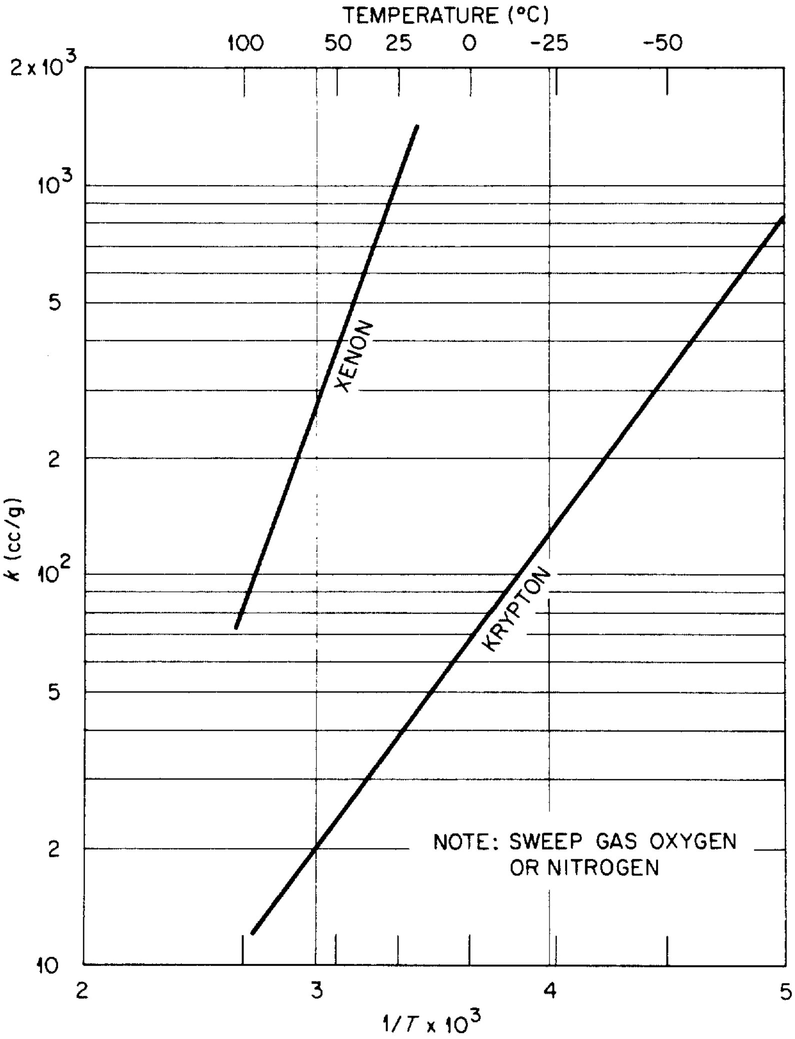

Fig. 20—Dynamic adsorption coefficients for krypton and xenon on charcoal with oxygen or nitrogen sweep gas.

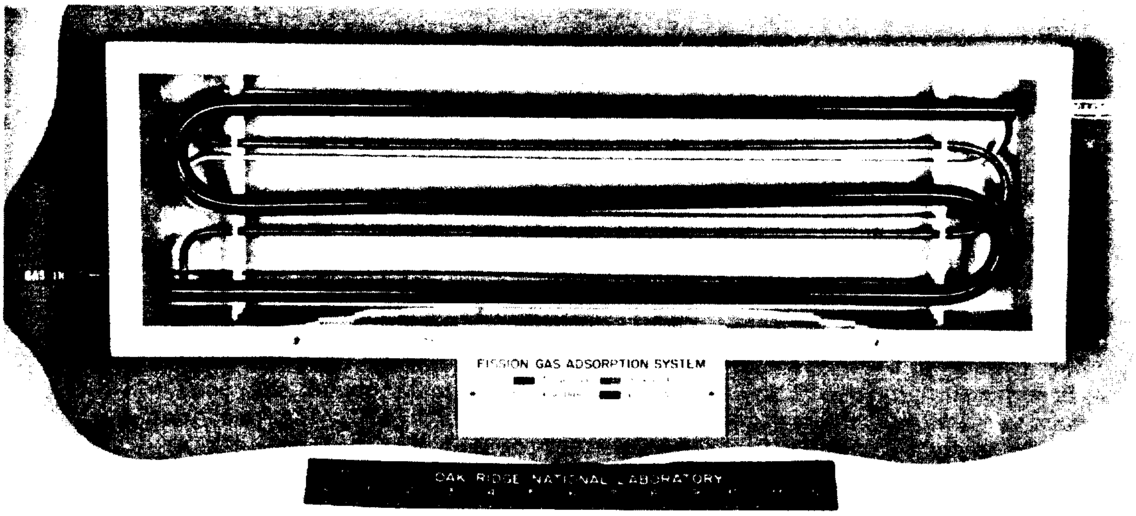

Fig. 21—Model of fission gas adsorption system used on 5 Mw fluid fuel reactor.

k = dynamic adsorption coefficient obtained by retention time experiments under the conditions for which the adsorber is being designed (cc atm/gm atm).

t_b = breakthrough time. Selected to provide time for decay of radioactive gases or for emergency shutdown of gas flow (min).

t_{max} = average retention time for fission gas atoms passing through adsorber. This quantity is strictly speaking the retention time for the greatest proportion of fission gas atoms and is very nearly identical to the average retention time (min).

Heat of radioactive decay may be removed by using small diameter pipes to contain the adsorbent and by immersing the pipes in cooling water. The pipes should be smaller near the entrance to the adsorber where the heat load is greatest and may be larger in diameter near the outlet. High temperatures interfere with adsorption of the fission gases and in the presence of an oxidizing gas can cause a fire hazard. We have observed ignition temperatures for charcoal in oxygen as low as 290°C. It is necessary to provide for measurement of the temperature of the adsorber so that if undesirable conditions occur, corrective action may be taken. A fire may be controlled safely by diverting the flow of the oxidizing gas to an alternate adsorber. This procedure has been tested experimentally as reported in ORNL-CF-58-6-6 (7), and was applied successfully to a fire which occurred accidentally in one of two charcoal adsorbers which were handling the fission gases in oxygen from a 5 MW homogeneous reactor.

Refrigerated adsorbers may be used to advantage where the size of the adsorber is important as with mobile reactors; however, it is necessary to take several precautions in their use. Failure of the refrigeration system produces an unsafe condition in which radioactive gases are desorbed as the adsorber warms up. In the applications where such a release cannot be tolerated, several alternatives are available, most of which require stopping the flow of radioactive gas from the reactor. The adsorber system may be sealed off in an emergency and designed for the very high pressures which may result or be provided with an expansion volume in the adsorber system inside the shielding enclosure. Emergency stand-by refrigeration systems with an emergency power source may be provided or an auxiliary adsorber system into which the gas from the main adsorber can be allowed to expand may be used. Another hazard is the possibility of explosion in the adsorber if oxidizing gases, even in trace concentrations, are exposed to the charcoal at very low temperatures. Allowance must be made for the fact that the heat released by radioactive beta decay of the fission gases will cause the central temperature of the adsorber to be higher than the wall temperature, and the refrigeration system must have capacity to carry away this heat of beta decay.

Applications

We have applied this information to the design of several adsorbers. In a fused salt in-pile loop experiment we used a 34 pound charcoal adsorber with a gas flow rate of 20 scfm of air at 26°C. It provided a one minute retention time for krypton, sufficient for scramming the reactor and for stopping the flow of air, leaving the krypton and xenon in the charcoal to decay. The procedures for designing a refrigerated adsorber for a similar application are given in ORNL-CF-58-7-71 (8).

We have also applied this information to an adsorber system used on a 5 MW homogeneous reactor (9). Figure 21 shows a model of one of the three adsorbers used. Each one contains 520 pounds of charcoal in pipes ranging from 1/2 to 6 inches in diameter. Two of the adsorbers are normally used in parallel and carry a total of 2500 cc/min of oxygen contaminated with fission gases. At 26°C the retention time for krypton is six days and for xenon sixty days, sufficient for virtually complete decay of all the fission gases except krypton-85 which is vented through a small stack. This system has performed satisfactorily for more than a year.

Conclusion

The physical adsorption of noble gases upon adsorbents such as activated charcoal may be used to delay the release of gaseous fission products from nuclear reactors. Two design philosophies have been used. The first employs an adsorber to provide a delay time during which the flow of the off-gas stream from a source of fission gases may be halted following an accidental release of radioactive gases. The second philosophy of design utilizes an adsorber to delay the radioactive fission gases for a time long compared to their half-lives so that they decay virtually completely in the adsorber. Only the ten year krypton-85 emerges from an adsorber of this type. This isotope may be discharged safely to the atmosphere under certain conditions in the case of low or medium power level reactors. High power reactors, especially near the heavily populated areas, will require an adsorber system of the first type for extracting krypton-85.

A theoretical analysis of the process whereby the fission gases are retained by an adsorber from a flowing gas stream provides the basis for design of practical units. Experimental data are provided which may be used under a wide variety of conditions in the design of adsorbers for the off-gas systems of nuclear reactors and of in-pile experiments.

The principal advantages of the dynamic adsorption process for controlling fission products are its simplicity and freedom from maintenance or replacement requirements. The entire fission gas processing unit is contained in metal pipes, which may be immersed in coolant water at ambient temperature, buried underground to confine the gamma radiation. The only requirement for instrumentation is thermocouples at a few representative points to verify the results of heat transfer calculations in the design of the adsorber and equipment for controlling or metering flow.

Acknowledgements

We acknowledge ideas contributed by C. C. Bolta, D. E. Guss, and T. W. Leland.

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4. W. E. Browning and C. C. Bolta, "Measurement and Analysis of the Holdup of Gas Mixtures by Charcoal Adsorption Traps", ORNL-2116, July 27, 1956.

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6. R. E. Adams and W. E. Browning, "Evaluation of the Iodine Vapor Fission Gas Adsorption Traps for ORR-705 Capsule Experiment, GCPR Capsule Irradiation Program", ORNL-CF-58-12-10, December 23, 1958.

7. R. E. Adams and W. E. Browning, "Estimate of the Probability and Consequences of Ignition of the HRT Charcoal Beds", ORNL-CF-58-6-6, June 3, 1958.

8. R. E. Adams and W. E. Browning, "Evaluation of Fission Gas Adsorption Traps for ORNL-MTR-44 Loop Experiment", ORNL-CF-58-7-71, July 18, 1958.

9. R. E. Adams and W. E. Browning, "Fission Gas Holdup Tests on HRT Charcoal Traps", ORNL-CF-58-4-14, April 2, 1958.

Discussion

Q. (W. B. Harris, NYOO) What does the title of the paper mean by disposal?

A. It means that the short-lived fission gases are converted to solid materials so that they are no longer in the gas stream.

Q. (L. Silverman, Harvard) Would like to know what the relative costs of treating this gas stream are and what volume can you handle in the system?

A. Equipment usually just involves pipes filled with charcoal and once they are installed they last more or less indefinitely. As far as volume of gases is concerned, it would depend on the pressure drop.

Recovering radio active gases will be important - developments this morning indicate ways of recovery and minimum environmental problems - they are handling small amounts of gas.

Q. Would like to have some idea of cost per cfm.

A. I don't believe I had better name a figure for the cost, I believe it is available.

THE RECOVERY OF FISSION PRODUCT XENON AND KRYPTON BY ABSORPTION PROCESSES

MEYER STEINBERG
Brookhaven National Laboratory, Upton, N. Y.

NOTE: This paper is not included in this publication because it has already been published as BNL-542 (T-140) and is available from the Office of Technical Services, U. S. Department of Commerce, Washington, D. C., for $0.75 per copy.

However, the discussion which followed the presentation of this paper is included here.

Discussion

Q. (F. T. Selleck, Fluor) Very much interested in the work on means of separating fission gases especially in its use for power reactors. - whether flow sheets shown by Steinbergh are process designs based on laboratory scale in pilot plants or at actual operating plants

A. Based on estimates from laboratory data and small pilot plants.

Q. Also interested in type of compressors used and whether or not you have any good history of leakage or was it a straight problem of higher pressure operation?

A. We don't have any real good operating data on compressors - engineering problem that will have to be looked into.

Q. Cost of CO_2 quoted - was that per liter of fission gases produced?

A. This is per liter of fission gases produced. I might add that you can recover the CO_2 in another process but you have to pay for this in some sort of way such as a hot carbonate process for recycling from CO_2 but you have to pay for a plant to do this.

C. (Silverman) I would like to give a comment here because I think this question of recovery of radioactive gases which is going to be a problem in the power economy program in the question of Nuclear Power. It's going to be very important.

I think these developments we heard this morning both Ackley's paper and Steinberg's paper indicate ways of recovering and possibly minimizing the environmental problem. In one case recovery for economic purposes and the other case for preventing an environmental problem. I have some knowledge of the system at Oak Ridge and it seems to me that they are handling a very small volume of gas with a very large detention system so that what I would like to have had was some figure of the cost per CFM. I know that the original freeze-out system here at Idaho cost about $500 per CFM but that was in the early days of trying to freeze out all of the rare gases.

A VENTURI SCRUBBER INSTALLATION FOR THE REMOVAL OF FISSION PRODUCTS FROM AIR

H. S. JORDAN and C. G. WELTY
Health Division, Los Alamos Scientific Laboratory,
Los Alamos, N. Mex.

ABSTRACT

A local exhaust collection system and a venturi scrubber installation for the cleaning of exhaust air contaminated with acid mists and mixed fission products are described in detail. The features of the collection system that are designed to offset the hazard of perchloric acid condensing in the collection system are stressed, and the feasibility of a venturi scrubber with a caustic solution for the removal of iodine vapors as a scrubbing medium is demonstrated. The efficiency of the scrubbing unit for removing acid mist, total fission products, and iodine vapor tested 90% or better. The performance of the units met design expectations and no major modifications were necessary.

INTRODUCTION

The construction of a new radiochemistry building at the Los Alamos Scientific Laboratory made it possible to design an entirely new control and air-cleaning system for the off-gas from the process of dissolving large filter papers containing fission products. In this process, a cellulose-type filter paper is dissolved in a hot mixture of nitric and perchloric acids. The off-gas is composed of: (1) perchloric acid mist, (2) nitric acid mist, (3) radioactive iodine vapor, (4) mixed fission products, and (5) oxides of nitrogen.

Two problems are associated with the off-gas: Condensation of the perchloric acid in the collecting system and the evolution of radioactive materials. Under certain imperfectly understood conditions, the accumulation of perchloric acid in an exhaust system gives rise to a serious explosion hazard. For this reason, special hoods with water sprays are frequently specified for operations in which perchloric acid fumes are evolved. The release of the radioactive material, mostly in the form of iodine vapors, to the atmosphere is undesirable because of health considerations and because of the possible increase in the airborne activity of the building intake air. A slight increase in the activity of this air creates serious difficulties by raising the background count of the elaborate electronic equipment in the radiochemistry building. It was a basic decision, therefore, that the new building be provided with facilities for cleaning the exhaust air from the dissolving process.

After considerable study, the Radiochemistry Group decided that dry boxes and the small laboratory fume hoods used in the old building were undesirable from an operational standpoint. It was determined that a laboratory fume hood, 8 feet long to permit the installation of two dissolving stations, would provide the most convenient setup for the operators. The required eight hoods of this type would exhaust approximately 16,000 cubic feet of air per minute (cfm), but cleaning this flow of air to the desired level of decontamination would require a large, expensive installation. Consideration was given, therefore, to small, local exhaust facilities located in close proximity to the source of contaminants and served by a separate exhaust system of approximately 350 cfm capacity. A typical hood installation is shown in Figure 1.

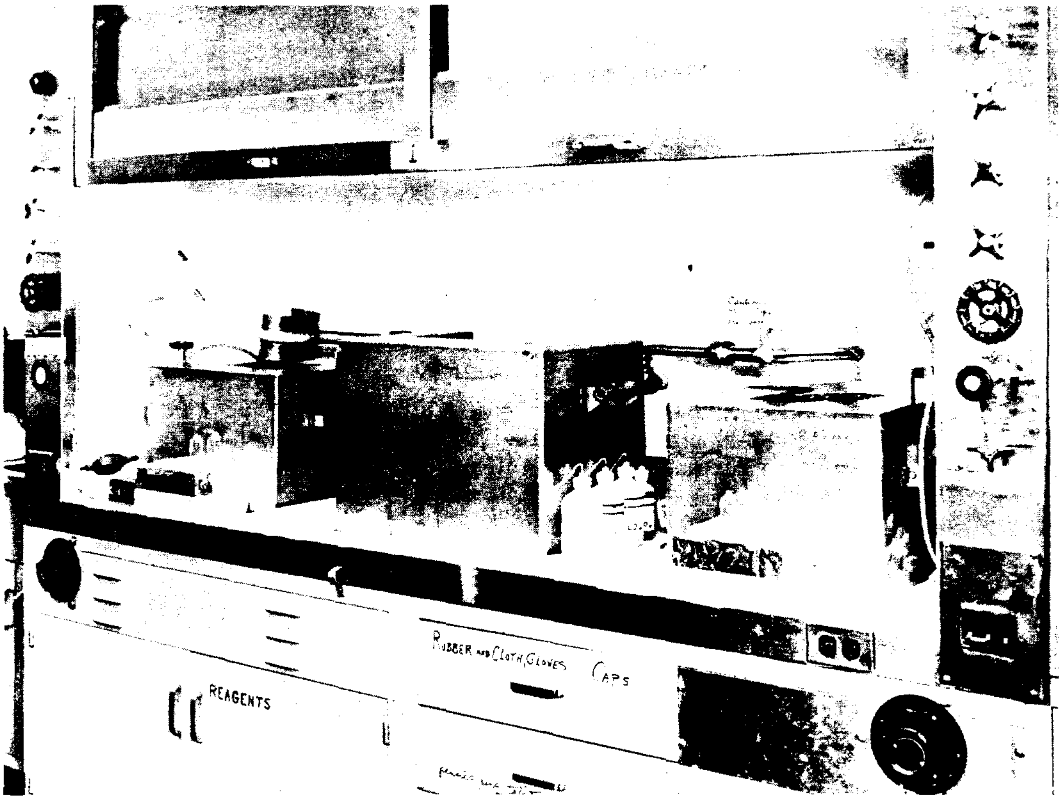

Fig. 1—Over-all view of hood and two dissolving stations.

The estimate of the air flow to be cleaned was a basic factor in determining the most suitable type of air cleaning. Other considerations in the cleaning of this particular exhaust air, however, posed a number of problems. The perchloric acid mist cannot be allowed to condense in the duct work and must, therefore, be controlled or removed at the hood. The oxides of nitrogen and iodine exist as gases or vapors. In addition, since the dissolving process is performed at irregular intervals, it should be possible to activate and deactivate the air-cleaning system without adversely affecting its performance.

Initial consideration was given to the use of wet filters for the removal of acid mists and a scrubbing tower using silver salts for the removal of the iodine vapors. The experience at the Los Alamos Scientific Laboratory with wet filters,[1] however, has not been entirely satisfactory, and estimates of the initial and maintenance cost for the complete system including a scrubbing tower were rather high. Also, the ability of this equipment to perform adequately under conditions of intermittent use was in serious question.

The use of a venturi scrubber as a means of removing acid mists and small particulate matter appeared attractive. The main question in connection with this type of scrubber was its ability to remove iodine vapors. A series of tests were, therefore, conducted on an existing venturi scrubber installation, and it was determined that the unit would not remove iodine vapors from the air stream if water was used as the scrubbing medium. A caustic solution was tried and removal efficiencies of about 95% were obtained for a variety of iodine vapor loadings. The normality of the caustic solution did not appear to be an important factor and 1.0 N sodium hydroxide was used in most experiments.

The use of the venturi scrubber with a caustic solution for this particular air-cleaning problem appeared to offer the following advantages:

1. A single unit would remove all contaminants of interest with good efficiency.

2. It had the ability to collect the contaminants in such a manner as to permit storage for radioactive decay and for ultimate disposal without exposing maintenance personnel.

3. The air collection and air-cleaning systems could be thoroughly decontaminated at the end of an operating period, and minimum maintenance would ensure maximum efficiency for the next operation.

4. Because of the simplicity of the system, it could be anticipated that maintenance would be minimal. The ease of decontaminating the unit would, in any case, simplify and reduce the cost of necessary repairs.

DESIGN CONSIDERATIONS

Local Exhaust Hood. The configuration of the local exhaust hood was determined by operating requirements, and the final design specified by the Radiochemistry Group is shown in Figure 2. Exhaust air requirements were determined empirically by varying the rate at which air was exhausted while the dissolving operation was actually being performed. For the initial studies, the effectiveness of the air flow pattern was determined by observing the capture of the fog generated when dry ice was dropped in beakers of boiling water. The studies indicated that a flow rate of 20 cfm would give satisfactory control under conditions in which the evolution of the fumes was at an anticipated maximum.

Venturi Scrubber. The design of the venturi scrubber was based on sixteen local exhaust hoods, exhausting 20 cfm each for a total flow rate of 320 cfm. At this flow rate, the anticipated loadings of interest are shown in Table I. Anticipated loadings are based on data obtained at the old dissolving installation and on the assumption that all dissolving stations would be operating.

The extremely low loadings and the existence of I^{131} in the vapor state were the major concerns of the Chemical Construction Corporation, fabricator of the venturi scrubber, in regard to the desired iodine removal efficiency of 95%.

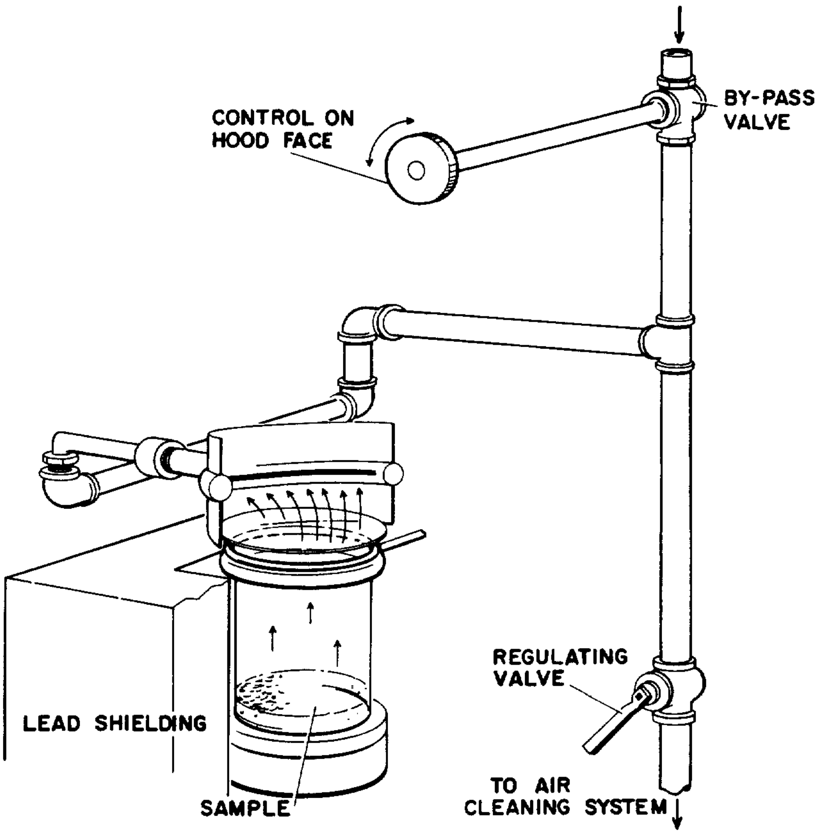

Fig. 2—Details of local exhaust hood and dissolving station.

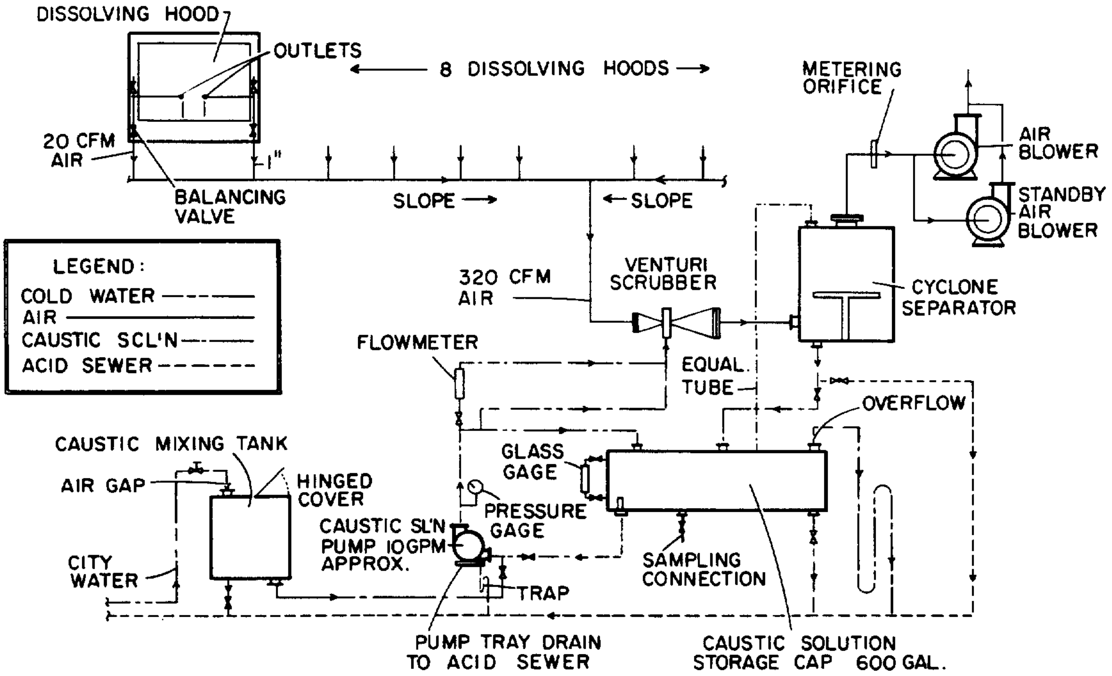

Fig. 3—Flow diagram—collection and air-cleaning systems.

TABLE I

Design Loading Factors

Material	Loading
Acid Mist (nitric and perchloric)	500 to 3000 mg/m^3
Total Radioactivity	1 to 6 mc/m^3
Expressed as I^{131}	0.008 to 0.05 μg/m^3
Expressed as Sr^{90}	5 to 30 μg/m^3
Solid Particulate Matter	< 10 mg/m^3
Range of Mass Median Size	0.58 to 11.0 μ

FINAL DESIGN

The final design of the entire system is shown in Figure 3 and discussed in detail below.

Local Exhaust Hoods and Exhaust Piping. The local exhaust hoods and piping were constructed of welded stainless steel. Horizontal runs of the piping were sloped, and regulating valves were placed only on vertical sections to facilitate drainage and washdown. A valve-controlled bypass was utilized to enable the operator to control the air flow through the hood and still maintain a constant flow through the venturi scrubber (see Figure 2).

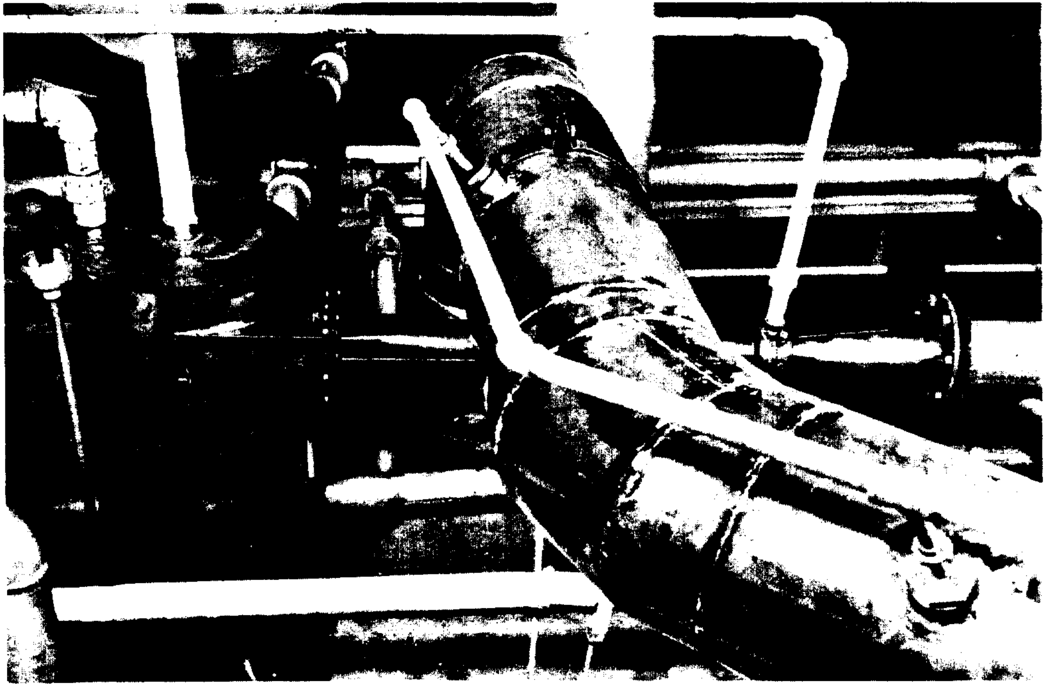

Fig. 4—Venturi scrubber and cyclone separator as installed.

Venturi Scrubber and Cyclone Separator. The venturi scrubber, approximately 48 inches in over-all length and with a throat diameter of 2-3/8 inches, was also constructed of stainless steel (Figure 4). To provide for possible future needs, the venturi scrubber was actually designed by the Chemical Construction Corporation to handle 475 cfm of exhaust air with an expected pressure drop of 36 inches of water, but capable of operating at 320 cfm and 25 inches of water pressure drop with good air-cleaning efficiency. The throat velocities would be 15,420 and 10,390 feet per minute (fpm), while exhausting 475 and 320 cfm, respectively. It has been reported that throat velocities over 12,000 fpm are generally used in venturi scrubbers with pressure drops between 10 and 15 inches of water.[2] The design feed rate for the scrubbing solution, 1.0 N sodium hydroxide, was established at 6 gallons per minute (gpm), at 15 pounds per square inch pressure (psi), with the system exhausting 320 cfm. This rate of approximately 19 gallons per 1000 cfm is higher than the reported rates of 2 to 9 gallons per 1000 cfm,[2] and accounts for the higher than usual pressure drop of 25 inches of water across the venturi scrubber.

The cyclone separator was not used as a cyclonic scrubber, although at one time such an arrangement was considered. A cyclonic scrubber in this system would have had a retention time of approximately one second, and it was thought that this factor would be important in absorbing the iodine vapors and oxides of nitrogen. The scrubbing solution, however, would have had to be fed to the cyclonic scrubber at a pressure of 100 psi. This would necessitate a separate pump or a high pressure system for both the venturi scrubber and cyclonic scrubber. It was decided, therefore, to convert the cyclone separator to a scrubber only if operating experience indicated it would be necessary.

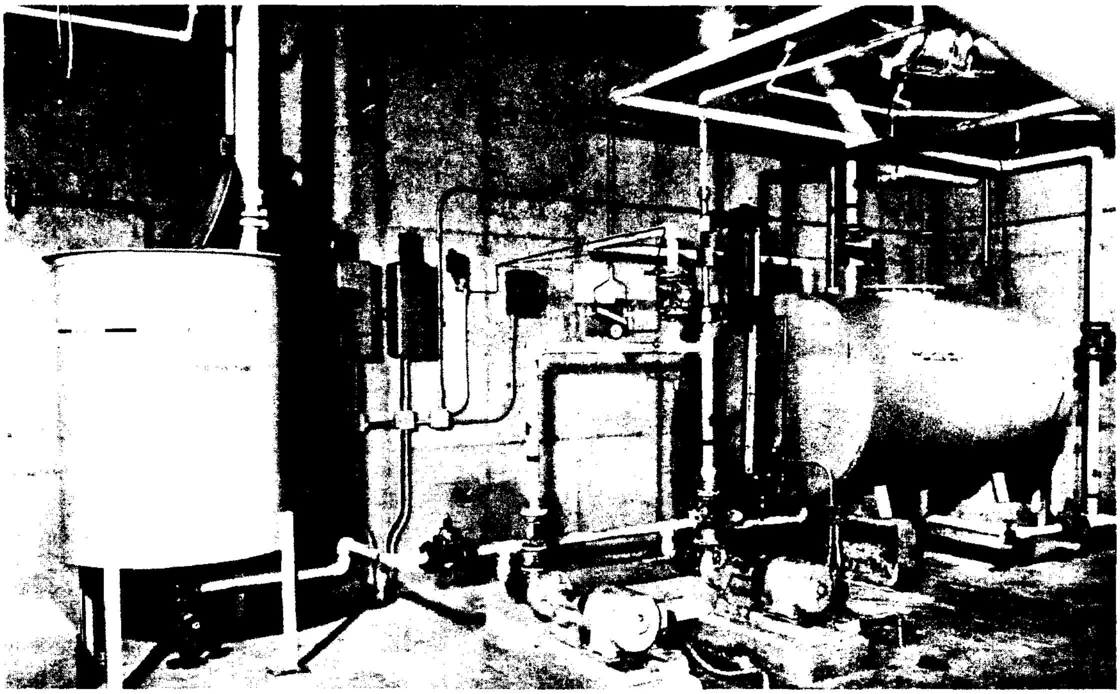

Fig. 5—Caustic solution recycling and mixing tank installation.

Caustic Solution Recycling and Mixing Tanks. Since the installation is used on an intermittent basis, the capacity of the recycling tank (600 gallons) was designed to provide storage for sufficient caustic solution for the maximum anticipated run. The mixing and recycling facilities are essentially a standard installation for this type of equipment and are shown in Figure 5. A few special details, however, are the result of operating experience at the Los Alamos Scientific Laboratory. Leakage of radioactive liquids creates serious difficulties and consequently the pumps were mounted in trays equipped with proper drains, and a bypass was provided for the rotameter.

Fans. Two exhaust fans (U. S. Hoffman Machinery Corporation, Model 4202, TYPE EBA), each with a rated capacity of 350 cfm at 50 inches of water, were specified for the installation. The extra fan was installed as a safety measure, and the electrical system so arranged that an outage in either fan automatically causes the other fan to operate.

EVALUATION OF AIR-CLEANING SYSTEM

The effectiveness of the air-cleaning system was determined by sampling upstream and downstream from the scrubbing units for total fission products, acid mists, and iodine vapors.

Acid Mists. The concentration of acid mists was determined by back titration of the caustic solution used as the collecting medium in two large impingers in series. A limited number of tests indicated that the air-cleaning efficiency of the unit for the combination of nitric acid mist and oxides of nitrogen was apparently 90% with peak loadings of 2×10^3 mg/m^3. In the case of perchloric acid, with peak loadings of 3×10^3 mg/m^3, removal efficiencies of 95% were obtained. There is some mixing of the acids, but in the main the acid mists come off in two separate fractions. The efficiency for total acid mist removal for a complete run was approximately 92% with an apparent average loading of 1×10^3 mg/m^3.

TABLE II

Air-Cleaning Efficiency for Total Fission Products

Run	Dissolving Stations Operating	Loadings mc/m^3	Air-Cleaning Efficiency %
1	6	0.3	94
2	5	0.1	95
3	4	0.05	94
4	4	0.01	91
5	6	0.4	96
6	4	0.15	92
7	3	0.05	93
		Average	94

Total Fission Products. Fission products were sampled from the air stream by means of a sampling train consisting of two large impingers with a caustic collecting solution in series and a high efficiency glass fiber filter paper. Aliquots of the collecting solution were evaporated to dryness on metal planchets. The radioactivity on the planchets and filter paper was determined by means of a gas flow proportional counter. The effectiveness of the system for total fission product removal is indicated by the results shown in Table II. The system was exhausting 320 cfm and the caustic solution was fed to the venturi scrubber at the rate of 6 gpm for all runs.

Radio-Iodine Vapors. Sampling for radioactive iodine was accomplished by a modification of a sampling train developed by Claude W. Sill, A.E.C., Idaho Falls, Idaho.[3] The train used in this study consisted of two high efficiency glass fiber filters, a Millipore membrane filter, and two Willson organic vapor respirator cartridges. Provisions for extremely high filtration efficiency are necessary to prevent trapping particulate matter in the cartridges. The second glass fiber filter was provided as a safety feature in the event the first filter, which is damaged by the acid mists, ruptured completely. Tests indicated that 99% of the iodine was collected in the first cartridge and no detectable iodine escaped through the second cartridge. Activity in the cartridges was determined by counting on a 2-1/2 inch NaI crystal counter, and identified as I^{131} activity by determining the radiological half life.

The efficiency of the scrubbing unit for removing iodine is indicated by the results in Table III.

TABLE III

I^{131} Removal Efficiency

Run	Dissolving Stations Operating	Loadings mc/m^3	Loadings µg/m^3	Removal Efficiency %
1	4	0.03	2.4×10^{-4}	97
2	4	0.7	5.7×10^{-3}	98
3	4	0.9	7.3×10^{-3}	97
4	4	0.3	2.4×10^{-3}	96
5	6	0.05	4.0×10^{-4}	85
6	4	0.1	8.0×10^{-4}	93
7	3	0.03	2.4×10^{-4}	96
				Average 95

SUMMARY

The local exhaust collection system and the venturi scrubber installation was designed for the cleaning of exhaust air contaminated with acid mists and mixed fission products. It was determined that 20 cfm exhausted by a local slot exhaust hood would control the maximum evolution of gases from a 1500 ml beaker. Features of the exhaust system that were designed to offset the hazard of perchloric acid condensing in the system included welded stainless steel construction, sloping horizontal runs, installation of regulating valves only on vertical sections, and the ability to wash down the system after use.

The feasibility of a venturi scrubber with a caustic solution as the scrubbing medium for low loadings of iodine vapors (2.4×10^{-4} to 7.3×10^{-3} µg/m^3) was indicated by an average removal efficiency of 95%.

Air-cleaning efficiencies for acid mists were dependent on the type of acid suspended in the air stream. Removal efficiencies of 90% were obtained with nitric acid and oxides of nitrogen loadings of 2×10^3 mg/m^3, and 95% with perchloric acid loadings of 3×10^3 mg/m^3. Total fission product loadings ranging from 0.01 to 0.4 mc/m^3 were removed from the contaminated air with an average efficiency of 94%.

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2. Friedlander, Sheldon K.; Silverman, Leslie; Drinker, Philip and First, Melvin W.: Handbook on Air Cleaning, Report AECD-3361 (September 1952).

3. Sill, Claude W.: Personal Communication (1957).

Discussion

C. (H. F. Johnstone, Univ. of Ill.) Passing suggestion out in facing difficult problems in the separation of gases which are unusual, rare and exotic in extremely small concentrations, don't overlook the possibility of using something that isn't in the text book. When you are dealing with very large quantities of gases or using something that isn't in the textbooks - that's a fluidized bed process. To our surprise we have found actual absorption of CO_2 in a fluidized bed and you can actually accomplish some gas **chromatography in such a bed.**

VENTILATION SYSTEMS AT ATOMICS INTERNATIONAL

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Abstract

A brief summary of ventilation systems employed on reactors, hot cells and critical facilities designed and/or operated by Atomics International is presented. The two power reactors discussed are contrasted by use of a rather loose building containment system in one (Sodium Reactor Experiment) and a very tight vapor container in the other (Piqua Organic Moderated Reactor). Similarly, of the two hot cells described, one operates with a comparatively large volume air flow, the other with a very low ventilation rate. Of the two remaining facilities considered, the Organic Moderated Reactor Critical Facility employs a somewhat unique dual ventilation system to avoid filter plugging by non-radioactive organic condensate. The Kinetic Experiment Water Boiler (KEWB) uses a sealed, static atmosphere during reactor operation with subsequent high volume flushing before re-entry of the test building.

Sodium Reactor Experiment (SRE)

Description

The SRE is a 20 Mwt sodium cooled graphite moderated reactor. The reactor is located in the Santa Susana mountains on the west end of the San Fernando Valley, approximately 900 feet above the valley floor. The reactor has been in operation approximately 2 years and has supplied power to valley communities through an Edison Company power plant.

The reactor and its heavily shielded heat transfer system vaults are located below grade and are housed by a 10,000 sq. ft. superstructure. The superstructure is a conventional type building of reinforced steel, 5.5" thick concrete tilt-up panels and has a poured gypsum roof. The building is not a pressure container, but is designed to be diffusion tight as long as no internal pressure exists. There is no stack associated with the main reactor floor area. These design features are permissible at the SRE since the reactor operates as a completely closed system, hence no radioactive effluents or radioactivity are released to the environs during normal operation except under controlled conditions (from the decay tanks through a stack). A helium atmosphere is maintained over the sodium in the reactor vessel and a nitrogen atmosphere is maintained in the vaults containing the heat transfer system.

Approximately 15,000 cfm of fresh air is supplied to the high bay area through Farr Air Cleanable Filters and unit heaters. An estimated 24,000 cfm of air is exhausted directly through two power roof ventilators designed to maintain a 1/8" H_2O negative pressure in the high bay area and to provide approximately 2 fresh air changes per hour. Standby MSA Ultra Aire glass filters have been added on the downstream side of each exhauster and may be cut in during an emergency, if needed. These were added to filter potential releases of activity from fuel handling operations or other maintenance operations involving contaminated sodium. These filters are by-passed during normal operation. The service and administration area is attached to the reactor building. This area is maintained at a positive pressure by fresh air supply fans and is exhausted directly through wall and roof louvers. The positive pressure insures against potential leakage of radioactivity from adjacent reactor building areas. The offices and control room are air conditioned to insure reliable operation of instrumentation and for personal comfort in hot weather.

The reactor and primary sodium system are operated at a low pressure and are contained in a closed system. The reactor top shield, which can be rotated to remove large core components, employs a cerrobend seal to prevent leakage of reactor cover gas. Fuel access plugs, located in the top shield, use double o-ring seals to prevent gas leakage to the reactor room. Welded stainless steel construction is used in the remaining parts of the system. The helium blanket gas of the reactor is normally maintained at a pressure of about 3 psig and no gases are released during normal operation. Four shielded decay tanks are provided to store fission product or other radioactive gases in the event the system must be emptied or vented. The four tanks have a capacity of 10,800 standard cubic feet at 100 psig. Activity may be bled from the tanks, under controlled conditions, to a stack which is equipped with a 25,000 cfm dilution fan. This stack discharges above the SRE roof. Cambridge absolute type filters (8" x 8") are provided before and after the decay tanks to remove particulates.
Because of possible sodium hazards the primary heat transfer and piping system is contained in concrete vaults containing an inert atmosphere (nitrogen). The system is designed to operate at a slightly positive pressure to exclude all oxygen. In the event of airborne activity, the vaults can be vented to the gas hold up system through absolute filters.

Experience

Sodium exposed to moist air ignites and burns. Contact of the smoke or hydroxide mist with the throat and lungs is very irritating, however, protection is easily afforded by a number of different types of breathing equipment.

In the two and one-half years of a vigorous experimental program at the SRE, no lost-time injuries have occurred due to sodium handling. Small sodium and NaK fires have taken place, but these have all been controlled successfully and no significant activity has been released to the environment. Leaking valves tend to plug themselves by the sodium freezing and clean-up of spilled sodium has been accomplished using direct methods (e.g., shovels and buckets).

To date, about 2,400 Mwd of operation have been accumulated, with the production of approximately 15 million kwh of electricity. The primary sodium is usually maintained at about 950°F. Higher temperatures have been attained and steam has been produced at 1000°F on occasion.

SRE Hot Cell

Description

The SRE building contains a hot cell area consisting of two cells, an operating area in front and a personnel air lock leading to a service area in the rear.

The cells are equipped with three windows and six manipulators. These cells are used for inspection and disassembly of SRE fuel elements and components, and for non-destructive testing of fuel. Potential radiological hazards in the cell may arise from sodium, NaK and fission products.

Since the hot cells are not designed to be gas tight, a conventional high volume air system is used to ventilate the cells. Raw outside air is drawn into the cells through normally open isolation dampers and a pre-filter. If the exhaust fan is denergized, the dampers close automatically to isolate the cell. The cell atmosphere is exhausted through American pre-filters (hood-type) located in the cell and three parallel Cambridge absolute filters, which are located outside of the cell. The absolute filters are followed by two 10 hp blowers (one standby) which discharge the air to a dilution stack, exhausting above the SRE roof level. Each blower is rated for 2400 cfm at 15" of water. During normal operation a negative pressure of approximately 0.25" of H_2O is maintained in the cell. When the service door is open, a conventional air flow of 100 fpm is maintained across the opening to prevent contamination of the service area. A 25,000 cfm fan located at the base of the stack dilutes the normal cell exhaust and discharges it above the SRE roof level. Service and operating area ventilation is discharged to the stack through Cambridge absolute filters (3500 cfm). Any leakage from the cell is therefore filtered before being discharged to the environment.

One of the cells is provided with a vent line leading to the SRE gas decay tanks in the event experiments are planned which could release hazardous quantities of fission product gases. Fire fighting equipment is installed in the cell.

Experience

The cell has been operated successfully for approximately 2 years. Two fires involving NaK, alcohol and Na^{24} have occurred in the cell during handling of irradiated fuel. Interior fission product contamination of the hot cell occurred on these occasions, but no significant contamination was discharged to occupied areas or the environment.

Component Development Hot Cell (CDHC)

The CDHC is a structure, owned, designed and operated by Atomics International in the Santa Susana mountains in California. It contains four large hot cells which have a combined floor area of 820 sq. ft. (metallurgical, physical test, fuel disassembly and reactor component disassembly cells). Each cell leads to a separate shielded decontamination cell in the rear, which in turn leads to a common service area behind the cells. This design was chosen so as to provide improved control over contamination. A common operating area in front contains nine windows in the cell block, and provisions for 18 manipulators, periscopes and other related viewing equipment.

The ventilation system which is employed is unique for hot cells. The unusual design was necessary because of the hazardous nature of the operations planned for the facility (handling Na, NaK and disassembly of spent fuel). Basically, it is a low volume system employing sealed cells with an exhaust gas hold-up and decay system. The interior is surfaced with welded sheet steel and openings are sealed with gaskets and/or inflatable seals. Normal operation is at 5 cfm per cell, the cells being maintained at a negative pressure of ¼" water. The cells can be filled and operated with an inert gas to accommodate special experiments requiring inert atmospheres. The cell exhaust is routed through Cambridge pre- and absolute filters (8" x 8") to a dilution stack or to a gas holdup system storing gases at 150 psig, if gaseous activity is present. The gas storage tank system is sized to keep one cell in operation for 3 days (5 cfm for 72 hours).

When the cell service doors are open, a conventional high volume (7200 cfm) system is employed to discharge the exhaust to the stack via pre- and absolute Cambridge filters (24" x 24" filters). The system is designed to provide a conventional air flow of 100 fpm through the opening with two of the service doors fully open. A 25,000 cfm dilution fan is provided at the base of a 65 foot stack to provide safe discharge of gases from the decay tanks.

Inflatable seals are used to hold the absolute filters for both the high and low volume exhaust system in place. New filters are installed by (1) placing a new filter in a horizontal duct on one side of the unit, (2) releasing the pressure on the inflated seal, (3) applying manual pressure to the new filter to force the old unit into a duct and plastic bag located on the opposite side and (4) inflating the seal once the new filter is in its proper location. This design provides a convenient and safe means of removing, handling and disposing of contaminated filters.

Organic Moderated Reactor Critical Facility

This facility is located in the Santa Susana mountains in California and is used to obtain nuclear parameters for organic moderated reactors. Basically, it consists of a large carbon steel tank containing fuel elements in a heated organic pool which is maintained at atmospheric pressure. The tank lid consists of loosely fitting pieces which can be readily removed to make necessary experimental changes. The reactor is contained in a section of the building which is isolated from the control room and administration area by concrete shield walls. Access to the reactor room is through a hallway and opening at one end of the shield wall. Sealed doors at each end of the hallway are kept locked when the reactor is on. Two ventilation systems are provided for the reactor room - a "reactor off" system and a "reactor on" system.

When the reactor is off, raw outside air is drawn through wall louvers and is exhausted directly through four roof mounted power exhausters equipped with motorized dampers. Exhaust filters are not used during this period since there is no danger of airborne radioactivity with the reactor off. If filters were continuously in use, the organic fume and condensation would require filter replacement at least daily. During shutdown periods a high room air change rate (8000 cfm) is employed for removing radiated heat and terphenyl fumes which escape from the organic system. The room may be occupied only when the reactor is off.

Interlocks require that the roof exhausters be turned off and the exhaust dampers closed prior to reactor start up. The intake louvers are spring loaded, equipped with fusible links and are tied into the scram network with a solenoid latch. These intake louvers close in the event of fire or a scram to reduce the air flow and pressure in the reactor room.

When the reactor is on, 3500 cfm of exhaust air is routed through a separate system. Components of this system consist of a local exhaust duct leading from the reactor atmosphere, an organic trap, a room exhaust grill mounted above the critical assembly, a filter system and a bypass system, a 7.5 hp exhaust blower and a stack which extends 10 feet above the roof level. The exhaust duct leading from the reactor atmosphere is routed through an air-cooled organic vapor trap. The terphenyl mixture melting point is 293°F. A 3 scfm CO_2 purge within the organic system expels fumes from the core tank through this exhaust duct and trap and is finally exhausted immediately in front of the room exhaust grill located above the critical assembly. This duct leads to two banks of fireproof pre- and absolute filters located just upstream from the blower (four 24" x 24" absolute filters in each bank). A water sprinkling system is located in the duct work to extinguish possible organic fires.

Normally, the above filters are bypassed to prevent their becoming clogged with organic fumes. A stack monitor continuously monitors the exhaust for radioactivity content. In the event of high activity, the reactor is automatically scrammed and fail-safe motorized dampers divert the exhaust through one of the two filter banks and automatically close the building intake shutters. The second filter bank is maintained as a reserve to be used in the event of clogging of the first bank. Manual operation of the dampers from the control room is also possible.

Kinetic Experimental Water Boiler (KEWB)

The KEWB is located in the Santa Susana mountains west of the San Fernando Valley. This facility is used for investigating the safety of solution type reactors by employing planned power excursions. The test building containing the reactor is buried in the ground and is controlled from a remote control station. The first test core has a nominal power rating of 50 kw.

The test building is unoccupied and sealed during all reactor runs. A continuous ventilation system was not provided since planned excursions are relatively infrequent and hazardous levels of air activity are not expected during normal tests. The interior atmosphere is continuously sampled by a re-circulating gas monitor. Substantial A^{41} concentrations are present in the test building following large power transients. Release of some Xe and Kr activity has occurred in the test building upon occasion. Before re-entry to the building, the intake vents are opened and a blower rated at 2000 cfm is turned on to discharge the A^{41}; the exhaust air leaves through two 24" x 24" absolute filters and a 60 foot stack. If excessive airborne contamination is detected by the air monitor, the room remains sealed to allow decay and/or is vented at a controlled rate through the absolute filter system. Control is obtained by a manually operated butterfly valve in the exhaust system which allows the admittance of dilution air to the stack during this venting. When this valve is opened, the rate of air discharged from the facility is considerably reduced. This procedure continues until access is possible.

Piqua Organic Moderated Reactor

Reactor Description

The Piqua reactor is a 45.4 Mwt organic cooled and moderated reactor presently under construction at Piqua, Ohio. The plant will be integrated with the existing municipal city power plant, in order that the present plant may continue to function as a conventional plant.

The reactor plant consists of a reactor building and an auxiliary building. The reactor building consists of a 73 foot diameter steel vapor containment shell half buried in the ground; the above grade portion is shielded by 18 inches of ordinary concrete. The shell houses the reactor, heat transfer rooms, fuel storage pool and reactor room. The reactor floor is at grade level whereas the heat transfer equipment is located in shielded rooms below the floor level. Normal organic operating temperature and pressure are 575°F and 120 psig, respectively. The auxiliary building contains reactor services, coolant purification and waste systems, a control room and an administration area. The superstructure is of conventional industrial design with a concrete shielded basement containing the process rooms. For convenience the ventilation systems of interest can be divided into the following categories:

(1) reactor building ventilation
(2) auxiliary building ventilation
(3) process off-gas system
(4) waste fired burner exhaust system
(5) reactor fume hood

Reactor Building Ventilation

During normal operation fresh air is supplied to the reactor building through fiber glass media filters (Rollamatic) by a 40 hp blower ($\sim$ 33,000 cfm) and is exhausted through fiber glass pre- and absolute filters, to a 90 foot stack using two 25 hp fans. The stack discharges at a height which is 20 feet above the top of the reactor building. The supply fans are located in the containment shell and are used for cooling the reactor building atmosphere in the event the normal ventilation system is interrupted. The exhaust fans are located outside the containment shell to save space. The reactor room is ventilated at the rate of two air changes per hour (approximately 10,000 cfm). Because of heat loads and a higher contamination potential, the basement rooms and heat transfer rooms located below the reactor floor are ventilated with a minimum of ten air changes per hour.

For basement rooms the pre-filters are installed at the outlet of each room to trap potential organic particulates and prevent contamination of the exhaust duct system.

The containment shell is equipped with isolating valves in the ventilation ducts which close if hazardous radioactivity levels are present. When the isolation valves close, the reactor atmosphere is re-circulated through the supply fans and a cooling system to prevent over-pressure on the containment shell. A vacuum breaker valve is provided to protect the shell against excessive underpressure. The containment shell is designed for 5 psig positive and 0.5 psig negative pressures, and for a maximum leakage rate of 0.2% of the total volume per psi per 24 hours.

Auxiliary Building

The auxiliary building ventilation system consists of a 10 hp supply fan delivering $\sim$ 23,000 cfm of air to the building through pre-filters and an air heating coil. Pre-filters are provided on the exhaust of all process rooms (filter located in the room) to prevent accumulation of organic material and contamination in exhaust ducts. One 20 hp exhaust fan draws air through absolute filters and discharges 22,000 cfm of air to the main stack. The flow pattern is always from areas of no contamination to areas of higher contamination potential. Ten air changes per hour are supplied to potentially contaminated areas. The total volume normally exhausted from the facility stack from both the reactor building and auxiliary building is $\sim$ 55,000 cfm.

Process off-gas System

During normal operation a stream of organic coolant is withdrawn from the reactor vessel, filtered, degassed and returned to the reactor with pressurizing pumps. This permits continuous removal of the small volume of gas formed by organic decomposition and also allows continued operation with minor water leaks and fuel cladding failures.

The decomposition gas flow rate from the degassifier is approximately 2 scfh and contains hydrogen, methane, and other light hydrocarbons. Water vapor and volatile fission products may also be present. This stream is routed through two activated charcoal absorbers to remove organic material, and a condenser to remove steam. The gas stream then flows through a waste gas decay system consisting of a series of tanks which is capable of delaying release of gases for a period of up to 48 hours. This amount of decay permits reactor operation to continue with minor fuel cladding failures. Continuous discharge of these gases to the stack through absolute filters is employed. In the event of a serious fuel rupture, wherein 48 hour holdup is not sufficient, the reactor will be shut down.

Waste Fired Burner

The coolant purification system continuously removes high molecular weight hydrocarbon components from the coolant by a vacuum distillation process. After sufficient radioactive decay, this organic waste is injected into a waste fired boiler and burned. In the present system, storage tanks are provided to hold the waste coolant for about 5 months before it is burned. If the radioactivity concentration in the organic wastes, after the 5 month decay period, is too high to burn safely the wastes can be packed in drums and stored or shipped off site for disposal. The development of methods for further improving the removal of particulate and gaseous activity from the combustion gases in order to permit burning the organic wastes with shorter decay times is currently underway at Atomics International. Present plans include a bag type pre filter and an absolute filter for removal of particulates from these combustion gases. Approximately 150 cfm of room air is mixed with the 250 cfm of air from the burner for cooling purposes. A fan discharges this air stream to the stack where it is diluted with the building ventilation.

Reactor Fume Hood

When the reactor top lid is removed, local ventilation is provided by a fume hood which prevents the escape of organic fumes to the reactor room. The fume hood uses lateral exhaust and is designed into the fixed shielding at the reactor top. Approximately 10,000 cfm of reactor room air is drawn into the opening at the top lid and is exhausted through a horizontal slot around the periphery of the opening. To remove organic material the air is filtered by an automatic filter unit consisting of a renewable roll type filter media with a leno-weave backing (similar to Farr Company Roll-Clean Model). The cleaned air is routed to the reactor building ventilation exhaust system which leads to the absolute filters and the stack.

Discussion

Q. (J. F. Newell, AEC Washington) If they have any operating experience on the quantities of fission products that are -- well, what is your experience with leakage from fuel into the sodium coolant and how is it retained in the coolant?

A. They have had experience in Idaho with fairly serious ruptures. Don't know exactly where all these fission products are at the moment.

Q. You mentioned burning of the residues from your organic - were these contaminated residues?

A. I think I can answer your question now. I had mentioned that we could run this reactor with a one centimeter area of uranium exposed. Normally the concentration in the organic primary loop is less than we might care to receive. With a one centimeter exposed fuel area the concentrations from fission products may be a factor much less than that - this gives no problem. The xenon, krypton and iodine would come off immediately in the gas system and go the stack with out hold-up. Whereas, the organic that is burned can be held up to a period of 6 months - these activities have been based on cooling rates, etc...

Q. In the - reactor they would be able to run for 48 hours after exposure - with the 10^{-9} mc to the top of the stack. Do you

really believe they would shut the reactor down if it reached 10^{-9} microcuries - or would they use some dissolution factor to the ground plus a long term average of concentration at the ground as is done everywhere else?

A. A 48-hour period gives an opportunity to search for the ruptured fuel element - the trend is toward shorter and shorter stacks - AI is limited due to proximity to the city.

Q. (F. T. Sellick, FLuor) Relative pressure on gas decay system or tanks - is this a pressurized gas or is it induced into a sphere by a vacuum?

A. It is pumped in by pressurized pumps.

Q. (W. Culkowski, Oak Ridge Weather Bureau) This pressure for shorter and shorter stacks, where is this pressure coming from?

A. The committees that reviews the hazard summaries reports brings up items like this. First the question of criteria - what was our criteria on the stack height. I think the first stack was 125 feet. It's written that they are going for shorter stacks. I understand that from talking to someone the other day it was mentioned that the English consider one person dies for every hundred foot of stack length that is built.

C. (A. Wolman) I might say that as one interested at least in some detail on AEC policy, I am a little astonished at Mr. Piccot's comments that AEC now, among other policies, decisions are moving toward no stacks at all. I have some doubts about that.

SUMMARY OF AIR CLEANING ACTIVITIES AT CHALK RIVER

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I have been asked to say a few words about our experience in air cleaning at the Chalk River Plant of the Atomic Energy of Canada Limited. I do not have a prepared paper with me, however, I will try to tell you as much as I can in the few minutes at my disposal.

On December 12, 1952, our N.R.X. reactor went out of control and the reactor was badly damaged. At that time the only filters on the exhaust air system from the reactor building were of the deep bed roughing type. Fortunately the wind direction was such that the air-borne radio-activity released was spread over a large uninhabited area. The other buildings in the plant were not seriously contaminated.

Following the successful removal of the damaged reactor vessel and the installation of a new unit the reactor was ready to go back into operation. Before start-up it was decided to install absolute filters in addition to the existing deep bed roughing filters. Thirty-two 1000 CFM filters were installed. These were installed in four plenum chambers, each chamber having a bank of eight absolute filters installed against a vertical frame.

After start-up it was noticed that the amount of radioactivity passing through the filters was greater than would be expected if the filters were working at their rated efficiency of 99.97% retention of 0.3 micron size particles. At the next shut down of the reactor an inspection was made of the absolute filters. It was found that some had been damaged in installation. There were obvious bruise marks on the filter media. Also the filter retaining frames were so rough, particularly at the welds, that there was considerable edge leakage past the filters.

It was decided that all installations of filters of this type should be inspected and approved by a small group. This group is made up as follows:

(a) One man from the building requesting the filter installation.

(b) One man from the Maintenance Branch responsible for the installation work.

(c) One man from the Radiation Hazard Control Branch.

This system has been in use for some years and has increased the overall efficiency of this type of filter installation.

Following the 1952 incident to N.R.X. reactor a complete survey was made of all air exhaust outlets in the plant. It was decided to install absolute filters on all outlets where either radio-activity was being released or where there was this possibility. It was also decided to form a Ventilation Specification Panel which would be responsible to examine all proposed ventilation installations and either approve or reject them. This panel is made up of senior representatives from the Design Branch, Maintenance Branch, Research Division, Operations Division and Radiation Hazards Control Branch. They submit their recommendations directly to senior management.

This Panel has made some recommendations which are now company policy. For example, because of the difficulty of ensuing a tight installation when installing a number of absolute filters in a plenum frame, all new installations are made with filters which are enclosed in a box to which are fitted an inlet and outlet nipple. These filters are of fire-proof media. The containing boxes are made fire-resistant by chemical treatment. The D.O.P. test is made at the supply company's plant before shipping, and the efficiency across the filter from nipple to nipple is marked on the box. On arrival at the Chalk River plant they are checked by a Radiation Hazard Control Branch inspector for any obvious damage or flaws in the filter media. They are stored with the spacers in the vertical position to avoid any possibility of sagging of these spacers occuring whilst in storage. When a multiple filter installation is made the main ducts before and after the filters are fitted with the required number of nipples to accommodate the filters. All filters are visually checked before installation using strong lights and are approved by the inspecting group previously mentioned. After the unit goes into operation air samples are taken before and after each filter and checked for radio-activity. Any filter not working to its rated efficiency is removed and replaced with a new filter. This is easily done as the inlet and outlet nipples are connected to the ductwork by rubber sleeves.

Some previous speakers have mentioned receiving a considerable number of defective filters. This to date has not been the case at Chalk River. However, on my return to the plant I hope to install a stricter inspection of all absolute filters received. The Defence Research Chemical Laboratories are located in Ottawa. They have a D.O.P. testing unit and as they have always been most cooperative with A.E.C.L. I feel that arrangements could be made with them to inspect some of our incoming absolute filters to ensure that they are being manufactured to specification.

HIGH-EFFICIENCY, HIGH-VELOCITY ELECTROSTATIC PRECIPITATORS

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The protection of personnel both ashore and at sea against objectionable or toxic aerosols is important today. A part of our work in this field at the Naval Research Laboratory has been an investigation of electrostatic precipitation.

Laboratory studies of electrostatic precipitation were initiated at NRL in 1949. The objective of this work was to determine if the aerosol removal efficiencies of standard, commercial, ventilation-type precipitators could be improved. It was hoped that efficiency-wise, they could be made competitive with paper filters while still retaining their great advantage of low air resistance.

At that time (and it is still generally true today) commercial, ventilation precipitators operated at linear air flows of about 300 feet per minute and had DOP aerosol penetrations of about 15%. The units used for these early studies were two-stage precipitators. They consisted of an ionizer section of high voltage wires separated by ground tubes while the collector section was a set of parallel plates with alternate plates at ground potential. We refer to this design as the two-stage plate type.

It was shown that dramatic improvement in performance of the commercial two-stage plate precipitator could be achieved by rather simple modifications. The first alteration included the liberal use of gaskets and seals to insure that no air by-passed the active zones of the precipitator. The effectiveness of the sealing was determined by the effect on the overall penetration of DOP aerosol. These penetrations were measured, using the NRL E-3 Light-Scattering Meter. The location of a leakage source was detected by the use of a sampling probe connected to the same meter.

The second alteration which improved the performance was the use of pre-filters of crimped screen. These filters provided a more uniform air flow through the precipitator which insured that the total cross section would operate with equal effectiveness. In addition, these smoothing filters assisted in the removal of large particulates (over 10μ) from the air stream.

Representative data from these studies are contained in figure 1. We have listed here the average DOP aerosol penetration obtained from the commercial units at air flow of 200 feet per minute. Included also is the DOP penetration at the same flow rate for the modified unit. It is readily apparent that there is more than a two order improvement due to the gasketing and smoothing of the air flow in the modified unit.

Type	Linear Flow Rate (FPM)	DOP Penetration (%)
Commercial	200	15
Modified	200	0.1

Fig. 1—DOP penetration of commercial precipitators.

Encouraged by these results, NRL initiated a program to investigate electrostatic precipitation more extensively. The program was sponsored by the Bureau of Ships.

The first phase of this program was the feasibility studies of precipitator performance aboard ship. At that time it was yet to be proven that precipitators could be used in a naval environment. For this purpose sixteen commercial units modified to NRL specifications were procured. These units after alteration were found to have a DOP penetration of 0.5% at 300 feet per minute. The units were installed aboard the light cruiser, USS ROANOKE, in auxiliary plenum chambers attached to the superstructure of the ship. Eight units were contained in an 8000 cfm vent system while the other eight were used in a 10,000 cfm system.

Hours Service	Aerosol Penetration - %	
	Fwd. System	After System
0	0.4	0.5
4000	0.8	0.2
8000	0.7	0.1

Fig. 2—DOP aerosol penetration at 300 fpm of precipitators aboard USS Roanoke.

After 8000 hours operation the units were removed as it was apparent that adequate information had been obtained. Figure 2 contains data taken at the time of installation, after 4000 and after 8000 hours of operation. The differences are not considered significant. It is to be noted that during this time there were no major component failures. Shock, vibration, salt air and corrosion did not limit their usefulness. These results are perhaps more impressive in that they were obtained with precipitator units obviously not designed for naval service. The conclusion was thus reached that it would be practical to use precipitators aboard naval ships.

The second phase of the precipitator program consisted of R and D contracts for basic and developmental studies. The ultimate goal of these contracts was to obtain prototype models designed for naval service. Since laboratory studies had shown that increased linear flow rates were possible, the models were to operate at maximum linear flow rate and provide aerosol penetration less than 0.1%. Pressure drop was not to exceed one inch of water. A limit of 0.1 part per million of ozone was set as maximum allowable.

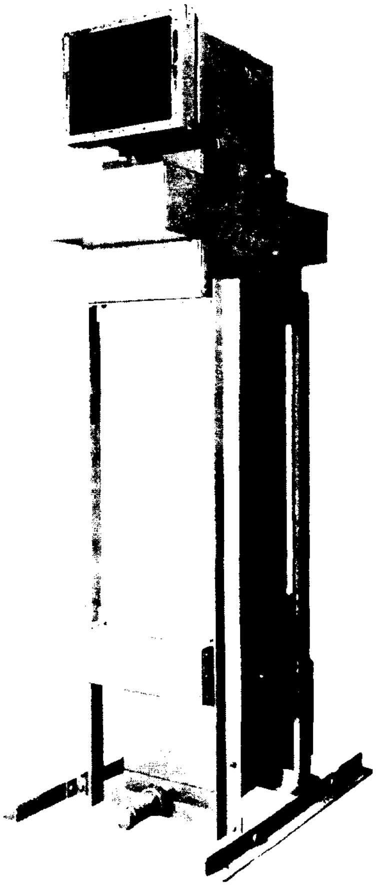

Fig. 3—Prototype model high-velocity, high-efficiency precipitator, 1500 cfm.

The design which came closest to meeting all these requirements was that of Research-Cottrell of Bound Brook, New Jersey. It is a two-stage tube-type unit. Two-stage plate-type units were found to be inferior for high-velocity use. A photograph of the tube-type model is shown in figure 3. Figure 4 is a schematic showing the main components. The ionizer which operates at voltages up to 40 KV

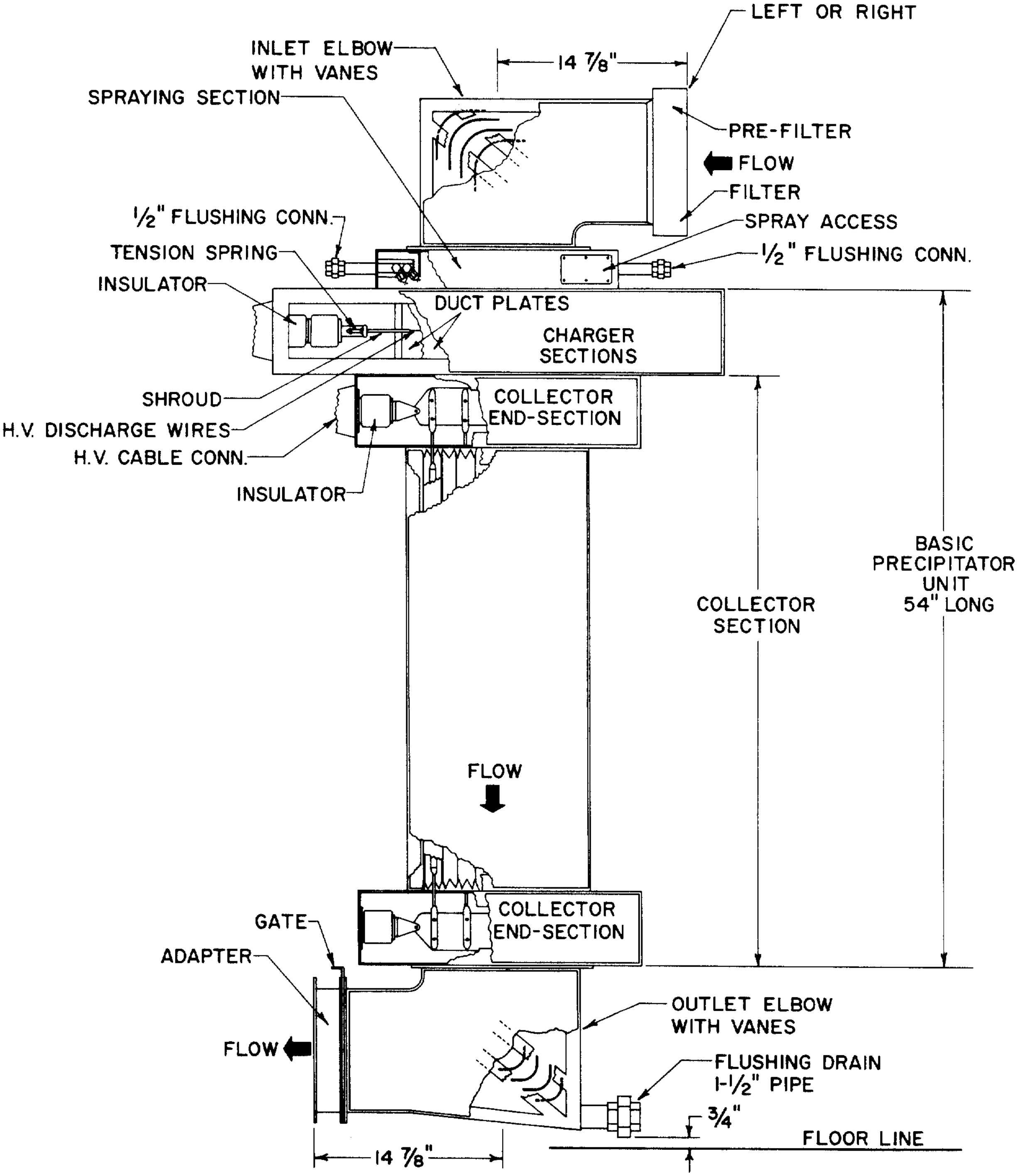

Fig. 4—Prototype model high-velocity, high-efficiency precipitator, 1500 cfm schematic.

is of wire and plate design. The collector contains nested ground tubes with high-voltage, centered rods. It operates at 20 KV maximum. The unit is complete with vaned turns at top and bottom. It also includes a set of spray nozzles for remote-controlled washing with hot water or steam. A drain is provided in the base. The requirement for remote washing was included to provide cleaning of the unit without physical contact in the event the collected material was hazardous.

An interesting and important result of the analysis of all the performance data reveals that the limiting factor in achieving optimum performance is the desired ozone level. The production of ozone (or total oxidants) is directly related to the coulombs of high voltage current generated. But as this also affects the charging of aerosols, setting a maximum for ozone and simultaneously setting a value of 0.1% penetration for aerosol in effect sets the values for all other variables.

Thus, although this particular unit can achieve an efficiency of 99.9% at 2000 feet per minute with pressure drop of 0.9 inches of water, the ozone produced is more than 0.1 part per million. It has thus been necessary to rate this model at 1500 feet per minute.

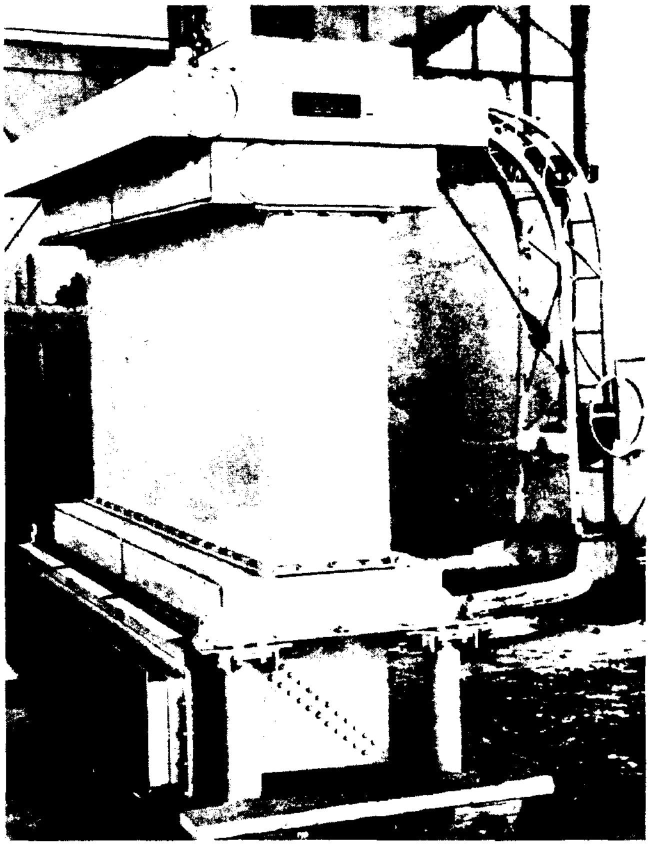

Fig. 5—High-velocity, high-efficiency precipitator, 9500 cfm.

A large unit of 9500 cfm capacity and based on the same design was also procured from the manufacture. A photograph of the unit is shown in figure 5.

Both of these units have received extensive evaluation; the smaller unit was run for 18 months ashore before installation in the ship which also contains the larger unit. There has been no difficulty with either unit and both have given completely satisfactory service.

Figure 6 contains the basic performance data as obtained from these units. We have listed here the aerosol penetrations at rated flow of 1500 feet per minute.

Unit	Air Flow		DOP Penetration	P
	FPM	CFM	(%)	(in H_2O)
Small	1500	1500	0.07	0.5
Large	1500	9500	0.02	0.6

Fig. 6 — Performance of high-velocity precipitators.

Figure 7 is a summary which illustrates the great improvement which has been achieved during the past ten years in the performance of ventilation type electrostatic precipitators. Air flow rates have been increased by a factor of eight while DOP penetrations have been reduced by a factor of 300.

Type	Linear Air Flow (FPM)	Average DOP Penetration (%)
Commercial	200	15
Modified	200	0.1
High Velocity	1500	0.05

Fig. 7 — Summary of electrostatic precipitators performance.

In conclusion, it has been shown that compact, high-velocity, high-efficiency precipitators can be manufactured for naval service. It has also been proven that they can be used aboard ship with full confidence of satisfactory performance.

THE USE OF IODINE AS AN INDICATOR FOR REACTOR MONITORING

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ABSTRACT

Radioactive iodine is a positive indicator of reactor fission products and distinguishes between these and neutron activation isotopes which are of far less importance biologically.

A comparatively simple method for collecting iodines is the use of filter paper or filter tape treated with silver nitrate to give Ag^o and Ag^+. A treated tape lends itself to a continuous fission product monitor; the use of activity read-out and gamma energy discrimination can easily be employed.

Laboratory evaluation of silver nitrate treated paper gave a 95% collection efficiency for gaseous iodine. Iodine collection efficiencies varying from 40-95% were characteristic of treated paper when the Chemical Processing Plant was used as a source. These erratic results were thought to be due to part of the iodine entering into a complex chemical form less susceptible to collection by the silver iodide treated paper.

Using an air cooled reactor as a source the treated paper collected over 55% of the gaseous iodine. The collection efficiency for total iodine - gaseous and iodine acting as particulate - was over 95%.

Introduction

The presence of radioactive iodine in a reactor effluent is positive evidence of fission products in the effluent. Since iodine is one of the earliest fission products to escape the cladding, its use as a fission product indicator has merit[1]. Activation products such as Argon-41, erosion products that have been neutron activated, and others may give radioactivity in the effluent but these are of far less biological importance and do not forewarn of increased future activity.

The use of a treated tape for the collection of gaseous fission product iodine would have considerable merit since the tape could be moved at regular intervals. The tape could also be read for activity with an energy discriminator if required.

From previous experience and discussions with others[2] it was expected that a portion of the iodine would plate out on dust particles and act as a particulate. The amount of this plating would depend on the dust concentration and contact time.

Method

The evaluation of the removal efficiency of treated paper against iodine was checked using the following methods:

1. Laboratory generated I-131 gas
2. Chemical Processing Plant used fuel element dissolution vapors
3. Effluents from an air cooled reactor

It was assumed that activated carbon had one hundred per cent removal efficiency against iodine[3]; therefore, the treated paper - $AgNO_3$ treated to give Ag^o and Ag^+ - were placed ahead of activated carbon to give a quanitative test.

Equipment

Two arrangements of sampling equipment were used. The first arrangement used a Hi-Vol, sampling at 12 c.f.m. or 182 f.p.m. face velocity (see Photo I). The filtering media were arranged in series as follows:

Untreated CC-6,	labelled #1
Treated CC-6,	labelled #2
Carbon chamber filled with activated carbon	labelled #3 and #4

The second piece of equipment (see Photo II) sampled at 2 c.f.m. or 30 f.p.m. face velocity. In this equipment the following filter media are in series (see Photo III):

Untreated CC-6,	labelled #1
Untreated CC-6,	labelled #2
Treated CC-6,	labelled #3
Treated CC-6,	labelled #4
Treated CC-6,	labelled #5
Activated Carbon cartridge,	unlabelled and in background

In evaluating the efficiency of treated paper for iodine removal in the laboratory, Oak Ridge I-131 was titrated into warm concentrated nitric acid. A pre-filter was used for moisture removal.

In the use of the air cooled reactor as a source, a mobile unit (see Photo IV) was used sampling downwind at not less than one mile distant from the reactor effluent stack.

Test Results

The removal efficiency of the treated paper under laboratory conditions is over 95% as shown in Table I:

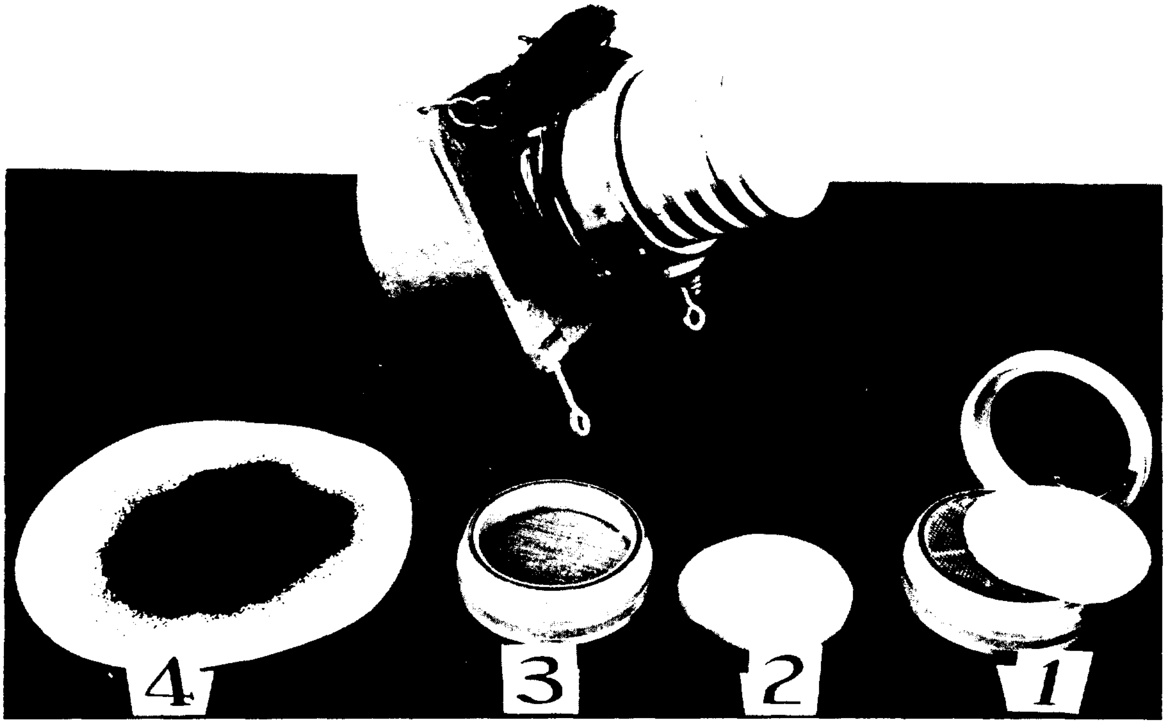

Photo I

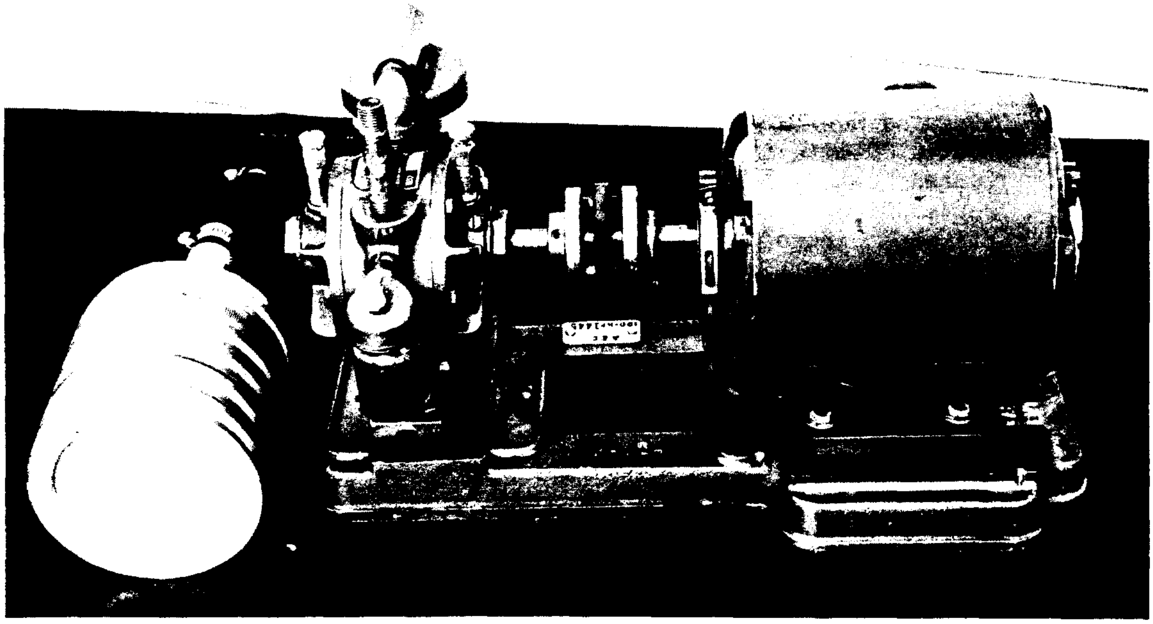

Photo II

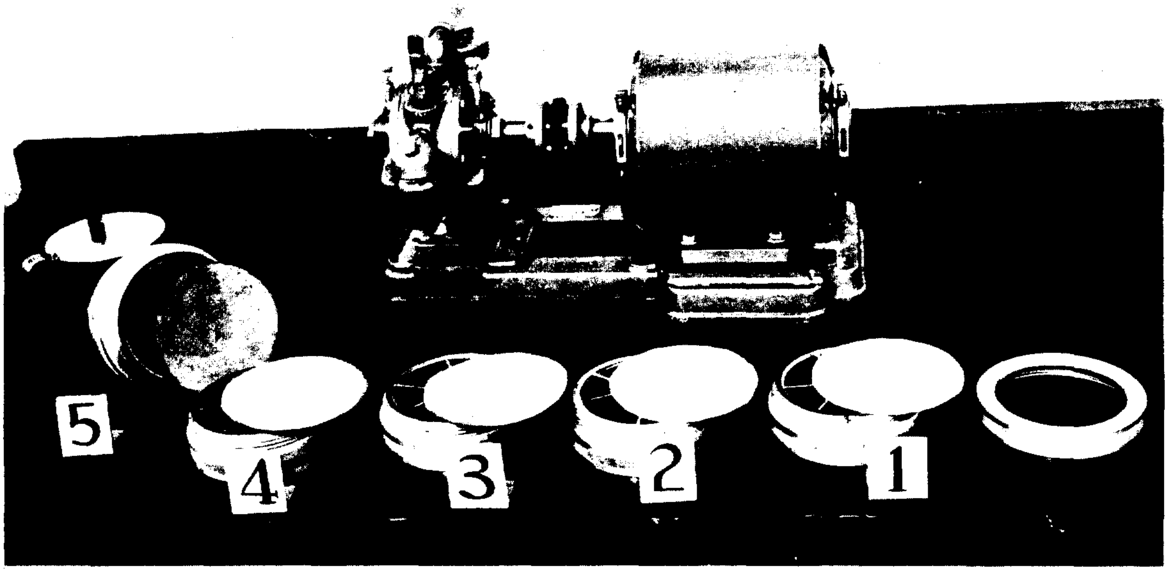

Photo III

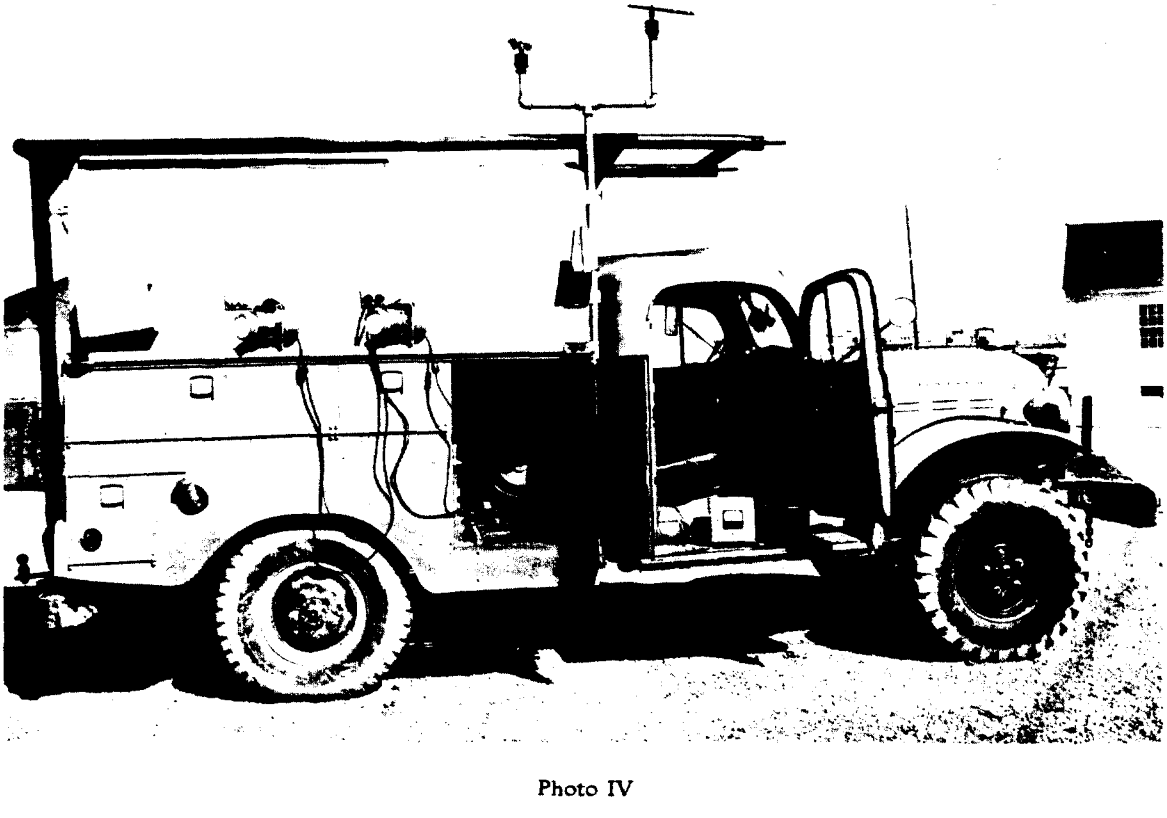

Photo IV

Table I

Sample Number	Sample Description	Disintegrations Per Minute	Distribution of Activity
1	1st Pre-filter	92,418 ± 485	——
2	2nd Pre-filter	33,748 ± 300	——
3	1st $AgNO_3$ treated filter	372,035 ± 968	96.22%
4	2nd $AgNO_3$ treated filter	2,445 ± 108	.62%
5	3rd $AgNO_3$ treated filter	1,438 ± 95	.37%
6	1st Carbon Sample	10,678 ± 170	2.76%
7	2nd Carbon Sample	108 ± 52	.03%

The removal efficiency of the treated paper using the Chemical Processing Plant fuel element dissolutions as a source was found to be unsatisfactory. The major percentage of the iodine released under this condition was either in the form where it acted as particulate or combined chemically in a form which inhibited collection on silver treated paper. Collection efficiencies varied between 40 to 95% for iodine, gas or vapors.

Using the air cooled reactor as a source, and sampling at over one mile from the stack allowed all the meteorological factors to come into play[4]. In all cases the first fission products to be identified were the iodine isotopes. In most cases the major portion of iodine was suspected to be in the particulate form or attached to particulates[5]. This particulate was removed by the untreated CC-6 paper. The gaseous iodine was then collected by the treated paper or by the activated carbon. Table II gives the results from two field tests. Data gathered after these dates gave similar collection efficiency for iodine but is not included here due to time limitations.

Table II

Test May 15

	Hi-Vol W	Hi-Vol Y	Low Vol. Sampler
Untreated CC-6	48,158 cpm	48,825 cpm	5,838 cpm
Untreated CC-6	not used	not used	0 cpm
Treated CC-6	7,143 cpm	5,540 cpm	443 cpm
Treated CC-6	not used	not used	683 cpm
Treated CC-6	not used	not used	391 cpm
Activated Carbon	790 cpm	1,952 cpm	0 cpm

Test May 19

	Hi-Vol Y	Hi-Vol S
Untreated CC-6	9,957 cpm	7,247 cpm
Treated CC-6	1,467 cpm	846 cpm
Activated Carbon	296 cpm	278 cpm

Notes:

All the above counts are gross gamma and are to be used for comparative purposes. Statistical variations are not given since they serve no useful purpose in this instance.

In the sample Hi-Vol Y from May 15 it is suspected that the treated paper may not have been seated properly and allowed activity to filter through to the activated charcoal.

Conclusion

The use of iodine as an indicator for reactor monitoring is feasible and can be accomplished by employing a material which has a high collection efficiency for this element.

A continuous treated tape has merit since the background activity can be reduced to a low level and energy discrimination can be employed in the read-out.

Collection efficiency of the silver nitrate treated filters is high using an actual operating reactor as a source.

Further evaluation of materials and equipment is in process to supply the necessary empirical data in sufficient quantity for confidence.

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2. Private communications with Dr. L. Silverman, April 1958 on plate out of iodine on dust.
3. C. W. Sill and J. K. Flygare, Iodine Monitoring at the National Reactor Testing Station, presented at the Annual Meeting of the Health Physics Society, June 1958.
4. This work correlated with U. S. Weather Bureau. Personnel of this Bureau and particularly Mr. C. R. Dickson, meteorologist, in private communications supplied necessary test data.
5. Gamma spectroscopy performed under direction of Mr. A. Harbertson on the 256 channel gamma spectrometer in the AEC NRTS Analysis Section Laboratories.

PROGRESS ON THE UNIVERSITY OF ILLINOIS CONTRACT

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The objective of the work at the University of Illinois is to study the properties and behavior of aerosol particles especially as they are related to problems in atmospheric pollution and gas cleaning connected with atomic energy operations. During the past two years attention has been given to the physical and chemical properties of solid aerosol particles as they occur in the air of industrial and urban communities. Two technical reports have been issued, as follows:

T.R. No. 15, (Serial No. COO-1017) "Electrostatic Effects in the Deposition of Aerosols on Cylindrical Shapes," March 15, 1958.

T.R. No. 16, (Serial No. COO-1018) "The Agglomeration of Solid Aerosol Particles," March 1, 1959.

Since copies of the reports were sent to AEC contractors and are generally available at the AEC Technical Information Service at Oak Ridge, Tennessee, only a brief summary of the work will be given here.

In T.R. No. 15 a fundamental study of the deposition of small particles on cylindrical collectors in the presence of electrostatic forces is described. Attention is given to three cases: (1) an uncharged cylinder is surrounded by an atmosphere of charged aerosol particles; (2) a charged cylinder is surrounded by an atmosphere of uncharged particles; (3) both the cylinder and the particles are charged. Mathematical equations were developed for the three cases and solved by the ILLIAC, an electronic digital computer. An experimental study was made of the efficiencies of collection of liquid aerosol particles on cylindrical collectors from a moving stream of gas under various electrostatic conditions. The experimental results agreed well with the theory and the results should be useful in the engineering design of aerosol collectors. An experimental study was also made of the effects of electrostatic charges on aerosol particles on the filtration efficiencies of glass fiber mats and tangled-wire dipole mats.

In T.R. No. 16, measurements are reported on the effective diameter, porosity, and uniformity of agglomerates formed from several species of aerosols. The studies were made by means of a Millikan Cell and the results were compared with electron micrographs of the agglomerates. The results show that:

(1) When an agglomerate is composed of particles of uniform size and shape the void space is minimal and the effective density is close to that of the primary particles from which the agglomerate is formed.

(2) When the primary particles are not uniform in size and shape there are wide variations in the density of the agglomerates and a plot of $CD^2\rho$ versus mass differs considerably from the line calculated from the normal density of the substance.

(3) When the primary particles have irregular shapes there is a difference between the drag diameter of the agglomerate determined from rising and falling velocities. This conclusion has practical significance in the efficiency of electrostatic precipitation of such aerosols.

(4) The cascade impactor can be used for determining the size and size distribution of agglomerates when the Millikan Cell is used to provide supplementary information about the nature of the agglomerates.

The study of agglomerates is being extended to include the effects of humidity, the presence of organic vapors, and the presence of several species of aerosols on the nature of the agglomerated particles. The results of this work should give important information for engineering purposes and on the physiological effects of breathing air containing aerosols.

Studies have also been made on the rate of growth of aerosol particles that act as nuclei in the condensation of water to form fogs and clouds. In this work, two experimental methods were used. In one, a method for measuring the instantaneous rate of growth of nuclei within the first 50 milliseconds after the particles are exposed to moist air was developed. The results with sulfuric acid nuclei show that the rate of growth becomes constant within this interval of time. Measurements are now being made on sodium chloride nuclei, and on nuclei of molybdenum oxide, lead oxide, and other oxides and salts that are representative of fission products in air.

Studies were also made on the equilibrium composition of fogs formed in the presence of mixtures of two species of nuclei. The objective of this work is to find if there is a selective effect in the nucleation of clouds or fogs so that one species or size of nuclei is preferred as condensation nuclei. Measurements were made on the equilibrium composition of fogs. The relative amount of fog droplets nucleated by each of two species was measured by the chemical properties of the droplets. Manganese sulfate nuclei and sodium chloride nuclei were used. The former catalyze the absorption and oxidation of sulfur dioxide from air, whereas the latter produce only inert fog droplets. When sodium chloride nuclei are present in about equal concentration and in about the same size range as the chemically active nuclei the total activity of fogs for the reaction is reduced to less than half of that when only manganese sulfate nuclei are present, so that it appears that for this pair of substances sodium chloride nuclei would be selected in the condensation of water in high clouds that are formed by adiabatic expansion. It has been observed that droplets of fog are formed when the relative humidity is below 100% and these are much more active for the absorption-oxidation reaction than the larger unsaturated droplets normally present in fogs. This work is also being continued to study the effects of very small aerosol particles in the nucleation of other reactions.

HARVARD AIR CLEANING RESEARCH ACTIVITIES 1957-1959

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My comments will serve to introduce the subsequent papers which will go into detail on the specific projects. I would like to indicate, however, that the description and discussion of Harvard activities as presented here are not solely Atomic Energy Commission supported contract work. The paper which Mr. Yoder will present on particle counting instrumentation, and the work Mr. Levenbaum will report, covering our pilot-plant studies on a high-temperature filter development and blast cleaning approaches, are supported by the American Iron and Steel Institute project at Harvard. In addition, I will mention briefly some work that is supported by our own University funds.

The major efforts since our Fifth Air Cleaning Conference at Harvard in 1957 have been devoted primarily to three particular items which will be described in detail in later papers. The first is the economic survey we are conducting on air and gas cleaning costs which will be presented by Mr. Fitzgerald. In our opinion, this is a most important project if atomic energy operations and applications are to be placed on a sound financial basis. For example, there is a need for some detailed evaluation and costs of air cleaning in proportion to the performance expected.

The next major project is the incineration study on which Mr. Dennis will report our progress and developments. I would like to add that we hope to have the final device as a prototype unit for manufacture completed this calendar year. We are as anxious as the AEC to get this particular type of equipment into field applications where they are needed.

The third major item is the development of inexpensive efficient low resistance and long-lived operating devices for the removal of radioactive iodine and other halogens. I will present extended data later in the session indicating our progress.

Aside from these major developments, which will be covered by separate papers, I would like to mention six other projects on which some progress has been made since the 1957 presentations.

One project which was not discussed at the 1957 meeting is the containment scrubber. This project was the result of discussions with Oak Ridge National Laboratory Waste Disposal groups working on the aerosol and gas emanations from ceramic waste fixation studies on liquid waste disposal. It appeared to us that there was a possibility of developing a simple procedure which would collect the evolved fission gases and aerosols that would occur in a much simpler manner than the elaborate multi-stage filter that had been proposed. In this regard we proposed a closed-cycle, educator type scrubber similar to the S-K unit. This scrubber could be used with a caustic solution which would serve as an absorbent and reactant with effluent materials. The performance of the scrubber is not critical because the collection efficiency can be enhanced by multiple passes through the unit in a recirculating system. At the present time we have a small (less than 100 cfm) unit set up in the laboratory and are trying to determine open-cycle efficiencies of the educator scrubber under various conditions. Very little information of this type exists in the literature. Once this phase is complete, we plan to proceed with typical nitrate waste boiling reduction to determine the kind of aerosol problem that would result. The final step would involve a closed circuit evaluation of such a system.

The second item on which we have continued further studies is that of the electrostatic fluidized bed and other approaches that were discussed at the Fifth Air Cleaning Conference. We have proceeded to develop this more completely in the way of actual design parameters and have now constructed a 100 cfm pilot plant to evaluate the principle on a much larger scale than the 1-2 cfm laboratory study. At the present time, we are having difficulty maintaining proper fluidization in this unit but we expect to overcome this by better gas distribution through the bed. In conjunction with the electrostatic project we have developed another approach in which single twisted fibers are charged by contact friction. These form the filtration targets within the gas stream. We have made a small laboratory scale unit for evaluating this procedure as well as a larger scale multiple fiber unit. The chief advantage of this system which appears promising at the present time is the fact that it offers practically no resistance to air flow and does not require an auxiliary charging system. However, actual performance data has not yet been obtained on the models constructed.

Under the program of evaluation of new approaches submitted to the Commission, we have continued to study the performance of the Pulverizing Machinery Company Mikro Pulsaire unit. We have tested this device as a large 500 cfm unit and have already completed studies with fly ash, iron oxide, and several other aerosols. It appears that cleaning is a function of the pressure level and is independent of the pulse diration. The cleaning of dusts $> 0.5\ \mu$ presents no problem using the pulse cleaning mechanism. However, the pulse effectiveness falls in performance if bag resistance is created by high resistance deposits such as extremely fine fume or aerosols. To date the equilibrium pressures with fly ash particulates produces relatively low resistances with equilibrium at reasonable values whereas those with finer aerosols result in pressure loss values which consequently produce low capacities in the unit. In order to evaluate this device at higher temperatures, a small 70 cfm model was supplied by the company. This has been tested at 530°F on fly ash and iron oxide fume. It was found that at temperature the capacity is reduced and the resistance at equilibration on fume shows the same limitation as the larger unit. It appears that the pulse cleaning mechanism is better suited to coarser aerosols which do not permeate the felt.

We have continued to evaluate miscellaneous media for possible applications to AEC and in this connection have looked at a number of newer fabrics of glass-plastic combinations and synthetic foams which may have some value as prefilters or roughing filters.

In closing, I might mention one Harvard project which may be of some interest -- a study of the use of fluidized beds for gas removal. Some early studies have been made in this regard and we have been looking at the problem of trying to eliminate sulfur dioxide from power plant effluents by means of fluidizing activated carbon. These studies to date indicate about 1 per cent attrition per pass in a fluidized carbon bed. While greater throughput is possible, the performance falls off rapidly due to the streaming through the large voids. It had been hoped that the turbulent and eddy diffusion would enhance collection despite the voids. From this study some idea of the ways in which carbon can be used in a moving bed have been developed. It is possible that these may be applicable to processes such as iodine removal in dissolver and other processes which involve iodine in the off-gas.

Discussion

Q. (Stevens) Any summary data available on tests of pulsating units?

A. (Silverman) We didn't bring it with us. We had thought originally of putting a complete paper on the program but it will be out as an AEC report during this year. I don't know if Dick has any data with him but I didn't bring anything but our progress reports. I tried to summarize this in terms of the load capacity in the high pressure drop of fine particulate. Do you have some comments on that?

C. Yes, we are trying out one of the units we have in our plan, running some tests of some of the burnouts we have. We just installed them. We haven't quite started the thing yet. I was wondering just what information you have available because we got some of the production people and maintenance pushing, as they see the unit they know their overrigged blow rings. They have been unhappy for many years over blow rings like so many other maintenance people and we have to give them some kind of an answer.

C. The difficulty we find with it is that while it works fine, coarse particulate to a CFM per square foot on fine particulates, the pressure drop builds up so that your capacity is down. In the air economy of 90 lb. air, multiple pulses is fairly critical. The thing we find is that it isn't the volume of air that does the cleaning, it is the flexing of the bag by the reverse pulse. So it is really sort of a snap cleaning and we have taken shock transducer measurements all over and we are pretty much convinced that air volumes are not critical but the pulse pressure is. The duration of the pulse pressure does not seem to be important.

ECONOMIC SURVEY OF AIR AND GAS CLEANING OPERATIONS WITHIN THE AEC

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Introduction

A preliminary survey of air and gas cleaning systems was initiated by personnel of the Harvard Air Cleaning Laboratory at the request of the Division of Reactor Development, U. S. Atomic Energy Commission. During the Fiscal Year 1959, eleven major AEC and subcontractor sites were visited for purposes of reviewing their air cleaning systems and to enlist their cooperation in the joint participation of a technical survey of air cleaning. Personnel and management at all sites have been very cooperative as indicated by the material compiled in the Appendices.

In the preliminary survey each site has analyzed its own air cleaning operations and prepared an analysis of the technical and economic aspects of air cleaning in a manner most appropriate for its own needs.

The cost and the effectiveness of air cleaning systems are important considerations. An economic survey of the air cleaning cost, however, is of little value unless we can integrate these costs together with the corresponding degrees of protection and radioactive decontamination that are achieved under stated conditions. Consequently, this study is essentially a technical air collection survey with the economics as an important but not the only factor considered in the total appraisal.

It should be clearly noted that at the present time it will continue to be difficult to compare the cost data from one site to the cost data from another since the conditions of collection and the requirements for air cleaning can and do vary considerably. Therefore, it shall be necessary in each instance to include significant qualifying remarks. No attempt in this report or in future reports will be made to compare data from individual sites. The data will be presented with qualifying remarks thus allowing individual comparisons. The differences in situations, however, may make the result of such comparison both unwise and unrealistic.

For an essentially complete analysis of the Economic Survey Program, it seems appropriate that we set forth the following questions for discussion, with respect to the purposes, status and plans of the Program.

What is the purpose of the program?

What progress has been made in the furtherance of this program?

What are the future plans?

Purpose of the Survey

The primary purpose of this survey is to provide appropriate and (physically and economically) efficient air cleaning systems. The prime mover of this survey is the Division of Reactor Development, U.S. Atomic Energy Commission. In the final analysis, however, good administrative and managerial practices in any technical operation require an analysis of the cost and effective use of air cleaning systems.

The methods and the schedules to fulfill the stated objective are listed in Table 1 below.

TABLE 1

Statement of Goal	Scheduled Completion Data	Comments
1. Establish Preliminary Criteria	1956	Criteria set forth on pages 95 to 97 in TID-7551
2. Promulgate the Criteria	1957	Announcement formally made at Fifth AEC Air Cleaning Conference (See TID-7551)
3. Make Preliminary Survey	1959	Eleven sites visited in 1959. See next section on Status of Survey
4. Evaluate Preliminary Data	1959	Preliminary evaluation of survey reported at Sixth AEC Air Cleaning Conference
5. Initiate Final Survey	1959	Includes the development of improved criteria and submission of the criteria to additonal sites for completion
6. Integrate Data	1960	Involves the compilation of all the data into an appropriate form for the most effective use by all concerned.
7. Recommend Appropriate Research	1960	On the basis of the survey, a recommendation will be made with respect to the research required to further the primary objective to provide appropriate and effective air cleaning systems.

8. Communicate Final Findings to Participating Groups	1960	Make available the basic data to the participating groups and obtain their comments and ultimately their acceptance of the material to be submitted in the future for general distribution.
9. Present Data at the Next Air Cleaning Seminar	1961	Make available reviewed data for general discussion and distribution.
10. Compile a Manual	1962	On the basis of the data compiled, draw up a manual on "Air Cleaning Management" for broad use in the Nuclear Industry.

The compilation of data from this survey will aid all sites in the beneficial and economical use of air cleaning systems. Such analysis and discussions have already been proven to be successful in the integration of available data on air cleaning systems. It is also evident that such analyses will indicate the need and type of research that will be most beneficial and effective. The need for a manual on air cleaning systems, their effectiveness and costs with respect to the growing nuclear industry is evident. This survey will serve as the basis for the compilation of an adequate manual that may be effectively used in the nuclear industry.

Status of the Survey

During 1959, eleven major AEC installations were visited wherein the Economic Survey was discussed. These surveyed installations included the Brookhaven National Laboratory, the Savannah River Plant, Oak Ridge National Laboratory, National Lead Company (Fernald, Ohio), the Connecticut Aircraft Nuclear Experimental Laboratory, the Knolls Atomic Power Laboratory, Aircraft Nuclear Propulsion Department, (G.E.), Argonne National Laboratory, Hanford Atomic Products Operations, University of California Radiation Laboratory (Berkeley andLivermore), and the Los Alamos Scientific Laboratory.

The preliminary economical survey criteria as set forth in TID-7551 were discussed. The preliminary data as compiled by the responsible personnel at the corresponding sites are presented in the Appendix. In each instance, the basic objectives of the survey were discussed and the individuals were given complete freedom as to the expression of their physical and economical air cleaning data. Consequently, there has been at this time no attempt made to standardize the data since significant data could have been omitted as a result of such standardization. In addition, the use of qualifying statements was encouraged to assure a more realistic analysis of the air cleaning costs and the effectiveness of these systems with respect to the basic requirements.

In addition, to the material compiled in the Appendix, the personnel of General Electric Atomic Nuclear Propulsion Department in Ohio, have compiled considerable economical data on their air cleaning activities which has not at this time been reduced to tabular form.

Data on air cleaning specifications as set forth by individual sites have been compiled and will be summarized in the final report on the Economic Survey. These specifications are, in general, performance specifications.

Several sites have developed simplified methods of classifying their air cleaning systems and areas. In general, a color code with transparent plastic overlays are employed to indicate the positions and the types of air cleaning systems used in their plants. These methods and procedures of classification will also be summarized in the final report.

Additional material is being prepared by several of the sites listed above and the material will be submitted for compilation into the final report.

The air cleaning systems that were reviewed included systems in reactor areas, separation processing areas, fuel and accessory fabrication areas, production areas, high level pilot plant and nuclear experimental areas. The collection media that are used in the air cleaning systems reviewed included roughing filters, absolute type filters, bag collectors, cyclone separators, electrostatic precipitators, scrubbers oil mist collectors, and deep bed filters. The capacity of these systems varied in flow rates from 10^2 cfm, to 10^7 cfm.

The space requirements range from approximately 10^{-2} ft^3/cfm to 10^{-4} ft^3/cfm. The efficiency requirements vary from 50% to 70% for precleaning filters; 90 to 99% for high efficiency procleaners and final filters; and greater than 99.9% for ultra high collection units. It should be noted here that in most instances, the actual collection efficiencies are not known. However, the "effectiveness" of the unit, in general, is known since measurements of the effluent are made in the stack and/or in the environs such that the occurrence of the release of quantities greater than the maximum permissible levels are prevented. From an operational and regulatory viewpoint, this measurement of the effectiveness of the collection media is more appropriate than a specific analysis of a collection unit using a liquid particle of a narrow particle size range considerably different in structure, particle size, density, etc., than the toxic material in theeffluent. From a cost-effectiveness viewpoint, however, it is somewhat difficult without before and after filter unit sampling data to assign an efficiency to the unit. Since the particle size distribution and the composition of the toxic aerosol can and frequently does change with various operations, an average efficiency would have to be applied. Consequently, a range of efficiencies with respect to a collection medium is presented in Figure 1 which expresses the relationship of the effectiveness of air cleaning systems to cost of these air cleaning operations.

The frequencies at which the collection media are changed vary from period of every two months to once in 10 years. In general, the roughing filters are changed at a frequency twice that required for absolute type filters. The collection media are changed on the basis of pressure drop, time cycle, operational requirements (e.g. time available during reactor shutdown), mechanical failure, pH value of the solution, and observations (indicate unit to be dirty). These collection units are changed when a request is made by a variety of groups including the health physics organization, the industrial hygiene unit, the operations group or the plant maintenance or service section.

The methods of handling, storage and disposal of the filter unit vary considerably from one location to another. Consequently, the costs of these waste management problem vary over a wide range.

Some handling problems involve airborne hazards while others pose a significant external radiation problem. Liquid waste problems may require special processing methods of neutralization. In some instances, materials are incinerated or baled before storage or shipment of the reduced volume to another site for burial or for sea burial.

The actual cost of the air cleaning operations have been expressed on the basis of equipment charges, labor charges and the cost of operations in terms of dollars and/or man-hours per unit volume of air process per year. It will, however, be readily observed that other factors may be more important in the assessment of the cost-efficiency relationship. In some instances, the volume of air processed is maintained at a relatively small value to collect the toxic material near the point of release rather than after dilution in a less toxic atmosphere. In such instances, the cost per curie collected on the filter per year may be a better and more justified assessment of the cost-efficiency relationships. Since, however, the dose-rates from some filter units are relatively higher per curie than from others and therefore requiring more frequent change and a less effective use of man power, etc., the cost per dose-rate per year relationships may be a more realistic ratio than those stated above under certain circumstances. It should be noted that the cost per cfm/year for the cases reviewed in the Appendix vary from $0.0004 to $7.0.

The technical and economical data presented in Appendix I (Tables 1 to 7) permits a preliminary assessment of the relationship between cost and efficiency of the various systems. It should be noted that the cost will vary with respect to the conditions expressed in the last section and the efficiencies will vary with respect to the materials present in the effluent. Consequently, a spread of cost values and efficiencies or penetration are presented in Figures 1 and 2.

In essence, one might expect a specific type (e.g. "Absolute Filter") of air collector that the cost would vary directly with the negative logarithm of the penetration. For composite air collection systems (e.g. Dustop followed by an Absolute Air;Filter) the date presented in Figure 1 indicate that the product of the cost and penetration is a constant. Such an approximation can be theoretically justified for small values of p, as indicated by the equation below:

Thecost-penetration relationships in general may be expressed by the following equation:

$$p = e^{-kC} \qquad (1)$$

where C is in dollars/cfm/year

p is in units of penetration

k = cost absorption coefficient in (cfm) (yr)/dollar

$$lu\ p = kC \qquad (2)$$

$$C = \frac{-2.3}{k} \log_{10} p \qquad (3)$$

For the special case where kC is much smaller than one, the following relationships is a valid approximation since $\frac{1}{p} = e^{kC}$. Since the value of K from the data appears to be in the range of 100 to 1000 cfm years/dollar,

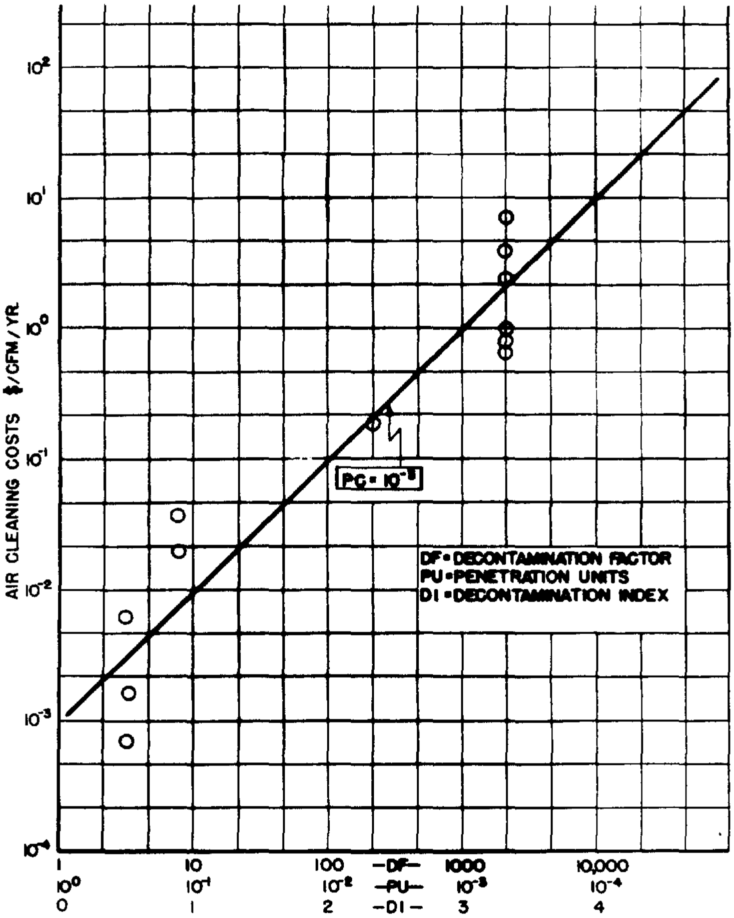

Fig. 1—Cost-penetration relationships of composite air cleaning systems.

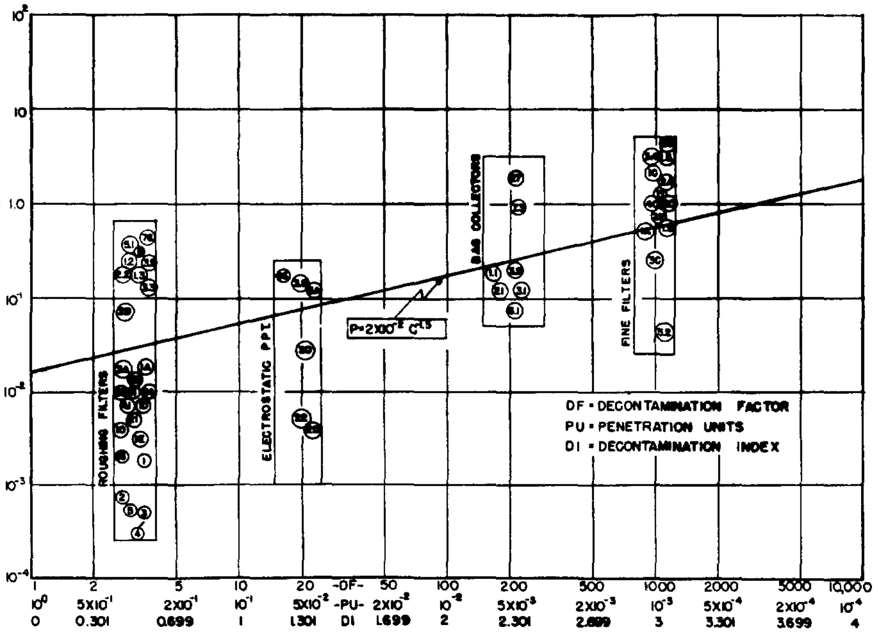

Fig. 2—Unadjusted cost-penetration relationships of individual air cleaning units.

then the cost must be in the range of 10^{-3} to10^{-4} dollars/cfm/year or less to make equation 4 valid.

$$\frac{1}{p} = 1 + kC \qquad (4)$$

$$C = \frac{1}{k}\left(\frac{1}{p} - 1\right) \qquad (5)$$

$$C = K \frac{(1-p)}{p} \quad \text{where } K = \frac{1}{k} \qquad (6)$$

Note that the specific case is only valid for kC values being much smaller than 1 and for values of p within the range of 0.5 to 1.0 (Specific Equation 6 within 20% at lower range).

The data presented in Figure 1 indicate that the cost-penetration for composite air cleaning systems relationship can be expressed by a relationship similar to Equation 6 but over a range of values for p approaching zero from 0.2 (within 25% at high value in the range).

$$C_p = K \cong 1 \times 10^{-3}$$

therefore

$$C = 1 \times 10^{-3}/p$$

The data presented in Appendix II and in Figures 2 and 3 indicate that for individual air cleaning units such as the Dustop Filter or the Absolute Filter, the cost-penetration relationship can be represented by the following equation:

Low Volume Requirement $C = -2.3 \times 10^{-1} \log_{10} P$

High Volume Requirement $P = 2 \times 10^{-3} \ C^{-1.5}$

Since there are so many variables associated with the use of these units, the estimations of the costs and the knowledge of the collection efficiencies, the use of only an approximate value is justified at this time. For comparative purposes, it may be observed that the adjusted costs for air cleaning units in radioactive areas are approximately the same costs determined by Silverman for non-radioactive areas. In the non-radioactive air cleaning systems, the loading may be higher but the waste disposal and handling costs should be less than those associated with radioactive cleaning systems. These factors might explain the agreement in costs but considerable data will be necessary to establish a relationship.

Future Plans

As indicated in Table 1, future plans will involve the reorganization of criteria, the initiation of the final survey, the inclusion of additional sites, the setting forth of recommendation on appropriate research and the compilation of an effective manual on Air Cleaning Systems Their Cost and Effectiveness.

Conclusions

This study to date has indicated the need for an improved system of communication with respect to air cleaning activities within the various laboratories and sites that we may make known in adequate time the findings

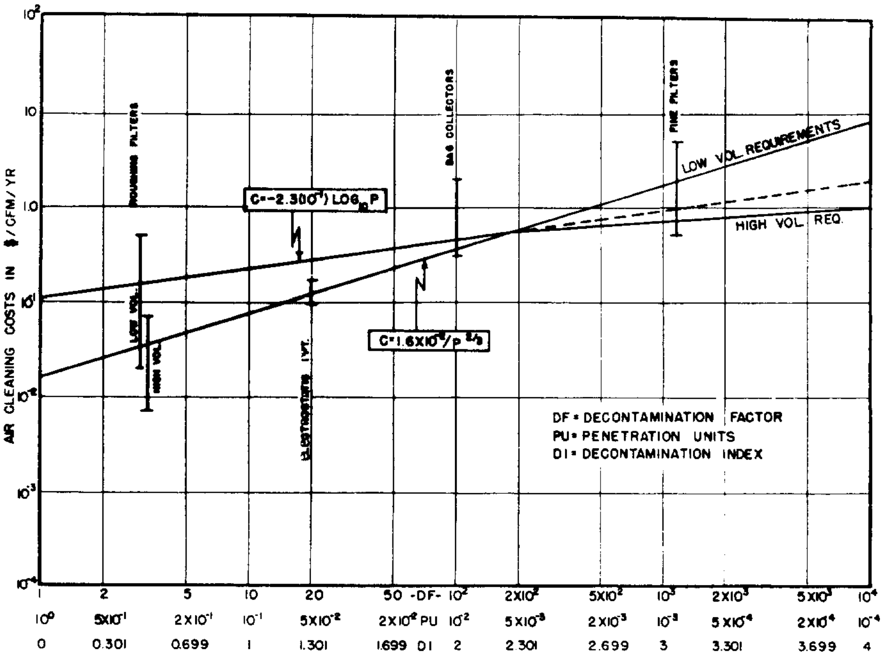

Fig. 3—Adjusted cost-penetration relationships of individual air cleaning systems.

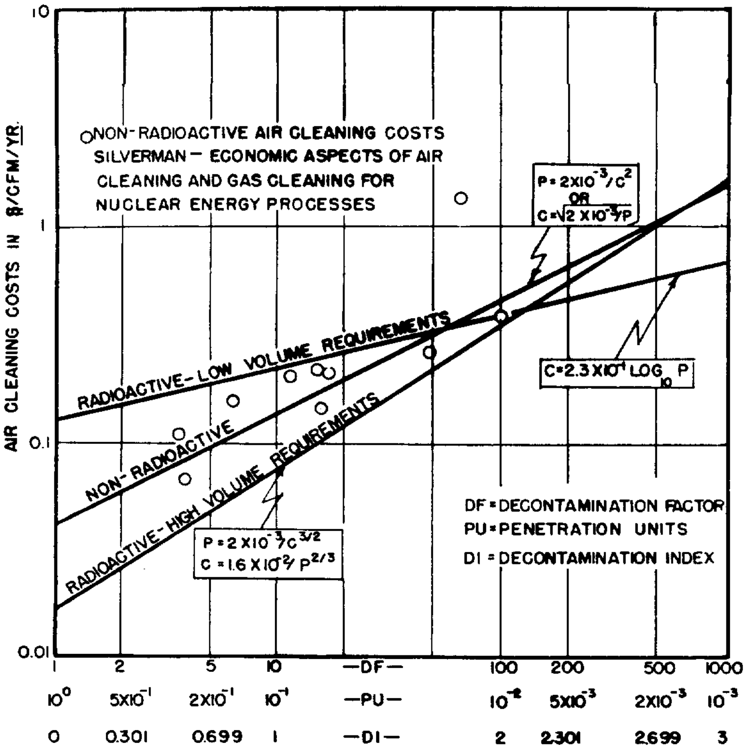

Fig. 4—Comparison of cost-penetration relationships of individual air cleaning units for non-radioactive and radioactive material effluents.

of each Laboratory. In this manner, we may all make progress more rapidly and effectively towards our main objective to provide appropriate and efficient air cleaning systems.

In addition, this preliminary survey has demonstrated the necessity for improved communications between the engineering service groups responsible for the development and maintenance of air cleaning systems and the industrial hygiene or health physics group responsible for the radiological engineering aspects which set the working standards with respect to the maximum permissible penetration of radioactive materials through an air cleaning system.

The preliminary data indicate that an approximate relationship exists between the cost of air cleaning and the maximum permissible penetration of materials through composite air cleaning systems. In general, at the present time we may approximate the cost by the following simplified formula.

$$C = 1 \times 10^{-3}/p$$

To illustrate the use of this formula, the cost of an air cleaning system requiring a collection efficiency of 99% of a penetration value of 10^{-2} would be $10^{-3}/10^{-2}$ or \$.1/cfm/yr. If an efficiency of 99.9% or $p = 10^{-3}$ were required, then the cost would be estimated at \$1/cfm/yr.

For a given maximum permissible penetration, there are many variables associated with the evaluation of the economical aspects of air cleaning. Consequently, all values must be well qualified. Listed below are some of the variables.

(A) Quantity of Air circulated or recirculated

(B) Quality of the air:

  (a) Concentrations of radioactive or toxic material
  (b) Concentration of inert material
  (c) Corrosive effective of material
  (d) Particle size distribution
  (e) Combin ation of filter units and the corresponding flow rates

(C) Operational philosophy:

  (a) Time cycle changing of filter units or cleaning of systems

(D) Quality of the radioactive material collected:

  (a) Dose rate problems
  (b) Airborne problems
  (c) Liquid waste problems

(E) Construction of the air cleaning systems such that operational costs are minimized or lessened.

(F) Managerial aspects influencing and forming policies which refer to the periods in which filter units, etc., are changed by specific groups.

(G) Research costs and the variations of overhead charges

(H) Write-off policy for the depreciation of the constructional materials.

The cooperation and participation in the program survey has been excellent - and the results have been expressedly beneficial to many sites even before the completion of the preliminary survey. All of the data presented are preliminary and they are presented through the courtesy of the Sites representatives that prepared and compiled the data. Although considerable benefits have been mutually accrued as a result of this cooperation and participation, we have at this time merely initiated the survey. Considerable information will be forthcoming in the future. Improved survey forms will be developed and then forwarded to each Site along with a sample copy of a completed form. The final survey is scheduled for completion before the end of next year (1960).

APPENDIX I

Technical and Economical Data

SURVEY OF AIR AND GAS CLEANING OPERATIONS

OAK RIDGE GASEOUS DIFFUSION PLANT
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE
March 23, 1959

NOTE: All equipment cost and labor charges are estimated since records of operating cost are not in this detail.

FILTER LOCATION	EQUIPMENT CHARGES	LABOR CHARGES AVERAGE YEARLY COSTS			DESCRIPTIVE AND OPERATIONAL DATA									REMARKS
	AVERAGE YEARLY COSTS REPLACEMENT PARTS COSTS $	ROUTINE MAINT AND INSPECTION MANHOURS	CLEANING OR REPLACING MEDIA MANHOURS	HANDLING AND DISPOSAL MANHOURS	MANUFACTURER AND/OR TRADE NAME	CLEANER CLASSIFICATION AND TYPE	SITE APPLICATION	MATERIAL HANDLED	MATERIAL REMOVED	SYSTEM CAPACITY SCFM OR CFM	METHOD OF REPLACING OR CLEANING OF MEDIA	CRITERIA FOR CLEANER CHANGES	HANDLING AND DISPOSAL METHODS	
1	2	3	3A	3B	4	5	6	7	8	9	10	11	12	
K-25 Basement Intake Filters	$1.64 4% of Filters per Year	24	864	None Included in Cleaning	Air-Maze Kleen-Flow	Screen Cloth	Building Ventilation	Outside Air	Dust	3,800,000 CFM	Washing & Reoiling	Unable to see thru or Annual	Water to Sewer	NOTE No. 1 - 189 Filters per bank - Two (2) Banks per Unit and 54 Ventilated Units in K-25
K-27 Basement Intake Filters	$200 4% of Filters per Year	6	144	None Included in Cleaning	Air-Maze Kleen-Flow	Screen Cloth	Building Ventilation	Outside Air	Dust	1,630,000 CFM	Washing & Reoiling	Unable to see thru or Annual	Water to Sewer	NOTE: No. 1 - Two (2) banks per unit and Nine (9) ventilated units in K-27
K-29 Basement Intake Filters	$55 4% of Filters per Year	6	176	None Included in Cleaning	Air-Maze Model P-5	Screen Cloth	Building Ventilation	Outside Air	Dust	2,700,000 CFM	Washing & Reoiling	Semi-Annual	Water to Sewer	NOTE No. 1 Eleven (11) banks or 890 filters in K-29
K-31 Basement Intake Filters	$70 4% of Filters per Year	6	244	None Included in Cleaning	Air-Maze Model P-5	Screen Cloth	Building Ventilation	Outside Air	Dust	5,400,000 CFM	Washing & Reoiling	When Dirty or Semi-Annual	Water to Sewer	NOTE No. 1 - Fourteen banks in K-31
K-33 Basement Intake Filters	$150 4% of Filters per Year	6	512	None Included in Cleaning	Air-Maze Model P-5	Screen Cloth	Building Ventilation	Outside Air	Dust	7,200,000 CFM	Washing & Reoiling	When Dirty or Semi-Annual	Water to Sewer	NOTE No. 1 - Two (2) banks per unit and eight units in K-33
K-25, K-29, K-31, & K-33 Alumina Traps	$300 $0.20 per Pound Alumina	100	75	30	5" Always Safe	Coarse Metal & Chemical	Operational Health	UF_6	UF_6		Replace Alumina	High Radiation Signal	Storage or Recovery	NOTE No. 1 - Cleaning done by purging unit traps
K-25, K-27, K-31, & K-33 Alumina Traps & Wet Filters	$1500 $0.20 per Pound Alumina	800	250	100	5" Always Safe	Coarse Metal & Chemical	Operational Health	N_2, Air, & UF_6	UF_6 & Oil	14,000 CFM	Replace Alumina	High Radiation Signal	Storage or Recovery	NOTE No. 1 - Approximately 400 traps in seal exhaust system
K-25 & K-27 Unit Instrument Air Headers	$40	30 for K-25 & K-27	12		Fulflo Commercial Filter	Cotton	Instrument Operation	Air for Instrument Control	Dust & Moisture	150 CFM per Filter See Notes No. 1 & 2	Replace Cotton	Pressure Loss	None	NOTES No. 1 Two filters per unit, 54 units in K-25 No. 2 Two filter per unit, 9 units in K-27
K-25 Cell Instrument Air Header	None	180	20	None	Taylor	Brass Baffles	Instrument Operation	Air for Instrument Control	Dust and Moisture	10 CFM per Filter See Note No. 1	Washed and Dried	Pressure Loss	None	NOTE One filter per cell, 384 cells in K-25
K-29, K-31 & K-33 Unit Instrument Air Header	$50	20	10		Fulflo 15 R/OT	Cotton	Instrument Operation	Air for Instrument Control	Dust	2,000 CFM per Filter See Note No. 1	Replace Cotton	Biannual	None	NOTES No. 1 Two filters per unit, three units in K-29 No. 2 One filter per unit, six units in K-31 No. 3 - One filter per unit, Eight units in K-33
K-29, K-31, & K-33 Cell Instrument Air Header	$250	80	45	None	Fulflo RA-5	Cotton	Instrument Operation	Air for Instrument Control	Dust	30 CFM per Filter See Note No. 1	Replace Cotton	Biannual		NOTES No. 1 Two filters per cell, 170 Cells total in K-29, K-31, & K-33 No. 2 - Refill cost $1.39 each
Plant Air Facilities Bldg K-1201 110 lb Air Intake to Compressors								Compressor Air	Dust	12,800 SCFM See Note No. 1		Annual		NOTES 1 Three compressors rated @ 2,000 CFM, Two compressors rated @ 3400 CFM 2 Filter cleaned in solvent and recoated with oil
Oil Trap	Uses Media from Dryer		16		Big Tank with Alumina	Roughing or Precleaning		Compressed Air	Oil	12,800 SCFM	Use Media from Dryer	Annual	Throw Away	NOTE No. 1 Temp. 100°F Saturated
Moisture Absorber or Dryer			32		Big Tank with Alumina	Roughing or Precleaning		Compressed Air	Moisture	12,800 SCFM	Replace Top Foot of Media	Annual	Use in Oil Traps	NOTES No. 1 - Temp. 40°F Saturated and Dry No. 2 - Two Absorbers per System
Afterfilter	$25 Cost of Felt		8		Rolls of Felt	Final Cleaner		Compressed Air	Dust	12,800 SCFM	Replace Felt	Annual Check	Throw Away	NOTES No. 1 - Temp. 40°F Dry No. 2 Three Filters per System
Bldg K-1101 Intake to Compressor Room	$25		8		Prichard Filters	Pre-Clean Cotton	Prefilter to 1101 Compressor Room	Air	Dust	26,000 SCFM	Replace Cotton Filter	Press. drop across filter shall not exceed 5-10" H2O	Throw Away	NOTE Temp. Atmos.
40 lb Air Moisture Absorber or Dryer										12,000 SCFM				NOTES 1 Four Prichard Filters in 40 lb Facilities 2 No maintenance required since installation 3 Temperature 40°F saturated & dry
3 lb Air Moisture Absorber or Dryer										14,000 SCFM				NOTES 1 Two Prichard Filters in 3 lb facilities 2 No maintenance required since installation 3 Temperature 40°F saturated & dry
K-892 125 lb Air Intake and After Filter										3,000 SCFM				NOTES 1 One intake to compressor and one after-filter in 125 lb facilities 2 No maintenance required since installation 3 Temperature 100°F
Powerhouse Stacks (5 Boilers)	No Replacement Cost to Date	90 for Inspection 1260 for Maint and Adjustment of Rectifier		2190	Cottrell Precipitator made by Research Corporation	Electrostatic Precipitator	Clean Exhaust Air Located in Gas Stream Prior to Boiler Stack	Non Combustible Ash from Coal and Gas to Stacks	Fly Ash	960,000 CFM See Note No. 1 & 2		Hopper Being Full	Fly Ash collected and dumped in Settling Dump in field	NOTES 1 One precipitator for each boiler. 2 Each precipitator shall remove 90% of the fly ash in gas under full load conditions of 320,000 CFM of flue gas at 360°F and the precipitator will not exceed 0.20" H2O at this rate of flow 3 Power costs for these precipitators is $6,307/yr
K-33 Switchhouse	300 gal of Oil @ 31¢/gal = $93	128			Continental Air Filter Inc Louisville, Ky Model 14-125	Rotating Screen Viscous Type	Supply Air General Ventilation for Equipment	Outside Air	Dust	108,000 CFM	Change Oil and Clean Screen	Annual	Drain Oil and Throw Away	NOTE 1 Two rotating screens in K-33 switch house
K-33 Switch house	None	16			Westinghouse Electric and Manufacturing Co	Electrostatic Precipitator	Ventilation for Equipment	Outside Air	Dust	19,000 CFM 333 F.P.M.	Air Purge and Wipe Precipitator Plates	Annual	Throw Away	NOTES 1 One precipitator for K-33 switch house 2 Dimensions 7'-6" hgt x 10'-0" wide
K-31 Switch house	200 gal of Oil @ 31¢/gal = $62	128			Continental Air Filter Inc Louisville, Ky. Model MS Size 9-96	Rotating Screen Viscous Type	Ventilation for Equipment	Outside Air	Dust	66,400 CFM	Change Oil and Clean Screens	Annual	Drain Oil and Throw Away	NOTES 1 Two rotating screens in K-31 switch house
K-27 Switch house	300 gal of Oil @ 31¢/gal = $93	192			Continental Air Filter Inc Louisville, Ky. See Note No. 1	Rotating Screen Viscous Type	Supply Air General Ventilation for Equipment	Outside Air	Dust	120,000 CFM	Change Oil and Clean Screens	Annual	Drain Oil and Throw Away	NOTES 1 Three rotating screens in K-27 switch house. Two (2) model MS & one (1) model V Both size 9-124
K-25 Switch house	300 gal of Oil @ 31¢/gal = $93	192			Continental Air Filter Inc Louisville, Ky Model MS Size 12-134	Rotating Screen Viscous Type	Supply Air General Ventilation for Equipment	Outside Air	Dust	180,000 CFM	Change Oil and Clean Screens	Annual	Drain Oil and Throw Away	NOTES 1 Two rotating screens in K-25 switch house
K-1421 Incinerator Stack			10		Hersh Cadmus & Ventilator Inc	Aerodyne Collector Type C Mechanical See Note No. 1	Final Cleaning Exhaust Air Production Area	Fly Ash Flue Gases	Fly Ash	8900 CFM	Vacuum Cleaning	Pressure Loss or Mechanical Failure	Burial or Storage	NOTES 1 This filter consists of a primary and secondary system. The primary consists of louvered filter. The secondary consists of a cyclone separator which collects the dust from the exhaust stream.
K-1420 Central Vacuum Cleaner	$784		56	6	The Spencer Turbine Co	Aeroturn Dust Collector Mechanical	Final Cleaning Exhaust Air Production Area	UF_6 U Oxides	UF_6 U Oxides	600 CFM	Replacement of Felt Bags	Pressure Loss or Mechanical Failure	Incineration	NOTES 1 This system consists of a primary and secondary filters. The primary consist of a cyclone separator. The secondary consists of four felt bag filters
K-1420 Vent System for Drum Dryer & Calciner for Product Recovery Feed	$132		8	4	Cambridge	Absolute Type	Final Cleaning Exhaust Air Production Area	U Oxides and Compounds Formed from Calcining	U Oxides	50 CFM @ 1" Water	Replacement of Filter Unit	Pressure Loss	Incineration	

Table 1 ORNL, K-25 Data

Table 2 ORNL, X-10 Data

BUILDING AND GENERAL USE	TYPE OF SYSTEM	CLEANER	SITE APPLICATION	CLEANING REQUIREMENT	SPACE REQUIREMENT	OPERATING CHARACTERISTICS	METHOD OF REPLACEMENT AND/OF CLEANING	CRITERIA FOR CLEANER CHANGES	COMMENTS	FREQUENCY OF FILTER CHANGE	MANPOWER (HOURS) REQUIRED PER CHANGE
3001 - Graphite Pile Reactor Cooling	Intake air for reactor cooling	Weather Louver and screen AAF PL-24 with 10 ply		Remove atmospheric dust		100 units Approximately 6700#/min flow	Replace media during reactor down period	Regular schedule or excessive drop		Once per year	12 hrs - millwright 12 hrs - Laborer 1 hr - foreman
	Exhaust air from reactor cooling	Prefilter - AAF Deep pocket - Fo-25-FG 50 media - 30 units - Final fire resistant Absolute - 25 x 24 x 11-1/2 - 60 units	Separate filter house with shielding	Filter particulate matter before release to atmosphere		Approximately 7400#/min flow	Replace media during reactor down period when activity level permits	Excessive pressure drop or ruptured unit(s	Change is a routine operation normally scheduled	Once every 4 - 5 years	12 hrs - rigger 4 hrs - Utility men 56 hrs - operator 65 hrs - laborer
3517 - Multicurie Fission Products Pilot Plant	Cell Ventilation Intake Air for cell space ventilation	2" throwaway (20 x 20 x 2)	Mounted at cell wall taking in inside building air	Remove sizeable atmospheric particulate	Approximately 4 cu-ft/ unit for each of 15 cells	Average 200 cfm/unit	Use new filter unit	Visual inspection of dirtiness	Used to assist cell cleanliness	No experience, system new and not yet properly adjusted.	
	Work Cell exhaust	2" throwaway (20 x 10 x 2)	Inside cell space	Remove sizeable particulate	Approximately 3 cu ft/ unit for each of 4 cells	Approximately 400 cfm/ unit	New filter unit by remote manipulation	Visual inspection of dirtiness or excessive activity	Space arrangement originally designed to accommodate AAF type H filter also	Changed once after 5 months of operation	4 hrs - rigger 4 hrs - millwright 2 hrs - operator
	Exhaust air from work cells and process cells	Prefilter - AAF Type H 20 x 20 x 2 - 16 units Final - fire resistant Absolute - 24 x 24 x 11-1/2 - 12 units	Underground shielded box (concrete) with surface access. Effluent conveyed by underground duct to 3039 stack	High efficiency particulate removal		3600 to 4000 cfm normal 12,000 cfm maximum flow during open cell operations Approximately 2 hp/1000 cfm	Raise bundled filters into plastic bagging and/or shielded coffin	Excessive pressure drop or radiation. (Considered for needs of long uninterrupted cell operations.)	Put into operation in Summer 1958. Filters removed to burial ground. System effluent discharged from 3039 stack (250 ft high)	One change of final filters to date	
3019 - Pilot Plant	Cell Ventilation (A) Exhaust air from cell spaces (C) plus thorium oxide furnace operations	Prefilter - AAF Deep pocket FG25 - FG50 media - 21 units Final - Fire resistant absolute - 24 x 24 x 11-1/2 - 18 units	Shielding box (concrete) at grade with top plug access 3 compartment arrangement after filtering effluent is discharged from 200 ft stack (3020)	High efficiency particulate removal		Normal 22,300 cfm flow Approximately 1.4 hp/ 1000 cfm	Intend to change filters by compartments with 2/3 remaining operable. New media in reuseable prefilter frames, and full filter unit replacement for final	Excessive pressure drop, failure of filters by corrosion or excessive activity	System put into operation 4/58: no filter changes to date. New 40 hp Class III fan unit scheduled to replace existing 30 hp fan unit	No filter changes to date.	
	Cell Ventilation (B) Exhaust air from cell spaces on west end plus laboratory hoods handling both corrosive and radioactive materials	Individual filters (absolute) on hoods only. Cell effluent not filtered.	Effluent is discharged from 200 ft stack (3020)	Remove mild conditions of fumes and airborne particulate from cells and hoods.		Continuous operation Approximately 22,000 cfm flow.			System of ductwork and emergency standby changes made 4/52.		
3039 - Stack Area	Cell ventilation air handling facilities for 4 central systems terminating from the same stack	No filters at this location except for one building (3042) which which serve as backup filters for "incell" filtration	Fenced area with limited access All effluent is discharged from a 250 ft stack		Area covers approximately 100' x 100'	Interconnecting ducts for manual standby conditions. Maximum possible flow approximately 200,000 cfm Normal - 50 to 70% maximum - 1.3 hp-1000 cfm.	Area includes two (2) interconnected steam driver standby fans affording approximately 40% maximum flow.		Plant radioactive off gas cleaning facilities are at this site also.	Filters for building 3043 changed approximately once every 6 months	3 hrs - millwright 3 hrs - rigger 3 hrs - operator 3 hrs - driver 1 hr - foreman
	Radioactive off gas cleaning for central system serving major part of plant area.*	Cottrell electrostatic precipitator followed by absolute type filters. Effluent is discharged from 250 ft stack (3039)	Above grade installation inside fenced area. Some shielding Dual final filters to minimize shutdown and allow decay of activity before removal.	High efficiency particulate removal	Utilizes approximately 700 sq ft of the 3039 stack area.	Maximum flow considered as 2000 cfm. Present normal approximately 1200 cfm. System uses 10 hp fan giving 9"wg negative pressure at suction.	Scheduled washdown of precipitator (manual); and replacement of absolute filters.	Arcing of precipitator and/or rigid schedule Filters - High activity or physical failure.	Recent trouble experience in filter failure due to high concentration of fumes - new type filter construction being sought.		

*Design is in progress which is expected to increase the plant radioactive off gas system flow capacity to 5000 cfm (total) and provide additional cleaning facilities for the 4000 cfm increase. The site of this equipment is expected to be near the 3039 stack area.

DESCRIPTIVE AND OPERATIONAL DATA

System Component	A. Manufacturer	B. Trade Name	C. Cleaner Classification & Type			D. Site Application					E. Cleaning Requirement & Process				F. Space Requirement		
			1. Roughing or Pre-Cl. Fan	2. High Eff. Pre-Cl. or Final Cleaner	3. Ultra Absolute Type	1. Prefilter (Supply)	2. Pre-Cl. (Exh.)	3. Final Clean.	4. After Clean.	5. Product Recov.	1. Dust Misc. Fume, Vapor, Rare Gases	2. Aerosol Composition	3. Particle Size Characteristics	4. Concentration - Wt. or Activity per Unit Volume of Gas	1. Overall Dimen. (Unit Col.) & Cap. CFM L x W x H	2. Cu. Ft. /CFM Clean. Cap.	3. Face Area /1000 CFM Clean. Cap.
BUILDING 9215 - SUPPLY AIR SYSTEM																	
(1) Filter	Continental Air Filter	Auto. Self-Clean.	Oil Coated Metal Screens	-	-	*	-	-	-	-	Dust	-	-	-	430,000 cfm	.033	5.5 sq.ft.
BUILDING 9766 - SPECIAL PROJECTS SHOP EXHAUST SYSTEM																	
(1) Filter	Farr	Automatic	Oil Coated Metal Screens	-	-	-	*	-	-	*	Dust	-	-	-	16,000 cfm	.081	41.8 sq.ft.
(2) Filter	Cambridge M.S.A. - Flanders	Absolute	-	-	All Glass	-	-	*	-	*	Dust	-	-	-	1,000 cfm	.00385	4 sq.ft.
BUILDING 9212 & 9998 - SUNFLOWER DUST COLLECTOR SYSTEM																	
(1) Bag Col.	Turner & Haws	Aeroturn	-	Felted Fabric (Wool)	-	-	-	*	-	*	Dust	-	-	-	42' x 9.5' x 32' x 2 units 300,000 cfm	.050	42.3 sq.ft.
BUILDING 9206 - WASTE INCINERATOR																	
(1) Cyclone	Cambridge M.S.A. - Flanders	Absolute	-	-	All Glass	-	-	*	-	*	Dust	-	-	-	2,200 cfm	.00385	4 sq.ft.
(2) Filter	Ducon Co.	Duclone Collect.	Cyclone	-	-	-	*	-	-	*	Dust	-	-	-	1,100	.00545	-
(3) Filter	Turner & Haws	Misc Filter	Woven or Felted Fabrics	-	-	-	*	-	-	*	Dust	-	-	-	2,200	.035	4.38 sq.ft.
BUILDING 9211 - NICHOLS-HERRESHOFF FURNACE EXHAUST SYSTEM																	
(1) Cyclone	Dustex	Multi-Cyclone	*	-	-	-	*	-	-	*	Radioactive Dust	-	Varies	-	18" x 40" x 60" 800 cfm	0.03	-
(2) Bag Col.	AAF	Amerjet	-	*	-	-	-	*	-	-	Radioactive Dust	-	Minus 15 Micron	-	67" x 55" x 161" 3,500 cfm	0.092	67.4

Table 3 ORNL, Y-12 Data

ECONOMIC SURVEY OF AIR & GAS CLEANING OPERATIONS
TYPICAL SYSTEMS IN OPERATION AT Y-12 PLANT
UNION CARBIDE NUCLEAR CO. - OAK RIDGE, TENN.

Information for J. J. Fitzgerald
Harvard University School of Public Health

June 22, 1959

DESCRIPTIVE AND OPERATIONAL DATA

System Component	A. Manufacturer	B. Trade Name	C. Cleaner Classification & Type			D. Site Application					E. Cleaning Requirement & Process				F. Space Requirement		
			1.Roughing or Pre-Cl. Fan	2.High Eff. Pre-Cl. or Final Cleaner	3.Ultra Absolute Type	1.Prefilter (Supply)	2.Pre-Cl. (Exh.)	3.Final Clean.	4.After Clean.	5.Product Recov.	1.Dust Misc. Fume, Vapor, Rare Gases	2.Aerosol Composition	3.Particle Size Characteristics	4.Concentration - Wt. or Activity per Unit Volume of Gas	1.Overall Dimen. (Unit Col.) & Cap. CFM L x W x H	2.Cu.Ft. /CFM Clean. Cap.	3.Face Area /1000 CFM Clean. Cap.
BUILDING 9212 - "E" WING MAIN EXHAUST SYSTEM																	
(1)Bag Col.	Pulverizing Mach.	Mikro-Col.	-	Felted Fabric (Wool)	-	-	-	*	-	*	Dust	-	-	-	15' x 11' x 29' 64,000 cfm	.046	89.4
(2)Filter	Continental Air Filter	CA-24	Synthetic	-	-	-	*	-	-	*	Dust	-	-	-	1,000 cfm	.0035	4 sq.ft.
(3)Filter	American Air Filter	FL-24	10-Ply Paper	-	-	-	*	-	-	-	Dust	-	-	-	1,000 cfm	.0035	4 sq.ft.
(4)Filter	Cambridge M.S.A. - Flanders	Absolute	-	-	Cellulose Asbestos	-	-	*	-	*	Dust	-	-	-	1,000 cfm	.00385	4 sq.ft.
(5)Filter	-	Absolute	-	-	Cellulose Asbestos	-	-	*	-	*	Dust	-	-	-	50 cfm	.0004	8.9 sq.ft.
BUILDING 9215 - "M" WING EXHAUST SYSTEM																	
(1)Bag Col.	Western Precipitation	Dual-Aire	-	Felted Fabric (Wool)	-	-	-	*	-	*	Dust	-	-	-	24' x 18' x 28' 85,000 cfm	.036	37.4 sq.ft.
(2)Filter	American Air Filter	FL-24	10-Ply Paper	-	-	-	*	-	-	*	Dust	-	-	-	1,000 cfm	.0035	4 sq.ft.
BUILDING 9215 - "O" WING EXHAUST SYSTEM																	
(1)Bag Col.	Western Precipitation	Dual-Aire	-	Felted Fabric (Wool)	-	-	-	*	-	*	Dust	-	-	-	24' x 18' x 28' 85,000 cfm	.036	37.4 sq.ft.
(2)Filter	Continental Air Filter	CA-24	Synthetic	-	-	-	*	-	-	*	Dust	-	-	-	1,000 cfm	.0035	4 sq.ft.
(3)Filter	American Air Filter	FL-24	10-Ply Paper	-	-	-	*	-	-	*	Dust	-	-	-	1,000 cfm	.0035	4 sq.ft.
(4)Filter	Cambridge M.S.A. - Flanders	Absolute	-	-	Cellulose Asbestos	-	-	*	-	*	Dust	-	-	-	1,000 cfm	.00385	4 sq.ft.
(5)Oil Mist Collector	Westinghouse Elec. Corp.	Oil Mist Prec.	-	High Voltage Electrostatic	-	-	*	-	-	-	Oil Vapor	-	-	-	1,200 cfm	.15	4 sq.ft.

(Continued)

DESCRIPTIVE AND OPERATIONAL DATA (Con't.)

G. Operating Characteristics														H. Method of Replacement or Cleaning of Media					
1.Fil. Vel. FPM	2.Pressure Loss - In. Water		3.Power Requirements (HP Per 1000 CFM Air)				4.Cleaner Service Life		5.Operating Temp. & Humidities	6.Water or Scrubbing Liquid Vol./1000 CFM Air			7.Col. Eff. Wt. & Act. Basis	1.Washing & Steam Clean.	2.Washing & Re-oiling	3.Replacement of Filter Media	4.Replacement of Complete Unit - i.e. Dust Stop or Absolute	5.Vacuum Cleaning	6.Other
	Initial	Max. Allow.	a.Fan System		b.Water Sprays or Scrub. Liquid Pump HP /1000 CFM Air	c.Elec. Power for Electrostatic Precipitators KW/1000 CFM Air	a.Before Clean. or	b.Replacement		a.Spray Nozzle Type & lbs./Sq.In.	b.Percent Recycle	c.Chemical Requirements lbs. reagent/1000 CFM Air							
			Base Clean. Press. Loss Only	Base Entire System															
11.4	1.00	5.00	1.22	1.89	-	-	-	6 Months	70°F, 50%	-	-	-	-	-	-	*	-	-	-
85.70	.10	.50	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	*	-	-	-
36.00	.15	.50	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	*	-	-	-
4.5	1.0	4.0	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	-	*	-	-
4.5	1.0	4.0	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	-	*	-	-
26.7	1.00	5.00	1.70	2.46	-	-	-	6 Months	70°F, 50%	-	-	-	-	-	-	*	-	-	-
36.0	.15	.50	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	*	-	-	-
26.7	1.00	5.00	1.39	2.16	-	-	-	6 Months	70°F, 50%	-	-	-	-	-	-	*	-	-	-
65.70	.10	.50	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	*	-	-	-
36.00	.15	.50	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	*	-	-	-
4.5	1.0	4.0	-	-	-	-	-	1 Month	" "	-	-	-	-	-	-	-	*	-	-
300	.50	1.50	.417	-	-	.050	1 Month	-	98°F	-	-	-	-	*	-	-	-	-	-
310	.328	-			-	-	-	-	Varies	-	-	-	-	-	*	-	-	-	-
382	.30	-	-	3.1	-	-	-	-	70°F, 50%	1.83 H2O .62 Oil	-	-	-	-	*	-	-	-	-
3	1.0	4.0	-	-	-	-	-	2 Years	" "	-	-	-	-	-	-	-	*	-	-
25.6	1.0	5.00	1.13	1.77	-	-	-	1 Year	70°F, 50%	-	-	-	-	-	-	*	-	-	-
2.5	0.5	4.0	2.7	4.5	-	-	-	Varies	150°F	-	-	-	-	-	-	-	*	-	-
2390	-	4.0	2.7	4.5	-	-	-	-	300°F	-	-	-	-	-	-	-	-	-	Clean Product Receiver
228	1.0	4.0	2.7	4.5	-	-	-	Varies	150°F	-	-	-	-	-	-	*	-	-	-
-	4	4	0.625	2.18	-	-	None Req'd.	Years	150°F	-	-	-	-	-	-	-	-	-	-
15	6	6	0.94	2.18	-	-	Continuous	-	90°F	-	-	-	-	-	-	*	-	-	-

DESCRIPTIVE AND OPERATIONAL DATA (Con't.)

I. Criteria for Cleaner Changes					J. Handling and Disposal Methods					K. Comments Relative to Foregoing Items			
1.Pressure Loss	2.Activity	3.Time Cycle	4.Other - (Mech. Failure Due to Erosion, Corrosion, Design or Application)	5.Who Determines Criteria for Maintenance (Health Phys., Engineering, Industrial Hygiene, Maintenance)	1.Personnel Protection	2.Packaging	3.Baling	4.Incineration	5.Burial or Storage	1.Reason for Selection of Any One Type Cleaner	2.Is Device Satisfactory as to Quality of Cleaning - Overall Cost?	3.Suggestion for Improving Based on Field Experience	4.Recommended Research
-	-	*	Material Recovery	Chem. Operations	Respirators	Plastic Bags	-	*	-	Efficiency Low Maint.	Yes	-	-
*	-	*	"	"	"	"	-	*	-	Material Recovery	"	-	-
*	-	*	"	"	"	"	-	*	-	Adequate Pre-Filter	"	-	-
*	-	*	"	"	"	"	-	*	-	Efficiency Material Recov.	"	-	-
*	-	*	"	"	"	"	-	*		"	"	-	-
-	-	*	Material Recovery	Mech. Operations	Respirators	Plastic Bags	-	*	-	Efficiency Low Maint.	Yes	-	-
*	-	*	"	"	"	"	-	*	-	Adequate Pre-Filter	"	-	-
-	-	*	Material Recovery	Mech. Operations	Respirators	Plastic Bags	-	*	-	Efficiency Low Maint.	Yes	-	-
*	-	*	"	"	"	"	-	*	-	Material Recovery	"	-	-
*	-	*	"	"	"	"	-	*	-	Adequate Pre-Filter	"	-	-
*	-	*	"	"	"	"	-	*	-	Efficiency Material Recov.	"	-	-
-	-	-	-	"	"	-	-	-	-	Efficiency	"	-	-
-	-	*	-	-	-	-	-	-	-	Efficiency Adeq. Filter	Yes	-	-
-	-	-	-	Mech. Operations	-	-	-	-	-	Automatic Features	Yes	-	-
*	-	-	-	"	Respirators	Plastic Bags	-	-	*	Efficiency	"	-	-
-	-	*	Material Recovery	Mech. Operations	Respirators	Plastic Bags	-	-	*	Efficiency	Yes	-	-
*	-	-	-	Chem. Operations	Respirators	Plastic Bags	-	-	*	Efficiency	Yes	-	-
-	-	*	Material Recovery	"	"	*	-	-	-	Adequate Pre-Filter	"	-	-
*	-	-	"	"	"	*	-	-	-	Pre-Filter	No	Better Media	-
-	-	-	Mechanical Failure	Operations	-	-	-	-	-	High Efficiency Low Maint.	Yes	-	-
-	-	-	Mechanical Failure	Operations	Respirators	-	-	*	-	High Efficiency Low Maint.	Yes	-	-

GAS CLEANING COSTS

System Component	I. Equipment Charges - Average Yearly Costs							
	A. Initial Collector Cost $/1000 cfm	B. Item A Based on 5 to 10 Yr. Write Off - $/1000 cfm/Yr. (Indicate Write Off Period)	C. Replacement Parts Overall Yearly Cost - $/1000 cfm/Yr.					D. Replacement Parts (Item C) Cost/Standard Replacement Unit
			1. "Throw Away"- Roughing Type	2. Ultra Filters AEC Type	3. Replacement Media	4. Filter Bags	5. Other	
BUILDING 9212 - "E" WING MAIN EXHAUST SYSTEM								
(1)Bag Collector	$308.20	$61.54 Five (5) Yr. Write-off	-	-	-	$130.00	-	$65.00/bag
(2)Filter	35.30	7.06 "	-	-	$81.60	-	-	6.80/blanket
(3)Filter	30.00	6.00 "	-	-	81.60	-	-	6.80/roll
(4)Filter	43.00	8.60 "	-	$516.00	-	-	-	43.00 ea.
(5)Filter	141.20	28.24 "	-	1694.00	-	-	-	7.06 ea.
BUILDING 9212 - "M" WING EXHAUST SYSTEM								
(1)Bag Collector	$302.00	$60.40 Five (5) Yr. Write-off	-	-	-	$ 65.00	-	$43.02/bag
(2)Filter	30.00	6.00	-	-	$81.60	-	-	6.80/roll
BUILDING 9215 - "O" WING EXHAUST SYSTEM								
(1)Bag Collector	$302.00	$60.40 Five (5) Yr. Write-off	-	-	-	$ 65.00	-	$43.02/bag
(2)Filter	35.30	7.06 "	-	-	$81.60	-	-	6.80/blanket
(3)Filter	30.00	6.00 "	-	-	81.60	-	-	6.80/roll
(4)Filter	141.20	28.24 "	-	$1694.00	-	-	-	7.06 ea.
(5)Oil Mist Col.	583.00	116.60 "	-	-	-	-	$12.00	7.00/set
BUILDING 9215 - SUPPLY AIR SYSTEM								
(1)Filter	$ 38.00	$ 7.60 Five (5) Yr. Write-off	-	-	-	-	$ 0.06	$ 0.25 gal.
BUILDING 9766 - MACHINE EXHAUST SYSTEM								
(1)Filter	$2000.00	$400.00 Five (5) Yr. Write-off	-	-	-	-	$0.007 0.17	0.07/1000 gal. water 0.25 gal. oil
(2)Filter	30.00	6.00 "	-	$ 30.00	-	-	-	$60.00
BUILDINGS 9212 & 9998 - SUNFLOWER AREA MACHINE & FOUNDRY EXHAUST SYSTEM								
(1)Bag Collector	$250.00	$50.00 Five (5) Yr. Write-off	-	-	-	$ 27.75	-	$65.00
BUILDING 9206 - WASTE DESTRUCTOR EXHAUST SYSTEM								
(1)Filter	$ 65.00	$13.00 Five (5) Yr. Write-off	-	$1200.00	-	-	-	None
(2)Cyclone	677.00	135.40 "	-	-	-	-	$317.00	None
(3)Filter	3820.00	764.00 "			$58.00			$58/change
BUILDING 9211 - NICHOLS-HERESHOFF FURNACE EXHAUST SYSTEM								
(1)Cyclone	$1187.50	$237.50 Five (5) Yr. Write-off	-	-	-	-		0.24
(2)Bag Collector	1208.30	241.60 Five (5) Yr. Write-off	-	-	-	-	-	

GAS CLEANING COSTS (Con't.)

II. Labor Charges - Overall Yearly Cost

	A. Installation Over & Above Equipment Cost Based on Equipment Write-Off Period Man Hours/1000 CFM/Year	B. Routine Maintenance & Inspection Man Hours/1000 CFM/Year	C. Cleaning or Replacing Filter Media Man Hours/1000 CFM/Year	D. Handling & Disposal Man Hours/1000 CFM/Year	E. Labor Charges - Individual Filter Replacement Man Hours/1000 CFM/Year		
					1. Cloth Bags	2. Absolute Filter	3. Other
			BUILDING 9212 - "E" WING MAIN EXHAUST SYSTEM				
(1)	Lump-Sum Contract	.48	.50	.50	1.48	-	-
(2)	.50	-	15.00	15.00	-	-	30.00
(3)	.50	-	15.00	15.00	-	-	30.00
(4)	8.00	-	6.00	6.00	-	12.00	-
(5)	6.00	-	120.00	120.00	-	240.00	-
			BUILDING 9212 - "M" WING EXHAUST SYSTEM				
(1)	Lump-Sum Contract	.48	.50	.50	1.48	-	-
(2)	"	-	15.00	15.00	-	-	30.00
			BUILDING 9215 - "O" WING EXHAUST SYSTEM				
(1)	Lump-Sum Contract	.48	.50	.50	1.48	-	-
(2)	"	-	15.00	15.00	-	-	30.00
(3)	"	-	15.00	15.00	-	-	30.00
(4)	"	-	120.00	120.00	-	240.00	-
(5)	"	1.00	2.00	-	-	-	3.00
			BUILDING 9215 - SUPPLY AIR SYSTEM				
(1)	Lump-Sum Contract	.07	.009	-	-	-	.079
			BUILDING 9766 - MACHINE EXHAUST SYSTEM				
(1)	-	.13	-	.75	-	-	.88
(2)	-	-	.53	.27	-	.80	-
			BUILDINGS 9212 & 9998 - SUNFLOWER AREA MACHINE & FOUNDRY EXHAUST SYSTEM				
(1)	Lump-Sum Contract	.43	.25	.25	.98	-	-
			BUILDING 9206 - WASTE DESTRUCTOR EXHAUST SYSTEM				
(1)	Lump-Sum Contract	1.00	20.00	10.00	-	31.00	-
(2)	"	-	-	30.00	-	-	30.00
(3)	"	-	13.30	6.65	-	-	19.95
			BUILDING 9211 - NICHOLS-HERESHOFF FURNACE EXHAUST SYSTEM				
(1)	-	-	-	-	-	-	-
(2)	-	-	-	-	-	-	-

GAS CLEANING COSTS (Con't.)

F. Costs - Clean Out & Repair of Hoods, Ductwork, Decontamination, Etc.	G. Miscellaneous Costs 1. Average Cost of Lost Production Due to Equipment Down Time	2. Fan Maintenance	3. Costs of Air Cleaning (% of Total Plant Maintenance)	4. Indirect Costs (Time to Other Departments Chargeable to Equipment Failure or Maintenance) i.e. Health Physics, Engineering, Etc.
BUILDING 9212 - "E" WING MAIN EXHAUST SYSTEM				
(1) $ .062	-		-	-
(2) 2.00	-		-	-
(3) 2.00	-		-	-
(4) -	-		-	-
(5) -	-		-	-
BUILDING 9212 - "M" WING EXHAUST SYSTEM				
(1) .062	-		-	-
(2) 2.00	-		-	-
BUILDING 9215 - "O" WING EXHAUST SYSTEM				
(1) .062	-		-	-
(2) -	-		-	-
(3) -	-		-	-
(4) -	-		-	-
(5) -	-		-	-
BUILDING 9215 - SUPPLY AIR SYSTEM				
(1) -	-		-	-
BUILDING 9766 - MACHINE EXHAUST SYSTEM				
(1) -	-		-	-
(2) -	-		-	-
BUILDINGS 9212 & 9998 - SUNFLOWER AREA MACHINE & FOUNDRY EXHAUST SYSTEM				
(1) .155	-		-	-
BUILDING 9206 - WASTE DESTRUCTOR EXHAUST SYSTEM				
(1) 10.00	-		-	-
(2) -	-		-	-
(3) 10.00	-		-	-
BUILDING 9211 - NICHOLS-HERESHOFF FURNACE EXHAUST SYSTEM				
(1) -	-		-	-
(2) -	-		-	-

Table 4 CANEL Project Data

SURVEY OF AIR & GAS CLEANING OPERATIONS
PRATT & WHITNEY AIRCRAFT - CANEL
MAY 27, 1959

Bldg. No. & Location	Descriptive & Operational Data									Equip.	Labor Charges - Dollars		
	Mfg. and/or Trade Name	Cleaner Classification & Type	Site Application	Cleaning Requirements	Space Requirements	Operating Characteristics	Method of Replacing or Cleaning	Criteria for Cleaner Change	Handling & Disposal Method	Charges Yearly	Maintenance & Inspection	Yearly Cleaning & Replacement	Disposal
Bldg. 440					Model 3A-85	CFM							
HV-1	Cambridge	Aerosolve	FA & RC	Dust	(6))	6150	None	Time Cycle	Incineration	$	$6.00	$ 4.00	$ 4.00
	Dust Stop	Spun Glass	FA & RC	Dust	(6) 23 3/8 x 23 3/8 x 2)		None	Time Cycle	Incineration	56.16	18.00	8.00	8.00
AC-2	Cambridge	Aerosolve	FA	Dust	(2) 3A-85)	1800	None	Time Cycle (1)	Incineration		2.00	2.00	2.00
	Dust Stop	Spun Glass	FA	Dust	(2) 23 3/8 z 23 3/8 x 2)		None	Time Cycle (6)	Incineration	18.72	4.00	6.00	6.00
					Model 1A-1000)								
AC-3	Cambridge	Absolutes	FA	Dust	(3) 24 x 24 x 11 1/2)	2800	None	Time Cycle (0)		168.00	4.00		
	Dust Stop	Spun Glass	FA	Dust	(3) 23 3/8 x 23 3/8 x 2)		None	Time Cycle (6)	Incineration	28.08	4.00	8.00	6.00
AC-4	Cambridge	Aerosolve	FA & RC	Dust	(4) 3A-85)	3500	None	Time Cycle (1)	Incineration		16.00	5.00	2.00
	Dust Stop	Spun Glass	FA & RC	Dust	(4) 23 3/8 x 23 3/8 x 2)		None	Time Cycle (6)	Incineration	37.44	4.00	8.00	6.00
AC-5	Cambridge	Aerosolve	FA & RC	Dust	(3) 3A-85)	3300	None	Time Cycle (1)	Incineration		12.00	2.00	2.00
	Dust Stop	Spun Glass	FA & RC	Dust	(3) 23 3/8 x 23 3/8 x 2)		None	Time Cycle (6)	Incineration	28.08	4.00	8.00	6.00
AC-6	Cambridge	Aerosolve	FA & RC	Dust	(3) 3A-85)	3300	None	Time Cycle (1)	Incineration		12.00	2.00	2.00
	Dust Stop	Spun Glass	FA & RC	Dust	(3) 23 3/8 x 23 3/8 x 2)		None	Time Cycle (6)	Incineration	28.08	4.00	8.00	6.00
AC-7	Cambridge	Aerosolve	FA & RC	Dust	(4) 3A-85)	4000	None	Time Cycle (1)	Incineration		16.00	5.00	2.00
	Dust Stop	Spun Glass	FA & RC	Dust	(4) 23 3/8 x 23 3/8 x 2)		None	Time Cycle (6)	Incineration	37.44	4.00	8.00	6.00
AC-8	Cambridge	Aerosolve	FA & RC	Dust	(4) 3A-85)	4000	None	Time Cycle (1)	Incineration		16.00	5.00	2.00
	Dust Stop	Spun Glass	FA & RC	Dust	(4) 23 3/8 x 23 3/8 x 2)		None	Time Cycle (6)	Incineration	37.44	4.00	8.00	6.00
AC-9	Cambridge	Aerosolve	FA	Dust	(2) 3A-85)	1200	None	Time Cycle (1)	Incineration		2.00	2.00	2.00
					(2) 23 3/8 x 23 3/8 x 2)					18.72	4.00	6.00	6.00
	Dust Stop	Spun Glass	IA	Dust	(2) 16 x 20 x 2)		None	Time Cycle (6)	Incineration	8.88	4.00	6.00	8.00
AC-10	Cambridge	Aerosolve	FA	Dust	(2) 3A-85)	1200	None	Time Cycle (1)	Incineration		2.00	2.00	2.00
					(2) 23 3/8 x 23 3/8 x 2)					18.72	4.00	6.00	6.00
	Dust Stop	Spun Glass	FA	Dust	(2) 16 x 20 x 2		None	Time Cycle (6)	Incineration	8.88	4.00	6.00	8.00
AC-11	Cambridge	Absolutes	FA	Dust	(4) 24 x 24 x 2	8000	None	Time Cycle			4.00		
	Dust Stop	Spun Glass	FA	Dust	(4) 23 3/8 x 23 3/8 x 2		None	Time Cycle (6)	Incineration	37.44	8.00	8.00	4.00
AC-12	Cambridge	Absolute	FA	Dust	(4) 24 x 24 x 2	8000	None	Time Cycle			4.00		
	Dust Stop	Spun Glass	FA	Dust	(4) 23 3/8 x 23 3/8 x 2		None	Time Cycle (6)	Incineration	37.44	8.00	8.00	4.00
HEF-21	E-Z-Kleen	Alumaloy	IA	Hood & Air	(2) 23 3/8 x 23 3/8 x 2	1800	Wash rinse & cote	Time Cycle	Dispose	10.30	4.00		
	E-Z-Kleen	Alumaloy	IA	RC	(2) 23 3/8 x 23 3/8 x 2		Wash rinse & cote	Time Cycle	Dispose	10.30			
HEF-9-4	E-Z-Kleen	Alumaloy	IA	Hood & Air	(2) 23 3/8 x 23 3/8 x 2	1200	Wash rinse & cote	Time Cycle	Dispose	10.30	4.00		
	E-Z-Kleen	Alumaloy	IA	Air Circ.	(2) 23 3/8 x 23 3/8 x 2		Wash rinse & cote	Time Cycle	Dispose	10.30			
HEF-104	E-Z-Kleen	Alumaloy	IA	Hood & Air	(2) 23 3/8 x 23 3/8 x 2	1200	Wash rinse & cote	Time Cycle	Dispose	10.30	4.00		
	E-Z-Kleen	Alumaloy	IA	Air Circ.	(2) 23 3/8 x 23 3/8 x 2		Wash rinse & cote	Time Cycle	Dispose	10.30			
RC AC-11	E-Z-Kleen	Alumaloy	R C	Dust	(8) 23 3/8 x 23 3/8 x 2		Wash rinse & cote	Time Cycle	Dispose	41.20	2.00		
					IB - 1000								
	Cambridge	Absolute	R C	Dust	(8) 24x 24 x 12		None	Time Cycle	Dispose	448.00	12.00		
RC AC-12	Dust Stop	Spun Glass	R C	Dust	(8) 23 3/8 x 23 3/8 x 2		None	Time Cycle (4)	Incineration	49.92	2.00	16.00	8.00
					IB - 1000								
	Cambridge	Absolute	R C	Dust	(8) 24 x 24 x 12		None	Time Cycle	Dispose	448.00	12.00		
NFEF-111	Dust Stop	Spun Glass	R C	Dust	(9) 23 3/8 x 23 3/8 x 2	2000	None	Time Cycle	Incineration	14.04	12.00		
	Cambridge	Absolute	R C	Dust	(9) 24 x 24 x 12		None	Time Cycle	Dispose	504.00	12.00		
NFEF-121	E-Z-Kleen	Alumaloy	R C	Dust	(9) 23 3/8 x 23 3/8 x 2	2000	Wash rinse & cote	Time Cycle	Dispose	46.35	12.00		
	Cambridge	Absolutes	R C	Dust	(9) 24 x 24 x 2		None	Time Cycle	Dispose	504.00	12.00		
Bryant #9	Dust Stop	Spun Glass	F	Dust	(1) 12 x 12 x 2		None	Time Cycle (6)	Incineration	3.96		4.00	
Bryant #10	Dust Stop	Spun Glass	F	Dust	(1) 12 x 12 x 2		None	Time Cycle (6)	Incineration	3.96		4.00	
Bldg. 140					(4) 12x 18 x 2								
EF 1-1	Fiberglas	Spun Glass	Ex Air	Dust	(2) 24 x 30 x 2	2200	Remove by hand	Time Cycle	Incineration	8.00	2.20	8.80	
	Absolute	A 1750	Ex Air	Dust	(2) 24 x 30 x 12		Remove by hand	Time Cycle	Incineration		2.20	4.40	
					(1) 18 x 24 x 2								
EF 1-2	Fiberglas	Spun Glass	Ex Air	Dust	(1) 24 x 30 x 2	1460	Remove by hand	Time Cycle	Incineration	4.00	1.46	5.85	
	Absolute	A 1250	Ex Air	Dust	(1) 24 x 30 x 12		Remove by hand	Time Cycle	Incineration		1.46	2.92	
					(3) 24 x 24 x 2								
EF 4-1	Fiberglas	Spun Glass	Ex Air	Dust	(9) 12 x 12 x 2	2500	Remove by hand	Time Cycle	Incineration	1.40	26.00	10.00	
	Absolute	A 1000	Ex Air	Dust	(3) 24 x 24 x 12		Remove by hand	Time Cycle	Incineration		26.00	5.00	

Remarks

()- After time cycle denotes changes per year
FA - Fresh air
RC - Recirculation
IA - Inside air

E-Z-Kleen
A-1 - $1.50 each per 1000 CFM
B- 4 changes per year per 1000 CFM
$1.00 per M CFM
A-2 - .25 per M CFM x 4 per year

Dust Stop
A-1 - Unit cost per 1000 CFM x 4 changes/year
A-2 - 25 per M CFM x 4 per year
B-4 - Changes per year per 1000 CFM @ 100/CFM
@ $1.00/M CFM
Aerosolve + Absolute
A-1 - Price
A-2 - 00.25 per M CFM x 4 per year
B - 2 changes per year per 1000 CFM @ $1.00/M
CFM
AC - Air conditioner
SF - Supply fan
EF - Exhaust fan

Bldg. No. & Location	Descriptive & Operational Data									A-1	A-2	B	
	Mfg. and/or Trade Name	Classification & Type	Site Application	Cleaning Requirements	Space Requirements	Operating Characteristics	Method of Replacing	Criteria for Cleaner Change	Handling & Disposal Method	Equip Charges Yearly Per 1000 CFM	Labor Charges - Dollars Maintenance & Inspection Per 1000 CFM/ hr.	Yearly Cleaning & Replacement Per 1000 CFM	Disposal
Gen. Lab Bldg. 140						CFM							
EF-27-1	Absolute	A-1200	Ex Air	Dust	1-24 x 30 x 12	1200	Remove by hand	Time Cycle	Incineration	$	$ 1.20	$ 2.40	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.40	1.20	4.80	
EF-41-1	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 24 x 2	1000	Remove by hand	Time Cycle	Incineration	2.88	1.00	2.00	
HEF 4-1	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 4-2	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24x 24 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 4-3	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 24 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 10-1	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 11-1	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 11-2	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 11-3	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 11-4	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 11-5	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 11-6	Absolute	Type 1 Size H	Ex Air	Hood	1-24 x 30 x 12	1250	Remove by hand	Time Cycle	Incineration		1.25	2.50	
	Fiberglass	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.30	1.25	5.00	
HEF 13-1	Absolute	Type 1 Size F	Ex Air	Hood	1-24 x 24 x 12	1000	Remove by hand	Time Cycle	Incineration		1.00	2.00	
	Fiberglas	Spun Glass	Ex Air	Dust	1-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.88	1.00	4.00	
EF 33-1	Aerosolve		Ex Air	Dust	3-24 x 24 x 12	1600	Remove by hand	Time Cycle	Incineration		1.60	3.20	
MEF 33-2	Absolute	Type 1 Size H	Ex Air	Dust	2-24 x 24 x 12	1100	Remove by hand	Time Cycle	Incineration		1.10	2.20	
	Fiberglas	Spun Glass	Ex Air	Dust	2-24 x 24 x 2		Remove by hand	Time Cycle	Incineration	5.24	1.10	4.40	
HEF 33-3	Absolute	A 1200	Ex Air	Dust	2-24 x 30 x 12	2800	Remove by hand	Time Cycle	Incineration		2.80	5.60	
	Fiberglas	Spun Glass	Ex Air	Dust	2-24 x 30 x 2		Remove by hand	Time Cycle	Incineration	2.28	2.80	11.20	
Bldg. 150													
EF 3-1	Dust Stop	Spun Glass	100% F.A. No RC	Throw away	1-23 3/8 x 23 3/8 x 2	620	None	Time Cycle	Contam. Spec. Handling & Disposal	Quarterly 6.24	4.00		
	Absolute	Flanders L. A. 1000	100% F.A. No RC	Dust	1-24 x 24 x 12		None	Time Cycle	Contam. Spec. Handling & Disposal				
EF 4-1	E Z Kleen	Alumaloy	Exhaust		4-23 1/2 x 29 1/2 x 2		None	Time Cycle	" " "	Quarterly 96.00	10.00	20.00	
	Absolute	Flanders l.A 1250	Exhaust		4-24 x 30 x 12	5000	None	Time Cycle	" " "				
EF 4-2	Dust Stop	Spun Glass	Exhaust	Special Attention	6-23 3/8 x 23 3/8 x 2	5500	None	Time Cycle	Spec. Handling & Disposal	37.44	8.00	16.00	12.00
	Absolute	Flanders l.E 1000	Exhaust	"	6-24 x 24 x 12	5500	None	Time Cycle	" " "				
EF 4-3	E Z Kleen	Alumaloy	Exhuast	"	6-24 x 30 x 1	9000	None	Time Cycle	" " "	127.44	10.00	20.00	15.00
	Absolute	Glanders l.A 1250	Exhaust	"	6-24x 30 x 12	9000	None	Time Cycle	" " "				
EF 6-1	Dust Stop	Spun Glass	Exhaust	Dust	1-24 x 24 x 2	1320	None	Time Cycle	Spec. Handling				
					(1)(2) 23 3/8 x 23 3/8 x 2								
EF 6-1	Absolute	Flanders 1 A 1000	Exhaust	Dust Spec. Att'n	2-24 x 24 x 12	1320	None	Time Cycle	Spec. Handling & Disposal				
EF 6-2	Dust Stop	Spun Glass	Exhaust	Dust	(2) 2-24 x 24 x 2	2600	None	Time Cycle					
					2- 23 3/8 x 23 3/8 x 2								
EF 6-2	Absolute	Flanders 1 A 1000	Exhaust	Dust Spec. Att'n	4-24 x 24 x 12	2600	None	Time Cycle	" " "				
EF 6-3	Dust Stop	Spun Glass	Exhaust	Dust	1-24 x 24 x 2 2-23 3/8 x 2 3/8 x 2	792	None	Time Cycle	Spec. Handling				
EF 6-3	Absolute	Flanders 1 A1000	Exhaust	Dust Spec. Att'n	2-24 x 24 x 12	792	None	Time Cycle	Spec. Handling & Disposal				
EF 6-4	Dust Stop	Spun Glass	Exhaust	Dust	1-24 x 24 x 2	1188	None	Time Cycle	Spec. Handling				
					2-23 3/8 x 23 3/8 x 2								
EF 6-4	Absolute	Flanders 1 A 1000	Exhaust	Spec. Att'n Dust	2-24 x 24 x 12	1188	None	Time Cycle	Spec. Handling & Disposal				
EF 6-5	Dust Stop	Spun Glass	Exhaust	Dust	2-24 x 24 x 2	1656	None	Time Cycle	Spec. Handling				
					2-23 3/8 x 23 3/8 x 2								
EF 6-5	Absolute	Flanders 1 A 1000	Exhaust	Spec. Att'n Dust	2-24 x 24 x 12	1656	None	Time Cycle	Special Handling & Disposal				
EF 6-6	Dust Stop	Spun Glass	Exhaust	Dust	4-20 x 20 x 2	3000	None	Time Cycle	Spec. Handling				
					3-24 x 24 x 2								
EF 6-6	Absolute	Flanders 1 A 1000	Exhaust	Dust	4-24 x 24 x 12	3000	None	Time Cycle	Spec Handling & Disposal				
"	E Z Kleen	Alumaloy	"	Spec. Att'n	4-23-3/8 x 23-3/8 x 2								
EF 6-7	E Z Kleen	Spun Glass	Exhaust	Dust	1-20 x 20 x 2		None	Time Cycle	Incineration	3.70	8.00	12.00	12.00
	"	Alumaloy	"	"	2-23-3/8 x 23-3/8 x 2								
	Absolute	Flanders	"	"	1-24 x 30 x 12	1320	None						
	American Maize		"	"	1-24 x 30 x 1								

Remarks

E-Z-Kleen
A-1 $1.50 each per 1000 CFM
A-2 .25 per M CFM x 4 per year
B 4 cleanings per year per 1000 CFM @ $1.00 per M CFM

Dust Stop (Glass)
A-1 Unit cost per 1000 CFM x 4 changes per year
A-2 .25 cents per M CFM x 4 per year
B 4 changes per year per 1000 CFM @ $1.00 per M CFM

Aerosolve + Absolutes
A-1 Price per 1000 CFM
A-2 .25 per 1000 CFM x 4 per year
B 2 changes per year per 1000 CFM @ $1.00/M CFM

HEF Hood exhaustion fan
MEF Machine exhaust fan

Note: All filters contaminated with radioactivity are handled as radioactive waste.

Bldg. No.	Room No.	Manufacturer	Classification	Application	Requirements	Size	CFM	Cleaning	Criteria	Initial Cost
102	None	Pease-Anthony	Scrubber	Final - Exhaust Air	Fume	5 Dia x 13' Ht	5000 CFM	Self-cleaning		$ 12, 500
10	Raw Mat'ls Insp.	Dust Kop (Aget) col.	Dust Collector	Pre-cleaning Exhaust	Dust	3' 0" x 1' 6"	1400	Pressure Loss		
10	Mockup	AAF Rotoclone	Dust Collector	Final Exhaust	Dust	12' x 8'	17000	Wood & Plastic Dust	Time Cycle	
10	Assembly	AAF Rotoclone	Dust Collector	Final Cleaning	Dust	3' 0" x 9' 0"	2500		Time Cycle	2, 000
10	Sheet Metal	AAF Rotoclone	Dust Collector	Final Cleaning	Dust	3' 0" x 6' 0"	2500		Time Cycle	2, 500
10	Tool Grinding	Dust Kop (Aget)	Dust Collector	Final Cleaning	Dust	3' 0" x 1' 6"	1400	Pressure Loss		
110	Carpenter Shop	Dust Kop	Dust Collector	Final Cleaning	Dust	6' x 6'	2050	Vacuum	Time Cycle	3, 289
110	Stone Saws	Dust Kop	Dust Collector	Final Cleaning	Dust	4' x 6'	2050	Vacuum	Pressure Loss	

Table 5 BNL Data

ECONOMIC SURVEY OF AIR AND GAS CLEANING OPERATIONS AT BROOKHAVEN NATIONAL LABORATORY

Survey by: L. Gemmell and T. D. Murphy February 1959

Filter Use at BNL	Manufacturer	Trade Name	Cleaner Classification and Type	Site Application	Cleaning Requirements and Process	Space Requirements	Operating Characteristic	Method of Replacement	Criteria for Cleaner Changes	Handling And Disposal Methods	Comments	Equipment Charges	Labor Charges
I. Reactor* Inlet	American Air Filter Co.	Deep Bed Air Filter Model A	High Efficiency Precleaner Glass Fibre Bed, Preformed FG-100 Filterdown	Prefilter Reactor Cooling Air	1.2. Atmospheric Dust 3. 20 μ & Less 4. $4.5x10^{-5}$ g/M^3	1. 2'3"x2'3"x3'0" Cap. ~1350 CFM 2. 0.011ft^3/CFM 3. 47.2ft^2/1000CFM	1. 21.1ft/min 2. a. 0.2"H_2O b. 3.5"H_2O 3. a.1 0.6HP/1000CFM a.2 22.5HP/1000CFM 4. Avg. 4 yrs. 5. 0-90°F R.H. to 100% 7. 75% Efficiency 0.3 μ particle	Replacement of Filter Media	1. Pressure loss 5. Pile Operations	Packaged for Sea Disposal if radioactive or burned on dups	1. Cost & Eff. 2. Yes 3. Nil 4. Nil	A. $420/1000CFM B. $42/1000CFM C. 1.35/1000CFM/yr D. $0.75	Man hours = mh B. 0.5mh/1000CFM/yr C. 0.45mh/1000CFM/yr D. Negligible E. 0.053mh/1000CFM/yr
II. Reactor Exhaust	Dollinger Corporation	Glasstex Woven Glass	High Efficiency Final Cleaner Preformed	Final Cleaning Exhaust Air Reactor Cooling	1. Dust 2. Radioactive Particles 3. See II-7 4. $1x10^{-5}$ g/M^3	1. 2'0"x2'0"x4" Cap. ~600 CFM 2. 0.0022ft^3/CFM 3. 6.8ft^2/1000CFM	1. 147 ft/min 2. 0.38"H_2O Present 3. 0.125HP/1000CFM 4. See 3 a.2 above 5. 130-140°C 7. 95% Efficiency For above 5 μ 25-30% below 5 μ particle	Haven't Been Replaced	If Replaced 1. Pressure loss 5. Pile Operations	No experience	1. Cost & Eff. 2. Yes 3. Nil 4. Nil	1. $265/1000CFM 2. 20.50/1000CFM/yr C. No experience D. Approximately, $30,000 for Replacement	B. 0.5mh/1000CFM/yr C. No experience D. " E. " F. "
III. Chemical Scrubber Hot Lab.	Homemade		High Efficiency Wet Chemical Scrubber	Final Cleaning Exhaust Air Production Area-I^{131}	1. Fumes-Vapors 2. Acids, Radio iodine 3. Less than 21 μ 4. Small	1. 4 scrubbers ea. 5'Hx2'dia. cap. 2500CFM 2. 0.025ft^3/CFM	6. 15 gal/min b. 100% c. 1lb/1000CFM/ caustic year	Replenish Cuastic Sol'n	Cuastic becomes neutralized	If necessary dumped into BNL Liquid System	1. Necessity of removing I_2 Cost & Eff. 2. Yes 3. Nil 4. Nil	No estimate has been made on initial cost of replacement	B. Negligible C. Negligible D. None
IV. Absolute Filters Hoods, Hot Cells, Dilution Rooms, Reclamation Area, etc.	Flanders Filters, Inc.	Air Pure	Ultra (Absolute) Filter (Glass)	Final Cleaning Lab Hoods High Level Radioisotopes	1. Dust, Mists 2. Radioisotopes 3. 0.3 μ 4. $4.5x10^{-5}$ g/M^3	1. 5 sizes 24"x24"x57/8" 24"x30"x57/8" 24"x30"x111/2" 24"x48"x57/8" 8x8x57/8" 2. 0.004-0.005ft^3/CFM 3. 200ft^2/1000CFM	1. 5.0 ft/min 2. a. 0.9"H_2O b. 2.0"H_2O 3. a.1 0.45HP/1000CFM a.2 1 HP/1000CFM 4. 4 years 5. 250° F Max. 75% R. H. 7. 99.95% Efficiency 0.3 μ particle	Replacement of Filter Unit	1. Pressure loss 100ft/min at hood face 5. Health Physicist	If highly radioactive packaged for sea disposal otherwise dumped	1. Cost & Eff. 2. Yes 3. Filters should be fire resistant	A. $600/100CFM B. $60/1000CFM C. $25/1000CFM D. $100/1000CFM	B. 0.15mh/1000CFM/yr C. See E below if Radioactive D. 1mh/1000CFM E. 1.0mh/1000CFM/yr F. 2.0mh/1000CFM/yr
V. Air Conditioning Filters Pile, Hot Lab, AGS, etc	American Air Filter Co. Owens-Corning Fibreglass Corp.	1. Air Mat Type C 2. Rollomatic Dust-Stop	Roughing 1. Fibre Bulk 2. Preformed Glass Same	Precleaning Final cleaning Air conditioning Same, but in small Package Units	1. Dust, Mists 2. Atmospheric Particles 4. $4.5x10^{-5}$ g/M^3	1. 24"x24"x6" Cap. 1000 CFM 2. 0.002ft^3/CFM 3. 25ft^2/1000CFM 1. All sizes 2. ~0.0003ft^3/CFM 3. 2 ft^2/1000CFM	1. 40 ft/min 2. a.1. 0.028"H_2O a.2. 0.5"H_2O 3. a. 0.10HP/1000CFM b. 0.5HP/1000CFM 4. a. 12 weeks 5. 0-70°F Up to 100% R.H. 1. 500 ft/min 2. 3. a. b. 2.5HP/min 4. 12 weeks 5. 0-70°F 100%R.H.	Replace Air-mat Paper & Dust Stop Unit Same	1. Pressure loss 5. Plant Maintenance Same	1. Dumped Same	1. Cost & Eff. 2. Yes 3. Nil 4. Nil	A. No way to tell B. " " " " C. $4.40/1000CFM/yr D. $1.10/1000CFM/ Replacement Unit A. No way to tell B. " " " " C. $2.50/1000CFM/yr D. $1.25/Replacement Unit/2000CFM	B, C, D, E, F Approximately, 0.25mh/1000CFM/yr

Table 6 Savanah River Plant Data

		AIR CLEANING DATA													
A-B Type Filter	C Type	D Application	E Requirements	F Size	G Operational Characteristics	G Pressure Loss	G Power Hp/1000 CFM	H Replacement	I Criteria for Changes	I Who Determines Criteria for Changes	J Disposal Methods	Replacement Frequency	Replacement Cost $/1000 CFM/yr.	Man-hrs/ 1000 CFM/yr.
Cambridge Type A	Absolute Glass-Asbestos	Final Cleaning Lab Hood	Particle Removing	24x30x11 1/2 24x24x11 1/2 8x8x11 1/2	250 FPM 200 FPM 200 FPM	Int. - 1 in. Fin. - 2.5	1 1/2 - 20 2 10	Complete Pkg.	Pressure loss Activity Time cycle Mech. failure	Bldg. Serv. Radn. Cont.	Pers. Prot. Packaging Burial	2 yrs.	$30/unit total $15	30 min/unit 1/4 man-hrs.(total)
Cambridge Type B	Absolute Glass-Asbestos	Final Cleaning Lab Hood	Particle Removing	24x30x11 1/2 12x12x5 7/8	250 FPM	Int. - 1 in. Fin. - 2.5	1 1/2 5	Complete Pkg.	Same as above	Bldg. Serv. Radn. Cont.	Same as above	2 yrs.	$50/unit	30 min/unit
Cambridge Type D	Absolute Glass-Asbestos	Final Cleaning Lab Hood	Particle Removing	24x30x11 1/2	250 FPM	Int. - 1 in. Fin. - 2.5	1 1/2	Complete Pkg.	Same as above	Bldg. Serv. Radn. Cont.	Same as above	2 yrs.	total $25	1/4 man-hrs.(total)
Cambridge Type F	Absolute Glass-Asbestos	Final Cleaning Lab Hood	Particle Removing	24x30x11 1/2 12x12x5 7/8	250 FPM	Int. - 1 in. Fin. - 2.5	1 1/2 5	Complete Pkg.	Same as above	Same as above	Same as above	2 yrs.		
Micro-Metallic	Porous Stainless Steel	Pre-Cleaning Process System (Moisture Sep.)	Particle & Vapor Removal					Wash with water	Pressure loss	Bldg. Serv.	Same as above	5 yrs.	No cost	-
Dollinger (Fiber)	Fiber (?)	Exh.-Process System (Moisture Sep.)	Vapor & Liquid Removal			Int. - 2 in. Final - 4 - 10	10	Complete Pkg.	Pressure loss Mech. failure	Bldg. Serv.	Same as above	2 yrs.	$10/unit total $50/yr.	1 man-hr/yr/unit 10 man-hrs.(total)
Research Product, Inc. Alumaloy	Oil Coated Metal Screen	Exh.-Special Hood	Particle Removal	12x12x2			3	Wash & Re-oil	Pressure loss Mech. failure Time cycle	Bldg. Serv. Op. Group	Cleaning & re-use	4 months	No cost	4 1/2 man-hrs(total)
Dust-Stop Prefilter	Glass Fibers	Prefilters Gen. Ventilat. Hoods	Particle Removal	25x25x2 20x25x2 16x20x2 12x12x2 8x8x2		Final - 0.5 in.	1 1/2 - 2 -5 10	Complete Pkg.	Pressure loss Activity Time cycle Mech. failure	Bldg. Serv. Radn. Cont. Op. Groups	Person prot., packaging, burial	3 months	$3	1/3 man-hrs.(total)
Air-Mat	Woven Fiber	Pre-filter Supply A/C	Particle Removal			Int. - 0.5 in. Final - 1.0 in.		Complete Pkg.	Time cycle Pressure loss Mech. failure	Bldg. Serv. Radn. Cont.	Same as above	3 months	?	3 man-hrs.(total)

Submitted by R. H. Hale, Savannah River Plant

Table 7 KAPL Data

ECONOMIC SURVEY OF KAPL AIR CLEANING OPERATIONS

Manufacturers	Trade Name	Cleaner Classification	Site Application	Cleaning Requirement and Process	Space Requirements Overall Dimensions	Space Requirements Capacity (CFM)	cu ft/CFM Cleaning Capacity	Face Area (sq ft) 1000 CFM Cleaning Capacity
American Air Filter Co.	Throw away type glass fibre filter.	Precleaning performed glass	Prefilter Supply Gen. Ventilation	Suburban Area atmosphere air prepared for nuclear fuel examination and waste processing areas.	2"x24"x24"	1200	$5.6x10^{-4}$	3.3
American Air Filter Co.	Multi-Duty Air Filter automatic, self-cleaning.	Precleaning, oil-coated metal screens, type MS	Prefilter Supply Air, Gen. Ventilation.	Suburban area atmosphere prepared for production machine shop and laboratories.	8'x8.5'-18'x12' All are 20" deep.	18,900-60,000	$6x10^{-3}$	36
Dollinger Co.	Dollinger automatic, self-cleaning.	Precleaning, oil-coated metal screens	Prefilter Supply Air, Gen. Ventilation.	Surburban Area atmosphere prepared for laboratories.	10'x12.5'-15'x12.5 All are 2' deep.	40,000 to 60,000	$6.25x10^{-3}$	3.14
American Air Filter Co.	Throw away type glass fibre filter.	Precleaning preformed glass	Precleaning Exhaust Air Multi-Curie Fission Product Lab.	Laboratory exhaust air prepared for subsequent ultra filtration.	2"x24"x24"	1000	$6.4x10^{-4}$	4
Flanders Filter Co,	Air pure, Cat. No. 2G70b	Ultra filter-F200 filter media	Final Cleaning Exhaust Air Multi-Curie Fission Product Lab.	Laboratory exhaust air prepared for public environment.	11"x24"x24"	100-1000	$4x10^{-2}$- $4x10^{-3}$	40-4

Western Precipitation Corporation	Multicone Type 9VG/2 Model P-19923-40	Precleaning cyclone separator	Precleaning Exhaust Air Production Mach, Shop	Machine Shop metal dust removal from exhaust air	8'x8'x8'	59,000	8.6×10^{-3}	---
Improvised	None	Final cleaner, Fibre bed preformed	Final Cleaning-Exhaust Air Production Mach.Shop	Machine Shop air prepared for public environment.	1'x10'x8'	59,000	1.4×10^{-3}	1.4

APPENDIX II

Estimated Costs of Air Cleaning Systems

Table 8. Air Cleaning Costs of Roughing and Precleaning Filters

				Cost in Dollars per cfm per year				
ID	**Flow Rate**	Depreciation	Equipment	Power	Labor	Total	Comments	Type
8c	--	--	0.003	2.775	0.002	2.780	Power Costs included and dominate	Dustop
7c	--	--	--	0.450	0.027	0.477	Initial Cost high	OCMS
5.1	16,000	.4000	0.0002	--	0.0053	0.4055	↑	OCMS
9	3840	--	0.0000	--	0.3120	0.3120	Labor Costs Dominate	Taylor
1.2	1000	.0071	0.0816	--	0.1800	0.2687	and	Ca-24
3.2	1000	.0071	0.0816	--	0.1800	0.2687	Equipment Charges	Ca-24
1.3	1000	.0060	0.0816	--	0.1800	0.2676	Relatively High	Pl-24
2.2	1000	.0060	0.0816	--	0.1800	0.2676	↓	Pl-24
3.3	1000	.0060	0.0816	--	0.1800	0.2676	↑	Pl-24
11	10200	--	0.0250	--	0.0750	0.1100		F:RA,5
1e	100,000	--	0.0324	--	0.0015	0.0339	High Flow	F:15R/OT
2b	1760	.0096	0.0558	--	0.0082	0.0736	Rates	Pl-24
1a	6847	--	0.0027	--	0.0161	0.0188	Low Equipment	Dustop
3a	92865	--	0.0023	--	0.0155	0.0178	and	Dustop
							Labor Costs	

Air Cleaning Costs of Roughing and Precleaning Filters (Cont'd)

23	65400	--	0.0010	--	0.0117	0.0127	↓	RSVT
25	120,000	--	0.0008	--	0.0096	0.0104		RSVT
24	120,000	--	0.0008	--	0.0096	0.0104		RSVT
4.1	430,000	0.0076	0.0001	--	0.0005	0.0082		OCMS
21	108,000	--	0.0009	--	0.0071	0.0080		RSVT
1d	65,000	--	0.0049	--	0.0030	0.0079		OCMS
10	40,000	--	0.0001	--	0.0045	0.0046		F:15R/QT
16	26,000	--	0.00010	--	0.00185	0.0020		Pritchard
1	3,600,000	--	0.00033	--	0.00148	0.0018		AM:KF
2	1,630,000	--	0.00012	--	0.00054	0.0007		AM:KF
5	7,200,000	--	0.00002	--	.00043	0.0005		AM:P-5
3	2,700,000	--	0.00002	--	.00041	0.0004		AM:P-5
4	5,400,000	--	0.00001	--	0.00028	0.0003		AM:P-5

OCMS: Oil Coated Metal Screen

RSVT: Rotating Screen Viscous Type

F:---, Fulflo----

AM:KF; Air Maze Kleen Flow

Table 9. Air Cleaning Costs of Electrostatic Precipitators

ID	Type	Flow Rate, in cfm	Depreciation	Equipment	Power	Labor	Total	Comments
1b	Electro-matic	184000	0.085	0.024	*	0.058	0.167	Adjusted power; equipment and labor costs indicate total cost of $.15 to 0.2 per cfm/year.
3.5	Oil Mist Prec.	1200	0.117	0.012	--	0.018	0.147	
5	Electro-matic	5380	0.104	--	0.028	--	0.132	
20	Cottrell Ppt	960,000	--	**	0.007	0.021	0.028	Depreciation costs not included. The depreciation and power costs would result in an estimated addition cost of $0.1 per cfm per year
22	West. Elect. Ppt	19,000	--	**	--	0.005	0.005	
2d	Oil Mist Prec.	65,000	--	*	--	0.0044	0.0044	

* Included under labor costs

** No costs to date

Table 10. Air Cleaning Costs of Bag Collectors

Cost, in Dollars per cfm per year

ID	Type	Flow Rate, in cfm	Depreciation*	Equipment	Power**	Labor	Total***	Comments
27	Aeroturn	600	--	1.307	--	0.620	1.927	Unit costs high with low flow rate
7.3	Disc. Filter	2200	0.764	0.058	--	0.120	1.942	High installation cost but low operational costs.
8.2	Amerjet	3500	0.238	0.0002	--	--	0.242	
1.1	Mikro-Col	64000	0.062	0.130	--	0.009	0.201	Costs decreases with increase in flow rate
2.1	Dual-Aire	85000	0.060	0.065	--	0.009	0.134	
3.1	Dual-Aire	85000	0.060	0.065	--	0.009	0.134	
6.1	Aeroturn	300,000	0.050	0.028	--	0.006	0.084	

* Write-off over a period of 5 years

*** Avg. labor costs of $6/man-hr were assumed

** Hp/1000 cfm requirements for the above collectors vary from 0.94 to 4.5 for 8000 hrs operations per year with fan and motor efficiency taken as 60%, 1 Hp/1000 cfm would result in a power cost of $0.150/cfm/yr. Power costs for ID 7.3 is estimated at $0.6/cfm/yr whereas the other power costs are approximated at $0.3/cfm/yr on the basis of $0.015/kw-hr.

Table 11. Air Cleaning Costs of High Efficiency Filters

Cost in Dollars per cfm per year

ID	Type	Flow Rate, in cfm	Depreciation	Equipment	Power	Labor	Total	Comments
28	Absolute	50	--	2640	--	1.440	4.080	Unit cost high at cont. flow rate. Add. 0.015 - Power and 0.028 for depreciation
3.4	Abs.(Cell-Asb)	1000	0.028	1.694	--	1.440	3.162	Units replaced each month. Add 0.30 for Power.
1.5	Abs. (Cell-Asb)	50	0.028	1.694	--	1.440	3.162	Low flow rate and monthly replacement. Add 0.015 for Power.
1c	Abs.(Glass-Cell)	--	--	0.015	2.025	0.002	2.042	High power costs dominate
2a	Abs.(Cell-Asb)	6847	--	0.261	--	1.460	1.721	High level activity area
7.1	Abs.(All Glass)	2200	0.013	1.200	--	0.186	1.399	Equipment costs dominate
2c	Abs. (Glass Cell)	--	--	0.025	0.975	0.002	1.002	Costs governed by power requirements
4c	Abs.(Glass-Cell)	--	--	0.025	0.975	0.002	1.002	
2e	Abs.(Glass)	100,000	0.680	0.027	--	0.020	0.727	Installation costs high, operational relatively low.
1.4	Abs.(Cell-Asb)	1000	0.008	0.516	--	0.072	0.596	Add 0.30 for power costs.
4a	Abs.(Cell-Asb)	92865	--	0.140	--	0.396	0.536	Flow rate high contributes to relatively low costs.

Air Cleaning Costs of High Efficiency Filters (Cont'd)

3c	Abs.(Glass-Cell)	--	--	0.025	0.225	0.002	0.252	Replacement costs low, filters changed every two years
5.2	Abs.(All Glass)	1000	0.006	0.030	--	0.005	0.041	Filters replaced every two years. Add 0.30 for Power.

Conclusions: Under conditions specified above the annual operational costs (including power and depreciative costs) for the use of Absolute Filters is estimated to be 0.5 to 5.0 dollars / cfm.

Table 12. Air Cleaning Costs of Composite Systems

Composite System					costs, in dollars/cfm/year					
	Flow Rate, in cfm	Eff.	F	D.F.	Depreciation	Equipment	Power	Labor	Total	Comments***
Rad.Materials Lab.	5380	99.95	.0005	2000	--	7.732	--	**	7.732	Includes LEF, HEF,EP
Exhaust Systems	67050	99.95	.0005	2000	--	2.614	--	1.881	4.495	Includes LEF, HEF, BC
Waste Incinerator	5500	99.95	.0005	2000	--	2.487	--	.486	2.973	Includes CY, HEF,BC
Ten Site	27600		?	2000	.361	.319	*	.218	.898	
Reactor Exhaust	100,000	99.95	.0005	2000	.680	.028	--	.020	.728	DPF, HEF
Chemical Metallurgical	35,000	99.95	.0005	2000	.195	.362	*	.118	.675	LEF,HEF,etc.
D.P.W.	184,000	99.5	.005	200	.095	.080	*	.066	.241	Includes LEF,EP
Reactor Supply Air	100,000	75	.25	4	--	.043	--	.006	.049	Includes LEF
Reactor Supply Air	100,000	75	.25	4	--	.032	--	.002	.034	Includes LEF
General Supply Air	430,000	60	.4	2.5	.0076	.0001	--	.0005	.0082	OCMS
General Supply Air	26,000	60	.4	2.5	--	.00010	--	.00185	.0020	LEF
General Supply Air	7,200,000	60	.4	2.5	--	.00002	--	.00043	.0005	AM

* Included new equipment and labor costs

** Included under equipment costs

*** LEF, Low Efficiency Filters, the Dustop, etc.

HEF, High Efficiency Filters, the Absolute Filter, etc.

EP, Electrostatic precipitators

BC, Bag Collectors

CY, Cyclone

DPF, Deep Pocket Filters

Discussion

Q. (C. E. Lapple, Stanford Research Lab.) I would like to ask you about your proposal to express equipment costs in terms of penetration. If I interpreted your suggestion correctly the first approximation you would present costs in dollars per year per CFM, for a unit of penetration, as being a rough constant. On that basis if you have 39% efficiency and want to raise it to 99.99 you say it would cost a hundred times as much per year to do that. Am I interpreting your suggestion right?

A. If you have 99% efficiency and want to raise it, you would use a factor of 100 - seems that would be extremely pessimistic - expect implementing cost would be factor of 3 to 4.

Suppose you have filter giving 99% efficiency and put an filter in series with it, if you have a homogeneous aerosol you would get 99% over all at just about twice the cost. Actually aerosol is not homogeneous so you would not get that much efficiency, but it would still be 99 something percent efficiency. I suggest consideration for presenting the costs in terms of dollars per year - for the present time, let's take what we have because we have to go along with experiment data. Experimental data shows penetration times the cost is equal to the constant.

Q. (Belter - AEC Washington) Joe, has any consideration been given especially after more data is accumulated to breaking down this data by the type of facility. Whether it would be say a laboratory facility or production site or perhaps a certain type of reactor site.

A. Yes, definitely. We have even started on that. Our data as I presented it, there are specific systems but we are also going to integrate that into the broad functions of the whole site. We must get the basic data and the essential data so that we can build up on it.

Q. (B. L. Rich, PPCo.) I was wondering -- an economic review seems to intimate that you would evaluate a process in terms of economics rather than evaluate in terms of process in regard to filteration problems. Is this part of your program?

A. Yes, as I pointed out - we are interested not only on the economics of the efficiencies with respect to the financial setup but also with respect to the physical or the effectiveness of that system. Thereby wherever we can be helpful in pointing out something in pointing out what others have done I think we would put into it as we have already done that in the survey. You will notice that the economics is just one phase of the whole evaluation.

PROGRESS REPORT ON HARVARD-AMERICAN IRON AND STEEL INSTITUTE RESEARCH PROJECT

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ABSTRACT

Research studies on removal of fine fumes ($< 0.5\mu$) from high temperature gases (1000°F) are being conducted at Harvard for the American Iron and Steel Institute. Four main phases of this project are discussed in this report: (1) agglomeration of fine fume; (2) heat transfer characteristics of rotary screw agglomerators; (3) shock wave cleaning of mineral wool filters; and (4) pilot plant investigations of use of mineral wool for high temperature fume filtration.

Through agglomeration, submicron particles in metallurgical furnace effluents can be increased in size, facilitating their removal by fiber filters and extending filter life. The rotary screw agglomerator used for this purpose has shown a heat transfer rate in excess of what normally might be expected which considerably reduces (100 to 600°F) the temperature of gases going to the filtering unit. Shock wave cleaning of mineral wool filters has been used to extend filter life in laboratory and field units as well as to reduce space requirements on a prototype unit. Using this shock wave cleaning method, as well as features from previous pilot plants, we have had very encouraging results on a 2000 cfm mineral wool filtering unit operated on fume from open hearth and electric furnaces.

Introduction

Many industries exhaust high temperature gases containing submicron fumes directly into the atmosphere. There is cleaning equipment available to control these situations, but because of the small particle size ($< 0.5\mu$) and the high temperatures ($>$ 1000°F), cost of such equipment presents an undesirable capital burden.

Steel industry problems are primarily concerned with removing visible (non-toxic) particulates from metallurgical furnace exhaust gases from the standpoint of air pollution control, and as such, they require removal of greater than 90% of the fumes. Results of these studies can be applied to certain AEC problems such as incinerator effluents, air or gas cooled nuclear reactors, certain gaseous, liquid and solid process wastes, etc.

TABLE 1

Characteristics of Experimental Rotary Screw Agglomerators

Nominal Diameter, Inches	3	6	12	24
Actual Diameter, Inches	2-3/4	6	12	24
Pitch or Lead, Inches	2	6	12	24
Screw Length, Inches	24	36	84	140
Number of Screw Turns	12	6	7	6
Shaft Diameter, Inches	1	2-$\frac{1}{2}$	3	4-$\frac{1}{2}$
Inlet and Outlet Size[a], Inches	1-$\frac{1}{2}$ID	3-$\frac{1}{2}$ID	6ID	In 24 x 4-3/4 Out 12ID
Cross-Section of Gas Path[b], Square Feet	0.011	0.080	0.38	1.625
Hydraulic Radius of Gas Path, Feet	0.025	0.062	0.136	0.289
Total Length of Gas Path, Feet	7.3	7.8	17.5	29.9
Spiral Channel Reynolds Number	10^4-1.5 x 10^5	10^4-1.5 x 10^5	10^4-1.5 x 10^5	1.5 x 10^5-3.5x10^5
Overall Resistance[c], Inches, Water	7.2	3.0	2.5	2.2
Gas Flow, cfm, STP	38	200	600	2400
Collection Efficiency[d], %	47LF	15LF	40FF	44FF
Spiral Channel Friction Factor (f)	0.013-0.0085	0.013-0.0085	0.013-0.0085	0.026

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a. Twenty-four inch model constructed with slotted inlet extending across two adjacent flights.
b. Assumed from a plane passing through the screw axis.
c. Inlet velocity 3000 feet per minute at stated gas flow.
d. LF = laboratory fume simulant, FF = field open hearth fume.

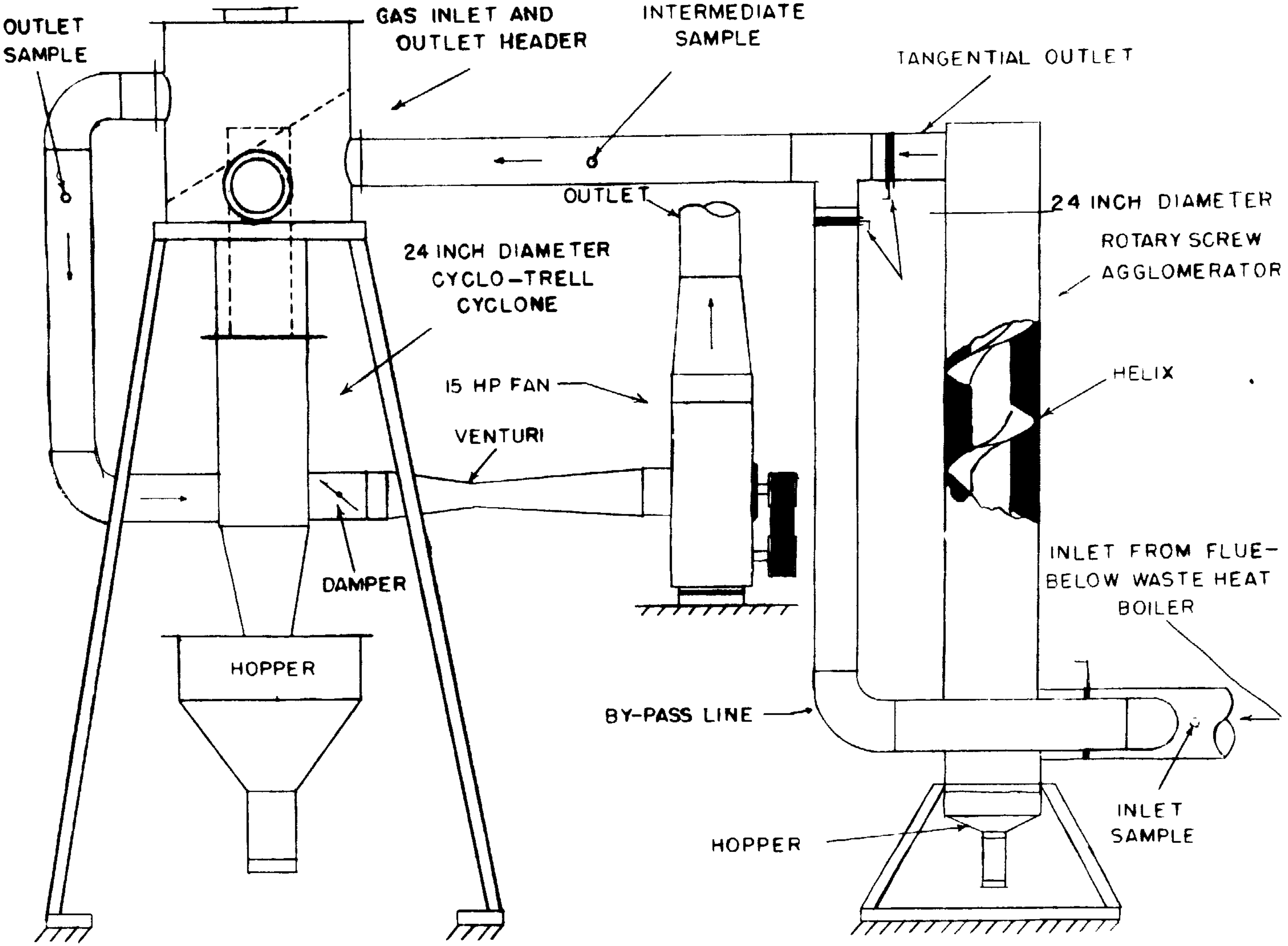

Fig. 1—Field installation of agglomerator and cyclone.

The principal objective of this project is to produce a gas cleaning unit that will require minimum floor space, low capital investment and low operational cost. Research work directed toward this end has shown that a rotary screw agglomerator can both increase particle size, facilitating subsequent fume filtration, and greatly reduce gas temperatures, simplifying the construction of the filtering unit. In addition, mineral wool fibers (1¢/lb.) can be used repeatedly on iron oxide fume when cleaned with shock waves to extend filter life. This development has been applied to a pilot plant unit presently being field tested which can filter and clean within the same chamber thereby reducing floor space and auxiliary equipment.

Agglomeration Studies

The study of agglomeration is divided into two parts; the particle concentration instrumentation, to be presented separately, and the means of producing agglomeration, mechanisms of which have been presented (1). This paper is a continuation of studies reported at the 5th Air Cleaning Conference, with some of this previous information being included in the tabulations.

A vertical 24 in. diameter rotary screw agglomeration unit (see Table 1) has been field tested on open hearth furnace effluent. A 24 in. diameter cyclonic vane type collector was operated in series with the agglomerator or with the agglomerator by-passed as shown in Figure 1. The field operations showed that neither intermittent nor continuous rotation of the screw caused any apparent change in collection efficiency above that when the screw was held stationary. Efficiencies of the various arrangements tested are listed in Table 2.

TABLE 2

Particle Removal Efficiency of Rotary Screw Agglomerators

Nominal Screw Size Inches	Aerosol*	Efficiency** %	Remarks
3	LF	0	Insulated, no settling chamber
	LF	2.5	Insulated, with settling chamber
	LF	47.0	Uninsulated, with settling chamber
6	LF	15.2	Uninsulated, no hopper
12	Fly Ash	22.0	Uninsulated, no hopper
	FF	40.0	Uninsulated, with long. hopper
24***	FF	43.8	Screw Agglomerator
	FF	15.5	Cyclone Eff. (following screw)
	FF	35.6	Cyclone Eff. (by-pass screw)
	FF	52.6	Cyclone and screw

* LF = laboratory simulant iron oxide, FF = field open hearth fume

** Inlet temperature 500°F or above, screw stationary or rotating at 1 to 2 rpm.

*** Screw unit in vertical position.

Collection efficiency of the 24 in. agglomerator (primarily not a collector) was slightly larger than the collection efficiency of the 24 in. cyclone.

TABLE 3

Performance[a] of Rotary Screw Agglomerators on Iron Oxide Fume

Sample Number	Particle Size[b], Microns								Unit Diameter Inches	Remarks
	Inlet			Outlet			% Increase			
	Mg	σ_g	Mg'	Mg	σ_g	Mg'	Mg	Mg'		
1	0.17	1.8	0.47	0.23	2.7	4.9	35	940	12	During lime boil
2	0.09	1.9	0.30	-	-	-	-	-	"	"
3	0.12	1.9	0.42	0.13	2.1	0.60	8	43	"	"
4	0.24	1.8	0.70	0.15	2.5	1.9	-38	170	"	"
Average	0.15	1.8	0.47	0.17	2.4	2.5	13	430	"	--
5	0.019	1.8	0.049	0.013	2.7	0.32	-32	550	24	During working period
6	0.11	2.1	0.63	0.23	2.1	1.6	109	150	"	"
7	0.015	3.4	1.6	0.017	2.3	0.13	13	-92	"	During flush-off period
Average	0.048	2.4	0.76	0.087	2.4	0.68	81	-10	"	--

[a] Results of electron microscope analysis of inlet and outlet particle size, average magnification 30,000 X.

[b] Mg = count median diameter, μ, σ_g = standard geometric deviation, Mg' = mass median diameter.

An analysis of electron-microscope targets of simultaneous inlet and outlet fume samples from the 12 in. and the 24 in. agglomerator are presented in Table 3. In 2 out of 3 cases for each agglomerator the outlet particle size is in excess of the inlet size and this increase is in excess of what might be expected for unaided diffusion coagulation.

Presently a 6 in. agglomerator is being adapted to use an additional agglomeration producing mechanism, the introduction of moving targets such as alundum shot or extended surface packings.

Another phase of the agglomeration studies is the examination of resuspended particles from a loaded filter. It was first suggested by E. Anderson (2) in 1934 that filters could act as agglomerators with reentrained larger particles collected subsequently by other devices. The results of these agglomeration tests using low level shock waves to dislodge particles from mineral wool filters are presented in Table 4. Line 1 shows the characteristics of the initially generated fume with the following tests being made on resuspended particles. Lines 2 and 2' are the results from the same grid of an electron microscope target but at different magnifications. The lower magnification evidently over-estimates the fume particle size by a factor of about the same as the ratio of the magnifications. Lines 2, 3 and 5 show that the dislodged particle size is larger than the generated size but that it is decreased as the blast pressure is increased.

Table 4. Particle Size of Iron Oxide Fume Removed From Mineral Wool Filters By Shock Wave Cleaning

Test No.	Particle Size - Microns[a] Mg	σg	Mg'	Magnification	Blast Pressure In.Hg
1	0.056	1.9	0.19	30,700	-[b]
2	0.12	2.1	0.62	30,700	3
2'	0.32	1.7	0.72	7,700	3
3	0.076	1.9	0.27	30,700	4
4	0.37	2.1	2.0	7,700	6
5	0.063	2.0	0.29	30,700	12

a. Mg = count median diameter, microns; σg = standard geometric deviation; Mg' = mass median diameter, microns.

b. Initial fume size as generated and filtered.

Heat Transfer Study on 6 in. Jacketed Agglomerator

One of the unanticipated but desirable aspects of the screw agglomerator has been its performance as a heat transfer unit. Because of the spiral flow and disturbed boundary layer, eddy transfer is enhanced. An added advantage of the unit is the walls may be cleaned by merely rotating the enclosed screw so that the agglomerator becomes a self cleaning heat transfer unit.

Unit Description

Our present model (Figure 2) consists of a helical screw within a vertical steel tube with an outer concentric steel tube forming a jacket for the cooling liquids. The 9½ in. outside diameter by 5 ft. long jacket has a 1 in. pipe inlet and outlet. High temperature gas is admitted by a rectangular tangential entry to the screw through the base of the jacket. A round tangential exit is above the expansion collar connecting the steel tubes. The 6 in. diameter by 6 in. pitch screw can be held stationary, rotated, or removed from the unit.

Table 5

SUMMARY OF HEAT TRANSFER CHARACTERISTICS OF ROTARY SCREW AGGLOMERATORS

Cooling Fluid	Screw	Inlet Temp. °F	Gas Flow lbs./hr.	Coeff. Btu/hr./ft.^{2}/°F	Temp. Drop °F
A. VALUES REPORTED IN PERRY, J.E., "CHEM. ENG. HANDBOOK"					
Nat'l. Conv., Gas	-	-	-	0.6-2	-
Forc. Conv., Gas	-	-	-	2 -6	-
Nat'l. Conv., Liquid	-	-	-	1 -3	-
Forc. Conv., Liquid	-	-	-	2 -10	-
Nat'l. Conv., Boil. Liq.	-	-	-	1 -10	-
B. SIX INCH DIA. UNJACKETED AGGLOMERATOR - LAB. STUDY (Scr. Horiz.)					
Nat'l. Conv., Air	Out	670	340-560	0.60-0.66	70-95
" "	In	700	370-550	1.3 -1.8	120-190
" "	In	1000	410-500	1.8 -2.4	220-360
Running Water Film	In	500	440-620	13 -17	220-230
" "	In	700	400-540	12 -16	320-350
" "	In	1000	310-480	10 -16	520-530
C. TWENTY-FOUR INCH DIA. UNJACKETED AGGLOMERATOR - FIELD STUDY (Screw Vert.)					
Nat'l. Conv. Air	In	840 to 1200	7600 to 12800	157,000* to 885,000* *Btu/hr.	55 to 270
150 hours operation analyzed for 12 days, upon rotation of screw the heat transfer rate increased 30%.					
D. SIX INCH DIA. JACKETED AGGLOMERATOR - LAB. STUDY - (Scr. Vert.)					
Nat'l. Conv., Air	In	1000	200-660	1-3	100-150
Forc. Conv., Air	In	1000	200-700	3-5.5	150-300
Forc. Conv., Water	In	1000	250-850	7-16	300-550
Boil. Water - Steam(100#)	In	1000	250-800	5-15	300-400
F.C. - Dowtherm A	In	1000	200-850	6-16	250-560
" "	In	1500	170-740	6-15	590-950
" "	Out	1000	190-820	3-13	270-350
" "	Out	1500	190-750	5-13	500-650

Test Results

Table 5 lists the results of heat transfer studies obtained with this unit using air, water, steam, and Dowtherm A, with the screw in place and removed. The results of previous tests on a 6 in. and 24 in. unjacketed agglomerator in addition to values from a standard reference are also reported. It is evident from these studies that

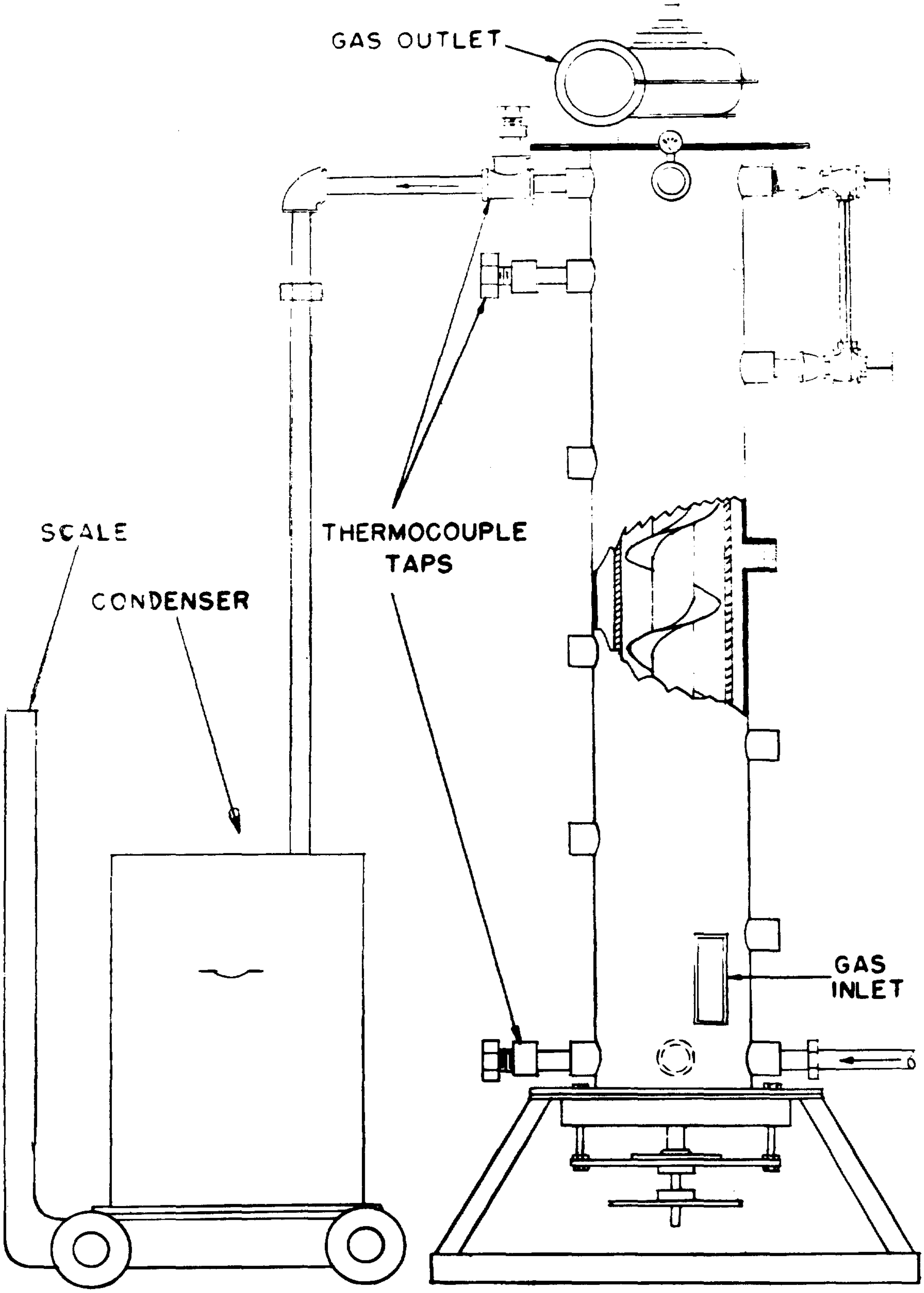

Fig. 2—Rotary screw agglomerator, heat transfer unit.

the overall heat transfer is on the order of 1.5 to 2 times greater than standard values. Studies are presently being continued with modifications to the 6 in. jacketed screw unit, to investigate heat transfer in addition to agglomeration effects, as mentioned previously.

Shock Wave Studies

Results of Previous Investigations

Prior to the start of the present study in the laboratory, a comprehensive investigation had been undertaken for the U. S. Atomic Energy Commission on the effects of shock waves on gas cleaning equipment, particularly filters and electrostatic precipitator plates. This AEC study was composed of two parts; (a) an investigation of filter damage and dust reentrainment from commercial Dust-Stop and AEC High Efficiency (Absolute) Space Filters held in a 20 in. diameter laboratory shock tube (3), and (b) an extended investigation of dust dislodged from 6 and 12 in. deep AEC absolute filters and electrostatic precipitator plates (coated and uncoated) in a ventilation system subjected to a shock wave from a detonated nuclear weapon (4). (Shock waves were produced in the laboratory tube by bursting calibrated Kraft paper diaphragms.) Both of these studies have been reported in detail in references cited, so only a partial summary of pertinent test results is presented in Table 6. Laboratory shock tube tests on standard Dust-Stop filters and 6 in. deep AEC filters (24 x 24 x 6 in.) indicated some structural failure occurred at overpressures of 1.5 and 6.0 in. Hg., respectively. Moderate damage or partial failure consisted primarily of movement of filter media within the filter frame, usually $\frac{1}{4}$ in. or more away from the blast direction.

Dust reentrainment studies from 6 and 12 in. deep AEC filters in laboratory and field installations indicate from 4 to 98% of initial dust loading is removed by weak shock waves, at overpressures ranging from 1.1 to 5.0 in. Hg. Dust removal (%L) from AEC filters tested in the field was found to be proportional to overpressure, initial dust loading, and inversely proportional to filter depth:

$$\% \, L = \frac{126 \, L_i \, P^{0.4}}{D^{0.8}} \qquad (1)$$

where the overpressure (P) is expressed in psi, the initial filter loading (L_i) in grams/sq.ft. of filter surface (100 sq.ft. for 500 cfm filter, 200 sq.ft. for 1000 cfm filter) and depth (D) in inches (6 or 12). The amount of dust removed from these filters was proportional to the amount of dust on the filter before the blast, i.e., a filter with 100% dust load (defined as amount required to double the initial filter resistance) lost essentially all of this dust when exposed to a shock wave. It was found experimentally that peak overpressure was a somewhat less important factor than had originally been suspected, i.e., a doubling of the overpressure with a constant amount of dust on the filter caused only a 30% increase in dust removal.

The purpose of these laboratory and field tests was to establish levels of shock wave overpressures that caused structural damage to elements of gas cleaning systems, particularly filters; to determine amount of dust reentrained from gas cleaning devices below critical (damage) pressures; and to determine effective means of controlling or minimizing both. The rather large amounts of dust removed by shock waves below damage level overpressures suggested this method

TABLE 6. -- DUST DISLODGED FROM FILTERS BY SHOCK WAVES

Test Device[a]	Shock Wave Pressure[b] in.Hg.	Initial Dust Load grams	Initial Dust Load %	Dust Loss grams-%		Remarks
A. Laboratory 20 Inch Diameter Shock Tube Study						
Dust-Stop	1.5	-	-	-		Blast effects study - moderate damage[c]
Dust-Stop	3.0	-	-	-		Blast effects study - complete failure
AEC-6	4.3	-	-	-		Blast effects study - no damage
AEC-6	6.3	-	-	-		Blast effects study - partial failure
AEC-6	12.1	-	-	-		Blast effects study - complete failure
AEC-6	3.4	155	75	152	98	
AEC-6	3.7	126	56	74	59	
AEC-6	3.8	26	10	8	32	
AEC-12	5.0	429	100	359	84	
AEC-12	4.7	39	8	20	51	
B. Field Study of Simulated Ventilation System Exposed to Shock Wave from Nuclear Explosion						
AEC-6	2.6	357	98	306	86	
AEC-6	3.2	213	30	155	73	
AEC-6	1.4	275	100	177	64	
AEC-6	1.3	212	25	110	52	
AEC-12	2.8	744	100	557	75	
AEC-12	2.4	575	31	331	58	
AEC-12	3.0	554	56	294	53	
AEC-12	1.1	826	69	460	56	
AEC-12	1.3	585	50	26	4	Filter preceded by blast attenuation device.
AEC-12	1.3	548	49	224	41	

a. Dust-Stop Fiberglas filter - 20 x 20 x 2 inch - 800 cfm rated capacity.
AEC-6: Pleated cellulose asbestos paper filter - 24 x 24 x 6 inch - 500 cfm rated capacity.
AEC-12: Same as above, 12 inches deep - 1000 cfm rated capacity.

b. Peak over-pressure; positive phase duration 800 millisec. in laboratory study, and 800 to 1000 millisec. in field study.

c. Extensive reentrainment of dust initially on filter, but not quantitated.

as a potential means of cleaning filters for reuse. This has led to the application of shock wave treatment to mineral wool filters used to collect open hearth fume, to lower their resistance periodically during use as described below.

Description and Operation of Test Equipment

To test the effectiveness of shock waves for cleaning of mineral wool filters, our standard 6 in. diameter filter test unit (5) was modified by addition of a 6 in. diameter by 6 ft. long (1.22 cu.ft.) pressure reservoir downstream of (behind) the filter test section and the blower used to draw air through the system was connected to a tee, as shown in Figure 3. During normal operation, room air (30 cfm for 150 fpm filtering velocity) was drawn into the 6 in. diameter pipe, entraining iron oxide fume generated by combustion of iron pentacarbonyl ($Fe(CO)_5$) at the inlet. Fume-laden air passed to the 6 in. diameter by 2 in. thick slag wool filter (from right to left in Figure 3) where fume was removed at 90-99% efficiency. The cleaned air was then exhausted through an orifice meter in the branch line to a fan. Up- and downstream samples (1 cfm) were withdrawn simultaneously at locations indicated, by means of sampling probes holding 1-9/16 in. diameter all glass filter papers. As fume accumulated on the slag wool filter, resistance rose to a predetermined level, whereupon generation of the aerosol was stopped and the valve on the branch leading to the fan was closed. A Kraft paper diaphragm (one or more sheets, as required) between the pressure reservoir and the filter was then burst by admitting compressed air to the reservoir (to the desired overpressure, usually 5 to 10 in. Hg.) and puncturing with the lance shown. This simple process caused a minor explosion which generated a shock wave that traveled down the tube through the slag wool filter (from left to right in Figure 3). This procedure of loading the filter with iron oxide and subsequently removing it with a shock wave was repeated until the filter efficiency decreased below 80%, when the test was stopped.

Figure 4 is a picture of the shock tube prior to the blast. The normal steel inlet is replaced with a transparent plastic tube to indicate the results of the blast shown in Figure 5.

Laboratory Results

The blast pressure should be large enough to reduce the filter resistance to the initial value, or near it, and yet not dislodge excessive amounts of the filter media. This value was found to be 5 in. Hg for an arrangement of 6/1.2/5 (6 in. diaphragm diameter, 1.2 cu.ft. blast chamber volume, 5 in. Hg overpressure). (See lines 1 and 4, Table 7.)

The ratio of the diaphragm to the filter area was varied from 1:1 to 1:7 and 1:9. Two orifice plates with 2.3 in. diameter openings holding a diaphragm between them were installed to give the 1:7 ratio. The chamber pressure had to be increased to 10 in. Hg overpressure to obtain adequate cleaning. A temporary 18 in. diameter filter holder with transition pieces was installed to operate in conjunction with the 6 in. diameter diaphragm. This arrangement also required at least 10 in. Hg overpressure for adequate cleaning. (See lines 1, 2, 3 & 5 in Table 7.)

The blast chamber size was varied from 1.2 to 0.72 and 0.44 cu. ft. by inserted objects. The 6/0.7/5 and the 2.3/0.7/10 arrangements tended to function similar to those using the 1.2 cu.ft. blast

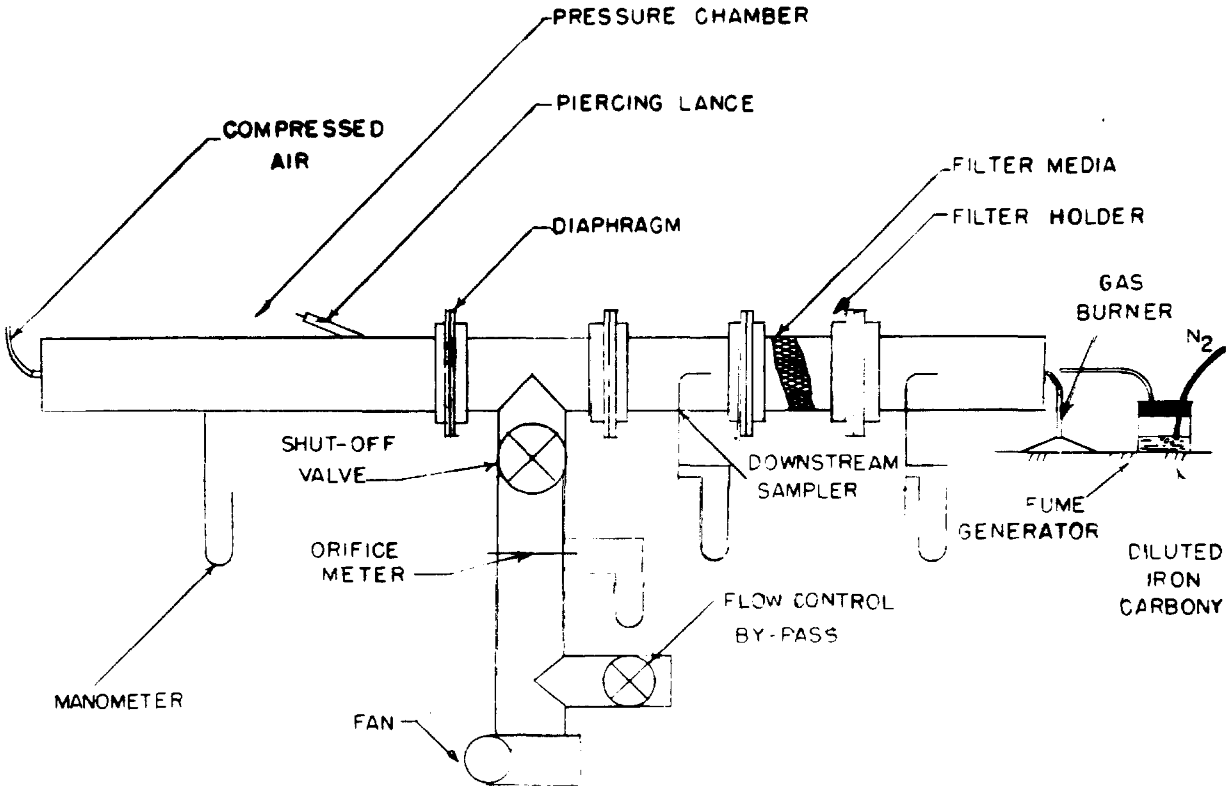

Fig. 3—Shock-tube setup.

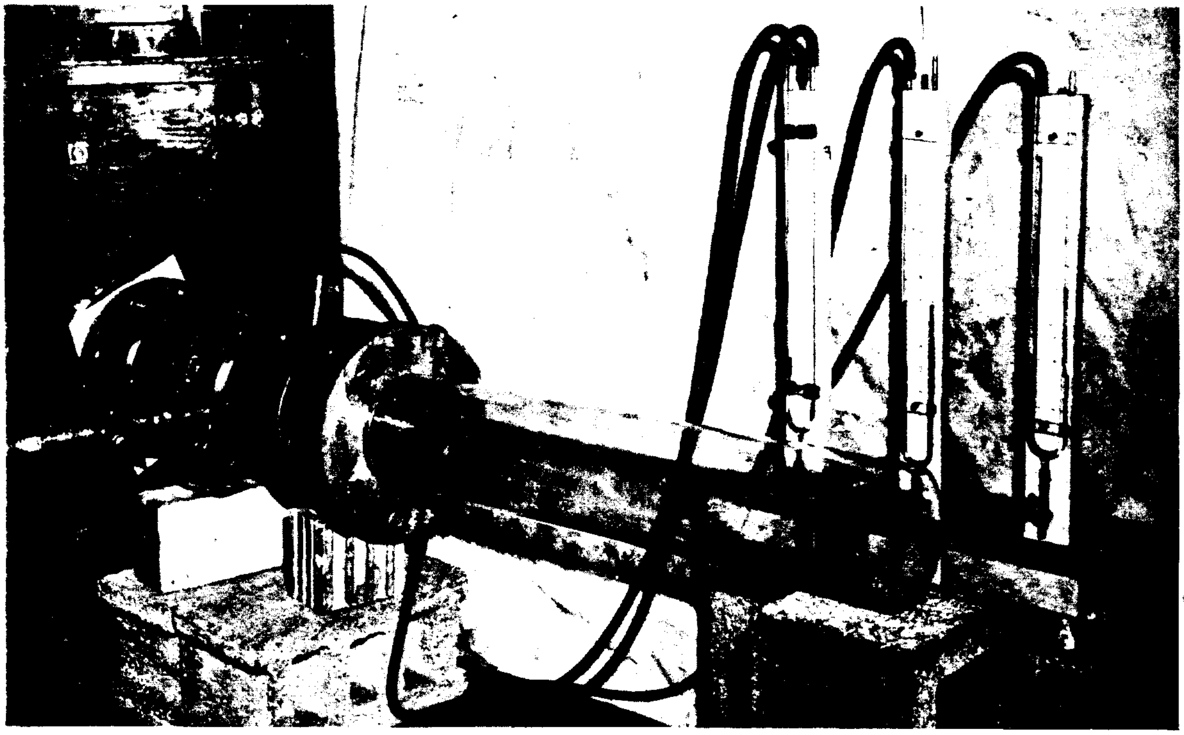

Fig. 4—Blast wave filter cleaning setup (photograph before blast).

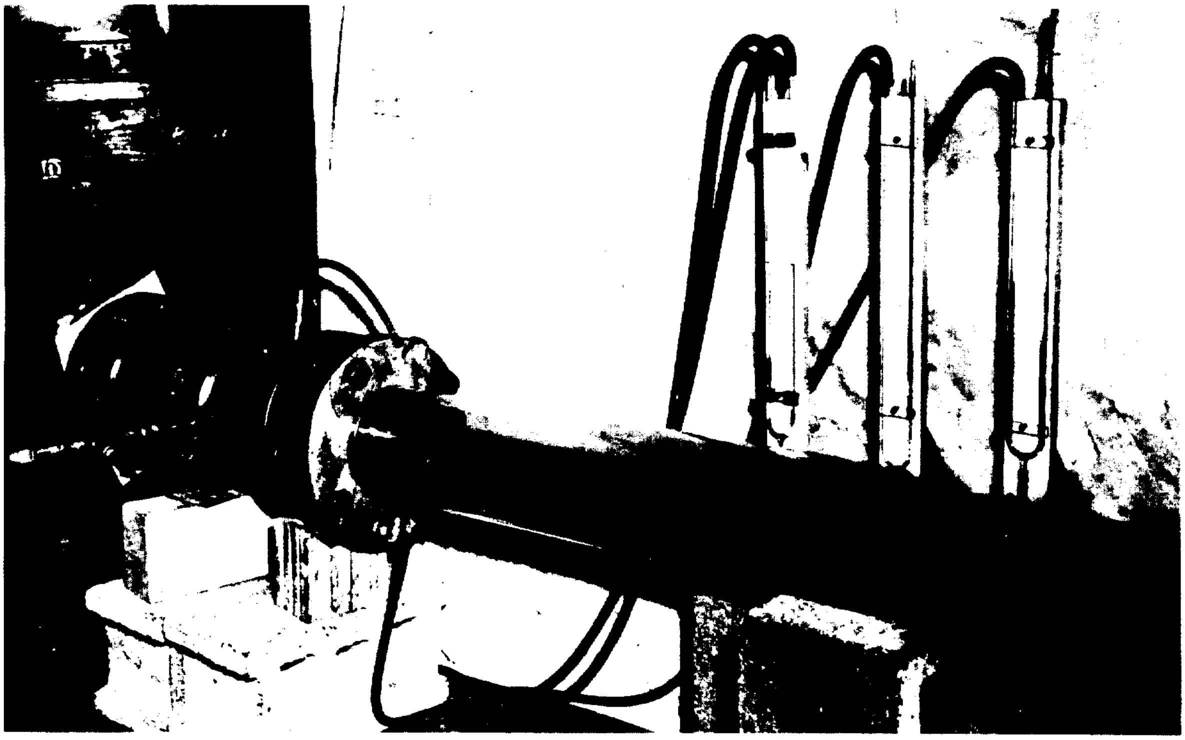

Fig. 5—Blast wave filter cleaning setup (photograph during blast).

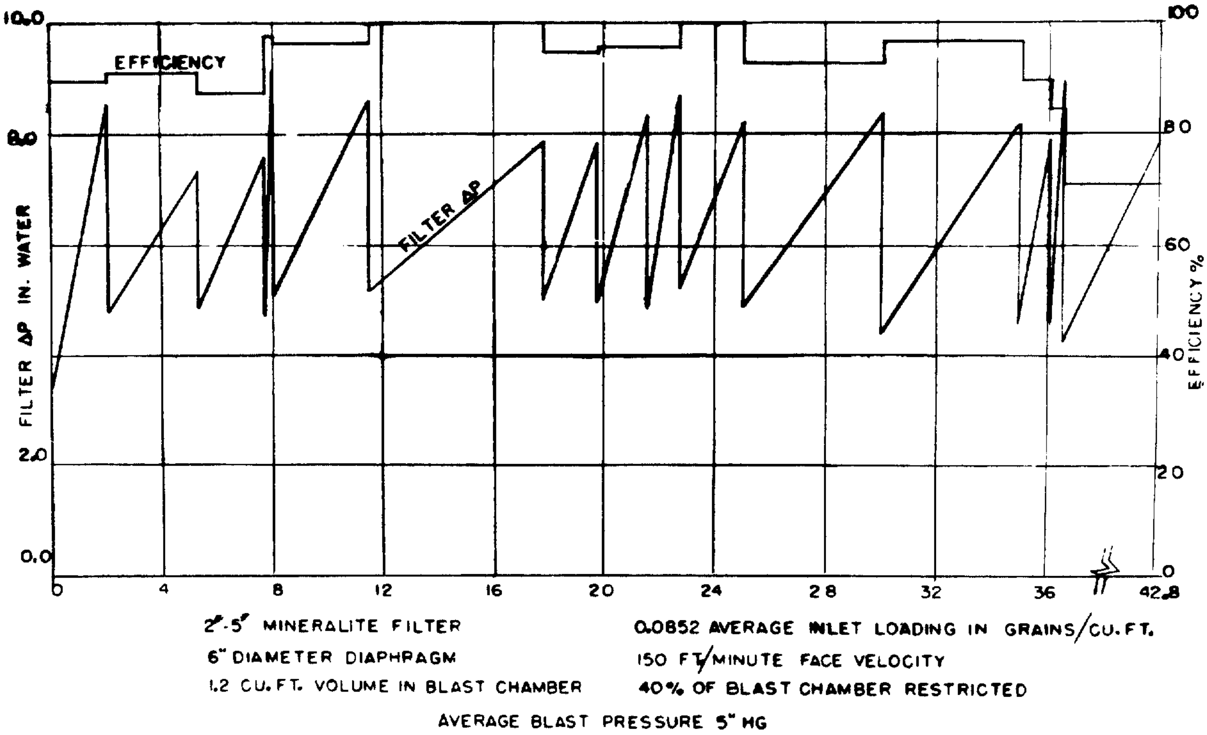

Fig. 6—Blast performance study curves.

Table 7. Summary of Shock Wave Cleaning Tests on Mineral Wool Filters[a] After Collection of Iron Oxide Fume

Total Tested[b]	Shock Tube Characteristics[c] Dia./R.V./B.P.			Inlet Conc. gr/cu.ft	Filter[d] Packing Density	Filter Resistance In. H_2O[e]			Avg.[f] Eff. %	Total[g] Number Bursts	Time Mins.	% Wt. Loss
						First	Init. Avg.	Fin. Avg.				
2	6	1.2	5	0.12	5	4.0	4.2	8.0	92	31	69	17
5	2.3	1.2	10	0.06	5	3.8	4.7	8.1	86	42	128	12
1	18[h]-6	1.2	10	0.01	5	2.6	3.3	4.0	81	13	188	-
2	6	0.7	5	0.03	5	3.6	4.8	8.2	90	32	89	8
1	2.3	0.7	10	0.06	5	3.6	4.1	7.9	91	10	16	9
3	6	0.4	5	0.07	5	3.3	5.2	7.5	90	29	59	3
4	6	1.2	8	0.05	3	2.1	2.3	5.5	77	13	88	12
1	6	1.2	5	0.02	7.5	7.5	9.0	14.1	99	13	44	-
1	6	1.2	5	0.02	10	9.4	14.7	28.2	99	13	84	0

a. Bethlehem Mineral Wool - 2 inches thick by 6 inches diameter (except in line 3, 18 in. diameter).
b. Number of filters used in total series of tests.
c. Dia. = diameter of burst paper diaphragm, inches; R.V. = reservoir volume, cu.ft.; B.P. = blast overpressure, in. Hg.
d. Filter packing density - pounds per cu.ft.
e. At 150 fpm filtering velocity, avg. initial does not include "first" value.
f. Average weight efficiency in all tests including last one of each series which was less than 80%, the criterion for stopping test.
g. Total number of exposures to blast of all filters tested.
h. 18 in. diameter (2 in. - 5 lb./cu.ft.) filter mounted on 6 in. reservoir.

chamber. The 6/0.4/5, however, was not as effective on cleaning as the previous two. (See lines 1, 4 and 6 in Table 7.)

Increasing the filter packing density resulted in increased efficiencies and initial resistances as was expected, but the 5 in. Hg overpressure shock wave cleaning was not as effective on the denser filters as can be seen in the difference between the first and the initial resistances. (See lines 1, 8, and 9 in Table 7.)

Filters can be cleaned from 10 to 20 times by low level shock waves before the efficiency is reduced below 80%, the arbitrarily set minimum. (See Figure 6.)

Slag Wool Filter Pilot Plant 4

A 2000 cfm pilot plant has been developed using slag wool for a high temperature filter media. The unit is designed to evaluate three methods of cleaning the filter media. Cleaning is done within the filter chamber conserving space and equipment. Another feature is the elimination of mechanical motion during filtration enabling the use of simple seals.

Unit Description

Major items in the pilot plant unit are a 700 gallon holding tank, 200-300 gpm slurry pump, a 30 HP gasoline engine driven fan and the 5 ft. diameter filter chamber. (See Figure 7.) The filter chamber consists of a 5 ft. steel cylindrical shell 7 ft. high, containing two reenforced expanded metal screens, a blast chamber on the top of the shell, and a compressed air manifold at the conical chamber base. The bottom screen, on which the slag wool filter is formed, can be rotated about a major axis to dump the spent wool. When not raised to storage position the top screen holds the bed in place between the screens for upward flow of gas or water. A 110 gal. chemical drum forms the blast chamber, which is equipped with a two ton jack to position a 2 ft. diameter diaphragm and a mechanical lance to puncture this diaphragm and create the shock wave. Compressed air is supplied to the manifold on the bottom for mixing slurries within the filter housing.

Operation

This unit incorporates three methods of cleaning the filter media, which are designated PP4, A, B, and C. The initial operations of each are quite similar with the slag wool being separated from the slurry to form the filter media, dried of almost all moisture, and exposed to the furnace effluent. The next operation differs in the cleaning method with PP4 A, B, and C being cleaned by a reslurrying of the media similar to the initial operation, a reverse flushing of water through the media, and a blast wave in opposite direction to the normal gas flow, respectively. The final mutual step consists of dumping of the spent wool and flushing it to waste or reclaiming processes. (See Figures 8, 9 and 10.)

Open Hearth Field Results

The data taken on the unit arranged to operate as PP4 A or B using the exhaust fume (700°F) from a local 20 ton cold metal open-hearth furnace are presented in Table 8, except for orientation runs 1 and 2. Runs 3, 5, 7, and 8 on new beds, which maintained a 3 in. H_2O initial filter resistance, showed increasing efficiencies of 55

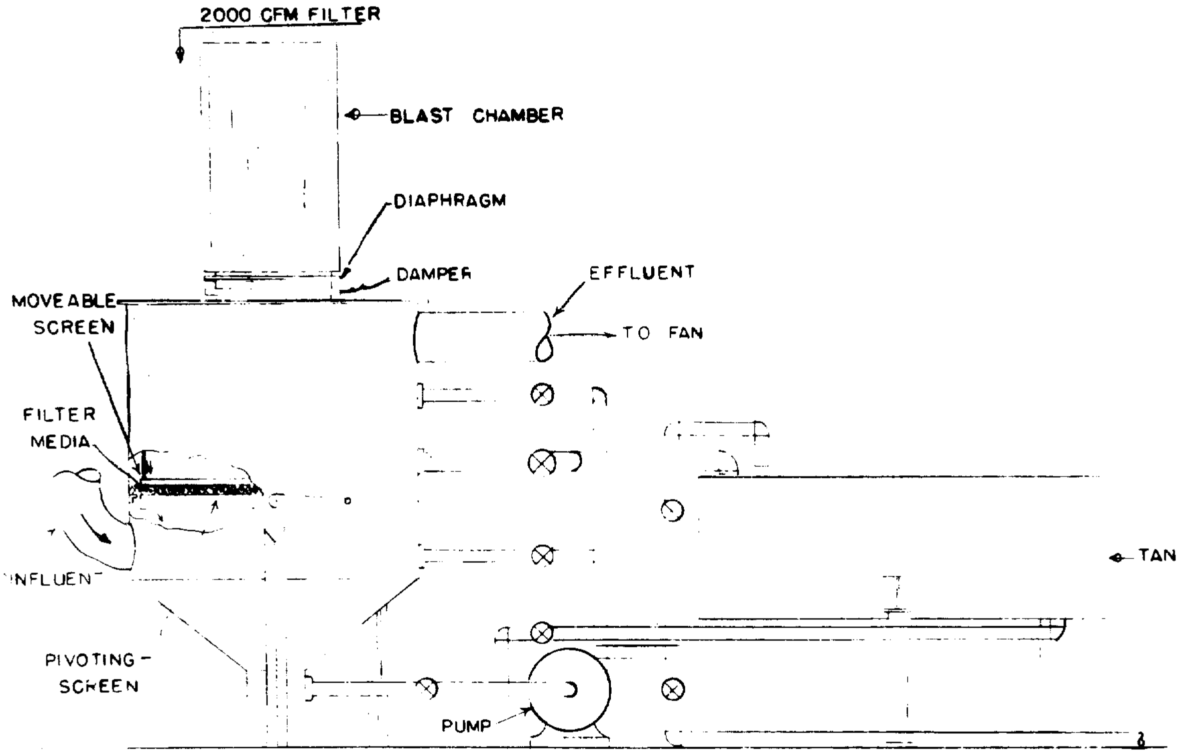

Fig. 7—Pilot plant 4A.

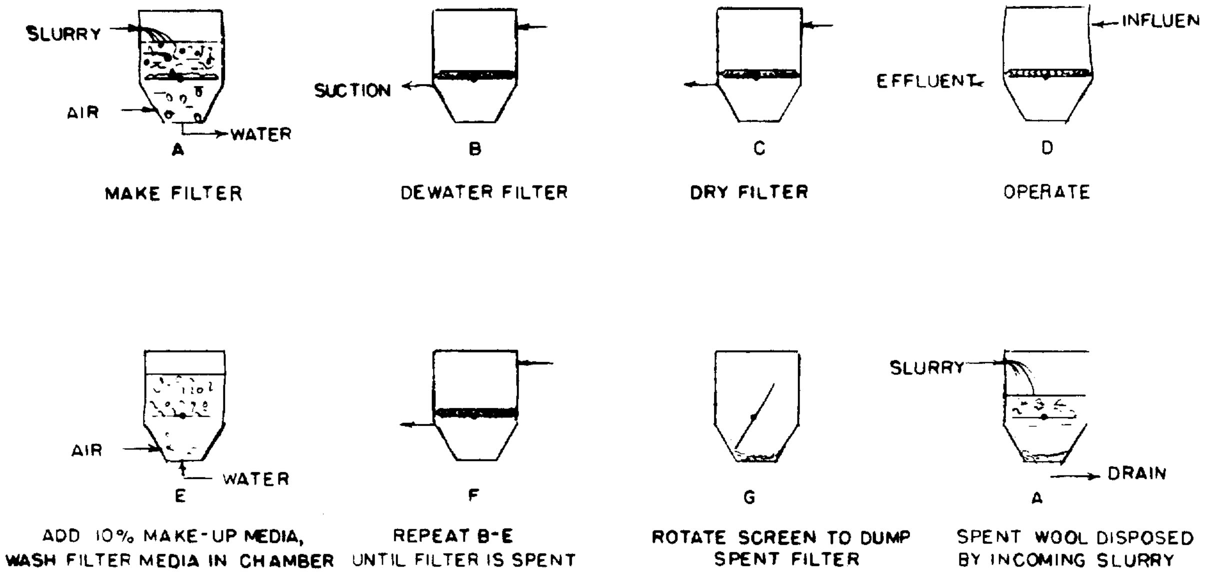

Fig. 8—Operation of pilot plant 4A (reslurry).

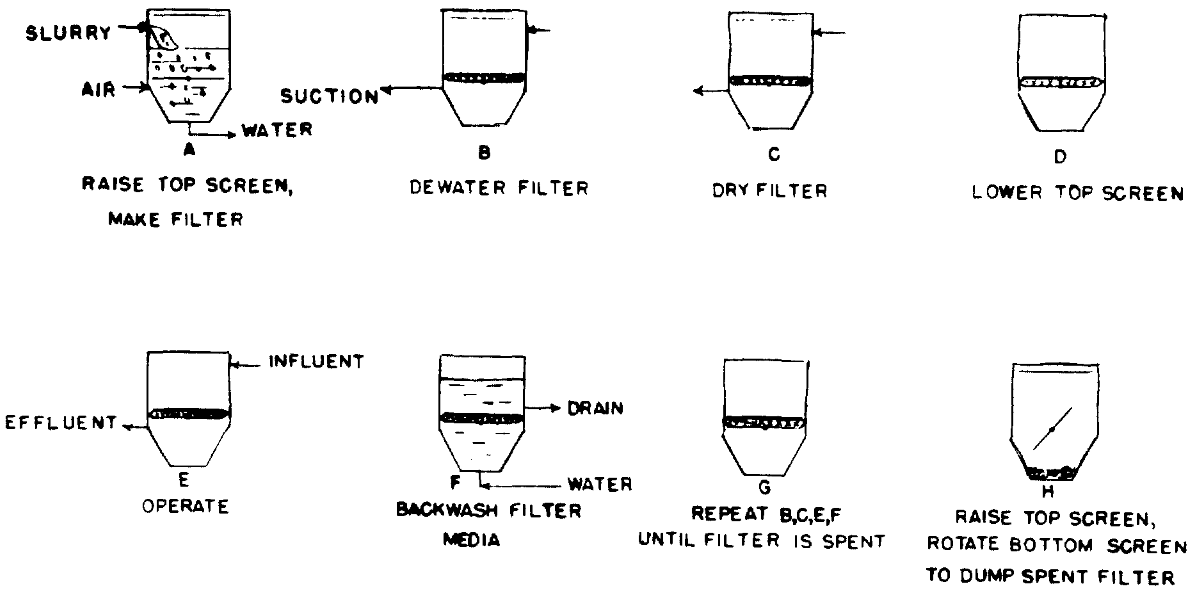

Fig. 9—Operation of pilot plant 4B (backwash).

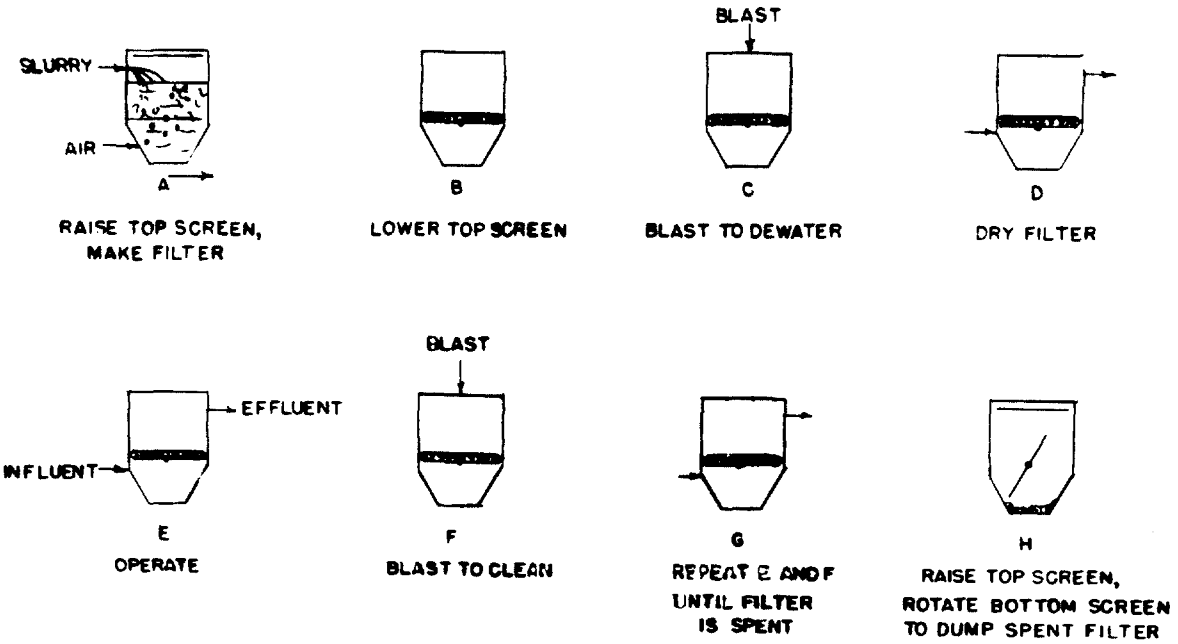

Fig. 10—Operation of pilot plant 4C (blast).

Table 8.

SUMMARY OF SLAG WOOL FILTER PILOT PLANT 4A, B TESTS ON 20 TON COLD METAL OPEN HEARTH FURNACE FUME

Test No.	Filt.Vel.[a]-fpm Init.	Fin.	In. Conc. gr./cu.ft.	Filt.Res.[b]-In.H_2O Init.	Fin.	Eff. %	Time[c] Min.	Temp.[d] °F	Remarks
3	96	90	0.02	3.3	5.2	55	48	550	New bed - 6# - DHG
4	95	83	0.02	5.7	7.5	94	46	580	Same bed
5	92	54	0.05	3.6	13.1	68	44	550	New bed
6	44	32	0.03	14.0	15.6	99	44	480	Same bed
7	90	45	0.10	3.4	14.4	89	60	540	New bed - 5# - DRA
8	90	42	0.09	3.2	14.0	95	52	510	New bed - DRA
9	89	54	0.05	4.7	12.5	98	48	500	New bed - 2#
10	50	32	0.03	12.7	15.2	99	47	440	Same bed
11	91	78	0.05	-	-	92	16	500	10 Backwashed
12	73	50	0.24	-	-	89	28	440	11 continued
13	67	37	0.11	9.3	15.2	99.7	53	430	New bed - 4# - DHG
14	31	18	0.05	15.5	18.0	-	23	370	Same bed
15	92	89	0.04	3.0	7.9	93	42	550	New bed - 3 - DRA
16	75	57	0.02	8.8	12.1	95	41	500	Same bed
17	93	83	0.05	2.0	8.4	68	48	540	16 Backwashed - DRA
18	85	78	0.03	8.2	10.0	31	62	530	17 Continued
19	93	93	0.10	2.3	2.5	44	52	520	18 Backwashed - DRA
20	93	88	0.09	3.2	8.3	97	50	520	New bed - 2
21	82	82	0.05	1.1	9.4	60	50	530	20 Reslurried in place

a. Filtering velocity, feet per minute at temperature indicated in column 8.
b. At temp. in column 8.
c. Total operating time, sampling time usually 1 to 10 min. less.
d. Average of max., min. from both inlet and outlet gas.
e. Indicates origin of bed, packing density in lb./cu.ft. when available and method of drying -
DHG = dried on hot clean furnace gas (furnace banked) for about 20 mins.;
DRA = dried on room air for about 4 hours.

Table 9. Shock Wave Cleaning Tests on 2000 CFM Slag Wool Filter (2"-5#/cu.ft.) With Electric Furnace Fume

Test No.	Filt. Vel.[a]-fpm Init.	Filt. Vel.[a]-fpm Final	In. Conc. gr/cu.ft.	Filt. Resist.[a]-In.H_2O Init.	Filt. Resist.[a]-In.H_2O Fin.	Filt. Resist.[a]-In.H_2O Aft. Bl.	Bl.Press. In.Hg	Eff. %	Time Mins.	Remarks
22	118	109	0.70	5.0	8.0	4.8	5	70	37	New filter
23	114	101	0.61	4.8	9.4	-	-	61	49	Same filter
24	117	101	0.05	5.4	8.7	5.6	5	79	42	New[b]
25	116	82	0.16	5.6	14.7	6.6	5	64	35	Same
26	111	90	0.03	6.6	12.3	6.5	5	73	24	"
27	111	92	0.02	6.5	12.3	-	-	67	29	"
28	117	90	0.08	5.2	11.7	6.2	5	84	31	New[c]
29	114	95	0.04	6.2	11.7	6.5	5	74	18	Same
30	113	90	0.17	6.5	11.7	-	-	82	10	"
31	113	87	0.08	5.2	12.3	6.0	4½	93[e]	22	New[d]
32	112	87	0.04	6.0	12.3	6.1	5	79	12	Same
33	109	-	-	6.1	12.3	6.2	5½	-	1	"
34	106	89	0.19	6.2	12.3	6.4	6	86	3	"
35	106	89	0.06	6.4	12.3	6.5	5½	79	7	"
36	108	86	0.04	6.5	12.3	6.8	5	92	17	"
	108	-	-	-	-	6.5	5	-	-	- (extra blast)
37	108	89	0.04	6.5	12.3	7.0	5½	96	16	"
-	104	-	-	-	-	7.0	5	-	-	"
38	108	85	0.02	7.0	12.3	7.5	5	88	22	"
-	106	-	-	-	-	7.0	5	-	-	"
-	106	-	-	-	-	7.0	5	-	-	"
39	106	89	0.04	7.0	12.3	6.6	8½	86	14	"
40	104	90	0.02	6.7	12.3	6.9	9	81	28	"

a. At gas temperature of 120°F, approx.
b. Periphery of filter provided with rubber tubing seal.
c. Periphery of filter packed with slag wool lightly by hand.
d. Periphery of filter packed with slag wool heavily by hand.
e. No plume visible from tests 31 through and including 40.

68, 89 and 95, respectively, as the layer formation procedure was improved. Higher efficiencies produced lower downstream loadings and in these field tests required changing of the downstream glass wool filled canister (weighing 50,000 mgs and collecting only a few mgs) to an 1106B glass filter disk (weighing about 100 mgs). Subsequent testing on similar new beds with 1106B filters indicated efficiencies over 90 per cent for runs 9, 13, 15 and 20. Again, the initial pressure drop was about 3 in. H_2O. Continued testing of beds already loaded with particulates (runs 4,6,10,12,14, and 18) gave generally higher efficiencies and higher filter resistance as was expected. Runs 11, 17 and 19, which were cleaned by backwashing the principle of PP4 B, had efficiencies of 92, 68 and 44, respectively, and run 21, which had been cleaned by reslurrying, the principle of PP4 A, had an efficiency of 60 per cent. These studies will be continued to evaluate the most feasible cleaning method.

Electric Furnace Field Results

Upon completion of the above studies an effluent test was made on a 13 ton electric furnace in the same vicinity. Furnace fume conditions were quite similar except that effluent temperatures were lower (150°F); so the unit was relocated with the required changes to function as PP4 C.

The unit was arranged and operated in essentially the same manner as at the O.H. location, except for the reversal of gas flow (upward) through the filter chamber, which necessitated the use of the top screen. Initial average efficiency of 65 per cent was due to leakage of the furnace fume past the edge (or periphery) of the filter. After a new filter bed was formed, a sand filled rubber hose was placed on the periphery of the filter media to act as a more positive edge seal, and this resulted in an increased average efficiency of 71 per cent for runs 24-27. The periphery of another new bed was then hand packed with additional dry wool giving a higher average efficiency of 80 per cent for runs 28-30, and when the periphery of still another new bed was tightly packed, the highest average efficiency of 87 per cent occurred with no visible effluent plume for 10 runs, 31-40. (See Table 9.)

The original resistance of filters tested with shock wave cleaning was about 5 in. H_2O (higher than expected), and subsequent cleaning by low level shock waves (5 in. Hg) gave generally increasing initial resistances. Following runs will be made with higher blast pressures (10-12 in. Hg). The unit is presently being modified to handle these higher pressures as well as to eliminate the need of hand packing the edges of the filter.

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DEVELOPMENT OF AN IONIZATION DETECTOR FOR THE MEASUREMENT OF AEROSOL PARTICLE CONCENTRATIONS

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ABSTRACT

A portable instrument has been developed which can readily detect aerosols in concentrations from 2 x 10^3 particles/cm.^{3} to 1 x 10^9 particles/cm.^{3}. The instrument consists of two ionization chambers connected as series arms of a Wheatstone bridge. The ionization is produced by a Radium D foil lying on the inner chamber wall. Aerosol particles passing through one of the ion chambers will carry away some of the ions in the sensitive volume and a decrease in the ion current will result. The change in current is proportional to the particle concentration.

A second ion chamber will compensate for changes in the carrier gas composition and battery fluctuations. The complete instrument weighs less than two pounds exclusive of a vacuum pump capable of drawing 5 liters per minute.

Introduction

In the study of dynamic aerosol systems it is frequently necessary to evaluate number concentrations of the suspension during the action of external forces. We are presently developing dynamic particle agglomeration devices whose performance is best evaluated in terms of a change in particle numbers per unit gas volume (particles/cc). Several methods have been used for actually measuring particle concentrations, among them being various electronic counters (cumbersome, expensive), light scatter (particle size shape and index of refraction dependent), and optical or electron microscopy (more or less absolute, but tedious and not adapted to "in vivo" measurements. Limitations of these methods appear to be excessive size, cost, or time required for analysis. What is required is a portable, inexpensive device which responds instantly to particle concentration changes in some readily discernable manner. We have investigated the cloud chamber technique originally used by Aitken as modified by Vonnegut (1) and by Saunders (2). The aerosol particles flow into a chamber with a collimated light source at one end and a photoelectric detector at the other; the air is saturated, and a slight vacuum is drawn on the chamber to permit moisture to condense on the particles, causing them to grow to a uniform size and interrupt the light beam in proportion to their number. This device was built and tested on industrial dust loadings. As was indicated by Vonnegut (1), when dealing with high number concentrations ($> 10^6$ particles/cm.^{3} approx.), the response curve no longer remains proportional to numbers present, but flattens out and the result becomes indeterminate. Dilution systems to reduce particle concentration from 10^9 particles/cm.^{3} or greater, down to $<10^6$ particles/cm.^{3}, are generally large, and must be very carefully calibrated to minimize the large order of magnitude error possible by successive dilution. A commercial model of this device is available, but is limited to about 10^6 particles/cm.^{3} (3).

Another unique method is presently under development utilizing the ionization of air by means of a small radioactive source and the collecting of the ions formed, by a central wire. The ion current so generated is measured on a microammeter. When an aerosol passes between the ion source and the collector wire, some ions attach themselves to particles, reducing the ion current in proportion to the number of particles present. This method has been used in principle by Drozin and La Mer (4) to measure particle size, and by others (5) to measure gas concentrations (by first forming the aerosol from the gas).

Instrument Design

An ionization current will flow between two oppositely charged electrodes if the gas between them is ionized by some external source, such as x-rays, ultraviolet light, or nuclear radiations. The ionization current is proportional to the intensity of the source of ionization, the gas composition between the electrodes and the geometry of the ion collecting system. Figure 1 shows the design of the ion chamber used to detect aerosols. The outer wall is a brass tube 10 centimeters long and 1.6 centimeters in diameter and the center electrode is a 0.020 in. diameter stainless steel wire. Each chamber is fitted with Lucite end pieces designed to allow gas flow through the chamber and also support the center electrode. Clean insulators are necessary as a leakage current as large or larger than the ionization current being measured may flow in the circuit thereby affecting the system balance and sensitivity. In any electric field some particles will be precipitated. A particle may be transpoxted through the field by the gas stream but be deflected by the weak field sufficiently to be deposited on the Lucite insulators. The conductivity of a gas (the

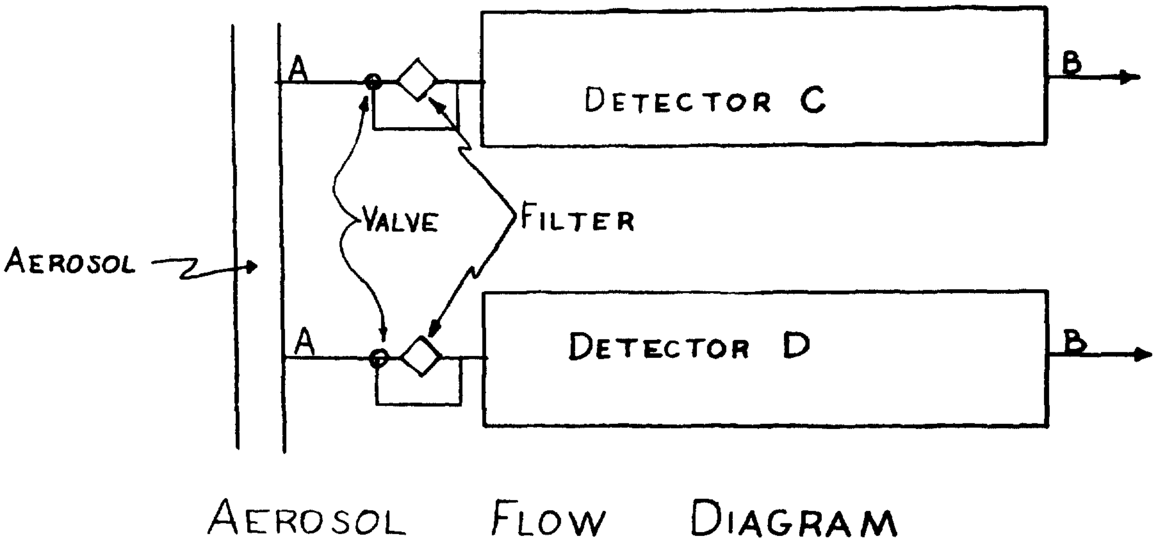

Fig. 1—Detector and compensator ion chambers.

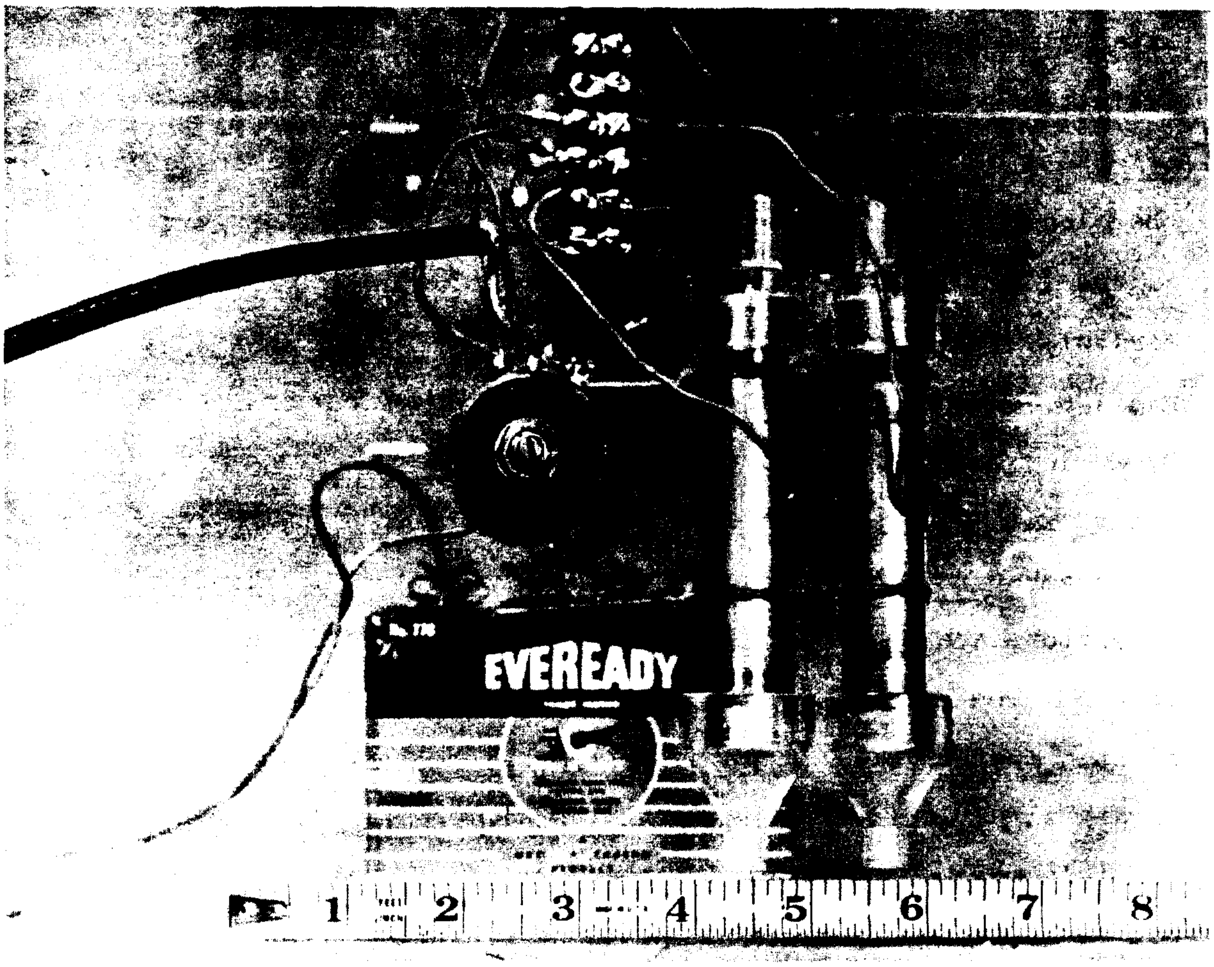

Fig. 2—Ion current vs. voltage in either detector or compensator chamber.

reciprocal of the resistance) varies with the potential difference established across the gas between the electrodes. Particles collected on the electrodes change the geometry of the electric field sufficiently to change the instrument sensitivity.

Ionization within the chambers is produced by a Radium D + E + F alpha source of approximately 500 micro-curies in a foil $\frac{1}{4}$" wide and 2" long located at the entry to the ion chamber. A 500 micro-curie alpha source produces 18.5×10^6 alpha particles per second. The alpha particles are produced by the decay of the 138 day half-life Po-210 (RaF) and each alpha has an energy of 5.03 Mev and will produce 1.4×10^5 ions (at 35 e.v./i.p.). There are available 26.4×10^{11} ions per second but at most only one-half enter the chamber and one would expect a current of 2.1×10^{-7} amp. Actually a much lower value of current occurs because the low voltage used allows a great deal of ion recombination. Figure 2 is a typical ion current vs. voltage curve, (and is similar to that for almost any ion chamber).

The interesting thing to note here is the independence of flow rate upon the ion current. For convenience a flow of 3 liters per minute has been arbitrarily selected for normal use. The highest signal to noise ratio will lie in the low voltage proportional region between 15 and 100 volts. At this voltage level any loss in ion current (or decrease due to particle capture) will be a larger fraction of the total current than at any higher voltage where a plateau is approached. Generally, 30 volts are used across each chamber. (Voltage is supplied by hearing aid batteries).

The electrical circuit of the detector is shown in Figure 3. A Wheatstone bridge is balanced with the variable resistors 1 and

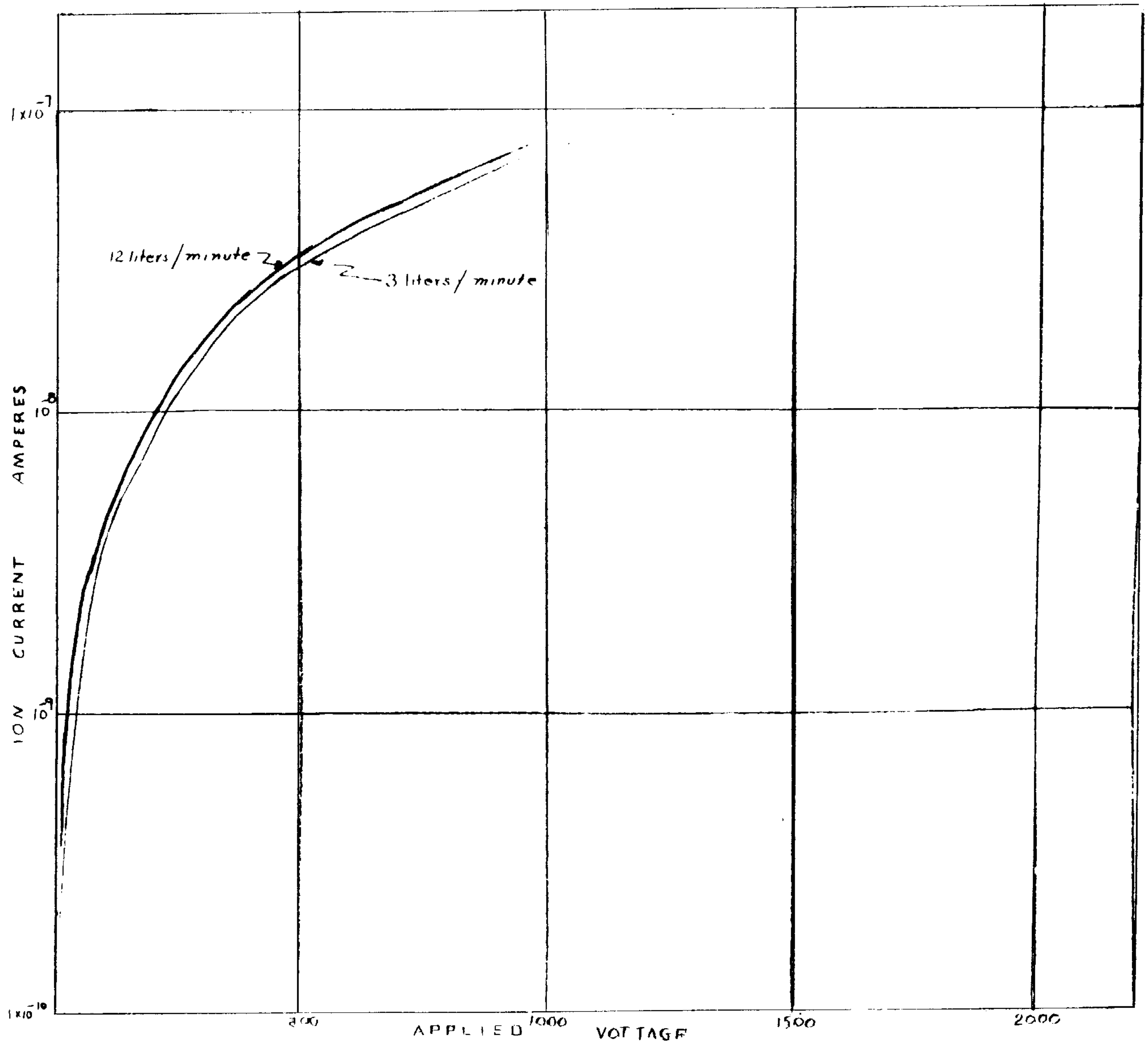

Fig. 3—Detector and electrometer circuit.

2, which have a value of 5 meg ohms. Electrical balance is determined with a high input impedence voltmeter (preferably an electrostatic unit should be used but a high quality, high input impedance vacuum tube voltmeter may be used). The electrometer circuit is then activated. If the chambers are dynamically balanced as regards impressed voltage, ionization activity and flow rate, no current will flow between junctions A and B. The tube used is relatively unimportant as long as it is a high quality electrometer tube with characteristics such that the grid current is less than 10^{-13} amperes. Some electrometer tubes are available with grid current of 10^{-15} amperes, and would be preferable, but are too delicate for a portable instrument. Any change in the conductance of either ion chamber will cause an unbalance in the bridge and will upset the grid bias thereby increasing or decreasing the current in the electrometer tube.

A flow diagram is shown in Figure 4. The aerosol enters the system at A, passes through chambers C and D simultaneously and exits at B. Air entering both chambers is filtered and the system balance is obtained. One chamber is then exposed to unfiltered air containing particulate material. Some of the ions present in the chamber will become attached to the aerosol particles which pass through the electric field. The charges captured by these particles are carried out of the chamber and a decrease in the ion current is measured.

Instrument Calibration

We are presently calibrating the instrument under various operating conditions. Table 1 presents a summary of data on detector-cell response in the presence of gases and aerosol particles of known diameter (approximately). Type of aerosol or gas alone is shown in Column 1, the response of the instrument

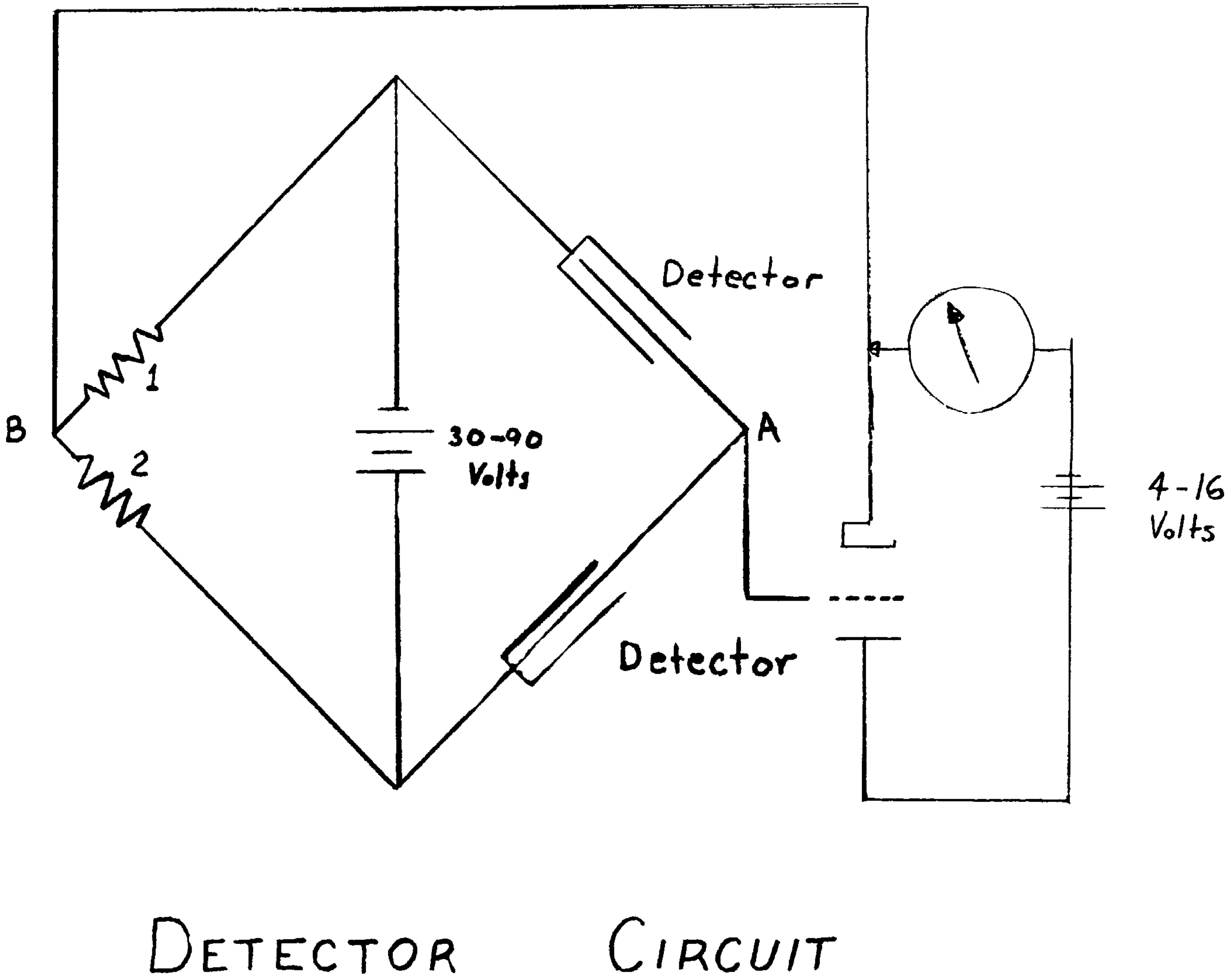

Fig. 4—Schematic aerosol flow diagram.

microammeter is shown in Column 2, and the approximate particle concentration in Column 3. Concentrations $<10^6$ particles/cm.^{3} are being determined by means of the continuous condensation nuclei meter developed at Oak Ridge by Saunders (2).

The first four tests shown were made with ambient air containing atmospheric dust, and with oil smoke (Diol 55). Calibration in the low ranges was determined with successive dilutions of filtered air. Since the instrument has been developed with a view toward uses on industrially occurring aerosols, such as open hearth furnace stack effluents, the presence of SO_2 gas was considered as a likely interference. By using a filtered stream through our detector chamber, the signal due to change in gas composition can be eliminated, since both chambers see the same amount of gas simultaneously,

TABLE I

INSTRUMENT RESPONSE

The following data was obtained using filtered (1106B glass paper) and unfiltered laboratory air and an oil smoke of 0.6 micron diameter

Aerosol	Meter Reading (μ a)	Particle Concentration particle/cm.^{3}
Filtered air	0.75	600
Laboratory air	1.25	15,450
Oil smoke (0.6 μ diameter)	5.0	38,700
Oil smoke 1:1 dilution	2.50	19,120
SO_2 in detector	Full Scale	
SO_2 in compensator	Zero	
SO_2 in detector and compensator	1.5	
Filtered air	1.5	

but the unbalance is caused by particles in one chamber.

We are presently investigating the influence of aerosol particle size on detector response, by means of homogeneous DOP particles from a LaMer-Sinclair (6) generator.

Conclusion

The development of an ionization-type aerosol detector for agglomeration studies has indicated that response is proportional to concentration of particles, at least in the lower ranges ($<10^6$ particles/cm.^{3}). Further development will continue with studies of particle size sensitivity, and response at higher loadings. By using two detector tubes, it is possible to eliminate spurious signals due to changes in gas compositions, as might be expected in industrial aerosols.

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IODINE COLLECTION STUDIES

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ABSTRACT

Several methods for the removal of radioactive iodine from process and laboratory gas streams are under investigation by the Harvard Air Cleaning Laboratory. Major test objectives are to develop collectors which (1) afford at least 90 per cent I^{131} collection, (2) have low resistance, (3) are relatively inexpensive and easy to fabricate and maintain, (4) have a long, i.e. up to 2 year service life in terms of holding capacity and corrosion resistance, (5) can function at gas temperatures up to 300°C, and (6) are non-combustible. None of the collectors now in field use, i.e. Hanford silver reductor, caustic scrubbers, and activated carbon satisfies all of the above requirements.

Preliminary studies were made with normal I^{127} to simplify analytical and handling techniques during the screening phase of the study.

Of the several chemical and metallic coatings applied to slag wool fibers (KI, $AgNO_3$, Cd, Cd-Sb, and Ag) vacuum plated silver on slag wool showed the highest efficiency, $>$99.9 per cent and lowest resistance, 1.1 in. water.

Tests on metal ribbon (Sn and Cu) and Zn granules indicated a very high efficiency for Cu, $>$99.99 per cent and low resistance, 0.1 in. water at 60 ft. per min. face velocity. Activated carbon was the only adsorbent showing high efficiency, but the resistance was considerably greater, 4-5 in. water.

Copper ribbon performed well at room temperature but failed after 25 hours of hot (300°C) operation. Silver plated copper ribbon showed no sign of breakdown after 100 hours of hot operation. Presence of moisture and high temperatures improved performance of both Cu and Ag-Cu ribbon indicating that chemisorption was the primary iodine collecting mechanism. NH_3, HNO_3, and H_2S did not interfere with iodine collection.

Special tests on Ag-Cu ribbon with mixed isotopes (1 mg/M^3 I^{127} and 10^{-8} to 10^{-6} mg/M^3 I^{131}) showed that iodine collection was (1) concentration dependent and (2) was the same for I^{127} and I^{131}. Increased metal surface area per unit collector volume, attained by increasing ribbon dimensions or increasing the packing density, improved collection efficiency significantly. Iodine^{131} efficiency of Ag-Cu (25 mil x 2 mil ribbon, 33 lbs./cu.ft.) was estimated to be 50 per cent with an inlet iodine concentration of 10^{-6} mg/M^3 (123 μc/M^3). For the same inlet loading the efficiencies of 5 mil x 4 mil ribbon (58 lbs./cu.ft.) and 3 mil x 2 mil ribbon (71 lbs./cu.ft.) were estimated to be >97 and >98 per cent, respectively.

INTRODUCTION

At the Fifth Air Cleaning Conference at Harvard (1) we presented a brief discussion of a new approach to the problem of iodine removal and at that time indicated that we were concentrating on the development of an inexpensive, practical unit for this purpose. As you know, the principal devices that have been used for iodine removal include caustic scrubbers (1), activated carbon beds (2), and heated reductors packed with silver nitrate-coated saddles such as are used for dissolver off-gas streams (3). Various other collectors have been tried such as other scrubbing liquors (4) and electrostatic precipitators (5).

It was our intent to develop a unit which would function at temperatures as high as 300°C and which would not offer significant resistance to air flow. It became apparent after due consideration that an appreciable compaction could be obtained by modifying the Hanford dissolver off-gas cleaning system. In this unit the particulates, including the iodine, are filtered through a fiberglass filter and then the iodine is subsequently removed by a silver nitrate granule reactor. We believed it was possible to combine the filtering and absorbing functions in a single device. At the Fifth Air Cleaning Conference we reported some preliminary data on the use of silver plating (chemically) on 4 micron diameter slag wool fibers. Although the efficiency was rather high, extended testing indicated a relatively short life for the chemical deposit. The major application for our project in 1957 is still an important consideration. A device is needed for large ($>$10,000 cu.ft. per min.) gas flows containing iodine in varying concentrations such as might be associated with a large air-cooled reactor. A successful high performance unit developed for this application could, of course, be adapted to many other problems. The use of scrubbers or activated carbon beds results in high resistance carryout or potential fire problems. We recognize that extended fine fiber beds can create high air flow resistance. However, the optimum size of coated fibers for iodine removal does not need to coincide with maximum aerosol collection.

The processes where iodine contamination is most likely to occur are off-gases from dissolvers, uranium and plutonium separations, reactor cooling air and contaminated exhaust air from hot laboratory facilities. There may be variations in gas volume from 100 to 40,000 cu.ft. per min. or greater and temperatures may range from ambient to 1500°C for air or gas cooled reactors.

For the design of iodine collecting equipment, the following tentative performance criteria were established.

1. Efficiency greater than 90 per cent (in some cases decontamination factors* of 10^4 to 10^6 may be required).

2. Retention of several grams of radioactive iodine without significant reduction in performance. (Efficiency and resistance constant if possible.)

3. Unmaintained collector life of two years if possible.

4. Efficient operation at temperatures from 20 to 300°C.

5. Satisfactory operation in the presence of oxides of nitrogen, nitric acid mists, ammonia, hydrogen fluoride, hydrogen chloride, or other corrosive substances or solvents found in dissolver and other off-gases.

6. Operate at face velocities of 1 foot per second or greater to conserve space.

7. Low resistance to gas flow (<1 inch of water at 1 fps).

8. Minimal space requirements (possibility of insertion in existing ducts or piping.

9. Fireproof or resistant to decay heat and combustion.

Although 90 per cent iodine removal appears to be rather low, it is believed that operation at this level may constitute satisfactory cleaning for many applications in which continuous losses rather than intermittent releases take place. On the other hand, decontamination factors on the order of 10^4 to 10^6 may be desirable, particularly where hazardous situations are likely to arise.

Holding capacity is somewhat arbitrary and is extremely conservative in view of the high specific activity of I^{131}.

A filter life of two years is a realistic target, particularly in operations presenting accessibility and handling problems.

Satisfactory performance at elevated temperatures or in the presence of corrosive gases may or may not be a specific cleaning requirement, depending upon the collector application.

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* Decontamination factor is defined as the ratio of upstream to downstream concentrations. Decontamination index is referred to as the log of this ratio.

Low collector resistance is desirable, but other considerations (high decontamination requirements, small gas volumes, etc.) may make higher pressure losses acceptable. High velocities associated with optimum removal will provide minimal space.

The several iodine removal methods investigated and reported here were selected on the basis that they would fulfill essentially all of the tentative performance requirements. It has been assumed that the effluent gas stream would require pre-cooling to temperatures not in excess of 300°C. This is based on the following facts:

1. Collection by physical adsorption is adversely affected by high temperatures.

2. Most chemical compounds of iodine either decompose or volatilize at temperatures above 300°C.

The number and type of tests on any one medium varied directly with its relative performance. When initial screening showed an efficiency less than 90 per cent, low holding capacity, or high resistance to gas flow, extensive tests were eliminated.

Iodine collectors employed in this investigation were composed of either granular or fibrous materials which were amenable to packing between supporting pads or screens in cylindrical filter holders. The primary mechanisms responsible for removal of gaseous iodine were either physical or chemical adsorption, or a combination of both, depending upon the chemical composition of the collector. The removal process should not be classified as filtration (although many of the finer carbon fibers are actually good particulate filters) except where there exists a possibility of iodine adsorption upon suspended solids prior to encountering the fibrous or granular collector, or where condensation might have occurred producing droplets containing iodine or iodide particles.

Detailed descriptions of test equipment and methods and evaluation of the various iodine collectors will be presented in a complete AEC report at the completion of this study. This report will summarize the principal results obtained.

Test Equipment and Procedures

Two types of filter holders were used in this study (a) a 12 in. long, 1 in. diameter Pyrex glass tube, (Figures 1 and 2), and (b) a 3 ft. long, 6 in. diameter steel pipe (Figure 3). Both granular and fibrous media were tested in the 1 in. glass cylinder whereas only fibrous materials were tested in the 6 in. steel pipe. Figure 2 shows a typical silver plated copper mesh test medium in place.

Most data were obtained at a constant air flow of 60 cu.ft. per min. per sq. ft. of media face area (60 ft. per min. face velocity). Velocity effects were studied in the 6 in. steel pipe over the range of 60 to 240 ft. per min.

Tests were conducted with normal iodine at inlet concentrations varying from 2 to 600 mg. per cu.m. Iodine vapors

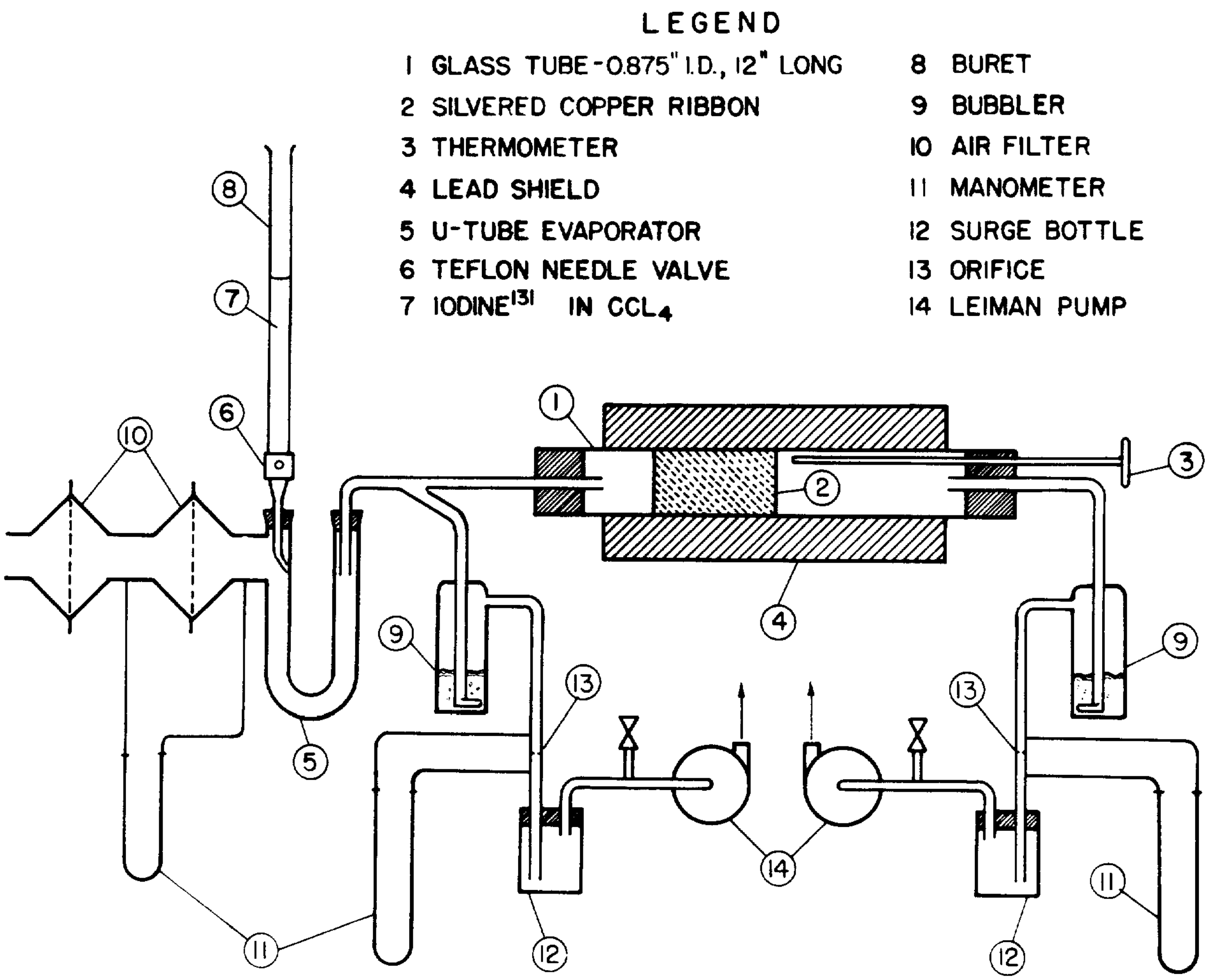
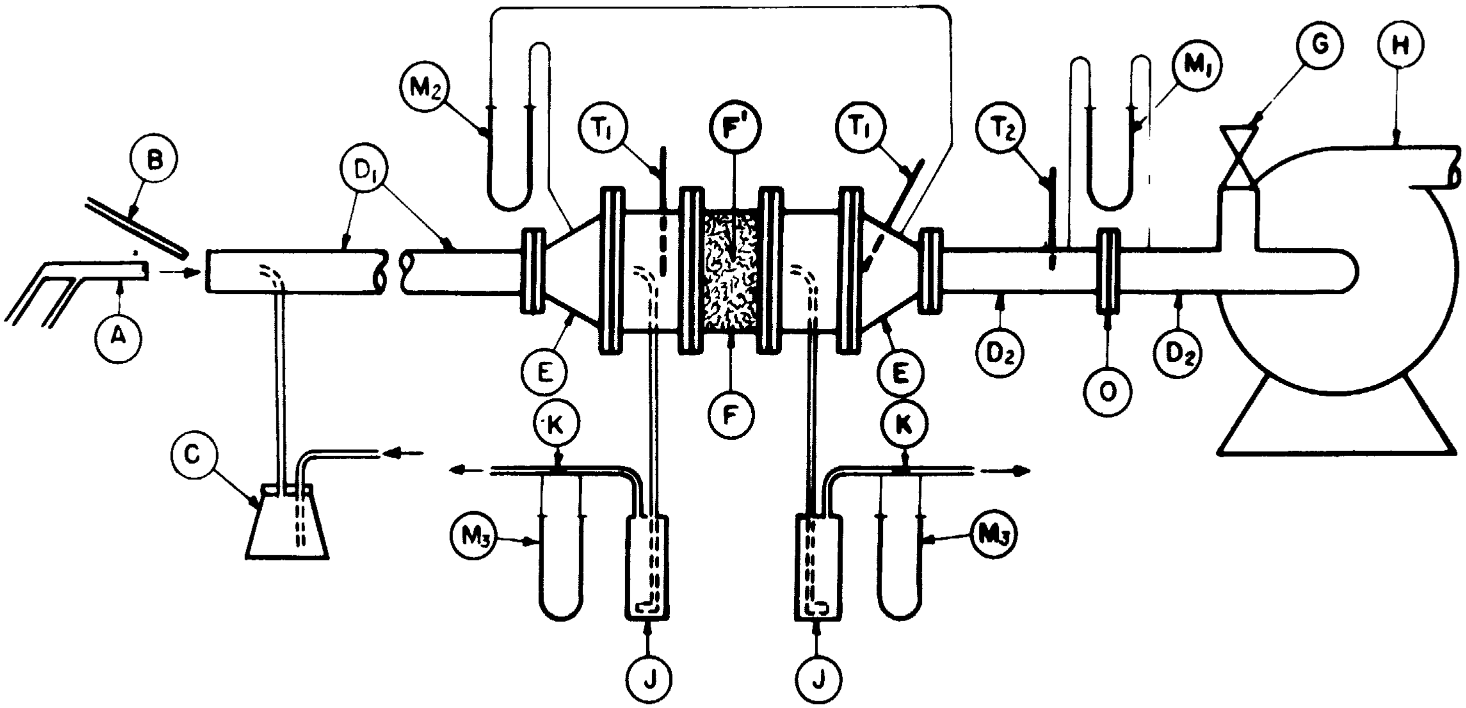


Fig. 1—Iodine-131 collection test apparatus.

Fig. 2—Silver-plated copper ribbon in glass tube, $^7/_8$ in. inside diameter, bed depth, 4.5 in.



A = GAS BURNER
B = STEAM SUPPLY
C = IODINE GAS GENERATOR
D_1 = 2" DIAM., 3'-4" LONG PIPE
D_2 = 2" DIAM. PIPES
E = 6" X 2" RED.
F = FILTER HOLDER, 6" DIAM., 2" DEEP
G = 2" VALVE, BY-PASS AIR FLOW CONTROL
H = EXHAUST FAN

F' = SILVER-PLATED COPPER RIBBON PACKING DENSITY 27 LBS./CU. FT.

J = FRITTED GAS ABSORBER
K = SAMPLE FLOWMETERS
M_1 = ORIFICE MANOMETER
M_2 = FILTER RESISTANCE MANOMETER
M_3 = SAMPLE MANOMETERS
O = ORIFICE
T_1 = THERMOCOUPLE
T_2 = THERMOMETER
← DIRECTION OF AIR FLOW

Fig. 3 — Experimental equipment for iodine collection studies.

were generated by sweeping an aliquot of the inlet air stream across the surface of iodine crystals. The sublimation rate was increased when necessary by applying heat to the iodine crystals. Radioactive iodine I^{131} was obtained from commercial sources as iodine I^{131} with normal iodine carrier in carbon tetrachloride, carrier free iodine from tellurium metal, or NaI^{131} in sodium sulfate (Na_2SO_3) solution. The carbon tetrachloride solution was volatilized as shown in Figure 1 in the U-tube evaporator. The carrier free iodine from tellurium was transferred to sodium thiosulfate ($Na_2S_2O_3$) and heated.

The carrier free iodine, prepared from Te^{130}, was handled by extraction with 5 per cent sodium thiosulfate ($Na_2S_2O_3$) which was then dried in aliquots and heated in a U-tube similar to that shown in Figure 1. The NaI^{131}, carrier free, was supplied in a 5 per cent Na_2SO_3 vehicle. This was treated by adding 5 per cent sodium thiosulfate in serial dilution. An aliquot was heated for each run. The carrier free studies reported in this paper are limited and will be presented in greater detail as more information is accumulated.

In later tests which are briefly mentioned here prefiltered air was employed by use of filters shown in location in Figure 1 to ascertain the effect of possible deposition of iodine on atmospheric nuclei. Chamberlain and DeWiffen (7) have indicated that very high concentrations of nuclei can adsorb carrier free I^{131}.

For high temperature measurements the gas stream was heated by indirect methods, electrical coils or gas burner in the case of the 1 in. Pyrex tube and by direct flame gas combustion products with the 6 in. steel pipe as shown in Figure 2. Thermocouples measured average gas temperature through the collection medium.

Fritted absorbers operating at 10 liters per min. and containing 50 ml. of 5 per cent potassium iodide were used to collect the iodine I^{127}. Collection efficiency was determined from iodine concentrations in the up- and downstream gas samples with a Klett-Summerson photoelectric colorimeter at 440 mμ. Absorber efficiencies were dependent upon the amount of iodine collected in the potassium iodide solution and ranged from 92 per cent at 150 mg. I_2 per liter of KI to 89 per cent at 500 mg. per liter. This, of course, was largely due to the volatility of the iodine in 5 per cent KI solution.

In the presence of materials which would liberate iodine from potassium iodide, i.e. nitric acid, carbon tetrachloride was substituted as the absorbent for potassium iodide. An ice-salt water bath was used to reduce CCl_4 evaporation losses. Iodine collected in the carbon tetrachloride was also determined colorimetrically in the photometer.

Iodine 131 distribution in the collection tube and collector was ascertained by scintillation detectors. Variations in I^{131} loading were determined by placing a scintillation head in contact with the absorber. Integral counting was employed with a pulse height of 200 MEV. The cumulative count rate was plotted against time with a recording galvanometer. The recording obtained indicated a nearly constant I131 feed rate. The collected absorber samples were measured by differential counting (350-370 KEV) of aliquots in a well scintillation detector calibrated with a simulated 0.067 μc source. Distribution of activity through the collector depth was checked by (a) traversing the tube surface through a port in a lead brick with the integral counter head in place and (b) actual assay by cutting the material (copper or silver-copper mesh) into segments which could be placed in the well scintillation detector. These results are reported as counts per minute per gram of collector. The concentration of I^{127} in the I^{131} isotope when carrier was present was determined colorimetrically and the initial mass ratio was determined from these data. After establishing the initial mass ratio the ratio at any time due to decay could be established.

Results

Data for all the tests reported here are summarized in a series of tables, Tables 1 to 8. Most of the initial study was performed with normal iodine since it could be readily utilized for screening of many materials.

The information in Table 1 refers to treatment of slag wool fibers with various surface coatings. An examination of the reactions of iodine with various metals and reagents indicates that several metals, metallic iodides and iodine reactants would have potential application. The most promising of these were tried at what appeared to be an optimum velocity of 60 fpm or 1 fps for space requirements. It is obviously not the most desirable velocity for collection in many of the cases shown in Table 1. The most effective unit shown was obtained by vacuum plating silver metal on the slag wool fibers (Test No. 8) since it afforded high efficiency at the lowest flow resistance. The silver nitrate treatment as used on berl saddles at Hanford however, gives comparable removal at somewhat higher resistance. The Rochelle salt mirroring was next in order of performance. In the case of Rochelle salts several milligrams of iodine could be collected but the efficiency decreased with extended use.

On a basis of these tests further screening was felt desirable so that a number of media were assayed as shown in Table 2. Of the solid adsorbents, activated charcoal from various sources was the best but because non-combustible adsorbents or absorbents might be necessary, activated alumina, Thirsty glass (microporous), Attapulgus clay, mossy zinc, tin foil and copper mesh were examined.

Over-all evaluation in terms of resistance, temperature, economy, total recovery, and collection efficiency indicated copper mesh to be one of the most promising of this series. Therefore, a more detailed test program was established for this medium.

Table 3 presents temperature and extended performance data for copper ribbon mesh placed in the 6 inch unit shown in Figure 3. The data are consistent with those of Table 2 when correction is made for the difference in packing density. The presence of water vapor added as steam was found to enhance performance of collector A. It was also observed however,

Table 1

Iodine Collection with Various Coatings on 4 Micron Diameter Slag Wool Fibers

Test No.	Collector Description[a]			Coating Material	Collector Performance	
	Weight grams	Depth inches	Packing Density #/cu.ft.		Initial Efficiency per cent	Resistance inches of water
1	178	1	24.0	KI[b]	23	2.4
2	As above moistened (H_2O)			KI[b]	80.2	5.3
3	133	1	17.9	Cd[c]	40	3.8
4	212	1	29.0	74% Cd-26% Sb[c]	31	5.2
5	As above moistened (H_2O)			74% Cd-26% Sb[c]	39	8.6
6	148	1.5	18.8	$AgNO_3$[d]	> 99.9[e]	5.8
7	208	2	14.0	Ag[f]	90.0	6.7
8	4.9[g]	4	2.0	Ag[h]	> 99.9	1.1

a. Slag wool pads, 6 inch diameter, face velocity 60 ft./min., 20°C.
b. Coated by dipping in saturated KI solution and drying.
c. Coated by spray metallizing one side, 7 layers in filter.
d. Coated by dipping, 61 grams $AgNO_3$ retained in filter.
e. Efficiency decreased to 97.7% after collecting 1.4 grams I_2.
f. Chemically plated, Rochelle salt technique.
g. Bed diameter = 1 inch.
h. Vacuum plated, 14 layers of fiber, plated one side only.

Table 2

Iodine^{127} Collection with Miscellaneous Media at 60 Ft. Per Min. Face Velocity

Collector Description	Temp. °C	Resistance In. water	I_2 Inlet Conc. mg/M^3	I_2 Retained grams	Collection Efficiency per cent Initial	Collection Efficiency per cent Final
Mossy Zinc - 76 grams, coarse granules	20	-	150	0.20	97.0	89.6
Potassium Hydroxide - 74 grams, pellets	20	-	750	0.56	99.8	99.9
Tin Foil - 20 grams, 30 x 3 mil ribbon	20	-	61	0.084	92.6	96.9
Tin Foil - 74 grams, 30 x 3 mil ribbon	120	-	360	0.84	99.0	95.0
Activated Alumina - 8/14 mesh, 36 lb/ft.^{3}, 2" bed, Aluminum Ore Co.	30	1.3	600	0.030	86 avg.	
	200	-	170	0.007	78 avg.	
Thirsty Glass - 53 lb./ft.^{3}, 2" bed, Corning Glass Works	20	0.3	150	0.008	45 avg.	
	200	-	150	0.004	37 avg.	
Attapulgus Clay - 15/30 mesh, 28 lbs/ft^3, 2" bed, Minerals and Chem. Corp. of America	20	1.4	6	0.00005	6 avg.	
Carbon Fibers - 24 lb/ft^3, 1 in. bed. Carbonized wool fibers, Atomic Laboratories, Inc.	27	2.4	240	0.024	40 avg.	
	150	-	60	0.0001	5 avg.	
Activated Charcoal - 8/14 mesh, 28 lbs/ft.^{3}, 1.7" bed, Columbia Carbon, Grade 60	30	4.8	250	0.018	>99.9 avg.	
	170	-	200	0.011	>99.9 avg.	
Activated Charcoal - 12/30 mesh, 30 lbs/ft^3, 1" bed, Pittsburgh Coke & Chem. Co., Type B PL	25	0.7	120	0.20	>99.98 avg.	
Copper Ribbon - 25x2 mil, 42 lbs/ft.^{3}, 3" bed - "Chore Girl" Scouring Pad, Metal Textiles Co., Roselle, N.J.	20	0.1	200	0.16	99.99	93.5
	120	-	500	2.96 (25 hr. test)	>99.9	90

Table 3

Effect of Steam and Temperature on Iodine^{127} Collection with Copper Ribbon (25 mil x 2 mil)

Collector	Test	Temp. °C	Test Period hrs.	Cumulative Test Period hrs.	I_2 Inlet Conc. mg/M^3	Collection Efficiency per cent	
A	1	25	0.33	0.33	50	97.4	
A	2 S	25	0.67	1.0	40	99.8	
A	3 S	300-350	0.16	1.16	120	> 99.98	
B	1 S	300	1	24	100	> 99.98	
B	2	25	1	25	100	13.4	
B	3 S	25	1	26	100	49.7	
B	4 S	300	1	27	100	> 99.98	
B	5 S	450	0.5	27.5	100	Negative*	
						Eff. per cent	Iodine Retained grams
C	1 S	300-350	7	7	100	> 99.98	6
D	1 S	300	24	24	100	> 99.98	6
D	2 S	300	6	30	100	87	7.3
E	1 S	300	24	24	100	> 99.98	1.0
E	2 S	300	5	29	100	77	1.2

Note: S indicates steam addition, 1 lb./1000 cu.ft. of air at indicated temperature.
A,B,C,D,E indicate separate collectors.

* Iodine lost as Copper Iodide and Iodine Vapor

Bed Packing Densities, 27 lbs./cu.ft. - Bed Depths, 2 in. - Face Velocities, 60 ft. per min.

(collector B) that the copper oxidized on extended use and that this media when again retested at room temperature gave poor results which could only be partially improved by steam. When elevated to 300°C it again performed well with steam present. At a temperature of 450°C the copper iodide was completely volatilized. As much as 29 hours of a high loading (100 mgs. per cubic meter) was used for exposure and apparently a 25 hour period was the limit for greater than 99 per cent efficiency.

The exact nature of the steam treatment is unknown but might be attributed to either a formation of Hl or a conditioning of the copper surface. The copper collector surface was also treated withhydrogen sulfide which performed as well as the copper surface in iodine removal. At elevated temperatures the copper sulfide behaved similarly to the copper alone. Since this medium could not be expected to be protected from oxidation effects at high temperature its use, as with copper, should be confined to room temperature operations or standby installations in an inert gas storage device.

The favorable performance of the mesh extended surface prompted us to explore the feasibility of plating the copper with a protective surface. Since silver is iodine reactive and fairly reasonable in cost and simple to obtain as a plating material on a copper base, it was selected for this purpose.

The results of I^{127} collection by the silver plated material (0.5 per cent Ag by weight) are presented in Table 4. The results are very favorable particularly at elevated temperature, whereas copper pads failed after 30 hours of operation. At comparable loadings the silver plated surface was still effective after 100 hours of service. Tests with silver plated copper indicated that the collector became relatively ineffective (31.5 per cent efficient) when used at room temperature after high temperature operation. However, once returned to high temperature use, the original performance was attained. The effect of silver oxide is thus apparent. It is not believed that this poses any operational problem as the operating conditions would not be expected to produce this variation. It does appear desirable to maintain fixed temperature limits for practical operation.

The silver surface was evaluated under conditions of nitric acid mist, ammonia and hydrogen sulfide exposure without observing any deterioration in performance.

The radioisotope evaluations with carrier iodine are shown in Table 5. These data indicate an efficiency of the silver-copper medium at room temperature between 89.5 and 95.9 per cent with increased removal at higher temperatures. Higher iodine loadings give a greater driving force for silver surface chemical reaction as shown in Figure 5. The data for the copper efficiency tests in Table 6 indicate, as found with I^{127}, that iodine removal at room temperature is significantly greater than with the silvered surface. The copper data indicate an apparent reverse effect of iodine concentration on removal, namely, lower values of loading give greater removal. At present we believe this inconsistency

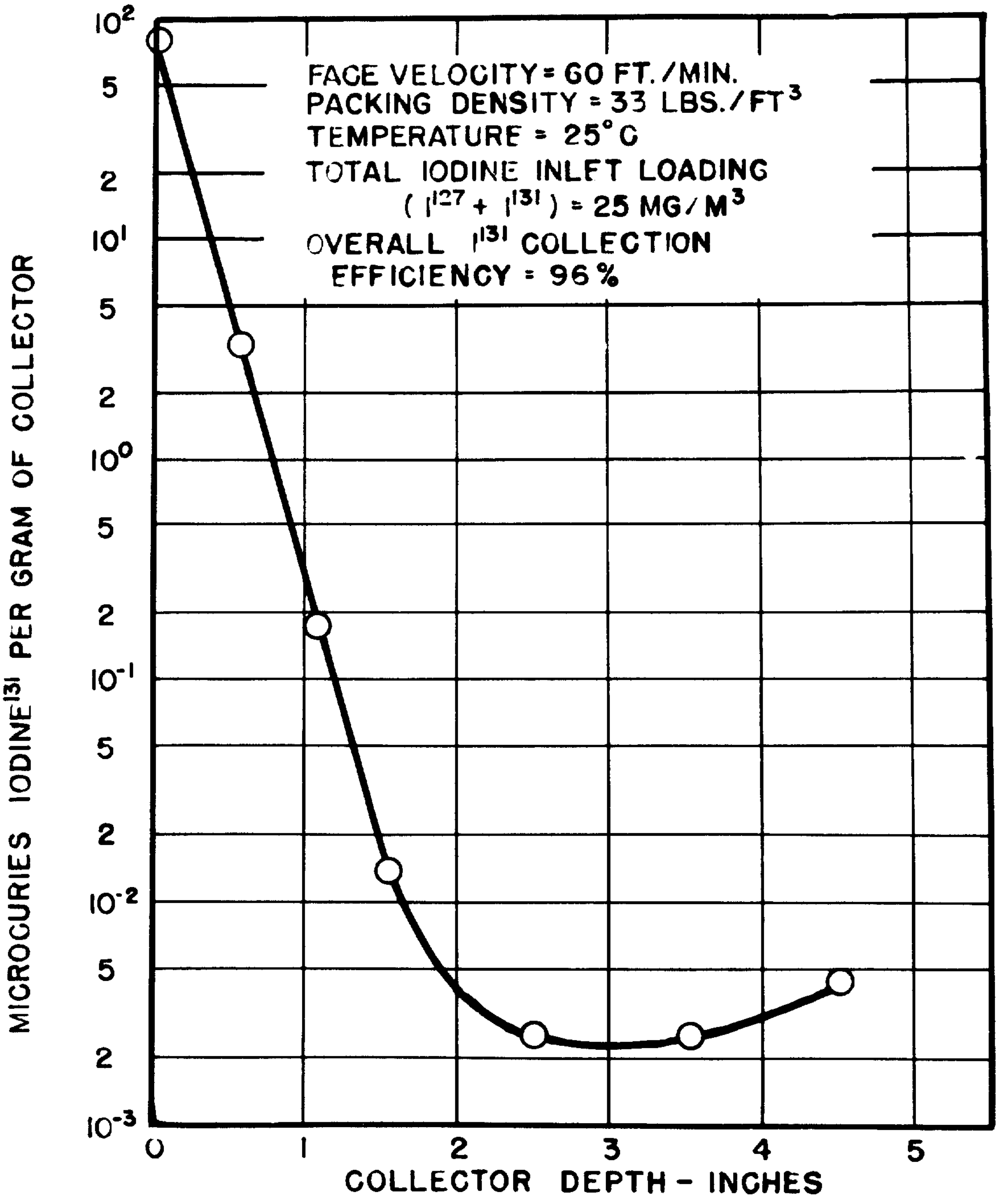


Fig. 4 —Iodine-131 distribution within 5-in. bed of silver-plated copper ribbon.

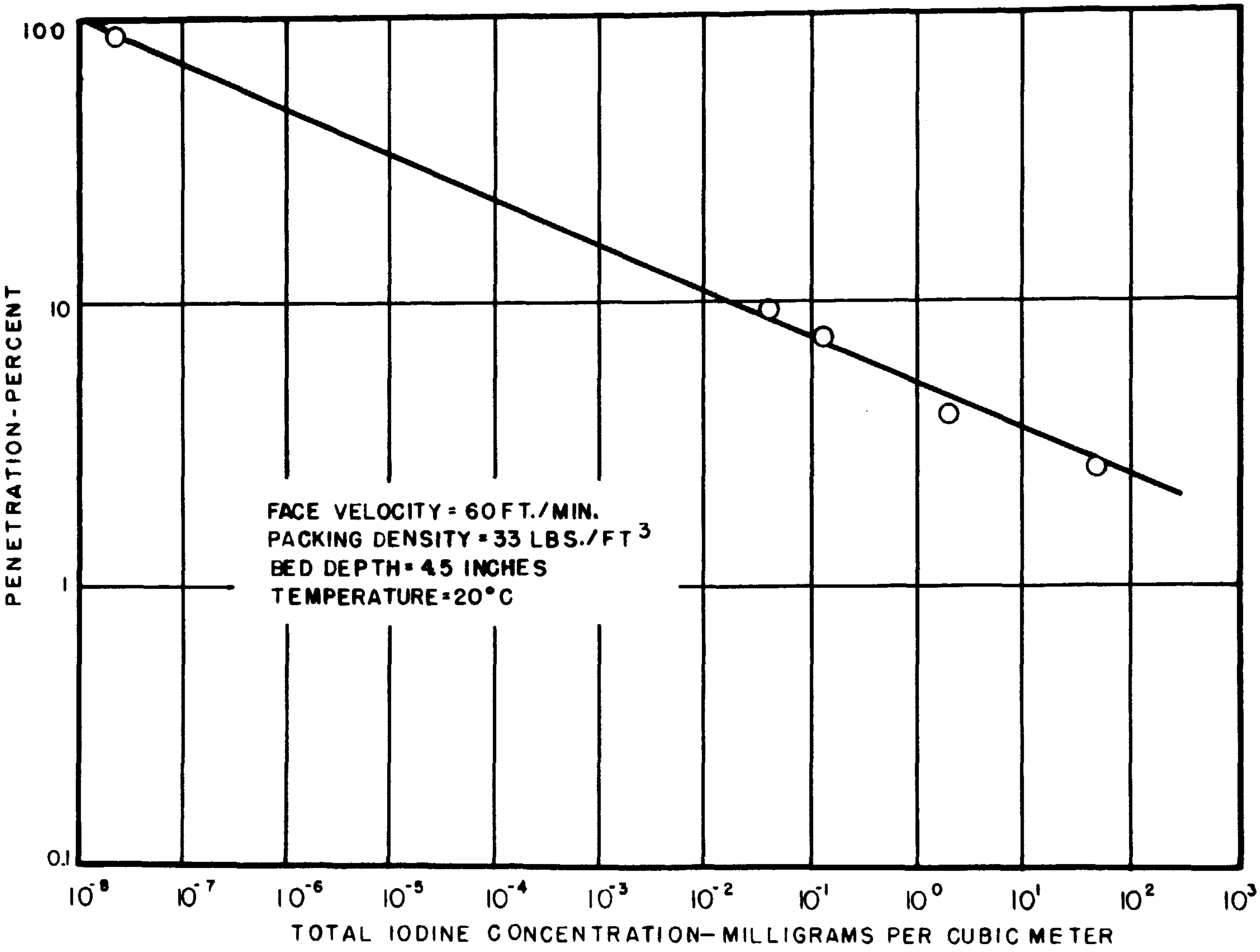


Fig. 5—Effect of iodine inlet concentration on penetration with silver-plated copper collectors.

Table 4

Iodine^{127} Collection by Silver Plated Copper (25 mil x 2 mil) Ribbon
at
60 Feet Per Minute Face Velocity

Collector[a]	Test	Temp °C	Test Duration Cumulative hrs.	Inlet[b] Iodine^{127} Conc. mg/M^3	Iodine^{127} Retained Cumulative grams	Collection Efficiency per cent	
						Initial	Final
A	1	20	0.16	378	0.038	-	99.91
A	2	20	0.50	738	0.186	99.91	98.2
A	3	20	0.83	192	0.224	98.2	84.2
B	1	300	2.25	715	0.966	99.997	99.986
B	2	300	4.75	1000	1.010	99.986	96.1
C[c]	1	300	100	150	2.3	>99.8	99.6

a. Collector A and B, Packing Density = 45 lbs./cu.ft., Depth = 2.5 in., Weight = 22 grams.: Collector C, Packing Density = 27 lbs./cu.ft., Depth = 2 in., Weight = 400 grams.

b. Loading constant with Collectors A and B, Intermittent with Collector C.

c. Efficiency reduced to 31 per cent when cooled, but greater than 99.6 per cent when reheated to 300°C.

Note: Silver content of plated ribbon = 0.5 per cent by weight.

Table 5

Iodine^{131} Collection by Silver Plated Copper Ribbon and Copper Ribbon in Presence of Carrier Iodine^{127} (25 mil x 2 mil ribbon)

Collector[a] No.	Weight grams	Temp.[b] °C	Inlet Iodine[c] Concentration I^{127} mg/M^3	I^{131} mg/M^3	I^{131} µc/M^3	Collection Efficiency Iodine^{131} per cent
Ag-Cu						
1a	22	28	0.049	3.8×10^{-8}	4.7	90.56
1b	44[d]	28	0.067	3.4×10^{-8}	4.2	89.50
1c	22	210	0.032	1.7×10^{-8}	2.1	99.44
2a	22	28	0.84	7.6×10^{-7}	93	94.62
2b	22	28	2.5	2.4×10^{-6}	295	95.96
2c	44	28	12.0	5.6×10^{-6}	690	95.94
Cu[e]						
3a	22	28	0.06	2.0×10^{-6}	246	98.99
3b	22	28	2.4	4.3×10^{-8}	5.3	99.75

a. Packing Density of all collectors - 33 lbs./cu.ft., Face Velocity - 60 ft./min., single test per collector, Resistance - 0.1 to 0.2 in. water.

b. Effect of temperature - compare collectors 1a and 1c.

c. Effect of total (I^{127} and I^{131}) concentration - compare 1a vs. 2b.

d. Effect of bed depth (4.5 vs. 9.0 in.) - compare 1a and 2b vs. 1b and 2c.

e. Comparison of Ag-Cu vs. Cu efficiency - 1a and 2b vs. 3a and 3b.

attributable to experimental error. The effect of bed depth is also shown in Table 5. These data indicate almost no effect indicating that most of the removal takes place in the first increment of the bed. This is shown graphically in Figure 4 where almost 99 per cent of the removal takes place in the first inch of medium.

Table 7 shows the effect of increasing packing density of the silver plated copper ribbon. It was found possible to get greater compression by employing a 5 x 4 mil ribbon as opposed to the 25 x 2 size used previously. These ribbons have approximately the same surface area per gram but as indicated in Table 7, the packing density of the former can be increased to 58 pounds per cubic foot. It should be noted that the air flow resistance under this condition is also increased about fourfold. The data of Table 7 indicate more effective I^{131} removal as well as comparable performance at 4 times the velocity of the previous tests (Table 5).

Our most recent tests on media that may afford better performance at room temperature operation are shown in Table 8. Tests with I^{127}, Table 2, and with carrier free I^{131}, Table 8 in addition to data reported by Browning et al (2) indicate that commercially available activated carbon is generally the superior collector. However, Lomac 40, a carbon impregnated rayon ribbon, developed by American Viscose Corporation for odor removal gives outstanding results at high velocity and low resistance and should prove useful in many applications where fire problems do not exist.

In the investigation for a non-combustible granular solid adsorbent we have already presented data in Table 2 for activated alumina and "Thirsty glass". Table 8 presents data for silica gel which like alumina has a primary preference for water vapor. It shows a comparable performance to Thirsty glass although alumina was considerably higher. By silver mirroring, however (which could also be done with the mineral adsorbents) the efficiency was raised to over 99.9 per cent.

The activated carbon of Table 2, when retested with carrier free I^{131} and prefiltered air indicated lower performance. This is in agreement with Chamberlain and Wiffen (7).

Table 8 also shows some preliminary data on a finer silver-plated copper ribbon with approximately twice the surface area per pound as the previous ribbons. This appears to be very promising on carrier free iodine even at velocities approaching 343 feet per minute or nearly 7 feet per second. This may be of especial value in instances where space requirements may demand such operating conditions.

Conclusions

Based on the data presented here the following conclusions may be drawn from this study.

1. No significant difference exists between I^{127} and I^{131} removal on silver-copper media assuming that comparable loadings, temperature, gas velocity, and packing density are maintained.

Table 6

Comparative Collection Efficiencies of Silver Plated Copper Ribbon (25 mil x 2 mil) for Iodine^{127} and Iodine^{131}

Collector[a]	Iodine Inlet Concentration I^{127} mg/M^3	I^{131} mg/M^3	I^{131} μc/M^3	Collection Efficiency per cent I^{131}[b]	I^{127}[c]
A	68.5	1.7×10^{-8}	2.1	98.12	98.21
B	62.9	1.6×10^{-8}	2.0	97.96	97.12
C	66.0	6.1×10^{-9}	0.72	98.22	96.57

a. 22 gram bed, 33 lbs./cu.ft. packing density, 60 ft./min. face velocity.
b. By radioactive count.
c. By chemical (colorimetric) analysis

Table 7

Iodine^{131} Collection with Silver Plated Copper Ribbon (5 mil x 4 mil) Effect of Bed Depth and Face Velocity

Collector[a] No.	Bed Depth In.	Face Velocity ft./min.	Iodine Inlet Concentration I^{127} mg/M^3	I^{131} mg/M^3	I^{131} μc/M^3	Collection Efficiency Iodine^{131} per cent
A	4	60	0.71	2.4×10^{-8}	2.9	>99.95
B	1	60	0.42	1.1×10^{-8}	1.3	>99.71
C	4	240	0.42	1.1×10^{-8}	1.3	>99.89
D	1	240	0.36	0.9×10^{-8}	1.1	97.1

a. Constant packing density - 58 lbs./cu.ft., resistance, 0.4 to 1.6 in. water.

Table 8

Iodine^{131} Collection With Miscellaneous Collectors (Room Temperature 25°C)

Collector Description	Face Velocity ft./min.	Resistance In. Water	Iodine Inlet Concentration			Collection Efficiency Iodine^{131} per cent
			I^{127} mg/M^3	I^{131} mg/M^3	I^{131} µc/M^3	
LOMAC-40 - 250 Denier Ribbon containing 40% act. carbon with rayon, 10.5 lbs/ft.^{3}, bed depth 1.5"	60	0.16	0.015	3.36×10^{-8}	4.2	99.72
17.4 lbs/ft.^{3}, bed depth 2.5"	166	2.12	0.10	2.1×10^{-8}	2.6	99.93
Silica Gel - 6/12 mesh Unimpregnated, bed depth 2.75"	60	2.75	0.38	2.4×10^{-8}	3.0	39.9
Silica Gel - 6/12 mesh Silver coated by Rochelle salts - 12 mg. Ag per gram of silica gel - bed depth 2"	60	2.75	0.16	1.0×10^{-8}	1.2	> 99.92
Activated Carbon - 8/14 mesh Air prefiltered with AEC Absolute Filter, bed depth 2"	60	4.8	0.0	1.4×10^{-8}	1.7	96.8
Silver plated copper ribbon (3 mil x 2 mil) 71.0 lbs/ft.^{3}, bed depth 4"	343	4.0	0.42	2.5×10^{-9}	0.3	99.45

2. At room temperature copper is more effective in iodine removal than the silver plated-copper mesh for I^{131}.

3. Iodine penetration of the media tested varies inversely with loading.

4. I^{131} removal varies inversely with velocity on a fixed bed.

5. Bed depth above a certain value which cannot be predicted at the present time is not a significant variable. Most of the I^{131} removal takes place in the first 20 per cent of medium surface or depth. It is anticipated that continued loading will cause progressive migration into the relatively unused portions.

6. Elevated temperature improves operational performance of copper or silver media and lowers performance of adsorbents.

7. Efficiency of removal of silver plated-copper surfaces, appears to be dependent upon concentration over the range 10^2 to 10^{-8} mgs. per cu. meter in iodine.

8. Steam enhances the performance of copper surfaces for iodine removal at room and elevated temperatures.

9. Preliminary data on fine mesh (2 x 3 in.) silver plated-copper with higher specific surface indicates better performance. However, greater air flow resistance results.

10. Iodine adsorption on atmospheric dust was not found responsible for low collection efficiency measured at low I^{131} loading under our test conditions.

11. Silver plated-copper media when once exposed to high temperature operation and then reused at room temperature shows markedly reduced performance. However, this same material when reheated shows values comparable to initial high performance. The failure at room temperature is attributed to oxide formation.

12. Practical adsorbents for use at high temperatures that are not combustible in themselves require chemisorption as well. With the aid of mirroring or chemical silver plating, silica gel becomes a useful selection. Resistance losses of all granular adsorbents are comparable at a given mesh size.

13. For room temperature operation at relatively high velocity with low air flow resistance, activated carbon impregnated fibers appear to be a new and useful development (assuming that fire or high temperatures do not exist).

14. Activated carbons in general where fire or high temperature hazards are not involved are highest in performance for decontamination of iodine bearing off-gases. Resistance losses are significantly greater than coarse fibrous media.

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Discussion

Q. (B. L. Rich, PPCo.) We are rather concerned with the special problem in regard to Idaho production at this facility - once you dissolve a fuel element in a caustic mixture - may be - for anyone of a dozen filter medias - do you plan to extend your studies to the more practical side in reference to introduction at some of the sites?

A. Planning to get some data on silver filters in regard to fuel element - air cooled reactor - as work in Oak Ridge when ruptures are a problem. We were looking originally for high volume, low pressure drop situation - using work done at Hanford with caustic scrubbers indicates silver is No. 1 in performance on dissolving. Also ran some bromine tests and got results comparable to normal iodine.

Q. You said you had a lead shield and viewing window in which you determined the efficiency of the bed by close scanning. Can you elaborate on this further?

A. we evaluate material deposited - collection gradient along the bed for more efficiency.

C. (Sabo - PHS) To answer the question on the CPP we use both the silver fiber which is similar to what you had, as a matter of fact it was developed from that and the treated paper. The reason you prefer paper is because of continuous sampling. We found the efficiency varied from 40% to 90%. We have collected as high as 90% of the iodine on the CPP process. At other times we have been down as low as 40 so there is no question about it. What they do there has a great tendency bearing on what you are able to sample. We sample off-site so we are a half mile to six miles away where concentrations are low and one must sample for long periods of time to even count.

C. Using a filter under those conditions, even silver nitrate, I think heating would be certainly recommended, because we find that the heating increases a collection of efficiency.

SPECIAL INCINERATION STUDIES – INSTITUTIONAL DESIGN

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Summary

The Harvard Air Cleaning Laboratory is currently engaged in designing incineration and gas cleaning apparatus for the disposal of low-level radioactive wastes from hospitals and biological laboratories. Previously, this laboratory had attempted to design a gas cleaning system for use with the BOMAEC-30 incinerator, developed by the U. S. Bureau of Mines. Operational and leakage problems, however, indicated that design changes would be necessary for practical application of the unit.

Tests on a small (10-15 lb. per hour burning rate) commercial home incinerator showed combustion characteristics which were nearly as good as those noted for the BOMAEC-30. Since the cost of the former unit was in the range of $100.00, it appeared feasible to construct a small incinerator from a 55 gallon drum with provision for accurate gas flow and temperature measurements. Our first experimental model was designed for single inlet, tangential, over-fire air admittance (somewhat like the Bureau of Mines unit). However, the burning chamber was lined with a 2 in. layer of fire-brick rather than stainless steel. A charge pre-drying chamber located above the burning section proved unsuccessful as a means of handling high-moisture waste. Therefore, a single side charge door was installed with a sliding rack to support wet materials within the burning chamber while the previous charge was burning. This procedure enabled continuous charging of wet materials once the burning chamber was at temperature, >2000°F. A secondary brick-lined cylindrical chamber located immediately above the burning area allowed for further high temperature combustion of unburned volatiles and particulates, since a secondary air inlet was located at the base of this section. Effluent gas was cooled by dilution air which entered tangentially at the top of this chamber.

Test results, based upon burning rate and volume of CO_2 produced per lb. of charge, show that the over-all performance of the current incinerator design, ACL II, is superior to that of the BOMAEC, based on cost, simplicity of operation, and the fact that wet wastes, up to 50 per cent moisture can be burned satisfactorily without the need for auxiliary gas firing.

Gas cleaning apparatus consists of a basket type filter, 10 sq. ft. surface, composed of graded glass fibers. Our present intention is to filter hot (600-800°F) to avoid installation of cooling and reheating apparatus.

Introduction

Earlier reports by this laboratory (1,2,3,4) furnish details on the evaluation of the stack effluent from a special incinerator, BOMAEC-30, designed by the U. S. Bureau of Mines, Combustion Research Section. The device was developed under contract with the U. S. Atomic Energy Commission for disposal of low-level radioactive waste materials from hospitals and research laboratories. Originally, this laboratory was requested by the Division of Reactor Development, U. S. Atomic Energy Commission to design a gas cleaning system that would prevent significant discharge of radioactive substances to the atmosphere. Our first approach was to establish the nature of the stack effluent under a variety of burning conditions. Initial studies (1,2) indicated that, under burning conditions deemed optimum by the Bureau of Mines personnel, the stack gas contained sufficient quantities of soot and condensable organics to make filtration by woven glass fabrics difficult. Further stack sampling after minor changes in incinerator design suggested by the first and second series of tests (3), showed no improvement in the stack effluent. Admission of secondary combustion air at the top of the burning chamber did not reduce significantly the amount of combustibles in the stack effluent although excess oxygen in the system was increased from nearly zero to 5 to 10 per cent. It appeared that the auxiliary air by-passed to the stack where temperatures were too low (about 1000°F) to initiate secondary burning. Mean stack temperatures dropped about 200 F° indicating that gas cooling was the major effect.

In the absence of auxiliary gas firing (which was installed for the third series of tests) wet rubbish containing $>$10 per cent moisture could not be burned. Furthermore, operational difficulties were encountered in the use of the auxiliary gas system which suggested that extreme caution and well designed (and costly) safety devices would be required for practical service.

Attempts to burn rubbish without auxiliary gas firing were unsuccessful even after eliminating most of the water. Stack temperatures dropped to low levels (600 to 800°F), a distinct odor of burning garbage was detected, and a sooty deposit appeared on the sampling filters.

Cooling of the gas stream by water sprays to about 400°F appeared to permit filtration through the glass bags without prohibitive increases in pressure loss. Although initial plugging caused a rapid rise from 1 to 5 inches of water (at 1.2 cu.ft. per min. per sq.ft. of cloth area) subsequent tests showed smaller increases, about 1 inch of water. Mechanical shaking reduced bag resistance to slightly less than 2 inches of water.

Although the bag effluent appeared to be free of soot particles, its moisture and condensable organic content was too high to permit final filtration through high efficiency AEC type filters. However, it is now our opinion that absolute filtration may not be required for many applications.

At the completion of the Pittsburgh field tests the BOMAEC-30 incineration unit was shipped to the Air Cleaning Laboratory so that extensive burnings could be made to establish the effective life of the glass bags. Past experience has indicated that these fabrics, which are inherently brittle, tend to fail under flexure in much shorter periods than do those composed of synthetic resin or natural fibers. If the glass bags proved unsatisfactory our intention was to develop other cleaning techniques which would be suitable for typical effluents particularly those resulting from poor burning conditions.

Prior to the equipment transfer, we considered that the lack of a means for continuous charging was a poor design feature. In its original form, Figure 1, the cover of the burning chamber, outlet pipe, heat exchanger, bag house, and exhaust fan were attached to a central hydraulic lift column. By elevating the above components about 6 inches and then rotating through a 90° arc, waste material could be dumped into the top of the combustion chamber. Therefore,

1. **INCINERATOR (29" INSIDE DIAMETER, 63" OVERALL HEIGHT)**
2. **NEW EXTENSION ON INCINERATOR (18" HIGH)**
3. **AIR INLET**
4. **PRE-HEAT AIR (SLOT) TEMPERATURE THERMOCOUPLE NO. 5**
5. **BACHARACH SMOKE METER**
6. **INCINERATOR STACK TEMPERATURE, NO. 4**
7. **INCINERATOR OUTLET SAMPLING PROBE**
8. **GAS TEMPERATURE ENTERING SPRAY TOWER, THERMOCOUPLE NO. 1**
9. **GAS SAMPLING POINTS FOR OXYGEN AND CARBON DIOXIDE RECORDERS**
10. **AIR TO SPRAY NOZZLE**
11. **WATER TO SPRAY NOZZLE**
12. **PNEUMATIC ATOMIZING NOZZLE (CONCURRENT OPERATION)**
13. **SPRAY TOWER**
14. **DRAIN PLUG**
15. **SPRAY TOWER SAMPLING PROBE**
16. **TO GLASS FILTER BAGS AND FAN**

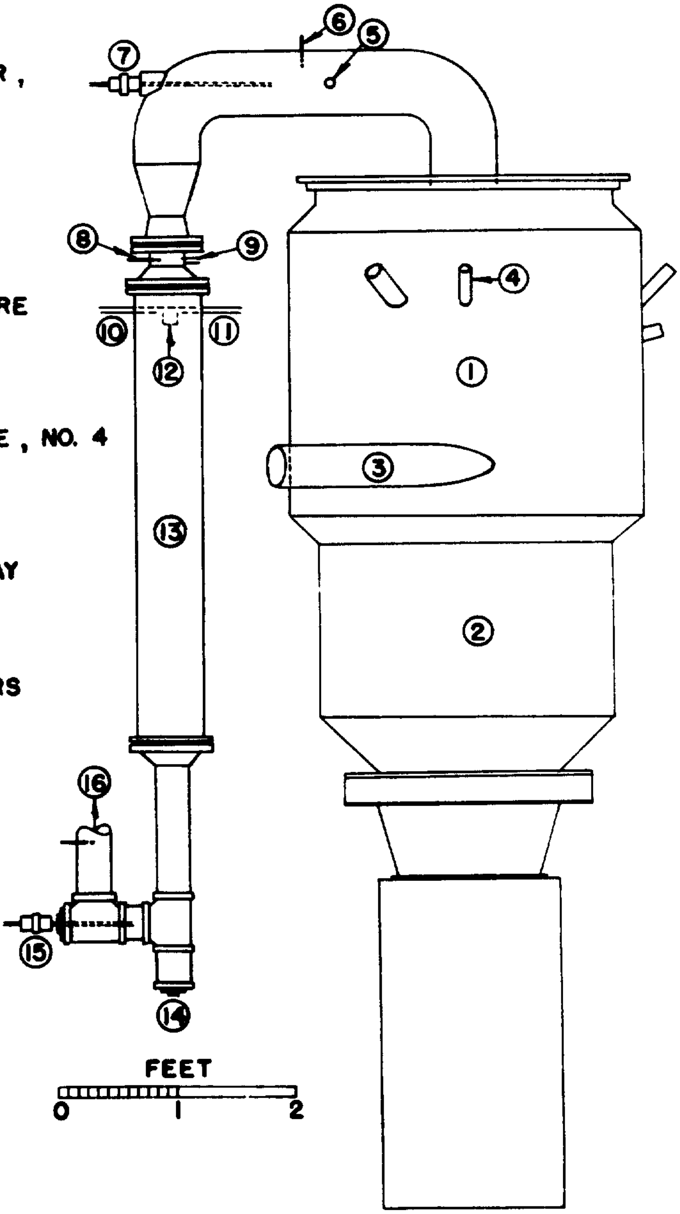


Fig. 1—Schematic drawing of revised institutional incinerator (BOMAEC-30) showing sampling points.

in order to charge the device safely, at least 30 minutes of cooling were required between burnings. Since dry, 25 lb. sawdust charges were burned completely in less than 30 minutes, the rated burning capacity (30 lbs. per hour) of the unit was essentially correct. Our tests with wet charges (15 to 50 per cent moisture) indicated much lower burning rates, 15 to 25 lbs. per hour, even with the use of continuous auxiliary gas firing. Allowing the unit to cool between burnings reduced its temperature such that the stack values seldom exceeded 1500°F and averaged 1200°F or less for the entire combustion period. We recognized that provision for continuous charging would ultimately be required if any improvement with single chamber combustion was to be attained.

BOMAEC-30 Incinerator - Final Tests

A. Evaluation of Glass Filter Bags

Prior to shipping the BOMAEC-30 unit to this laboratory, the incinerator was altered so that charging could be accomplished without elevating accessory parts. A portion of the top cover was hinged to swing upwards and secured with dogs to provide a tight gas seal. Our laboratory tests, which were conducted with sawdust to simulate earlier Pittsburgh studies, produced an effluent which caused rapid plugging of the glass bags. Major difficulties appeared to be created by air leakage at several points in the system (at least 100 per cent of primary air flow). Stack gas temperatures did not exceed 800 to 900°F at any time, the gas flow within the burning chamber lacked the characteristic spiral pattern, and the flame color as observed through the view port was a dull, smoky orange.

Three glass bags ripped at the seams and with new replacements resistance could not be kept below 10 inches of water. At this point it appeared that glass bags would not be suitable unless some precleaning unit was used to screen out a good part of the carbonaceous material.

B. Evaluation of Slag Wool Filter

Our tests with various mineral and slag wool filters with open hearth fume (5) indicated that most of the particulates in the incinerator effluent could be retained without prohibitive resistance provided that tar formation was not excessive. Due to structure of most bulk fiber collectors cleaning by mechanical shaking is not effective. However, the low cost of mineral wool justifies fabrication of disposable units provided that sufficient filtration area can be used to allow a practical service life. Although no experimental evidence is yet available on the amount of activity that might penetrate the slag wool we think that this media alone may provide adequate gas cleaning.

The first test filter was constructed by placing two concentric expanded metal screens within a 55 gallon drum and sandwiching the slag wool filter between them. Side and bottom area of this basket device provided approximately 9.4 sq.ft. of filtration surface.

Two filters were prepared (4), the first by passing a wet slurry of the slag wool fibers through the screen and the second by making a dry hand-packed bed. Efficiency for the first filter (wet slurry) was low, 60 per cent, since drying of the bulk fibers led to channel formation and subsequent leakage.

The hand-packed filter was >90 per cent efficient in solids removal and showed moderate resistance, 1 inch of water at 3 to 5 ft. per min. face velocity. However, gas samples collected downstream of the filter showed large quantities of condensed tars which had passed through the filter in the gaseous phase (500 to 600°F). Further testing of this cleaning system in conjunction with the BOMAEC incinerator was discontinued since it became impossible to control the burning conditions. Gradual warping of the heated surfaces of the incinerator shell produced variable leakage which could not be corrected with high temperature sealing compounds. An attempt to evaluate the slag wool media by using a small experimental incinerator, 3 to 5 lbs. per hour, was unsuccessful apparently due to scale down effects on gas flow patterns.

"Incinor" - Home Type Incinerator

A. Test Apparatus

Since available incineration apparatus was not amenable to good combustion control it was decided to investigate the utility of home type incinerators as a means of generating a reproducible effluent. A small unit, the "Incinor" (34 in. high and 20 in. outside diameter) was purchased for about $100.00. In its original form the burning chamber was cylindrical in shape, constructed of steel, and surrounded by a concentric outer steel shell with an inner fiber glass lining. A gas burner was located above the grate for igniting purposes and also for drying damp charges. Supply air was a combination of under- and overfire air with no specific entry pattern. Normally, the exhaust gases discharged at the rear wall of the combustion chamber and vented by natural draft into the flue.

The following design changes were made prior to conducting any tests:

a) A two-inch thick, fire brick liner was installed in the combustion chamber.

b) An inlet pipe was attached to the base of the unit so that underfire air could be metered.

c) Provision was made to meter total volume of effluent gas so that the amount of overfire air could be estimated.

d) A rectangular drying chamber was placed on top of the incinerator for predrying wet charges prior to dumping into the combustion chamber, Figure 2.

e) A filter unit, Figure 3, consisting of a circular 2 inch bed (2.8 sq.ft. of filter surface) of slag wool fiber, 6.5 lbs. per cu.ft. packing density, and housed in half of a 55 gallon drum was connected to the incinerator outlet pipe about 8 ft. downstream of the incinerator. An 8 inch layer of 1/4 inch gravel was placed in the bottom of the drum so that coarse particulates could be screened from the effluent gas prior to passing upward through the slag wool bed.

f) An exhauster was installed downstream of the filter housing so that the entire system could be operated under negative pressure.

g) A water cooled condenser was placed in the hot gas line coming from the incinerator so that bed temperatures could be varied in the slag wool filter unit.

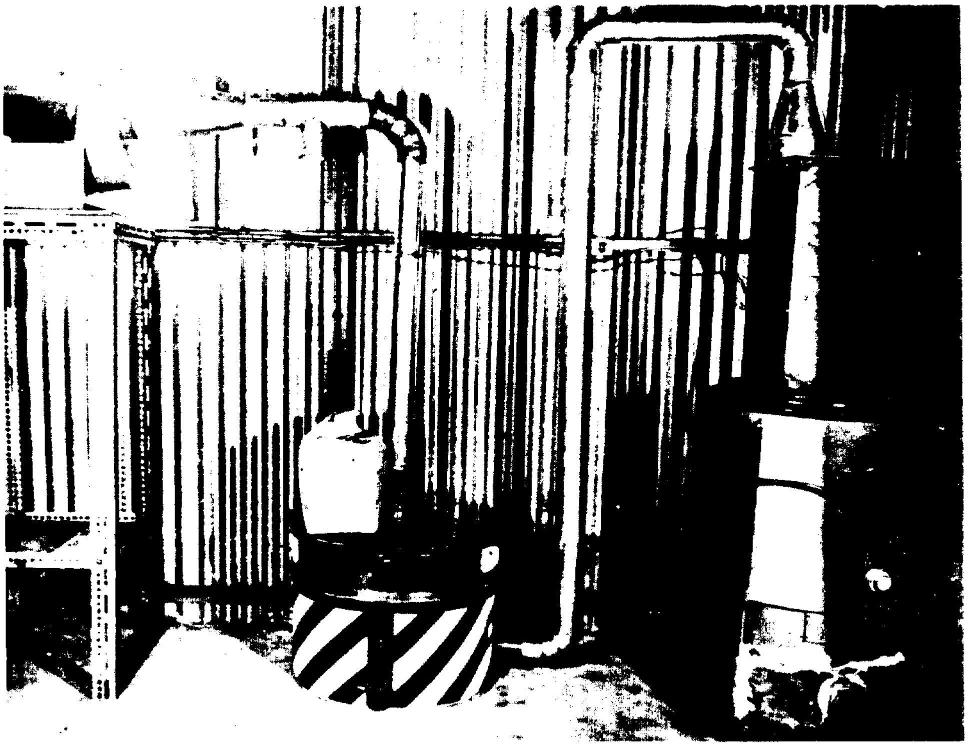


Fig. 2 — Incinor general arrangement of unit and filter holder.

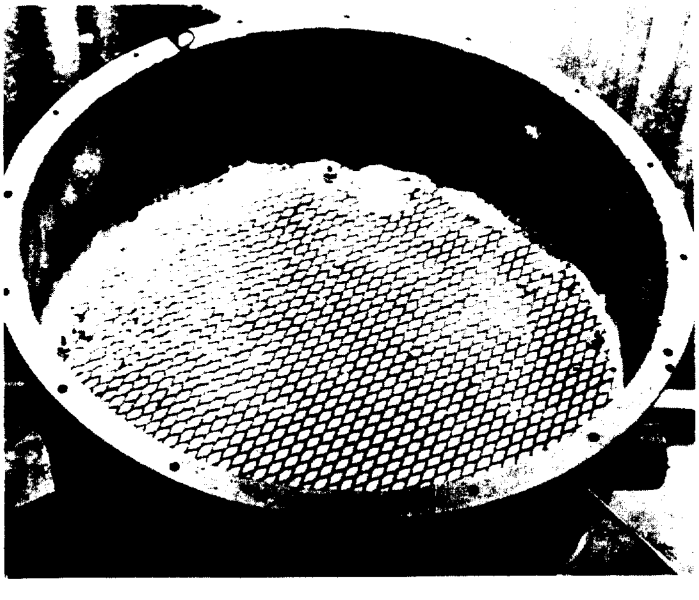


Fig. 3 — Slag wool filter — ACL Incinerator I and Inconor (packing density, 6.5 lb/ft^3; bed depth, 2 in.; area, 2.78 ft^2).

h) Sampling ports were provided for determining dust loadings before and after the filter. Provision was also made for estimating gas composition (O_2, CO_2, and combustibles reported as CO) and gas temperatures throughout the system.

B. Stack Sampling Procedures

Sampling equipment was designed to furnish a distinct cut between particulates (mineral or carbon) and condensation products. This was accomplished by passing the stack effluent through an all-glass filter disc (MSA 1106B paper) followed by a condenser and an A.C. electrostatic precipitator. Cooling to ambient temperatures removed water which condensed in a trap and permitted capture of any condensed volatiles (tars) in the glass precipitator tube. Tar products were estimated quantitatively by dissolving in acetone and comparing the color photometrically with that obtained with standards prepared from the tar extract.

In the case of filter samples collected upstream of the slag wool unit, a distinction was made between the coarse, readily captured material entrained in the gas stream and finely divided carbon particles. Separation was accomplished by lightly tapping the filter which dislodged gross particles.

C. Test Results

Preliminary testing on the "Incinor" consisted of burning 5 lb. sawdust charges, packed in paper bags, using underfire and overfire air flow rates of 30 and 20 cu.ft. per min., STP, respectively. Sawdust was again selected as the combustible charge so that some comparisons could be made with previous BOMAEC-30 performance. From a test viewpoint there were two advantages in using this material: 1) the effluent contained a high volatile loading which presented a filtration problem, and 2) the sawdust charge was reasonably uniform and amenable to convenient packaging.

Burning rates for sawdust charges averaged 20 to 25 lbs. per hour exclusive of the time required to load and seal the predrying chamber. Incinerator exit temperatures ranged from 1600 to 1800°F and filtration temperatures within the slag wool bed varied from 200 to 800°F depending upon the amount of gas cooling employed. During the test period required to burn 300 to 400 lbs. of sawdust, no significant rise in filter resistance above the initial value of 1 in. water was noted. However, at bed temperatures less than 200°F, resistance increased to 1.7 in. water during one test as a result of water condensation. When gas cooling was reduced so that bed temperature exceeded 300°F, the slag wool filter resistance returned to about 1 in. water.

The incinerator effluent prior to filtration contained approximately 0.05 grains per cu.ft. of solids of which 25 to 40 per cent were acetone-soluble tar products. The filter effluent appeared to be composed primarily of tar products which either passed through the filter as a fine mist or fog or condensed beyond the filter as a result of lowered gas stream temperature.

It was possible to burn a synthetic charge composed of 3 lbs. of sawdust and 2 lbs. of shredded cabbage without resorting to gas firing. Moisture content of this mixture was estimated to be greater than 40 per cent. However, burning rates were reduced to 15 lbs. per hour and incinerator effluent temperatures were considerably lower, 1200 to 1300°F in contrast to 1600 to 1800°F for sawdust alone.

D. Discussion

Perhaps the most obvious conclusion to be drawn from the above tests is that the over-all performance of a relatively simple commercial incinerator design was better in many respects to that of the BOMAEC-30 unit. A scale-up of the "Incinor" or similar device to the size needed for disposal of 30 lbs. of bulk waste per hour should cost much less than the BOMAEC-30.

Resorting to a firebrick liner permits light weight construction with mild steels and allows much higher temperatures in the combustion chamber. It is emphasized that stainless steel construction was used in the BOMAEC-30 unit to eliminate the possibility of contamination of firebrick and its attendant problems as well as possible erosion and subsequent entrainment of contaminated firebrick in the gas stream. We do not think that this problem should exist with customary low activity waste material. Unfortunately, stainless steels limit incinerator temperatures to levels inadequate for good combustion and ultimately led to warping in the case of the BOMAEC unit. (This was also observed in the Argonne incinerator when overheating took place.)

We were not completely satisfied with the "Incinor" as an experimental unit since it was not possible to determine gas flow distribution or precisely where overfire air entered the unit. In addition, the device was designed for batch charging from the top which also was not desirable for continuous burning. It did permit production of a reproducible effluent and, most important, furnished the basis for a new experimental unit.

ACL I - Experimental Incinerator

A. Design Considerations

In formulating the design for a new incinerator the following factors were taken into consideration:

1) Tests on both the BOMAEC-30 and "Incinor" units indicated that tars and combustible gases in the incinerator effluents were minimized when overfire air alone was supplied. Although underfire air in various proportions produced higher burning rates the resulting stack gas was more difficult to filter due to the increased volatile and solid loading.

2) From the point of view of simplicity, the single chambered unit with overfire, tangential admission of supply air appeared to be the best design for a compact unit. In this respect we confirmed the Bureau of Mines evaluations assuming that a scale-down of a double chamber municipal incinerator would not be acceptable for disposal of low level wastes.

3) The ultimate design of the new incinerator should provide a simple safe means of charging the unit continuously since under these circumstances the combustion chamber is maintained as hot as possible.

4) Ceramic liners should be installed to maintain high combustion temperatures and allow use of ordinary construction steels.

5) The design of covers, doors, etc., should be such that warping caused by high temperature does not cause air leakage in critical locations.

6) It should be possible to burn high moisture wastes (up to 50 per cent moisture either by constructing a practical predrying device or by charging directly to the combustion chamber.

B. Description

Figure 4 shows the first model of an incinerator (ACL I) which was constructed according to the above design principles. A 55 gallon steel drum was lined with 2 inches of firebrick to provide a burning chamber 29 inches deep and 18 inches in diameter. An ash pit, 6 inches deep, was located immediately below the grate and provided with a clean-out port which also could be used if necessary as an underfire air inlet. A single tangential overfire air inlet was located about 10 inches below the top of the burning chamber. By inserting ceramic wedges the width of the entry air slot could be varied according to test requirements. Except for the fact that we employed a single, rather than multiple entry (4 symmetrically spaced inlet ports in the BOMAEC-30 unit) the external geometry of the ACL-I model was similar to that of the Bureau of Mines' unit.

A charging and predrying section, 24 in. high and 12 in. x 12 in. square was placed directly above the burning chamber. The bottom of this hopper, located about 8 inches above the incinerator proper, was hinged to the sidewall so that by swinging downward its contents were dumped into the combustion chamber. In the open position the hopper bottom partially blocked the opening to the 3 inch diameter flue pipe which connected to this chamber 3 inches below the hinged bottom. This served to prevent any by-passing of unburned materials to the incinerator outlet pipe during the dumping process.

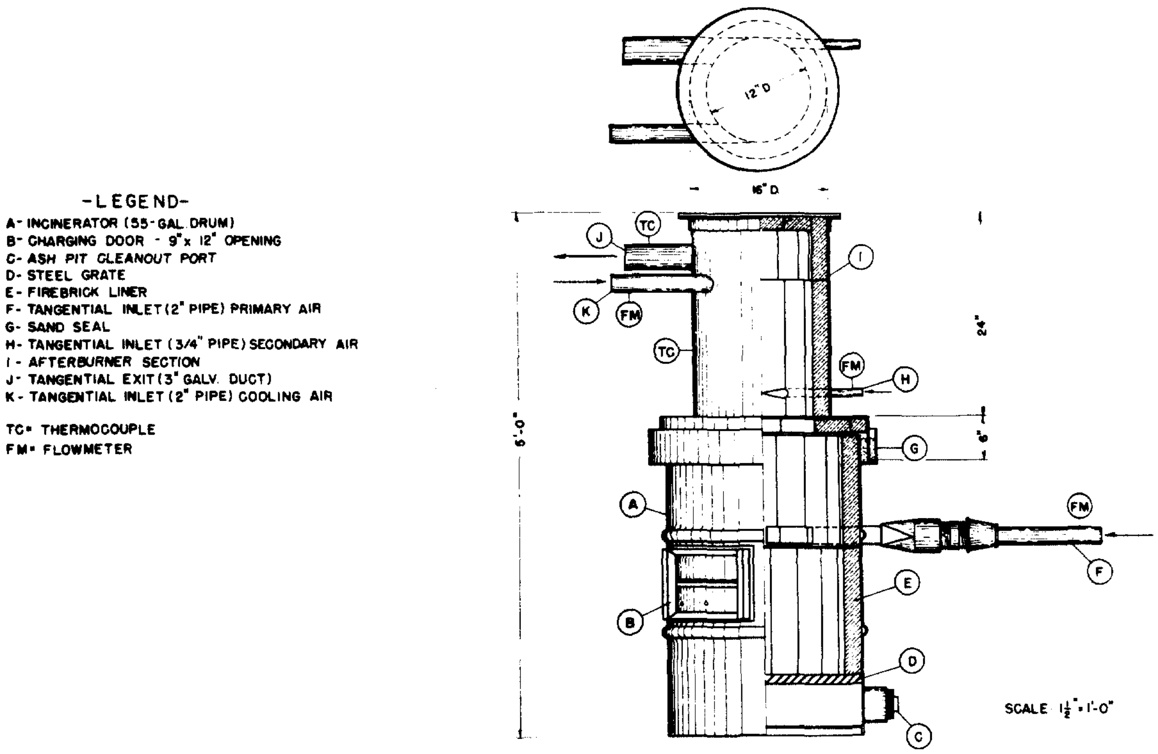
In order to eliminate leakage, the incinerator cover and predrying hopper were fabricated as a single piece. The lower rim of the cover rested in a 4 in. deep, sand-filled circular channel section which was an integral part of the incineration chamber. This construction permitted ready access for repair or internal modifications and reduced air leakage to insignificant quantities (1 to 2 cu.ft. per min. or <5 per cent).

The top of the predrying hopper was gasketed and held in place by metal clamps during testing to eliminate stray leakage at this point. The incinerator stack effluent passed through approximately 8 ft. of 3 in. diameter duct prior to entering the base of the slag wool filter unit. The latter device was the same one that had been used during tests on the "Incinor".

Test procedures for the ACL-I incinerator were the same as those reported for the "Incinor".

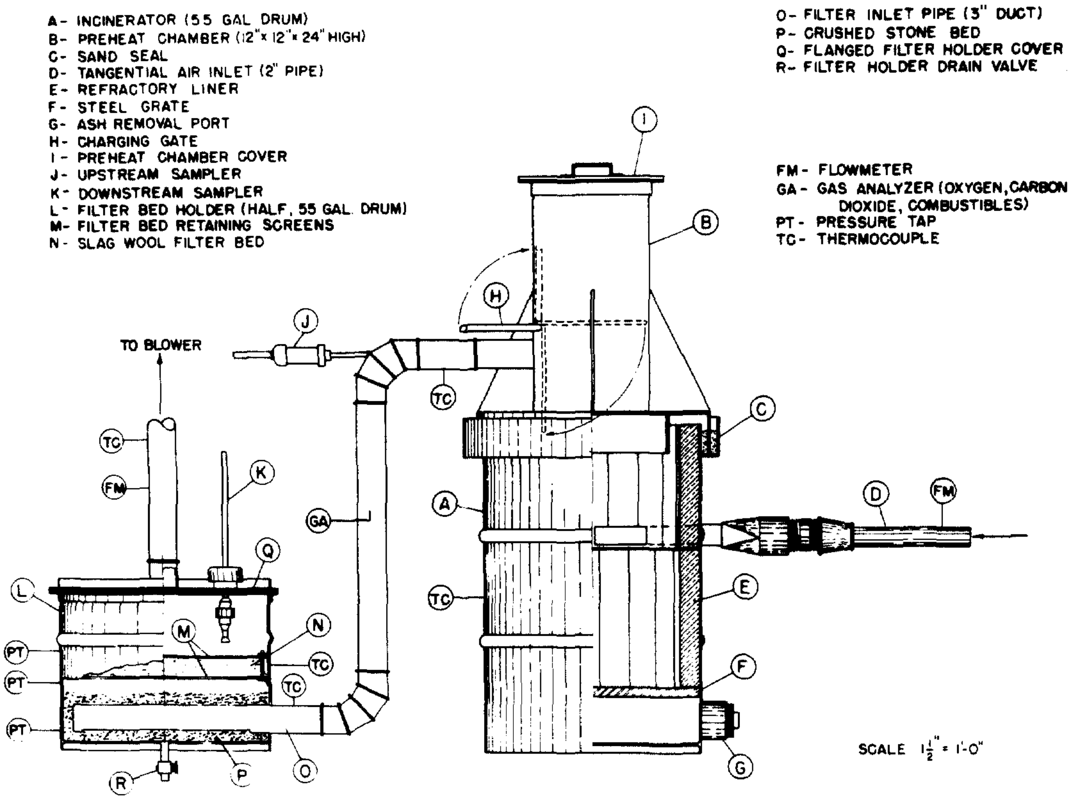
C. Test Results

Results of several combustion tests on the ACL-I incinerator are summarized in Table 1. The major variables were the quantity and type of air supply, i.e. overfire or underfire. Data for several air flow conditions, Tests 1-7, represent average conditions for the combustion of 6 to 10 separate 5 lb. sawdust charges. Each charge was allowed to burn nearly to completion (based upon return of O_2 levels to 18 per cent in the stack effluent) before the next charge was introduced. Indicated burning rates do not include the time required to open and close securely the predrying hopper (about 5 minutes) since no such delay in charging would exist in the final model.


-LEGEND-
A- INCINERATOR (55-GAL. DRUM)
B- CHARGING DOOR - 9"x 12" OPENING
C- ASH PIT CLEANOUT PORT
D- STEEL GRATE
E- FIREBRICK LINER
F- TANGENTIAL INLET (2" PIPE) PRIMARY AIR
G- SAND SEAL
H- TANGENTIAL INLET (3/4" PIPE) SECONDARY AIR
I- AFTERBURNER SECTION
J- TANGENTIAL EXIT (3" GALV. DUCT)
K- TANGENTIAL INLET (2" PIPE) COOLING AIR

TC= THERMOCOUPLE
FM= FLOWMETER

Fig. 4—Institutional type incinerator and gas cleaner for disposal of low level activity wastes, ACL-I.


A- INCINERATOR (55 GAL. DRUM)
B- PREHEAT CHAMBER (12"x 12"x 24" HIGH)
C- SAND SEAL
D- TANGENTIAL AIR INLET (2" PIPE)
E- REFRACTORY LINER
F- STEEL GRATE
G- ASH REMOVAL PORT
H- CHARGING GATE
I- PREHEAT CHAMBER COVER
J- UPSTREAM SAMPLER
K- DOWNSTREAM SAMPLER
L- FILTER BED HOLDER (HALF, 55 GAL. DRUM)
M- FILTER BED RETAINING SCREENS
N- SLAG WOOL FILTER BED
O- FILTER INLET PIPE (3" DUCT)
P- CRUSHED STONE BED
Q- FLANGED FILTER HOLDER COVER
R- FILTER HOLDER DRAIN VALVE

FM- FLOWMETER
GA- GAS ANALYZER (OXYGEN, CARBON DIOXIDE, COMBUSTIBLES)
PT- PRESSURE TAP
TC- THERMOCOUPLE

Fig. 5—Institutional type incinerator for disposal of low level activity wastes, ACL-II.

Overfire air entered the burning chamber tangentially whereas underfire air was admitted from below the grate area with no particular flow pattern. In both cases the air rates were adjusted to constant STP flow conditions. The volume of CO_2 and CO produced per pound of sawdust was obtained by graphical integration of the gas percentage versus time curve with respect to the instantaneous air flow rate and the amount of sawdust burned during the test period. The following relationships are indicated in Table 1.

TABLE 1

ACL-I INCINERATOR - TYPICAL COMBUSTION TESTS

Test No.	Supply Air cu.ft./min.		Flue Gas cu.ft./lb. of sawdust		Burning[a] Rate lbs./hr.	Stack Temperature Maximum °F
	Overfire	Underfire	CO_2	CO		
1	50[b]	0	14.8	2.6	15.0	1600
2	50	0	15.1	1.3	16.0	1450
3	10	30	12.3	1.1	13.6	1430
4	30	10	12.9	0.8	12.0	1260
5	30	0	-	0.4	9.5	1260
6	0	30	11.4	3.3	12.6	1380
7	0	50	12.7	1.9	15.0	1570

a. 5 lb. dry sawdust charges in paper bags.

b. Tangential inlet area = 4 sq. in. for Test 1, 2 sq. in. for Tests 1 through 7.

1) The burning rate increased with total air flow (overfire plus underfire) from average values of 11 lbs. per hour at 30 cu.ft. per min. to 15 lbs. per hour at 50 cu.ft. per minute.

2) Burning rates also were generally higher for underfire air supply than for overfire air.

3) Average CO_2 production per lb. of sawdust was highest with overfire air supply.

4) The quantity of combustibles in the effluent gas were generally higher with underfire than with overfire air supply.

5) Stack temperatures were higher with underfire air supply.

In addition to the above items, it was noted that the unfiltered stack effluent was more smoky whenever underfire air was used. This condition was also observed during previous tests on the BOMAEC-30 incinerator.

D. Discussion

The selection of optimum operating conditions was based primarily on burning rate and combustion efficiency. On the basis of burning rate, no distinction could be made between 50 cu.ft. per min. overfire or underfire air flow. However, the volume of CO_2 produced, 15.1 and 12.7 cu.ft. per lb. of sawdust, respectively, indicated more complete combustion for overfire air supply. The amount of combustible gases in the effluent gas stream (reported as CO) did not furnish a reliable measure of combustion efficiency, unless correlated with other system characteristics. For example, in all tests made with underfire air supply, combustible gas concentrations noted during the first 10 minutes of operation were significantly higher than those determined for overfire air tests. Simultaneously, stack samples and visual observations of the incinerator effluent indicated much heavier smoke formation. It appeared that rapid distillation of resins and oils resulted in partial combustion only so that the percentage converted to low molecular weight volatiles, organics, or CO was lower than that detected for overfire burning. Although distillation also occurred in the latter case, the skimming action of the rotating air stream tended to produce more uniform burning of the cellulose and tar components of the sawdust.

A comparison of Tests 1 and 6 indicates that the relative CO emission was about the same. However, the CO_2 production with 30 cu.ft. per min. underfire air was much lower, 11.4 vs. 15.1 cu.ft. per lb., and the presence of soot and tars in the stack effluent very pronounced. The CO discharge in this case was not due to partial combustion of tar products so much as to the low oxygen levels in the burning zone.

We did not consider it worthwhile to attempt further correlation of the data in Table 1 since there were some variables which could not be controlled. Although burning rates were fairly uniform for the first 15 to 20 minutes of identical tests, erratic combustion was noted during the final phase, depending upon the position and degree of spread of the charge on the grate. Occasionally some sawdust fell into the ash pit and continued to burn at a slow rate. This extended the apparent burning period when CO_2 and O_2 concentrations were used as a measure of operating time.

There were also variations in sawdust composition even though the same grade was specified for all tests. However, based upon these data and visual observation of the stack effluent we concluded that use of 50 cu.ft. per min. overfire air would provide adequate burning capacity and highest stack temperatures without excessive smoke production.

When the area of the tangential overfire air inlet was reduced from 4 to 2 sq. in. a reduction in soot formation was observed, Test 2. Although CO_2 production appeared slightly higher, the total volume of combustion gases were not altered appreciably. Burning rate, however, was slightly higher and the CO concentrations were lower than those in Test 1 with a 4 in. sq. inlet and uniform throughout the burning period.

E. Slag Wool Filter Rating

It was intended to operate the incinerator at 50 cu.ft. per min. overfire air flow while burning several sawdust charges so that the filter life of the slag wool filter could be estimated under typical burning conditions. However, since there was not adequate fan capacity for this procedure, air flow rates were reduced to 30 cu.ft. per min. overfire. The only previous objection to the above flow rate was that the burning rates were considerably lower, about 9.5 lbs. per hour. Double charging, 10 lbs. instead of the previous 5 lb. package, increased the burning rate to nearly 22 lbs. per hour. The average of several stack sampling tests indicated that total particulate loadings in the incinerator effluent were about 0.15 grains per cu.ft. Half of the collected material dissolved in acetone indicating the presence of condensed tar products. Previous tests on the BOMAEC-30 unit showed incinerator stack loadings ranging from 0.02 to 2 grains per cu.ft. and averaging 0.25 grains per cu.ft.

At the start of the loading tests the filter resistance was approximately 0.5 in. water. After burning 150 lbs. of sawdust resistance rose to 0.66 in. water but showed very little increase during the subsequent combustion of 750 lbs. (Final resistance, 0.7 in. water). According to downstream sampling measurements the slag wool media varied from 90 to 98 per cent efficient on a weight basis. It appeared that the material collected on the downstream sampling filter was primarily condensation products which had passed through the filter in vapor form. Upon firing these filters (all glass media) negligible amounts of mineral ash remained. Examination of the slag wool filter showed evidence of edge leakage which probably contributed to the passage of some carbon particles. Our present opinion is that the mineral wool fibers, although constituting and effective filter, should be prepared as a bonded preformed bed to improve sealing characteristics. Furthermore, it appeared that a thinner filter with a lower packing density than that used with the current unit (2 in. depth, 6 lbs. per cu.ft.) would furnish satisfactory cleaning. When this filter was removed from its holder it was found that actual dust and soot penetration was confined to a very thin layer, 1/2 to 1/4 inch.

F. Charging Device

Although better combustion and proportionately greater burning rates were realized with the ACL I incinerator than those attained with the BOMAEC-30 and Incinor units, the overhead predrying and charging system presented operational problems. Dumping of the bagged sawdust charges into the burning chamber occasionally extinguished the flame. Since residual chamber heat was sufficient to distill volatile materials, re-ignition at times produced minor explosions. A second difficulty was the premature ignition of charges stored in the predrying chamber. Although we believe that the above charging system could have been made operable, it appeared that the necessary modifications would lead to additional cost and complexity. Therefore, the overhead charging technique was discarded in lieu of a simple charge door located on the side of the cylindrical burning chamber. Our previous objection to the latter method of charging was based upon the expected interference with the vortical gas flow pattern within the burning chamber, However, in the design discussed in the following section, minimal disturbance with flow pattern was attained by careful control of air leakage through the door.

ACL II Incinerator

A. Description

Our second incinerator design, Figure 5, incorporated the same burning chamber used in the ACL I model. A side charging door, 13 in. x 8 in. was located 6 in. above the grate and lined with firebrick so that the inner cylindrical contouring was maintained. "Thermoflex"* gasketing reduced stray air leakage to sufficiently

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* Johns-Manville, New York 16, N.Y.

low levels, <10 per cent primary air flow, such that the spiral gas pattern was not altered significantly.

A two pronged sliding fork was inserted in the door, Figure 6, so that wet charges (up to 50 per cent moisture) could be supported along the wall of the combustion chamber. By means of this device, wet material exposed to high radiant temperatures and hot swirling gases was dried in less than one minute provided that the incinerator was heated to operating temperature. When the fork was withdrawn the dried charge fell to the grate and burned completely. This drying method did not disturb the already existing fire in the burning chamber and eliminated the need for auxiliary preheating facilities. Removal of the overhead charging unit allowed space for an afterburning section which we believed would afford some advantage over the single burning chamber. A cylindrical, brick-lined chamber, 20 in. high and 11 in. inside diameter, was mounted directly above the burning chamber. Entry to the afterburner from the burning chamber was made through a short brick-lined conical section. A tangential inlet was provided at the base of the afterburner so that auxiliary combustion air or gas could be admitted. A tangential exit was placed at the top of the afterburner so that the spiral gas flow pattern could be maintained in the system. Since exit gas temperatures were in the range of 2000°F, it was necessary to use either special heat resistant ducting or to provide some means of gas cooling. We choose the latter method and installed an extra air inlet pipe at the top section of the afterburner. Under present operating conditions dilution air, about 50 cu.ft. per min., enters tangentially and mixes within the afterburner to produce an effluent which can be handled with ordinary ventilation piping.

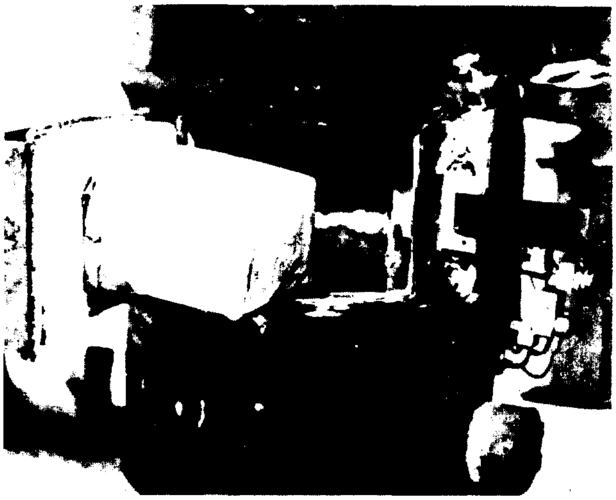

Fig. 6—ACL Incinerator II, charging door open with charge in drying position.

Valves were provided for all air inlets so that optimum flow rates could be determined experimentally. Although facilities were available for admission of auxiliary gas to burn materials not oxidized in the combustion chamber itself we preferred to avoid this system in view of the cost and potential hazards. Since the temperatures in both combustion and afterburning chambers were greater than 2000°F it was postulated that a secondary air supply to the zone of oxygen depletion (<2 per cent by volume during the initial distillation phase of sawdust tests) would be a simple and practical method of soot and tar reduction.

B. Combustion Characteristics

Preliminary combustion tests on the ACL II incinerator were similar to those made on the ACL I unit. Over-all performance was estimated in terms of the volume of CO_2 produced per pound of charge, the volume of combustible gases reported as CO, the burning rate, and average stack temperature.

Two standard charges were used, the first consisting of 3.5 lb. packages of sawdust and the second a mixture of 2.3 lbs. of sawdust and 1.2 lbs. of shredded cabbage. The 7 lb. (double charge) listed in Table 2 consisted of two of the above 3.5 lb. bags.

TABLE 2

ACL-II INCINERATOR - TYPICAL COMBUSTION TESTS

Test No.	Type of Charge[a]	Flue Gas cu.ft./lb. of Sawdust		Burning Rate lbs./hr.	Stack Temperature °F		
		CO_2	CO		Maximum	Minimum	Mean
A.	Primary Air Flow - 48 cu.ft./min. STP, No Dilution (Cooling) Air						
1	S, 3.5 lbs.	12.2	1.0	21.1	1790	1250	1500
2[b]	S, 2.3 lbs. C, 1.2 lbs.	14.3	0.6	17.6	1350	770	1130
3	S, 7.0 lbs.	11.5	1.8	21.1	2010	1250	1590
4[b]	S, 7.0 lbs.	9.5	0.7	21.2	2110	1340	1730
B.	Primary Air Flow - 48 cu.ft./min. STP, Dilution Air - 50 cu.ft./min.						
5	S, 3.5 lbs.	14.9	0.3	19.3	1600	960	1260
6	S, 2.3 lbs. C, 1.2 lbs.	11.5	0.7	19.7	1000	780	870
7[c]	S, 2.3 lbs. C, 1.2 lbs.	15.8	1.1	17.6	1130	790	950
8	S, 7.0 lbs.	13.3	1.2	21.3	1710	910	1270
9[b]	S, 7.0 lbs.	13.7	<0.1	20.1	1720	910	1280
10[b]	S, 4.6 lbs. C, 2.3 lbs.	17.1	0.6	21.2	1210	890	1040

a. S = Dry sawdust (<10 per cent moisture); C = Shredded cabbage.

b. Secondary (auxiliary) air admitted - 10 cu.ft./min. STP

c. Auxiliary gas firing.

The major variables investigated with the ACL II incinerator were the size and type of charge, the quantity and point of admission of primary and secondary combustion air, and the amount of the cooling air.

1. Size of charge. Comparison of several tests in Parts A and B of Table 2 indicated that the amount of charge placed on the grate had very little effect on the burning rate (Tests 1,3,5,8). This conformed to previous studies which showed that the volume of overfire air appeared to be the controlling factor in combustion rate for a constant inlet velocity. These results were not surprising since, with tangentially admitted air, the major burning occurs in the peripheral zone of the grate. With typical loading procedures the main part of the charge is centered on the grate such that burning is initiated at the outer edge.

A noticeable effect of increased charge was the greater amount of combustible gases (reported as carbon monoxide) in the effluent gas stream. Generally, the appearance of filter samples collected in the stack correlated with combustible gas concentrations, i.e. a distinguishable soot deposit with increased combustible gases. When double sawdust charges were placed on the grate there was sufficient heat in the chamber to distill most of the volatile fraction of the charge. However, with a constant air supply, the oxygen demand of the increased volatile loading was exceeded which caused less efficient combustion.

Measurement of carbon dioxide concentrations in the effluent gas were consistent with carbon monoxide results for Test pairs 1-3 and 5-8, i.e. less CO_2 with more CO. However, some data with respect to CO_2 values were inconsistent with other test observations, i.e. Test 4, wherein burning rate, stack temperature, and CO emission showed generally improved combustion.

Mean stack temperatures appeared to increase slightly with double charges which should have indicated increased burning rate. However, mean values were based upon operating time and did not reflect changes in supply air volume with temperature variation. In Test 3, for example, the double charge produced higher peak temperatures during the distillation phase of the combustion. As a result the supply air volume was somewhat lower than that reported for a single charge, Test 1. Therefore for identical combustion rates of 21.1 lbs. per hour in Tests 1 and 3, one would expect to find a higher stack temperature in the system having the lower total gas flow.

2. Type of charge. Burning rates of mixed charges of sawdust and shredded cabbage (about 50 per cent moisture on a dry basis) were slightly lower than those for sawdust under most conditions, Tests 2, 6 and 7. Since the burning rate was based upon total charge the amount of dry sawdust burned was actually about 40 per cent less in these tests. Combustion products, which were based on sawdust weight only, were essentially the same as those for sawdust alone. Since the sawdust burning rate was much lower and the air volumes were unchanged, the stack gas temperatures were correspondingly lower for these wet charges. Lowered values did not reflect poor combustion. When secondary combustion air and dilution air were admitted to the afterburner (Test 10) the combustion efficiency for wet charges appeared higher than for dry sawdust based upon CO_2 emission. We think that the presence of moisture retarded the volatilization of tar products thus affording a better chance for more uniform burning.

3. Air supply.

a. Auxiliary (secondary) air. Admission of secondary (auxiliary) air at the base of the afterburner reduced soot formation in the stack and resulted in lower carbon monoxide emission, Tests 3, 4-8, 9. Although no significant change in burning rate was attained, higher gas temperatures were observed in the stack. These data indicated that the introduction of secondary air to a zone of depleted oxygen supply was a definite adjunct to better combustion. Since the gas temperature exceeded 2000°F in the afterburner there was no chance for the auxiliary air to dilute and cool the main gas flow to temperatures below the ignition point of partially burned combustibles.

b. Cooling air. The chief reason for admitting cooling air at the top of the afterburner was to cool the effluent gas to temperatures within the practical operating range of mild steel piping. It was also presumed that with a tangential entry the vertical gas flow pattern within the afterburner would be accentuated. This would result in less entrainment of gross particles and increased gas retention time. According to our tests however, cooling (dilution) air improved incinerator operation assuming that a reduced CO emission indicated better combustion (Part B, Table 2). This could be attributed to two factors: a) the cooling air acted in part as a secondary air supply, and b) the increased vorticity within the afterburner extended down to the main combustion chamber. In the latter case, changes in the gas flow pattern and the ensuing turbulence might have improved burning in this region. Comparison of the following test pairs in Table 1 (1-5, 3-8 and 4-9) shows better combustion when cooling air was employed.

4. Gas temperatures. We have pointed out certain limitations in the use of gas temperature alone as a measure of combustion efficiency. The range between maximum and minimum temperature was largest when distillable components of the charge were readily volatilized. For example, although average burning rates were similar in Tests 1 and 3, the effect of double charging was to release volatiles at a higher rate during the first part of the burning. Thus, temperature ranges (maximum to minimum) were about 550 and 750F°, respectively, for Tests 1 and 3.

Mean temperatures, unless correlated with instantaneous gas flow rate did not necessarily reflect the total heat output (which was related directly to combustion efficiency). Since our fan speed was not changed during a combustion test the air supply rate decreased to a minimum at maximum temperature and gradually approached the initial values as the run progressed. Therefore, in comparing Tests 1 and 3, and 5 and 8 (and the slightly higher mean temperature values reported for Tests 3 and 8) one must take into account that total gas volumes were lower in the latter case.

However, the temperature increases noted for Test pairs 3-4 and 8-9, appeared to be associated with a real improvement in combustion efficiency since with Tests 4 and 9, addition of secondary air led to increased gas volumes. Similarly the rather low mean temperatures shown for wet charges were caused by the decreased heating value of the charge (about 66 per cent of that for the dry sawdust charge) and not by poor combustion. In addition, during wet tests a significant fraction of the heating values were utilized in evaporating the moisture load.

It was found that the mean stack temperatures reported in Part A, Table 2, were in reasonable agreement with predicted values (based upon a heating value of 7000 BTU per lb. for sawdust). However, it was noted that the indicated stack temperatures were actually higher than predicted values for most tests wherein cooling air was used. We believe that this inconsistency was caused partly by radiation to the stack thermocouple from the afterburner section. This effect was much more pronounced when cooling air was added. It was also possible that gas mixing was not complete such that the thermocouple did not record true average temperature in the duct cross-section.

C. Gas Cleaning

Our tests indicated that the slag wool filter employed in previous studies did not provide adequate filtration area when cooling air was added to the system. Pressure loss rose to prohibitive values after the combustion of relatively little sawdust <500 lbs. Examination of the slag wool media showed a sooty surface coating to be responsible for the high resistance. Actually, the plugging was restricted to less than 1/4 in. of the 2 in. filter depth. We think that the only possible way to make dry cleaning feasible is to employ increased filtering area with a gradation in fiber diameter. A "basket" type filter having more than 8 sq. ft. of filtering surface is now under construction, Figure 7. In order to eliminate leak problems associated with hand-packed bulk fiber we intend to experiment with two fiber sizes of bonded glass fiber, FG-25 (2 to 5 microns) and Type G Airmat (10 to 20 microns).

Fig. 7—ACL Incinerator II, filter unit.

D. Discussion

Comparison of average burning conditions for the various incinerators tested by this laboratory, Table 3, indicates that the latest model, ACL II, provides the best combustion in terms of flue gas composition and stack temperature. The burning capacity of the ACL II was proportionately greater than that of any previous unit tested on the basis of effective burning rate. Aside from the above improvements, the ACL II model was the only device that could be used to incinerate wet charges without using auxiliary gas firing. This was impossible to accomplish with the BOMAEC-30 unit. Furthermore, by resorting to a simple side charge door and a loading fork, waste materials could be introduced wet or dry without disrupting the combustion process. The actual time required to open the incinerator door and place a charge on the loading fork amounted to less than 5 seconds. During the open period air motion through the door may be insufficient to prevent occasional release of gas to the loading zone. Therefore, auxiliary hooding should be provided to protect personnel involved in charging operations.

Our test data appeared to show a significant improvement in the quality of the stack effluent as a result of using secondary air and cooling air. However, increased air volumes present a problem in restricting dry filtering units to a practical size. There is no simple way of reducing gas temperatures to levels that will not damage filter media other than dilution cooling since the use of water sprays or wet scrubbers are not considered acceptable for the present system. For typical applications in hospital or research laboratories, it is unlikely that facilities will be available for liquid radioactive waste disposal. Although some gas cooling may be achieved through the use of extended surface heat exchangers(fins, coils, etc.) we believe that complete cooling by the above methods would be too expensive.

TABLE 3

COMPARISON OF BURNING CONDITIONS IN VARIOUS INCINERATORS

	Lbs. Sawdust per chg.	Burning Rate lb./hr.	Volume CO_2 cu.ft./lb. chg.	Max. Stack Temperature °F
BOMAEC-30	25	45-60[a]	9.09	1455
Incinor	5	20-25	-	1832
ACL Incinerator I	5-10	14-22	10-13.6	1256-1800
ACL Incinerator II	3.5-7	17-26.5	9.5-17.1	1000-2112

a. **Effective burning rate approximately 30 lbs./hr. allowing for charging time.**

E. Future Plans

The major problem at present is to develop an efficient and economical filter unit to clean the incinerator effluent. Tests are scheduled to evaluate FG-25 and Type G Airmat media under typical burning conditions to determine filter life characteristics. A major requirement in collector design is that fabrication cost be low since the entire unit including housing will be disposed of once the rated resistance has been exceeded. In view of this fact it appears that special temperature resistant fibers, i.e. aluminum oxide, would be excluded.

Conclusions

A. BOMAEC-30 Incinerator

1. Our tests on the BOMAEC-30 incinerator indicated that several design changes would be necessary before this unit could be used successfully in the field. These included the following:

- **a) Provision for continuous charging and burning of wet materials.**
- **b) Installation of secondary burning chamber.**
- **c) Use of ceramic liners to maintain high temperatures and minimize warping of metal surfaces.**

d) Construction features which would minimize stray air leakage.
e) Development of a gas cleaning system that would collect particulate materials at reasonable resistance and have a useful service life under high temperature operation.

2. It was not practical to reconstruct the BOMAEC-30 unit in order to incorporate design changes indicated above.

B. ACL II Incinerator

1. An experimental incinerator, ACL II, designed by this laboratory and including the tangential overfire air supply system of the BOMAEC-30 unit, appears to overcome many of the disadvantages of the BOMAEC device.

2. A charging door on the side of the burning chamber permitted continuous loading of the incinerator so that high combustion temperatures could be maintained.

3. A sliding loading fork inserted through the door provided support for packaged wet materials. Waste containing up to 50 per cent moisture dried rapidly in the chamber and did not delay the combustion process.

4. A firebrick lining within the combustion chamber permitted temperatures greater than 2000°F which improved the combustion process.

5. A cylindrical afterburner mounted vertically above the burning chamber reduced the amount of tar products in the effluent when secondary air was admitted tangentially at the base of this section.

6. Use of a sand seal rather than a bolted flange reduced air leakage to negligible quantities at the connection between the main burning chamber and the afterburner.

7. Admission of dilution air at the top of the afterburner appeared to reduce tar concentrations in the effluent as well as affording a partial precooling facility for the effluent gas.

8. Combustible particulate loadings in the incinerator effluent were lower than those obtained with the BOMAEC-30 unit and comparable to those reported for two chamber municipal type incinerators.

9. A gas cleaning device consisting of a basket type filter containing bulk or preformed graded mineral or glass fibers appeared to be the most practical method of cleaning the effluent gas provided that inlet gas temperature did not exceed 750°F.

10. Absolute filtration of the effluent will be an expensive operation since cooling and reheat facilities must be provided to remove moisture and condensed tar products. Ordinarily these substances will pass through mineral fiber filters in the gaseous phase and cause no filter plugging.

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A REVIEW OF THE EXISTING REACTOR CONFINEMENT PROGRAM AT HANFORD

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ABSTRACT

This paper summarizes the current status of the confinement program relative to the existing production reactors at Hanford. Included is a description of the over-all system plus a more detailed review of the principal system components: 1) Fog Spray, 2) Filters, 3) Ventilation Control, and 4) the Electrical and Instrumentation being provided for necessary control and monitoring of the entire system. A brief outline of the associated testing and development programs is also included as well as several charts which more clearly delineate the physical and control aspects of the system.

INTRODUCTION

As many of you are aware, a project is now under way at Hanford to provide confinement facilities for both the eight existing reactors as well as the New Production Reactor. Mr. Pursel will be covering the design aspects of the NPR in a few minutes as a separate topic since there are many considerations which are not common to the two projects.

To begin with, it is important to note that these projects are both referred to as confinement rather than containment. This is because in neither case is the familiar containment sphere utilized; rather, the objective is to control the flow of the ventilation air to such an extent that it will be confined to definite paths which will insure that the exhaust air is routed through filters and other appropriate decontamination facilities prior to release from the stack. This approach is considered necessary due to the inherent massiveness of HAPO-type reactors and this will become more evident as some of the design features are illustrated; however, it is very important to realize that this is an entirely different concept for controlling fission product release than was utilized for Dresden, PWR, and many of the other recently completed reactors.

BASIC CRITERIA

Without getting into extensive discussion of the early Hanford confinement studies, it was concluded that, in consideration of immediate goals, it should be feasible to remove approximately 99.9% of the particulates, 50% of the halogens, but none of the noble gases which may be released from reactor incidents.

Accordingly, the basic features of the initial confinement facilities for the existing Hanford reactors will include:

1. A dense, finely atomized spray system within the rear face enclosure of each reactor which will remove some halogen vapors and particulates as well as afford some degree of decontamination, thermal cooling, and pressure control;
2. A filtering facility which will remove a very high percentage of all particulate matter from the exhaust ventilation air prior to release from the stack;
3. Space within the filter building facility for the future addition of a "dry" halogen collector; and
4. Suitable instrumentation which will monitor and record, where necessary, critical operating conditions.

In addition, it was decided to extend further study and testing toward:

1. The development of a suitable method for the "dry" removal of halogens which would provide decontamination factors of 20 or higher, and
2. Establishing the feasibility of sealing and/or structurally reinforcing the existing reactor buildings to withstand a nominal build-up of internal pressure such as may accompany higher order incidents.

GENERAL FACILITY LAYOUT

Before getting into some of the specific design details, it may be well to orient ourselves with the general facility layout. As noted on the first slide, (Figure I) the reactor block is located within the external reactor building structure such that there is a ventilated space between the block and the outside walls. While the eight existing reactors differ slightly, the layout shown is typical in principle. Without going into the details of how air is supplied to the ventilated areas, it will be seen that the air passes over the reactor block surfaces and is drawn into a common plenum on the suction side of the exhaust fans. In the past the fans have discharged the air directly to the stack; however, you will notice that the air will now be diverted through a filtering facility prior to this release.

The question may arise as to why the filters and their associated ductwork were not installed on the suction side of the fans. It is recognized that this method would have certain inherent advantages; however,

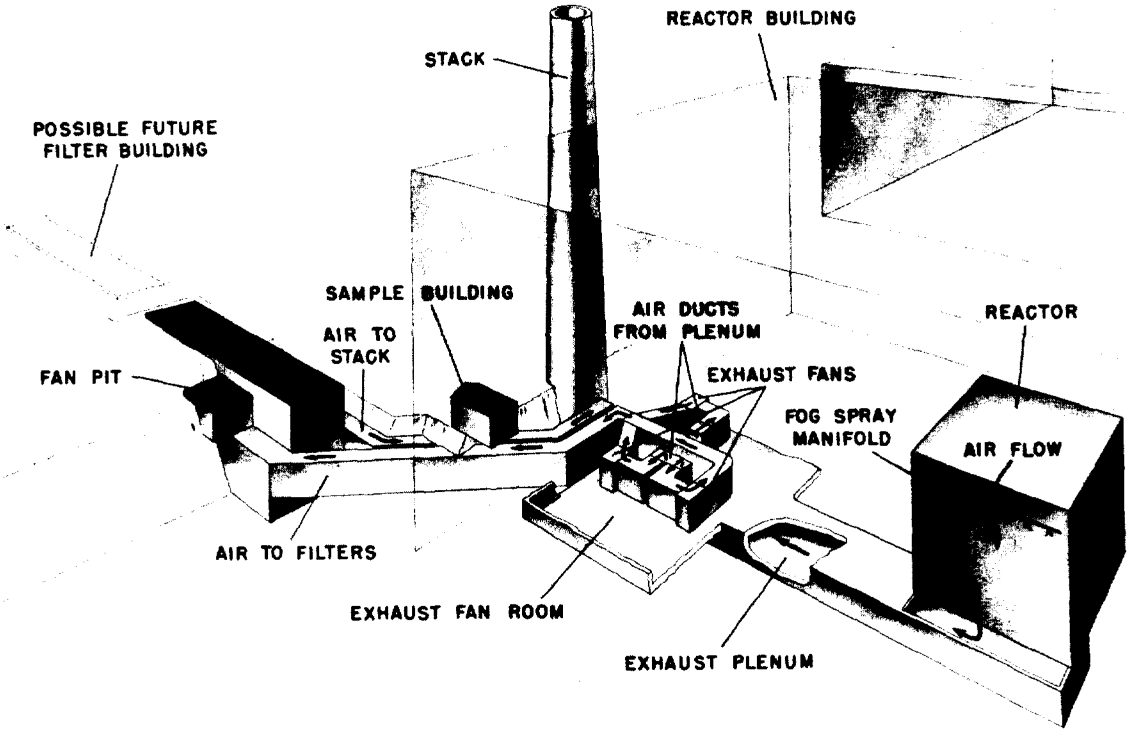

Fig. I—Facility layout.

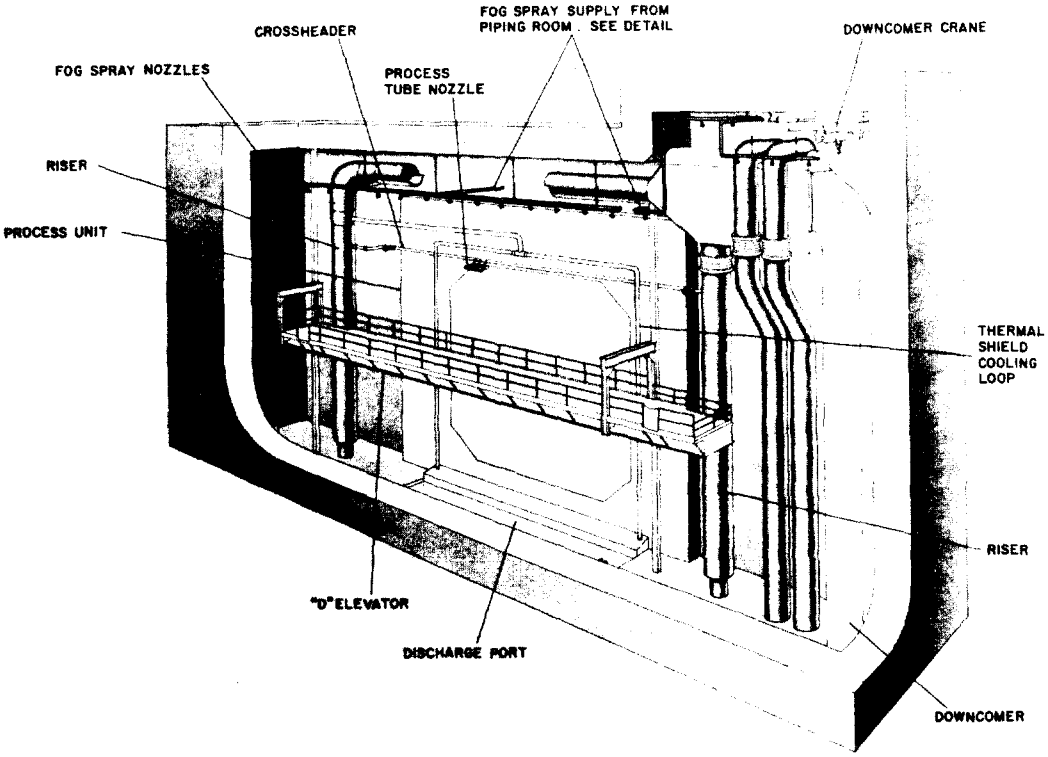

Fig. II—Fog spray system.

it was not done in this case since (1) the construction of the original buildings makes such a tie-in appear unfeasible, (2) all exhaust fans either are or will be shielded, and (3) we are satisfied that, by utilizing demonstrated techniques, our facility will be relatively easy to seal against the rather nominal static pressures which will occur.

The sample building houses the bulk of the instrumentation associated with the confinement facilities with the exception of a small portion which is located in the reactor building control room.

FOG SPRAY SYSTEM

It will be noted that there is a spray system located within the rear face enclosure which is designed for automatic or manual operation. This is shown in more detail on the next slide (Figure II).

Specifically, the spray system is designed for the multi-fold purpose of:

1. Absorbing a portion of the halogen vapors which may be given off during a uranium fire.

2. Condensing on and settling out a portion of the airborne particulate matter which may be released during slug fires or other gross contaminating incidents.

3. Washing down exposed surfaces within the rear face enclosure for removal of contaminated particles.

4. Providing some degree of thermal cooling to exposed fuel elements which may be lodged within the rear face enclosure.

5. Condensing any steam that may be formed to prevent unnecessary pressure build-up within the rear face enclosure.

The automatic control feature of the spray system is centered around a gamma scintillation detector which is located in the Sample Building. This detector is equipped to continuously monitor the reactor building exhaust air and is set to trip the spray system whenever the presence of radio-iodine is detected in the air-stream. Signals from the chamber are also continuously recorded on a strip chart recorder. During reactor shutdown or other periods when personnel may be within the rear enclosure, the spray system will not operate automatically until all personnel have evacuated the rear face area and the access doors have been closed.

A lock-type switch is located in the reactor building control room which has four positions in addition to the automatic position:

1. Automatic--Fog spray will be actuated upon a signal from the gamma scintillation detector provided rear face access doors are closed.

2. Normal On--System is manually actuated provided rear face access doors are closed.

3. Emergency On--System is manually actuated regardless of rear face door status.

4. Normal Off-System is manually shut off; however, this control will be overridden by a signal from the scintillation detector provided rear face doors are closed.

5. Emergency Off--System is manually shut off and completely bypassed.

FILTERING FACILITY

As is indicated on the next slide (Figure III), the filter building is of reinforced concrete construction and is almost entirely below grade. Although the normal radiation activity on the filters should be quite low, it was decided to utilize an underground installation since, (1) earth is cheap shielding; (2) the building and associated ductwork would cause less hindrance to movement of vehicles and personnel within the area; and (3) abandonment, in place, would be much simpler should this ever become necessary.

The volume of air being filtered is as high as 150,000 cfm in one area and the total number of filters are housed in two cells of the filter building, each of which can be individually isolated by means of a water seal pit from the exhaust air flow for filter replacement. Each filter building cell contains provisions for three banks of filters in series and each bank is composed of two halves, each of which is structurally integral units for ease of filter replacement.

The three banks of filters in each compartment will be roughing filters, fine or "absolute" filters, and halogen collectors, respectively, and all are designed on the basis that future filters and/or halogen collectors may be up to two feet in thickness. This flexibility was provided since design of the filter building structure ran concurrently with, and was completed prior to the completion of, the filter life tests which will be described by Mr. Wisehart in a few minutes.

The final selection of the roughing filter for this facility has not been made as of this time; however, it is expected that it will be a conventional filter of the dry strainer type for the purpose of protecting the second stage or fine filter. The fine filter is the key to the filtration system and will be the improved CWS type which is rated for continuous operation at 200°F at a relative humidity of 100 per cent. These, as you know, are commonly rated at an efficiency of 99.9 plus per cent when tested with 0.3 micron dioctyl-phthalate smoke. Initial resistance of these filters is approximately 1.0 inch w.g. when operated at rated capacity with air at standard conditions.

The third filter bank will not be installed initially but will be reserved for the future addition of a "dry" halogen removal system. This particular component is the subject of a testing contract which is now underway and will be further discussed later.

Design of all filter banks is based on normal filter replacement being accomplished by use of a portable crane and without access to the interior of the filter cells. In order to prevent contaminated material from blowing out of the filter cells during times when cell covers are removed for filter replacement, an exhauster is provided for creating a positive sweep of outside air into the cell opening which is then routed through the filters in service. After isolation of the filter cell from the ventilation air stream, start-up of exhauster to create a slightly negative pressure within the cell and removal of the cell cover, the filter bank will be withdrawn into a plastic bag for transporting to the burial ground.

While the probability of a serious incident is very low, an incident involving several tubes of fuel elements would no doubt contaminate the filters to the extent that replacement is somewhat problematical. Of

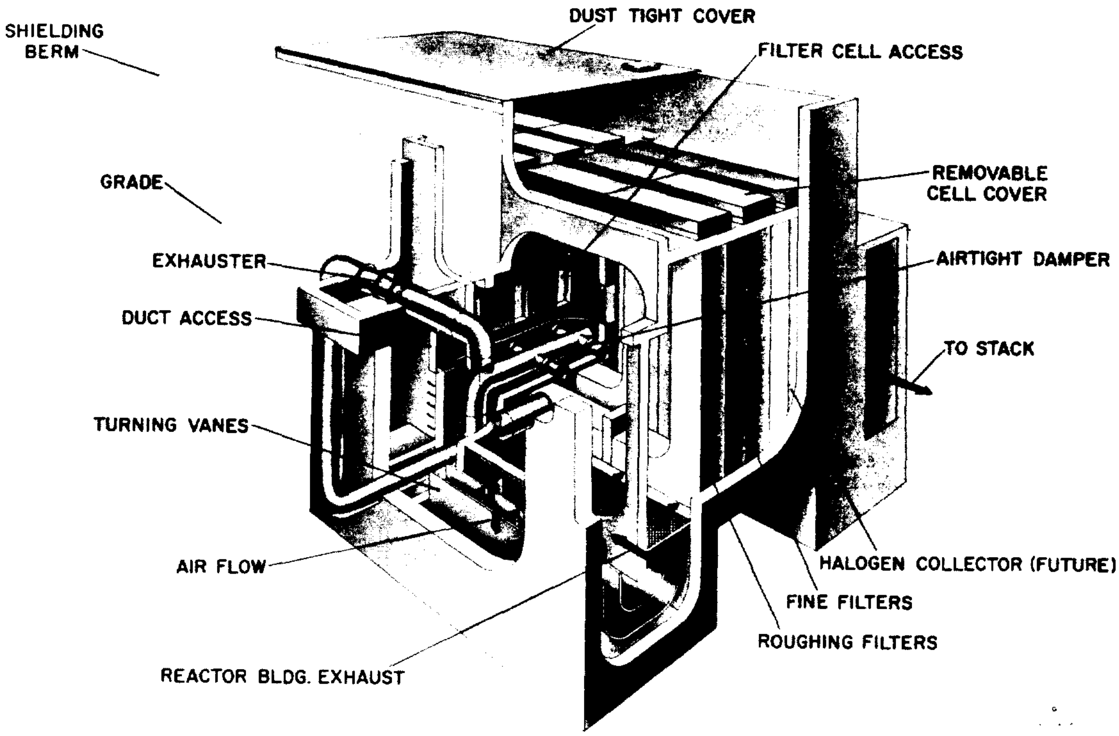

Fig. III—Filter building.

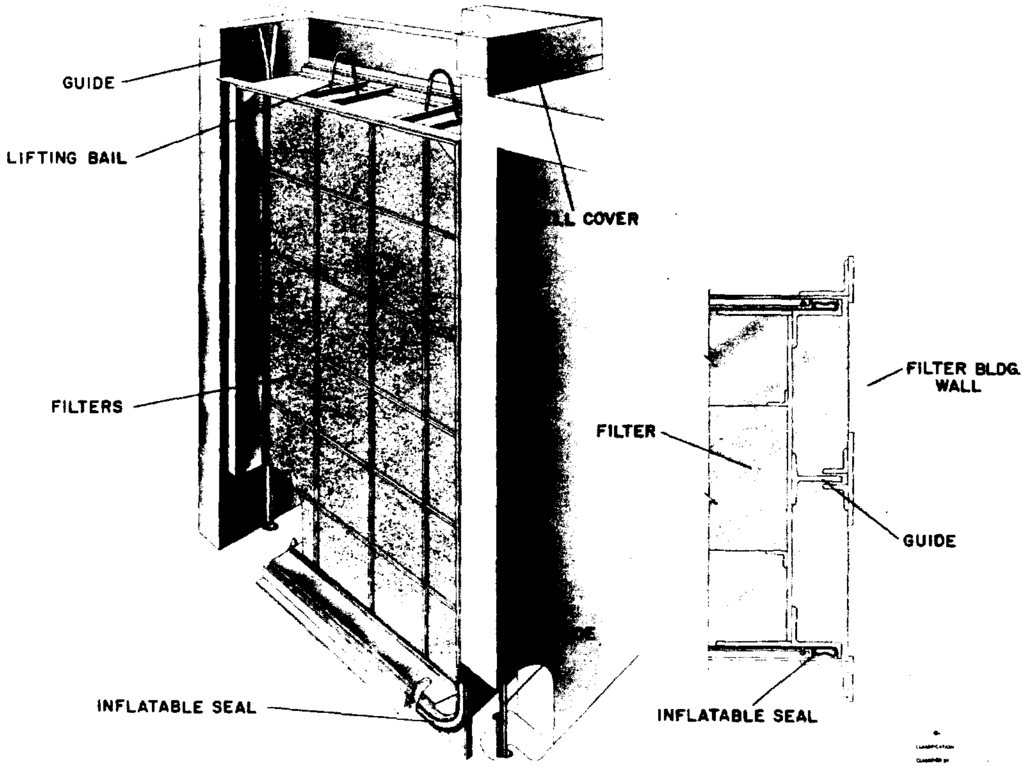

Fig. IV—Typical filter bank arrangement.

course, the incident itself would not dictate immediate replacement of the filters since they are well shielded. However, when the pressure drop through the filters had reached the point that would make continued operation of the ventilation system untenable, the decision must be made as to the relative feasibility of replacing the filters or constructing an entirely new filter building. To provide for this latter eventuality, filter building design has included means for making such an extension and space has been reserved for the possible new building.

The next slide (Figure IV) shows an enlarged isometric detail of the filter frame construction. Individual filters are mounted in the filter frame in a more or less conventional method, utilizing compression gaskets to provide the seal for individual units. Because of the requirement that filter replacement must be affected by semi-remote methods, the filter frame itself utilizes a continuous inflatable seal around the entire periphery of both the upstream and downstream faces. Following placement of the filter bank into the cell, seals will be inflated with instrument air and monitored continuously for leakage.

VENTILATION SYSTEM

Inasmuch as the confinement facilities are being added to an existing building, the criteria for modification of existing fans and system balancing are few:

1. Although there will be no change in normal ventilation flow, the addition of the filtering facilities will increase the static head of the system by about six inches w.g. This change in the system characteristic can generally be accommodated by increasing the speed and horsepower of the fan drives; however, new fans may be required in a few instances.

2. In order to insure that the exhaust ventilation air will, in fact, be "confined" and routed through the filtering facilities, the building ventilation balance must be checked to insure that the static pressure in zones which are potentially subject to gross contaminating incidents is maintained at a level sufficiently below atmospheric. Critical zones will be annunciated so that operating personnel will be immediately aware of any significant change in the ventilation balance.

3. Fan drive reliability must approach that of the reactor cooling system, since the entire confinement facility philosophy is based upon being able to insure that the air will pass through the filters. To this end, the electrical system to the fans is being examined and improved where necessary with automatic emergency fan drive power also being provided.

INSTRUMENTATION

The next slide (Figure V) shows an over-all engineering diagram of the confinement facilities and the associated instrumentation. Starting in the lower left hand corner, you will see the filtered water supply to the rear face fog spray system. Significant loss of pressure in this line will be annunciated as indicated. The fog spray valve is a normally closed valve which requires energization to open. Accordingly, the valve does not open upon loss of power and a manual by-pass valve is provided for this eventuality. Annunciation is provided to indicate flow regardless of how it is initiated.

Moving to the right, the air flow through the rear enclosure is depicted, with a pressure switch provided to annunciate a significant disruption of the ventilation balance.

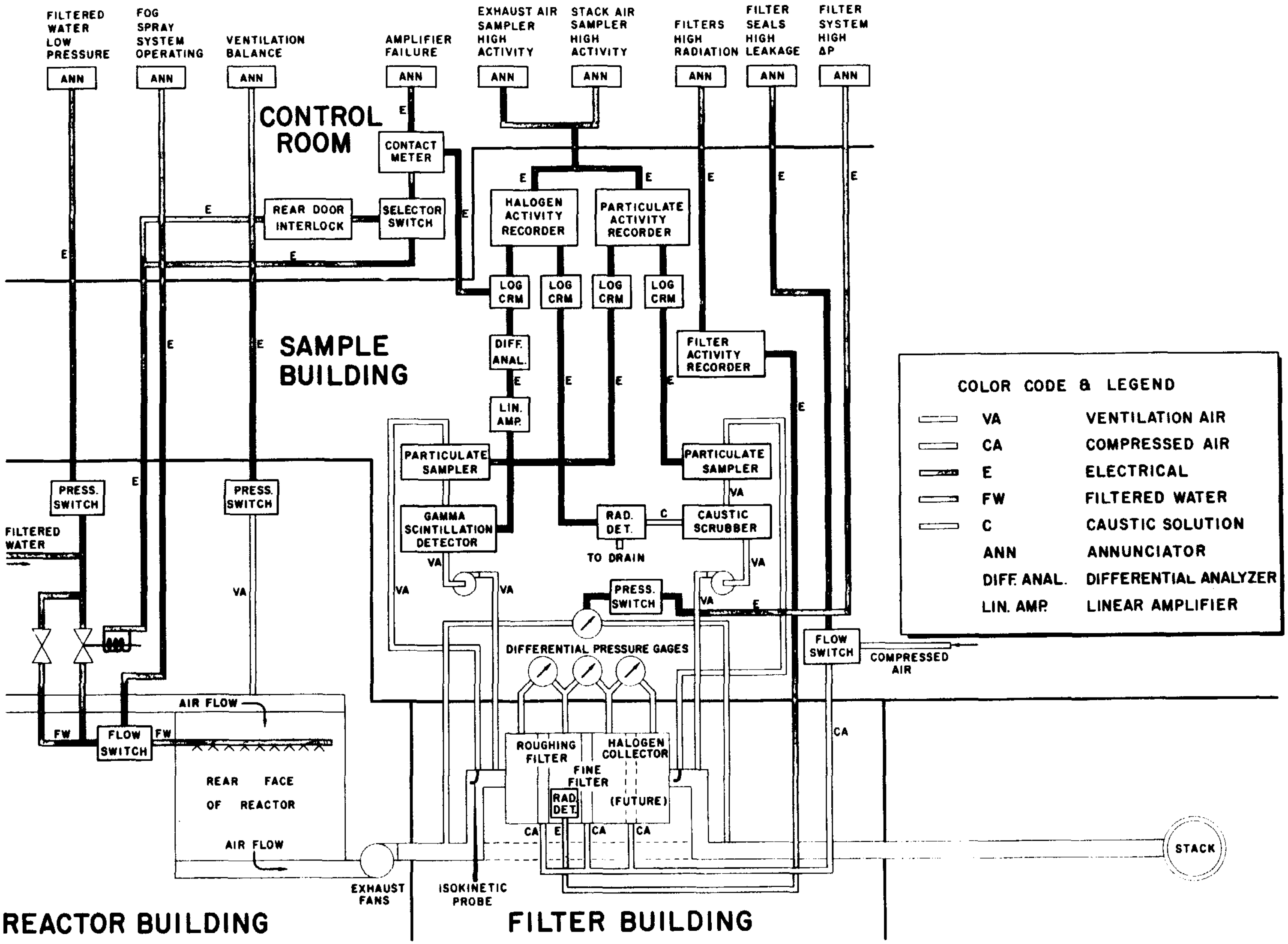

Fig. V—Engineering flow diagram.

After the air leaves the exhaust fans but prior to reaching the filter building, an isokinetic probe is mounted in the duct which draws a continuous sample of the exhaust air. This air sample is routed through a particulate sampler of the strip filter type and then through a gamma scintillation detector before being discharged back into the main airstream. The electrical signal from the two sampling devices is directed to recorders through the use of suitable instrumentation and annunciation is provided for high activity. It will now be seen that the electrical impulse from the gamma scintillation detector also provides the signal to the contact meter and through the selector switch for selected operation of the fog spray system. Failure of electronic components will give a downscale trip of the contact meter which will be annunciated but which will not actuate the spray system.

Within the filter building proper, there are three essential monitoring systems. One of these is a set of differential pressure gauges which are common to all filter installations. An additional feature is an annunciator for high total system drop. This is provided as a more positive method of insuring that filters will be replaced before the ventilation system balance is significantly affected.

Also in the filter building is a radiation detector which allows remote indication and recording of filter activity. Finally, there is a network of air lines to the inflatable seals on the filter frames. Leakage of any individual seal will be accompanied by air flow through the flow switch which is annunciated. By valving, the defective seal can be determined.

Downstream of the filter building, a second isokinetic probe is mounted for the purpose of sampling the air which will be discharged from the stack. This is basically the same system as is used for sampling the air upstream of the filter building with the exception of the caustic scrubber which is utilized instead of the gamma scintillation detector for halogen sampling and recording.

TESTING PROGRAM

The testing program in support of the existing reactor confinement project consists essentially of design tests or tests of specific components rather than development tests in which a component or system is developed from basic criteria. I will mention some of these briefly but will gladly discuss them further during the discussion period as time permits.

1. Rear Face Fog Spray Nozzle Spacing - This test was for the purpose of determining a suitable nozzle type and orientation for adequate spray coverage. Four different nozzles were tested with the final decision to use Rockwood Sprinkler Co. Model L-11A nozzles at a spacing of 10 feet and at an operating pressure of 40-60 psig which gives a total flow of about 400 gpm.

2. Exhaust Air Filter Frame Seal - This test is for the purpose of determining the sealing characteristics of the proposed inflatable filter frame seal. Testing is partially completed and the only significant problem which has been encountered has to do with the quality of the splice in the seal. The seals will be extruded from 50 durometer Hypalon 40 which is rigid enough to prevent effective sealing at low internal pressures unless the splice is fairly smooth. Accordingly, testing is being extended to include additional specimens.

3. Filter Life Tests - These are the tests which will be described by Mr. Wisehart in a few minutes, so for the moment, I will

only mention that the purpose of the tests is to determine the optimum combination of roughing and fine filters for best economic life.

4. Halogen Collector Test Program - This is by far, the most extensive (and expensive) test program being performed as part of the design activities connected with reactor confinement. Basically, the test is merely for the purpose of evaluating the effectiveness of several candidate halogen collectors which have been proven on laboratory scale, but certain complications exist through the use of trace amounts of radioiodine. Both the controlled injection of the tracer and the sampling techniques associated with this test are relatively difficult and, therefore, costly. These tests are just getting underway at the A. D. Little Co., and there are no reportable results as yet. The components being tested are (1) activated charcoal in the configuration of a particulate filter, (2) silver-coated copper mesh, (3) molecular sieve, and (4) the particulate filters themselves.

5. ORNL Irradiated Uranium Burning Tests - Because of the noticeable lack of basic quantitative data regarding the fission product release from various types of reactor incidents, Mr. G. W. Parker has performed several controlled burning experiments. Irradiated HAPO fuel was utilized for these tests and the data obtained is in general agreement with that previously obtained with trace irradiated material except that the burning rate is significantly higher. Since these tests were of a design test nature and confined to selected parameters, a more general program of this nature is now being continued at Hanford.

SUMMARY

As you have noticed, there is nothing particularly unique about any of the components which go to make up the confinement system. Rather, the emphasis has been to arrange the components in a manner which will considerably reduce the environment hazards associated with inadvertent fission product release and to do so in a manner which will have the least possible effect on the continuity of normal production operations. Design of the facilities is essentially complete as of this time and it may be noted that the only problems of significance have been a result of the accelerated program with its associated overlapping of scoping, testing, detail design, and construction rather than matters regarding technical feasibility.

If there are questions or comments of general interest, I will be happy to try to answer them during the discussion period and if someone has questions of a more detailed nature, I will be available at the close of this session. Thank you very much for your attention.

PRELIMINARY REPORT OF ACCELERATED LIFE TESTS ON CERTAIN AIR-CLEANING FILTER MEDIA

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A study has been initiated to gain information pertinent to the performance of certain air-cleaning filter media. The purpose of the study is to obtain data on performance of available filter media that will aid in the proper selection of filters for air cleaning purposes. This preliminary report concerns study objectives, test equipment, and certain results that have been obtained to date.

Factors to be considered in selecting air-cleaning filters are filter efficiency, filter life and resistance of the media to humid atmospheres.

The toxicity, concentration and location of the aerosol contaminant will determine the filter efficiency required and to some extent initial and replacement costs as such costs tend to be proportional to filter efficiency. Filter life dictates when replacement is necessary, if the contaminant aerosol is radioactive, replacement may be costly, difficult and hazardous and long filter life becomes extremely desirable. Another factor that determines filter selection is the effect of atmospheres containing large amounts of water vapor or other substances that may weaken the filter media.

The objective of this study then is to gain information that will prompt optimum filter selection with regards to efficiency, filter life and resistance to humid atmospheres.

Obviously the optimum test to determine a filter's performance for a certain situation would be to place the filter in actual operation and observe its efficiency and loading characteristics over a period of months or years. However, in this event, one has been committed to filter selection and may not have installed the optimum unit. Also, low efficiency filters may be used in a location where high efficiency air cleaning is necessary. Thus, for this study, time limitations necessitated some sort of accelerated life tests to provide a means of comparing filter units and combinations of prefilters and absolute filters.

Test Procedure:

The test procedure used consists essentially of first generating a test aerosol and then passing it through a filter media or a combination of filter media and measuring the filter loadings and efficiencies obtained.

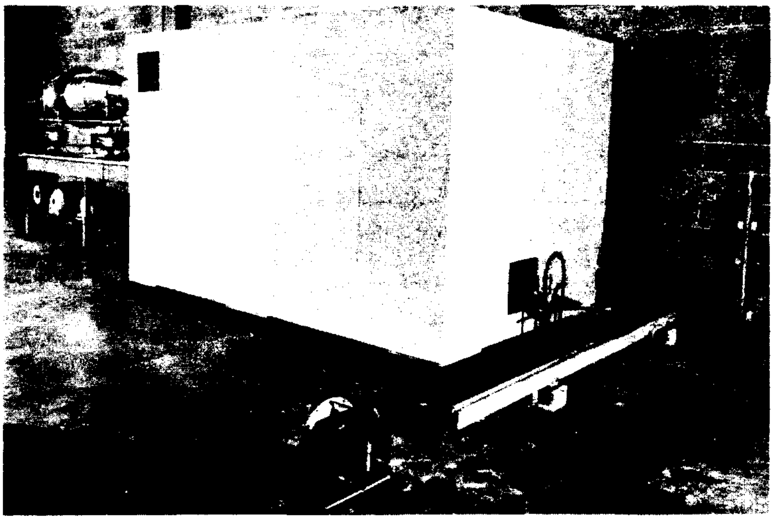

Fig. I—Dust generating apparatus.

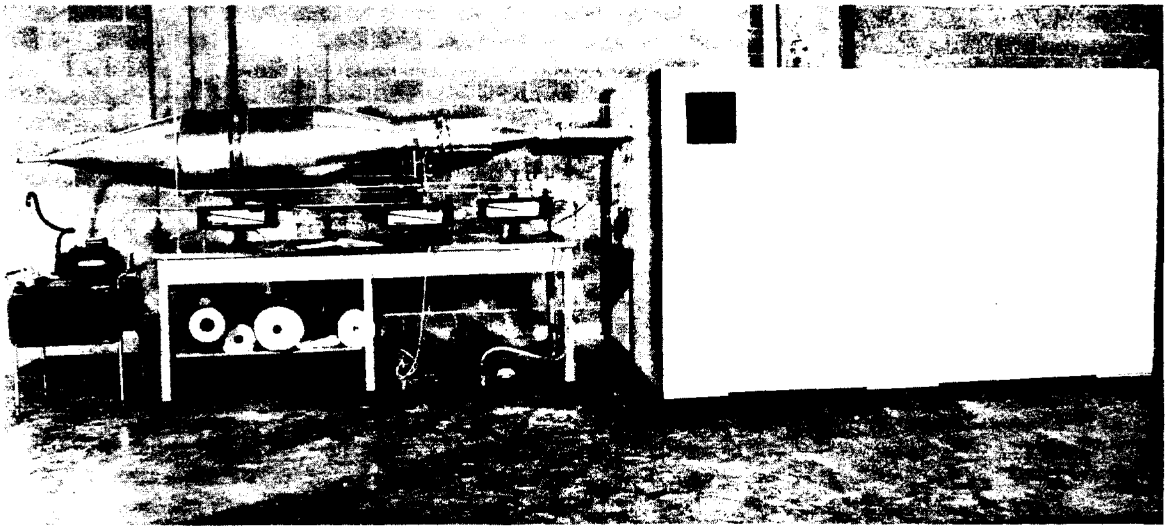

Fig. II—Filter test assembly.

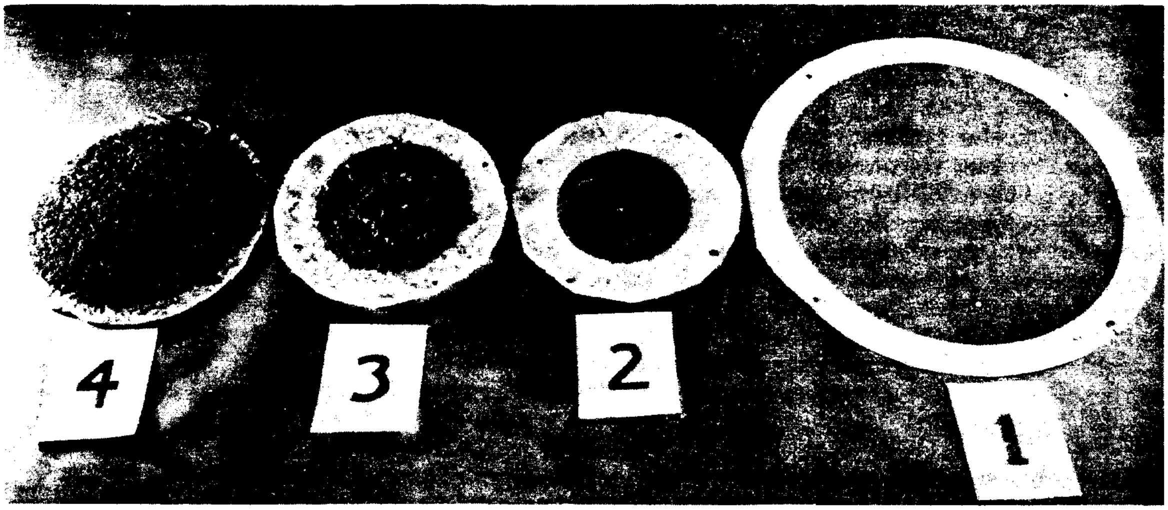

Fig. III—Test media.

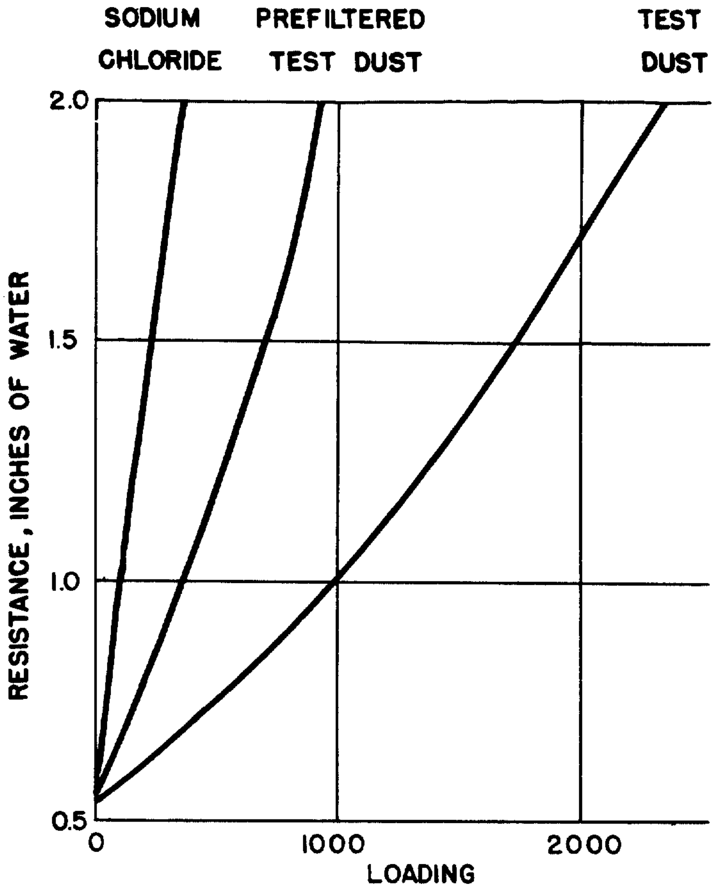

Figure IV

LIFE CURVES FOR AEROSOLVE 35 FILTERS

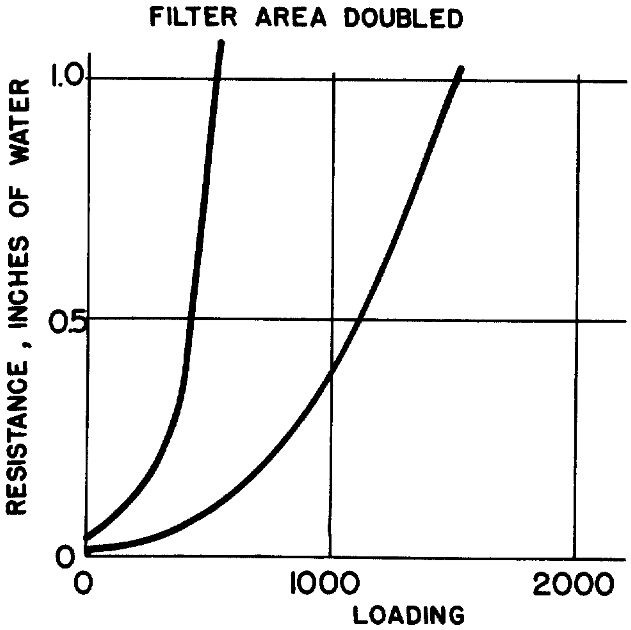

Figure V

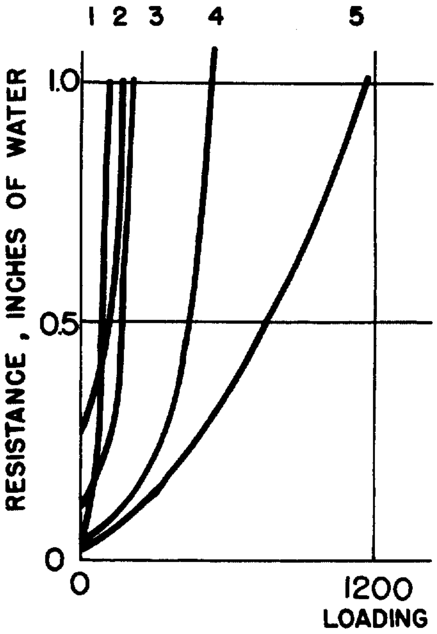

Figure VI

The aerosols used consisted of a test dust, prefiltered test dust and sodium chloride particles. The apparatus used to generate the test dust is shown in Figure I. Attic dust that has been passed through a 65 mesh screen is placed in a trough placed on rollers. The trough is drawn past a clock mechanism at the rate of two feet per hour. Suction is provided by an air ejector which transports the dust into the bottom of the settling chamber which collects slightly more than 99 per cent of the dust. The portion of dust passing through the settling chamber was used as a test dust. The prefiltered test dust used is the effluent dust obtained by passing the test dust through a roughing filter. The sodium chloride aerosol used was generated by vaporizing the salt with a hot nichrome wire coil. Particle size analysis performed of the test aerosols indicated mass mean diameters of 5.5 microns for the test dust, 2 microns for the prefiltered dust and 0.5 microns for the sodium chloride aerosol.

The filter test assembly used is shown in Figure II. It consists of a series of expanded sections for various prefilter and absolute filter media. Actual filtering areas are controlled by placing plate orifices and expanded sections between the flanges. Pressure taps and isokinetic sampling probes are placed upstream and downstream of the flanges. Also, sampling holes are present for obtaining relative humidity measurements. The test apparatus is scaled by a factor of 0.01. Controlled relative humidities are obtained by mixing steam with the influent air of the test assembly.

Test Results

Several types of media that have been loaded with the test dust are shown in Figure III. For the purpose of these tests, prefilter media are loaded to 1 inch of water pressure drop and absolute filter media is loaded to 2 inches of water pressure drop.

The results obtained by loading 5 prefilter media with test dust are shown in Figure IV. The pressure drop is plotted versus relative loading. From a loading standpoint the lifes of the various prefilters vary considerably.

The effect of doubling the filtering area of a prefilter while holding the air flow constant is shown in Figure V. The dust holding capacity is increased by about 2.8. This demonstrates the gain in life-loading by utilizing filter units of greater capacity then indicated by design airflows.

The effect of particle size on the dust holding capacity of ultra filter media is indicated in Figure VI. The capacity for test dust is 2.5 times that for the prefiltered dust and 6.2 times that for the sodium chloride dust.

The purchaser of filters for air cleaning purposes normally does not have adequate information to select the optimum units available from manufacturers for his particular air cleaning problem. Accelerated life tests of the type described in this report should indicate relative lines and efficiencies of filter units available and aid in optimizing selection.

THE T-SONDE, A LOW LEVEL AIR TEMPERATURE MEASURING DEVICE

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I. Introduction

A system to study the temperature-height relationship in the atmosphere to heights of 1500-2000 meters above the ground has been proposed. Meteorological towers and tethered blimps have been employed for such studies, but each has its height limitation. The U. S. Weather Bureau radiosonde system which observes pressure and humidity as well as temperature is more elaborate and expensive than is believed required. An economical system employing modified radiosondes and simpler receiving equipment has been tested recently by the Weather Bureau at the National Reactor Testing Station. The purpose of this paper is to describe the system and to discuss its performance.

II. Description and Operation

The T-Sonde system consists essentially of a radio transmitter and thermistor and gound receiving equipment. The transmitter (Signal Corps T69F/AMT-2) consists of the tube 5910 for the relaxation oscillator, the tube JRP-5703 for the radio frequency oscillator, and a single rod antenna. This transmitter emits a frequency modulated signal with a basic frequency of 403 mc. The type of modulation is the relaxation (squegging) oscillator with a dipole, end fed antenna.

The transmitter was modified by removing the external plug and cord and a permanent jumper was put across the "on" switch from the power supply. The precision fixed resistor which was originally in series with the temperature sensing element was removed, and two ML 405 thermistors were placed in series to form the new temperature sensing element. The two thermistors in series increase the total resistance thereby improving the accuracy. Finally, the leads were brought out for connecting to the thermistor and the cover was replaced on the unit.

Equipment at the receiving station includes a radio receiver, an oscilloscope with an elliptical sweep, and a carefully calibrated audio oscillator. The oscilloscope sweep frequency is derived from the audio oscillator, and the T-Sonde subcarrier signal is fed from the receiver to the vertical amplifier of the oscilloscope. In operation, the receiver is tuned to the carrier frequency of 403 mc and the audio oscillator controlling the oscilloscope sweep frequency is adjusted to cause the mark for the T-Sonde subcarrier to stand motionless on the scope's face. Under this condition the T-Sonde subcarrier and audio oscillator frequencies are synchronized. The subcarrier frequency can then be read from the dial of the audio oscillator and referred to the calibration curve for conversion to a temperature reading.

The components of the receiving station are relatively inexpensive. The receiver, a Navy RDO type with a frequency range of 38-1000 mc, was obtained for $75 and the RDJ pulse analyzer and oscilloscope cost $50. The transmitters were obtained from surplus property for $1 each and were modified at a cost of $3 each.

III. Calibration

An antenna was fitted and power was supplied to the transmitter. After a brief period of warm up for stabilization, the carrier frequency was calibrated at 403 mc with the temperature measuring element (ML 405 thermistors) attached. The element was connected to a transmitter and then placed into a calibration medium, which was a quantity of xylene whose temperature can be effectively varied from -20 to 100 C. As the xylene bath was changed through a range of temperature from -18 to 50 C., simultaneous readings both of temperature and transmitted frequency were recorded. Calibration curves were then drawn for specific transmitter-thermistor combinations.

In general a liquid bath can be held to a closer temperature tolerance than an air environment. It allows more power to be dissipated in the thermistor, it has a much higher thermal conductivity which allows more rapid stabilization of test units, and because of its greater thermal inertia, remains closer on temperature after the entrance of a test fixture holding one or more thermistors. A standard kinematic viscosity type thermometer made to American Society of Testing Material specifications was used to obtain the temperature of the test bath.

Since the T-Sonde transmitters are modified standard radiosondes, the resulting error of the T-Sonde should be quite similar to that of the radiosonde whose over-all probable error is ± 0.5 C. The error due to the lag constant of the thermistor will be reduced with the T-Sonde, because the ascent rate will be reduced to approximately one-third that of the 300 meters per minute ascent of the normal radiosonde. Finally, the error introduced by frequency drift of the oscillator will be minimized with the T-Sonde because of the reduced time of the flight and the limited range of temperature observed.

IV. Vehicle

The T-Sonde package consisting of transmitter, thermistor, and battery pack weighs 15 ounces and can be conveniently carried aloft with a helium filled 100 gram pilot balloon. The battery pack consists of two 45-volt Radio B batteries (miniatures), one 22½ volt

B battery (miniature), six 1½ volt pen light batteries for a total of 112½ volts of B batteries and 9 volts of A batteries with an approximate operating life of 45-60 minutes. Tracking the balloon by the double theodolite method provides means of computing the heights of the balloon at one minute intervals following release and also allows computation of wind direction and speed for given levels. The addition of a standard radiosonde reel, which has had the pendulum increased in length to give a longer period for the string to unwind, and a paper parachute increases the weight of the train to 22 ounces, but provides a means of cut off and recovery without seriously over inflating the 100 gram balloon. The components of one T-Sonde package and flight vehicle are shown in Figure 1.

Fig. 1—Components of the T-Sonde.

The reel is secured to the balloon and the T-Sonde unit is suspended from the parachute. A line from the apex of the parachute is wound on the reel. The length of line wound on the rachet-controlled reel to attain the desired height was determined by experience by varying the inflation of the balloon with a given pay load. The parachute and T-Sonde descend when the line is reeled off to permit eventual recovery of the transmitter, thermistor and parachute. When lead-acid standard radiosonde 6-cell type batteries are substituted, the pay load was increased to 35 ounces. The greater pay load required inflation of the 100 gram balloon to near the burst limit to provide an ascent rate of 100 meters per minute. Hence, for fifteen-minute flights of 1500 meters with the greater pay load, 300 gram balloons are more desirable.

The T-Sonde is essentially an all weather system restricted only by extensive low clouds. The use of a tethered balloon is more seriously restricted by strong winds, which make handling the balloon difficult as well as limiting the height attained.

V. Performance

Examination of the T-Sonde data for the initial flights has been encouraging. Plots of temperature versus height display curves which are as expected for the particular time of day. Figure 2 illustrates the character of the temperature-height curves obtained by the system. The temperature lapse rate shown is that which normally is expected at early morning hours with clear skies in summer months. The nocturnal temperature inversion of the preceding night can be seen from Figure 2. It is the purpose of the program to investigate the height and intensity of such stable atmospheric layers and to relate the temperature distribution to the intensity of turbulence in the boundary layer atmosphere.

The growth of the nocturnal inversion may be seen in Figure 3. The temperature-height curves of this figure illustrate the changing temperature distribution on a clear night resulting from nocturnal terrestrial radiation and turbulent heat exchange within the layer nearest the ground. From midnight to sunrise the layers nearest the ground are cooled as the radiational heat loss continues.

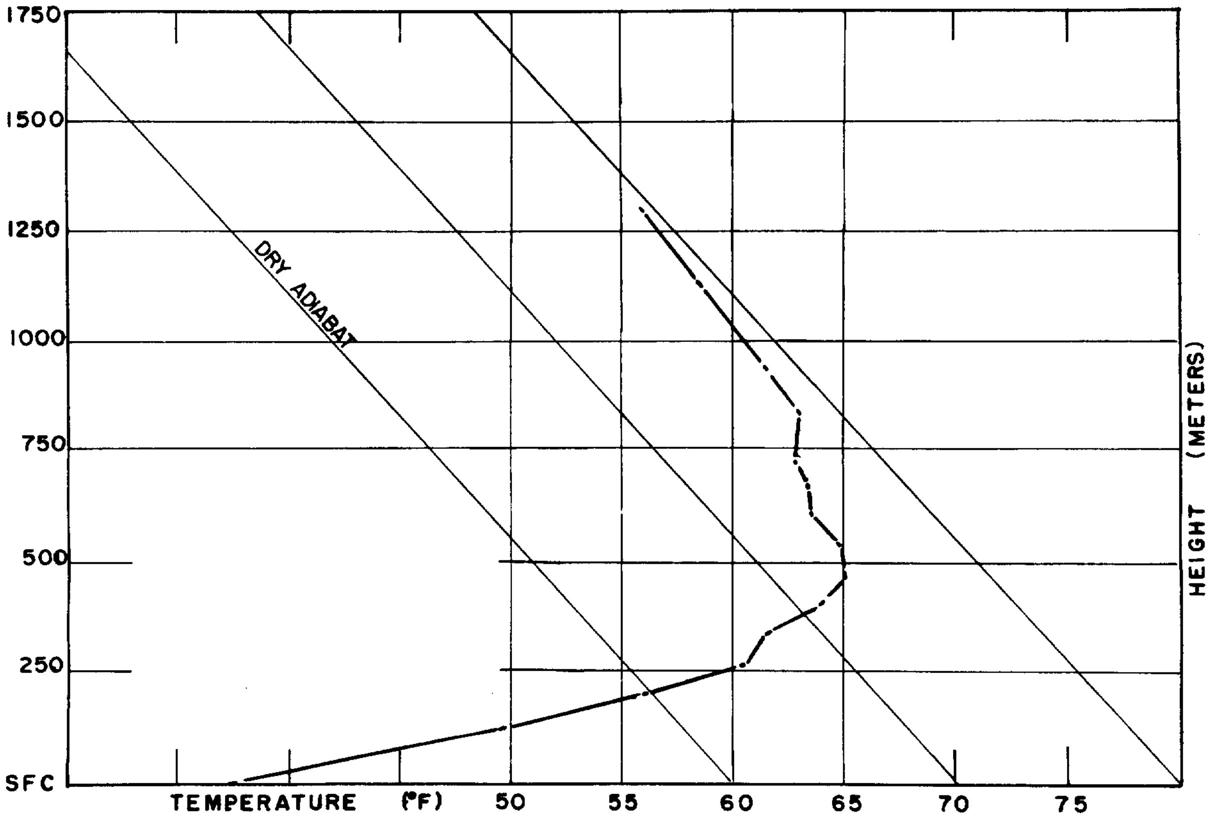

Fig. 2—Details of a nocturnal inversion resulting from a T-sonde flight.

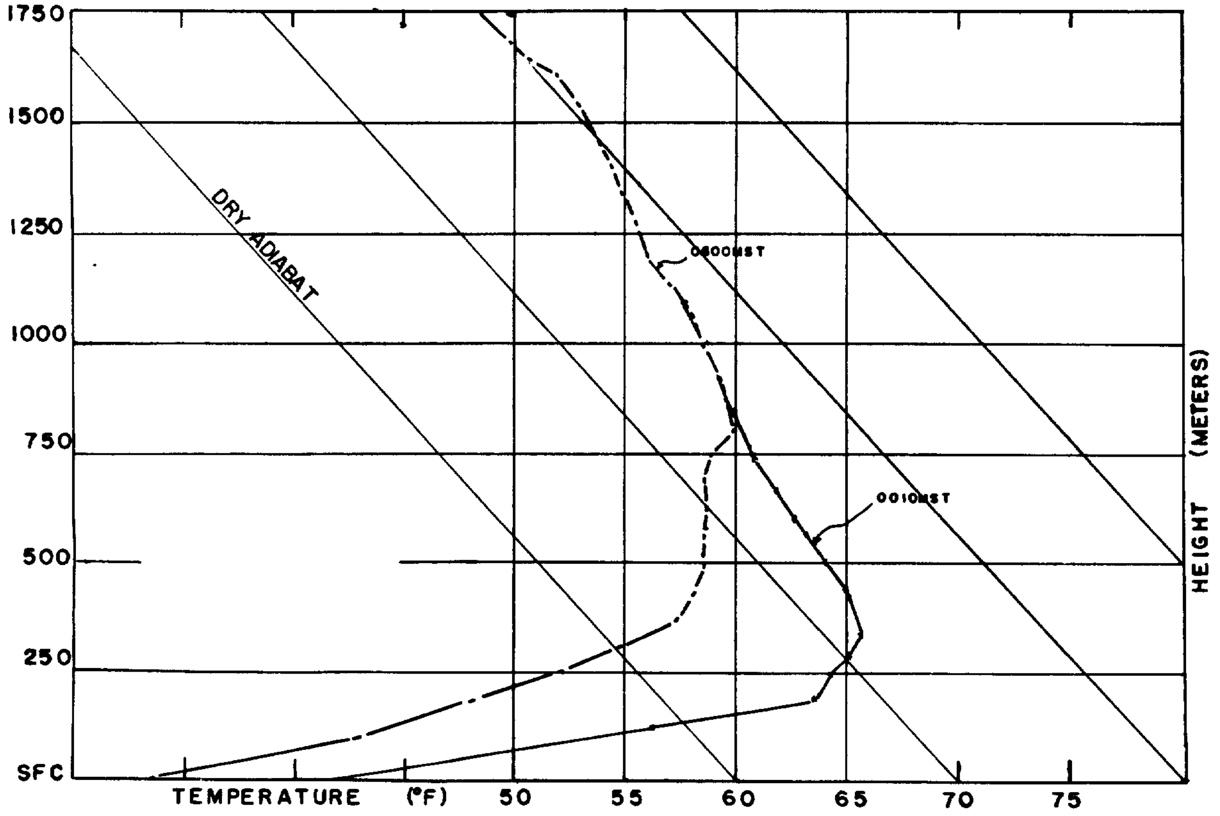

Fig. 3—Growth of a nocturnal inversion.

During this time the height of the top of the inversion increased from 275 to 800 meters. It is apparent that the greatest cooling occurs in the first 250-300 meters; however, sufficient heat loss occurs at higher levels to cause the growth of stable layers to 500-800 meters. Cooling in the region 250-800 meters has been best explained by the mechanism of turbulent heat transfer from the top of the inversion to the ground where it is effectively dissipated by the radiation process.

It is concluded that the system observes the temperature of elevated layers with reasonable accuracy, and that the resulting temperature height curves derived from the soundings for different time of days are consistent with radiation and turbulent phenomena in the lower atmosphere. It then appears that the performance of the system is good to show the complete temperature structure of the lower atmosphere.

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