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TID-7513(Pt. 3)

Subject Category: RADIOACTIVE WASTE

UNITED STATES ATOMIC ENERGY COMMISSION

FOURTH ATOMIC ENERGY COMMISSION AIR CLEANING CONFERENCE HELD AT ARGONNE NATIONAL LABORATORY, NOVEMBER 1955

June 1956
[TIE Issuance Date]

Division of Reactor Development
Washington, D. C.

Technical Information Extension, Oak Ridge, Tennessee

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was released from the burning cellulose material (not necessarily filter media, but with similar burning characteristics) prevented continuation of the project and rendered the all-metal building unusable ever since. Fortunately the project was almost complete so project time and dollar loss was low but the building still stands abandoned as a stark reminder of a serious problem. There are too many vital production, research and development facilities within the AEC program where filter fires could cause similar disasters on a much larger and more serious scale.

II. CONVENTIONAL FIRE PROTECTION STANDARDS FOR VENTILATION SYSTEMS

Before we pursue recent filter fires at AEC installations, I would like to review briefly some of the conventional fire protection standards for ventilation and air conditioning systems. The code adopted for the AEC that incorporates reasonable provisions based on minimum requirements for safety to life and property from fire is the National Fire Protection Association Code No. 90A "Standards for the Installation of Air Conditioning and Ventilation Systems of Other than Residence Type." The standards were revised and approved last May and the 1955 edition was published July 30th. Most of you are quite familiar with this code and use it regularly. This code like all of the other National Fire Codes are henceforth being revised and published annually, and I urge you to keep up-to-date by getting the latest edition around August each year.

These standards apply to the air-duct systems employing mechanical means for the movement of air and used for heating, ventilating, and air conditioning including filtration. Important consideration is given smoke removal systems, particularly in windowless structures where panic hazards are likely. Although personnel loads are usually light the panic problem is applicable to some of our AEC buildings. The construction of duct systems is of prime consideration in the code and one of serious importance to older AEC installations where combustible ducts and plenums are in use, or where non-combustible, easily shattered, materials are laid over combustible frames and supports. Fires are occurring in such duct work at AEC plants.

I would like to quote Paragraph 115 of the NFPA Ventilation standards: "Work involving the use of torches shall not be undertaken on ducts until the system has been shut down, the duct cleared, and all combustible lining and covering material has been removed from the portion of the duct being repaired."

Failure to comply with Paragraph 115 is the prime cause of most fires in ventilation systems at AEC plants and in private industry. A typical disasterous fire in the duct work and ventilation system started by a welder's spark, occurred in Rochester, New York, in a high-value film warehouse of the Eastman Kodak Works. Before extinguishment was accomplished a $3,000,000 fire loss had been incurred and the entire plant was virtually closed down. See the NFPA Quarterly of January 1952 for details. Code 90A emphasizes the need for inspection and clean-out openings.

These are particularly needed on each side of fire damper installations. The requirements for installation of ducts is quite clearly stated. Section 130 "Automatic Fire Doors and Dampers" is a vital guide for the design of a system that will not convey fire through fire walls and fire partitions. This section is frequently ignored or lightly treated in even new design work that is being reviewed. A solid 12-inch fire division wall is only as good as the poorest cutoff in the duct work that pierce it. A cardinal guide, at least from the fire protection view-point, should be to never pierce a fire wall with duct work if it can possibly be avoided.

The sections on fans and controls are of serious consideration, particularly the tying in of controls to fire alarm systems so prompt shutdowns can be made where conditions warrant it. Compliance with the "National Electric Code" and required clearances of heating equipment is understandably included. The section on Smoke Detectors is informative, but these devices as well as sprinkler systems are generally lacking from most AEC installations. The recommended

FIRE CONSIDERATIONS IN FILTER DESIGN

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Since my first walk across the roof of the old "Site B" on the University of Chicago campus, the fire hazards of filters and filter systems have been of personal concern and interest. The sight of an 8- × 8- × 8-foot light frame and tar-paper roof house covering a bank of wood and paper filters, sitting on the roof of an old brewery building, surrounded by higher apartment buildings and residences, was a shock to a fire protection engineer still very new to the fire problems of the atomic age. The primary purpose of that installation was a very efficient air-cleaning performance—which they were getting. The fire hazards of the set-up were known and accepted as a necessary "calculated risk" in getting the job done.

A "calculated risk" is a term used by management, that fire protection engineers must often accept for financial or other quite valid reasons. Our concern is whether the true fire risk, with all its ramifications, is known, and if the risk can be reduced by the application of good fire protection engineering principles. This is a dual problem for the fire protection engineers at atomic energy facilities where elaborate ventilation and air supply systems are needed and where so many combustible filters are in use. We feel that we must emphasize the importance of the fire considerations in filters and filter designs, and we must assist in the search for better methods or media to reduce this fire problem.

In looking back it is amazing how few fires developed in the filter banks, large and small, of the old asbestos-cellulose units, that were and still are in use at most of the major AEC installations. Not a single major fire occurred in filters or resulted from filter fires during Manhattan Engineering District days nor in the early history of AEC. Some minor fires that were potentially serious did occur in those early years to point up the concern of fire and safety personnel. In the fire and safety field it is easy to sell improvements after disasters, but we prefer doing it before, as we are attempting to do in the filter field.

I. COMBUSTIBLE FILTERS POSE PROBLEM

Those early high efficiency filters, originally developed by the Chemical Warfare Service, were deliberately designed to be combustible so they could be readily reduced by burning so as to recover any contamination contained therein. A need for such a filter still exists. I'm sure, it can be lived with if precautionary measures are taken. As fire protection engineers always do, we are forever advocating the elimination of burnable materials, so we're strongly recommending that most of these combustible units be replaced with equally efficient filters that can withstand high temperatures and not contribute to the fire itself. Of grave concern is the possible release of the contained radio-active material from these burning filters; the results from such a release can be devastating. The P-11 fire that occurred at Hanford in 1950 is an example of what can result from the release of contamination from a fire. The contamination that maintenance procedure is an excellent appendix to the code.

I don't think the standards emphasize enough the need for accessability to ventilation systems. This is the prime problem in most fire fighting situations. When firemen cannot get at the seat of a fire, vast amounts of accumulated heat and smoke is given off, causing excessive fire and smoke damages and in turn force the fire fighters out of congested basements and crowded machinery spaces. When radioactive materials are airborne in such duct work the fire control problem becomes nigh impossible.

Another consideration of conventional standards that is of concern in the "hot" atmosphere, is the filter media used in intake air cleaning equipment. Because of the possible exposure from outside fire sources, particularly leaves, tumble weed, alley rubbish, etc., from our experience we recommend that flame treated or non-combustible filters be used at least in the first bank of intake filters. Burnable and burning materials are easily sucked into many such installations, but they can be readily stopped if treated media is used.

Also to be considered are the many large banks of combustible filters whether these be intake filters or the absolute filters in the exhaust systems. Frequently these banks contain literally millions of B.T.U.'s of heat potential. Based on the average figure of 7500 BTU per pound of paper, a bank of 100 or 120 24- × 24- × $11\frac{1}{2}$-inch CWS-Type 6 filter units, such as we have at Hanford, represents roughly 25,000,000 of BTU of potential heat. The effect of such a heat release at the unprotected steel supports and structural members of an all-metal building would literally collapse most of the building in a matter of minutes.

III. RECENT FILTER FIRES IN AEC

Recent fires in filters and small filter banks at AEC installations have borne out the concern safety and fire personnel have always had for these highly combustible installations. Known fires have been reported here at Argonne, at Idaho Falls, at Hanford, and at Oak Ridge. I suspect there have been others. Two resulted from small particles of hot carbon residue, the costliest was started by a welding spark, one indirectly from a fire caused by spontaneous ignition, and the fifth from spontaneous ignition through nitric acid fume action. All were in the asbestos-cellulose CWS Type 6, or improved AEC 1 type. Although these filters consist of fine asbestos fibers mixed with coarser cellulose fibers to give mechanical strength and act as a support for the asbestos, according to "AEC's Handbook on Air Cleaning," the asbestos offers little fire retardant qualities to the filter.

Argonne Incidents

The first incident I would like to cite occurred here at Argonne on February 19, 1953, in the fan loft of the 310 Building. The radio-active waste incinerator was in use when the operator noticed a pressure drop across the filter in the uptakes. Almost simultaneously smoke was noticed coming from the outside stack. The fire department was called while building personnel investigated the apparent fire. They found the single unit filter in the incinerator uptake burning briskly and proceeded to remove it from the housing. Two 15-pound carbon dioxide fire extinguishers did not completely extinguish the fire. Water pump cans were used by the firemen to completely extinguish the burning filter.

On investigation it was found that the three small electric after heaters located in the duct above the scrubbers glowed red hot when in normal use. It was found in test that small carbon particles in the stack gases could pass through the scrubbers, accumulate in the duct and occasionally pieces would peel off and become heated on the red hot heater elements. These heated particles would occasionally reach the filter face and with the proper size, air velocity, and heat, the filter had ignited.

An almost identical fire of unknown cause had occurred in the same uptake and filter a year previous — February 27, 1952. At that time the incinerator was not in use but the heaters had been on while some control adjustments were being made. From the '53 incident the cause was verified. A non-combustible filter was recommended after both fires. Loss from each of these fires was only about $150, but the potential was serious.

Serious Oak Ridge Incident

In the incident at the Oak Ridge Y-12 plant a $17,500 fire loss and a serious production interruption resulted. The fire, or series of fires, was in the C and A air conditioning systems of Building 9204-2 and harrassed plant personnel and Oak Ridge firemen from April 19 through 21 of this year. Following the extinguishment of the initial fire, which had been caused by a spark from a welding job dropping into the plenum chamber on to a filter, re-ignition occurred on each of the two following days. About 500 pounds of CO_2 were used to control the first fire while filters were removed from the building. Water could not and was not used at any time during the fire because of the likely reactivity of the entrapped chemical dust. Eight filters damaged in the fire were replaced, the plenum cleared and the unit returned to use after a $5\frac{1}{2}$-hour delay. But the fire was not over.

The magnitude of each of these banks should be understood. Each of the plenum chambers involved in this fire is approximately 70 feet long, 10 feet wide and 18 feet high, and contains 70 standard filter units stacked in banks 7 units high. This is a package of around <u>20,000,000 BTU's waiting to be released in an essentially frame building.</u>

After 15 hours of normal operation smoke was again noticed coming from the plenum. Warm and very hot areas were found in the joints of the duct-work lining which was built of layers of combustible fiber board sandwiched between sheets of transite. All joints showing evidence of fire were cut out and after a 13-hour production delay the system was restored to use.

Within 12 hours more fire was noticed and inspection revealed that the filters were again on fire. Despite the use of portable CO_2 extinguishers to retard the fire as previously, the intense heat made a hit-and-run method of attack necessary during attempts to remove and isolate the burning filters. Since this work was slow, difficult, and hazardous the decision was made to apply CO_2 in massive attack. Approximately a ton of CO_2 from a large liquid CO_2 truck was applied and knocked out the fire. Many of the burning filters were finally extinguished outside the building with water.

During the series of fires about 5000 pounds of CO_2 were used in all from the portable extinguishers and the Cardox truck. About 115 hours of production time was involved, along with the $17,500 damages, indirect losses and general upset.

P-11 Hanford Fire

The aforementioned P-11 fire at Hanford also involved filters. The hot gases and heat from the paper-boxed materials was being exhausted through the absolute CWS-type hood filters. Naturally the filters caught fire. Considerable difficulty was experienced in the fire in the hood filters. It was necessary under difficult working conditions to break open the filter units to put out the flames and prevent further spread of radioactive material to the atmosphere. This was the first experience of the Hanford fire personnel with the stubborn difficult filter fire extinguishing job.

Idaho Falls C.P.P. Filter Fire

The fifth incident that illustrates another aspect of filter fires occurred at the Phillips Petroleum plant, National Reactor Test Station, Idaho, on the day following the Oak Ridge fire—April 22, 1955. The fire took place in a case of four filters in the blower room of the CPP-602 Building. These filters filtered exhaust air from laboratory hoods on the floor below. Water was necessary to bring the blazing bank under control. Total loss was about $800 for the four filters, the blackened filter case, blower case, and stack.

Investigation indicated that the fire could only have originated in the filters themselves, since no other source of ignition was available and inspection of the duct work showed that the fire had not travelled from the hoods to the filters. Release of nitric acid fumes from the hoods apparently was sufficient to cause deep nitration of the cellulose filter media kicking off a hot fire.

Detailed information on any one of these fires may be obtained through the Safety and Fire Protection Branch, Washington Office, USAEC.

In the case of this and the other fires mentioned, with the exception of P-11, very little radio-active material was contained in the filters that burned. Adequate precautions including assault masks, with radiation monitoring, etc., were taken by laboratory, brigade and fire department personnel in all of these instances. Fortunately, personnel were always around to detect and report these incidents promptly. In none of these instances were standard automatic detection or sprinkler protection provided. Obviously such fortuitous circumstances cannot always be expected when filter fires occur.

The potential seriousness of these filter fires, and others unreported, cannot be over emphasized. We mentioned earlier that filter fires can result in two serious effects—damage-wise and production-wise. The first and the more serious is the release of highly radio-active materials into vital buildings or areas around them. That radio-active material is a serious hazard to all personnel working in or around that building, particularly the fire fighters. Sometimes the released material is not particularly radio-active but it is highly toxic, as are some of the materials we deal with at Hanford. In any case the facility is untenable temporarily and only after costly decontamination and delay can it be returned to use—or if not econonically feasible, as in the case of Hanford's P-11 Building, abandoned.

The second serious effect from a filter fire is the release of tremendous heat energy in confined spaces. Combustion is rapid because of the nature of the cellulose-asbestos filter media—the wood frame is a lesser fuel contributor—and the velocity of the air moving through the units. Most of the buildings at AEC facilities where the most filtration is necessary are usually large all-metal or light noncombustible structures, with many of the older ones frame or partially frame. In either case, if not quickly controlled, sufficient heat to weaken and collapse the unprotected steel structural members or ignite the frame is available. Often in these very buildings fire fighting forces have limited access and delayed attack because of security requirements and complex construction and layout. Generally fire divisions in these buildings are inadequate. Total fire losses can be expected in such buildings, even when there is very little to burn. No building has yet been built that can sustain a fire and not suffer loss from it. If the combustible material is not originally available, someone will at some time or another drag in enough to make it possible.

We have never had a serious filter fire at Hanford although some of the conditions I've mentioned do prevail there, but a series of test fires in filters convinced all who witnessed them that they can be serious and are nasty to deal with.

IV. FILTER FIRE TESTS

As an outgrowth of the P-11 fire a study, involving many members of the General Electric and AEC staffs at Hanford, was made into the filter field. The committee investigating that fire among other recommendations included—and I quote—"d. A study should be undertaken to provide non-flammable filter elements for application where conditions of high levels of radioactivity or toxicity exist."

An indirect result of this recommendation were the filter fire tests conducted at Hanford in April 1953. Previous to these tests a series of studies were made by General Electric personnel on the means of protecting the thousands of combustible filter units already in use.

Numerous possibilities were considered but the ultimate conclusion was that the proper solution to the problem would be the installation of non-combustible type filter elements.

These studies spurred the filter fire tests of the CWS Type-6 units as a "yardstick" for estimating the probable fire that could result, and size and type extinguishing agent needed to put it out. The purpose of the tests was to check the advisability of continued use of CWS Type 6 filters in the 234-5 Building. (See Fig. 1.)

A scaled-down model ventilation system was constructed in a large quonset hut, consisting of 30 feet of 18-inch round pipe going into a plenum chamber 54- × 54-inch in which four standard size 24- × 24- × $11\frac{1}{2}$-inch CWS filters were installed in a framework of the same type construction as exists in the actual filter rooms. The plenum was then reduced down to an exhaust fan which exhausted to the outside. (See Fig. 2.)

All air flows were established to correspond to actual conditions in the 234-5 Building exhaust systems. The air velocity through the 18-inch round duct to the plenum was regulated at 950 fpm and through the filters at 100 fpm. Thermocouples were installed to blanket the test filters.

A total of ten tests were run using varying ignition sources and situations. In Tests 1, 2, and 3, pieces of Kleenex, paper towels, and a handful of lint were lighted and thrown into the air stream 30 feet from the filters. All these materials were virtually burned out before reaching the plenum chamber or dropped harmlessly to the plenum floor with the drop in air velocity. It should be mentioned that the filters were placed vertically in the plenum and the air movement was horizontal.

In Test 4 a small metal tray was loaded with paper tissues, towels, and excelsior and ignited. A hot fire developed throwing off showers of sparks. Most of the sparks were out before reaching the filters; the few that did, appeared to strike the perforated aluminum face plate and go out.

In Test 5 a large wad of excelsior was thrown into the air stream and results similar to Test 4 observed. A lighted cigarette was thrown into the stream, with negative results.

Test 6 was more drastic for the same amount of excelsior was introduced 15 feet or half the distance from the plenum. Sparks appeared to shower the filter face plate for a few seconds but ignition did not take place.

Test 7 was the most drastic of all (see Fig. 3) and very nearly destroyed the test equipment prematurely. A full pad of excelsior was stuffed in the end of the intake duct 30 feet from the plenum. It was ignited and allowed to pre-burn for about 3 minutes before the blower was started. The excelsior burned fiercely, creating a mass of flame that virtually filled the 18-inch round duct and directly touched the filters. All four filters were seen to flash over and glow, then ignite almost simultaneously and the temperature of the discharge air jumped to 600°C. The filters burned fiercely and created intense heat. Small "puffs" or explosions occurred within the plenum chamber, the wire-glass inspection windows cracked, the fan caught fire, and the fan housing distorted. Before the instrument men hastily removed their potentiometer, temperatures of 1112°F were recorded on the filter faces and the exhaust air stream had risen to 1472°F. Higher temperatures were probably reached before the firemen moved in to extinguish the blaze and save the mock-up. A acrid smoke was given off from the adhesive used to bond the filter media to the frame. All personnel evacuated the building.

The firemen directed $1\frac{1}{2}$-inch fog-nozzle streams discharging about 150 gallons of water per minute against the exhaust side of the filter. This seemed to momentarily accelerate burning and the temperature increased. It took almost ten minutes to extinguish the fire with two fog streams with a wetting agent, and even then only half of the burnable material had burned. The wood frames were relatively unmarked from the fire. (See Figs. 4 and 5.)

After clean-up of the mock-up and replacement of the filters a final series of three tests were run to check the spread of fire from filter to filter in a bank.

In Tests 8 and 9 an oily rag and Kleenex tissue were placed at the base of the filter bank and at the face but they burned out without igniting the filters.

In Test 10 an oily rag was hung on the filter face and ignited. The filter ignited immediately and burned for approximately 8 minutes before the others ignited. The others caught fire on the down-stream side due to the intense radiant heat accumulating on that side of the plenum chamber. The fire department extinguished the fires before they became as hot as in Test 7.

It is concluded from these fire tests, and from actual filter fires, that the need for a non-combustible filter with equivalent or better filtering characteristics, even at a somewhat higher cost, is an urgent necessity.

The following comments and conclusions were arrived at from the tests and the actual fires that have happened since:

1. It seemed more difficult to set the filters afire in the tests than it has been in some of the actual fires.

2. In any case the high-air velocity in most exhaust systems tends to reduce the liklihood of ignition, but enhances the fires once ignition has occurred.

3. A non-combustible pre-filter greatly reduces the liklihood of burning material or even flame to get through it to combustible CWS type filters. Thin sheet fiberglass is used at some installations for this purpose.

4. Where large banks of absolute filters are installed only the non-combustible filters should be used. There is too large a fire loading to depend on a non-combustible picfilter only.

5. The prime fuel in filter fires is the filter media and paper separators, not the wooden frame.

6. It seemed relatively difficult for the fire to spread from filter unit to filter unit in the test fires and then only on the down-stream side, yet in actual fires where more than one filter unit was involved it has always occurred.

7. Fires in filter rooms would be extremely difficult to combat. Normally only one side of the filter bank can be available for attack, yet wetter water as used in the tests could not penetrate through the filter. Application must be made from both sides.

8. Carbon dioxide installations and a single sprinkler head would be helpful to retard flame spread, but will usually be inadequate for extinguishing a full-blown filter fire. Heroic systems would be needed to protect large banks.

9. The problem of fire fighting in areas of radiation exposure tend to hamper the firemen because of protective clothing and limited exposure times. Immediate, effective fire attacks usually cannot be carried out.

10. By actual test it was found that the ignition temperature of the CWS filter media was 419°F. All the component parts of the filter unit including the cardboard dividers and adhesive binding materials ignited at 490°F.

V. RECOMMENDED CRITERIA FOR FIRE SAFE ABSOLUTE FILTERS

The perfect filter from the fire protection aspect has not been developed although tests at Hanford have indicated that one or two of the manufacturers have units that with modification should provide the required characteristics.

It is our opinion that the ideal criteria for a fire-safe filter should be—

a. Maximum operating temperature for one hour—1000°F. Such a media is already on the market and temperatures of over a 1000°F would only arise in an already well started fire. A filter unit that will not contribute to a fire starting in it is the best that can be asked for at this time. This unit can be disposed of elevated temperature and/or by crushing.

b. Maximum flow resistance at 5 fpm—.10%. Fire is not a factor here except that the resistance should not increase even after the filter has been subjected to the 1000°F one-hour test.

c. Loading capacity—Comparable to or better than the CWS-6 or AEC-1 media. One manufacturer claims a 1/3 greater capacity because a thinner media and more folds per filter as a result.

d. Frame—$^{1}/_{16}$-inch steel with steel rivets with all exposed metal painted with fire retardant paint. Hanford experience with the steel frame has not been good, so we feel the 1-inch wood frame with exterior coated with a fire retardant paint will be superior until better adhesives and better expansion and contraction controls are developed. Experience in fires and fire tests to date indicate the wood frame was not a prime fuel.

e. Dividers and separators—Use only fiber-glass types. Flame treated paper types readily lose their flame resistance even in dry atmospheres. The thin aluminum types rapidly deteriorate in acid and wet chemistry atmospheres and in a few months the aluminum salts will load up the filter media until it is useless. Also the aluminum dividers (m.p. 1218°F) noticeably weakened in the 1000°F one-hour test.

f. Filter media—Either the Regal, Type A fiber glass or the MSA type are acceptable from a fire point.

g. Stability—Maintain stability under saturated atmospheres for a minimum 24-hour test. Although not a direct fire necessity any unit that tends to buckle or sag, or pull apart is more easily affected when fire exposed.

Whether or not the high efficiency filter with all these characteristics can be manufactured at competitive prices is not known. Fire and safety people at AEC installations are anxious to assist the ventilation and filter specialists in bringing about such a filter.

Earlier reference was made to the NFPA Code No. 90A as an excellent guide. Another reference newly published this year in May, also by the National Fire Protection Association, is their NFPA Code No. 801 "Recommended Safe Practice for Laboratories Handling Radioactive Materials." This is a guide for fire protection specialists, designers and operators of these laboratories on practices necessary for fire safety. I would like to quote the fourth paragraph of Section 5.1 entitled "Heating and Ventilating" which states: "The use of combustible filter permits easy disposal as an ash, but introduces a fire hazard into the venting system and requires automatic sprinklers or special fire protection measures. In the absence of sprinklers within the ducts, fires in combustible filters are extremely difficult to extinguish."

This we have tried to say, but as we've previously stated automatic protection must always be considered for protection of combustible filters, but the installations will usually be inadequate. Instead we recommend the widespread use of the non-combustible types.

VI. CONCLUSION

We have not touched on the problem for disposing of spent filters. Since we advocate the types that will not burn except at elevated temperature we seem to be adding a problem to the filter-use program. I am anxious to learn how these non-combustible units are disposed of, particularly where it is necessary to recover entrapped materials.

In conclusion I would like to acknowledge the work done in the fire tests, the filter tests, and numerous other studies by General Electric personnel at Hanford, particularly Mr. Palmer who is your next speaker, and the fire protection personnel of the plant.

We have attempted to present some information gained in the filter field through fires and fire tests. More so, I hope we have stimulated your interest in considering the fire aspect in your future design or operation of ventilation systems and filters—The problem is getting more serious! Further, I personally hope to learn a lot more about filters and ventilation systems while at this meeting.

Fig. 1

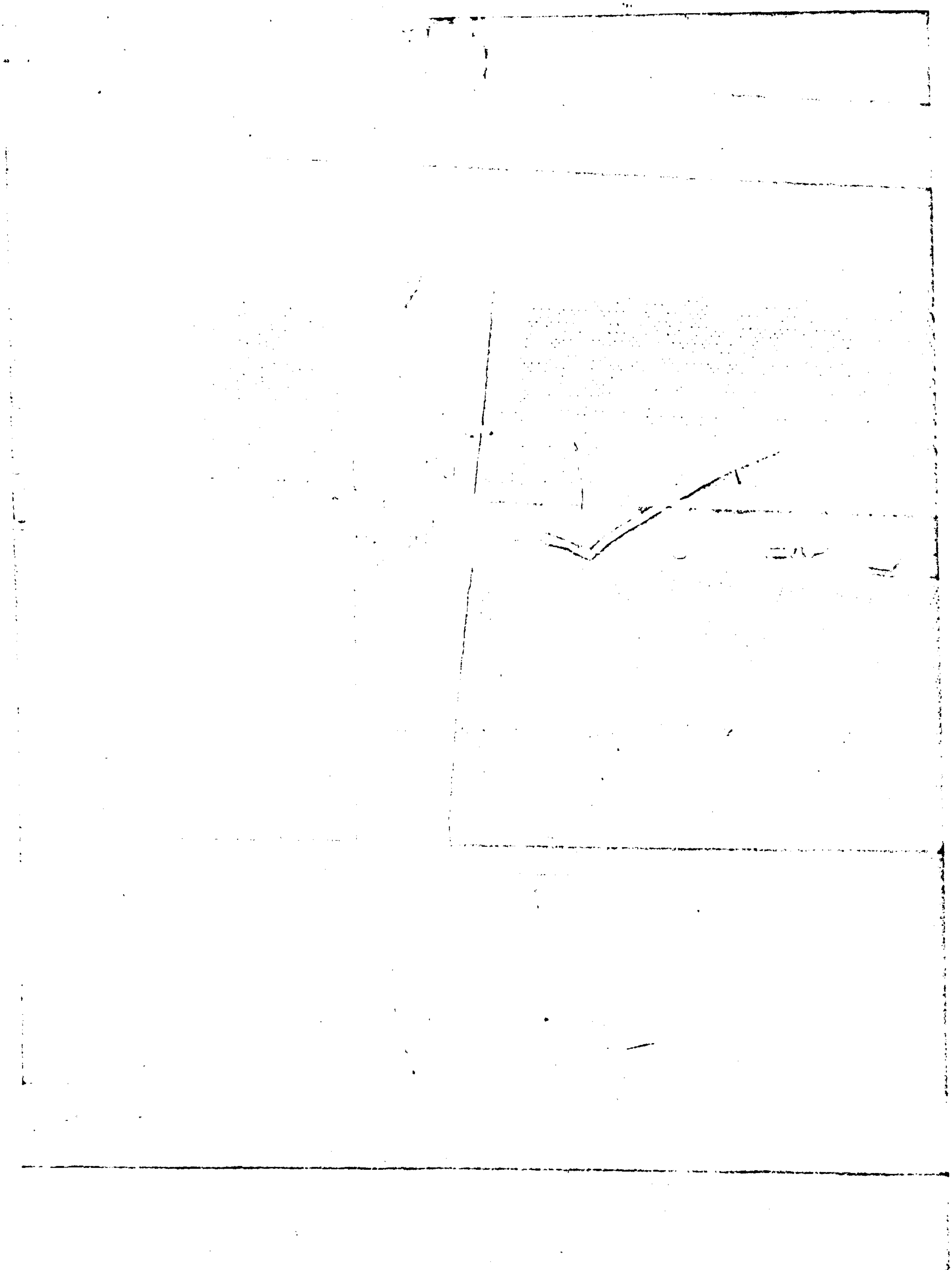

Fig. 2

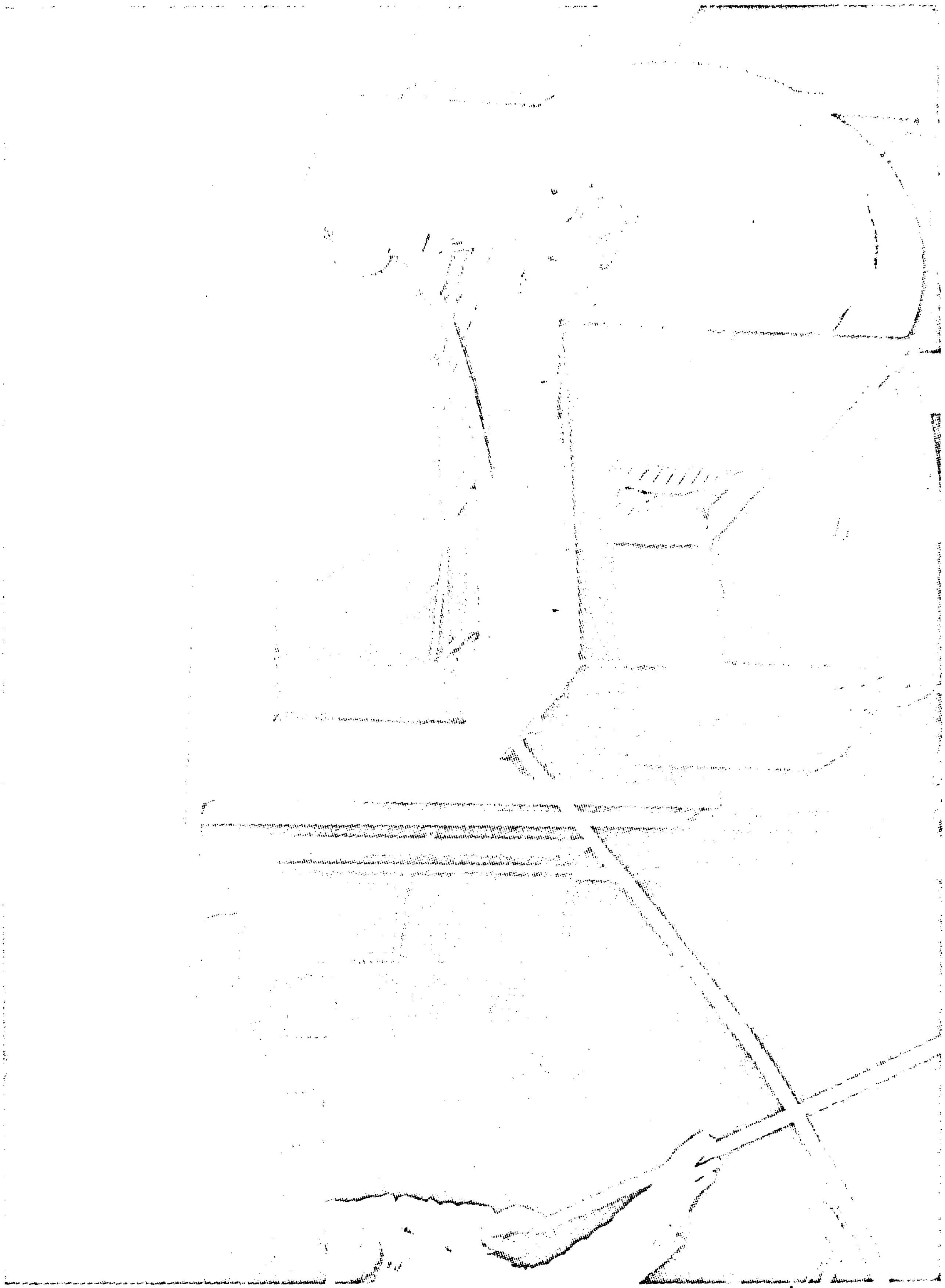

Fig. 3

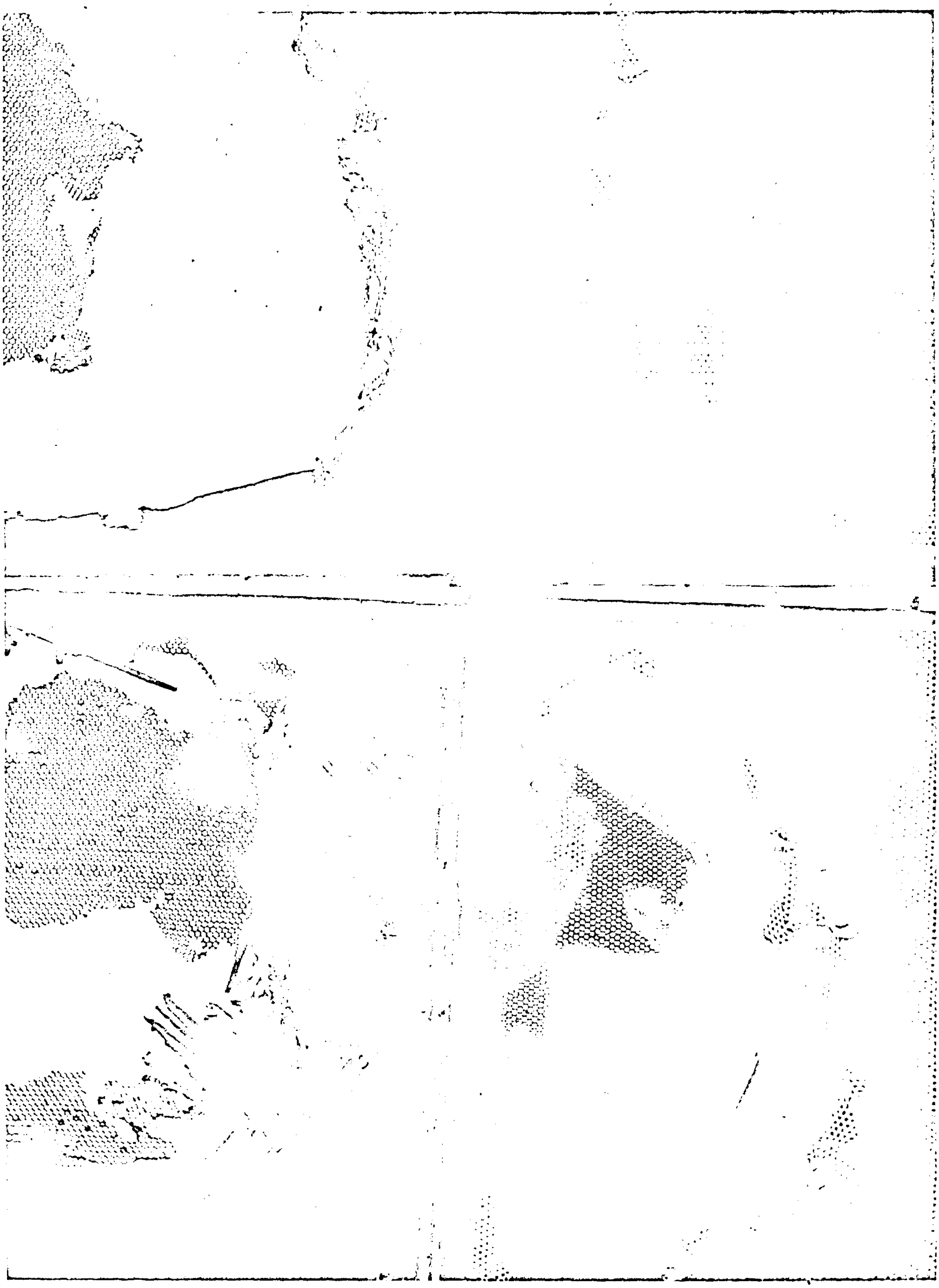

Fig. 4

Fig. 5