VENTILATION AND DUST CONTROL IN REFINING URANIUM ORES AND CONCENTRATES

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The metallurgical processing of most ores and concentrates is attended by the presence of noxious or nuisance dusts and gases that must be controlled to varying degrees depending on the toxicity of materials encountered. The refining of uranium ores and concentrates into the metal is typical in a general way, involving heavy metal dust, hydrogen fluoride, and oxides of nitrogen. To these are added the unusual categories of radioactivity of radium during the early stages of the refining process, and radioactivity of the uranium and its daughter products throughout. Operations involving these elements call for control of air pollution, both within and outside of the operations area, to an unusually high degree. Fortunately standard ventilation and dust control equipment can be adapted to the purpose.

This paper presents some of the problems and their solutions in the design of control facilities for health protection in a large uranium producing plant operated for the Atomic Energy Commission.

Design criteria called for maintaining an operations atmospheric pollution level for radioactive dust not to exceed 70 disintegrations per minute per cubic meter of air (which for uranium is equivalent to 50 micrograms per cubic meter). This figure served for dust control of uranium and any dusts associated with it, including pitchblende dust with its radium content. Uranium is an alpha-ray emitter. Direct radiation from it is unimportant, being stopped by almost any barrier, including the normal skin. However, inhaled or ingested into the body where it attains close proximity to tissue it can do serious harm. Uranium slowly breaks down into daughter products, UX_1 and UX_2 which are beta-ray emitters. The beta rays encountered in this process are readily stopped by thin glass or metal so that hood or hopper may provide ample protection from radiation.

The radium in the pitchblende ore and in the process rejects is a gamma ray source and constitutes the most serious direct radiation hazard in the process. Design criteria called for a maximum weekly exposure of 300 mr. of gamma radiation. Actual design was predicated on a tolerance of half this amount to allow for inevitable short periods of high level exposure by operators subject to unusual duties. Radium is always accompanied by its daughter product, radon gas, for which the design criteria limit was 10^{-8} curies per cubic meter of air (or approximately 7×10^{12} parts per million).

Other contaminants were to be limited in accordance with currently accepted standards for maximum allowable concentrations.

INTEGRATION OF DESIGN

The project group handling the industrial hygiene phases also bore the responsibility for radiation protection and for the general heating and ventilating of buildings, in order to coordinate effectively all these interrelated functions. This group of specialist engineers produced completely integrated design to satisfy the requirements for process, health, and comfort in the working environment. It is not especially pertinent to this paper, but of general interest as to coordination of effort, that this project group also designed (1) a medical dispensary completely equipped to do X-ray work and minor surgery; (2) a "health-physics" laboratory, with instrument repair and calibration facilities, machine shop, dark room, and chemical laboratory, with associated equipment; and (3) a decontamination room, furnished with fixed and portable equipment suitable for treatment of surfaces contaminated with radioactive materials; even a repair shop for contaminated shoes was set up in this room. These features, along with specifications covering issue clothing and shoes, were done in consultation with medical and health specialists of the Atomic Energy Commission and Operating Contractors, who made available their wealth of experience.

The design approach for ventilation and dust control did not differ, except in degree, from usual industrial hygiene methods. They had to be adapted, as necessity dictated, to the interposing of radiation barriers and remote control.

The methods may be briefly listed as (1) isolation of process, (2) application of local and/or general exhaust ventilation, (3) highly efficient filtration of solids from collected air, and neutralization of acid vapors where appropriate, (4) dispersion of effluent gases by discharge through high stacks, (5) provision of adequate tempered make-up air to replace that exhausted, and (6) wet handling. Although it is impossible to separate out each entity for discussion in its own right because of the general interrelationship, an attempt is made in the remainder of this discussion to indicate briefly examples or considerations for the methods listed.

ISOLATION OF PROCESS

The value of the materials, as well as their toxicity, required that special effort be made to utilize tightly inclosed equipment, such as elevators, conveyors, blenders, batch dumping equipment. Theoretically these can be maintained dust-tight, but actually poor maintenance must always be presumed. Where there is any possibility of dusting out, local exhaust ventilation must be applied to the inclosure. In fairly tight systems there arise the problems of air quantities and the maintaining of conveying velocities for dust laden air under varying circumstances. A discussion of these matters is given under EXHAUST VENTILATION below.

The major point to be emphasized in this connection is the importance of keeping process materials within the process stream and thereby minimizing the health and economic problems of rehandling that portion collected as dust.

An example of a process not amenable to control by closely applied cover or exhaust ventilation was the weighing and deheading of drums of pitchblende. These operations had to be walled off because of gamma radioactivity, and incidence of radon and dust. For protection of plant employees these operations were established in a closed ventilated room utilizing remotely operated equipment. It was expedient further to isolate the operator in a concrete walled room that projected into the processing area. The concrete walls and a lead glass window provided for his complete protection.

The handling of hydrogen fluoride is obviously a dangerous operation, and where it was necessary to do so indoors, the bulk of the equipment was isolated in a walled off area of the building, provided with continuous supply and exhaust ventilation at about fifteen air changes per hour. Emergency ventilation fans were furnished that would move up to about sixty air changes per hour and these were linked electrically with automatic dampers in the exterior walls which would open when the fans operated, insuring adequate inflow of air to the space.

EXHAUST VENTILATION

Both local and general exhaust ventilation were employed wherever needed throughout the project.

Dust control claimed the major portion of all the design work done on the industrial health aspects, embracing a variety of processes in several buildings. Self-balancing systems were designed such that at the desired rates of flow the total pressures at main and branch junction points were calculated to be identical.

It is not infrequently the case on construction contracts, and this was no exception, that dust collecting and other air handling equipment must be ordered very early in the design period to insure delivery on time. This meant estimating collecting requirements before the process equipment was fully known. Then, after process design was firm, however changed, it meant recalculating the local exhaust systems to (1) give the desired control, (2) be self-cleaning, (3) be self-balancing, and (4) be adaptable to the collectors bought. Heat losses in some buildings were only a fraction of the heat required for replacing ventilating air, so that the procurement and adequacy of supplied air heaters and blowers were directly affected by the early estimates. Successful accomplishment of this type of work necessitates specialists of considerable experience and judgment.

The handling of hot corrosive dust laden gases, sometimes accompanied by water vapor, required alloy ductwork and collectors as well as judicious cooling by water jacketing of ductwork in some instances or introduction of dilution air.

Air quantities for local exhaust ventilation were determined by the needed inflow through actual and anticipated openings to prevent contaminant from getting out. Volumes and entrance losses for the unusual types of hooding were readily determined, but, for tightly closed vessels receiving dry materials, venting for egress or ingress of air had to be provided, and for reasonably tight systems some provisions had to be made for inspection ports which might be left open or panels not tight. Three measures were employed.

1. Where a vessel was perfectly tight and was to fill or empty at a steady rate, a breather bag of large size was suspended vertically, the top end closed and the lower end tied over a short vent pipe on the vessel. Usually a dust collector bag was used. A weather cover was furnished on outdoor installations. No exhaust ventilation was applied.

2. For tight weigh vessels, not tolerating a breather bag, a conical or bell-shaped exhaust system inlet was located over and around the top of the vent, but not touching it. This is an adaptation of the familiar draft diverter stack connection used on domestic gas furnaces. The required velocity of air for dust carrying is maintained in the exhaust branch without physical connection or undue draft on the vessel, yet any escaping dust is captured. Volume and velocity of the exhaust air must be adequate for any expected surges when filling the vessel.

3. For fixed vessels or reasonably tightly enclosed systems a rigid duct connection was made. A port was cut into the side of the duct close to the connection and a sliding sleeve installed to permit covering as much of the port as necessary for control. This device permits application of draft to the vessel or system exactly as needed and allows sufficient by-pass air through the port to maintain carrying velocity.

Powered roof ventilators were widely employed for general ventilation for the removal of heated air generated by process or summer sun. A five degree F temperature rise over ambient was usually taken as permissible for calculating volumes to be removed. (Make-up air was not provided for heat removal exhaust).

An exhaust system of some interest was that provided in a pitchblende thawhouse for removal of radon. A thawhouse is a necessity in winter for treatment of frozen drums of ore prior to processing. Enormous quantities of heated air would be needed for the combined requirements of radon removal and thawing under ordinary circumstances. Using the isolation principal, the thawhouse was made up as a tight box, the drums of pitchblende traversing it on powered conveyors between steam heated plate coils. Inlet and outlet doors were self-closing, counter balanced, open only for introducing or releasing drums. An exhauster, discharging to a high stack, was made to operate continuously. It could draw little air except when a thawhouse inlet or outlet door was opened, and even then it was dampered to about half capacity. Should access by personnel be necessary either or both of two large purge doors in the sides of the thawhouse could be opened, whereupon the exhauster damper would automatically open wide and the chamber would be purged of the heated, highly radon-contaminated gases. Blocking open the end doors would hasten the purging. Following the emergency, shutting the purge doors cause the fan to be dampered as before. (Of course the radiation hazard is serious in this building so that operators having to enter can stay only a very limited time.)

For completeness, it is well to mention that a piercing device was placed at each inlet door for perforating heads of drums prior to their introduction. By this means any dangerous steam pressure buildup in the drums during thawing was averted.

FILTRATION OF SOLIDS

The choice of air filtration equipment for uranium dust and associated materials was the reverse jet suspended bag-type collector. Cost, adequacy of filtration, commercial availability, practicability for maintenance, and successful experience in similar operations were all important considerations. Although not subjected to the heavy loadings for which this type collector was designed it had been found to give better than 99 per cent recovery at fractional grain loadings of comparable dust. An optimum filtration rate of 10 to 11 cfm per square foot of filter cloth was determined on an efficiency - horse-power - maintenance basis; 15 cfm per square foot was the design maximum. The bags employed were a special resin treated wool felt, and ranged from 9 to 18 inches in diameter, depending on the vendor. Their top operating temperature was limited to 180°F. Recently, calendared orlon bags have become available and some were furnished to the project on an experimental basis. These show much promise in regard to acid and alkali resistance, high temperature (275°F.) and wear.

Fixed vacuum cleaner systems were established for cleanup work, and in some instances to provide or supplement local exhaust ventilation. The effluent air from these, having been filtered in cotton bags, is directed to reverse jet bag-type collectors for cleanup. The vacuum cleaner systems in many instances also provide dust collector unloading facilities. Those collectors so served are fitted at bottoms of hoppers with a unique wind-swept valve connected to the vacuum system. All dust caught in several collectors can be transported to one locality where the material can be placed in drums and returned to process. Dust collectors were thoroughly instrumented. Each stack is monitored by a photoelectric haze detector with alarm to warn of leaking or broken bags. To reduce wear on bags and to maintain a high filtration efficiency, blowring operation is controlled by differential pressure across the bags, usually being placed in operation at four inches water gage and cutting off at two inches water gage. Each collector has a low differential pressure alarm, normally set at one inch water gage. This device also detects broken bags.

Wet collectors were specified for handling steamy dusty air, utilizing the principle of passing air around an underwater baffle. Provision was made for fiberglass after-filters, should they be required. Electrostatic mist collectors were provided for handling uranium bearing oil mist from machining operations, the cleaned air being returned to the room.

MAKE-UP AIR

In buildings having exhaust ventilation the provision of make-up air is an important factor in the control of toxic dusts or gases. It is often overlooked. Where small volumes are withdrawn infiltration may be adequate, but it is always well to investigate. To prevent rooms or buildings becoming airbound and to insure the unimpaired functioning of hoods and inclosures connected to exhaust systems, make-up air was carefully distributed, tempered as needed, in amount equal to or slightly greater than that withdrawn. In most instances it was further heated to take care of the winter heating requirements of the building. To conserve steam the large make-up air units were automatically dampered to recirculate room air when exhaust ventilation systems were shut down. Each such supplied air unit consists of a standard steam coil and blower set supplemented by a moving frame automatic oil-type air filter and by a damper set and controls that permit outdoor air for make-up and recirculated air for the remainder. The filter protects the heating coils and keeps dirt out of the distribution system. The oil in the filter is itself cleaned by pumping it through a replaceable cartridge filter similar to that in an automobile oil system.

Supplied air distribution systems followed the usual ASHVE practice. Stainless steel and protective-coated steel had to be provided in corrosive areas. Certain recirculating air heating coils were protected by a baked-on protective coating.

WET METHODS

The handling of the reject gangue materials with which the radium leaves the process stream offered a potential hazard as (1) radioactive dust, (2) a source of direct gamma radiation, and (3) a source of radon gas. Catalytic's process engineering group worked out a system such that the material is never handled in dry form. Following digestion of the ore, the insolubles are filtered and washed and the wet filter cake is repulped immediately. The resultant slurry, carrying the radium, is pumped to large covered concrete storage tanks located well away from the operations area. The solids settle out in those tanks and the clear decant liquor is recycled for use again as the repulping medium. The filtration is done in ventilated rooms behind barrier walls.

Reference was made earlier to the use of fixed vacuum cleaning systems for cleanup of dry materials. For wet spills sump systems were provided into which the floor and platform washings can be directed. Sump contents are subsequently introduced into the process stream in wet form.

SPECIAL PROBLEMS

There were many unusual problems. One wherein processing and health were equally demanding involved the ventilation of a rotary pitchblende dryer. As much as five per cent of the charge could be carried over in the off-gases, which were to be in the vicinity of 400°F., undoubtedly 100°, or more, higher at times. Bag filtration was the method of choice, but bag allowable temperature was limited at the time to 180°F. To cool the gases a heat exchanger was procured, having a water tube bundle suspended in an insulated shell through which the gases should pass. To prevent condensation on the tubes (gases could have as high as 130°F. dew point) and to minimize dust adherence to cold surfaces a recycling system for the cooling water was designed to maintain its entrance temperature at about 100°F. (A higher temperature gave too little spread for cooling.) To relieve the cooler of the great burden of dust a multi-cyclone was provided ahead of the cooler. Both cyclone and cooler were equipped with rotary feeders continually discharging the accumulated dust to a process conveyor. Finally, the riser from dryer to multi-cyclone was made as large as practicable to reduce the velocity and the carryover (about 1400 fpm was the lowest attainable). Such a system is more complex than desirable, but with attention will pay for itself in values saved many times over.

TESTING

All heating and ventilating and vacuum cleaning systems were subject to rigid performance testing by the construction contractor prior to turnover to the operating contractor. Catalytic specifications covered air quantities, balancing, permissable instruments for testing and methods of conducting tests, as well as workmanship and furnishing of specified materials and equipment. Very generally +15 to -5 per cent of design rating was allowable for dust collector systems, with a ± 10 per cent for balancing. Supplied air systems, being less complex and being balanced by dampering, were required to be balanced to ± 5 per cent.

In conclusion it is worth noting that the work done on this project on heating and ventilating and dust control occupied the efforts of six engineers for 1-1/2 to 2 years and resulted in installations in these categories approximating some $2 million, installed cost, or about 2-1/2% of total project cost.

In the six major plants - Ore Refining, Green Salt, Metals, Metals Fabrication, Sampling, and Scrap - there are 34 dust collectors and 34 fixed vacuum cleaners, plus certain auxiliary continuous exhausters, emergency exhausters, and requisite make-up air heaters. Based on procured equipment only (not including piping, ductwork, conduit or any installation costs) all such heating and ventilating equipment represented about 4 per cent of the total process equipment cost for these plants. The variation was 2-1/2% to 10%. Hersey-type collectors ranged in size from 600 cfm (at equipment cost of $3 to $6 per cubic foot depending on design and use of stainless steel) to 15,000 cfm (at $0.95 to $1.35 per cubic foot).

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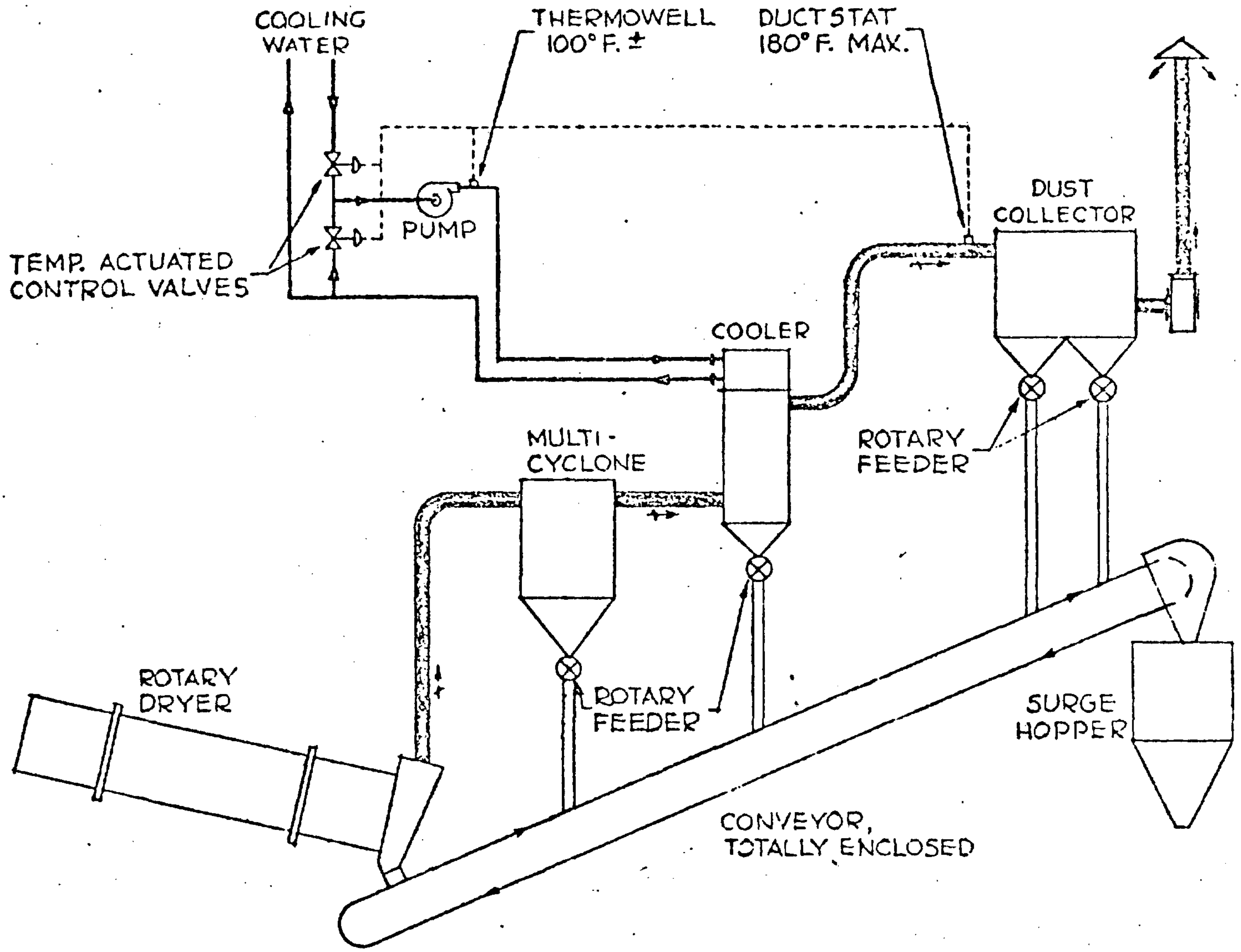
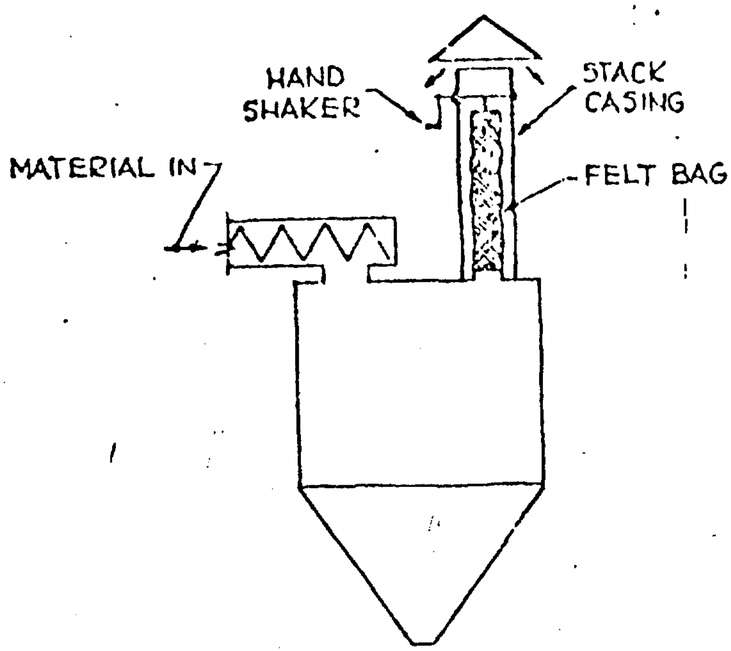


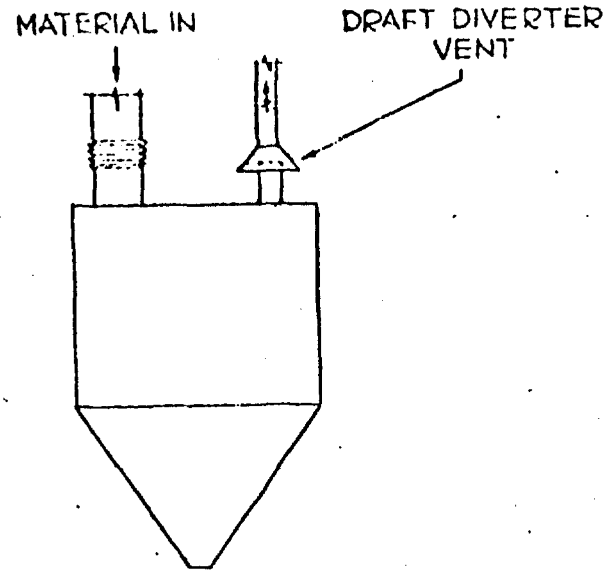
Figure 1

FLOW DIAGRAM

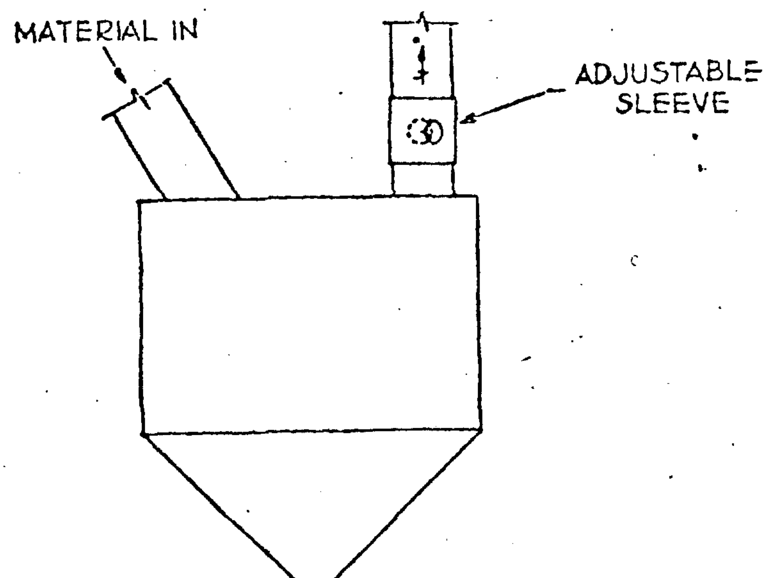
DUST COLLECTION - DRYER SYSTEM



HOPPER VENT
DUST FILTER



FLOATING OR
WEIGH HOPPER



STATIONARY
SURGE HOPPER

Figure 2