Fluidized Drying and Cooling of Granulated Salt

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ABSTRACT

A description and discussion of the operational characteristics of a fluidized bed unit used as a dryer-cooler and as a cooler for Granulated Salt. Instrumentation, materials of construction and production rates are given, and conclusions drawn as to the product quality and fuel consumption when compared to kiln and filter drying and cooling.

Fluidized bed drying and cooling of a uniformly sized crystalline material, such as vacuum evaporated salt (sodium chloride) has been found to possess many merits. Prior to 1955, vacuum evaporated salt produced by The Carey Salt Company was dried and cooled in the classical manner: first, by filtration on a continuous vacuum filter, resulting in a product containing about 3% moisture, followed by drying in direct fired rotary kilns, then cooling in unfired rotary kilns by an induced draft of cool air. The salt to the dryer was fed counter-current to the hot furnace gases and the product was heated to between 400° and 500° F. in the process. Since the hot entering gases impinged directly on the dry salt, there was a great amount of decrepitation and crystal damage done in the kilns. Power requirements were relatively high, the floor space needed was great, and maintenance of the kilns was expensive. Due to the high humidity and heat conditions, corrosion was a problem, and the accepted material of construction for such kilns was nickel-clad steel, with Monel flights, so the capital expenditure necessary was very high. By this method, one ton of salt could be dried with approximately 350 cubic feet of ten thousand B.T.U. natural gas. The product presented a rather dull, dead-burned appearance and despite the high temperatures used, the salt often caked, or "set up" in the bins.

In 1949, Midwest Research Institute, of Kansas City, Missouri, was retained to study the feasibility of fluidized bed drying of salt. Fluidized bed techniques, which utilize the fact that a finely divided solid will exhibit many characteristics of a liquid when suspended in a liquid or gaseous phase, have long been used when rapid and complete physical or chemical reactions are sought. Its great advantage in drying or in chemical reactions is the fact that intimate contact is maintained between the separate phases. In the drying and cooling of vacuum evaporated salt, most of the drying and cooling must take place on the surface area of the crystals. A pilot plant was constructed and tests run at the Hutchinson Plant indicated that vacuum evaporated salt containing 3% moisture could be successfully dried to 0.03% moisture and cooled to approximately 150° F. in a two-bed fluidized dryer-cooler; one bed being utilized as a dryer, and the second as a cooler. Vacuum evaporated salt is composed of remarkably uniform cubical crystals, all passing a 20 mesh sieve and approximately 99% retained on a 100 mesh sieve. Its uniform configuration, narrow range of particle size, and the absence of occluded moisture made the product a

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prime subject for this type of drying. Concurrent tests run on flake type salt which, by comparison, is of widely divergent crystal size and configuration, indicated that the successful drying of this type of salt was doubtful.

In 1951, Combustion Engineering, Inc., Flash Dryer Division of Chicago, was contracted to build a two-bed, fluidized dryer-cooler unit capable of drying five tons per hour of granulated salt and cooling the product to 150° F. This unit (2) as shown in Figure 1, consisted of a vertical cylindrical shell, 17 feet in height, 8 feet in diameter and composed of four stacked sections. The top section was the drying bed, and it was separated from the second section by a flat, perforated plate of one-quarter inch thick aluminum. The aluminum plate was perforated on one-half inch centers with 0.055 inch diameter holes, the bed serving as a diffuser for the hot fluidizing air. In the center of the plate was an 8 inch diameter downcomer, extending through the second chamber and terminating in a rotary feeder which discharged the hot, dry salt into the third chamber. The bottom of the third chamber was another perforated aluminum bed plate. The aluminum bed plate of the bottom bed was also equipped with an 8 inch centrally located downcomer, with another rotary feeder which served to control the removal of salt from the unit. Passage of salt through the unit was from top to bottom, warm moist salt being fed to the top bed through the two diametrically located rotary feeders. Drying was accomplished in the top bed, the dry salt was removed constantly by the downcomer and spread on the lower bed plate, where it was cooled, then removal of the product from the unit was accomplished by the lower bed rotary feeder.

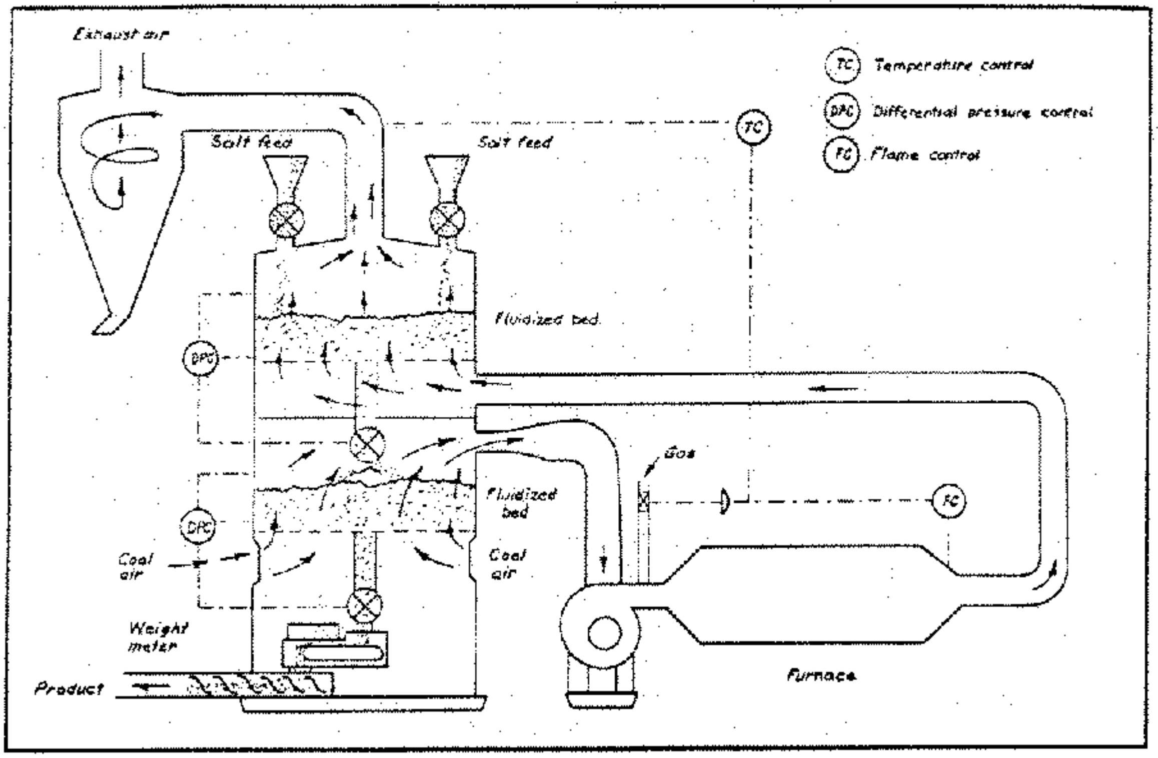

Fig 1 - Fluidized bed cooler - dryer

Cool atmospheric air was drawn upward through the lower bed plate and the dry salt on the lower bed by the suction of a rotary blower, rated at 2500 cubic feet per minute at 3 pounds per square inch pressure, and powered by a 40 horsepower, 3600 RPM electic motor. The cool air withdrew heat from the dry salt, cooling the salt and preheating the air. Following the blower was a cylindrical, steel plate furnace, equipped with an internally located nozzle-type gas burner. The air was heated to not over 500° F. by the heater and piped to the plenum chamber below the top, or drying, bed. Passing upward through the aluminum bed plate, the hot air fluidized the salt, and effectively removed the moisture. The hot, moist air was then discharged to the atmosphere through a rubber-lined cyclone dust collector.

In operation, the top bed was charged with a layer of dry salt, to a depth of eight to ten inches. The blower was then started and the furnace lit. The hot furnace gases fluidized the salt, heating it to a temperature of approximately 230° F. Control of the furnace flame was by a thermocouple in the outlet duct of the top bed. The output of the thermocouple was fed to a potentiometer type recorder controller. Deviation of this recorded temperature from set point, in this case 235° F., resulted in a modulated three to fifteen pound air signal which positioned a valve in the gas line to the furnace. Control of the temperature of the outlet gases could be held to plus or minus two degrees F. When the apparatus reached equilibrium, the wet salt was introduced to the top bed through the two inlet feeders. The level of salt in the bed was measured by finding the differential pressure between a point just above the perforated bed plate and a point above the level of the salt bed. This differential pressure (zero to eighteen inches) was directly proportional to the depth of the bed of fluidized salt between the two pressure taps. It was fed to a differential converter which converted the differential pressure to a three to fifteen pound air signal. This signal was fed to a pneumatic recorder controller as a record of the differential pressure in inches of water, which, incidentally, very nearly equalled the depth of the bed of salt. Deviation of this recorded pressure from a set point was translated into a three to fifteen pound air signal, which, working through Conoflow piston, positioned a variable resistor in the phase shift circuit of a Thymotrol unit. The direct current output from this unit, with a voltage dependent upon the position of the variable resistor, was used to drive a three-quarter horsepower gear motor at speeds dependent upon the varying field voltage signal from the Thymotrol unit. Thus an increase of salt feed rate would result in an increase in the bed depth, which, in turn, caused an increase in the pressure differential between the two pressure taps. An increase in this pressure, measured in tenths of an inch of water, was sensed by the differential converter whose three to fifteen pound output would increase. This increase in pressure would result in an upchart movement of the pen of the recorder. The pneumatic system of the controller then reacted with an increased signal pressure to the Conoflow piston, which repositioned the variable resistor in the Thymotrol unit in such manner that the voltuage to the field of the DC gear motor was increased. The result was an increase in the speed of the motor, thus increasing the rate of withdrawal of salt from the bed, tending to balance the increase of salt feed and thereby maintain the constant bed level. Control was excellent, and bed depths could be controlled to plus or minus one-half inch, even though feed rates were highly variable.

The bottom, or cooling bed, was instrumented in the same manner and control was equally effective. Other controls and instruments found useful included a four-point potentiometer type strip chart recorder, which recorded temperatures at various points in the system. One temperature recorded was the temperature of the furnace gases. Since the materials of construction of the unit were such that a temperature of 600° F. was considered to be a limiting factor, this temperature was constantly monitored and the gas to the furnace was automatically shut off when the limits were exceeded. Other points monitored by this recorder were the outlet salt temperature and the temperature of the salt in the drying bed directly under the wet salt feeders. Since there was always the possibility of component failure, such as the failure of a bed motor or the blower, the controls were integrated in such manner that a failure of any component would result in stopping the feed to the unit, and, if necessary, shutting off the gas to the main burner.

The eight foot fluidizer unit was designed for a production rate of five tons per hour. It was found that its capabilities far exceeded this figure. Sustained runs of eight to ten tons per hour were common, and variations of feed rate, subject to the ten ton per hour limitation caused no difficulty. Normal periods of continuous operation between shutdowns was one week, but sustained runs of three to four weeks have been made. Normal servicing periods required the services of one man for three or four hours, during which time the beds were emptied, inspected and cleaned if necessary. The fine salt was removed from the plenum chamber below the top bed.

Since this was a prototype unit, it was to be expected that some difficulties would be encountered. The preheated inlet air to the furnace (see Figure 2) carried with it a small amount of salt dust, which accumulated on the pilot burner of the furnace, causing flame difficulties. This was solved by shielding the burner nozzle in a two and one-half inch diameter pipe. The assembly finally used consisted of a two and one-half inch pipe extending through the wall of the furnace

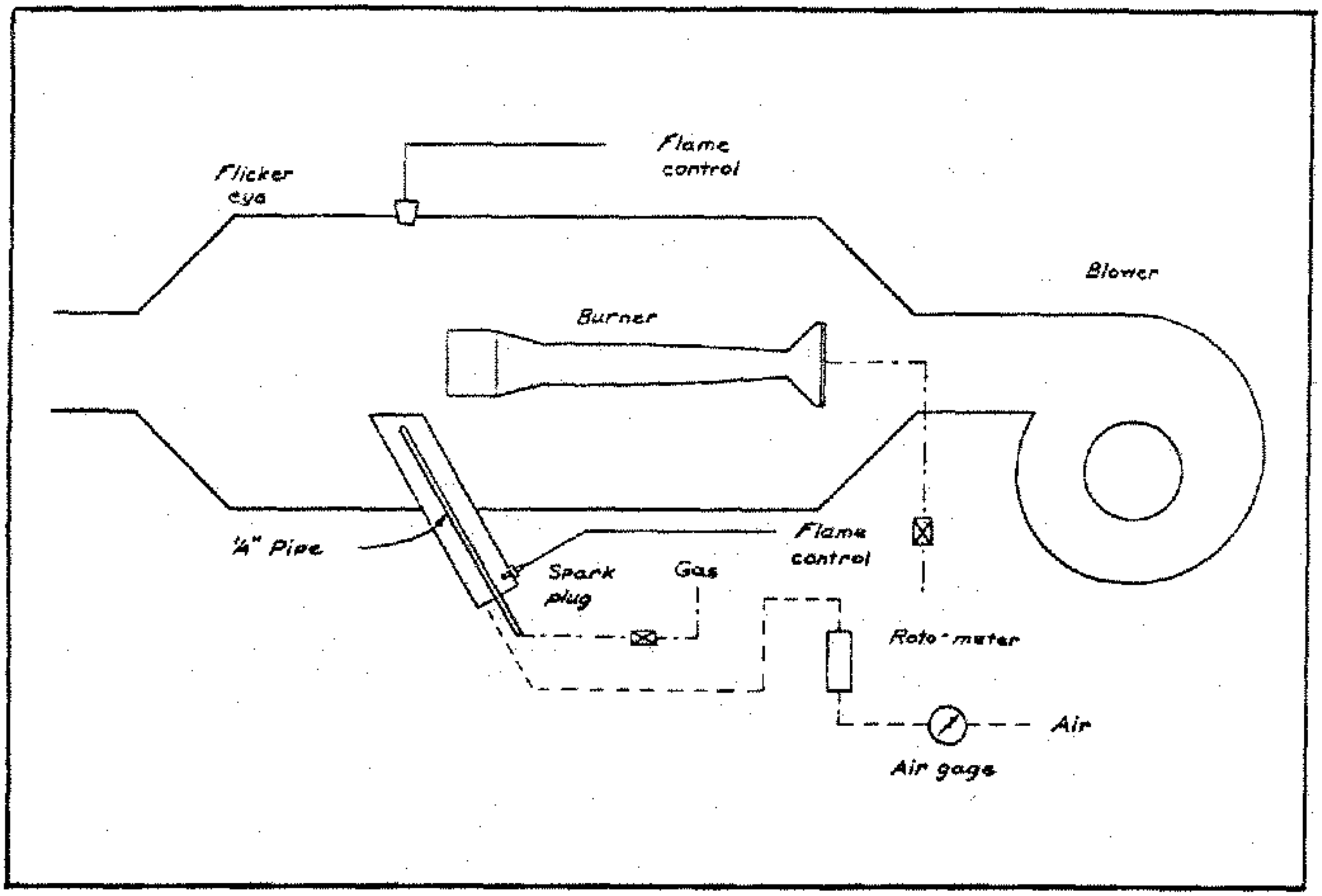

Fig 2 - Detail of furnace

to the periphery of the main burner. The end extending outside of the furnace was capped and drilled for a fitting to introduce compressed air. Also extending through the two and one-half inch pipe, and terminating some two inches from the open end was a one-quarter inch pipe. The end in the furnace was capped and a one-eighth inch diameter hole drilled in the cap. The exterior end, which extended through the cap of the larger pipe, was connected to the natural gas line and equipped with a solenoid valve actuated by the control network of the Flametrol unit. The portion of large pipe outside the furnace was drilled to accept a spark plug, and a hole about one-sixteenth inch in diameter was drilled through the wall of the one-quarter inch pipe directly opposite the electrodes of the plug. The plug was activated by the light-off section of the Flametrol unit. The correct amount of air to be added to the large tube was controlled by a rotometer in the air line to the burner. Gas escaping from the small hole drilled through the wall of the one-quarter inch pipe was ignited by the sparking plug and the flames were swept toward the end of the large tube by the movement of the added air. With proper gas to air ratios, the flame would burn at the end of the large tube, where it was monitored by the flame control element. This unit was not susceptible to salting, and it was found that the pilot flame could burn indefinitely without blowout.

Flame was originally monitored by a flame rod in the detection circuit of the Flametrol unit. However, the rod would salt over, thus losing emissive surface and much difficulty was experienced in maintaining the proper rod-ground ratio. Substitution of a lead sulfide "Flicker Eye" detector unit solved this problem.

It was found that fine salt carried by the furnace air, together with individual crystals from the bed of salt on the bed plate tended to plug the holes in the aluminum bed plates. Once plugged, the only satisfactory method of opening the holes was to drill them. Considering the thousands of holes involved, this was a formidable task. At the suggestion of Combustion Engineering, the aluminum plates were replaced by twenty gauge stainless steel perforated plates, supported on spiders fabricated from one-quarter inch by two inch stainless steel members. It was felt that the flexibility of such plates would decrease the chances of plugging and that if plugging did occur, the holes could be opened by brushing or washing. This proved to be true, and little plugging was observed after the change was made. The thin plates have withstood the service well and, after approximately four years of service, are still in use.

The wet salt feeders caused some difficulty due to buildup of salt in the cups of the feeder and in the opening directly below the feeders. Air jets in the feeder body, directing air into the cups as they emptied helped this situation, and some satisfactory results had been obtained by using a thin coating of Teflon on the cups.

The unit was originally constructed of one-quarter inch black iron pipe. Corrosion in the top bed was a problem, therefore the salt bed chambers were lined with 20 gauge stainless steel, Type 304. Subsequent findings indicate that Type 316 stainless steel would have been a better choice, though corrosion is very slight for the Type 304.

It was found that the dryer-cooler could make sustained runs at a production rate of eight to ten tons per hour, with a feed containing 3% moisture, giving a cool (150-160° F.) product containing not more than 0.03% moisture. Thermocouple probes in the drying bed showed that the maximum temperature attained by the salt was 230° F. There was little or no tendency for the top bed to build up with agglomerates of salt, with a subsequent loss of fluidizing ability, but occasionally the lumps would accumulate in the lower bed after long production runs, with a loss in cooling capacity. The appearance of the product was excellent, possessing a high luster and sparkle. Dusting losses never exceeded one-half of one per cent and a large portion (ten to twenty per cent) of this dust was calcium sulfate, which resulted in an upgrading of the purity of the product. The binning qualities of the salt were excellent. Fuel consumed per ton of product was 120 cubic feet of 1000 B.T.U. natural gas. The unit replaced one kiln dryer and one kiln cooler, and despite the fact that it was not conveniently located in respect to the existing kilns, no particular difficulty was experienced in its operation, and no extra operational labor was needed.

Trial runs on flake type salt were made, but in the main they proved unsuccessful. Probably due to the fact that flake salt is of such highly divergent crystal size and configuration, the salt had a tendency to segregate into different particle sizes. For instance, after startup the dried product issuing from the unit was composed mainly of the flat and flaky particles, leaving the more dense, large particles in the bed. After some period of operation, the beds would fill with these coarser particles and agglomerates and lose its uniformly fluidized condition, and severe channeling would occur. Then, too, flake salt contains a relatively large amount of occluded moisture, and it was felt that the contact time was not of sufficient duration to permit total diffusion of this moisture to the crystal face; thus the product would contain the entrapped moisture which, in time, would diffuse to the surface and create difficulties in the bin.

In 1957, the decision was made to go to drying on the filter, using the fluidizer as a two-bed cooler. In this role (see Figure 3) the only major change was the removal of the furnace and the opening of the cups of the feeders to accommodate the increased through put rate. Drying of the salt is now performed on a top feed filter, which delivers up to twenty tons per hour of salt, with a moisture content of approximately 0.2%. This salt passes through the two beds of the fluidizer, as before, but no added heat is needed. Salt entering the unit at 225° F. and containing 0.2% moisture is cooled to a temperature of 170° F. and will contain approximately 0.03% moisture on discharge. Further cooling may be accomplished by adding controlled amounts of water to the salt before cooling; the temperature of the exit salt being lowered about seven degrees for each one-tenth of one per cent of water added in this manner.

In conclusion, fluidized bed drying and cooling of vacuum evaporated salt has been found to be highly satisfactory. For comparison, the fluidized bed system used about 120 cubic feet of 1000 B.T.U. natural gas per ton of salt dried, whereas the kiln type dryer and cooler used about 350 cubic feet of natural gas per ton. The filter dryer-fluidized bed cooler system uses about 300 cubic feet of natural gas per ton. The fluidized bed dryer-cooler produced a product of superior appearance and binning quality over the kiln dried method; however, these qualities are also exhibited by the salt from the filter dryer-fluidized bed cooler method. Floor space savings

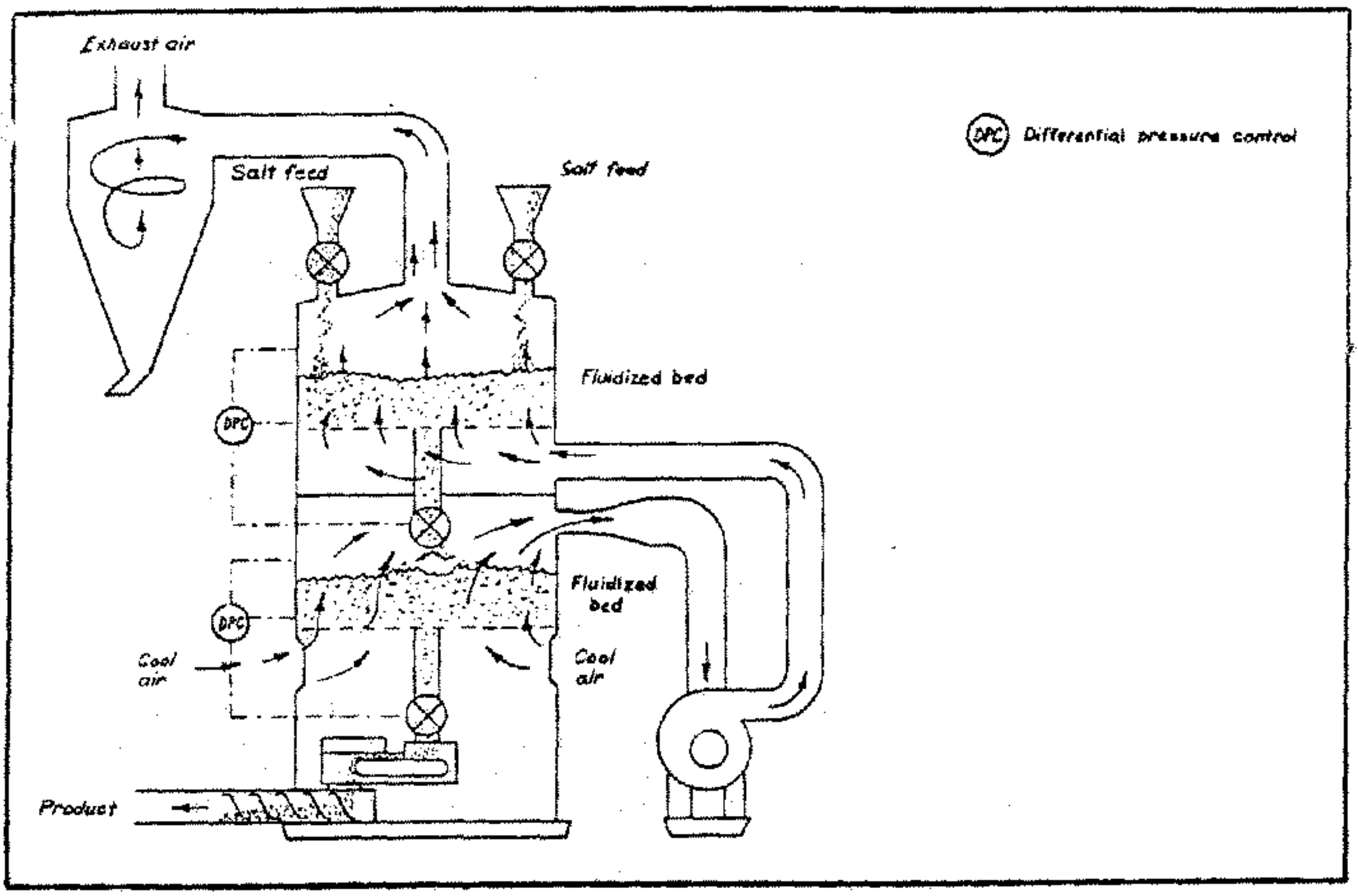

Fig 3 - Fluidizer bed cooler

over the kiln dryer method is appreciable, but the filter dryer-fluidized bed cooler requires even less space. Operational labor is less for the filter dryer-fluidized bed cooler method. Maintenance costs are down considerably with the fluidizer but drying on the filter results in somewhat increased maintenance costs to the filter. Power requirements are about the same in all cases.

REFERENCES

1. At the time of development of process, P. V. Imes was Chief Chemist, The Carey Salt Company and C. Jobes was Process Engineer, The Carey Salt Company.
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