Washing of Strip-Mined Rock and Solar Salt

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ABSTRACT

The basic reason for washing salt is that it is not suitable for sale in its present form or that a higher profit can be realized if the product were improved. To determine the proper washing technique, a product specification is necessary and should include the minimum percent sodium chloride, moisture requirement, objectionable impurities, impurities which cannot be tolerated at all, screen analysis, and appearance.

Analysis of the crude salt to be processed must also be known. This includes a complete chemical analysis for all variables which we have determined affect the suitability of the product. The physical nature of objectionable impurities are required to help determine the methods for their removal.

Scrubbing and washing are the counterparts of crushing and concentration and are the methods usually employed with salt. Methods of scrubbing are: (A) Jet Impact, (B) Tumbling, and (C) Stirring. Washing can be considered a fluid separation on a size basis between particles differing widely in size. Slurrying salt with brine with subsequent pumping materially assists in suspending impurities for later removal.

Leslie Salt Company makes extensive use of stirring scrubbers, such as twin screws, and jet impact scrubbing to wash both solar and rock salt. Strip mined rock salt containing as little as 40% NaCl is successfully washed to a purity of over 98% on a moisture free basis. Washed solar salt is produced at a purity of 99.5%.

INTRODUCTION

I have been asked to discuss the washing of solar and strip mined rock salt. The Leslie Salt Company, is one of the world's largest producers of solar salt with production facilities in the San Francisco Bay and Salt Lake, Utah, area. Leslie also recovers rock salt from a strip mining operation in the California Mojave Desert.

First of all I will discuss some of the variables which you must consider before deciding whether or not it is actually necessary to wash the salt. Then I will discuss the various methods available to accomplish the desired results. Finally, I will tell you how we wash solar and rock salt and show you some pictures which describe our operation.

Since no two sets of conditions are identical, I have included a discussion of the "why" as well as the "how" in order to explain the basis for our decisions. The methods which we use are certainly not the only way of doing the job but merely one which has proven successful to date in meeting the demands of our market.

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PURPOSE OF WASHING ROCK OR SOLAR SALT

Basically, the only reason for further processing salt is that it is not suitable for sale in its present state or that a higher profit can be realized if the product were improved in some manner. Generally, salt is not acceptable because it is not pure enough, has a poor appearance, or is not the proper crystal size. Many times it must be processed for a combination of these reasons.

PRODUCT SPECIFICATION NECESSARY

In order to intelligently decide on the proper equipment required to produce an acceptable product, we must determine answers to the following questions:

A. What purity is required? This may seem like an easy question but it is often difficult to get a precise answer. With salt we must know the minimum percent sodium chloride required to meet the market needs. Further, the amount of moisture which can be tolerated. In many cases the water or impurities are not objectionable in themselves but the freight on the water or impurities is. This is particularly true with salt where the transportation cost is often higher than the cost of the product. On occasions, surface moisture which can be removed by drying is tolerated while occluded moisture is objectionable.

   After the percent NaCl and H_2O are set, we must know what impurities can be tolerated and in what amount. It is most helpful to know the reason why the impurity is objectionable. Is it because the customer must remove the impurity for operating convenience, or because the process cannot tolerate even minute amounts of the contaminant?

   To be specific, $CaSO_4$ is objectionable in the electrolytic production of HCl and NaOH because it would deposit on the tubes of the caustic evaporators, reducing the heat transfer coefficient and further because it would reduce the purity of the NaOH. Normally, the calcium is removed by treatment with Soda Ash and the sulfate removed by purging or in some cases by treatment with Barium Chloride. The economics of the added cost to the producer to improve product purity must be balanced against the cost to the customer. Again considering the electrolytic industry, the presence of certain trace metals cannot be tolerated at all or in only minute amounts.

   As mentioned, certain impurities are more objectionable than others and the additional processing cost to the customer for each impurity which can be tolerated would be most helpful. In this way the lowest total cost to the consumer can be determined. In some contracts the price received is on a sliding scale, varying with the purity of the product.

B. Another question which must be answered is "what about appearance? Appearance may not seem too important to a production man, but to the salesman it is an important tool. Products will have a greater acceptance if they are whiter, have more sparkle, etc. While the purity may be identical, appearance may be the extra plus which makes the sale.

C. Now screen analysis must certainly be considered. Crystal size can be important for many reasons. Let's look at some of these reasons. In the preservation of hides there is a definite preference and this varies with the type of hide and individual customers. Size affects the rate of dissolution and may be important for this reason. Small crystals in general cake to a greater extent and may create a handling problem. If the salt is to be blended with other ingredients, crystal size would be important to obtain a uniform mix. Some customers require a small crystal because they are going to pulverize the salt and the smaller size crystals require less equipment and energy to reduce them to the desired size. Large crystals are often preferred for soft water regeneration. For these many reasons the relative demand for various size crystals must be known.

D. Competition and obsolescence. Two more variables should be considered before we establish a product specification. First, we must consider what tomorrow's market will demand and secondly, what competition might reasonably be expected to produce competitively. We don't want the production facilities to become obsolete due to changing customer demands nor can our equipment be so limited that it can't meet competition.

Each of the previous points must be considered and a specification determined. Since the product must be suitable for many customers and not merely one, compromises are often necessary. In any event, the considerations are the same.

RAW MATERIAL

Once we have determined the market requirements, we can turn to the raw material which we propose using to satisfy this market. If we have a choice of raw materials so much the better -- we can then choose the one which allows the lower overall production costs.

What must we know about the raw material? Naturally a complete chemical analysis for all impurities which we have already determined affect the suitability of the product. Next we would want to know the source of these impurities. Are they physically separated from the salt, adhering to the surface, or occluded? What is the phase of the impurity, that is, liquid, solid, or gaseous? Knowing this we can start determining how this impurity can best be removed. Is the contaminant one which can, because of its size, be floated off or perhaps it can be settled out? Does the impurity tend to "ball up," break apart easily, or congeal? With what severity can the salt be handled? If the salt crystals degradate easily and samll crystals are undesirable, then the choice of refining methods would be more limited. What is the variation in the raw material to be processed? The equipment chosen must be able to handle the worst set of conditions anticipated. The source and quantity of available fluidizing liquid would certainly have to be considered if a fluid separation was required. If the quantity were limited, the choice of method and equipment used to accomplish the task might be altered.

METHODS AND EQUIPMENT

I would like now to discuss methods and types of equipment which are commonly used to accomplish our task. The methods used are generally "scrubbing" and "washing." If we look up the definition of "scrubbing" and "washing" (Handbook of Mineral Dressing -- Taggart, Wiley Handbook Series) we find that they may be considered the counter parts of crushing and concentration. ...ames which carry over from parallel familiar household activities and implying the same actions ...re soaking, rubbing, pounding, agitating, and spraying. Particle size is usually the property upon which separation is based and water or brine is the usual separating medium. The water or brine is subsequently removed, carrying the smaller solids in suspension, leaving the larger solid phase behind. By these means clay, sand, mud, gypsum, and the like are separated from the salt.

Scrubbing

Let's look at scrubbing. Scrubbing specifically is disintegration effected by forces which are relatively light but are sufficient to break down soft unconsolidated material such as clay and mud. Scrubbing is usually effected by rubbing the larger and harder grains together, as by tumbling, but in some cases the force of a water jet is sufficient. Scrubbing normally precedes washing but the two may proceed simultaneously.

Principles of Scrubbing: As previously stated, the materials to be scrubbed, the form and character of the material to be removed by the scrubbing, and the results demanded determine the method and equipment used. There are three methods of scrubbing which I shall discuss briefly. They are: jet impact, tumbling, and stirring. Each of these may sometimes advantageously be preceded by soaking. Additionally, in some cases crushing and/or grinding are employed.

Jet-impact Scrubbing: Jet-impact scrubbing is used for primary disintegration of the impurities. The underlying principle is the subjection of the solid to the mechanical impulse of the jet, at the same time supporting it against a rigid or semi-rigid backing so as to utilize as much of the jet energy as possible in setting up internal stresses in the lump, rather than in effecting transportation. The size and velocity of the jet to be employed depend upon the size of the material and the method of backing. If possible, the salt should be moving toward the jet as it is struck, in order to increase the force of the impact.

Tumbling Scrubbers: Tumbling scrubbers are rotatable cylindrical shells, set more or less horizontally, with end closures sufficient to maintain a body of liquid within them and with flights that serve to tumble the load on rotation. They usually operate at slow speeds and depend primarily on rubbing between the lumps of hard material in the feed, supplemented by such impact as occurs in cascading. Ordinary clays can be disintegrated relatively completely under the proper operating conditions.

Stirring Scrubbers: The last method for scrubbing which I am going to discuss is stirring scrubbers which are essentially stirring devices in which thick pulps, ordinarily too fine or too soft to be scrubbed effectively by tumbling, are treated. Some of them, such as the pug mills and mulchers, depend upon moving blades to actually cut through soft clay lumps; the majority, however, attempt by thorough stirring to produce repeated rubbing together on hard-particle surfaces in order to rub off adherent films of softer materials.

Washing

Now let us look at washing. Washing is the separation on a size basis between particles differing so widely in size that the smaller are readily suspended in a fluid current which fails to suspend the larger. Washing usually involves more or less scrubbing. This is particularly true with crudes which require light scrubbing only. The principal apparatus used for washing are screens for sizes coarser than 1/8 inch. A washing screen is an ordinary screen provided with more or less powerful water jets playing on the oversize material, suitably housed to lead away the fluidized undersize and confine splash. Rotary washing screens are used when a considerable amount of disintegration, usually of clayey material, is necessary, when tumbling and some resultant breakage of oversize is not harmful, and when separation is to be made at sizes not finer than 1/8 inch. Rotary screens without lifters have been widely used for light washing and sizing. They have been largely displaced, however, by vibrating screens in most modern installations of this type.

LESLIE SALT COMPANY PROCEDURE

I will now describe how Leslie Salt Company accomplishes the washing of solar and rock salt. First let us take solar salt.

Solar Salt is produced in the San Francisco Bay area by concentrating the bay sea water to saturation with respect to sodium chloride and then flooding crystallizers with this saturated brine. Upon additional evaporation, with the aid of solar energy, salt crystallizes directly on the crystallizer bottom (Figure 1). The harvested salt has impurities for several reasons. The floor of the crystallizers is heavy clay soil and bay mud. The bay mud is a fine silt deposited by tidal action. When the salt is harvested, some of the clay and mud is picked up along with the salt -- even though the ponds have been accurately planed and rolled. Further, all of the calcium sulphate did not crystallize out during the concentration of the bay water to saturation and a small amount crystallizes out with the sodium chloride. As much as possible of this gypsum must be removed. Another impurity is the concentrated brine, called bittern, remaining with the salt. The major impurities in this liquid are magnesium sulphate, magnesium chloride, some potassium chloride and a relatively small amount of bromine.

To remove the solid phase impurities, the salt is dumped into a pit where it mixes with saturated brine (Figure 2). This 20% salt slurry is then pumped by a centrifugal pump to the bottom of the pond area of a double screw washer two feet in diameter by 20 feet long (Figure 3). The pumping of the slurry serves to both scrub and convey the salt. Counter-current washing takes place in the dewatering screws and dirty wash brine, containing the solid phase impurities, overflows the pond end and dewatered salt is discharged from the beach end of the screw.

The dewatered salt is fed to a wire woven belt 4 feet wide and 25 feet long (Figure 4). The belt is made of galvanized wire with oak reed inserts. The salt is given a series of washings with saturated brine by means of fish tail spray nozzles to displace the dirty mother liquor as it is conveyed from the screw washer to a drag conveyor. About 100 gallons of saturated brine is used per ton of salt washed. The salt is now given a final washing in a chain drag dewatering conveyor 6 feet wide by 70 feet long, the lower section of which is perforated to allow the salt to drain (Figure 5). On the drag, the salt is spray-washed with about 85 gallons of saturated brine per ton of salt and finally by fresh water sprays. The amount of fresh water used is determined by the

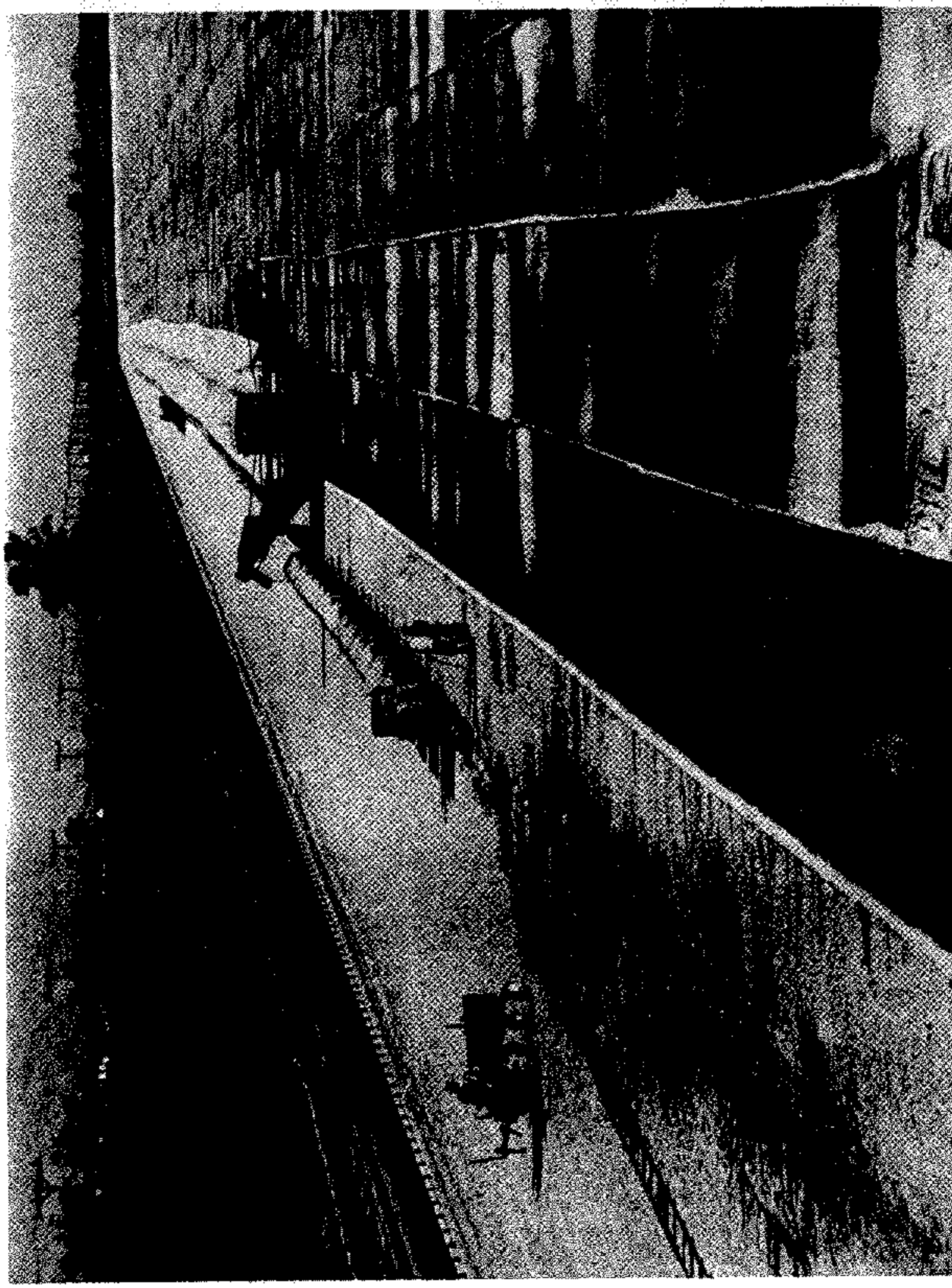

Figure 1. Harvesting of Solar Salt.

Figure 2. Dumping of Solar Salt into Slurrying Pits.

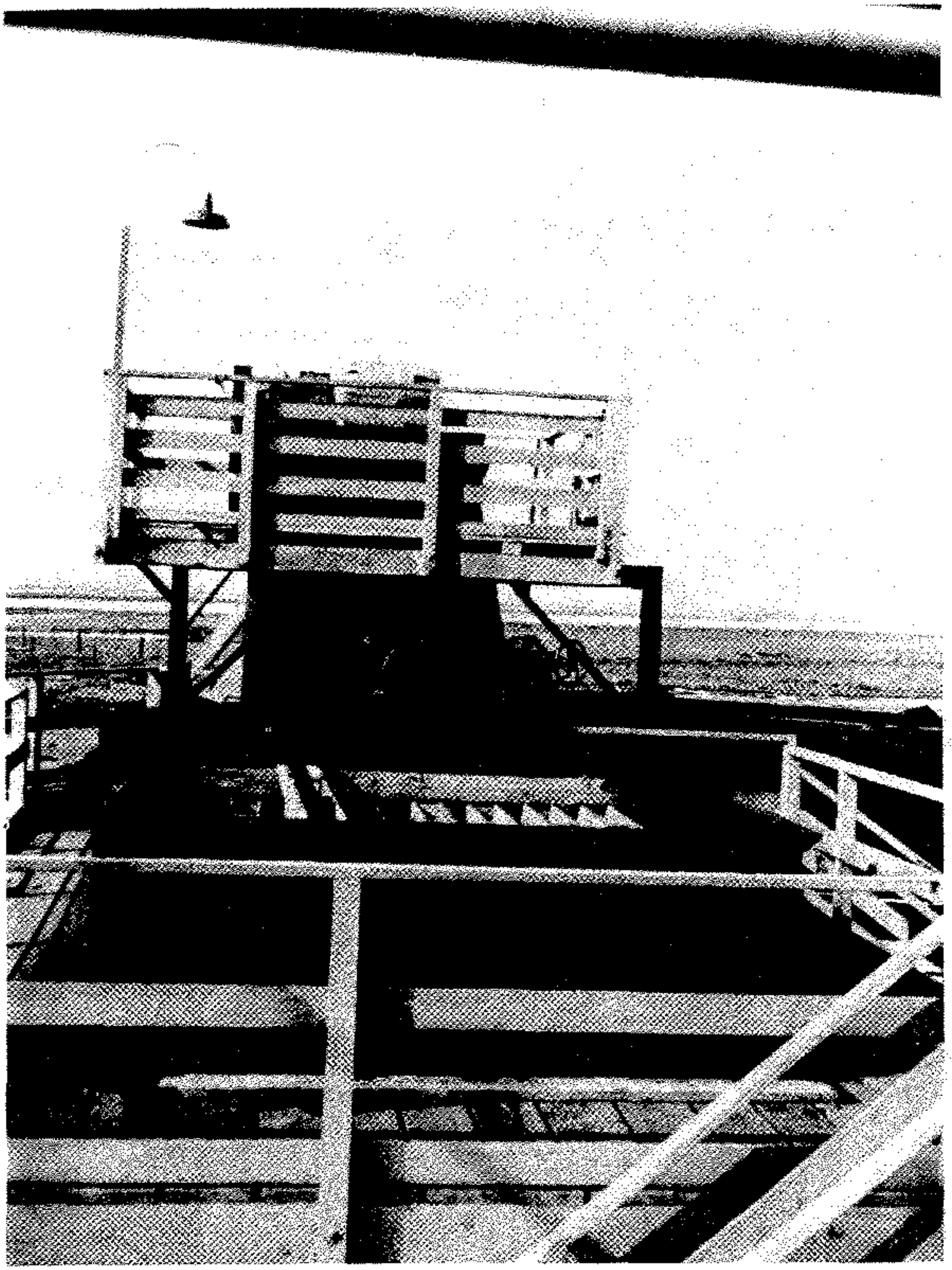

Figure 3. Dewatering Screws for Washing Solar Salt.

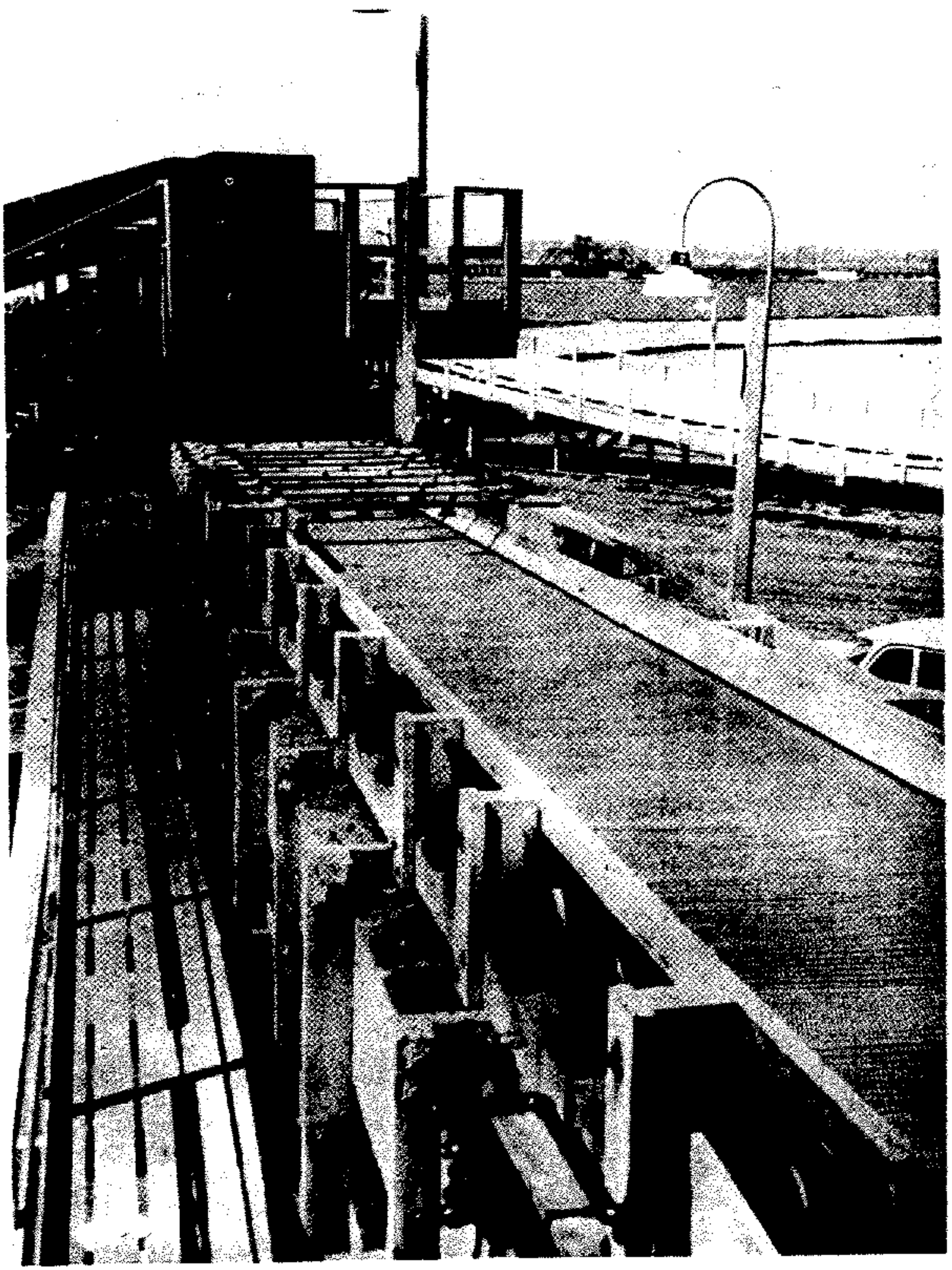

Figure 4. Wire Woven Screen for Washing Solar Salt.

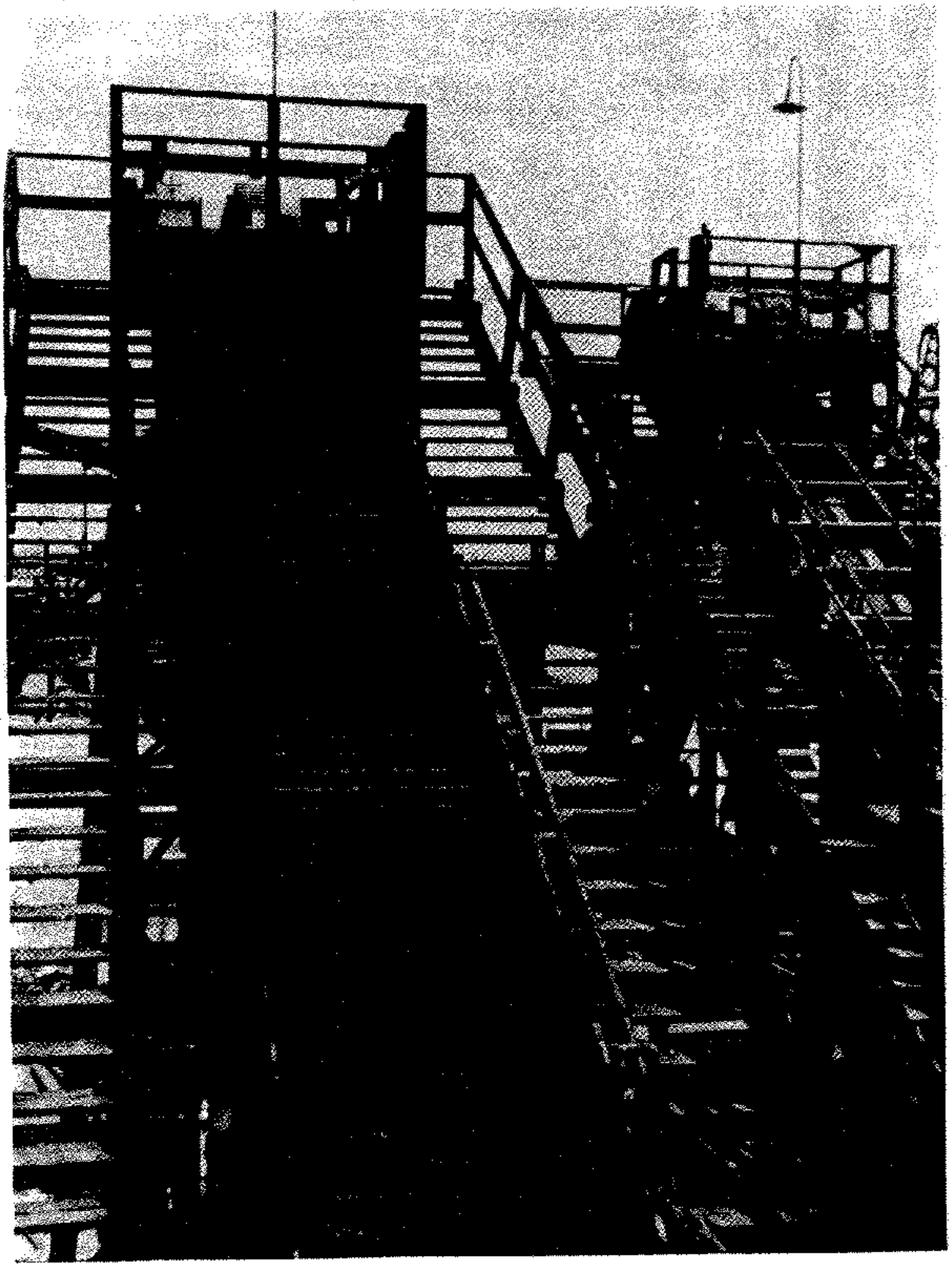

Figure 5. Drag Conveyor for Washing Solar Salt.

concentration of liquor phase impurities in the product and normally averages 11 gallons per ton of salt produced.

The wash water cycle is essentially countercurrent. Clean virgin saturated brine is first used for spray washing on both the drag conveyor and wire woven belt. The drainage liquor recovered from these operations is added to the dumping pit where it joins the recycled saturated brine from the settling pond. The overflow wash water from the screw washer, the dirtiest wash brine, is sent back to a 16 acre settling pond where the gypsum, clay, and mud settle out. Some wash brine is continuously bled off to prevent build-up of magnesium salts.

The final washed salt has had the clay and mud reduced from 0.1% to 0.02%, and the gypsum from 0.60% to 0.15%. The total $MgSO_4$ and MgCl have been reduced from almost 1.0% to 0.20%.

ROCK SALT

So much for solar salt. Now I will tell you about the washing of rock salt. The raw material obtained from our strip mining operation is materially different. The salt, as mined, contains on the average 78% salt and 15 to 20% gypsum, clay and sand. In addition, the amount of insolubles varies over a wide range depending upon the area being mined. The crude rock salt is recovered by stripping off the overburden and blasting the crude salt deposit. The crude is loaded into 5-8 cubic yard mine cars by a drag line (Figure 6). The cars are hauled to the mill and dumped into a dry pit (Figure 7). The salt is then fed to a primary crusher where the size is reduced to 3 inches by means of Jeffrey 30" x 36" double roll crusher (Figure 8).

The salt is now conveyed by belt to the primary washer, an 18" diameter double screw which is inclined and 36 feet long (Figure 9). From the primary washer the salt is fed to the secondary crusher where the size is further reduced to 1/2". The salt is fed to the secondary washer -- a horizontal double screw with screws the same size as the primary washer (18" diameter x 36 feet long) (Figure 10).

Finally the salt goes to a series of single 18" dewatering screw conveyors with perforations added near the top of each trough to drain the salt. There are two sections of 3 standard 12 foot length screws (Figure 11).

The wash water cycle is once again essentially countercurrent as follows: Fresh water is fed to spray bars on both sections of the dewatering screws. Fresh water is also added by spray bars on the second screw washer. Wash water drainings from the second washer and dewatering screws is fed to a middlings cyclone where most of the larger salt crystals are recovered. The overflow from the cyclone is fed to the pond area of the first screw washer and fresh water is added through spray bars near the discharge.

The present washing system reduces the mud and gypsum from about 15 to 20% to 1%; the $CaCl_2$ from 1% to about 0.1%; and the salt is improved in purity from 78.5% to 96.8%. The final salt contains about 2.0% moisture.

It is our opinion that because of the high quantity of insolubles better scrubbing action could be obtained with a log washer or a tumbling scrubber rather than dewatering screws. Tests are currently underway to confirm this. Consideration will be given along these lines when the present equipment is replaced.

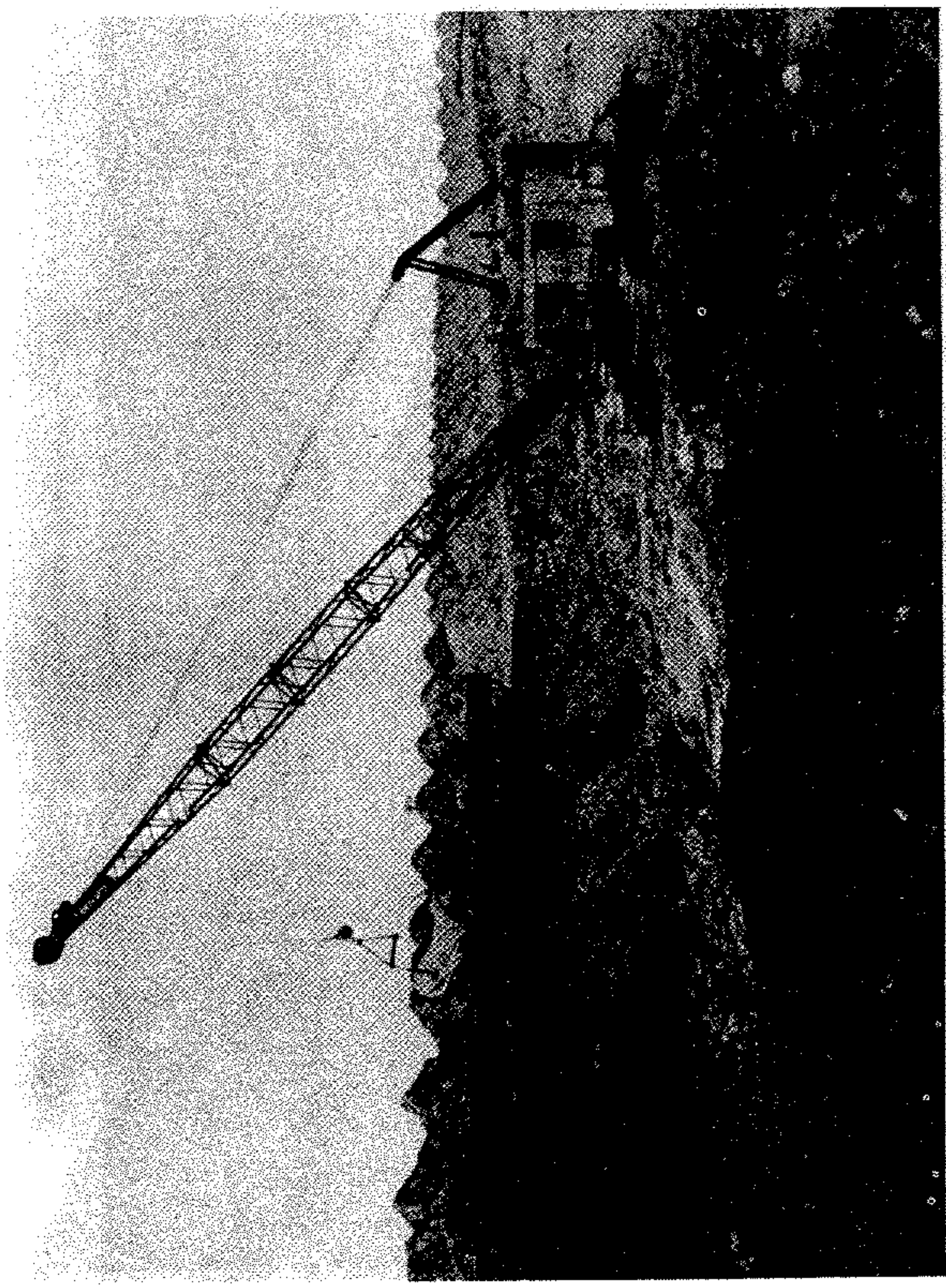

Figure 6. Loading of Mine Cars with Rock Salt.

Figure 7. Dumping Rock Salt from Mine Cars to Pit.

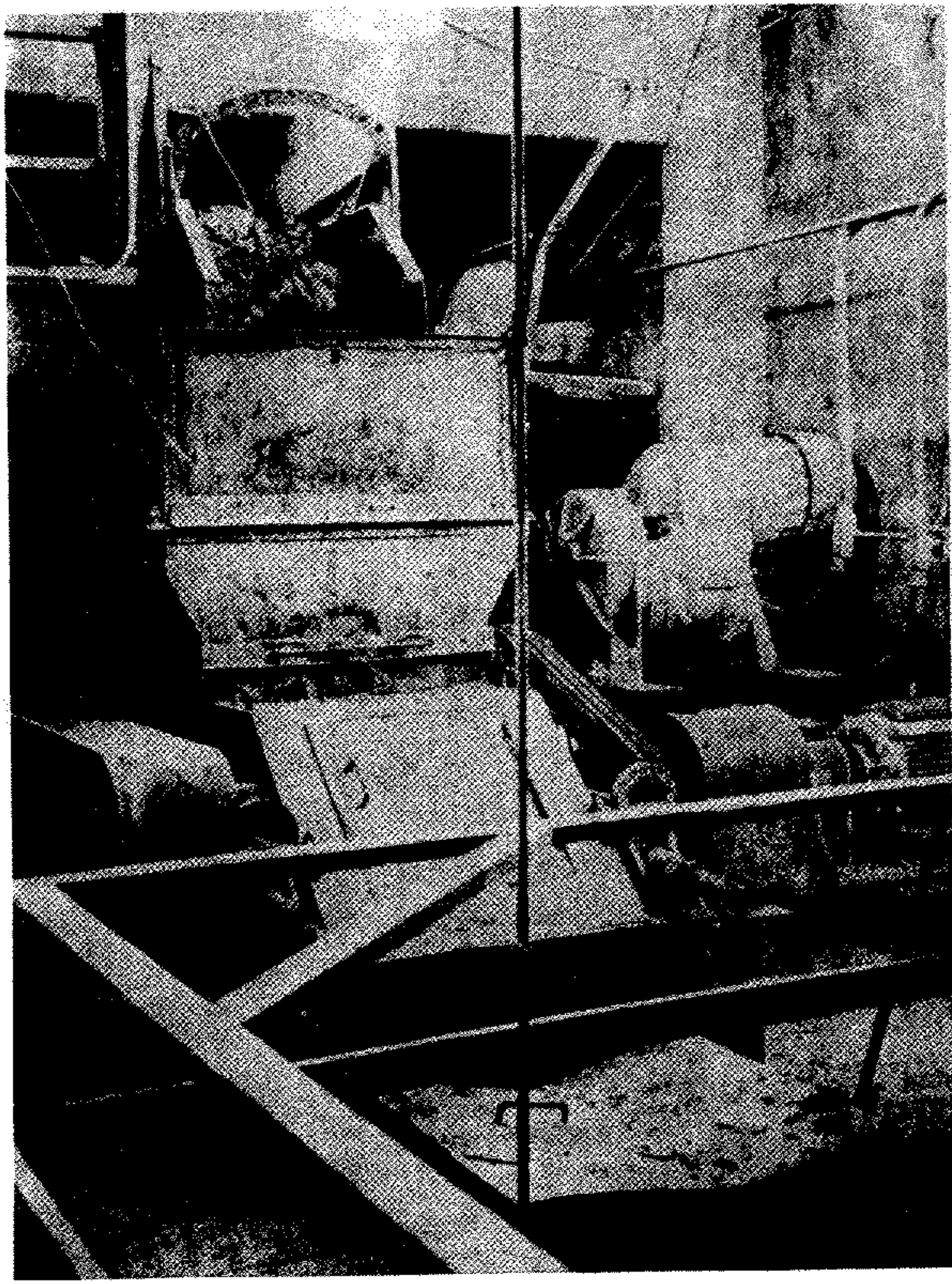

Figure 8. Crushing Rock Salt.

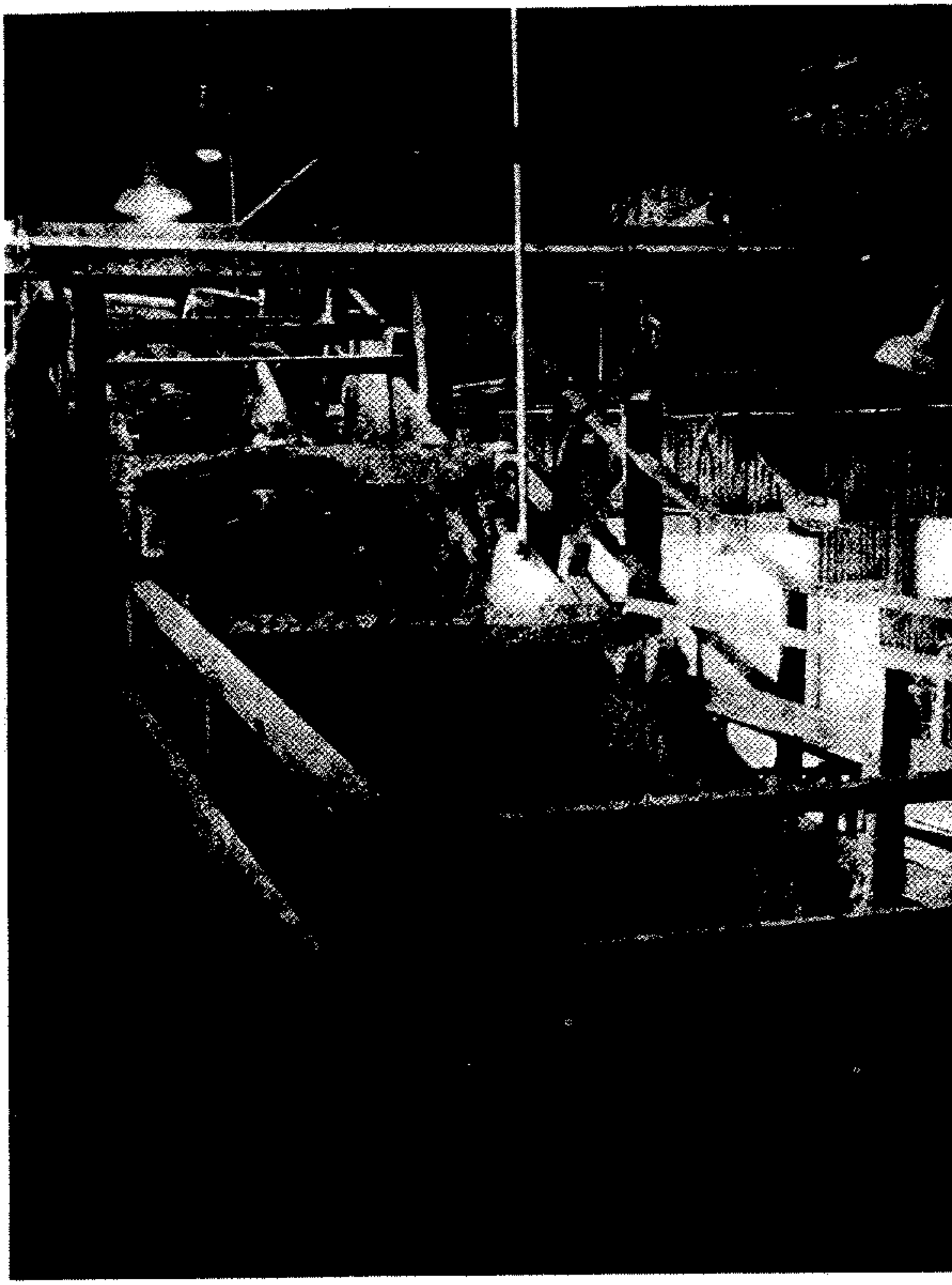

Figure 9. Primary Washer for Rock Salt.

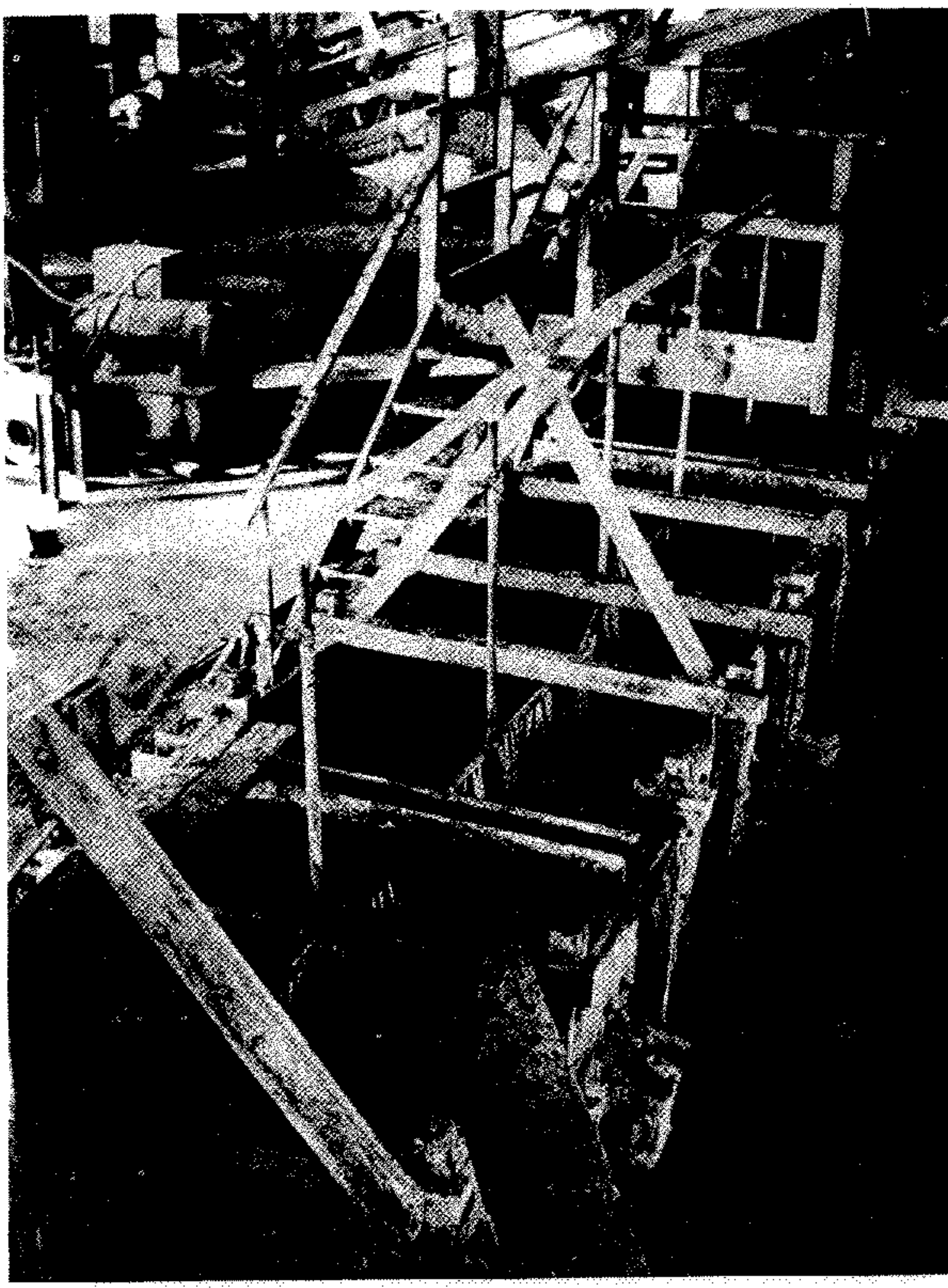

Figure 10. Secondary Washer for Rock Salt.

Figure 11. Dewatering Screws for Washing Rock Salt.