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AN ECONOMIC ANALYSIS OF AN OIL SHALE, NAHCOLITE, DAWSONITE COMPLEX IN COLORADO. OPTION III

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15. Supplementary Notes This is one of three reports evaluating hypothetical industry-scale projects for mining and processing oil shale and/or associated sodium minerals in Colorado.

16. Abstracts Option III concerns mining and processing a nahcolite deposit in the Piceance Creek basin, Colorado, plus an underlying measure of oil shale containing 14.6 percent nahcolite and 11.6 percent dawsonite by weight, and yielding 37 gallons of shale oil per ton. Principal products are soda ash, alumina, and shale oil. Coke, sulfur, and ammonia are evaluated as byproducts.

A two-level shaft mining operation, retorting, partial refining, and a minerals processing plant requires a capital investment of $636,973,000 in 1971 dollars to process 8,000 tons per calendar day of white nahcolite ore and 60,000 tons per calendar day of mineral-bearing oil shale. An income of $257,599,600 based on 1971 prices requires $151,373,400 annual operating expenditures including labor, materials, maintenance, taxes, insurance, overhead, and depreciation. The discounted cash flow rate of return is 14.45 percent based on a weighted average depreciation life of 14.155 years. This option differs from Option II in depth of the shale bed mined and analysis of the deposit.

17. Key Words and Document Analysis 17a. Descriptors

Sodium	Mine design
Alumina	Colorado
Oil shale minerals	Shale oil
Spent shale	Nahcolite
Mineral processing	Dawsonite

17b. Identifiers/Open-Ended Terms

Piceance Creek Basin	Nahcolite processing economics
Rio Blanco County	Dawsonite mining processing
Oil shale mine design	Oil shale mineral economics

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FOREWORD

(Option III)

This report is one of three which present the results of studies entailing preliminary design, costing, and financial evaluation of hypothetical industry-scale complexes for mining and processing of oil shale and/or associated sodium minerals occurring in a certain area of the Piceance Creek basin, Colorado. The studies were made in recognition of the interest that began to develop some years ago when it was learned that nahcolite, a natural form of sodium bicarbonate, and dawsonite, sodium dihydroxy aluminum carbonate (from which alumina can be derived), were associated in significant concentrations with the oil shale in this area. The particular location chosen for study purposes is defined in the mining sections and on maps included in the reports.

The studies, which consider a range of possibilities in regard to depth and characteristics of the measures assumed to be mined and processed, were based originally on 1966 conditions. Subsequently, the economics were updated to 1971 and are presented on this basis in the current reports. No similar updating of the technology was attempted because lack of definitive knowledge concerning actual underground conditions in the area of interest and of reasonably large quantities of representative raw materials for processing studies precludes setting mining and processing parameters with assurance. This situation is discussed in more detail later.

The following report, covering Option III of the three-part study, is concerned with an integrated operation involving a so-called "white nahcolite bed," containing a high concentration of sodium bicarbonate and occurring at a depth of about 1,900 feet, plus an underlying measure of oil shale-nahcolite-dawsonite material at a nominal depth of 2,600 feet. This latter material is characterized on the basis of limited investigation, a point discussed more fully in the report, as containing 14.8 weight percent nahcolite and 11.6 weight percent dawsonite (a carbonate mineral containing both sodium and aluminum), and yielding 37.0 gallons of shale oil by Fischer assay. The sales products in this option include soda ash derived both from the white nahcolite bed and from the nahcolite and dawsonite contained in the underlying measure, alumina stemming from the dawsonite, a pipeline-quality shale oil, and oil-related byproducts of coke, sulfur, and ammonia.

The first report, covering Option I, is concerned only with the same "white nahcolite bed" of Option III. The sales product in Option I is limited to soda ash.

Option II, the subject of the second report, is closely similar to Option III except that the oil shale-nahcolite-dawsonite measure occurs at a nominal depth of 2,400 feet. The available characterization data for this material indicate a nahcolite concentration of 25.2 weight percent, a dawsonite concentration of 9.2 weight percent, and a potential shale-oil content by Fischer assay of 23.0 gallons per ton. The same sales products are considered in Option II as in Option III; however, the quantities differ in keeping with compositional differences of the lower-level raw material.

The studies described above were predicated largely upon information supplied by the U.S. Geological Survey, based on the results of examinations and analyses of the relatively few subsurface samples available from the area in question. In addition, a limited amount of related laboratory work was done by the Bureau of Mines in connection with the sodium-minerals processing aspects of the studies. It is stressed that a much more comprehensive investigation would be required prior to starting actual operations to define with adequate assurance such factors as extent, attitude, and characteristics of the deposits, mining conditions, operating conditions and costs, and product yields. The need is recognized for an extensive drilling program and possibly even a pilot mining operation, neither of which has been effected to date.

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CIRCA 1971

AN ECONOMIC ANALYSIS OF AN OIL SHALE, NAHCOLITE, DAWSONITE COMPLEX IN COLORADO, OPTION III

SUMMARY

An oil shale and sodium-minerals processing complex located as shown in figure 1, consisting of a two-level shaft mining operation, retorting, partial refining, and a minerals processing plant, requires a total capital investment of $636,973,000 based on 1971 values. The complex is designed to process 8,000 tons per calendar day of a selected white nahcolite ore and 60,000 tons per calendar day of a nahcolite-dawsonite-oil shale material to produce the products listed in table 41.

The sale of products will yield an annual income of $257,599,600 based on 1971 prices (see table 41). To produce this income an annual expenditure of $151,373,400 is required which includes the cost of labor, materials, maintenance, taxes, insurance, payroll overhead, and depreciation. The interest rate of return or discounted cash flow rate is 14.45 percent based on the weighted average life for depreciation of 14.155 years.

As indicated in figure 10, the white nahcolite ore is processed directly in one section of the sodium-minerals plant for production of soda ash. The nahcolite- and dawsonite-bearing material, except for a

portion of the high nahcolite material which is handled separately, is retorted to yield raw shale oil and spent shale; the latter constitutes the charge to another section of the sodium-minerals plant. The oil is refined by coking and hydrocracking to yield a pipeline quality product and various byproducts. The spent shale is processed to yield additonal soda ash and alumina. The denuded spent shale and other solid wastes are ultimately disposed of as mine fill.

Operations throughout the complex are conducted essentially on a round-the-clock, seven-day-per-week basis. Downtime for maintenance, inspection of equipment, and similar functions is provided for in the design capacities of the various sections of the complex. The mine operates 20 shifts per week or 95.24 percent of the time. The on-stream factors for the processing sections are 95.89 percent for the sodium-minerals plant, 95 percent for the refinery, and 90 percent for the crushing, screening, briquetting, and retorting. Sufficient surge capacity in the form of stockpiles or other storage facilities is provided between all principal sections of the complex to permit normal downtime of individual sections without disruption of operations in the complex.

The mining measures selected for this study, 9 feet in the case of the white nahcolite and 60 feet in the case of the nahcolite-dawsonite-oil shale measure, occur at nominal depths of 1,900 feet and 2,600 feet respectively. The bilevel mining layout that is visualized is large enough to support operations for 20 years; however, further investigation would be required to verify sufficient reserves and the minability of the deposits prior to starting an actual development.

The land requirement for the integrated complex is 940 acres. This includes total plant area of 300 acres, 315 acres for the water reservoir, and 325 acres for the waste disposal pond.

The detailed equipment lists are given in tables 2 through 18 and the cost summaries are shown in tables 19 through 36.

MINING

General

As indicated in figures 1 and 2, the hypothetical mining operation is located in Rio Blanco County, Colorado. For purposes of the study, a contiguous land area of some 11 sections of land is involved: Sections 13, 14, E1/2 15, 23, 24, 25, 26, 27, 28, T 1 S, R 98 W, W1/4 sec 17 and 20, sec 18 and 19, T 1 S, R 97 W.

Production is from two different levels, a nahcolite zone approximately 1,900 feet below the surface and a nahcolite-dawsonite-oil shale zone about 2,600 feet below the surface (fig. 3).

The location, size, and attitude of the white nahcolite deposit and the nahcolite-dawsonite-oil shale zone are assumed mostly from analytical and other information provided by the U.S. Geological Survey and a preliminary isopach map of the white nahcolite bed (fig. 2). On the 2,600-foot level the location of the nahcolite-dawsonite-oil shale beds with respect to the white nahcolite bed was specified by the U.S. Geological Survey.

A 1968 report by the U.S. Geological Survey on the water conditions in the area considered in this study indicates that a water-bearing leached zone probably exists immediately above the nahcolite bed to be mined. However, sufficient information to evaluate this condition as well as to define other mining conditions with assurance is lacking. Such information normally would be obtained from an extensive drilling program or even a pilot mining operation, neither of which have been effected.

Since sufficient exploration has not been done to determine the actual mining conditions and limitations, the following assumptions have been made for the 1,900- and 2,600-ft levels.

Assumptions concerning the 1,900-ft level, nahcolite bed, are:

1. A uniform, more or less flat lying bed of nahcolite with a minable thickness of 9 feet occurs approximately between 1,879 feet and 1,890 feet below the shaft collar.

2. The mining zone is overlain by a competent member including the upper two feet of the interval mentioned above which, when rock bolted and supported on pillars, will carry the overlying material across the mine openings.

3. Rooms and entries 16 feet wide will stand open indefinitely when rock bolted on 5-foot centers and mining is limited to a 50 percent overall extraction rate.

4. Hardness, fragmentation, and swell factor of the nahcolite are similar to that of trona. Specific gravity is 2.24, equivalent to 140 pounds per cu ft or 14.3 cu ft per ton in place. Swell factor is 0.535, equivalent to 75 pounds per cu ft or 26.8 cu ft per ton of broken material.

5. Methane gas will be encountered, therefore all electrical equipment must be permissible[1] and ventilation must be adequate for the conditions.

6. Impervious beds lie adjacent to the mining zone so that the mine is dry.

In further regard to the immediately preceding assumption No. 6, it is recognized that no significant inflow of water could be tolerated in the white nahcolite mine because of the solubility of the pillars to be left for support and the difficulty of mining and handling the nahcolite if wet. If a significant inflow were found to exist, it might well be subject to engineering control at some cost; however, no such cost is assigned in this study in view of the sparsity of information presently available about actual water conditions.

Assumptions concerning the 2,600-ft level, nahcolite-dawsonite-oil shale bed, are:

1. A uniform, flat lying bed of nahcolite-dawsonite-oil shale with a minable thickness of 60 ft occurs approximately between 2,530 feet and 2,590 feet below the shaft collar.

2. The mining zone is overlain by a competent member which, when rock bolted and supported by pillars, will support the overlying material across the mine openings.

3. Haulageways 30 ft wide will stand open indefinitely when rock bolted on 10-ft centers and mining is limited to a 45 percent overall extraction.

1"Permissible" means a machine, material, apparatus, or device has been investigated, tested, and approved by the Bureau of Mines and maintained in permissible conditions. Reference: Federal Register, v. 34, No. 11, Jan. 16, 1969.

4. Specific gravity is 1.97, equivalent to 123 pounds per cu ft or 16.3 cu ft per ton in place. Swell factor is 0.75, equivalent to 92.2 lb per cu ft or 21.7 cu ft per ton of broken material.

5. Methane gas will be encountered; therefore, all electrical and diesel equipment must be permissible and ventilation must be adequate for the conditions.

The mining area designated for this study was sized to provide enough ore, including a reasonable amount for unminable areas, to operate the shale oil and minerals processing plants for a period of 20 years at a 45 percent mining extraction. This extraction rate was computed using the physical characteristics of the oil shale and column of overburden to determine the size of openings and size of pillars which should be left as support.[2]

The processing capacity is 68,000 tons per calendar day (24,820,000 tons per year), 8,000 tons from the 1,900-ft level and 60,000 tons from the 2,600-ft level, with allowance in design to provide for 15 non-operating days per year, or equivalent time at reduced capacity for maintenance and repair. The mine and processing plant operates round-the-clock seven days per week.

No cost or time has been shown or allowed in making this study for company formation or organization, acquisition of property rights, ownership blocking up, title clearance, or other legal problems.

The amount of pre-developmental drilling required would vary considerably depending on the uniformity and consistency of both the bedded

[2] Obert, L., W. I. Duvall, and R. H. Merrill. Design of Underground Openings in Competent Rock. BuMines Bull. 587, 1960, 36 pp.

deposit to be mined and the adjacent beds. If early drilling indicates complete uniformity, a minimum of additional drill holes would give adequate information. Discontinuous and/or nonuniform formations would require closer hole spacing to evaluate the ore body. Under average conditions one core hole in each 1/4 section (44 holes on 11 sections) could provide sufficient information to delineate the ore body. Three rigs would require about 1 year to drill the 44 holes which, along with the required engineering and assaying, would cost about $1,936,200. For the purpose of this evaluation, it is assumed that average conditions do exist in the area under consideration and $1,936,200 is included in the cost estimates for pre-developmental drilling, engineering and assaying.

Development

Assuming that the preliminary exploration and feasibility study indicate the advisability of proceeding further, a mine development program, estimated to require 38 months as detailed below, would ensue.

Time Schedule

	Month start	Month finish	Time req.	Production TPCD
Temporary access road for exploration and construction purposes only, involving virtually no excavation or structures but with adequate surfacing (3-1/2 mi)				
Site preparation (shaft and hoist house)	0	1	1 mo	
1 service shaft (30-ft diam.) 2 production shafts (20-ft diam.)	1	25	24 mo	
Install headframe and hoists Station preparation at three shafts	25	28	3 mo	
Lower equipment and begin development	28	29	1 mo	
1,900-ft level				
Drive 7 main entries 16 ft x 9 ft in two directions (38 working faces). Drive and ream the ore pass between the 1,900 ft level and 2,600-ft level.	29	33	4 mo	600
Add necessary entry development and equipment	33	34	1 mo	1,200
Begin panel development, add mining equipment	34	36	2 mo	4,000
Start full production in 38th month	36	37	1 mo	8,000
2,600-ft level				Average
Drive haulage drifts, ventilation drifts and complete all preproduction development	29	35	6 mo	17,300
Start production in 36th month				60,000

Shafts

The three shafts, located approximately in the center of the area subject to development, will be concrete lined. They can be sunk simultaneously. The two 20-ft diameter production shafts will be sunk about 150 ft below the producing level to allow for the sump, surge bin, and skip pocket. Depending on the amount of water encountered during excavation, this will require about 24 months. Three 30-ft diameter by 62-ft deep concrete lined surge bins (2 at one shaft, one at the other) with apron feeders for delivering the material into skip measuring pockets at the production shafts will be excavated in the station areas on the 2,600-ft level. One surge bin at one shaft will be used to handle the nahcolite.

The 30-ft diameter service shaft will be sunk 50 ft below the 2,600-ft level to allow for a sump. Maintenance shop and supply rooms will be excavated near the service shaft station area on both the 1,900-ft and the 2,600-ft levels. The shafts will have a 2-ft thick reinforced concrete lining to about 100 ft below the collar. From there to the shaft bottom the lining will be about 1 ft thick. Grouting will be required to seal off any water inflow to the shaft. The shaft contract estimate includes a water clause that will cover the cost of handling water during excavation and of any grouting required. Shaft sizes were determined by production requirements and ventilation needs.

A 4-ft (inside diameter) ore pass from the 1,900-ft level to the 2,600-ft level will be drilled and lined to transfer the nahcolite to the 2,600-ft level for hoisting to the surface. Conveyer transfer equipment on the surface is arranged to stockpile the ores separately.

Entry Drifts - 1,900-ft Level

After the shafts and shaft stations are completed the seven main entries are driven north and south from the shafts. Initially the pillars are 100 ft by 84 ft in the seven 16-ft wide by 9-ft high main entries for a distance of about 400 ft from the shafts at which point they would change to 64 ft by 54 ft. Pillars in the bleeder and butt entries are 64 ft by 54 ft while pillars in the panels would be 34 ft by 39 ft (fig. 4). Barrier pillars 200 ft wide are left between main, butt, and bleeder entries and the panels; 50-ft pillars are left between the panels. The final size of the pillars left for support, which dictates the distance between crosscuts, would be determined in an actual development as experience was acquired. However, for the purpose of this estimate, they are sized as above.

One mining unit (men and equipment) is used in the north main entry and one in the south main entry on each shift. Each unit--consisting of a cutting machine operator, driller, powderman, loader operator, two shuttle car operators, roof bolter operator, two utility men, and a unit boss with a set of mining equipment--can complete ten 10-ft rounds per shift. A total of 400 ft advance per day will be completed using two units on each of two shifts. It is about 1,200 ft from the shaft to the butt and bleeder entries in each direction. Because of lateral excavation for crosscuts perpendicular to the entry, 1.66 ft of heading excavation must be driven for each foot of entry advance. About 27,890 ft of heading excavation at 400 ft per day equals 70 working days or 14 weeks. An estimate of 4 months is made for this work, allowing for off-time and delays.

At this time butt and bleeder entries will be started and driven to panel drifts, with full production being realized about 10 months after the shafts are finished. Panel development begins on the panels adjacent to the shaft and progresses outward,

Entry Drifts - 2,600-ft Level

After the shafts, shaft stations, surge bins, and loading pockets are completed, the haulage drifts, shops, and drifts necessary for ventilation and access will be driven. The drifts will be 30 ft wide by 33 ft high. This provides sufficient cross section for ventilation as well as limiting the unsupported span to a safe distance. Crosscuts between the drifts will provide access from one drift to another and will aid in the ventilation. It allows flow of air from one drift to another in case an obstruction would occur in portions of a drift. A 100-ft pillar will be left between the haulage drifts; 115-ft pillars will be left between the haulage drifts and the panels (fig. 5).

The number of personnel employed for preproduction development will vary depending upon the number of working faces available. In general, the crews will be increased as the development progresses. The time required for the preproduction underground development will be approximately 6 months. During this time approximately 58,000 ft of drifts and shop areas will be excavated; tonnage of material produced during this development phase is approximately 3.5 million tons.

After the mine is in production it is necessary to excavate approximately 9,630 ft of drift in 93 days to develop a panel for production.

The development heading round will be 30 by 33 ft in cross section, depth of the round will be 20 ft. Approximately 1,215 tons of material will be broken per round. A powder factor of 0.55 pounds of ANFO will be used per round.

The equipment used in a development heading round will be the same as that used in mining in the panels.

The drill rig consists of two rotary-hydraulic-electric machines mounted on a truck. A self contained water system, tank and pump, is mounted on the truck to provide water for drilling purposes: also a compressor is mounted on the unit to provide air to aid in the removal of cuttings from the hole. The drill rig has a 33-ft feed change so a 33-ft hole can be drilled in one pass; the rig is designed so the holes near the back of the 33-ft high face can be reached. Two miners, a miner's helper, and a truck driver are required per drill rig. The penetration rate is assumed to be 10 ft per minute. It is estimated that a development heading round can be drilled in 1.7 hours after full production has been achieved.

After a round has been drilled the drilling crew will move to another working area. A crew composed of two powdermen and a truck driver will then charge the holes in the development heading. The equipment will consist of a truck containing a tank for transporting the ANFO (ammonium nitrate-fuel oil mixture) in bulk form. The unit is equipped to pneumatically charge the ANFO into the holes. A hydraulic lift powered by the truck motor allows access to the holes near the back. Positioning controls on the loading platform are conveniently located for the powderman. One powderman places a primer in the hole while the other charges the ANFO. The truck driver would service the equipment. The 3-ton ANFO container on the truck is removable so that a similar container can be filled with ANFO on the surface, brought underground and interchanged with the container on the truck. It is estimated that a development heading round can be charged in 1.7 hours. Upon completion of the charging phase which includes wiring of the round, the crew moves to another heading.

After the area has been cleared of smoke from the blast and the back tested for soundness, the loading and haulage units will commence loading and transporting the broken material to the surge bins at the production shafts. After the preproduction development is completed the material will be hauled to the crusher units located in a panel; the crushed material will then be conveyed to the surge bins. A front end articulated loader with a 20-ton capacity bucket will be used to load the material into 75 ton trucks. The number of trucks required per loader during preproduction development will depend upon the haulage distance. Sufficient trucks will be provided to keep the loader working continuously. It is estimated that a loading rig can load 1,755 tons per hour allowing for 90 percent availability and 10 minutes moving time per hour.

All of the backs in the mine will be rock bolted on a 10 ft by 10 ft pattern. This pattern may change as experience is obtained in actual mining operations. In addition the backs and ribs will be scaled of all loose material. For this work a special truck equipped with a telescoping boom capable of providing access to the mine roof will be used. A drill for roof bolting will be operated from the platform. The boom is remotely controlled by the drill operator at the platform. One miner and a truck driver are required per rig. It is estimated the scaling and placement of 6 roof bolts per development round will take 0.7 hours. A bulldozer equipped with a bucket or blade will be used to clear the area of boulders after scaling and roof bolting.

Production - 1,900-ft Level

The cost estimate is based on a modified room and pillar mining method similar to that used in some of the trona mines in southwestern Wyoming, underground coal mines, and other bedded deposits (figs. 6 and 7). Operations are highly mechanized and the mining personnel are organized into mining units of men and equipment which are independent of each other.

Each unit consists of 10 men - a cutter operator, driller, powderman, loader operator, two shuttle car operators, a roof bolter operator, two utility men, and a unit foreman. Each phase of the mining cycle takes 20 to 30 minutes. Barring unusual delays a unit can complete 14 to 16 cycles per 8-hour shift. Enough working faces are made available (15 to 16) to insure a unit loses no time waiting for a heading in which to work. Thus at the beginning of a shift there may be three rounds blasted ready to load out, three headings cleaned out ready to rock bolt, etc. Production will average about 1,500 tons per unit per shift at 100 tons per round. Two units operating on three shifts, 20 shifts per 7-day week can produce 60,000 tons per week. This production rate provides sufficient reserve mining capacity to insure maintaining the required 56,000 tons per week allowing for all maintenance and repair, unscheduled downtime, etc. Two complete sets of spare equipment are kept underground as spares to avoid undue production delays when break-downs occur.

The dimensions (16 ft wide by 9 ft high) of a development and a production heading are the same so that it makes little difference in costs whether the ore is mined from development or production headings.

A description of each phase of the mining cycle follows.

Cut

An electric-powered coal cutting machine that has been modified by strengthening design changes for operation in harder material is used to make a cut at the face of the heading to which the round would break. The 10-1/2-ft deep cut is made the width of the face as near the roof as is practical. The machine is operated by one man; the operation normally takes 20 to 30 minutes.

Drill

The drill jumbo, powered with a 115-hp electric motor driving a hydraulic system, has two drills, each mounted on a hydraulically controlled extendable boom arm. All controls are centrally located so that the machine can be operated by one man. Thirteen to 18 holes (depending on the size of the heading and the toughness of the material) are drilled in a fixed pattern to break to the cut at the roof. The holes are 1-3/4 inches in diameter and are drilled about 11 ft deep using tungsten carbide bits and auger steel. This operation takes 20 to 30 minutes.

Blast

Although ANFO is not designated as a permissible explosive it is assumed no problem would be encountered in acquiring written permission from the proper authorities to use it in this mine. ANFO is used in the trona mines of Wyoming which are classified as gassy mines.

A small diesel-powered loading truck, provided with a small compressor and pressurized system, is used to pneumatically charge the blasting agent, ANFO, into the holes. Millisecond-delay electric blasting caps are provided with iron lead wires so they can be removed from the ore by magnets and are placed in the bottom of the hole in a 1-inch by 6-inch primer of 65 percent permissible dynamite. The ANFO is charged to within about a foot of the collar of the hole. A plastic bag (about 1-1/2-inch diameter by 1-ft long) is filled with water and used for tamping or stemming in the collar of each hole. In addition to its use as stemming, the water also acts to quench the flash from the blasting agent. The round breaks about 10 ft deep. About 100 tons of ore are broken each round, with most of the material falling in the size range of 12 to 18 inches. One man charges and blasts the round in about 20 to 30 minutes. About 10 minutes must be allowed before the subsequent loading operation begins so that the dust- and smoke-laden air can be cleared out by the small auxiliary ventilation fans.

Load and Haul

A 160-hp gathering-arm-type coal loader, modified by strengthening design changes for operation in nahcolite, is used to load the broken rock. The ore is gathered onto a bar-flight-feeder on the loader and conveyed over the loader into a shuttle car. The loader is capable of loading from 21 to 33 tons per minute and is operated by one man. Two 14-ton electric powered shuttle cars, used to haul the ore to the conveyor, operate with one loader. The maximum haulage distance is normally limited to 500 feet because of the trailing cable on the electric powered shuttle cars. One man operates each shuttle car. The loading phase of the operation takes 20 to 30 minutes. To control the dust, the muck pile is wetted with water piped to the working area through the water distribution system. The underground operation requires 20,000 gallons of water per day.

Rock Bolt

An electric-hydraulic rock-bolting machine is used to drill the rock-bolt holes, and to insert and tighten the 54-inch rock bolts across the back of each newly blasted development and production heading. A hydraulic-driven auger drill, similar to the drills used in the production headings, is mounted on a hydraulic, extendible boom arm. Vertical holes, about 1-1/2 to 1-3/4-inches in diameter, are drilled on 5-ft centers. The bolts, 54 inches long by 3/4-inch in diameter, complete with expander and plate, are pushed into position and tightened with the drill to the proper torque. One man can place the bolts in a heading in 20 to 30 minutes.

Convey and Hoist

The shuttle cars unload the ore into a crusher-conveyor feeder where it is reduced to minus 10-inch material. This feeder is started with an on-off switch which has a pull cord conveniently located for the shuttle car operators. It has an automatic shutdown mechanism that stops the crusher-conveyor feeder when it empties. Its operation is monitored by the shaft station crusher attendant through a closed circuit TV system so that he can dispatch repairmen in case of trouble. The material is then conveyed by the 36-inch transfer conveyor to the secondary transfer conveyors or to the main entry conveyor. Near the shaft the main entry conveyor discharges into a screen feeder which delivers all plus 5-inch material to a secondary crusher where it is crushed to minus 5 inches, the size material that can be handled efficiently through the ore handling system.

The ore is then conveyed to an ore pass which transfers the material to a surge bin on the 2,600-ft level. Apron feeders under the surge bin convey the ore to a skip measuring pocket. The skip measuring pocket fills the skip as it is lowered into position; simultaneously, the other bottom dump skip discharges at the surface.

On the surface the ore is conveyed to a stockpile. This is sized at 56,000 tons, one week's mill requirements, to provide for continuous processing in the event of short term emergency mine shutdown, mine holidays, and to provide reasonable flexibility in mining operations. To eliminate contamination problems, this stockpile is a paved and roofed area, 300 ft x 150 ft, 40 ft high at the eaves.

Ventilation

Primary ventilation for this two level mining operation is provided by two fans mounted near the service shaft on the surface. The fans are capable of producing 1,240,000 cfm at 8-inch water gage: approximately 240,000 cfm used to ventilate the 1,900-ft level and the remainder used to ventilate the 2,600-ft level. If needed, regulators are used to control the quantity of air flowing to each level. The air is circulated through the mine and exhausted through the production shafts. Brattice cloth, airlocks, and overcast drifts are used to control the direction of the air flow. Portable blowers and flexoid tubing provide secondary ventilation at each "dead end" working face. Direction of air flow within the 1,900-ft level of the mine is shown in figure 4. The crusher-conveyor feeders are located in exhaust entries and arranged so that the shuttle car operators are upwind from the crusher, protecting them from the small amount of dust that is generated. Exhaust air moves from the crusher located at the production shaft directly into the shaft to prevent a dust problem in this area. If dust should prove to be a problem, dust collectors could be installed. Maximum air velocity through the system is 555 feet per minute or 6.3 miles per hour.

Production - 2,600-ft Level

The mining system believed suitable for the 2,600-ft level is a modified room and pillar system within a panel (figs. 8 and 9). The 60-ft thick bed of nahcolite-dawsonite-oil shale is mined using a 33-ft top heading round and a 27-ft bench round. The 33-ft top round is at the same level as the haulage drifts; the bench round bottoms 27 feet below the floor of the haulage drifts. Ramps will provide access for hauling the broken material from the bench round. The pillars left on an evenly spaced pattern are 70 feet square; the rooms are 50 feet wide.

The mining operation is highly mechanized with equipment and men assigned to a specific phase of the operation such as drill, blast, load and haul, and scale and rock bolt. As a unit completes its specialized task in one heading, it moves onto another to perform the same task. Sufficient headings are available so these phases can continue without interruption. Sufficient units are provided to produce 60,000 tpcd; there is sufficient capacity in the spares (required for repair and maintenance) to increase production if warranted. Labor requirements to operate these spares is temporarily taken as needed from a labor pool. Approximately 10 percent of the daily production is provided from the development headings. This development is necessary to provide production working areas in advance.

Drill

The heading round, 33 ft high by 30 ft deep by 50 ft wide, is drilled with a rig identical to that used in the development heading. A V-cut pattern round is used to pull a 30-ft round. Experimental work in oil shale has demonstrated that a round using a powder factor of 0.55 pound of ANFO per ton of broken material will pull satisfactorily and produce sufficient fragmentation; similar loading is assumed for the current study. A round requires 2.6 hours for drilling and produces 3,037 tons of broken material.

A bench round, 27 ft high by 30 ft deep by 50 ft wide is drilled with two rotary-hydraulic-electric machines mounted on a truck. The feed mechanism permits holes to be drilled to the full depth of 27 ft. in one pass. Experimental work has shown that no subdrilling is required because the shale breaks to a parting plane. Three tenths pound of ANFO per ton of broken material provides satisfactory fragmentation producing 2,484 tons of broken material. Manpower required for the drill rig is two miners, a miner's helper, and a truck driver. Estimated time to drill the round is 1.7 hours at a penetration rate of 10 ft per minute.

Manpower requirements per shift are six miners, three miner's helpers, and three truck drivers. Two heading drill rigs and one bench drill rig are required.

Blast

The same type equipment is used to charge both the heading and bench rounds. It is estimated that a development heading round can be charged in 1.7 hours, a panel heading round in 2.1 hours, and a bench round in 1.4 hours. About 50 percent of a hole is charged which satisfactorily pulls the round and gives acceptable fragmentation. Stemming is used as necessary.

Although ANFO is not designated as a permissible explosive it is assumed that permission has been obtained from the proper authorities to use it in this mine. ANFO is used in the trona mines of Wyoming which are classified as gassy mines.

The ammonium nitrate and fuel oil are mixed on surface in a plant supplied by a powder company. No powder magazine is necessary for storage of ammonium nitrate on surface or underground. On the surface the ammonium nitrate prills remain on a powder truck until needed in the mine, the truck being stationed when not in use in a shielded area protected by embankments. The procedure for delivering explosives underground has been previously described. Two of these units with the required manpower are required to maintain a production rate of 20,000 tons per shift.

Separate facilities are provided for the storage of both primers and caps on the surface and underground.

Load and Haul

Two front end loaders and six 75-ton rear dump trucks are used to load and transport the ore from the working area to a semi-portable roll crusher located in a panel being mined. The average haulage distance is 1,500 feet. Each loader is capable of loading 1,755 tons of broken material per hour. A loader cycle, i.e., load, dump in a truck, and return to the muckpile, takes 32 seconds (this estimate was obtained from the loaders manufacturers for a haul distance of 50 feet). Four loader buckets, 20 tons per bucket, fill a 75-ton truck. It is estimated that a truck cycle, i.e., load, dump, and return to the loading site, requires 6.1 minutes.

Water trucks provide water for wetting the haulageway and the muckpile. The underground operations require 100,000 gallons of water per day for dust control during drilling, loading, and haulage.

A motor patrol is provided to keep the haulageway clear.

Scale and Rock Bolt

All backs and ribs in the heading are scaled to remove loose material and the back is then bolted as close to the face as practical;[3] bolts are placed on 10-ft centers in staggered rows. It is estimated that a round in a development heading is scaled and rock bolted in 0.7 hour and in a panel heading in 1.5 hours. A bench heading can be scaled in 0.8 hour. Two scaling and rock bolting rigs and operating crews are necessary to maintain a production rate of 60,000 tons per calendar day. In addition, one rig is used to test the backs for soundness in the permanent haulageways. Details concerning the rig have been previously described in the development segment of this report.

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[3] East, J. H., Jr., and E. D. Gardner. Oil-Shale Mining, Rifle, Colo., 1944-1956. BuMines Bull. 611, 1964, 163 pp.

Convey and Hoist

The haulage trucks unload the ore into a receiving hopper from which it is conveyed via an apron feeder to a grizzly feeder. Minus 10-1/2-inch material passes through the grizzly and onto the transfer conveyor. The plus 10-1/2-inch ore is fed to the roll crusher, crushed to minus 10-1/2-inch material and then is picked up on a transfer conveyor. One or more transfer conveyors deliver the sized ore to the main conveyor. Near the production shafts the main conveyor discharges the material into one of two 2,000-ton capacity surge bins (fig. 9).

The crushing unit (hopper, feeders, and crusher) is portable so that it can be moved from one location to another as mining progresses. Two units are in operation and a third is provided so that a unit can be moved and set up at a new location without loss of production. Dust collectors are provided at the crushing site to alleviate dust problems.

Apron feeders under the surge bin fill the skip measuring pockets with a skip load.

The skip fills from the measuring pocket at the same time the other bottom dump skip discharges at the surface. Filling of the skip measuring pocket and skip is automatic; the production hoist also is automated so that only one man is needed to monitor the system.

Ventilation

Primary ventilation is provided by the same fans used to ventilate the 1,900-ft level. These fans are mounted near the service shaft on the surface. Air is forced down the service shaft, circulated through the mine and exhausted via the two production shafts. Direction of the air flow is controlled by use of air locks, regulators, overcasts, and bulkheads (fig. 8). Ventilation to the development headings is provided by fans and ventilation tubing. "Dead-end" headings in the production area are similarly ventilated. Direction of air flow within the mine is also shown in figure 8. The maximum velocity attained is approximately 505 ft per minute or 5.7 miles per hour.

Surface Storage

Provisions are made for stockpiling a week's supply of ore on the surface in a roofed and paved area 1,200 ft long, 200 ft wide, 50 ft high at eaves. Also, conveyors are provided for transport to the storage piles and for distribution over the storage areas.

RETORTING

Of the total material that is mined, the 60,000 tons per calendar day from the 2,600-ft level makes up the feed, via preparatory crushing and screening facilities to the retorting plant. Subsequently, the spent (retorted) shale is processed in one section of the sodium minerals plant for production of soda ash and alumina. The balance of the mined material, 8,000 tons per calendar day of white nahcolite from the 1,900-ft level, is not retorted, although its organic content, representing less than five gallons of potential oil per ton, is utilized as fuel in the section of the sodium minerals plant to which it is fed directly from its stockpile. Details of both sections of the sodium minerals complex appear later in this report.

The retorting plant, including its preparatory crushing, screening and briquetting facilities, is located in the general plant area designated in figures 1 and 2. This area overlies a portion of the mine.

Based on data provided by the U.S. Geological Survey, the raw material from the 2,600-ft level (termed the dawsonite-rich zone on occasion hereafter) is characterized as follows:

Specific gravity (in-place).........		1.97
Oil yield by Fischer assay..	(gal/ton)	37.0
Nahcolite..................	(wt. pct.)	14.8
Dawsonite..................	(wt. pct.)	11.6

In relatively recent years, a number of process and cost evaluations of hypothetical oil-shale industries have been made by the Bureau of Mines and others. In making such studies, it has been possible to base the crushing, screening, briquetting, and retorting steps on a considerable amount of experimental data derived from various investigations in which typical Green River oil shale was actually processed in equipment ranging in size from laboratory scale to large pilot or engineering scale. In contrast, only a meager amount of small-scale work is known to have been done with materials containing significant amounts of nahcolite and dawsonite such as that characterized above. Consequently, it was necessary in designing and specifying the operating results of the crushing, screening, and retorting facilities that are described in the immediately following sections of this report to rely heavily upon engineering judgment rather than directly-applicable experimental results. In general, equipment requirements and operating characteristics were estimated by drawing upon known experience with more typical Green River oil shales, taking into account the expected effects of the nahcolite and dawsonite components. In the latter regard, it was necessary to estimate such factors as changes in unit heat requirements stemming from anticipated compositional changes during retorting and the operational effects of large releases of carbon dioxide and water from such decomposition reactions.

Further aggravating the retort design problems, a heating system was adopted in this study that involves circulation through the retort of hot gases rather than use of the internal combustion feature that typifies most recent retorting experience. This modification was considered necessary in order to achieve adequate control of temperatures, believed to be a critical factor in the subsequent efficiency of sodium minerals processing as discussed more fully later.

Possibly more important, if one were seriously contemplating an actual commercial operation involving a retorting complex such as is described, is the question of whether or not the 46-ft-in-diameter units visualized for the purposes of this study could actually be operated as effectively as is optimistically assumed (an on-stream efficiency of 90 percent and an oil yield of 100 percent of Fischer assay when operating at a unit throughput rate of about 500 pounds of shale per hour per sq ft of cross sectional area). Although relatively small experimental operations indicate the possibility of efficiencies of this degree, no unit even approaching the size visualized has actually been demonstrated on typical oil shale let alone on material containing high concentrations of nahcolite and dawsonite.

Crushing and Screening

The shale from the stockpile (60,000 tons per calendar day) is fed to a belt conveyor (located in a tunnel under the stockpile) by apron feeders. The minus 10-1/2-inch material is fed to a surge bin and then by apron feeders over grizzly bar screens for removal of undersize before being fed to the secondary crushers. The crusher product at minus 4-1/2 inches along with the undersize from the grizzlies flows to a surge bin where the stream is divided and fed by apron feeders over vibrating screens for removal of undersize prior to the tertiary crushers. The product from the crushers along with undersize material at minus 3 inches is conveyed to 24-hour storage, provided by two surge bins. Figure 11 is a schematic flow diagram of the crushing and screening plant.

The shale from the surge storage is fed by apron feeders onto a belt conveyor which transports it to the screen house. The shale is received in surge bins and then fed by apron feeders to eight parallel double-deck vibrating screens. The screens separate the plus 3/16-inch minus 3-inch fraction from the fines. The coarse shale is sent to intermediate storage for transport to the retorts. The fines, also, are sent to storage and are then conveyed to the minerals processing plant.

An allowance of 600 tons per calendar day is made for dust loss which is removed by a dust control system.

The coarse shale fraction amounts to 51,550 tons per calendar day and 7,850 tons per calendar day are fines.

The fines after leaching in the minerals plant are recycled to the retort feed stream. This recycle stream amounts to 5,187 tons per calendar day of shale plus 1,678 tons per calendar day of moisture on the leached shale fines. Of this recycle stream 86.5% is fed directly to the retorts and 13.5 percent is used in the briquetting plant.

Briquetting Plant

Part of the recycled fines (4,487 tons per calendar day, dry basis) are returned directly to the retort feed stream. The rest (700 tons per calendar day, dry basis) are dried, mixed, and briquetted with 318 barrels per calendar day of crude shale oil to produce 750 tons per calendar day of briquettes which are fed to the retort. The dried shale fines are conveyed to a surge bin and by vibratory feeders to a hammermill which reduces them to minus 14-mesh. The shale is conveyed to a surge bin from which it is fed to a mixer to be mixed with crude shale oil (binder). The material flows by gravity from the mixer to a briquetting machine. The briquettes are conveyed to a surge bin and then to the retorts.

Retorting Plant

The shale is retorted in seven retorts, each 46 ft in diameter (see figure 13), patterned generally along lines of the Petrosix retort. These retorts are equipped with the Cameron and Jones improved feeding and discharge mechanisms. The process is discussed in general terms and the feeding and discharge mechanisms are described in detail in "The Colorado School of Mines Quarterly," v. 60, No. 3, July 1965, in a paper presented at the Second Oil Shale Symposium. The Petrosix process was chosen as it allows more precise temperature control and maintenance of a lower peak temperature in the shale bed than does an internal combustion type such as the Gas Combustion retorting process. This factor is discussed in more detail later.

The shale from the crushing and screening plant, the briquetts from briquetting, and the remainder of the recycle fines are fed to the surge bins at the retorting plant. The shale from the surge bins is fed by bucket elevators to the feed hoppers atop the retorts.

The retorts process 58,239 tons per calendar day of coarse shale, briquettes and wet recirculated fines, including the moisture on these fines, and produce 52,354 barrels of crude shale oil and 41,678 tons of retorted shale per calendar day. On a moisture-free basis, the charge rate is 56,787 tons per calendar day, including briquettes.

The shale bed is maintained at a depth of about 20 feet and the heat required for retorting is supplied by a hot recycle gas stream at 1,350°F which is injected into the bed about 6 feet above the bottom. This recycle gas is heated by direct fired gas heaters fueled with retort product gas. A cold recycle gas stream is fed to the bottom of the shale bed to cool the retorted shale prior to discharge.

The shale is fed to the top of the retorts and is heated to approximately 1,000°F by contact with the countercurrent hot recycle gas. By the time the shale reaches this temperature, it is completely retorted. Before the material reaches this temperature the nahcolite and dawsonite undergo degradation reactions due to heat, forming sodium carbonate and sodium aluminate with evolution of carbon dioxide and water vapor. The chemical reactions are as follows:

$$2NaHCO_3 \longrightarrow Na_2CO_3 + CO_2 + H_2O$$

$$NaAl(OH)_2CO_3 \longrightarrow NaAlO_2 + CO_2 + H_2O$$

It is important that the temperature not be allowed to rise much above 1,000°F to avoid further reactions that would occur at higher temperatures, resulting in impairment of the extractability of the sodium and aluminum mineral values.

The 130°F gas from the top of the shale bed with entrained crude shale oil is sent through rotoclones and electrostatic precipitators for oil removal. The gas stream then flows to blowers where it is compressed to 1.6 psig. Subsequently, it is divided into the recycle gas stream and the make gas stream. Most of the latter gas is burned in the recycle-gas heater: excess gas is used in the steam plant. (See figures 10 and 13.)

The recycle stream is then split into two streams: 913,836,000 std cu ft per calendar day is sent through the recycle blower to the recycle-gas heater where its temperature is raised to 1,350°F for injection into the shale bed: and 857,076,000 std cu ft per calendar day at 130°F is sent to the bottom of the retort. The recycle blower compresses the gas to 2.1 psig.

The spent shale is sent to a storage pile and then to the sodium-minerals plant. The crude shale oil, via a storage system, is charged to the refinery.

REFINING

The crude shale oil, produced at a rate of 52,354 barrels per calendar day in the "study" retorting plant, is characterized on the basis of laboratory retorting and inspection work by the U.S. Geological Survey and the Bureau of Mines, as follows:

Characteristics of Crude Shale Oil

Gravity..................... (°API)	24.8
Sulfur.................. (wt. pct.)	0.63
Nitrogen................ (wt. pct.)	1.76
Pour point..................... (°F)	70
Viscosity......... (S.U.S. @ 100°F)	64

The oil is further characterized by a black color and rather disagreeable odor typical of Green River shale oil.

As has been generally recognized in earlier studies, such oils require upgrading to yield an oil suitable for transport by pipeline, a necessary step if any significant market is to be claimed. In the current study, a two-step refining sequence was adopted, consisting of recycle delayed coking of the raw oil followed by hydrocracking of the coker distillate to yield 46,113 barrels per calendar day of a high quality pipeline oil as the major product. This oil, discussed and characterized later in more detail along with other products, is comparable to that for which a value of $3.08 per barrel was set on the basis of industry judgment in the 1968 report of the Department of the Interior, "Prospects for Oil Shale Development: Colorado, Utah, and Wyoming."

The refinery visualized for study purposes is located adjacent to the retorting plant in the general processing area overlying the mine.

Of the various segments of the visualized complex, the refining steps are probably the least conjectural. By virtue of a variety of work by industry as well as the Bureau of Mines, the applicability of coking and hydrogenation processes to shale oil has been reasonably well demonstrated on scales ranging from laboratory to a full-scale test in a commercial refinery several years ago. Thus, although many details such as precise operating conditions and hydrogen requirements undoubtedly would warrant further consideration to arrive at the optimum situation for an actual commercial venture charging the particular oil in question, the general refinery design and operating results specified in the following sections are considered adequate for the present evaluation purposes.

Delayed Coking

The crude shale oil from the retorting plant constitutes the feed to the refinery. The oil is first processed in a delayed coking unit with a heater outlet temperature of 940°F and a coke chamber pressure of 30 psig. The products include a coker distillate, stabilized to retain the C4's produced and having an end point of 680° to 700° F, plus a good quality coke suitable for sale as green metallurgical grade material. In addition, the C3's and lighter fraction contain an appreciable amount of hydrogen sulfide which is recovered and also serves as a source of hydrogen. The sulfur recovery and hydrogen producing plants will be described later.

Hydrocracking

The coker distillate is further processed by hydrocracking at 835° F and 1,500 psig, maintaining a liquid-hourly-space velocity of 0.9. The system is typified generally by the Union Oil Companys' Unicracking-JHC process, featuring a sulfur and nitrogen resistant, Cobalt-molybdate type catalyst. Hydrogen consumption is about 1,300 scf per barrel of feed, and the hydrogen recycle is about 800 scf per barrel. The major product from hydrocracking is a 56.9° API distillate containing essentially no sulfur or nitrogen and containing about 60 volume percent material in the gasoline boiling range and 40 volume percent material in the diesel fuel boiling range which also meets other D-2 diesel specifications. The overall hydrogenated distillate contains all C4's and heavier material produced to a final boiling point of from 680° to 700°F.

The hydrocracker gas is relatively rich in hydrogen sulfide and ammonia due to the hydrogenation of the sulfur and nitrogen contained in the distillate charge. The sulfur and ammonia are both recovered and sold as byproducts.

The hydrogen requirement is produced by reforming the coker and hydrocracker off-gas after removal of hydrogen sulfide as described later.

Ammonia and Sulfur Recovery

The sulfur and ammonia products come from the coker and hydrocracker gases, the former containing 1.75 to 1.80 mole percent hydrogen sulfide and the latter containing approximately 4 mole percent hydrogen sulfide and in excess of 20 mole percent ammonia. The recovery system involves scrubbing the coker and hydrocracker gases with aqueous solutions recycled in a closed circuit within the sulfur and ammonia plants. The rich scrubber liquids are fed together to a hydrogen sulfide stripper, the overhead fraction (rich in hydrogen sulfide) is sent to a conventional Claus plant for sulfur recovery. The bottom stream from the hydrogen sulfide stripper, rich in ammonia, is again stripped to separate the ammonia from the bulk of the water and a small amount of residual hydrogen sulfide, then the ammonia is dried and liquefied for storage and sale.

The fuel gas produced contains the excess gas from coking, the sweet tail gas from the hydrogen plant, and the purified gas from hydrocracking. The total fuel gas has a heating value of about 23.2×10^9 Btu per calendar day and a unit heating value of 1,218 Btu per std cu ft.

All parts of the refining system operate with an on-stream efficiency of 95 percent including the coking plants. Although the coking units are cyclic in nature, they operate continuously; as one coker is removed from the flow pattern a decoked chamber is brought into service without disruption of the onstream schedules.

The integrated flow pattern and material balance for the refinery is shown in Figure 14.

MINERALS PROCESSING, WHITE NAHCOLITE

Nahcolite Preparation

The area visualized for the white nahcolite processing facility overlies a portion of the mine area as shown in figure 1.

The process adopted for this evaluation, shown schematically in figures 15 and 16 is designed to effect recovery of dense soda ash (sodium carbonate) having an estimated purity of 99.9 plus percent as the marketable product, starting with the stockpiled white nahcolite provided by the previously described mining operation. Four principal processing steps are involved: Nahcolite preparation, including calcining; leaching; crystallization; and product dehydration.

Characterization data for the raw white nahcolite were provided by the U.S. Geological Survey. In the absence of a comprehensive sampling program such as would be needed to define mining and processing parameters with a high degree of assurance it was assumed that a composite sample obtained and analyzed by the Geological Survey, through the white nahcolite section at one location typifies the average 9-ft measure adopted for the mining evaluation as discussed earlier. Inspection of this sample indicated an in-place specific gravity of

2.24, a potential oil yield by Fischer assay of 4.8 gallons per ton, and cold water solubility data as follows:

Cold-water insolubles, wt %	15.52
Cold-water-soluble ions,	
wt. % of original material:	
CO_3	6.34
HCO_3	48.00
Na	23.09
Cl	0.13
SO_4	0.10
Ca	0.01
Mg	Negl.
K	<0.01
Al	Negl.
Total	93.20
Water (assumed)	6.80

The above data, supplemented by pertinent fundamental chemical and physical property data and by published information concerning closely allied processes such as recovery of soda ash from trona, were used by the Bureau of Mines as bases for estimating process requirements for purposes of the present evaluation. In the absence of actual industrial experience or even pilot plant results for processing white nahcolite, it also was necessary to assume plant operating parameters in many instances, basing values on knowledge of typical equipment performance and general engineering judgment. Such values as settling rates in thickeners, solids contents of filter and centrifuge cakes, and dust losses in crushing and calcining were generally set in this manner.

A detailed description of each process step in the white nahcolite plant follows:

White nahcolite ore is recovered from beneath the mine stockpile by pushing it onto one of six apron feeders with a bulldozer. The feeders are so spaced as to reduce the amount of bulldozing required and are sized so that only one is needed to supply the plant at any time. A 30-inch, 675-ft-long belt conveyor transports the ore from the feeders to a hopper above the primary hammermill. The ore is crushed in the hammermill from minus five inches to one inch and is conveyed to a hopper above two secondary hammermills operating in parallel. These hammermills reduce the ore to 1/8 inch. The 1/8-inch ore falls directly onto vibrating screens from which plus 1/8-inch ore is recycled to the hopper above the secondary hammermills, and minus-1/8-inch ore is conveyed to storage silos. Figure 16 is a flow diagram of the white nahcolite processing plant.

The minus-1/8-inch ore from the silos is conveyed to hoppers which feed three 12.5- by 249-foot gas-fired rotary calciners operating at 1,000° F. The sodium bicarbonate contained in the nahcolite is decomposed to sodium carbonate by the following reaction:

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2.$$

The greatly increased solubility of sodium carbonate facilitates the following leaching step. Although decomposition will occur below 1,000°F, this temperature is used so that all of the organics present in the raw material are burned. The organics, if left in the system, would cause foaming in crystallization and would discolor the product, judging from experience in the trona industry. A credit for the heat of combustion for the organics is included in the heat calculations for calcining. The sodium carbonate is cooled to 150°F in rotary coolers and is conveyed to a hopper in the leaching section.

Dust collection equipment is included for all conveyor transfer points, hammermills, and screens. Separate systems are designed for the raw nahcolite before calcination and for the calcined material. Separate bag collectors are used for each. Material balances and flows in nahcolite preparation section are shown in figures 17 and 18.

Leaching

Calcined material is fed from a hopper into an agitated leach tank operating at 100°F where the sodium carbonate and other water soluble compounds are dissolved during a 15 minute period. Steam is added directly to the leach tank to maintain the temperature. It is assumed that the water soluble components dissolve under the above conditions.

From the leach tank, the slurry is pumped to a 240-ft diameter settler where the insolubles settle at a rate of 0.6 ft per hour and are removed in the underflow which contains 48.5 percent solids. The settler underflow is washed countercurrently in four 170-ft diameter thickeners from which the underflow is pumped to a tailing pond, and the overflow is recycled to leaching. The same settling rate and solids content are used in sizing the countercurrent wash thickeners as were used in sizing the settler. Condensed water from the carbonate crystallizers is used for washing.

Overflow pregnant solution from the settler is clarified in pressure leaf filters at a rate of 500 gallons of filtrate per sq ft per day to remove any solids that were not removed during settling and is pumped to surge tanks before crystallization. The filter cake contains 50 percent solids. The materials balance and general flow diagram for leaching are shown in figures 19 and 20.

Crystallization

Fifty-five percent of the sodium carbonate in the pregnant solution from the leaf filters is crystallized from solution as sodium carbonate monohydrate in a seven-effect forced-circulation evaporator. The last effect is maintained at 1.6 inches mercury, and 100 psig steam is used in the first effect to give a temperature difference of about 29°F per effect. A heat-transfer coefficient of 450 Btu per hr-sq ft-°F is used for sizing the crystallizer.

Based on solubility data[4] at 68°F, the solubility of sodium carbonate is estimated to be 29.5 grams per 100 grams of saturated solution at 100°F when considering the effect of sodium chloride and sodium sulfate which are also present in the solution. Water evaporated during crystallization is condensed and used as wash water in the countercurrent wash thickeners. It is assumed that the slurry withdrawn from the crystallizer would have the same 30 percent solids content as the slurry processed by the trona industry.[5]

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[4]Linkl, W. F. Seidell's Solubilities of Inorganic and Metal Organic Compounds, v. 2, 4th ed., Am. Chem. Soc., 1965, pp. 933-944.

[5]Sommers, H. A. Soda Ash from Trona. Chem. Eng. Prog., v. 56, No. 2, February 1960, pp. 76-79.

Cooling water requirements for the crystallizer's condenser and ejector are supplied by a cooling tower. The tower operates at a wet bulb temperature of 65°F with hot and cold water temperatures of 89° and 70°F respectively. The wood-filled tower has a circulation rate of 13,409 gallons per minute and process makeup water requirement of 408,000 gallons per day.

The crystal slurry from the crystallizer is pumped to four 54-inch bowl centrifuges where the monohydrate crystals are separated from the mother liquor, washed with 110°F water, and conveyed in screw conveyors to drying. During washing 2 percent of the monohydrate crystals is assumed to dissolve and 85 percent of the mother liquor is washed free.

To avoid excessive chloride and sulfate impurities in the product, 2.5 percent of the mother liquor is discarded as a purge solution. The remaining mother liquor is recycled to leaching.

The material balance and equipment flow diagram are shown in figures 21 and 22.

Drying and Product Storage

The centrifuged cake, containing about 4 percent solution, is fed into four 12 by 108 ft gas-fired rotary dryers operating at 600°F. During drying, moisture and water of crystallization are driven off. Dehydration of the monohydrate crystals to form soda ash may be represented by the following reaction:

$$Na_2CO_3 \cdot H_2O \longrightarrow Na_2CO_3 + H_2O.$$

The monohydrate crystals are assumed to decompose to the dense form of soda ash having the following composition as determined by a material balance.

	Percent
Na_2CO_3	99.93
NaCl	0.05
Na_2SO_4	.02
	100.00

Soda ash from the dryers is cooled in rotary coolers to about 150°F and conveyed to storage silos on a 24-inch belt conveyor.

Ten 100,000 cu ft silos provide storage for up to 7 days. The product is loaded into covered hopper cars by belt feeders from the silos. The product loading system operates one shift 5 days per week. The materials balance and general flow diagram are given in figures 23 and 24.

MINERALS PROCESSING, RETORTED SHALE

Complementing the white-nahcolite processing facilities described in the preceding section of this report, an independent and relatively complex processing sequence is required to recover the soda ash and alumina values stemming from the nahcolite and dawsonite contained in the 60,000 tons per calendar day of ore mined from the dawsonite-rich zone. Figure 25 shows a general flow diagram of the sodium minerals plant.

Two raw feed streams are involved: The retorted shale, which comprises the bulk of the charge to minerals processing and which contains extractable sodium carbonate and sodium aluminate derived from the nahcolite and dawsonite present in the original raw material; and a stream of unretorted fines diverted from the crushing and screening section of the retorting plant. This fines stream, sized to 3/16-inch and smaller particles, is relatively rich in nahcolite in comparison to the original ore by virture of the tendency of this mineral to decrepitate more readily in crushing than does the oil shale itself.

Briefly, the processing afforded the shale fines stream involves calcining to convert the nahcolite to sodium carbonate, leaching to dissolve the sodium carbonate, separation of the solution from the undissolved shale, crystallization and final conversion of the sodium carbonate (monohydrate form) to soda ash, and return of the undissolved shale fraction to retorting. Ultimately then, the shale portion of the fines makes up a part of the retorting charge and in retorted form is returned to the minerals processing plant as a part of the total spent or retorted shale that constitutes the major flow stream through this plant.

The spent shale is crushed and then is leached with weak caustic solution to dissolve its alumina and soda content. The solution is separated from the undissolved residue; this residue constitutes the major portion of the solid waste disposed of in the mine. The solution is treated with lime to reduce its silica content and is carbonated to precipitate aluminum trihydrate. The latter material is separated from the soda-rich mother liquor and is calcined to yield alumina as one of the final products.

The mother liquor mentioned above, combined with the sodium carbonate solution from the shale fines processing line, is evaporated and crystallized to produce sodium carbonate monohydrate which subsequently is calcined to form dense soda ash, the second sales product of the sodium minerals plant.

Each step of the processing scheme is detailed in the following descriptive sections of this report and in the pertinent tables and diagrams that are referenced later. Overall, design of the retorted-shale section of the sodium minerals complex is based on charging 43,464 tons per operating day of retorted shale plus 8,186 tons per operating day of dawsonite-rich shale fines, yielding 1,834 tons per operating day of alpha-alumina and 7,802 tons per operating day of dense soda ash. Adding the soda ash product from processing the white nahcolite, as previously discussed, the total soda ash product is 12,047 tons per operating day. The plant is assumed to operate 350 days per year for an onstream efficiency of 95.89 percent. On a calendar-day basis, then, the daily yields of alumina and soda ash are 1,759 tons and 11,552 tons, respectively.

Except for product loading and limestone receiving operations, which are handled on an eight-hour-per-day, five-day-per-week basis, normal plant operation is round-the-clock and seven days per week.

In addition to characterizing the material mined from the dawsonite-rich zone as containing 14.8 weight percent nahcolite and 11.6 weight percent dawsonite as discussed under "Retorting," the U.S. Geological Survey provided the following data for water-soluble ions of particular interest as potential impurities to be coped with in the sodium minerals plant:

Cold-Water-Soluble Ion Characterization,
Dawsonite-Rich Zone

Chloride..................	(wt. pct.)	0.05
Sulfate....................	(wt. pct.)	0.23
Calcium....................	(wt. pct.)	0.05
Magnesium..................	(wt. pct.)	Trace
Potassium..................	(wt. pct.)	Trace

At the low concentrations indicated, "impurities" were not considered significant in design or other considerations, other than to account in the material balances for the sulfate. Additional analytical data used for design purposes included a variety of test results obtained by the Bureau of Mines on retorted samples of the same "dawsonite-rich" material. The retorting work was performed by the U.S. Geological Survey using small bench scale equipment in which low-temperature, indirect-heating conditions were achieved in simulation of the conditions visualized for the plant-scale retorts described earlier.

The laboratory data mentioned above, supplemented by published information ranging from standard chemical and physical property data to technical articles relating to pertinent operations in the trona and alumina industries, were used in designing and judging the capabilities of the retorted-shale sodium minerals plant. In much the same manner as was true in respect to the white-nahcolite plant, it also was necessary in many instances to rely on engineering judgment in setting such factors as performance of particular items of equipment, since industrial and/or pilot-plant experience using the particular raw material in question is lacking. A rigorous design for construction and operation of an actual plant of the scale visualized obviously would require considerably more information, from pilot or preferably prototype operations in particular.

Data sources as well as operating conditions, equipment performance parameters and the like that were set for estimating purposes are detailed in a step-by-step manner in the following descriptive sections of this report.

Retorted Shale Crushing

The spent shale is conveyed from the retorting operation to hoppers above hammermills which reduce the material to 1/8 inch. Crushed material from the hammermills flows by gravity to vibrating screens. Plus 1/8-inch material is recycled to the hammermills, and minus 1/8-inch material is conveyed to hoppers in the leaching section. The material balance and equipment flow diagram are shown in figures 26 and 27.

A cyclone dust collection system is included for minimizing dust losses from conveyor transfer points, hammermills, and screens. The system is located so that the dust is fed into hoppers above the retorted shale leaching step.

Retorted Shale Leaching

Minus 1/8-inch material and recovered dust from the retorted shale crushing section is fed into leaching tanks operating at 100°F. The alumina and soda content is dissolved by 0.8 normal sodium hydroxide solution[6] during a 15 minute period. It is assumed that the alumina and soda, originally present in the raw shale as dawsonite and/or nahcolite, are present as sodium aluminate, $NaAlO_2$, and sodium carbonate, Na_2CO_3. During leaching 99 percent of the soda originally present as nahcolite, and 95 percent of the soda and 78 percent of the alumina originally present as dawsonite are dissolved.[7]

The dissolved material is separated from the undissolved material in settlers having a settling rate of about 0.7 foot per hour,[7] and the solution is clarified in pressure leaf filters that are designed on the basis of 500 gallons of filtrate per sq ft per hour.

Underflow from the settlers, containing 48.5 percent solids,[7] is washed countercurrently in wash thickeners whose underflow, also containing 48.5 percent solids, is pumped to tailings disposal.

Overflow from the wash thickeners is recycled to leaching. Because the overflow contains sodium carbonate, lime is added during leaching to causticize the sodium carbonate according to the following reaction:

$$Na_2CO_3 + CaO + H_2O \longrightarrow 2NaOH + CaCO_3.$$

The sodium hydroxide formed is considered part of the 0.8 normal solution used for leaching. It is assumed that 80 percent of the alumina entering the process with the lime forms sodium aluminate.

A material balance and an equipment flow diagram are shown in figures 28 and 29 respectively.

[6]Nielsen, Irvin. Importance of Deep Deposits of "Oil Shale" and Sodium Minerals in Northwest Colorado. Paper presented to Colorado Plateau Section of the AIME, May 24, 1968.

[7]Laboratory data, College Park Metallurgy Research Center, College Park, Md.

Desilication

Clarified solution from the pressure leaf filters contains silica equivalent to 0.0025 percent of the retorted shale charge to leaching for the nahcolite-rich zone process.[8] This silica must be removed or it will contaminate the products. Lime is added to the solution in lime slakers and is pumped to desilication tanks operating at 176° F. During a 30-minute retention period the silica precipitates as does three percent of the alumina in the solution.[9]

The desilicated solution is separated from the residue in settlers having a settling rate of 135 pounds per sq ft per hr. Underflow from the settlers, containing approximately 50 percent solids, is washed in thickeners. The underflow from the thickeners is pumped to tailings disposal. Overflow from the settlers is clarified in pressure leaf filters, designed on the basis of 500 gallons of filtrate per sq ft per hr, combined with overflow from the wash thickeners, and pumped to storage tanks.

The material balance and equipment flow diagram are shown in figures 30 and 31.

Alumina Precipitation and Calcination

The desilicated solution from desilication is carbonated at 194° F for 12 hours.[10] A "seed" solution containing alumina as alumina trihydrate, the alumina being equivalent to about 25 percent of the

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[8]Work cited in footnote 7.

[9]Copson, R. L., J. H. Walthall, and T. P. Hignett. Progress Report on the Extraction of Alumina From Clays by the Lime-Sinter Modification of the Pedersen Process. PB57498, Jan. 14, 1944.

[10]Work cited in footnote 9.

alumina present in the desilicated solution, is added to carbonation. During the 12-hour retention period 85 percent of the alumina in the desilicated solution precipitates as alumina trihydrate[11] using the "seed" alumina trihydrate as nuclei. The precipitation reaction is as follows:

$$2NaAlO_2 + CO_2 + 3H_2O \rightarrow Al_2O_3 \cdot 3H_2O + Na_2CO_3.$$

In addition to the precipitation reaction the sodium hydroxide in the solution is converted to sodium carbonate following the reaction:

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O.$$

Coarse alumina trihydrate is separated from the "seed" in a primary thickener having a settling area of 12 sq ft per ton of dry solids per day.[12] Overflow from the primary thickener is settled in a secondary thickener having a settling area of 30 sq ft per ton of dry solids per day.[12] Underflow from the secondary thickener, containing 45 percent solids,[13] is recycled to carbonation as "seed" while the overflow is pumped to the soda ash crystallization and dehydration section.

Underflow from the primary thickener, containing 55 percent solids,[13] is washed in wash tanks in series and is filtered in internal

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[11]Peters, F. A., P. W. Johnson, J. J. Henn, and R. C. Kirby. Methods for Producing Alumina from Clay, An Evaluation of a Lime-Soda Sinter Process. BuMines Rept. of Inv. 6927, 1967, 38 pp.

[12]Perry's Chemical Engineers' Handbook, ed. by R. H. Perry, C. H. Chilton, and S. D. Kirkpatrick. McGraw-Hill Book Co., Inc., New York, 4th ed., 1963, pp. 19-49.

[13]Peters, F. A., P. W. Johnson, and R. C. Kirby. A Cost Estimate of the Bayer Process for Producing Alumina. BuMines Rept. of Inv. 6730, 1966, 23 pp.

drum filters having a filtering rate of about 2 tons of dry solids per sq ft per day. The filter cake, containing 75 percent solids, is calcined at 2,000°F in gas-fired rotary kilns to produce α-alumina according to the reaction:

$$Al_2O_3 \cdot 3H_2O \longrightarrow Al_2O_3 + 3H_2O.$$

The alumina product is cooled to 150°F in rotary coolers and conveyed to silos having a total capacity for 14 days production. Belt feeders feed the alumina into covered hopper cars for shipping.

A cyclone dust collector is included for minimizing dust losses from all conveyor transfer points. The material balance and flow diagram are shown in figures 32 and 33.

Shale Fines Leaching

Raw oil shale fines, containing nahcolite, is conveyed from the retorting operation to hoppers feeding gas-fired rotary kilns operating at 460°F. The nahcolite is calcined to produce sodium carbonate by the reaction:

$$2NaHCO_3 \longrightarrow Na_2CO_3 + CO_2 + H_2O.$$

The sodium carbonate is cooled to 150°F in rotary coolers and conveyed to a hopper above a leaching tank. Sodium carbonate is dissolved at 100°F in water during a 15 minute period and is then separated from the undissolved material in a settler having a settling rate of approximately 0.6 ft per hr.[14] Underflow from the settler, containing 48.5 percent solids, is washed in a thickener whose underflow, also containing 48.5

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[14]Work cited in footnote 7.

percent solids, is filtered on rotary vacuum filters having a filtering rate of approximately 76 pounds of dry cake per sq ft per hr.[14] The filter cake, containing 75 percent solids, is conveyed to the retorting operation. Filtrate from the filters is used in the wash thickener, and overflow from the wash thickener is recycled to leaching. The material balance and equipment flow diagram are shown in figures 34 and 35.

Overflow from the settler is clarified in pressure leaf filters designed on the basis of 500 gallons of filtrate per sq ft per hr and is then pumped to the soda ash crystallization and dehydration section.

Soda Ash Crystallization and Dehydration

Overflow from the secondary thickener in the alumina precipitation and calcination section and sodium carbonate solution from the shale fines leaching section are mixed, and the resultant solution is evaporated in 7-effect crystallizers to crystallize sodium carbonate monohydrate according to the reaction:

$$Na_2CO_3 + H_2O \rightarrow Na_2CO_3 \cdot H_2O.$$

The last effect of the crystallizers operates at 100° F, equivalent to about 28 inches mercury vacuum.

The material balance and equipment flow diagram are shown in figures 36 and 37.

The crystal slurry, containing 30 percent solids,[15] is pumped to continuous centrifuges where the crystals are separated from the saturated solution, which contains about 33.7 percent sodium carbonate,[16]

[14]Work cited in footnote 7.
[15]Work cited in footnote 5.
[16]Work cited in footnote 4.

and washed. During washing, some of the sodium carbonate monohydrate dissolves. The cake from the centrifuge, containing 4 percent moisture, which includes some aqueous sodium carbonate, is calcined at 600°F in gas-fired rotary dryers to drive off the moisture and to produce dense soda ash by the reaction:

$$Na_2CO_3 \cdot H_2O \longrightarrow Na_2CO_3 + H_2O.$$

The product is cooled to 150°F in rotary coolers and is conveyed to silos having a total capacity for about 14 days operation. Two belt feeders for each silo feed the soda ash into covered hopper cars for shipping.

The solution from the centrifuge is divided with part recycling to the crystallizers and the rest going to the sodium sulfate removal step. In the sodium sulfate removal step lime is added to the solution to react with sodium sulfate and with sodium carbonate. The reactions involved are as follows:

$$Na_2SO_4 + CaO + 3H_2O \longrightarrow 2NaOH + CaSO_4 \cdot 2H_2O,$$

and,

$$Na_2CO_3 + CaO + H_2O \longrightarrow 2NaOH + CaCO_3.$$

The caustic solution, thus produced, is filtered on rotary vacuum filters, having a filtering rate of 50 pounds of dry cake per sq ft per hr, to remove the solids. The cake, containing 55 percent solids, is washed, repulped with raw water (not shown in the material balance) which reduces the solids content to approximately 39 percent, and the slurry is pumped to tailings disposal. Filtrate from these filters is diluted with water and pumped to storage tanks in the retorted shale leaching section.

OPTION III

Water evaporated from the last effect of the crystallizers is condensed in barometric condensers and is recycled with the cooling water to a cooling tower in closed circuit with the crystallizers. This condensed water is considered as part of the makeup water required in the cooling tower. Water condensed in the last 6 effects of the crystallizers is recycled for use within the process. Steam condensed in the first effect is returned to the steam plant.

A cyclone dust collector is included for minimizing dust losses from conveyor transfer points, and the dust is returned to hoppers feeding the rotary dryers.

Limestone Calcination and Flue-gas Processing

Limestone is received by rail and is stored in the open in a storage area capable of holding a 14-day supply. The limestone is withdrawn from storage on apron feeders located at various positions under the storage area. Any one of the feeders is capable of withdrawing limestone at the required rate for the process. The limestone is conveyed from the feeders to a hopper feeding a standard-head cone crusher which reduces minus 5 inch limestone to 1 inch. This ore is conveyed to a hopper feeding short-head cone crushers which further reduce the ore to 1/4 inch. This 1/4-inch material flows by gravity onto a vibrating screen where the plus 1/4-inch material is removed and recycled to the hopper feeding the short-head cone crushers. The minus 1/4-inch material is conveyed to hoppers above gas-fired rotary kilns that operate at 2,200°F. The minus 1/4-inch limestone is fed into the kilns where the calcium carbonate decomposes to lime by the reaction:

$$CaCO_3 \longrightarrow CaO + CO_2,$$

and the silica reacts with lime to form insoluble dicalcium silicate according to the reaction:

$$2CaO + SiO_2 \rightarrow 2CaO \cdot SiO_2.$$

The burnt lime product is cooled to 150°F in rotary coolers and conveyed to silos where it is stored for further use in the process.

A cyclone dust collector is included for minimizing dust losses from conveyor transfer points, crushers, and screens.

Flue gas from the rotary kilns contains a large quantity of carbon dioxide which is used for carbonation in the alumina precipitation and calcination section. The flue gas is cooled from 1,100°F to 350°F in waste-heat boilers to recover heat as 100 psig steam.

Part of the flue gas, the percentage being based on the quantity of carbon dioxide required for carbonation, is passed into gas scrubbers where any remaining dust is removed, and the gas is cooled to 90°F. This washed flue gas is compressed to 50 psig and the temperature of the gas from the compressor is maintained at approximately 194°F. The compressed flue gas supplemented by carbon dioxide from the hydrogen plant serving the refinery (see figures 14 and 38) is fed to the carbonation section.

Cooling water used to cool the flue gas in the gas scrubbers along with water condensed out of the flue gas is pumped to a cooling tower in closed circuit with the gas scrubbers. Water used for cooling in the compressors is cooled in a cooling tower in closed circuit with the compressors.

Flue gas not required for use in carbonation is vented to the atmosphere ahead of the gas scrubbers. The material balance and equipment flow diagram are shown in figures 38 and 39.

WASTE DISPOSAL

General

The solid wastes produced by processing of the white nahcolite and the dawsonite-rich material are disposed of underground in mined-out areas, including space in both the white nahcolite mine and the shale mines. This material is piped in the form of a slurry from the plant area to the desired underground location and allowed to settle. The liquid which "bleeds" from the slurry as it settles is collected and returned to the surface for treatment and reuse as process water. Ultimately, all solid wastes are accommodated in this manner as mine fill; however, it is necessary during the early life of the project to store a portion of the wastes in temporary surface ponds, as certain of the mine workings cannot be filled immediately.

Other waste streams, such as the relatively small amount of purge solution from the white-nahcolite processing plant, tank drainings, and the like, are impounded on the surface in ponds or diked areas designed to safeguard against pollution of the surrounding terrain and natural water courses.

Basis and Procedure for Mine Waste-Disposal Concept

It is estimated that the solids content of the waste slurries generated in the sodium minerals complex will range in particle size from about 1/4-inch to dust, with the bulk of the material falling in the size range of 8 to 20 mesh. The combined slurry from all sections of the complex, made up of 47.6 weight percent solids and the balance water, is judged to be readily pumpable. When allowed to settle undisturbed over a period of time, the slurry is estimated to dewater to an ultimate composition by weight of 80 percent solids and 20 percent water, in which state the material is assumed to be reasonably stable, compositionally and structurally, although it has little support strength. The bulk density in this ultimate state is approximately 100 pounds per cu ft.

Information from published sources,[17] augmented by the judgment of BuMines mining research personnel, indicates that the waste material described above will be suitable for disposal as fill in the mine. It is judged further that the initial slurry will not exhibit undue abrasive or corrosive effects in regard to pumps and piping: thus, delivery to the desired mine location via a piping system is adopted as the most feasible approach in this evaluation.

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[17] Colorado School of Mines Research Foundation, Inc. Transportation of Solids in Steel Pipelines, 1965.

Babcock, Henry A. Test Work and Data Required for Slurry Pipeline Design. Paper presented to 1967 AIME Conference.

Wayment, W. R. Correspondence dated Aug. 19, 1968. Spokane Mining Research Laboratory.

The waste slurry from the sodium minerals complex is produced at a rate of 83,187 tons per calendar day, representing 39,597 tons of solids or 49,496 tons of 80 percent solids fill. The various streams from individual sections of the complex are piped to a surge pond sized to accommodate 10 hours' production and provided with agitation equipment to achieve uniformity of mixture and to prevent premature settling. Fron this point, mine personnel assume responsibility for handling, pumping the mixture underground on a normal schedule of 6 hours per shift or 18 hours per calendar day. Transport to the general areas to be filled is via four 12-inch steel lines, with extendible, readily movable, sections of 12-inch plastic piping suspended from the mine roof being used to deliver the slurry to the specific locations within panels or elsewhere as desired. Line sizing is such that under normal pumping rates the suspended slurry will not tend to separate enroute to its point of deposition. In addition, one 12-inch line is required for return of "bleed" water to the surface, and one spare line is provided for handling slurry or water as desired should normal schedules be disrupted or other emergency situations occur.

The general operating plan involves discharge of slurry behind timber dams positioned to restrain movement of the material while settling is in progress. As the excess water leaves the fill material, it filters through brattice cloth supported on the dams to trap remaining solids, then is picked up by pumps from sumps provided near the panel entries or elsewhere as appropriate depending upon the particular part of the workings being filled with waste. From these pickup sumps, the water is transported to larger sumps near the mine shafts for final clarification before being returned to the surface for treatment and reuse.

The mobile plastic lines are supported in plank troughs anchored to the mine back (roof) with rockbolts. Two men attend each line and water pickup pump each shift during filling operations with part-time assistance of one two-man crew for moving discharge lines within the immediate fill areas. Periodically, assistance also is required in removing and installing the discharge lines and pumps, for example from one panel to another, and in providing electrical service, pump maintenance, and the like (see Table No. 38). Filling operations are integrated between upper (1,900-ft) and lower (2,600-ft) mine levels, one piping system only being used periodically on the upper level. One of the operating crews from the lower level is assigned above when needed. Drain water from upper-level filling operations is dropped to the main sumps on the lower level for return to the surface.

Overall consideration of available mine volume in relation to the volume of the waste fill material at its stable condition of 80 weight percent solids indicates that all such waste can eventually be emplaced underground. This conclusion includes the conditions that space in the white-nahcolite mine as well as in the lower-level shale mine will be used, and that emplacement is feasible to 90 percent and 98 percent, respectively, of the total mine height on each level (leaving roughly one foot of unfilled height in each case). However, until the time that mine development and production have progressed to the extent that one panel has been mined out and a second started, all slurry must be retained aboveground. This period approximates 150 days, at which time filling operations are initiated on the lower level. In about 180 days, the first panel in the white-nahcolite level also becomes available for fill. This latter time is not critical, as filling operations are confined to the lower level during the intermediate 30-day period.

Over the ensuing period of about five years, a further limitation exists in waste-fill operations, in that only the panels proper may be utilized. Other parts of the workings--the various drifts and entry systems--must be kept open to provide access to and from the current production mining areas. Thus, a relatively small portion of the waste slurry must continue to be "backlogged" on the surface during this 5-year period. Subsequently, mining operations are advanced enough that it is possible not only to dispose of all solid wastes underground as 80 percent solids fill material but also to work out the "backlog" at a rate to eliminate all surface storage essentially within the assumed 20-year mine life.

Considering both filling limitations--the 150-day-prefill period plus the 5-year-partial-rate period--a surface retaining pond of approximately 12 million cubic yards capacity is required, based on the premises that surface storage will be in the same state of 80 percent solids/20 percent water that is estimated for the mine-fill condition, that the material will be reslurried as it is eventually picked up and transported underground, and that approximately 10 percent excess outage should be provided to safeguard against spillover during storms, reslurrying operations, and the like. In terms of tonnages as based on the 80 percent ultimate fill state, "pond" waste accumulates at the full production rate of 49,496 tons per calendar day for 150 days, then at a reduced rate of approximately 3,200 tons per calendar day for the ensuing 5 years, for a maximum accumulation of approximately 11 million tons.

Disposal of Miscellaneous Wastes

The purge solution from the white nahcolite crystallization system is piped to a diked-off portion of the settling pond. The volume allowed can be increased as the solids wastes are pumped to the mine. Therefore, the total volume available is sufficient for the life of the plant.

Provisions for disposal and reclamation of water from the refinery are included in plant facilities.

CAPITAL INVESTMENT

Table 1 is a summary of the total capital investment required to install the complex to mine and process 8,000 tons per calendar day of white nahcolite ore and 60,000 tons per calendar day of nahcolite-dawsonite-oil shale material. Included are initial catalyst and chemicals, interest during construction, startup expense, and working capital. The total estimated investment is $636,973,000. Detailed equipment lists are given in tables 2 through 18. The capital requirement for the mine, including development, is shown in tables 19 and 20. Cost summaries for each of the processing systems are shown in tables 21 through 36.

The cost of refinery processing units, except for delayed coking, are based on "black box" information. This consists of the cost of the equipment and utilities required in a processing step but not the number, size, or arrangement and type of the individual items of equipment.

The sources of information for the various processes are given below:

Process	Reference number, investment	Reference number for utility requirement
Hydrocracking	1	3
Hydrogen production	1	2
Sulfur recovery	4	4
Ammonia recovery	4	4

1. Hydrocarbon Processing and Petroleum Refiner, September 1964.
2. Critical Materials Requirements for Petroleum Refining, March 1966. National Petroleum Council.
3. The Oil and Gas Journal, April 5, 1965.
4. Engineering Estimates of Capital Requirements and Operating Costs for Retorting and Refining Oil Shale. NPC Subcommittee on Synthetic Fuels, Oil Shale Engineering Group, August 1, 1951.

Working capital requirements are shown in table 37. Interest during construction (5%) assumes a 3-year construction period with 2% of total expenditures made in the first year, 20% in the second, and 78% in the third year. An allowance of $19,520,400 is included for startup expenses.

A utility summary is given in table 44. The cost of providing steam, power, cooling water, sanitary water, etc., is included in plant utilities. The cost of administrative buildings, roads, fences, rolling stock, etc., is included in plant facilities.

OPERATING COST

The direct labor, maintenance labor, and the required supervisory and administrative personnel are listed in table 38. Also included is the annual cost of the listed personnel as well as wages and salaries.

Table 39 is a summary of the estimated annual operating cost. These costs include labor, labor supervision, maintenance, maintenance supervision, and administration and general overhead as taken from table 38, and in addition, 25 percent of the payroll is allowed for payroll overhead.

The operating costs also include natural gas, limestone, catalyst and chemicals, water charges, royalties, taxes, insurance, and depreciation. The depreciation schedule is shown in table 43.

The annual operating cost is $151,373,400 before Federal income tax or return on investment.

FINANCIAL ANALYSIS

Table 41 lists the annual receipts available from the sale of products. The receipts total $257,599,600 per year leaving a balance or gross income of $106,226,200 (see table 42). Allowing total depletion of $34,831,700, the taxable income becomes $71,394,500. Then allowing 50 percent for Federal income tax the net profit becomes $35,697,250.

The interest rate of return or discounted cash flow (DCF) rate of return is 14.45 percent. The interest rate of return or DCF method of evaluating profitability account for the time value of money and are a measure of the discounted positive cash flows over the weighted depreciable life of the installation. The positive cash flow is the sum of net profit, depreciation, and depletion.

UNIT OPERATING COST

Table 39 shows the total annual operating cost for the complete complex. Table 40 shows a modification of annual operating cost and charges the direct components to the major operating processes. The elements of the operating cost are prorated and charged to the processing steps on an appropriate basis. The table also gives the capital investment prorated and charged using the same procedure.

AN OIL SHALE, NAHCOLITE,
DAWSONITE COMPLEX, OPTION III

TABLE 1. - Capital investment summary

Unit	Capital investment
Mine	$37,917,200
Soda ash recovery from white nahcolite:	
Preparation	8,559,800
Leaching	3,903,700
Crystallization	6,362,300
Product drying and storage	4,288,700
Retort plant:	
Crushing and screening	4,222,400
Briquetting	1,212,900
Retorting	54,801,400
Delayed coking	9,548,800
Refining	48,329,100
Dawsonite-rich material processing:	
Retorted shale crushing	2,309,200
Retorted shale leaching	10,808,600
Desilication	5,192,100
Alumina precipitation and calcining	31,101,000
Shale fines leaching	7,298,500
Soda ash crystallization and dehydration	64,361,600
Limestone calcination and flue gas processing	16,391,800
Plant facilities	61,405,300
Plant utilities	106,175,500
Total construction cost	484,189,900
Initial catalyst and chemicals	3,324,100
Total plant cost (tax and insurance base)	487,514,000
Interest during construction (5%)	24,075,700
Startup expense	19,520,400
Subtotal (depreciation)	531,110,100
Working capital	105,862,900
Total capital investment	636,973,000

TABLE 2. - Detailed equipment list, mine, 1,900-ft level

MINING AND HAULAGE

Cutting machine (4 required)
Model: Joy 15RU.
Voltage: 440 A.C.
Hp: 225.

Electric drill (4 required)
Model: 2 boom Joy CD-73.
Voltage: 440 A.C.
Hp: 115.

Powder wagon (4 required)
Air compressor mounted on vehicle.
Pneumatic loader capacity: 300 lbs/hr.
Power: Diesel.

Loader (4 required)
Model: Joy 14 BU 10-11D.
Voltage: 440 A.C.
Hp: 160.

Shuttle car (8 required)
Model: Joy 10 SC 27A.
Voltage: 440 A.C.
Hp: 135.

Roof bolter (8 required)
Model: Joy RBD.
Voltage: 440 A.C.
Hp: 50.

Power center (8 required)
4,100 volts to 440 volts with accessories.

CONVEYING AND CRUSHING

Belt conveyor (3 required)
Size: 42"wide by 6,000' long.
Belt speed: 500 fpm.
Hp: 200.

Belt conveyor (3 required)
Size: 36" wide by 6,000' long.
Belt speed: 500 fpm.
Hp: 150.

Crusher feeder (3 required)
Type: Belt.

Crusher (1 required)
Type: Roll.
Size reduction: Minus-10" to minus-5".

TV system (1 required)
Closed circuit.

Shops and auxiliary

Mancar (1 required)
Power: Diesel.

Bulldozer (1 required)
Model: D-6.
Power: Diesel.

Personnel car (6 required)
Battery powered golf cart.

Battery charger (1 required)
For personnel cars.

Machine shop (3 required)
Portable.

Machine shop (1 required)
Main shop, not portable.

Ventilation

Fan (30 required)
Hp: 15.
For secondary ventilation, main fans under 2,600-ft level.

TABLE 2, continued - mine, 2,600' level

MINING AND HAULAGE

Heading jumbo (3 required)
Drive: Electric.
Type: Hydraulic-electric; 2 drill.
Hp: 150.

Bench jumbo (2 required)
Drive: Electric.
Type: Hydraulic-electric, 2 drill.
Hp: 150.

Powder truck (4 required)
Capacity: 3 tons.
Equipped with pneumatic delivery system.
Hp: 100.
Drive: Diesel.

Scaling and rock bolting rig (4 required)
Aerial life: Truco Model TaL 70-75.
Chassis: FWD Model 66-15-CC.
Drive: Diesel.
Hp: 150.

Front end loader (4 required)
Model: Hough 400.
Bucket capacity: 20 tons.
Drive: Diesel.
Hp: 500.

Haulage truck (9 required)
Capacity: 75 tons.
Drive: Diesel.
Hp: 700.
Model: 75A Haulpak, WABCO.

Motor patrol (2 required)
Drive: Diesel.
Hp: 150.

Bulldozer (4 required)
Model: Hough D-90C.
Dr[illegible]: Diesel.
Hp: [illegible]00.

Water truck (4 required)
To deliver water to drills and water haulage.

CRUSHING AND CONVEYING

Hopper (3 required)
Portable.
Capacity: 150 tons.

Apron feeder (3 required)

Grizzly screen (3 required)

Double roll crusher (3 required)
Size: 48" x 60".
Drive: Motor.
Hp: 150 each roll.

Conveyor system (1 required)
Type: Belt.
Size: 60" wide by 3.5 miles long.
Hp: 2,100.
Drive: Motor.

Dust collector (3 required)

Ventilation equipment

Main ventilation fan (2 required)
Serves both the 1,900' and 2,600' levels.
Capacity: 650,000 cfm to 7" W.G.
Hp: 1,000.
Drive: Motor.
Model: Joy H-120-65.

Auxiliary ventilation fan (1 required)
Service: Machine shop.
Capacity: 70,000 cfm to 5" W.G.
Hp: 36.
Drive: Motor.

Air lock (3 required)
3 sets of service doors near service shaft hydraulically operated.
Size: 15' by 20' with 200' between doors.

Auxiliary fan (20 required)
Service: Development and production headings.

TABLE 2, continued

Miscellaneous mining equipment

Power center (6 required)
4,100 volts to 440 volts or 220 volts. (Includes switchgear.)

Fuel oil storage tank underground (1 required)
Capacity: 20,000 gallons.

ANFO transport trailer (3 required)
Capacity: 3 tons.
Lining: Wood.

Truck (14 required)
Type: Pickup.

Fuel truck (1 required)

Ambulance (1 required)

Bus (2 required)

Supply truck (4 required)

Underground machine shop (1 required)
Size: 50' by 500' (near service shaft).
Includes 15-ton crane.

1,900-ft and 2,600-ft levels

Production hoist (2 required)
Type: Koepe, 6 rope.
Speed: 1,800 fpm.
Hp: 7,000.
Drive: Two 3,500 Hp motors.

Headframe (3 required)
Type: Koepe.
Construction material: Reinforced concrete and WF beams.
Concrete required: 511 cu yds.
Estimated steel: 75,000 lbs.

Service and hoist (1 required)
Type: Koepe.
Speed: 1,200 fpm.
Hp: 1,200.
Drive: Motor.

Hoist house (2 required)
Size: 1,200 sq ft.

Buildings and surface

Underground surge bin
Capacity: 2,000 tons (1 @ 1,900' level, 2 @ 2,600' level).

Ore pass (1 required)
Size: 4' diameter from 1,900' to 2,600' level.

Powder magazine (1 required)
Primers only.
Capacity: 60,000 lb.
Size: 16' by 26'.

Magazine (1 required)
Caps only.
Size: 17' by 20'.

Warehouse (1 required)
Size: 40' by 150'.

TABLE 2, continued

Fabrication and welding shop

Size: 20' by 100'.

Electric shop (1 required)
Size: 20' by 100'.

Change house, lamp room, and office (1 required)
Size: 13,655 sq ft.[2]

Conveyor (1 required)
Type: Belt.
Size: 60" wide by 1,100' long.
Hp: 350.
Drive: Motor.

Boom conveyor, oil shale (2 required)
Type: Belt.
Size: 60" wide by 200' long.
Hp: 100.
Drive: Motor.

Boom conveyor, nahcolite (2 required)
Type: Belt.
Size: 60" wide by 70' long.
Hp: 80.
Drive: Motor.

TABLE 3. - Detailed equipment list, nahcolite preparation section, recovery of soda ash from white nahcolite

Apron feeder (P1)

Number: 6.
Size: 42 inches x 10 ft.
Speed: 20 fpm.
Drive: Motor.
Hp: 5.

Belt conveyor (P2)

Number: 1.
Enclosed.
Size: 30 inches x 675 ft.
Rise: 35 ft.
Speed: 300 fpm.
Drive: Motor.
Hp: 40.
Weightometer included.

Hopper (P3)

Number: 1.
Capacity: 4,635 cu ft.

Apron feeder (P4)

Number: 1.
Size: 42 inches x 10 ft.
Speed: 20 fpm.
Drive: Motor.
Hp: 5.

Hammermill (P5)

Number: 1.
Size: 40 inches x 40 inches.
Drive: Motor.
Hp: 300.

Belt conveyor (P6)

Number: 1.
Enclosed.
Size: 30 inches x 150 ft.
Rise: 45 ft.
Speed: 30 fpm.
Drive: Motor.
Hp: 25.

Hopper (P7)

Number: 1.
Capacity: 4,514 cu ft.

Apron feeder (P8)

Number: 2.
Size: 24 inches x 10 ft.
Speed: 20 fpm.
Drive: Motor.
Hp: 2.

Hammermill (P9)

Number: 2.
Size: 60 inches x 40 inches.
Drive: Motor.
Hp: 400.

Hopper (P10)

Number: 2.
Capacity: 2,498 cu ft.

Vibrating screen (P11)

Number: 4.
Size: 200 sq ft.
Drive: Motor.
Hp: 20.

TABLE 3. - (Continued)

Belt conveyor (P12)

Number: 1.
Enclosed.
Size: 14 inches x 85 ft.
Rise: 25 ft.
Speed: 200 fpm.
Drive: Motor.
Hp: 3.

Transfer hopper (P12A)

Number: 1.
Capacity: 30 cu ft.

Belt conveyor (P12B)

Number: 1.
Enclosed.
Size: 14 inches x 85 ft.
Rise: 25 ft.
Speed: 200 fpm.
Drive: Motor.
Hp: 3.

Belt conveyor (P13)

Number: 1.
Enclosed.
Size: 30 inches x 280 ft.
Rise: 85 ft.
Speed: 300 fpm.
Drive: Motor.
Hp: 50.

Belt conveyor (P14)

Number: 1.
Enclosed.
Size: 30 inches x 110 ft.
Speed: 300 fpm.
Drive: Motor.
Hp: 10.
Tripper included.

Storage silo (P15)

Number: 6.
Concrete.
Capacity: 100,000 cu ft.

Belt feeder (P16)

Number: 6.
Capacity: 9,000 cu ft/hr.
Size: 48 inches x 10 ft.
Drive: Motor.
Hp: 3.

Belt conveyor (P17)

Number: 1.
Enclosed.
Size: 30 inches x 210 ft.
Rise: 30 ft.
Speed: 300 fpm.
Drive: Motor.
Hp: 20.

Belt conveyor (P18)

Number: 1.
Enclosed.
Size: 30 inches x 50 ft.
Speed: 300 fpm.
Drive: Motor.
Hp: 10.
Tripper included.

Surge bin (P19)

Number: 3.
Capacity: 1,441 cu ft.

Screw feeder (P20)

Number: 3.
Capacity: 2,900 cu ft/hr.
Drive: Motor.
Hp: 3.

TABLE 3. - (Continued)

Rotary kiln (P21)

Number: 3.
Size: 12.5 ft diam x 249 ft long.
Lining: 6 inches, fireclay brick.
Drive: Motor.
Hp: 125.

Cyclone dust collector (P22)

Number: 9.
Capacity: 27,984 cu ft/min.

Blower (P23)

Number: 9.
Capacity: 27,984 cu ft/min.
Drive: Motor.
Hp: 60.

Rotary cooler (P24)

Number: 3.
Size: 11.5 ft diam x 183 ft long.
Drive: Motor.
Hp: 75.

Cyclone dust collector (P25)

Number: 6.
Capacity: 31,596 cu ft/min.

Blower (P26)

Number: 9.
Capacity: 21,064 cu ft/min.
Drive: Motor.
Hp: 40.

Bag dust collector (P27-nahcolite ore)

Number: 1.
Capacity: 58,414 cu ft/min.

Blower (P28-nahcolite ore)

Number: 2.
Capacity: 29,207 cu ft/min.
Drive: Motor.
Hp: 50.

Bag dust collector (P29-calcined material)

Number: 1.
Capacity: 6,305 cu ft/min.

Blower (P30-calcined material)

Number: 1.
Capacity: 6,305 cu ft/min.
Drive: Motor.
Hp: 10.

Service crane (P31)

Number: 1.
Capacity: 20 tons.
Type: Bridge.

TABLE 4. - Detailed equipment list, leaching section, recovery of soda ash from white nahcolite

Belt conveyor (D1)

Number: 1.
Enclosed.
Size: 30 inches x 210 ft.
Rise: 50 ft.
Speed: 30 fpm.
Drive: Motor.
Hp: 20.

Surge bin (D2)

Number: 1.
Capacity: 7,891 cu ft.

Apron feeder (D3)

Number: 1.
Size: 36 inches x 10 ft.
Speed: 20 fpm.
Drive: Motor.
Hp: 5.

Pump (D4)

Number: 1.
Capacity: 1,968 gpm.
Drive: Motor.
Hp: 50.

Pump (D5)

Number: 1.
Capacity: 12 gpm.
Drive: Motor.
Hp: 1.5.

Leaching tank (D6)

Number: 1.
Capacity: 54,494 gal.
Drive: Motor.
Hp: 50.
Agitator included.

Pump (D7)

Number: 1 + 1 extra.
Capacity: 5,086 gpm.
Drive: Motor.
Hp: 75.

Thickener (D8)

Number: 1.
Size: 10 ft x 240 ft.
Drive: Motor.
Hp: 10.

Pump (D9)

Number: 5 + 5 extra.
Capacity: 431 gpm.
Drive: Motor.
Hp: 10.

C.C.D. thickener (D10)

Number: 4.
Size: 10 ft x 170 ft.
Drive: Motor.
Hp: 7.5.

Pump (D11)

Number: 4.
Capacity: 1,857 gpm.
Drive: Motor.
Hp: 20.

Waste mixing tank (D12)

Number: 1.
Capacity: 20,955 gal.
Drive: Motor.
Hp. 20.
Agitator included.

TABLE 4. - (Continued)

Pump (D13)

Number: 1 + 1 extra.
Capacity: 488 gpm.
Drive: Motor.
Hp: 15.

Pump (D14)

Number: 2.
Capacity: 2,327 gpm.
Drive: Motor.
Hp: 50.

Pressure filters (D15)

Number: 7.
Size: 60 inch diam.
Area: 1,645 sq ft.

Sump tank (D15A)

Number: 7.
Capacity: 317 cu ft.

Surge tank (D16)

Number: 1.
Capacity: 361 gal.

Pump (D17)

Number: 1 + 1 extra.
Capacity: 17 gpm.
Drive: Motor.
Hp. 1.5.

Surge tank (D18)

Number: 2.
Capacity: 53,605 gal.

TABLE 5. - Detailed equipme list, crystallization section, recovery of . a ash from white nahcolite

Pump (C1)

Number: 1 + 1 extra.
Capacity: 4,645 gpm.
Drive: Motor.
Hp: 100.

Crystallizer (7-effect)(C2)

Number: 1.
Area per effect: 12,750 sq ft.
Type: Forced circulation.
Barometric condenser.
Capacity: 13,220 gpm.
Steam ejector.
Capacity: 297 lb dry gas/hr.

Surge tank (C4)

Number: 5.
Capacity: 91,665 gal.

Pump (C5)

Number: 1.
Capacity: 1,857 gpm.
Drive: Motor.
Hp: 20.

Pump (C6)

Number: 1.
Capacity: 13,419 gpm.
Drive: Motor.
Hp: 150.

Pump (C7)

Number: 1 + 1 extra.
Capacity: 2,787 gpm.
Drive: Motor.
Hp: 60.

Centrifuge (C8)

Number: 4.
Size: 54 inch bowl diam.
Drive: Motor.
Hp: 150.

Heat exchanger (C9)

Number: 1.
Size: 7 sq ft.
Type: Fixed-tube.

Surge tank (C10)

Number: 1.
Capacity: 45,086 gal.

TABLE 6. - Detailed equipment list, drying and product storage section, recovery of soda ash from white nahcolite

Screw conveyor (S1)

Number: 4.
Size: 16 inches x 30 ft.
Capacity: 1,600 cu ft/hr.
Drive: Motor.
Hp: 5.

Rotary dryer (S2)

Number: 4.
Size: 12 ft x 108 ft.
Drive: Motor.
Hp: 50.

Bag dust collector (S3)

Number: 12.
Capacity: 27,940 cu ft/min.

Blower (S4)

Number: 12.
Capacity: 27,940 cu ft/min.
Drive: Motor.
Hp: 60.

Rotary cooler (S5)

Number: 4.
Size: 9 ft x 56 ft.
Drive: Motor.
Hp: 20.

Belt conveyor (S6)

Number: 1.
Enclosed.
Size: 24 inches x 330 ft.
Rise: 85 ft.
Speed: 30 ft/min.
Drive: Motor.
Hp: 25.

Belt conveyor (S7)

Number: 1.
Enclosed.
Size: 24 inches x 200 ft.
Speed: 300 ft/min.
Drive: Motor.
Hp: 7.5.
Tripper included.

Storage silo (S8)

Number: 10.
Concrete.
Capacity: 100,000 cu ft.

Belt feeder (S9)

Number: 10.
Capacity: 2,400 cu ft/hr.
Size: 24 inches x 15 ft.
Drive: Motor.
Hp: 1.5.

Belt feeder (S10)

Number: 10.
Capacity: 2,400 cu ft/hr.
Size: 24 inches x 30 ft.
Drive: Motor.
Hp: 1.5.

Bag dust collector (S12)

Number: 1.
Capacity: 12,622 cu ft/min.

Blower (S13)

Number: 1.
Capacity: 12,622 cu ft/min.
Drive: Motor.
Hp: 20.

TABLE 7. - Detailed equipment list, shale crushing, screening, and storage

Shale surge bin No. 1 (1 required)
Holdup: 20 minutes.
Size: 30 ft x 30 ft x 31 ft s.s. height with 2 hopper bottom.
Material of construction: Reinforced concrete.

Apron feeder (4 required)
(Two for secondary and 2 for tertiary crushing).
Size: 9 ft x 20 ft.
Speed: 55 fpm.
Drive: 40 hp motor.

Grizzly bar screen (2 required)
Bar opening: 4.5 in.
Size: 6 ft x 24 ft (including deckplate).
Drive: 15 hp motor.

Secondary gyratory crusher (2 required)
Capacity: 662 tons per hour.
Drive: 250 hp motor.

Belt conveyor No. 1A & 1B (2 required)
(Conveys from crushers to conveyor No. 2.)
Size: 54 in. x 50 ft.
Drive: 20 hp motor.

Belt conveyor No. 2 (1 required)
(Main conveyor to tertiary crushing.)
Size: 60 in. x 100 ft.
Rise: 40 ft.
Drive: 125 hp motor.

Splitter (1 required)
Size: 20 ft x 20 ft x 20 ft s.s. height with two hopper bottom.
Material of construction: Reinforced concrete.

Scalping screen (4 required)
Size: 6 ft x 16 ft.
Drive: 7.5 hp motor

Tertiary gyratory crusher (2 required)
Capacity: 440 tph.
Drive: 250 hp motor.

Belt conveyor No. 3A & 3B (2 required)
(Conveys from tertiary crushers to conveyor No. 4.)
Size: 54 in. x 50 ft.
Drive: 20 hp motor.

Belt conveyor No. 4 (3 required)
(Main conveyor to 24-hr storage.)
Size: 60 in. by 200 ft.
Rise: 80 ft.
Drive: 350 hp motor.

Surge bin No. 2 (2 required)
Holdup: 24 hrs.
Size: 100 ft x 100 ft x 68 ft s.s. height, 60° sloping bottom.
Material of construction: Reinforced concrete.

Apron feeder (4 required)
(From 24-hr storage-2; from coarse oil shale storage-2.)
Size: 10-1/2 ft x 20 ft
Speed: 55 ft per min.
Drive: 35 hp motor.

Screen feed hopper (2 required)
Holdup: 20 minutes.
Size: 30 ft x 30 ft x 30 ft s.s. height, 60° sloping bottom.
Material of construction: Reinforced concrete.

Apron feeder to double deck screen (8 required)
Size: 42 in. x 10 ft.
Drive: 7.5 hp motor.

Screen (8 including 2 spares)
Opening: 3/16 inch.
Type: Double deck, scalp to 1 in. top, remove -3/16 in. material on bottom.
Size: 5 ft x 16 ft.
Drive: 7.5 hp motor.

Belt conveyor No. 5 & 6 (2 required)
24 hour storage to screen house; screen house to coarse shale storage.
Size: 60 in. x 100 ft.
Rise: 40 ft.
Drive: 125 hp motor.

OPTION III

TABLE 7, continued

Surge bin No. 3 (2 required)
Coarse shale storage.
Holdup: 3 hours.
Size: 50 ft x 50 ft x 42 ft
with pyramidal bottom.
Material of construction:
Reinforced concrete.

Surge bin No. 4 (2 required)
Nahcolite rich fines.
Holdup: 24 hours.
Size: 60 ft x 60 ft x 36 ft with
pyrimidal bottom.
Material of construction:
Reinforced concrete.

Belt conveyor (2 required)
Nahcolite rich fines to storage.
Size: 30 in. x 400 ft.
Rise: 70 ft.
Drive: 25 hp motor.

Exhauster (1 required)
Δp: 2 psi.
Hp: 1,200.
Cfm: 50,000

Cyclone (1 required)
Cfm: 50,000

TABLE 8. - Detailed equipment list, briquetting

Surge bin No. 1

Number: 2.
Capacity: 80 tons.
Size: 12 ft ID x 12 ft s.s. height; 60° conical bottom.
Material of construction: Steel.

Vibratory feeder No. 1

Number 1.
Size: 18 in. x 42 in. with 6 in. deep pan.
Drive: 0.75 kwhr magnetic.

Hammer mill

Number: 1.
Capacity: 33 tph.
Drive: 30 hp motor.

Mixer and briquetting machine

Number: 1.
Mixer:
Type: 2-shaft horizontal paddle.
Capacity: 33 tph.
Briquetting machine:
Drive: 35 hp motor.

Surge bin No. 2

Number: 1.
Capacity: 80 tons.
Size: 12 ft ID x 12 ft s.s. height, 60° conical bottom.
Material of construction: Steel.

Surge bin No. 3

Number: 1.
Capacity: 80 tons.
Size: 12 ft ID x 12 ft s.s. height, 60° conical bottom.
Material of construction: Steel.

Belt conveyor No. 1

Number: 1.
(To bin from briquetting machine.)
Size: 14 in. wide x 100 ft long.
Rise: 20 ft.
Drive: 5 hp motor.

Belt conveyor No. 2

Number: 1.
(To bin from hammer mill.)
Size: 14 in. wide x 100 ft long.
Rise: 20 ft.
Drive: 5 hp motor.

Vibratory feeder No. 2

Number: 1.
Size: 18 in. x 42 in. with 6 in. deep pan.
Drive: 0.75 kwhr magnetic.

Belt conveyor No. 3

Number: 1.
(Fines from soda ash recovery plant.)
Size: 14 in. wide x 50 ft long.
Rise: 0.
Drive: 2 hp motor.

Belt conveyor No. 4

Number: 1.
(Briquets to retort feed conveyor.)
Size: 14 in. wide x 500 ft long.
Rise: 120 ft.
Drive: 15 hp motor.

Belt conveyor No. 5

Number: 1.
(Fines from dryer.)
Size: 14 in. wide x 500 ft long.
Rise: 120 ft.
Drive: 15 hp motor.

TABLE 9. - Detailed equipment list, retorting plant

Retort

Number: 7.
Size: 46 ft ID x 20 ft high retorting section.
Type: Petrosix and the Cameron and Jones[1] improved feeding and discharge mechanism.
Refractory: 9 in. firebrick, 9 in. K-30 insulating brick (retort section).
Drive for feeding and discharging: Motor-activated hydraulic.
Hp: 110 top (feed); 200 bottom (discharge).

Rotoclone[2]

Number: 49.
Capacity: 45,000 cfm.
Drive: 125 hp motor.
Head developed: 12 in. water.

Retort gas blower, centrifugal

Number: 7.
(Recycle and product gas.)
Drive: 2,250 hp motor.

Air blower, centrifugal

Number: 7.
Drive: 300 hp motor.

Electrostatic precipitator

Number: 14.
Size: 13 ft ID x 20 ft high.
Capacity: 156,500 cfm.
Power: 60 kwhr per hr.

Pump

Number: 7.
(Shale oil to storage.)
Capacity: 250 gpm.
Δp: 20.
Drive: 5 hp motor.

Retort feed hopper

Number: 7.
Size: 20 ft 3 in. ID x 20 ft 3 in. high, 60° conical bottom.
Holdup: 1 hour.
Material of construction: Steel.

Retort feed belt conveyor

Number: 1.
Size: 54 in. x 200 ft.
Drive: 100 hp motor.

Retort discharge belt conveyor

Number: 1.
Size: 54 in. x 625 ft.
Rise: 0.
Drive: 100 hp motor.

Stacker belt conveyor

Number: 1.
Size: 2 - 54 in. x 50 ft.
Rise: 12 ft.
(extend to each side of main conveyor.)
Drive: 25 hp motor, each side.

Heat exchanger

Number: 7.
Area: 62,192 ft^2
Operating pressure: 15 psia.
Operating temperature:
Hot gas side: 2,350°F.
Cold gas side: 1,350°F.
U: 6.

Bucket elevator feed hopper

Number: 7.
Size: 20 ft 3 in. ID x 20 ft 3 in. high, 60° conical bottom.
Holdup: 1 hour.
Material of construction: Steel.

Bucket elevator

Number: 21.
Capacity: 150 tph
Length: 200 ft.
Bucket size: 16 in. x 8 in. x -1/2 in.
Drive: 40 hp motor.

Recycle gas blower, centrifugal

Number: 7.
Drive: 325 hp motor.

[1, 2]Reference to specific makes or models of equipment is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

TABLE 10. - Principal items of equipment list, delayed coking

Oil heating furnace

Number: 2.
Heating capacity: 276 MM Btu/hr.
Tube surface: 37,320 sq ft.

Main fractionator

Number: 2.
Size: 13 ft ID; 8 plates.

Stripper

Number: 2.
Size: 5 ft 2 in. ID; 5 plates.

Absorber

Number: 2.
Size: 6 ft ID; 20 plates.

Coke drum

Number: 4.
Size: 20 ft ID; 65 ft long.

Coke cutter

Number: 2.
With car and auxiliary coke handling equipment.

Accumulator

Number: 2.
Holdup: 10 minutes.
Size: 6 ft 8 in. x 20 ft.

TABLE 11. - Detailed equipment list, retorted shale crushing section, dawsonite-rich zone

Belt conveyor (R01)

Number: 1.
Enclosed.
Size: 60 in. x 650 ft.
Rise: 50 ft.
Speed: 450 ft per min.
Drive: 200 hp motor.

Belt conveyor (R01A)

Number: 1.
Size: 60 in. x 250 ft.
Speed: 450 ft per min.
Drive: 60 hp motor.
Tripper included.
Weightometer included.

Hoppers (R02)

Number: 5.
Capacity: 7,057 cu ft.

Belt feeders (R03)

Number: 5.
Size: 48 in. x 10 ft.
Drive: 3 hp motor.

Hammermills (R04)

Number: 5.
Capacity: 398 tons per hr.
Drive: 1,000 hp motor.

Vibrating screens (R05)

Number: 15.
Size: 180 sq. ft.
Drive: 20 hp motor.

Belt conveyor (R05A)

Number: 1.
Size: 36 in. x 200 ft.
Speed: 400 ft per min.
Drive: 15 hp motor.

Belt conveyor (R06)

Number: 1.
Enclosed.
Size: 36 in. x 70 ft.
Rise: 27 ft.
Speed: 400 ft per min.
Drive: 25 hp motor.

Transfer hopper (R06A)

Number: 1.
Capacity: 30 cu ft.

Belt conveyor (R07)

Number: 1.
Enclosed.
Size: 36 in. x 70 ft.
Rise: 27 ft.
Speed: 400 ft per min
Drive: 25 hp motor.

Belt conveyor (R08)

Number: 1.
Size: 60 in. x 240 ft.
Speed: 450 ft per min.
Drive: 40 hp motor.

Belt conveyor (R08A)

Number: 1.
Enclosed.
Size: 60 in. x 130 ft.
Rise: 40 ft.
Speed: 450 ft per min.
Drive: 125 hp motor.

TABLE 11. - (Continued)

<u>Belt conveyor (R08B)</u>

Number: 1.
Size: 60 in. x 100 ft.
Speed: 450 ft per min.
Drive: 50 hp motor.
Tripper included.

<u>Service crane (R09)</u>

Number: 1.
Size: 40 ton.

<u>Cyclone dust collectors (RRRR)</u>

Number: 4.
Capacity: 53,000 cu ft per min.

<u>Blowers (RRRR)</u>

Number: 8.
Capacity: 26,402 cu ft per min.
Drive: 50 hp motor.

TABLE 12. - Detailed equipment list, retorted shale leaching section, dawsonite-rich zone

Hoppers (L01)

Number: 4.
Capacity: 7,022 cu ft.

Belt feeders (L02)

Number: 4.
Size: 48 in. x 10 ft.
Drive: 3 hp motor.

Leaching tanks (L03)

Number: 4.
Capacity: 98,318 gal.
Agitator Drive: 50 hp motor.

Hoppers (L04)

Number: 4.
Capacity: 103 cu ft.

Belt feeders (L05)

Number: 4.
Size: 12 in. x 10 ft.
Drive: 0.5 hp motor.

Pumps (L06)

Number: 1 + 1 extra.
Capacity: 28,839 gal. per min.
Drive: 300 hp motor.

Settlers (L07)

Number: 4.
Size: 250 ft diam.
Drive: 10 hp motor.

Pumps (L08)

Number: 4.
Capacity: 3,110 gal. per min.
Drive: 60 hp motor.

Thickeners (L09A)

Number: 3.
Size: 250 ft. diam.
Drive: 10 hp motor.

Pumps (L09B)

Number: 3.
Capacity: 4,147 gal per min.
Drive: 75 hp motor.

Thickeners (L09C)

Number: 3.
Size: 250 ft diam.
Drive: 10 hp motor.

Pumps (L09D)

Number: 3.
Capacity: 4,272 gal per min.
Drive: 50 hp motor.

Pumps (L09E)

Number: 3.
Capacity: 4,147 gal per min.
Drive: 75 hp motor.

Thickeners (L09F)

Number: 3.
Size: 250 ft diam.
Drive: 10 hp motor.

Pumps (L09G)

Number: 3.
Capacity: 4,272 gal per min.
Drive: 50 hp motor.

TABLE 12. - (Continued)

Pumps (L10)

Number: 3.
Capacity: 4,272 gal per min.
Drive: 125 hp motor.

Storage tanks (L11)

Number: 4.
Capacity: 98,914 gal.
Agitator drive: 50 hp motor.

Pumps (L12)

Number: 4.
Capacity: 3,461 gal per min.
Drive: 50 hp motor.

Pumps (L13)

Number: 4.
Capacity: 4,099 gal per min.
Drive: 100 hp motor.

Clarifying filters (L14)

Number: 31.
Area: 1,645 sq ft.

Repulp tanks (L15)

Number: 2.
Size: 16 ft x 126 ft x 1 ft high.

Pump (L16)

Number: 1.
Capacity: 176 gal per min.
Drive: 20 hp motor.

Pumps (L17)

Number: 3.
Capacity: 4,147 gal per min.
Drive: 250 hp motor.

TABLE 13. - Detailed equipment list, desilication section, dawsonite-rich zone

Desilication tanks (D02)

Number: 5 + 1 extra.
Capacity: 89,002 gal.
Agitator Drive: 75 hp motor.

Hopper (D03)

Number: 1.
Capacity: 175 cu ft.

Table feeders (D04)

Number: 1 + 1 extra.
Diameter: 48 in.
Drive: 2 hp motor.

Lime slakers (D04A)

Number: 1 + 1 extra.
Capacity: 45,536 gal.
Agitator Drive: 40 hp motor.

Pump (D04B)

Number: 1.
Capacity: 1,669 gal per min.
Drive: 20 hp motor.

Pumps (D05)

Number: 5 + 1 extra.
Capacity: 3,263 gal per min.
Drive: 40 hp motor.

Settlers (D06)

Number: 2.
Size: 250 ft. diam.
Drive: 10 hp motor.

Pumps (D07)

Number: 2.
Capacity: 91 gal per min.
Drive: 3 hp motor.

Thickeners (D08)

Number: 2.
Size: 250 ft diam.
Drive: 10 hp motor.

Pumps (D09)

Number: 2.
Capacity: 91 gal per min.
Drive: 10 hp motor.

Pumps (D10)

Number: 2.
Capacity: 47 gal per min.
Drive: 3 hp motor.

Pumps (D11)

Number: 2.
Capacity: 8,066 gal per min.
Drive: 200 hp motor.

Clarifying filters (D12)

Number: 26.
Area: 1,645 sq ft

Repulp tanks (D12A)

Number: 2.
Size: 16 ft x 102 ft x 1 ft high

Pump (D12B)

Number: 1.
Capacity: 1 gal per min.
Drive: 0.5 hp motor.

Storage tanks (D13)

Number: 5.
Capacity: 92,732 gal.
Agitator drive: 50 hp motor.

TABLE 14.- Detailed equipment list, alumina precipitation and calcination section, dawsonite-rich zone

Pump (C01)

Number: 1.
Capacity: 16,228 gal per min.
Drive: 300 hp motor.

Carbonation tanks (C02)

Number: 112.
Size: 98,874 gal.

Pumps (C03)

Number: 1 + 1 extra.
Capacity: 16, 918 gal per min.
Drive: 200 hp motor.

Primary thickener (C04)

Number: 1.
Size: 232 ft diam.
Drive: 10 hp motor.

Pump (C05)

Number: 1.
Capacity: 16,064 gal per min.
Drive: 200 hp motor.

Secondary thickener (C06)

Number: 1.
Size: 164 ft diam.
Drive: 7-1/2 hp motor.

Pump (C07)

Number: 1.
Capacity: 16,338 gal per min.
Drive: 250 hp motor.

Pumps (C08)

Number: 1 + 1 extra.
Capacity: 260 gal per min.
Drive: 15 hp motor.

Pumps (C09)

Number: 1 + 1 extra.
Capacity: 853 gal per min.
Drive: 75 hp motor.

Wash tank (C10)

Number: 1.
Size: 33 ft diam x 60 ft high.

Pump (C11)

Number: 1.
Capacity: 534 gal per min.
Drive: 7.5 hp motor.

Pumps (C12)

Number: 1 + 1 extra.
Capacity: 853 gal per min.
Drive: 20 hp motor.

Wash tank (C13)

Number: 1.
Size: 33 ft diam x 60 ft high.

Pump (C14)

Number: 1.
Capacity: 534 gal per min.
Drive: 5 hp motor.

Internal drum filters (C16)

Number: 5.
Area: 300 sq ft.
Drive: 20 hp motor.

Pump (C17)

Number: 1.
Capacity: 534 gal per min.
Drive: 20 hp motor.

TABLE 14. - (Continued)

Screw convevors (C18)

Number: 5.
Size: 10 in. diam x 30 ft long.
Drive: 5 hp motor.

Rotary kilns (C19)

Number: 5.
Size: 13 ft diam x 330 ft long.
Lining: 9 in. alumina brick.
Drive: 150 hp motor.

Cyclone dust collectors (C20)

Number: 30.
Capacity: 25,629 cu ft.

Blowers (C21)

Number: 30.
Capacity: 25,629 cu ft per min.
Drive: 50 hp motor.

Rotary coolers (C22)

Number: 5.
Size: 7 ft diam x 50 ft long.
Drive: 20 hp motor.

Belt conveyor (C25)

Number: 1.
Enclosed.
Size: 18 in. x 130 ft.
Speed: 250 ft per min.
Drive: 3 hp motor.
Weightometer included.

Belt conveyor (C25A)

Number: 1.
Enclosed.
Size: 18 in. x 225 ft.
Rise: 110 ft.
Speed: 250 ft per min.
Drive: 15 hp motor.

Belt conveyor (C25B)

Number: 1.
Enclosed.
Size: 18 in. x 200 ft.
Speed: 250 ft per min.
Drive: 5 hp motor.
Tripper included.

Silos (C26)

Number: 5.
Concrete.
Capacity: 92,000 cu ft.

Belt feeders (C27)

Number: 10.
Size: 24 in. x 15 ft.
Drive: 1.5 hp motor.

Bag dust collector (CCCC)

Number: 1.
Capacity: 3,000 cu ft per min.

Blower (CCCC)

Number: 1.
Capacity: 2,837 cu ft per min.
Drive: 7.5 hp motor.

TABLE 15. - Detailed equipment list, shale fines leaching section, dawsonite-rich zone

Belt conveyor (F01)

Number: 1.
Enclosed.
Size: 30 in. x 700 ft.
Rise: 40 ft.
Speed: 300 ft per min.
Drive: 40 hp motor.

Belt conveyor (F01A)

Number: 1.
Size: 30 in. x 135 ft.
Speed: 300 ft per min.
Drive: 10 hp motor.
Tripper included.
Weightometer included.

Hoppers (F02)

Number: 6.
Capacity: 757 cu ft.

Screw feeders (F03)

Number: 6.
Size: 24 in. x 5 ft.
Drive: 1.5 hp motor.

Rotary kilns (F04)

Number: 6.
Size: 12 ft diam x 109 ft long.
Drive: 50 hp motor.

Cyclone dust collectors (F05)

Number: 12.
Capacity: 29,190 cu ft per min.

Blowers (F06)

Number: 12.
Capacity: 29,190 cu ft per min.
Drive: 60 hp motor.

Rotary coolers (F07)

Number: 6.
Size: 7 ft diam x 63 ft long.
Drive: 20 hp motor.

Belt conveyor (F10)

Number: 1.
Enclosed.
Size: 30 in. x 150 ft.
Speed: 300 ft per min.
Drive: 7.5 hp motor.

Belt conveyor (F10A)

Number: 1.
Enclosed.
Size: 30 in. x 125 ft.
Rise: 40 ft.
Speed: 300 ft per min.
Drive: 20 hp motor.

Hopper (F11)

Number: 1.
Capacity: 3,983 cu ft.

Belt feeder (F12)

Number: 1.
Size: 48 in. x 10 ft.
Drive: 3 hp motor.

Leaching tank (F13)

Number: 1.
Capacity: 38,917 gal.
Agitator drive: 60 hp motor.

Pump (F14)

Number: 1.
Capacity: 2,853 gal per min.
Drive: 40 hp motor.

TABLE 15. – (Continued)

Settler (F15)

Number: 1.
Size: 122 ft diam.
Drive: 5 hp motor.

Pump (F16)

Number: 1.
Capacity: 1,843 gal per min.
Drive: 40 hp motor.

Thickener (F17)

Number: 1.
Size: 156 ft diam.
Drive: 7.5 hp motor.

Pump (F18)

Number: 1.
Capacity: 1,659 gal per min.
Drive: 40 hp motor.

Pump (F19)

Number: 1.
Capacity: 1,843 gal per min.
Drive: 40 hp motor.

Rotary vacuum filters (F20)

Number: 10.
Area: 610 sq ft.

Belt conveyor (F21)

Number: 1
Enclosed.
Size: 24 in. x 500 ft.
Speed: 300 ft per min.
Drive: 25 hp motor.

Pump (F22)

Number: 1.
Capacity: 651 gal per min.
Drive: 10 hp motor.

Pump (F23)

Number: 1.
Capacity: 1,738 gal per min.
Drive: 30 hp motor.

Clarifying filters (F24)

Number: 2.
Area: 1,645 sq ft.

Repulp tank (F24A)

Number: 1.
Size: 16 ft x 15 ft x 1 ft high.

Pump (F24B)

Number: 1.
Capacity: 17 gal per min.
Drive: 3 hp motor.

Cyclone dust collector (FFFF)

Number: 1.
Capacity: 6,305 cu ft per min.

Blower (FFFF)

Number: 1.
Capacity: 6,305 cu ft per min.
Drive: 15 hp motor.

TABLE 16. - Detailed equipment list, soda ash crystallization and dehydration section, dawsonite-rich zone

Mixing tanks (S01)

Number: 1.
Capacity: 89,502 gal.
Agitator drive: 75 hp motor.

Pump (S02)

Number: 1.
Capacity: 19,690 gal per min.
Drive: 125 hp motor.

Crystallizers (S03)

Number: 10.
Evaporator, 7 effect.
Area per effect: 13,747 sq ft.
Type: forced circulation.
Barometric condenser.
Capacity: 10,381 gal per min.
Steam ejector.
Capacity: 246 lb dry gas per hr.

Condensate tanks (S03A)

Number: 10.
Capacity: 34,102 gal.

Pumps (S03B)

Number: 10.
Capacity: 1,250 gal per min.
Drive: 40 hp motor.

Pumps S04)

Number: 1 + 1 extra.
Capacity: 5,102 gal per min.
Drive: 150 hp motor.

Centrifuges (S05)

Number: 7.
Size: 54 in. bowl.
Drive: 150 hp motor.

Pump (S06)

Number: 1.
Capacity: 3,571 gal per min.
Drive: 40 hp motor.

Screw conveyors (S07)

Number: 7.
Size: 12 in. diam x 30 ft.
Drive: 5 hp motor.

Rotary dryers (S08)

Number: 7.
Size: 12 ft diam x 120 ft long.
Drive: 50 hp motor.

Cyclone dust collectors (S09)

Number: 28.
Capacity: 24,832 cu ft per min.

Blowers (S10)

Number: 28.
Capacity: 24,832 cu ft per min.
Drive: 50 hp motor.

Rotary coolers (S11)

Number: 7.
Size: 7.5 ft diam x 81 ft long.
Drive: 20 hp motor.

Belt conveyor (S14)

Number: 1.
Enclosed.
Size: 36 in. x 180 ft.
Speed: 400 ft per min.
Drive: 10 hp motor.
Weightometer included.

TABLE 16. - (Continued)

Belt conveyor (S14A)

Number: 1.
Enclosed.
Size: 36 in. x 225 ft.
Rise: 110 ft.
Speed: 400 ft per min.
Drive: 60 hp motor.

Belt conveyor (S14B)

Number: 1.
Enclosed.
Size: 36 in. x 400 ft.
Speed: 400 ft per min.
Drive: 20 hp motor.
Tripper included.

Silos (S15)

Number: 20.
Concrete.
Capacity: 96,000 cu ft.

Belt feeders (S16)

Number: 20.
Size: 24 in. x 15 ft.
Drive: 1.5 hp motor.

Belt feeders (S16A)

Number: 20.
Size: 24 in. x 25 ft.
Drive: 1.5 hp motor.

Desulfating tanks (S25)

Number: 1.
Capacity: 31,953 gal.
Agitator drive: 30 hp motor.

Hoppers (S26)

Number: 1.
Capacity: 1,092 cu ft.

Belt feeders (S27)

Number: 1.
Size: 24 in. x 10 ft.
Drive: 1.5 hp motor.

Pumps (S28)

Number: 1 + 1 extra.
Capacity: 1,491 gal per min.
Drive: 25 hp motor.

Rotary vacuum filters (S29)

Number: 6.
Area: 790 sq ft.

Repulp tanks (S30)

Number: 6.
Capacity: 3,705 gal.
Agitator drive: 2 hp motor.

Pump (S31)

Number: 1.
Capacity: 1,185 gal per min.
Drive: 75 hp motor.

Pump (S32)

Number: 1.
Capacity: 1,031 gal per min.
Drive: 40 hp motor.

Pumps (S35)

Number: 10.
Capacity: 10,605 gal per min.
Drive: 200 hp motor.

Bag dust collector (SSSS)

Number: 1.
Capacity: 5,700 cu ft per min.

Blowers (SSSS)

Number: 1.
Capacity: 5,675 cu ft per min.
Drive: 15 hp motor.

Water storage tank (SSSS)

Number: 1.
Capacity: 1,055,040 gals.

TABLE 17. - Detailed equipment list, limestone calcining and flue-gas processing section, dawsonite-rich zone

Hoppers (T01)

Number: 11.
Capacity: 1,111 cu ft.

Belt conveyors (T01A)

Number: 11.
Size: 18 in. x 20 ft.
Speed: 250 ft per min.
Drive: 1.5 hp motor.

Belt conveyor (T02)

Number: 1.
Enclosed.
Size: 42 in. x 440 ft.
Speed: 400 ft per min.
Drive: 30 hp motor.
Weightometer included.

Belt conveyor (T02A)

Number: 1.
Enclosed.
Size: 42 in. x 115 ft.
Rise: 60 ft.
Speed: 400 ft per min.
Drive: 75 hp motor.

Belt conveyor (T02B)

Number: 1.
Enclosed.
Size: 42 in. x 300 ft.
Speed: 400 ft per min.
Drive: 40 hp motor.
Tripper included.

Apron feeders (T04)

Number: 1 + 2 extra.
Size: 24 in. x 10 ft.
Drive: 2 hp motor.

Belt conveyor (T05)

Number: 1.
Enclosed.
Size: 24 in. x 150 ft.
Rise: 50 ft.
Speed: 300 ft per min.
Drive: 15 hp motor.

Hopper (T06)

Number: 1.
Capacity: 1,968 cu ft.

Cone crusher, standard head (T08)

Number: 1.
Size: 5 ft.
Drive: 100 hp motor.

Vibrating screen (T09)

Number: 1.
Size: 140 sq ft.
Drive: 15 hp motor.

Belt conveyor (T10)

Number: 1.
Enclosed.
Size: 14 in. x 55 ft.
Rise: 27 ft.
Speed: 200 ft per min.
Drive: 3 hp motor.

Transfer hopper (T10A)

Number: 1.
Capacity: 30 cu ft.

Belt conveyor (T11)

Number: 1.
Enclosed.
Size: 14 in. x 55 ft.
Rise: 27 ft.
Speed: 20 ft per min
Drive: 3 hp motor.

TABLE 17. - (Continued)

Belt conveyor (T12)

Number: 1.
Size: 24 in. x 95 ft.
Rise: 50 ft.
Speed: 300 ft per min.
Drive: 15 hp motor.

Hopper (T13)

Number: 1.
Capacity: 2,599 cu ft.

Cone crushers, short head (T15)

Number: 2.
Size: 5.5 ft.
Drive: 200 hp motor.

Belt conveyor (T16)

Number: 1.
Enclosed.
Size: 24 in. x 100 ft.
Rise: 40 ft.
Speed: 300 ft per min.
Drive: 15 hp motor.

Belt conveyor (T16A)

Number: 1.
Enclosed.
Size: 24 in. x 100 ft.
Speed: 300 ft per min.
Drive: 7.5 hp motor.
Tripper included.

Hoppers (T17)

Number: 4.
Capacity: 492 cu ft.

Screw feeders (T18)

Number: 4.
Size: 18 in. diam x 5 ft.
Drive: 1 hp motor.

Rotary kilns (T19)

Number: 4.
Size: 13.5 ft diam x 279 ft long.
Lining: 9 in superduty fireclay brick.
Drive: 150 hp motor.

Cyclone dust collectors (T20)

Number: 24.
Capacity: 27,074 cu ft per min.

Blowers (T21)

Number: 24.
Capacity: 27,074 cu ft per min.
Drive: 60 hp motor.

Waste-heat boilers (T21A)

Number: 4
Size: 12,493 sq ft.

Blowers (T22)

Number: 12.
Capacity: 28,115 cu ft per min.
Drive: 60 hp motor.

Gas scrubbers (T23)

Number: 4.
Capacity, inlet: 62,226 cu ft per min.

Pumps (T23A)

Number: 4.
Capacity: 1,803 gal per min.
Drive: 30 hp motor.

Compressors (T24)

Number: 4.
Pressure: 50 lb per sq in.
Capacity: 16,979 cu ft per min.
Drive: 850 hp motor.

TABLE 17. - (Continued)

Pump (T24A)

Number: 1.
Capacity: 81 gal per min.
Drive: 3 hp motor.

Rotary coolers (T25)

Number: 4.
Size: 8 ft diam. x 38 ft long.
Drive: 20 hp motor.

Belt conveyor (T28)

Number: 1.
Enclosed.
Size: 20 in. x 100 ft.
Speed: 250 ft per min.
Drive: 3 hp motor.

Belt conveyor (T28A)

Number: 1.
Enclosed.
Size: 20 in. x 225 ft.
Rise: 110 ft.
Speed: 250 ft per min.
Drive: 20 hp motor.

Belt conveyor (T28B)

Number: 1.
Enclosed.
Size: 20 in. x 240 ft.
Speed: 250 ft per min.
Drive: 5 hp motor.
Tripper included.

Silos (T29)

Number: 6.
Concrete.
Capacity: 100,000 cu ft.

Belt feeders (T30)

Number: 6.
Size: 30 in. x 10 ft.
Drive: 2 hp motor.

Belt conveyor (T31)

Number: 1.
Enclosed.
Size: 20 in. x 240 ft.
Speed: 250 ft per min.
Drive: 5 hp motor.

Belt conveyor (T31A)

Number: 1.
Enclosed.
Size: 20 in. x 90 ft.
Rise: 45 ft.
Speed: 250 ft per min.
Drive: 7.5 hp motor.

Belt conveyor (T31B)

Number: 1.
Enclosed.
Size: 20 in. x 1,600 ft.
Speed: 250 ft per min.
Drive: 20 hp motor.
Tripper included.

Service crane (T32)

Number: 1.
Capacity: 40 ton.

Cyclone dust collector (TTTT)

Number: 1.
Capacity: 25,000 cu ft per min.

Blower (TTTT)

Number: 1.
Capacity: 24,275 cu ft per min.
Drive: 50 hp motor.

TABLE 18. - Detailed equipment list, tankage

Service	No. of tanks	Size, bbls	Diam., feet	Height, feet	Type
Retort crude rundown	14	10,000	45	36	Cone roof
Crude storage	4	250,000	134	100	Cone roof
Coking charge	4	30,000	70	45	Cone roof
Coker distillate rundown	4	25,000	70	37	Pontoon roof
Coker distillate storage and hydrocracking charge	4	25,000	70	37	Pontoon roof
Hydrogenation plant rundown ..	4	30,000	70	45	Pontoon roof
Slop tanks	2	6,000	35	36	Cone roof
Emergency fuel	1	800	20	15	Cone roof
Ammonia, liquid	2	1,200	9	53	Horizontal pres. vessel
Sulfur, molten	2	1,070	20	20	Cone roof
Hydrocracked distillate storage	2	250,000	120	125	Pontoon roof

TABLE 19. - Capital investment summary, mine

Unit	Deferred expenses	Depreciable	Total cost
1,900-ft level			
Mining and haulage		$1,764,400	
Crushing and conveying		1,414,400	
Shops and auxiliary		369,200	
Ventilation		30,000	
2,600-ft level			
Mining and haulage		3,404,900	
Crushing and conveying		5,035,100	
Shops and auxiliary		488,400	
Ventilation		160,700	
Common to 1,900 and 2,600 levels			
Ventilation (surface installations)		216,600	
Exploration and development	$911,600		
Shafts and hoisting equipment ..	12,069,000	3,375,200	
Buildings and surface	12,100	1,318,800	
Total direct	12,992,700	17,577,700	$30,570,400
Field indirect 0.5 (16,979,600 x 0.10)......................			849,000
Engineering 0.05 (12,081,100 + 17,577,700 + 849,000).........			1,525,400
Overhead and administration..................................			1,525,400
Subtotal.....................................			34,470,200
Contingency at 10 percent....................................			3,447,000
Total..			37,917,200

TABLE 20. - Equipment cost summary, mine - 1900-ft level

	Description	Cost each	Depreciable Total cost
	Mining and haulage		
4	Joy 15RU cutters	$109,000	$436,000
4	Joy CD-73 2 boom electric drills	73,500	294,000
4	Powder wagon	7,600	30,400
4	Joy 14BU 10-11D loaders	73,500	294,000
8	Joy 10SC 27A shuttle cars	67,200	537,600
4	Joy RBD 8 roof bolters	43,100	172,400
	Grand total		1,764,400
	Conveying and crushing		
3	42-in. conveyors, motors, controls	210,500	631,500
3	36-in. conveyors, motors, controls	188,400	565,200
3	Crusher-conveyor feeders	53,300	159,900
1	Roll crusher at shaft -10 in. to -5 in.	50,700	50,700
1	Closed circuit TV	7,100	7,100
	Grand total		1,414,400
	Shops and auxiliary		
1	Mancar	5,700	5,700
1	Diesel tractor, blade and winch	48,400	48,400
6	Personnel cars	2,700	16,200
8	Transformers 4100-440V	9,100	72,800
1	Battery charger (underground)	300	300
3	Portable machine shops	11,300	33,900
1	Main machine shop	113,400	113,400
	Electric distribution wire,		
	17,500 ft size 0		
	5,000 ft 3-conductor #4	51,300	51,300
	Water line	27,200	27,200
	Grand total		369,200
	Ventilation		
	Main ventilation fans[1]		
30	Heading ventilation fans	1,000	30,000
	Grand total		30,000

1/ See ventilation section for the 2600-ft level.

TABLE 20. - Equipment cost summary, mine - 2600-ft level, continued

Mining and haulage

	Description	Cost each	Depreciable cost
3	Heading jumbo	$171,400	$514,200
2	Bench jumbo	89,500	179,000
4	Powder trucks with pneumatic loading system	22,100	88,400
4	Scaling and rock bolting rig	82,700	330,800
400	Starting drill steel inventory	6/ft	2,400
18	Rotary bits, 3-1/2" and 4"	32	600
4	Hough 400 front end loader	143,300	573,200
9	Haulage trucks	143,940	1,295,500
2	Motor patrol	36,800	73,600
4	Bulldozer	75,400	301,600
4	Water truck	11,400	45,600
	Total		3,404,900

Crushing and conveying

	Description	Cost each	Depreciable cost
3	Hopper	5,100	15,300
3	Apron feeder	17,900	53,700
3	Grizzly feeder, switch gear and motor	25,500	76,500
3	Double roll crusher, switch gear and motor	124,900	374,700
1	Conveyor system	4,492,100	4,492,100
3	Dust collector	7,600	22,800
	Total		5,035,100

TABLE 20. - Equipment cost summary - 2600-ft level, continued

Shops and auxiliary

	Description	Cost each	Depreciable cost
6	Power center transformers	$9,100	$54,600
1	Fuel oil pipeline	27,200	27,200
1	Fuel oil storage tank, underground	8,400	8,400
9,000	ft Electric size "0" main line	75/ft	6,800
3	ANFO transport trailer	1,700	5,100
14	Pickups for supervisors, etc.	4,000	56,000
2	Fuel and service trucks	14,700	29,400
1	Ambulance	5,900	5,900
2	Bus	9,100	18,200
4	Supply truck	5,900	23,600
1	Underground machine shop	253,200	253,200
	Total		488,400

Ventilation

1	Auxiliary ventilation fan	2,700	2,700
20	Auxiliary fans for headings	1,580	31,600
10,000	ft Ventilation tubing 24" diameter	2.38/ft	23,800
30,000	ft Electric cable	2.08/ft	62,400
3	Air locks for ventilation control	13,400	40,200
	Total		160,700
2	Main ventilation fans 1/		216,600
	Total		216,600

1/ These fans provide primary ventilation to both levels.

TABLE 20. - Equipment cost summary, 1900- and 2600-ft levels. continued

Shaft and hoisting equipment

Quantity	Description	Deferred expense	Depreciable
2	Shaft and equipment hoists, Koepe with motors and controls for production $1,016,000 each		$2,296,200
2	Headframe; reinforced concrete structures $107,000 each		241,800
1	Hoist, Koepe with motors and controls for service		367,200
1	Headframe; reinforced concrete structures		120,900
	Installation of hoist and cables		61,000
	Freight and truck haulage		29,500
	Wire rope - 2" - 27,700 ft @ $3.75/ft		117,400
	4 ore skips, 2 cages, ore chute		141,200
2	Production shaft excavation, lining guides, 20 ft inside diameter	$5,693,000	
1	Service shaft excavation, lining guides, 30 ft inside diameter	4,727,500	
3	Underground surge bin	607,100	
6	Shaft stations at levels	879,700	
1	Ore pass 1900 level to 2600 level	40,100	
2	Excavation and structures for loading station and pockets	121,600	
	Total	12,069,000	3,375,200

TABLE 20. - Equipment cost summary, 1900- and 2600-ft levels, continued

Buildings[1/] and surface

Quantity	Description	Deferred expense	Depreciable
1	Access road (temporary)	$12,100	
1	Surface stockpile feed system		$1,318,800
	Total	$1,330,900	

1/ Buildings included in plant facilities charges.

TABLE 21. - Equipment cost summary, nahcolite preparation section, recovery of soda ash from white nahcolite

Item	Quantity	Cost, dollars		Total cost
		Material	Labor	
Apron feeder..............	6	53,300	8,000	
Belt conveyor.............	1	95,400	17,200	
Weightometer..............	1	3,400	900	
Hopper....................	1	7,600	400	
Apron feeder..............	1	8,900	1,400	
Hammermill................	1	30,900	4,300	
Belt conveyor.............	1	27,300	5,000	
Hopper....................	1	7,500	400	
Apron feeder..............	2	10,100	1,500	
Hammermill................	2	79,200	11,200	
Hopper....................	2	9,300	500	
Vibrating screen..........	4	57,300	6,800	
Belt conveyor.............	1	11,800	2,200	
Transfer hopper...........	1	100	100	
Belt conveyor.............	1	11,800	2,200	
Belt conveyor.............	1	45,800	8,200	
Belt conveyor.............	1	23,600	4,200	
Belt feeder...............	6	23,100	3,400	
Belt conveyor.............	1	36,000	6,500	
Belt conveyor.............	1	12,200	2,200	
Surge bin.................	3	6,900	400	
Screw feeder..............	3	20,800	3,200	
Rotary kiln...............	3	1,470,900	441,300	
Cyclone dust collector....	9	64,400	6,500	
Blower....................	9	43,000	4,300	
Rotary cooler.............	3	750,100	150,000	
Cyclone dust collector....	6	46,200	4,600	
Blower....................	9	30,900	3,100	
Bag dust collector........	1	19,900	2,500	
Blower....................	2	9,100	900	
Bag dust collector........	1	3,200	400	
Blower....................	1	1,100	100	
Service crane.............	1	31,100	3,100	
		3,054,200	707,000	$3,761,200
Foundations........................		152,700	203,600	
Structures.........................		122,200	61,100	
Buildings..........................		152,700	152,700	
Insulation.........................		-	-	
Instrumentation....................		61,100	24,400	
Electrical.........................		183,300	137,400	
Piping.............................		152,700	76,400	
Painting...........................		9,200	27,600	
Miscellaneous......................		122,200	97,800	
		956,100	781,000	1,737,100
Total direct.......................		4,010,300	1,488,000	5,498,300
Field indirect.....................				744,000
Storage silos......................				495,000
Total construction.................				6,737,300
Engineering........................				336,900
Overhead and administration........				336,900
				7,411,100
Contingency........................				741,100
				8,152,200
Fee................................				407,600
				8,559,800

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TABLE 22. - Equipment cost summary, leaching section, recovery of soda ash from white nahcolite

Item	Quantity	Cost, dollars Material	Labor	Total cost, dollars
Belt conveyor............	1	31,900	5,700	
Surge bin................	1	10,400	600	
Apron feeder.............	1	6,800	1,000	
Pump.....................	1	1,900	100	
Pump.....................	1	400	100	
Leaching tank............	1	9,800	600	
Pump.....................	2	10,200	200	
Thickener................	1	286,700	28,700	
Pump.....................	10	20,800	400	
C.C.D. thickener.........	4	729,300	72,900	
Pump.....................	4	6,700	200	
Waste mixing tank........	1	5,400	300	
Pump.....................	2	4,500	100	
Pump.....................	2	4,000	100	
Pressure filter..........	7	124,400	12,500	
Sump tank................	7	7,500	800	
Surge tank...............	1	200	100	
Pump.....................	2	2,100	100	
Surge tank...............	2	10,000	1,000	
		1,273,000	125,500	1,398,500
Foundations.................		57,300	76,400	
Structures..................		50,900	25,500	
Buildings...................		50,900	50,900	
Insulation..................		12,700	19,100	
Instrumentation.............		63,600	25,500	
Electrical..................		114,600	85,900	
Piping......................		381,900	191,000	
Painting....................		5,100	15,300	
Miscellaneous...............		63,600	50,900	
		800,600	540,500	1,341,100
Total direct................		2,073,600	666,000	2,739,600
Field indirect..				333,000
Total construction......................................				3,072,600
Engineering...				153,600
Overhead and administration.............................				153,600
				3,379,800
Contingency...				338,000
				3,717,800
Fee...				185,900
				3,903,700

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TABLE 23.-Equipment cost summary, crystallization section

Item	Quantity	Cost Material	Cost Labor	Total cost
Pump	2	$5,800	$200	
Crystallizer 7 effect	1	1,688,800	84,400	
Surge tank	5	142,700	4,200	
Pump	1	1,800	100	
Pump	1	5,500	100	
Pump	2	10,000	200	
Centrifuge	4	271,900	27,200	
Heat exchanger	1	300	100	
Surge tank	1	5,900	600	
		2,132,700	117,100	$2,249,800
Foundations		96,000	128,000	
Structures		85,300	42,700	
Buildings		85,300	85,300	
Insulation		21,300	32,000	
Instrumentation		106,600	42,700	
Electrical		191,900	144,000	
Piping		639,800	319,900	
Painting		8,500	25,500	
Miscellaneous		106,600	85,300	
		1,341,300	905,400	2,246,700
Total direct		3,474,000	1,022,500	4,496,500
Field indirect				511,200
Total construction				5,007,700
Engineering				250,400
Overhead and administration				250,400
				5,508,500
Contingency				550,800
				6,059,300
Fee				303,000
				6,362,300

TABLE 24. - Equipment cost summary, product drying and storage section

	Quantity	Cost, dollars Material	Labor	Total cost
Screw conveyor...........	4	$12,900	$1,900	
Rotary dryer.............	4	690,300	110,500	
Bag dust collector.......	12	216,900	28,200	
Blower...................	12	50,700	5,100	
Rotary cooler............	4	245,200	39,200	
Belt conveyor............	1	37,000	6,600	
Belt conveyor............	1	28,000	5,100	
Belt feeder..............	10	34,100	5,200	
Belt feeder..............	10	52,000	7,700	
Bag dust collector.......	1	4,600	500	
Blower...................	1	1,800	200	
		1,373,500	210,200	$1,583,700
Foundations......................		68,700	91,600	
Structures.......................		54,900	27,500	
Buildings........................		68,700	68,700	
Insulation.......................		-	-	
Instrumentation..................		27,500	11,000	
Electrical.......................		82,400	61,800	
Piping...........................		68,700	34,300	
Painting.........................		4,100	12,300	
Miscellaneous....................		54,900	43,900	
		429,900	351,100	781,000
Total direct.....................		1,803,400	561,300	2,364,700
Field indirect..				280,600
Storage silos...				730,300
Total construction....................................				3,375,600
Engineering...				168,800
Overhead and administration...........................				168,800
				3,713,200
Contingency...				371,300
				4,084,500
Fee...				204,200
				4,288,700

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TABLE 25. - Equipment cost summary, crushing, screening, and storage

Item	Quantity	Material, dollars	Labor, dollars	Total cost, dollars
Surge bin No. 1................	1	25,900	2,600	
Apron feeder....................	4	255,600	25,600	
Grizzly bar screen.............	2	27,900	2,800	
Secondary crusher..............	2	134,400	13,400	
Conveyor........................	4	49,700	5,000	
Conveyor........................	3	82,200	8,200	
Splitter........................	1	10,100	1,000	
Scalping screen.................	4	39,600	4,000	
Tertiary crusher................	2	134,400	13,400	
Surge bin No. 2.................	2	260,800	26,100	
Apron feeder....................	4	255,600	25,600	
Conveyor........................	1	39,700	4,000	
Screen feed hopper..............	2	34,500	3,500	
Apron feeder....................	8	131,900	13,200	
Screen..........................	8	79,100	7,900	
Surge bin No. 3.................	2	57,200	5,700	
Surge bin No. 4.................	2	65,200	6,500	
Conveyor........................	2	76,400	7,600	
Exhauster.......................	1	30,400	7,600	
Cyclone.......................	1	6,100	600	
		1,796,700	184,300	1,981,000
Foundations..........................		89,800	119,400	
Structures...........................		71,900	36,000	
Buildings............................		89,800	89,800	
Insulation...........................		-	-	
Instrumentation......................		35,900	14,400	
Electrical...........................		107,800	80,900	
Piping...............................		89,800	44,400	
Painting.............................		5,400	16,200	
Miscellaneous........................		71,900	57,500	
		562,300	458,600	1,020,900
Total direct.........................		2,359,000	642,900	3,001,900
Field indirect..				321,400
Total construction..				3,323,300
Engineering...				166,200
Overhead and administration.................................				166,200
				3,655,700
Contingency...				365,600
				4,021,300
Fee...				201,100
				4,222,400

TABLE 26. - Equipment cost summary, briquetting

Item	Quantity	Cost, dollars Material	Cost, dollars Labor	Total cost, dollars
Surge bin No. 1............	1	5,800	600	
Vibratory feeder No. 1.....	1	1,600	200	
Hammermill.................	1	3,600	800	
Mixer-briquetting machine..	1	79,200	7,900	
Surge bin No. 2............	1	5,800	600	
Surge bin No. 3............	1	5,800	600	
Conveyor No. 1.............	1	7,400	700	
Conveyor No. 2.............	1	7,400	700	
Vibratory feeder No. 2.....	1	1,600	200	
Conveyor No. 3.............	1	5,000	500	
Conveyor No. 4.............	1	27,600	2,800	
Conveyor No. 5.............	1	27,600	2,800	
		178,400	18,400	196,800
Foundations..........................		8,900	11,800	
Structures...........................		7,100	3,600	
Buildings............................		8,900	8,900	
Insulation...........................				
Instrumentation......................		3,600	1,400	
Electrical...........................		10,700	8,000	
Piping...............................		8,900	4,500	
Painting.............................		500	1,500	
Miscellaneous........................		7,100	5,700	
		55,700	45,400	101,100
Total direct.........................		234,100	63,800	297,900
Field indirect.......................				31,900
Total construction...................				329,800
Engineering..........................				16,500
Overhead and administration..........				16,500
				362,800
Contingency..........................				36,300
				399,100
Fee..................................				20,000
				419,100
Dryers (2)...........................				793,800
				1,212,900

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TABLE 27. - Equipment cost summary, retorting plant

Item	Quantity	Cost, dollars Material	Cost, dollars Labor	Total cost, dollars
Rotoclone	49	1,295,300	323,800	
Heating gas blower	7	182,900	45,700	
Electrostatic precipitator	14	4,842,700	968,500	
Retort gas blower	7	2,207,900	552,000	
Combustion air blower	7	292,300	73,100	
Recycle gas heater	7	2,001,000	200,100	
Shale oil pump	7	11,600	2,900	
Retort feed hopper	7	109,300	10,900	
Retort feed conveyor	2	102,700	10,300	
Bucket elevator feed hopper	7	109,300	10,900	
Apron feeder	21	410,000	41,000	
Bucket elevator	21	242,900	24,300	
Retort discharge conveyor	1	113,000	11,300	
Traveling stacking conveyor	2	63,700	6,400	
Retorts	7	2,781,000	278,100	
		14,765,600	2,559,300	17,324,900
Foundations		1,107,400	1,476,600	
Structures		1,107,400	553,700	
Buildings		590,600	590,600	
Insulation		443,000	886,000	
Instrumentation		738,300	295,300	
Electrical		590,600	443,000	
Piping		5,906,200	2,953,100	
Painting		118,100	354,300	
Miscellaneous		1,181,200	945,000	
		11,782,800	8,497,600	20,280,400
Total direct		26,548,400	11,056,900	37,605,300
Field indirect				5,528,400
Total construction				43,133,700
Engineering				2,156,700
Overhead and administration				2,156,700
				47,447,100
Contingency				4,744,700
				52,191,800
Fee				2,609,600
				54,801,400

OPTION III

TABLE 28. - Equipment cost summary, delayed coking

Item	Quantity	Material, dollars	Labor, dollars	Total cost, dollars
Coke chamber	4	956,400	95,600	
Main fractionator	2	196,400	19,600	
Oil heating furnace	2	1,009,000	201,800	
Depropanizer	2	10,800	1,100	
Absorber	2	57,800	5,800	
Coke cutter	2	392,800	98,200	
Accumulator	2	7,800	800	
		2,631,000	422,900	3,053,900
Foundations		105,200	139,900	
Structures		197,300	98,700	
Buildings		105,200	105,200	
Insulation		78,900	157,800	
Instrumentation		184,200	73,700	
Electrical		105,200	78,900	
Piping		1,052,400	526,200	
Painting		13,200	39,600	
Miscellaneous		263,100	210,500	
		2,104,700	1,430,500	3,535,200
Total direct		4,735,700	1,853,400	6,589,100
Field indirect				926,700
Total construction				7,515,800
Engineering				375,800
Overhead and administration				375,800
				8,267,400
Contingency				826,700
				9,094,100
Fee				454,700
				9,548,800

TABLE 29. - Equipment cost summary, refining

Item	Material, dollars	Total cost, dollars
Hydrogen production..........	13,682,400	
Hydrocracking................	19,065,000	
Ammonia recovery.............	1,190,300	
Sulfur recovery..............	1,144,400	
Tankage......................	2,957,300	
Total construction...........................		38,039,400
Engineering..................................		1,902,000
Overhead and administration..................		1,902,000
		41,843,400
Contingency..................................		4,184,300
		46,027,700
Fee..		2,301,400
		48,329,100

TABLE 30. - Equipment cost summary, retorted shale crushing section, dawsonite-rich zone

Item	Quantity	Cost, dollars Material	Cost, dollars Labor	Total cost, dollars
Belt conveyor...........	1	176,000	31,700	
Belt conveyor...........	1	34,700	6,200	
Weightometer............	1	3,700	900	
Hopper..................	5	53,800	2,700	
Belt feeder.............	5	13,400	2,000	
Hammermill..............	5	244,300	34,200	
Vibrating screen........	15	160,300	19,300	
Belt conveyor...........	1	22,400	4,100	
Belt conveyor...........	1	15,800	2,800	
Transfer hopper.........	1	100	100	
Belt conveyor...........	1	15,800	2,800	
Belt conveyor...........	1	35,800	6,500	
Belt conveyor...........	1	42,000	7,500	
Belt conveyor...........	1	20,200	3,800	
Service crane...........	1	43,900	4,400	
Cyclone dust collector..	4	38,700	3,800	
Blower..................	8	30,100	3,000	
		951,000	135,800	1,086,800
Foundations.		47,600	63,400	
Structures...................		38,000	19,000	
Buildings....................		47,600	47,600	
Instrumentation..............		19,000	7,600	
Electrical...................		57,100	42,800	
Piping.......................		47,600	23,800	
Painting.....................		2,900	8,700	
Miscellaneous................		38,000	30,400	
		297,800	243,300	541,100
Total direct.................		1,248,800	379,100	1,627,900
Field indirect..				189,600
Total construction..				1,817,500
Engineering...				90,900
Overhead and administration..				90,900
				1,999,300
Contingency...				199,900
				2,199,200
Fee...				110,000
				2,309,200

TABLE 31. - Equipment cost summary, retorted shale leaching section, dawsonite-rich zone

Item	Quantity	Cost, dollars Material	Labor	Total cost, dollars
Hopper.................	4	37,900	1,900	
Belt feeder............	4	9,500	1,500	
Leaching tank..........	4	61,600	3,300	
Hopper.................	4	1,200	100	
Belt feeder............	4	5,100	800	
Pump...................	2	20,000	500	
Settler................	4	823,000	82,300	
Pump...................	4	17,100	300	
Thickener..............	3	617,300	61,700	
Pump...................	3	14,500	300	
Thickener..............	3	617,300	61,700	
Pump...................	3	4,500	200	
Pump...................	3	14,500	300	
Thickener..............	3	617,300	61,700	
Pump...................	3	4,500	200	
Pump...................	3	7,700	300	
Storage tank...........	4	51,200	3,500	
Pump...................	4	5,900	300	
Pump...................	4	17,300	300	
Clarifying filter......	31	551,000	55,100	
Repulp tank............	2	6,700	700	
Pump...................	1	1,900	100	
Pump...................	3	25,000	500	
		3,532,000	337,600	3,869,600
Foundations..................		158,900	211,900	
Structures...................		141,300	70,600	
Buildings....................		141,300	141,300	
Insulation...................		35,300	53,000	
Instrumentation..............		176,600	70,600	
Electrical...................		317,900	238,400	
Piping.......................		1,059,600	528,800	
Painting.....................		14,100	42,300	
Miscellaneous................		176,600	141,300	
		2,221,600	1,498,200	3,719,800
Total direct.................		5,753,600	1,835,800	7,589,400
Field indirect..				917,900
Total construction..				8,507,300
Engineering...				425,400
Overhead and administration...............................				425,400
				9,358,100
Contingency...				935,800
				10,293,900
Fee...				514,700
			OPTION III	10,808,600

TABLE 32. - Equipment cost summary, desilication section dawsonite-rich zone

Item	Quantity	Material, dollars	Labor, dollars	Total cost, dollars
Desilication tanks	6	101,400	6,000	
Hopper	1	500	100	
Table feeders	2	5,500	800	
Lime slakers	2	23,500	1,500	
Pump	1	1,000	100	
Pumps	6	20,700	400	
Settlers	2	464,800	46,500	
Pumps	2	2,500	100	
Thickeners	2	464,800	46,500	
Pumps	2	3,300	100	
Pumps	2	800	100	
Pumps	2	8,900	400	
Clarifying filters	26	522,000	52,200	
Repulp tanks	2	6,600	600	
Pump	1	400	100	
Storage tanks	5	70,900	4,700	
		1,697,600	160,200	1,857,800
Foundations		76,400	101,900	
Structures		67,900	33,900	
Buildings		67,900	67,900	
Insulation		17,000	25,500	
Instrumentation		84,900	34,000	
Electrical		152,800	114,600	
Piping		509,300	254,600	
Painting		6,800	20,400	
Miscellaneous		84,900	67,900	
		1,067,900	720,700	1,788,600
Total direct		2,765,500	880,900	3,646,400
Field indirect				440,400
Total construction				4,086,800
Engineering				204,300
Overhead and administration				204,300
				4,495,400
Contingency				449,500
				4,944,900
Fee				247,200
				5,192,100

OPTION III

TABLE 33. - Equipment cost summary, alumina precipitation and calcination section, dawsonite-rich zone

Item	Quantity	Cost, dollars Material	Cost, dollars Labor	Total cost, dollars
Pump	1	6,100	300	
Carbonation tank	56	535,900	53,600	
Carbonation tank	56	535,900	53,600	
Pump	2	14,500	300	
Primary thickener	1	178,500	17,800	
Pump	1	7,200	100	
Secondary thickener	1	110,500	11,000	
Pump	1	5,100	200	
Pump	1	2,700	100	
Pump	2	7,100	100	
Wash tank	2	27,200	2,700	
Pump	1	600	100	
Pump	2	4,700	100	
Wash tank	1	27,200	2,700	
Pump	1	600	100	
Internal drum filter	5	211,800	21,200	
Pump	1	800	100	
Screw conveyor	5	10,300	1,600	
Rotary kiln	5	6,809,500	2,042,800	
Cyclone dust collector	30	165,800	16,600	
Blower	30	97,500	9,700	
Rotary cooler	5	260,600	65,200	
Belt conveyor	1	16,100	2,900	
Weightometer	1	2,900	800	
Belt conveyor	1	24,600	4,400	
Belt conveyor	1	25,100	4,500	
Belt feeder	10	22,000	3,300	
Bag dust collector	1	3,600	500	
Blower	1	600	100	
		9,115,000	2,316,500	11,431,500
Foundations		410,200	546,900	
Structures		364,600	182,300	
Buildings		364,600	364,600	
Insulation		91,100	136,600	
Instrumentation		455,700	182,300	
Electrical		820,300	615,200	
Piping		2,734,500	1,367,200	
Painting		36,500	109,500	
Miscellaneous		455,700	364,600	
		5,733,200	3,869,200	9,602,400
Total direct		14,848,200	6,185,700	21,033,900
Field indirect				3,092,800
Silos				352,600
Total construction				24,479,300
Engineering				1,224,000
Overhead and administration				1,224,000
				26,927,300
Contingency				2,692,700
				29,620,000
Fee				1,481,000
				31,101,000

OPTION III

TABLE 34. - Equipment cost summary, shale fines leaching section, dawsonite-rich zone

Item	Quantity	Cost, dollars Material	Cost, dollars Labor	Total cost, dollars
Belt conveyor...........	1	87,000	15,600	
Belt conveyor...........	1	14,700	2,700	
Weightometer............	1	3,000	800	
Hopper..................	6	9,400	400	
Screw feeder............	6	44,700	6,700	
Rotary kiln.............	6	1,044,600	167,100	
Cyclone dust collector..	12	68,000	6,800	
Blower..................	12	45,200	4,500	
Rotary cooler...........	6	325,500	52,100	
Belt conveyor...........	1	24,100	4,400	
Belt conveyor...........	1	20,700	3,700	
Hopper..................	1	5,900	300	
Belt feeder.............	1	2,400	300	
Leaching tank...........	1	9,200	400	
Pump....................	1	2,900	100	
Settler.................	1	71,600	7,200	
Pump....................	1	3,500	100	
Thickener...............	1	103,900	10,400	
Pump....................	1	1,200	100	
Pump....................	1	3,500	100	
Rotary vacuum filter....	10	364,800	36,500	
Belt conveyor...........	1	51,400	9,200	
Pump....................	1	700	100	
Pump....................	1	1,100	100	
Clarifying filter.......	2	35,600	3,600	
Repulp tank.............	1	900	100	
Pump....................	1	1,000	100	
Cyclone dust collector..	1	2,100	200	
Blower..................	1	900	100	
		2,349,500	333,800	2,683,300
Foundations.........................		105,700	140,900	
Structures..........................		94,000	47,000	
Buildings...........................		94,000	94,000	
Insulation..........................		23,500	35,200	
Instrumentation.....................		117,500	47,000	
Electrical..........................		211,500	105,700	
Piping..............................		704,800	352,400	
Painting............................		9,400	28,200	
Miscellaneous.......................		117,500	94,000	
		1,477,900	944,400	2,422,300
Total direct........................		3,827,400	1,278,200	5,105,600
Field indirect..				639,100
Total construction......................................				5,744,700
Engineering...				287,200
Overhead and administration.............................				287,200
				6,319,100
Contingency...				631,900
				6,951,000
Fee...				347,500
				7,298,500

TABLE 35. - Equipment cost summary, soda ash crystallization and dehydration section, dawsonite-rich zone

Item	Quantity	Cost, dollars Material	Cost, dollars Labor	Total cost, dollars
Mixing tank............	1	11,900	700	
Pump.....................	1	2,900	100	
Drystallizers............	10	17,704,300	885,200	
Condensate tank..........	10	51,600	5,200	
Pump.....................	10	12,000	600	
Pump.....................	2	13,000	200	
Centrifuge...............	7	347,200	34,700	
Pump.....................	1	1,300	100	
Screw conveyor...........	7	16,100	2,400	
Rotary dryer.............	7	1,335,100	213,600	
Cyclone dust collector...	28	149,900	14,900	
Blower...................	28	89,100	8,900	
Rotary cooler............	7	504,600	80,700	
Belt conveyor............	1	31,500	5,700	
Weightometer.............	1	3,000	800	
Belt conveyor............	1	38,200	6,800	
Belt conveyor............	1	69,800	12,600	
Belt feeder..............	20	44,000	6,600	
Belt feeder..............	20	64,800	9,800	
Desulfating tank.........	1	7,400	400	
Hopper...................	1	2,100	100	
Belt feeder..............	1	1,700	200	
Pump.....................	2	6,200	100	
Rotary vacuum filter.....	6	249,200	24,900	
Repulp tank..............	6	11,100	800	
Pump.....................	1	4,000	100	
Pump.....................	1	1,100	100	
Pump.....................	10	40,000	2,000	
Bag dust collector.......	1	5,400	700	
Blower...................	1	900	100	
Water storage tank.......	1	30,200	3,000	
		20,849,600	1,322,100	22,171,700
Foundations........................		938,200	1,250,900	
Structures.........................		834,000	417,000	
Buildings..........................		834,000	834,000	
Insulation.........................		208,500	312,700	
Instrumentation....................		1,042,500	417,000	
Electrical.........................		1,876,500	1,407,400	
Piping.............................		6,254,900	3,127,400	
Painting...........................		83,400	250,200	
Miscellaneous......................		1,042,500	834,000	
		13,114,500	8,850,600	21,965,100
Total direct.......................		33,964,100	10,172,700	44,136,800
Field indirect.....................				5,086,300
Silos..............................				1,435,500
Total construction.................				50,658,600
Engineering........................				2,532,900
Overhead and administration........				2,532,900
				55,724,400
Contingency........................				5,572,400
				61,296,800
Fee................................				3,064,800
				64,361,600

TABLE 36. - Equipment cost summary, limestone calcining and flue-gas processing section, dawsonite-rich zone

Item	Quantity	Cost, dollars Material	Cost, dollars Labor	Total cost, dollars
Hopper.....................	11	26,500	1,300	
Belt conveyor..............	11	29,500	5,300	
Belt conveyor..............	1	86,000	15,500	
Weightometer...............	1	3,600	900	
Belt conveyor..............	1	26,800	4,800	
Belt conveyor..............	1	69,100	12,400	
Apron feeder...............	3	15,700	2,400	
Belt conveyor..............	1	53,600	9,600	
Hopper.....................	1	3,800	100	
Cone crusher, standard head	1	73,800	7,400	
Vibrating screen...........	1	8,500	1,000	
Belt conveyor..............	1	8,400	1,500	
Transfer hopper............	1	100	100	
Belt conveyor..............	1	8,400	1,500	
Belt conveyor..............	1	15,600	2,800	
Hopper.....................	1	4,800	300	
Cone crusher, short head...	2	161,800	19,400	
Belt conveyor..............	1	16,400	2,900	
Belt conveyor..............	1	18,300	3,300	
Hopper.....................	4	4,900	300	
Screw feeder...............	4	19,900	3,000	
Rotary kiln................	4	2,509,100	752,700	
Cyclone dust collector.....	24	150,400	15,100	
Blower.....................	24	97,300	9,800	
Blower.....................	8	49,800	4,900	
Gas scrubber...............	4	64,400	6,500	
Pump.......................	4	4,900	300	
Compressor.................	1	323,600	32,300	
Pump.......................	1	400	100	
Rotary cooler..............	4	180,700	45,100	
Belt conveyor..............	1	15,300	2,800	
Belt conveyor..............	1	29,000	5,200	
Belt conveyor..............	1	34,100	6,100	
Belt feeder................	6	12,600	1,900	
Belt conveyor..............	1	30,600	5,500	
Belt conveyor..............	1	14,200	2,500	
Belt conveyor..............	1	150,600	27,100	
Service crane..............	1	43,900	4,400	
Cyclone dust collector.....	1	7,600	800	
Blower.....................	1	3,600	400	
		4,377,600	1,019,300	5,396,900
Foundations........................		175,400	233,500	
Structures.........................		175,400	87,500	
Buildings..........................		175,400	175,100	
Insulation.........................		131,300	196,900	
Instrumentation....................		306,400	122,600	
Electrical.........................		350,200	262,700	
Piping.............................		1,532,200	766,100	
Painting...........................		17,500	52,500	
Miscellaneous......................		175,400	140,300	
		3,039,200	2,037,200	5,076,400
Total direct.......................		7,416,800	3,056,500	10,473,300
Field indirect..				1,528,200
Silos...				495,000
Waste heat boilers....................................				410,800
Total construction....................................				12,907,300
Engineering...				645,400
Overhead and administration...........................				645,400
				14,198,100
Contingency...				1,419,800
				15,617,900
Fee...				780,900
				16,398,800

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TABLE 37. - Estimated working capital.

Inventory - 30 calendar days' production	$21,172,600
Account Receivable - 90 calendar days' production	63,517,700
Cash - 30 calendar days' production	21,172,600
	105,862,900

TABLE 38. - General manning table

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
GENERAL ADMINISTRATION AND SERVICES											
President of company	1			1	1					50,000	50,000
Vice President	3			3	3					35,000	105,000
Secretary-Treasurer	1			1	1					35,000	35,000
Sales Manager	1			1	1					27,500	27,500
Salesman	5			5	5					20,500	102,500
Secretary (President)	1			1	1					9,600	9,600
Secretary	5			5	5					8,300	41,500
Personnel Officer	1			1	1					12,400	12,400
Personnel Clerk	2			2	2					8,300	16,600
Payroll Clerk	3			3	3					10,300	30,900
Contract Officer	1			1	1					16,500	16,500
Accountant	3			3	3					12,400	37,200
Guard	3	3	3	9	12.6	3.70	266.40	365	97,236		
Janitor			5	5	5	2.50	100.00	260	26,000		
Messenger	1	1	1	3	4.2	3.60	86.40	365	31,536		
Stock Clerk	2	2	2	6	8.4	3.80	182.40	365	66,576		
Safety Engineer	1			1	1					16,500	16,500
Assistant Safety Engineer	1			1	1					12,400	12,400
Nurse	1	1	1	3	4					7,600	30,400
Chief Chemist	1			1	1					17,900	17,900
Doctor	1			1	1					27,500	27,500
Chief Draftsman	1			1	1					10,300	10,300
Supt. Construction & maintenance	1			1	1					13,800	13,800
Chief Engineer	1			1	1					20,500	20,500
Sample Collector & tester	4	4	4	12	16.8					12,400	208,320
Gas Analyst	1			1	1					12,400	12,400
Sample Prep.	2	2	2	6	8.4					12,400	104,160
Shale Analyst	2	2	2	6	8.4					12,400	104,160
Subtotal				85	102.8				221,348		1,063,040

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TABLE 38, continued

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
PLANT OPERATION											
Administration and services											
Superintendent	1			1	1					27,500	27,500
Assistant Superintendent	3			3	3					22,000	66,000
General Foreman	3	3	3	9	12.6					17,900	225,540
Mechanical engineer	3			3	3					16,500	49,500
Chemical engineer	2			2	2					16,500	33,000
Civil engineer	1			1	1					16,500	16,500
Draftsman	3			3	3					9,600	28,800
Warehouseman	3	3	3	9	12.6	4.50	324.00	365	118,260		
Warehouseman helper	3	3	3	9	12.6	4.15	298.80	365	109,062		
Timekeeper	4			4	4					6,900	27,600
Stenographer	8			8	8					6,200	49,600
Subtotal				52	62.8				227,322		524,040
Production											
White Nahcolite Processing											
Foreman	2	2	2	6	8.4					12,400	104,160
Storage pile operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Belt operator	2	2	2	6	8.4	4.50	216.00	365	78,840		
Hammermill operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Kiln operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Helpers	4	4	4	12	16.8	4.50	432.00	365	157,680		
Pumper	1	1	1	3	4.2	4.50	108.00	365	39,420		
Thickener operator	2	2	2	6	8.4	4.50	216.00	365	78,840		

TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Helper	1	1	1	3	4.2	4.25	102.00	365	37,230		
Crystallization operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Helper	1	1	1	3	4.2	4.25	102.00	365	37,230		
Dryer operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Conveyor operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Helper	1	1	1	3	4.2	4.25	102.00	365	37,230		
Head loader	1			1	1	4.80	38.40	260	9,984		
Loaders	2			2	2	4.50	72.00	260	18,720		
Loaders helper	3			3	3	4.25	102.00	260	26,520		
Subtotal				66	90.0				766,098		104,160
Oil Shale Crushing, Screening, Briquetting, and Retorting											
Crushing and screening											
Foreman	1			1	1					12,400	12,400
Operator	2	2	2	6	8.4	4.80	230.40	365	84,096		
Operator helper	2	2	2	6	8.4	4.50	216.00	365	78,840		
Briquetting											
Dryer operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Briquetting operator	1	1	1	3	4.2	4.15	99.60	365	36,354		
Operator helper	1	1	1	3	4.2	4.00	96.00	365	35,040		
Retorting											
Shift foreman	1	1	1	3	4.2					12,400	52,080
Operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Operator helper	8	8	8	24	33.6	4.15	864.00	365	315,360		

TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Sampler	1	1	1	3	4.2	4.50	108.00	365	39,420		
Heavy equipment operator	1			1	1.4	4.80	38.40	365	14,016		
Heavy equipment operator helper	1			1	1.4	4.50	36.00	365	13,140		
Boiler Fireman	1	1	1	3	4.2	4.50	108.00	365	39,420		
Controlman	2	2	2	6	8.4	4.80	230.40	365	84,096		
Subtotal				66	92.0				821,250		64,480
Sodium and Aluminum Recovery											
Retorted shale crushing											
Foreman	1	1	1	3	4.2					12,040	52,080
Storage pipe operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Hammer mill operator	2	2	2	6	8.4	4.80	230.40	365	84,096		
Operator's helper	4	4	4	12	16.8	4.50	432.00	365	157,680		
Retorted shale leaching											
Foreman	1	1	1	3	4.2					12,400	52,080
Leach tank operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Settler operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Filter operator	4	4	4	12	16.8	4.80	460.80	365	168,192		
Thickener operator	3	3	3	9	12.6	4.80	345.60	365	126,144		
Helpers	7	7	7	21	29.4	4.50	756.00	365	275,940		
Desilication											
Foreman	1	1	1	3	4.2					12,400	52,080
Desilication tank operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Settler operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Filter operator	2	2	2	6	8.4	4.80	230.40	365	84,096		
Operator helper	2	2	2	6	8.4	4.50	216.00	365	78,840		

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TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Alumina precipitation and calcination											
Foreman	1	1	1	3	4.2					12,400	52,080
Carbonation tank operator	4	4	4	12	16.8	4.80	460.80	365	168,192		
Thickener operator	2	2	2	6	8.4	4.80	230.40	365	84,096		
Filter Operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Kiln and cooler operator	3	3	3	9	12.6	4.80	345.60	365	126,144		
Operator helper	7	7	7	21	29.4	4.50	756.00	365	275,940		
Loader	2			2	2	4.80	76.80	260	19,968		
Loader helper	3			3	3	4.50	108.00	260	28,080		
Shale fines leaching											
Foreman	1	1	1	3	4.2					12,400	52,080
Conveyor operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Kiln and cooler operator	3	3	3	9	12.6	4.80	345.60	365	126,144		
Leach tank operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Settler and thickener Operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Filter operator	3	3	3	9	12.6	4.80	345.60	365	126,144		
Repulp tank operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Operator helper	6	6	6	18	25.2	4.50	648.00	365	236,520		
Soda ash crystallization and dehydration											
Foreman	1	1	1	3	4.2					12,400	52,080
Crystallizer operator	3	3	3	9	12.6	4.80	345.60	365	126,144		
Centrifuge operator	3	3	3	9	12.6	4.80	345.60	365	126,144		
Dryer and cooler operator	4	4	4	12	16.8	4.80	460.80	365	168,192		
Desulfating operator	1	1	1	3	4.2	4.80	115.20	365	42,048		

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TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Filter operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Operator helper	6	6	6	18	25.2	4.50	648.00	365	236,520		
Loader	8			8	8	4.80	307.20	260	79,872		
Loader helper	12			12	12	4.50	432.00	260	112,320		
Limestone calcination and flue gas processing											
Foreman	1	1	1	3	4.2					12,400	52,080
Conveyor operator	2	2	2	6	8.4	4.80	230.40	365	84,096		
Crusher operator	2	2	2	6	8.4	4.80	230.40	365	84,096		
Kiln and cooler	2	2	2	6	8.4	4.80	230.40	365	84,096		
Stockpile operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Operator helper	6	6	6	18	25.2	4.50	648.00	365	236,520		
Crane operator	1			1	1	4.80	38.40	260	9,984		
Loader	2			2	2	4.80	76.80	260	19,968		
Loader helper	3			3	3	4.50	108.00	260	28,080		
Subtotal				331	451.0				4,108,872		364,560
Shale Oil Processing											
Coking plant and hydrocracking											
Coke unit foreman	1	1	1	3	4.2					12,400	52,080
Operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Controlman	1	1	1	3	4.2	4.25	102.00	365	37,230		
Fireman	1	1	1	3	4.2	4.50	108.00	365	39,420		
Decoker	3	3	3	9	12.6	4.15	298.80	365	109,062		
Hydrocracking foreman	1	1	1	3	4.2					12,400	52,080

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Table 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Fireman	1	1	1	3	4.2	4.50	108.00	365	39,420		
Compressor operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Helper		1	1	2	2.8	4.50	72.00	365	26,280		
Controlman	1	1	1	3	4.2	4.80	115.20	365	42,048		
Hydrogen plant, ammonia and sulfur recovery											
Foreman	1	1	1	3	4.2					12,400	52,080
Hydrogen plant operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Hydrogen general helper	1	1	1	3	4.2	4.15	99.60	365	36,354		
Controlman	1	1	1	3	4.2	4.80	115.20	365	42,048		
Operator (NH_3 and sulfur plant)	1	1	1	3	4.2	4.50	108.00	365	39,420		
Operator helper	2	2	2	6	8.4	4.25	204.00	365	74,460		
Pumping and loading											
Head pumper and loader	1	1	1	3	4.2	4.80	115.20	365	42,048		
Pumper and gauger	2	2	2	6	8.4	4.50	216.00	365	78,840		
Coke, sulfur & ammonia loader	3			3	4.2	4.15	99.60	365	36,354		
Subtotal				71	99.4				803,292		156,240
Utilities and Facilities											
Shift foreman	2	2	2	6	8.4					12,400	104,160
Steam plant operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Powerplant operator	1	1	1	3	4.2	4.80	115.20	365	42,048		
Water plant operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Helper	3	3	3	9	12.6	4.15	298.80	365	109,062		

TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Cooling tower operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Sewage disposal operator	1	1	1	3	4.2	4.50	108.00	365	39,420		
Pumper	9	9	9	27	37.8	4.80	1,036.80	365	378,432		
Waste disposal operator	4	4	4	12	16.8	4.80	460.80	365	168,192		
Waste disposal pumper	2	2	2	6	8.4	4.80	230.40	365	84,096		
Waste disposal driver	1	1	1	3	4.2	4.80	115.20	365	42,048		
Subtotal				78	109.2				981,558		104,160
TOTAL PRODUCTION				612	841.6				7,481,070		793,600
Maintenance										12,400	1,041,600
Shift foreman	20	20	20	60	84	4.50	576.00	260	149,760		
Carpenter	12	2	2	16	[1]16	4.15	531.20	260	138,112		
Carpenter helper	12	2	2	16	[1]16	4.50	1,620.00	365	591,300		
Pipefitter	15	15	15	45	63	4.15	1,494.00	365	545,310		
Pipefitter helper	15	15	15	45	63	4.25	340.00	260	88,400		
Painter	10			10	[1]10	4.80	1,382.40	365	504,576		
Welder	12	12	12	36	50.4	4.15	1,195.20	365	436,248		
Welder helper	12	12	12	36	50.4	5.15	2,224.80	365	812,052		
Instrument technician	18	18	18	54	75.6	3.50	952.00	260	247,520		
General maintenance	14	10	10	34	[1]34	4.80	1,843.20	365	672,768		
Electrician	16	16	16	48	67.2	4.50	1,728.00	365	630,720		
Electrician helper	16	16	16	48	67.2	4.50	1,512.00	365	551,880		
Mechanic	18	12	12	42	58.8	4.15	1,394.40	365	508,956		
Mechanic helper	18	12	12	42	58.8	4.80	230.40	260	59,904		
Bricklayer	6			6	[1]6	4.50	216.00	260	56,160		
Bricklayer helper	6			6	[1]6	5.15	494.40	365	180,456		
Master machinist	4	4	4	12	16.8	4.80	1,382.40	365	504,576		
Machinist	12	12	12	36	50.4						

[1] Five-day week.

TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Heavy equipment operator	8	5	5	18	25.2	4.80	691.20	365	252,288		
General helper	30	30	30	90	126	3.50	2,520.00	365	919,800		
TOTAL MAINTENANCE				700	944.8				7,850,786		1,041,600
TOTAL PLANT OPERATIONS				1,364	1,849.2				15,559,178		2,359,240
MINE OPERATIONS											
Administration and Services											
Mine superintendent	1			1	1					30,300	30,300
Assistant superintendent	1			1	1					22,000	22,000
Mine foreman (general)	1			1	1					19,300	19,300
Assistant mine foreman	2			2	2					18,600	37,200
Chief mine engineer	1			1	1					19,300	19,300
Mine engineer	5			5	5					16,500	82,500
Surveyor	3			3	3					12,400	37,200
Engineering aide	8			8	8					10,300	82,400
Accountant	1			1	1					17,900	17,900
Draftsman	2			2	2					9,600	19,200
Stenographer	2			2	2					8,300	16,600
Clerk typists	2			2	2					6,000	13,800
Aidman	1	1	1	3	3.5					10,300	36,050
Electrical engineer	1			1	1					16,500	16,500
Payroll clerk	2	2	1	5	5.8					10,300	59,740
Purchasing agent	1			1	1					17,900	17,900
Mechanical engineer	1			1	1						
										16,500	16,500

TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Geologist	1			1	1					16,500	16,500
Assistant geologist	1			1	1					13,800	13,800
Warehouseman	2	2	1	5	5.8	5.21	208.40	365	76,066		
Subtotal				47	49.1				76,066		574,690
Production, 1,900 ft level[2]											
Shift foreman (general)	1	1	1	3	3.0					17,900	53,700
Cutter operator	2	2	2	6	7.0	5.67	272.16	365	99,338		
Driller	2	2	2	6	7.0	5.25	252.00	365	91,980		
Powderman	2	2	2	6	7.0	5.21	250.08	365	91,279		
Loader operator	2	2	2	6	7.0	5.67	272.16	365	99,338		
Shuttle car operator	4	4	4	12	14.0	5.25	504.00	365	183,960		
Roof bolter	2	2	2	6	7.0	5.44	261.12	365	95,309		
Utility man (unit)	4	4	4	12	14.0	5.14	493.44	365	180,106		
Unit foreman	2	2	2	6	7.0	6.65	319.20	365	116,506		
Ventilation operator	4	4	4	12	14.0	5.21	500.16	365	182,558		
Conveyor attendant	1	1	1	3	3.5	5.21	125.04	365	45,640		
Utility man (service)	5	5	5	15	17.5	5.14	616.80	365	225,132		
Crusher operator (station)	1	1	1	3	3.5	5.21	125.04	365	45,640		
Subtotal				96	111.5				1,456,786		53,700
Maintenance, 1,900 ft level											
Mechanic foreman	1	1	1	3	3.0					16,500	49,500
Mechanics & electricians	9	9	9	27	31.5	5.74	1,239.84	365	452,542		
Maintenance foreman	1	1	1	3	3.0					16,500	49,500
Maintenance mechanic	1	1	1	3	3.5	5.74	137.76	365	50,282		
Subtotal				36	41.0				502,824		99,000

[2] Mine operates 7 days per week, 3 shifts per day. [illegible] rates are increased to include an average shift differential and adjusted to include a [illegible]. Mine operates 365 days per year [illegible] per year.

TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Production, 2,600 ft level[3]											
Shift foreman	2	2	2	6	7.0					17,900	125,300
Miner	8	8	8	24	28.0	5.25	1,008.00	365	367,920		
Miner's helper	3	3	3	9	10.5	5.14	370.08	365	135,079		
Heavy duty truck driver	6	6	6	18	21.0	5.21	750.24	365	273,838		
Front-end loader operator	2	2	2	6	7.0	5.67	272.16	365	99,338		
Bulldozer operator	3	3	3	9	10.5	5.25	378.00	365	137,970		
Motor patrol operator	1	1	1	3	3.5	5.25	126.00	365	45,990		
Powderman	6	6	6	18	21.0	5.21	750.24	365	273,838		
Light truck operator	9	9	9	27	31.5	5.14	1,110.24	365	405,238		
Crusherman	2	2	2	6	7.0	5.21	250.08	365	91,279		
Hoistman	3	3	3	9	10.5	5.21	375.12	365	136,919		
Cage tender	1	1	1	3	3.5	5.14	123.36	365	45,026		
Laborer	17	17	17	51	59.5	5.14	2,097.12	365	765,449		
Carpenter	2	2	2	6	7.0	5.25	252.00	365	91,980		
Traffic controller	2	2	2	6	7.0	5.21	250.08	365	91,279		
Lamp and dry room attendant	2	2	2	6	7.0	5.60	268.80	365	98,112		
Conveyor attendant	4	4	4	12	14.0	5.21	500.16	365	182,558		
Subtotal				219	255.5				3,241,813		125,300

[3]Some of this labor is chargeable to both the 1,900 and 2,600 levels.

TABLE 38. - (Continued)

Unit and personnel	Shift day	Shift aft	Shift night	Shifts per day	Total per-sonnel	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
Maintenance, 2,600-ft level											
Foreman	4	4	4	12	14.0					16,500	231,000
Electrician	8	8	8	24	28.0	5.74	1,102.08	365	40[illegible],259		
Electrician's helper	8	8	8	24	28.0	5.21	1,000.32	365	365,117		
Mechanic	10	10	10	30	35.0	5.74	1,377.60	365	502,824		
Mechanic's helper	10	10	10	30	35.0	5.21	1,250.40	365	456,396		
Machinist	4	4	4	12	14.0	5.74	551.04	365	201,130		
Welder	3	3	3	9	10.5	5.54	398.88	365	145,591		
Subtotal				141	164.5				2,073,317		231,000
TOTAL MINE				539	621.6				7,350,806		1,083,690
GRAND TOTAL				1,988	2,573.6				23,131,332		4,505,970

TABLE 39. - Estimated annual operating cost

	Annual cost, dollars
Natural gas - 85,005,700 M scfy x $0.30 per M scf........	25,501,700
Limestone - 1,562,565 tons per year x $1.78 per ton......	2,781,400
Catalyst and chemicals..................................	1,454,000
Raw water - 8,164,100 M gal/yr x $0.10/M gal.............	816,400
Charge for use of water - 8,164,100 M gal/yr x $0.026/M gal..	212,300
Direct labor..	12,179,700
Direct labor supervision................................	972,600
Maintenance labor.......................................	10,426,900
Maintenance labor supervision...........................	1,371,600
Maintenance material (100% of plant maintenance labor)...	7,850,800
Maintenance material (mine)..............................	2,257,700
Operating supplies (20% of plant maintenance, plant only)	3,348,600
Operating supplies (mine)...............................	2,685,900
Payroll overhead (25% of payroll)........................	6,237,700
Royalty on minerals at 5% of mineral receipts............	9,506,700
Royalty on shale at $0.21/ton = 60,000 x 365 x $0.21.....	4,599,000
Administration and general overhead......................	2,686,500
Taxes, mining property -(based on gross proceeds)........	3,472,400
Taxes on improvement, mine - (0.04 x 1/3 x $21,802,000)..	290,700
Insurance, mine (0.01 x $21,802,000)....................	218,000
Taxes, plant - 0.04 ($449,596,800 x 1/3).................	5,994,600
Insurance, plant - 0.02 ($449,596,800)...................	8,991,900
Depreciation - (see table 43)............................	37,516,300
	151,373,400

TABLE 40. - Total capital investment and annual operating cost, dollars

Item	Mining	Retorting	Refining	Minerals Processing	Total
CAPITAL INVESTMENT					
Equipment investment........	37,917,200	60,236,700	57,877,900	160,577,300	316,609,100
Facilities & utilities......	21,005,200	28,872,000	31,405,700	86,297,900	167,580,800
Initial catalyst............	-	-	3,324,100	-	3,324,100
Int. during construction (5%)	2,930,000	4,429,900	4,439,600	12,276,200	24,075,700
Startup expense.............	2,375,600	3,591,800	3,599,600	9,953,400	19,520,400
Working capital.............	33,600,900	12,703,500	12,767,100	46,791,400	105,862,900
Total capital requirement..	97,828,900	109,833,900	113,414,000	315,896,200	636,973,000
ANNUAL OPERATING COST					
Natural gas..................	4,054,900	4,242,500	4,807,600	12,396,700	25,501,700
Limestone....................	-	-	-	2,781,400	2,781,400
Catalyst & chemicals.........	-	-	1,433,600	20,400	1,454,000
Raw water....................	-	6,500	128,100	681,800	816,400
Charge for use of water......	-	1,700	33,300	177,300	212,300
Direct labor.................	4,821,600	990,300	987,200	5,380,600	12,179,700
Direct labor supervision.....	192,100	82,500	175,700	522,300	972,600
Maintenance labor............	2,576,100	1,696,600	1,630,600	4,523,600	10,426,900
Maintenance labor supervision	330,000	225,100	216,300	600,200	1,371,600
Maintenance material (plant).	-	1,696,600	1,630,600	4,523,600	7,850,800
Maintenance material (mine)..	2,257,700	-	-	-	2,257,700
Payroll overhead (25% of payroll)..................	1,980,000	748,600	752,400	2,756,700	6,237,700
Operating supplies (plant)...	-	723,600	695,500	1,929,500	3,348,600
Operating supplies (mine)....	2,685,900	-	-	-	2,685,900
Royalty on minerals..........	9,506,700	-	-	-	9,506,700
Royalty on shale.............	4,599,000	-	-	-	4,599,000
Administration & general overhead..................	1,058,400	286,200	287,700	1,054,200	2,686,500
Taxes, mining property.......	3,472,400	-	-	-	3,472,400
Taxes on improvement, mine...	290,700	-	-	-	290,700
Insurance, mine..............	218,000	-	-	-	218,000
Taxes, plant.................	282,300	1,197,100	1,199,500	3,315,700	5,994,600
Insurance, plant.............	423,500	1,795,700	1,799,300	4,973,400	8,991,900
Depreciation.................	4,518,600	5,937,700	6,126,300	20,933,700	37,516,300
Total annual operating cost	43,267,900	19,630,700	21,903,700	66,571,100	151,373,400
Cost per ton of total ore mined......................	1.743	0.791	0.883	2.682	6.099
Cost per barrel of shale oil product................	2.571	1.166	1.301	3.955	8.993
Cost per ton of total mineral products...........	8.906	4.040	4.508	13.702	31.156

TABLE 41. - Product selling price and annual receipts

Coke :	1,077.1 ton/cd x $8/ton x 365 day/yr............	$3,145,100
Oil :	46,113 bbl/cd x $3.72/bbl x 365 day/yr..........	62,612,200
Sulfur :	45.698 short ton/cd x $13.39/short ton x 365 day/yr..................................	223,300
Ammonia :	116.302 ton/cd x $35/ton x 365 day/yr...........	1,485,800
Alumina :	1,759 ton/cd x $63/ton x 365 day/yr.............	40,448,200
Soda ash:	11,552 ton/cd x $35.50/ton x 365 days/yr........	149,685,000
	TOTAL ANNUAL RECEIPTS..........................	257,599,600

	Selling price	Freight allowance
Coke, ton...............	$20.00	$12.00
Oil, barrel.............	4.12	0.40
Sulfur, long ton........	15.00	
short ton.......	13.39	
Ammonia, ton............	35.00	
Alumina, ton............	75.00	12.00
Soda ash, ton...........	35.50	

TABLE 42. - Financial analysis

Total capital investment....................	$636,973,000
Annual sales................................	257,599,600
Annual operating cost.......................	151,373,400
Gross income................................	106,226,200
Depletion on minerals (0.15 x $190,133,200)..	28,520,000
Depletion oil shale (base on value of oil) 0.15 x $42,078,100[1].......................	6,311,700
Taxable income..............................	71,394,500
Federal income tax at 50%...................	35,697,250
Net income..................................	35,697,250

Discounted cash flow

Annual cash flow (net income + depreciation + depletion)................................	108,045,250
Present value[2] at i = 14.5	635,541,800
i = 14.4	638,577,900
Interest rate (by interpolation) i =	14.45

[1] Value after retorting assumed to be $2.50 per barrel.

[2] Present value of n payments of $1 = $\frac{(1+i)^n-1}{i(1+i)^n}$, where i = interest rate per period. n = 14.155 yr

TABLE 43. - Operating cost depreciation schedule

Item	Life, years	Depreciation base, dollars	Annual depreciation, dollars
Mine (depreciable)	10	21,802,000	2,180,200
Mine (deferred expense)	20	16,115,200	805,800
Soda ash recovery plant (white nahcolite)	11	23,114,500	2,101,300
Retorting plant	16	60,236,700	3,764,800
Refining	16	57,877,900	3,617,400
Retorted oil shale processing plant	11	137,462,800	12,496,600
Plant facilities	20	61,405,300	3,070,300
Plant utilities	20	106,175,500	5,308,800
Interest during construction ...	11	24,075,700	2,188,700
Startup expense	11	19,520,400	1,774,600
Initial catalyst and chemicals .	16	3,324,100	207,800
			37,516,300

TABLE 44. - Utility summary, annual basis

	Operating hours per yr	Steam production and consumption: 900 psig at 1,000° F, Thousands of pounds, Produced	Steam production and consumption: 900 psig at 1,000° F, Thousands of pounds, Consumed	Steam production and consumption: 100 psig at saturation, Thousands of pounds, Produced	Steam production and consumption: 100 psig at saturation, Thousands of pounds, Consumed	Power, million kwhr/yr	Natural gas, MM scf/yr, 953 Btu per scf	Cooling water, MM gpy	Raw water MM gallons per year
Mine	8,343					153.837			43.8
Crushing & screening	7,884					22.320			
Briquetting	7,884					5.645	231.0		
Storage						3.414			
Delayed coking	8,322				292,100	36.783	4,820.3	74.4	
Retorting	7,884					80.460	-3,783.1		
Hydrogen production	8,322					9.778	3,494.5	9,187.5	214.7
Hydrocracking	8,322					164.726	-3,589.4	11,530.3	
Ammonia recovery	8,322				715,700	6.108		15.5	
Sulfur recovery	8,322					0.965	2.1	13.5	
Tankage					9,408,200				
Nahcolite preparation	8,400					17.783	894.6		
Nahcolite leaching	8,400				27,700	2.932			178.9
Nahcolite crystallization	8,400				1,793,400	5.032		6,758.1	17.6
Nahcolite prod. dry. & stor.	8,400					6.292	1,714.4		
Retorted shale crushing	8,400					41.286			
Retorted shale leaching	8,400				1,819,400	22.327			6,487.5
Desilication	8,400				7,756,600	9.005			47.9
Alumina precip. & calcin.	8,400					23.327	5,281.6		154.7
Shales fines leaching	8,400					10.273	1,478.6		508.0
Soda ash cryst. & dehyd.	8,400				12,684,800	40.320	3,445.3	52,396.8	-1,626.9
Limestone calcination & flue gas processing	8,400			282,200		30.937	5,719.4	3,593.0	105.8
Waste disposal	8,400					53.000			-2,459.4
Subtotal				282,200	34,497,900	746.550	19,709.3	83,569.1	3,672.6
Steam plant[1]	8,483	18,438,700		21,930,400		26.170	63,131.0		239.2
Power plant[1]	8,357		16,777,500	16,777,500					
Cooling tower[1]	8,381					50.177			3,080.0
Plant lighting	8,760					4.380			
Water system	8,760					115.527			
General facilities	8,760					4.380			315.4
Misc. & contingencies	8,400		1,661,200		4,492,200	60.724	2,165.4	2,505.6	856.9
Total		18,438,700	18,438,700	38,990,100	38,990,100	1,007.908	[2]85,005.7	86,074.7	8,164.1

[1]Weighted average onstream time.
[2]Excess gas production credits included in unit values.

Gas produced in delayed coking used as H_2 feed.

Option III

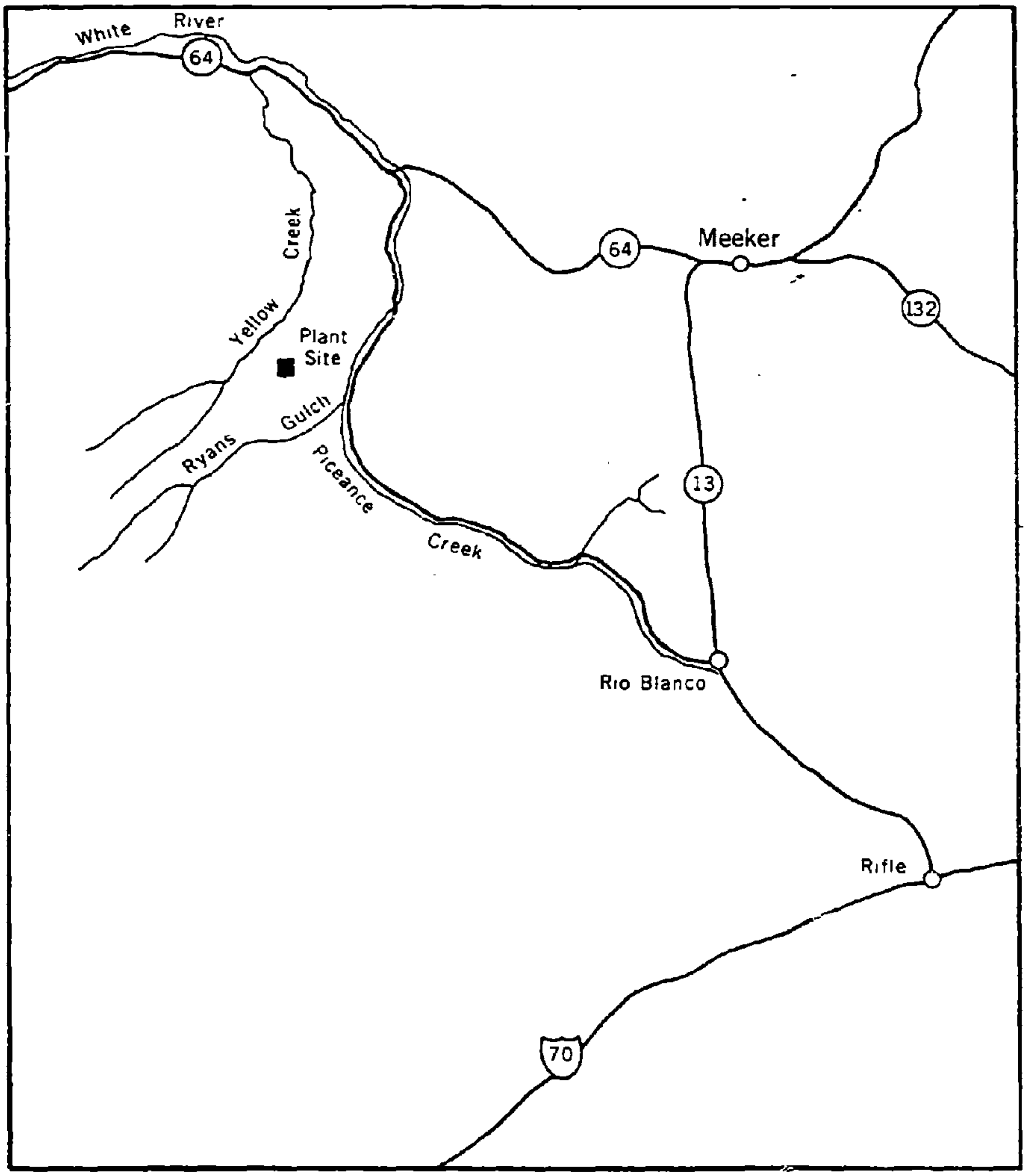

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FIGURE 1. - Location of 68,000 TPCD Project, Rio Blanco County, Colo

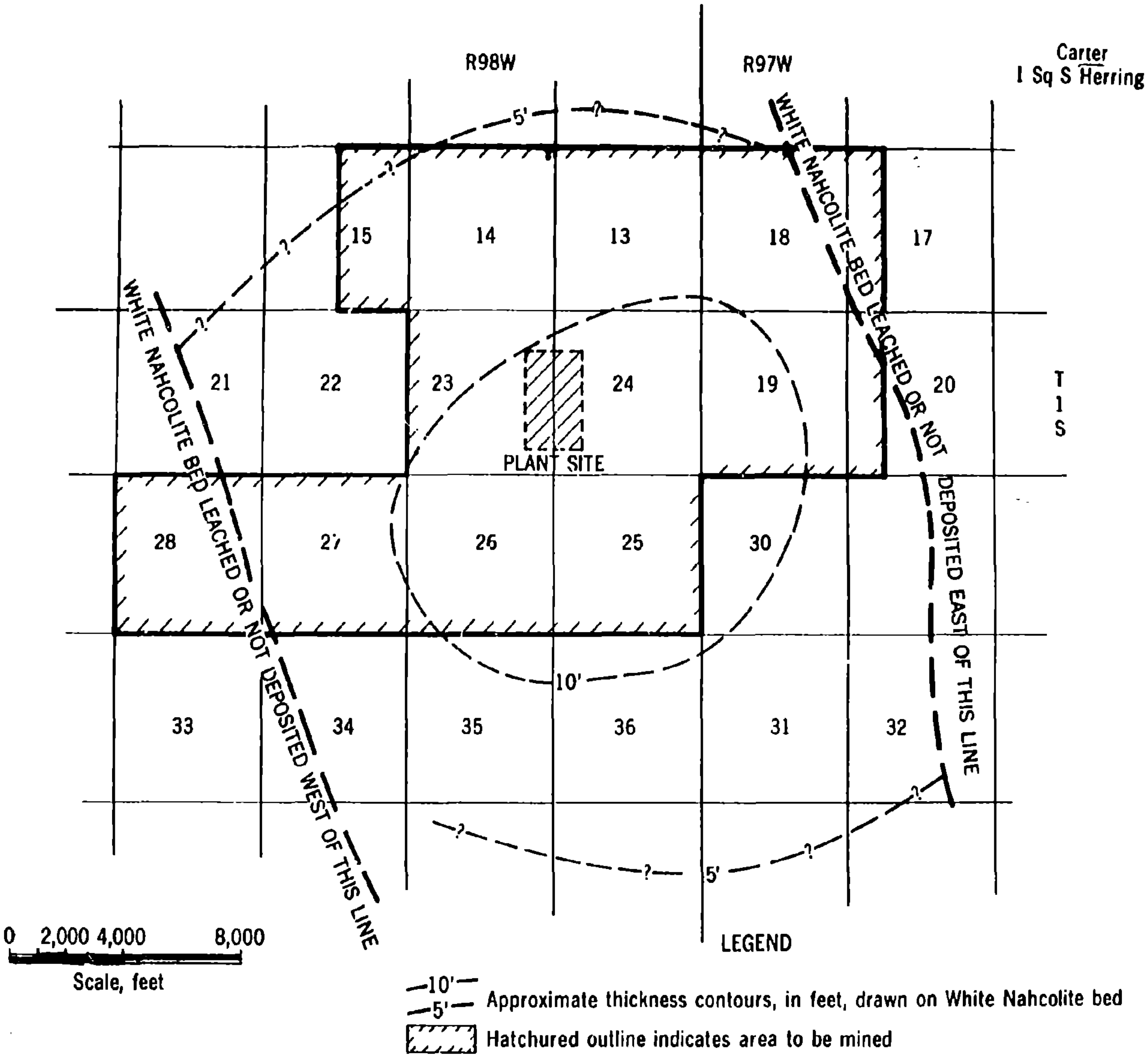


FIGURE 2. - Preliminary Isopach Map of the White Nahcolite Bed and Selected Mine Site for 68,000 TPCD Project, Rio Blanco County, Colorado.

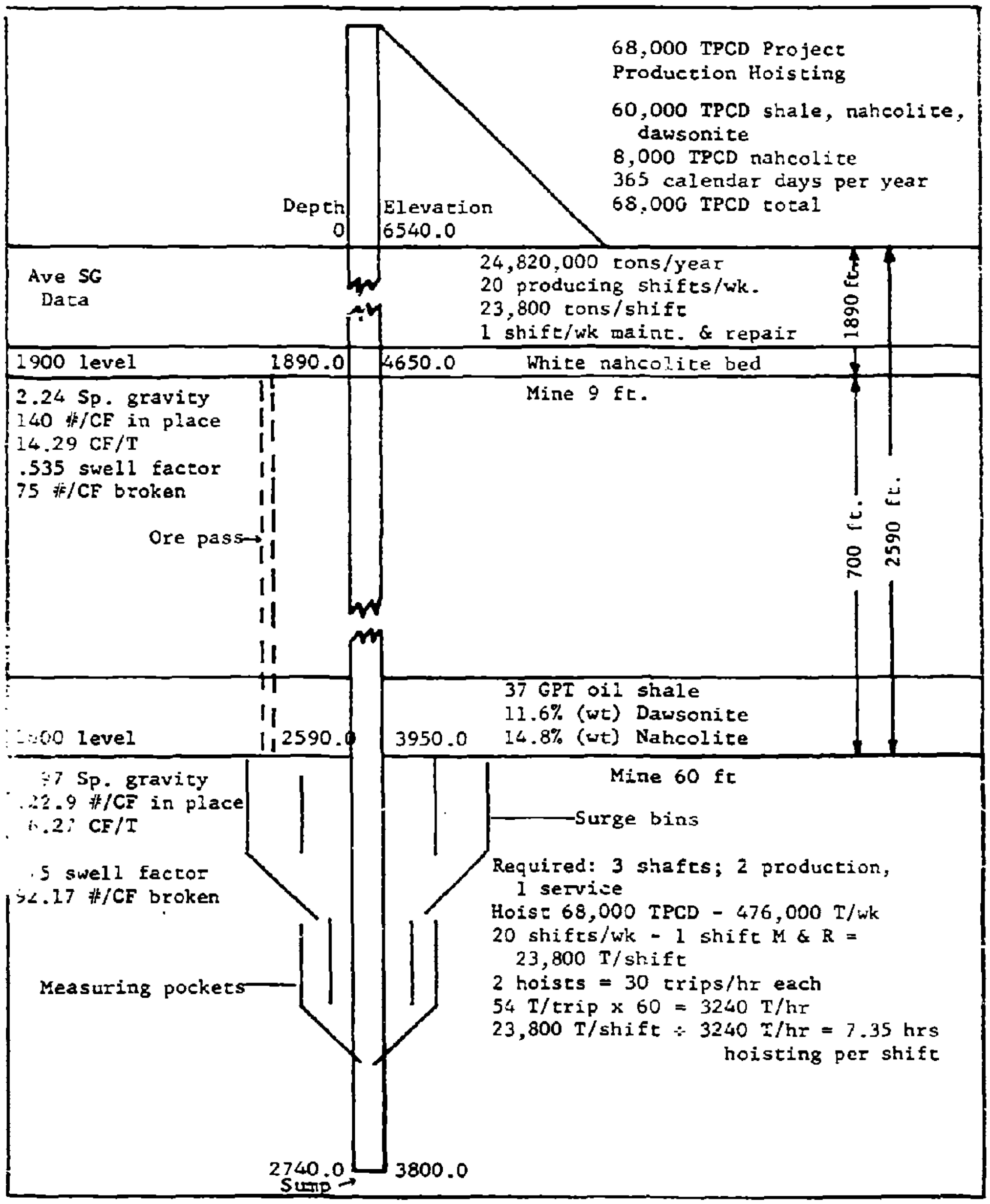


FIGURE 3. - Schematic diagram of shaft and mine levels for the 68,000 TPCD project.

OPTION III

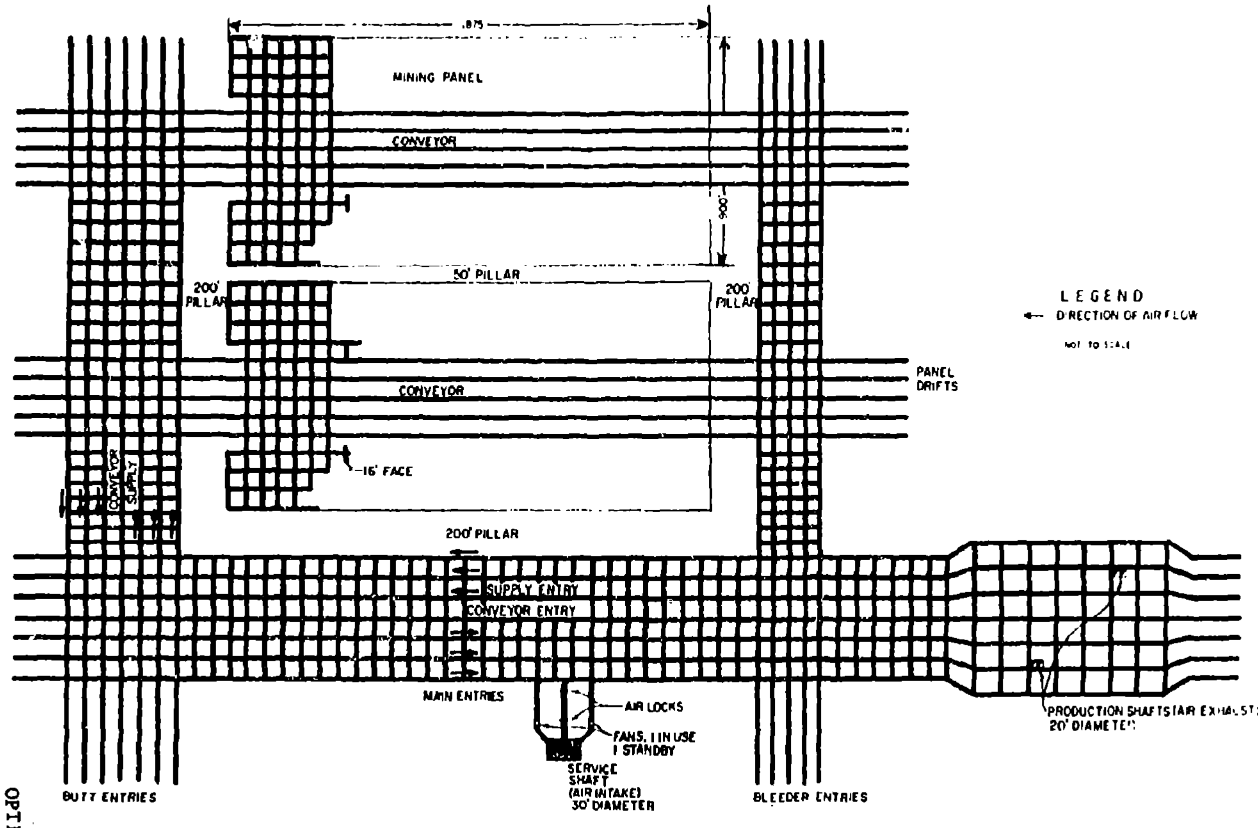


FIGURE 4.- Layout of Conceptual Mining Method for 1900 Level, 68,000 TPCD Project See Insert A, Figure 6.

OPTION III

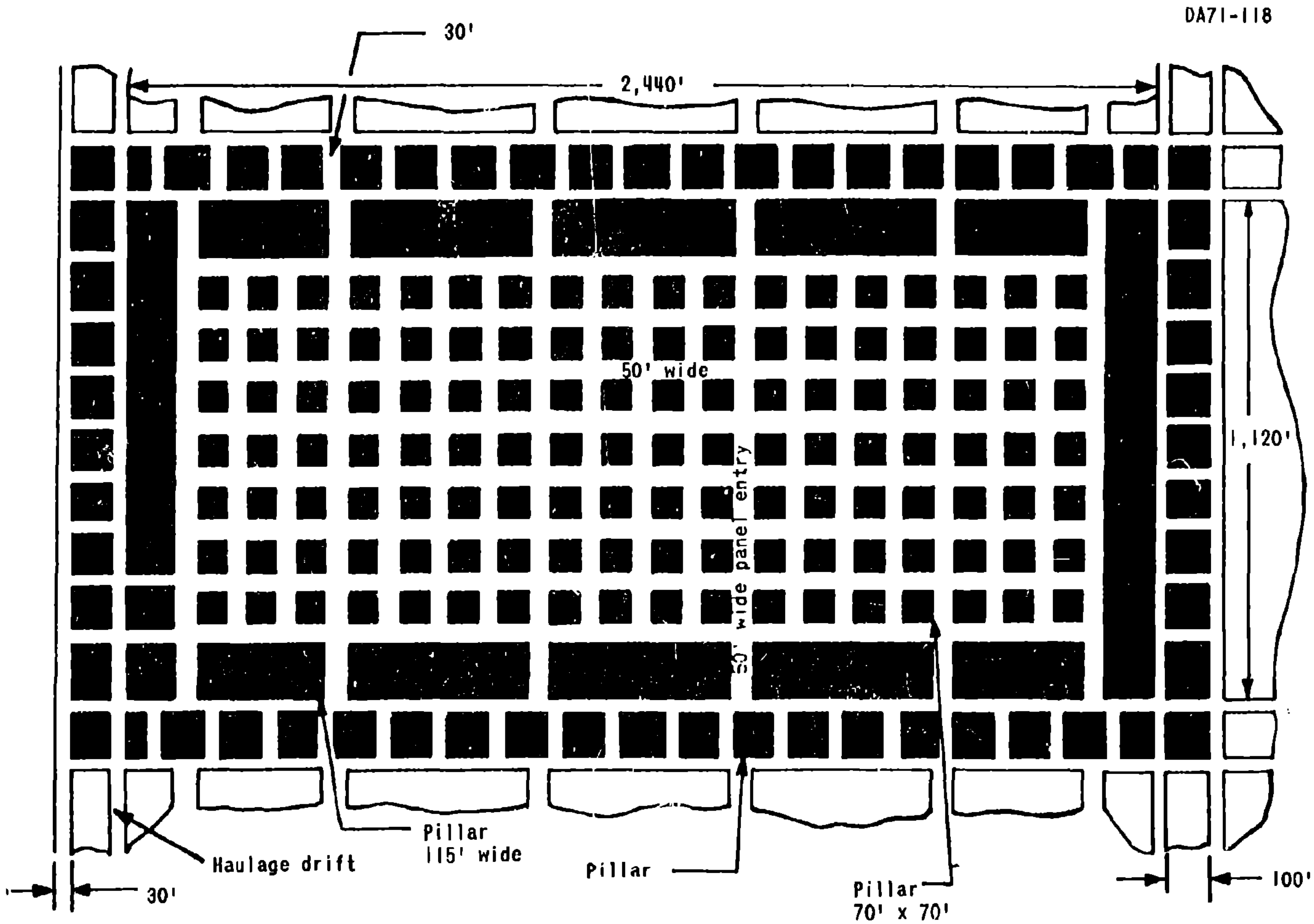


FIGURE.5. - Layout of a Conceptual Mining Method for the 2,600 Level of the 68,000 TPCD Project.

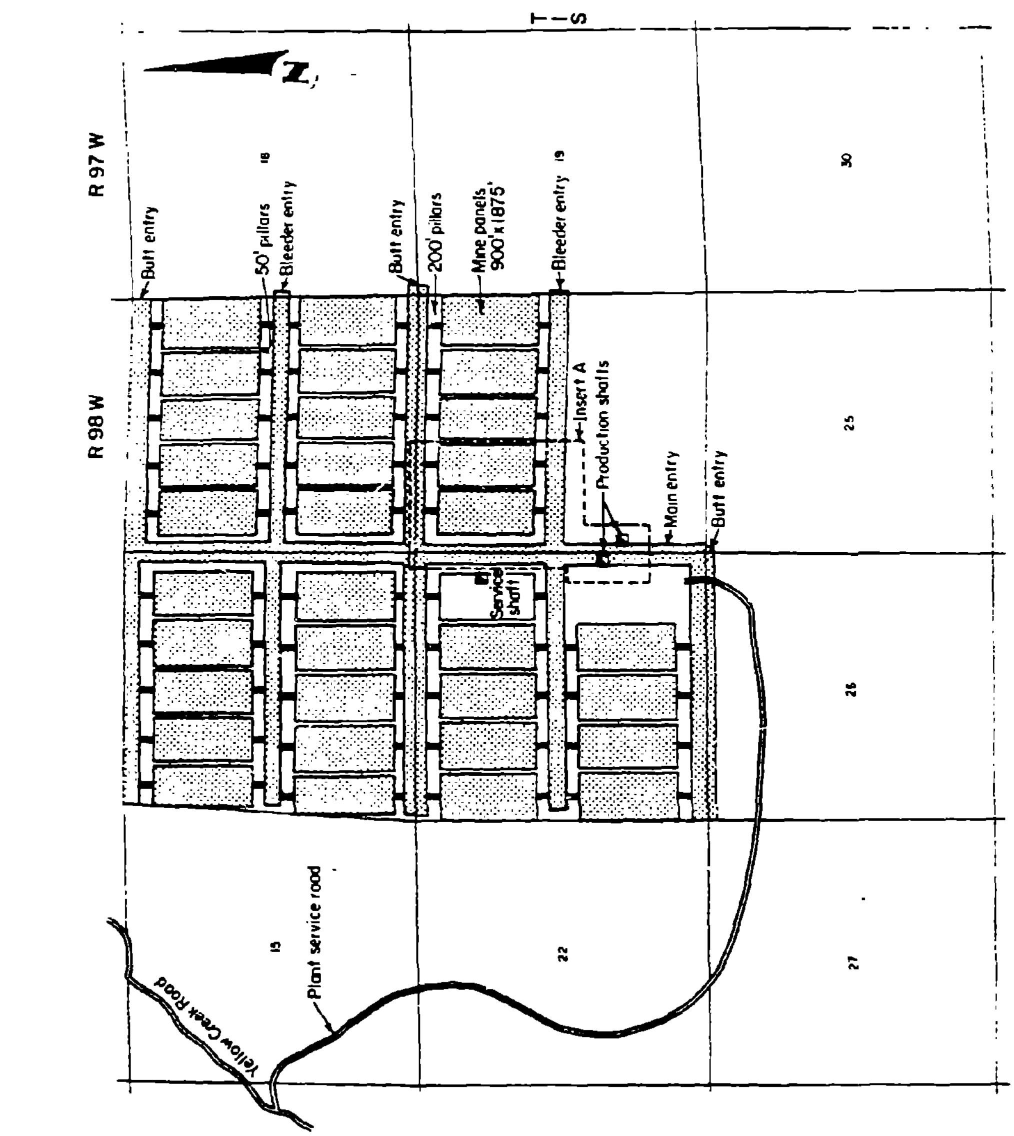


FIGURE 6.-Schematic Diagram of Conceptual Mining System, 1900 Level for 68,000 TPCD Project

OPTION III

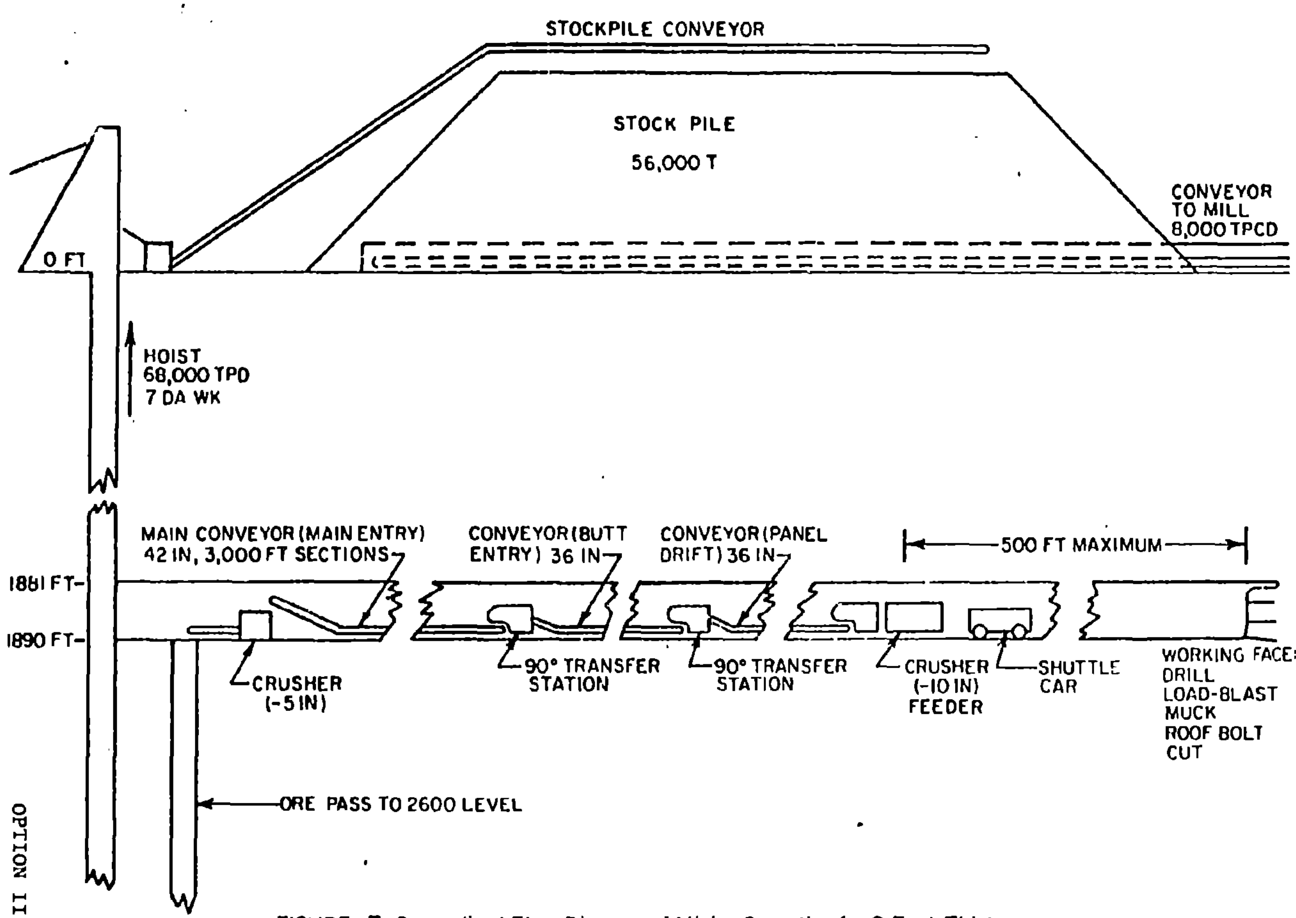


FIGURE 7.-Generalized Flow Diagram of Mining Operation for 9-Foot-Thick Nahcolite Bed for 1900 Level, 68,000-TPCD Project.

OPTION III

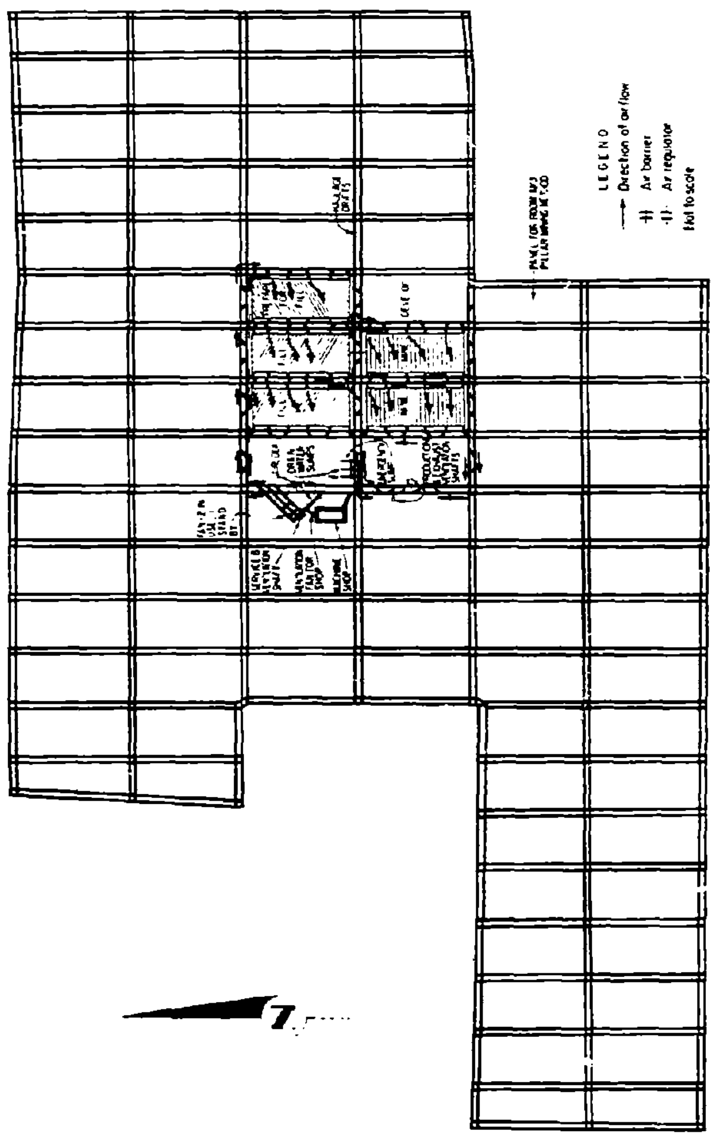


FIGURE 8-Schematic Diagram of Conceptual Mining System for 2600 Level, 68,000 TPCD Project

OPTION III

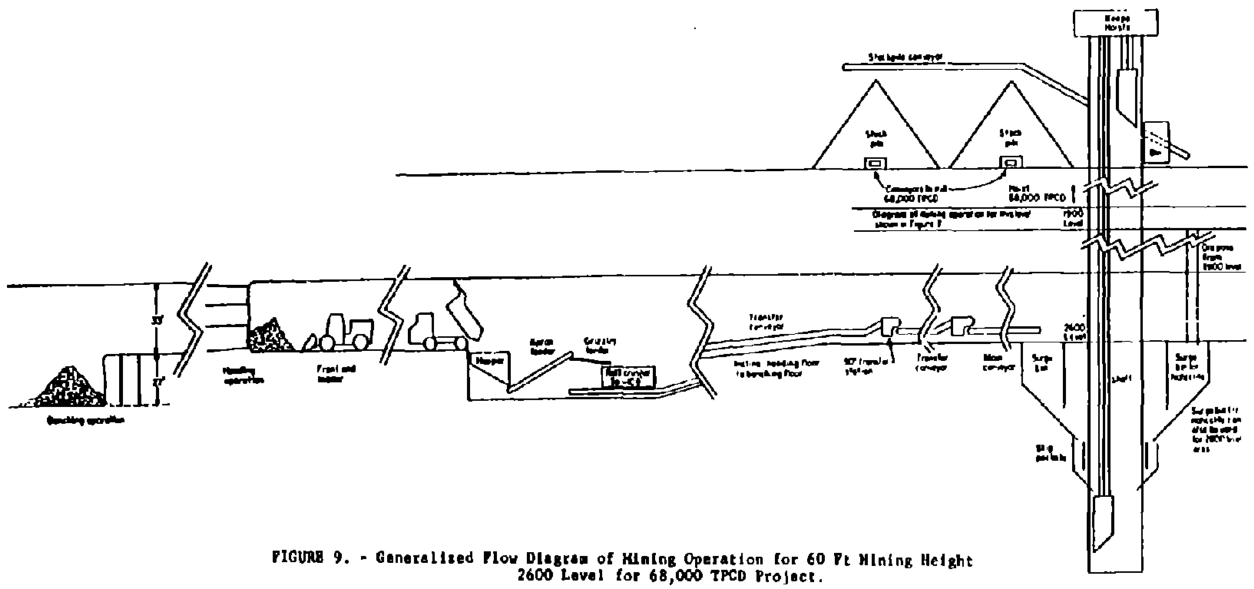


FIGURE 9. - Generalized Flow Diagram of Mining Operation for 60 Ft Mining Height 2600 Level for 68,000 TPCD Project.

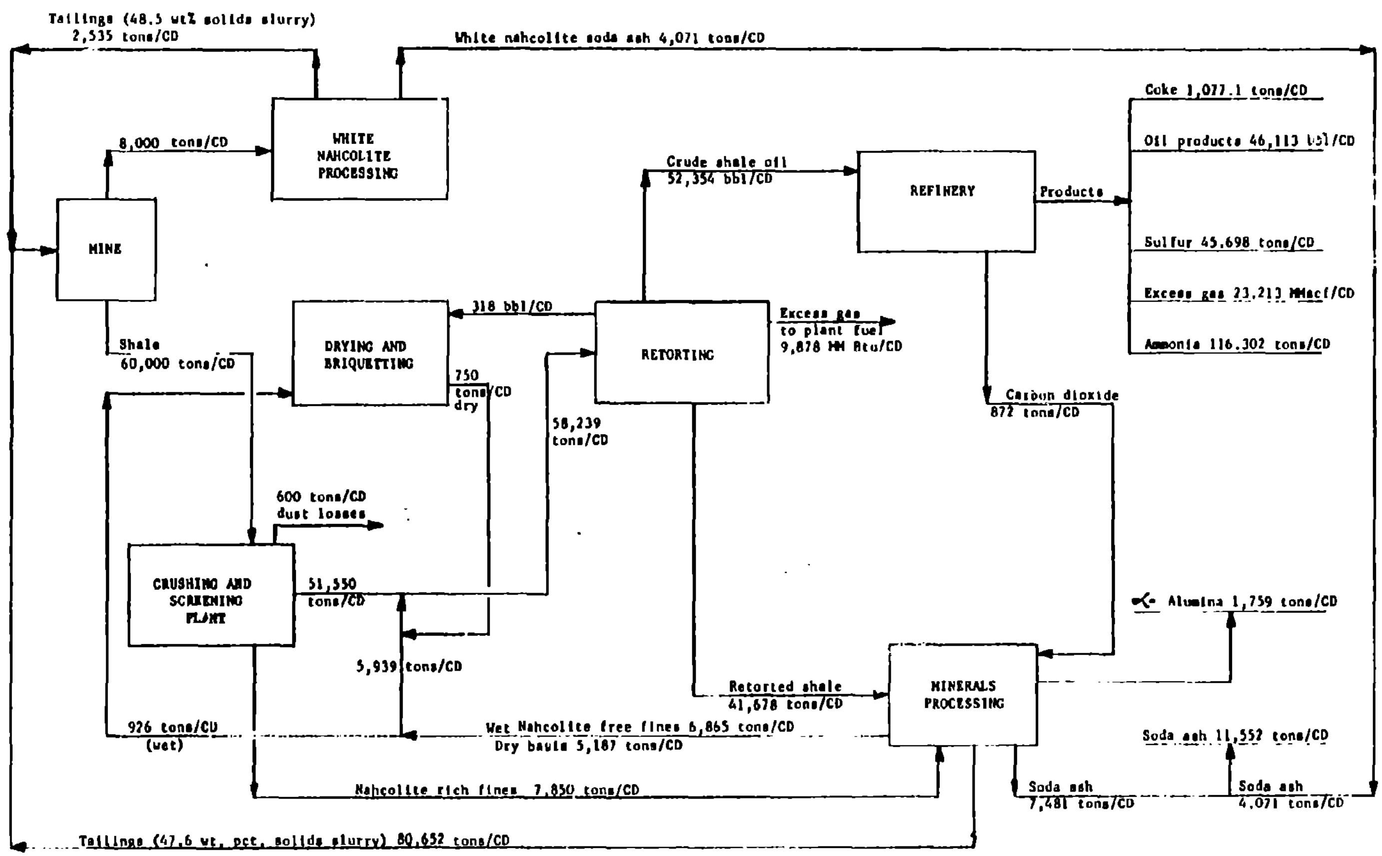
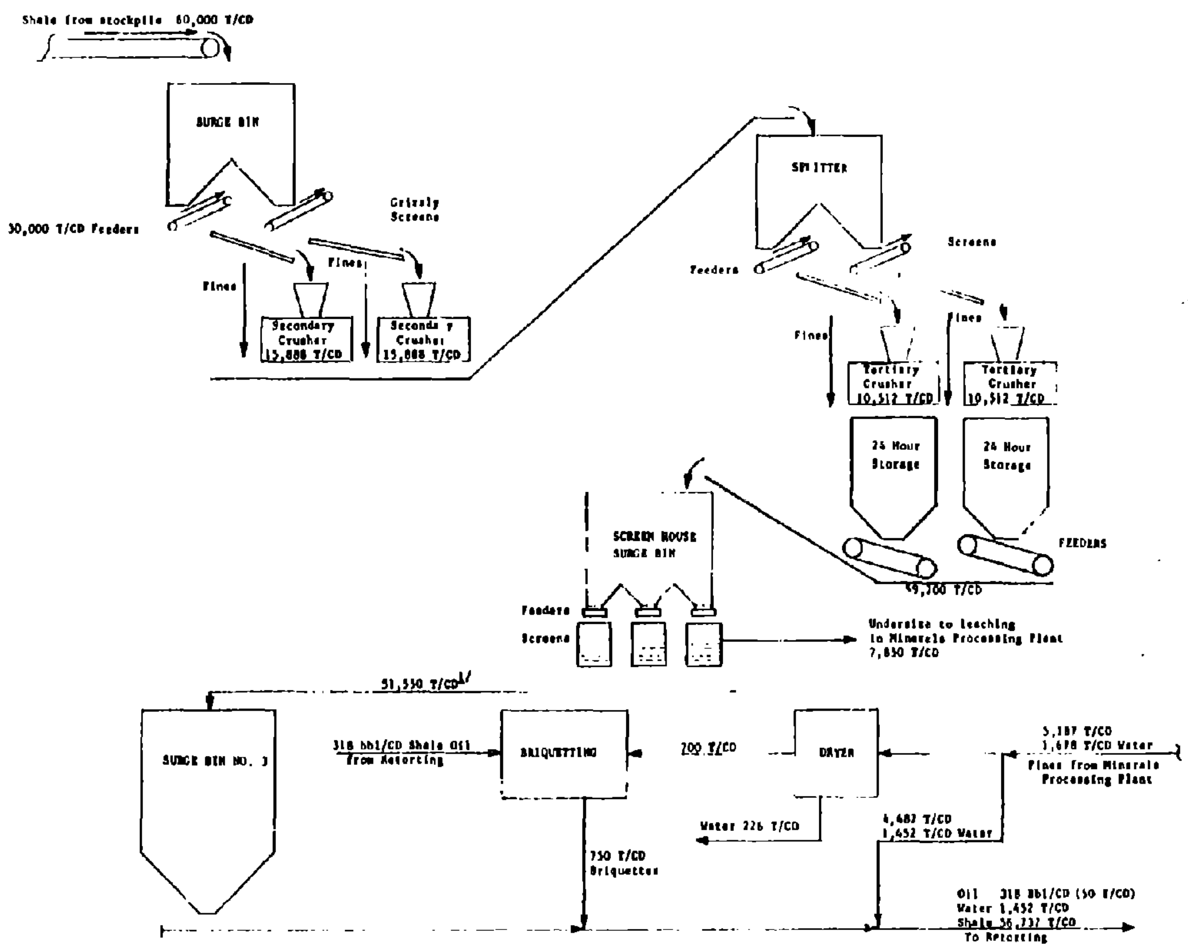


FIGURE 10. - Block diagram of the integrated operation, Option III.

832-997



1/ 600 tons per calendar day are allowed for dust losses.

FIGURE 11. - Schematic flow diagram of the crushing and screening plant, Option III.

833-003

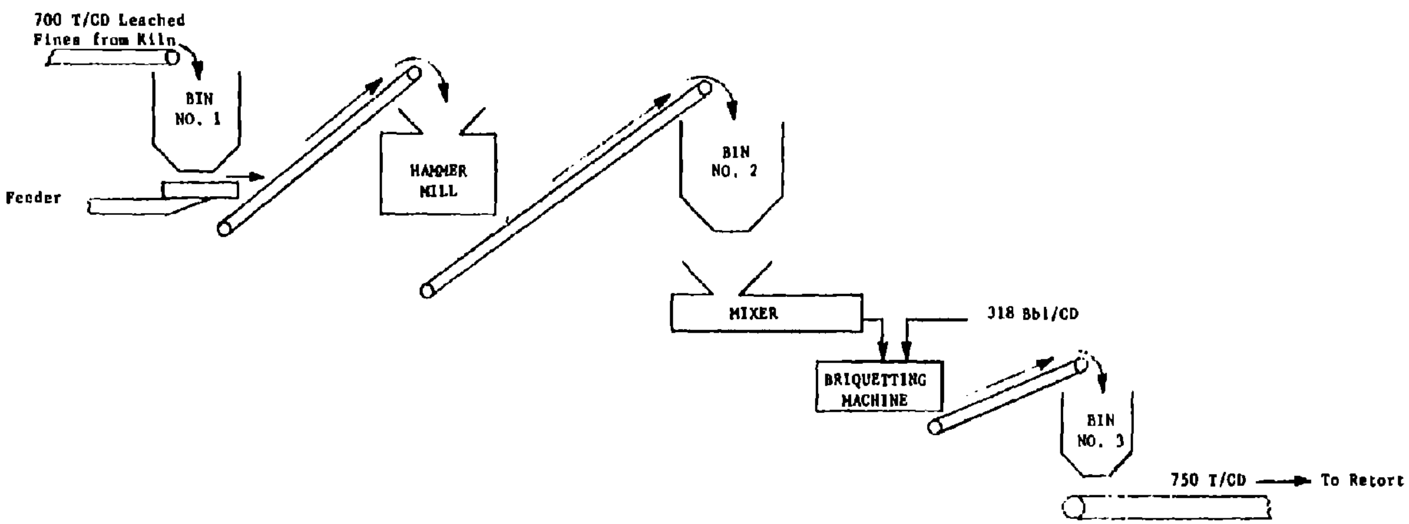


FIGURE 12. - Schematic flow diagram of the Briquetting Plant, Option III.

833-004

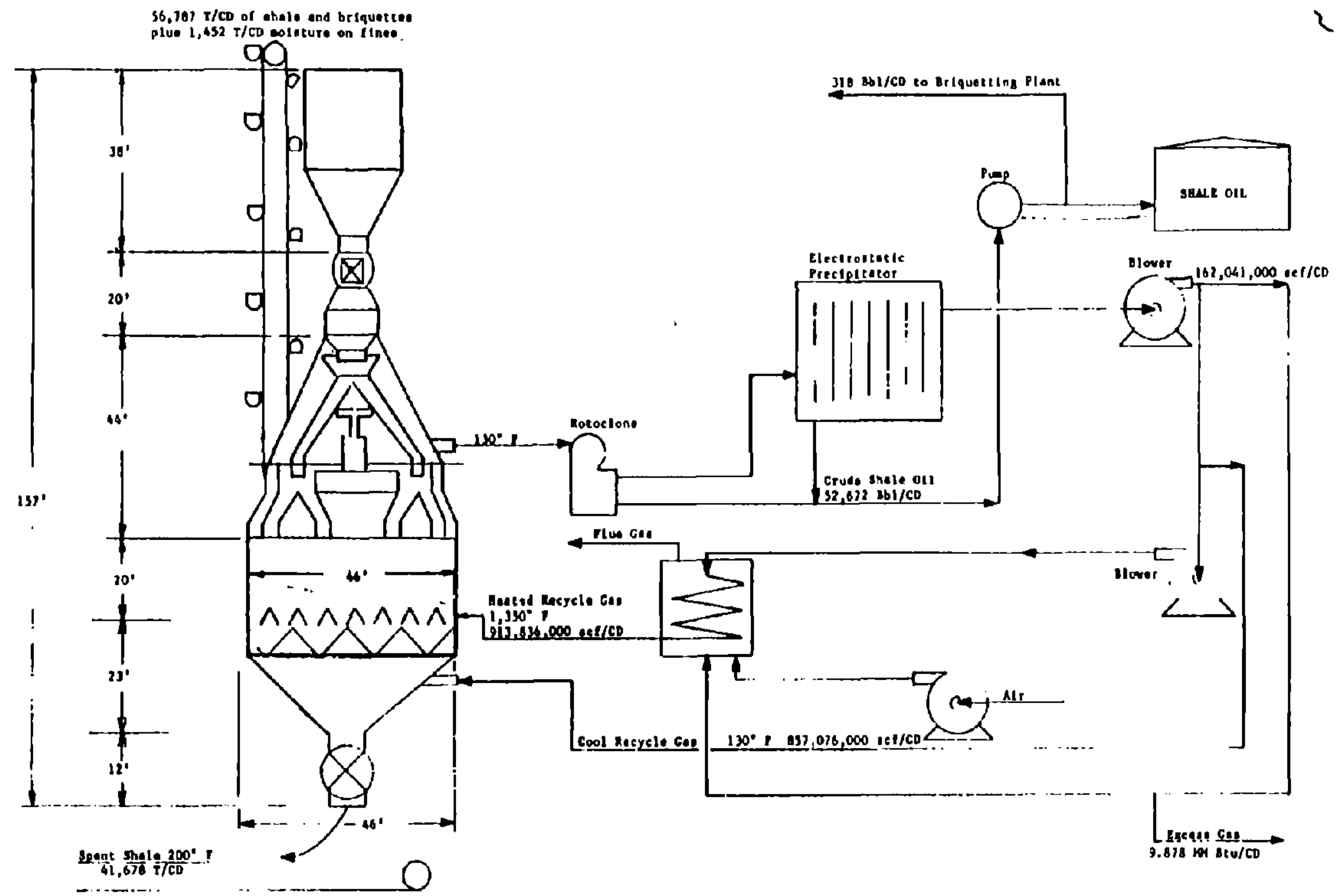


FIGURE 13. - Schematic flow diagram, retorting plant, Option III.

833-002

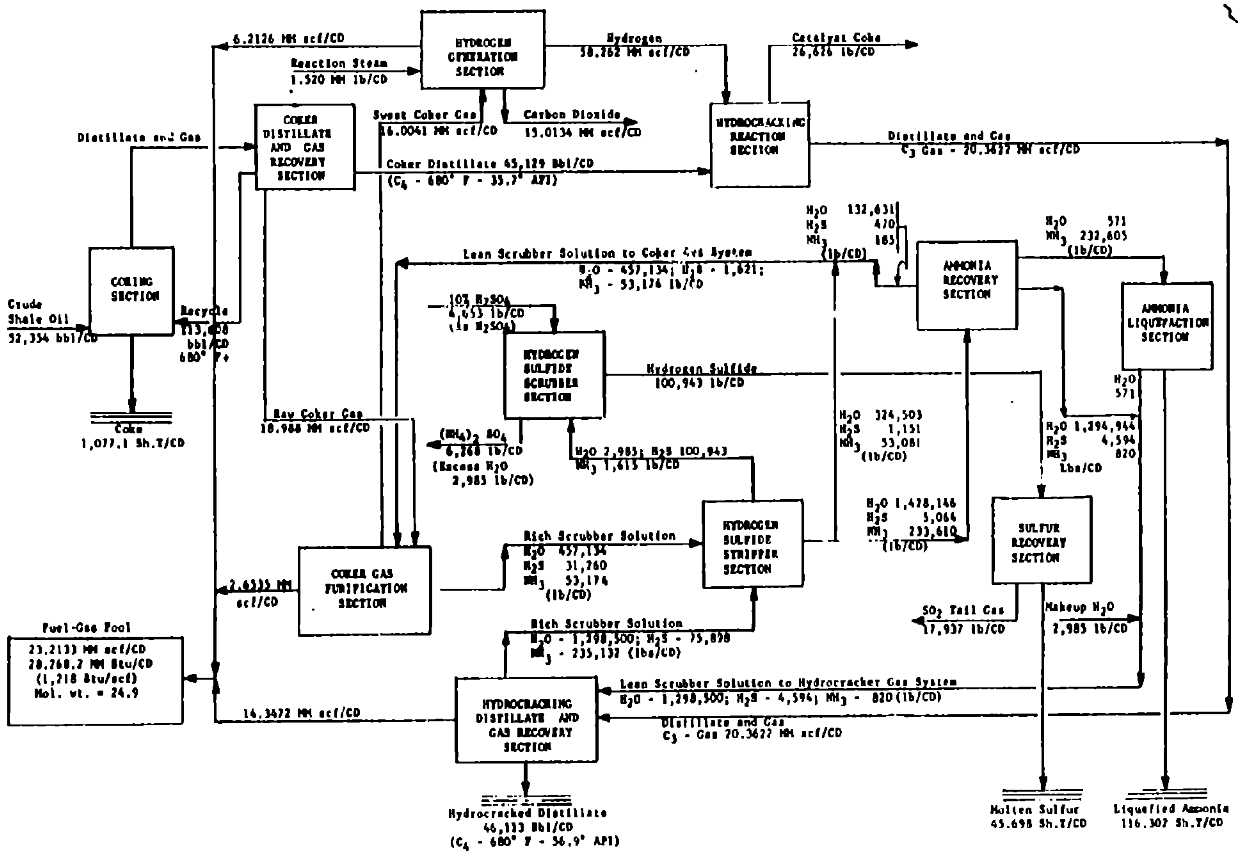


FIGURE 14. - Schematic flow diagram, refinery, Option III.

933-005

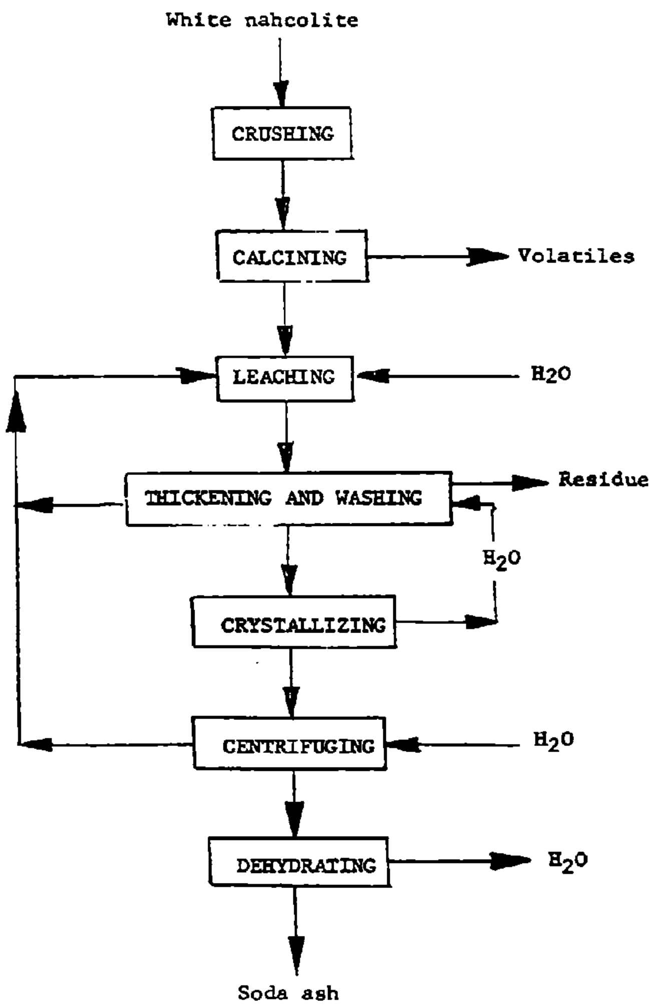


FIGURE 15. - Recovery of soda ash from white nahcolite

OPTION III

AII-857

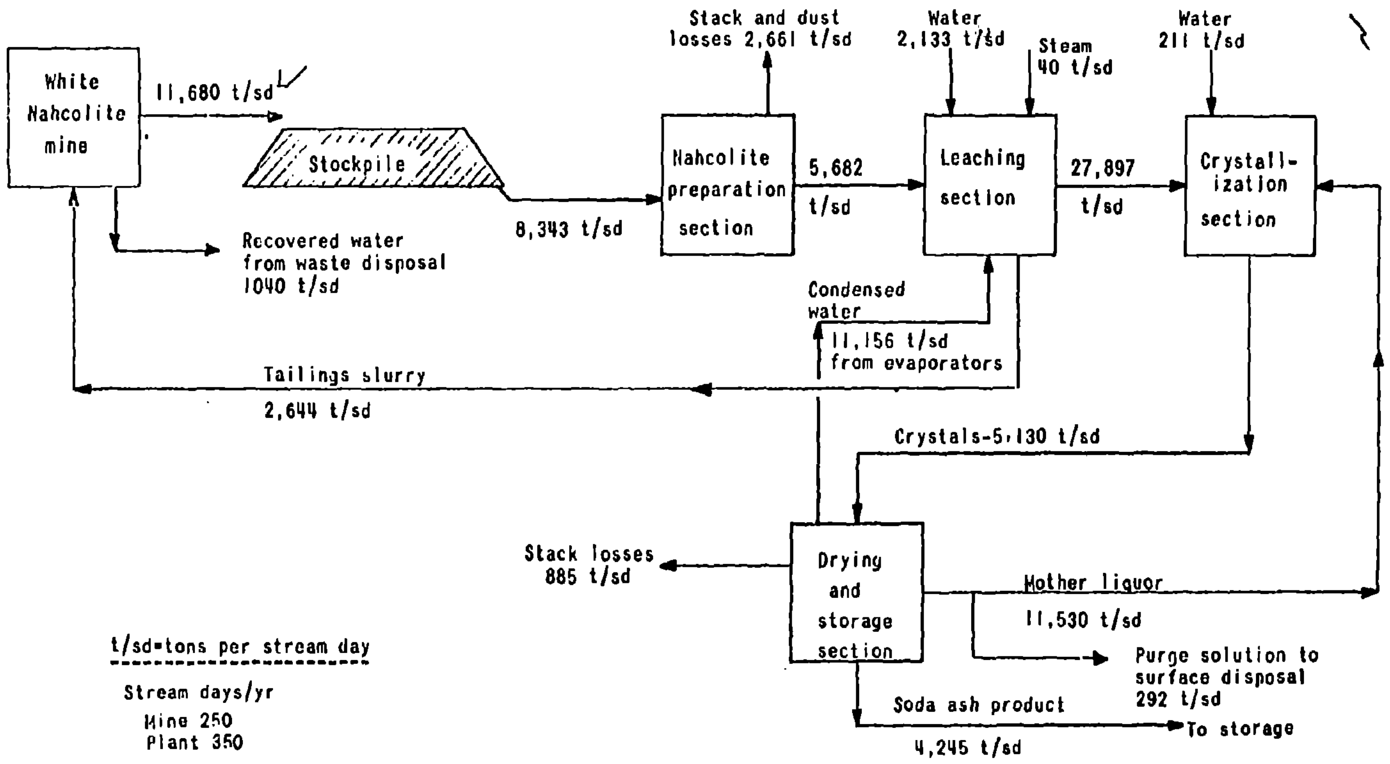


FIGURE 16.– Schematic Flow Diagram, White Nahcolite Process

OPTION III

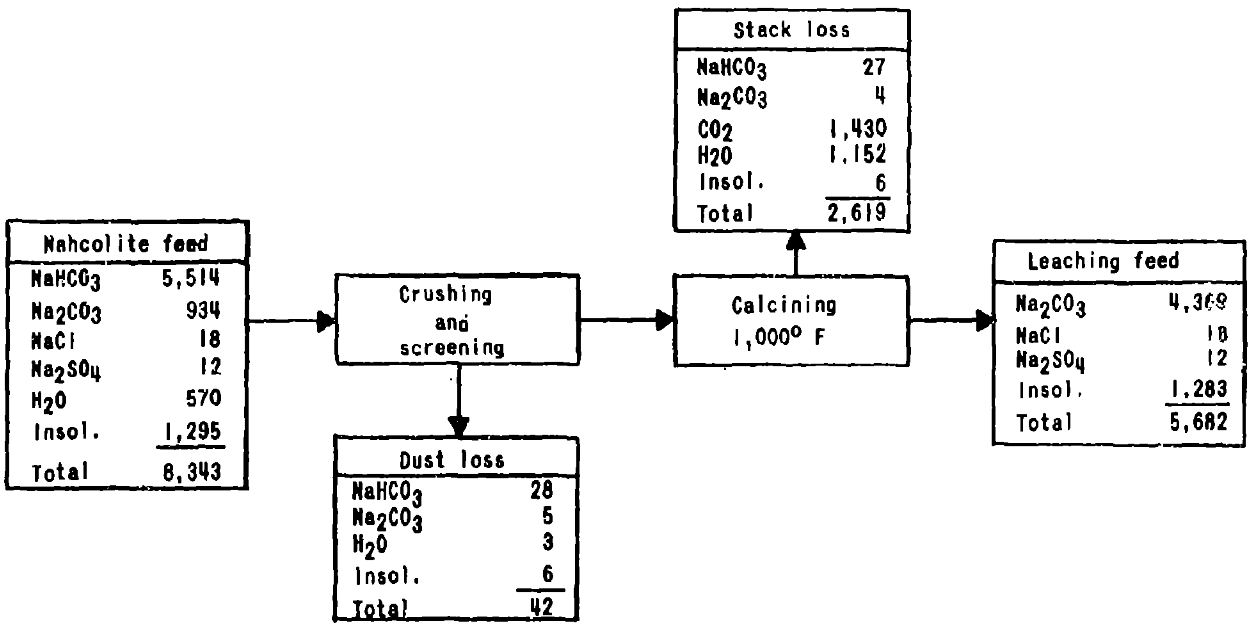


FIGURE 17. - Material Balance, Nahcolite Preparation Section, Recovery of Soda Ash From White Nahcolite (Tons per Day).

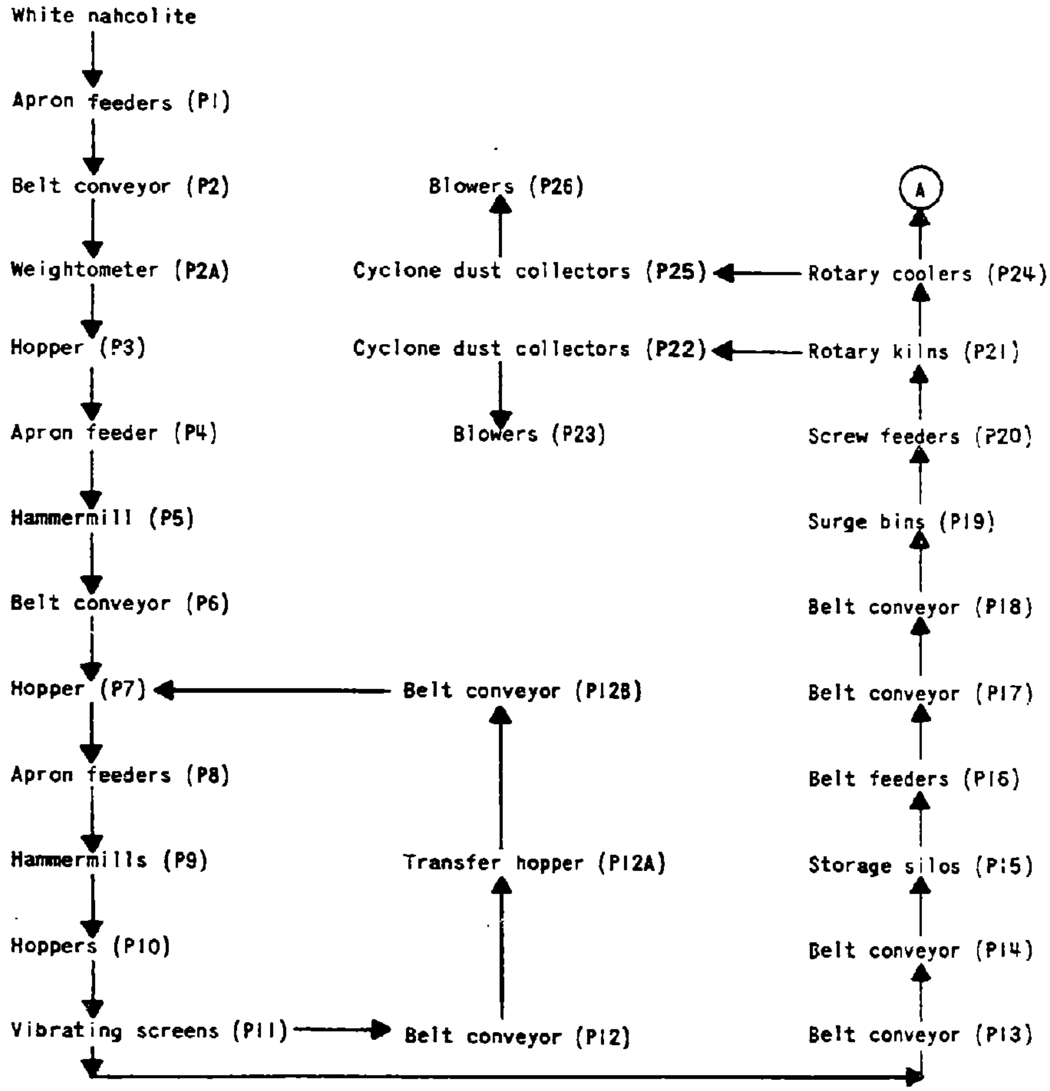


FIGURE 18. - Equipment Diagram, Nahcolite Preparation Section. Recovery of Soda Ash From White Nahcolite.

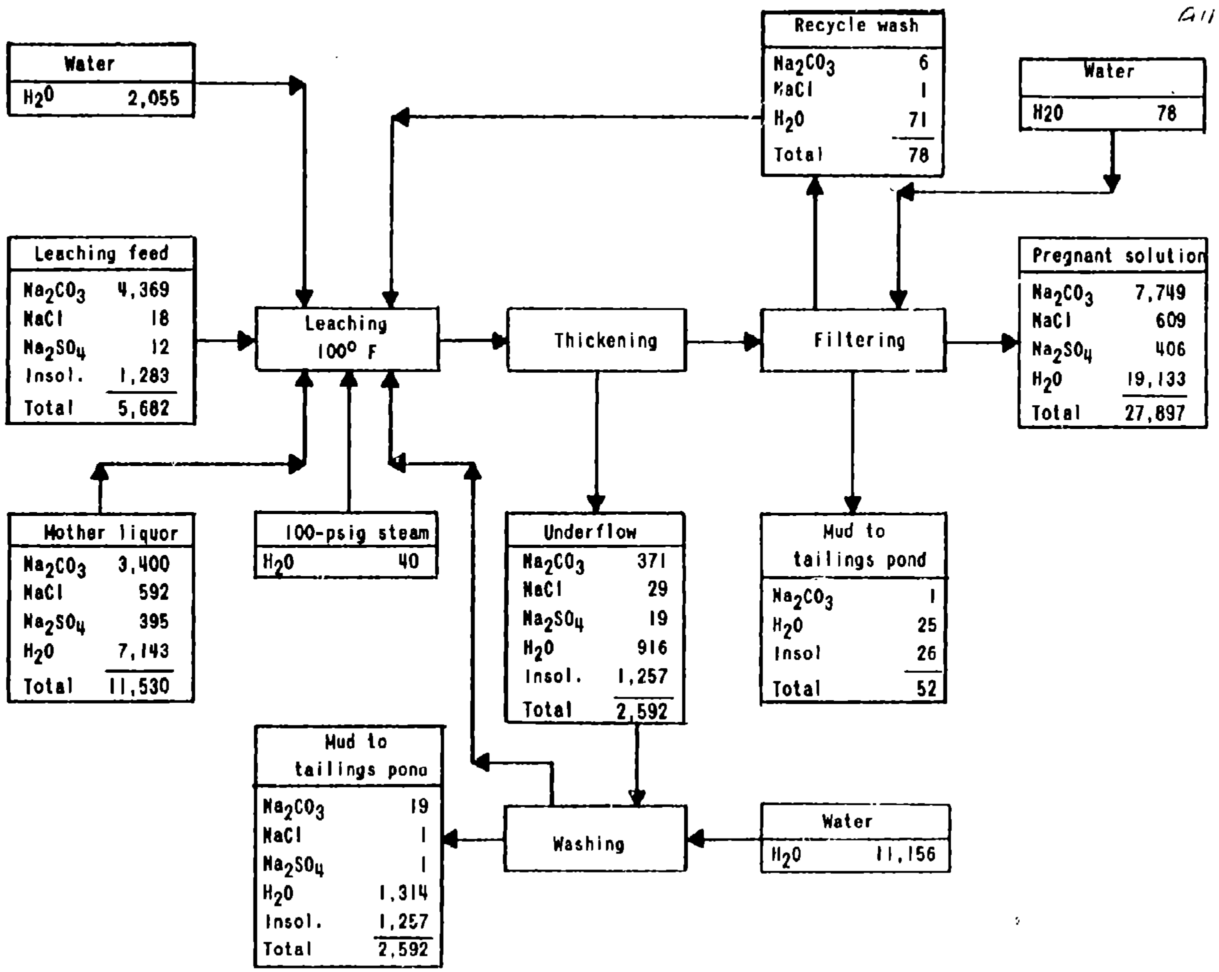


FIGURE 19.- Material Balance, Leaching Section, Recovery of Soda Ash From White Nahcolite (Tons per Day).

OPTION III

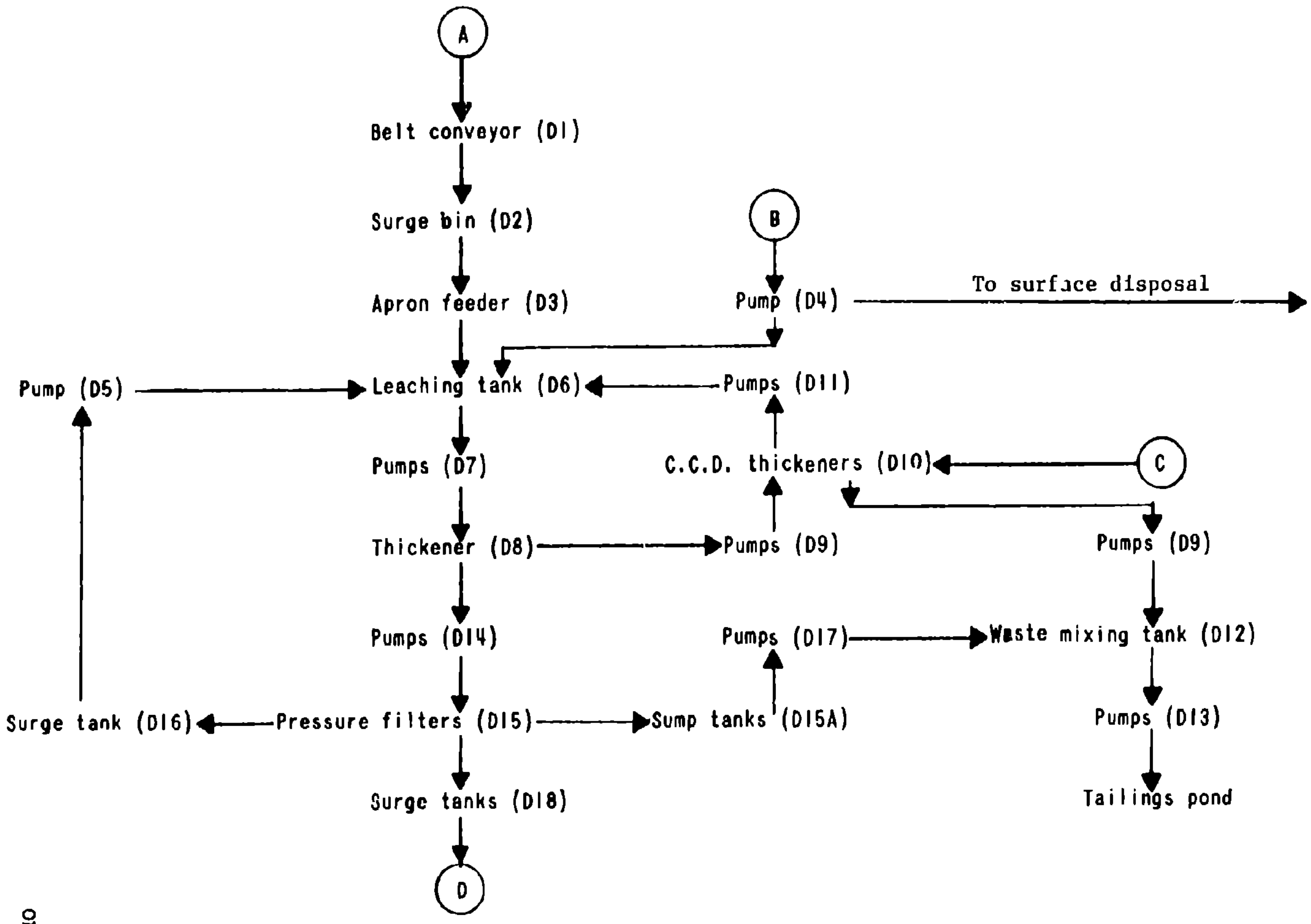


FIGURE 20. - Equipment Diagram, Leaching Section, Recovery of Soda Ash From White Nahcolite.

OPTION III

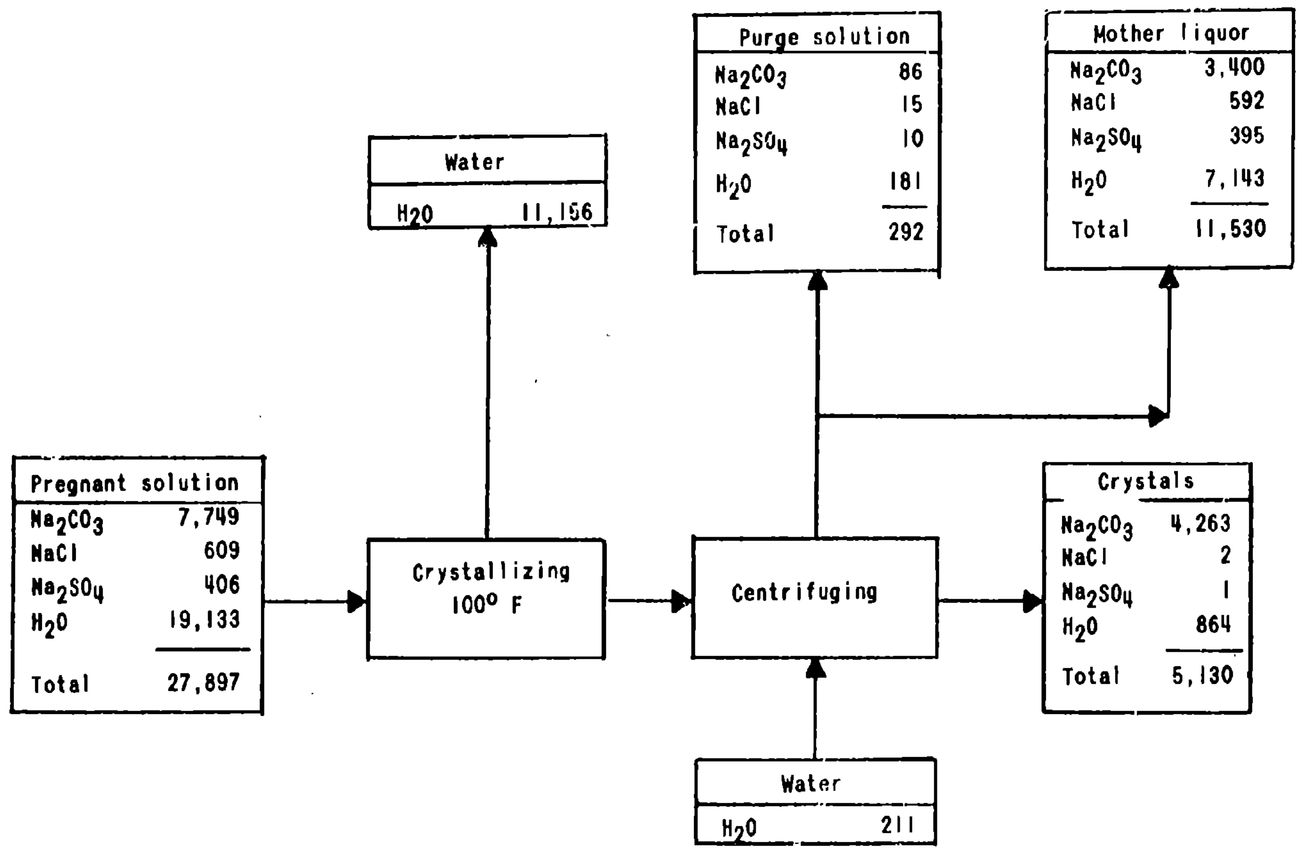


FIGURE 21. - Material Balance, Crystallization Section, Recovery of Soda Ash From White Nahcolite (Tons per Day).

OPTION III

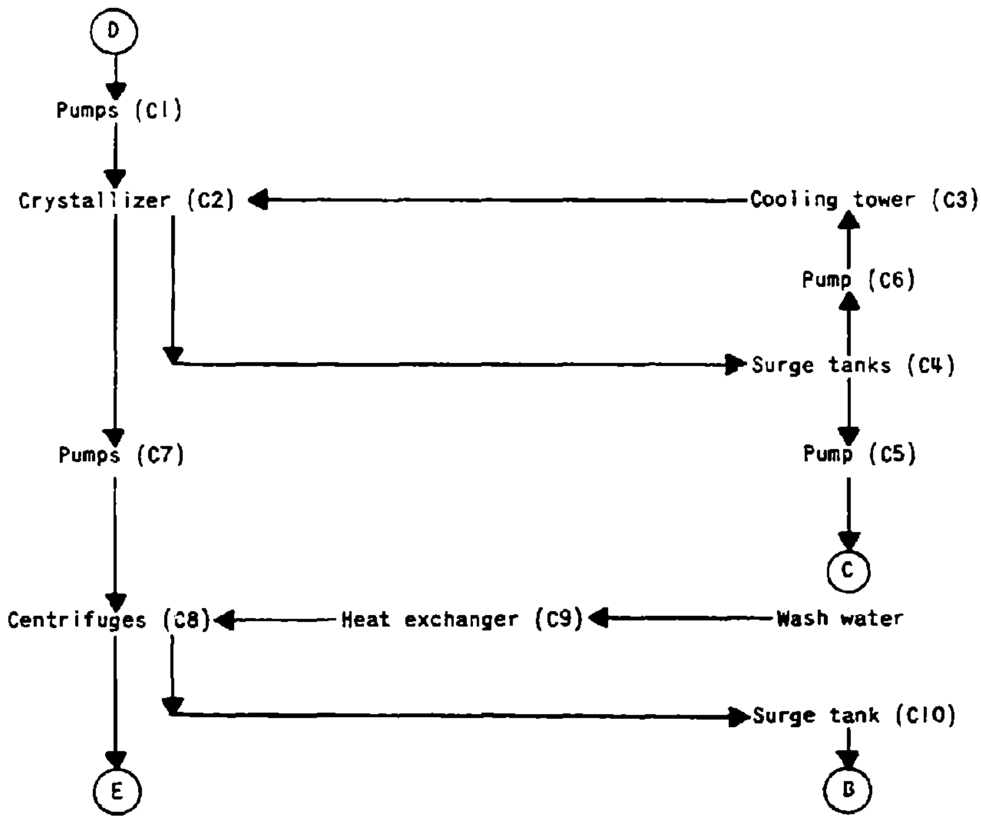


FIGURE 22. - Equipment Diagram, Crystallization Section. Recovery of Soda Ash From White Nahcolite.

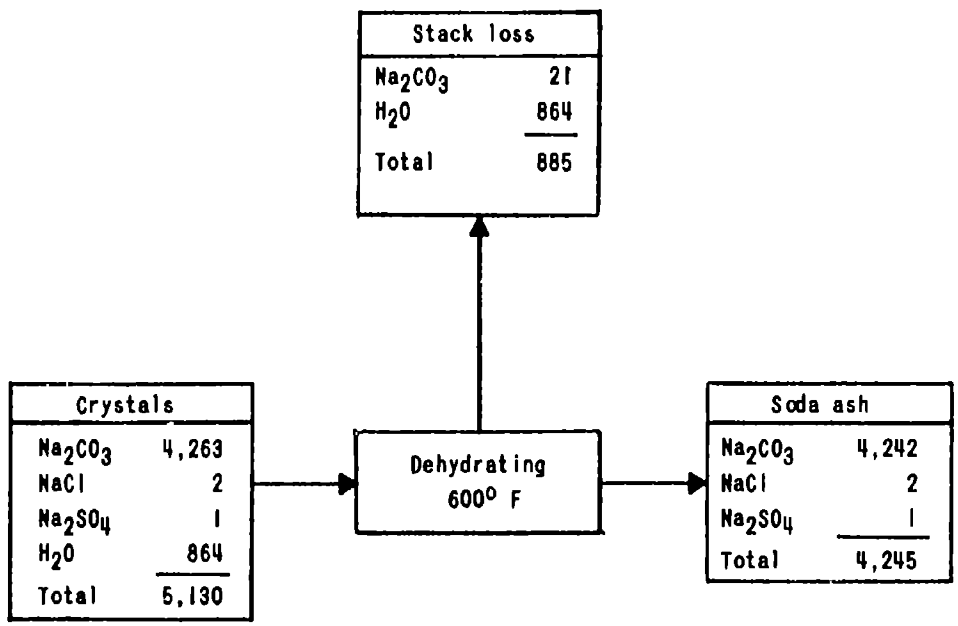


FIGURE 23. - Material Balance, Drying and Product Storage Section, Recovery of Soda Ash From White Nahcolite (Tons per Day).

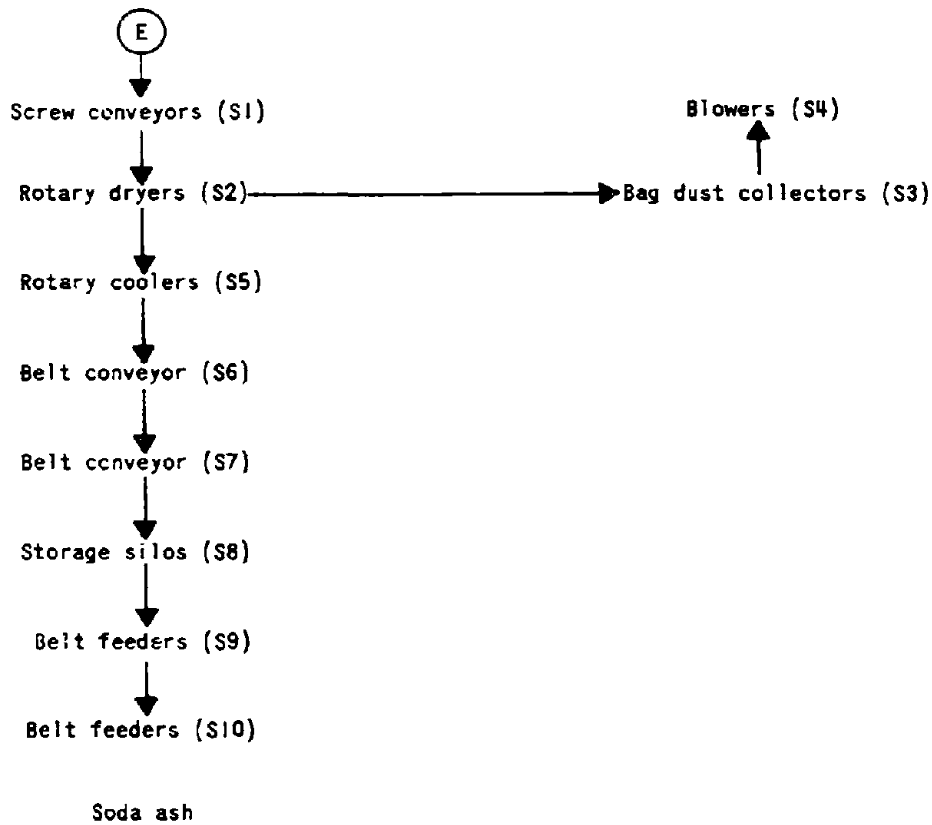


FIGURE 24. - **Equipment Diagram, Drying and Product Storage Section, Recovery of Soda Ash From White Nahcolite.**

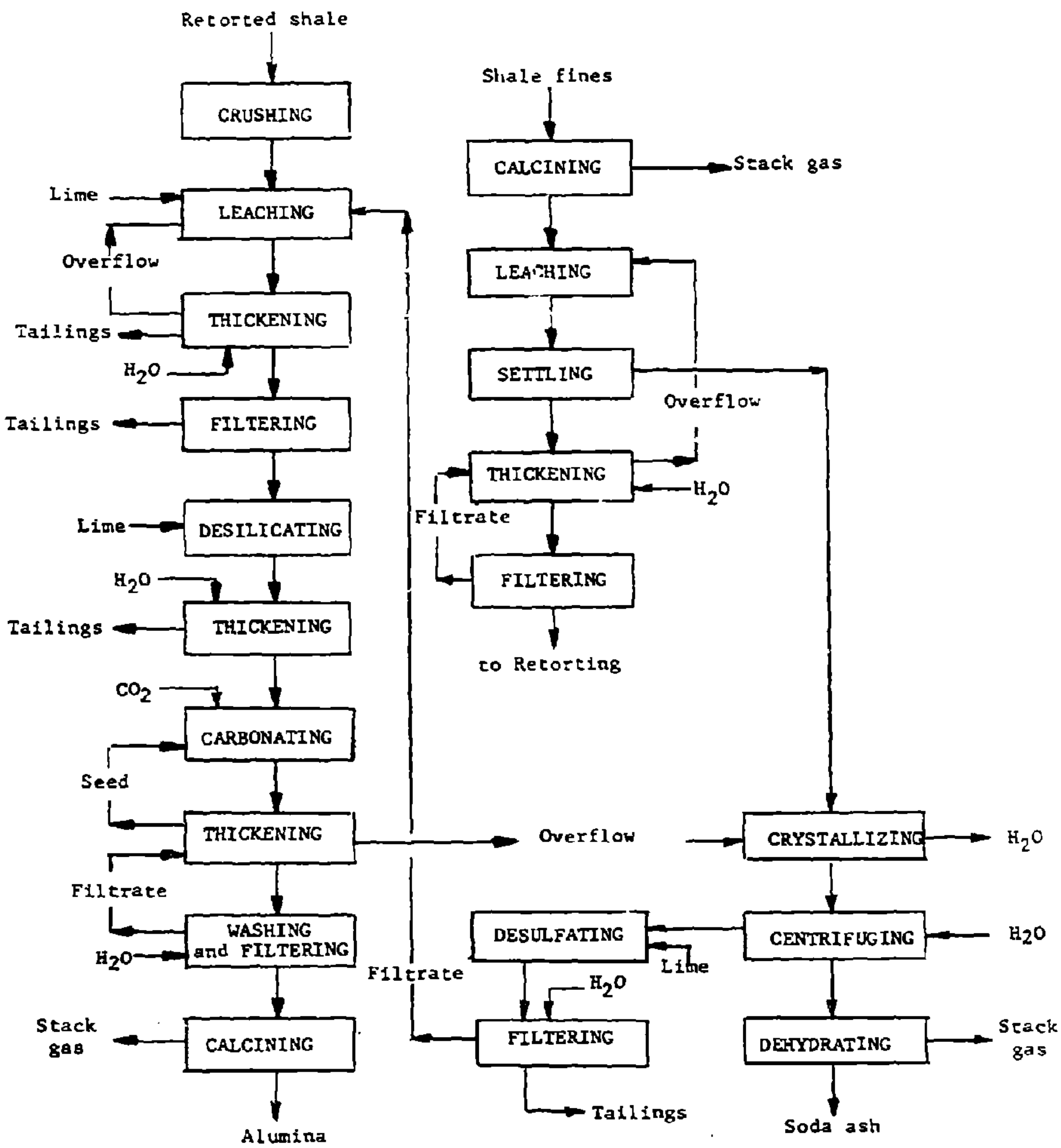


FIGURE 25. - Production of alumina and soda ash from dawsonite-rich oil shales

OPTION III

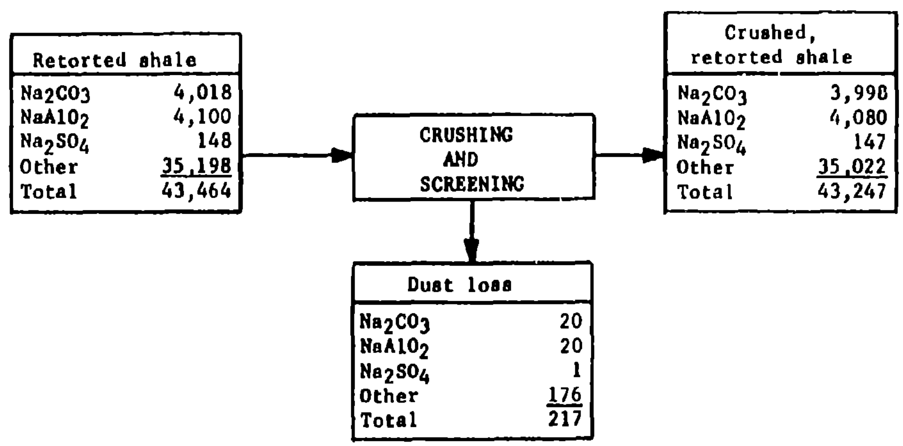


FIGURE 26. - Material balance, retorted shale crushing section, Dawsonite-rich zone (tons per day).

3.

A11-893

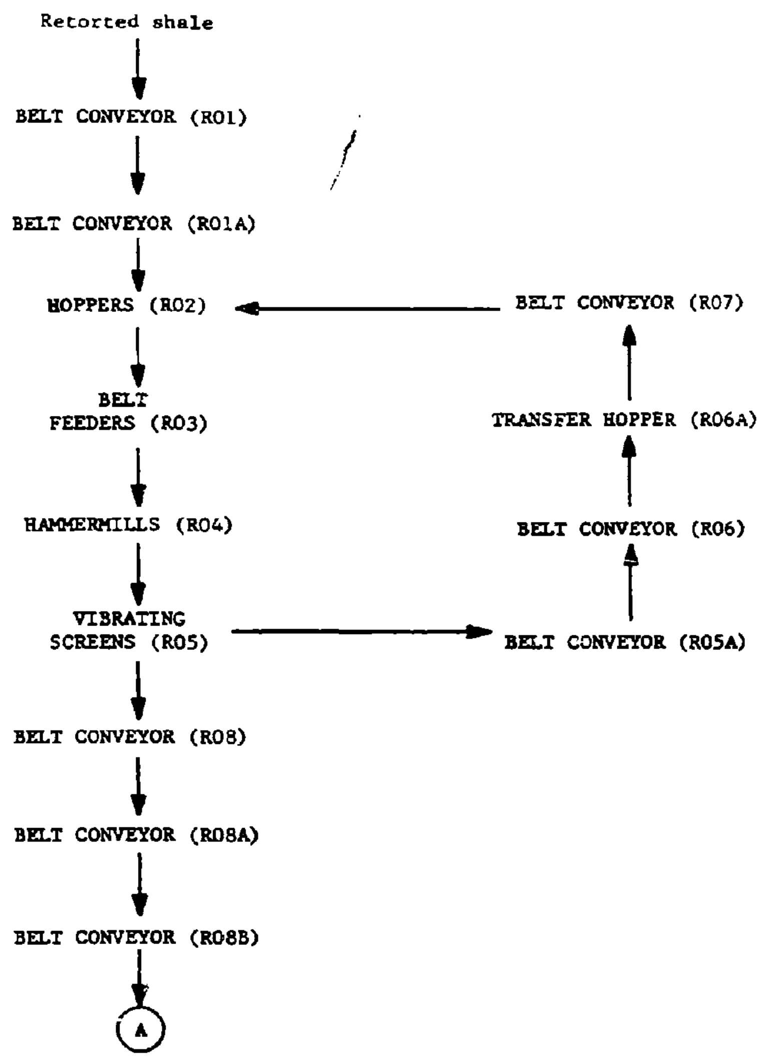


FIGURE 27. - Equipment diagram, retorted shale crushing section, Dawsonite-rich zone.

OPTION III

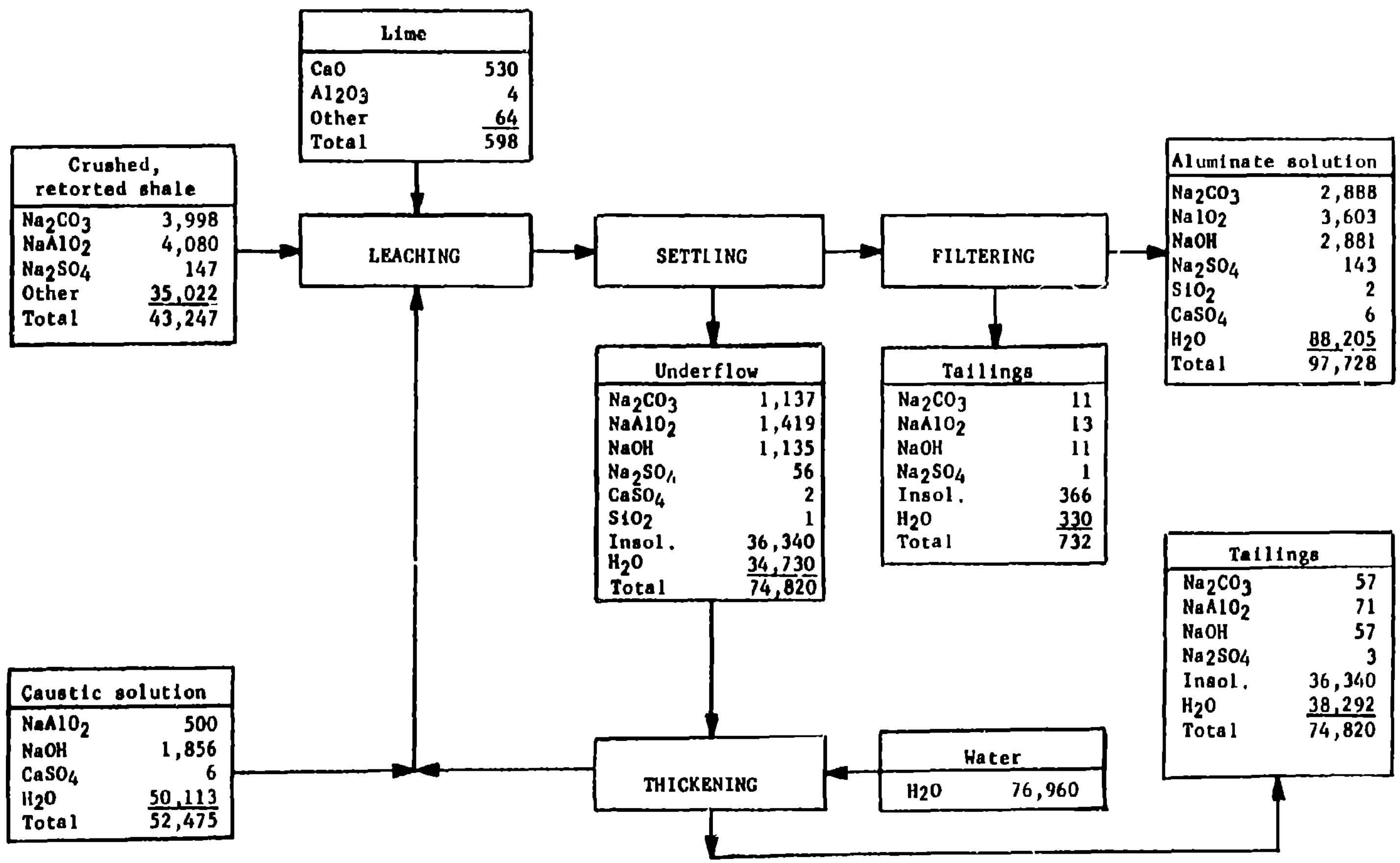


FIGURE 28. - Material balance, retorted shale leaching section, Dawsonite-rich zone (tons per day).

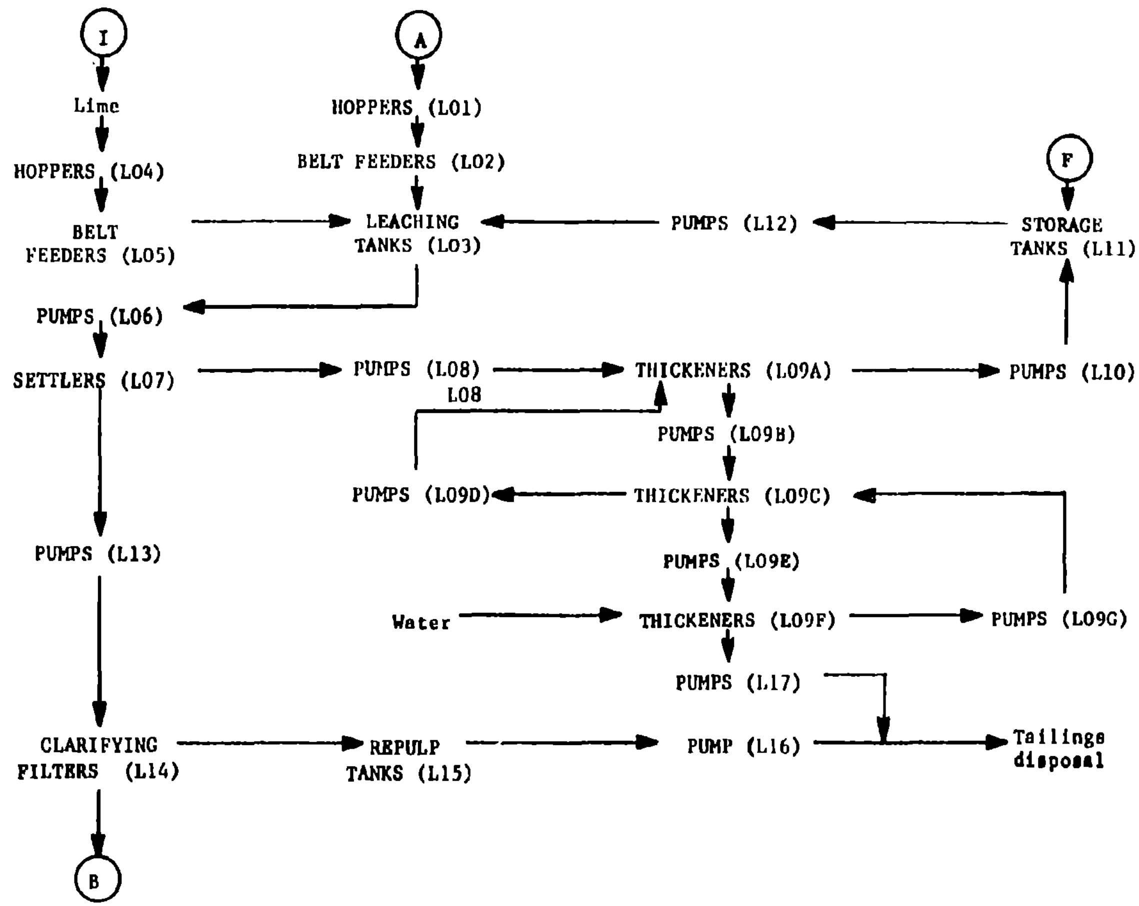


FIGURE 29. - Equipment diagram, retorted shale leaching section, dawsonite-rich zone.

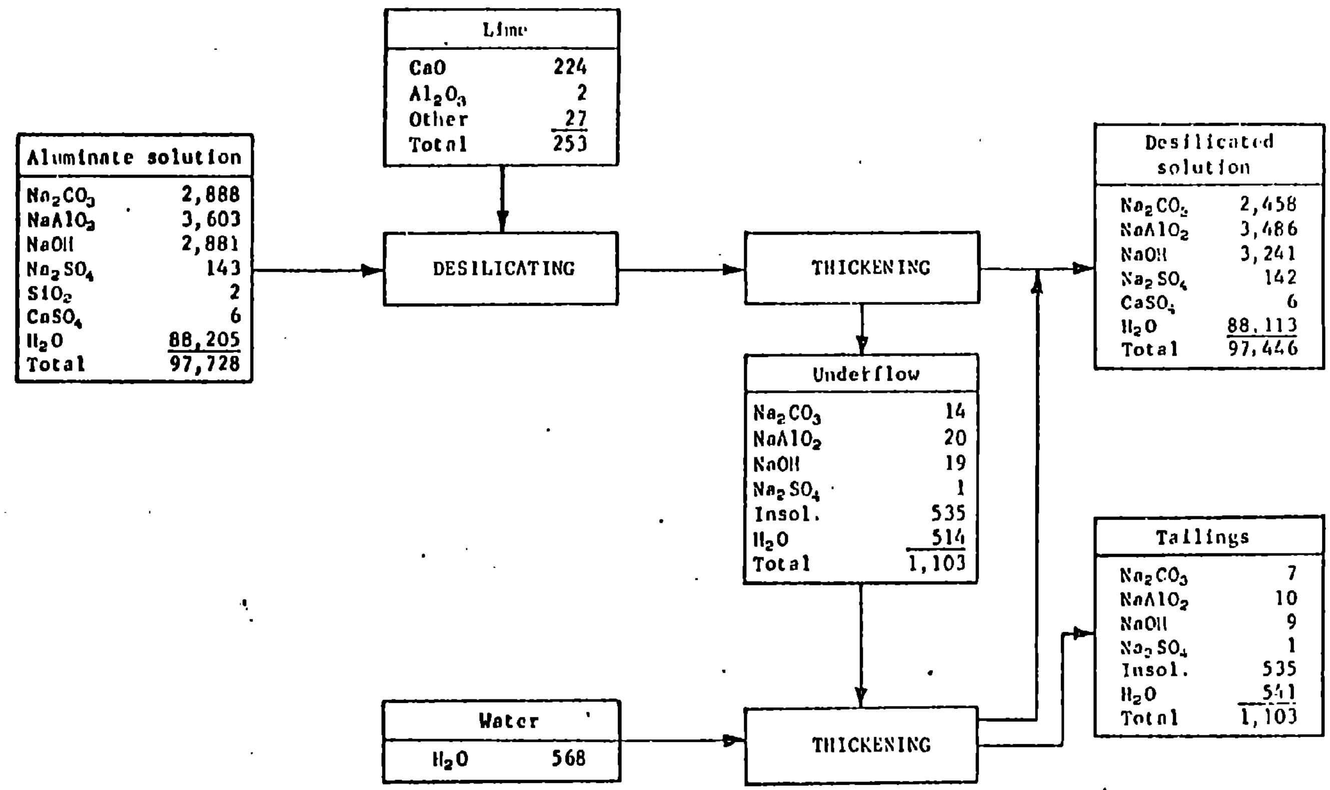


FIGURE 30. - Material balance, desilication section, Dawsonite-rich zone (tons per day).

OPTION III

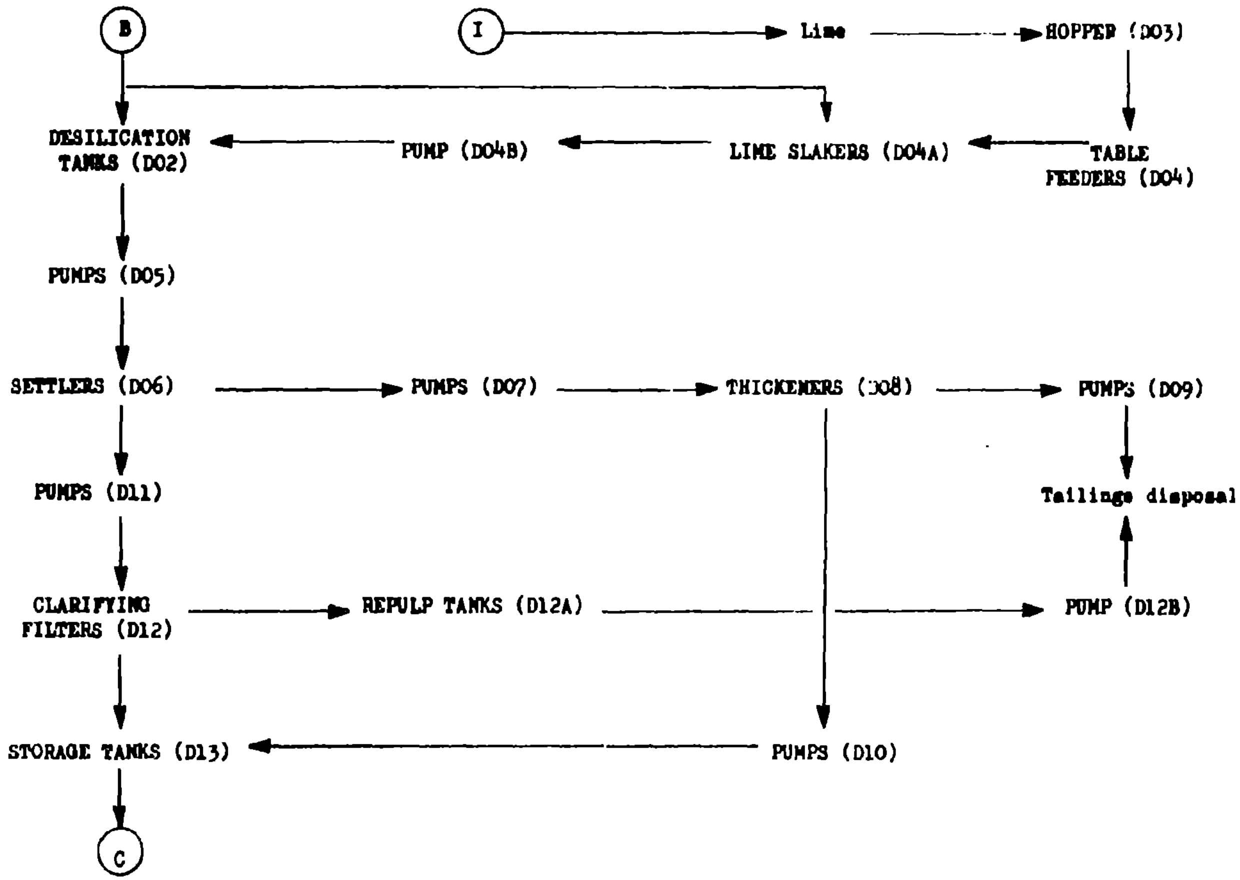


FIGURE 31. - Equipment diagram, desilication section, dawsonite-rich zone.

All-898

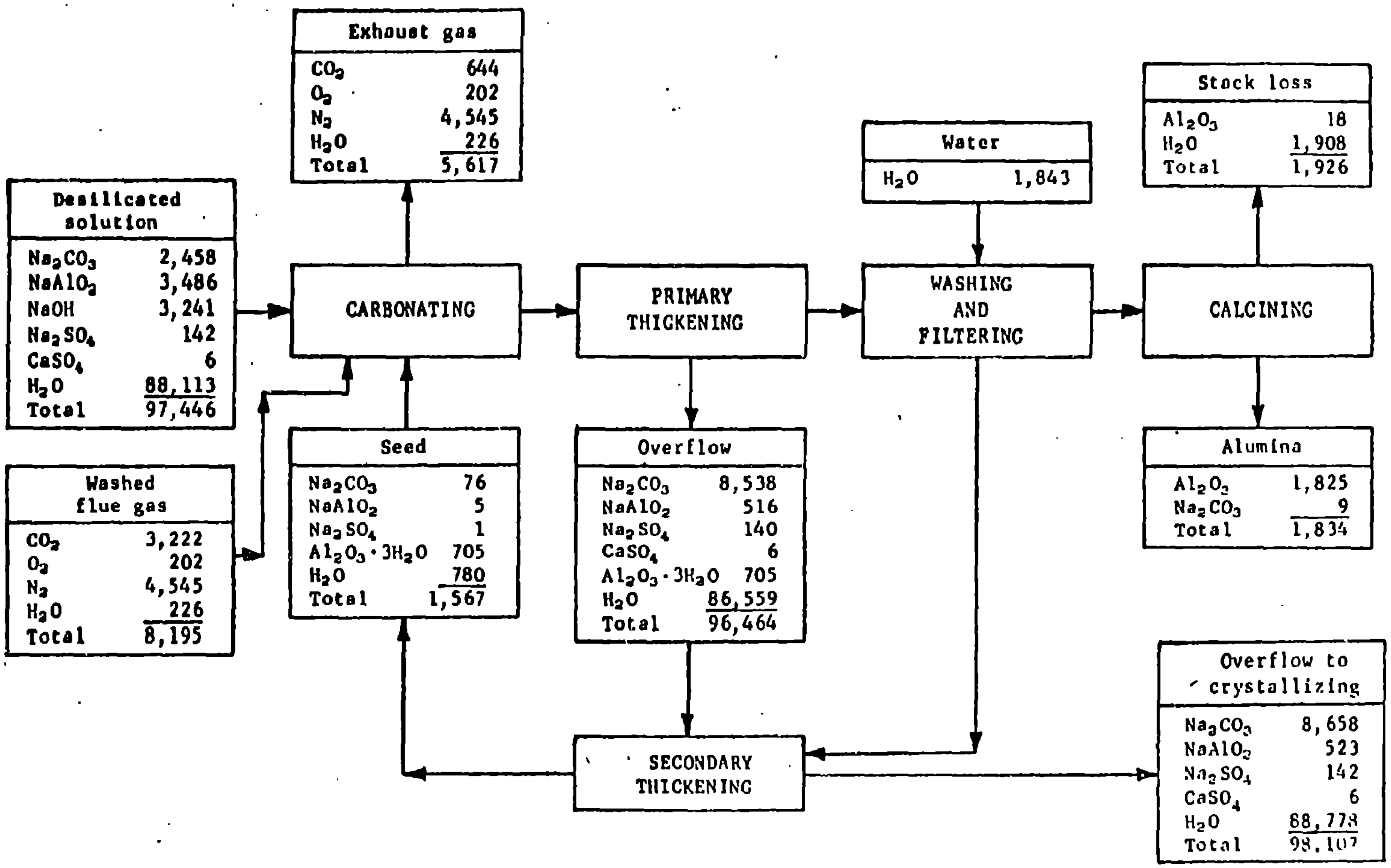


FIGURE 32. - Material balance, alumina precipitation and calcination section, Dawsonite-rich zone (tons per day).

OPTION III

A11-899

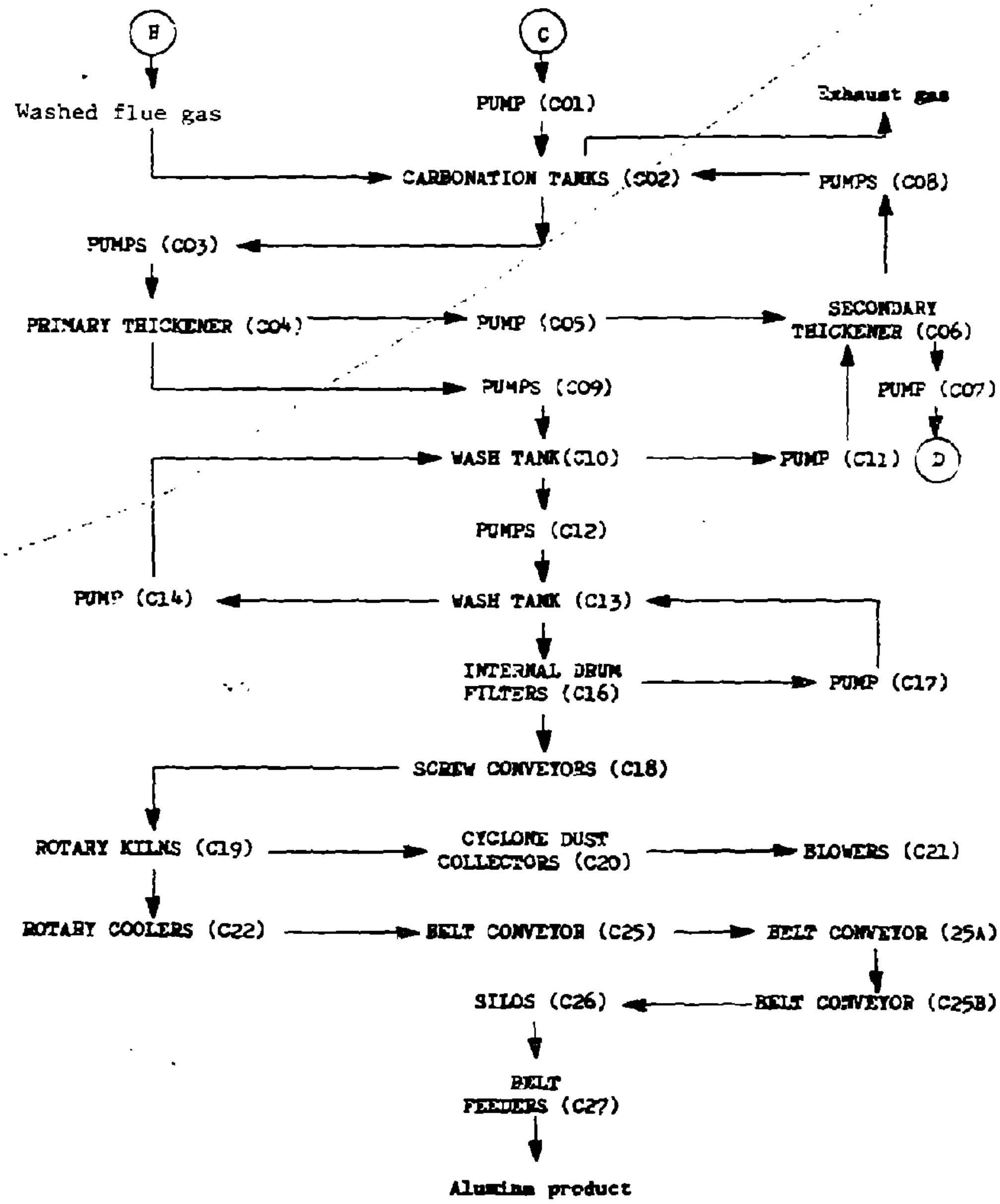


FIGURE 33. - Equipment diagram, alumina precipitation and calcination section, dawsonite-rich zone.

OPTION III

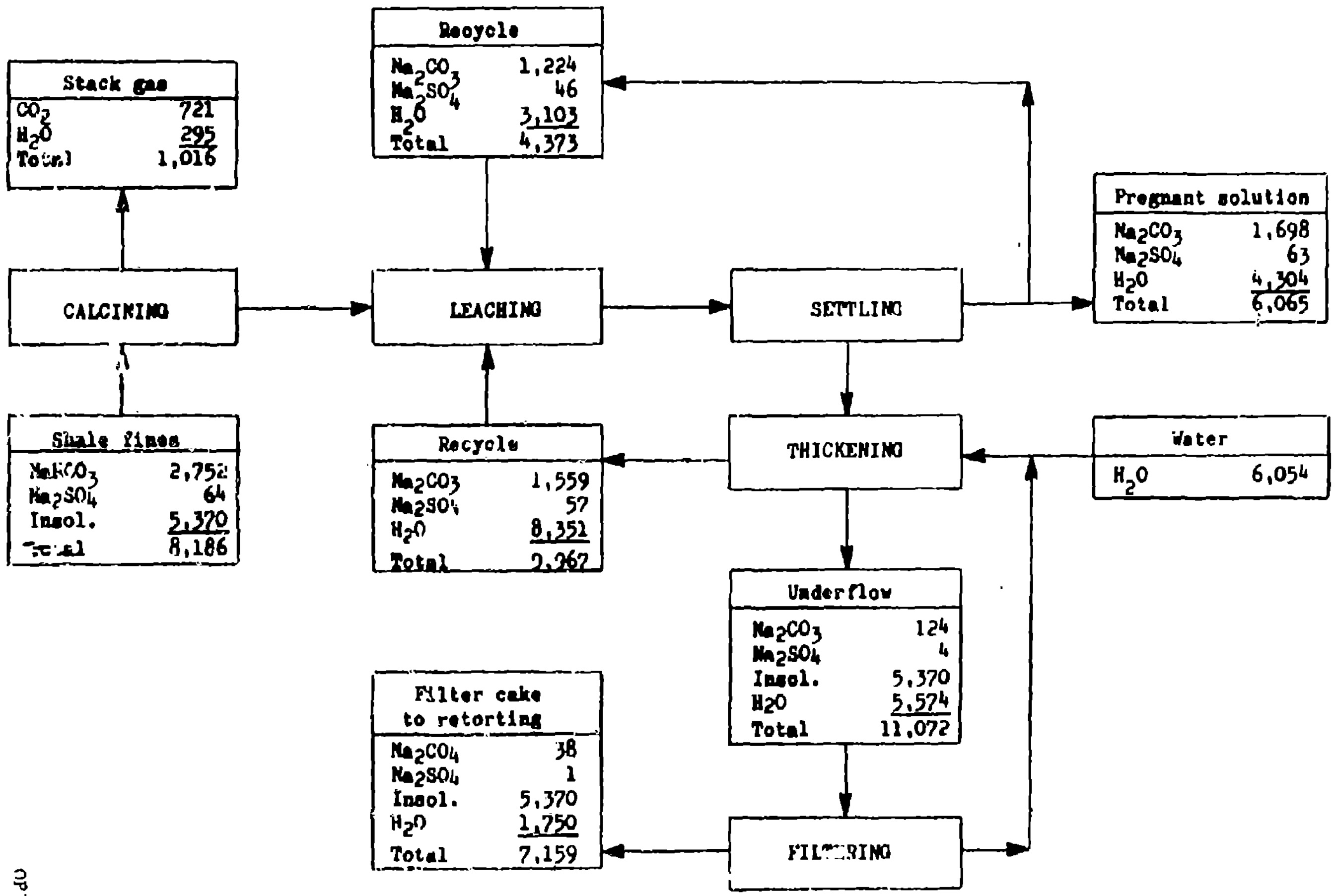


FIGURE 34. - Material balance, shale fines leaching section, dawsonite-rich zone (tons per day)

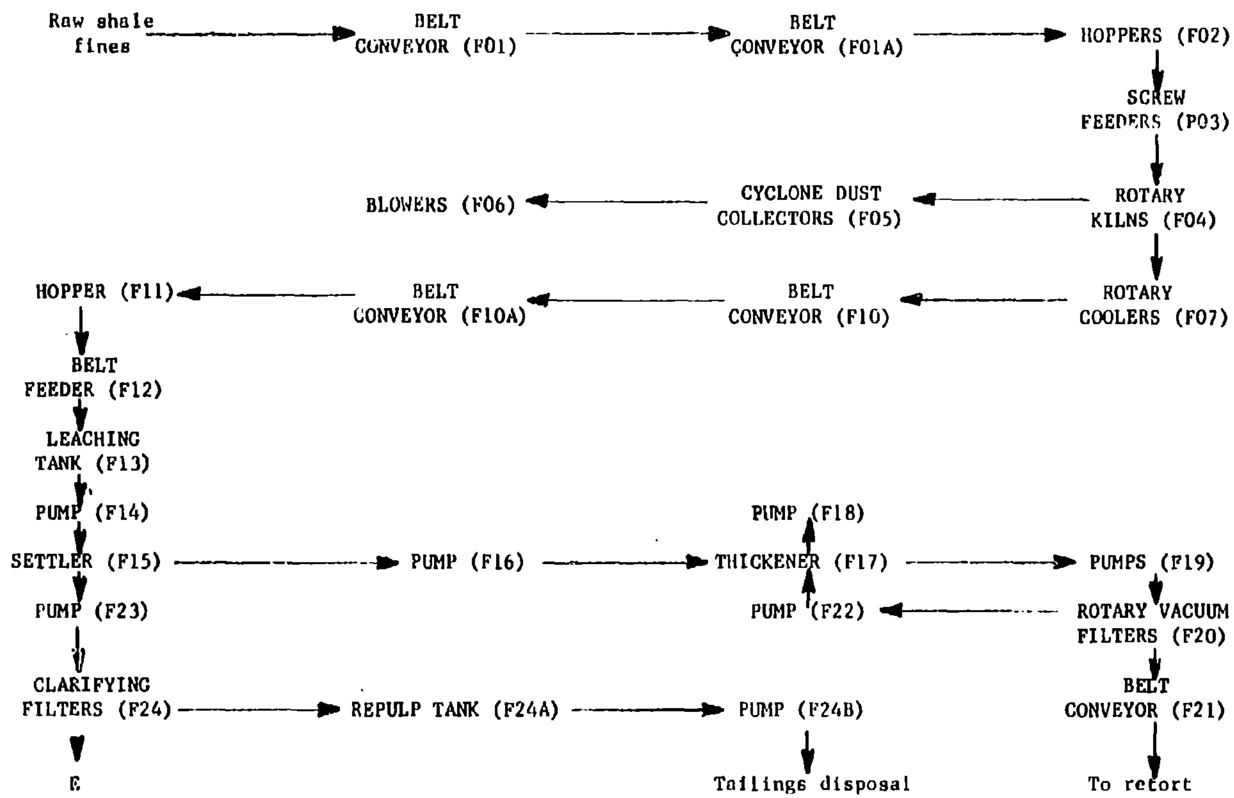


FIGURE 35. - Equipment diagram, shale fines leaching section, Dawsonite-rich zone.

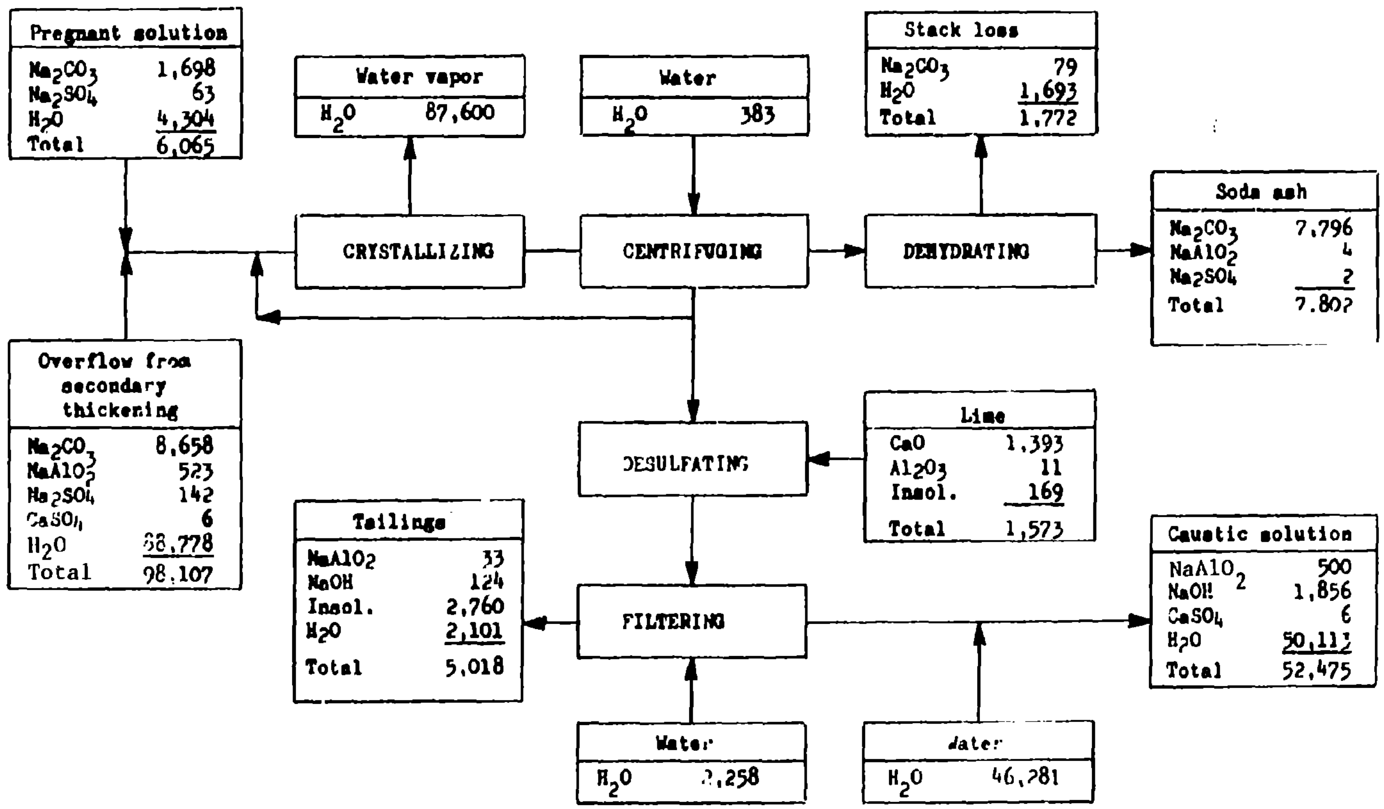


FIGURE 36. - Material balance, soda ash crystallization and dehydration section, dawsonite-rich zone.

OPTION III

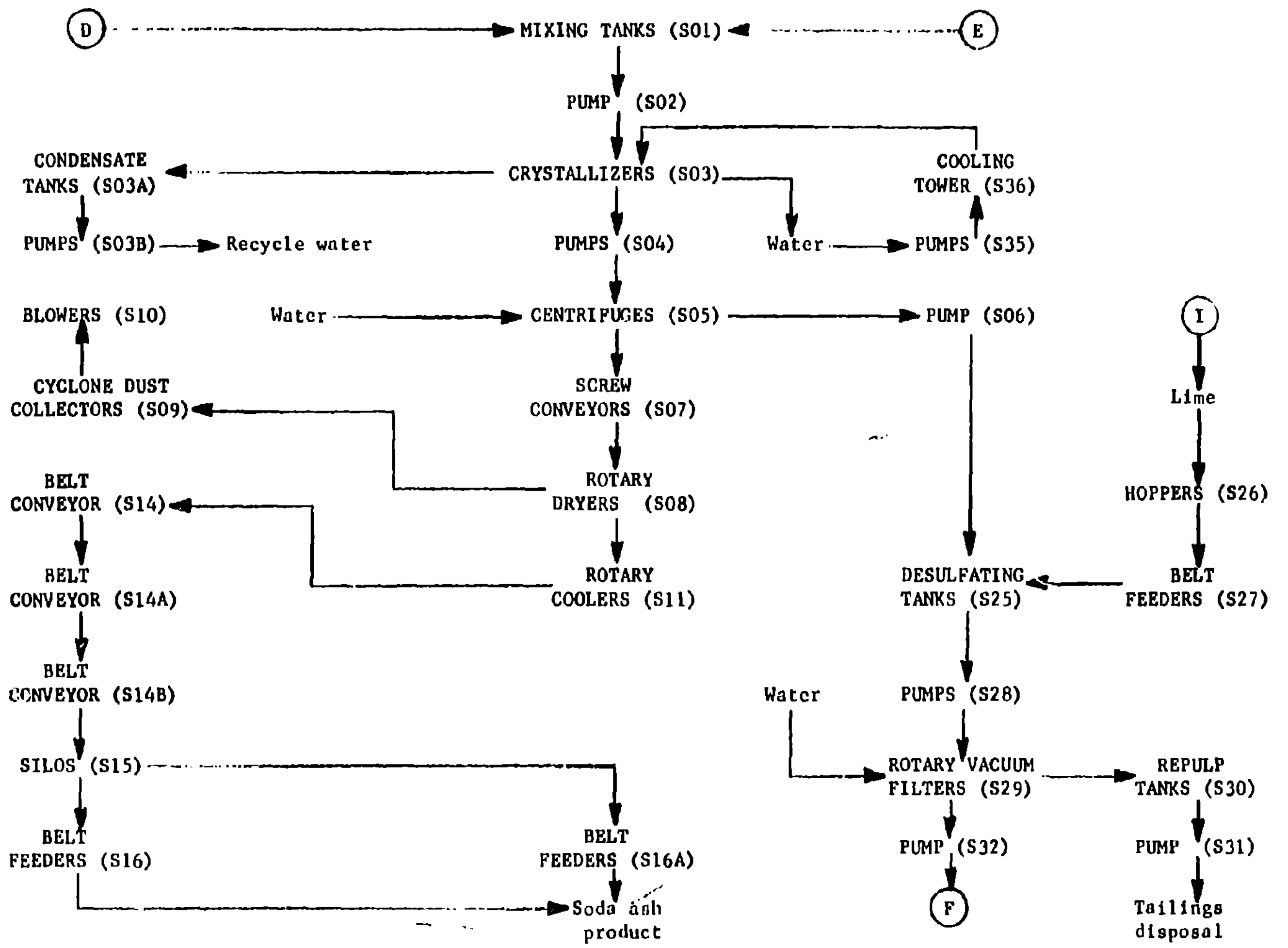


FIGURE 37. - Equipment diagram, soda ash crystallization and dehydration section, dawsonite-rich zone.

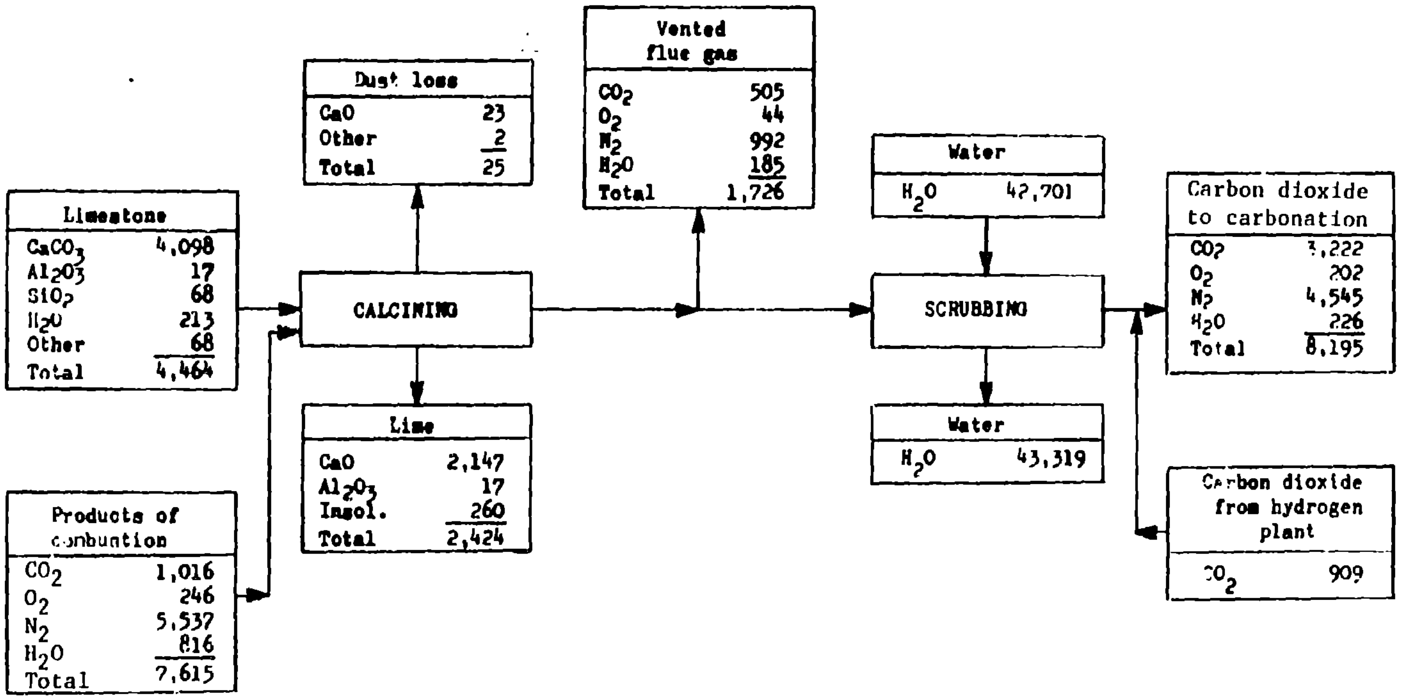


FIGURE 38. - Material balance, limestone calcination and flue-gas processing section, dawsonite-rich zone (tons per day).

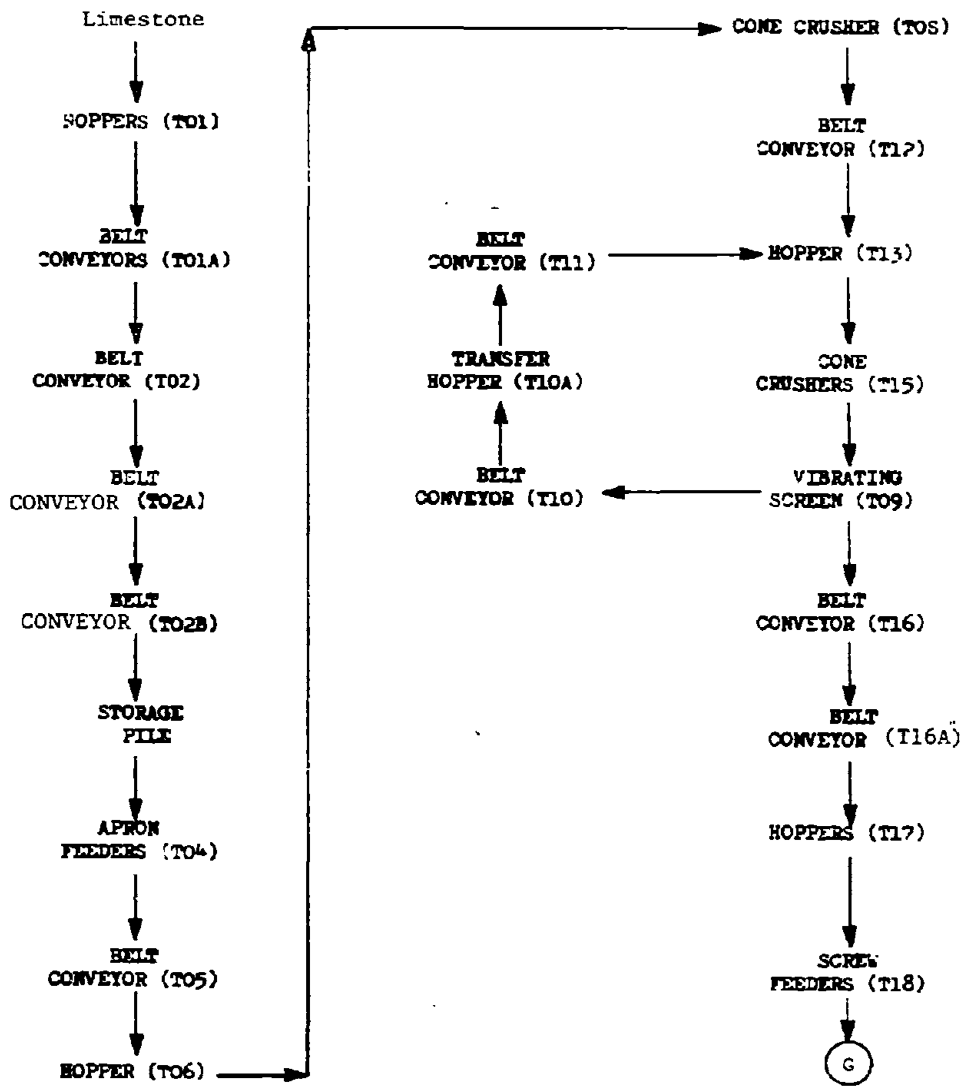


Figure 39. - Equipment diagram, limestone calcination and flue-gas processing section, dawsonite-rich zone.

OPTION III

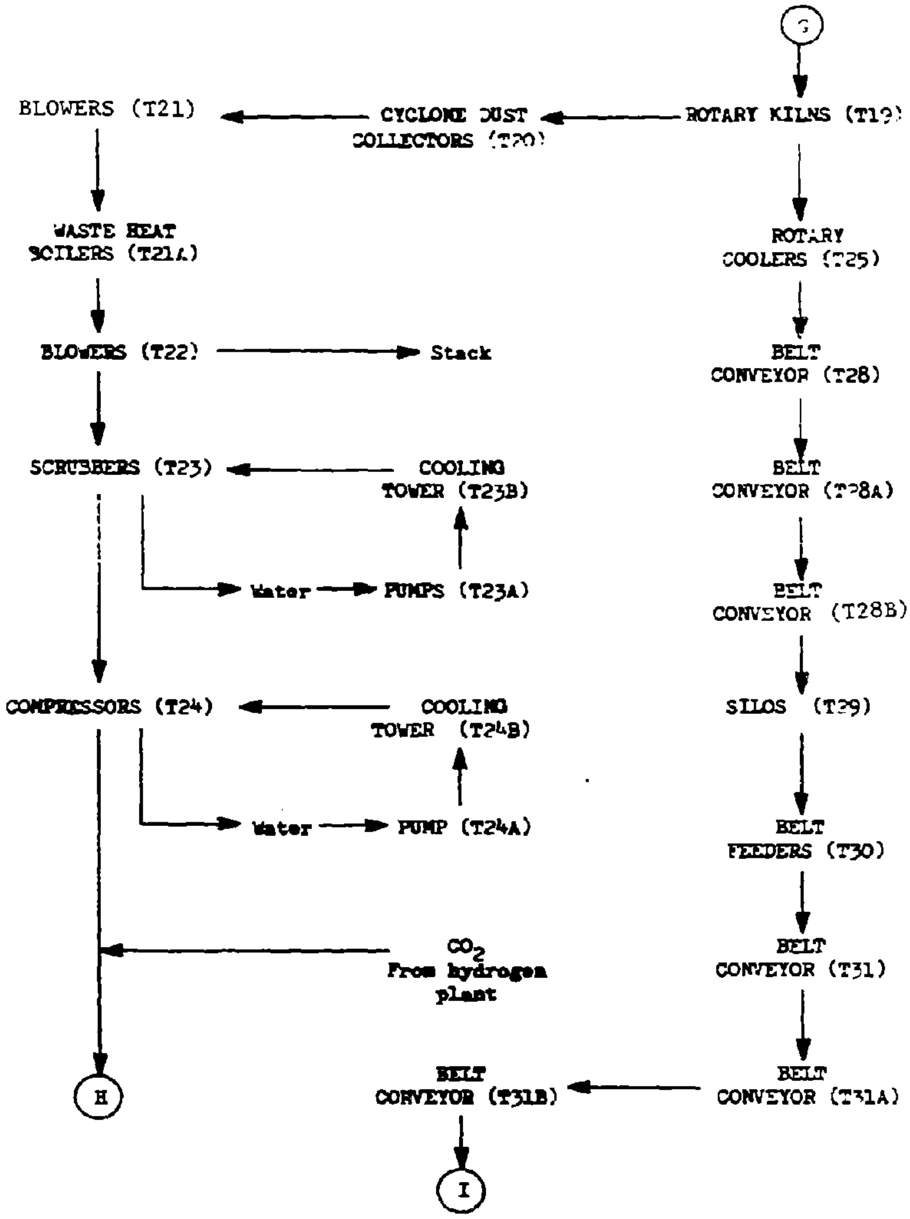


FIGURE 39. - Continued

OPTION III