bulk solids handling Volume 1, Number 2, May 1981

Coal Slurry Storage and Reclaim Facility

D. B. Cobb, C. O. Giles, J. D. Hornbuckle and F. O. Leavitt, USA

Lagerung und Rückgewinnung von Kohle Feststoff-Fluid-Gemischen
Stockage et récupération des mélanges solides-liquides de charbon
Almacenaje y recuperación de pulpa de carbón

スラリの貯蔵・リクレーム設備

煤渣贮存与回收设备

تسهيلات تخزين ملاط الفحم واستعادته

Lagerung und Rückgewinnung von Kohle Feststoff-Fluid-Gemischen

Das Mohave Kraftwerk im südlichen Zipfel Nevadas ist ein Kohlekraftwerk mit zwei Einheiten zu je 790 MW. Die Anlage gehört den Gesellschaften Nevada Power, Southern California Edison (SCE), Salt River Project und dem Los Angeles Amt für Wasser und Energie und wird von der SCE betrieben. Die Daten der Inbetriebnahme waren der 1. April und der 1. Oktober 1971. Die Kessel werden mit pulverisierter Kohle beschickt, die durch eine 440 km lange 18-inch Rohrleitung als fest/flüssig Gemisch angeliefert wird. Es ist erforderlich, die Kohle in einem Zwischenspeicher am Kraftwerk zu lagern, um im Falle abbautechnischer Schwierigkeiten oder beim Ausfall der Rohrleitungsanlage den Kraftwerksbetrieb fortsetzen zu können. Bei Lagerung setzt sich die Kohle ab, sie muß jedoch für den Einsatz im Kraftwerk wiederum in eine Trübe verwandelt und in die Tankanlagen des Kraftwerkes gepumpt werden.

Der Bau runder Becken für Lagerzwecke und der Einsatz des Marconaflo DYNAJET Rückgewinnungs-Systems in diesen Becken hat zu einer zufriedenstellenden, zuverlässigen und finanziell vertretbaren Lagerung und anschließender Wiederherstellung des Feststoff-Fluid-Gemisches am Kraftwerk geführt.

Stockage et récupération des mélanges solides-liquides de charbon

L'usine génératrice Mohave dans le partie sud du Nevada est une centrale alimentée au charbon avec deux unités, chacune de 790 MW. L'installation appartient aux sociétés Nevada Power (NP), Southern California Edison (SCE), Salt River Project (SRP), et au Bureau Central de Los Angeles pour l'Eau et l'Énergie, et est dirigée par la SCE. La mise en service s'est faite le 1er avril et le 1er octobre 71. Les chaudières sont alimentées par du charbon pulvérisé qui est amené par une canalisation de 440 km de long et de 18-inch de diamètre, sous forme de mélange solide-liquide. Il est nécessaire d'entreposer le charbon dans un silo-tampon près de la centrale pour avoir un fonctionnement continu de la centrale en cas de difficultés techniques d'exploitation du charbon ou bien lors d'une défaillance du système de canalisation. Lors du stockage, le charbon se dépose, mais pour l'employer, on doit le retransformer en pulpe et le pomper dans les réservoirs de l'usine. La construction de bassins ronds pour le stockage et l'utilisation du système de récupération du Dyna et Marconaflo dans ces bassins, a conduit à un stockage satisfaisant, fiable et financièrement acceptable et ensuite à un rétablissement du mélange solide-liquide dans l'usine.

Almacenaje y recuperación de pulpa de carbón

La central de energía de Mohave situada al cabo sur de Nevada, trabaja a base de carbón y se compone de dos unidades de 790 MW cada una. La planta pertenece a las Sociedadas Nevada Power, Southern California Edison (SCE), Salt River Project y a la Autoridad para Energía y Aguas. La planta es manejada por la SCE. Las fechas de la puesta en marcha fueron el 1º de Abril y el 1º de Octubre de 1971. Las calderas son alimentadas por carbón pulverizado que es suministrado a la planta por medio de una tubería de 18 inches de diámetro y 440 Km de longitud y en forma de pulpa. No es necesario de almacenar el carbón en un depósito intermediario en la central de energía, que tendría el fin de proseguir el trabajo en la planta en caso de dificultades de explotación ó de paro en la tubería. En el depósito se asienta el carbón y debe ser nuevamente convertido en pulpa para poder ser bombeado a los tanques de la central de energía.

La construcción de depósitos circulares para el almacenaje y la aplicación del sistema de recuperación Marconaflo DYNAJET han conducido a un almacenaje satisfactorio, seguro y económico con una contigua reconstitución de la pulpa en la central de energía.

Summary

The Mohave Generating Station, located in the southern tip of Nevada, is a coal-fired power plant with two units at a power rating of 790 MW each. The coal plant is jointly owned by Nevada Power, Southern California Edison, Salt River Project and L.A. Department of Water and Power and is operated by SCE. Firm operation dates of the units were April 1 and October 1, 1971. Base fuel for the boilers is pulverised coal, delivered to the station via a 275 mile, 18" pipeline in the form of a coal-water slurry. It is necessary to store coal onsite to sustain operations during periods when coal deliveries may be interrupted due to operational problems with the coal mine or the pipeline. When stored, the coal in the slurry settles out, but to be suitable for station use, it must be re-slurried and returned to the Station's active slurry tanks. The construction of circular ponds for additional onsite storage and the installation of the Marconaflo DYNAJET coal reclaim system with those ponds have provided more adequate, reliable and economical facilities for the storage and reslurry of coal at the station.

D.B. Cobb, Asst. Plant Engineer, C.O. Giles, Project Engineer, J.D. Hornbuckle, Project Manager, F.O. Leavitt, Construction Engineer, Southern California Edison Company, USA

Presented at Coal Technology '79, 2nd International Coal Utilisation Conference and Exhibition, Houston, Texas, November 6–8, 1979, by W.N. Sims, Vice President-General Manager, Marconaflo, USA

Correspondence to be addressed to: R. Bromley-Martin, Babcock Hydraulic Handling, 10/18 Spurgeon Street, London SE1 4YP, England

1. Introduction

The Mohave Generating Station, located near Laughlin, Nevada at the southeastern tip of the state, is a participant-owned, coal-fired power plant with a combined unit rating of 1580 MW. The plant site is comprised of 2500 acres of land and is situated near the Colorado River directly across from Bullhead City, Arizona where ambient temperatures range from 25 °F to 125 °F. The generating facility, consisting of two 790 MW units, is jointly owned by the Nevada Power Company, the Southern California Edison Company, the Salt River Project Agricultural Improvement and Power District, and the Los Angeles Department of Water and Power. Firm operation began in 1971 under the management of the Southern California Edison Company.

The plant's steam generators were designed and constructed by the Combustion Engineering Company. Each steam generator is rated to provide 5,587,000 lbs/h of 3500 psig steam at 1000 °F superheat temperature to the General Electric turbine-generators. Design reheat conditions to the turbines is 644 psig at 1000 °F. Base fuel for the tangentially fired, supercritical boilers is pulverized coal from a total of twenty Raymond bowl mills located symmetrically on each side of the units. Particulate removal from the exit flue gas streams is accomplished by electrostatic precipitators which remove 98.6 % of the fly ash passing through the two boilers and exiting through the common 500-ft stack.

The coal is delivered to the Station via an 18-inch pipeline from its source at Kayenta, Arizona, 275 miles to the east. The coal is pulverized at the mine and after introduction of water, 50 % by weight to form a slurry, the mix is pumped to the Station. The coal delivery system is unique and is believed to be the longest of its type in the industry.

Onsite storage of coal is necessary to maintain operation of the Station, particularly during times when pipeline deliveries may be interrupted. Initial Station design provided for 12 days inactive coal storage and a reclaim system which required a high degree of manual operation.

The development of the hydraulic type coal reclaim system to provide more adequate, reliable and economical facilities for the Mohave Station is the subject of this paper.

2. Coal Slurry System

Three basic coal slurry systems are maintained at the station: the slurry storage and transfer system, the slurry feed system, and the reslurry systems.

2.1 The Slurry Storage and Transfer Systems

Slurry received from the Black Mesa Pipeline is normally directed to any one of four coal slurry *active* storage tanks. Each tank is 87 ft in height and is rated at a total storage volume of eight million gallons. Philadelphia Gear paddle type agitators are provided for continuous mixing of the material.

Piping arrangements also have been provided to divert flow from the incoming pipeline to any one of seven onsite storage ponds. These ponds are identified as the East and West *inacitve* storage ponds (approximately 120,000 t capacity each), the coal dump pond (approximately 50,000 t), and the four coal slurry storage and reclaim facility ponds (approximately 88,000 t capacity each).

This latter facility was added recently and is the topic for this paper.

Piping also has been provided to transfer slurry from one active storage tank to any inactive storage pond. Each pipeline associated with the above systems is provided with flush water connections for purging.

2.2 The Slurry Feed Systems

During generating unit operation, slurry is pumped from the active storage tanks, through a slurry heat exchanger and on to the fuel processing equipment at each boiler. A return line to the active storage tanks is provided to maintain continuous flow in the supply lines. Water separation from the coal is accomplished by 20 Dynacone centrifuges per generating unit. These centrifuges are oriented in such a fashion that each coal pulverizer is directly fed from two centrifuges. Coal thus delivered to the pulverizers contains a moisture content of approximately 20 %. Water leaving the centrifuges (referred to as *centrate*) is directed to thickener tanks (referred to as *clariflocculators*), where the 5—6 % solids concentration is chemically separated from the water. The sludge thus formed (referred to as *underflow*) is pumped to the boilers and is diffused into the furnace fireball and is thus burned as fuel. Water from the clariflocculator tanks is directed to the plant's cooling water system [3,4].

Approximately 350—370 t/h of coal fuel is consumed by each boiler at full load operation. This corresponds to slurry flow rates of approximately 2300 GPM to 2500 GPM, respectively.

2.3 Reslurry Systems

By original design, slurry required during periods when the normal delivering system is not available is mechanically prepared at the station from inactive storage. Coal which has been diverted to the East or West inactive ponds or to the coal dump pond is allowed to settle and the water is decanted for use in the cooling water systems. After a drying period of 2—3 months, the coal is then excavated and relocated to a storage bunker east of the active storage tanks. Under emergency conditions this coal is then again loaded into trucks and transported to two underground hoppers. The coal is then fed onto a conveyor belt which delivers it to a mixing chamber where water is introduced. The mixture thus formed is screened of rocks and other debris and directed into mixing tanks where the consistency and density of the material is corrected. The slurry formed by this operation is then pumped into the active storage tanks at rates up to 900 t/h.

3. Station Reslurry Requirements

Several factors have determined the need for a back-up fuel source [1,2,3]:

3.1 Unit Capacity Factor

Station capacity factors have generally improved since firm operation began. By design, the Black Mesa Pipeline can deliver coal at rates ranging from 560 t/h to 660 t/h. This supply has proved to be adequate under general circumstances; however, during high production periods, the station has consumed approximately 2000t per day of coal in excess of the maximum pipeline delivery rate. Under sustained periods of such high production, there is a need for additional onsite fuel inventories.

3.2 Pipeline Related Problems

Although operation of the Black Mesa Pipeline has proved to be extemely reliable, provisions must, of course, be made for onsite fuel inventories in the event of pipeline outages.

Such outages are most likely to occur as a result of:

1. Mechanical failure of critical piping, valves and pumps,
2. Electrical interruption to pumping stations due to storm conditions, or
3. Difficulties in maintaining water inventories due to well pump related problems.

3.3 Mine Related Problems

In 1975 and again in late 1977, normal coal supply to the station was interrupted as a result of mine worker strikes. During each instance, major reslurry efforts were required in order to maintain electrical power production at the station. The possibility of labor disputes poses the most obvious interruptions to continuous coal fuel supply; however, mechanical and environmental hazards also exist. Such hazards could possibly take the form of dragline failure, conveyor belt failure or storm or blizzard conditions. Such failures have been rare in the past; however, provisions for onsite fuel inventories must be available in the event of their occurrence.

3.4 Coal Quality

An operating handicap which should fall under the category of *Mine Related Problem*, but may not be a direct result of any equipment or labor force failure, is poor coal quality. Experience has proven that at sustained higher load operations when coal containing ash in excess of boiler design concentrations is consumed, furnace ash hopper pluggage likely will result. Because of this, coal slurry of excessive ash content normally, with adequate advance notice, will be directed to storage ponds for later disposition. During such times, coal will be reslurried for unit operation.

3.5 Production Cost Factor

Each of the factors discussed above directly affects one of the Company's central objectives: maintaining continuous electrical service to the consumer at reasonable cost. When considered from a production cost standpoint, these factors are particularly significant. The 1977 Btu production cost at the Mohave Generating Station averaged approximately 44 cents per million Btu. This, when compared to 253 cents per million Btu for oil* and 185 cents per million Btu for gas*, provides for significant cost savings to the Company and so to the consumer for each kWh produced at the station.

4. Need for an Improved System

As early as 1974, Station Management determined that a more economical and reliable means of reclaiming coal from onsite storage was desirable. Several additional factors have further emphasized this need.

* Average for Southern California Edison's major oil and gas fired generating stations

4.1 Environmental Factors

The process of developing and maintaining a dry storage bunker, as described earlier, requires that the coal be allowed to stand dry while in the inactive storage ponds and then again while in the storage bunker. Winds, which are prevalent at certain times of the year in the desert environment blowing across the dry storage, raise coal dust which can on occasion become a major problem. Several coal pile sealants have been utilized with varying degrees of success; however, during times when the coal must be transported, the danger of airborne dust contamination continues to exist.

4.2 Time Factors

Experience has shown that from three to six months lead time is required to fill, drain and empty an inactive storage pond. Because of this time lag, the ponds must be continually worked if acceptable inventories of available coal are to be maintained.

4.3 Operational Cost Factors

During the development of a dry storage bunker, the coal must be handled twice — once during the emptying of the inactive storage pond and again during the actual reslurry process. At present equipment and labor rates, the coal hauling and reslurry operational costs are in excess of $ 16,000 for each day of operation, resulting in an increased cost for fuel thus produced of $3.60 per ton. This figure assumes a 700t/h reslurry rate. Costs would naturally be less for higher rates and more for lower production rates.

4.4 Reliability Factors

The problems associated with the large amount of equipment and manpower involved during the reslurry process adversely affected the reliability factor of the system.

Problem areas have included the vibratory apparatus, feeders, screens, pumps, motors and conveyors. Even under ideal operation conditions (weather and coal moisture content), the system has proved to be a major maintenance *manhour-eater*.

In November of 1974, a new concept of coal recovery was tested at the Station. Representatives from Marconaflo Inc. and station personnel designed a temporary system whereby a Marconaflo reclaim capsule could be suspended from a mobile crane over the East inactive storage pond. A temporary water supply was connected to the Marconaflo support equipment where the water pressure was boosted and supplied to the capsule via flexible high pressure water hoses. A portable generator supplied power to the support equipment. A capsule discharge line and booster pump station was also fabricated to transfer reclaimed coal to the active slurry tanks. The unit was tested for a total of nine hours during which time the system reslurried coal at an average solids concentration of 37.5%.

The Marconaflo reclaim system was utilized again under emergency conditions from January 16, 1975 through March 8, 1975. The reclaim system and support components were set up similar to the previous test. During this period, approximately 77,000t of coal were reslurried at an approximate cost of $2.54 per t. In spite of the major costs associated with the rented capsule and support equipment, the operation demonstrated the system's capability to reslurry fuel economically. Upon the completion of the successful demonstration of the Marconaflo reclaim system, Company management approved the station's request for a production scale coal recovery system utilizing the *Marconaflo* principle, and the Engineering and Construction Department of the Company was thus presented with the task of its realization.

Edison's Engineering and Construction Department utilizes the project management approach in the engineering and construction of its projects. The projects may be handled entirely by in-house personnel or by outside engineer-constructors or a combination of both. It was decided that this project would be handled in-house for the engineering, design, material procurement and construction management. The construction would be accomplished using outside contractors with four major construction contracts let during the two phases of construction (to be discussed later in the paper) on a firm-price, competitive bid basis.

5. Engineering and Design Phase of the Project

5.1 Major Parameters for the Project

Before proceeding with detailed design, the following basic parameters were established:

1. Days of additional coal storage needed. Although 45 days had been requested originally, further discussion reduced this to 20 days actual storage (approximately 350,000 t) with space reserved for 25 days of future storage, if needed.
2. Reclaim rate. The reclaim rate agreed upon was 880 t/h based on using two reclaim units of 440 t/h each, producing coal slurry having an average density of 50 % solids by weight.
3. Facility Service Factor. A service factor of 25 % was agreed upon; i.e., 90 days per year on a continuous or intermittent basis.
4. Coal storage pond shape, size, number and configuration. This parameter was more difficult to establish and is discussed in greater detail in the following section.
5. Type of Marconaflo reclaim units to install — the *fixed* type or the *portable* type (DYNAJET). This parameter was not readily determined because it had to be established in conjunction with pond shape and size. With the *fixed* type, the high pressure water jets and the slurry pump would be a fixed installation at the bottom of a pond. In constrast, the portable type unit (DYNAJET) consisted of the high pressure water jets and a slurry pump packaged into a capsule which would be lowered into the material from the top of the pond.

   While the first three parameters above were settled early, a major study was necessary to select the optimum pond/reclaim system combination. This study is worthy of a more detailed discussion.

5.2 Pond/Reclaim System Study

Several basic factors were considered during our quest for the optimum pond/reclaim system combination.

First, in order to evaluate properly the size and shape of ponds in which the Marconaflo hydraulic reslurrying units were to operate, it was necessary to keep in mind the operation principle of those units. In the Marconaflo system, a slowly oscillating high energy jet stream of water is directed from a central location into a bed of material to undercut that material. The material collapses into the stream of water and is reslurried — then flows back to a slurry pump located near the jet. During the flowback, the slurry does not encounter the jet stream and must maintain sufficient velocity to keep the particles in suspension. This forms a natural slope leading back to the pump, generally in the shape of a crescent.

Prior to our studies, Marconaflo nozzles had been designed to funtion effectively at distances up to 100 ft. For the Mohave coal reclaim application, it was believed that nozzles could be designed to be effective 150 ft or more. Marconaflo Inc., however, based on experience to the time of our study, would guarantee reslurrying at a distance of only 100 ft, while producing slurry at an average density of 50 % solids.

Another important factor — completely unrelated to the reclaim units — had a strong impact on the shape of the pond bottoms. This factor was the type of material with which we planned to line the ponds. Due to the proximity of the Mohave Station to the Colorado River, it would be necessary to line the ponds with a material that was impermeable, to prevent seepage of water from the ponds into the underground water system and thence to the river. Also, the liner must be strong enough to support vehicular traffic during occasional cleanouts of the pond. Hot-mix asphaltic concrete 4" thick was determined to be the most suitable material to meet the foregoing requirements. To construct this asphaltic concrete (AC) liner with the required 97 % density, it was necessary to limit the inside slopes of the ponds to 3:1 (horizontal: vertical). Therefore, the selection of the AC liner determined the shape of the outer section of the pond as a 3:1 slope.

The depth of the ponds was limited to 40 ft working depth in order to maintain integrity of the lining. Our geologists advised that for ponds deeper than 40 ft we would run a high risk of damage to the lining when the ponds were empty due to groundwater pressure beneath the lining. In fact, after selection of pond configuration we designed subdrain systems beneath the linings to remove any such groundwater.

With these factors in mind, twelve different pond/reclaim system schemes were considered before selecting three schemes for serious investigation. The twelve included rectangular, square, circular and semi-circular shapes, and considered the use of mobile cranes, gantry cranes, tower cranes and monorail hoists to lower the DYNAJET into the pond. The three configurations studied seriously were Schemes 6, 8 and 10, as follows (Figs. 1 and 2):

Scheme 6 — Four rectangular five-day ponds with two gantry cranes and two Marconaflo DYNAJETS.

Scheme 8 — Two circular ten-day ponds, each with a center tower, bridge and one Marconaflo DYNAJET.

Scheme 10 — Four circular five-day ponds, each with a center silo, bridge and fixed Marconaflo reclaim unit in the silo.

From a processing standpoint, the four rectangular ponds with two gantry cranes and two DYNAJETS appeared to be the only scheme that would reclaim 100 % of the coal from the ponds at the desired rate and percentage solids. In this scheme, each pond was 1000 ft long, 210 ft wide and 30 ft deep. The two gantry cranes were 230 ft long, to span the

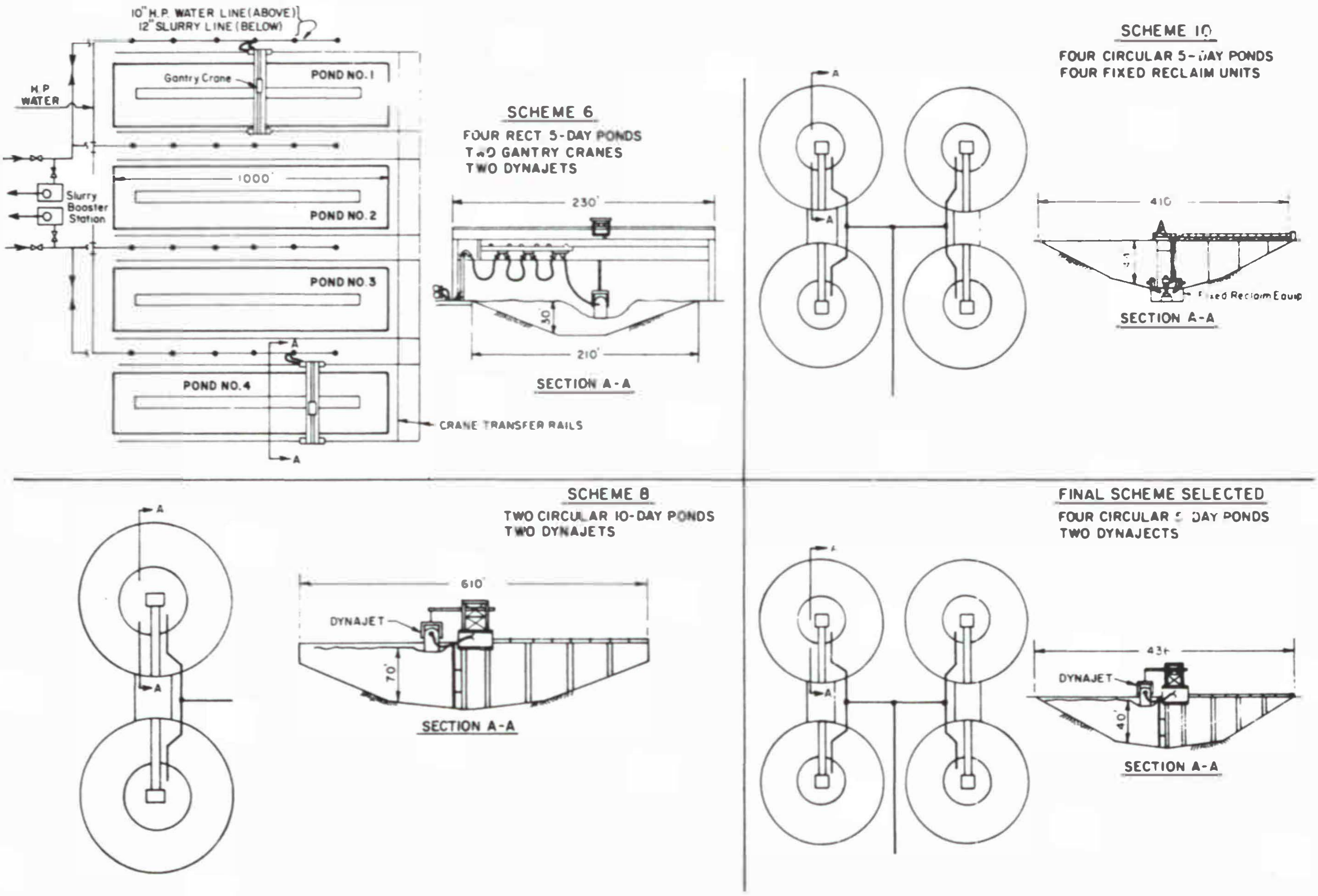

Fig. 1: Pond/reclaim system study

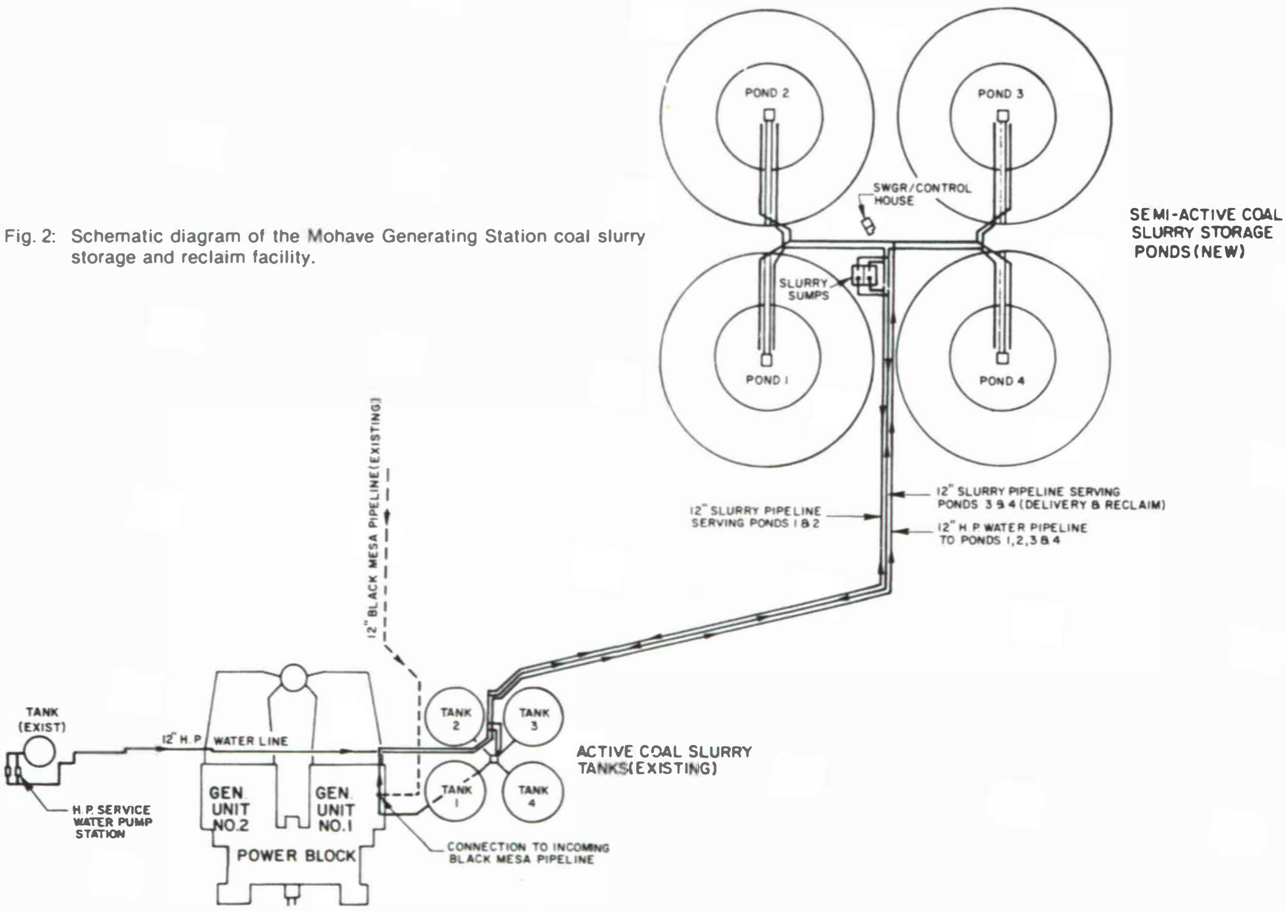

Fig. 2: Schematic diagram of the Mohave Generating Station coal slurry storage and reclaim facility.

pond width. The DYNAJET would be moved laterally across the pond along the gantry crane with the crane travelling the 1000 ft length of the pond. A special transfer system was provided at one end of the ponds to transfer the two gantry cranes to adjacent ponds. The major problems associated with the scheme were the size, cost and complexity of the two travelling gantry cranes and the need to uncouple and couple the large 10- and 12-inch hoses to the crane as it worked its way down the pond length.

In the two circular ten-day pond scheme, the ponds were 610 ft in diameter and 70 ft deep. Each pond would have a DYNAJET suspended from a tower at its center and a bridge to the tower for access. With an effecitve DYNAJET operating radius of 100 to 150 ft, most of the pond volume would be considered dead storage, requiring some supplemental form of recovery. Also, the depth of this pond exceeded the 40 ft limit recommended by our geologists.

In the four circular five-day pond scheme, the ponds were 410 ft in diameter and 44 ft deep at the center. A concrete vault (or silo) would be constructed at each pond center and would house two fixed MARCONAJETS plus a sump and vertical slurry pump. A bridge would be provided to the silo for access. It was doubtful that the two fixed MARCONAJETS would be capable of removing the entire contents of the pond without some form of outside assistance. Also, for the intermittent type of reclaim operation contemplated, it was concluded that maintaining operable equipment in the damp environment of the silo would not be desirable. For major maintenance, either repair in place or removal of major items from the silo would be difficult. Finally, if instrumentation and control problems were encountered, making manual operation necessary, the above-grade DYNAJET installation would be easier to operate manually than the relatively blind silo installation. If additional ponds were added to the system at a later date, complete duplication of reslurry equipment would be required for each pond if a fixed system were installed. With the DYNAJET system, the initial two DYNAJETS could be used for any additional ponds.

5.3 Pond/Reclaim System Scheme Selected

After a detailed analysis of the three schemes, we decided upon a variation of the third: four circular five-day ponds and two portable reclaim units (DYNAJETS) for the following reasons:

1. Circular ponds appeared to be the shape most compatible with the operation of the rotating jet type reclaim units offered by Marconaflo, and the most economical shape to provide the storage capacity required.
2. Ponds of this size showed promise of near full recovery of pond contents by the reclaim unit operating at the pond center.
3. The portable type reclaim units (DYNAJETS) were considered more reliable, easier to maintain and lower in cost for multiple pond application since the units could be moved from pond to pond.

5.4 Description of the Pond/Reclaim Scheme Selected

The four ponds finally selected were dish-shaped, 436 ft in diameter and 40 ft deep at their centers. A structural steel tower with a monorail and 15-t hoist was located at the center of each pond to lower and raise the DYNAJET during operation. An H-4 reinforced concrete highway bridge, connecting the tower to the pond dike, was provided for transporting the DYNAJET equipment to the pond center and to support the required pipelines and electrical power and control cables.

The movable DYNAJET reclaim unit at the pond center was connected to the 10-inch high pressure service water pipeline and the 12-inch slurry pipeline on the bridge through two large rubber hoses suspended in special counter-balanced support systems — one on either side of the tower. The DYNAJET contains a 3000 GPM, 150 HP motor-driven slurry pump and numerous electrical sensors and hydraulic controls. To serve these DYNAJET power and control needs, it was necessary to provide flexible connections of three hydraulic hoses and three electric power and instrument cables between the bridge and the DYNAJET during its movement up and down at the pond center. This was accomplished by serving the DYNAJET through hoses and cables installed on spring-operated reels mounted on a *skid support unit* which remains on the bridge deck during the reclaim operation. Hydraulic power to operate the DYNAJET components is supplied from a hydraulic system also mounted on the skid support unit. Electrical and control power for the DYNAJET and skid support unit are provided to the skid support unit through plug-in connectors at each pond center.

5.5 DYNAJET Operating Controls and Instrumentation

The DYNAJET Unit may be operated locally from the skid unit control panel on the bridge at the pond center or from the control console in the control room located between the ponds. The skid unit panel has pushbuttons for transfer of control from the skid panel to the control console and vice versa.

Instrument signals for slurry flow, density and pressure — measured at each pond center — are transmitted to instruments on both the skid panel and the control console.

The control console contains two subpanels, *A* and *B*, for control of the DYNAJETS. Subpanel *A* is for the DYNAJET in Pond No. 1 or No. 2, while Subpanel *B* is for the DYNAJET in Pond No. 3 or No. 4. Other instruments and controls on the control console include recorders for slurry flow (GPM and t/h) and slurry density (percent solids), digital totalizers for coal reclaimed (t), slurry booster pump control switches and an annunciator panel.

5.6 Pond Arrangement and Balance of Facility

The four ponds are arranged on a four-leaf clover configuration with a switchgear/control house located at the center of the pond complex. The switchgear room is constructed at grade level with the control room located above it so the station operator can look out over the four ponds and the slurry booster station.

The slurry booster station is located near the switchgear/control house and contains two slurry sumps and two 12-inch vertical booster pumps. This booster station receives slurry from the DYNAJET at the pond center and pumps it to the active slurry tanks near the Station power block. One sump is connected by 12-inch pipeline to Ponds Nos. 1 and 2 and the other to Ponds Nos. 3 and 4. The sumps are designed to maintain the slurry in suspension as it passes through them. Therefore, they are remarkably small and have sides sloping down to the pump suction. Agitation nozzles also are installed near the pump suction for occasional use as needed. Each sump has an overflow channel leading back to either Pond No. 1 or No. 4. These overflow channels permit recirculation of slurry from the sumps back to the pond when beginning the reslurry operation until satisfactory density has been established.

5.7 Piping System Design

Several years of coal slurry experience at Mohave taught us to respect coal slurry. Therefore, in designing the coal slurry piping system, two things were kept in mind: 1) coal slurry must be kept flowing within a certain velocity range to prevent line plugs at low velocity or excessive pipeline erosion at high velocities, and 2) coal slurry at acceptable line velocities is still highly erosive to valves and fittings where the slurry flow experiences abrupt changes in direction.

Consequently, we sized slurry piping systems to maintain velocity between 5 and 10 ft/s, used standard wall seamless steel pipe with three-radius elbows made from extra strong seamless steel pipe, plug valves for mainline shutoff and rubber boot type valves, *pinch valves,* for throttling service. Special design attention was given to piping system layout to avoid line plugs or, if plugs occurred, to facilitate location of plugged sections and cleanout of those sections. Piping was run above grade with gradual changes in elevations where possible and with a minimum number of directional changes. Cleanout and flushing hose connections were provided on the line at each change in direction, with valved drain connections located in the bottom of the line at appropriate intervals. A low section in the pipeline between the slurry storage pond area and the active slurry tanks was necessary due to terrain elevation. This low section was spread out over about 500 ft of line so that upon an interruption of pumping, the settled particles would not plug the line completely and could be re-entrained upon resumption of pumping.

Coal slurry flow and density were measured with magnetic flow meters and nuclear density meters. Pressure instrument lines were equipped with diaphragm gauge protectors mounted on top of the slurry lines to minimize plugging of those sensing lines. Flushing water lines were connected to the slurry lines at key locations for manually flushing lines immediately following slurry transport.

5.8 Auxiliary Systems

The major auxiliary system for this reclaim facility was the high pressure service water system, required to supply 400 psig water to the DYNAJET nozzles. After studying various sources of water, we decided to pump it from the existing station service water tank located north of the Station power block. Therefore, we installed two 1200 GPM horizontal pumps at the service water tank and a 12-inch pipeline through the power block and on south to the ponds. It was necessary to run two new underground 5 kW power feeders from the power block to the 450 HP drive motors for these pumps.

Electrical power for the storage pond area was provided by two more underground 5 kV feeders from the station power block. These feeders terminated at the 4160/480 volt, 2000 kVa transformer located at the switchgear house in the middle of the pond complex. All motors in the pond area are 480 volt, including the 150 HP DYNAJET slurry pumps and the 250 HP slurry booster pumps.

6. Construction Summary

6.1 Philosophy of Construction

Three prime contractors were selected by firm price, competitive bid for the major portions of the work, as follows:

Phase I:

Excavation and grading, including paved pond liners; Mechanical, including pipeline and pipe supports.

Phase II:

Electrical, including manholes and ductbanks; Mechanical, including the control building and installation of the Marconaflo unit and components. (The same contractor was low bidder on the mechanical work for both phases.)

Four major subcontractors were involved in portions of the work, and minor crafts and specialties were involved as required for the control building.

Administration of the prime contracts and coordination of the overall work was furnished by the Construction Management Division of the Company.

6.2 Phase I in Construction

Site Preparation — Grading and Excavation: The site selected for the storage facility occupies land which has been used for disposal of fly ash since initial operation of the station. Much of the 350,000 yd^3 excavated for the four ponds was unsuitable for use as compacted fill, and additional fill material was imported to the site from a location on Company property nearby. The 436 ft diameter ponds, as completed, are 30 ft below, and 10 ft above, original grade with sides sloping at 3:1 to a bottom diameter of 224 ft. An access ramp 20 ft wide spirals from top to bottom in each pond.

To ensure 95 % compaction on the faces of the ponds, the sides and bottoms were over-excavated 3 ft, then backfilled, recompacted and trimmed to grade.

Bridges: Required for access to the center of each pond for the Marconaflo Unit, are constructed of pre-stressed concrete sections mounted on reinforced concrete columns, nominal 40 ft in height above the floor of the pond. The columns extend to 30 ft below the floor of the pond for bearing support — total length of columns, 70 ft. Unstable soil conditions encountered at the lowest elevations drilled for the support columns required the addition of 300 yd^3 of cement-sand slurry to enable placement of concrete for the columns.

Four-Inch Asphaltic Concrete Pond Liners: A temporary batch plant was set up on Company property approximately 3/4 mile from the job site. Aggregate for batching was available in the immediate vicinity, requiring only suitable screening for size distribution.

The pavers and compactors used to place and roll the AC required assistance to negotiate the steep 3:1 slopes. Cables powered by winches located at the top of the slopes were attached to the moving equipment to aid in negotiating the slopes from bottom to top.

Extensive rolling was necessary to achieve the 97 % density necessary for the required permeability of the liners. Rubber-tired, multi-wheel compactors were used throughout, steel rollers were unsatisfactory due to the slight concavity of the ponds. Placement was monitored full time for suitable compaction using a nuclear density probe.

Coal Slurry Fill Lines: A new 12" coal slurry pipeline was installed to convey coal slurry directly from the Black Mesa Pipeline to the new storage ponds. Tie-in of this line at its source required a 17-hour shutdown of the pipeline delivery from the mine.

6.3 Phase II in Construction

Installation of Mechanical Equipment:

1. High pressure water pumps were installed adjacent to the service water tank to furnish water to the Marconaflo re-slurry unit at approximately 400 psig working pressure. A new 12-inch pipeline was installed from the service water source to the pond area, approximately 4000 feet, to provide 2400 GPM.
2. In the active slurry tanks area, 12-inch riser pipelines were installed to return reslurried coal to the active slurry tanks.
3. Intermediate sumps were installed in the pond area, with two 250 HP slurry booster pumps.
4. A pressure-reducing station was installed in the sump area to provide utility water at 100 psig.
5. The Marconaflo unit was installed in place at the end of the bridge in Pond No. 1. This included the 10-inch and 12-inch flexible hoses, hose saddles, counterweights and separate, skid-mounted auxiliary unit.
6. The steel towers installed on the ends of the bridges included trolleys and movable hoists for raising and lowering the Marconaflo unit, and to assist in handling the flexible hoses.

Installation of Electrical Equipment:

1. The storage ponds are sited some distance from the main part of the station. The 5kV power feeders are installed in approximately 6500ft of multi-conduit ductbanks. Fifteen additional cast-in-place concrete manholes were required. Approximately 2500ft of ductbank and five of the new manholes were installed in congested, operating areas of the station. Extremely adverse conditions prevailed during portions of the excavation including loose, sandy soil; dense, concrete-like, compacted fly ash; and unknown and unforeseen underground obstructions.
2. Approximately 33,000ft of 5kV power cable were required. This included 4 major circuits, each fed from a different 4kV auxiliary bus:
   - Main feed to Marconaflo pond complex
   - Auxiliary feed to Marconaflo pond complex
   - Feed to North high pressure water pump
   - Feed to South high pressure water pump
3. Approximately 97,000ft of low voltage cable were installed for controls and instrumentation (including approximately 2000 terminations).
4. Major equipment included:
   - Two 450HP motors for high pressure water pumps, mounted for horizontal operation.
   - Two 250HP motors for slurry booster pumps mounted atop the pumps for vertical operation.
   - One 2000kVa, 4160/480 volt transformer for power in the pond complex.
   - Control console for remote control of the reslurry-slurry recovery operation.
   - Conduit and wiring on each of the four bridge structures.
   - Annunciation and controls to the station main control room.
   - Communications for providing PAX dial phone service to each bridge.

Installation of Control Building: The control building is located centrally in the Marconaflo pond complex and houses the control console and 480 volt switchgear. The two-story structure is designed and airconditioned for use in the Mohave environment. Its construction was done with conventional materials and methods and presented no unique construction problems.

6.4 Problems During Construction

The station is located in a remote area of the Mohave Desert, and the labor market is in Las Vegas, Nevada, approximately 95 miles distant. Craft labor is highly organized and is available only through rigid agreements which are scrupulously observed. Travel and per-diem expenses tend to increase the unit cost to the Company of labor over costs of labor for the same work in other locations in the system.

Extremely adverse weather is experienced in the summer, with temperatures averaging 115°F during the middle of the day, and high winds are common. These conditions tend to reduce productive manhours.

A 100-year storm hit the southwest in September, 1976, on three successive weekends. The timing could not have been worse — each pond was in some stage of excavation, varying from *just excavated* to *nearly complete*. Extensive rework required approximately one month at a loss to the contractor estimated to be $120,000.

Although the natural water table is far below the elevation of the ponds, water from heavy rains during construction ran through the site for an extended period on a clay layer approximately 10ft below original grade. During placement of the AC liner in Ponds 1 and 2, the hydraulic pressure from this water caused several *bubbles* in the liner which required removal and patching overlay to correct.

Storm damage delayed completion of Phase I work until after winter weather had set in. Installation of the asphalt pond liners occurred between the middle of October and the middle of January. During this particular season, temperatures did not rise above 60°F until 10:30 am, and dropped below 60°F again by 3:00 pm; it was impossible to maintain the temperature of the hot asphalt mix sufficient to obtain the required 97 percent compaction when the ambient temperature was below 60°F. This situation was aggravated by frequent high winds, which introduced a chill factor.

7. Startup of the Completed Facility

All new pipelines were subjected to hydrotest and flushing before introducing coal slurry and high pressure water for operation. Initially, each pond was filled to capacity with coal slurry, approximately 80,000t each. With both generating units of the Station in normal operation, coal consumed at approximately the same rate as it is delivered via the coal slurry pipeline. Therefore, the diversion of slurry to fill the ponds was necessarily coordinated with a corresponding outage or reduced load on one or both of the units.

Filling of a pond involved the following steps:

1. Introduce coal slurry into the pond via the 12-inch bypass line, direct from the mine delivery line.
2. Fill to within a few feet of the top of the pond. The slurry, which is approximately 50% water and 50% pulverized coal by weight, separates almost immediately, with the coal settling rapidly to the bottom.
3. Decant (portable pumps were used) the nascent water, transferring it to the Station's cooling water system and leaving room for additional slurry.
4. Repeat Steps 2 and 3.

The coal has a tendency to mound in the center on the first filling, but spreads to the side with subsequent additions of slurry. For fire protection and dust control, the filled ponds were maintained with a layer of water, approximately 1 ft in depth. Under this condition, the coal was observed to spread to a uniform level across the pond; it was found that the ponds could be filled *brimful* of coal without difficulty.

8. Operating Experience to Date

Approximately 1,000,000 t of coal have been successfully reslurried by the system through July 1979. Densities have ranged from 40 to 55% solids with averages of 46—48%, and production rates over extended periods of reslurry operation have well exceeded 500 t/h (single DYNAJET operation) (Fig. 3).

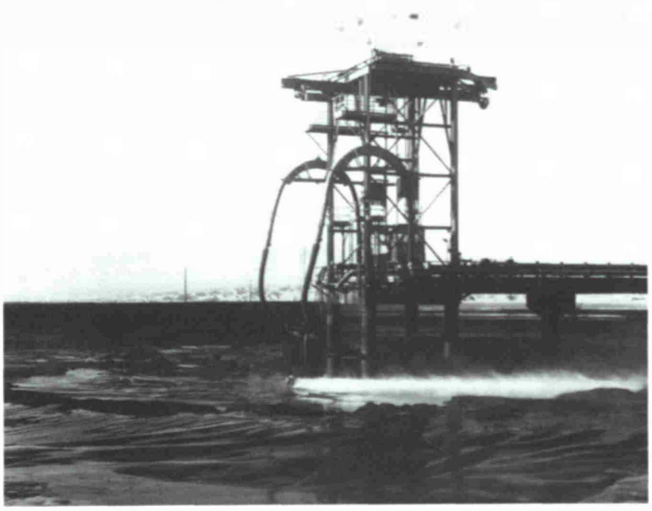

Fig. 3: Mohave Generating Station, near Laughlin, Nevada, employs three basic slurry systems: Pipeline transportation system, storage and slurry reclaim and slurry feed.

Initially, we were concerned with whether the DYNAJET would reach to the edge of the pond, approximately 215 ft, to enable reslurry of all the coal contained in the pond. In fact, the DYNAJET proved to be capable of reaching beyond the pond's edge, but at that distance the force of the jet stream was insufficient to provide impetus necessary for reslurry action; at lower elevations, reslurry is complete to the sides of the pond. Coal recovery from each pond exceeds 95%.

Density of solids in the slurry should range from 45 to 55% to be compatible with the Station systems which process the slurry for removal of water. As Station operators gained familiarity with the Marconaflo reclaim system and skill in its operation, it was found that density ranges within 2—3%, of 50% were easily maintained. Controls and instrumentatio for the system have so far proven adequate and satisfactory.

The period of operation to date has been too brief to develop any estimates for maintenance costs, or for life of various components of the system, although no unusual maintenance problems have been encountered nor are they expected.

Due to favorable results, the second set of four ponds is now under construction. This will increase the storage in these eight ponds to approximately 40 days.

It is further demonstrated that being able to store the coal as a slurry and maintaining a level of water on the surface have eliminated two problems normally associated with coal stockpiles. There is no coal dust in the atmosphere and no spontaneous combustion has occurred.

These results have been obtained with the greatly reduced operating costs for the storage and reclaim from more than $3.00 per t to approximately 20c per t.

Aside from early (and normal) problems associated with startup of elements of the system, operational experience has well demonstrated that the facility is a technical and operational success.

References

[1] Dina, M.L., "Operating Experiences at the 1580 MW Coal Slurry Fired Mohave Generating Station"
Presented to the International Conference on Slurry Transportation at Battelle Memorial Institute, Columbus, Ohio, February 3, 1976

[2] Montfort, J.G., "Operation of the Black Mesa Pipeline System", September 23, 1975

[3] Marconaflo, Inc., Storage/Pond/Reclaim Unit Arrangements, Various Reports, 1975

[4] Fluor Utah, Inc., Pond Configuration and Design, November, 1975