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Energy Conservation In A Fertilizer Complex

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I. Introduction

Electric power is presently priced at three times and fuel oil four times their 1972 costs. These increases have made many marginal projects economically viable. A program has been developed to investigate and advocate energy saving projects at Agrico's South Pierce Plant. However, two projects, wet rock grinding and electric power production, were started in advance of the formal program.

II. Wet Grinding

In 1973, the Number 2 Ball Mill at South Pierce was converted, on a trial basis, from dry to wet grinding. The primary motivating factor was the possibility of saving drying costs, including approximately two gallons of fuel oil per ton (U.S.) of rock. The number 2 Mill is a Kennedy-Van Saun Unit, 11.5 ft. (3.5 m) diameter X 17 ft. (5.2 m) long with a 1000 H.P. synchronous motor drive. The associated fans for the classification system and the pneumatic export conveyor increase system power to nearly 1400 horsepower. The mill will dry grind at a rate of 65 (U.S.) tons per hour with resulting horsepower per ton ratios of 15.4 for the mill only, and 21.5 for the system.

The experimental wet system used an open circuit design. Rock, containing 8% to 10% moisture, was supplied to the Mill with a weigh belt feeder. Water was metered at the feed chute to give 65% solids slurry (1.8 sp. gr.). Slurry discharged through a trommel screen from which + 20 mesh oversize was recycled. A small 10,000 gallon (37,600 l) agitated surge tank gave 10 minutes retention time. A centrifugal pump with 40 horsepower motor and variable speed drive pumped the slurry to the phosphoric acid reactor. A nuclear density meter was installed on the export line but was unsatisfactory for this service. A bubble type density meter is now used. The mill was able to grind 65 (U.S.) tons per hour with 3% + 35 mesh and 50% + 200 mesh. After a nine month test run, many of the cast iron liners were broken or disintegrated and it was decided to use rubber liners for wet grinding.

The Number 2 Mill was then returned to dry grinding for TSP Plant service and a KVS rod mill was moved from the Pierce Drying Plant to South Pierce.

This Mill (No. 3) is 12.5 ft. (3.8 m) in diameter and was lengthened 6 feet (1.8 m) to 23 ft. (7.0 m). It has a 1500 horsepower synchronous motor drive, turns at 15.5 rpm. and is now a ball mill. The feed system, surge tank, screen and pump are basically as described for the Number 2 Mill, except the pump has a 75 horsepower motor.

No. 3 Mill grinds 90 tons per hour with an energy ratio of 16.6 horsepower per ton for the mill and 17.8 for the system. The rubber liners in this mill have a life of 1½ years. The life of lifter bars is approximately one year. It is possible that more frequent replacement of the lifter bars will lengthen the life of the shell liners. Lifter bars with stainless steel inserts and polyurethane bars are also being tested. Ball wear is higher on wet service, averaging 0.8 pounds (0.36 kg.) per ton of rock versus 0.2 pounds (0.09 kg.) for dry grinding.

The Number 1 Mill was converted in 1976. It is also a Kennedy-Van Saun, 1500 horsepower unit, 11'-6" (3.5 m) diameter X 24' (7.3 m) long. Results in horsepower per ton are essentially the same.

In connection with liner wear, it should be noted that Agrico's Faustina Plant installed a 16.5 ft. (5.0 m) diameter X 23 ft. (7.0 m) long mill in 1975. This mill also uses open circuit wet grinding and processes 200 tons/hr. with 4 to 6% + 35 mesh. Ball usage is 0.55 pounds (0.25 kgms.) per ton of rock. The original Ni-Hard liners are still in the mill and are expected to last another three years. It is possible that the decision at South Pierce to switch to rubber liners was premature.

Conversion to closed circuit grinding is being studied. It appears that appreciable power savings may be possible.

III. Power Generation

South Pierce has two 1800 ton per day sulfuric acid plants. Excess steam from these plants is condensed using a large pond for cooling. It was decided to investigate the possibility of producing electric power with this waste heat. The first step was to prepare a steam balance of the Plant. Figure No. 1 shows the preturbine steam balance. It is a calculated balance as the distribution system had very few meters.

High pressure steam having been available, it was the practice to pipe 550 psig. (38.7 kg./sq/ cm.) steam around the plant and reduce to the desired pressure at the point of use. The steam consumers were examined next and listed in order of the ease of conversion to low pressure use. Consumers of some size were: the Fluoride Salts Plant, the GTSP Plant, sulfur pump turbines, boiler feed water turbines and the Phosphoric Acid Plant ejectors.

The turbine driven pumps had electric motor standby units. Since it is more efficient to produce electricity and operate the motor drives than to utilize these small turbines, the turbine equipped units were switched to standby duty.

Most of the Fluoride Plant and the GTSP plant could be converted to use steam from the 35 psig. (2.5 kg./sq. cm.) system. New low pressure branch lines would be necessary. In view of the problems involved, it was decided to shelve conversion of the ejectors to vacuum pumps until a more accurate steam balance could be established. South Pierce's "nominal" sulfuric acid production rate is in the 3000 tons per day range and a search was started to find a used turbine to fit the balance at this rating.

A used 7500 kW turbogenerator was located in a small town in Iowa. The unit could be converted to the South Pierce steam conditions, 550 psig. and 575°F, (302°C) with minor changes to the throttle valves and diaphragm drains.

A second steam balance was prepared incorporating the proposed changes and the turbine. This balance is shown in Figure 2. The turbine matched the conditions quite satisfactorily; it was immediately available, and its cost was considerably less than that of a new machine. It came complete with exciter, voltage control, breaker, condenser and condensate pumps. A decision was made to proceed with this machine.

There remained three problems to resolve: (1) Fitting the 13,800 volt power produced to the South Pierce power grid. (2) Controlling the steam input to the turbine. (3) Determining if the two extraction systems on the turbine should be utilized.

Power System

South Pierce is supplied by the power company with 69 kv power. It is reduced in four 7500 kva transformers to 4.16 kv and distributed through four distribution centers. The 13.8 kv power could be transformed to 4.16 kv and fed to the distribution centers. This would have the advantage of only one transformation; however, it would be necessary for an operator to switch substations from utility power to Agrico power as the generator output increased and to switch back as output decreased. The alternative was to transform to 69 kv and connect to the incoming power lines. In this configuration the generator could "float" on the line continuously with only the initial closing of the breaker. The latter system was chosen and a 10,000 kva, 13.8/69 kv transformer was installed. A schematic drawing of the system is shown in Figure 3. An oil circuit breaker connects to the incoming power lines and has over current, reverse power, differential and ground fault relays. It also interlocks and cannot be closed if the 13.8 kv breaker at the power house is closed.

The generator is connected to the 13.8 kv tie line with an air circuit breaker. This breaker has underfrequency, differential phase (current), generator reverse power, over current and turbine trip and throttle valve relays. This is the breaker used to take the generator on and off the line.

<u>Control System</u>
The steam supply is an independent variable. We requested Worthington to set up a control system which would utilize all the available steam (to the limit of the turbine) and still maintain normal pressure in the plant export steam header. Worthington has supplied what is in effect a back pressure controller sensing the steam supply pressure. Output from the controller goes to a positioner connected to the throttle valve control.

The turbine is brought up to speed, synchronized, and put on the line with the governor. The back pressure controller is then put in control. As the pressure exceeds 550 psig. the throttle valves open, and close as line pressure fails. The governor overspeed trip and the maximum power limit remain functional.

<u>Extraction System</u>
The turbine has two extraction points, an uncontrolled extraction on the sixth stage and a controlled extraction on the tenth stage. The uncontrolled extraction was blanked off. Ten pound (0.71 kg./sq. cm.) steam is extracted at the controlled extraction valves and fed to the acid plant Deaerators. The Deaerators normally operate at 3 to 5 psig. (0.2 to 0.3 kg./sq. cm.) and are supplied from the 35 psig. (2.5 kg./sq. cm.) system. If the Phosphoric Acid Plant evaporation load increases, the 35 psig. system may lose pressure. As the pressure falls, a cascade type controller will raise the set point on the 10 psig. (0.7 kg./sq. cm.) system controller to activate the extraction steam valve to open and supply steam as required.

The turbine was started May 13th. and brought to full rate the second day of operation. When generating at capacity, it produces 50% of the normal Plant power requirements. Start up was six weeks late. Delays were due primarily to the need for more extensive repair and cleanup than anticipated. It was necessary to circulate oil for three weeks and acid wash the oil piping three times before scale would no longer contaminate the oil. The basic machine is sound, however, and the steam rate with no extraction, is 11.8 pounds per kWh.

IV. Cooling Water System
As a part of the formal energy conservation program, the cooling water pumping system has been studied. This installation consists of three 500 horsepower vertical pumps rated at 11,500 gpm.

and 145 ft. (725 l/s and 44 m) of head. The service consists of approximately 24,000 gpm. for the Sulfuric Acid cooling load and 2,000 gpm. for miscellaneous plant services. The low volume duties are located at distant points and elevations. It has been necessary to operate three pumps at 8800 gpm. and 160 ft. of head (555 l/s and 49 m) to supply the highest points of use. The Sulfuric Plant requires less than 100 ft. (30 m) of head and two pumps could supply the required volume at this point on the curve with very little additional power to each pump as the horsepower curve on these pumps is essentially flat. It is planned to install a separate pump for the high pressure service and to permit the existing pumps to operate at higher volumes and lower head.

In this regard, it may be of value to point out that established habits of thinking should be carefully examined. The turbogenerator requires 12,000 gpm. (45,000 l/m) and it was decided to install a duplicate of the existing pumps for convenience of maintenance and spare part supply and to save installation of a separate supply pipeline. Actual head required for this service is 40 ft. (12 m) and we are wasting power throttling the 69 psig. (5 kg./sq. cm.) cooling water system. In retrospect and in light of present power costs, this was probably a poor decision.

Along the same line, we have installed the steam jets that came with the turbine on the condenser. It will probably be wise to replace these with a vacuum pump.

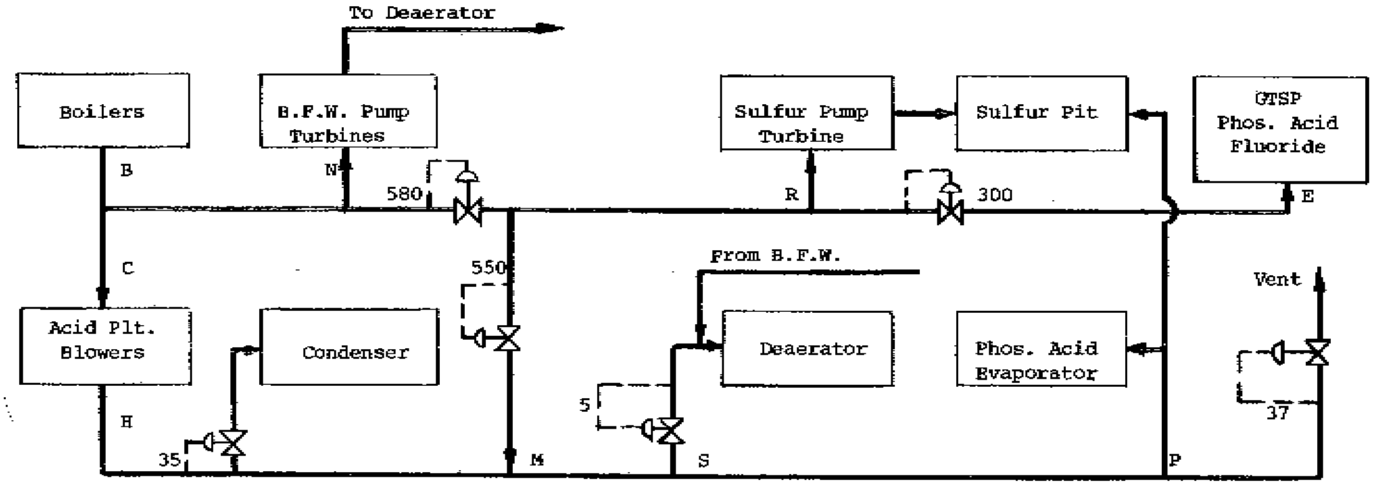
V. Other Conservation Items

The conservation program includes many projects which have smaller rewards. These range from checking pipe insulation and steam traps to examining equipment for efficient loading. We sometimes find that equipment configuration has changed through the years. This may leave fans or pumps that are much too large for the remaining duty and operating inefficiently.

VI. Conclusion

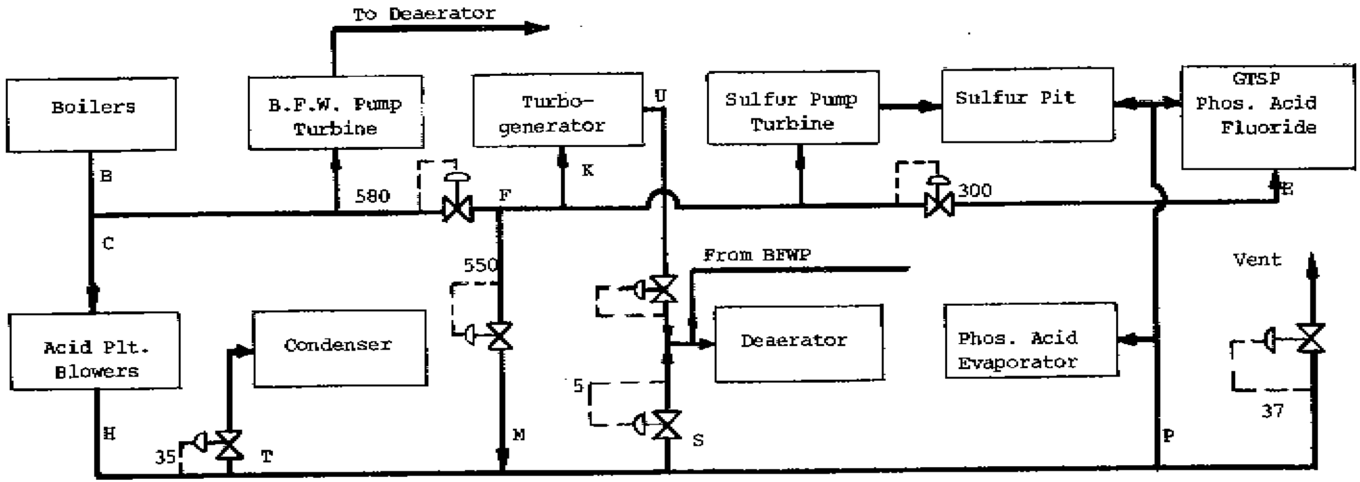
The upward trend of power cost makes the continual review of all areas of energy consumption imperative. Other companies may want to consider installing generating equipment in their plants.

Fig. 1 Steam Balance (1000 lbs/hr.)



Tons Sulf. Acid Per Day	Steam Prod. B	To Blowers C	B.F.W. Pump N	Sulf. Pump R	GTSP Phos. Acid Fluoride E	Excess H.P. M	L.P. Supply H	Deaer-ator S	L.P. Sulf. Pit Process P	Con-denser T
1800	199	100	9	3	35	52	100	22	93	37
2400	265	136	18	6	47	58	136	28	117	49
3000	331	190	18	6	47	70	190	35	142	83
3600	396	210	18	6	47	115	210	42	165	118

Fig. 2 Steam Balance (1000 lb/hr.)



Tons Sulf. Acid Per Day	Steam Prod. B	To Blowers C	H.P. Process Required E	Bal. H.P. Available F	Low Pressure From Blower H	Low Pressure Process Required P	L.P. To Condenser T	L.P. To Turbine K	H.P. To L.P. M	Deaerator From 35# S	Deaerator From 10# U	Gen. kW
1800	199	100	24	75	100	104	4	71	4	-	22	5200
2400	265	136	36	93	136	128	0	93	-	8	20	7500
3000	331	190	36	105	190	152	19	89	16	35	-	7500
3600	396	210	36	150	210	176	53	89	61	42	-	7500

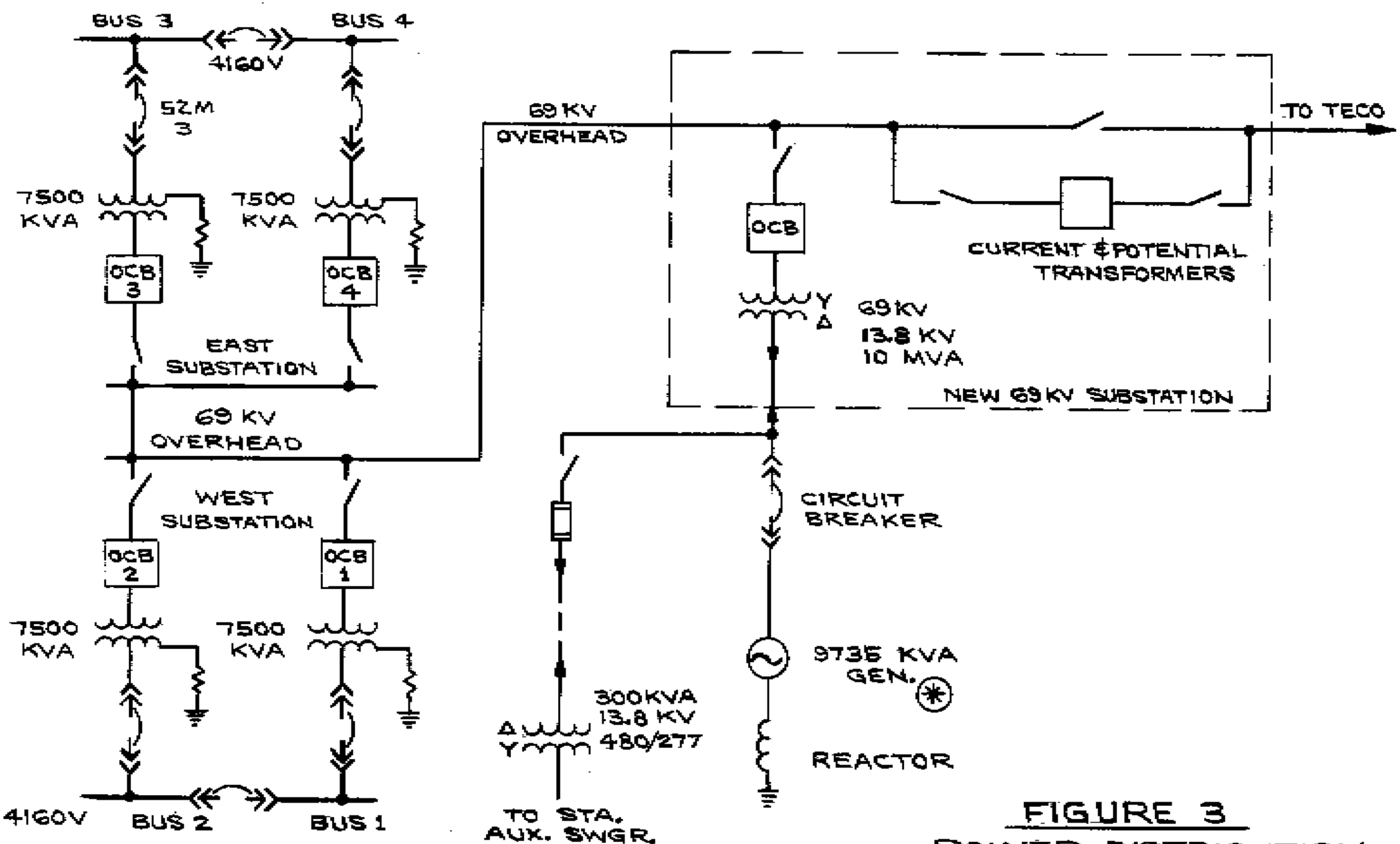


FIGURE 3
POWER DISTRIBUTION