New Wales Energy Project:

Relocating a Turbo-Generator

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Abstract

Over the past several years oil and gas prices have continued to climb higher. These higher fuel prices are making the justification to produce electrical power in Phosphate chemical plants much more attractive. Mosaic has taken the opportunity to obtain a used turbo generator that fit our needs and relocate it to the New Wales chemical plant in Mulberry Florida. This paper will address the challenges and planning necessary to relocate a used power generation unit and the expected benefits.

Background Information

New Wales presently has two turbo-generators in service, TG1 rated at 10 MW non-condensing, TG2 rated at 58 MW condensing. Total TG output is 65 MW. Export about 11MW.

This third TG3 project was justified on an average power value for a blend of avoided purchase power and as-available sales to the utility. The project benefit was 12.15 MW with 7.71 MW sold, so 4.44 MW is avoided purchase. Gas was assumed to be worth $9/MM BTU.

Locating and sizing a third TG for New Wales

The search for a third turbo-generator began with the goal of optimizing the power generation potential at New Wales, and there were a couple of different paths available to Mosaic. The size of the machine, the capital cost, the revenue, and the accessibility to obtain the machine were all considerations in the process of choosing a turbo-generator. A new TG was not an optimal choice because of the cost and delivery time for a new machine. The Nichol's Plant TG was considered, however it was not large enough for the New Wales Plant. In terms of accessibility to obtain the machine, Mosaic had already obtained the TG and auxiliary equipment from USAC as part of the deal to cancel the rock supply contract, and thus USAC'S TG was theoretically a "free" unit for the project. It was also large enough for New Wales, and therefore it was the best choice.

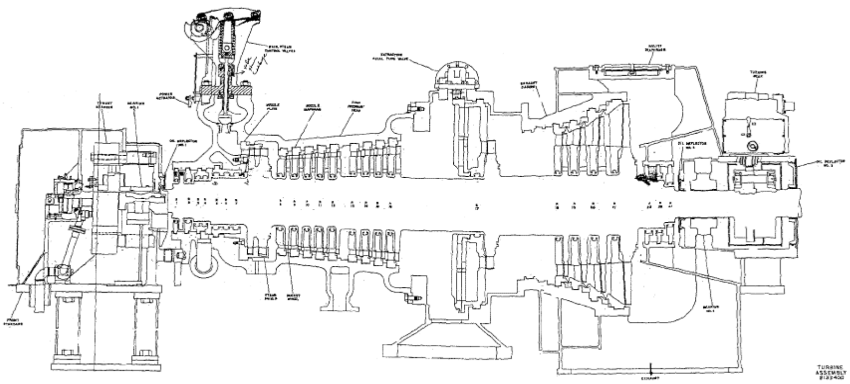
Cost Comparison: Repair a TG or Purchase a New TG?

Utilizing the US Agrichemicals TG saved time and money. The USAC turbo-generator, costing $8.1 MM to relocate and install, allowed for an installation time of at least one year ahead as compared to a new machine (machine costing $10-12 MM or more). This provided annual revenues, cost savings and tax credits of $7.2 MM at least one year earlier. The re-rate of the machine cost approximately $1 MM.
Decision was made to re-rate the USAC TG versus using any other used machines or purchasing a new TG.

Time Table

Began engineering design in October 2006 with an expected completion date of May 2008.

Existing USAC TG Capabilities



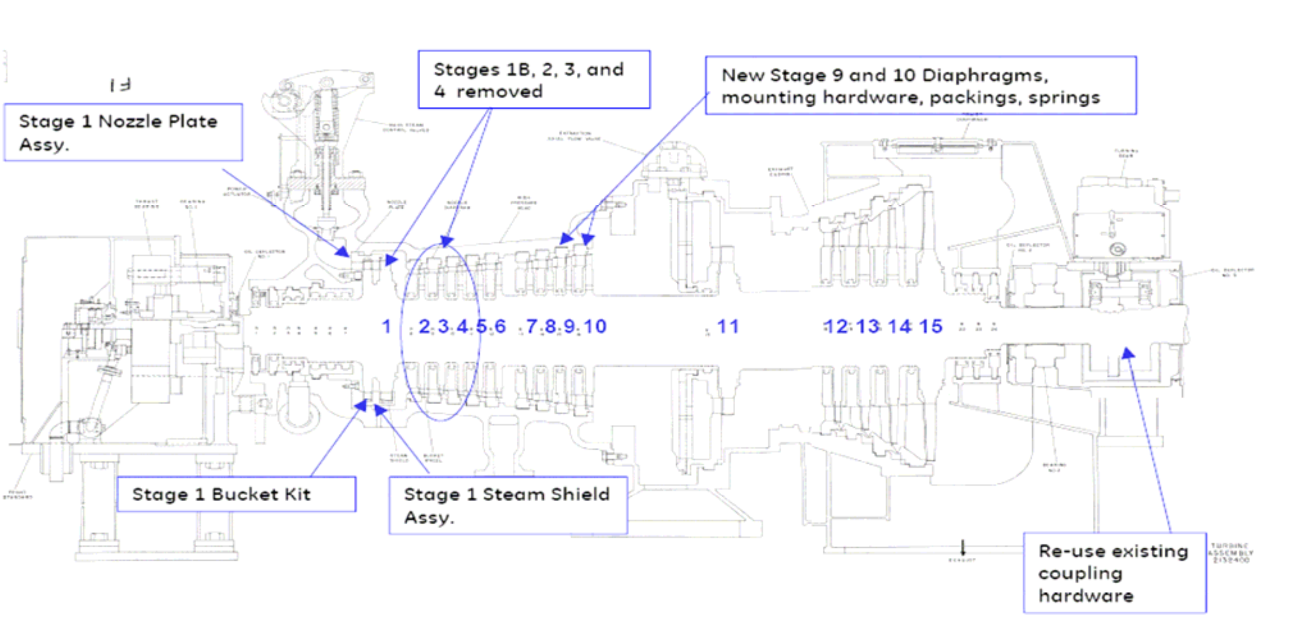
The USAC machine was capable of 31.7 MW using 290,000 Lb/hr of 770 psig, 900 degree F steam. The generator was rated 37,700 KVA, so the power factor was about 85%. The condensing section was rated for 218,000 Lb/Hr with 35 psig at the extraction. The turbine consisted of 15-Stages: 10 high pressure stages and 5 low pressure stages.

Modifying USAC's TG: Re-Rate

Unmodified, the USAC TG would accommodate only 232,000 Lb/hr at the throttle due to the lower steam density at New Wales high pressure steam system operating conditions of 575 psig and 720 degrees F. We needed 335,000 Lb/Hr of throttle flow capability so we elected to pursue the re-rate.

The re-rate achieved the target throttle flow by:

- Replacing the first stage nozzles and blades
- Increasing the trim size on four of the six inlet control valves and replacing the valve rack camshaft.
- Removing stages 2, 3, and 4. This got the machine back near design pressures at the medium pressure steam uncontrolled extraction port.
- Installing new diaphragms for the two stages upstream of the controlled extraction at 35 psig, in order to alleviate a blade stress problem at the higher mass flow rate.



The maximum condensing capacity increased to 271,000 Lb/hr (from 218K) by allowing the extraction port pressure to rise to 45 psig. We will install a back pressure valve to be able to hold 45 psig at the extraction while the low pressure header, and therefore the blower turbines, run at lower pressure. We will normally extract at 35 psig to maximize energy removed from the steam but can boost extraction pressure to maximize condensing capacity as needed.

The re-rated machine at New Wales steam conditions is capable of 30,028 KW, 95% of what it could make at USAC.

Modifying USAC's TG: Sulfuric Acid Energy Recovery Projects

There is from time to time more low pressure steam available than can be condensed in the existing condensing TG. This constitutes "free" energy available to TG3. It occurs maybe 40% of the time, but chiefly during evaporator washes associated with PhosAcid reactor down days.

Compressors and their drive turbines were upgraded to improve efficiency and make high pressure steam available to the new TG. This steam will be typically extracted at 35# to replace the lost blower turbine exhaust steam. The blower turbines' typical exhaust pressure dropped from 45 to 35 psig, further reducing the steam required.

A boiler feed water preheater was added to heat 1600 gpm of deaerator feed water from 95 degrees to 200 F, saving low pressure steam in the deaerators serving all five acid plants. This amounts to 85 MM BTU/hr. This exchanger is made of MECS Zecor alloy, which alleviates concerns about achieving passivation in an anodically protected preheater. Mosaic has had good experience with an Edmeston SX preheater in the Riverview plant. Zecor and SX behave similarly from a corrosion perspective.

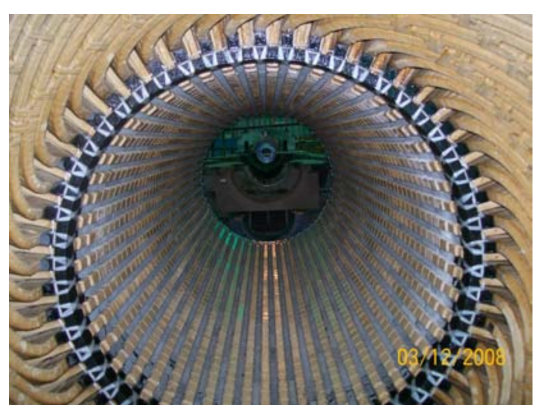
An HRS heater was added to the existing HRS in the 03 plant to generate more medium pressure steam. The 03 HRS was installed without it originally because it was not needed to meet that project's target of supplying the site's medium pressure steam requirement.

Temperature control loops were added to the drying tower acid supply. This raises sulfur furnace inlet air temperature and therefore makes more high pressure steam per ton of acid. Previously, the acid temperature fluctuated with the cooling water temperature and cooler fouling. Eliminating diurnal temperature fluctuations is expected to improve plant gas strength control, making it easier for the operators to optimize the plant performance.

The TG was located between the sulfuric and PhosAcid plants, reducing the pressure drop in the low pressure steam lines and allowing lower turbine extraction or exhaust pressures.

Modifying the USAC's TG: Unexpected Problems

The stator tested well, but the wedging was loose. It was recommended that the stator winding be re-wedged. Tampa Armature Works removed existing wedges and took dimensional data of the wedging system. The new wedging system was designed with



ripple springs and wedges. A flux probe was installed to monitor the field windings.

The current retaining rings' material was never replaced when GE changed its standards. Therefore, it was recommended that the rotor's retaining rings be removed and replaced using the induction heating method. The insulation was also repaired. A high speed balance test followed the replacement of the retaining rings and insulation, which included a flux probe test and heat run.

<u>Disassemble, ID, and Relocate USAC Equipment</u>

Prior to removing all of the equipment from USAC, a database was created that had all of the equipment listed with all of the following information: equipment name, equipment number, equipment description, plant location, and department.

There was a priority assigned to each item 1 through 5:

1 – "Will Take" Mosaic had the opportunity to remove from list
2 – "Required Inspection" if in acceptable condition taken
3 – "Required Cost Analysis" Removed if Cost effective
4 – "Do not Want" Have no use for this equipment
5 – "Claimed but impractical to move"

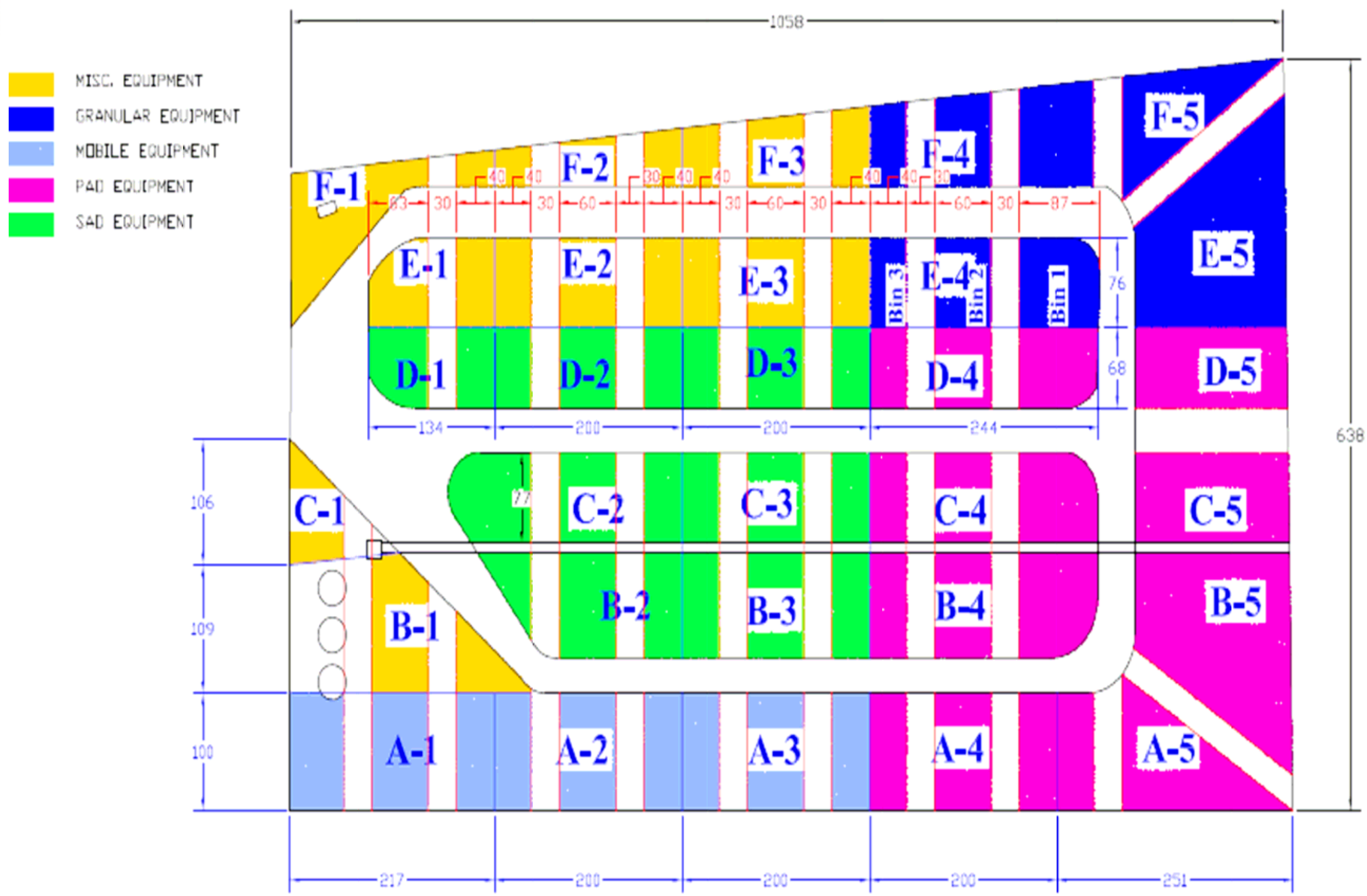
We utilized this master list to obtain and track the movement of all of the equipment and assigned a bar-tag number to each piece of equipment. The master list was broken down into smaller more manageable lists by plant and area. Once onsite we obtained copies of the plant drawings and began to locate equipment in general areas. We had a designated crew responsible for the location and tracking of the equipment for removal. Each piece of equipment had to be physically located and tagged prior to removal. This crew was given a list of equipment daily to locate and tag. When a piece of equipment was located it was tagged and scanned with a barcode scanner. Once the equipment was tagged the list was returned to our database administrator to be sure all were located. Any added items were also tagged and given a bartag number and then added to the database by our database Administrator. Then when it was removed from the location shown on the database it was scanned again as removed. Then scanned again when loaded onto a truck for shipping and finally scanned when offloaded at the laydown yard at Fort Meade and assigned a final location, storage condition, and Equipment condition. Each time a tag was scanned it was time, date, and personnel stamped with the most recent information.

The turbo-generator was disassembled at USAC and installed at New Wales by Turbine Diagnostics. The rotor and upper casing were sent to GE for refurbishing.

<u>Deciding to not Repair USAC'S Cooling Tower and E & I Equipment</u>

It was decided that US Agrichemicals' cooling tower would not be relocated to Fort Meade and used for this project because it was a wooden structure that was over twenty years old. It was not capable to move the structure in one piece, and it would have had to be torn into multiple pieces and then reassembled during installation at New Wales. It was determined that it would be more economically feasible to build a new cooling tower rather than repair USAC'S wooden cooling tower.

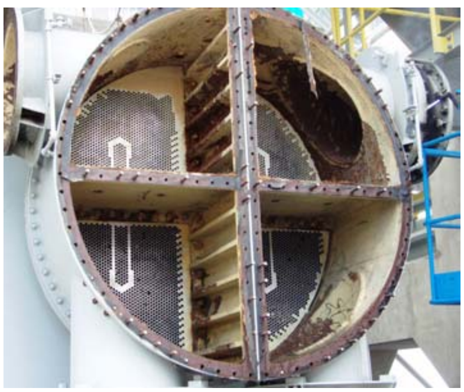
The following chart outlines the laydown yard at Fort Meade by the five categories: Miscellaneous equipment, granular equipment, mobile equipment, phosphoric acid equipment, and sulfuric acid equipment. Within the five categories, the equipment is separated by a priority of 1-5.


MISC. EQUIPMENT
GRANULAR EQUIPMENT
MOBILE EQUIPMENT
PAD EQUIPMENT
SAD EQUIPMENT
1058
638
F-1
F-2
F-3
F-4
F-5
E-1
E-2
E-3
E-4
E-5
Bin 3
Bin 2
Bin 1
D-1
D-2
D-3
D-4
D-5
C-1
C-2
C-3
C-4
C-5
B-1
B-2
B-3
B-4
B-5
A-1
A-2
A-3
A-4
A-5
134
200
200
244
217
200
200
200
251
106
109
100
76
68

Engineering’s Role in Reconditioning Equipment

The majority of the ancillary equipment for the TG was from relocated from USAC. We inspected and refurbished the following: the lube oil system and piping, inter/after condenser, gland seal system and piping, condensate pumps, circulating pumps, pressure relief valves and non-return valves, and the turbine condenser.

Engineering’s role in reconditioning equipment is evident in the condensate and circulating pumps. The condensate pumps were re-bowled to meet the new requirements given by engineering: a flow rate of 600 GPM, a total discharge head of 152 ft, and a process stream temperature of 110 F. The cooling tower circulating pumps were given new requirements as well, and in response to the new requirements the pumps were lengthened and re-bowled.



When the turbine condenser was inspected by eddy current testing, it was noticed that some of the condenser tubes showed minor weld fusion problems. Further metallurgical testing indicated that the tubes needed to be replaced. Out of the 6000 tubes, a total of 26 tubes showed distress, and two were questionable. Engineering/production weighed the risks and determined that repair was optimal solution.

From Piles to Building: Installation of the TG-3 Building

Electrical Considerations

The relocated generator produces an output voltage of 13.8KV. There are several connection points available at this voltage within the facility. Investigation however, showed that we would exceed the short circuit rating of the electrical distribution equipment by connecting this generator to an existing plant bus. Additional studies dictated that we connect this generator at the 69KV level using a step-up transformer with load tap changer. This connection will minimize the impact of short circuit currents potentially produced by this installation.

The step-up transformer must have a rating of 38MVA to carry the full load output of the generator. A transformer of this size with load tap changer costs approximately $600,000.00. We were fortunate to have an available spare transformer that met all of the electrical requirements at one of our facilities. The unit was tested, refurbished, relocated and re-tested for about $100,000.00 for a savings of $500,000.00. An added benefit of this connection adds an additional 13.8KV bus for future load addition in the facility.

We chose not to relocate any of the electrical equipment associated with the generator for several reasons. The equipment was 25 years old and in poor condition. Spare parts are not readily available and modern electrical protection equipment is superior to the equipment found in this older gear. Mosaic requires the highest possible reliability to increase the operating factor and project payback.

The equipment chosen has programmable solid state protective relays and added features such as infrared inspection windows for on-line preventative maintenance inspections.

The turbine control equipment was not re-used. A new “Turbonet” controller was installed for high reliability turbine control, and vibration monitoring.

A PLC was installed for control of all motors, instrument loop control, and monitoring. This PLC also allows data collection to our PI historian as well as sequence of events (SOE) recording to troubleshoot unscheduled shutdowns. This together with operator control screens increases operability and reliability when compared with the pneumatic field controllers and pushbutton hardwire controls at the original installation.

Expected Benefits & Conclusion

The new re-rated TG3 is capable of producing 30MW of power. This phase 1 project will load an additional 13 MW of power. Future energy enhancement projects will eventually load this machine to full capabilities.
Due to some delays, this project is expected to startup in early July 2008 and do not expect any major problems. Vigorous testing of equipment in the vendors shop and field should minimize any unexpected surprises.
Project has so far experienced no safety incidences. This project will maximize energy extraction from the existing five sulfuric acid plants with no additional green-house gases being emitted. A truly environmentally friendly project.

Acknowledgements

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