2009-OCTOBER-21

# HARMATTAN GAS PLANT COMPRESSOR CONVERSION
# 09-IAGT 306


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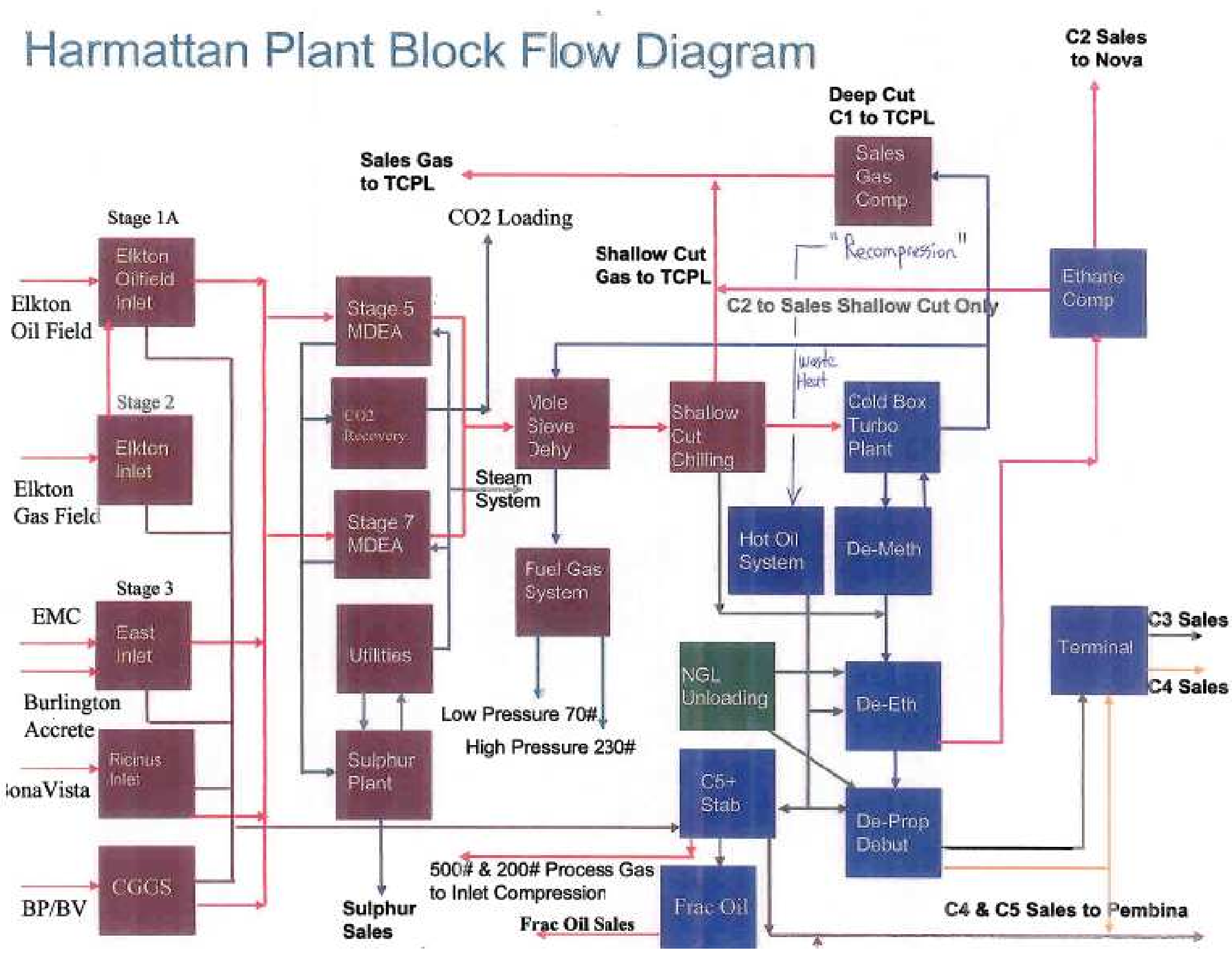
In the fall of 2008, Taylor NGL LP, now AltaGas Ltd., installed a 3500 kW Solar Centaur 50LS gas turbine (nominal iso rating 4680 kW) compressor set with waste heat recovery. This paper will review the project from concept to execution and show how reciprocating compressors were economically replaced with a gas turbine.

Altagas Ltd. is an income trust based out of Calgary. They are a midstream operator of many gas plants and energy infrastructure assets like Harmattan. AltaGas has no proprietary oil or gas production of its own and makes money by charging a fee for service to gas producers to process their gas. The commercial arrangements at the Harmattan Gas Plant between Altagas and its producer customers generally provide the producers with fees at fixed rates over the long term, with small annual increases to reflect consumer price inflation. Altagas bears the operating and maintenance (O&M) costs including repair and major overhauls to rotating equipment. Therefore, Altagas has an incentive to invest in projects that lower O&M costs.

Like at most gas processing plants, Altagas as plant operator is permitted to utilize the producers' fuel as required to operate the gas processing facilities. Unlike most other plants, Altagas operates some additional facilities unrelated to primary gas processing that consume fuel and which require Altagas to purchase fuel. Although Altagas does not have primary production from wells, they do purchase and process 3$^{rd}$ party trucked in natural gas liquids (NGL's) and therefore need to provide an allocated share of fuel for the heat required to fractionate these liquids. This is important in that it provides a heat sink for Altagas to use for the waste heat recovered from the gas turbine.

Electrical power is also paid for by AltaGas and not flowed through to the gas producers. This makes compressor conversions to electric drive near impossible because of the numerous contracts with producers that would need to be modified. For this project, we did consider electrification, but additional reduction in projected O&M cost did not compensate for the waste heat benefit that was generated by the turbine.

The project was implemented at the Harmattan Gas Plant located approximately 20km west of Didsbury, Alberta. The plant has typical processing units such as amine treating, sulfur recovery, refrigeration, dehydration and treating. In 1999, a deep cut turbo expander train was added for the extraction of ethane and in 2003 a spec $CO_2$ unit was added. The plant was initially built in 1961 and has gone through many modifications since then. Below is a schematic of the gas plant and the major processing units.



Because of this constant metamorphosis over the past 50 years, the plant is a mix of new and old equipment. For example, the turbo expander train was built with all new equipment except for the final recompression where seven 1960's vintage slow speed integrals were recylindered to provide recompression horsepower. Recompression in a turbo expander plant is required to compress sales gas after most of the ethane and heavier components have been removed. Typically, about 35 kW/mmscfd (50 hp/mmscfd) of compression power is required; Harmattan requires about 4000 kW of power to compress gas from 3000 kPa to 6200 kPa. It is from these 7 compressors that the project arose.

Harmattan is a virtual museum of compression from the past. There are 22 IR (Ingersoll Rand) slow speed (330 rpm) integral compressors that were originally installed in the 1960's that still operate. Most of them have been reconfigured several times as process conditions changed. Each of them are in the 1000 – 1500 kW size range. Operation of these integrals is well understood by the plant operations and maintenance staff, and has proved to be very reliable over the years. However, these units have not been built for many years and parts and the mechanics that can still tear them apart are getting harder and harder to find. As mentioned above, we have seven IR'S in recompression gas service that provide the basis for this project. Typically, these compressors will go 40,000 to 50,000 hours between major overhauls and cost around $500,000 per overhaul. Additionally, annual costs of approximately $46 per kilowatt per year ($62/hp/yr) are required to keep these compressors running. Below is a table of the expected operating costs for these compressors over time and how it compares to the expected operating cost for the turbine.

Table 1.

Maintenance Cost Comparison (CDN $1000)

| | | First 5 years | | Next 10 Years | | Total 15 Years |
|---|---|---|---|---|---|---|
| IR Overhauls | $ | 3,525 | $ | 2,975 | $ | 6,500 |
| General Maintenance | $ | 1,524 | $ | 3,674 | $ | 5,198 |
| **Total IR O&M** | **$** | **5,049** | **$** | **6,649** | **$** | **11,698** |
| | | | | | | |
| Turbine Overhaul | $ | 900 | $ | 2,913 | $ | 3,813 |
| Turbine Maintenance | $ | 737 | $ | 1,778 | $ | 2,515 |
| **Total Turbine O&M** | **$** | **1,637** | **$** | **4,691** | **$** | **6,327** |
| | | | | | | |
| *Turbine Advantage* | *$* | *3,412* | *$* | *1,958* | *$* | *5,370* |

(1) 6 of the 7 recips were due for major overhaul in the next 5 years
(2) turbine overhauls are assumed every 3 years or 25,000 hours
(3) assumes inflation on maintenance and overhaul at 2.5% per year
(4) annual turbine maintenance is assumed at $22/kW/yr ($30/hp/yr)

The turbine ultimately selected was the Solar Centaur 50LS. The unit delivers approximately 3500 kW (4690 hp) at site elevation or 1140 m (3750 ft) and 15 C. The compressor was designed for 2400 E3m3/d (85 mmscfd), although the plant currently produces over 3000 E3m3/d (105 mmscfd). The projected maintenance cost for the turbine used in table 1 for comparison was obtained from Solar and other sources. You can see from the data that the turbine offers a maintenance benefit of $3.4MM over the first five years and $5.4MM over the 15 year life of the project. Several of the IR compressors were past due on major overhauls and others were not far behind. This had the effect of promoting the turbine installation to avoid these costly overhauls. Our philosophy going forward with these machines is that we would keep them as spares for when the turbine is down, but will not do any major overhauls on them.

Another significant maintenance issue associated with the integrals is foundation cracking. Over time we find that the massive concrete foundations crack due to relentless vibration from the compressors. As the foundation deteriorates shaft deflection increases to the point that the unit becomes unusable. We have undertaken efforts to repair and stabilize these blocks with limited success. It is very costly to do though as the unit has to be stripped to the bare block and jack and rolled off the foundation. Even stripped down, the engine block weighs about 150,000 lbs each. For comparison, the entire Solar Centaur skid weighs around 80,000 lbs. We have found that each foundation repair can cost between $100,000 and $200,000.

The biggest economic driver for the project was waste heat recovery off the turbine. The plant requires approximately 45 GJ/hr of process heat for the fractionation of NGL liquids. This heat is supplied by a direct fired heater that operates less than 70% thermal efficiency GHV (greater heating value). As mentioned earlier AltaGas purchases and fractionates trucked-in NGL's, and therefore must supply about half of this heat requirement by purchasing fuel. It is this heat sink that provided AltaGas with the opportunity to reduce fuel gas consumption. Effectively, fuel gas that was used in the 3 to 5 operating reciprocating compressors was used in the turbine, with the waste heat being a free benefit. Although, in theory the heat rate of the recip engines is lower than that of the turbine, close analysis shows that this is not necessarily the case. Table 2 shows the fuel consumption and heat rate for recompression before and after the turbine was installed. Because the producer supply all the fuel required for compression, it was important that the fuel consumption did not increase when the prime mover was changed from engine to turbine drive. There are several reasons why the engines don't perform to their original heat rates. Age and lack of capacity control are contributing factors. As you can see, the turbine simple cycle efficiency is better than that of the engines, so the producers have actually benefited from the project even though they did not participate.

Table 2

Fuel Usage Comparison

| | Before Turbine | After Turbine |
|---|---|---|
| Fuel Usage (GJ/hr) | 54 | 49 |
| Heat Rate for Compression (kJ/kW-hr) | 15415 | 14002 |
| Heater Fuel Used (GJ/hr) | 75 | 50 |
| Waste Heat Recovered (GJ/hr) | 0 | 20 |
| **Overall Cycle Efficiency** | **23%** | **66%** |

(1) Fuel is based on a greater heating value basis (GHV)
(2) Design at 1140 m elevation and 15 C.

The waste heat from the turbine is transferred to hot oil. The design was to cool the exhaust from 510 C to 175 C with 100 m3/hr of oil rising in temperature from 160 C to 240 C. The waste heat exchanger provides about 20 GJ/hr of heat duty, or an equivalent reduction of fuel at the fired heater of 25 GJ/hr. The design of the exchanger has the turbine exhaust enter the side of the exchanger and then turn and go vertically through a somewhat typical convection section, where heat is transferred to the hot oil. The oil flows through 4 passes from top to bottom. One decision made to simplify the exhaust and cut costs was to eliminate the exhaust bypass. Simply what this means is that if hot oil circulation is interrupted, the turbine must go down until circulation is reestablished. This is not really an issue as there is no need to run the recompressors if hot oil circulation is not available because the plant can not process liquids without the hot oil.

Figure 2 Waste Heat Exchanger

Another decision made to cut installation costs was to remove two of the integral compressors off their foundations and reuse these foundations for the turbine. This eliminated the requirement for a new gas compressor building and kept the piping quite simple. We decided to span the turbine skid, which is 35 feet long across two 20 foot foundations. Six of the seven skid anchors were put into one block and the seventh was put into the adjacent block.

Figure 3 Foundations Cut

Figure 4 Foundations Re-leveled

However, this presented several design challenges. Once the old integrals were removed the cracking in the concrete foundations were worst then expected. A repair procedure of cutting the blocks down with concrete cutters, drilling and installing stabilizing anchors was completed to shore up the foundation. Once the anchors were grouted, 35 cm of concrete was poured to make up the elevation back to what was required. Another construction issue with the foundations occurred with the anchor bolts for the skid. These were predrilled into the existing concrete and then grouted in with epoxy. After the skid was jack and rolled into place, it was found that the anchor bolts did not hold and were pulling out of the hole. Subsequent investigation found that the grout had been poured into the holes with the anchors already in place and the grout did not properly fill the void space. Consequently, the grout did not provide enough tension strength. Rather than picking up and moving the skid it was decided to cut into the foundation from the side to access the anchor bolts and provide addition clamping at each location. This proved to be successful and the anchors have all held since then. At the end of the day, I am not sure if reusing the existing foundations and compressor building to install the turbine skid saved any money at all. However, since it has been completed it does fit in well and the operations staff are pleased with it.


Figure 5 Turbine Final Installations

Because the project was essentially a fuel reduction project, an environmental benefit of reduced greenhouse gas (GHG) emission was also realized. At the time the project was approved by management, $CO_2$ reduction credits were not included as a tangible benefit, although they were identified as project upside. Based on actual fuel consumption factors, we estimate that $CO_2$ emissions have dropped by 10,700 tonnes per year. Assuming $15 per tonne for GHG reduction, it works out to about $160,000 per year in additional benefit.

The integral engines that the turbine replaced are old style rich burn high NOx engines. The emission factors of the engines varied between 7 gm/kW-hr to 23 gm/kW-hr depending on the engine vintage and whether or not some form of emission reduction technology had been employed or not. Regardless, none of the engines met the current guideline of 6 gm/kW-hr required for new engines over 600 kW. The turbine has an emission factor of 0.78 gm/kW-hr, which is far lower than that of the engines. It is estimated that we have cut the full load NOx emissions from the facility by about 8% and the actual operating emissions by about 25% due to the vastly lower NOx output from a turbine vs. that of rich burn engines. As mentioned above, many of the engines have been retrofitted lower NOx technology, but the emissions factors are still an order of magnitude higher than that of the turbine. This was an important consideration with Alberta Environment in allowing us to move forward with the project.  The turbine was equipped with Solar's SoLoNOx technology which specifies an out NOx concentration of 38 ppm. We don't do continuous emissions monitoring, but while the unit was being commissioned in October of 2008, NOx emissions were found to be much less than the 38 ppm guaranteed.

The project was budgeted for $11.1 MM CDN and came in slightly under budget. The schedule was about 6 weeks late when compared to the original estimate when the project was sanctioned. As the previous analysis has shown, Altagas was able to proceed with the project based on maintenance and fuel gas savings. About 25% of the project value was based on reduced maintenance over time while the other 75% of benefit was realized by fuel savings. Had the project only been fuel reduction related, the IRR would not have been high enough to fund the project. It is important to note that the contracts between midstream operators and gas producers play an important role in how easily projects like this can proceed. This project at Harmattan was able to be funded without any producer subsidy or contract revisions. This is how AltaGas was able to economically replace aging reciprocating compressors with a single turbine driving a centrifugal compressor in 2008.