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UNION GAS BRIGHT COMPRESSOR STATION RETROFIT

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Abstract

In 2008, Union embarked on an unprecedented expansion project at the Bright Compressor Station. Unlike traditional expansion projects that have been built on 'greenfield' sites, this project consisted of replacing the two existing Rolls-Royce Avon compressor packages with larger Rolls-Royce RB211-DLE packages, all within the existing building footprints.

Specifically, the details of expansion project include:

- 4000 m of pipe installation;
- 23,000 diameter inches of pipe welds;
- 60,000m of power and communication cable laid;
- Replace Avon 1533/1534 packages c/w RT-48 Power Turbines with (2) packaged Rolls Royce RB211-24G-DLE units c/w RT-62 Power Turbines; acoustic enclosures, air inlet filters and exhaust stacks;
- Re-aero all 3 compressors to provide increased head and accommodate for parallel operation of all (3) units;
- Installation of 10 fan, 72 MBTUH aerial gas after cooler, to prepare the plant for future summer operations;
- Installation of one 500 kW auxiliary power generator to provide additional back-up power necessary to support the new aftercooler and gas generator systems.

The final commissioning of the plant was completed in early 2009. Essentially, the project increased the overall net compression/output power of the station by over 54,000 hp.

1.0 Introduction

Union Gas Limited (Union) is a natural gas storage, transportation, and distribution company based in Ontario, Canada. Union currently owns and operates approximately 41,000 km (22,400 mi) of natural gas mainline piping, 4,700 km (2,900 mi) of which is considered transportation or transmission piping. In addition to this pipeline network, Union also owns and operates the Dawn Hub, Canada's largest underground natural gas storage facility, with 22 depleted gas pools in Lambton County that are now used for storage. Together, Union's pipeline and storage facilities serve as an important link within the natural gas transportation network of the North Eastern United States and Eastern Canada.

1.1 The Dawn Trafalgar Pipeline System

Approximately 870 km of Union's transportation system is made up of 4 parallel transmission pipelines known as the Dawn-Trafalgar pipelines. These pipelines are used to transport natural gas from the Dawn Hub to Union's Parkway/Trafalgar stations, located at the west border of Mississauga, Ontario. The diameters of these pipelines are 742mm (26"), 972mm (34"), 1147mm (42"), and 1214mm (48"). Figure 1.1 on the following page provides a geographic illustration of the Dawn Trafalgar System.

Transportation of gas through the Dawn Trafalgar pipelines is managed using available compression at four locations along the system: Dawn, Lobo, Bright and Parkway/Trafalgar. In the early 2000's, Union recognized that market demands would soon reach the compression capabilities along Dawn Trafalgar system, and that the requirement for additional horsepower was on the horizon. This additional horsepower potentially would be required at all 4 compressor stations along the Dawn Trafalgar system, including the Bright Compressor Station.

1.2 History of the Bright Compressor Station

The Bright Compressor Station (Bright) was originally constructed in 1973, and consisted of one Rolls Royce Avon 1533 gas generator c/w RT48 turbine coupled to a RFB36 compressor, and all necessary gas carrier pipe, supporting systems and structures. The original station was designed and constructed to accommodate the installation of a second Avon 1534 package, which was installed within 2 years of the first Avon package. The two, nearly identical, compressor plants were named Bright Plants A1 and A2, respectively, and together they provided approximately 22,300 kW (30,000 hp) of compression to the Dawn Trafalgar System. In 1990, the Bright compressor Station was reconstructed, and the third compressor facility, otherwise known as Plant B, was added to the Bright fleet. Plant B consisted of a Rolls Royce RB211-24 gas generator c/w RT6462 power turbine coupled to a RFBB42 compressor. The new compressor package provided an additional 29,800 kW (40,000 hp) of compression to the Bright station.

With the addition of Plant B in 1990, the Bright yard piping was reconfigured to enable two general modes of operation. The first was an all parallel operation for the 3 plants, during which the overall head increase across the station was limited to 1200 kPa (175 psi). The benefit to this mode was the redundancy offered in the event that one of the three plants was to experience a shut down. The second mode, known as "Mode 9", was a two stage operation in which Bright A1 and A2 operated in parallel and discharged gas to the suction side of Bright B, which further boosted the pressure to provide an overall head increase of approximately 2070 kPa (300 psi) across the station. Although this mode would prove beneficial in maintaining minimum system pressures in the Dawn Trafalgar system during peak flow periods, it offered no plant redundancy, and therefore was considered to be a higher risk mode, reserved only for those peak operational periods.

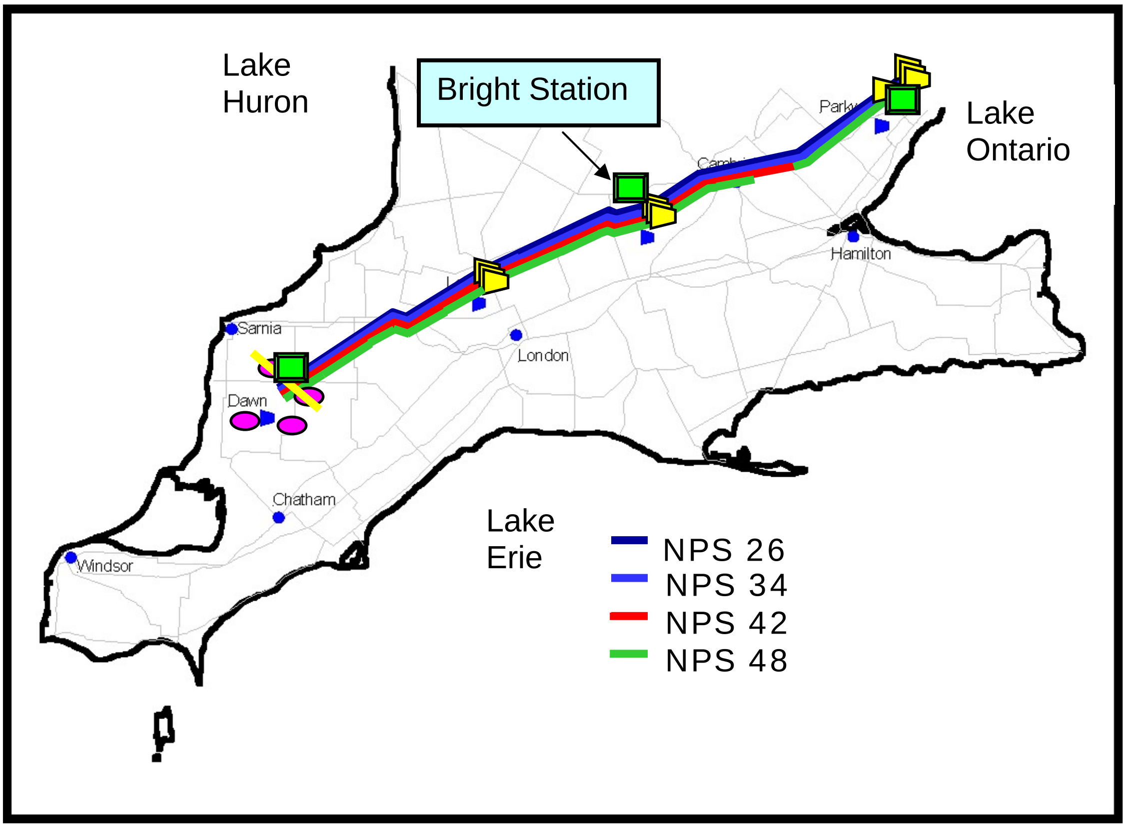

Figure 1.1: Map of the Dawn Trafalgar System

1.3 Development of the Retrofit Concept

In the early 2000s, the long term forecasted demands for the Dawn Trafalgar system warranted the addition of 31,300 kW (42,000 hp) to the Bright Compressor Station. The original plan to achieve this was to add a new compressor package to the station that would operate in parallel with the existing A1, A2 and B plants. This package would most likely have been an RB211-24GTDLE-RT61 turbine package coupled to two tandem RFBB36 compressors. However, Union saw this expansion project as an opportunity to eliminate the higher risk “Mode 9” operation from the A and B plants, which had become a more common operating condition since the B plant was installed in 1990. This opportunity, coupled with concerns of the remaining service life and reliability of the 34 year old Avons, led Union to investigate another alternative.

Through some detailed review of the required operating points and the modifications that would be required to the existing compressors at Bright, the concept of retrofitting the RFB 36 compressors at Plants A1 and A2 with RB211-24G-DLE gas generators c/w RT-62 Power Turbines was developed. Following some further review of the compressor wheel maps and associated horsepower requirements and operating points by Rolls Royce, the concept was deemed feasible, and they proceeded with a preliminary proposal. After receiving the proposal, Union conducted a complete cost estimate for the full scope of the retrofit option, including all yard piping and supporting systems. This estimated cost was approximately 60% of the total cost to construct a new compressor plant, and would provide approximately 8,940 kW (12,000 hp) more compression. These economics, coupled with the additional reliability provided by removing “Mode 9” from Bright’s operation provided the basis to proceed with the retrofit option.

2.0 Engineering

Engineering of the new Bright A1 and A2 compressor plants proved to be a substantial task for both Rolls Royce and Union Gas. In addition to the tight spatial constraints of the existing compressor buildings, which had to be carefully predetermined and factored into the design, the changes to environment, health and safety legislation that had occurred since construction of the original Bright A1 and A2 plants created a myriad of challenges for the engineering teams. These challenges were met with unique and fully customized designs for the new RB211 packages, which took Rolls Royce months of pre-engineering and field measurement to develop. While development of the RB211 package designs was ongoing, Union’s engineering team worked diligently to develop a design for the supporting systems and structures which was compliant with environment, health and safety regulations, and would provide necessary access for maintenance activities.

2.1 Rolls Royce’s Custom RB211 Package Design

The decision by Union and Rolls Royce to retrofit new driver packages to existing RFB36 compressors without moving them added a great deal of constraint to the RB211 package design. Specifically, the foundation block for the original Avon packages would have to be re-used for the RB211 packages, which meant custom skids would be required. In addition, to ensure the economic viability of the project, Union decided that the existing A1 and A2 compressor buildings would be re-used to house the new RB211 packages. This meant that in addition to custom skids, the acoustic enclosure and all of the ducting would have to be specially engineered to fit within the existing structures.

2.1.1 Custom Ducting and Acoustic Enclosure Designs

Under Union’s Certificate of Approval from the Ontario Ministry of Environment, the noise levels from the new A1 and A2 RB211 packages could not exceed 85 dBA at 1m. To meet this requirement, the packages would have to be equipped with acoustic enclosures. Because the original Bright A1 and A2 compressor buildings were designed to house Avon 1533 or 1534 gas generators with no acoustic enclosures, they are relatively small for an enclosed RB211 driver package. To illustrate this point, Union’s Parkway B building, which houses an enclosed RB211-24GTDLE-RT61 driver package, is 14m (45’) tall with a total floor area of 515 m^2 (5540 ft^2). In contrast, the Bright A1 and A2 buildings are only 8.5m (28 ft) tall, and have a floor area of only 223m^2 (2399 ft^2). Figure 2.1 on the following page illustrates the difference in building size between the two compressor plants.

Parkway B **Bright A1**

Figure 2.1: Relative Building Sizes for Bright A1 and Parkway B

The limited building space would warrant several custom features for the enclosure and duct. The general arrangement that was developed for the enclosure and duct work is shown in Figures 2.2(a) and Figure 2.2(b) on the following page. There are some items worth noting about this arrangement.

1. Several duct segments were custom fabricated to fit within the buildings' structural frames;
2. The lower portion of the exhaust silencer had to be offset from the vertical and horizontal planes to fit through the building's structural frame and final clearances were limited to less than 100mm. (4");
3. The acoustic enclosure had to be located partially outside, so a weather flange had to be added to the enclosure for flashing, whereas this is normally part of the ducting;
4. The air inlet filters had to be custom designed to fit limited space between the buildings on the outside; and
5. The gas generator chamber in the enclosure had to be reduced from the standard length to fit the available footprint within the building space which meant the standard electric starter and gas generator lube oil (GGLO) console would not fit inside of the enclosures.

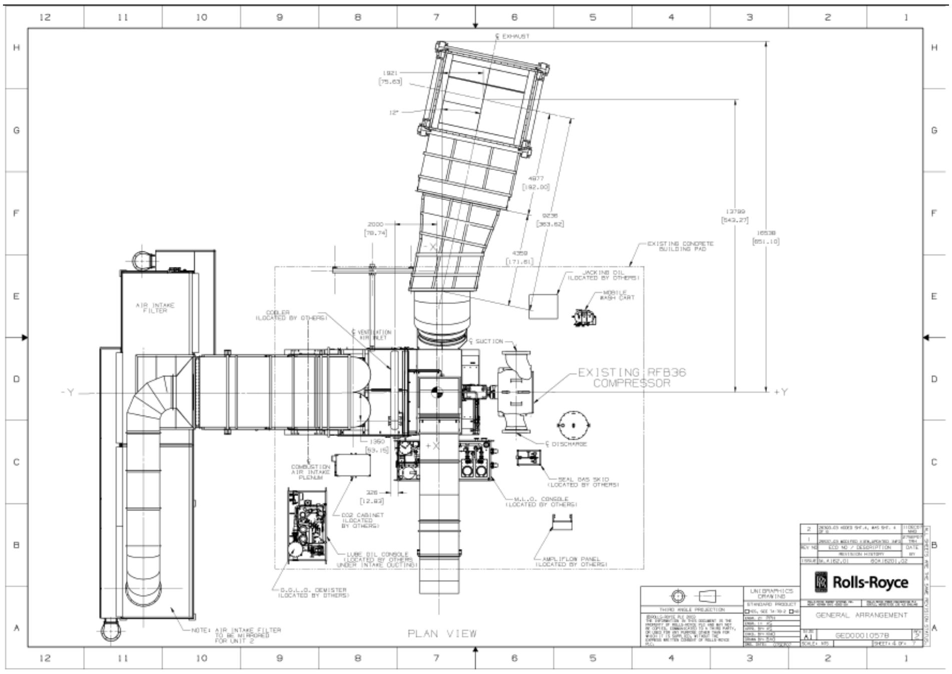

Figure 2.2(a): Custom RB211 General Arrangement Plan View Drawing

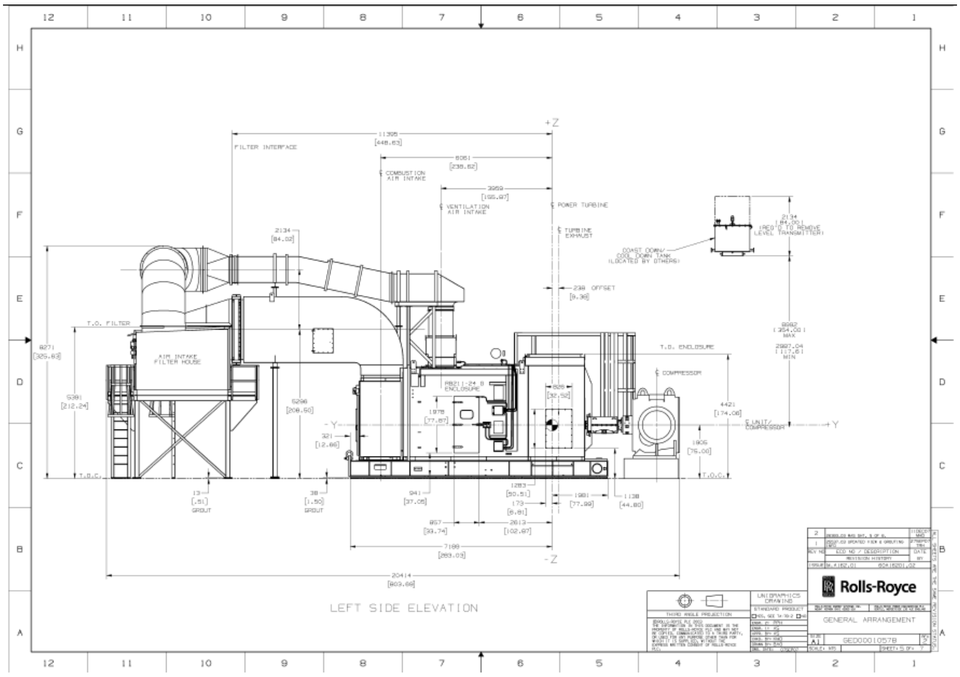

Figure 2.2(b): Custom RB211 General Arrangement Elevation Drawing

2.1.2 Custom Hydraulic Starter Motor

The reduced enclosure space could not house a standard electric starter for the RB211s. As such, Rolls Royce proposed gas driven hydraulic starters for the packages. The incorporation of the gas hydraulic starter motor would present additional challenges to Union's design team. However, these issues were manageable, and the hydraulic starter was deemed feasible and was accepted in the proposal.

2.1.3 Custom Skid Design

The foundation blocks had originally been designed to support the skids for the Avons as well as their combustion air inlet filters. To ensure the RB211 skids would fit within this footprint, Rolls Royce developed a tapered skid/enclosure design. The design incorporated a narrower I-beam frame, with a gusseted flange extension welded to the upper flange. Figure 2.3 below illustrates.

The narrower frame, of course, meant that Rolls Royce would have to review dynamic loads on each anchor bolt to ensure they could handle the additional tensile loads. The review indicated that the original bolts had the necessary tensile strength to do so with the addition of one bolt per skid along the driven edge. Figure 2.4, on the following page, shows the proposed anchor bolt pattern.

At the time the new RB211 packages were in design, the Avon packages were still in place and in service at Bright. As a result, only 7 of the 15 bolts on each package were accessible to take measurements. These measurements, coupled with original vendor drawings were used to estimate the location and exposed lengths for all of the existing anchor bolts. This created some installation challenges which will be described later in Section 3.1.

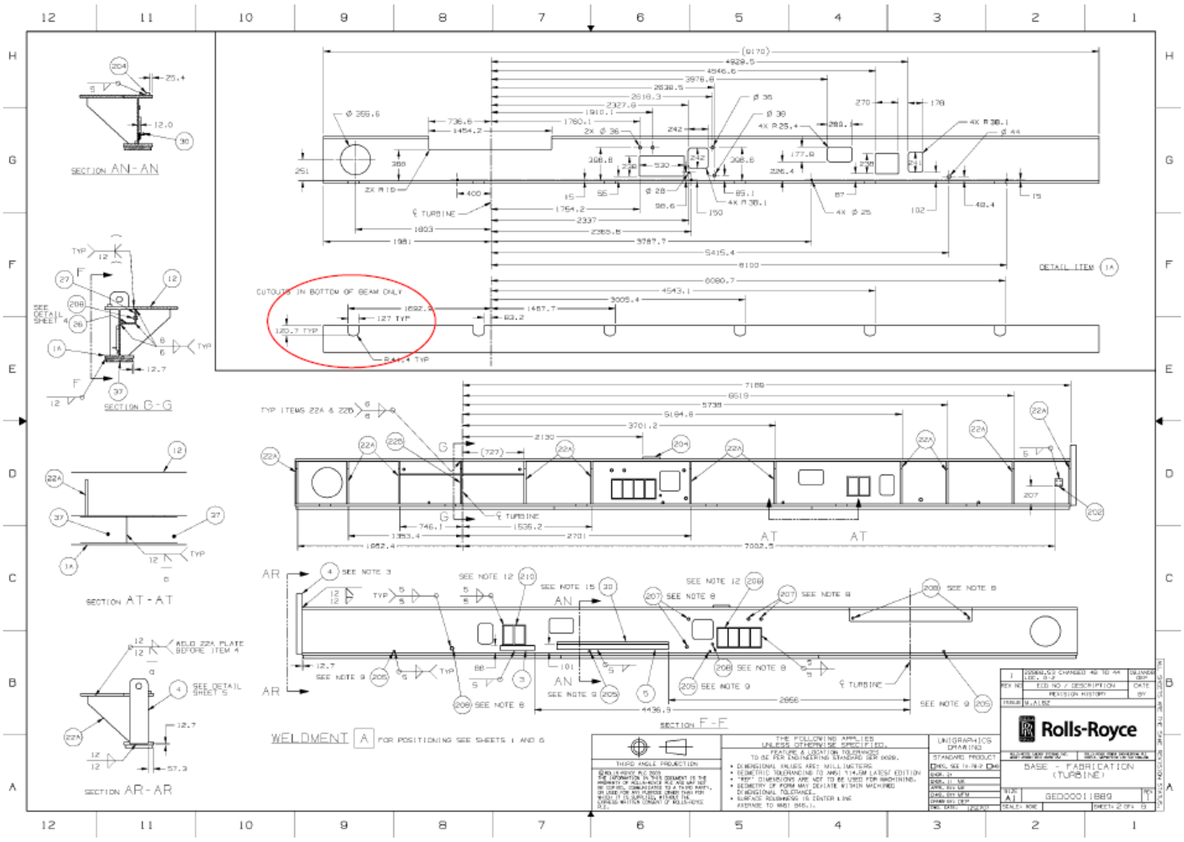

Figure 2.3: Custom RB211 Skid Design

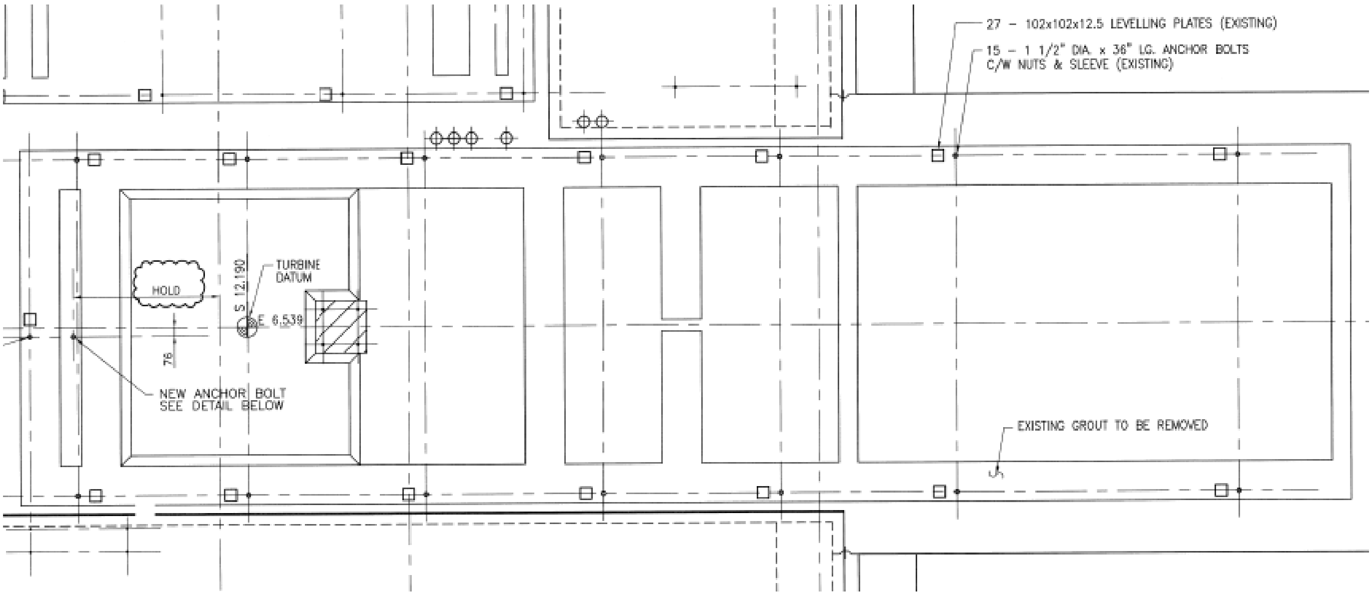

Figure 2.4: Existing Anchor Bolt Layout for A2 Compressor Building

2.1.4 Custom Power Turbine (PT)/Compressor Mineral Oil System

The PT/Compressor mineral oil system consisted of all of the standard components normally supplied with an RB211 package. The key components included a lube oil console for oil storage, pumping, filtering, and heating; an aerial cooler; a cool down head tank to provide flow to the bearings during unit shut downs; and associated vents and demisters.

2.1.4.1 Cooldown Tank Design

The cool down tanks provide lubrication to all bearings for a relatively short period, known as the coast down period. However, their primary purpose is to provide cooling to the RT62 Power Turbine disk end journal bearings after shut down. One of the custom features included in the lube-oil system is a larger diameter coast down line to accommodate reduced elevation for the cool down tanks so they could be fit within the existing buildings' framework. Specifically, the internal oil tubing run to the RT62 power turbines was increased in size from 9.5mm (0.375") to 19mm (0.75") tubing. This enabled Union to install the cool down tank at a minimum bottom-of-tank elevation of 3.0m above the PT centreline.

2.1.4.2 Aerial Cooler Design

The original coolers that supported the Avon units cooled both the PT/Compressor mineral oil and the GG synthetic oil through two separate tube bundles cooled by a single fan. The increased cooling capacity required for the RB211 GG synthetic lube oil warranted a separate cooler, which will be discussed in section 2.1.5. In addition, because Union's design ambient temperature had increased to 37°C (98°F) for the purposes of the retrofit project, the PT/compressor tube bundle was no longer adequately sized and would have to be replaced.

Fortunately, because the gas generator oil was now to be cooled by a separate cooler at a different location, there was room for additional coils within the building space taken by the existing cooler housings. As a result, the cooler supplier, was able to design and supply new aerial coolers for the PT/Compressor oil systems using the same housing dimensions as the existing coolers, enabling Union to replace the cooler with little design work.

2.1.5 Custom Gas Generator Lube Oil System

As indicated in Section 2.1.1, the customized acoustic enclosure warranted that the GGLO console be located in a separate building. In addition, as indicated in Section 2.1.4, cooling capacity in the existing oil cooler coil was not sufficient for the new gas generators' lube oil. As a result, a remote lube oil console and oil cooler were added to the list of custom features for the RB211 packages.

2.1.5.1 Remote Lube Oil Console

Due to limited space in the enclosure and compressor buildings, Union opted to install a separate, external building for the GGLO console. The primary challenge created by the addition of the new buildings was spatial constraints placed on the RB211 air inlet duct work and its supports. Union was able to work with Rolls Royce and their building vendor to develop designs for the building and overhead duct work that would enable all systems to fit in a constrained area. Figure 2.5 illustrates the arrangement.

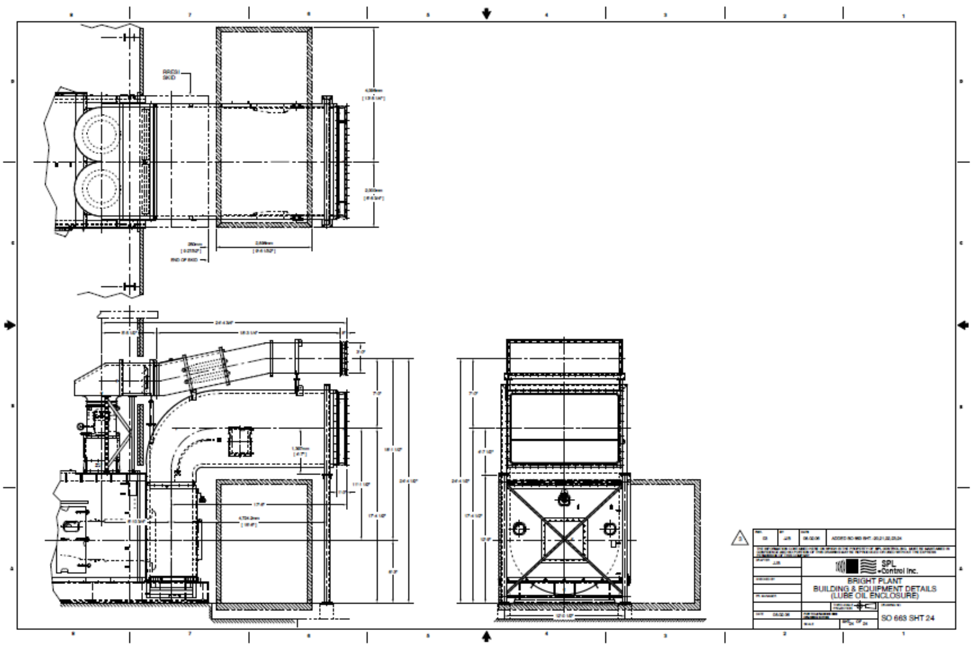

Figure 2.5: Ventilation and Combustion Air Ducting Design w/ GGLO Building in Place

2.1.5.2 Custom GGLO Cooler

Due to the spatial constraints within the building, a separate aerial cooler would not be possible. Coincidentally, Union required additional heat to pre-heat the fuel gas to the RB211 packages. A heat balance quickly revealed that the fuel gas could provide sufficient cooling to the GGLO through the installation of an appropriately sized shell and tube fuel gas to GGLO heat exchanger. The obvious benefits to this option quickly fuelled the decision to pursue the installation of a GGLO to fuel gas heat exchanger and Rolls Royce worked with their sub vendor to develop a workable design.

2.2 Engineering of Supporting Systems and Structures for the Custom RB211 Packages for Bright A1 and A2 Compressor Plants

With the gas generator, power turbine, and supporting equipment being designed by Rolls Royce and their sub-vendors, the Union Gas design team was tasked with completing the design for the remainder of the Compressor Station. Section 2.2 will focus on this portion of the design with particular attention being paid to the systems that directly support the operation of the new RB211 packages.

2.2.1 Plant A1 and A2 Engine Block Modifications

As indicated in Section 2.1.3 dynamic load assessments for the new RB211 packages indicated that one additional anchor bolt would have to be added to the existing foundations, as shown in Figure 2.4. The anchor bolt would be of standard Rolls Royce design and was to be installed by core drilling the concrete block to the necessary depth, removing residual concrete and rebar, and setting the anchor bolt by filling the annulus surrounding the bolt sleeve with an epoxy grout.

2.2.2 Compressor Building Modifications

In addition to some minor structural modifications, noise restrictions warranted that the A1 and A2 compressor buildings undergo additional acoustical treatment. This was necessary to attenuate noise from the new enclosures. Treatments included replacement of the existing roof vents with silenced vents, and installation of noise attenuating hoods over the building louvers and the new aerial oil cooler louvers.

2.2.3 Compressor Building Layout and Access

One of the most challenging issues in retrofitting the RB211 packages into the existing Bright A1 and A2 compressor buildings was maintaining proper access. Addition of doorways, customized access platforms and ladders, and specially designed overhead equipment and piping supports were all tools used to ensure safe access and egress was maintained in the final building layouts. Figure 2.6, on the following page, provides some perspective of the remaining building space around the enclosed RB211 package in the A1 compressor building. The layout of the A2 compressor building was nearly identical.

Figure 2.6: Bright A1 Compressor Building Following Installation of the RB211 Package

2.2.4 Fuel/Start Gas Heating System

With the addition of start gas to the load on the fuel gas system, the existing fuel gas heating system was reviewed to determine if there was adequate heating capacity to meet the required gas temperature at the skid edge. The Bright A heating system consists of a 3.69 GJ/hr (3.5 MMBTU/H) York Shipley hot water boiler which provides hot water to several unit heaters in the Plant A control and compressor buildings, as well as the heat exchangers for the Plant A1 and A2 engine fuel gas. An initial heat balance, looking strictly at BTU consumption of all unit heaters and fuel gas heat exchangers when operating in unison, revealed that the existing boiler could not meet the demands of the fuel gas heat exchangers and the unit heaters at the same time. However, as mentioned earlier, a GGLO to fuel gas heat exchanger was to be installed in series with the existing fuel gas heat exchangers, and would serve to pre-heat the gas. In fact, performance data for the GGLO to gas heat exchangers indicated that sufficient heat was available to offload the existing fuel gas heat exchangers entirely. So the heating system was not upgraded.

2.2.5 Fuel/Start Gas Vent System

Location of the fuel and start gas connection of each RB211 skid were such that the vent piping for both would have to exit the south wall of each compressor building, less than 5m away from the combustion and ventilation air inlet filters. The primary issue in locating the vents in this fashion is that prevailing winds at Bright in the winter months might redirect vented gas towards the inlet filters. The initial strategy to resolve this matter was to directly the vented gas into the wind. However, during periods of strong northwest winds over the 2008/2009 operating season, gas detectors in the combustion air inlet ducting for Bright A2 tripped while the A1 starter was operating. In an attempt to resolve this from reoccurring, the A1 starter vent will be elevated and the silencer will be modified to vent vertically in an effort to keep gas out of the wind's boundary layer as it blows across the building roofs.

3.0 Construction

In the spirit of brevity and maintaining focus on the systems that immediately support and are affected by the gas turbines and their control systems, the full scope for the Bright compressor station re-design has not been thoroughly described in Section 2 of this report. However, for the purposes of providing the reader an appreciation of the magnitude of this project and the time constraints under which it was constructed, it is worth highlighting the key items in the project scope. The following is a high level summary of the full scope of work for the project, including items already described in previous sections:

- Removal of two Avon 1533 /1534 packages c/w RT48 power turbines including four off-skid lube oil consoles, interconnect piping, cables, oil coolers, gage panels, air inlet filters and inlet scrolls, exhaust ducts, exhaust silencers and their support structures, motor control centres and PLC panels.
- Installation of the new RB211 packages, including all ducting, inlet filters, exhaust silencers, foundations for filters and silencers, PT and GG lube oil consoles and coolers, and fire suppression system
- Replacing the hubs, bearing housings and bundles in one RFBB42 compressor and two RFB36 compressors
- Installing 4000m (23,000 welded diameter inches) of new pipe in the entire Bright yard and buildings. New piping included the following:
  - Installing independent yard suction and discharge piping and valves for Plants A1, A2, and B
  - Adding a 76 GJ/hr (72 MBTU/H) aerial cooler and providing "cold recycle" lines and control valves for all 3 plants
  - Installing a new NPS 42 suction scrubber and relocating the two existing NPS 42 and NPS 48 scrubbers such that each plant has an independent suction scrubber
  - Adding two new yard blow down silencers and associated valves and piping
  - Installing all necessary drip, power gas, fuel gas and blow down recovery piping necessary to accommodate the new yard configuration and the installation of the RB211s
  - Replacing the hot water/glycol piping between the boiler and the Plant A1 and A2 compressor buildings
- Installation of eight new large bore (NPS 30 – NPS 42) buried ball valves and actuators

- Installation of a new 7.9m x 22.0m (26'x72') pre-cast auxiliary building which housed the aftercooler motor control centres, two new 93 kW (125 hP), 688 sm3/h (403 scfm) air compressors to support the RB211 instrument and pulse air requirements, and the new 500 kW back up generator for Plants A1 and A2
- Installation of two 4.8m x 7.3m (16'x24') and 3.7m x 4.9m (12'x16') precast concrete buildings to house "cold recycle" control valves
- Installation of two 3.0m x 9.1m (10'x20') precast concrete buildings to house the GGLO consoles for Plants A1 and A2
- Renovation of existing Plant A control building to provide adequate space for the new RB211 MCCs and PLC panels, as well as upgrading the building's HVAC system to accommodate increased heat rejection by the new MCCs and PLC panels, and completing other upgrades to ensure the building would be compliant with the latest edition of the Ontario Building Code
- Installation of an 83 m (272 ft) long, 1.2m (3.9 ft) deep x 1.8m (5.9 ft) wide pre-cast concrete cable trench and sub base from the service building to the east wall of each compressor building
- Installation of approximately 60,000m of new power and control cable

Cumulative man-hours to complete these tasks totalled 132,000 and the available construction window was March 17th, 2008 through November 1st, 2008.

3.1 Anchor Bolt Misalignment

Following removal of the Avon packages, the existing anchor bolts were assessed for condition and measured for compatibility with the bolt pattern for the new RB211 skid frames, which was to be identical to the original bolt pattern design for the Avon skid frames. Figure 3.1, on the following page, illustrates the condition in which each of the anchor bolts were found after removing the Avon packages. Notice that the annulus in the tube around the bolt is filled with grout. Normal practice is to fill this annulus with sand or wax to provide some play in the bolt. As a result of grout having been poured, the orientation of the anchor bolt relative to the sleeves was fixed.

After measuring the anchor bolts for alignment relative to the new proposed power turbine centreline, it immediately became apparent that the bolts did not align with the bolt pattern on the new RB211 skids, with the worst misalignment being out by 25mm (1"). In addition, many of the bolts were not standing vertically. A further investigation of the old Avon skids revealed that sections of 3/4" plate had been welded on top of the bottom flange of the I-beam frames, and new mounting holes had been burned through these plates and the frames at the time the Avons were installed. Figure 3.2, on the following page, illustrates. As such the actual bolt pattern did not match the original designed hole pattern in the Avon skids. Unfortunately, this could not be seen when measurements were being taken during the design phase of the project because the Avon packages were still in service and access to the bolts was limited.

The 38mm deep bolt holes in the new RB211 skids have a 44.5mm (1.75") diameter, which meant there was only 6mm of play. So, not only would the anchor bolt positions have to be adjusted, the anchor bolts would have to stand relatively vertically to fit through the bolt holes. After discussing the issue with Rolls Royce it became apparent that the skids could not accommodate a change in the bolt hole size or location without significant impacts to the project schedule. As a result, Union decided to remove the grout inside each bolt sleeve by coring and chiselling, and attempt to tilt the bolts back to the correct position. They were successful in obtaining the necessary offsets in all but one of the existing anchor bolts. Figure 3.3 illustrates the realignment of some of the anchor bolts.

Figure 3.1: Bright A1 Existing Anchor Bolt

Figure 3.2: Field Modified Avon Skid Anchor Bolt Hole

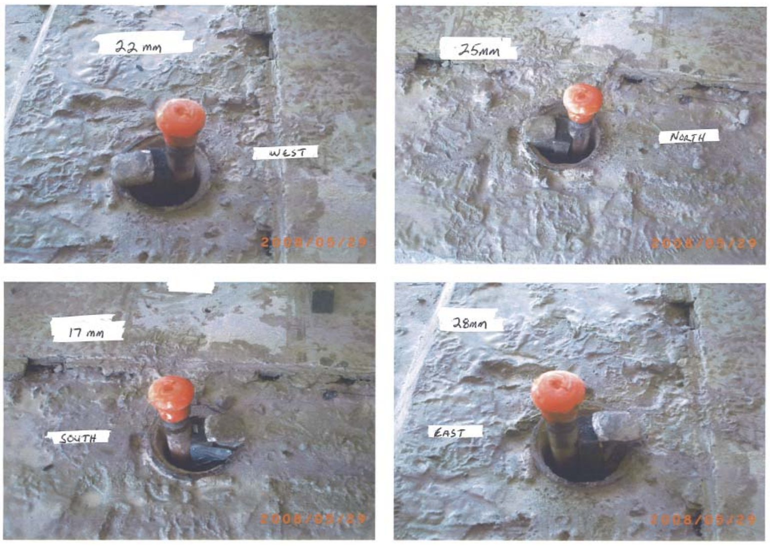

Figure 3.3: Cored and Realigned Anchor Bolts

The anchor bolts that could not be set to the proper position using this method were removed and replaced entirely. Removal was completed using an 8" coring bit to remove concrete around the sleeves and base plates for these anchor bolts.

3.2 Installation of the RB211 Packages

In order to minimize reconstruction of the existing compressor buildings, the new RB211 packages were installed through the south wall of each building. Installation was carried out by lifting the drive end of each package with a 200 ton crane from outside of the building, and rolling the driven end into position along the block. The packages were pulled into position using two come-alongs chained around the suction and discharge elbow support piers. Installation of each package took approximately 3 days from the time the skids arrived to the time they were lowered over the anchor bolts. Figure 3.4 illustrates the alignment of the A1 RB211 package taking place.

Figure 3.4: A1 Alignment

Once each skid was lowered over the anchor bolts, the power turbine and compressor shafts needed to be aligned. Alignment of each package took approximately 3 days. Table 3.1 below summarizes the results of the initial alignment of the RT62 turbine shafts relative to the original RFB 36 compressor shafts for the Bright A1 and A2 plants prior to grouting each RB211 package.

Table 3.1: Pre-Grouting Alignment Figures

A1 Actual – Target Offsets (mils)				A2 Actual – Target Offsets (mils)			
Offset Horizontal	Gap Horizontal	Offset Vertical	Gap Vertical	Offset Horizontal	Gap Horizontal	Offset Vertical	Gap Vertical
-2.0	-2.3	1.7	-3.3	-0.3	2.8	0.9	-4.7

Once alignment was completed, and Rolls Royce accepted the initial alignment, an epoxy grout was poured under the frame of each skid, per Union's standard practice. After the grout had dried, another alignment check was completed to verify that there was no movement in the package as the grout was installed. The measurements are summarized in Table 3.2:

Table 3.2: Post Grouting Alignment Figures

A1 Actual – Target Offsets (mils)				**A2 Actual – Target Offsets (mils)**			
Offset Horizontal	**Gap Horizontal**	**Offset Vertical**	**Gap Vertical**	**Offset Horizontal**	**Gap Horizontal**	**Offset Vertical**	**Gap Vertical**
-1.5	-1.6	-0.4	-0.2	0.2	0.2	0.5	-1.1

These numbers were considered acceptable to Rolls Royce and Union Gas.

3.3 Installation of new A1 and A2 Bearing Housings and Hubs, Dry Gas Seals, and Compressor Bundles

Installation of the new, bearing housings and hubs, dry gas seals, and compressor bundles was originally scheduled to be completed prior to installation of the RB211 packages so that the new RT62 power turbine shafts could be aligned to the new compressor shafts. However, due to manufacturing delays, the new compressor bundles, bearing housings, hubs and seals were not received until after the RB211 packages had been installed, so these had to be installed with the packages grouted into position.

Installation of the bearing housings, hubs and dry gas seals was completed with generally little difficulty. However, when installing the new compressor discharge walls, there was some interference between the discharge wall and the inside wall of the case, where the discharge nozzle transitions to the main chamber of the case. To resolve the matter, approximately 6.4 mm (0.25”) of material was removed from the interfering surface of the discharge wall.

3.4 Final Alignment

With the new bearing housing, compressor bundle and shaft in place, the final alignment was checked prior to installation of the coupling. To the surprise of both Union and Rolls Royce, the alignment for each compressor had shifted considerably. These measurements are tabulated in Table 3.3.

Table 3.3: Post-Bearing Replacement Alignment Figures

A1 Actual – Target Offsets (mils)				**A2 Actual – Target Offsets (mils)**			
Offset Horizontal	**Gap Horizontal**	**Offset Vertical**	**Gap Vertical**	**Offset Horizontal**	**Gap Horizontal**	**Offset Vertical**	**Gap Vertical**
-21.9	-9.6	-13.4	-8.6	15.4	2.8	104	13.8

The A1 alignment was initially rejected by Rolls Royce. However, through some discussions, Union Gas and Rolls Royce agreed that alignments of 0.5 mils per inch length of coupling had been the accepted tolerance for several of Union’s older compressor packages at the time they were installed, and that these compressors had successfully operated for decades. For the new RB211 packages, the coupling length was 1219.2mm (48”). So the older tolerance had been met by the A1 alignment. On this basis, Rolls Royce accepted this alignment with the understanding that vibration would be closely monitored upon commissioning of the package and that if any issues arose, the alignment would have to be corrected.

The vertical misalignment in the A2 compressor package was far more substantial than that in A1. Through several additional measurements, it was confirmed that the driven end of the A2 compressor would have to be elevated by 40.3 mils and the drive end would have to be lowered by 17.6 mils, at the compressor feet, in order to correct the offsets and angularity. It was Rolls Royce's initial recommendation that the compressor be released, the suction and discharge flanges unbolted and if necessary, the connected piping be cut and repositioned to enable realignment with the A2 power turbine shaft. Due to schedule constraints, Union felt that the time required to complete this work would put the Dawn Trafalgar system at risk in terms of maintaining system throughput and line pressure.

To resolve the matter, Union developed a step by step plan to jack the compressor into alignment without releasing the nozzles or connected piping. The obvious concern with doing so was the potential nozzle loads that would result, and the potential for misalignments from straining the case. However, if the appropriate steps were followed, it was the opinion of Union Gas that the case could be moved without over stressing the nozzles. The basic procedure involved releasing all anchor points to the compressor and checking for movement as this was where each anchor point was released. Any movement would be attributed to existing strain on the nozzles and associated loads would have to be back-calculated and factored into a stress analysis to which the stress of jacking the compressor into alignment would be added.

Fortunately, minimal movement was noted at any point in the compressor or connected piping as it was released, so assumed existing nozzle loads were minimal. Following this, Union hired a 3rd party engineering firm to complete a finite element model of the compressor piping up to the thrust blocks on either side. The model was used to determine what nozzle loads would result from jacking the compressor into the aligned position. These loads were then checked against the allowable loads as specified by Rolls Royce, and were within the Rolls Royce specifications. Union reviewed the results of the analysis with Rolls Royce and both agreed to accept the alignment on the basis that any vibration that occurs after commissioning of the A2 package would have to be addressed at that time, potentially by releasing the pipe connected to the compressor.

4.0 Commissioning

Commissioning of the entire Bright yard, including the RB211 packages overlapped with the construction period and was carried out over the course of approximately 4 months. There were several components in the plant that had to be checked for operational functionality once power became available, and the control sequences for each component had to be run to ensure the station control logic was sound. Although it was a time consuming and tedious process, commissioning for the station components outside of the compressor buildings was completed without any significant problems.

Commissioning of the RB211 packages took approximately 6 weeks to complete. A1 was commissioned first, then A2. The benefit of having two identical packages to commission was that lessons learned from A1 could easily be transferred to A2, shortening the overall window for commissioning of the two plants. There were, however, several challenges to overcome in completing this process.

4.1 Cold Ambient Enclosure Temperatures

The ventilation systems for the new RB211 enclosures are designed to move 47,600 m^3/h (28,000 cfm) of outside air through the enclosures when the gas generators are running. The Bright Compressor Station is designed to operate at a minimum ambient temperature of -26°C (-15°F). When ambient temperatures fall this low, there is a substantial cooling affect on the equipment, instrumentation, tubing and piping inside of the enclosures.

The first impact of this affect was chilling of the fuel gas piping inside of the enclosure. Fuel gas generally reached the skid edge at a temperature of 50-55°C, which is well above the maximum dew point of the fuel gas in Union Gas's system, and minimum required fuel gas temperature at the skid edge. However, fuel gas temperature measurements just inside the enclosures showed temperatures in the 30-35°C range on days when the ambient enclosure temperature reached the -20°C range. This reduction in temperature cannot be attributed entirely to the inside enclosure temperature, but trending has revealed that the two are closely related. The full cause is still under investigation.

The second negative effect of the cold ambient ventilation air was freeze off of the local bleed air valve due to ice build up in the instrument air supply line. This caused several surges of the RB211 unit in the A1 plant during the commissioning phase. Following some investigation, it was determined that the ice build up was caused by a combination of cold ambient air and trickle flow through a small leak in the line. As a result, the matter was easily resolved by repairing the leak.

Through a review with the Rolls Royce design team it was revealed that an engine shield, previously used to deflect any debris pulled through the ventilation air system, had been removed from the enclosed RB211 package designs. This shield would have served to trap some of the heat surrounding the gas generator when in operation. Unfortunately, the standard deflection shields could not be fit into the customized Bright A1 and A2 RB211 enclosures. To resolve this matter, Union and Rolls Royce worked together to develop a deflection shield which could be mounted off of the gas generator removal crane rail. The result of installing these shields was positive and the RB211s were able to operate through the winter months of 2008 and 2009 without fuel gas or bleed air system freeze offs while the engines were running. However, this solution is considered temporary and Union is currently working with Rolls Royce to develop a permanent solution.

4.2 Failure of the GGLO Cooler to Adequately Heat the Fuel Gas

At the same time that the cold fuel gas temperatures inside the RB211 enclosures was being investigated, the heating system underwent a review to ensure adequate heat was being supplied to the fuel gas heat exchangers. Although adequate heat was available, Union discovered that the system was not functioning as it had been designed. As mentioned in Section 2.2.7.1, the fuel gas heating system for Bright A1 and A2 consisted of a fuel gas to GGLO heat exchanger in series with a hot water/glycol to fuel gas heat exchanger. The intent of this arrangement was that the hot water/glycol system would provide the necessary heat to the fuel gas during start up only. Once the gas generator lube oil temperature reached high enough temperatures to sufficiently heat the fuel gas on its own, hot water/glycol circulation through the start up heat exchanger would be shut down. Unfortunately, when the performance data for the fuel gas to GGLO heat exchanger was reviewed at the design phase, it was reviewed only for cooling capability for the GGLO at peak oil temperatures, as this is its primary function. Because the GGLO rarely sees these temperatures, the available heat to transfer to the fuel gas is generally less than what was assumed during design of the fuel gas heating system. As a result, there is still substantial heat being supplied by the Plant A boiler to the fuel gas. Having said this, the GGLO to fuel gas exchangers still pre-heat the gas, so there is some thermal efficiency gained in the fuel gas systems by having these exchangers in place, and they are certainly integral to the gas generator lube oil system.

5.0 Conclusion

Generally speaking, the Bright Retrofit project was considered to be a success by both Union Gas and Rolls Royce. The new RB211 units were initially put into operation in early December of 2008 and remained in service through the winter operating season until late March 2009, adding approximately 38,700 kW (54,000 hp) to Union's Dawn-Trafalgar system. The final cost for installation of these units and reconstruction of the Bright plant was approximately 60% of the total estimated cost to construct a new compressor plant, which would run in parallel with the existing Bright plants and supply only 31,300 kW (42,000 hp) of compression to Union's Dawn Trafalgar system.