Design Aspects Surrounding the Alberta Gas Trunk Line's New 20,000-HP Gas Turbine Compressor Set

R. B. WILLIAMS
Design Engineer,
The Alberta Gas Trunk Line Co., Ltd.,
Calgary, Alberta, Canada

The Alberta Gas Trunk Line's new 20,000-hp gas turbine compressor set is one of the largest and most modern aircraft derivatives available to industry to date. This paper describes the various aspects of station and unit design for the compressor package. The additional operational flexibility gained as a result of adding this unit to our existing 12,500-hp station is described. The paper will also present a description of the station's control system, including unit controls, surge controls, and other features of the instrumentation. Trunk Line is concerned with keeping the availability of the unit high, and as such, the paper will describe some features which help keep downtime to a minimum.


Copies will be available until January 1, 1973.
Design Aspects Surrounding the Alberta Gas Trunk Line's New 20,000-HP Gas Turbine Compressor Set

R. B. WILLIAMS

INTRODUCTION

The gas transmission industry had a growing need in the past few years for more powerful, efficient, and reliable gas turbine/compressor units. This is a reflection on the ever-increasing demand for natural gas, as well as the increasing distance between the source and the market for the gas. More powerful units are required to reduce installation and capital costs, more efficient units are required to cut down on fuel and other transportation expenses, and more reliable units are required due to the increasing complexity of transmission networks. These are some of the factors which have contributed to the development of modern compression packages. The compressor manufacturing industry has responded to the gas transmission industry's needs by producing the technologically advanced gas turbine/compressor units in both industrial and aircraft versions. The users of these machines have taken care to ensure that the design of their compressor stations complement and enhance the high quality of the design of the machines themselves.

The goal in today's compressor station design is to produce a station which is efficient, reliable, and is inexpensive in both installation and operating costs. The author's company, The Alberta Gas Trunk Line Company Limited, Fig. 1, applies all of these precepts in its compressor station design.

In its search for more powerful and efficient gas turbine/compressor sets, Alberta Gas Trunk Line recently purchased and installed an Ingersoll-Rand JP200/CDP-230 gas turbine compressor unit. This unit features 20,000 NEMA horsepower at a guaranteed full-load efficiency of 33 percent. This is an impressive efficiency for a simple, open-cycle aircraft derivative gas turbine without either heat-recovery equipment or a regenerator of any kind. It compares most favorably with about 26 percent efficiency for other aircraft derivative type turbines.

PACKAGE DESCRIPTION

The JP200 designation refers to the free power turbine part of the package. This turbine is a two-stage turbine and is designed to run at 5250 rpm but is capable of continuous operation at 105 percent of that speed. A two-stage tur-
bine was required because of the high-pressure ratio across the turbine, the higher inlet temperature to the turbine, and the tremendous amount of work extracted from the turbine. The up-to-date design of this turbine contributes to the excellent efficiency of the package.

The other major component of the power generation portion of this package is the General Electric LM2500 gas generator. The LM2500 is the industrial version of G.E.'s newest aircraft jet engine, the CF-6 which powers the McDonnell Douglas DC-10. A great deal of the improved efficiency in the package is a result of the advanced technology utilized in the LM-2500 gas generator. It features a 16-stage axial flow air compressor operating at about a 17:1 compression ratio. There are seven rows of variable stator blades which greatly improve part-load efficiencies and eliminate the need for stage bleeding for surge control. Higher firing temperatures, yet lower metal operating temperatures, have been achieved by a very sophisticated blade design and cooling arrangement. Although gas temperatures are high, therefore contributing to a higher efficiency, actual metal temperatures are quite conservative.

The JP200 drives the CDP-230 which is a well proven, two-stage centrifugal pipeline compressor. The only modifications required to enable this machine to take the increased horsepower of the JP200 was an enlargement of the two journal bearings supporting the main shaft, plus an enlarged coupling. With these modifications, the maximum horsepower rating of the CDP-230 is in the order of 29,000 hp. At Alberta Gas Trunk Line's site, the unit is expected to produce around 22,500 hp at low ambient conditions.

STATION DESCRIPTION

Alberta Gas Trunk Line's Clearwater Compressor Station was expanded to accommodate the JP200. Earlier this station had existing compression facilities in the form of a 12,500-hp unit for base load operation as well as a 6000 hp portable unit which was used as standby. The station piping configuration, as shown in Fig. 2, provides for operation of the JP200 in either series or parallel with the existing 12,500-hp unit. This gives the station a great deal of operational flexibility. The station can cope with large pressure differentials and lower flows at first as a series configuration, and then with large flows and smaller differentials in the parallel configuration.

The original station design provided for a one-unit expansion in the 12,500-hp range. When the decision was made to use a 20,000-hp unit, instead of the planned 12,500-hp unit, the sizing of all expanded station components was checked to ensure they could accommodate the larger unit. As it turned out, the sizing of these components was adequate to accommodate the needs of the larger unit, and, as a result, station costs for a 20,000-hp addition were about the same of those for a 12,500-hp addition.

It is interesting to note that Alberta Gas Trunk Line's JP200 is convertible to a 12,500-hp unit with relative ease. This is accomplished by removing the G.E. LM2500 gas generator and replacing it with the G.E. LM1500 gas generator. The JP200 power turbine would also be removed and be replaced by a JP125 power turbine. All other components would remain essentially the same. Since base installation costs remain the same, this feature offers some economic advantages to a station whose horsepower requirements could grow or decrease.
STATION DESIGN

The station design began with a piping layout to the additional unit. This layout was analyzed for stress and flexibility and was adjusted until stresses and flexibility of the piping were acceptable. This fixed the position of the unit and enabled soil testing for the unit foundation to commence. The soil under the unit was fill, poorly compacted and unsuitable for construction. At this point, it appeared that a foundation on pipe piles was the most practical type of foundation. However, an analysis of the dynamic response of the machine - foundation - soil system indicated that a rather large number of piles were required to avoid a resonance condition. Engineered fill became practicable, and approximately 12 ft of the old fill material under the foundation was removed and replaced with compacted pit run gravel. This provided a good firm base on which to build the foundation slab for the unit and the building floor slab. The unit foundation slab was separated from the building floor slab, thus making it easier to construct both slabs and, at the same time, allowing the unit foundation slab to be recessed into the building floor slab. This brought the operating floor level to the top of the unit skid instead of the bottom, resulting in all auxiliary piping being below the floor which gave a very neat installation as well as decreasing the building height. Another benefit was that the floor slab could be made much thinner than the unit foundation slab.

The foundation slab is 13 ft x 47 ft x 2 ft-6 in. thick reinforced block floating on engineered fill, 2 ft below the operating floor level. The building floor covers an area of 44 x 72 ft and is an average of 10 in. thick. The compressor building walls rest on a perimeter grade beam.

The compressor building is a carefully designed structure. Apart from the usual structural qualities, such as design for snow loads, wind loads, and earthquakes, the building has been carefully designed for proper heating and ventilating, acoustics, and maintenance of the unit. The heating system is designed to maintain the interior building temperature at 60 F with the unit not running and with an outside temperature of -50 F. Just as important as keeping the building warm in the winter is keeping it cool in the summer. With the JP200's immense heat rejection of about one million Btu's per hour and without proper ventilation, temperatures in the compressor building could reach 150 to 200 F, which could cause problems primarily with instrumentation and the human element. With this in mind, the compressor building has 250 sq ft of louver area feeding a natural draft ventilator on the roof, as well as four roof-mounted power ventilators, each capable of extracting 10,000 cfm. Both the fans and the natural draft ventilator are sized to permit a 15-deg approach between the temperature inside the compressor building and the ambient air temperature outside.

Acoustically, the building has been designed to reduce noise inside the building, as well as to
prevent noise escaping to the outside. This was accomplished by laying a 2 1/2-in. fiberglass friction-fit thermal insulation next to the exterior wall sheathing; a 1-in. fiberglass acoustic sheet is applied over the thermal insulation which is separated from the thermal insulation by a polyethylene vapor barrier. Finally, the acoustic insulation is faced with 20 GA aluminum with 1/8-in. dia holes on a 3/8- or 5/16-in. triangular pitch. Of course, the intake and exhaust on the unit are equipped with silencers.

In order to ensure ease and speed of maintenance, the compressor building has a large work area and is equipped with two cranes. The work area provided is 65 percent of the floor space in the building, the rest being taken up by the unit and its auxiliaries. This area is large enough to allow disassembly of the unit without having to remove sections from the building in the process. The two cranes provided, one 6-ton and one 15-ton, can reach any point within the building. Since the exhaust stack of the unit protrudes through the middle of the building, it was necessary to provide a special stack lifting mechanism, which will enable the cranes to pass through the stack. Two large overhead doors were provided in the side and compressor end of the building to allow truck entry and thus provide access to the cranes, for the delivery or removal of parts or pieces.

Other support facilities for the unit are contained in separate buildings on site. Fuel gas facilities are contained in a metering and regulating building. Heating facilities, the auxiliary power unit, compressed air, unit and station controls, the motor control center, and other associated equipment, as well as service areas,
as the rest of the station. Its source is
Each of these three main pumps is backed up by an
main hydraulic pump, the main seal and lube oil
driven off of the JP200 power turbine
Each of these three main pumps is backed up by an
main pipeline and all station high pressure pip-
droops below a certain value, the unit is shut
clear the compressor from the station piping are
The Alberta Gas Trunk Line specifies that
is quite satisfactory, as there is usually enough
time in the 4-hr period to allow for the restor-
a hydraulic system is utilized to drive
the lube oil cooler fans. The main hydraulic oil
driven off of the JP200 power turbine
In addition to the
main hydraulic pump, the main seal and lube oil
pumps are also driven off the JP200 power turbine.
the station requirements. The d-c backup system is not powerful
unit to sustain operation during a complete
component, such as chart drives and
timers, the a-c power comes from an inverter sup-
plied by the batteries. This arrangement enables
the unit to sustain operation during a complete
The batteries are sized to permit
shut the unit down. This objective, however, is
quite satisfactory, as there is usually enough
time in the 4-hr period to allow for the restor-
ament available to the dispatcher from the station
there are nine pieces of information
available to the dispatcher from the station
panel. Some of them are: station suction tem-
perature and pressure, unit suction temperature
and pressure, station discharge pressure, unit
speed, etc. This information is manipulated in
in the supervisory system computer to give additional
information for system optimization, computing
flows at various points, etc. Alarms are also
provided to the dispatcher, such that if any-
thing goes wrong, he will have enough information
to act in the proper manner. Because of the
limited space in the telemetering equipment, not
all shutdowns or alarms can be identified exactly.
However, these alarms are grouped according to the
seriousness of the matter. A warning alarm (high
lube oil temperature, high scrubber liquid level,
etc.) allows continued running, but indicates a
potential shutdown. A unit or station restart-
able shutdown alarm indicates to the dispatcher
that some condition has shut the station down but
is resetable. The dispatcher may reset the sta-
station, if the condition has cleared, and restart
it. If, however, a unit or station lock-
out alarm occurs, the station cannot be put back
on line until it has been reset locally after
clearing the shutdown condition.
The function just described was the station
on remote control. However, a selector switch on
the station panel can transfer this function to local control. On local control, all supervisory control functions to control panels are blocked out. On local, the operator may choose a manual station discharge pressure setpoint with automatic speed control or manual speed control as control functions.

The unit panel is part of the unit control section and contains all of the devices and circuitry necessary for start sequencing, stop sequencing, and operation of the unit. This panel is concerned solely with the safe operation of the unit and not with the overall operation of the station. In some respects, one might consider the unit control panel the slave controller in a cascaded control system. It contains the following: start/stop pushbuttons, auto/manual selector switch, start counters, speed control station, surge controller, vibration monitors, digital read-outs, an annunciator, a relay sequence logic system, etc. Most of this equipment is required by the manufacturer to run his unit; however, there are several features which Alberta Gas Trunk Line has ordered as maintenance tools. One is a provision in the circuitry which would allow calibration or replacement of certain devices required in the logic while the unit is running. This feature allows maintenance of these devices on a routine basis rather than having to schedule maintenance during shutdowns. Another tool, which has been added for maintenance, is a six-channel trend recorder. With this recorder, it is possible to select a variety of inputs, such as temperatures, pressures, or vibration levels, and record six of them at a time. It is anticipated that various critical parameters related to "aging" of the unit or its components will be recorded at regular intervals for periods of several hours to days. The graphs so obtained will then be compared with the mechanical condition over a period of time, and a preventative maintenance schedule for the particular piece of equipment will be determined. The recorder unit will also be used for spot checking for transients which might otherwise be missed if left unrecorded.

There are several sub-panels in the unit control section which act primarily as information gatherers and control dispensers. One such panel is the surge control panel. Here, process transmitters determine the differential pressure across the compressor and the flow through the compressor. This information is sent to the surge controller which interprets it as a point on the operating curve of the machine. When this point approaches the surge line, the surge controller causes the compressor recycle valve to open, and thus avert a dangerous operating condition.

Apart from these devices, there are many more locally mounted instruments, such as pressure gages, temperature indicators, differential pressure gages, and level indicators on the unit. All of these devices tell an experienced operator at a glance how his machine is running.

CONCLUSION

The continuing use of these technologically complex machines will promote a continuing refinement of the design of the compressor stations which utilize them. These refinements will be principally concerned with increasing the efficiency of the station while reducing costs and downtime.