

## Performance and Optimization Examples: Centrifugal Compressor

As part of our monitoring and field services, BETA can assist with performance assessments for rotating equipment such as gas turbine/centrifugal compressor trains.

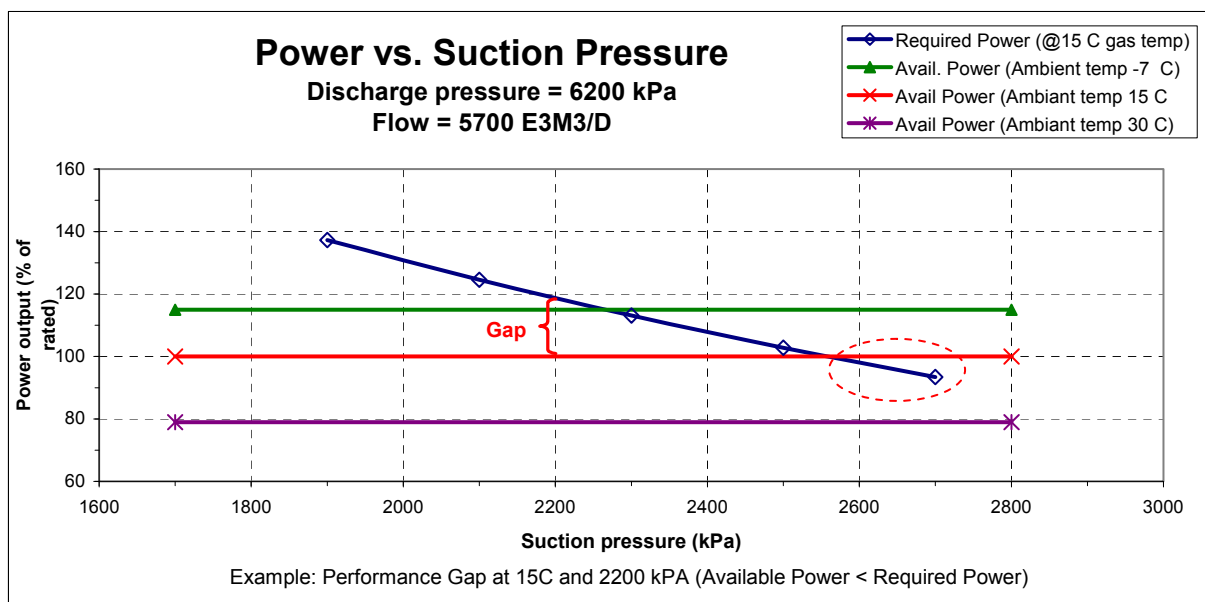
### 1. Centrifugal Performance Assessment: Changing Operating Conditions

This gas plant was planning to change the inlet gas supply volume. BETA was retained to evaluate the compressor's performance and determine if the unit could handle 35% increase in gas throughput.

Historical and current operating data were used in Beta's performance model to predict throughput and power requirements. It was found that the available engine power could handle the additional volume at certain operating conditions – and not at others. The key variables in the analysis were suction pressure and ambient temperatures.

As shown below, there is a gap between Required Power (for the compressor), and Available Power. The chart below compares compressor input power vs suction pressure, and examines 1 inlet gas temperature and 3 different ambient temperatures that occur at this Canadian location.

- At higher suction pressures and low ambient temperatures, the unit can handle the increased throughput (power output exceeds the required power. For example, at 15 C operation is possible above a suction pressure of 2550 kPa, in the area highlighted below (red oval).
- At other conditions there is insufficient power for the required load. This is illustrated by the gap between required power and compressor power output (see example at 15 C and 2200 kPa).



## 2. Should Turbo Expander Be Rebuilt? (Turbo Expander and Centrifugal Compressor Example)

For this midstream pipeline company, the customer was unsure if the turbo expander should be rebuilt. Would the improved performance (and economics) support the associated repair cost?

The process involves a turbo expander that compresses low pressure gas, which then feeds the centrifugal compressor. The turbo expander currently has a discharge pressure of 2100 kPa. A major overhaul of the turbo expander would increase the discharge pressure to 2460 KPA (which is the suction pressure for the centrifugal compressor). The benefit of this higher suction pressure is to improve the performance of the centrifugal compressor - decreasing the load and fuel requirements. The cost for this overhaul is \$150,000.

BETA predicted the reduced power requirements and reduced fuel consumption and evaluated the economics. As shown below, the overhaul would payout in 65 to 87 days – a very good investment.

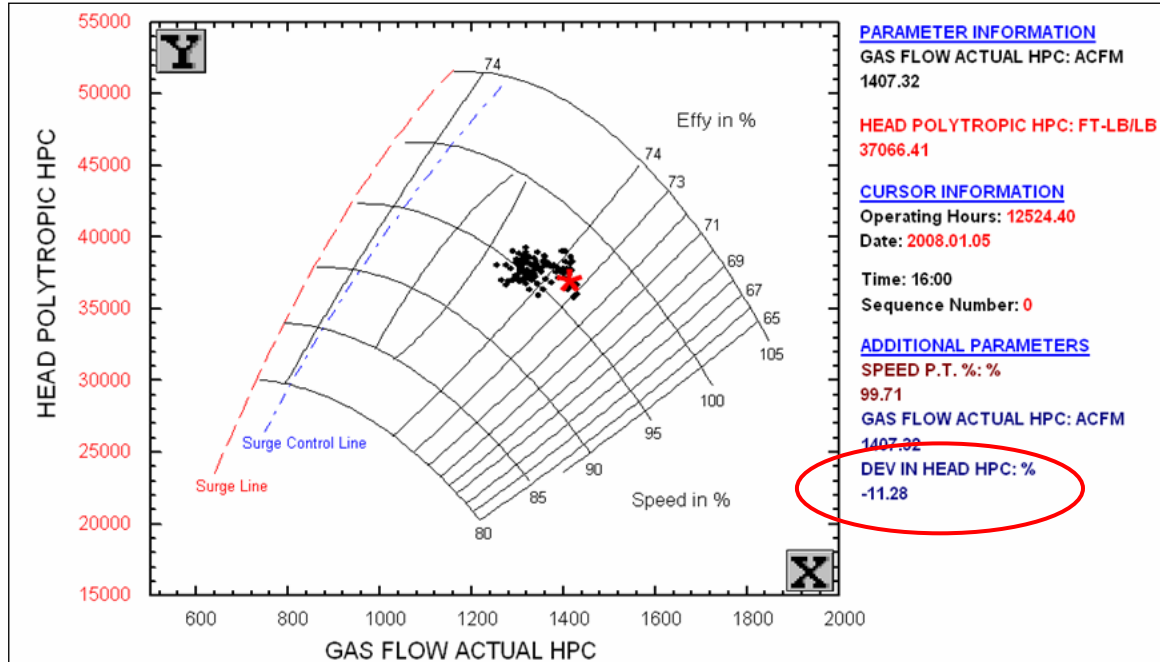
This table shows the centrifugal compressor performance results, including fuel savings (\$) for the typical discharge pressure (Pd), two flow rates (Q) – before and after the change in suction pressures (Ps).

|                                                   | Pd = 6200 kPa                            |                                          |
|---------------------------------------------------|------------------------------------------|------------------------------------------|
|                                                   | Q= 4250 e <sup>3</sup> m <sup>3</sup> /d | Q= 5700 e <sup>3</sup> m <sup>3</sup> /d |
| Before overhaul:<br>Power (Bhp) at Ps = 2100 kPa: | 11640                                    | 15611                                    |
| After overhaul:<br>Power (Bhp) at Ps = 2460 kPa:  | 9795                                     | 13136                                    |
| Power Savings from<br>overhaul (Bhp):             | 1845.0                                   | 2474.1                                   |
| Fuel Savings (MSCF/day):                          | 344.1                                    | 461.5                                    |
| Fuel Savings: (\$/day):                           | \$1,720.55                               | \$2,307.25                               |
| Fuel Savings (\$/year):                           | <b>\$627,999.69</b>                      | <b>\$842,147.58</b>                      |
| Payback on Investment (days):                     | <b>87</b>                                | <b>65</b>                                |

### 3. Centrifugal Compressor Performance Degradation

Centrifugal compressor performance is evaluated against the wheel curve baseline for this particular unit.

As shown below, this unit had an 11% deviation in head at the point shown, likely due to impellor fouling, impellor wear, and/or increased clearances.



BETA monitors the compressor’s performance to detect changes in performance. The wheel curve is one of our analytical tools that is tracked regularly.

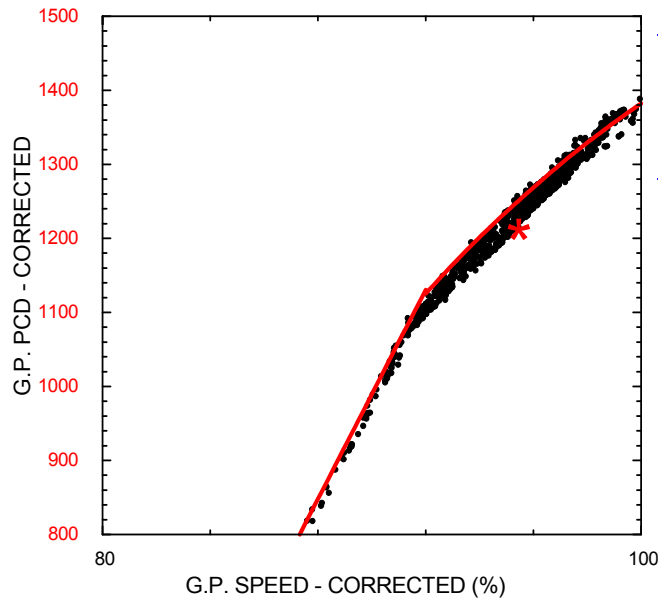
*Cash Flow Impact of Performance Deviation is about \$142,500/year.* This is based on 63 MMSCFD throughput and 325 BHP of extra power is required because of the stage performance degradation (measured as head deviation). Fuel gas costs are based on engine BSFC of 10,000 BTU/BHP-hr and fuel gas valued at \$5/MCF.

### 4. Gas Turbine: Impact of Improved Blade Wash

Turbine blade wash is a required maintenance activity. However, the operator will realize improved cash flow by optimizing the maintenance cycle for blade washing. Avoiding unnecessary blade washing improves capacity throughput, yet excessive delays will result in pressure deviation (lower performance).

BETA's monitoring identifies optimal maintenance cycles. Operating data from the turbine is collected daily and converted into normalized baseline curves (see figure at right). This baseline consists of normalized gas producer speed (horizontal) versus normalized compressor pressure deviation.

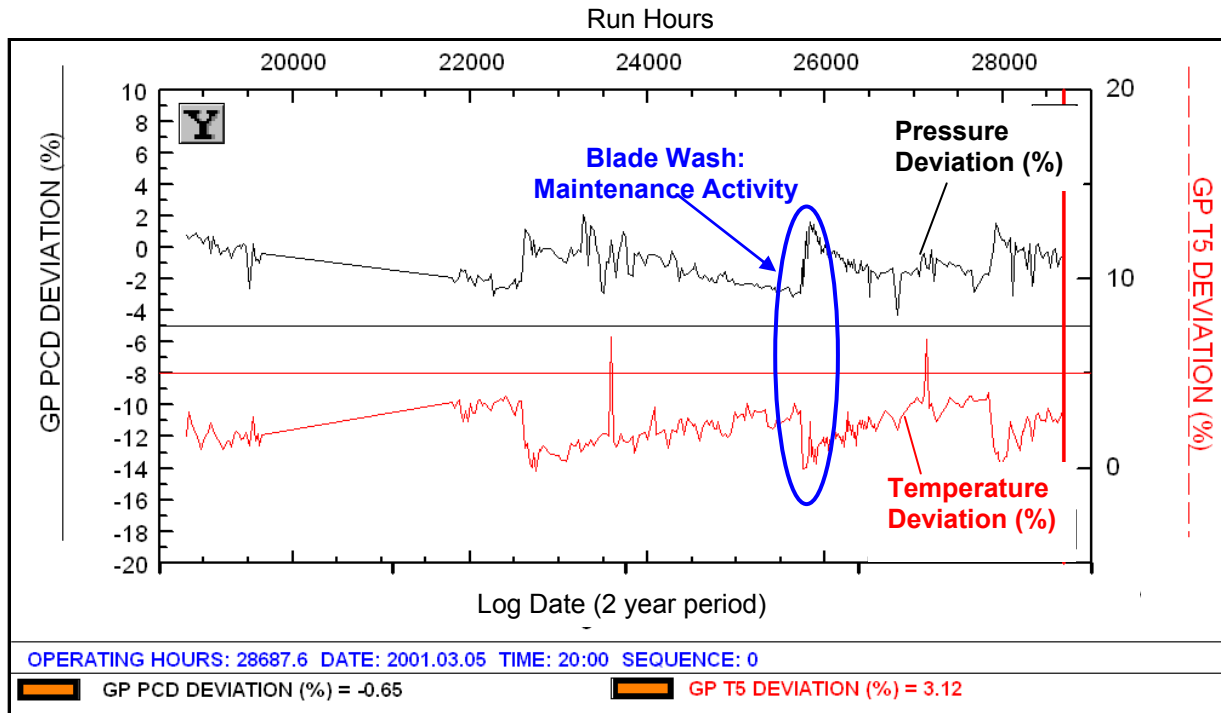
Deviations between current operating condition and the baseline curves are trended (see figure below).



The pressure and temperature deviation is used to determine the optimal maintenance interval. The figure below illustrates multiple blade washing activities. In each case the pressure and temperature is reduced. The deviation starts to increase until the next wash cycle.

**Impact:**

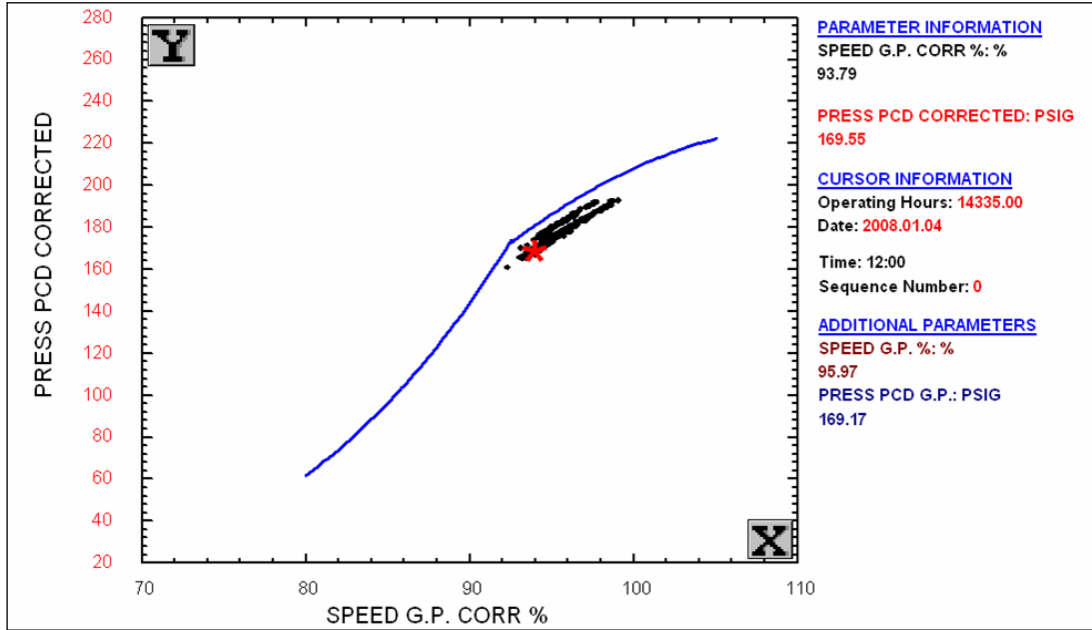
- Avoiding an unnecessary blade wash will result in reduced downtime and operating costs. The preserved production can represent hundreds of thousands of dollars in cash flow.
- On the other hand, decreased compressor efficiency causes increased fuel consumption and the resulting increased T5 temperatures can shorten component life. These factors also represent very large economic impacts.



### 5. Gas Turbine: Performance Monitoring (Identifies \$250,000 per Year Cost Saving)

Compressor discharge pressure (PCD) is a key factor in gas turbine performance. Beta’s MAO service determines the deviation in PCD from a baseline relationship with gas producer speed, N1. In the case shown here, PCD looks unremarkable, but the deviation in PCD tends to be jump between -7% and -3%.

The performance graph below shows the same behavior, with the operating points falling either 3% or 7% below the baseline.



The most likely cause of this problem is inlet guide vane linkage malfunction (looseness or “hanging up”).

**Impact:**

Measured fuel flow rate was about 10% higher at the increased PCD deviation condition. Under typical operating conditions for this unit, this represents incremental fuel valued at about \$250,000 per year, assuming \$8/MCF.

For more performance and condition monitoring examples, contact BETA’s application support team.