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Improve energy recovery in gas processing plants using an HPT

Utilizing this innovative technology can help realize substantial savings

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Throttling the high-pressure amine-rich stream in the contactor level control valve contributes significantly to economic loss in operating gas processing (GP) plants. To alleviate this situation, especially in larger plants, energy recovery turbines such as direct-coupled multistage reverse-running pump turbines and gear reduction connected high-speed single-stage turbines are used to recover hydraulic energy in the form of mechanical shaft power. This is transmitted to the motor/pump reducing the motor's net load. These turbines have significant operational drawbacks such as gas evolution in the impellers and limited capacity vs. efficiency downturn capability. Additionally, the turbine's initial capital cost and supported ancillary and control equipment are often quite high. Many of these units sit disconnected at the clutch from the motor they were designed to help.

An alternate to the traditional energy recovery turbine is an integral turbine driven pump called a hydraulic turbocharger (HTC). Its shaft is not connected to the high pressure charge pump and is able to operate at non-synchronous speeds, making it possible for single-stage high-efficiency design. Because the unit contains an integral pump section, the charge pump, motor and supporting electrical system can be substantially downsized. Thus its capital savings can offset some or all of its costs. Such a unit was installed at an amine GP plant owned by Duke Energy and located in Bishop, Texas. The hydraulic turbocharger (a modified HTC rated for GP service and called an HTP) is used to recover the waste energy in the amine-rich stream as it is depressurized from the contactor column.

Reverse osmosis desalination plants. The HTC has been used in over fifteen hundred installations in the reverse osmosis (RO) desalination industry. In an RO plant, membranes are used to separate salts from a sea water feed stream at high-pressure, typically around 800–1,200 psi. A portion, about 30–50%, is produced as potable water at near atmospheric pressure, while 50–70% of the feed stream is rejected by the membranes at approximately 25–50 psi below the feed pressure. Feed water from a motor-driven high-pressure pump is discharged at 680 psi where it enters the pump end of the HTC (Fig. 2). The pump impeller in the HTC further raises the pressure an additional 320 psi to 1,000 psi at the membrane. The high-pressure brine (about 975 psi) is depressurized in the HTC turbine section.

Mechanical energy produced by the turbine is transmitted to the pump impeller by a common shaft. Thus, the waste stream hydraulic pressure energy is converted to feed stream hydraulic pressure energy through two steps of hydraulic/mechanical energy interchange. The process is similar to using a reverse running pump turbine to unload a feed pump motor drive. However, there are important differences and advantages for the turbocharger in comparison to mechanical drive turbines.

High efficiency. The HTC is economical even at small capacities (40 gpm flow). High speed operation up to 40,000 rpm drastically reduces power-robbing wetted surfaces; a 100 gpm unit with a rotor diameter of 1.875 in. will display pump and turbine efficiencies in the 70–80% range at 2,000 ft, differential head drop on the turbine end and 1,000 ft head rise on the pump end.

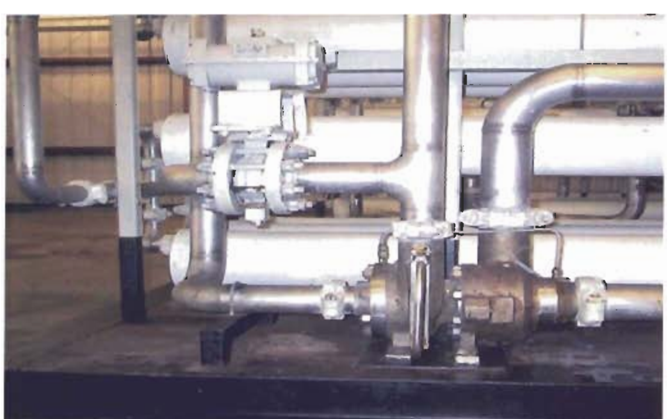

FIG. 1 Typical HTC installation in an RO application.

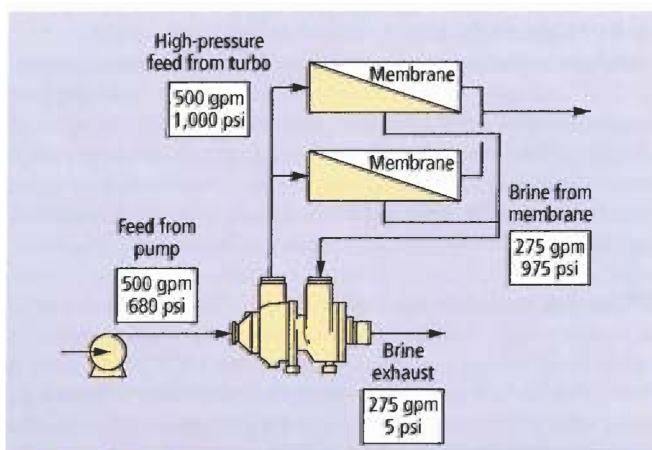

FIG. 2 HTC schematic in an RO system.

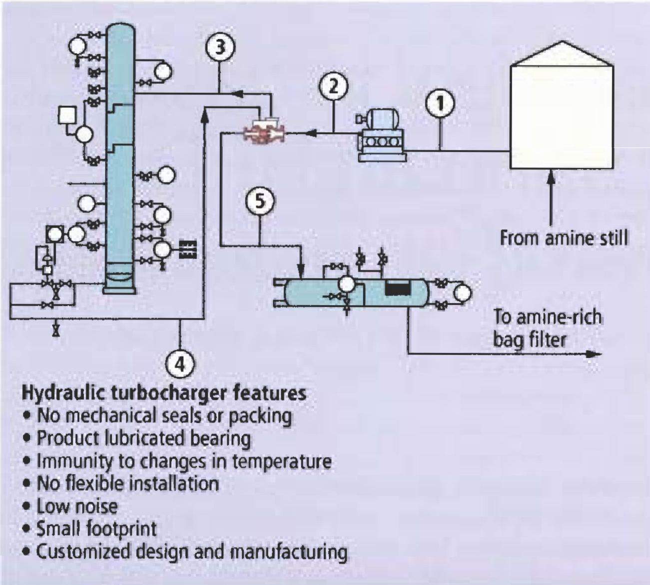

FIG. 3 HPT placement in the GP stream.

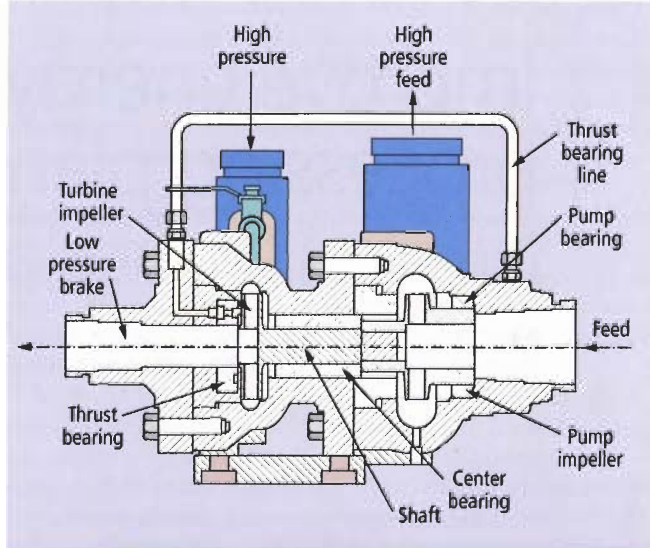

FIG. 4 HTC cross section.

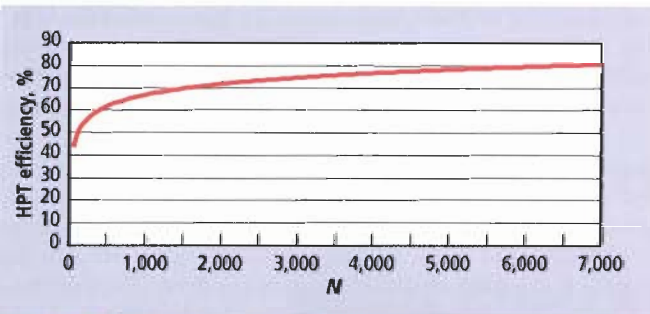

FIG. 5 HPT efficiency ratings.

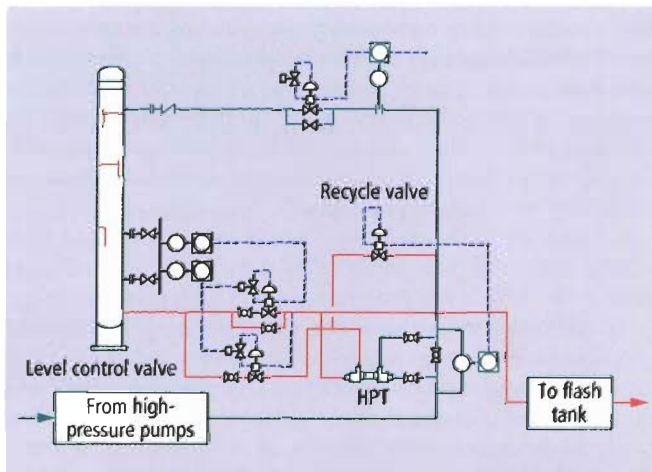

FIG. 6 Typical PID for turbocharger installation.

Reliability. With no shaft seals, the rotor is completely contained in the casing. Product lubricated ceramic bearings result in 50,000+ hour bearing life.

Easy to operate and control. A secondary, valve controlled, turbine nozzle provides variable pressure and flow to the turbine at near constant efficiency.

Motor driven high-pressure pump. This is downsized because the HTC contains its own highly efficient pump, and the feed pump pressure requirements are reduced by 45–65% or more in GP applications, thus allowing single stage centrifugal pump usage in many instances. This would be accomplished by reducing the number of stages in other applications and lowering stresses and improving positive displacement pump reliability and longevity.

HPT in gas processing. For a GP plant, the HPT placement in the process stream is illustrated in Fig. 3. The lean amine from the high-pressure charge pump is emitted to the HPT pump section where pressure is boosted for contractor admission. The amine, having absorbed various impurities in the gas stream, collects in the contactor column bottom, which is rich in amine. It then enters the HPT, where it is depressurized for further processing through the flash tank and reboiler. A liquid level control valve is placed between the contactor and turbine side inlet to aid in level control.

HPT features. The following properties are major components:

- No mechanical seals or packing
- Product lubricated bearing
- Immunity to changes in temperatures
- No expensive dry seals needed/no shaft penetrations
- Flexible installation
- Low noise
- Small footprint
- Customized design and manufacturing (Fig 4).

Calculating boost pressure. To apply HPT to any process system requires the turbocharger boost pressure to be known. The boost pressure is the differential pressure developed by the pump section of the turbo. Once this is known for all potential system operating regimes the high-pressure charge pump differential head can be determined.

FIG. 7 REDA pump installation at the Bishop facility.

FIG. 8 Control valve and thrust bearing filtration system.

FIG. 9 HPT in service at the Bishop GP facility.

The following formula is used to calculate boost pressure:

$$P_{Boost} = N \times (QT/QP) \times PT_{diff}$$

where:

N = Turbocharger hydraulic transfer efficiency = turbine end efficiency × pump end efficiency
QT = turbine flow
QP = pump flow
PT_{diff} = turbine differential pressure

For example: A 2,000 gpm capacity amine GP plant that has a 1,200 psig contactor pressure and a 50 psig flash tank pressure.

Since $QT = QP$ or nearly so, then:

$$P_{Boost} = .72 \times 1 \times 1150 \text{ psig} = 828 \text{ psig}.$$

The value for N is taken from the PEI hydraulic transfer efficiency chart (Fig. 5). Once the boost pressure is known, then the charge pump differential pressure is easily calculated by subtracting P_{Boost} and charge pump inlet pressure from the contactor pressure.

Pump differential pressure = 1200 psig – 828 psig – 25 psig = 347 psig

Note that a single stage pump would now be selected for the charge pump and that pump power is reduced from about 1,671 hp to about 505 hp.

HPT startup and control. Unlike an RO plant, where HTC startup occurs automatically and near instantaneously when starting the high-pressure pump, GP applications for HPT require additional considerations and equipment. In RO, the entire loop is incompressible liquid at essentially equal and relatively low-pressure (30–50 psi) when the high pressure pump is started. The HTC turbocharger comes up to speed nearly instantaneously as the system is pressurized by the high-pressure feed pump.

However, in GP, the rich and lean streams are somewhat independent of each other and pump and turbine performance are decoupled, at least until the contactor is in equilibrium. A different control scheme approach is required. For instance, the contactor may be at low-pressure when the amine system is started or it may be at operating pressure (500–1,500 psi) when started. In addition there may or may not be any amine in the contactor to operate the HPT at initial startup.

The Bishop plant's staff analyzed various starting scenarios in relationship to using a centrifugal pump as the high-pressure charge pump. A piping and instrumentation drawing (Fig. 6) was developed that allows turbocharger startup and control under all conditions.

The key component to system startup is the flow control valve (recycle valve). This is used on centrifugal pump driven amine systems to bypass flow directly from the turbocharger pump side to the turbine side, thereby providing the flow that will power the turbine on startup and create turbo boost pressure sufficient to charge the contactor during startup. A liquid level control valve was placed upstream of the HTC turbine side inlet and after the contactor. This valve allows for contactor level control.

Turbocharger process overview. The facility's normal operating pressure is 730 psi. The high-pressure liquids (amine-rich) in the amine contactor bottom serve as the hydraulic power for the HPT. During HPT operation the level control valve operates with a 50 psig delta to give 680 psi inlet pressure. The turbocharger exhausts the rich amine at 80 psi to the amine flash tank.

The mechanical energy generated by the turbine is transferred via a common shaft to the turbo pump's impeller where incoming lean amine is boosted from a 470 psi inlet to 792 psi discharge pressure. A differential pressure transmitter (DPT) measures the difference in pressure between the turbocharger's inlet and outlet. If the differential falls below the 320 psi setpoint, then the recycle valve will open to admit lean amine directly to the turbine thereby increasing flow and turbo boost pressure back to the desired level.

Operational results. The HPT turbocharger has produced the following results at this GP facility:

Capital cost savings potential. This site was a first-time HPT implementation, thus two 50% capacity pumps at full pressure and one 100% capacity at half pressure pump and an HPT was installed. Under non beta site conditions only the HPT and one half pressure pump would have been selected. In addition to pump, motor and supporting electrical system capital cost savings, designs exist that can eliminate the level control valve by properly sizing the multiport nozzles in the turbocharger (Fig. 7).

Energy savings. The HPT produces a 322 psi boost pressure at a 280 gpm flow rate. This equates to 52.5 fluid hp. At a 70% pump and a 0.93 motor efficiency, the total electrical power saved is 60.2 kW. The annual power cost savings would be 60.2 kW × 8,000 h (annual usage) × $.07/kWh = $33,712/year.

Maintenance factors and cost. Because the HPT turbocharger is equipped with ceramic bearings and ceramic-coated shaft-bearing surfaces, the time between overhauls should be 50,000+ hours. The REDA charge pumps should also benefit from the pressure produced by the turbo, meaning reduced seal box pressure; decreased axial load on the thrust bearing and a shorter stiffer shaft. Also, replacing worn parts such as casing and impeller rings and interstage bushings should be nearly halved in number and cost (Fig. 8).

What was gained. The amine GP facility at Bishop, Texas was retrofitted with new feed pumps and an HPT in an effort to reduce total life cycle cost for the high-pressure charge pump system. Because the HPT provides independent boost pressure, the REDA charge pump stages and the motor horsepower were reduced nearly in half (Fig. 9).

With the HPT operating, the high-pressure charge pump motor required 126A at 500V. When the HPT is not operating, two standby one-half capacity full pressure pump motors required a total of 266A at 500V. This represents a substantial and impressive 53% power and energy cost savings. The turbo has now operated for about eighteen months without incident or maintenance since startup. **HP**

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BIBLIOGRAPHY

Gopalakrishnan, S., "Power recovery turbines for the process industry." Third International Pump User Symposium, Houston, Texas.

Labonoff, V. S. and R. R. Ross, "Hydraulic power recovery turbines," *Centrifugal Pump Design & Applications*, Second Edition, Gulf Publishing Co. Houston, Texas, 1992.

Oklejas, R. A., "HPT for gas processing—technical and application manual," Pump Engineering, Inc., 2002.