PUMP AND COMPRESSOR OPERATION

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Summary

The proper operation of pump and compressor stations is important to ensuring pipeline capacity and efficiency. Much of the operation of these stations is automatic and little intervention by operators is normally required. An important function in modern pipeline technology is monitoring for abnormal conditions in order to anticipate and detect problems before they become serious. A good understanding of the operation of

all station equipment, particularly pumps, compressors and their drivers is fundamental to being able to carry out this monitoring. The following description of pump and compressor station operation is general in nature and, for specific pipeline applications, applicable company operating procedures and vendor manuals need to be consulted and used.

1. Introduction

Pump and compressor stations are not independent entities and should always be seen as a part of the total pipeline system. At the design stage, the best estimate is usually made as to their required operating conditions—that is, suction and discharge pressures, minimum and maximum flow, and fluid composition and properties. These often change during the life of the station, and result in less-than-optimum performance and efficiency. If the change is too large, it may be necessary to modify the pump or compressor internals to match the new requirements or to consider even more major modifications, such as adding a new pump or compressor.

A compressor or pump station consists of a number of units (driver and driven equipment) that are connected by piping and valves to the main pipeline. An example of a multi-unit compressor station with gas cooling and above-ground piping is shown in Figure 1.

Figure 1 – An Example of a Compressor Station

Liquid pipelines have terminals at each end of the pipeline, with tank farms to control the delivery of product into the pipeline and to manage batches where required. An example is shown in Figure 2. Note the pump station and loading facilities to the right of the tank farm.

Figure 2 – An Example of a Pump Station

2. Operation of Pump and Compressor Stations

2.1. General

There is a large variety in actual pump and compressor station design due to the types of drivers and driven equipment as well as differences in technology that is dependent on the age of the equipment and design practices. The overall design of a compressor or pump station is dependent on:

- BL Type, size, and configuration of drivers and pumps or compressors
- Climatic conditions, including temperature, humidity and airborne contaminants
- Location relative to support resources
- Regulatory, environmental and safety requirements
- Proximity to inhabited areas

Pump or compressor units may be configured in series, parallel or a combination of both. This will be the result of design decisions on type of driver, pump and compressor desired within constraints of available equipment and energy supply. If flow requirements increase, the addition of new units may cause additional challenges if, for example, a turbine/centrifugal compressor is added to existing reciprocating compression.

Many different combinations of drivers and driven equipment are used in pipeline operation (see Table 1).

Application	Driver	Driven Equipment	Comments
Mainline pumping	Induction electric motor-constant speed or VFD	Centrifugal pump	Most common size is 1 to 3 MW

General pumping	High/medium speed reciprocating engine	Centrifugal pump	Wide range from 500 kW to 10 MW
Lower volume pumping	Constant speed induction electric motor	Centrifugal pump	Up to 1 MW
Terminal boost pumps	Electric motor	Vertical centrifugal pump	Range up to 500 kW
Mainline compression	Gas turbine	Centrifugal compressor	Wide range from 3 to 25 MW
Mainline compression	Synchronous electric motor with VFD	Centrifugal compressor	Wide range from 10 to 30 MW
Mainline compression	Induction electric motor with VFD	Centrifugal compressor	Wide range from 1 to 15 MW
Mainline compression	Induction electric motor with VFD	Centrifugal compressor integrated with motor	Range from 5 to 22 MW, oil-free with magnetic bearings
High volume/low ratio compression	Slow speed reciprocating engine	Reciprocating compressor	Mostly legacy compressors
Lower volume/higher ratio compression	High/medium speed reciprocating engine	Reciprocating compressor	Range from 500 kW to 8 MW
Lower volume/higher ratio compression	Constant speed induction electric motor	Reciprocating compressor	Range from 500 kW to 8 MW

Table 1. Chart of Drivers and Driven Equipment Used on Pipelines

The most common driver for large pump and compressor units is the gas turbine. Electric motors are common for pump stations. For smaller pump and compressor units, the internal combustion engine is still a popular choice. The centrifugal compressor is widely used for pipeline compression due to its ability to handle large flows at a modest compression ratio. Where larger compression ratios are required, the reciprocating compressor becomes a viable option although multistage centrifugals are also a good choice. Likewise, centrifugal pumps are the most suitable and commonly used choice for liquid pipelines that carry light hydrocarbons. Where the viscosity is too high, rotary pumps may need to be installed.

Pump and compressor equipment are often placed in individual buildings for climatic, safety and noise reasons, but may be open to the environment where the weather allows it. Station and unit controls are placed in a separate building along with general support facilities such as backup power, main electrical panels, workshop space, inventory storage, and operations and maintenance staff offices. In addition to pumps and compressors, a pump or compressor station will normally include a number of other components and systems, including:

- Scrubber or inlet separator to remove liquids (compressor station only)
- Filter to remove contaminants (pump station only)
- Gas coolers (compressor station only)

- Heater and coolers (pump station)
- Fuel gas system to filter and heat pipeline gas used for fuel(compressor station only)
- Station flow measurement using a device such as an orifice
- APU (auxiliary power unit) for backup power
- Compressed air system
- Power gas system
- High voltage electrical system for electric motor drivers
- Electrical and uninterruptible power system (UPS) system
- Security system
- Building heating system

2.2. Unit Selection

The successful application of any pump or compressor unit is dependent on satisfying requirements related to desired performance, economic operation and expected equipment life. This requires a thorough understanding of various available designs, how equipment is rated and knowledge of trade-offs that might need to be made.

The selection of a pump or compressor unit for any specific application will depend on factors such as:

- Performance ratings and load cycles expected
- Installation requirements and constraints such as weight and size
- Configuration options
- Type of energy source available
- Maintenance support resources available
- Life cycle (capital, operating and maintenance) costs
- Noise and exhaust emission requirements

For a new pipeline, the complete range of equipment available can be considered, but for additions to existing systems, choosing equipment similar to that already installed is especially beneficial to operation and maintenance. Maintenance support should be taken into consideration before a final selection is made. This includes the availability of skills, spare parts and other support requirements. When selecting equipment, it is very important to consult with manufacturers on recommendations for proper application, rating and configuration of their equipment.

2.2.1. Driver Selection

The performance and range of power output required is the major factor in choosing a specific pump or compressor driver. The major choices are gas turbines, electric motors and reciprocating engines. Gas pipelines have traditionally used reciprocating engines and gas turbines because pipeline quality natural gas is a desirable fuel that delivers an efficient, economic and environmentally acceptable solution. Not many pump drivers use fuel from the pipeline itself, since it may not be of high enough quality or the use of batching results in unacceptable changes in fuel quality. This has resulted in the widespread use of electric motors on liquid pipelines.

Gas turbine characteristics include:

- For large horsepower applications the gas turbine engine usually has a lower installed cost than the reciprocating engine does
- Relatively compact and light in weight, which allows for modular construction
- Variable speed range for flexible operation

The gas turbine can operate from maximum rated power down to about 50% and efficiency is typically about 30 to 40%, somewhat less than can be achieved by reciprocating engines or electric motors. This makes it important to choose a gas turbine that will operate at or near its maximum power capabilities. Smaller gas turbines are less efficient, typically 25 to 40%, although waste heat recovery or combined cycle applications can be more efficient. Weight and size restrictions usually favor a gas turbine over other types of engines such as reciprocating internal combustion engines, especially for higher power applications. Aeroderivative engines normally provide the lowest weight solution.

Engines are usually used when electric power is not available or as a backup for electric power failure for pipeline pumps. Reciprocating engine driver characteristics include:

- Variable speed range for flexible operation
- High installed cost
- Relatively large size and heavy weight

Configuration options for reciprocating engines include whether the engine should be naturally aspirated (no compression of intake air) or turbocharged. A naturally aspirated engine is simpler but performance is affected by altitude and ambient temperatures. A turbocharged engine is less affected by these and also produces more power output. It does, however, require a more complicated turbocharger and after-cooler configuration.

Expected load cycles have to be carefully analyzed for their feasibility and impact on operation and maintenance. Many reciprocating engines can operate for periods at higher-than-normal rating or peak load but at the expense of increased maintenance effort (i.e., reduced maintenance intervals) and costs. Similarly, operation at light loading is possible but is not desirable for longer time periods since operation may be erratic and cylinders will be overlubricated.

Most internal combustion engines are available with low and high compression. High compression is restricted to high quality fuel whereas low compression is suitable for lower quality fuels and less stringent emission requirements. Most manufacturers have a method for calculating a fuel rating to ensure that detonation is prevented.

The most common pump driver is the electric motor. Electric motor driver characteristics include:

- Low installed cost
- High efficiency

- High reliability
- Flexible applications
- Clean, compact arrangement

The major choice for electric motor selection is whether to use a constant or variable speed motor. The variable speed motor provides more flexibility but at increased complexity for the electrical equipment and higher initial cost.

Most noise generated in a pump or compressor system originates from the driver. Any special noise limits must be specified. A usual noise limit of 85 to 110 is recommended. Additional sound insulation may be required for exhaust systems in particular if the site is close to an inhabited area.

2.2.2. Pump and Compressor Selection

Almost all pumps used for liquid pipelines are of the centrifugal variety. Required systems hydraulics will suggest the best configuration for the pump as to its capacity and number of stages. A preferred operating point is defined along with required variation in operating conditions.

For centrifugal pumps, brake power is the required power calculated for the rated conditions. Run-out horsepower is the required power calculated for maximum flow (the end of curve) conditions. It is generally preferred to have the pump able to handle the run-out conditions, but this can become expensive in larger sizes. Many users specify small (less then 75 hp) pumps be sized to meet run-out while the larger pumps use a 110% factor.

Inclusion of specific gravity in centrifugal pump applications should be remembered. The driver must be sized for the worst case, i.e., the lowest specific gravity. Also, viscosity corrections must be considered when selecting a suitable driver. Often the viscosity varies if batching is undertaken or during start-up. A trade-off is usually required to balance the driver size with start-up limitations. To allow future expansion plus inevitable condition changes in the field, it is generally recommended to size pump drivers conservatively. Field changes can become complicated and expensive if a new base plate, driver support or coupling is necessary.

Modern gas pipelines prefer centrifugal compressors for larger flow requirements, but reciprocating compressors may be more appropriate for smaller power output and higher compression ratio applications.

All installations should be checked to ensure that there is enough power to start the pump or compressor, although it is usually a concern for large drivers (usually over 200 hp). The pump-required power depends on whether the pump is started against a closed valve, a partially open valve, an automatic recirculation valve or an open valve. The driver characteristics need to be examined for off-design conditions such as a reduced voltage start in an electric motor situation.

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Biographical Sketch

Thomas Van Hardeveld has B.Sc. (1972) And M.Sc. (1974) degrees in mechanical engineering (fluid mechanics) from the University of Calgary, Canada and is a Professional Engineer in the province of Alberta, Canada.

He has experience in many aspects of the operation and maintenance of oil and gas equipment such as gas turbines, compressors, pumps and other rotating equipment with extensive experience in maintenance management of all types of equipment as well as reliability techniques and risk and integrity management. In addition to a long career with a major gas transmission company in Canada, he has been involved more than 20 years in international consulting and training activities in Pakistan, New Zealand, Kuwait, Thailand, Argentina, Trinidad, Mexico, Malaysia, Kazakhstan and the Middle East. This includes conducting training courses on pipeline operation and maintenance, compressors, gas turbines, maintenance management, maintenance planning and scheduling, Reliability Centered Maintenance and condition monitoring. He has conducted maintenance assessments, performed Reliability Centered Maintenance analyses, implemented condition monitoring systems and consulted on various aspects of rotating equipment operation and maintenance.

He is actively involved in standardization activities with the IEC/TC56 Committee on Dependability as a working group convener and chair of the Canadian committee for IEC/TC56 and was primarily responsible for a new standard on Maintenance and maintenance support that was published by the International Electrotechnical Commission in 2004. He has instructed for the SAIT Polytechnic locally and internationally. Recently, he co-authored a book on Pipeline Operation and Maintenance: A Practical Approach published by ASME Press.