Basic Guide to Pipeline Compressor Stations

By Saeid Mokhatab, Greg Lamberson and Sidney Pereira dos Santos

As natural gas moves through a pipeline, the pressure decreases due to friction of the gas along the pipe wall and the gas must be recompressed to maintain the flow. Gas compressor stations are installed at optimum locations along the pipeline as the load profile changes and are sized to sufficiently boost the gas pressure and maintain flow through the pipeline. Compressor stations may be small, situated on gathering lines (Figure 1) or laterals, or large on major trunk line transmission systems. However, all are built up from the same functional blocks of equipment. Each functional element (Figure 2) plays a role in the work of the station and the design and sizing of each is essential to the efficient and safe operation of the plant.

The functional elements include gas scrubbing and liquid removal, compressor and driver units, aftercoolers, pipes and valves. Controls — including Supervisory Control And Data Acquisition (SCADA) system, monitoring and data recording, alarms and shut down procedures, both routine and emergency — are an integral part of the station. Provision also has to be made for venting the compressor and driver housing and buildings, complete with ventilation and fire protection, and safety equipment.

The financial elements include cost-of-service calculations which include the installed cost of the equipment, fuel, maintenance and operating costs for the expected project life (typically 10 – 25 years). A risk simulated discounted-cash-flow (DCF), rate-of-return (ROR) method of investment (Santos, 2003) analysis is recommended. Fuel cost is the major item in this calculation and the projection for escalation is recommended. Fuel cost is the major item in this calculation and the projection for escalation is recommended. Fuel cost is the major item in this calculation and the projection for escalation is recommended.

Inlet Receiving

The gas in a main transmission line is nominally clean and dry while that in gas gathering lines may contain liquids prior to processing, but in all cases there can be entrained liquids during upset conditions.

The gas compressor station’s inlet receiving facilities consist of “pig” receivers and a slug catcher to remove large solid and liquid contaminants followed by filter coalescers to remove fine solids and hydrocarbon mist. A filter coalescer also cleans the gas in each fuel supply to the turbines and gas engines. Removed liquids flow to a hydrocarbon storage tank where they are separated by gravity and then transported by truck as saleable hydrocarbon liquid or disposed of as waste product.

Design Pressures

The design pressure for station gas piping should be at least equal the MAOP of the pipeline. For single-stage stations, the suction and discharge piping should have the same design pressure. For multi-stage stations, the suction piping design pressure should be at least equal the highest attainable suction pressure under all operating and startup modes, and the interstage and discharge piping design pressures should at least equal the maximum discharge pressure. Multi-pressure systems must be designed to ensure that each system is not over-pressured during normal operation and is protected to the appropriate pressure level during upset conditions.

It is a general rule to use design pressures to accommodate use of a standard ANSI Class rating for compressor station piping components. The cost to increase design pressure to a standard ANSI Class is minimal and will provide greater flexibility in future use of the equipment and materials.

Compression

The gas pressure in the pipelines is increased by a combination of one or more compressors connected in parallel or in series to the...
pipelines by the station piping. Typically for
mainline stations, gas turbine-driven centri-
fugal compressors are used as the base units to
compress the majority of the flow. These are
compressor drivers that are turbine engines
using natural gas for fuel.

Driver selection is based on detailed
analysis of the operating conditions in terms of
flow and pressure ratio needed by the pipeline
hydraulics. Frequently these conditions will vary
to accommodate all the expected conditions. From
transient analysis based on predicted ramp-p
flow profiles a set of values is defined that will be
used to pre-select compres-
sor units, depending on the installation layout,
whether series or parallel (Santos, 1997; 2004).

Typically the conditions for most mainline
stations will require compressors with one or
two stages, and the compressor design may
be of the overhung rotor or barrel design.
The determination of operating conditions and
hence the development of the compressor characteristics will have to take into account
the gas characteristics, suction and discharge
pressure, and suction temperatures, usually
involving equations of state for the particular
gas composition, and the process environment
(i.e., climate, altitude, location, etc.).

The pipeline and station designer will make
sure that the equipment selection and arrange-
ment including maintenance strategy and level
of availability will be subject to a feasibility
study (Santos, 2004).

Compressor power will be determined from
the compressor characteristics and thus the
driver BHP can be calculated. Driver selection
is principally influenced by energy consump-
tion (fuel used) and power capability to drive
the compressor. Since gas turbines do not come
in an affinity of ratings, it is usually necessary
to select the nearest match for power above the
maximum requirement. The optimum selection
of compressor and driver is a complex process,
involving much negotiation with the suppliers,
and is beyond the scope of this article.

It is recommended that all potential areas
of pipe stress be evaluated very carefully due
to the large temperature variations present in
compressor system piping and the stresses
occurring in large-diameter piping. Particular
care should be taken to ensure that pipe stresses
do not impart excessive forces on compres-
sor nozzles. Shaft misalignment with resulting
vibration and/or excessive wear can be caused
if high loads from the piping are transmitted to
the compressor case. Compressor manufactur-
ers will provide the maximum allowable loads.
A complete pipe stress analysis should be
performed on compressor gas piping systems if
operating temperatures are greater than 200°F.

Mostly in the case of a gas gathering system,
gas compressor station inlet receiving facilities
consist of pig receivers and a slug catcher to
remove large solid and liquid contaminants,
followed by filter coalescers to remove fine solids
and hydrocarbon mist to reciprocating compres-
sor cylinder and valves protection. A pig refers
to a device that is pushed by the gas through the
pipe either to clean the pipe of obstructive mate-
rial or inspect the pipe for defects (roundness or
thickness reduction from corrosion process).

A slug refers to volumes of hydrocarbon li-
quids and water that accumulate in the pipeline
as entrained liquids in saturated natural gas con-
dense. Slugs also occur from cleaning solutions
injected into the pipeline for integrity mainte-
nance pigging. Normal gas flow by-passes the
slug catcher to reduce pressure losses. Flow is
switched through the slug catcher for as-needed
use. Where liquid slugs may be received, the
station should include a slug-catch system
with adequate storage capacity for the largest
expected slug. Typical slug catchers are con-
structed of pipe and fittings and create a change
of direction of the gas stream, allowing dropout
of the liquid slug (Figure 3).

Some facilities, (e.g. gas-fired power plants)
use natural gas reciprocating booster com-
pressors. Turbine manufactures may require
carryover limited to 0.1 to 0.003 ppm (wt.)
range. A downstream coalescer filter will pre-
vent lubricating oil from compressor cylinders
affecting turbine integrity. Filter and turbine
manufactures specifications and also field
experience should be considered to guarantee
proper equipment selection.

The compressor foundation should also be
designed taking vibration into consideration.
Pressure drop in the compressor suction, interstage
or discharge piping system including scrubbers,
valves and related items in each system should be
no more than 3 psi per stage or system (excluding
coolers and any gas treating facilities).

Station Control

Control functions are typically based on
personnel safety, the operating parameters
of the station, and the types and number of
compressor units installed at the station.

Compressor station controls can be divid-
ed into two sections, unit control and sta-
tion control. Digital technology is now used
throughout both systems. The unit control
utilizes a microprocessor which will control
the turbine compressor unit to run to set
points under the direction of the operator or
the station control system. The set points can
be flow or pressure. Commonly, a flow or
suction pressure will be the control parameter
with discharge pressure and/or suction pres-
sure as overrides. The control protocol will
include limits to ensure safe operation. These
limits will include pressure and temperatures
on discharge and suction on the compressor
as well as speed and flow and pressure ratio
in relation to surge.

The unit control will monitor the compres-
sor operation to ensure that it will not run
into surge. If the operation of the compres-
sor nears the surge line, the unit control will
instruct the recycle valve to open and so
maintain safe operation. Should the recycle
condition continue for a time, and if coolers
are not provided in the recycle line or com-
pressor discharge, the unit will be shut down on
high discharge temperature.

In addition to control and safety, the unit
control will monitor key operating parame-
ters and provide video output on demand and
printout on a routine basis to provide a con-
tinuous record of operation. These readouts
and records can be used for troubleshooting
and maintenance. The station control system
will oversee the unit operation and also pro-
vide the interface between the operators and
the plant. It will provide video and print data
recording of all key station parameters. It has
become more common to operate stations and
units remotely from central dispatch stations
and the station-control systems will report to
the central station via a SCADA link.

The overall control of a major gas pipe-
line transportation system typically originates
from a central “Gas Control” office that is
remote from all of the compressor stations.
Gas control monitors flow measurement for
the total station throughput as well as each
compressor’s throughput and fuel consump-
tion. The programmable logic controller
(PLC) in each compressor unit’s control panel
communicates to gas control the operating
parameters for that compressor and the posi-
tions of the valves controlling the gas flow
through that compressor. This example sta-
tion offers redundant communication using
microwave, satellite, or conventional leased
telephone systems. This station is designed
for the option of completely unmanned oper-
ation by Gas Control. The PLC compressor
on/off operation, performance set points, and
all station-critical valves may be remotely
controlled. Gas Control may monitor all sta-
tion alarms and shutdowns.

Gas turbine-driven centrifugal compressor
unit panels typically include unit protective
functions, local and remote starting, auto-
matic unit valve operation and equipment
and process monitoring instrumentation. If
a multi-unit station is involved, a separate
station panel may be used to automatically
control station operation.

Acoustical Treatment
Noise is a significant environmental pol-
Site Selection

Site Selection is primarily defined from thermo-hydraulic simulation optimizing, fuel usage and transmission costs. Site selection depends upon pipeline hydraulic considerations and land availability. Consideration should be given to possible future expansion of the facility. Access to the station shall be granted at any weather conditions or climate. When it is not possible or feasible to locate adjacent to a public road, which may occur due to remoteness of the pipeline route, private roads are used, providing an agreement has been made with the property owners for ingress and egress.

Additional factors to consider in site selection include proximity to the connecting pipeline and avoidance of crossing pipelines, especially foreign pipelines; prior land use (soil contamination, archaeological history, wildlife habitat, etc.); soil conditions (load bearing and stability, fill materials); topography (required cut and fill, drainage); availability of required utilities (electric power, water, communications); and environmental permit and noise requirements - and if sour gas is present - the proximity to the public and prevailing wind.

Emissions And Environmental Rules

Equipment should be installed with provisions for containing leaks, spills and wash water as required to comply with federal, state and local regulations and permits. Tanks should be installed above ground unless specific conditions require burial, and in either case, must comply with all environmental regulations and state and local permits. For tanks that contain fluids potentially damaging to the environment, proper spill containment is included.

Compressor station reliability and availability are paramount to overall gas pipeline delivery dependability. Reliability considerations are incorporated into many areas of the facility. Some reliability considerations are listed below.

The total amount of installed compression (stand by units) must be more than the normal design requirement to allow for scheduled and unscheduled maintenance.

Spacing between compressors or compressor groups aims at preventing fire damage to one compressor from harming others and to ease maintenance work.

Using redundant and parallel filter coalescers prevents unexpected large amounts of contaminants from impeding the gas flow and allows filtration cartridge replacement without interrupting compressor operation.

Monitoring and trending of vibration, bearing temperatures, and other critical operational parameters by the compressor PLC identify service needs to prevent catastrophic equipment failures.

Maintenance systems should be developed to manage all aspects of maintenance prior to station startup.

All below ground steel pipe, conduit and structures are coated with a corrosion protective and electrically insulating coating. Additionally, steel pipe installed below ground is protected from external corrosion using cathodic protection.

Sufficient operational and capital spare parts inventories should be available based on reliability-availability-maintenance (RAM) analysis and life cycle cost considerations.

Equipment should be standardized as feasible to minimize spare parts requirements.

Good human factor practices should be used in evaluating access to and viewing of operating data, manipulation of controls, installation of isolation devices, and removal and replacement of equipment (e.g. equipment and personnel access and egress, lifting points, pull clearances, materials movement, etc.).

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REFERENCES


Santos, S.P., “Series or Parallel Arrangement for a Compressor Station – A Recurring Question that Needs a Convincing Answer,” paper presented at the Pipeline Simulation Interest Group, California, USA (2004).

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