July 2018
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COMPRESSORS

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1.0 SCOPE

This data sheet provides loss prevention recommendations for dynamic and positive displacement compressors. The recommendations are intended to prevent or minimize the effects of equipment failures, fires, and explosions involving compressor units.

Other data sheets that address specific compressor applications are:

- DS 7-35, *Air Separation Process*
- DS 13-26, *Internal Combustion Engines* (addresses integral engine-compressor units; reciprocating units)

For the purposes of this data sheet, a compressor unit includes the following sections: casing(s) and associated utility and support systems including lube oil, seal oil (when included), shaft couplings, shafts, increaser/reduction gears, intercoolers, separators, filters, etc.

1.1 Changes

October 2024. Interim revision. Minor editorial changes were made for additional clarity on surge system guidance.

1.2 Superceded Information

This data sheet incorporates and supersedes Data Sheet 7-95, *Compressors*, and Data Sheet 7-100, *Dynamic Compressors*, which have been retired.

2.0 LOSS PREVENTION RECOMMENDATIONS

Use FM Approved equipment, materials, and services whenever they are applicable. For a list of products and services that are FM Approved, see the *Approval Guide*, an online resource of FM Approvals.

2.1 Construction and Location

2.1.1 Locate oxygen compressors outdoors or in dedicated noncombustible buildings. Do not locate flammable gas compressors in the same building or area as oxygen compressors.

2.1.2 Locate flammable gas compressors outdoors or in open structures, such as a canopy. Where this is not practicable, locate flammable gas compressors in a building with damage-limiting construction in accordance with Data Sheet 1-44, *Damage-Limiting Construction*.

2.1.3 For compressors or associated process equipment exposed by an external supply of lube oil, support the compressor on a concrete or protected steel foundation.

2.1.4 For compressors with external supplies of lube oil, provide containment or emergency drainage designed to prevent lubrication oil releases from flowing to and exposing adjacent equipment areas. Design emergency drainage and containment systems in accordance with Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*.

2.1.5 Provide natural-draft ventilation in all buildings containing flammable gas piping by installing continuous-ridge or amply sized unit ventilators in the roof and louvers at the floor level.

2.2 Occupancy

2.2.1 Locate air compressor intakes away from sources of flammable vapor, gas, steam, dust, cooling tower exhaust, or other contaminants. Provide suitable intake-air filters to remove suspended solids.

2.2.2 Provide basements or below-grade spaces containing flammable gas piping with continuous positive ventilation of 0.5 cfm/ft^2 (0.15 m^3/min/m^2) of ceiling area. This ventilation is not needed where only welded piping is used (no leakage points such as valves, fittings, etc.).

2.2.3 Where flammable gas compressors are installed, provide grated tops with at least 50% open area for piping in trenches and tunnels. Alternatively, provide positive exhaust ventilation of 1 cfm/ft^2 (0.3 m^3/min/m^2) of ceiling area throughout flammable gas pipe trenches and tunnels located indoors.

2.2.4 Limit ordinary combustibles in the compressor area to the minimum required for routine operation and maintenance. Store oil, spare parts, filters, etc. in a separate storage room or warehouse.

2.3 Fire and Explosion Protection

2.3.1 Detection

2.3.1.1 Provide an FM Approved combustible gas detection system for flammable gas compressors (including natural gas compressors), designed as follows:

A. Establish alarm and trip “set points” below 25% of the lower explosive limit (LEL) of the fuel, and at least the lowest feasible gas concentration to avoid spurious trips.

B. Interlock the detection to shut down the compressor system upon reaching the trip “set point,” including closure of all inlet and discharge gas lines and opening of all blowdown valves in the compressor building.

2.3.1.2 Provide FM Approved flame or heat detectors arranged in accordance with Data Sheet 5-48, *Automatic Fire Detection*, for flammable gas compressors (including natural gas compressors). Arrange the fire detection system to shut down the compressor system upon actuation. Arrange all inlet and discharge gas lines to close, and all blowdown valves in the compressor building to open upon shutdown. This fire detection system is not necessary where automatic sprinkler protection is provided and interlocked to shut down the compressor system upon actuation.

2.3.1.3 Design detection systems to transmit an alarm to a constantly attended location.

2.3.2 Fire Protection

2.3.2.1 Provide fire protection based on the occupancy of the installed compressor, as follows:

A. For compressors installed for the purposes of refrigeration without external oil systems, refer to Data Sheet 7-13. For compressors with external oil systems, see Section 2.3.2.4(A).

B. For air separation compressors, refer to Data Sheet 7-35.

C. For natural gas transmission stations, refer to Data Sheet 7-107.

D. For liquefied natural gas, refer to Data Sheet 7-53.

2.3.2.2 For steam turbine driven compressors, provide fire protection in accordance with Data Sheet 7-101.

2.3.2.3 For gas turbine/expander, provide fire protection in accordance with Data Sheet 7-79.

2.3.2.4 For compressor installations not covered in Sections 2.3.2.1 through 2.3.2.3, provide fire protection based on the surrounding occupancy as follows:

A. For compressors with an external lube-oil system, design automatic sprinkler systems in accordance with Table 1.

Table 1. Sprinkler Protection for Compressors With a Lube-Oil Hazard

Response, Nominal Temperature Rating, Orientation	*K factor gpm/psi$^{0.5}$ (L/min/bar$^{0.5}$)*	*Density gpm/ft^2 (mm/min)*	*Demand Area ft^2 (m^2)*	*Hose Streams gpm (L/min)*	*Duration minutes*
SR/High/Any	≥8.0 (115)	0.3 (12)	4000 (370)	500 (1900)	60
SR/Ordinary/Any			6000 (560)		

B. Where sprinklers are not necessary for the compressor or lube-oil hazard, but are needed to protect another hazard in the area (e.g., the building or adjacent occupancy is combustible), design automatic sprinkler protection for the surrounding occupancy. At a minimum, design the protection for a Hazard Category 2 (HC-2) occupancy in accordance with Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*.

2.3.3 Oil Systems

2.3.3.1 Design and install oil equipment and piping to minimize chances of a break in a pipe or fitting, including the use of noncombustible system components, welded pipe fittings, proper support of piping and instruments, protection against mechanical damage, and other safeguards listed in Data Sheet 7-32, I*gnitable Liquid Operations.*

2.3.3.2 Where applicable, separate oil and steam lines from each other as far as practicable by distance or by noncombustible baffles to prevent escaping oil from contacting the hot pipe surfaces. Wherever possible, locate the oil piping below steam lines.

2.3.3.3 Insulate any surface with temperatures approaching the autoignition temperature of the lubricating oil to prevent ignition of escaping oil. Provide insulation that is impervious to oil or cover it with sheet metal.

2.3.3.4 Provide a means, in a safe location (accessible), for remotely stopping the oil pumping equipment during a fire or other emergency.

2.3.3.5 Provide hinged covers for oil tanks associated with seal oil for flammable gas compressors to minimize damage from an internal flammable gas-air explosion. Provide vents on the flammable gas seal oil system, flammable gas detraining tanks, with pipes venting to a safe location.

2.4 Equipment and Process Protection

2.4.1 General Compressor Protection

2.4.1.1 Inspect and clean process gas filters regularly to prevent clogging and reduction of flow. Contaminants in compressor gases cause excessive wear and erosion and contribute to the formation of hazardous deposits.

2.4.1.2 Provide pressure-relief devices on the discharge line between the compressor and any shutoff valves, between stages of compressors having two or more stages, on all pressure containers, air compressors, and positive-displacement compressors. Design and set pressure-relief systems per Data Sheet 12-2, *Vessels and Piping*, and/or Data Sheet 12-43, *Pressure-Relief Devices*.

2.4.1.3 Discharge vents (e.g., startup, de-inventory, purge) and pressure-relief devices to a safe location.

2.4.1.4 Provide a check valve in the discharge line of the compressor wherever backflow may result in damage.

2.4.1.5 Design, install, and perform in-service inspections for compressor piping systems per Data Sheet 12-2, *Vessels and Piping*. Of particular concern are piping joints at compressor nozzles.

2.4.1.6 Flammable Gas and Oxygen Compressors

2.4.1.6.1 Where applicable, provide dry-gas seal systems for dynamic compressors.

2.4.1.6.2 Provide a low-pressure interlock on the suction line to shut down the compressor if the suction pressure is below the minimum design operating conditions.

2.4.1.6.3 Vent piston-rod housings on positive-displacement compressors and the seals on dynamic compressors to a safe location.

2.4.1.6.4 For refrigerants and refrigerating systems, follow the guidelines outlined in Data Sheet 7-13, *Mechanical Refrigeration*.

2.4.1.6.5 Provide explosionproof doors on rotary-type positive displacement compressors.

2.4.2 Dynamic Compressor Safeguards

2.4.2.1 Table 2 is a list of protective devices, alarms, and trips that should typically be installed on dynamic compressors. Settings for alarms and trips should be as recommended by the compressor manufacturer.

Table 2. Summary of Recommended Alarms and Trips for Protective Systems for Dynamic Compressor

Protective Function	*Alarm*	*Trip*
Surge Protection	X	
High differential pressure across process gas inlet filter	X	**[1]**
Low process gas intake pressure for each stage	X	X
High process gas intake temperature for each stage	X	
High discharge temperature from each stage and/or compressor	X	X
High vibration (installed instrumentation)		X
High temperature in thrust bearings pads or high axial deflection (reduced thrust-bearing clearance)	X	[2]
High temperature at bearing oil drain or in journal bearing metal	X	**[2] [3]**
Bearings & Lube Oil System		
High differential pressure across lube-oil filter	X	
Low lube-oil pressure at lubricated equipment bearing	X	X
Low level in lube oil reservoir	X	
High oil temperature leaving oil cooler (to bearings)	X	**[3]**
Low lube-oil rundown tank level (gravity or pressurized tank)	X	
Seal Oil System (if system installed)		
High differential pressure across seal-oil filter	X	
Low seal oil pressure at equipment seal	X	
Low level in oil reservoir (if separate from lube oil reservoir)	X	
Low level for each seal-oil overhead tank or low seal oil differential pressure for each seal oil level.	X	X

Notes:
[1] A reduction in load or unit trip is acceptable depending on the process and operating limits, or a runback condition also possible. May result in collapsing ductwork, failing expansion joints, or FOD.
[2] Trip in accordance with standard operating procedure (see Section 2.4.2.6). An automatic trip is expected when axial clearances have exceeded limits designated by the OEM.
[3] In some cases, thrust trip may be interlocked to trip with a high Babbitt temperature alarm.

2.4.2.2 To avoid damage caused by surge, provide a surge protection system that includes surge detection and anti-surge control systems. The specific system design is process and OEM dependent. Surge protection lines should be directed to intrinsically safe areas for the process involved. The surge detection and anti-surge control systems should be functionally segregated to help prevent common point failures.

2.4.2.3 Provide lube-oil, seal-oil (if required) and oil-purification systems in accordance with the OEM’s recommendations. The lube and seal oil system may be combined or separate, depending on the application. These systems may service either a single component or a train of components. A compressor train includes components such as a steam turbine or gas turbine drivers, compressors, gearbox, coupling, etc. If there is a common lube-oil system for these components, ensure the oil and systems used are compatible with all of the components serviced.

2.4.2.4 Provide a separate source of oil for each train (or component) supplied.

2.4.2.5 Ensure the lube-oil system configuration, including electrical and mechanical support systems, are inherently resilient (i.e., no single failure can result in a loss of equipment lubrication).

2.4.2.6 Lube-oil temperature is a critical operating parameter and if the compressor operates for an extended period of time at elevated temperatures the bearings can be damaged. Provide high lube-oil or bearing metal temperature trips as follows:

A. For an attended unit: Provide an alarm on high lube-oil or bearing metal temperature and have a procedure in place for the operator to respond promptly to diagnose the source of the high temperature. If the high temperature condition cannot be corrected and the oil temperature reaches the design limit, direct the operator to trip the unit, or have the unit automatically trip when the temperature reaches the trip set point.

B. For an unattended unit: If the oil or bearing metal temperature reaches the design set point, have the unit automatically trip.

2.4.2.7 Units With Hydrodynamic Bearings

2.4.2.7.1 Provide a lube-oil system with redundant oil-supplies, including an emergency source capable of furnishing oil during a unit shutdown.Typical lube-oil systems are likely to include one of the following configurations depending on the OEM, the frame size, and the age of the system:

A. Two 100% capacity ac lube oil pumps and an emergency dc motor or steam driven pump.

B. A main shaft driven pump, one 100% capacity ac motor-driven auxiliary pump, and an emergency dc motor or steam driven pump.

C. Same as (B) except that, in place of the emergency pump, a gravity or pressurized drain tank (designed in accordance with OEM recommendations) is used for emergency backup.

2.4.2.7.2 If a dc emergency pump is provided, ensure the dc motor thermal overload protective devices are not wired to trip the motor, but only to trigger an alarm. In areas where the alarm only may not be possible, use the maximum amperage settings allowed. Provide an appropriately sized magnetic-type circuit breaker, not a fuse, for short circuit protection. Provide a dc emergency lube-oil pump motor starter that is fail-safe (deenergizes) upon loss of power; that is, automatically starts the pump when ac power is lost.

2.4.2.8 Units With Rolling Element Bearings

2.4.2.8.1 For units with rolling element bearings, provide the following:

A. Lube-oil supply pump and scavenge pumps

B. Chip detector(s) in either the bearing sumps or the scavenge lines to detect the presence of metallic wear products

2.4.3 Positive Displacement Compressor Safeguards

2.4.3.1 Tables 3a and 3b list protective devices, alarms, and trips that should be installed on all positive displacement compressors. Settings for alarms and trips should be as recommended by the compressor manufacturer.

Table 3a. Recommended Protective Devices, Alarms, and Trips for Reciprocating Compressors

Protective Function	*Alarm*	*Trip*
Reciprocating Compressor		
High vibration (installed instrumentation) **[1]**	X	X
High gas discharge pressure for each cylinder	X	X
High-temperature at compressor or stage discharge	X	X
High differential pressure across process gas inlet filter	X	
Cooling water jacket, high-temperature (if cooling jacket present)	X	X
Low lube-oil pressure downstream of pressure regulator	X	X
High lube-oil temperature **[2]**	X	X
Low level in lube oil reservoir	X	
Cylinder lube-oil, failure	X	
High Level in separator	X	X
Seal Oil System (if system installed)		
High differential pressure across seal-oil filter	X	
High or low seal oil pressure	X	X
High or low seal oil temperature **[2]**	X	X
High or low level in seal oil reservoir (if separate from lube oil reservoir)	X	
Low level for each seal-oil overhead tank or low seal oil differential pressure for each seal oil level.	X	**[3]**

Notes:
[1] Refer to Section 2.5.2.1 for additional guidance on unmonitored units.
[2] Trip in accordance with operational procedure (see Section 2.4.2.6).
[3] May not be required by OEM.

Table 3b. Recommended Protective Devices, Alarms, and Trips for Rotary Screw Compressors

Protective Function	*Alarm*	*Trip*
Rotary Screw Compressor		
Axial Position Movement	X	
Overspeed	X	X
Unit Shutdown	X	X
Operation of Spare lube oil/seal oil pump	X	
High winding temperature	X	
High vibration (installed instrumentation) **[1]**	X	X
High bearing temperature	X	
High inlet-air-filter differential pressure	X	
High lube oil filter differential pressure	X	
High-temperature at compressor or stage discharge	X	X
High gas differential pressure	X	
High thrust bearing drain temperature	X	
High temperature to compressor jacket (if cooling jacket present)	X	X
High Level in separator	X	
High or low lube-oil temperature **[2]**	X	X
High or low level in lube oil reservoir	X	**[3]**
Low coolant flow to compressor jacket (if cooling jacket present)	X	
Low lube-oil pressure downstream of pressure regulator	X	X
Low buffer gas pressure	X	
Seal Oil System (if system installed)		
High differential pressure across seal-oil filter	X	
High or low seal oil pressure	X	
High or low seal oil temperature **[2]**	X	
High or low level in oil reservoir (if separate from lube oil reservoir)	X	
Low level for each seal-oil overhead tank or low seal oil differential pressure for each seal oil level.	X	X

Notes:
[1] Refer to Section 2.5.2.1 for additional guidance on unmonitored units.
[2] Trip in accordance with operational procedure (see Section 2.4.2.6).
[3] May not be required by OEM.

2.4.4 Discharge Filters

2.4.4.1 Clean filters periodically to prevent oil accumulations, at a frequency no longer than that recommended by the manufacturer. Do not use ordinary steel wool or activated charcoal filters with air compressors that require oil lubrication because they are subject to spontaneous heating if contaminated by oily residues.

2.4.5 Separators

2.4.5.1 When an air filter/separator is specified by OEM, provide an alarm and differential pressure indicator across the filter(s).

2.4.5.2 Ensure that solids are being removed by an inlet separator and do not pass through the screw compressor. It is possible to damage the rotor, rotor housing, and oil pump due to the collection of particles in the discharge separator.

2.4.6 Intercooling Systems

2.4.6.1 Intercooling may be accompanied by condensing moisture in the working gas. If sufficient moisture accumulates in the gas-side piping of intercoolers it can be ingested into the compressor casing with damage to the rotor.

2.4.6.2 Provide drains for intercoolers, separators, and knock-out pots to draw off liquid. The drain may be automatic or manual.

2.4.7 Expanders

Refer to Data Sheet 13-3, *Steam Turbines*.

2.5 Operation and Maintenance

2.5.1 Operations

2.5.1.1 Operate the unit within the limits specified by the OEM. Ensure operations personnel have adequate knowledge of equipment operation and the ability to acknowledge adverse conditions to prompt a process of analysis and/or investigation for excursions of key operating parameters.

2.5.1.2 Monitor the gas properties to ensure it is delivered in accordance with the compressor manufacturer's recommendations for the unit.

2.5.2 Condition Monitoring

2.5.2.1 Vibration Monitoring

2.5.2.1.1 Where fixed vibration instrumentation is in place, have a visual check of the vibration readings at each bearing of a compressor/driver combination made at least daily. In applications that allow the exclusion of installed vibration instrumentation, have manual readings taken and recorded at all bearings at least weekly. Where continuous monitoring is in place to log data and trend conditions automatically, develop a baseline operating profile. Compare the results to process conditions to better understand loading and cycling profiles.

2.5.2.2 Performance Monitoring

2.5.2.2.1 Periodically evaluate the performance of compressors (other than plant or instrument-air) and analyze it for trends to determine unit operating deterioration. Plot flows and speeds, corrected for inlet temperature and pressure, and pressure-ratios on a compressor map. Trend surge-margins. Base the intervals between inspections on what is appropriate for the operating conditions from normal and upset conditions.

2.5.2.2.2 If performance (e.g., pressure-ratio at a given corrected flow) is deteriorated by 5%, or if the surge-margin drops below 5%, clean the compressor to help restore performance.

2.5.2.2.3 If performance cannot be restored, dismantle and overhaul the compressor at the next maintenance opportunity. Do not allow performance to deteriorate more than 10%. Keep surge-margin below values stated in OEM guidelines.

2.5.2.2.4 Base performance and surge-margin calculations on the inlet pressure, defined as downstream of the inlet filter if one is installed.

A. The condition of the inlet filter is important in avoiding axial-flow compressor blade failures. Monitor condition of the inlet filter by the differential-pressure sensor as recommended in Table 2.

B. If the alarm level established by the filter manufacturer is exceeded, clean or replace the filter as indicated.

C. Do not permit pressure drop through the filter to exceed 2 in. H_2O (0.5 kPa).

2.5.2.3 Testing of Emergency Lube-Oil System

2.5.2.3.1 If there is a separate emergency lube-oil pump in the system, test it in accordance with the OEM's recommendation but at least **quarterly**. If a unit is started at least once every quarter and part of the startup procedure is to test the emergency lube-oil pump, this is an acceptable alternative to quarterly testing.

2.5.2.3.2 Test and calibrate the pressure sensors in the system in accordance with the OEM's recommendation but at least **annually**.

2.5.2.3.3 Where gravity-type emergency lube-oil systems are used, test the tank low-level alarm at least quarterly. Possible ways of determining low-levels include pressure transducer, ultrasonic detection, RF, float, and manually sounding the tank.

2.5.2.3.4 For units that will run continuously for longer than the recommended test intervals, ensure the installation makes provision for the components of the emergency lube-oil system unit to be tested and/or replaced while the unit is in operation.

2.5.2.4 Lube- and Seal-Oil Testing

Establish an effective lube-oil system condition monitoring program that includes written documentation setting forth goals and requirements that are acceptable to the manufacturer for the compressor application, operating history, and the risk.

The basic elements of an effective lube-oil management, inspection, testing, and maintenance program include, but are not limited to, the following:

A. Provide purchase specifications with every purchase order for replacement oil.

B. Store replacement oil in properly identified, sealed containers. To prevent contamination, store oil in a clean, controlled environment.

C. Sample the replacement oil prior to use to ensure it is the specified oil and not contaminated.

D. Perform oil reservoir pre-closure inspection and sign-off to prevent debris from entering the oil system following any maintenance work and following refill. Follow OEM recommendations for startup of units as it relates to reservoir cleaning and screen mesh requirements.

E. Do an oil analysis two to four times annually, depending on operating conditions and history. Additionally, conduct an analysis prior to outage planning to obtain information pertinent to the outage. Using a qualified lab, analyze oil samples to detect the presence of excess moisture, metallic particles, and contaminants (including varnish if the operating conditions make this a concern). Trend conditions to identify ongoing issues.

F. If oil is to be recycled onsite during an outage, ensure provisions for the conditioner specify the oil used, the purity required, and the contaminants that could reasonably be encountered.

2.5.3 Asset Integrity

Establish a documented inspection, testing, and maintenance program to verify and maintain compressor unit integrity and reliability is in place that addresses the inherent compressor operating hazards and OEM guidelines. See Data Sheet 9-0, *Asset Integrity*.

2.5.3.1 Establish an inspection and cleaning program to keep safety devices, valves, and other compressor components in good condition and prevent formation of excessive deposits in the compressor system. Include cylinders, discharge valves, air piping, water jackets, receivers, intercoolers and aftercoolers, and air filters in the program.

2.5.3.2 Include the following actions in the inspection program:

A. Dynamic compressors: Inspect and refurbish the components of the surge control system, such as bleed valves and flow controllers, as required during every major dismantle or more often if operating conditions or history dictate but at least biennially. For hydraulically controlled surge valves, perform testing and trending of oil quality that can impact valve functionality.

B. Axial-flow compressors: Inspect and refurbish the variable-geometry stator vane system as necessary but at least every major dismantle. Inspect bushings for excessive wear, check links for distortion or cracks, inspect pins distortion and wear. Refurbish or replace parts as necessary.

C. For positive displacement air compressors, blow out piping receivers and aftercooler’s low points regularly to remove oil residues and sludge.

D. Shaft and coupling failures are a significant mode of failure in driver-compressor trains. Check the alignment of the compressor unit and attached components at every dismantle. Inspect shaft(s), bearings, coupling(s), gear(s), and associated compressor unit components and support systems as part of the inspection, testing, and maintenance program. Refer to Data Sheet 13-18, *Industrial Clutches and Clutch Couplings*, for additional loss prevention recommendations for couplings.

E. Inspect and clean intercoolers and aftercoolers in accordance with OEM recommendations or more often as monitoring of the temperature drop through the cooler indicates. Identify the nature of any deposits found on gas-side heat transfer surfaces and determine their source if possible. If hydrocarbon deposits are found, examine the compressor oil seals for deterioration.

F. Inspect and functionally test emergency isolation and check valves (manual, automatic, and/or remote manual operated) as part of the inspection, testing, and maintenance program. Completely disassemble and inspect the check valve in the compressor discharge line at every major dismantle but at least biennially.

G. Calibrate instrumentation associated with protective devices and inherent process or system components annually.

H. Inspect and maintain compressor piping, bolting and support systems. Piping supports should be inspected for cold and operational settings.

I. Inspect and maintain insulation systems, including corrosion under insulation where applicable.

J. Inspect compressor mounting/installation to address the service and process conditions.

K. Purge all flammable gas piping to a safe location with inert gas after completing any work on piping that may have admitted air.

2.5.3.3 Implement a robust foreign material exclusion program during all maintenance and inspection activities. For further guidance on foreign material exclusion, see Data Sheet 9-0, *Asset Integrity*.

2.6 Ignition Source Control

2.6.1 Install electrical equipment in flammable gas compressor buildings or areas as specified in Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*.

2.7 Operator Training

Refer to Data Sheet 10-8, *Operators*.

2.8 Contingency Planning

2.8.1 Equipment Contingency Planning

2.8.1.1 When a compressor breakdown would result in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable compressor equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

In addition, include the following elements in the contingency planning process specific to compressors:

A. OEM design information for the compressor and driver

B. Processes and procedures needed for removal, dismantling, transportation, availability, and installation of a compressor unit and/or components

C. Review of any service contracts with the OEM and/or vendors to identify the duration of delivery of the compressor unit and/or components. Review compressor repair/replacement options/sources strategy, focusing on rotors/impellers, blading and stationary elements.

D. OEM and/or third-party vendor review to determine the optimum spare part strategy

2.8.2 Sparing

Sparing can be a mitigation strategy to reduce the downtime caused by a compressor breakdown depending on the type, compatibility, availability, fitness for the intended service, and viability of the sparing. For general sparing guidance, see Data Sheet 9-0, *Asset Integrity*.

2.8.2.1 Routine Spares

2.8.2.1.1 Routine compressor spares are spares that are considered to be consumables. These spares are expected to be put into service under normal operating conditions over the course of the life of the compressor, but not reduce equipment downtime in the event of a breakdown. This can include sparing recommended by the original equipment manufacturer. See Section 3.1.3 for routine spare guidance.

3.0 SUPPORT FOR RECOMMENDATIONS

This data sheet address compressors, which are mechanical devices used to compress a fluid (gas or gas/liquid mixture) into a smaller volume, increasing pressure and temperature. Compressors take a mass of fluid through the inlet at initial pressure and temperature and increase that pressure and temperature, compressing the volume to the required parameters at the discharge.

Compressors are used for a variety of processes and/or services, such as process air or gas, process refrigeration, gas transmission and storage, gas separation processes, and general facility service air. They are also used to transport compressible fluids such as air, natural gas, oxygen, nitrogen, carbon dioxide, ammonia synthesis gas, propane, ethylene, hydrogen, and hydrocarbon mixtures.

There are many types of compressors and the one selected for a particular application depends on several factors. These factors include performance requirements (such as the type of gas being compressed), the flow rate (typically expressed in cubic feet per minute (cfm) or meters cubed/second [m3/s]), and the discharge pressure (typically expressed as pounds per square inch (psi) or kilopascals [kPa]).

Compressors are classified as either **positive-displacement** or **dynamic machines**. Figure 1 shows the main types of compressors.

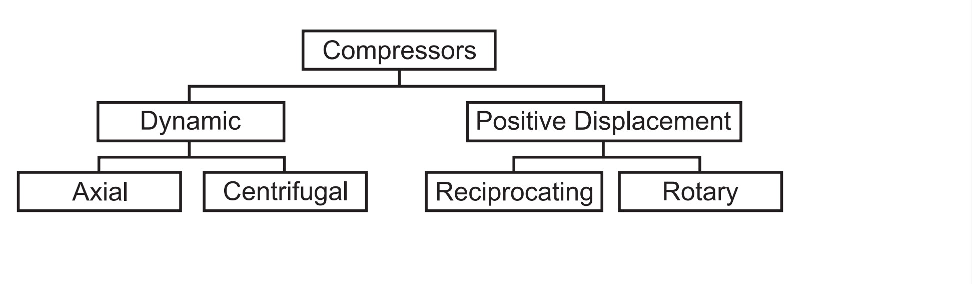

Fig. 1. Main types of compressors

Dynamic compressors, also known as turbocompressors, use centrifugal or axial force to accelerate the gas and convert the velocity of the gas to pressure. Centrifugal and axial-flow compressors are the main types of dynamic compressors.

In centrifugal compressors, the fluid flows radially through the compressor. The compressor impeller is used to force the fluid to the rim of the impeller, increasing the velocity. Stationary diffuser/guide vane/diaphragms between impeller sections direct and convert the velocity energy to pressure energy. Centrifugal compressors have lower volume (flow rate) and higher pressure ratios (discharge pressure/suction pressure) compared to axial compressors so they are used in applications where those performance parameters are required.

In axial compressors, the fluid flows straight through the compressor (parallel to the compressor shaft) through blade airfoils set in rows as pairs - One compressor (rotor) and one stationary (vanes). The compressor airfoils accelerate the fluid. The stationary airfoils turn and decelerate the fluid to prepare and redirect the flow for the rotor blades of the next stage. Axial compressors have higher volume (flow rate) and lower pressure ratios (discharge pressure/suction pressure) compared to centrifugal compressors. Axial compressors also offer a higher efficiency, speed capability and higher capacity for a given size compared to a centrifugal compressor. However, axial compressors have a relatively low pressure capability and a narrower operating range so they are used in applications where those performance parameters are required.

Positive-displacement compressors physically reduce the initial volume of the gas in a closed chamber to increase the pressure. These compressors may use screws, sliding vanes, lobes, gears, or a piston to trapping a set amount of gas and with each stroke force it into a smaller volume. The two main types of displacement compressors are reciprocating and rotary.

Compressor trains may contain several compressors along with drive unit(s), coupling(s), gear set(s) and clutch(s). These components are addressed in the following data sheets:

Drivers:

- DS 5-17, *Electric Motors*

- DS 13-3, *Steam Turbines*
- DS 7-101, *Fire Protection for Steam Turbines and Electrical Generators*
- DS 13-17, *Gas Turbines*
- DS 7-79, *Fire Protection for Gas Turbines and Electrical Generators*
- DS 13-26, *Internal Combustion Engines*

Other components:

- DS 13-7, *Gears*
- DS 13-18, *Industrial Clutches and Clutch Couplings*

3.1 Equipment Exposures

Mechanical breakdown is among the leading causes of compressor failure that can lead to fire and/or explosion following the breakdown. The scope of an asset integrity program, condition and performance monitoring of operating conditions that can be used to determine inspection, testing, and maintenance intervals and remaining life assessments and adequately sized, installed, and maintained safety devices are key to maintaining compressor integrity and reliability. The asset integrity program should be developed and implemented to ensure the compressors are maintained in suitable condition for the intended service throughout the design life, based on the OEM's parameters and operating experience. This program is an essential strategy for operational integrity.

Compressor performance-based monitoring analysis takes into consideration the following parameters as compared to OEM guidelines for the operating range based on the machine's design and properties of the gas properties being compressed:

- Inlet (suction) temperature and pressure
- Discharge temperature and pressure
- Compressor speed
- Mass flowrate
- Differential pressure and temperature across the machine
- Atmospheric pressure
- Relative humidity and wet bulb temperatures

These properties determine the mass flow through the machine. This is based on volume, flow, pressure, and temperature readings, gas properties and conditions and the work/power required to produce the required head to determine efficiency and surge margins for comparison to the compressor performance curves.

Compressor condition-based monitoring focuses on vibration, temperature, pressure, auxiliary conditions (lube, control, seal oil) and associated process control and safety device integrity.

Routine evaluation of these parameters for trending will provide indicators of potential operating problems that can lead to a breakdown and provide input on the scope and interval for the inspection, testing, and maintenance program.

Adequacy of safety devices to protect the compressor from operating exposures as identified in the review of process hazards is also essential to reduce the consequence of a compressor breakdown. The integrity of the devices to function properly when called upon will help reduce the consequences of a process upset resulting in equipment damage and business interruption.

3.1.1 Dynamic Compressor Hazards

3.1.1.1 Loss of Lube and Seal Oil Systems

The lube-oil system is designed to supply filtered lubricant at the proper pressure, temperature, and viscosity for the operation of the compressor unit or train; therefore, a loss of lube oil and/or seal oil could cause severe damage. Loss of lube oil would prevent the absorption of heat produced by the bearings, and could terminate the supply of oil for the seal- and control-oil systems (if equipped), putting the machine in an off-normal condition.

3.1.1.2 Journal Bearing Wiping

There are many causes of journal bearing wiping. Breaking of lube lines, pump failure, blown seals, and dirty filters resulting in insufficient lube oil to the bearings are contributing factors. A major cause can be loss of normal and/or emergency oil pump operation.

3.1.1.3 Thrust-Bearing Wiping

Some of the causes of journal bearing wiping, such as lubrication deficiency and absence of emergency supply of oil during an upset in the main supply, also apply to thrust-bearings. Another cause of this type of failure is packing or seal deterioration, especially in multi-stage compressors.

Labyrinth seals are used between stages to prevent back-flow from the inlet of a stage to the discharge side of the preceding stage. An additional function is to balance the overall thrust load on a compressor (as a result of the increase in pressure through it) between the rotor and the stator. These seals are subject to various forms of deterioration, such as erosion, rubbing wear, corrosion, fatigue due to vibration, and they can break up to the extent that they no longer seal properly. When this happens some of the load on the stationary diaphragms is transferred to the rotor. Compressor rotors are usually very delicately positioned by means of the balance piston. A relatively small transfer of load from diaphragms to rotor may represent a large increase in rotor thrust and cause the oil film at the thrust-bearing to break down. When this happens, the thrust collar may rub through the Babbitt on the thrust-bearing pads into the backing metal. The rotor will shift forward and the impeller may rub against its shroud.

It is, therefore, essential that packings be maintained in good condition. Fortunately, excessive packing wear can be detected by monitoring the performance of the compressor; this being one of the items that can be the cause of a reduction in efficiency, flow, or pressure-ratio, at a given rpm or input shaft horsepower.

The labyrinth seals at the balance piston are of even greater importance in preventing thrust-bearing failures. However, they are usually easily accessible and can be inspected without opening up the compressor and, therefore, they are rarely involved in failures. Surge is another cause of thrust-bearing failures.

3.1.1.4 Impeller Blade or Vane Fatigue (Centrifugal)

Impeller blade or vane failures are almost always due to high-frequency fatigue, which in turn is due to resonant vibration.

A condition of resonance exists when the natural frequency of a vane coincides with the frequency of a potential excitation source. Potential exciters of impeller vane vibration are the harmonics in the variations of velocity or pressure around the flow path.

Ideally, pressure or velocity of the flow entering an impeller stage would be uniform (i.e., there would be no flow distortion), but a vane would encounter average conditions as it rotates through one revolution of the rotor. However, there is always some distortion, which can be represented as a non-uniform velocity around the flow path from 0° to 360°.

3.1.1.5 Blade Failures in Resonant Vibration (Axial)

Blade failures are the most common type of failures in axial-flow compressors given the higher volume (flow rate) and lower pressure ratio (discharge pressure/suction pressure) design as compared to centrifugal compressors. The most common cause of such failure is resonant vibration, where the dynamic forces on the blades coincide with the blade’s natural frequency beyond design limits.

3.1.1.6 Blade Failures in Flutter (Axial)

Flutter is an aero-elastic instability in which aerodynamic forces deflect a blade, and the blade deflection in turn changes the aerodynamic forces in a direction that makes them more severe. This has a bootstrapping or “negative damping” effect, and if unchecked the blade amplitude can build up to a destructive value. Flutter is a problem that affects all types of airfoils. It is sometimes referred to as “self-excited vibration.”

When a gas flows over a body such as an airfoil, vortices of the type shown in Figure 2 are developed in the wake. The vortices are alternately clockwise and counterclockwise. They are shed from the airfoil in a regular manner, and they produce alternating sidewise forces acting on the airfoil.

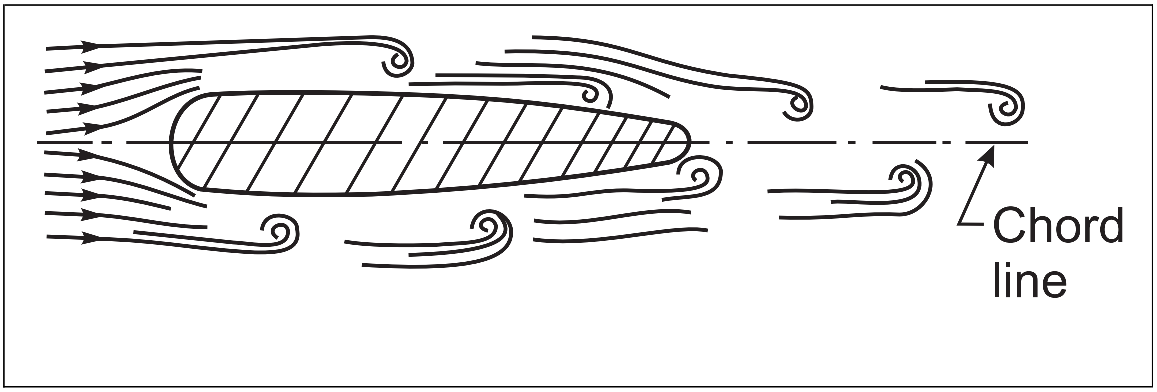

Fig. 2. Vortices acting on an airfoil

3.1.1.7 Shaft and Coupling Failures

Most failures of shafts and couplings are due to bearing offset misalignment between the driver and the driven compressor. This includes both high-cycle fatigue failures and cracking of shafts and couplings and severe wear of gear teeth in splined couplings. In the latter category is the type of wear known as “worm-tracking.” There is typically no warning of failure due to offset misalignment unless adequately monitored by vibration analysis. See Data Sheet 13-18, *Industrial Clutches and Clutch Couplings*.

3.1.1.8 Surge

Surge is behavior in axial and centrifugal compressors in which the pressure at the compressor inlet drops to the extent that the flow through the compressor reverses. For surge to occur the inlet flow is reduced to the point where the compressor head cannot overcome the discharge pressure. This results in flow instabilities, causing reversal of flow in the compressor, significant reduction in discharge pressure and increase in internal temperatures. The resulting axial forces/stress on compressor internal and external components, including impellers, blades, vanes, shafts, bearings, housings, casings and piping systems can result in component damage and failures. The increased internal temperatures can result in rub damage due to different expansion rates of the compressor components.

Surge can be avoided with properly designed control systems. These systems prevent compressor operation in unstable ranges where damage can occur. Surge avoidance (“anti-surge-control”) consists of a recycle loop that can be activated by a fast-acting valve (“anti-surge valve”) when the control system detects that the compressor is approaching its designed surge limit. The anti-surge valve recycles gas from the discharge to the suction when low flow is detected. Typical control systems use suction and discharge pressures and temperatures, together with the flow through the compressor to calculate the relative distance (“turndown”) of the present operating point to the predicted or measured surge line of the compressor. The surge control system must protect the compressor without causing fluctuations or disruptions in the process. Control system sizing must account for both steady state operations to meet process demand requirements (including normal startup and shutdown) and emergency shutdown conditions where reducing the pressure differential across the compressor to an acceptable range is required.

Surge systems require adequate inspection, testing and maintenance to verify operational integrity. Performance deterioration of the compressor should be corrected before it becomes excessive, since a deteriorated compressor may have a reduced surge margin.

3.1.1.8.1 Surge Hazards in Centrifugal Compressors

In centrifugal compressors the impellers act as the rotating aerodynamic components. A significant hazard from surge in centrifugal compressors is the impeller inlet and outlet surfaces (shrouded impellers) and blade surfaces (open impellers) are subjected to large stresses. These forces can cause impeller cracking and fracture, damaging internal components.

3.1.1.8.2 Surge Hazards in Axial-Flow Compressors

Axial compressors are designed to a certain airflow and blade velocity. Surge in axial compressors results in flow instability in the blade rows and is characterized by high-speed reversals of flow. At a given rpm, reversal occurs at low flows and may originate about midway along the compressor (i.e., the blade row that first becomes unstable is usually not in one of the early stages).

A significant hazard from surge in axial-flow compressors is that the blades are subjected to oscillating forces and deflection stresses which can cause blade cracking or failure and/or contact with the preceding row of stator vanes. This phenomenon is known as “clashing,” and it is characterized by distinctive triangular imprints of the rotating blades on the stationary vanes at their outer ends. This can result in blade liberation and the resulting upstream and downstream damage.

3.1.1.9 Control Systems

To maintain operating conditions within compressor/process design ranges, a control system is provided for monitoring operating parameters and to administer adjustments of variable inlet guide and stator vanes. In addition, the system provides cooling bypass between inlet and discharge blow-off, as well as speed variation control. Surge avoidance is provided via control systems as described in Section 3.1.1.7.

3.1.2 Positive Displacement Compressor Hazards

Of the different positive displacement compressor configurations depending on the service requirements, reciprocating and rotary screw compressors are among the most common and are also loss leaders.

Reciprocating Compressors (Diaphragm, Single/Double Acting)

Large, reciprocating process compressor (vertical in-line and/or balanced opposed) inherent hazards focus on the integrity of internal components, including crankshaft, piston/piston rods/rings/crossheads, bearings, seals and valves. Depending on the design for the intended service, these compressors can be lubricated or be equipped with oil free compression.

Rotary Compressors (Screw, Vane, Lobe, Scroll)

Screw compressor inherent hazards focus on the integrity of intermeshing (without contact) screw rotors, associated bearings, seals and shafts.

3.1.3 Routine Spares

The following are common routine spares for compressors. Store and maintain the routine spares per original equipment manufacturer recommendations to maintain viability. Refer to Data Sheet 9-0 for additional guidance.

Depending on the type of compressor, compressor breakdown exposure, criticality to the process and OEM recommendations, common routine spares can include the following:

- Gears, seals, and bearings
- Couplings
- Pistons/rods (reciprocating)

3.2 Facility Hazards

The fire and explosion hazard potential of a compressor installation is a function of the size and type of compressor, driver, lubrication system, and the type of gas being handled. Other important factors are the temperature and pressure of the gas being handled and external exposures to the compressor system.

Fire and explosion losses occur more frequently with positive displacement compressors than with dynamic compressors, but the associated damage is usually less severe. This can be attributed to the fact that failure of positive displacement compressors is generally credited to an electrical failure, overheating of lube oil or motor, failure of a pipe or similar component, or the physical size is usually smaller.

Conversely, fire and explosion events involving dynamic compressors are usually preceded by a severe mechanical breakdown. The ensuing fire or explosion can damage the surrounding equipment and building which could require replacement of the compressor rotor and/or ancillary components. This also drives the associated business interruption, given the long lead times associated with replacing dynamic compressors and associated equipment such as turbine drives.

With regard to sprinkler protection, the presence of automatic sprinklers is a clear positive factor in limiting fire losses. FM loss history shows that the average property damage for positive displacement compressors where sprinkler protection was not provided was approximately four times more than sprinklered positive displacement losses.

Given the significant mechanical damage that often precedes dynamic compressor fires, the impact of sprinklers on this type of equipment is less quantifiable. Focusing on mitigating the loss drivers (mechanical or electrical breakdown) will help reduce fire/explosion following losses. In addition, automatic sprinkler protection serves to limit the ensuing fire damage.

3.2.1 Internal Fires and Explosions

Internal fires in centrifugal air compressors usually occur as a result of leakage of oil from bearings or from the seal-oil system in the case of high-pressure units. This oil may form carbon deposits on intercooler tubes, cutting down the heat transfer to the cooling water. Eventually the cooling effect may become so reduced that the air becomes hot enough locally to permit spontaneous ignition of the deposits, even though the average temperature of the intercooler may not appear dangerously high.

A fire or explosion can also occur, under the right conditions, within the compressor itself. This seems to be associated with a reduced auto-ignition temperature for oil entrained in air in the form of mist at the higher pressures. This process may be enhanced by frictional heating of the oil mist as it is pumped through the impeller.

Regarding positive displacement compressors, air compressor explosions and fires originate from oil and carbon deposits in the compressor systems.

Excessive deposits in the system are the result of over lubrication, use of unsuitable lubricants or dirty or chemically contaminated suction air.

The above hazards can best be avoided by a combination of maintenance practices. Lube- and seal-oil consumption should be monitored and action taken to refurbish and repair bearing seals if an otherwise unaccounted-for increase in consumption is detected. Intercoolers should be rodded or chemically cleaned at regular intervals. If carbon deposits are found, the compressor seals should be examined for deterioration. Discharge temperature instrumentation should be well-maintained and in good calibration and trips and alarms should not be permitted to be inoperative.

In the case of seal-oil systems, protection should be provided against low pressure-differentials as well as against high values. Low differentials may imply excessive seal oil flow into the compressor.

A number of fires have occurred in oxygen compressors. In these compressors the only realistic source of fuel is the metal of the impeller. The oxidation may be so intense that a complete impeller may be consumed.

While in some cases the causes may have been the same as described above in connection with air compressors (i.e., oil mist and carbon deposits), in other cases there seemed to be different causes. In one case, a shower of sparks was seen at the compressor just prior to the fire. Thus, ignition may have been the result of a severe internal rub following a spark-producing thrust-bearing failure. Another incident also involved a severe thrust-bearing failure.

3.2.2 Oil System Hazards

Severe oil fires have resulted from mechanical failures caused by surge, excessive vibration/thrust, misalignment, and other mechanical failure mechanisms on the compressor train, causing the oil piping to fracture and release oil under pressure. When these oil fires occur in a building, heat and smoke will interfere with effective firefighting. The result can be extensive physical damage to the building and equipment and prolonged business interruption.

In addition to the lube-oil fire hazard, there is a possibility of over-pressurizing the oil reservoir through the seal-oil system. However, units equipped with dry gas seals may have fewer issues with the duration of oil fires versus seal-oil systems because the seal oil must remain in service until the process gas pressure is reduced.

The fire hazard associated with external oil systems can often be mitigated by shutting off pumping systems quickly in the event of a release or fire. Rundown times for compressor trains are typically short in duration (depending on the system design). If the oil release is limited, the presence of basic sprinkler protection will serve to control the fire and limit fire spread, but the size of both the fire and equipment should be considered.

Although the compressor rundown time may be limited, the impact of driving equipment on the fire hazard of the complete system should also be considered. For example, pressurized lube oil to a steam turbine driver cannot be shut down until the turbine has reached a point where significant additional equipment damage will not occur. This can represent a severe fire hazard, as oil can be fed to a fire while the unit is running down.

Additional information on the hazards associated with turbine oil systems, including the potential for spray fires, three-dimensional spill fires, and pool fires, is provided in Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*, and 7-79, *Fire Protection for Gas Turbines and Electric Generators*.

3.2.3 Air Compressors

Under conditions of high temperature and pressure, contaminants and oily carbon deposits may oxidize and ignite spontaneously, creating an ignition source for vapor and residue. Glowing particles may be carried to a point in this system where there is a combustible or explosive mixture. Localized heating may weaken the equipment walls to the point of failure.

Another important cause of air compressor fires and explosions is excessively high discharge temperatures. Abnormal temperatures are caused by recompression due to leakage through faulty valves or to blow-by in double-acting cylinders, by inadequate cooling water jackets and after-coolers, by high cylinder pressure due to severe restriction of discharge lines by deposits, or by mechanical friction or broken compressor parts.

Other air compressor fires and explosions have originated in the compressor drive motor, controls or associated electrical equipment. A few fires have been caused by friction due to slippage of drive belts or pulleys; by external ignition sources that involved oily residues; by solvent cleaners or combustibles in the vicinity of the compressor that in some cases heated the compressor system to a point where internal carbon deposits ignited; and by oily lint or other combustibles in contact with outside surfaces of hot compressor parts.

The frequency of fires in oil-flooded rotary-screw compressors is much greater than other air compressors. Currently, the cause of this increased frequency is not entirely understood. Oil overheats and ignites within the compressor or the receiver. Complete, well maintained interlocks are essential.

3.2.4 Oxygen Compressors

Compressor components can burn in an oxygen atmosphere. An internal fire, regardless of origin, could work its way through the system causing extensive damage to the compressor.

If any flammable gases or ignitable liquids enter the system, an explosion and/or fire could result. Petroleum-based lubricating oils form explosive mixtures with oxygen; they are also highly susceptible to spontaneous ignition in an oxygen atmosphere. Although petroleum-based lubricating oils are not used directly in contact with oxygen, accidents have occurred when oil from reciprocating compressor crankcases leaked along the piston rod into the compressor cylinder.

A break or leak in the system piping downstream of the compressor could result in an intense fire involving combustibles in an oxygen-rich atmosphere.

3.2.5 Flammable-Gas Compressors

The hazards of a flammable-gas compressor system are internal and external explosions and torch fires caused by rapid ignition of gas escaping from a leak or break.

An internal explosion is possible if air is drawn into the system through leaking packing glands, fittings or valves under conditions of negative pressure produced by a suction line obstruction. These explosions frequently lead to external fires.

An external explosion and/or jet fire can occur from a mechanical failure of high pressure piping or equipment under pressure inside or immediately outside of the compressor, with delayed ignition of escaping gas.

A severe flammable-gas fire can best be extinguished by shutting off the gas supply and immediately venting the gas piping to a safe location. The ability to de-inventory the compressor system of the flammable gas to a flare system that reduce the fire/explosion exposure as part of the operating procedures requires evaluation. Plants with sufficient separation and provision for promptly shutting off the gas flow and blowing down the high-pressure piping from a safe remote control station have received significantly less damage from such an incident.

3.3 Loss History

FM loss history shows the leading cause of compressor loss is mechanical/electrical breakdown, which in turn can result in a fire or explosion.

4.0 REFERENCES

4.1 FM

Data Sheet 1-44, *Damage-Limiting Construction*
Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*
Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*
Data Sheet 5-48, *Automatic Fire Detection*
Data Sheet 7-13, *Mechanical Refrigeration*
Data Sheet 7-14, *Fire Protection in Chemical Plants*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-35, *Air Separation Process*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-45, *Instrumentation and Control in Safety Applications*
Data Sheet 7-79, *Fire Protection for Gas Turbines and Electric Generators*
Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*
Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 12-2, *Vessels and Piping*
Data Sheet 12-43, *Pressure Relief Devices*
Data Sheet 13-3, *Steam Turbines*
Data Sheet 13-7, *Gears*
Data Sheet 13-17, *Gas Turbines*
Data Sheet 13-18, *Industrial Clutches and Clutch Couplings*
Data Sheet 13-26, *Internal Combustion Engines*

4.2 Others

American Petroleum Institute (API). API 617, *Axial and Centrifugal Compressors and Expander-Compressors*

American Petroleum Institute (API). API 614, *Lubrication, Shaft-Sealing and Oil-Control Systems and Auxiliaries*

American Petroleum Institute (API). API 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*

American Petroleum Institute (API). API 619, *Rotary-type Positive Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries*

APPENDIX A GLOSSARY OF TERMS

Compressor train: Includes compressor unit(s), driver(s), shaft coupling/clutches, support systems, etc.

Compressor unit: Includes the following sections: casing(s) and associated utility and support systems including lube oil, seal oil (when included), shaft couplings, shafts, increaser/reduction gears, intercoolers, separators, filters, etc.

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Ignitable liquid: Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn. An ignitable liquid is one that has a fire point.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

October 2024. Interim revision. Minor editorial changes were made for additional clarity on surge system guidance.

July 2022. Interim revision. Minor editorial changes were made.

January 2022. Interim revision. Minor editorial changes were made.

October 2020. Interim revision. Minor editorial changes were made.

July 2020. Interim revision. Updated guidance on foreign material exclusion programs.

April 2020. Interim revision. Updated guidance on equipment contingency planning and sparing.

July 2018. This document has been completely revised. Major changes include the following:

A. Modified fire protection recommendations.

B. Updated loss prevention recommendations.

C. Revised equipment and processes section and restructured guidance for protective systems.

D. Modified operation and maintenance section to reflect loss history and condition-based monitoring strategy.

E. Incorporated guidance from DS 7-95, *Compressors*, and DS 7-100, *Dynamic Compressors*.

May 2000. Data sheet content revised.

September 1990. Data Sheet first published.