ASME B19.1 95 ■ 0759670 0573166 464 ■



The American Society of
Mechanical Engineers

# SAFETY STANDARD FOR AIR COMPRESSOR SYSTEMS

AN AMERICAN NATIONAL STANDARD

**ASME B19.1-1995**
(Revision of ASME B19.1-1990)

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## FOREWORD

(This Foreword is not part of ASME B19.1-1995.)

Use of compressed air has been an important method of transmitting and storing useful energy for over one hundred years. Experience has shown that the use of compressed air as a utility can be both safe and effective if certain basic safety features and practices are used. However, since compressed air does represent instantly available energy, serious consequences can result from failure to use these basic safety features and practices.

User experience provides a solid basis for safety requirements of air compressor systems. Full information on good practice has not been readily available to all who design, produce, install, operate, or maintain these systems. Therefore, the B19 Committee was organized and sponsored by The American Society of Mechanical Engineers in accordance with the rules of the American National Standards Institute. A standing committee will be maintained to review current safety problems and to interpret, where necessary, provisions of this Standard. To promote uniformity, all requests for interpretation and suggestions for revision should be addressed to the Secretary, ASME B19 Committee, in care of The American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

Safety codes and standards are intended to enhance public health and safety. Revisions result from committee consideration of factors such as technological advances, new data, and changing environmental and industry needs. Revisions do not imply that previous editions were inadequate.

This Standard, which was approved by the ASME B19 Committee and by the Sponsor, was approved and adopted as an American National Standard by the American National Standards Institute on August 17, 1995.



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Secretary, B19 Main Committee
The American Society of Mechanical Engineers
United Engineering Center
345 East 47th Street
New York, NY 10017

*(b) Proposing Revisions.* Revisions are made periodically to standards to incorporate changes which appear necessary or desirable, as demonstrated by the experience gained from the application of the standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s) and providing the proposed wording and a detailed description of the reasons for the proposal, including any pertinent documentation.

*(c) Interpretations.* On request, the B19 Committee will render an interpretation of any requirement of this Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the Main Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his request in the following format.

Subject: Cite the applicable paragraph number(s) and provide a concise description.

Edition: Cite the applicable edition of the standard for which the interpretation is being requested.

Question: Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings which are necessary to explain the question; however, they should not contain proprietary names or information.

Requests which are not in this format will be rewritten in this format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

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# ASME B19 COMMITTEE
# Safety Standards for Compressors

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## ASME B19.1-1995
## SUMMARY OF CHANGES

The 1995 Edition of ASME B19.1 includes all revisions and corrections introduced in B19.1a-1991 and B19.1b-1994, as well as the following changes, identified by **(95)**.

| *Page* | *Location* | *Change* |
|---|---|---|
| ix | Contents | Updated |
| 4 | 1.5 | (1) ISO heading editorially revised<br>(2) ISO 1940/1 added |
| 5, 6 | 2.1.1.1 | Reference to Appendix A added |
| | 2.1.3 | First sentence editorially revised |
| 7 | 2.1.6 | Last sentence editorially revised |
| 12 | 2.2.4(b)(3) | Editorially revised |
| 15, 16 | 4.2.1 | Revised in its entirety |
| | 4.2.2 | Last five sentences added |
| | 4.2.3 | Last three sentences added |
| | 4.2.4 | Title revised |
| | 4.2.5 | Revised in its entirety |
| | 4.2.6 | Revised in its entirety |
| | 4.2.7 | Added |
| | 4.3.2 | Revised |
| | 4.4.1 | Second sentence revised |
| | 4.4.1(a) | Editorially revised |
| | 4.4.1(c) | Revised |
| | 4.4.2 | (1) Original para. redesignated as 4.4.1.1<br>(2) New para. 4.4.2 added |
| | 4.4.2.1 | Added |
| 19 | Appendix A | Added |



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# SAFETY STANDARD FOR AIR COMPRESSOR SYSTEMS

## Section 1 — General

### 1.1 Scope

This Standard addresses all aspects of air compressor systems from the entrance to the inlet device through the compressor and associated heat exchangers, dryers, and pulsation suppression devices to the point of entry to the distribution system.

The following types of air compressor systems are specifically excluded from this Standard:

*(a)* those having ratings of 5 psig (0.34 bar gage) or less differential pressure. This eliminates fans and low pressure blowers, but includes mechanical air vacuum pumps;

*(b)* those having drivers rated at less than $1\frac{1}{2}$ horsepower (1.1 kW);

*(c)* those which operate as part of facilities for processing petroleum, petrochemicals, or chemicals, including air separation plants;

*(d)* those functioning as part of automotive and transportation equipment. Examples are truck air brake systems, aircraft air conditioning systems, and automotive emission control compressors;

*(e)* thermal compressors such as steam jet ejectors;

*(f)* turbochargers and superchargers that are part of a prime mover.

### 1.2 Purpose

This Standard classifies and makes available general information on practices, specific requirements, and recommendations covering safety for air compressors, their drives, and auxiliaries.

Safety requirements, recommendations, and suggestions described in this Standard provide guidance to those who design, produce, install, maintain, and/or operate air compressor systems.

The general subject of compressed air is extremely broad. It is the intention of this Standard to cover safety in all aspects of the generation of compressed air.

### 1.3 Application

The provisions of this Standard apply to air compressor systems except as excluded below. Other exceptions may be necessary with regard to systems of unusual design, complexity, or function. In such cases, the system designer has the responsibility to develop equivalent safety features.

This Standard does not apply to the following:

*(a)* basic mechanical design. This Standard assumes as essential that the compressor and air compressor system components be designed by qualified engineers in accordance with recognized standards and specifications;

*(b)* design and operation of the compressed air distribution system. Distribution system refers to the compressed air system beyond the compressor and associated heat exchangers, dryers, and pulsation suppression devices;

*(c)* design and operation of the equipment or apparatus which uses the compressed air;

*(d)* air compressor systems that are an integral part of facilities for processing petroleum, petrochemicals, or chemicals, including air separation plants. These are covered by ASME B19.3, Safety Standard for Compressors for Process Industries.

The principles promoting safe generation and use of compressed air are not restricted to new air compressor systems. It is recommended that all air compressor systems be reviewed to consider possible changes due to revision of this Standard.

### 1.4 Definitions

*aftercooling* — involves cooling of air in a heat exchanger following the completion of compression to reduce the temperature and to liquefy condensable vapors

*capacity* — the inlet volumetric flowrate

*compressor* — The principal types of compressors are shown in Fig. 1 and are defined below. Cam, diaphragm, and diffusion pumps or compressors are not shown because of their specialized applications and relatively small size.



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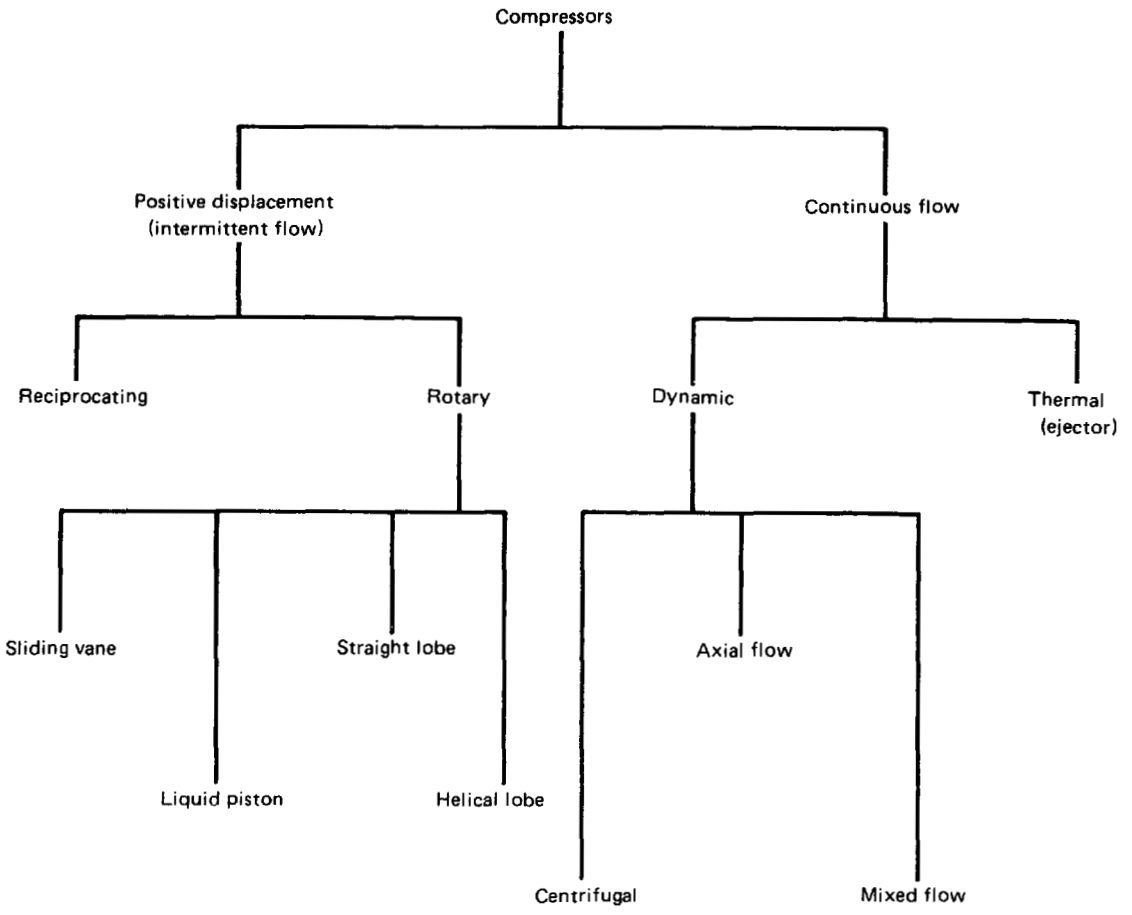



**FIG. 1 PRINCIPAL COMPRESSOR TYPES**



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*compressor, axial* — a dynamic machine in which air acceleration is obtained by the action of the bladed rotor. Main air flow is axial.

*compressor, centrifugal* — a dynamic machine in which one or more rotating impellers, usually shrouded on the sides, accelerate the air. Main air flow is radial.

*compressor, dynamic* — a rotary continuous flow machine in which the rapidly rotating element accelerates the air as it passes through the element, converting the velocity head into pressure, partially in the rotating element and partially in stationary diffusers or blades

*compressor, helical or spiral lobe* — a rotary positive displacement machine in which two intermeshing rotors, each with a helical form, compress and displace the air

*compressor, liquid piston* — a rotary positive displacement machine in which water or other liquid is used as the piston to compress and displace the air handled

*compressor, mixed flow* — a dynamic machine with an impeller form combining some characteristics of both the centrifugal and axial types

*compressor, positive displacement* — a compressor in which successive volumes of air are confined within a closed space and elevated to a higher pressure

*compressor, reciprocating* — a positive displacement machine in which the compressing and displacing element is a piston having a reciprocating motion within a cylinder

*compressor, rotary positive displacement* — a machine in which compression and displacement is effected by the positive action of rotating elements

*compressor, sliding vane* — a rotary positive displacement machine in which axial vanes slide radially in a rotor eccentrically mounted in a cylindrical casing. Air trapped between vanes is compressed and displaced.

*compressor, thermal (also known as ejector)* — a device that uses a high velocity air or steam jet to entrain the inflowing air, then converts the velocity of the mixture to pressure in a diffuser

*compressor, two impeller straight-lobe* — a rotary positive displacement machine in which two straight mating lobed impellers trap air and carry it from intake to discharge. There is no internal compression.

*discharge pressure* — the air pressure at the discharge flange of the compressor

*discharge temperature* — the air temperature existing at the discharge flange of the compressor

NOTE: In a multistage compressor, the various stages will have different discharge pressures and temperatures.

*gage pressure* — force per unit area as determined by most instruments, gages, and manometers. It is defined as absolute pressure minus barometric pressure.

*heat* — energy transferred because of a temperature difference

*horsepower* — the unit of power equal to 33,000 ft-lb of work per minute (1hp = 746 W)

*hydrostatic test pressure* — the pressure above the maximum allowable working pressure to which the manufacturer has tested a component

*inlet pressure* — the lowest air pressure in the inlet piping to the compressor

*inlet temperature* — the air temperature at the inlet flange of the compressor

NOTE: In a multistage compressor, the various stages will have different inlet pressures and temperatures.

*intercooling* — the cooling of air between stages of compression to reduce the temperature, to reduce volume to be compressed in the succeeding stage, to liquefy condensable vapors, or to save energy

*maximum allowable discharge temperature* — the temperature determined by the manufacturer at the maximum discharge pressure at which the compressor can be continuously operated

*maximum allowable working pressure* — the maximum pressure for which the manufacturer has designed the compressor (or any part to which the term is referred, such as an individual cylinder or casing), when handling the specified gas at the specified temperature

*maximum continuous speed* — the highest speed at which the manufacturer's design will permit continuous operation with overspeed and governor mechanisms installed and operating

*normal discharge temperature* — the temperature of the air leaving the compressor (or a stage of the compressor) when the compressor is in good operating condition and all utilities and ambient conditions are as designed

*rated input power* — the power at the rated capacity and the specified inlet temperature and pressure and discharge pressure

*surge point* — the capacity below which operation becomes unstable at the operating speed of a centrifugal or axial compressor

*vacuum pumps* — compressors with inlet pressure more than 1 psi (0.1 bar) below ambient atmospheric pressure

## 1.5 References

This Standard is supplemented by the following standards. Since revisions in and additions to these other standards do occur, the edition bearing the latest date of issue shall be used. It is expected that best current practice will prevail.



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The following standards shall, to the extent specified herein, form a part of this Standard.

ANSI — AMERICAN NATIONAL STANDARDS INSTITUTE, INC.

Z35.1, Specifications for Accident Prevention Signs

API — AMERICAN PETROLEUM INSTITUTE

618, Reciprocating Compressors for General Refinery Services

ASME — THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

A13.1, Scheme for the Identification of Piping Systems
B15.1, Safety Standard for Mechanical Power Transmission Apparatus
B19.3, Safety Standard for Compressors for Process Industries
B31.3, Chemical Plant and Petroleum Refinery Piping
ASME Boiler and Pressure Vessel Code, Section VIII

COMPRESSED GAS ASSOCIATION

G-7.1, Commodity Specifications for Air

(95) ISO — INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

(95) ISO 1940/1, Mechanical Vibration — Balance Quality Requirements of Rigid Motors
ISO R508, Identification Colours for Pipes Conveying Fluids in Liquid or Gaseous Condition in Land Installations and on Board Ships

NEMA — NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

ICS1, General Standards for Industrial Control and Systems
ICS2, Industrial Control Devices, Controllers, and Assemblies
MG1, Motors and Generators
MG2, Safety Standard for Construction and Guide for Selection, Installation, and Use of Electric Motors and Generators

NFPA — NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 70, National Electrical Code
NFPA 70B, Electrical Equipment Maintenance
NFPA 70E, Electrical Safety Requirements for Employee Workplaces

OSHA — OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

Part 1910, Occupational Safety and Health Standards

The following additional standards are valuable references:
ANSI B93.5, Practice for the Use of Fire-Resistant Fluids for Industrial Hydraulic Fluid Power Systems
ANSI B95.1, Terminology for Pressure Relief Devices
ANSI C50.10, General Requirements for Synchronous Machines
ANSI S5.1, Test Code for the Measurement of Sound From Pneumatic Equipment
ANSI/IEEE 43, Recommended Practice for Testing Insulation Resistance of Rotating Machinery
ANSI/IEEE 56, Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery (10 KVA and Larger)
ASME Guide SI-1, Orientation and Guide for Use of SI (Metric) Units
ASTM E 380, Metric Practice Guide
ISO R226, Normal Equal-Loudness Contours for Pure Tones and Normal Threshold of Hearing Under Free Field Listening Conditions
ISO R408, Safety Colours
ISO 2151, Measurement of Airborne Noise Emitted by Compressor/Primemover-Units Intended for Outdoor Use
UL 508, Electric Industrial Control Equipment
UL 873, Electrical Temperature-Indicating and Regulating Equipment
UL 900, Test Performance of Air Filter Units

### 1.6 Format

The mandatory rules of this Standard are characterized by the use of the word *shall*. If a statement is of an advisory nature, it is indicated by the use of the word *should*, or is stated as a recommendation.



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### 1.7 SI (Metric) Units

This Standard contains SI (metric) units as well as customary units. The SI units in the text have been directly (soft) converted from the customary units. Further information on the use of SI units is contained in ASTM E 380, Metric Practice Guide, and ASME Guide SI-1, Orientation and Guide for Use of SI (Metric) Units.

Current committee policy is to neither encourage nor discourage steps toward metrication, but to have standards published with information in the form which will best serve the needs of those who use the standard. It is not the intent of the standard to favor a design in SI units over one made in customary units, or conversely. In converting to SI units, an effort has been made to maintain the precision of the original values so that the accuracy of the converted values is neither exaggerated nor understated. Therefore, if there is a difference in the dimensions or the results of calculations between the two systems of units, the customary units govern.

## Section 2 — Requirements Applying to All Air Compressor Systems

### 2.1 Design and Installation

**2.1.1 Piping.** All piping carrying air at pressures in excess of 15 psig (1 bar gage) shall be in accordance with ASME B31.3.

Color coding or other marking of piping systems is recommended. Piping system markings shall comply with OSHA Sections 1910.144 and 1910.145. Coding to ANSI/ASME A13.1, ISO R508, or labels identifying line contents are preferred.

Foreign material (dirt, weld splatter, oil residue, rust, and debris) shall be eliminated from the intake line before startup.

The potential for discharge line fires can be minimized by reducing or eliminating the lubricating oil in the discharge line.

Piping exposed externally to corrosive conditions should be adequately protected for the conditions involved. Protective coatings should be inspected at regular intervals.

Deviations from manufacturer's recommendations will often result in reduced performance. The wrong length or size of inlet, interstage, or discharge line can create problems. When furnished, manufacturer's recommendations regarding piping should be followed unless a conflict exists with a duly appointed authority or prior standard.

**2.1.1.1 Pressure Pulsations.** Pulsation-induced vibration shall not cause a cyclic stress level in excess of the endurance limit of the material used. The peak-to-peak (double amplitude) pulsation level, expressed as a percentage of the average absolute line pressure at the compressor flange, shall not exceed the value determined by use of the appropriate design approach specified in API Standard 618, Section 3.9 (see Appendix A). (95)

Due to the pulsating nature of the flow of air through positive displacement compressors, it is possible that piping systems can experience excessive pressure pulsations where acoustic frequencies are close to the exciting frequency of the compressor. Such pulsations can cause:

*(a)* compressor driver to be severely overloaded;

*(b)* piping to vibrate with overstress occurring at fittings, valves, and structural supports;

*(c)* noise;

*(d)* vibrations in surrounding structures;

*(e)* damage to compressor valves;

*(f)* reduced capacity and performance.

Methods commonly used to correct pulsations include but are not limited to:

*(a)* commercial pulsation damping devices;

*(b)* strategically located orifices and/or choke tubes;

*(c)* volume bottles;

*(d)* a change in pipe length to avoid acoustic resonance.

Improved performance can be obtained by minimizing pulsation levels in the compressor and associated piping systems.

**2.1.1.2 Valves.** The type of shutoff valve used shall be selected with consideration given to the effects of pulsation. Generally, plug or ball valves are recommended for pulsating flow.

**2.1.1.3 Piping Supports**

*(a)* Pipe supports and stays shall be spaced to avoid resonance of the piping with the compressor.

*(b)* Piping anchors and supports shall be arranged to limit the forces and moments exerted on the air compressor system components to values recommended by the manufacturer, taking into account thermal expansion of piping.

*(c)* Piping systems should include supports, as required, to minimize vibration and stress at fittings and valves.

**2.1.2 Drainage.** Areas and locations within the air compressor system that collect liquids shall be provided with valved drain connections so designed that accumulations can be removed and observed without danger to the operator or maintenance personnel. Such



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areas include intercoolers, aftercoolers, pulsation control vessels, separators, traps, receivers, jackets, and low points in the piping.

Small pipe-tapped drainage connections are subject to thread wear and pullout, particularly in cast iron parts.

Drainage pipe should be designed to avoid undue vibration or potential breakage from accidental contact. Heavy wall pipe is recommended to avoid mechanical damage. Drainage receptacles, if not of the open type, shall be capable of withstanding the maximum pressure of the system to which they are connected.

Minimum drain size in cast iron parts should be as follows:

| Driver Power, hp | Minimum Size |
|---|---|
| 1½ through 15 (1.1 kW through 11.2 kW) | 1/4 NPT |
| Over 15 (11.2 kW) | 1/2 NPT |

Minimum drain size in malleable iron, ductile iron, or steel should be ¼ NPT.

In all cases, the opening size should be such as to preclude bridging or plugging by contaminants.

Those areas subject to freezing shall be reviewed for complete drainage.

(95) **2.1.3 Overpressure Protection.** The system shall be protected by pressure relief devices in any case where it is possible for:

*(a)* the compressor or driver to cause overpressure, or

*(b)* an external or internal fire to cause overpressure.

These devices shall prevent pressure in the weakest system component from exceeding 110% of the maximum allowable working pressure for that weakest component.

The maximum pressure setting of relief devices shall adhere to the requirements of UG-133 of the ASME Boiler and Pressure Vessel Code, Section VIII.

Sizing of relief valves shall be in accordance with the formula given in UG-131 of the ASME Boiler and Pressure Vessel Code, Section VIII.

Shutoff valves or restrictions shall not be installed between the pressure relief device and the system being protected.

Suitable pressure relief devices include spring loaded valves (see ASME Boiler and Pressure Vessel Code, Section VIII, UG-126) and rupture disks (see ASME Boiler and Pressure Vessel Code, Section VIII, UG-127).

Manufacturer's data and instructions should always be followed.

Lines connecting the system being protected and the pressure relief device shall have a flow area at least as great as the flow area of the pressure relief device.

Relief device outlet lines shall be no smaller than the relief device outlet size and shall not be restricted in any way. Short outlet lines with a minimum of fittings should be used. Elbows should be long radius.

Valves shall not be installed in relief device outlet lines.

Relief device outlet lines shall be so designed and installed as to preclude the collection of liquid at any point in the flow stream. They should be so located that effluent streams can be observed conveniently.

Relief devices shall have their outlet lines designed to preclude movement, shall be directed away from possible operator positions, and shall be directed to a safe point of discharge.

Relief valve and piping shall be adequately supported where the exit reaction forces would cause excessive motion or vibration.

**2.1.4 Overtemperature Protection.** Compressors over 15 hp (11.2 kW) and with a discharge pressure over 50 psig (3.4 bars gage) shall be fitted with high discharge temperature shutdown devices located within 4 pipe diameters downstream of each discharge connection with the temperature sensing element in the main hot air stream. The devices shall be located as follows:

| Compressor Type | Shutdown Sensor Location |
|---|---|
| Nonintercooled positive displacement | Compressor discharge |
| Air intercooled | Before every second cooler and at compressor discharge |
| Liquid intercooled | Before each cooler and at compressor discharge |

High temperature shutdown devices shall have a maximum shutdown setting of 50° F (28° C) above the normal discharge temperature.

This overtemperature setting is maximum and, in many cases, should be reduced. It takes into account the heat dissipating capabilities of the normal system. (Normal discharge temperature should be obtained from initial operation or from the compressor manufacturer.) Overtemperature shutdown devices shall positively stop all energy input to the system and should be the manual reset type. An alarm set at a lower temperature than the shutdown device should precede the overtemperature shutdown device. In those instances where a compressor shutdown would create a more hazardous condition than overtemperature, an alarm set at a lower temperature shall precede the shutdown device.

*(a) Overtemperature — Water Cooled Engines.* Water cooled engines shall be provided with a high liquid temperature shutdown device. In those instances where an engine shutdown would create a more hazardous condition than overtemperature, an alarm set at a lower temperature shall precede the shutdown device.



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*(b) Overtemperature — Combustion Gas Turbines.* Combustion gas turbines shall be provided with a high gas temperature shutdown device set at the manufacturer's stated upper temperature limit. In those instances where a turbine shutdown would create a more hazardous condition than overtemperature, an alarm set at a lower temperature shall precede the shutdown device.

**2.1.5 Inlet Systems.** All compressor systems shall be provided with inlet systems that will prevent entry of foreign material larger than can be ingested by the compressor and the remainder of the air compressor system without damage to either.

Air compressor systems using compressors with sliding, rubbing, or rolling contact should be fitted with high efficiency air filters to avoid high temperatures resulting from open clearances caused by excessive wear. The use of filter pressure drop indicators is recommended.

Inlet systems shall be so arranged or located as to preclude entry into the air compressor system of toxic or flammable fumes or gases. Inlet systems shall be so arranged, located, and/or guarded as to preclude the possibility of catching and holding personnel or clothing. The inlet system should be capable of withstanding the full inlet pressure difference (usually vacuum) that can be generated by the compressor, or be protected by a differential pressure shutdown device.

The location and design of the compressor shall be considered in the location of the compressor inlet so as to prevent damage to the surroundings. When pulsating or large flows are involved, consult with manufacturers regarding their effects on large flat surfaces such as walls, doors, windows, ceilings, and roofs.

(95) **2.1.6 Protective Guards.** All exposed moving parts shall be provided with personnel protection guards. These guards shall be designed and constructed so as to avoid risk of injury to personnel. Moving parts are defined as those having movement that is not hand powered and which move during normal operation. Guards shall comply with ASME B15.1.

Guards shall be made of solid materials, with or without a liner, when necessary to meet the area classification (NFPA 70 and/or similar governing document).

Guards shall be securely fastened to the machine supporting structure or to the machines themselves.

Guard construction shall be such that heat buildup or concentration of corrosive materials will not adversely affect personnel or the parts being guarded.

**2.1.7 Bearing Lubrication System Protection.** Air compressor systems having power input exceeding 30 hp (22.4 kW) shall be provided with shutdown devices in each lubrication system to protect against loss of bearing lubrication. Consideration should also be given to installing loss of lubrication protection devices on systems having power input of 30 hp (22.4 kW) and less.

Rotary oil flooded screw compressors are excluded from this requirement because the high discharge temperature device performs this function on rotary oil flooded screw compressors.

The shutdown system should be designed and installed in such a manner that a simulated low lubricant pressure, flow, or differential pressure test may be safely made while the compressor is in operation. An alarm, set at a pressure or flow higher than the shutdown setting, should be included.

**2.1.8 High Temperature.** External surfaces subject to temperatures in excess of 175°F (80°C) with which personnel may have contact, shall be guarded or insulated.

**2.1.9 Primary Safety Controls**

**2.1.9.1 Overspeed.** Compressor drivers, except as covered below, shall be equipped with an overspeed shutdown which positively stops all energy input to the system if the system overspeeds for any reason. This overspeed shutdown shall be independent of any other governing or regulating apparatus. The overspeed shutdown shall be of the manually reset type with provision for manual tripping. Exceptions are as follows:

*(a)* diesel and gasoline engines having fuel flow-limiting devices known to limit the maximum speed to 100% of designed rated speed of the limiting machine when the engine is unloaded;

*(b)* line frequency operated synchronous or induction alternating current electric motors;

*(c)* gas generator sections of gas turbines where they are proven to be speed-limited by design.

Manufacturer's recommendations on speed setting of the overspeed governor should always be followed. In the absence of recommendations, the following settings are suggested:

| Driver Type | Trip Speed as a Percentage of Rated Speed of Limiting Machine |
|---|---|
| Steam engine | 110 |
| Steam turbine | 110 |
| Gasoline engine | 120 |
| Natural gas engine | 110 |
| Combustion gas turbine | 105 |
| Diesel engine | 110 |
| Energy recovery expander | 105 |

The overspeed shutdown device shall be tested regularly and should be tested at least on an annual basis.



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Three consecutive tests of the device should be conducted to ensure repeatability of the overspeed setting.

**2.1.9.2 Isolating Valves.** Isolating, fuel, steam, or energy source valves shall provide tight shutoff and shall be arranged to close automatically on shutdown of the driver. Fuel lines between the isolating valve and gas turbine shall be vented or drained automatically on shutdown of the turbine.

Internal combustion engines and gas turbines shall be provided with a block valve at a readily accessible location in the main fuel supply to the engine.

**2.1.9.3 Reverse Rotation.** Any compressor which can be rotated by reverse air flow shall be provided with a check valve or mechanical device which prevents such rotation. Positive displacement compressors employing automatic valves have built-in check valves; therefore, additional check valves are not normally required. However, they should be considered. Undamped flapper-type check valves are not recommended. If a separate discharge check valve is used, it shall be downstream of any compressor overpressure protection relief device. An exception is made for oil flooded compressors, in which the check valve is normally located immediately adjacent to the discharge to minimize oil logging and reverse rotation.

### 2.1.10 Secondary Safety Controls

**2.1.10.1 Speed Limiting.** Compressor systems with power input greater than $7\frac{1}{2}$ hp (5.6 kW) that are driven by variable-speed drivers shall be fitted with a governing system having a maximum speed limit. The maximum speed setting of these governors should be such that mere removal of the compressor load does not cause the overspeed governor to trip.

Two-shaft gas turbines shall be provided with governing or protective systems having a maximum speed limit for each shaft.

**2.1.10.2 Discharge Pressure Control.** All compressors having operating characteristics that would permit a system overpressure shall be fitted with a discharge pressure control system, which in normal operation controls the compressor delivery capacity to prevent operation of the overpressure relief device.

Typical acceptable pressure control systems for 100 psig (6.9 bars gage) operation include:

*(a) Constant Speed Drives*

*(1) Reciprocating Compressors*

*(a)* suction throttling

*(b)* discharge venting

*(c)* suction valve unloading

*(d)* combinations of suction valve unloading and clearance control

*(2) Rotary Positive Displacement Compressors* — various combinations of suction throttling and discharge venting as controlled by maximum temperature or torque limits

*(3) Dynamic Compressors* — various combinations of suction throttling, variable guide vanes, and discharge venting as controlled by surge limit or maximum temperature

*(b) Variable Speed.* Vary the governor speed as needed under action of the system pressure.

*(c) Automatic Start/Stop Control.* Pressure cycles between upper and lower set points.

**2.1.10.3 Antisurge Control.** An antisurge device shall be used if system requirements indicate that the compressor may operate in surge for extended periods.

**2.1.10.4 Vibration Control.** Many factors influence the maximum vibration severity level to which compressor equipment, drivers, and transmission devices may be exposed. The manufacturer should be consulted for values related to specific equipment. Vibration and shaft movement alarms and shutdowns should be used to avoid destructive failures.

### 2.1.11 Parallel Operation

**2.1.11.1 Reverse Flow.** Air compressor systems employing compressors operating in parallel shall include individual discharge check valves.

**2.1.11.2 Isolating Valves.** Air compressor systems with compressors operating in parallel shall be provided with individual compressor discharge block (or isolating) valves. These valves shall be so designed and installed as to permit maintenance to be performed in a safe manner. Check valves and flow or pressure control valves shall not be used as block (or isolating) valves.

Selection of the valve operating rate shall consider the potential hazards of pressure shock or explosion due to rapid closure.

The preferred arrangement for block valving is a positive closing valve with a vent valve located between it and the compressor, as shown in Fig. 2.

An acceptable alternate arrangement is the use of a three-way valve operating as a combined block and vent valve, as shown in Fig. 3. If a three-way valve is used, it shall be provided with stops to prevent venting the piping while keeping pressure on the compressor.

Isolating valves, to best serve maintenance procedures, should be located just prior to the junction of the individual compressed air piping (lateral) into the first common piping (header).



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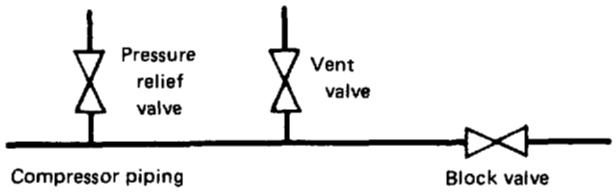



**FIG. 2 BLOCK VALVING**

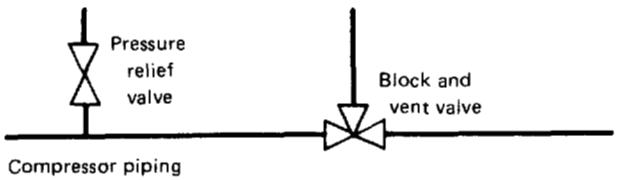



**FIG. 3 COMBINED BLOCK AND VENT VALVE**

**2.1.12 Noise.** Protection against the effects of noise exposure shall be provided in accordance with OSHA Section 1910.95. Compressor manufacturers should be consulted regarding expected noise levels. Other system components such as valves, inlet piping, and separators can generate noise, and the manufacturers of these components should be consulted also. Manufacturers are able to offer system components that have been specifically designed or treated to reduce their noise levels. Should a system not meet OSHA requirements, the affected area shall be clearly identified and warning signs posted at all entrances.

### 2.1.13 Remotely Controlled Air Compressor Systems

**2.1.13.1 Warning Sign.** Remotely controlled air compressor systems shall prominently display a sign on the compressor exterior reading:

WARNING
This compressor is remotely controlled and may start or stop at any time.

A sign should also be installed on the building access door or enclosure gate. When practical, the sign should conform to the requirements of ANSI Z35.1.

Air compressor systems operating on automatic start-stop, dual control, or automatic dual control are considered here to be remotely controlled.

**2.1.13.2 Local Shutdown.** Remotely controlled air compressor systems shall include a local shutdown near the compressor. The local shutdown system shall include provisions to prevent remote starting of the compressor. Such shutdown shall be clearly marked.

**2.1.14 Nameplate and Rotation Arrows.** Each major component of the air compressor system shall have a permanently attached and clearly visible nameplate made from corrosion resisting material and carrying, as a minimum, the information listed below by component type.

Rotation arrows shall be cast in or permanently attached to each major item of rotating equipment.

**2.1.14.1 Compressor.** The nameplate on the compressor shall show:

*(a)* manufacturer
*(b)* model designation
*(c)* serial number (if applicable)
*(d)* maximum allowable working pressure
*(e)* maximum allowable operating speed

The following additional information should be considered for inclusion on the nameplates:

*(a)* instruction manual number
*(b)* maximum allowable cooling water pressure and temperature
*(c)* maximum allowable discharge temperature
*(d)* capacity
*(e)* rated inlet pressure
*(f)* rated discharge pressure
*(g)* rated operating speed
*(h)* rated input power
*(i)* hydrostatic test pressure

**2.1.14.2 Constant Speed Drivers.** Constant speed electric motors shall include nameplates as specified in the NEMA MG1 standard. In addition, motors for use in hazardous locations shall show ambient classes for which they are suitable.

**2.1.14.3 Variable Speed Drivers**

*(a) Internal Combustion Engines.* The nameplate shall show:

*(1)* manufacturer
*(2)* model designation
*(3)* serial number
*(4)* maximum allowable operating speed

*(b) Steam Engines, Steam Turbines, and Energy Recovery Expanders.* The nameplate shall show:

*(1)* manufacturer
*(2)* model designation
*(3)* serial number
*(4)* rated inlet pressure



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(5) rated inlet temperature
(6) rated discharge pressure
(7) rated power output
(8) maximum allowable operating speed

(c) *Combustion Gas Turbines.* The nameplate shall show:
(1) manufacturer
(2) model designation
(3) serial number
(4) rated power output and basis for rating
(5) maximum allowable operating speed
(6) maximum allowable operating temperature
(7) fuel type
(8) fuel pressure limits
(9) water or steam injection pressure limits (if applicable)

(d) *Electric Motor Controls.* Electric motor control devices shall include a nameplate to NEMA standards. The following information should be considered for inclusion on the starter panel nameplate:
(1) enclosure type
(2) line voltage
(3) number of phases
(4) control voltage if other than line voltage

(e) *Heat Exchangers.* Nameplates on heat exchangers that are remote components of an air compressor system shall show:
(1) manufacturer
(2) model designation
(3) serial number
(4) pressure rating (both sides if shell and tube)
(5) temperature rating (both sides if shell and tube)
(6) ASME pressure vessel information (if applicable)

(f) *Pressure Vessels and Relief Valves.* Nameplates on pressure vessels and relief valves shall conform to the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code.

(g) *Miscellaneous Components of Air Compressor Systems.* Components not covered above and which are not pipe, fasteners, conduit wire, or similar hardware shall be marked to identify:
(1) manufacturer
(2) model designation
(3) maximum pressure (if applicable)
(4) operating voltage (if applicable)
(5) direction of flow (if applicable)

Components would include items such as air dryers and line filters. The function of these devices should be described in the operator's manual.

**2.1.15 Foundations.** Foundations for compressors shall be designed and constructed to minimize machine vibration, foundation movement, and transmission of vibration to surrounding structures. Where compressors are designed to be fixed to the foundation, movement shall not be permitted between the compressor and the foundation. Where compressors are designed for flexible mounts (vibration isolators), all piping and electrical connections shall be designed with adequate flexibility to withstand movement.

In the case of compressors which are grouted in, the following points are suggested.

(a) Wedges, plates, jackscrews, and shims should be removed after grouting.

(b) The compressor should be attached to its foundation in accordance with the manufacturer's recommendations.

(c) The compressor should not be operated until the grouting material has thoroughly hardened.

The premises surrounding a new compressor installation should be carefully inspected by the owner to locate and correct resonant vibrations which may occur in building walls, piping, stacks, and other structures as a result of the compressor operation.

**2.1.16 Lifting Provisions.** Components or assemblies weighing more than 100 lb (45 kg) and which can be damaged by incorrect rigging procedures shall be provided with obvious lifting eyes, lugs, lifting provisions, or eyebolts, or shall be accompanied by lifting instructions.

Components of air compressor systems should not be shipped or moved in larger sections than can be safely handled. Damage due to incorrect handling can include misalignment, distortion, line breakage, or crimping. Such damage, if undetected, can present a serious safety hazard.

**2.1.17 Electric Motors.** Electric motors, their controls, and wiring shall be designed and installed in accordance with NFPA 70 and NEMA MG1, MG2, ICS1, and ICS2. Motors should be maintained in accordance with the manufacturer's instructions and NFPA 70B. Should a conflict exist, the manufacturer's instructions should be given preference. Safety requirements shall be in accordance with NFPA 70E.

**2.1.18 Air Receiver Tanks and Other Pressure Containing Compressor Auxiliaries.** Air receiver tanks and other pressure containing auxiliaries (air dryers, heat exchangers, filters, aftercoolers, and pulsation suppression devices) shall be designed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII.

Piping shall be designed, manufactured, installed, and tested per ASME B31.3, as outlined in para. 2.1.1.



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Air receiver tanks and other pressure containing auxiliaries shall be maintained and retested on a regular basis to comply with the regulations of the jurisdiction in which the vessels are located and OSHA Section 1910.169. Manufacturer's instructions should list a schedule of recommended maintenance and testing procedures.

**2.1.19 Air Reheaters.** Direct fired reheaters shall not be used. Compressed air shall not be reheated to a temperature higher than the maximum allowable compressor discharge temperature if oil carryover or other fire-causing contaminants are possible. If reheating is necessary, oil free compressors are recommended, as well as filtered inlet air. Reheating can be minimized by controlling moisture intake.

## 2.2 Operation and Maintenance

**2.2.1 General.** Before placing the equipment in operation (initially and each succeeding startup), the operating chief and/or supervisor shall ensure that the manufacturer's recommendations and all appropriate safety codes (ASME B15.1, for example) have been met regarding safety and protection of personnel in the equipment vicinity. This includes items such as installed guards, closed electrical enclosures, insulation of hot pipes, and visible, readable warning signs.

Good maintenance and repair procedures can contribute to the safety of the maintenance crew as well as operating personnel. Therefore, supervisors should establish comprehensive maintenance and operating procedures with periodic reviews with affected personnel and instruction for new hires. These procedures should cover startup, break-in period, routine operation, routine maintenance, preventive maintenance, troubleshooting, and overhaul, with the manufacturer's instructions as a basis.

Competent observation of compressor performance is one of the best methods of determining need for maintenance which, in turn, can be the best safety precaution available. Any damage observed or suspected should be reported to supervisors. If the condition impairs safe operation, the machine shall be taken out of service for repair in the prescribed safe manner. Safeguards that have been altered or damaged should be reported so appropriate action can be taken to ensure against worker injury.

Records showing the history of operation, maintenance, inspections, and testing should be kept and reviewed regularly. These records should be a part of normal operation and maintenance. Such records form an important diagnostic tool. This tool can result in a safe working place, optimum operation, minimum maintenance expense, and aid predictive maintenance. The air compressor system supplier is normally able to assist the owner and supervisors in establishing the type of records to be kept.

**2.2.2 Lockout Procedure.** Lockout procedures shall be in accordance with OSHA 1910. Since maintenance or repair workers could be exposed to electrical elements and hazardous moving machine parts in the performance of their jobs, the power sources and control power shall be shut off and locked out before the work begins. Warning signs or tags are inadequate protection against the untimely energizing of the mechanical equipment.

Suitable starting prevention systems could be:

*(a)* pulling fuses and locking the fuse box cover;

*(b)* locking the power switch in the open position with a lockout clasp for both the power source and the control power;

*(c)* removing ignition components from spark ignited engines and combustion gas turbines;

*(d)* blanking off the steam supply or gas supply to steam turbines and expanders, respectively;

*(e)* closing double block valves and venting between them for fluid powered drivers;

*(f)* Disconnecting the coupling between the driver and the compressor is also recommended in addition to de-energizing the driver.

Tagging, in addition to lockout, is recommended to clearly establish the repairs being made and to alert remote operators so that safe operation of the entire plant can be achieved.

NOTE: When in doubt, overprotect.

Responsibility for restart shall be in the hands of the person performing the maintenance. Positive prevention against rollover should be achieved by crankshaft blocking and rotor blocking.

**2.2.3 General Operating Procedures.** Pressure relief valves, shutdown and alarm devices, and air inlet filters shall be checked on a regular basis (refer to the manufacturer's instructions for suggested frequency and procedures). The frequency of cleaning and testing should be annual unless the manufacturer recommends shorter intervals or the operating history indicates shorter intervals are necessary to provide safe operation.

Pressure relief valves should be removed on a regular basis for cleaning and testing with pressure so that the seats will be blown clear of foreign matter.

Filters cease to function properly when they are plugged with dirt or have openings or bypass areas that allow foreign matter to enter the compressor. The manufacturer's recommendations concerning maximum filter pressure drop and normal cleaning period should be followed. Dirt in an air compressor system causes abnormal



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wear, inefficient compression, air contamination, inefficient heat transfer surfaces, and in some cases, fires.

Oil wetted or oil bath type air inlet filters shall use oils that have a flash point greater than the flash point of the compressor lubricant. Filters and filter elements shall not be cleaned with combustible solvents.

The overspeed shutdown device shall be tested regularly and should be tested at least on an annual basis. Three consecutive tests of the device should be conducted to ensure repeatability of the overspeed setting.

Any safety device required by this Standard shall not be jumpered, bypassed, or defeated by any person. In the event that shutdown of the air system would impose a more hazardous condition, the owner shall install a backup air system drive train to maintain safe operation of the overall plant.

**2.2.4 General Maintenance Procedures.** Before maintenance procedures involving the disassembly of the system are begun, the system shall be relieved to atmospheric pressure and locked out per para. 2.2.2. Venting shall be through a lockout system, such as a locked open valve, and/or removal of a closure (blind or plugged connection). Prior to removing the blind or plugged connection, be sure all pressure has been relieved. Tag the opening and the control panel so that startup does not occur prior to replacement.

Volatile, flammable, or cleaning fluids injurious to the health of personnel shall not be used to clean parts. After cleaning, all parts shall be rinsed and dried. Consult the Federal Register, OSHA Section 1910, for specific details regarding ventilation and exposure limits.

*(a) Crankcase and Heat Transfer Surfaces.* If a compressor crankcase is to be opened for any reason, a minimum of 15 min shall elapse between shutdown and exposure of the crankcase to the atmosphere. A warning plate shall be provided by the manufacturer and also noted in the owner's maintenance procedures if opening the crankcase would present a hazardous condition.

Heat transfer auxiliaries shall be inspected and cleaned regularly to prevent fouling that could cause a fire or a system overpressurization due to sludge buildup.

*(b) Startup Procedures.* On initial startup and any startup after disassembly of compressor or system internals, the following items shall be performed.

*(1)* Check all valves for proper positioning.

*(2)* Remove all blinds installed for maintenance safety.

(95) *(3)* Check and remove all foreign objects from the system.

*(4)* Follow the established lockout device(s) procedure for removal.

*(5)* Replace all safety guards.

*(6)* Replace all warning/safety signs.

*(7)* Open and reclose all drains.

*(8)* Notify all personnel in the area that startup is about to occur.

NOTE: Also notify remote operators.

*(9)* Manually rotate the equipment to ensure that no mechanical interference exists.

NOTE: Reciprocating compressor unloaders shall be in the full load position.

*(10)* Ensure that driver rotation is correct.

*(11)* Check and verify proper operation of all safety devices, especially overspeed trip, and pressure relief devices.

*(12)* Observe that normal combustion has occurred on engines or gas turbines; if not, shut down immediately and take corrective action. Consult the manufacturer's instruction.

**2.2.5 Fires and Explosions.** Fires or explosions involving air compressors can be classified into two general categories: those in which compressor lubricating oil is in contact with airstream and those involving closed-loop operation.

*(a) Lubricating Oil in Contact With Airstream.* The majority of fires or explosions in air compressor systems have involved reciprocating machines. The fuel for air compressor fires is the cylinder lubricating oil itself or the carbonaceous products formed by oxidation of the lubricating oil. The formation of carbonaceous deposits in air compressor systems depends on the amount and type of the lubricating oil used and the temperature of the metal surface on which the oil is deposited. These effects appear to be interrelated, i.e., an operating temperature which is satisfactory with the correct amount of oil may cause carbon deposition if excess oil is used. The mechanism by which the fuel in air compressor fires is ignited is not definitely known; however, a factor common to all theories of ignition is excessive temperature, which may involve either the gas itself or a localized condition resulting from mechanical friction. High temperature is also important because it promotes deposition of carbon in the compressor system. Excessive temperatures are generally caused by valve or cooling water failures or by operation at unusually high compression ratios. High operating speeds combined with ineffective jacket design also promote high cylinder temperatures. To minimize the risk of fires and explosions in positive displacement air compressors, the following precautions are recommended.



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*(1)* Use nonlubricated compressors.

*(2)* Provide high temperature alarms and cutouts in compressor discharge.

*(3)* Use the minimum amount of lubricating oil that will lubricate the cylinder satisfactorily and train operators to detect significant increases in lubricating oil consumption. Use the least viscous oil that will satisfy operating conditions.

*(4)* Train operators to detect faulty compression cylinder valves and have repairs made promptly.

*(5)* Take inlet air from a cool, clean location. Provide air filters (preferably of a dry type) and service at regular intervals.

*(6)* Provide intercoolers to maintain interstage suction temperatures at the lowest practicable level. Keep intercoolers and cylinder jackets free of deposits.

*(7)* Inspect reservoirs, cylinder, pulsation dampener, discharge pipe, afterfilters, etc., regularly. Remove deposits and oil accumulations. Provide access for inspection and cleaning.

*(b) Closed-Loop Compressor Operation.* Leakage of lubricating oil from seals or bearings into a closed loop can create a flammable mixture, and if, coincident with such a condition, an element in the machine becomes overheated, a serious explosion may result. To prevent disasters of this type, bearings and oil seals of centrifugal or axial compressors for closed-loop air systems should be designed to prevent lubricant carryover into the compressor. If there is any possibility of oil carrying into the compressor, closed-loop air systems shall not be used.

### 2.3 Synthetic and Fire Resistant Lubricants

Synthetic or fire resistant lubricants shall not be substituted for the originally supplied lubricants in compressed air systems without written agreement from the air compressor manufacturer. Items of concern are toxicity, carryover effects, compatibility with seals (gaskets and O-rings) and hoses, compatibility with other components in the air system, plugging of air lines, and lubrication effects.

## Section 3 — Requirements and Conditions Applying to Air Compressor Systems by Cooling Type

### 3.1 Air-Cooled Systems

**3.1.1 Ventilation.** Essentially, most of the energy supplied to the compressor is dissipated to the air in the form of heat. Unless this heat is removed, it can raise the air temperature of the compressor's surroundings to a dangerous level.

Sufficient ventilation shall be provided in air cooled installations to comply with the manufacturer's ambient temperature limits.

**3.1.2 Cooler Fouling.** The air-cooled air compressor system shall be so maintained that intercooler and aftercooler effectiveness is not seriously impaired. The effectiveness should not be allowed to fall below 65% of the effectiveness when new. Effectiveness as a percentage of new effectiveness is here defined as the ratio of the air temperature drop in the cooler in the fouled condition to the temperature drop when new.

Fouling can occur on either the tube side or the ambient side. Tube side fouling is usually in the form of lubricating oil residue and normally is the result of improper lubricating oil, dirt passing through the inlet filter, poor maintenance, operation at higher than rated pressures and temperatures, or poor ventilation.

The majority of fires and explosions in air compressor systems involve oil lubricated compressors. The fuel for the fire is cylinder lubricating oil or the carbon products formed by oxidation of the lubricating oil. Excessive temperatures tend to encourage fires. Every effort should be made to maintain normal operating temperatures.

Fouling on the ambient side is usually in the form of dust, leaves, and other debris. Clean surroundings and elimination of oil leaks will minimize the problem.

Manufacturer's instructions should be consulted for both prevention and cure.

**3.1.3 Fans**

*(a) Guards.* Fans and their drives shall be guarded (see OSHA Part 1910).

*(b) Blades.* Fans shall be operated at a speed not exceeding the manufacturer's rating. Fans with adjustable blades should be provided with devices which positively prevent the blade from leaving the hub during operation.

*(c) Critical Speeds.* Fan systems are relatively low power, high inertia systems that are particularly vulnerable to critical speed and vibration problems. All fan drives shall be capable of:

*(1)* accelerating to operating speed and decelerating safely with their design driver;

*(2)* operating throughout their design speed range safely;

*(3)* surviving excursions to and through emergency overspeed shutdown, including shutdown deceleration.

*(d) Balance.* If a fan becomes unbalanced, the condition shall be corrected immediately. Balance shall be in accordance with ISO 1940, Balance Quality Grade 6, 3 or the manufacturer's limit, if more stringent.



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The manufacturer should be consulted for vibration limits. Consideration should be given to automatic vibration shutdown devices on large fans.

### 3.2 Liquid-Cooled Systems

**3.2.1 Cooler Fouling.** The liquid-cooled air compressor system shall be so maintained that intercooler effectiveness and aftercooler effectiveness are not seriously impaired. The effectiveness should not be allowed to fall below 65% of the effectiveness when new. Effectiveness as a percentage of new effectiveness is here defined as the ratio of the air temperature drop in the cooler in the fouled condition to the temperature drop when new.

Air side fouling is usually in the form of lubricating oil and its residue and normally is the result of improper lubricating oil, incorrect lubricator settings, poor maintenance, or operation at higher than rated pressure.

The majority of fires and explosions in air compressor systems involve oil lubricated compressors. The fuel for the fire is the cylinder lubricating oil or the carbon products formed by oxidation of the lubricating oil. Excessive temperatures tend to encourage fires. Every effort should be made to maintain normal operating temperatures.

Fouling on the water side is almost always in the form of scale and water derived sludge. While there may be no cure for all sludge and scale formation, certain combinations of water flow rate and temperature control are often used to minimize the problem. In closed water systems using cooling towers, attention should be given to pH, dissolved solids, blowdown rate, and circulation rate to minimize scale and sludge formation.

Water jackets, tubular or radiator-type exchangers, piping, and liquid holding tanks shall be provided with drainage facilities to prevent freezing during idle periods.

#### 3.2.2 Radiator-Cooled Systems

**3.2.2.1 Thermal Expansion.** Where an air compressor system employs a radiator-type heat exchanger for heat dissipation, the system shall include provision for thermal expansion of the working fluid. Usually a surge tank is mounted directly above the radiator to provide for expansion. Alternatively, the system shall be provided with a pressure relief device.

##### 3.2.2.2 Fans

*(a) Guards.* Fans and their drives shall be guarded. See OSHA Part 1910 and ASME B15.1 for more details.

*(b) Blades.* Fans shall be operated at a speed not exceeding the manufacturer's rating. Fans with adjustable blades should be provided with devices which positively prevent the blade from leaving the hub during operation.

*(c) Critical Speeds.* Fan systems are relatively low powered, high inertia systems and are particularly vulnerable to critical speed and vibration problems. All fan drives shall be capable of:

*(1)* accelerating to operating speed and decelerating safely with their design driver;

*(2)* operating throughout their design speed range safely;

*(3)* surviving excursions to and through emergency overspeed shutdown, including deceleration.

*(d) Balance.* If a fan becomes unbalanced, the condition shall be corrected immediately. Balance shall be in accordance with ISO 1940, Balance Quality Grade 6, 3 or the manufacturer's limit, if more stringent.

The manufacturer should be consulted for vibration limits. Consideration should be given to automatic vibration shutdown devices on large fans.

**3.2.3 Pressure.** Water outlet throttling devices shall not be used where the water supply pressure is higher than the maximum working pressure of any water-cooled portion of the air compressor system.

An inlet pressure control device shall be used to control the water pressure, and a suitable pressure relief device shall be installed downstream of the pressure control valve.

Block or isolation valves shall not be installed between the pressure control valve and the pressure relief valve.

The piping arrangement shall be such as to preclude siphon action.

**3.2.4 Leaks.** Before initial startup and after maintenance involving the cooling system(s), the following procedures shall be followed.

*(a)* Check the system for leaks, particularly for leaks into compression and lubricating oil sections.

*(b)* Check the cooling system to be sure the water flow is adequate.

**3.2.5 Strainers.** To reduce cooler system fouling and blockage, suitable filters should be used to remove solid materials.

**3.2.6 Pressure Relief Devices.** Water cooling systems which can be closed off by valving or other means shall be fitted with devices that provide for thermal expansion of the fluid, or, alternatively, shall be provided with a pressure relief device.

## Section 4 — Requirements and Conditions Applying to Special Air Compressor Systems

### 4.1 Hand Portable Systems

Hand portable systems are defined as air compressor systems of such size, weight, and design that they can be transported by one or two persons by manual lifting or by moving wheelbarrow style.



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**4.1.1 General.** Hand portable mountings shall be specifically designed to protect an untrained and unsuspecting operator.

**4.1.2 Air Receivers.** All air receivers shall be designed in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code, regardless of size. All weldments and other attachments to air receivers shall meet that Code's requirements. Air receivers shall be provided with facilities to permit bottom drainage.

**4.1.3 Electric System.** The electric system shall be in accordance with NFPA 70.

**4.1.4 Electric Motors.** Electric motors shall be protected against overload.

**4.1.5 Instructions.** Operating instructions or reference to the proper operating manual shall be clearly printed on a visible surface of the air compressor system.

## 4.2 Mobile Compressors

Mobile compressors are defined as self-contained air compressor systems mounted on a wheeled and readily mobile chassis.

The air receivers on such systems shall be depressurized prior to being transported.

(95) **4.2.1 General.** The mobile air compressor shall be operated by trained personnel who have read and understand the operating manuals. Use and operation of the air compressor shall be in full compliance with all OSHA requirements and all pertinent federal, state, and local codes or requirements.

Park or locate the compressor on level areas, if possible. If not, park or locate the compressor across grade on a firm surface that can support the weight. Park or locate the compressor such that the wind tends to carry away the exhaust fumes and the radiator heat from the compressor inlet, and where the compressor will not be exposed to excessive work site dust, or endanger personnel or property.

Erect hazard indicators, barriers, and flares if the compressor is parked on, or adjacent to, public roads and in the vicinity of people.

Follow the manufacturer's recommendation regarding flow limiting valves when the compressors have manifolds or use long runs of hoses. Flow limiting valves may also be needed to reduce pressure in case of hose failure.

Do not use tools, air hoses, pipes, valves, filters, etc., that have a pressure rating below the maximum allowable working pressure of the compressor.

Prior to servicing the air compressor, depressurize and tag the compressor and its air system. Disable and tag the driver. For drivers with battery starting systems, disconnect the battery and battery charging device according to the manufacturer's safety instructions.

Do not remove oil filter caps if the compressor is running or is pressurized.

Mobile compressor drivers shall be shut down during refueling unless specifically designed by the manufacturer to be refueled while in service.

Fuel tanks shall be located such that spills or overflow will not contact the engine, exhaust, or electrical parts.

Keep access doors closed and guards in place except when servicing or making adjustments. Lock them when not in use to prevent tampering.

Lifting the compressor shall be done in full compliance with OSHA Standard 29 CFR. Make sure the lifting device and gear have a rated capacity of 110% of the gross weight of the air compressor unit. Before disengaging the lifting hook or straps, set the parking brakes and block or chock both sides of all wheels.

Do not allow anyone to ride on the mobile compressor.

Operate the unit within the guidelines established by the manufacturer.

Prior to starting, make a visual check to ensure no one tampered with the unit while idle. Check that all supports are in place and that the wheels are blocked or chocked.

**4.2.2 Towing System.** The towing system, back to and including the chassis and running gear, shall have all stressed members made of ductile material. (95)

The towing vehicle, its coupling device, and points of chain attachment shall be rated to tow at least 110% of the gross weight of the air compressor system. Coupling devices shall be fully engaged, closed, and locked prior to moving the air compressor.

All mounting supports, including rear stabilizer legs, shall be retracted and locked into towing position before moving the air compressor.

Tires for both vehicles shall be inflated to the specified pressure, of the correct size, and in good operating condition. Wheel bolts, lugs, or nuts shall be tightened to the specified torque.

**4.2.3 Safety Chains.** Mobile compressors shall be provided with a safety chain towing system. Safety chains shall pass through the point of attachment on the towing vehicle, then hook each chain to itself by passing the grab hook over a link. Safety chains, the brake light, and other electrical connections shall be properly connected and checked to ensure that they do not restrict or interfere with the motion of the towing vehicle or the air compressor. Sufficient slack to prevent strain when cornering or maneuvering and to prevent dragging on the road is required. (95)



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(95) **4.2.4 Lights and Reflectors.** Mobile compressors shall be provided with two reflectors on the rear and at least one on each side.

All lights, including stop lights, warning lights, turn signals, and clearance lights shall be checked for cleanliness and proper operation before moving the air compressor.

(95) **4.2.5 Towing Speed.** All mobile compressors designed for over-the-road use shall have a safety sign which lists the maximum safe towing speed. Allow extra stopping distance for the total combined weight of the towing vehicle and the mobile compressor.

(95) **4.2.6 Oversteering.** Four-wheeled mountings shall include an oversteer safety mechanism or turn limiting device to prevent damage to the running gear in the event that the towing vehicle has a shorter turning radius than the mobile compressor.

(95) **4.2.7 Air Receivers.** All air receivers shall be designed in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code, regardless of size. All weldments and other attachments to air receivers shall meet that Code's requirements. Air receivers shall be provided with facilities to permit bottom drainage.

### 4.3 Nonlubricated Reciprocating Compressors

**4.3.1 Instruction Manual.** Instruction manuals for nonlubricated reciprocating compressors shall clearly explain all special maintenance procedures. Particular attention shall be given to avoiding metal-to-metal sliding contact.

(95) **4.3.2 Inlet Piping.** Inlet lines to nonlubricated reciprocating compressors shall have noncorroding inner surfaces or shall be made of noncorroding material downstream of the inlet filter.

### 4.4 High Pressure

(95) **4.4.1 General.** Those portions of an air compressor system operating at pressures in excess of 175 psig (12.1 bars gage) will be referred to as high pressure. Higher air pressures increase the risk of fire and explosion because of the following effects:

(95) *(a)* Oxygen partial pressure increases (more oxygen per unit of compressed air volume).

*(b)* Oxidation reactions, including combustion, take place at higher rates of speed and at lower temperatures.

(95) *(c)* Stored energy increases, with attendant increase in destructive capacity if mishandled.

**4.4.1.1 Piping.** High pressure piping should be carefully designed with attention given to the avoidance of accumulation of coke and other deposits on inner surfaces and temperature effects. (95

Added attention should be given to pipe inspection to avoid sludge buildup.

**4.4.2 Lubricants.** Consideration should be given to the use of high temperature and oxidation resistant lubricants such as synthetics. When special lubricants are required, the type shall be clearly marked near the lubricant fill nozzle. (95)

**4.4.2.1 Piping.** High pressure piping should be carefully designed with attention given to the avoidance of accumulation of coke and other deposits on inner surfaces and temperature effects. (95

Added attention should be given to pipe inspection to avoid sludge buildup.

**4.4.3 Overtemperature Protection.** Additional requirements shall be as follows.

*(a)* High discharge temperature shutdowns shall be installed before each cooler.

*(b)* Shutdown setting shall not exceed 50°F (28°C) above normal operating temperature. (This is a maximum setting and should be reduced where practical.)

### 4.5 Vacuum Pumps

Systems incorporating vacuum pumps shall be designed in accordance with the mandatory practices given elsewhere in this Standard.

### 4.6 Systems Providing Air for Human Respiration

ANSI/CGA G-7.1 shall apply.

### 4.7 Engine Starting Systems

*(a) Causes of Explosions.* Numerous fires and explosions which have occurred in starting air systems while starting large internal combustion engines have been traced to accumulations of lubricating oil in the starting air line, coincident with faulty air check valves. When these conditions exist concurrently, the following sequence of events is possible.

*(1)* Leakage of fuel gas through a check valve that is stuck or leaking creates a flammable mixture in the starting air line.

*(2)* The mixture can be ignited from the power cylinder.



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*(3)* Flame propagates through the air check valve and starting air line.

*(4)* Depending on pressure, temperature, and quantity of lubrication oil or gas in the starting air line, a fire or explosion may follow. Detonations in starting air lines are particularly destructive because they travel at a very high speed, and they produce very high localized pressures due to shock waves. For these reasons, relief valves or rupture disks have not prevented rupture of starting air lines when conditions were favorable to detonation.

*(b) Prevention of Explosions.* To minimize the risk of explosions in starting air systems, the following precautions are recommended.

*(1)* Thermometers, thermocouples, or other temperature sensing devices installed in discharge piping should be monitored to detect fouled or defective valves.

*(2)* Any increase in compressor oil consumption should be investigated.

*(3)* Intake air filters should be kept clean.

*(4)* Discharge temperature of any stage of a starting air compressor shall not exceed 350°F (177°C) for lubricated compressors.

*(5)* Starting air header on engine should be vented during normal operation.

*(6)* Receivers and low spots in air piping should be blown down on a regular schedule. Low spots in piping should be fitted with drains.

*(7)* Air receiver and interconnected piping should be inspected on a regular schedule. Oil or dirt accumulation should be removed.

*(8)* Starting air check valves and air pilot valves on engines should be included as part of regularly scheduled maintenance.

*(9)* Use nonlubricated compressors.

*(c)* Automatic compressor shutoff for high temperature shall be provided. Visible and audible alarms for high discharge temperature of each stage in the starting air compressor is also recommended.

## 4.8 Underground Systems

The standards of the United States Bureau of Mines shall apply.



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# APPENDIX A
# PULSATION AND VIBRATION CONTROL REQUIREMENTS[1]

(95)

(This Appendix is not part of ASME B19.1-1995 and is included for information only.)

## 3.9 Pulsation and Vibration Control Requirements

**3.9.1 General.** The basic techniques used for control of detrimental pulsations and vibrations are the following:

*(a)* pulsation suppression devices such as pulsation filters and attenuators (including proprietary commercial designs based on acoustical suppression techniques), volume bottles without internals, choke tubes, orifice systems, and selected piping configurations;

*(b)* system design based on studies of the interactive effects of pulsations and the attenuation requirements for satisfactory piping vibration, compressor performance, and valve life.

### 3.9.2 Design Approaches

**3.9.2.1** The purchaser shall specify the design approach for pulsation and vibration control. The purchaser shall also indicate when existing compressors and their associated piping systems are to be included in the acoustical simulation (see 3.9.2.8). Three techniques are normally used.

*Design Approach 1:* pulsation control through the use of pulsation suppression devices designed using proprietary and/or empirical analytical techniques to meet the pulsation levels required in 3.9.2.5 based on the normal operating condition. If specified, a simplified analysis of the purchaser's piping system shall be performed to determine critical piping lengths that may be in resonance with acoustical harmonics. Acoustical simulation analysis is not required.

*Design Approach 2:* pulsation control through the use of pulsation suppression devices and control of piping system response using proven acoustical simulation techniques. This approach includes the evaluation of acoustical interaction between compressor, suppression devices, and piping, including pulsation effects on compressor performance and an evaluation of acoustical shaking forces as specified in 3.9.2.6. Items a and b, to meet the requirements of 3.9.2.7.

*Design Approach 3:* the same as Design Approach 2, but also employing a mechanical analysis of the compressor manifold and associated piping systems, including interaction between acoustical and mechanical system responses as specified in 3.9.2.6. Both acoustical and mechanical methods are used to arrive at the most efficient and cost-effective plant design in compliance with the requirements of 3.9.2.7.

NOTE: The extent of the piping system to be analyzed by acoustical simulation techniques is usually defined as all associated piping systems to a point where piping changes will have only insignificant effects on the parts of the system under study and in determining the acoustical characteristics of the design. Typically, these requirements are satisfied by beginning the simulation with the inlet of a major process vessel or volume on the suction side of the compressor unit(s), continuing through all interstage systems (if any), and terminating the study at the outlet of a major process vessel or volume on the discharge side of the unit(s). Included are lateral lines to or from this system, such as relief valve lines and bypass lines.

**3.9.2.2** Pulsation suppression devices and techniques in accordance with Design Approaches 1, 2, and 3 shall satisfy the criteria in 3.9.2.2.1 through 3.9.2.2.5.

**3.9.2.2.1** Pulsation-induced vibration shall not cause a cyclic stress level in excess of the endurance limit of the material used. (For carbon steel pipe with an operating temperature below 700 F (371 C), the peak-to-peak cyclic stress range shall be less than 26,000 pounds per square inch [179 megapascals] considering all stress concentration factors present and with all other stresses within applicable code limits.)

NOTE: Cyclic stresses normally are not calculated for Design Approaches 1 and 2; however, these criteria should still be used as guidelines for Design Approaches 1 and 2.

**3.9.2.2.2** For Design Approach 1, and for initial commercial sizing according to Design Approaches 2 and 3, pulsation suppression devices shall have minimum

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suction and discharge surge volumes, excluding liquid collection chambers, determined from Equations 1 and 2, but in no case shall either volume be less than 1 cubic foot.

$$V_s = 8\,(PD)\left(\frac{kT_s}{M}\right)^{1/4} \quad (1)$$

$$V_d = \frac{V_s}{R^{1/k}} \quad (2)$$

where

$V_s$ = minimum required suction surge volume in cubic feet
$V_d$ = minimum required discharge surge volume in cubic feet
$k$ = isentropic compression exponent at average operating gas pressure and temperature
$T_s$ = suction temperature, degrees Rankine
$M$ = molecular weight
$PD$ = total net displaced volume, in cubic feet per revolution, of all compressor cylinders to be manifolded in the surge volume
$R$ = stage pressure ratio at cylinder flanges (absolute discharge pressure divided by absolute suction pressure)

The internal diameter of the surge volume shall be based on the minimum surge volume length required to manifold the compressor cylinders. For single-cylinder surge volume, the ratio of surge volume length to internal diameter shall not exceed 3.0. The inside diameter of spherical volumes shall be calculated directly from the volumes determined by Equations 1 and 2.

NOTE: Equations 1 and 2 will provide satisfactory sizes for most applications. In some instances, however, it may be necessary to alter the sizes based on the results of the acoustical simulation study employed by Design Approaches 2 and 3. Sizing requirements can be substantially influenced by the effects of high pressures, single-acting cylinders, and/or interaction among the elements of the overall system. The magnitude of these effects cannot be accurately predicted at the outset.

**3.9.2.2.3** Unless other criteria (such as loss in compressor efficiency) are specified, the unfiltered peak-to-peak pulsation level at the compressor cylinder flange, as a percentage of average absolute line pressure, shall be limited to 7 percent or that determined by Equation 3, whichever is lower.

$$P_{cf}(\%) = 3R \quad (3)$$

where

$P_{cf}(\%)$ = maximum allowable unfiltered peak-to-peak pulsation level expressed as a percentage of average absolute line pressure at the compressor cylinder flange
$R$ = stage pressure ratio

For those special cases where pulsation levels exceed these values, and a reasonable increase in volume will not satisfy the requirement of 7 percent or that determined by Equation 3, higher limits may then be used as agreed upon by the purchaser and the vendor.

NOTE: The phase relationship and amplitude of pressure pulsation at the compressor valves can significantly affect compressor performance. Pulsation levels measured at the compressor cylinder flange will not necessarily be the same as those levels existing at the valves. Experience has shown, however, that pulsation limits at the cylinder flanges, as specified above, result in compressor performance within the tolerances stated in this standard.

**3.9.2.2.4** Unless otherwise specified, the pressure drop based on steady flow through a pulsation suppression device at normal operating conditions shall not exceed 0.25 percent of the average absolute line pressure at the device, or the percentage determined by Equation 4, whichever is higher.

$$\Delta P(\%) = \frac{1.67\,(R-1)}{R} \quad (4)$$

where

$\Delta P(\%)$ = maximum pressure drop based on steady flow through a pulsation suppression device expressed as a percentage of the average absolute line pressure at the inlet of the device
$R$ = stage pressure ratio

When a moisture separator is an integral part of the pulsation suppression device, the pressure drop based on steady flow through such a device shall not exceed 0.33 percent of the average absolute line pressure at the device, or the percentage determined by Equation 5, whichever is higher.

$$\Delta P(\%) = \frac{2.17\,(R-1)}{R} \quad (5)$$

**3.9.2.2.5** Operation with alternate gases or startup conditions shall be specified on the data sheets, and pulsation suppression devices shall be mechanically suitable for all specified conditions. When a compressor is to be operated on two gases of dissimilar molecular weights (for example, hydrogen and nitrogen), pulsation levels at the cylinder flanges and elsewhere in the entire piping system shall be optimized for the gas on which the unit must operate for the greater length of time. Pulsation



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levels shall be reviewed for the alternate gas to assure that pulsation levels will be acceptable under both operating conditions.

**3.9.2.3** The peak-to-peak pulsation limitations specified in 3.9.2.2.3 (for Design Approaches 1, 2, and 3), 3.9.2.5 (for Design Approach 1), and 3.9.2.7 (for Design Approaches 2 and 3) shall apply to the normal operating conditions specified.

**3.9.2.4** General guidelines for the purchaser in specifying the appropriate design approach are given in 3.9.2.4.1 and 3.9.2.4.2. These guidelines should not be used, however, without knowledgeable review by qualified personnel for the specific services involved.

**3.9.2.4.1** The following table gives the numerical designations of the recommended design approaches (as defined in 3.9.2.1) for a system in which:

*(a)* Final discharge pressure is less than 1000 pounds per square inch gage (69 bar effective), or driven power is less than 500 horsepower (373 kilowatts); and

*(b)* No interaction is anticipated between adjacent machines.

| Number of Stages | Single Cylinder | Two Cylinders | Three or More Cylinders |
|---|---|---|---|
| One | 1 | 1 | 2 |
| Two or more | — | 3 | 3 |

**3.9.2.4.2** The following table gives the numerical designations of the recommended design approaches for a system in which:

*(a)* Final discharge pressure is 1000 pounds per square inch gage (69 bar effective) or more;

*(b)* Driven power is 500 horsepower (373 kilowatts) or more; or

*(c)* Service alternates between gases of significantly different molecular weights; or

*(d)* Two or more machines discharge into or take suction from the same piping system, and interaction of pulsation is anticipated (including most compressors of more than 150 horsepower [112 kilowatts] operating in parallel).

| Number of Stages | Single Cylinder | Two Cylinders | Three or More Cylinders |
|---|---|---|---|
| One | 2 | 2 | 3 |
| Two or more | — | 3 | 3 |

**3.9.2.5** Pulsation suppression devices used in accordance with Design Approach 1 shall limit peak-to-peak pulsation levels at the line side of the pulsation suppression device to a value determined by Equation 6.

$$P_1(\%) = \frac{10}{P_L^{1/3}} \quad (6)$$

where

$P_1(\%)$ = maximum allowable peak-to-peak pulsation level at any discrete frequency expressed as a percentage of average absolute pressure

$P_L$ = average absolute line pressure in pounds per square inch absolute

**3.9.2.6** Acoustical evaluation for Design Approaches 2 and 3 shall be accomplished with proven acoustical simulation techniques that model the compressor cylinders, pulsation suppression devices, piping, and equipment system, and that consider dynamic interaction among these elements. Mechanical evaluation for Design Approach 3 shall include an analysis of compressor manifold and piping systems, including pulsation suppression devices, and the study of the interaction between acoustical and mechanical system responses at all specified operating conditions. In addition to the requirements stipulated in 3.9.2.2, the following steps are required to accomplish the proper evaluation for Design Approaches 2 and 3:

*(a)* determination of the acoustical response of the system, including the amplitude and the spectral frequency distribution of pulsations. This analysis shall ensure minimum degradation of cylinder performance by the effects of dynamic interaction among cylinder, suppression device, and piping.

*(b)* determination and control of acoustical unbalanced forces produced within the pulsation suppression devices, piping, heat exchangers, or vessels with internals. Location of inlet and outlet nozzles and internal baffles and choke tubes shall be arranged to minimize these forces. See 3.9.3.9, 3.9.3.17, and 3.9.4.

*(c)* determination and control of significant pulsation amplitudes at the compressor cylinder valves that fall within the range of the mechanical natural frequencies of the valves. The mechanical natural frequencies of standard compressor cylinder valves are generally in the range of 50 to 100 hertz. Acoustical responses within this range in the valve ports or at the valves have been known to cause valve failures.

*(d)* for Design Approach 3, determination of the mechanical response of the piping system, including mechanical natural frequencies and mode shapes of the compressor cylinder-manifold system. This analysis shall also establish allowable limits for pulsation-induced shaking forces in the piping system based on the cyclic stress levels they can produce.



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*(e)* for Design Approach 3, determination of the required pulsation suppression based on acoustical and mechanical responses and their interactions. To obtain the desired vibration/pulsation control, selective use should be made of both acoustical and mechanical control techniques. These techniques include the elimination of coincidences between acoustical and mechanical resonant frequencies, the use of acoustical filtering techniques, and changes in mechanical configurations.

NOTE: When evaluating the need for possible modifications to the piping and/or pulsation suppression devices during an acoustical simulation study, consideration should be given to acoustical shaking forces and the effect of pulsations on compressor performance. When Design Approach 3 is used, consideration should also be given to mechanical system responses and the use of mechanical vibration control techniques. Pulsation levels (expressed as a percentage of line pressure) should not be used as the sole criterion for making modifications to the piping and/or pulsation suppression devices.

**3.9.2.7** For Design Approaches 2 and 3, based on normal operating conditions, the peak-to-peak pulsation levels in the initial suction, interstage, and final discharge piping systems beyond pulsation suppression devices shall satisfy the requirements of 3.9.2.2. For systems operating at line pressures between 50 and 3000 pounds per square inch absolute (3.45 and 207 bar absolute) this requirement is usually satisfied when the peak-to-peak pulsation level of each individual pulsation component is limited to that calculated by Equation 7.

$$P_I(\%) = \frac{300}{(P_L \times ID \times f)^{1/2}} \qquad (7)$$

where

$P_I(\%)$ = maximum allowable peak-to-peak level of individual pulsation components corresponding to the fundamental and harmonic frequencies, expressed as a percentage of average absolute line pressure (see 3.9.2.8).

$P_L$ = average absolute line pressure, in pounds per square inch absolute

$ID$ = inside diameter of line pipe, in inches

$f$ = pulsation frequency, in hertz, derived from the following equation, in which *rpm* is machine speed and $N = 1, 2, 3 \ldots$, corresponding to the fundamental frequency and harmonics thereof:

$$f = \frac{(rpm)\,N}{60}$$

For pressures lower than 50 pounds per square inch absolute (3.45 bar absolute), use the peak-to-peak levels in pounds per square inch (not percentage) of individual pulsation components calculated for 50 pounds per square inch absolute (3.45 bar absolute). For pressures greater than 3000 pounds per square inch absolute (207 bar absolute), the corresponding calculated cyclic stresses shall be carefully evaluated to assure compliance with 3.9.2.2.1.

NOTE: Pulsation limits may exceed the levels defined by 3.9.2.7. However, it must be demonstrated that all other requirements in 3.9.2.2 are satisfied.

**3.9.2.8** When the compressor unit is to be installed in parallel with other compressor units, an interactive acoustical simulation study should normally be specified. If the interactive study indicates a requirement for modifications to piping or pulsation suppression devices to meet the requirements of 3.9.2.7, modifications shall be based on mutual agreement between the purchaser and the vendor.

### 3.9.3 Pulsation Suppression Devices

**3.9.3.1** As a minimum, pulsation suppression equipment shall be designed and fabricated in accordance with Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. Pulsation suppressors shall be stamped with the ASME Code symbol and registered with the National Board of Boiler and Pressure Vessel Inspectors when specified on the data sheets. If another code is required, this code shall be noted on the data sheets.

**3.9.3.2** The maximum allowable working pressure for any component shall not be less than the setting of the relief valve serving that component.

**3.9.3.3** Unless otherwise specified on the data sheets, the corrosion allowance for shell and internals shall be $\frac{1}{8}$ inch (3.2 millimeters).

**3.9.3.4** When specified, all butt welds shall be 100-percent radiographed.

**3.9.3.5** All flanged branch connections shall be reinforced in such a way that the reinforcement provides a metal area equal to the cutaway area regardless of the metal thickness in the connection wall. Stress concentration factors shall be considered in the selection of branch connections to assure compliance with 3.9.2.2.

**3.9.3.6** When specified, the suction pulsation suppression device(s) shall include a final moisture removal section as an integral part of the vessel. The moisture removal section shall have a reservoir extended below the suppressor shell and shall be equipped with a drain connection of at least 1 inch nominal size. The moisture removal section shall remove 99 percent of all droplets of 10 microns or larger. Pressure drop shall be as defined in 3.9.2.2.4.



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**3.9.3.7** The nozzle length from the shell of the pulsation suppression device to the cylinder flange shall be held to a minimum, consistent with thermal flexibility and misalignment. The nozzle area shall be at least equal to the area of the nominal compressor cylinder flange size. Adequate space shall be allowed for access to and maintenance of the cylinder's working parts. Suction pulsation suppressors shall be designed to prevent trapping of liquid that can be carried over into the cylinder.

**3.9.3.8** Manufacturing tolerances and fit-up procedures for pulsation-suppressor/compressor-cylinder nozzle connections and line connections shall be adequate to allow bolting of flanges without the use of external forces such as jacks and come-alongs, which may result in excessive stresses, misalignment, or rod runout. When two or more cylinders are to be connected to the same pulsation suppression device, the flanges shall be fitted to aligned cylinders and welded in place to assure proper final alignment and minimize residual stresses. This procedure is especially important for ring joint flanges.

**3.9.3.9** Orientation of the pulsation suppression devices and their nozzles shall be specified by the purchaser, subject to practical limitations imposed by the vendor and dynamic design requirements. Ratings, types, and arrangements of all connections shall be agreed upon by the purchaser and the vendor.

**3.9.3.10** Three-quarter-inch pressure test connections shall be provided at each pulsation suppressor inlet and outlet nozzle. An external drain connection of at least 1 inch nominal size shall be provided for each compartment where practicable. Where multiple drains are impracticable, circular notched openings in the bulkheads extending to the vessel wall may be used with the purchaser's approval. The effect of such drain openings on pulsation suppressor performance must be considered. Arrangement of internals shall ensure that liquids will flow to drain connections under all operating conditions.

**3.9.3.11** The cylinder nozzle of each discharge pulsation suppressor shall be provided with two connections located to permit, without interference, the purchaser's installation of thermowells of at least 1 inch nominal size for a high-temperature alarm or shutdown element and a dial thermometer. When specified, a thermowell connection of at least 1 inch nominal size shall also be provided for the cylinder nozzle of each suction pulsation suppressor.

**3.9.3.12** Flanged connections 1½ inch and smaller, although reinforced in accordance with 3.9.3.5, shall be designed to minimize overhung weight and shall be gussetted back to the main pipe or reinforcing pad in at least two planes to avoid breakage due to pulsation-induced vibrations.

**3.9.3.13** Main connections for the compressor cylinder and line shall be fitted with weld-neck flanges unless otherwise specified by the purchaser. Pulsation suppressors 18 inches (457 millimeters) and greater in diameter shall have studded pad-type inspection openings at least 6 inches (152 millimeters) in diameter, complete with blind flanges and gaskets, to provide access to each compartment. For suppressors less than 18 inches (457 millimeters) in diameter, 4-inch (102-millimeter) studded pad-type inspection openings are permitted.

**3.9.3.14** Pulsation suppressor connections other than those covered by 3.9.3.13 shall be flanged or threaded as specified on the data sheets. All threaded fittings shall have a minimum rating of 6000 pounds per square inch (414 bar).

**3.9.3.15** Flanges shall be in accordance with ANSI B16.5, except that lap-joint flanges shall not be used unless specifically approved by the purchaser. The finish of the gasket contact surface of flanges other than ring-joint type shall be no less than 125 microinches (3.2 micrometers) and no greater than 250 microinches (6.4 micrometers) $R_a$. Either a serrated-concentric or serrated-spiral finish having 24 to 40 grooves per inch (0.6-millimeter to 1.0-millimeter pitch) shall be used. The surface finish of the gasket grooves of ring joint connections shall conform to ANSI B16.5.

**3.9.3.16** When specified, provisions shall be made for attaching insulation. All connections and nameplates shall be arranged to clear the insulation.

**3.9.3.17** All internals of pulsation suppression devices shall be fabricated and supported considering the possibility of high acoustical shaking forces. Dished baffles in lieu of flat baffles shall be used. The same welding procedures as applicable to external welds shall be followed.

**3.9.3.18** All butt welds shall be full-penetration welds.

### 3.9.4 Supports for Pulsation Suppression Devices

**3.9.4.1** If specified, supports for the pulsation suppression devices and piping shall be furnished by the vendor. These supports shall be designed considering acoustical shaking forces and mechanical responses and shall not impose harmful stresses on the compressor,



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piping system, or pulsation suppression devices to which they are attached. In calculating stress levels, compressor frame growth as well as crosshead-guide and branch connection flexibilities shall be considered. When adjustable supports are used, they shall be adjusted by the purchaser at normal operating conditions.

NOTE: To the extent possible, the support foundation should always be integral with the compressor foundation. The mounting plate for the support should be anchored in the foundation.

**3.9.4.2** Springs or resilient mounts may be used for pulsation suppressor or piping supports if analyses indicate that they will not adversely affect system stress and vibration.



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