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Revision Memo

12/98 Page 2: Note 1 added. No other changes.

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SCOPE

This section presents aspects of axial compressors relating to compression service design. Background material is included to acquaint the compression service designer with factors which affect equipment selection and installation design.⁽¹⁾

REFERENCES

DESIGN PRACTICES

Other subsections of [Section XI](#)

INTERNATIONAL PRACTICES

- [IP 10-3-4](#), Axial Compressors for Air Service
- [IP 10-4-1](#), Reciprocating Process Compressors
- [IP 10-14-1](#), Lube and Seal Oil Systems for Machinery
- [IP 15-1-2](#), Instrumentation for Compressors and Drivers

OTHER REFERENCES

- API 617, *Centrifugal Compressors for Petroleum, Chemical, and Gas Industry Services*.
- ASME-PTC10, *Power Test Code for Compressors and Exhausters*.
- Hild, W.H., *Application of Axial Compressors to Process Gas Service*.
- Provenzale, G.E. and Nathanson, S.L., *Application of Large Machinery Utilizing First Body Axial Compressors for the Maracaibo LNG Project*, EE Report No. EE.10LD.70.
- Knudson, S.A., Margolis, R.L., Nathanson, S.L., Provenzale, G.E., *LNG R&D Large Compressor/Driver Study, Phase II*, EE Report No. EE.13LD.70.

DEFINITIONS

Compressor Stage - A compressor stage consists of a rotating blade row and the following stationary blade row in an axial compressor.

Process Compression Stage - A process compression stage is the compression step between two adjacent pressure levels in a process system. The process compression stage may consist of one or more compressor stages.

BACKGROUND

GENERAL

In Exxon process plants, axial compressors are applied in processes requiring a high capacity of air, such as Flexicracking and Flexicoking air blower duty. In such services, it competes with the centrifugal compressor. See [Section XI-B](#), [Appendix A](#), *Axial Compressors Versus Centrifugal Compressors*.

The possibilities of Exxon applications in clean high inlet volume flow process gas services have been studied, verifying the technical feasibility and evaluating the economic merits, but no process gas service applications have been made in Exxon facilities. There have been applications by others, most significantly in LNG plant refrigeration service. When process gas applications are considered, specific evaluation of closely related vendor and industry experience is required along with an evaluation of case economics.

SERVICEABILITY AND SPARING

See [Section XI-C](#), *Compression Machinery Serviceability and Sparing*, for reliability factor information and recommended sparing practices.



Note:

- (1) API compressor data sheets specify pressure in psi, bar, and kPa. In this section, bar is the metric unit used for pressure.

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BACKGROUND (Cont)

OPERATING PRINCIPLES

Compressors can be classified as either dynamic or positive displacement machines. The basic principle of any type of dynamic compressor is the conversion of gas velocity to pressure. Axial compressors belong to the dynamic machinery category.

In an axial compressor, the flow is parallel to the machine axis with the gas passing through alternating rows of stationary and rotating blades. Kinetic energy is imparted to the gas by the rotating blades and is converted into pressure by diffusion in the space between individual rotating and stationary blades. The amount of diffusion occurring in the stationary and rotating blading varies based on design. A primary function of the non rotating blades is to redirect the flow from one rotating blade row into the next rotating blade row at an efficient blade entry angle. A typical axial compressor is shown in **Figures 1 and 2**.

PERFORMANCE CURVES

Axial compressors have head capacity curves which are much steeper than those of centrifugal compressors. A typical comparison is shown in **Figure 3**. To achieve a range of flow versus head, speed variation or adjustable stator blades, or a combination of both are used. **Figure 4** is a typical operating characteristic for an axial compressor with variable speed. **Figure 5** is a typical operating characteristic for an axial compressor having a fixed speed and adjustable stator blades. Stator blades are adjustable during operation and alter the operating characteristic of an axial compressor by changing the entry angle of the gas into the rotating blade rows. Stator blade control may be applied to any number of axial compressor stages. Vendors can vary flow path designs to achieve requirements such as high flow turndown, high efficiency in a certain flow range, and a steep or flatter head versus flow operating characteristic.

BASIC CONSTRUCTION

Casings - Axial compressors with multiple compressor stages have cast or fabricated casings which are horizontally split to facilitate rotor removal. The stator blading is supported by either the main pressure casing or by an inner casing called a blade carrier. Most casing designs are limited to 100 to 150 psig (7 to 10 barg).

Rotor - The rotors are usually of forged solid design. Welded hollow rotors may be applied to limit the moment of inertia in larger capacity compressors. Balancing pistons to achieve equalization of rotor axial thrust loads are generally integral with the rotor. Rotating blades are located in peripheral grooves in the rotor.

Stator Blades - Stator blades may be fixed or adjustable. The position of stator blades can be varied by an actuator. The actuator drives a control linkage which rotates the stator blades thus altering the compressor performance characteristics to achieve the desired change in compressor delivered flow.

Seals - Standard axial compressors are designed with labyrinth seals. Vendors could supply oil and dry gas seals for services other than air.

BASIC DESIGN CONSIDERATIONS

PROCESS COMPRESSION STAGING

The choice of the number of process compression stages is influenced by discharge temperature, compressor head generating capability, and the need for process connections at intermediate pressure levels.

Discharge Temperature - The maximum discharge temperature of a process compression stage should be limited to approximately 450°F (232°C). Special designs allow even higher temperatures. Above 450°F (232°C), machinery specialist advice should be sought to verify the adequacy of a single process compression stage arrangement.

This limit applies to air compressors only. For applications on gases other than air, machinery specialists should be consulted.

Head Capability - As a rule of thumb two axial compressor stages, where a compressor stage consists of one rotating blade row and the following stationary blade row, are required to produce the same head as one centrifugal compressor stage. Each axial compressor stage can develop 4500 ft (1400 m) to 5500 ft (1700 m) of head on air and slightly less on gases heavier than air. As many as 17 compressor stages may be assembled into a single casing.

Side Streams - Almost all axial compressor models have simple straight through gas flow paths using one casing for one process compression stage. The normal construction is not readily adaptable to side stream nozzles.

Some manufacturers produce a combination axial/centrifugal compressor model which can incorporate two or three process compression stages in one casing. This compressor is arranged in two or three sections with flow in opposite directions. The primary inlet flow enters at one end, is withdrawn from the midsection and piped to the opposite end, readmitted, then discharged from the midsection. Centrifugal impellers are used for the last one or two compression stages to allow radial instead of axial exit flow thus minimizing casing length.

Most of the services in which axial compressors are applied can be met with one process compression stage.