S70-210 IB/MAY 2004

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SCREW COMPRESSOR FOUNDATIONS

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General

The first requirement of the compressor foundation is that it must be able to support the weight of the compressor package including coolers, oil, and refrigerant charge.

Screw compressors are manufactured to extremely low levels of rotating imbalance and because of this do not generally require the massive foundations used with older reciprocating compressors or large engines. However, it must be recognized that screw compressors are capable of converting large quantities of shaft power into gas compression in a relatively small space and that the installation of any high-speed, high-power equipment should not be approached casually. The predominant frequency of vibration produced in a screw compressor package is at lobe-passing frequency. This is normally 200 to 600 Hertz, depending on drive speed and compressor model. Much less mass is required to effectively dampen these relatively high-frequency vibrations compared to low-frequency vibrations found in lower speed equipment.

Firmly anchoring the compressor package to a suitable foundation by proper application of grout and elimination of piping stress imposed on the compressor is the best insurance for a trouble-free installation. While a compressor may operate successfully on a poor foundation it is certain that vibration levels on the compressor package, and noise levels emanating from the compressor package will be higher if it is not firmly tied to the foundation mass. It is not unusual to see a ten fold increase in vibration level measured on a screw compressor package when comparing a properly mounted package to one that is not tied to the foundation mass.

Use only the certified general arrangement drawings from Frick to determine the mounting foot locations and to allow for recommended clearances around the unit for ease of operation and servicing. Foundations must be in compliance with local building codes and materials should be of industrial quality.

Preferred Installation Method - Concrete Foundations

Preparation and Anchoring

The floor should be a minimum of 6 inches of reinforced concrete. Anchor bolts are required to firmly tie the unit to the floor. If the floor is new, it is recommended that “L” or “J” type anchor bolts be installed at the time the concrete is being poured, at the correct locations for the foot anchor holes on the package. If desired, temporary sleeves can be used around the upper portion of the anchor bolts to allow slight adjustment in bolt position prior to application of final grout, (Figure A). These temporary sleeves are to keep the concrete away from the upper surfaces of the anchor bolts. The clearance around the bolts must be filled completely during the grouting process, (Figure B).

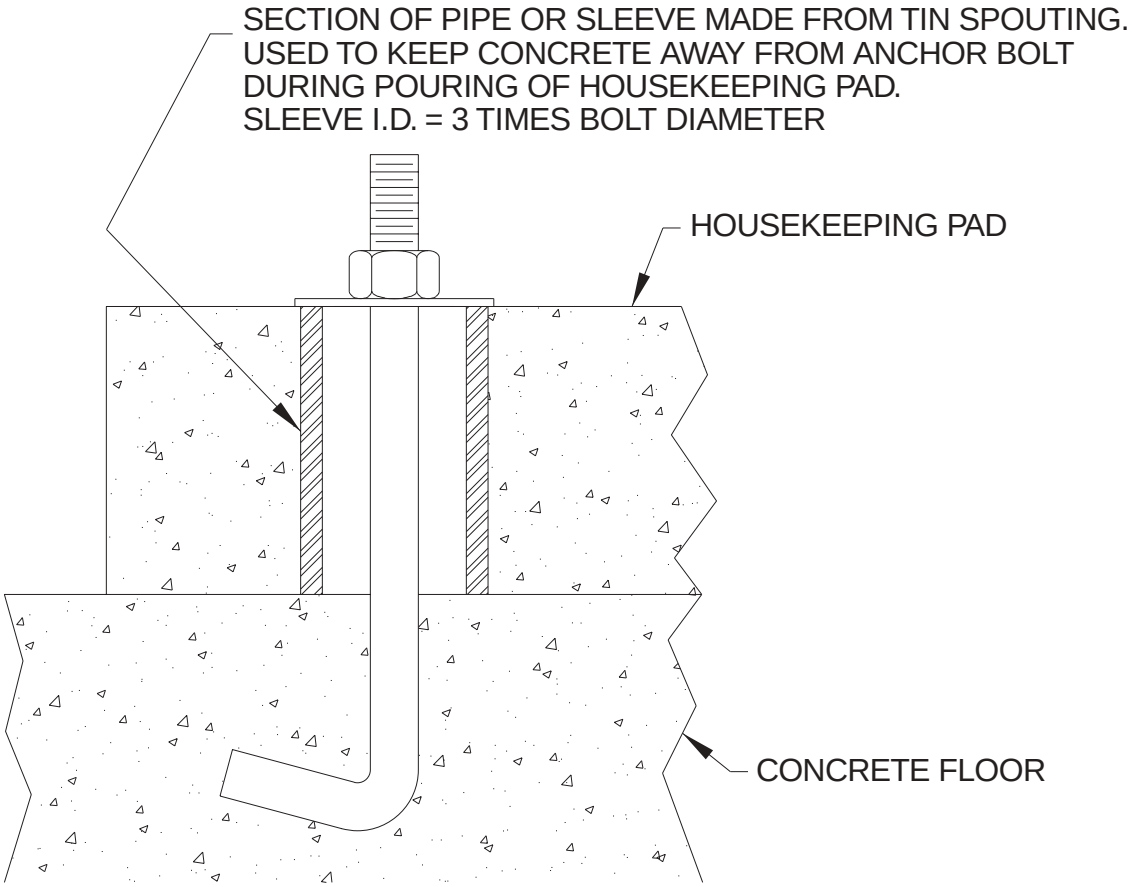


Figure A

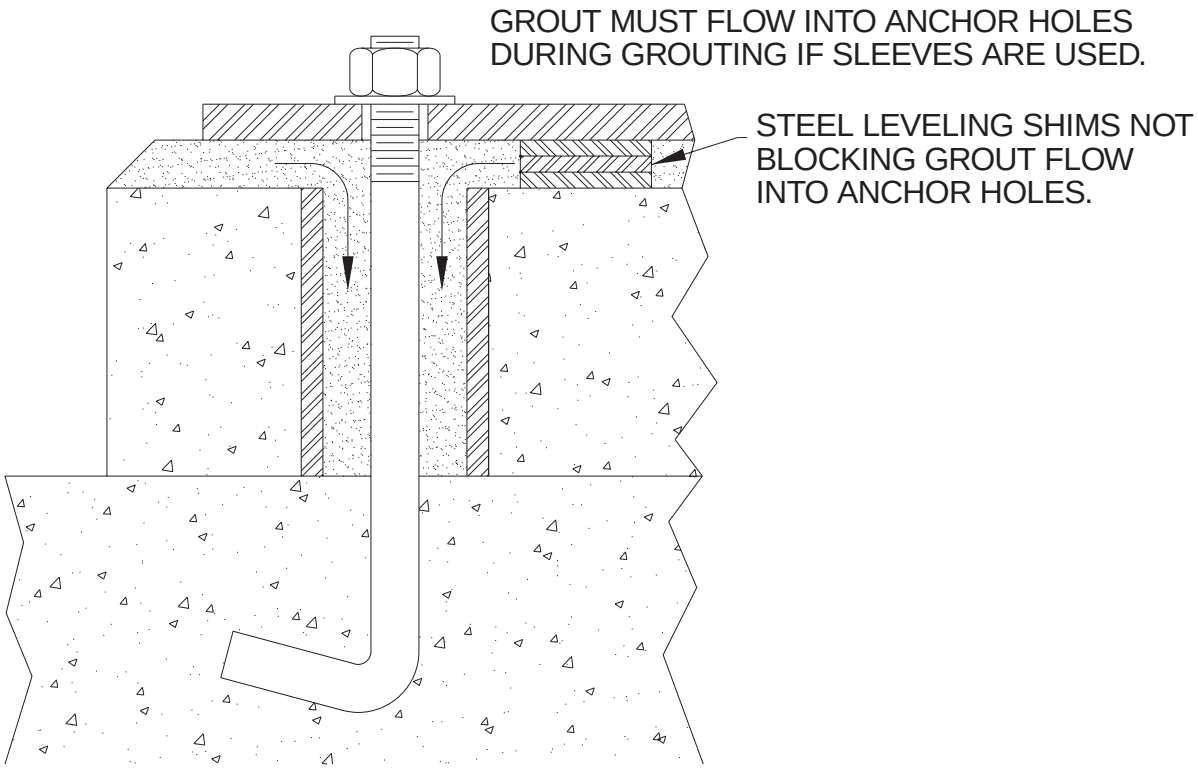
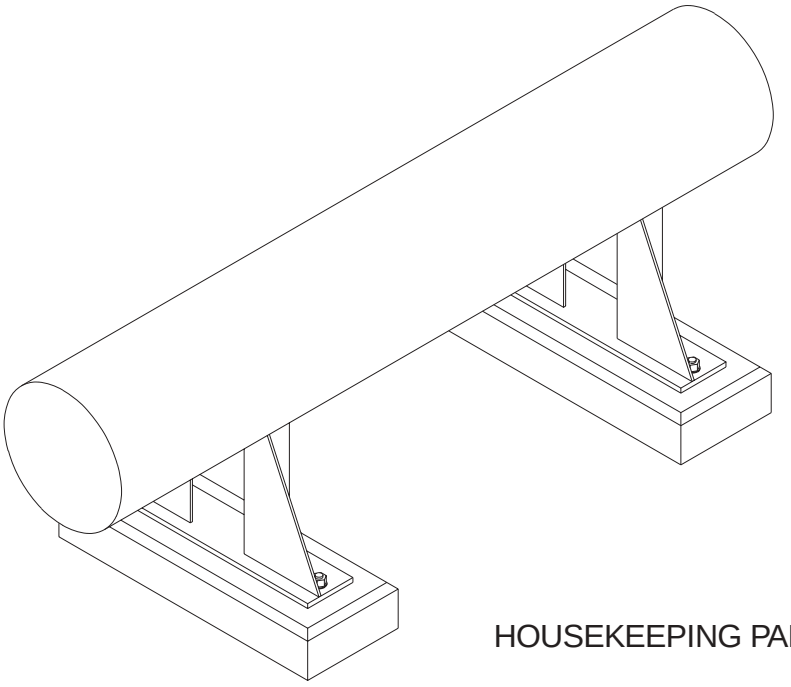


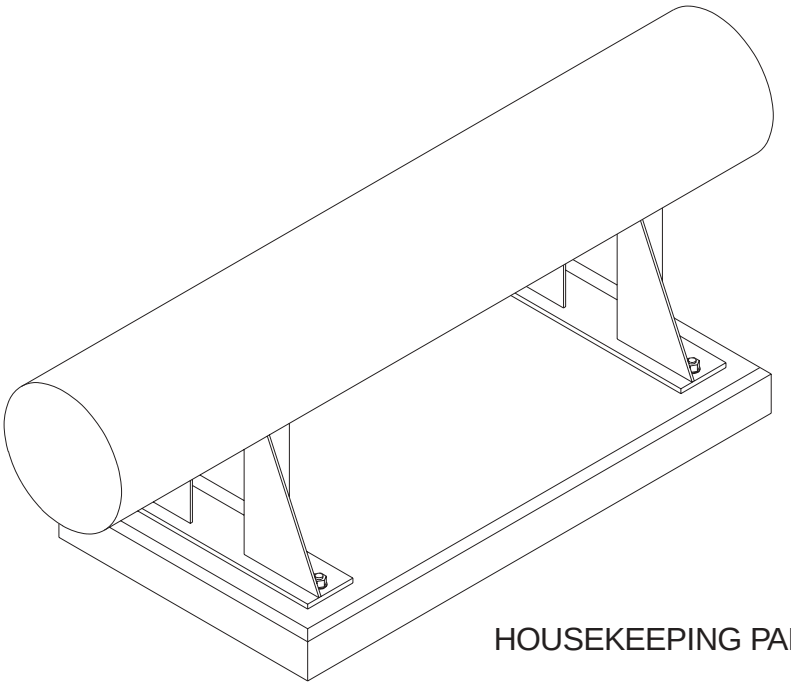
Figure B

If equipment is being installed on existing concrete flooring, anchor holes can be drilled and high quality expanding anchors used to attach the unit to the concrete, providing the anchors are designed to withstand vibratory loading, and the concrete meets the minimum strength specified by the manufacturer of the anchor.

Six-inch thick concrete housekeeping pads are recommended where possible. These can be either under the entire length of the package between the mounting feet or only under the structure of the feet, (Figure C). The anchor bolts must be of sufficient length to extend from the base through the housekeeping pads and through the steel frame of the package, allowing roughly 1 1/2 bolt diameters for nut installation, and allowing 1 inch for grout installation, (Figure D).



HOUSEKEEPING PADS UNDER FEET ONLY



HOUSEKEEPING PAD UNDER ENTIRE UNIT

Figure C

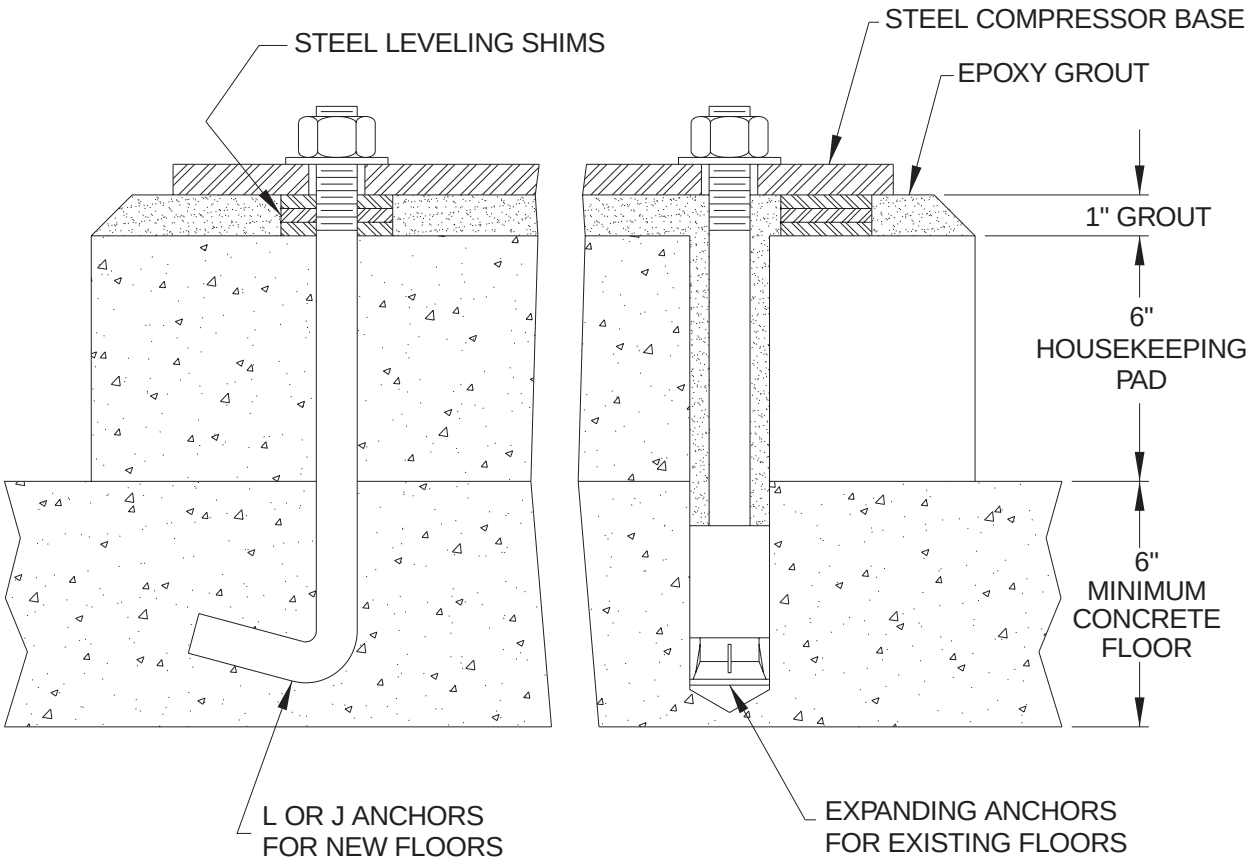


Figure D

Once the concrete foundation is cured, the unit can be rigged into proper position. Use proper lifting points as defined in the Installation Operation and Maintenance manual. Please note that some units, particularly with installed oil coolers or economizer vessels, can be top heavy. Caution must be exercised to avoid tipping the unit.

The unit is first positioned with the anchor bolts passing through the attachment holes in the feet. The feet must then be shimmed in order to level the unit. The shims should be placed to position the feet roughly one inch above the housekeeping pad to allow room for grouting. If sleeves were used around the anchor bolts the unit should be shimmed at some other position in order to allow the grout to fill the space around the anchor bolts. If sleeves were not used around the anchor bolts, then steel shims can be used under each anchor bolt position.

Leveling and Grouting

The unit should be leveled in both directions, primarily for aesthetics and square piping connections, and should bare equally on all shim locations. Wet the concrete pad in accordance with the grout manufacturer's instructions.

Mix a sufficient quantity of grout. An expansion-type epoxy grout must be used. We have had good experience with Chockfast® Foundation System products, although other high quality, nonshrinking grouts are also acceptable. Follow the manufacturer's recommendations for setting, precautions, mixing, working time, grout placement, finishing, and curing.

The grout must be worked under all areas of the base with no voids. If the grout is allowed to settle with a slight outward slope, oil and water will be able to run off the base.

All metallic-based grouts should be sealed after curing to prevent oxidation from destroying the grout.

Once the grout is fully cured, tighten the anchor bolts.

Installation on a Steel Base

When a Frick® screw compressor package is to be installed in a customer-packaged refrigeration system, it is common to mount the compressor unit directly onto a steel system base. In these cases the design of the system base and the mounting of the system base to the customers foundation are very important factors in minimizing vibration. The following guidelines are provided as an aid in properly designing a system base.

1. Use I beams in the skid where the screw compressor will be attached to the system base. The I beams should run parallel to the package feet and support the feet for their full length.

2. The compressor unit feet should be continuously welded to the system base at all points of contact.

3. The compressor unit should not be mounted on vibration isolators in order to hold vibration levels down on the package.

4. The customer's foundation for the system base should fully support the system base under all areas, but most certainly under the I beams that support the compressor package.

5. The system base should be leveled and grouted to the customers foundation with the same precautions as noted above for a single compressor unit mounted directly on concrete.

6. The system base should be firmly bolted to the customers foundation with suitable anchor bolts.

7. Whenever possible, the entire system base should be designed without piping runs inside of the I beam base.

8. Whenever possible the system base should be completely filled with concrete as an added precaution to prevent vibration. The concrete must be allowed to fully cure without the unit operating so it will maintain contact with the steel structure.

9. To attach a compressor base to a foundation, use anchor bolts at the primary points on the skid where component weight bears on the main beams, not between main load bearing locations. See Figure E. Additional anchor points can be used to supplement attachment, as long as the load-bearing points are included as primary anchor locations.

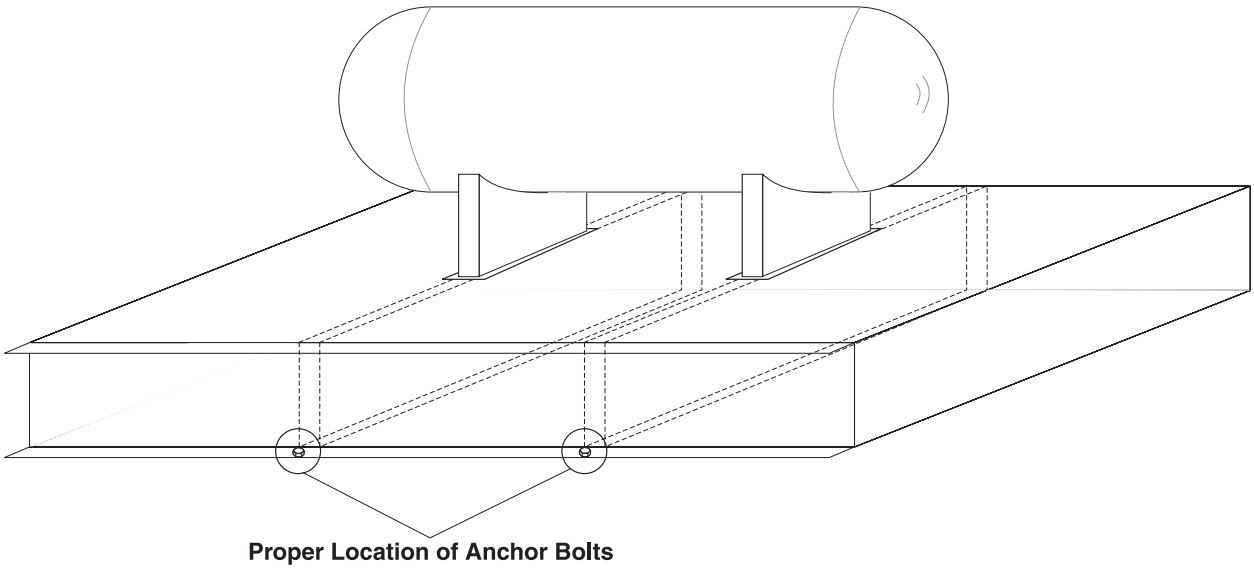


Figure E

Installation on Upper Floors of Buildings

When screw compressors are to be mounted on upper floors of buildings, extra precautions should be taken to prevent normal package vibration from being transferred to the building structure where it might cause unacceptable noise or vibration. It is important that no structural resonance of the building is near the primary frequencies generated by the screw compressor, (lobe passing frequency and its harmonics). If this is the case the vibration levels of the screw compressor unit can be greatly magnified by the structure of the building.

When a compressor is to be mounted directly on a steel building structure, it is essential to use rubber or spring isolators, or a combination of both, to prevent the transmission of compressor vibration directly to the structure. The choice of the proper type of isolation is important. Neoprene rubber isolation pads (VMC Shear-Flex for example) have been used effectively in many applications. Pad type and surface area (square inches) are based on total weight and deflection of the pad. In applications where very low levels of transmitted vibration are required, spring isolators may be necessary. It is best to employ a vibration expert in the design of a proper mounting arrangement, taking account of spring, mass, and damping requirements to meet the customer's desired end result.

If a screw compressor package is fully isolated from the foundation, and not tied to any structural mass, the vibration and noise levels on the screw compressor package will likely be higher than typically encountered in the more normal concrete base installations because the vibrating components are not tied to any foundation mass.

The mounting and support of suction and discharge lines is also very important in situations with the compressor isolated from the structure. Even with very effective isolation of the compressor feet to the building, any piping that is tied directly to the structure can also transmit noise and negate the advantages of isolation. Rubber or spring pipe supports are generally required to avoid exciting the building structure at any pipe supports close to the compressor package.

All metal contact paths from an isolated package to the foundation must be broken. For example, metal conduit from skid to floor should not be used.

Piping Stress

In any screw compressor installation, once the package is installed, properly grouted, and anchored, it is important that the piping bolted to the screw compressor not impose excessive forces or moments on the compressor. Suction and discharge lines should be supported in pipe hangers so that the lines won't move if disconnected from the compressor. The attached Figure E gives maximum allowable flange loadings for various size compressors.

Gas or Diesel Engine Driven Packages

It is becoming more common to drive screw compressors with large stationary engine or turbine drives in order to reduce electrical demand or reduce electric energy consumption. Some special considerations should be given to foundations for engine drives in order to avoid vibration problems on these skids.

1. The engine or turbine manufacturer will normally give foundation mass requirements for the driver. These are normally much heavier than would be used with an electric motor driven screw compressor. A typical, large (500 HP), gas engine drive may require 4 feet of concrete foundation thickness under the engine in order to absorb the normal vibration associated with the engine. When the engine is skid mounted with a screw compressor, it is not acceptable to spread the recommended foundation mass requirement for the engine under the entire screw compressor driveline. In other words, 1 ft thick concrete under a 20 ft long package is not equivalent to 4 ft thick concrete under the 5 ft length of the engine. The foundation requirement for the engine must be under the engine. Too much foundation will never hurt, but as a minimum the engine must be over and firmly anchored to its required foundation mass.

   A licensed architect should be consulted to determine the proper foundation requirements for any large engine or turbine drive.

2. A torsional vibration analysis should always be performed by a capable party before final component selection in order to avoid torsional resonance in any engine or turbine-driven screw compressor. This analysis will determine the recommended coupling inertia and stiffness to tune the system torsional natural frequency, and its harmonics, away from the operating speed or speeds. Once the proper couplings have been specified, no substitutions should be made unless the substitute coupling type is again checked by a new torsional analysis.
3. The attachment of an engine or turbine base to a screw compressor must be of sufficient rigidity to maintain coupling alignment specifications at the compressor. For Frick compressors this is normally within .004 inch TIR radial and axial. It is recommended that the driver and compressor be on the same structural steel skid or that separate skids for the driver and compressor be bolted together through dowelled connection pads.

4. Engine drive compressor packages can be quite heavy and the weight will normally be concentrated on the engine end of the skid. Extra precaution should be exercised in lifting and rigging of large heavy skids. It is likely that the greatest stress on the skid will occur during rigging and lifting into position. Improper lifts can permanently distort a skid and be very expensive to fix. Before rigging and lifting a heavy skid, make sure adequate lifting points are being properly supported.

5. As an option on engine driven screw compressors, the system designer should always consider the cost of a gear driven speed increaser between the engine and compressor compared to a direct-driven larger compressor to produce the same displacement. The larger direct drive compressor will have a considerably simpler drive and coupling arrangement and simpler alignment procedures. This will normally produce lower noise and vibration levels and may be more cost effective as well.

High Power Applications

Screw compressors are very flexible in their ability to compress a wide variety of gases over a wide range of pressures. In general, those applications with high suction and discharge pressures on dense gases will absorb the greatest power per unit displacement. The more energy involved in the compression, the stronger the gas pulsations will be coming out of the compressor discharge ports. These pulsations are the driving force to excite the oil separator and discharge line to act like a speaker and produce noise, as well as to produce structure-born vibration. An application at 350 psi. discharge pressures on a dense refrigerant can be expected to produce more noise and vibration than the same compressor at 200 psi. discharge pressure or compressing a refrigerant of lower density.

In applying screw compressors at high pressures, the customer must be prepared for the fact that package vibration and noise will be higher than the values predicted for normal refrigeration duty. Proper foundations and proper installation methods are vital at high power conditions and even then, the customer must be prepared for the possibility that sound attenuation or noise curtains may be required to reduce noise to desired levels. Because many applications are somewhat different from previous experience, it is impossible to accurately predict overall noise and vibration levels before equipment is started and running at plant conditions.

The guidelines given in this paper can prevent most noise and vibration problems with screw compressors, but for high pressure custom applications, a guaranteed noise level is impossible to predict prior to installation. Customer expectations must be tempered with the understanding that customized compression systems will vary from one application to another in achieved noise and vibration levels. If these issues are addressed before a system is installed, a more satisfied end user will be the result.

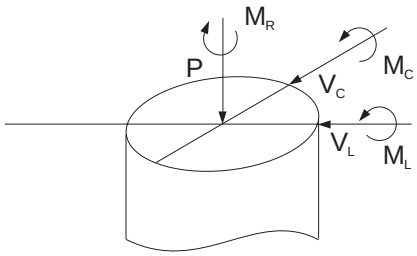
ALLOWABLE FLANGE LOADS : ANSI CLASS 150, 300

NOZZLE SIZE	MOMENTS (ft-lbf)			LOAD (lbf)		
NPS INCHES	AXIAL	VERTICAL	LATERAL	AXIAL	VERTICAL	LATERAL
	M_g	M_c	M_L	P	V_C	V_L
1	25	25	25	50	50	50
1.25	25	25	25	50	50	50
1.5	50	40	40	100	75	75
2	100	70	70	150	125	125
3	250	175	175	225	250	250
4	400	200	200	300	400	400
5	425	400	400	400	450	450
6	1000	750	750	650	650	650
8	1500	1000	1000	1500	900	900
10	1500	1200	1200	1500	1200	1200
12	1500	1500	1500	1500	1500	1500
14	2000	1800	1800	1700	2000	2000

External piping loads impose forces and moments in three geometric planes. Since circumstances vary from installation to installation, there is no one set of flange loading values which Frick can provide for all cases. Our experience indicates that maintenance of coupling alignment, especially for compressors and pumps, is the critical limiting factor. From a practical or service point of view, alignment is more of a concern than flange strength, pipe stress, joint stress, casing stress, etc.

Although the ideal loading on any flange or connection is “zero”, it is not practical to expect “no” affect from external piping forces and thermal expansion.

The above Table reflects a realistic approach to allowable flange loadings and provides some guideline for the installation of Frick equipment.



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