OEM Bulletin

Carlyle Compressor Sales

Carlyle Compressor Sales, 6376 Wavel Street, Syracuse, New York 13206

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RECOMMENDATIONS TO MINIMIZE REFRIGERANT LINE VIBRATION

INTRODUCTION

Refrigerant leaks have always been a major concern in any air conditioning or refrigeration system. Costs associated with refrigerant replacement and the reliability of the unit have given system designers and manufacturers the incentive to keep these refrigerant losses to a minimum. Recently though, the effect of refrigerant discharges on the environment have created an additional concern.

Ozone depletion has become a major topic of interest in the nation and the world. The Environmental Protection Agency (EPA) believes fully halogenated chlorofluorocarbons (CFC's) are one of the causes of ozone depletion. Unfortunately the most common refrigerants used today in refrigeration applications (R-12, R-502) are all CFC's. The proposed EPA regulations on CFC's are expected to affect both price and availability of these refrigerants and will result in a greater emphasis on avoiding the accidental discharge of fully halogenated CFC's.

Carlyle has written the following bulletin to assist equipment manufacturers in the design of refrigeration and air conditioning systems to avoid refrigerant line vibration problems. Vibration problems can often result in broken refrigerant lines. This bulletin addresses design and retrofit considerations for refrigerant piping problems.

REFRIGERANT LINE VIBRATION

THEORY

Causes of vibration in discharge lines can be primarily separated into the following categories:

1. Structural Resonances
2. Forced Vibration
3. Acoustical Resonances

Of the above causes of vibration, structural resonances are the most common cause followed by forced vibration and acoustical resonances. Vibration can also be caused by multiple combinations of the above. The following will discuss each type of vibration in the order listed.

STRUCTURAL RESONANCES

Structural resonances occur when the natural frequency of the discharge piping matches the frequency of the discharge gas pulsations (exciting frequency). When the exciting frequency matches the frequency of the piping, the vibration of the piping becomes greatly amplified. Imagine a tuning fork, it has a specific frequency that it resonates at, and that is where the most vibration occurs. Thinking of a piping system as a very large tuning fork, it would have to be designed so that it did not have a structural resonance at or near the exciting frequency of the gas pulsations. The resonant frequency is a function of the stiffness and mass of the line. A discharge line should be designed as stiff and light as possible to reduce the chance of vibration problems. However, in systems where start and stop kicks or other system motion occurs, flexibility must be designed into the piping system to absorb the motion. A stiff and light discharge line will have a higher frequency at which it resonates than one that is less stiff and/or has more mass. Troublesome discharge gas pulsations occur at relatively low frequencies, therefore systems with higher natural frequencies will have less chance of being affected by structural resonances. Structural resonances are very difficult to predict. Extensively testing a piping design in a laboratory environment, is the best method for avoiding structural resonances. When a design is found to be free of structural resonances, the exact design should be used consistently in the future. Any changes to a structural resonance free design, such as moving a fitting, would require retesting the design.

FORCED VIBRATION

Forced vibration is the vibration caused by movement of the compressor (compressor driven vibration) and/or discharge gas pulsations (pulsation driven vibration) emitting from the compressor. The term forced vibration excludes vibration due to any piping system resonances.

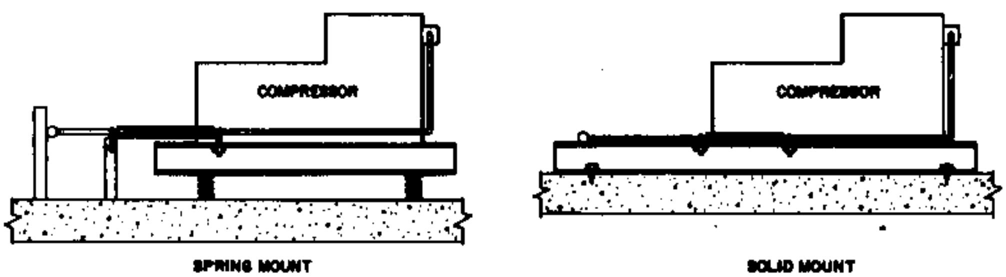
Compressor driven vibration is not a typical problem when the compressor is solid mounted, but when the compressor is spring mounted the chances of vibration problems are greater. Spring or rubber mounting kits are typically used in environments where vibration transmitted from the compressor to the floor may cause excessive noise or damage to a sensitive area. When spring or rubber mounting kits are used, the piping system (which is where most vibration problems occur) must be designed to absorb start and stop kicks, and handle the additional motion of the compressor during operation. This is usually accomplished by using flexible piping (vibration absorbers) and spring piping hangers.

Although these items may reduce the transmission of movement of the compressor to the system, they may greatly enhance the effects of piping system vibration. The chances of pulsation driven vibration and structural resonances increase with the introduction of springs into the system. Spring or rubber mounting of compressors is sometimes necessary depending on environment and/or rack or unit design. Spring mounting generally makes piping geometry more complex and increases the possibility of vibration problems. As a general rule, if there is no reason for spring mounting compressors or racks, don't.

On solid mount applications utilizing flexible piping (vibration absorbers), clamp the inlet and outlet of the vibration absorber. Allowing one or both ends of the vibration absorber to flex can increase the chance and/or magnitude of vibration problems. Carlyle doesn't recommend the use of vibration absorbers in solid mounted compressor systems, unless they are securely clamped at both ends.

On spring mounted applications, vibration absorbers should be used only in accordance with manufacturers requirements and recommendations. Typically vibration absorbers should be parallel to the crankshaft with the inlet clamped to the compressor or spring mounted base and the outlet clamped to the solid mounted frame. When piping spring mounted compressors, try to arrange the compressor and piping to the straightest possible piping geometry, using as few bends as possible. The previous statement holds true on solid mount systems as well, but spring mounted systems usually become more of a problem because the discharge line has to be parallel to the crankshaft. Careful planning can eliminate excessive piping and bends.

PREFERRED CLAMPING METHODS
FOR SYSTEMS WITH FLEX PIPE



NOTE: ONLY DETAILS WHERE CLAMPS SHOULD BE PLACED IN RELATION TO FLEX PIPE, NOT ALL PIPING.

Gas pulsation driven vibration is the most common cause of forced vibration. Pulsation driven vibration does NOT mean that the compressor is emitting such high pulsations that it forces the line to vibrate regardless of the piping geometry. All reciprocating compressors emit discharge gas pulsations (a reciprocating compressor generates a constant stream of pulsating flow). When discharge gas pulsations react with the piping system geometry in such a way as to set up an oscillating force, discharge pipe vibration may occur. An example of this is when the discharge line comes off the compressor service valve and enters 1, 2, 3 or more elbows. Picture the pulsating discharge gas flowing from the compressor through the first straight section of discharge pipe. The discharge gas then hits the first elbow and bounces into the next section of straight pipe. An oscillation in the gas has already started and each elbow may increase the oscillation creating a significant amount of line vibration. Designing the discharge piping as straight as possible will reduce the chances of pulsation driven vibration occurring. Another cause of forced vibration is the "Bourdon Tube Effect". When discharge piping forms a U shape, the high pressure discharge gas tries to straighten the piping, resulting in vibration. Gas pulsations have little if any affect on discharge lines composed of a single straight pipe.

ACOUSTICAL RESONANCES

Acoustic resonances result from the specific discharge gas properties and the piping system geometry (not the structural dynamics). The effect of acoustical resonances is to amplify the gas pulsations at specific location in such a magnitude as to cause significant vibration. There are many types of acoustic resonances and most are very difficult to predict. The most common type results from longitudinal standing wave patterns.

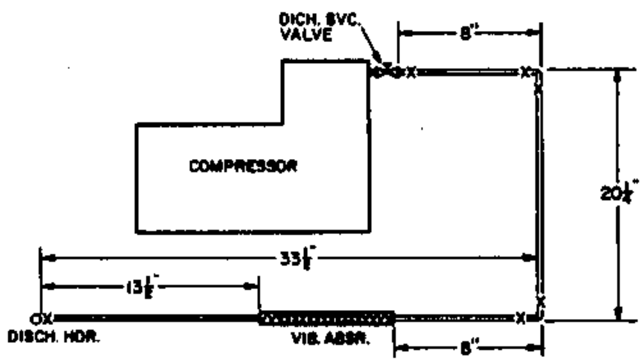
The following page details a sample calculation for a standing wave resonance.

The following paragraphs detail a critical length calculation. Although critical length calculations are straight forward, if the terminology is not familiar it can become very confusing. Becoming familiar with the following definitions will make the critical length discussion more comprehensible.

Standing wave	— Specific type of acoustical resonance.
Exciting frequency	— The frequency of the discharge gas pulsations in hertz, denoted by the symbol f. The dominant frequencies for Carlyle compressors are as follows: 2 Cylinder — 58 hertz. 4 Cylinder — 117 hertz. 6 Cylinder — 58 & 117 hertz.
Element	— Segment of discharge pipe between two terminations. A termination is defined as a compressor, muffler, elbow, header. . .
C	— Speed of sound of the discharge gas, in feet/second. (See Appendix)
L	— Wave length for an exciting frequency.
L/2	— One half the wave length for an exciting frequency.
Critical Length	— An integer multiple (1, 2, 3. . .times) of one half the wave length for an exciting frequency (L/2).

Simple "standing wave" resonances occur when an "element" matches a "critical length". Critical lengths can be easily calculated using the following formula:

$$L/2 = C/2f$$



CRITICAL LENGTH CALCULATION

For this example we will assume a four cylinder compressor, therefore, the significant exciting frequencies will occur at two and four times rotating speed (58 and 117 hz). We will also assume the refrigerant to be R-22 at 110 F SCT and 185 F discharge gas temperature. With a sonic velocity of 588 ft./sec. The sonic velocity was determined using the attached graphs.

$$\frac{L}{2} = \frac{588}{(2)58} = 5.06 \text{ ft.} = 60.82 \text{ in.}$$

Allowing a + or - 10% margin for variation in the system conditions, the critical lengths to avoid would be:

At 58 hz — 55 to 67 inches

At 117 hz — 27 to 34 inches (four times operating speed will be exactly half of two times operating speed).

Evaluating the diagram above, there are no lengths between discontinuities which fall into the critical length ranges calculated. An example of a potential acoustic resonance would be if the first elbow was located in the 27 to 34" range. If a potential acoustic resonance occurs the fitting would have to be moved out of the critical length range to avoid it.

One half of the critical length (L/4) should also be avoided between the service valve and the muffler.

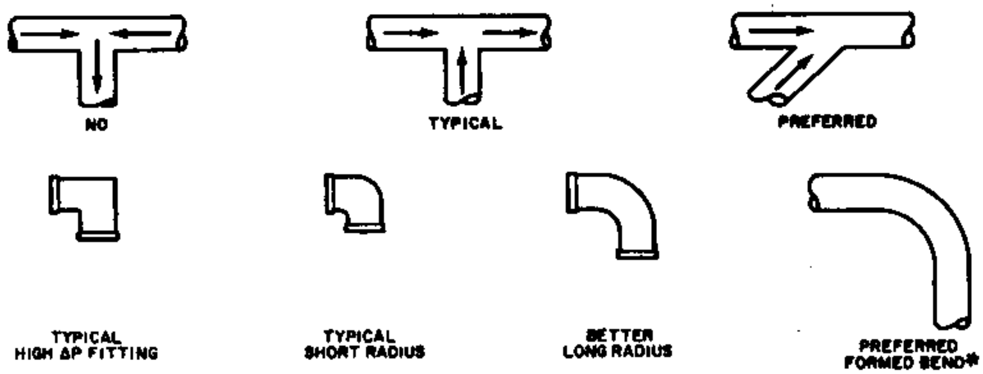
DESIGN RECOMMENDATIONS

Through the utilization of good design practices forced vibration, and acoustical and structural resonance problems can be kept at a minimum. There is no design method that will eliminate all possible vibration problems 100% of the time except through experimental testing of each system. From the previous material, it is shown that predicting vibration problems can be very difficult and complex. It should be noted that when a system is designed and found to be free of vibration problems, that particular design should be reused in its entirety. NOTE: Vibration problems may be created by any changes to the design — i.e., different dimensions, additional fittings, different mufflers. . . In conclusion if you find a design that works, keep it.

The following is a list of good design practices:

1. Keep line as stiff and light as possible. Keep in mind that the line may require inherent flexibility to handle any system motion (start and stop kicks. . .).
2. Keep lines as straight as possible. Use formed discharge lines in place of elbows wherever possible. If elbows must be used, use long radius in place of short radius. Use 45 degree elbows or bends in place of 90's wherever possible. Use Y's or a 45 degree bend in place of T's wherever possible. Use fittings of the proper size, don't reduce line size for fittings. Don't use fittings that have large pressure drops, such as sharp 90 degree elbows.

PIPING PRACTICES



*A FORMED RADIUS OF 10 PIPE DIAMETERS ACTS ACCOUSTICALLY AS A STRAIGHT LINE.

3. Use largest practical discharge line diameters possible. Practically speaking, if a line is sized for a given load and proper oil entrainment, there is usually no significant increase in line size possible.
4. When using solid mount compressors with vibration isolators, clamp the isolator at both ends.
5. Detemine whether spring or solid mounting is appropriate.
6. If natural frequencies have been occurring in existing designs, redesign piping system.
7. System geometry should be checked by calculating standing wave resonance.
8. Carlyle compressors are supplied without valves to allow flexibility in sizing refrigerant lines. Always calculate both suction and discharge line sizes and use the appropriate service valves. Although we recommend using the most generous discharge line diameters practical, please note that oversizing lines can result in oil return problems. Refrigerant lines should always be sized to handle the design, maximum and minimum load conditions.
9. When using mufflers, place them as close to the service valve as possible and/or before the first fitting. Ideal placement of the muffler is not always possible, but note that a muffler is ineffective upstream of itself.

EXISTING SYSTEMS

To eliminate vibration problems in existing system, the cause of the vibration should first be determined. Structural resonances are the most common problem, they can usually be detected and corrected by the addition of mass to the line. This may sound contradictory to the statement that lines should be designed as light as possible. When a system has a structural resonance it is because the piping has a natural frequency at the same range as the discharge gas pulsations. The easiest way to eliminate this problem is to add mass to the discharge line which can effectively lower the natural frequency of the piping. This is a very effective method of tuning the system out of the range of the gas pulsations frequency. The addition of mass can be in the form of a muffler and in some cases an existing muffler can be the culprit in the system. For example, if your system is designed so that the natural frequency of the line is greater than that of the gas pulsations, the addition of a muffler may add sufficient mass to drop the natural frequency of the discharge line to the range of the gas pulsations. The addition of mass could also be in the form of a plastic molded weight that could be slid up and down the discharge line. Moving the mass around the piping to find its most effective position, can be a very effective means of tuning a system. If a weight is used in a system, make sure it is rigidly attached to the refrigerant line. If a weight is allowed to move independent of the line it may cause wear and potentially a leak. Clamps may also be added to increase the stiffness of the line, and are very effective. The use of clamps is discussed later in this section.

NOTE: In the event of trying to tune a system using a plastic or lead molded weight, use caution. Make sure the high temperature of the discharge line doesn't melt the material or cause it to give off toxic gas.

Forced vibration is the next most common cause and can be corrected by using mufflers, baffle plates, larger discharge lines, reduction of bends, long radius elbows, formed discharge lines, and clamps. To determine if a muffler will be effective, throttle the discharge valve for approximately 20 PSI increase in discharge pressure. The pressure increase does not occur until the valve is almost completely front seated **(WARNING: Do not completely front seat valve. This will cause extreme internal compressor pressure which may cause compressor damage and potentially rupture the compressor)**. If the piping vibration subsides with the throttling of the discharge valve, a muffler will usually be an effective application.

Forced vibration is generally due to gas pulsations, but in rare instances may be due to compressor imbalance. Motor or coupling problems can also be the cause of forced vibration in open drive compressors. To determine whether the vibration is due to compressor imbalance or gas pulsations the following method can be used.

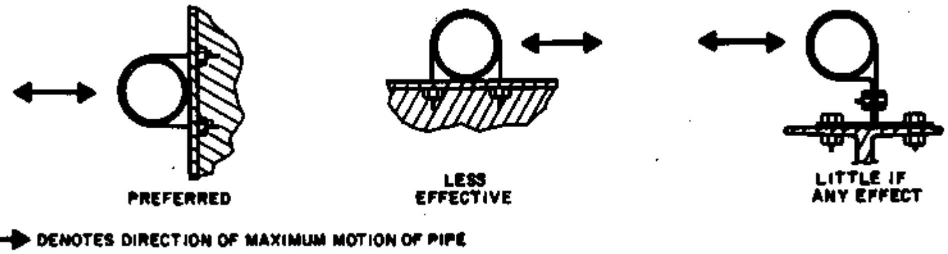
1. Turn compressor off.
2. Shut the suction and discharge service valves.
3. Bleed all pressure from compressor.
4. Remove both service valves.
5. Secure a rag over the discharge port to separate oil mist.
6. Run the compressor for a short period of time (10 to 15 seconds) on air.
7. During run time examine compressor for imbalance.

WARNING: Oil mist is extremely flammable, be sure to use the oil separation method in step #5. Make sure both service valves are removed from compressor.

This method quickly determines imbalance problems on 06D/E compressors, but on 5F/H compressors it has only narrowed it down. On 5F/H compressors, if imbalance occurs after running the compressor on air, check the coupling alignment and then run the motor by itself. When using the above methods, take into account any start and stop kicks due to the mounting method of a weak base.

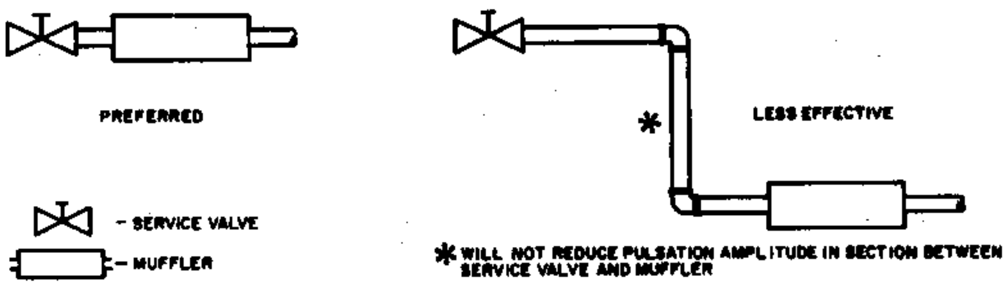
Muffler and baffle plate pros and cons will be discussed later in this bulletin. Please note that when using clamps they will be most effective if placed in the direction of maximum motion. If a line is moving horizontally and you clamp it vertically, the clamp is less effective. Clamping lines can be very effective and is usually the easiest method to correct vibration problems, but unless the lines are clamped properly, the problem may become even worse. When clamping lines, they must be clamped to something that is more stiff than the discharge line to be effective. Clamping a discharge line to a light piece of channel may cause the channel to resonate. If the channel begins to resonate it may cause noise, and/or transmit vibration. The clamp itself should be made of a rigid material that is more stiff than the discharge line.

CLAMPING METHODS



Checking the discharge piping system geometry for acoustical resonances using the calculations given previously and the muffler placement chart should be done. Discharge piping may have to be lengthened before reaching discontinuities (mufflers, elbows. . .). Some redesign of the discharge piping may be in order. It may be required to eliminate mufflers, elbows, check valves. . .

MUFFLER ARRANGEMENT

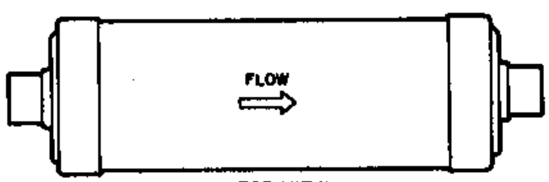


MUFFLERS

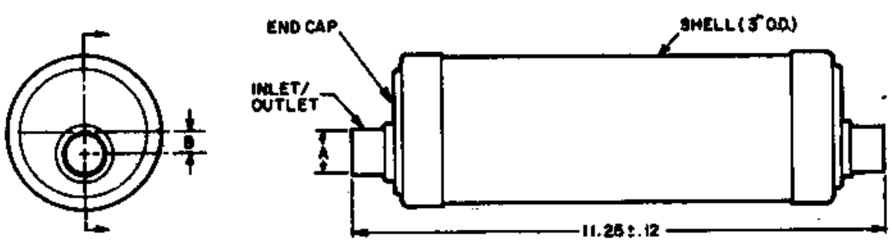
Mufflers can reduce discharge gas pulsations and effectively eliminate vibration problems downstream of them. In most cases, mufflers are ineffective at low frequencies, this primarily depends on the muffler itself. Carlyle Compressor Sales is now offering a new muffler which has been designed to reduce gas pulsation, specifically in Carlyle 06D and 06E compressors. Muffler placement is very important, they should be placed as close to the compressor as possible, but should be kept out of the critical ranges calculated for longitudinal standing wave patterns.

NEW CARLYLE MUFFLER DESIGN

CARRIER PART NO.	DIMENSIONS	
	A	B
06DA605594	.628/.633 I.D.	.750
06DA605604	.878/.883 I.D.	.440
06DA605614	1.128/1.133 I.D.	.440



TOP VIEW



END VIEW

SIDE VIEW

Mufflers are typically not needed in system designs. Reciprocating compressors emit gas pulsations and these pulsations sometimes react with specific system designs and cause vibration. In these systems where pulsation driven vibration has proven to be a problem, a properly sized muffler should be used.

Mufflers can be used to effectively reduce piping system noise. Lengthy piping runs often develop an audible pulsating noise. The use of mufflers in systems with remote condensers has proven very effective at reducing piping noise levels. The new muffler offered by Carlyle is recommended for 06D compressors in systems with piping noise problems.

As discussed previously the addition of a muffler can add sufficient mass to a discharge line to cause the natural frequency of the line to fall into the range of the gas pulsations. Mufflers can cure problems if used properly and can also create them. The question of whether a muffler is needed should be thought out in the design process.

CARLYLE RECOMMENDATIONS

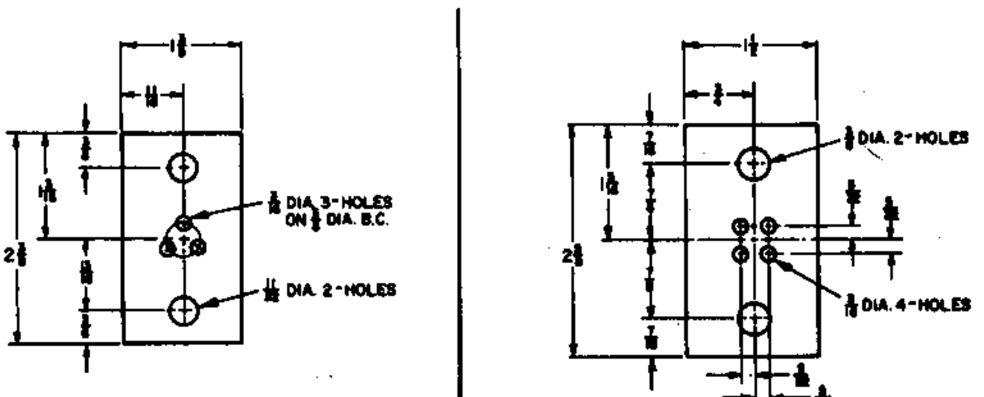
1. Mufflers should be used on all 06ER166 (now becoming obsolete) and 06ER099 compressors.
2. Mufflers should be used on all 06EM266 (now obsolete) and 06EM199 compressors.
3. Mufflers should be used on all 06E compressors with capacity control.
4. Mufflers should be considered on all 5F/H standard stroke compressors and are required on all 5F/H long stroke compressors.

BAFFLE PLATES

Baffle plates are basically an orifice used to create a pressure drop and reduce discharge gas pulsation amplitude. Baffle plates can be very effective at low frequencies, where mufflers offer limited attenuation. The use of baffle plates will increase the discharge temperature, but for most applications the amount is insignificant. Baffle plates are also very easily installed in a system. The orifice on a baffle plate is designed to reduce discharge gas pulsation amplitude at full load, but when unloaders are used the baffle plates effectiveness becomes very limited. In effect a baffle plate can eliminate vibration problems at full load, but at part load vibration problems may appear because of the lower mass flows.

NOTE: Baffle plates are designed to create a 6 - 10 psi pressure drop.

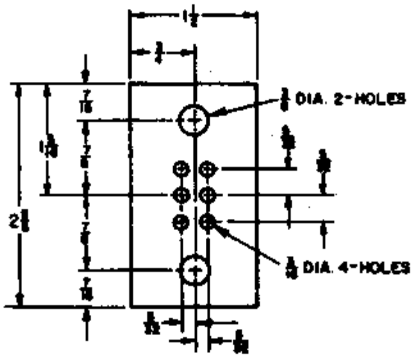
06D/E DISCHARGE BAFFLE PLATES



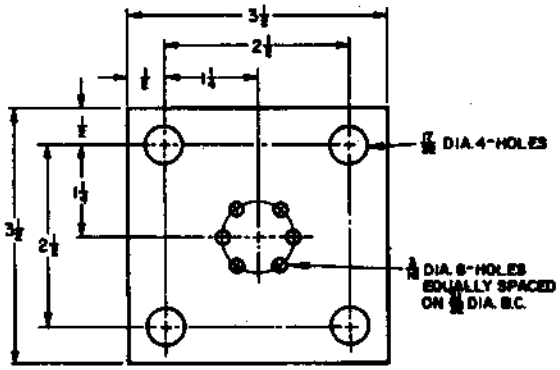
13, 16, 18 & 20 CFM

24, 28, 37 & 50 CFM
LOW TEMP. APPLICATIONS

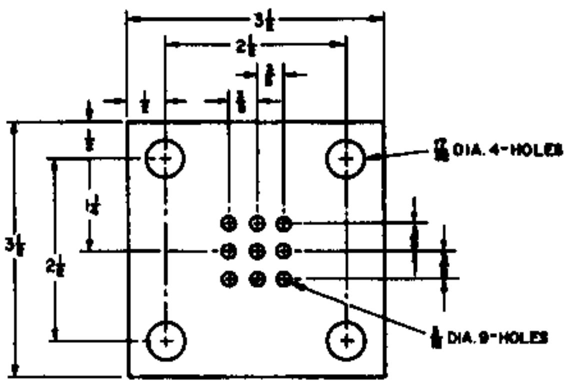
06D/E DISCHARGE BAFFLE PLATES (CONT.)



24, 28, 37 & 50 CFM
MEDIUM TEMP. APPLICATIONS



FOR 06ER 75 & 99 COMPRS
LOW TEMP. APPLICATIONS



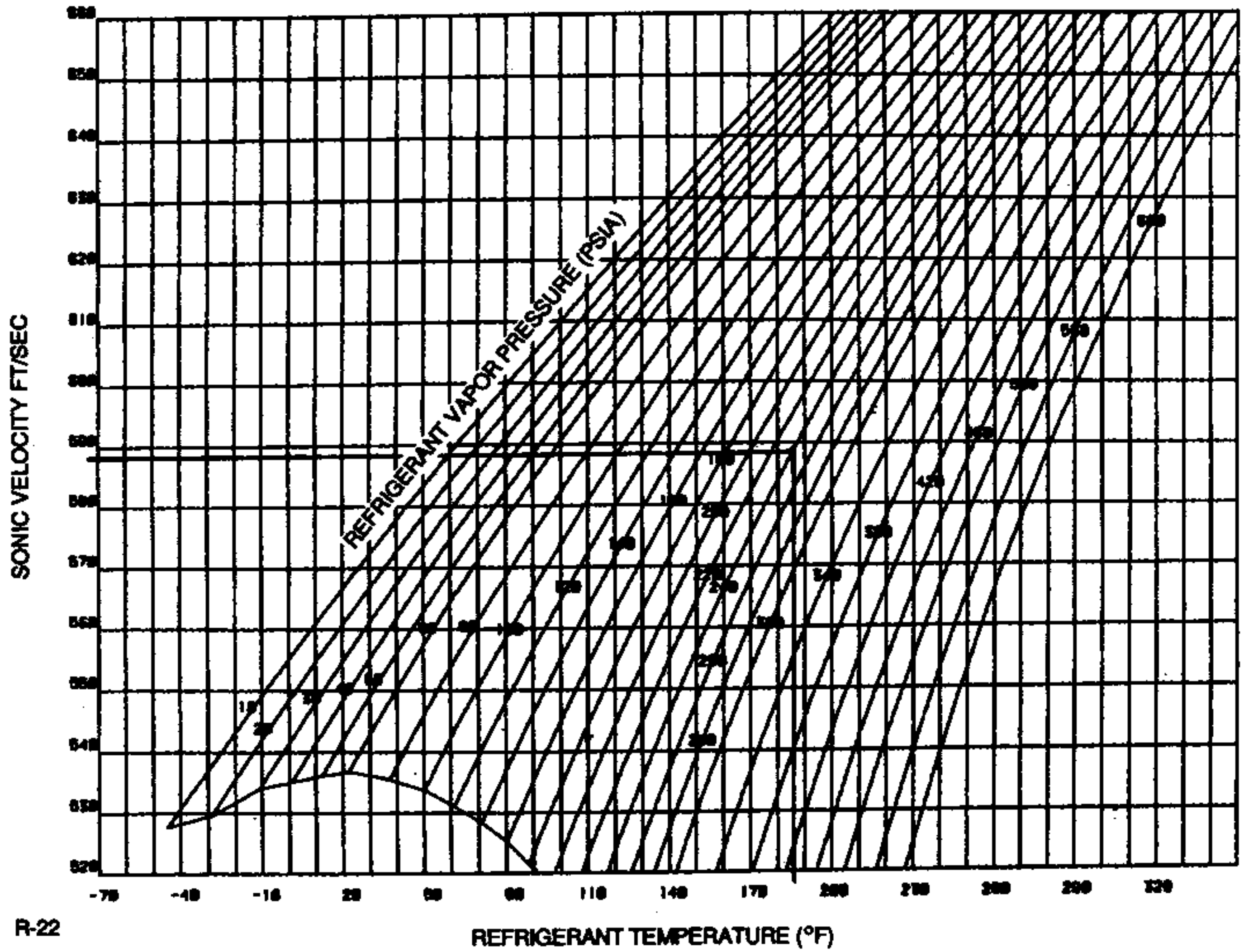
FOR 06EM 75 & 99 COMPRS
MEDIUM TEMP. APPLICATIONS

Carlyle recommends changing the piping geometry, and/or adding clamps or mufflers as the most effective means of reducing discharge line vibration problems. Baffle plates can be an inexpensive and effective fix, but increase discharge pressure, temperature and also result in slight losses in capacity and performance.

PRESSURE SWITCH CONNECTIONS

Presently Carlyle recommends the use of cap tubes and braided flexible steel hoses for use with pressure switches. Using tubing larger than cap tube (ex. 1/4" tubing) may result in a line break because cap tubes are more effective in reducing pressure pulsations through them. Carlyle has found in the past that using 1/4" hard copper on some accessories for 5F/H compressors often resulted in broken lines. To remedy the situation Carlyle changed from hard to soft 1/4" copper tubing and eliminated the piping breaks. Hard copper tubing is not as flexible as soft copper and should not be used.

CARLYLE COMPRESSOR COMPANY



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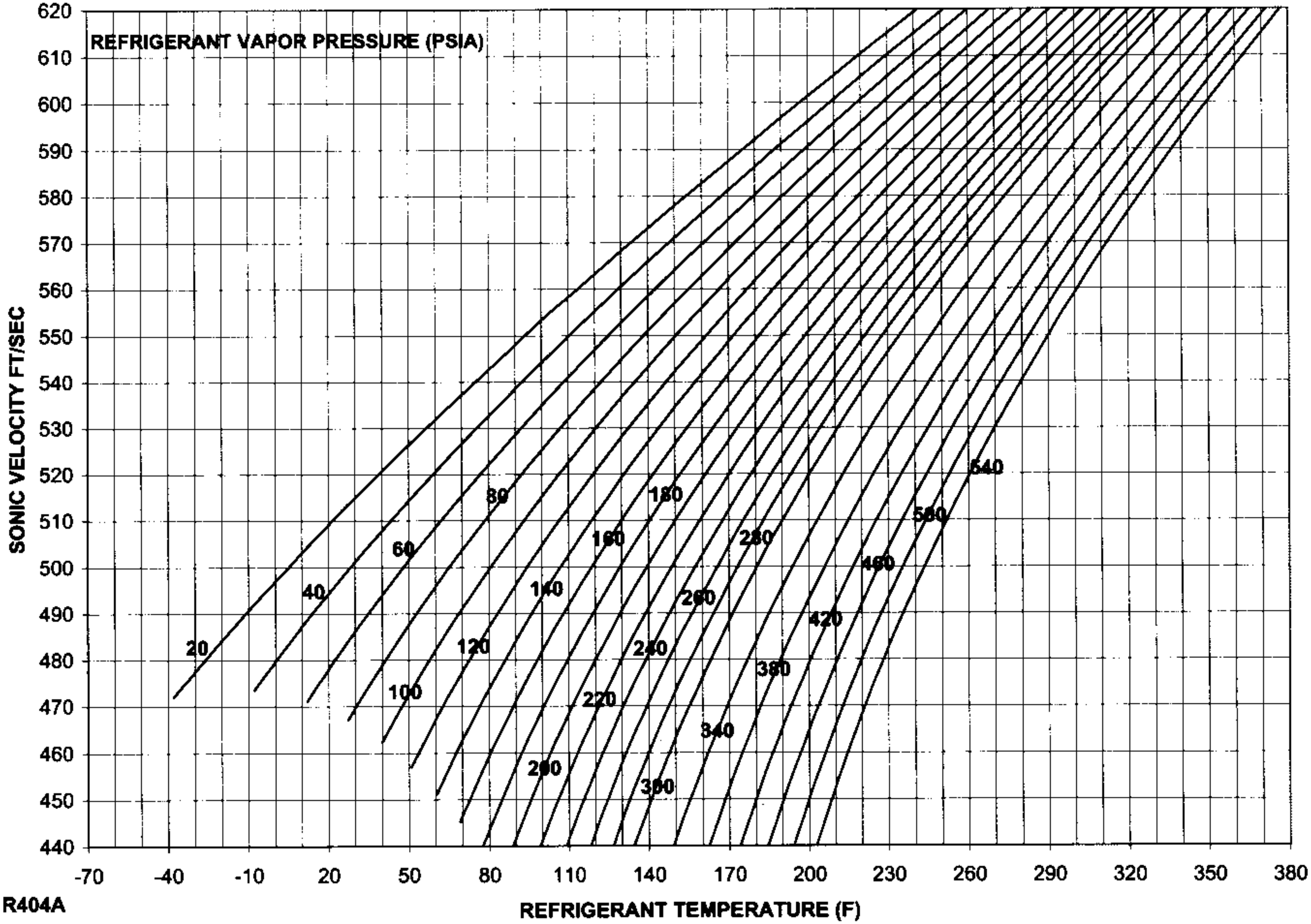

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