VIBRATION AND NOISE FROM CENTRIFUGAL WATER PUMPS

Supersedes: Nothing | 360 | Form 55.60-NM9 (2MB)

To control vibration from water pumps it is always best to reduce to a minimum, the disturbance at its source. The first and most important step is to select the pump to operate at its best efficiency point.

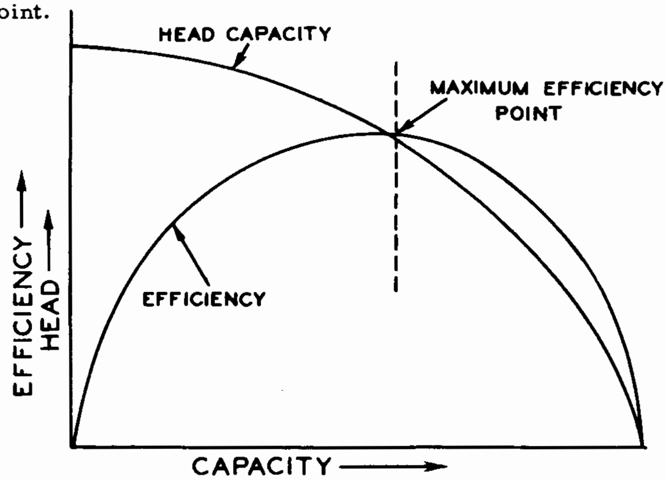


Fig. 1 - Typical efficiency and performance curve for centrifugal pumps.

At the best efficiency point, there will be minimum of hydraulic shock within the pump because the angle of flow of water from the tip of the impeller vane will be correct for the impeller casing design. Every pump is designed to operate at the best efficiency point, and operation at any other point on the characteristic curve is a compromise. The further away from the best efficiency point a pump is made to operate, the greater the turbulence and hydraulic shock existing within the pump and, therefore, the greater the noise generated. The amount of hydraulic turbulence increases as the operating condition approaches shut-off. Likewise, hydraulic turbulence increases when the pump operates in the area where cavitation commences. Except for unusual conditions, centrifugal pumps should be selected to operate slightly to the left of the best efficiency point. Engineers frequently over-estimate the system head. Some add a percentage for safety. Pumps selected for these conditions will operate farther out on the curve toward cavitation.

The minimum turbulence occurs at the maximum efficiency point. Refer to Fig. 2.

The preferred operating zone for centrifugal pumps is the region close to the maximum efficiency point. Refer to Fig. 3.

Operating a centrifugal pump at its best efficiency point is desirable not only for lower hydraulic turbulence, but also for the minimum shaft deflection. Shaft deflection in any pump increases toward the shut-off as well as towards the cavitation zone. Shaft deflection can be a source of noise because extra load is imposed on the bearings. In some cases, the coupling can be thrown sufficiently out of alignment to cause noise. Refer to Fig. 4.

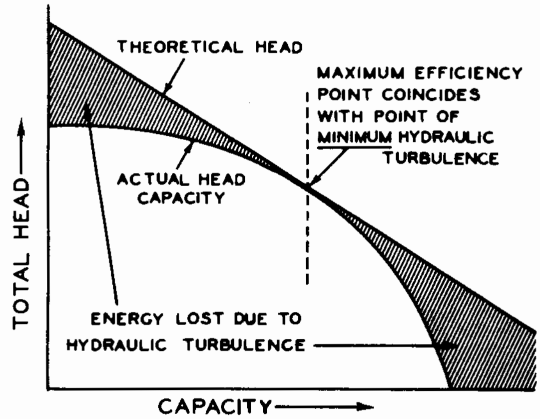


Figure 2

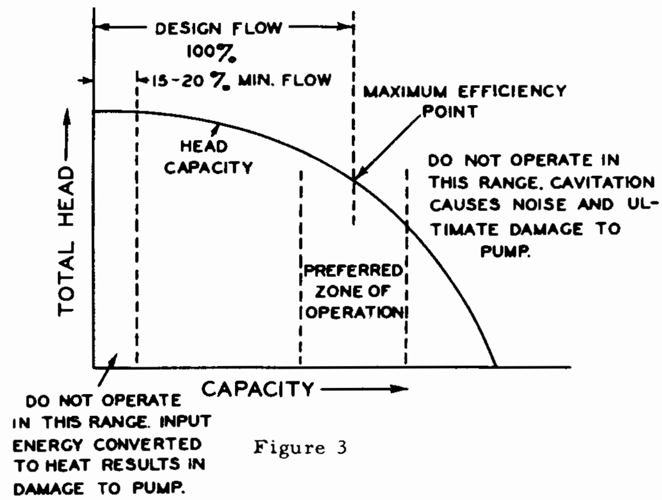


Figure 3

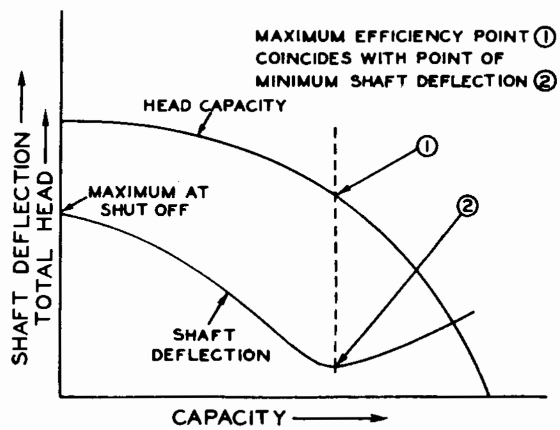


Figure 4

There are many sources of noise that should be considered. It may be caused by any one or a combination of the following conditions:

1. Coupling misalignment.
2. Bent shaft in pump or motor.
3. Rotating part rubbing on stationary part.
4. Distorted base plate due to uneven or improper tightening of foundation bolts.
5. Improper seating of pump baseplate.
6. Pipe strains on pump casing.
7. Defective or loose bearings.
8. Unbalanced rotor in either pump or motor.
9. Excessive axial play on motor rotor.
10. Excessive windage noise - poor fan design.
11. Pump operating in "cavitation" range.
12. Pump operating in "hunting" or unstable condition.
13. Pump "churning" back near shut-off.
14. Water hammer.
15. Piping not properly supported.

Common sense precautions will generally permit the use of an inexpensive standard pump of highest hydraulic efficiency. Excessive noise in most cases can be traced to coupling misalignment. The alignment should be checked after the pump has been secured on its foundation, the piping has been installed, and the system is operating at its normal temperature. Alignments should be made with a dial indicator shaft to shaft.

From here we will now go to the problem of isolating the pumps. Here we have two problems to consider. We must first prevent the vibration from traveling into the building structure through the floor and secondly, we must consider the piping problem. Let's consider the problem of pump isolation first.

While we have seen pumps and fair size ones at that, mounted directly on isolation rubber-in-shear rails, we feel that except for the smallest pumps, this is very poor practice. We begin our pump isolation problem by calling for a "floating" concrete foundation which weighs approximately 1-1/4 times the weight of the pump and its motor and it should not be less than 8" thick. The concrete serves two purposes:

Its first function is to provde a rigid base to which the pump can be grouted. Pump bases are generally castings that were meant to be installed this way and even though they might not crack without the concrete foundation, they will definitely flex which leads to coupling misalignment, coupling noises, coupling failure, motor bearing or water seal difficulties. The second purpose for the concrete foundation is to reduce the motion of the isolated pump by providing a mass and so we begin immediately to cut down on our piping difficulties. In most cases, this concrete foundation should be T - shaped in order to provide support areas for the suction and discharge elbows near the pump.

While other methods of foundation construction may be used, we have successfully used the one shown in Fig. 5.

The maximum isolation can be obtained by using steel springs to suit the loading.

The small additional cost in the overall of using springs compared to other materials makes their use a wise choice. Please note that in all cases there is a neoprene pad in series with the spring to isolate the high frequencies.

We strongly recommend against the use of rubber as an isolating medium for pump foundations because the common mistake made is to overload it. It has been so easy to overload rubber under pump foundations due to the tremendous weight of piping connections compared to the weight of the pump and motor. The efficiency of rubber as an isolator falls off very sharply when it is overloaded. Rubber then takes a permanent set and will not be effective as an isolator after the load has been relieved. Obviously, springs can be ineffective if they are collapsed, however, they will become effective again when the load is relieved.

For your information, the efficiency chart (Drawing No. VMA5346-0), Fig. 6, following, shows the basic principle of the relationship between spring deflection and speed or frequency of the disturbing equipment and the degree of isolation that results. Knowing the R. P. M. of the pump, the chart can be used to select the required static deflection to determine the theoretical efficiency of a particular mounting. This chart should be used with caution as the results are only theoretical. The formula is based on massive floors of great rigidity. The lighter the floor construction and consequently the greater its deflection, the less effective will be the isolation. It is necessary to compensate for this by going to greater deflection in the mounting for increased deflection of the floor. As a practical approach to this problem that would fit the majority of problems encountered, we would select for say an 1800 R. P. M. pump and that is a good pump speed incidentally, springs having 1" deflection.

Having selected 1" deflection in the example above, then refer to chart attached called "Load Deflection Diagram" (Drawing No. VMA3020-3), Fig. 7, and select the springs giving you the loading you require for a 1" deflection, being careful to pick them near their rated capacity indicated by circles and certainly to the left of the maximum capacities indicated by X. From this, you can determine the type of spring required, indentified on the chart as a #30 or #40 spring for the example cited and by referring to Drawing VMA 3220-0, Fig. 8, select the specification of the VMLN mounting to order.

The load to be supported divided by the loading per spring you have just determined, results in the number of springs required.

Now that we have the pump isolated from the floor, let's look at the piping. It is common practice to put an ell at the pump and then proceed off to the pipe lines. Going vertically either up or down from this ell presents no particular problem so far as operation of the pump is concerned. Laying the ell horizontally however, does introduce a problem of throwing the water to one side of the impeller and creating cavitation and undue thrust. If you must come in horizontally, straighten out the water stream before it gets to the pump by having a straight piece of pipe between the pump suction and the ell in length of at least 5 to 10 diameters.
Further consideration of the piping to reduce noise and vibration has to do with rubber connections in the water lines. The following photographs of flexible hose connections and typical installations are taken from Vibration Mountings, Inc. Bulletin RFP-10. Here is what they have to say about them. Note what they have to say about not expecting too much for reducing vibration unless you have sufficient mass to anchor the end going out to the mains.

"In general rubber hoses such as these are meant to absorb vibration in a direction transverse to their axis whereas expansion joints (which we can also supply) are meant to work in an axial direction. We feel that the hose is inherently better than the expansion joint as the noise attenuation is a function of the rubber length and these connections are considerably longer flange to flange than the rubber expansion joints. The rubber hose also has the advantage of limited axial lengthening under pressure whereas an expansion joint is meant to work like an accordion and so it is built without axial re-straint. These expansion joints must always be used with tie bars between the flanges whereas in the great majority of cases we do not use these bars with the hose. Theoretically the hose can elongate as much as 4% of its length under maximum pressure conditions. However, we have not experienced this problem in the field and other than some of the hose sections taking a slight S-shape, there have been no problems. We are not satisfied with this 4% figure and we are working on the problem of special construction to completely eliminate this elongation if it is at all possible without raising the cost to the point where the connections would not be installed.

"If the location is in the basement and you are fortunate enough to have a heavy foundation wall nearby to which the piping end of the hose can be securely anchored you can stop the pipe line vibrations at this point. In most installations, however, there is no opportunity to do this and as the connections must be quite rigid in themselves in order to withstand the pressure, a good part of the pump vibration carries by. While some of the vibration continues in the pipe line the hose does do a good job of knocking out pipe line transmitted noise which is generally the biggest problem unless there is excessive turbulence in the water which generates the noise further up the line. This is the prime purpose of the hose - to stop the noise. This is particularly true in the larger diameters, 4" and up. We might comment that the ideal position for the hose is in the horizontal direction and parallel to the pump shaft. This allows the foundation to move up and down and radially in direction to the pump shaft which is generally the direction that the vibration takes. While this position is ideal, in most cases the hose goes in vertically as shown in the following pump photographs. This is a question of good space conservation practice rather than good vibration engineering. You can readily see that with the hose vertical, should the foundation settle, the hoses must stretch. Please notice too that the valves are always installed on the pipe line side of the hose. Refer to page 8.

"Should the hose develop a leak or require servicing the pump can then be shut off from the rest of the system without draining of the connecting piping.

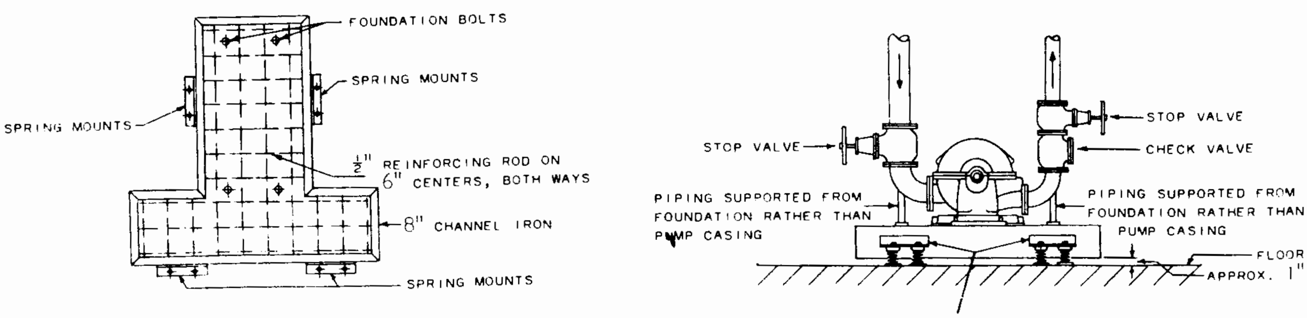
"Since we have conceded that because of the lack of an adequate anchoring point the vibration continues to travel through the pipe lines, we find ourselves in need of flexible hangers."

Most applications will have to depend on flexible hangers for the balance of vibration isolation. We feel the spring hanger or the combination Rubber-In-Shear and spring hanger should be the hanger to use. As in the case of selecting springs for the foundation, they should be selected for a 1" deflection for 1800 RPM pumps and should be used for a minimum distance of 30' to 40' from the pump and beyond where the piping travels through critical areas.

Print VMA 4430-0, Fig. 9, together with the load deflection diagram, Drawing No. VMA 3020-3, Fig. 7, will enable you to select the proper hangers to use. Here again the weight to be supported must be calculated and the proper spring hanger selected.

The following references were used in the preparation of this material:

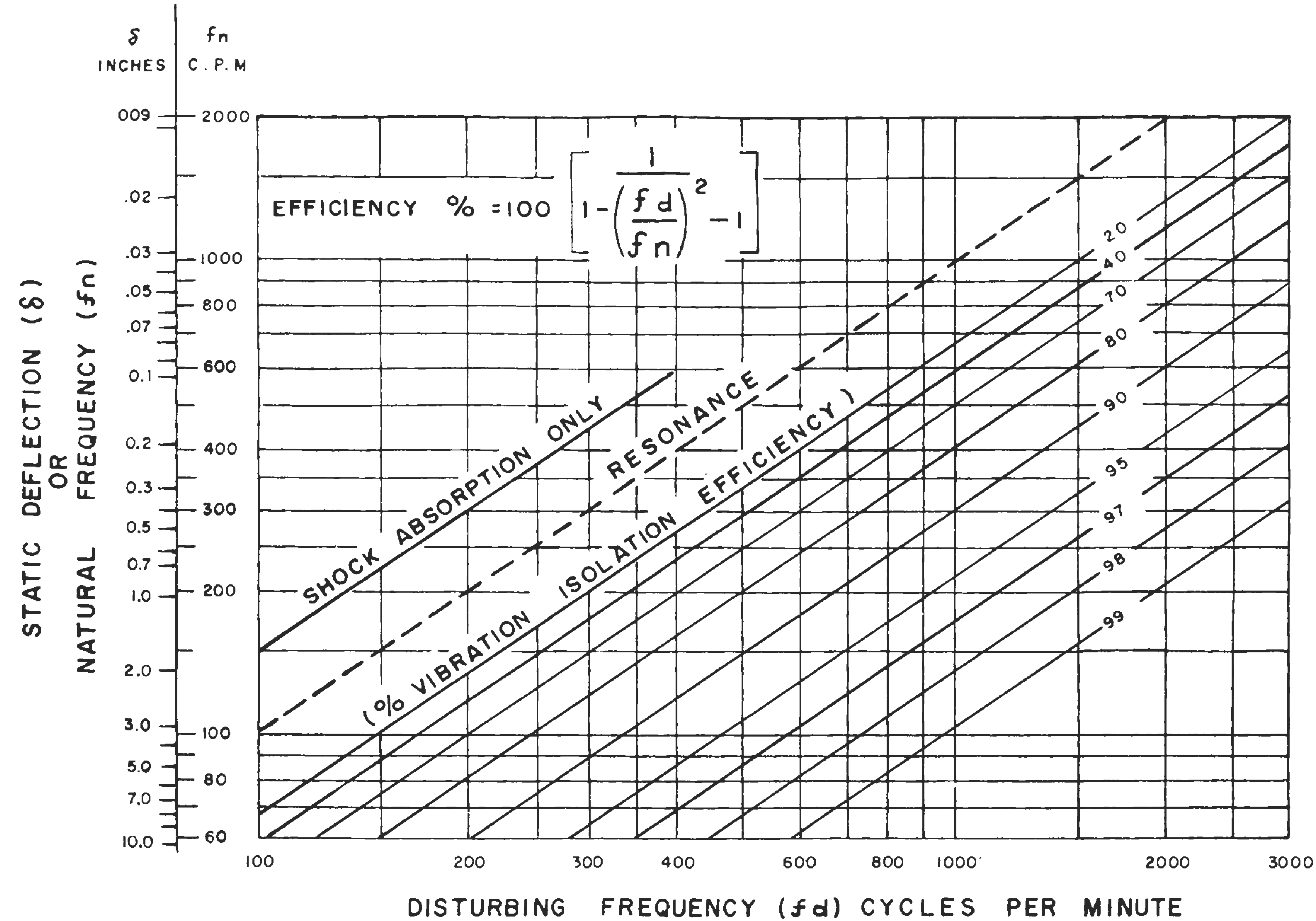
Vibration Mountings, Inc.
Journal of Acoustical Society of America Vol 4 No. 1 January 1958
Power and Fluids Spring - 1956
Noise and Vibration by Slocum
Journal of ASRE - February 1941
Vibration Problems in Engineering - S. Timoshenko D. Van Nostrand Company, Inc. New York



Place roofing paper or plywood on floor to provide bottom for concrete form. Place channel in place with reinforcing, foundation bolts, etc., and pour concrete. Afterwards entire assembly can be jacked up at the angles and the springs inserted.

3 x 3 x 3/8" angle 12" long with holes drilled for jack screws; electrically welded to channel at such height above floor to permit loading VMLN SPRING-FLEX VIBRATION MOUNTING so as to permit 1" spring deflection.

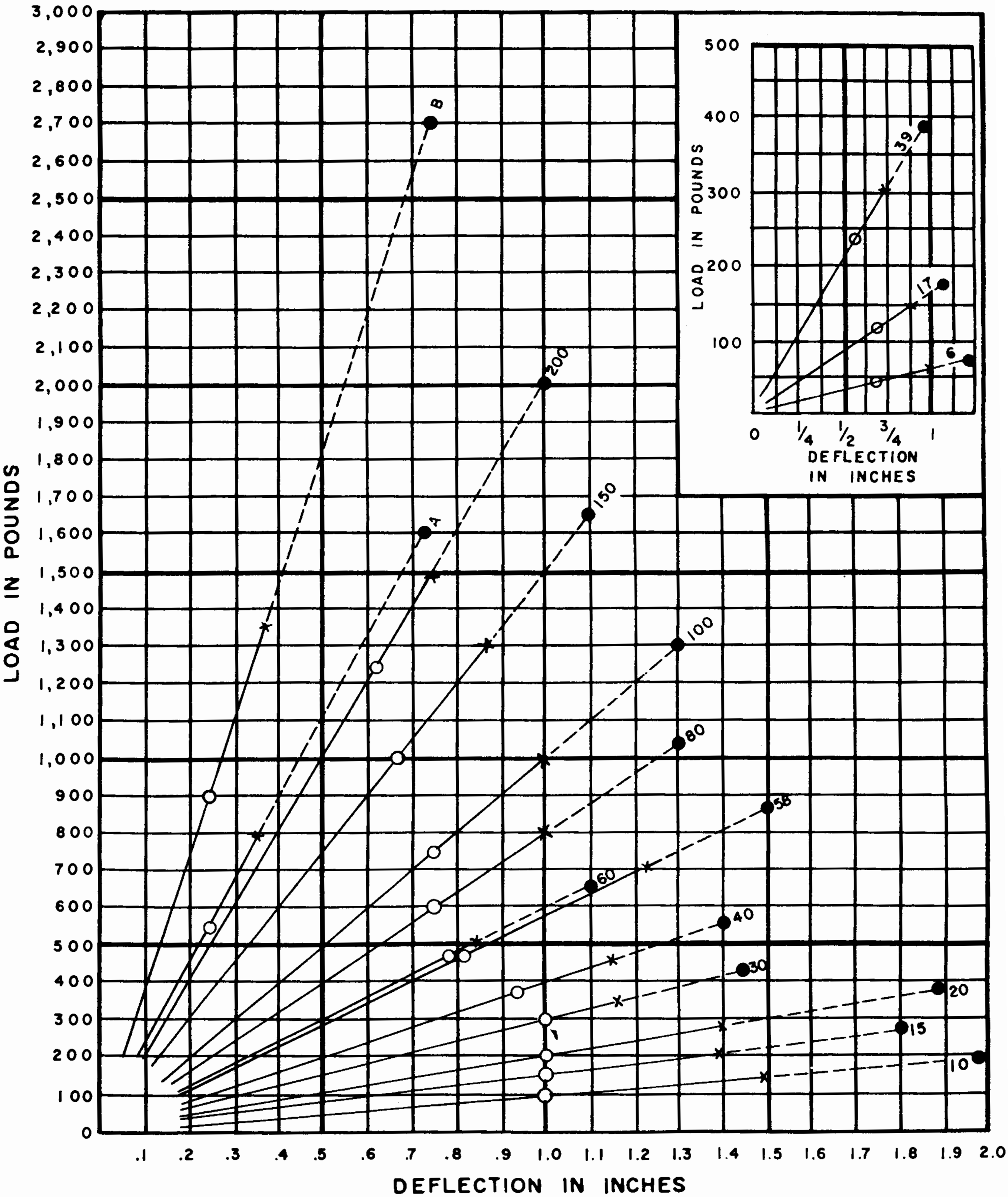
FIG. 5 - SUGGESTED PUMP FOUNDATION

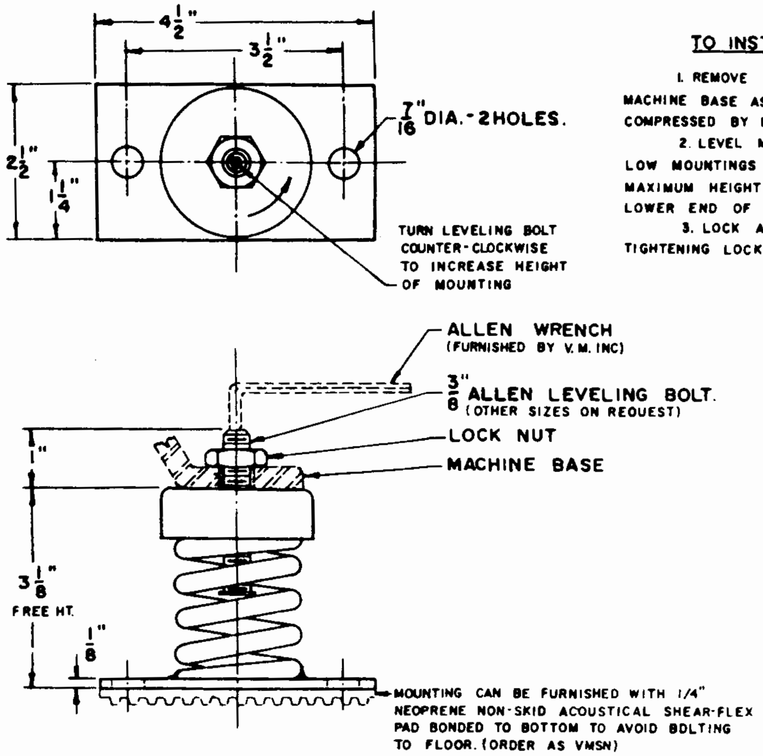


NO	ALTERATION	DATE	DWN. BY: C.T. CHK. BY: A.S SCALE: DATE: 11 - 4 - 58	EFFICIENCY CHART Fig. 6	VIBRATION MOUNTINGS, INC CORONA NEW YORK DRAWING NO: VMA-5346-0

SPRING CHART

O = RATED CAPACITY OF SPRING X = RECOMMENDED MAXIMUM CAPACITY ● = SPRING SOLID



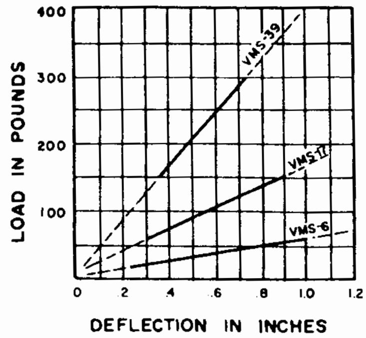


TO INSTALL AND ADJUST MOUNTINGS

1. REMOVE LOCK NUTS AND INSTALL MOUNTINGS UNDER MACHINE BASE AS SHOWN. SPRINGS WILL BE PARTIALLY COMPRESSED BY MACHINE WEIGHT.

2. LEVEL MACHINE BY TURNING LEVELING BOLTS OF LOW MOUNTINGS COUNTER CLOCKWISE WITH ALLEN WRENCH. MAXIMUM HEIGHT ADJUSTMENT LIMITED TO 1/2" BY STOP AT LOWER END OF BOLT.

3. LOCK ADJUSTMENT AND SECURE MACHINE LEG BY TIGHTENING LOCK NUT.



SOLID LINES INDICATE RECOMMENDED LOADING

TYPE	LOAD RANGE
VMS-6	20-60 LBS.
VMS-17	60-150 LBS.
VMS-39	150-300 LBS.

NO	ALTERATION	DATE

DWN BY: K.T. CHK BY:
SCALE: 1/2" = 1"
DATE: 5-2-'55.

TYPE-VMS
ADJUSTABLE
SPRING FLEX MOUNTING

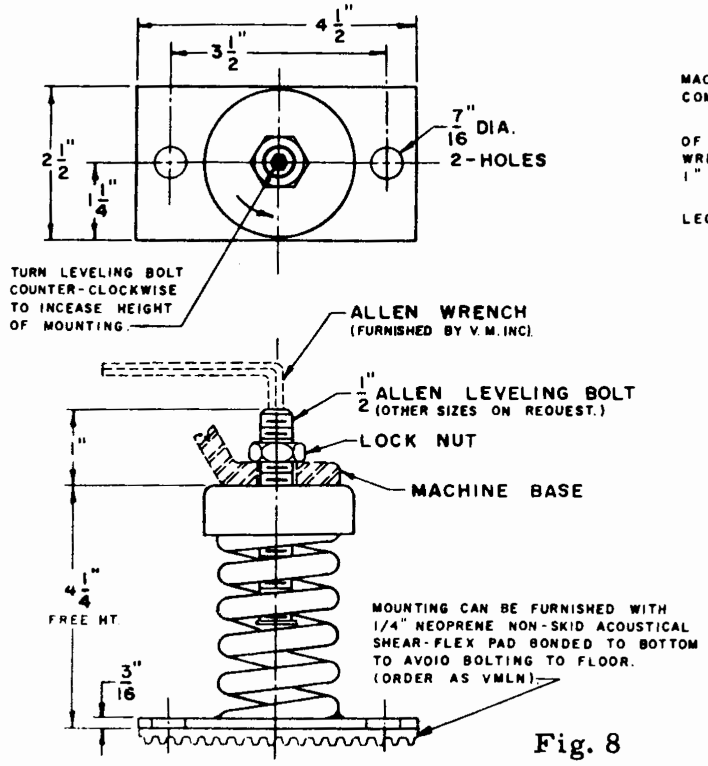
VIBRATION MOUNTINGS, INC.
CORONA, NEW YORK.

DRAWING NO: VMA-3125-0

CERTIFIED FOR:

CUSTOMER: ______________________
P.O. NO: ______________________
JOB NO: ______________________
JOB NAME: ______________________
V.M. NO: ______________________

FOR UNITS:



TO INSTALL AND ADJUST MOUNTINGS

1. REMOVE LOCK NUTS AND INSTALL MOUNTINGS UNDER MACHINE BASE AS SHOWN. SPRINGS WILL BE PARTIALLY COMPRESSED BY MACHINE WEIGHT.

2. LEVEL MACHINE BY TURNING LEVELING BOLTS OF LOW MOUNTINGS COUNTER-CLOCKWISE WITH ALLEN WRENCH. MAXIMUM HEIGHT ADJUSTMENT LIMITED TO 1" BY STOP AT LOWER END OF BOLT.

3. LOCK ADJUSTMENT AND SECURE MACHINE LEG BY TIGHTENING LOCK NUT.

TYPE	SPRING RATE	LOAD RANGE
VML-10	100*	50-100*
VML-15	150	100-150
VML-20	200	150-200
VML-30	300	200-300
VML-40	400	300-375
VML-60	600	375-475
VML-80	800	475-600
VML-100	1000	600-750
VML-150	1500	750-1000
VML-200	2000	1000-1250

SPRING RATE IS DEFINED AS THE LOAD REQUIRED TO COMPRESS SPRING 1".
SPRING DEFLECTION IS PROPORTIONAL TO LOAD.
(SEE SPRING CHART VMA-3020-3.)

Fig. 8

NO	ALTERATION	DATE

DWN BY: K.T. CHK BY:
SCALE: 1/2" = 1"
DATE: 9-22-'55

TYPE-VML
ADJUSTABLE
SPRING FLEX MOUNTING

VIBRATION MOUNTINGS, INC.
CORONA, NEW YORK.

DRAWING NO: VMA-3220-0

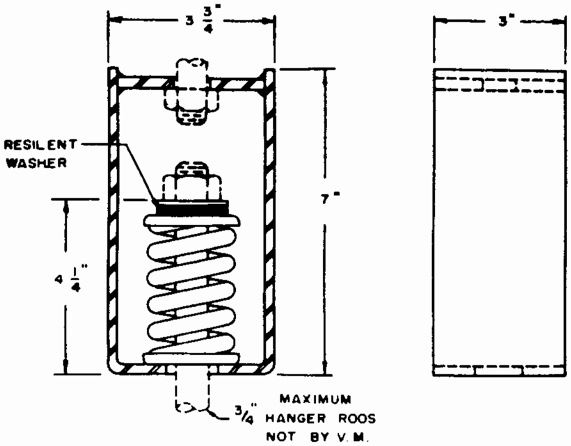
SPRING TYPE VIBRATION HANGERS

FOR PIPE AND AIR CONDITIONING EQUIPMENT

HANGERS ARE STANDARD FOR ROD DIAMETERS SHOWN. HANGERS FOR LARGER RODS ON REQUEST.

DEFLECTION RANGE 1/2" TO 1"

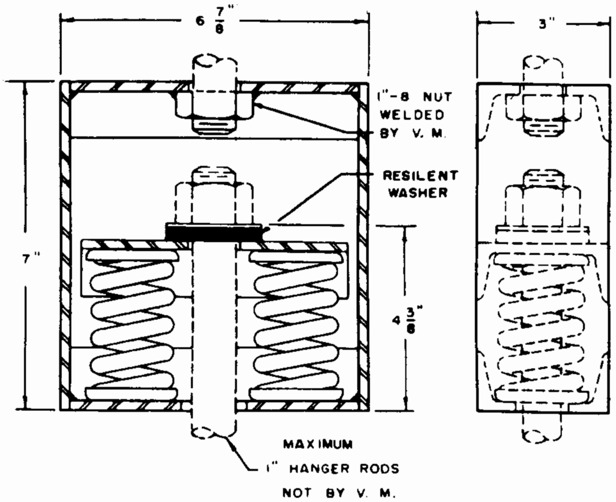
FOR EXACT SPRING DEFLECTIONS, SEE CHART ON DRAWING VMA-3282-1



TYPE SHB HANGER

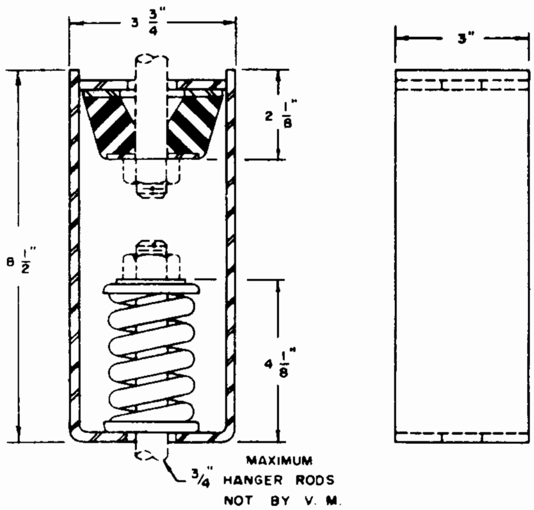
TYPE SPRING NO	LOAD RANGE
SHB - 10	50 - 100
SHB - 15	100 - 150
SHB - 20	150 - 200
SHB - 30	200 - 300
SHB - 40	300 - 375

TYPE SPRING NO	LOAD RANGE
SHB - 60	375 - 475
SHB - 80	475 - 600
SHB - 100	600 - 750
SHB - 150	750 - 1000
SHB - 200	1000 - 1250



TYPE SHB-2 HANGER

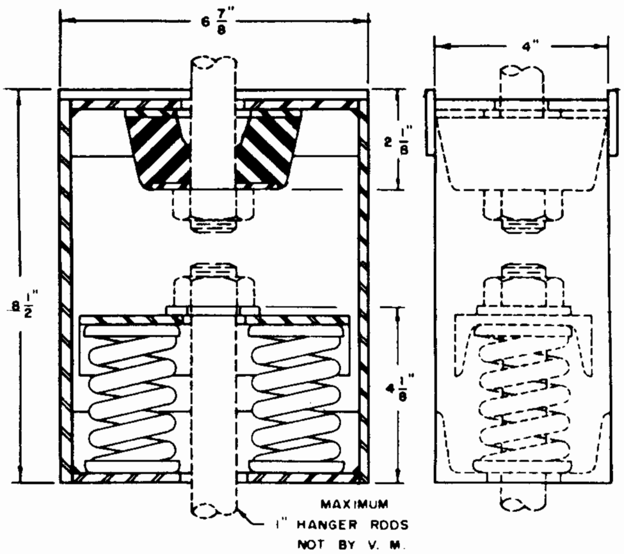
TYPE SPRING NO.	LOAD RANGE
SHB-2 - 100	1200 - 1500
SHB-2 - 150	1500 - 2000
SHB-2 - 200	2000 - 2500



TYPE RSH HANGER

TYPE SPRING NO	LOAD RANGE
RSH - 10	50 - 100
RSH - 15	100 - 150
RSH - 20	150 - 200
RSH - 30	200 - 300
RSH - 40	300 - 375

TYPE SPRING NO.	LOAD RANGE
RSH - 60	375 - 475
RSH - 80	475 - 600
RSH - 100	600 - 750
RSH - 150	750 - 1000
RSH - 200	1000 - 1250



TYPE RSH-2 HANGER

TYPE SPRING NO.	LOAD RANGE
RSH-2 - 100	1200 - 1500
RSH-2 - 150	1500 - 2000
RSH-2 - 200	2000 - 2500

CERTIFIED FOR

CUSTOMER: ____________

P. O. NO.: ____________

JOB NO.: ____________

JOB NAME: ____________

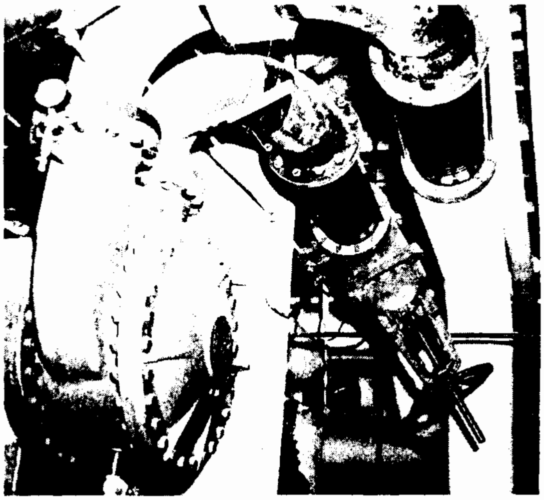
V. M. NO.: ____________

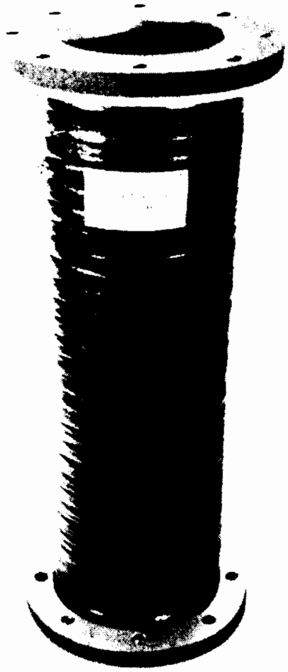
FOR UNITS:

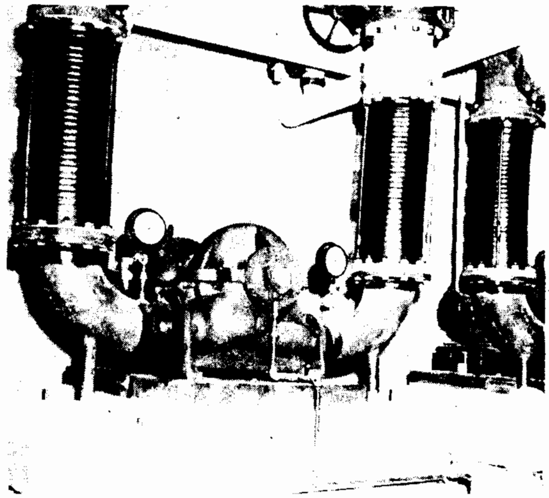
VIBRATION MOUNTINGS, INC. Fig. 9 CORONA 68, N. Y.

PRINTED IN U S A

DWG. NO. VMA-4430-0







Courtesy of Vibration Mountings, Inc.
Corona, New York

YORK®

P.O. Box 1592, York, Pennsylvania USA 17405-1592

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