WR MATTCO RECIPROCATING PUMP PULSATION CONTROL EQUIPMENT

WR Mattco Mud Pump Pulsation Control Equipment

State of the Art Pulsation Control Equipment for Lowest Mud Pump System Life Cycle Cost

WR Mattco has a broad range of pulsation control equipment for mud-pump systems to meet almost any customer need based on price or performance. The company offers not only time-tested, high-pressure mud-pump discharge dampeners, but is also offering State-of-the-Art Suction Stabilizers and Discharge Dampeners.

A wide range of innovative Mud Pump Pulsation Control Equipment from WR Mattco is available to enhance the performance of your Triplex Mud Pump. Included are conventional and premium maintenance free suction stabilizers and discharge dampeners. The Premium Pulsation Control Package consisting of a Cellular Suction Stabilizer Manifold and Combination Discharge Dampener significantly improves the Mud Pump System Dynamics that results in improved safety, improved MWD signal processing by eliminating mud pump and system dynamic noise, and extended life of the mud pump system components. Additional benefits include the ability to operate your mud pumps at maximum design conditions without adversely affecting the pump or drilling system which also prevents premature relief valve activation.

This document contains the elementary physics associated with the application of the pulsation control equipment. The equations are not intended to be used as actual sizing and performance criteria.

Maintenance-Free Suction Pulsation Control Equipment

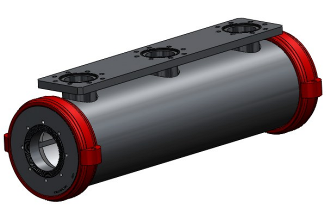
WR Mattco Suction Stabilizers are designed to stabilize the velocity variation of the pump suction feed stream using a large liquid volume and a closed cell foam that does not require nitrogen charging. Proper sizing and setup is important to performance of the pulsation control equipment. Installed location of the pulsation control equipment is critical to its performance. Recommended location for the pulsation control equipment is within 6 times the nominal pipe diameter of the pump manifold connections. Suction Stabilizers are not effective when installed away from the pump.

CSS (Flow Through Cellular Suction Stabilizer)

The inline maintenance-free cellular suction stabilizers have been the best suction stabilizer for the drilling industry for a number of years. The performance is based on its ability to store and release fluid to reduce the velocity variation to the pump suction manifold. The residual peak-to-peak flow induced pressure variation (DP) is a function of the fluid velocity variation in the suction piping. Suction stabilizers reduce the velocity variation in the suction piping by its ability to store and release fluid to meet the pumps demand for fluid. Pump volume variation (DV_p) is stabilized using gas and fluid compressibility. Residual peak-to-peak hydraulic pressure variation (DP) is calculated using both gas volume variation (DV_g) and suction stabilizer nitrogen volume (V_g) at operating pressure (P_0) and liquid volume variation (DV_l) divided by the fluid compressibility β (bulk modulus) and suction stabilizer liquid volume (V_l). A synergistic effect occurs between the two dampening mechanisms as you solve for how the pump DV is split between that which is applied to the gas DV_g and the liquid DV_l. Acceleration head loss is significantly reduced when compared to an appendage pneumatic or air tank suction stabilizer.

$$\Delta P_g = P_O - \frac{P_O V_g}{V_g + \Delta V_g} \qquad \Delta P_l = \frac{\Delta V_l}{\beta V_l} \qquad \Delta P_g = \Delta P_l \qquad \Delta V = \Delta V_g + \Delta V_l$$

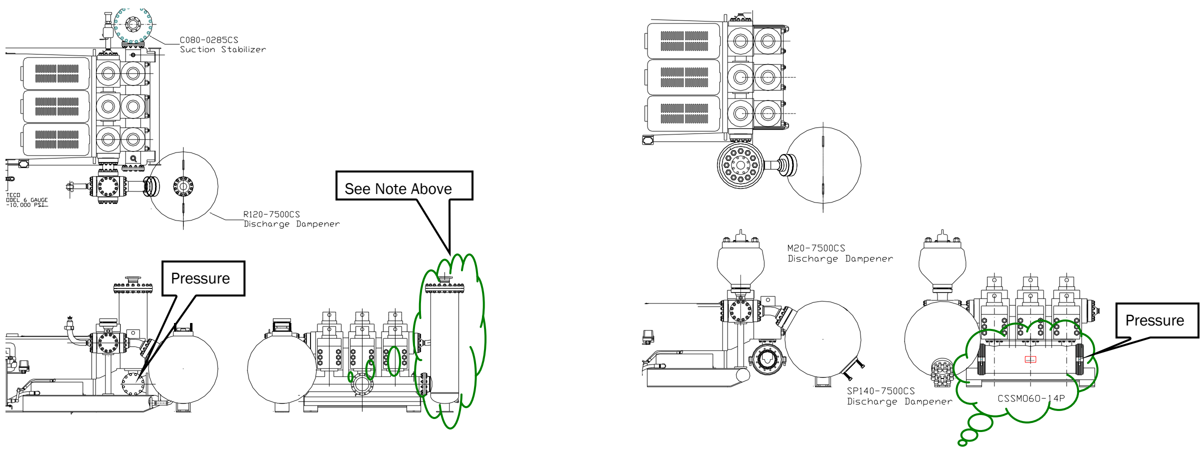
CSSM Cellular Suction Stabilizer Manifold (Premium)

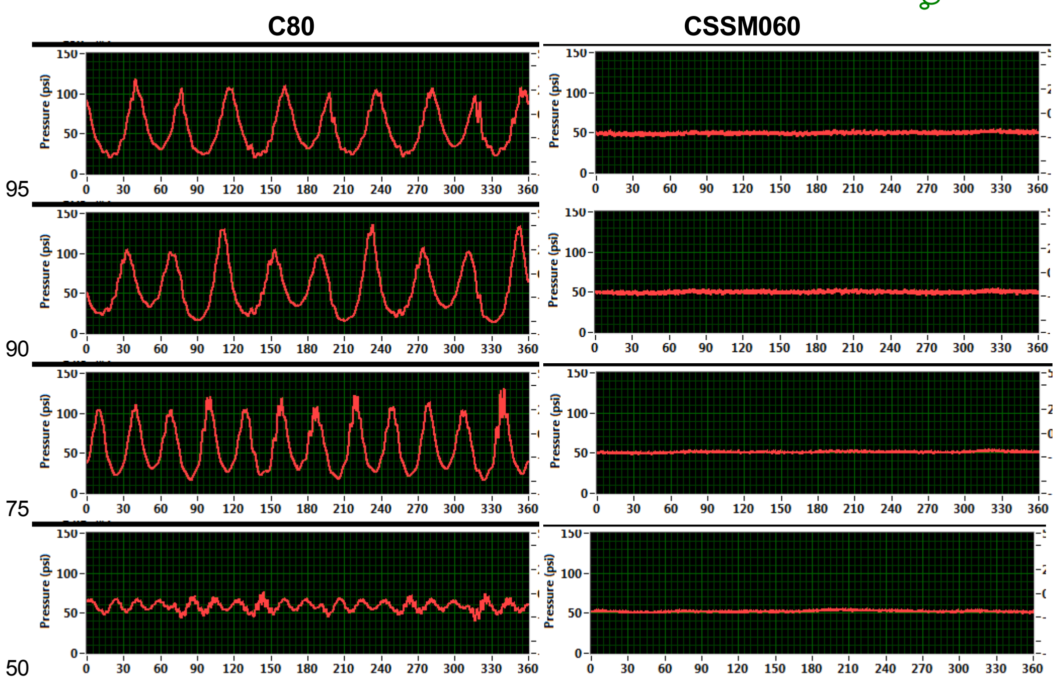


The maintenance-free Cellular Suction Stabilizer Manifold (U.S. Patent No. 7,621,728) provides the optimum performance by eliminating pump suction acceleration head loss. The unit reduces the peak-to-peak hydraulic pressure variation to near zero. By eliminating flow and acceleration peak-to-peak hydraulic pressure variation in the pump manifold, hydraulic resonance cannot occur in suction piping.

CSSM Cellular Suction Stabilizer Manifold Performance

Comparative performance of pressure in the Suction Manifold of a 5.5” X 14” Mud Pump is displayed for a WR Mattco CSSM060 Cellular Suction Stabilizer Manifold (dP=2-psi) versus a Hydril C80 Suction Stabilizer (dP=120-psi) for one pump revolution with the pump operating from 50 to 95 strokes per minute. The C80 was not installed correctly. The unit was mounted vertically with the inlet at the bottom and piped from the top to the standard pump suction manifold. The maintenance-free CSSM (Cellular Suction Stabilizer Manifold) performance eliminates acceleration head loss and crosshead shock forces that can lead to power-end crank and bearing failures as well as preventing hydraulic resonance in the suction piping. By holding the pump suction manifold peak-to-peak hydraulic pressure variation to 2 psi, the potential for cavitation through the suction valves is significantly reduced.





Peak-to-peak hydraulic pressure variation in the Suction Manifold

Discharge Pulsation Control Equipment

WR Mattco Pulsation Dampeners are designed to stabilize the velocity variation of the mud pump. Proper sizing and setup is important to performance of the pulsation control equipment. The pipe shaking load (F) is equal to the peak-to-peak hydraulic pressure variation (DP) times the pipe cross section area (A_p). Location of the pulsation control equipment is critical to its performance. Recommended location for the pulsation control equipment is within 6 times the nominal pipe diameter of the pump discharge manifold. Discharge dampeners are not effective when installed away from the pump.

$$F = A_p \Delta P$$

M20-7500 (Pneumatic Discharge Dampener with Nitrogen Charge)

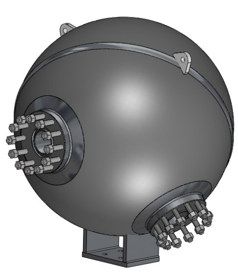
The 20 gallon pneumatic discharge dampener has been the drilling industry standard for the past 50 years. Performance is based on its ability to store and release fluid to reduce the velocity variation in the discharge piping system. The residual peak-to-peak pressure variation (DP_g) is a function (Gas Laws) of the pump volume variation (DV_p) and discharge dampener nitrogen volume (V_g) at operating pressure (P_0).

$$\Delta P_g = P_O - \frac{P_O V_g}{V_g + \Delta V_p}$$

Two M20-7500 (Pneumatic Discharge Dampeners with stepped Nitrogen Charge)

With the increase in pump size and operating pressure, a single pneumatic discharge dampener is inadequate for the 2000+ horsepower pumps at higher operating pressure. Two pneumatic discharge dampeners with different charge pressures are recommended to provide a higher level of performance.

SP140-7500-SB (Liquid Maintenance-Free Discharge Dampener)



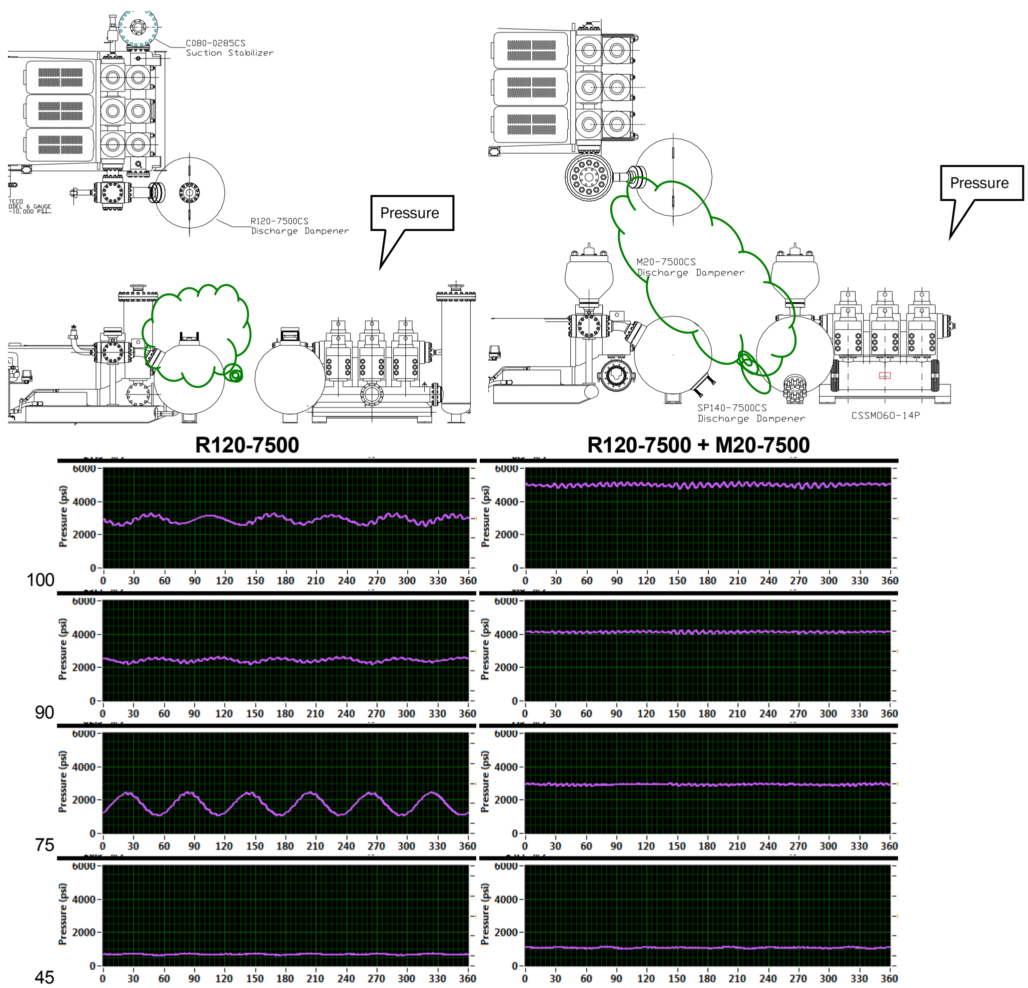
The 140 gallon Liquid Maintenance-Free Discharge Dampener has been used in the drilling industry for the past 14 years as an effective high pressure discharge dampener that does not require nitrogen charging or diaphragm replacements. Performance is based on its ability to store and release fluid to reduce the velocity variation in the discharge piping system. The residual peak-to-peak pressure variation (DP_l) is a function of the pump volume variation (DV) divided by the fluid compressibility β (bulk modulus) and discharge dampener liquid volume (V_l) with a forced pressure drop (DP_{WB}) at the outlet where Wave Blocker orifice coefficient (k) is multiplied by the fluid velocity (v). The unique advantages to the Liquid Maintenance-Free Pulsation Dampener is that all the parameters that determine performance remain constant over the entire pump operating pressure range.

$$\Delta P_l = \frac{\Delta V}{\beta V_l} \qquad \Delta P_{WB} = k v^2$$

SP140M20-7500-SB Combination Dampener (Premium Low Maintenance)

The SP140M20-7500-SB (U.S. Patent No. D626,819) is the combination of the Mattco Liquid Maintenance-Free and Pneumatic Discharge Dampeners into a single unit with a strainer on the outlet to replace the conventional two dampeners and strainer block. The same pressure pulsation dampening mechanisms as described in the Cellular Suction Stabilizer applies to the combination discharge dampener. Combination dampeners have proven to be effective in preventing hydraulic resonance in discharge piping of Mud Pumps. Both types of dampeners reduce the residual pump flow variation. The inline Liquid Maintenance-Free Discharge Dampener is effective in reducing the amplitude of the acceleration pressure spikes and prevents them from going downstream to excite hydraulic or mechanical resonance. The following chart displays the actual performance where hydraulic resonance was occurring with the R120-7500. Addition of the M20-7500 eliminated the hydraulic resonance with the pump operating between 45 and 100 strokes per minute.

Peak-to-peak hydraulic pressure variation in the Discharge Manifold



Anticipated Discharge Dampener Performance 5.5” X 14” Triplex

A 14” Stroke Mud Pump with 5.5 inch liner delivers 454 gpm (1718 lpm) at 7475 psi (525.5 kg/cm^2) when operating at 105 strokes per minute. The traditional discharge dampener sizing criteria for mud pumps has been 3% of operating pressure. This design criteria is inadequate with increased operating pressures and system complexity. Experience has shown that the peak-to-peak hydraulic pressure variation must be below ~80 psi to prevent mud pump fluid dynamic interaction with the mud pump discharge piping.

M20-7500 (Pneumatic Discharge Dampener with Nitrogen Charge)

A single 20 gallon pneumatic discharge dampener is totally inadequate because of very limited operating range and no dampening below the dampener charge pressure.

Two M20-7500 (Pneumatic Discharge Dampeners with stepped Nitrogen Charge)

Performance of two 20 gallon pneumatic discharge dampeners is marginal because of limited operating range and none dampening below the dampener nitrogen charge pressure. In the example of two pneumatic dampeners, there is potential damage to the diaphragm when operating near 4000 psi.

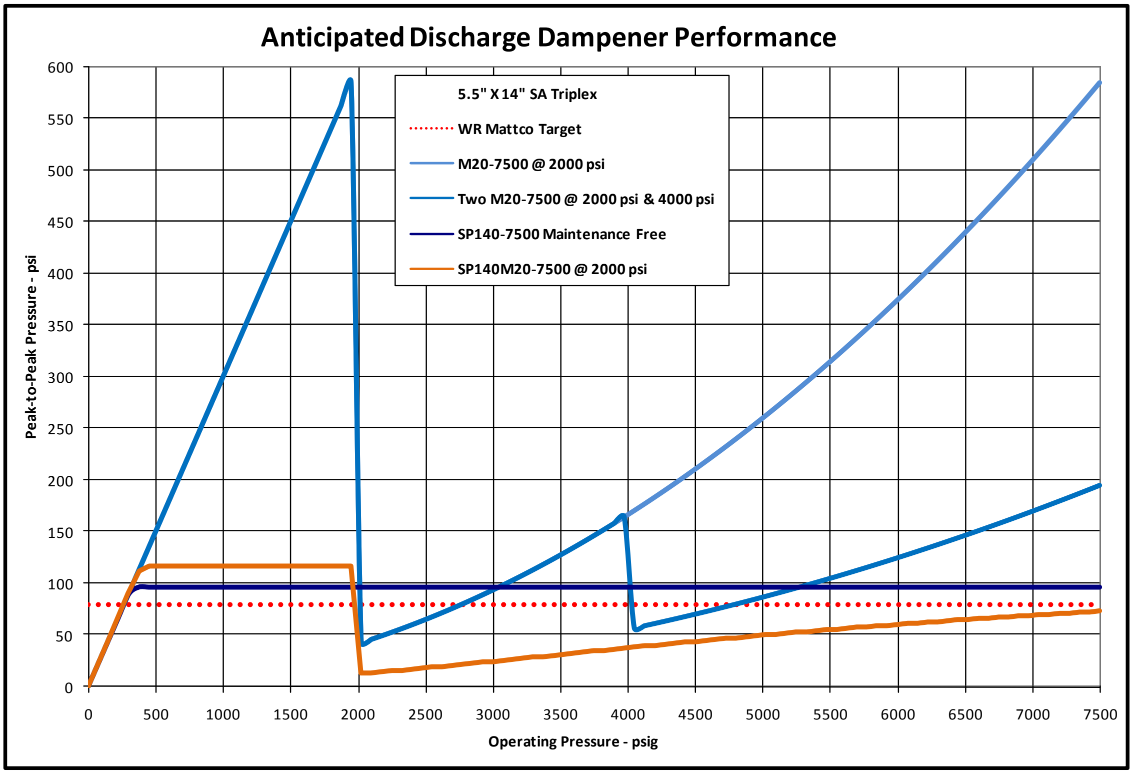
SP140-7500-SB (Liquid Maintenance-Free Discharge Dampener)

The 140 gallon liquid volume discharge dampener will provide a maximum peak-to-peak hydraulic pressure variation of 97 psi over the entire operating pressure range. However, depending on mud pump discharge system configuration, hydraulic resonance can occur.

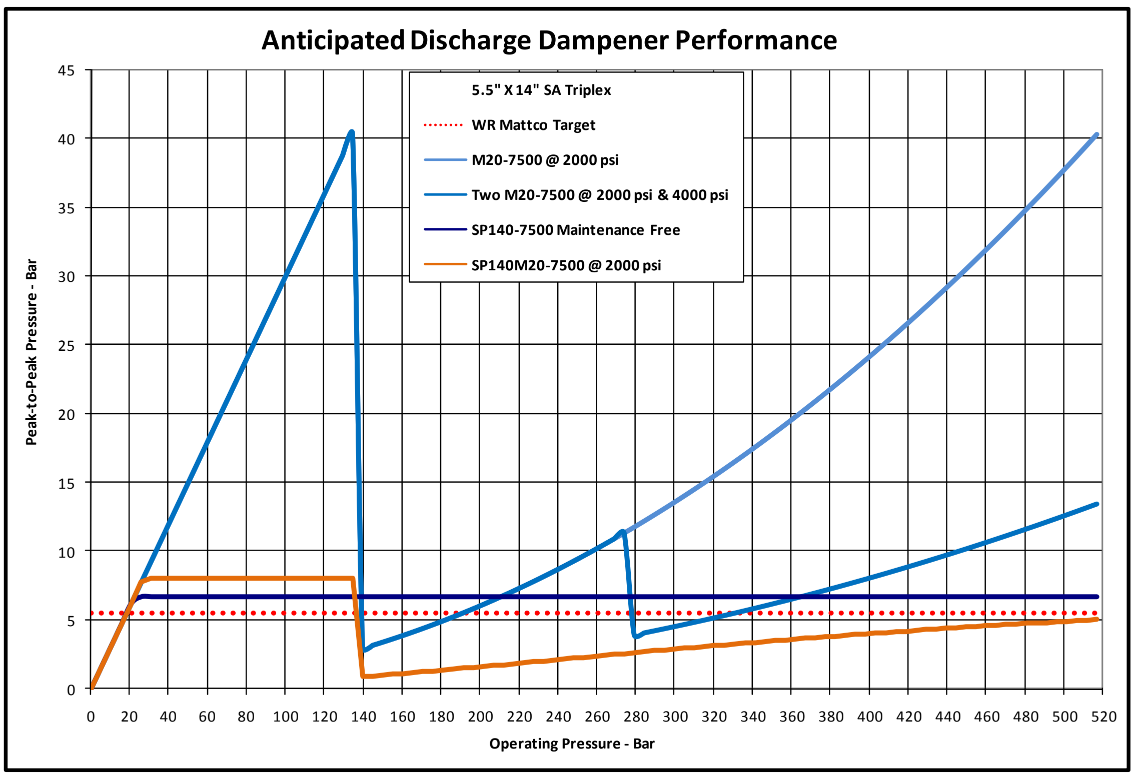
SP140M20-7500-SB Combination Dampener (Premium)

The SP140M20 is the integration of the Liquid Maintenance-Free and Pneumatic Discharge Dampeners into a single discharge dampener. A Strainer/Wave Blocker is used on the dampener outlet. The SP140M20 combination discharge dampener will provide a maximum peak-to-peak hydraulic pressure variation of 117 psi when operating below the nitrogen charge pressure and less than 73 psi when operating above.

Anticipated Discharge Dampener Performance 5.5” X 14” Triplex

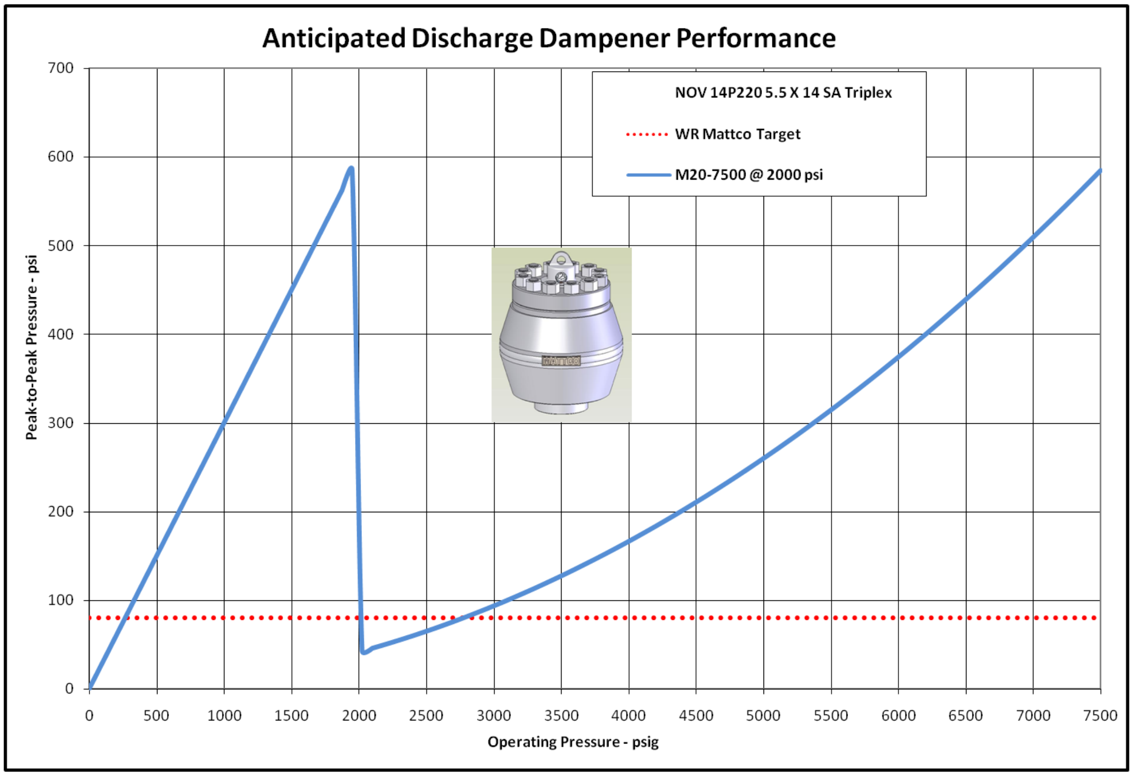


454 Gallon per Minute at 105 Strokes per Minute

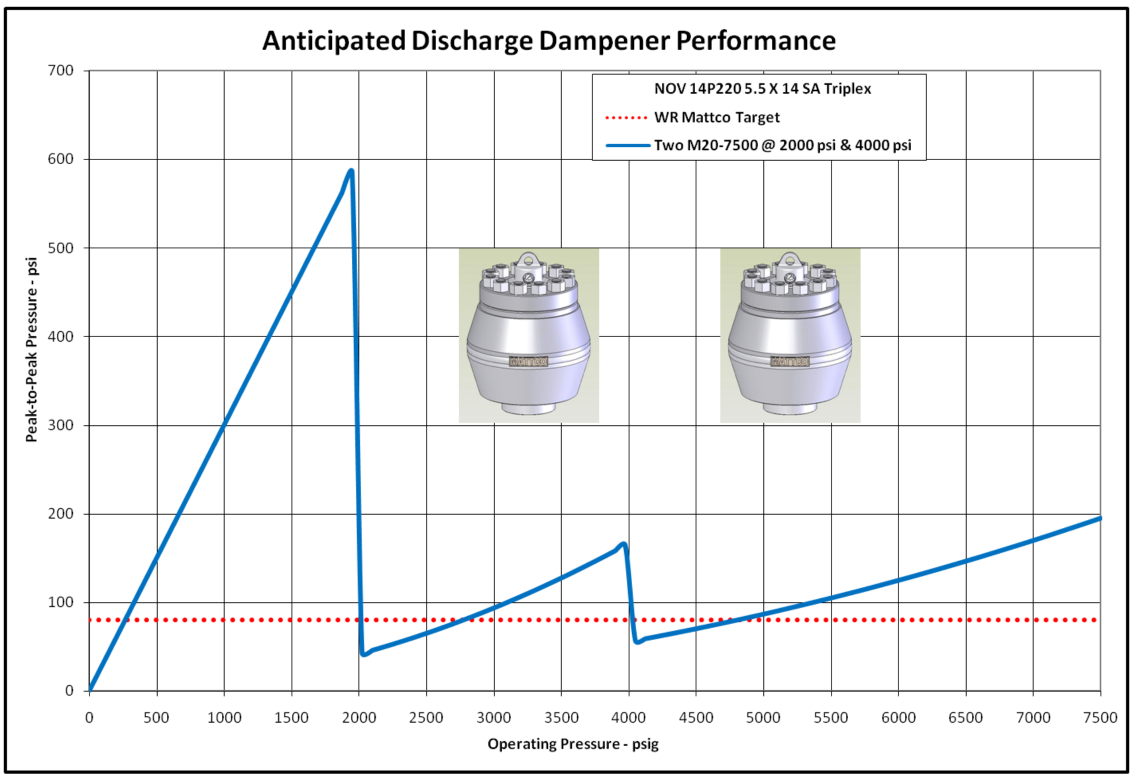


1719 Liters per Minute at 105 Strokes per Minute

Anticipated Discharge Dampener Performance 5.5” X 14” Triplex

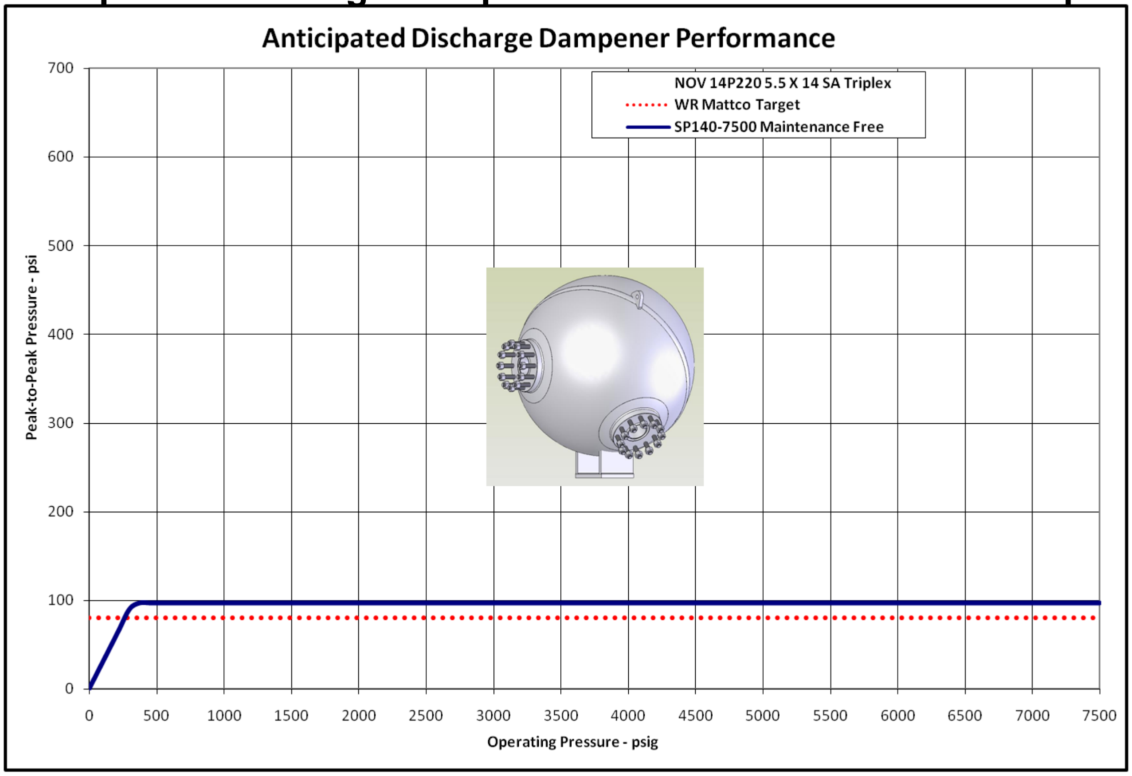


Single M20 Pneumatic Dampener

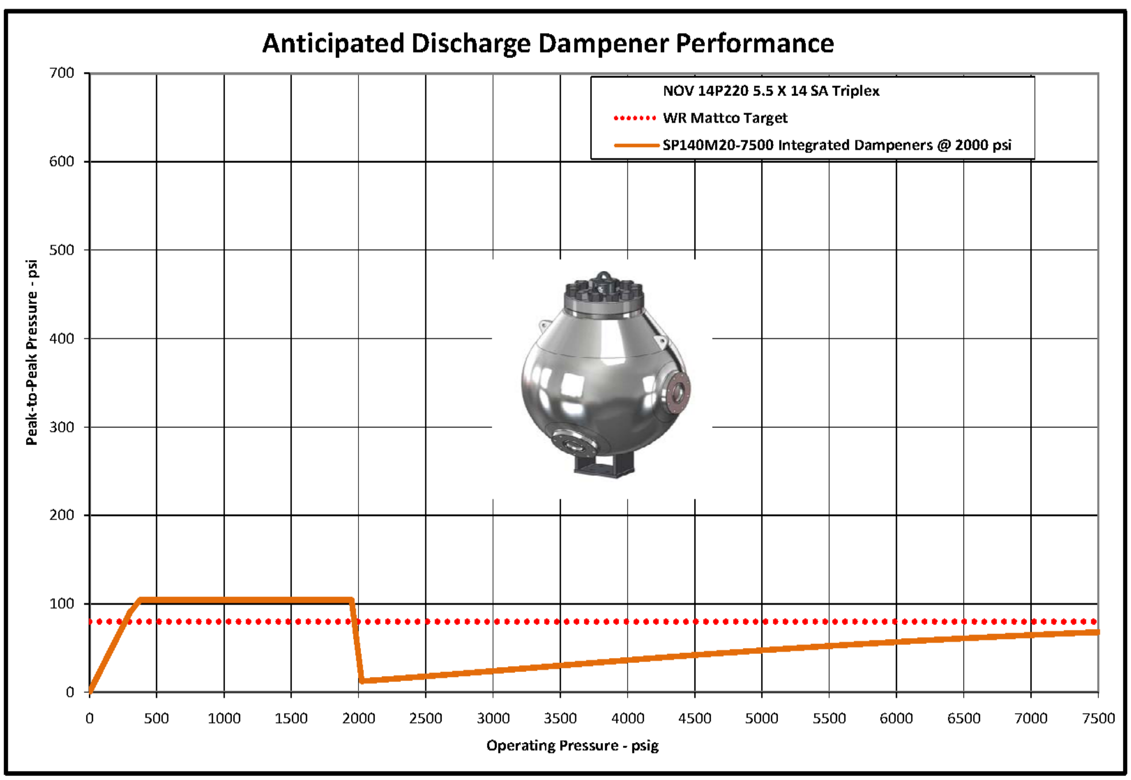


Dual M20 Pneumatic Dampeners

Anticipated Discharge Dampener Performance 5.5” X 14” Triplex



SP140 Liquid Maintenance Free Dampener including Strainer



SP140M20 Combination Dampener including Strainer

Anticipated Discharge Dampener Performance 7.5” X 14” Triplex

A 14” Stroke Mud Pump with 7.5 inch liner delivers 843 gpm (3191 lpm) at 4025 psi (277.5 kg/cm^2) when operating at 105 strokes per minute. The traditional discharge dampener sizing criteria for mud pumps has been 3% of operating pressure. This design criteria is inadequate with increased operating pressures and system complexity. Experience has shown that the peak-to-peak hydraulic pressure variation must be below ~80 psi to prevent mud pump fluid dynamic interaction with the mud pump discharge piping.

M20-7500 (Pneumatic Discharge Dampener with Nitrogen Charge)

A single 20 gallon pneumatic discharge dampener is totally inadequate because of very limited operating range and no dampening below the dampener charge pressure.

Two M20-7500 (Pneumatic Discharge Dampeners with stepped Nitrogen Charge)

Performance of two 20 gallon pneumatic discharge dampeners is marginal because of limited operating range and none dampening below the dampener nitrogen charge pressure. In the example of two pneumatic dampeners, there is potential damage to the diaphragm when operating near 4000 psi.

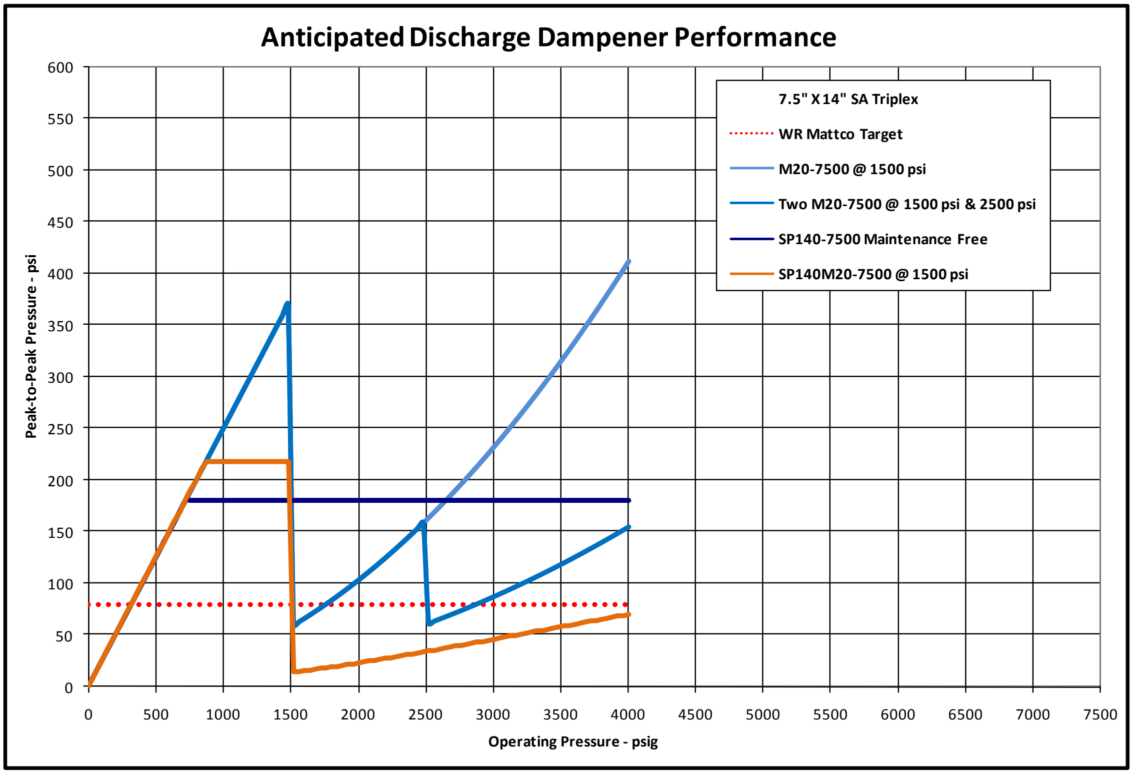
SP140-7500-SB (Liquid Maintenance-Free Discharge Dampener)

The 140 gallon liquid volume discharge dampener will provide a maximum peak-to-peak hydraulic pressure variation of 180 psi over the entire operating pressure range. While the 180 psi peak-to-peak hydraulic pressure variation may be acceptable, this level of performance is marginal because of the high potential of hydraulic resonance.

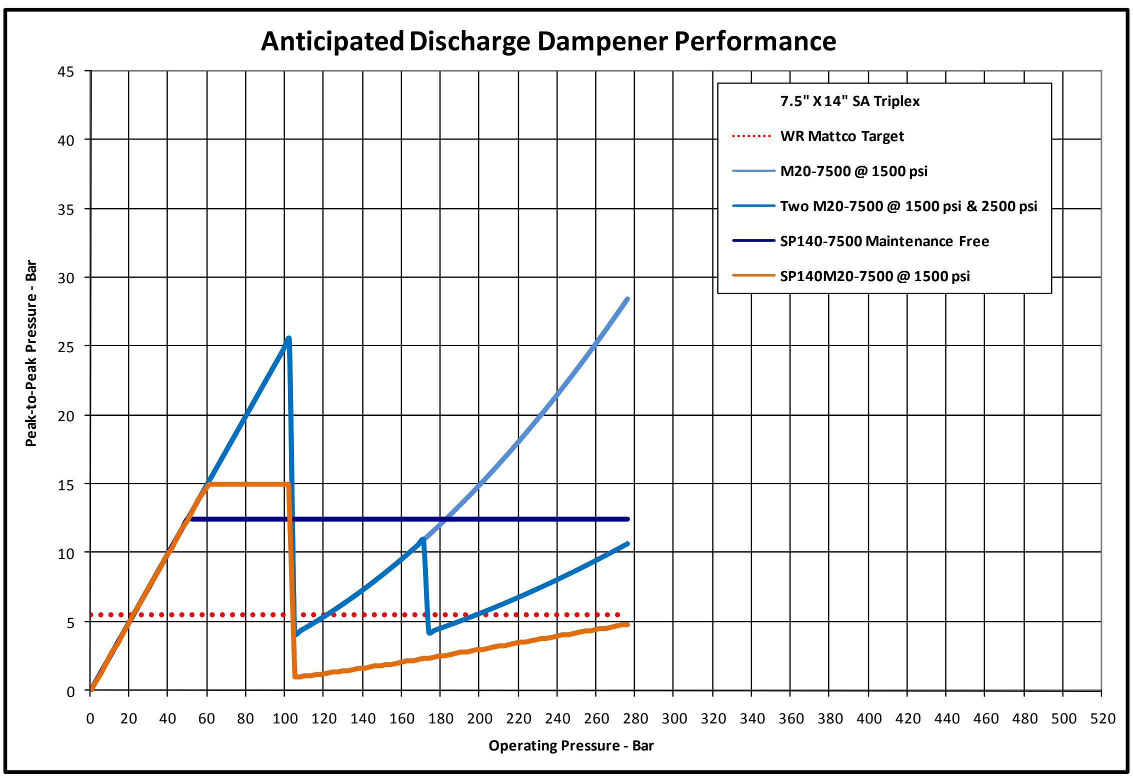
SP140M20-7500-SB Combination Dampener (Premium)

The SP140M20 is the integration of the Liquid Maintenance-Free and Pneumatic Discharge Dampeners into a single discharge dampener. A Strainer/Wave Blocker is used on the dampener outlet. The SP140M20 combination discharge dampener will provide a maximum peak-to-peak hydraulic pressure variation of 218 psi when operating below the nitrogen charge pressure and less than 69 psi when operating above.

Anticipated Discharge Dampener Performance 7.5” X 14” Triplex



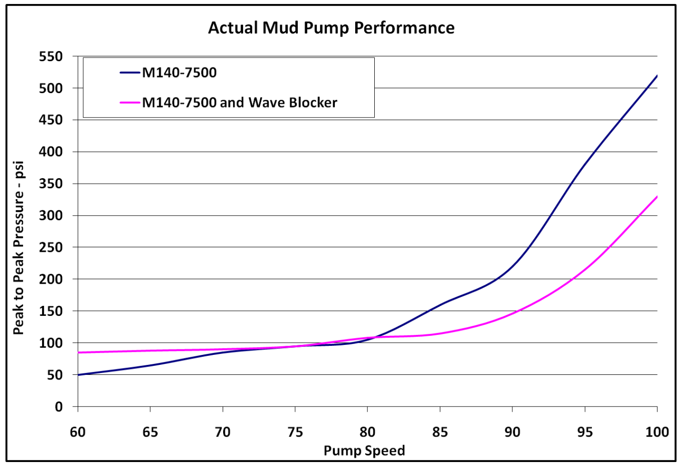
843 Gallon per Minute at 105 Strokes per Minute



3191 Liters per Minute at 105 Strokes per Minute

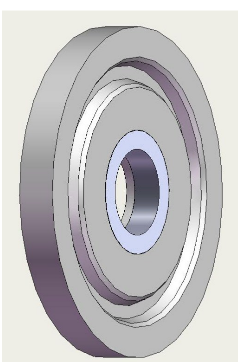
Wave Blockers

Wave Blockers are specially designed orifices with Ceramic Inserts for long life of 3 to 5 years and are installed in the discharge flow line for three different purposes. These are as an integral part of the liquid only dampeners, to enhance pneumatic discharge dampener performance, and detune discharge piping hydraulic response. Resonance response has been reduced from 30% to 70% when installed down stream of the pump in the discharge piping of pump systems experiencing hydraulic resonance.



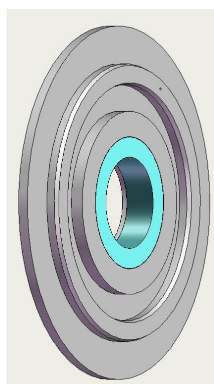
Wave Blocker Types

Wave Blocker Plate—API Ring Joint



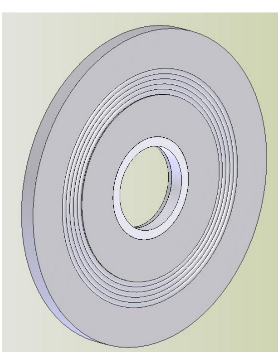
Wave Blocker Plates are designed with a flange face on each side to be installed between two Flanges with two Gaskets. These units require 1" spacing plus one additional gasket thickness.

Wave Blocker Ring—API Ring Joint



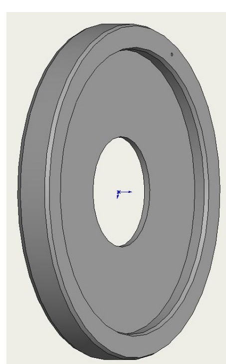
Wave Blocker Rings are designed to replace the existing BX Style Ring Gasket where an orifice is required to reduce the piping system hydraulic resonance. These units require only 0.25" additional spacing and no additional gaskets.

Wave Blocker Plate—ANSI Raised Face



ANSI Raised Face Wave Blockers are designed for low pressure large diameter connections such as suction line and slurry discharge piping. These units require 1" spacing for installation.

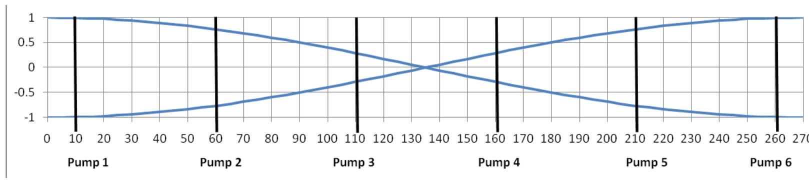
Test Wave Blocker Ring



The Test Wave Blocker Ring is designed to replace an existing BX Style Ring Gasket to evaluate the benefit of a Wave Blocker. These units require only 0.06" additional spacing and no additional gaskets. Life expectancy is a couple of months.

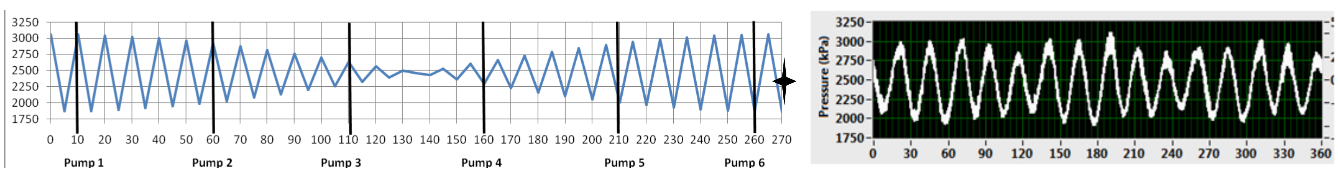
Wave Blocker Performance

The following figures display the relative and actual peak-to-peak hydraulic pressure variation for a pipe header section of 270 feet operating with 6 pumps. The end pump was operating at 33.3 strokes per minute.

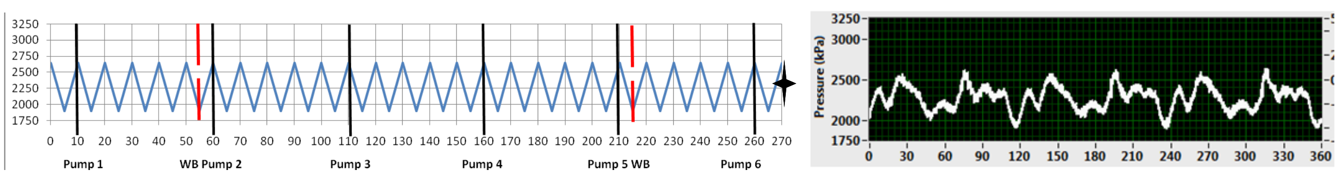


Relative Peak-to-Peak Hydraulic Pressure Variation of 8.4 Hz Standing Wave along 270 ft Pipe Section

Wave Blockers installed in the header at Pumps 2 and 5 reduced the peak-to-peak hydraulic pressure variation 38% by changing the frequency response of the piping. The high peak-to-peak hydraulic pressure variation of 1194-kPa was occurring at the pump station's discharge piping 8.4 Hz half wave natural frequency when pumping water. After installation of the Wave Blocker on the pump, the reduced peak-to-peak hydraulic pressure variation of 739-kPa was at the normal pump excitation frequency of 3.3 Hz. The Wave Blockers are a custom product that can be effectively applied with the assistance of WR Mattco.



Actual Peak-to-Peak Hydraulic Pressure Variation along 270 ft Discharge Pipe Section without Wave Blockers



Actual Peak-to-Peak Hydraulic Pressure Variation along 270 ft Discharge Pipe Section with Wave Blockers

System Operating Conditions and Dynamics

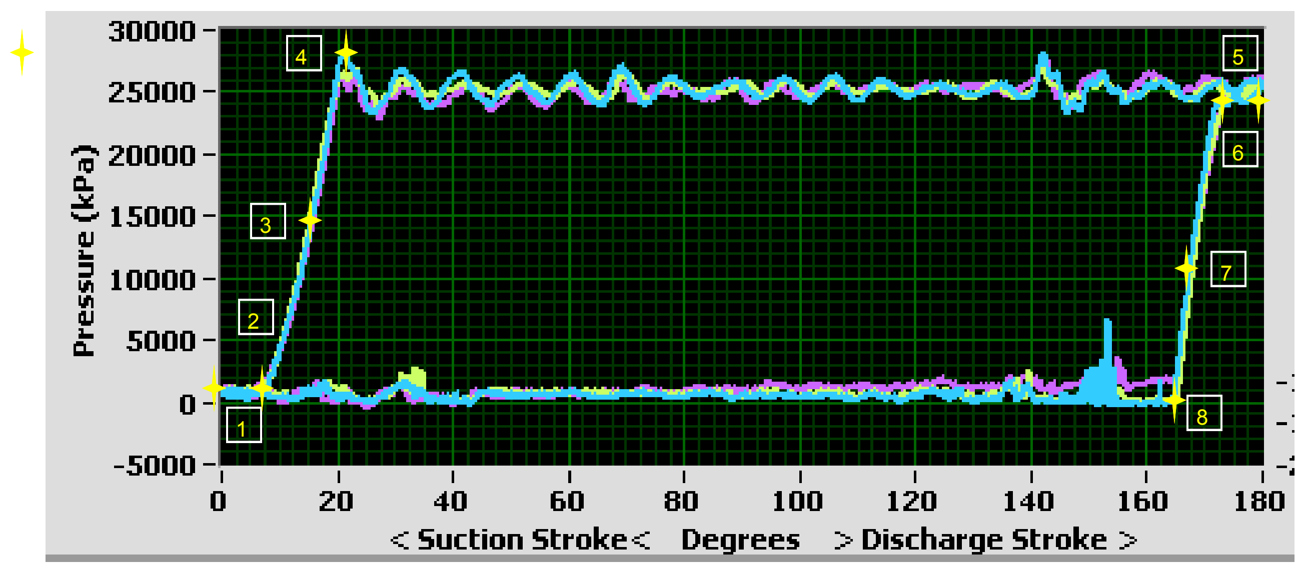
Proper Mud Pump operation is dependent on adequate suction stabilizers and discharge dampeners installed and working properly, and hydraulic resonance not occurring in the piping system. All Mud Pumps have the potential to excite the piping mechanical and/or hydraulic resonant frequencies. Excess hydraulic pressure variation will occur if the pump excitation frequency matches the piping hydraulic resonant frequency. This process leads to piping and piping system component failures, and premature relief valve activation as well as mechanically over-stressing the Pump Fluid-End and Power-End.

Pumps generate two forms of hydraulic pressure disturbances in the suction and discharge manifold and piping. These hydraulic pressure variations are the result of fluid flow and fluid acceleration. A discussion of the pump cycle follows to understand the mechanisms that result in Pump Fluid Dynamics.

Pump Cycle

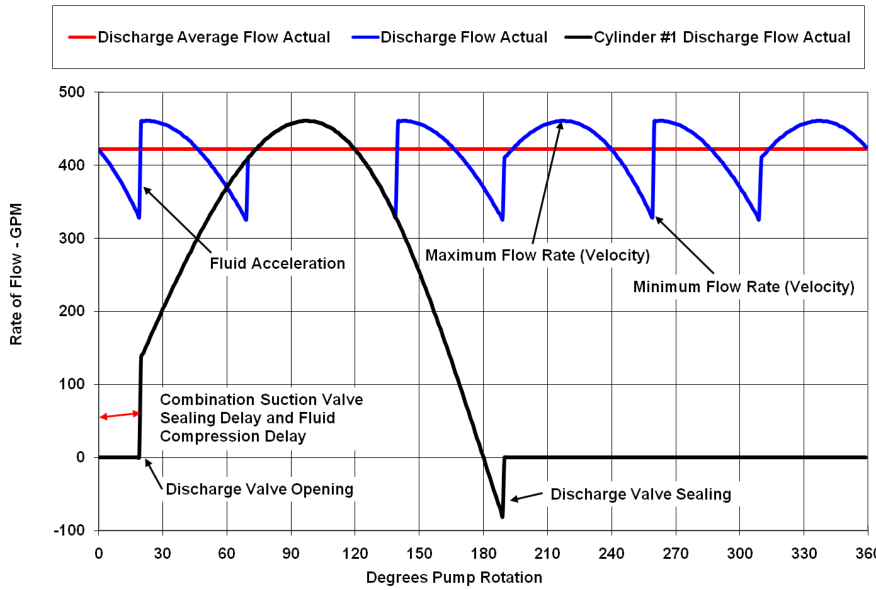
Fluid Dynamics of a Triplex Mud Pump is dependent on the action of the pump suction and discharge valves and how the fluid responds in each pump chamber. The following pump chamber pressure curve based on crank angle is typical. Discharge stroke is from 0 to 180 Degrees and suction stroke is from 180 back to 0 Degrees.

1.Start of discharge stroke - 0 Degrees
2.Suction valve seal ~ 10 Degrees
3.Compression of the fluid in the pump chamber ~10 Degrees
4.Overshoot pressure in pump chamber prior to discharge valve opening ~ 20 Degrees
5.Start of suction stroke - 180 Degrees
6.Discharge valve seal ~ 190 Degrees
7.Decompression of fluid in pump chamber ~ 8 Degrees
8.Suction valve open ~ 198 Degrees



Pump Flow Dynamics

The following curve represents a typical fluid flow pattern with 10 degree suction and discharge valve seal delay, and 10 degree compression and 8 degree decompression delays.



Fluid pressure disturbances are generated because of the velocity variation (flow rate variation) resulting from the pump crank driving mechanism.

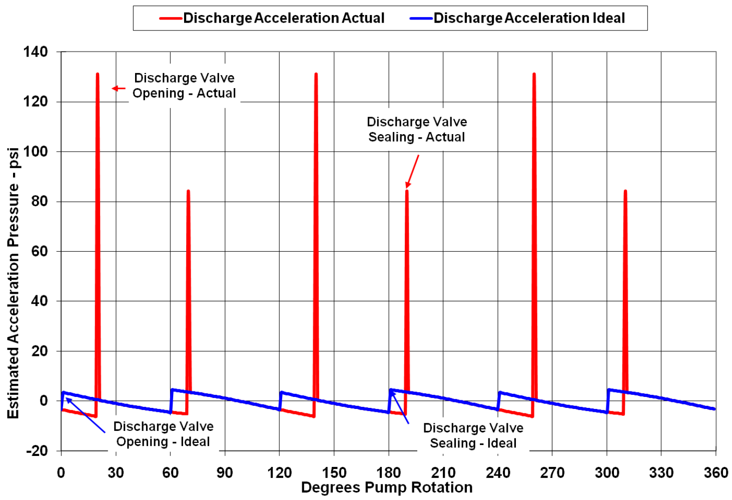
Velocity induced pressure disturbances occur at harmonics (3 and 6 times) of the pump rotating frequency (Pump Speed). With the piping system acting as the pressure drop coefficient (k), the discharge system experiences peak-to-peak hydraulic pressure variation (ΔP) by the square of the fluid velocity difference (Δv) between the maximum and minimum. Peak-to-peak hydraulic pressure variation is proportional to the operating pressure and will be 20% to 35% when no discharge dampener is used.

$$\Delta P = k\Delta v^2$$

Suction stabilizers and discharge dampeners act as velocity compensators and are sized based on the volume of fluid represented by the area above the average flow rate that is stored and then released when the flow rate drops below the average. The larger the pump, the larger the pulsation dampener required to provide an acceptable level of residual peak-to -peak hydraulic pressure variation.

Pump Acceleration Dynamics

The following curve represents a typical fluid acceleration pressure pattern with 10 degree suction and discharge valve seal delay, and 10 degree compression and 8 degree decompression delays.

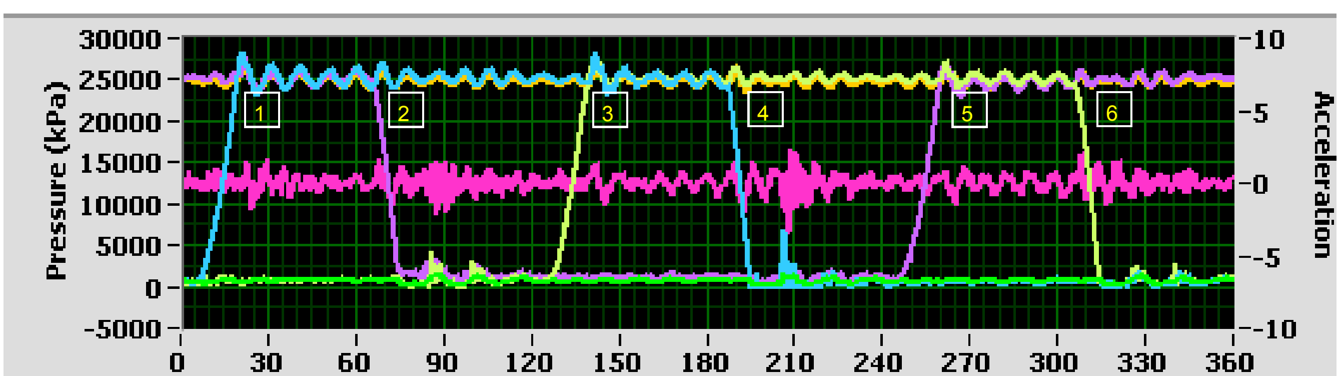


Acceleration induced pressure disturbances occur when the Pump valves open and close (seal) that result in step changes in the fluid velocity, i.e. acceleration.

$$\Delta P = m\alpha$$

These shock or acceleration induced pressure spikes result from a mass of fluid (m) being accelerated (α) that occurs 6 times per pump revolution. Shock pressure ranges from 5% to 13% of operating pressure depending on pump suction and expendable parts conditions. The following chart displays the pressure for the three pump chambers and the acceleration pressure occurring when the discharge valve opens and closes (seals).

1. Chamber 1 Discharge Valve - Open
2. Chamber 3 Discharge Valve - Seal
3. Chamber 2 Discharge Valve - Open
4. Chamber 1 Discharge Valve - Seal
5. Chamber 3 Discharge Valve - Open
6. Chamber 2 Discharge Valve - Seal



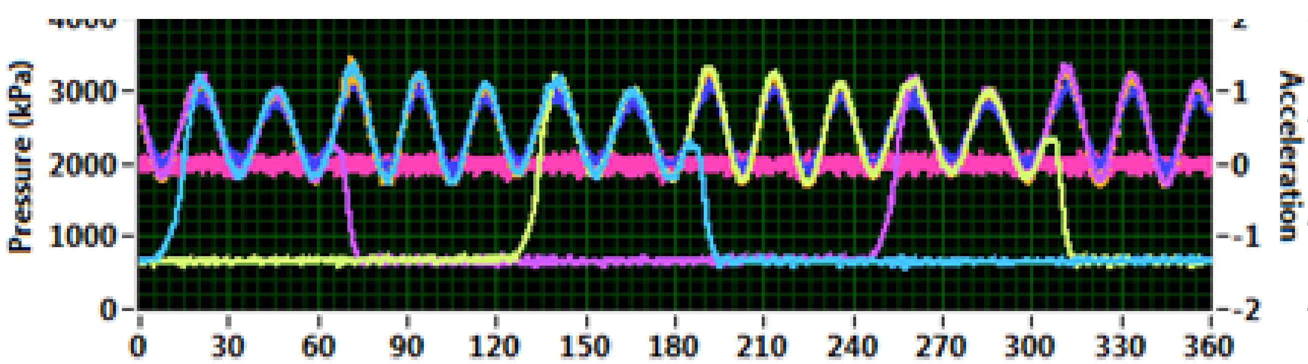
Discharge Piping System Response

Pump suction and discharge piping system can have two forms of response to the fluid dynamics. They are hydraulic and mechanical resonance that may result in excessive mechanical stress of the pump and piping.

Piping System Hydraulic Resonance

A third form of peak-to-peak hydraulic pressure variation occurs when the system has a standing wave generated (hydraulic resonance). Hydraulic resonance occurs when the pump driving frequency harmonic matches the hydraulic resonant frequency of the piping system. Piping hydraulic resonate frequency (**f_h**) is a function of the fluid acoustic velocity (ή - velocity of sound wave in the fluid) divided by the wavelength (**l**-any given pipe length in the pump piping system).

Hydraulic resonant frequency excitation potential $f_h = \frac{\eta}{\lambda}$ increases with the number of pumps in a common piping system and when a variable speed pump is used. Hydraulic resonance can increase the fluid peak-to-peak pressure variation by a factor of 10 or more as displayed. Stiffer pipe or more piping supports can be used to reduce the pipe vibration but it does not change the hydraulic forces that are affecting the pump and the energy that is being transferred to the supporting structure.



Piping Mechanical Resonance

Suspended piping and piping appendages have mechanical natural frequencies. Relatively small peak-to-peak hydraulic pressure variation occurring at the mechanical natural frequency of the piping can cause excessive pipe vibration and pipe support failure. Piping mechanical resonant frequency (**f_m**) is a function of a differential equation solution for the pipe mechanical properties (**δM)** divided by the Pipe Free Length (L).

$$f_m = \frac{\delta M}{L^2}$$

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