# Cavitation Caused By High Pulsations And Accumulator Ineffectiveness Chief Causes Of
# Pipeline Pump Vibration and Failure

**LIQUIDS PIPELINE REPORT**

**By J.C. Wachel,**
*President, Engineering Dynamics Inc., San Antonio, Texas*

Engineering Dynamics Inc. was asked to investigate and make recommendations to alleviate problems experienced on a crude oil line in South America. The investigation included modeling of the acoustical characteristics of the suction and discharge piping systems using a digital simulation technique and as well as a detailed field study to measure and evaluate the pulsation and vibration characteristics of the pumps.

Four triplex reciprocating crude oil pumps operating in parallel with a rated speed of 275 rpm and a capacity of 388 gal. per min experienced repeated failures of the piping and pump components. The pumps were installed at the Dina Station on a major crude oil pipeline in Colombia. Several changes were made in the piping system and accumulators in an attempt to improve the vibrations and reduce the failures. However, the failures continued.

Solutions developed to eliminate the problems were installed in January 1985. A follow-up field study was made to determine if the modifications were adequate for long-term reliability. Since the recommended modifications were installed, the pumps have delivered 40,000 bbl per day with no piping failure and only normal maintenance.

**Field investigation.** The initial vibration and pulsation surveys at selected points in the suction and discharge piping (Fig. 1) revealed high vibration and pulsation amplitudes indicating large excitation forces present in the piping. Analysis of the pressure pulsation waveforms showed severe cavitation in the suction piping system. The plunger pressure-time wave (Fig. 2) indicates that cavitation occurs on the suction stroke. The presence of cavitation can be observed on the complex wave as pulsations will "square off" at the trough of the waves when the vapor pressure is reached. The effect of the static pressure and speed on the cavitation was investigated by raising the nominal suction pressure of 60 psig to 90 psig (Fig.3).

The frequency analysis of the suction pulsation as a function of speed indicated that the largest pulsation components (100 to 150 psi peak-to-peak) occurred at acoustical resonances near 130 to 150 Hz, which were associated with length of the suction manifold, the accumulator, and the pump internal passage volumes.

Pulsations in the discharge manifold had levels exceeding 1,000 psig. The high pulsations were caused by acoustical resonances as dictated by the acoustical properties of the bladder-type accumulator and the piping system.

The pressure pulsations of 200 psig peak-to-peak measured in the discharge lateral caused shaking forces of 9,000 lb at the bends in the discharge piping. These forces caused excessive vibration, resulting in repeated fatigue failures. Forces this large are difficult to control with normal pipe clamps and supports.

**Acoustic pulsation modeling.** The acoustic response of the suction and discharge piping systems were simulated digitally using an EDI program (Fig. 4). The pulsations in the suction manifold at each harmonic of pump speed from minimum to maximum speed were calculated and plotted (Fig. 5). The harmonic numbers are indicated adjacent to the appropriate curve. The interaction of the individual harmonics with the acoustic resonant frequencies at 130 and 140 Hz can be seen.

The analyses showed that pulsation levels inside the suction manifold would be lower if the installed gas-charged, flow-through liquid accumulator was located 2 ft closer to the pump flange and an orifice installed at the pump flange. All four pumps were so modified.

The pulsations predicted in the discharge piping system indicated that the bladder-type accumulator was not effective when the discharge pressure dropped to 700 psig from the normal 1,600 psig because the bladder became fully expanded and blocked off the entrance of the accumulator and voided the beneficial effects of the gas volume (Fig.6). An all-liquid, low-pass, acoustic filter was designed that significantly lowered the pulsation levels.

The improvement in the pulsation can be seen in Fig. 6. Liquid filters do not need a gas charge to be effective and require no maintenance.

An all-liquid filter was installed on the discharge of each pump, the suction

Vibration and pulsation problems at this pump station were improved following analysis of acoustical characteristics of the piping systems and installation of all-liquid filters and modifications to suction piping.

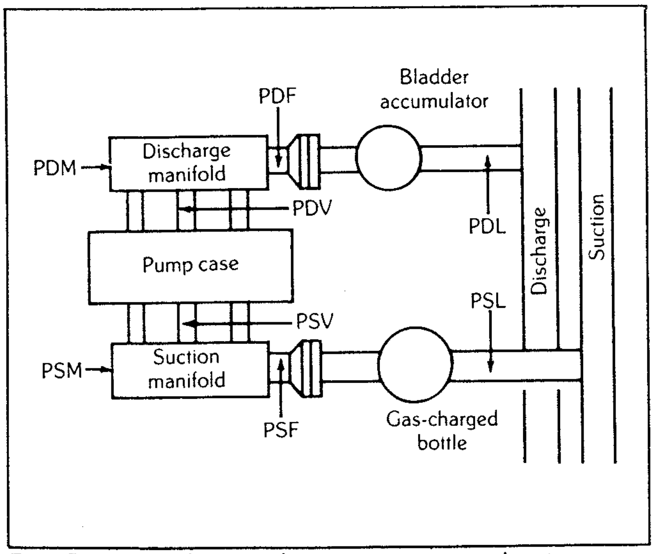



Fig 1. Pump piping layout and pressure measurement locations.

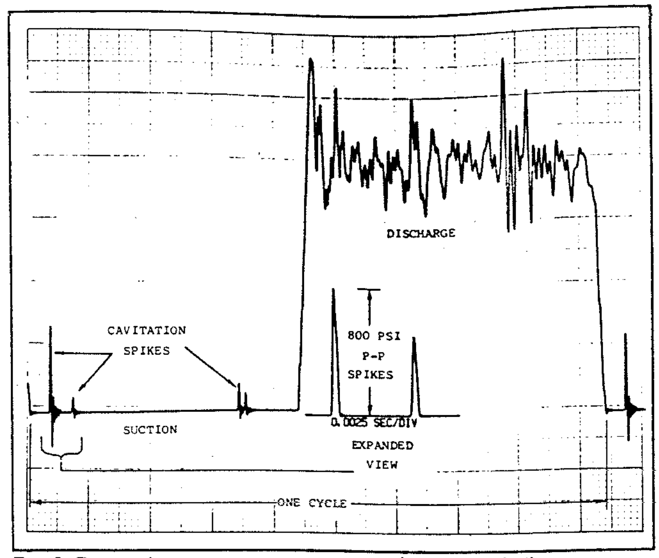



Fig. 2. Pump plunger pressure-time wave showing cavitation.

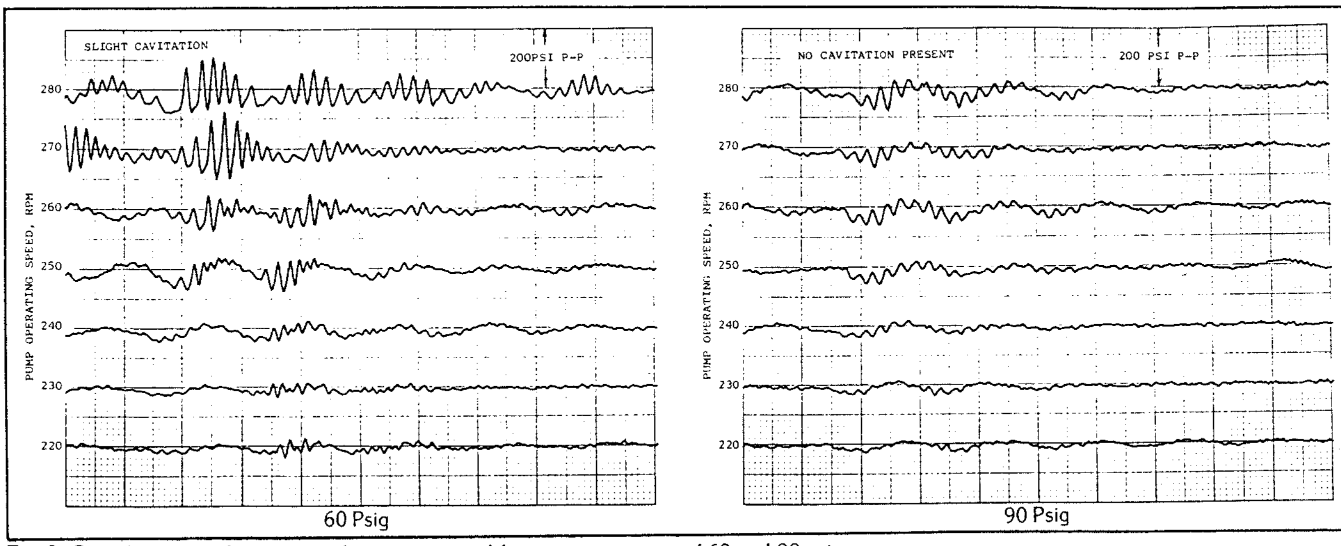



Fig. 3. Complex wave of pressure pulsations vs speed for suction pressure of 60 and 90 psig.

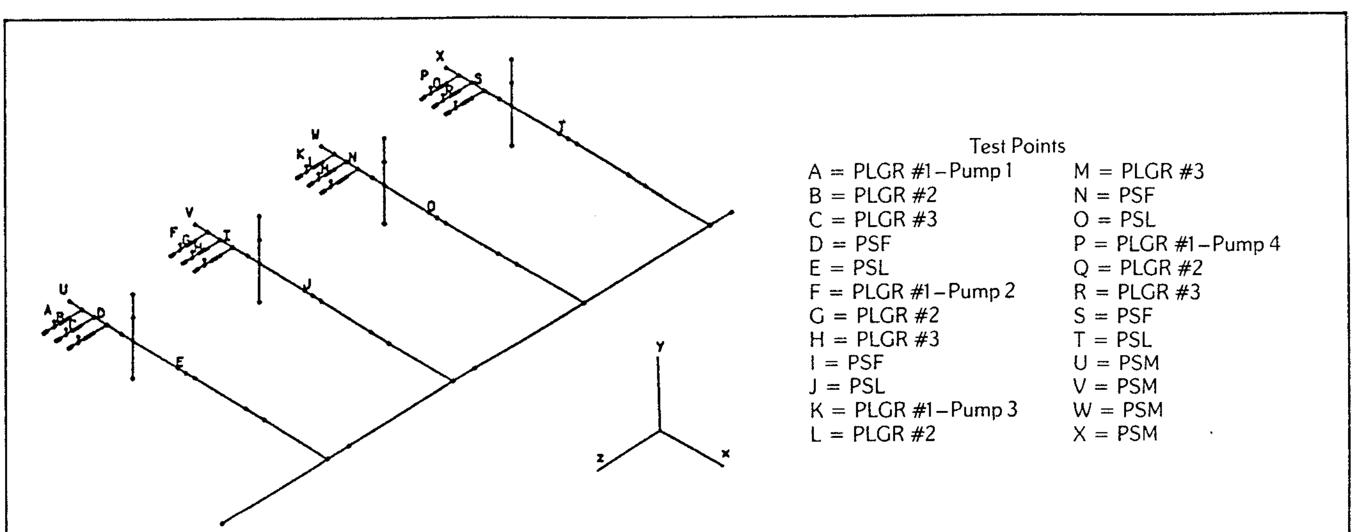



Fig. 4. Pump/piping simulation model.

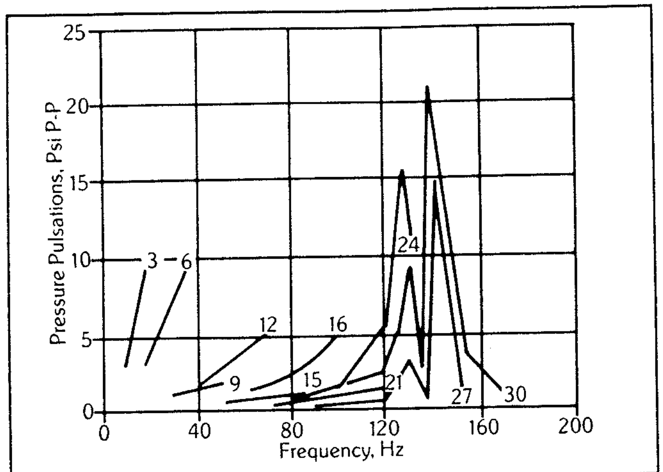



Fig. 6. Predicted discharge pulsations for normal operation and low discharge pressure with bladder-type accumulator and for proposed all-liquid filter.

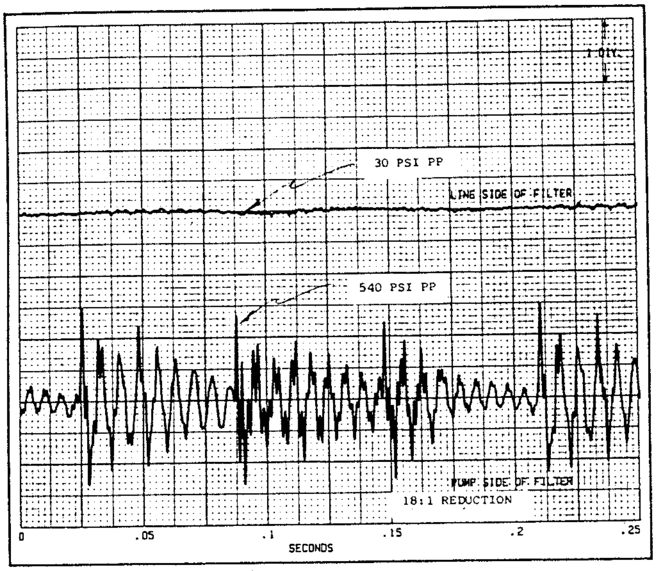



Fig. 5. Pulsations predicted in existing suction piping system.

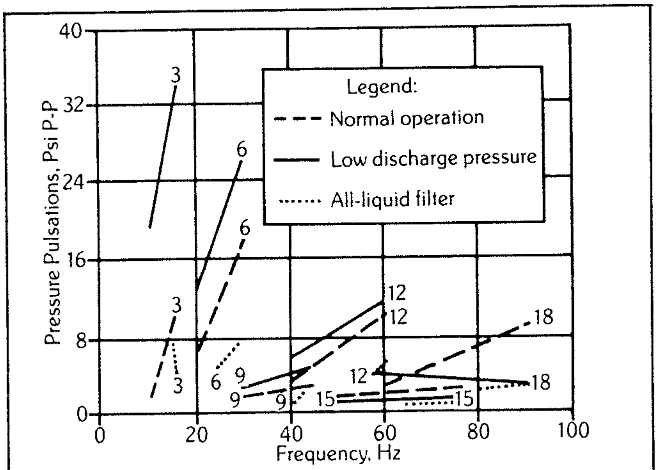



Fig. 7. Comparison of discharge flange and lateral line pulsations.

pressure was increased to 145 psia by a new booster pump, and the gas-charged, flow-through accumulator was moved closer to the pump flange. Significant reduction in the pulsations and vibrations were observed.

With the new filters, the piping vibrations were less than 10 mils and significant reduction in the discharge pulsation was obtained (Fig. 7).

Since the installation of the all-liquid filter and the suction modifications, the pumps have delivered 40,000 b/d with only normal maintenance problems. The piping failures have been completely eliminated due to elimination of the large pulsation-induced shaking forces in the piping.

**Conclusions.** The results of the field tests and the acoustical analyses led to these conclusions:

1. Suction pulsations caused the instantaneous pressure level to drop below the fluid vapor pressure and resulted in severe cavitation. Pulsations were amplified by acoustical resonances of the suction piping system.

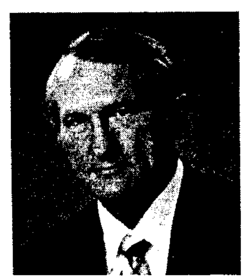
2. The piping and pump component failures in the piping were caused by large shaking forces resulting from high pulsation levels in the discharge piping and the severe cavitation in the suction piping.

3. As with this problem, many vibration and failure problems in reciprocating pumps are caused by system-related acoustical resonances that cause high level pulsations in the suction and discharge piping.

The acoustical characteristics of pump and compressor station piping systems can be analyzed using a digital simulation procedure that considers the fluid acoustic properties, the pump internals, and piping geometry. Multiple pumps can be simulated so that interaction between pumps can be studied. Design changes that will reduce pulsation levels can be determined in the design stage to prevent failures. P&GJ

### References

1. Hicks, E.J., and Grant, T.R., "Acoustic Filter Controls Reciprocal Pump Pulsation," *Oil & Gas Journal*, Jan. 15, 1979, pp 67-73.
2. Ludwig, M., "Design of Pulsation Dampeners for High Speed Reciprocating Pumps," Div. of Transportation, API, Vol.36 V 1956, pp 47-54.
3. Sparks, C.R. and Wachel, J.C., "Pulsations in Centrifugal Pumps and Piping Systems," *Hydrocarbon Processing*, July 1977, pp 183-189.
4. Wachel, J.C., and Szenasi, F.R., "Vibration and Noise in Pumps," Pump Handbook, 1st Edition, McGraw-Hill, 1976, pp 9-87 to 9-97.
5. Miller, J.E., "Liquid Dynamics of Reciprocating Pumps—Parts 1 and 2," *Oil & Gas Journal*, April 18, 1983.
6. Wachel, J.C., Szenasi, F.R., and Denison, S.C., "Analysis of Vibration and Failure Problem in Reciprocating Triplex Pumps For Oil Pipelines," ASME Paper 85-PET-10, Feb. 17-21, 1985.



**ABOUT THE AUTHOR**

**J.C. "Buddy" Wachel** is president of Engineering Dynamics Inc., an independent consulting firm specializing in the solution of vibration and failure problems in reciprocating and rotating machinery, piping, and structures. He has more than 25 years experience and has published in excess of 30 technical papers in the field. Wachel has bachelors and masters degrees in mechanical engineering from The University of Texas and is a registered professional engineer in Texas.