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CRV Test Results

Benefits of Using a Cheng Rotation Vane (CRV) in a Vertical Pump

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Section 1

Introduction

When a fluid travels through an elbow or curved conduit in a piping system, it becomes turbulent. The flow stream next to the outer radius must travel a longer distance than the flow stream near the center. When this happens, the pressure distribution becomes uneven and the fluid separates into numerous secondary flows that swirl, rotate, and have accelerated and reverse flows. Thus, the velocity pattern at the exit of the elbow becomes turbulent. This is the reason why a curved conduit can produce a greater pressure loss than a straight section of pipe. This flow turbulence will continue downstream from the elbow and will be detrimental to the operation of rotating equipment connected within 10 pipe diameters of the bend. The Cheng Rotation Vane (CRV) was invented to eliminate the flow turbulence caused by an elbow or bend in a piping system.

The Cheng Rotation Vane (CRV) consists of a set of stationary vanes in a cylindrical body, and is placed immediately upstream of an elbow in a piping system. The CRV's vanes are specifically designed so that they impart a gyroscopic motion to the flowing fluid. This gyroscopic motion counteracts the rotating motion of the fluid that is produced by the elbow. The CRV enables the fluid to negotiate the turn through the elbow and exit the elbow with a flat uniform velocity profile. Other flow benefits achieved when using a CRV are a reduced pressure drop through the elbow, no fluid turbulence, less noise, less vibration, and no fluid separation. The CRV improves the flow of fluid through any type of elbow, and thus turns the elbow into the equivalent of a straight length of pipe.

Vertical pump manufacturers have experimented with new pump impeller and bowl designs to increase pump efficiencies, but they have not addressed the internal flow through the "piping portion" of the pump. Unlike horizontal pumps, vertical pumps have interior elbows and turns that cause turbulence, and this can impact the overall efficiency of the pump, especially at high flow rates. Recently, a flow test was performed by a major vertical pump manufacturer to determine the amount of improvement that could be expected in pump performance, by placing a Cheng Rotation Vane (CRV) at the vertical pump's discharge head elbow.

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Test Details

SET UP: The pump manufacturer selected a three-stage, 12" discharge, vertical turbine pump, because it is a mid-ranged, popularly marketed model. Designed for 3400 gallons per minute (GPM) at 257 ft total differential head (TDH) at 1770 revolutions per minute (RPM), the pump had a 300 HP vertical motor driver. Since the 12" diameter outer can was approximately 10 feet long, the pump was installed in a 15-foot test pit, with the discharge nozzle connected to a 12" elbow, followed by a straight length of pipe, and then a control valve that discharged into a water holding tank. The pump suction inlet was piped back to the holding tank for a closed loop configuration.

INSTRUMENTATION: Gage elevations, barometric pressure, and ambient temperature were recorded at the beginning of the test. Bourdon tube pressure gages measured pressures upstream of the CRV in the discharge column and downstream of the discharge elbow. A venturi located downstream of the discharge elbow along the straight length of pipe measured flow rate by mercury manometer readings. An IDR VibraPac monitored and recorded vibration data in the x and y planes of the pump discharge nozzle. A high-resolution counter with magnetic pick-up measured pump speed in RPM, and pump horsepower was calculated from wattmeter readings.

PROCEDURE: The pump was started against a partially opened control valve, and the air was purged from the system. Allowing for a few moments for the flow system to stabilize, the manual control valve was adjusted for each test point at about 400 GPM increments. At a range of plus and minus 25% of the best efficiency point (BEP) of 3400 GPM, test point increments were reduced to 200 GPM. The full range of test points covered from 0 to 4500 GPM. Each test point included reading of pressure (two points), flow, water temperature, speed, power, vibration, and elapsed time.

After the test data was performed without the CRV, the pump was stopped and the CRV was installed as close as possible to the discharge head elbow. The CRV was specially designed CRV with a hollow core in its center, allowing the pumps shaft to fit through with a relatively tight clearance, and with flanges for bolting to the column and elbow. With the pump reassembled, the test was rerun using the same flow points, and the data was similarly recorded. The test results compare the before and after data in graphic form.

Section

3

Test Results

Approximately, 20 measurements were taken over a range of flow rates from 0 to 4500 GPM. Figure 1a shows the comparison in pump head with and without the CRV installed in the pump. Figure 1b shows the increase in pump head with a CRV. The data shows that at low flow rates (i.e. less than 2500 GPM), the CRV does not give head losses. At the rated flow of the pump (3400 GPM), there is an increase of 5 ft of pump head. The data also shows that significant higher increases in pump head, (beyond flow rates of 4000 GPM) were achieved by adding a CRV.

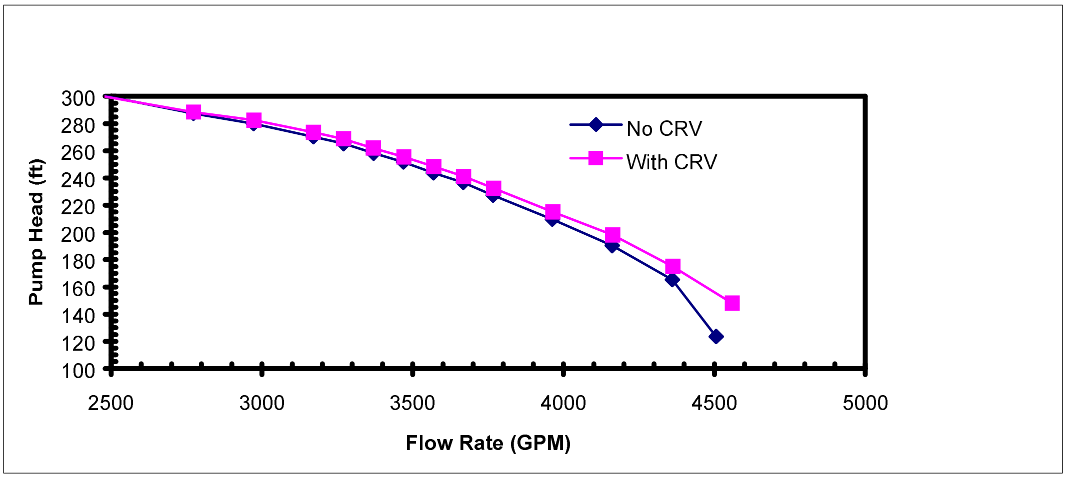


Figure 1a. Pump Head Comparison

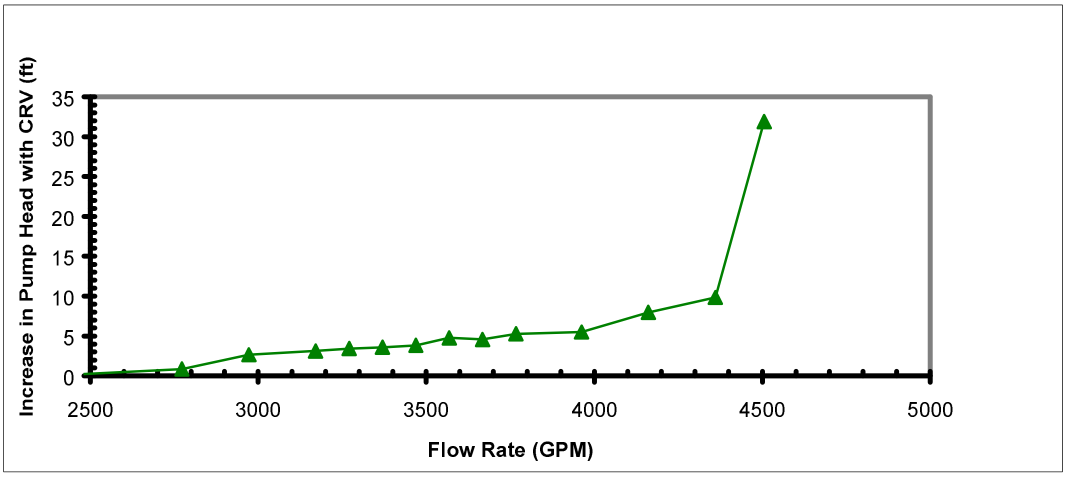


Figure 1b. Increase in Pump Head With CRV

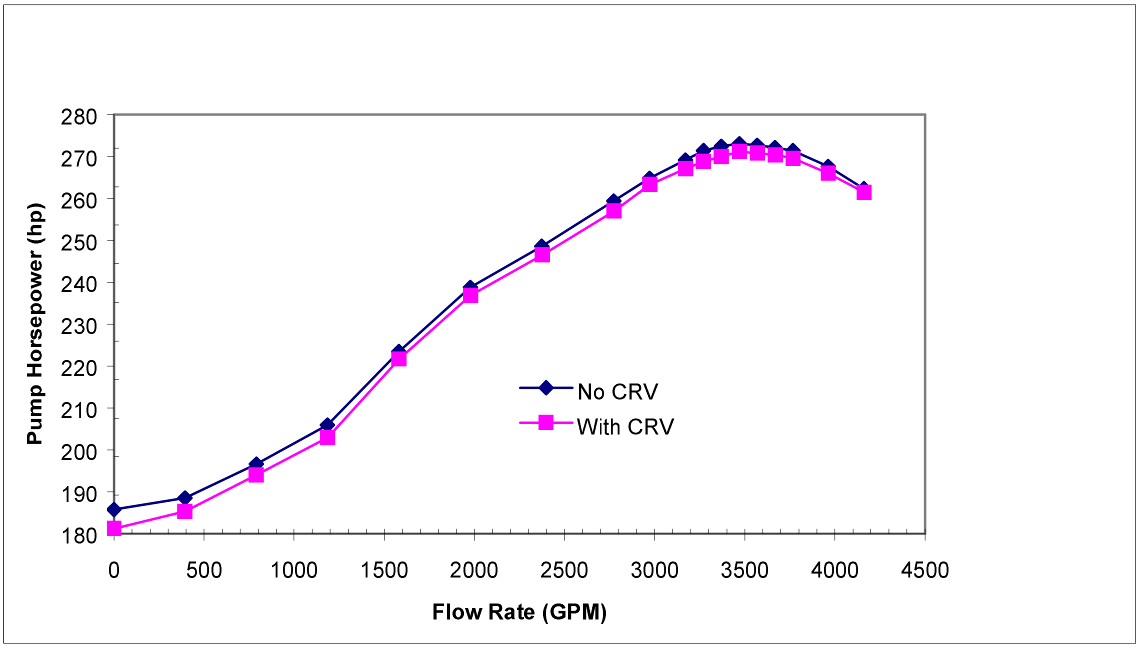


Figure 2a. Pump Horsepower Comparison

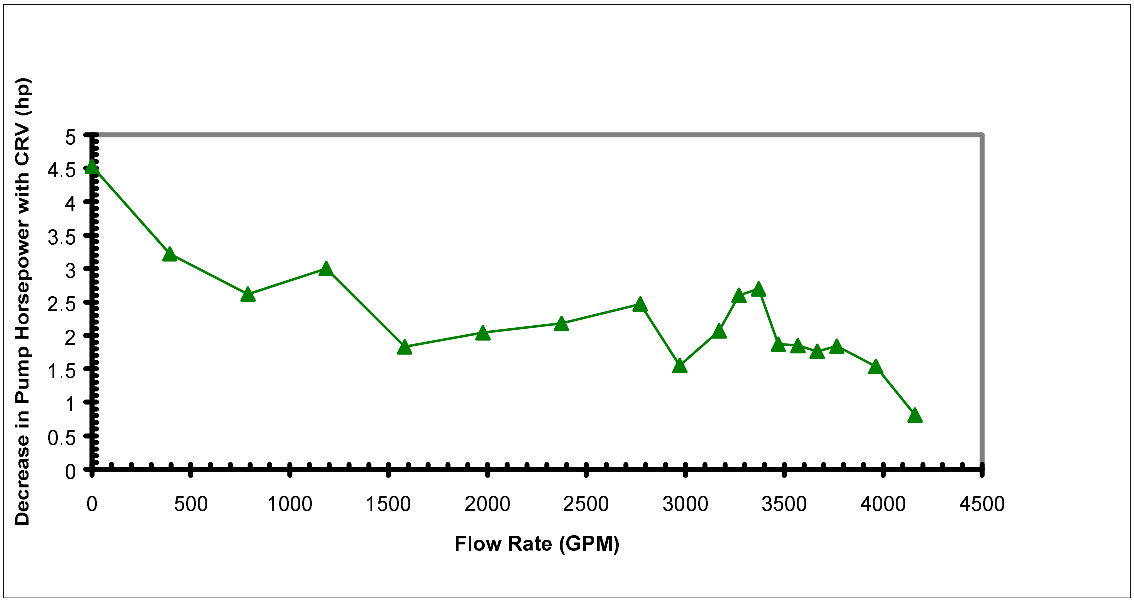


Figure 2b. Decrease in Pump Horsepower with CRV

Figure 2a shows the comparison of the two tests in required pump horsepower. At the rated pump flow of 3400 GPM, the data in Figure 2b shows a decrease of 2.7 horsepower was required to pump the water through the discharge elbow.

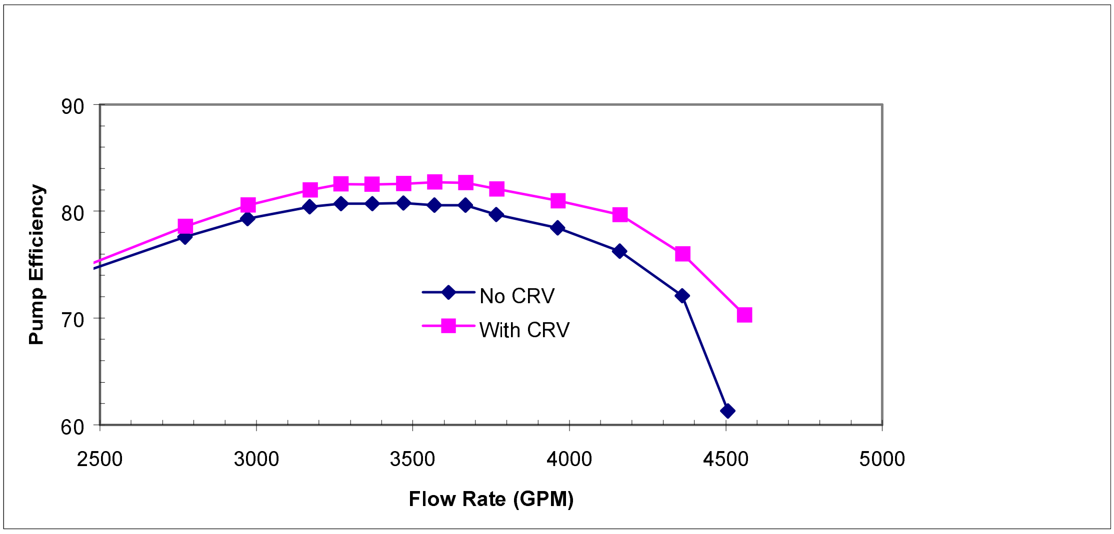


Figure 3a. Pump Efficiency Comparison

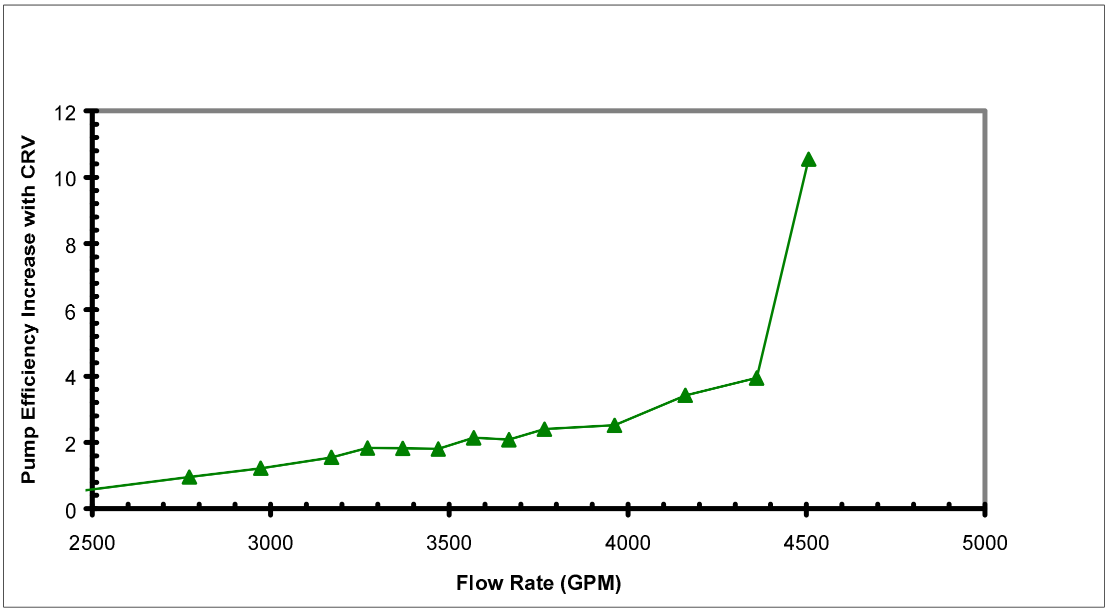


Figure 3b. Increase in Pump Efficiency by Installing a CRV

Figure 3a compares the pump efficiencies between the two tests. An increase in pump efficiency (Figure 3b) of approximately 1% was recorded for flow rates less than 2700 GPM with a CRV installed in the system. At the rated pump flow of 3400 GPM, there was an increase of pump efficiency of 2 points. Efficiency improvements of 3 to 11% were achieved at flow rates above 3400 GPM. The flow rates over which the pump efficiency stayed over 80 percent expanded from 3170 GPM to 3767 GPM without a CRV, to 2973 GPM to 4163 GPM with a CRV, almost a 100% range increase.

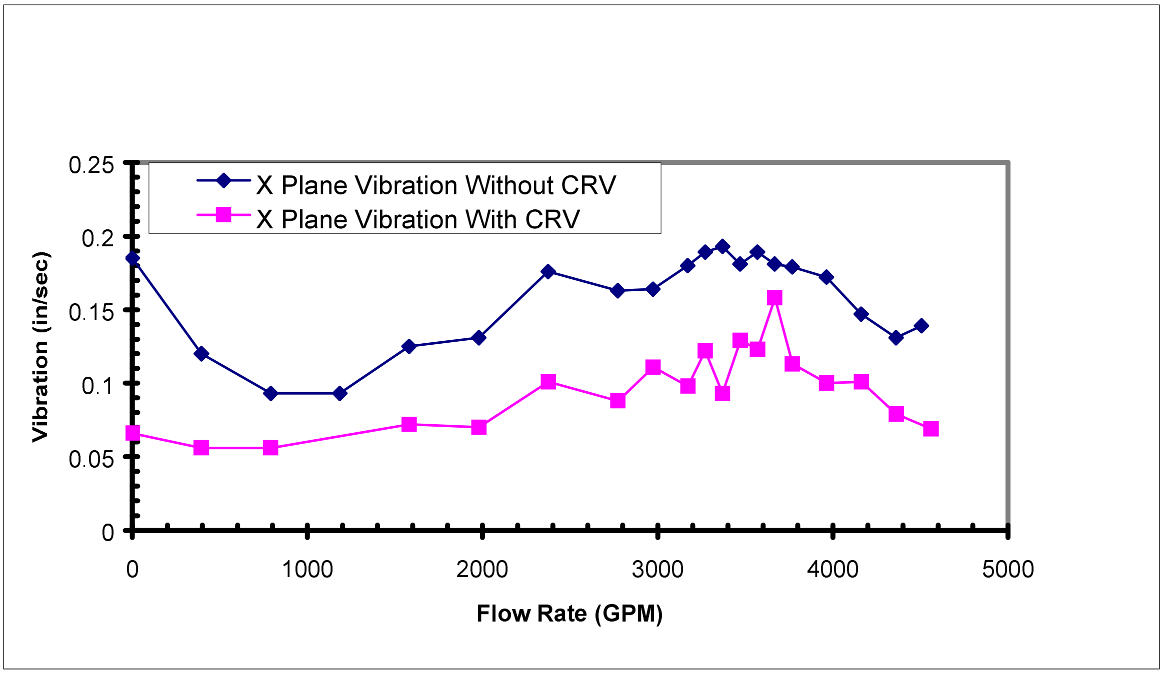


Figure 4a. Comparison of X Plane Vibration on Top of Pump Discharge Head

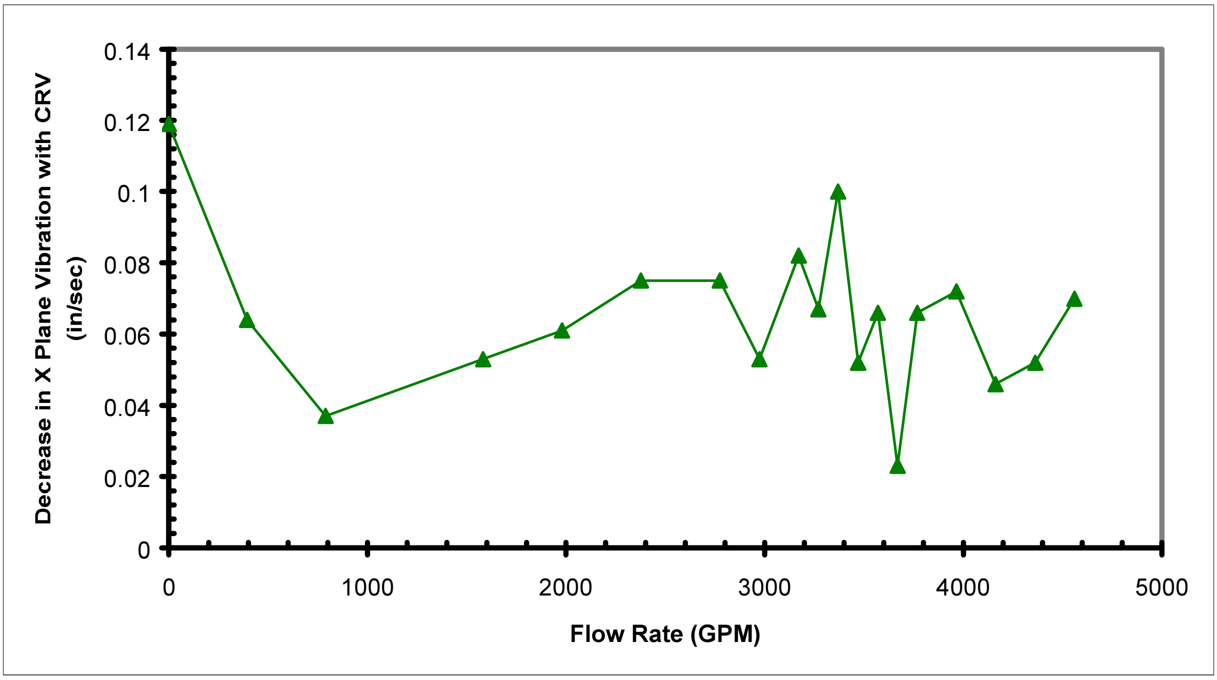


Figure 4b. Decrease in X Plane Vibration on Pump Discharge Head With CRV

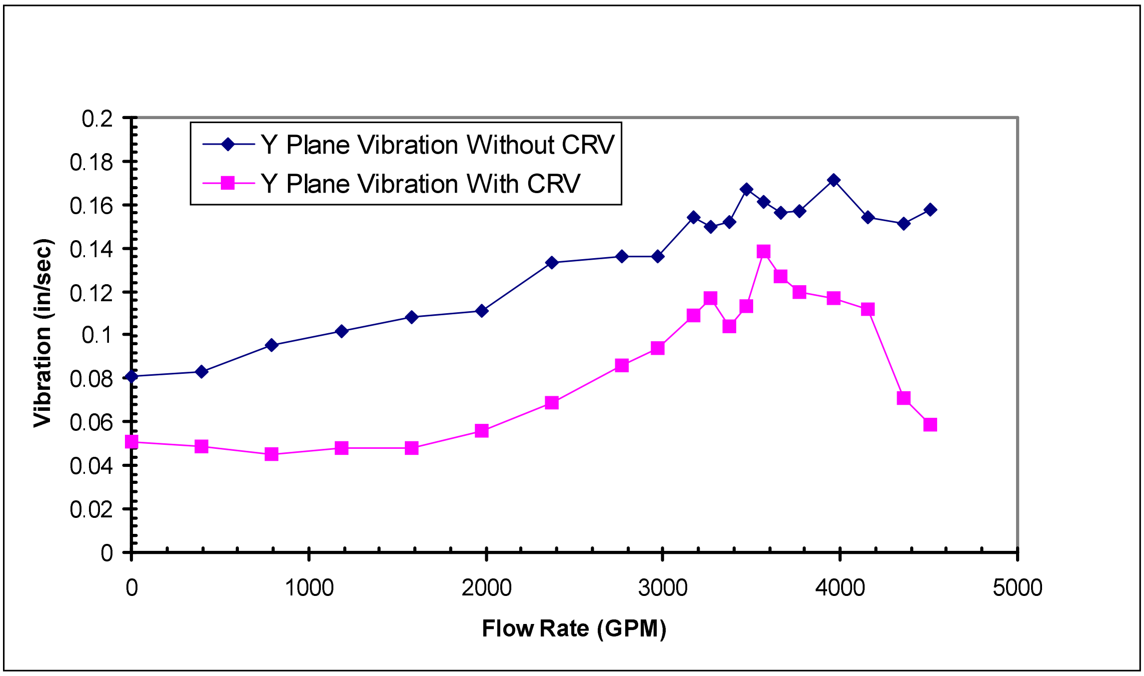
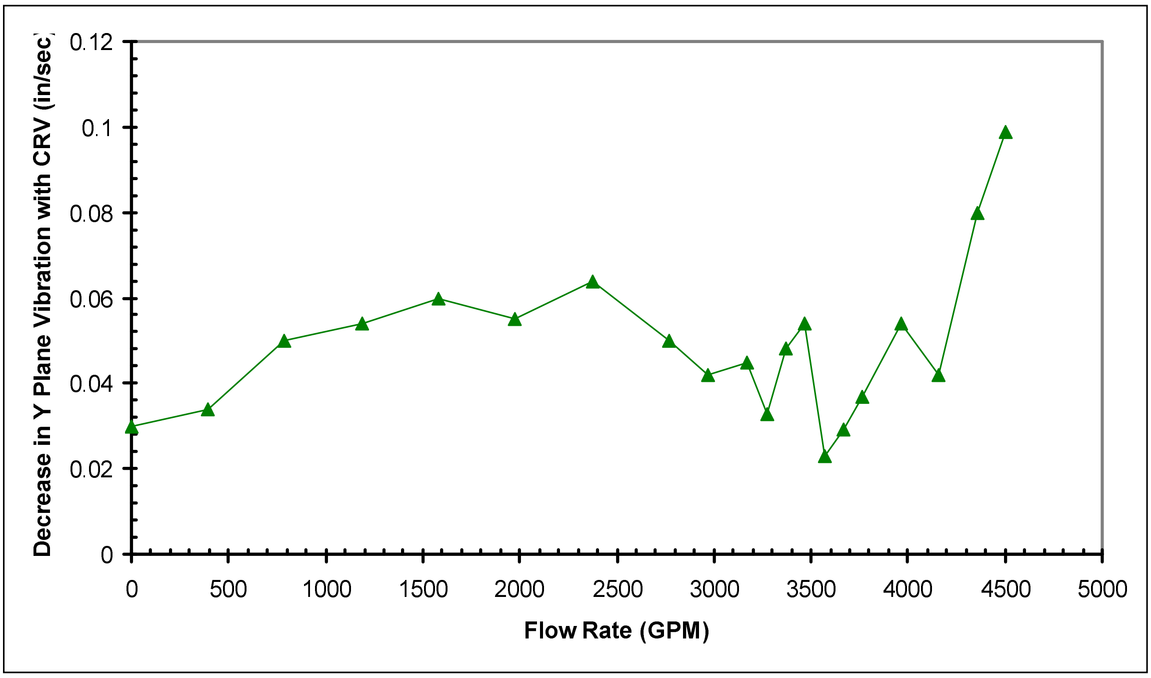


Figure 5a. Comparison of Vibration Measurements on Y Plane of Pump Discharge Head



Figures 4a and 5a show the comparison of the vibration measurements on both the x and y plane of the pumps discharge head. Figures 4b and 5b show the amount of vibration decrease that is observed with a CRV. From these graphs, the benefit of adding a CRV at the inlet to the discharge head elbow results in reduced vibration at the pump discharge head, at all flow rates. The decrease in vibration in the x plane at the rated flow of 3400 GPM is 0.052 in/sec (a 29% reduction in vibration). There is a similar decrease in the y plane at the rated flow of 3400 GPM of 0.054 in/sec (a 32% reduction in vibration). The overall reduction in vibration is approximately 37%.

The benefits of adding the CRV shows that the pumps performance can be improved significantly by understanding the turbulence caused by the elbow and solving that problem. This will translate into a significant cost savings for the customer. (For example, since the amount of horsepower decreases by 2.7 hp when running the pump at 3400 GPM with a CRV installed, the average electricity savings is estimated to be at $1060 + / year*.) Additional savings will also be realized, because the uniform flow created by the CRV will eliminate the harmful flow effects caused by fluid separation, turbulence, and vibration in the pump. Eliminating this source of vibration caused by fluid turbulence will increase shaft and impeller life, bearing and seal wear, and reduce pump noise. This translates into additional cost savings by reducing maintenance intervals, with less downtime, and a higher operating reliability.

*(This saving was obtained by assuming a 2.7 hp savings with 8767 hours/year of operation with a cost of electricity of 6 cents / kW hour.)

Section 4

Conclusions

A summary of the benefits gained by using a CRV in a three-stage vertical turbine pump is shown below.

a) At low flow rates (less than 2500 GPM) there is no loss in pump head; there is an increase in pump efficiency; and a decrease in pump horsepower occurs.

b) At the pumps best efficiency point of 3400 GPM, there is an increase of pump head of 5 feet (an increase of 2%); a decrease in pump horsepower of 2.7 hp (a decrease of 1%), and an increase of pump efficiency of 2 points.

c) The flow range in which the pump efficiency stays above 80% has expanded from 3170 - 3767 GPM without a CRV, to 2973 GPM - 4163 GPM with a CRV (almost a 100% range increase).

d) There is an overall average decrease in the pump vibration at the discharge head of approximately 37%.

e) The increased efficiency, decreased pump power consumption, and increased head results in improved pump performance. The average electric savings at 3400 GPM can be estimated to be more than $1060 per year.