PUMP PERFORMANCE WITH SAND WEAR[1]

Charles Burt[2]
Kyle Feist[3]

ABSTRACT

In many installations, pump performance declines over time due to sand wear. In order to pinpoint the type and rate of wear caused by pumping water with higher-than-average sand concentrations and its direct effect on various pump impeller materials, vertical pump impeller/bowl assemblies of approximately 900 GPM were each pumped for up to 2500 hours with high concentrations of sand in the water. Two different impeller materials were used for a total of five configurations. Well pump operation was simulated by maintaining a constant discharge pressure. The degrading performance, in terms of changing flow rate and kilowatt load, was recorded over time.

INTRODUCTION

During a literature search, the authors were unable to find anything but anecdotal information regarding sand wear, and subsequent impacts on performance, related to different pump impeller materials. Information is easily available regarding cavitation resistance or typical metal characteristics such as hardness. However, sand wear creates a different wear pattern on the impellers/bowls than does cavitation, and the sand wear does not occur uniformly across flow paths.

Southern California Edison funded this and other research in order to create a knowledge base about the loss of pumping efficiency due to sand wear. The Irrigation Training and Research Center (ITRC) completed the testing at the Water Resources Facility (WRF) at California Polytechnic State University in San Luis Obispo, CA. A major goal of the research was to pinpoint the type and rate of wear caused by pumping water with higher-than-average sand concentrations and its direct effect on various pump impeller materials. Of particular interest was the effect on deep-set vertical turbine pumps. Therefore, the testing procedures and setup were created to mimic the pumping conditions found in deep-set well pumps.

Testing Setup

The test water/sand recirculation design utilized a 15 HP, 1760 12MB Peerless vertical turbine pump (impeller 2624332/MC) with a cast iron bowl. Impellers of three materials were used at various times: bronze, stainless steel (316 SS), and aluminum bronze. The specifications included a requirement that the impellers be polished and dynamically balanced. The invoice from Peerless stated that the performance was 900 GPM at 50

[1] Presented at USCID Conference in Reno, NV 2012.
[2] Chairman, Irrigation Training and Research Center (ITRC), California Polytechnic State University (Cal Poly), San Luis Obispo, CA. USA 93407-0730. cburt@calpoly.edu
[3] Engineer, Cal Poly ITRC. kfeist@calpoly.edu

feet TDH with an bowl/impeller efficiency of 81.2% and included a performance curve (see Figure 1).

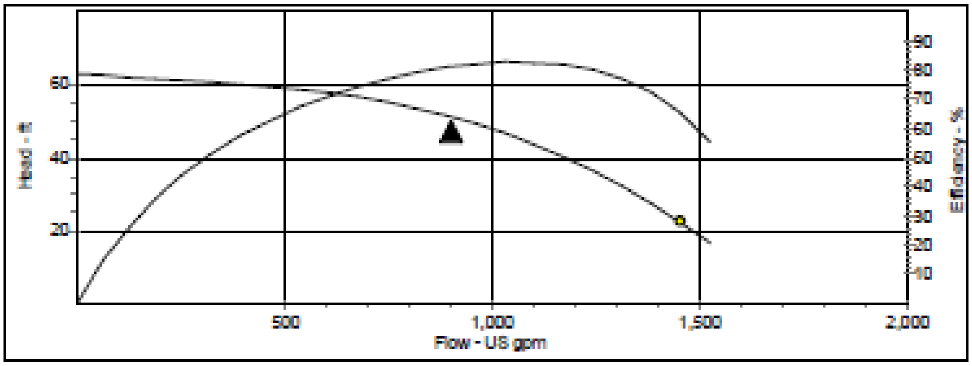

Figure 1. Peerless 12 MB Pump Performance Curve Supplied with Invoice from Peerless

The initial water flow rate was approximately 900 GPM. The target discharge pressure (which was maintained at all times, simulating a fairly constant elevation lift in a well), was about 20 PSI.

The pump was placed in an 18” diameter pump sump. The pump discharged into a 6-inch pipe. Figure 2 illustrates the relative location and description of the test’s pertinent hardware.

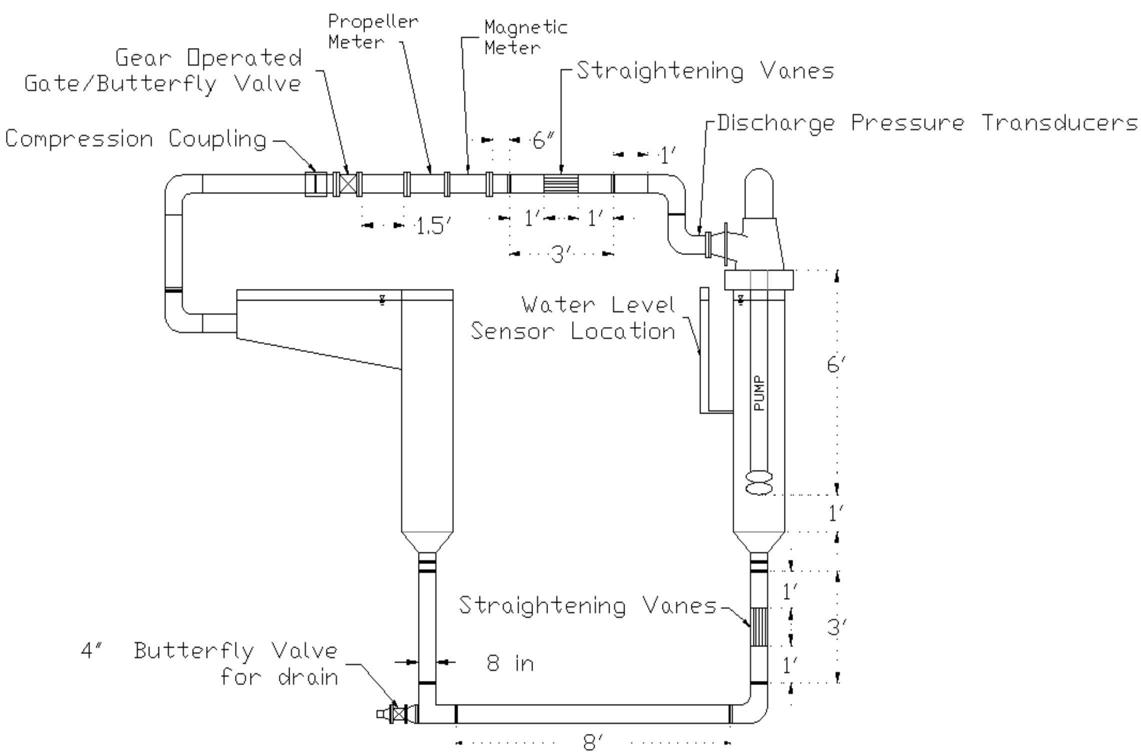

Figure 2. Testing Layout

Datalogging

All relevant data was logged on a half-hour basis via a Programmable Logic Controller (PLC) as well as daily hand-written logs. A Control Microsystems SCADAPack350 was installed to receive data from the following items and their respective uses:

1. KPSI 0-30 PSI Pressure Transducers (2): Monitoring pump discharge pressures
2. Seametrics AG2000: Monitoring pump flow rates and volumes
3. McCrometer McPropeller: Monitoring pump flow rates and volumes
4. Endress + Hauser 0-10 ft Water Level Sensors (2): Monitoring pump sump water levels
5. Shark 100 meter: Monitoring pump motor electric inputs (HP, volts, amps)

Testing Configurations

A total of five test configurations were used to compare three impeller materials at various sand concentrations. The details of each configuration are laid out in Table 1.

Table 1. Test Configurations

Test #	Impeller Type	Bowl Type	Sand Concentration (ppm)
1*	Bronze (New)	Cast Iron (New)	200
2	Bronze (New)	Cast Iron (New)	1000
3	Bronze (Used from Test 1)	Cast Iron (Used from Test 1)	5000
4	NiAl-Bronze (New)	Cast Iron (New)	5000
5**	Stainless Steel (New)	Cast Iron (New)	5000

* Test #1 was ended early because the wear occurred very slowly. The impeller and bowl combination was reused at a higher sand concentration in Test #3.

** Test #5 was terminated almost immediately because of the poor performance of the new impellers.

Pre-Test

The pump and system were set to allow each impeller and bowl combination to begin each test at peak efficiency. To determine this, a complete pump curve (flow rate vs. TDH) was developed at the beginning of each test. The impeller height was also adjusted to obtain the maximum efficiency.

A preliminary test was undertaken to find the optimum impeller height. An impeller height of 0.1875 inches above the bowl bottom proved to be the most efficient position. This impeller height was applied to each impeller and bowl combination.

Next, each impeller and bowl combination was run through an eighteen-point pump curve test to find the optimum point on the pump curve. As shown in Figure 3, Test #2 was started with a flow rate of 940 GPM at a *target discharge pressure* of **22 PSI**, resulting in a 68.5% wire-to-water overall pump efficiency. Neglecting shaft horsepower and bearing losses, and assuming a 90% motor efficiency, the approximate peak bowl/impeller efficiency was 76.1% Three more (for a total of four per test) of these pump and TDH curves were recorded throughout each test's duration, with the final pump curve taken directly before the bowl and impeller were removed.

Table 2. Pump and TDH Table, from Test #2

Test #	Target Q (gpm)	Actual Q (gpm)	Pressure gauge Disch. P (psi)	Input kW	Dist. Trans. To WL (in)	Dist to WL from Trans, ft	P1 (psi)	P2 (psi)	Avg Disch P, ft	Minor losses, ft	WL1 (ft)	WL2 (ft)	TDH, ft	WHP	IHP		W-W Eff (%)	Pump Eff (less motor)
1	520	523.7	27	11.45	9	0.8	27.37	27.32	63.2	0.9	-0.65	-0.72	64.8	8.57	15.35		55.81	62.0
2	560	562	26.8	11.515	9.5	0.8	27.17	27.1	62.7	1.0	-0.7	-0.76	64.5	9.15	15.44		59.27	65.9
3	600	605	26.2	11.935	9.7	0.8	26.86	26.79	62.0	1.1	-0.74	-0.8	63.9	9.77	16.00		61.04	67.8
4	640	640	26	12.23	10.1	0.8	26.6	26.4	61.2	1.3	-0.77	0.83	63.3	10.24	16.39		62.44	69.4
5	680	678	25	12.57	10.6	0.9	26.25	26.25	60.6	1.4	-0.8	-0.9	63.0	10.78	16.85		63.97	71.1
6	720	723	24.5	13	11.2	0.9	25.65	25.7	59.3	1.6	-0.88	-0.95	61.9	11.30	17.43		64.83	72.0
7	760	764	23.5	13.3	12	1.0	25.2	25.14	58.1	1.8	-0.9	-0.97	61.0	11.76	17.83		65.98	73.3
8	800	803	23	13.59	12.5	1.0	24.55	24.59	56.8	2.0	-0.98	-1.02	59.8	12.13	18.22		66.58	74.0
9	840	838	22.3	13.82	12.9	1.1	24.08	24.1	55.6	2.2	-1	-1.1	58.9	12.47	18.53		67.30	74.8
10	880	884	21.5	14.09	13.5	1.1	23.28	23.3	53.8	2.4	-1.06	-1.12	57.4	12.81	18.89		67.81	75.3
11	**920**	**924**	**20.2**	**14.25**	**14**	**1.2**	**22.65**	**22.6**	**52.3**	**2.7**	**-1.1**	**-1.17**	**56.1**	**13.09**	**19.10**		**68.53**	**76.1**
12	**960**	**962**	**19.5**	**14.43**	**15**	**1.3**	**21.8**	**21.8**	**50.4**	**2.9**	**-1.17**	**-1.22**	**54.5**	**13.24**	**19.34**		**68.45**	**76.1**
13	1000	1001	18.5	14.61	15.9	1.3	20.97	21.01	48.5	3.1	-1.26	-1.3	52.9	13.38	19.58		68.34	75.9
14	1040	1044	17	14.79	16.5	1.4	20.01	20.05	46.3	3.4	-1.31	-1.39	51.1	13.46	19.83		67.89	75.4
15	1080	1076	16.3	14.8	17	1.4	19.15	19.2	44.3	3.6	-1.4	-1.46	49.3	13.40	19.84		67.57	75.1
16	1120	1110	15.3	14.83	17.5	1.5	18.3	18.5	42.5	3.9	-1.5	-1.53	47.8	13.40	19.88		67.42	74.9
17	1160	1158	14	14.90	19.5	1.6	17.3	17.2	39.8	4.2	-1.52	-1.53	45.7	13.35	19.97		66.86	74.3
18	1200	1200	12.5	14.85	20	1.7	16.25	16.2	37.5	4.5	-1.66	-1.71	43.7	13.23	19.91		66.45	73.8

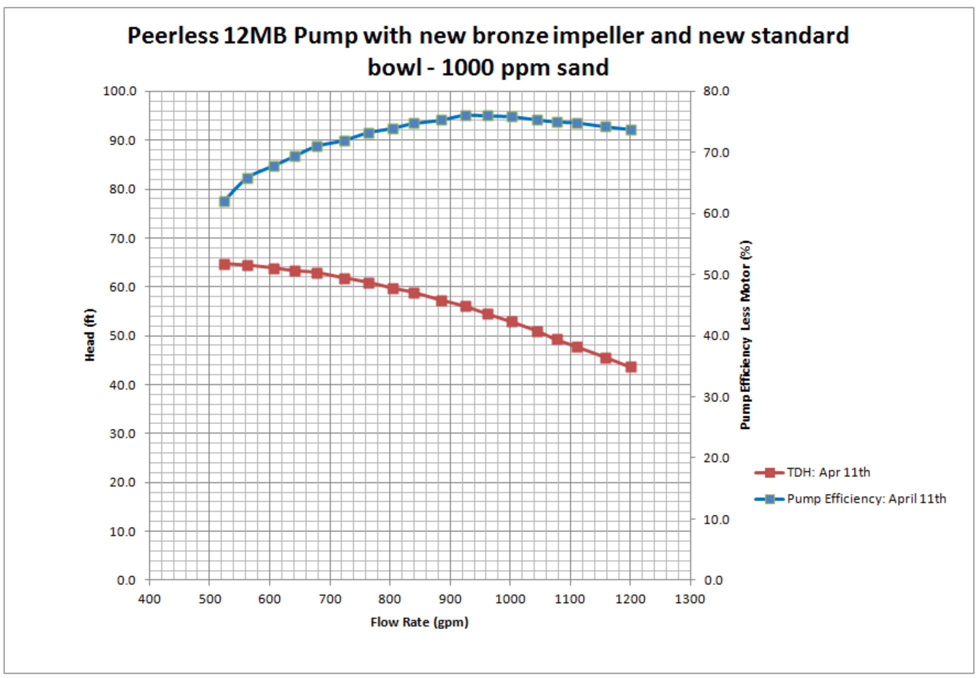

Figure 3. Pump and TDH Curve Chart, from the Beginning of Test #2

A comparison of Figures 1 and 3 shows some difference in terms of the location and magnitude of peak efficiency.

Procedure

Two characteristics of the system were maintained throughout each individual test: pump discharge pressure and sand concentration. As noted earlier, the test was designed to mimic pumping characteristics found in wells. In most instances, the static lift and drawdown on well pumps makes up a large percentage of the total dynamic head (TDH). Thus, a deep well pump's TDH will remain relatively constant throughout considerable flow rate changes due to sand wear, as the change in velocity head and friction loss are still only a small fraction of the TDH requirement. Instead of having a deep lift, this test simulated the same condition by imposing a constant discharge pressure.

Pressure. To more closely imitate this environment, the pump discharge pressure was monitored five times per week and re-adjusted if necessary to maintain the target pressure within +/-0.1 PSI.

Sand Concentration. Maintaining the circulating sand concentration through weekly sampling was a priority throughout the testing. Samples were extracted by utilizing a nylon sock at the end of the open discharge, which passed the complete flow rate for a given duration. The duration of the sampling was less than the recirculation time of sand through the system. It was also limited by an effort to obtain a manageable sample mass at higher sand concentrations. At 5000 ppm, the sample duration was shortest, at 4 seconds.

Silica sand was added if necessary to maintain the target concentration +/-5%. A log of sand additions and drainage recoveries was kept throughout the testing.

Changing Impellers. Every time a new impeller was used, a new bowl was also used.

Stainless Steel Impeller. The stainless steel impeller's initial performance is shown in Figure 4. It can be seen that the approximate bowl efficiency is below 70%, and the TDH is lower than stated in Figure 1. This is even though the published information indicates a performance similar to what is seen in Figure 3. When Peerless Pump was contacted, the company response was that such is the nature of stainless steel impellers. Because the initial results with stainless steel were so poor, it was decided that there was no point in testing a product that started so poorly.

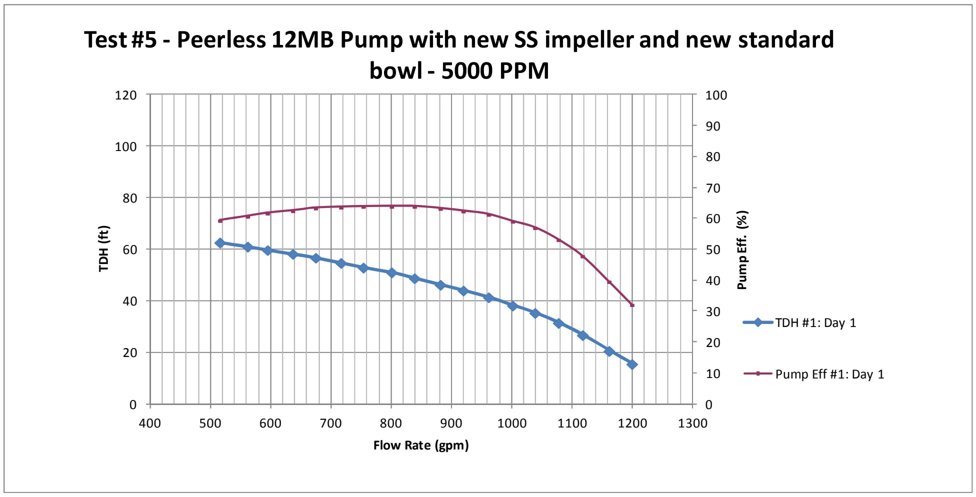

Figure 4. New Peerless Stainless Steel Impeller Performance

RESULTS

After testing, the recorded data was plotted to compare wear rates and extents for each test. Figure 5 illustrates the percent reduction in flow rate in relation to the hours of operation at different sand concentrations.

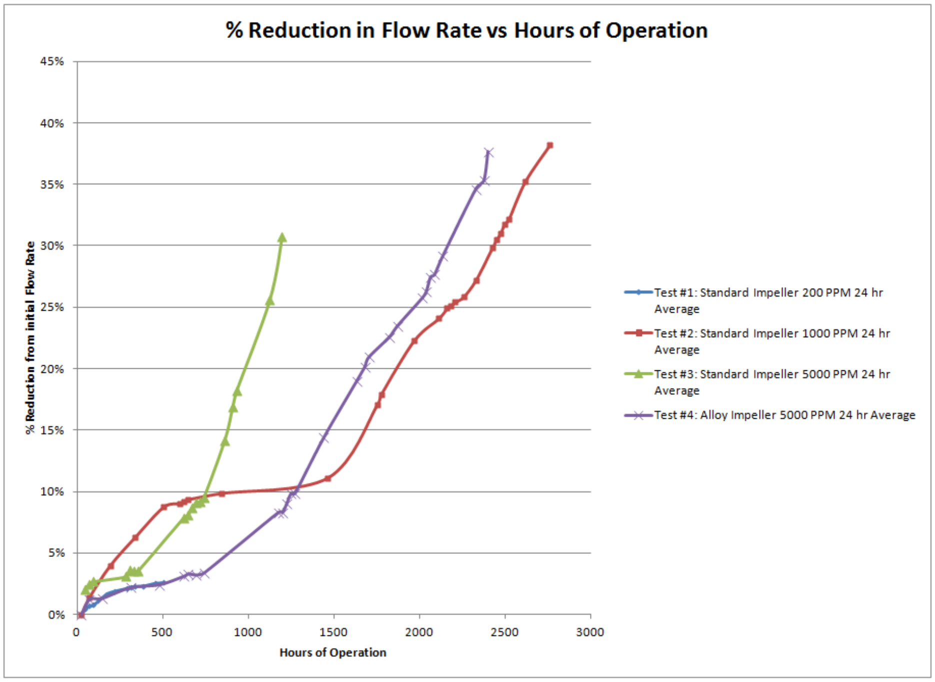

Figure 5. Wear Rates and Extents of Each Test

Material Wear

The change in weights and geometries of the bowls and impellers were taken after Tests #2-5 to further describe the margin and type of wear caused by sand. Table 3 highlights these changes; larger changes in either geometry or weight are categorized by a **bold** number. As seen in Table 3, there are considerable weight and geometric changes to both the bowls and impellers.

Table 3. Dimensions and Weights of Impellers and Bowls

	Test #2			Test #3			Test #4			Test #5		
Point of Measurement	Bronze New Impeller #2	Bronze Worn Impeller #2 After Test #2	% Change	Bronze Worn Impeller #1 Before Test #3	Bronze Worn Impeller #1 After Test #3	% Change	#3: B-Ni-Al New Impeller	#3: B-Ni-Al Worn Impeller	% Change	#4: SS New Impeller	#4: SS Worn Impeller	% Change
Weight (lb)	10.95	9.66	**-12%**	10.87	9.645	**-11%**	11.64	9.35	**20%**	33.48		
Perimeter Vertical Vane Thickness (in)												
1	0.103	0.066	-36%	0.144	0.15	4%	0.09	0.056	**38%**	0.14		
2	0.081	0.08	-1%	0.145	0.14	-3%	0.09	0.057	**37%**	0.18		
3	0.77	0.09	**-88%**	0.161	0.136	**-16%**	0.09	0.0545	**39%**	0.18		
4	0.77	0.06	**-92%**	0.14	0.138	-1%	0.087	0.0525	**40%**	0.18		
5	0.76	0.07	**-91%**	0.151	0.142	**-6%**	0.093	0.051	**45%**	0.17		
6	0.116	0.08	-31%	0.143	0.139	-3%	0.089	0.061	**31%**	0.16		
Interior Vertical Vane Thickness (in)												
1	0.112	0.23	**105%**	0.16	0.154	-4%	0.1	0.252	**-152%**	0.18		
2	0.113	0.21	**86%**	0.147	0.18	**22%**	0.11	0.261	**-137%**	0.17		
3	0.11	0.22	**100%**	0.16	0.195	**22%**	0.11	0.254	**-131%**	0.17		
4	0.109	0.23	**111%**	0.148	0.2	**35%**	0.07	0.244	**-249%**	0.17		
5	0.107	0.24	**124%**	0.149	0.192	**29%**	0.1	0.234	**-134%**	0.17		
6	0.113	0.23	**104%**	0.144	0.2	**39%**	0.09	0.251	**-179%**	0.18		
Wear Ring Thickness (in)	0.373	0.347	-7%	0.373	0.364	-2%	0.375	0.359	**4%**	0.36		
Bottom Flange Thickness (in)	0.138	0.1295	-6%	0.157	0.143	-9%	0.14	0.124	**11%**	0.16		
Top Flange Thickness (in)	0.161	0.1395	-13%	0.152	0.138	-9%	0.184	0.135	**27%**	0.15		

Description	Bowl #2: New	Bowl #2: Worn After Test #2	% Change	Bowl #1: Worn Before Test #3	Bowl #1: Worn After Test #3	% Change	Bowl #3: New	Bowl #3: Worn After Test #4	% Change	Bowl #4: New	Bowl #4: Worn After Test #4	
Weight (lb)	120.29	107.13	**-10.9%**	122.81	111.65	**-9.09%**	114.82	103.11	**-10.2%**	129.55		

Costs

The costs of various options for this particular pump are provided in Table 4.

Table 4. Costs for Pump Options (not including tax and shipping)

Item	Subitem(s)	Cost, $	% cost increase above base unit
Pump assembly	Oil lubricated, 6' sump. 8" diameter column. One bronze impeller, cast iron bowl	9,974	
Extra costs for spare parts	Extra 2' length	87	
	Extra bowl (no impeller)	1,082	
	Spare bronze impeller (polished and balanced)	807	
Additional costs for upgrades	Polish and dynamically balance impeller	150	1.5%
	Switch from bronze to 316 SS impeller	1,391	14%
	Switch from bronze to Ni Al bronze impeller	1,111	11%
	Switch from cast iron to 316 SS bowl	10,110	101%
	Switch from cast iron to Ni Al bronze bowl	16,888	169%

CONCLUSIONS

1. The Ni Al bronze impeller, with five times the sand concentration, performed as well as a standard bronze impeller that had the lower sand concentration.

2. Rapid deterioration of performance is evident past a 10% reduction in flow rate.

3. There appears to be no clear correlation between test results under 10% flow rate reduction. This may be due to manufacturing variability.

4. A bronze impeller with 5000 ppm sand shows a 25% reduction in flow at 1000 hours of operation versus 2000 hours with 1000 ppm. Therefore, the level of wear is not directly proportional to the sand concentration at these levels.

5. ITRC does not recommend purchasing a 12 MB stainless steel impeller from Peerless Pump.

6. The stated new bowl/impeller efficiencies were not verified by ITRC.

7. It appears worth the money to polish and mechanically balance new impellers. While the Hydraulics Institute indicates that typical agricultural well pumps will only have a 0.5% increase in efficiency due to polishing, manufacturers often cite several percentage points improvement.

8. It appears very worthwhile to specify Ni Al bronze impellers if sand wear is anticipated.