OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

July 6, 1967

To: L. T. Oehler, Director
Research Laboratory Division

From: C. J. Arnold

Subject: Damaged Impellers for Storm Water Pumps
Report No. R-643. Project No. 67 G-155

This is in reply to a request from N. C. Jones to R. L. Greenman, dated April 18, 1967, and will supplement my letter of May 4, as requested by Mr. Greenman.

Summary of Results

It appears that foreign material has entered the pumps and initiated the impeller failures. While we have not determined precisely what caused the impeller failures, it is extremely unlikely that they were caused by water pressure alone, since the same pumps are capable of operating against considerably greater hydraulic heads than encountered in our pumphouses. Our "foreign materials" theory of failure is based on observations, availability of debris, and the laws of mechanics and probability.

The pumps can be made more resistant to such damage by using stronger material in the impellers, but the solution to the problem seems to lie in preventing debris from entering the pumps. This can probably be accomplished by installation of screening material such as chain link fence at the sump entrance, placing a low barrier across the sump floor, and following a planned program for cleaning the screen and sump. We realize that this screen would clog more easily than the grating, and might cause some problems during floods if not cleaned regularly. However, the extra maintenance of the sump entrances should pay dividends of decreased pump maintenance.

If the Office of Design wishes to make a material change as a preventive measure, it is suggested that SAE Standard Alloy No. 63 would provide some additional strength and erosion resistance at a slight increase in cost, and that cast steel or stainless steel materials should provide still more protection at considerably higher cost. Based on the small proportion of impellers that have failed, it does not seem advisable to recommend any expensive changes. The specification of SAE Standard Alloy No. 63 in new and replacement impellers would be most reasonable, if any change is deemed necessary.

This report has expanded and explained the reasons for the statements made in my letter of May 4th but the basic conclusion of that letter that damage was caused by debris has remained unchanged.

Discussion

Chemical test results submitted by Mr. Jones indicated no differences in the composition of the two samples (good performance material and poor performance material) that could be expected to cause any significant difference in the physical properties of the materials for the use in question. We would, therefore, assume that the poor performance of the one sample was due to some cause other than material.

It was found that the samples checked by the Detroit Testing Laboratories did not represent the "good" and "poor" impellers that were obtained for examination in the Research Laboratory. Additional samples of "poor" impellers were obtained from Wayne County for examination. The pump-houses were inspected and the problem discussed with the county representative, Mr. George Japp. The "good" impeller was reportedly removed from a Peerless pump after about 15 years of service, and was still in fine condition. The "poor" impellers were removed from Johnston pumps after about one year of operation and were no longer usable. It must be noted that the two types of impellers are of different design and there is no correlation between the environments to which they were exposed.

The Peerless impeller shows very little evidence of physical damage from debris, while all of the Johnston impellers show definite marks from ingested material. Blade tips on the Johnston impellers were folded back in a manner that considerably reduced the area of the opening between blades. One of the impellers shows damage to the trailing edge of a blade. This must have occurred while the pump was free-wheeling in reverse. These impellers also show considerable erosion in the deformed area of the blades. However, it was impossible to determine whether this erosion preceded and aided the deformation, or vice-versa. Once the blade tips are deformed to the extent indicated in the samples, the pump will no longer work effectively. It will continue to run but with very little output, and the deformed blades will generate a great amount of turbulence. Since shut-off is controlled by water level, a pump with a damaged impeller could run for long periods of time, and if there were any abrasive material in the water, the rate of erosion could be severe. Alternatively, eroded blades are thinner and consequently weaker than normal and could be more easily deformed. Three bad impellers were reportedly found in one pump house at one time, with no foreign material present at the time of replacement. The cause of these failures has not been determined and we can only state that the impellers show signs of mechanical damage apparently due to interference during rotation.

Samples from the "good" and "poor" impellers were prepared in the laboratory for physical and chemical testing, and the results are shown in Table 1.

The table shows that material used in the Peerless impeller is about 40 percent stronger, considerable harder, and more ductile than that used in the Johnston impellers. The Peerless material also has more tin and less lead and zinc. The chemical composition of the Peerless material meets the requirements for Leaded Gun Metal Castings, SAE Standard No. 63, while the physical properties exceed the requirements for that alloy. The Johnston material has composition and physical properties that approximate, but do not completely meet, the requirements for Composition Bronze, ASTM Designation B-62, or Red Brass Castings, SAE Standard No. 40. The specification requirements for SAE Alloys No. 40 and No. 63 have been included in the table for comparison. The June 19 report by J. T. Ellis discussed specification requirements indicated by the pump manufacturers and includes comments made by the manufacturers' representatives, along with discussion of the metallurgy involved. It is recommended in the report that the Department specify a higher strength material than SAE 40, such as SAE 63, cast steel or stainless.

TABLE 1

RESULTS OF PHYSICAL AND CHEMICAL TESTS
ON SAMPLES FROM PEERLESS AND JOHNSTON IMPELLERS.
(Requirements for SAE No. 40 and No. 63 are included for comparison.)

Material	Average Ultimate Strength, psi	Average Ultimate Elongation, percent	Average Hardness Rockwell "B"	Chemical Content, percent				
				Tin	Lead	Copper	Nickel	Zinc
Peerless (Good)	45,200	21	71	9.61	1.60	88.52	0.17	less than 0.01
Johnston (Poor)	32,700	9	32	4.69	6.45	85.95	0.30	2.53
Johnston (Poor)	------	------	------	4.69	5.34	86.35	0.05	3.50
SAE-40	26,000 min	15 min	------	4-6	4-6	84-86	0.75 max	4-6
SAE-63	30,000 min	10 min	------	9-11	1-2.5	86-89	0.50 max	0.50 max

Mr. J. Niles, the Johnston Pump Co. representative in Grand Rapids, has advised me that the company can supply impellers that will meet requirements of SAE No. 63. The cost is estimated by the company to be about 20-percent more than the standard impeller. It must be borne in mind that specification of SAE No. 63, instead of SAE No. 40, does not guarantee that the material will be equivalent to that used in the manufacture of the Peerless impeller tested in the laboratory. Further reference to Table 1 will show that the Peerless material was considerably better than the specification required. However, since it is typical for materials to exceed minimum strength requirements by a reasonable amount, and because the SAE No. 63 material should exhibit more resistance to erosion, the additional expenditure should be worth while. It would also be possible to specify higher strength and ductility than listed by the SAE specifications. Alternatively, the Department could purchase cast steel or stainless impellers that would cost two and three times as much, respectively, as the standard impellers.

If cast steel or stainless impellers are adopted, pump bowls should also be changed to the same material. This would cause additional work and expense that does not seem to be warranted by the small number of failures that have occurred to date.

There have been cases in the past where debris has been thrown into the pumps from the outlet end by children playing in the area. Although the access to the pump exit is probably controlled in most instances, the possibility of such occurrences cannot be overlooked.

Mr. Japp said that the collection of debris at a pumphouse is relatively high during the first few months of operation, due to construction residue collected by the storm sewer system. The county installs special screens of fencing material and boards over the grating of their new pumphouses to trap as much of the debris as possible at the sump entrance. Pumphouses are then inspected every week and checked after storms to determine when sumps need cleaning. The screening should be considered for adoption by the Department for new installations.

Wooden grade stakes are evidently quite prevalent among the debris and can pass readily through the grating in the approach to the sump. Several stakes were seen in the pumphouse during inspection and it seems possible that the flow could draw these water-soaked stakes into the pumps. Since the Johnston impellers are relatively soft and travel at 1200 rpm, wooden stakes might damage the blade tips. Screens at the inlet should eliminate stakes from the sump.

Heavier materials such as stones have obviously entered at least one of the pumps but this seems less probable than the ingestion of wood because the dense materials should tend to settle out. High velocity water is required to lift such materials, although they could be rolled along the floor of the sump by lower velocities. Maximum velocities in the sump should occur near the entrance and the pump intake. For this reason, it seems that a relatively low barrier across the floor of the sump between the entrance and the pump intake area would remove the larger aggregates, and probably most of the smaller ones as well. The top part of such a barrier could be made of grating or mesh of some sort to allow some water to flow through. The openings should be small so as to reduce the velocity of the flow in the vicinity of the barrier top. Since the size of particles that can be carried by the flow is proportional to the square of the velocity, a reduction of the velocity by one-half will reduce the size of particles that can be carried by a factor of four. If all particles larger than the clearance between the impeller and the housing could be removed from the flow, the impeller problem should be reduced to one of erosion or wear. This wear should be a relatively slow process under ordinary circumstances, resulting in more reasonable life for the impellers.

Mr. Niles estimates that there are about 150 Johnston pumps in the Wayne County area, all having impellers of the same material as the four or five that failed. Further, the impellers that were used as replacements were of the same material and have served satisfactorily for about two years since installation.

We can only conclude that the impellers were deformed by some force, as yet undetermined, and that the problem does not seem to be sufficiently widespread to warrant any extensive revision of specifications for pumps.

OFFICE OF TESTING AND RESEARCH

C. J. Arnold

C. J. Arnold, Supervisor
Structures Unit
Research Laboratory Division

CJA:sjt