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NOV 1 7 1981

Docket Nos.: STN 50-483
and STN 50-486

Mr. D. F. Schnell
Vice President - Nuclear
Union Electric Company
Post Office Box 149
St. Louis, Missouri 63166

Dear Mr. Schnell:

Subject: Long Term Operability of Deep Draft Pumps

IE Bulletin 79-15, dated July 11, 1979, was issued to all licensees and holders of construction permits as a result of deep draft pump deficiencies that were identified at facilities both operating and under construction. For pending OL applications, long term operability of deep draft pumps is now being reviewed by the staff during the normal licensing review process.

In order to facilitate this review, enclosed is a document entitled, "Guidelines for Demonstration of Operability of Deep Draft Pumps". Within 30 days from the issuance date of this letter, you should provide a schedule indicating when a response, in the form of a supplement to FSAR Section 3.9.3, would be provided that discusses your assurance program for demonstrating long term operability of your deep draft pumps and the extent to which it conforms to the various portions of these Guidelines. Emphasis should be placed on (1) the establishment of installation procedures that are followed each time these pumps are disassembled and reinstalled, and (2) the testing requirements and bearing wear criteria. The instrumentation called for in the Guidelines should not be considered a requirement.

These Guidelines establish an acceptable method of assuring long term operability of deep draft pumps. They do not necessarily constitute the only method for demonstrating long term operability. The staff will review the information you submit to determine whether your long term operability assurance program for deep draft pumps is in sufficient conformance with these Guidelines to assure long term operability. If not, the staff will determine whether you have established and utilized other methods and procedures, preferably with the assistance of the pump manufacturer, that also demonstrate and assure that these pumps will perform their intended functions for the length of time required.

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If you have any questions regarding this matter, please contact Dr. G. E. Edison, the Licensing Project Manager for your facility.

The application/reporting requirements contained in this letter have been approved by the Office of Management and Budget; OMB Approval No. 3150-0011.

Sincerely,

Original signed by
Robert L. Tedesco

Robert L. Tedesco, Assistant Director
for Licensing
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Office of Nuclear Reactor Regulation

Enclosure:
Guidelines for Demonstration
of Operability of Deep
Draft Pumps

cc w/enclosure:
See next page

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ENCLOSURE

GUIDELINES FOR DEMONSTRATION OF OPERABILITY OF DEEP DRAFT PUMPS

DISCUSSION

I.E. Bulletin 79-15 dated July 1979, identified problems associated with deep-draft pumps found at operating facilities and near term operating licensee facilities. Deep draft pumps, which are also called "vertical turbine pumps" are usually 30 to 60 feet in length with impellers located in casing bowls at the lowest elevation of the pump. The motor (driver) is located at the highest pump elevation with the discharge nozzle just below the motor.

Bulletin 79-15 was initiated because several nuclear power plant facilities could not demonstrate operability of their pumps. The pumps were experiencing excessive vibration and bearing wear. The rapid bearing wear suggested that these pumps could not perform their required functions during or following an accident. As a result of the staff's initial review of the responses to IEB 79-15, several plants were identified as having potential problems with their deep draft pumps. These guidelines are provided for these plants so that the licensee or applicant involved may have a method acceptable to the staff for demonstrating the operability of deep-draft pumps.

DEEP DRAFT PUMP OPERATING CHARACTERISTICS

In order to better understand the operating characteristics of these pumps, a rotor dynamics analyses[1] was performed to ascertain the response of the pump rotor under steady state operation. The analyses considered journal bearing to shaft dynamic response at various eccentricities and fluid viscosities. The model for the analysis depicted a typical deep draft pump utilized by the nuclear industry. The analysis resulted in recommendations for improving the stability of the pump rotor from externally applied inputs and by self-generated inputs.

The conclusions which were derived from the analysis and staff evaluations of North Anna, Beaver Valley and Surry facilities with similar pumps include:

1.) Pumps with this type of configuration are prone to bearing whirl vibration problems due to the flexibility of the rotor and casing structure. This phenomenon is accentuated as journal bearing clearance becomes large. This phenomenon leads to bearing wear (Journal bearings).

[1] "Low Head Safety Injection Pump Rotor Dynamic Analyses", by Franklin Research Center, Report FC4982, dated May 1980.

2.) There may be natural frequencies associated with the pump assembly which occur near the operating speed of the pump. Pump operation will drive these frequencies and can cause bearing wear. The severity of this condition is dependent on bearing diametral clearance, rotor unbalance conditions and housing flexibility. As an example, if the wear in column journal bearings becomes sufficiently large (twice the original diametral clearance) so that these bearings are no longer active and the undamped critical frequency near the operating speed of the pump is allowed to expand, the additional uncontrolled bearing wear will occur. This wear can continue until the shaft rubs against the support structure of the bearing and can potentially sever the shaft.

3.) One acceptable method for correcting instabilities in the pump shaft is to utilize a journal bearing design which exhibits stable characteristics. One such design is the "Taper land bearing". This design is more stable than the plain journal bearing, is less susceptible to wear because of the taper and will cause the bearing to form a hydrodynamic film quickly during startup.

4.) Stiffening of the column sections of the pump is advantageous if there is a column frequency near the operating speed of the pump. The shifting of the column frequency to a higher level will eliminate any coupling between the pump operating speed and the column frequency.

5.) Flow inlet conditions to the pumps and sump designs can be important to pump operability. Certain installations have demonstrated flow characterist'cs which produced vortexing at the bellmouth of the pump. This vortexing is due to sump design or sump supply line entrance conditions. This condition can contribute to additional pump vibration and wear. Flow straightener devices, reduction of bellmouth diameters, and bottom clearance reductions have proven to be effective in eliminating this problem.

6.) This type of pump has exhibited operational problems due to design and installation deficiencies. The high flexibility of the shaft and column make this design rather forgiving when it comes to installation deficiencies such as misalignment between the shaft and column, low-precision coupling assemblies, and non-perpendicular mounting flanges. This fact however, can lead to excessive bearing wear without significant noticeable change in pump operating characteristics. To ensure proper pump operation, proper alignment should be established between all mating surfaces and measures should be emphasized which prevent column and shaft eccentricities. These measures can include optical alignment of the column segments, use of high precision couplings and use of accurate techniques to establish that the sump plumb line is perpendicular to the pump mounting flange.

The above findings and conclusions have contributed significantly to the development of these guidelines. The guidelines listed below are divided into installation and test areas. The subjects to be addressed in these areas are considered to be of prime importance when establishing a pump operability assurance program. The extent to which each of the two areas are implemented at a specific facility is dependent on specific symptoms which have been identified with these pumps while in operation and during service periods.

Implementing the measures outlined below, at North Anna 1 & 2 in total, has been shown to provide reasonable assurance that the pumps will be operable when required for their safety function. These guidelines are not intended to replace the requirements of Standard Review Plan 3.9.3, Regulatory Guide 1.68 or any other requirements presently enforced by the staff. Rather, the guidelines are to be used as supplementary material for establishing deep-draft pump operability.

GUIDELINES FOR OPERABILITY INSTALLATION

1.0 INSTALLATION PROCEDURES

Experience has shown that these pumps are prone to having operability problems as a result of poor installation procedures. The guidelines emphasize those areas of the installation procedure, which if implemented, could significantly improve the likelihood of an operable pump. The procedures utilized should be submitted to the staff for review.

1.1 PUMP INSTALLATION

a. Determine by measurement that all shaft segments are straight within tolerances specified by the manufacturer.

b. Determine by measurement or provide certification that all couplings (for shaft segments & pump to motor coupling) are of high precision as specified by the manufacturer.

c. Determine by measurement that all pump segment flanges are perpendicular to the centerline of the segment, that the segments are straight and that any mating surfaces are concentric to an established datum. Where journal bearing guides (SPIDERS) are used, establish concentricity between this assembly and its mating surface.

d. Align full pump casing assembly optically to assure maximum straightness and concentricity of the assembly. Any equivalent method is acceptable, as long as the procedure stresses column straightness and concentricity.

e. Assure pump to motor flange perpendicularity and that proper coupling installation is performed .

f. Assure that all mating surface bolting is properly attached and that manufacturer torquing sequences are adhered to.

1.2 SUMP INSTALLATION

a. Assure (where used) that sump/pump mating flange is perpendicular to the sump pump line.

b. Assure that sump design prevents fluid anomalies such as vortexing or turbulence near the intake to the pump bellmouth and that incoming piping is not so designed as to allow fluid conditions favorable to these anomalies (i.e., sharp bends in piping prior to entrance into sump).

c. Assure that interference does not exist between the sump and any pump appendage such as a seismic restraint.

2.0 Testing Requirements

The installation procedures are essential in establishing pump operability. In addition to careful installation, testing may be required which will verify proper operation of these pumps. After completion of the installation checks, licensees or applicants should evaluate the need for further testing and report the results of this evaluation together with the details of any test plans to the staff. Should tests be required, an acceptable test procedure should include the items listed below. The staff recognizes that the instrumentation and procedures outlined below may be difficult to implement at all facilities and, therefore, the staff is emphasizing good installation practices which lead to operable components. If tests demonstrating operability cannot encompass all the items listed below, then alternative procedures should be proposed for evaluation by the staff. The tests should emphasize measurement of pump dynamic characteristics and wear data at different stages of testing, culminating with an extrapolation of the data to the desired life goal for the pump.

2.1 Test Instrumentation

The following instrumentation should be incorporated into the test procedure aside from normal flow measurement, pressure and vibration instrumentation:

a.) X, Y proximity probes at three axial locations on the pump column, for measuring and recording radial positions of shaft with respect to the column.

b.) X, Y, accelerometers (at proximity probe locations) for measuring and recording radial accelerations of the column.

c.) Dynamic pressure transducers for measuring fluid pressure at the following locations:

1. Bottom of Column (suction)
2. Mid-Column
3. Top of Column.

d.) Shaft Rotational speed and dynamic variation instrument.

2.2 PRE-TEST DATA

With the pump disassembled, measure all journal bearing O.D.'s, bearing I.D.'s and calculate bearing diametral clearances. In addition with pumps fully assembled and using the proximity probes, obtain the "clearance circle" at each of the three axial stations by rolling the shaft section within the clearance volume of its bearings and in this way, establish proper operation of the probes.

3.1 PHASE 1 Testing (6 hours plus start-stop)[2]

This phase of testing should be comprised of 6 hours of testing (Break-in) followed by start-stop testing. Test conditions should simulate as nearly as possible normal and accident conditions. Parameters to be considered are flow, temperature, debris, and chemical composition of fluid being pumped. Static torque tests should be performed before and after the test (i.e. measure amount of torque required to turn shaft by hand). Data should be taken during the six hour test at 1/2 hour intervals. A total of 12 start-stop tests will be performed consisting of a start up from zero speed up to full-speed, 10-minute dwell at full-speed and a shutdown from full speed to zero speed, with recording of all instrumentation during full cycle of start-stop.

Upon completion of Phase 1 testing, the following data should be obtained and recorded:

1.) Obtain the "clearance circles" using the three sets of proximity probes.

[2] Tests at North Anna 1 & 2 and Manufacturers input indicates that 6 hours is an adequate time interval for bearing "break in" period.

2.) Measure and record the following dimensions for each bearing:

a.) Journal O.D.

b.) Bearing I.D.

c.) Bearing to Journal diametral clearance

d.) Establish Phase 1 test bearing wear.

THE ACCEPTANCE CRITERIA IS AS FOLLOWS:

1.) If wear is $>$ 5 mils for any bearing,[3] wear is unacceptable and test should be terminated.

2.) If wear is $<$ 5 mils for all bearings[3]

a.) Reassemble the pump

b.) Obtain "clearance circles"

c.) Reinstall pump in test loop.

2.4 Phase 2 Testing (48 hours)

Phase 2 testing is to be performed at full system pressure and temperature and fluid conditions simulating those expected during accident and normal operation. Before start and at completion of Phase 2 test, obtain measurement of static torque. Data should be recorded continuously during the start-up period,

[3] This acceptable wear value may be modified based on manufacturers recommendation.

and during the shutdown period. Data should also be recorded at 1-hour time intervals during the 48 hour test.

The following measurements should be made at the completion of Phase 2 of the test:

1.) Obtain the "clearance circles" using the three sets of proximity probes.

2.) Measure and record the following dimensions for each bearing:

   a.) Journal O.D.

   b.) Bearing I.D.

   c.) Bearing to Journal diametral clearance.

   d.) Establish accumulated bearing wear.

THE ACCEPTANCE CRITERIA IS AS FOLLOWS:

1.) If accumulated bearing wear on any bearing is >7 mils, wear is unacceptable[3] and test should be terminated.

2.) If accumulated wear on all bearings is <7 mils for all bearings:[3]

   a.) Reassemble pump

   b.) Obtain "clearance circles"

   c.) Reinstall pump in test loop.

5.) Phase 3 Testing (96 hours)

Phase 3 testing is to be performed at full system pressure and temperature and fluid conditions simulating those expected during accident and normal operation. The same procedures should be followed as in Phase 2 testing except that data may be taken with less frequency.

The same measurements should be taken at the completion of this phase as with the other phases with the following acceptance criteria:

1.) If accumulated bearing wear is > 8 mils for any bearing,[3] wear is unacceptable and test should be terminated.

2.) If accumulated wear is < 8 mils for all bearings,[3] a decision needs to be made to establish:

a.) the need for additional testing or

b.) whether or not the bearing wear will be acceptably low.

The recommended decision process is outlined below.

Plot the values of accumulated wear versus time (H) for each bearing after Phase 2 and Phase 3 tests, namely.

Wear at H2 = 54 hour

Wear at H3 = 150 hours

Straight lines are then drawn through the plotted values of wear and extended to the right (See example Figure 1). If the extension intercepts the maximum acceptable value of wear (8 mils) at a value H less than th goal for this pump, additional testing should be performed. , the intercept of the line with wear of 8 mils exceeds the life goal for this pump, no additional testing is required and bearing wear is acceptable. If additional testing is deemed necessary it should be done in a similar manner to that performed during Phase 3 with similar acceptance criteria and decision process. It is expected that such additional testing will either show a stable pump operation with no increase in bearing wear or increased bearing wear with unacceptable results.

2.6 Evaluation of Pump Acceptability

If bearing wear (after all testing phases) is acceptably low (as per decision process) and if vibration levels over the frequency spectrum of 3 cps to 5000 cps are acceptably low and show no unfavorable trend of increasing magnitude during the testing, the pump may be judged acceptable for its intended use.

Figure 1 - Accumulated Wear of Brg Bore Diameter as a Function of Time for "Critical" Bearings