Entergy	CONDITION REPORT	CR-PNP-2002-12941

Originator: Gaedtke,Joseph R
Originator Group: Eng Sys Mech Staff
Supervisor Name: Lamoureux,Joseph R
Discovered Date: 12/13/2002 16:35

Originator Phone: 8659
Operability Required: Y
Reportability Required: Y
Initiated Date: 12/13/2002 16:40

Condition Description:

While re-packing the P-208D ("D" Salt Service Water Pump) under MR02118339, it was noticed that the Pump's shaft had excessive pitting in the area of the shaft's chrome plating at the packing contact area. The pump shaft's base material is Monel and the area of the shaft's bearings and packing contacts are Chrome Plated to improve wear characteristics of the shaft (Reference FRN98-01-17 and Dwg#M8-4). These shafts were installed during the pump's last overhaul on 5/2/00 under FRN98-01-17 and MR #10000369. These Chrome Plated shafts are also installed on P-208E during its last overhaul on 1/27/00 under FRN98-01-17 and MR #19702057. P-208E is also in need of re-packing (MR#02122446). Warehouse inventory of new and/or refurbished shafts are also chrome plated.

This condition is NOT an Operablity Concern. The packing leakage rate prior to repacking was ~2-3 gpm. The current leakage rate after the repacking is <1 gpm.
The SSW Flow Rate Operability Test (8.5.3.14) was also performed satisfactorily on 12/11/02. This indicates that the amount of leakage before repacking is not impacting the minimum flow required for that loop ia accordance with that test. This pump's last operability test (8.5.3.2.1) was performed on 10/16/02. At that time, the pump's Total Discharge Head was 96.13 ft. The acceptable IST range is 94.7 to 109.7 ft.

Immediate Action Description:

Clean shaft with scotch brite or low abrasive cleaning pad and re-pack pump. Generate CR to identify this condition.

This is not an operablity concern, the packing leakage prior to repacking was ~2-3 gpm.
The SSW Flow Rate Operability Test (8.5.3.14) was also performed satisfactorily on 12/11/02. This indicates that the amount of leakage before repacking is not impacting the minimum flow required per that test.

Suggested Action Description:

Monitor the packing leakage after this repack and make recommendations if Chrome Plated Shafts are the best design for addressing shaft bearing and packing wear.

EQUIPMENT:

Tag Name	Tag Suffix Name	Component Code	Process System Code
		PUMP	

Entergy	ADMIN	CR-PNP-2002-12941

Initiated Date: 12/13/2002 16:40 **Owner Group :** Eng Design Mgmt

Current Contact: R. HUNNEFELD+

Current Significance: B - EFA (DCA)

Closed by: Hunnefeld,Ralph E 8/26/2003 12:22

Summary Description:

Remarks Description:

PR=EF

Closure Description:

All CA's associated with this CR were reviewed by the responsible manager. Upon the manager's recommendation, this CR is being closed.

Entergy	OPERABILITY	CR-PNP-2002-12941

OperabilityVersion: 1

Operability Code: EQUIPMENT OPERABLE

Immediate Report Code: NOT REPORTABLE

Performed By: McDonnell,Michael P 12/13/2002 17:18

Approved By: McDonnell,Michael P 12/13/2002 17:25

Operability Description:

This condition is NOT an Operablity Concern. The packing leakage rate prior to repacking was ~2-3 gpm. The current leakage rate after the repacking is <1 gpm.
The SSW Flow Rate Operability Test (8.5.3.14) was also performed satisfactorily on 12/11/02 (per System Engineer J Gaedtke)

Approval Comments:

Evalute future performance of chrome shaft.

Entergy	ASSIGNMENTS	CR-PNP-2002-12941

Version: 1

Significance Code: B - EFA (DCA)

Classification Code: NON-SIGNIFICANT

Owner Group: Eng Design Mgmt

Performed By: Buckley,Patricia A 12/16/2002 13:32

Assignment Description:

Provide an Equipment Failure Analysis/Direct Cause.
Owner: R. Pace

Entergy	REPORTABILITY	CR-PNP-2002-12941

Reportability Version: 1

Report Number:

Report Code: NOT REPORTABLE (3)

Boilerplate Code: NOT REPORTABLE

Performed By : Brennion,Carl S 12/16/2002 10:32

Reportability Description:

Not reportable - This event does not meet the screening criteria of WI 3.06-01.

Entergy	CORRECTIVE ACTION	CR-PNP-2002-12941

CA Number: 1

	Group	Name
Assigned By:	Engineering Director	Bethay,Stephen J
Assigned To:	Eng Design Mgmt	Pace,Raymond M
Subassigned To :	Eng DE Mech Civil Struct Staff	Harizi,Philip D

Originated By:	Buckley,Patricia A	12/16/2002 13:33:26
Performed By:	Pace,Raymond M	1/15/2003 16:00:11
Subperformed By:	Harizi,Philip D	1/14/2003 18:40:07
Approved By:		
Closed By:	Pace,Raymond M	1/15/2003 16:00:11

Current Due Date: 01/15/2003 **Initial Due Date:** 01/15/2003

CA Type: DISPOSITION - EFA

Plant Constraint: NONE

CA Description:

Please provide an Equipment Failure Analysis/Direct Cause and develop a corrective action plan using the guidance provided in LI-102. CR03.00031 WAS CLOSED TO THIS ACTION. CONSEQUENTLY, THE EQUIPMENT FAILURE ANALYSIS MUST CONSIDER AND INCLUDE REFERENCE TO CR03.00031.

Response:

The attached CA response is adequate for closure. The two recommended CA's are issued.

Subresponse :

An Equipment Failure Analysis is attached along with new Corrective Actions required. See attached.

Closure Comments:

Attachments:

Subresp Description

Equipment Failure Analysis

Attachment Header

Document Name:

CR-PNP-2002-12941 CA-00001

Document Location

Subresp Description

Attach Title:

Equipment Failure Analysis

EQUIPMENT FAILURE ANALYSIS CR-PNP-2002-12941

CONDITION REPORT No. **CR-PNP-2002-12941 CA-00001**

1. Problem Description: While re-packing the P-208D ("D" Salt Service Water Pump) under MR02118339, it was noticed that the pump shaft had excessive pitting in the area of the shaft's chrome plating at the packing contact area. The pump shaft base material is Monel and the area of the shaft bearings and packing contacts are Chrome Plated to improve wear characteristics of the shaft (Reference FRN98-01-17 and Dwg#M8-4). These shafts were installed during the pump's last overhaul on 05/02/2000 under FRN98-01-17 and MR #10000369. These Chrome Plated shafts were also installed on P-208E during its last overhaul on 01/27/2000 under FRN98-01-17 and MR #19702057. P-208E is also in need of re-packing (MR#02122446). Warehouse inventory of new and/or refurbished shafts are also chrome plated.

   Please provide an Equipment Failure Analysis/Direct Cause and develop a corrective action plan using the guidance provided in LI-102. CR03.00031 WAS CLOSED TO THIS ACTION. CONSEQUENTLY, THE EQUIPMENT FAILURE ANALYSIS MUST CONSIDER AND INCLUDE REFERENCE TO CR03.00031, which contains the following Condition Description:

   While attempting to adjust excessive packing leakoff on P-208B ("B" Salt Service Water Pump) under MR02123533, it was noticed that the pieces of the Pump shaft chrome oxide coating were delaminating and several pieces were found in the pump discharge head. The pump shaft base material is Monel and the area of the shaft bearings and packing contacts are coated with Chrome Oxide to improve wear characteristics of the shaft (Reference FRN97-01-100 and Dwg#M8-4). These shafts were installed during the pump's last overhaul on 01/12/98 under FRN97-01-100 and MR #19702726. These Chrome Oxide coated shafts were also installed on P-208A during its last overhaul on 10/19/97 under MR #19702607 and P-208C, rebuilt on 02/08/97 under MR19503415.

2. Direct Cause: The chrome plating was found to be pitted and exfoliating in pieces from the shaft surface. Pure metallic chromium is not a good hardfacing for Monel base metal because Monel is galvanically more noble than chromium such that in seawater, which is an aggressive electrolyte, chromium will become anodic and gradually deteriorate by way of pitting and exfoliation, essentially de-plating from the surface.

   The cracking and breakage of the chrome oxide plasma-coated hardfacing is due to the brittleness of this metallic oxide ceramic compound and inadequate or inconsistent bond strength for this application. Metallic oxide coatings are galvanically neutral and this coating problem is due to failure of the mechanical bond to the base material rather than galvanic action. The thermal plasma coating process is not able to consistently produce an acceptably strong bond for these very brittle metallic oxide coatings.

   See attached additional information on the "History of SSW Pump Shaft Hardfacing".

3. Contributing Causes: The only potential contributing cause to hardfacing failures on the SSW Pump shafts is related to shaft vibration and deflection. It is known from vibration analysis performed in the past that the SSW Pumps exhibit shaft deflection during operation due to the proximity of shaft critical speed and column resonances to the pump running speed. Shaft deflection can induce fatigue in the hardfacing and/or the bond line to the base material and may have contributed to the chrome oxide coating failures.

4. Maintenance Rule Failure: YES **NO** N/A

5. Extent of Problem: The gradual deterioration of the chrome plating is likely occurring at all bearing journal locations. The breakage of the chrome oxide plasma coating may be occurring at some bearing journal locations although this is not predictable. There is no immediately adverse effect on pump operation caused by any of these hardfaced coating failures. The coating thicknesses are typically in the range of 0.020" to 0.030". Complete loss of the coating at a bearing journal may result in gradually increasing pump vibration, which will be detected by routine pump In-service Testing (IST). The purpose of the hardfacing is mainly economic in that it reduces the shaft journal wear rate and allows shafts to be reworked and reused. Any failure of the coating is not significantly different than operating with uncoated shafting as was done in the past.

6. Corrective Actions Completed (include Dates if possible) None

7. Corrective Actions Required (if not required, state "N/R")

   Action Required/New CA Number: N/R, The existing SSW Pumps should continue to be operated until they fail to meet any acceptance criteria under the routine pump In-service Testing (IST) program. No specific action is required for the currently operating pumps based on this evaluation.

8. Corrective Actions required to eliminate and/or reduce the likelihood of recurrence of identified cause(s) and contributing cause(s).

   Action Required/New CA Number: **CA-00002** A PDC is required to implement a design change for the SSW Pump lineshaft hardfacing to be used for all future pump overhauls. The recommended hardfacing is a nickel-chrome-boron alloy to be applied by the fused coating process in accordance with the attached evaluation. This alloy is well matched galvanically to the Monel shaft and is metallurgically fused with a weld-like bond to the base metal. The shaft deflection and vibration cannot be changed and it is expected that the fused hardfacing alloy will have suitable strength and ductility to withstand the deflections without fatigue effects.

   Action Required/New CA Number: **CA-00003** "Peer Reviews" for PDCs produced within Mechanical/Civil/Structural Engineering should be extended to include Limited PDCs and FRNs whenever possible.

History of SSW Pump Shaft Hardfacing

To aid in this evaluation, it is first necessary to describe the five basic hardfacing processes that are applicable to the SSW Pump shafts at this time:

1. Metallizing - A thermal spraying process in which a fuel gas such as acetylene or propane is the source of heat for melting the surfacing material. The combustion gases and additional inert compressed gas serve to atomize and propel the surfacing material onto the substrate. The surfacing material is a metal alloy and may be in the form of wire or powder. This process is often called "flame spraying". An alternative "arc spraying" process creates the thermal spray using an electric arc between two consumable electrodes of the surfacing materials and uses a compressed inert gas to atomize and propel the material onto the substrate. These processes result in mechanical bonding of the surfacing alloy with the base material, which is typically not heated above 250°F.

2. High Velocity Oxygen Fuel (HVOF) - This is a high velocity flame spraying process using fuel gas and oxygen in which the surfacing material is in powder form and may be a metal alloy or metallic oxide ceramic. The hot combustion gases serve to atomize and propel the surfacing material onto the substrate at extremely high velocities. The higher velocities and temperatures result in a higher density sintered coating with a more weld-like mechanical bond to the base material.

3. Plasma Spray - A thermal spraying process in which an electric arc is used as the source of heat to ionize an inert gas stream to extremely high temperatures (well above 10,000°F) that melt and propel the surfacing material, which is in powder form, onto the substrate at very high velocities. The surfacing material may be metal alloy or metallic oxide ceramic. The processes results in mechanical bonding of the surfacing alloy with the base material, which is typically not heated above 250°F.

4. Fused Coatings - A thermal spraying process that is followed by a high temperature fusing process. This uses the same application processes to atomize and propel the surfacing material onto the substrate as in the metallizing process above but the surfacing material is in powder form and consists of special "self-fluxing" metal alloy mixtures of nickel, chromium, cobalt, and other metals with fluxing agents such as boron and silicon. After applying the surfacing alloy to a predetermined thickness, an oxygen-acetylene torch system is used to uniformly heat the part up to approximately 2000°F to fuse the coating within itself and to the base metal, thereby achieving a true metallurgical weld-like bond. The fluxing agents serve to "wet" the substrate and improve the fusing process.

5. Electroplating - A process of electro-deposition of a pure metal onto the same or a different base metal or alloy. Plating is performed in a chemical bath with an ionic solution of the surfacing metal and in which the part to be plated is electrically charged to become the cathode. It is essentially the reverse of the corrosion process of metals. The process results in a metallurgical bond the characteristic of which depends on the match between the deposited metal and the base metal.

The SSW Pump lineshaft is an assembly of five shaft segments joined by threaded couplings within the 42 foot long SSW pump columns. The assembly includes the pump shaft contained in the pump bowl assembly, three 120" intermediate lineshaft segments, and one 120" headshaft that contacts two lineshaft bearings plus the shaft packing in the stuffing box. The entire shaft assembly is fabricated from Monel alloy (approximately 65% nickel 30% copper 5% other) and the lineshaft bearings are bronze and rubber. Monel nickel-copper alloy is excellent in seawater but has a relatively low hardness. It was found that abrasives in the seawater were causing significant wear of the Monel at each lineshaft bearing location such that any shaft that had been in service would be rejected for reuse due to the wear and scoring at the bearing locations. The shaft wear was often greater than 0.020" depth and this resulted in increased pump vibration. Monel is a very high-priced alloy and entire new lineshaft assemblies were often needed as part of routine pump overhauls.

In 1995 (FRN 95-03-33), the first use of hardfacing was introduced for the SSW Pump lineshafts along with several other pump upgrades. The purpose of the hardfacing was two-fold. First, the hardfacing would eliminate the shaft wear, even after extended service of 4 to 6 years, so that vibration would not increase to unacceptable levels. Second, the hardfacing could be removed and completely reworked as needed to produce a new surface so that the Monel shafting could be reused. After some research, it was decided to employ chromium oxide hardfacing applied by the plasma spray process at each bearing journal location. At the time, the HVOF and fused coating processes described above were still recent developments and were not considered commercially available options. The pump vendor (Johnston Pump) concurred with the plasma spray selection and had already started using it elsewhere although they did not yet have much actual field experience with the process.

The observed performance of the chromium oxide hardfacing has been mixed. It has been found in several instances to have fractured and broken away from the surface. This was found to happen on one bearing location while all other hardfaced locations on the same shaft were perfectly intact and showed no measurable wear. Nonetheless, this was considered to be unacceptable and in 1998 an alternative was requested from the pump vendor. Johnston Pump had experienced similar problems with chrome oxide plasma coatings in their other applications since it had been adopted at PNPS and recommended that chromium electroplating be used for hardfacing rather than another plasma spray process. There was agreement to begin using the chrome plating process although no independent research was done by PNPS prior to that decision (see discussion below). FRN 98-01-17 was issued to use the chrome-plated hardfacing for the subsequently installed lineshafts.

The actual performance of the chromium electroplate does not appear to be acceptable. Lineshafts with this hardfacing have only been installed in two pumps and neither has yet been disassembled for an overhaul. However, the hardfacing can be examined at the stuffing box location and this has been done on P-208D & E. The chrome plating was found to be pitted and exfoliating in small pieces from the shaft surface. An independent review by PNPS since this discovery now concludes that pure metallic chromium is not a good hardfacing for Monel base metal. This is because Monel is galvanically more noble than chromium such that in seawater, which is an aggressive electrolyte, chromium will become anodic and gradually deteriorate in the form of pitting and exfoliation, essentially de-plating from the surface. The vendor's prior

experience had apparently been with chromium plating on the more commonly used stainless steel shafting in which the galvanic mismatch is more favorable for the chromium, as it also is when plated onto steel base metals.

The vendor's recommendation to use the electroplating process was based on their loss of faith in the plasma spray process as experienced at PNPS and other applications. There were certainly good reasons to discontinue using the plasma spray process altogether, rather than simply changing to another of the many different metallic oxide plasma-coating materials available. It appeared that the mechanical bond of the plasma spray process was not able to consistently produce an acceptably strong bond for these very brittle metallic oxide coatings even though in most instances it did perform with excellent results.

Electroplating is a viable process for hardfacing but only pure metals can be plated and the common choice of chromium is based on its very high hardness. Chromium plated hardfacing has probably been used more than any other method in industry although it has been losing favor in recent years because of rising environmental compliance costs due to the hazardous electroplating chemical solutions involved in the process. Better results would likely have been achieved if nickel electroplating had been used for this application. Nickel is the predominant metal in Monel alloy so that there is no galvanic mismatch, but pure nickel plating would also have considerably lower hardness. It would also probably not have been possible to find a sub-vendor that could handle the long shaft segments for nickel plating since it is not normally used for such parts while chrome plating is often used for shaft hardfacing.

In retrospect, it cannot be recalled why there was no independent research or critical review done for the vendor's recommendations in 1998. It is assumed that those involved, including the writer, were preoccupied with other issues and relied on the judgment of this particular vendor, who otherwise has a very good record with PNPS. A Mechanical/Civil/Structural Engineering Self-Assessment performed in 2001 has already identified that similar types of problems have occurred due to reliance on vendor design engineering and field services. This evaluation provides further justification for that conclusion and the need for more critical review of vendor recommendations.

A remedy that has been effectively employed since the Engineering Self-Assessment is the use of critical "peer reviews" for PDCs, although Limited PDCs and FRNs have not typically received this added scrutiny. Since this evaluation deals with design changes that would likely be handled by the Limited PDC or FRN process, it is now recommended that ALL PDCs and FRNs be subjected to such a peer review whenever possible. It should be noted that peer reviews are done in addition to the Independent Review for safety-related design changes.

Recommendation for SSW Pump Shafts

It has been concluded that the SSW Pump lineshafts should continue to be hardfaced. Overall, the Monel base material has been very good in service but does need a renewable hardfacing at the bearing journal and shaft packing locations. However, it has also been concluded that there has been an over-emphasis on the degree of hardness required. It is not necessary to achieve a nil wear rate for the hardfacing, it is more important to achieve a strong bond with a material that is either a metallic alloy that is galvanically well-matched with Monel or to use a metallic oxide that is galvanically neutral. The problem with very high hardness materials is that they are inherently more brittle and are more susceptible to cracking.

In response to the chrome plating problems, the vendor (Johnston Pump) has recommended using a nickel-chrome-boron-tungsten fused coating. This is a self-fluxing metallic alloy coating that is thermally fused after spray application to form a weld-like metallurgical bond to the base metal (see process descriptions above). The recommended alloy is one that has a very high hardness ($Rc \approx 60$) predominantly due to the addition of tungsten. As a result of this evaluation, PNPS concurs with the use of the fused coating process but has required that a different alloy be used. The alloy that will be used is a nickel-chrome-boron alloy that has a higher nickel content that produces what is referred to as a "machinable fused coating" of lower hardness ($Rc \approx 30$) that is less susceptible to cracking than the harder self-fluxing alloys. The harder coatings can only be finished by grinding due to their brittleness while this coating can be machined with carbide tools, which indicates that it has some degree of ductility.

The proposed alloy is similar in its nickel and chromium content to the wear ring alloy that has been very successfully used in the SSW Pumps since 1995 (also from FRN 95-03-33). The wear ring alloy, known as Waukesha 88 (ASTM A494 Grade CY5SnBiM), is 75% nickel and 12% chromium and is mounted directly on the Monel impeller.

Entergy	CORRECTIVE ACTION	CR-PNP-2002-12941

CA Number: 2

	Group	Name
Assigned By:	Eng DE Mech Civil Struct Staff	Harizi,Philip D
Assigned To:	Eng DE Mech Civil Struct Staff	Harizi,Philip D
Subassigned To :		

Originated By:	Harizi,Philip D	1/15/2003 13:51:25
Performed By:	Harizi,Philip D	6/25/2003 14:34:43
Subperformed By:		
Approved By:		
Closed By:	Harizi,Philip D	6/25/2003 14:34:43

Current Due Date: 06/30/2003 **Initial Due Date:** 06/30/2003

CA Type: CORRECTIVE ACTION

Plant Constraint: NONE

CA Description:

Prepare a PDC to implement a design change for the SSW Pump lineshaft hardfacing to be used for all future pump overhauls. The recommended hardfacing is a nickel-chrome-boron alloy to be applied by the fused coating process in accordance with the Equipment Failure Analysis attached to CA-01 of this CR. This alloy is well matched galvanically to the Monel shaft and is metallurgically fused with a weld-like bond to the base metal.

Response:

PDC 03-056 "SSW Pump Lineshaft Nickel-Chrome-Boron Alloy Hardfacing" was issued on 25-JUN-2003.

Subresponse :

Closure Comments:

Entergy	CORRECTIVE ACTION	CR-PNP-2002-12941

CA Number: 3

	Group	Name
Assigned By:	Eng DE Mech Civil Struct Staff	Harizi,Philip D
Assigned To:	Eng DE Mech Civil Struct Staff	Pace,Raymond M
Subassigned To :		

Originated By:	Harizi,Philip D	1/15/2003 15:15:52
Performed By:	Pace,Raymond M	1/16/2003 15:11:13
Subperformed By:		
Approved By:		
Closed By:	Pace,Raymond M	1/16/2003 15:11:13

Current Due Date: 03/30/2003 **Initial Due Date:** 03/30/2003

CA Type: CAPR

Plant Constraint: NONE

CA Description:

Consider extending the use of "Peer Reviews" for PDCs produced within Mechanical/Civil/Structural Engineering to include Limited PDCs and FRNs whenever possible. Informal Peer Reviews have been effectively employed for PDCs, although Limited PDCs and FRNs have not typically received this additional review. This CR deals with design changes using vendor input and recommendations that would likely be handled by the Limited PDC or FRN process and would have benefitted from a more critical, questioning peer review. It is recommended that ALL PDCs and FRNs that make significant changes to plant equipment be subjected to such a peer review whenever possible. This should be discussed at a Mechanical/Civil/Structural Engineering group meeting and the result reported as the response to this CA.

Response:

Discussed this issue in detail at the Thursday 01/16/03 Tailgate meeting. Stressed the importance of Peer Reviews for vendor inputs. While an independent review is great it is only one person's view. An additional peer review by the senior group members will drive out vendor issues. This was well received by MCS and other examples were brought up by the group. This CA is considered closed by this response.

Subresponse :

Closure Comments:

Entergy	CORRECTIVE ACTION	CR-PNP-2002-12941

CA Number: 4

	Group	Name
Assigned By:	CA&A Staff	
Assigned To:	Eng Design Mgmt	Pace,Raymond M
Subassigned To :		

Originated By:	McWilliams,Dorena C	7/8/2003 15:20:00
Performed By:	Pace,Raymond M	7/10/2003 11:31:57
Subperformed By:		
Approved By:		
Closed By:	Pace,Raymond M	7/10/2003 11:31:57

Current Due Date: 07/23/2003 **Initial Due Date:** 07/23/2003

CA Type: CR CLOSURE REQUEST

Plant Constraint: NONE

CA Description:

Please review the closed corrective action(s) to verify adequacy and completeness to remedy the identified condition, by using the guidance in Section 5.8.1 of LI-102. If the CR is appropriate for closure, please indicate your concurrence by closure of this action. Should the closure not be satisfactory, issue a new action item to correct the deficiency.

Response:

The responses to the CAs assigned under this CR are adequate for closure of the CR in accordance with the requirements of LI-102.

Ray Pace 07/10/03

Subresponse :

Closure Comments: