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COMPONENT ANALYSIS REPORT
LINE SHAFT PUMP BUSHINGS
WARM SPRINGS STATE HOSPITAL
WARM SPRINGS, MONTANA

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1.0   Introduction

On 29 January 1981, the Failure Analysis Laboratory at Radian Corporation received two spider bushings from the State Hospital at Warm Springs, Montana, for metallurgical analysis. The bushings are from a 19 stage, 200 hp Worthington line shaft vertical turbine pump. The pump was set at 830 feet to test a low temperature geothermal well. One bushing was originally set near the top of the well; the other bushing had been set deep in the well. The bushings were reportedly manufactured from bronze sleeve-bearing material.

After approximately 50 hours of intermittent operation, the pump began to experience severe vibration. The vibration appeared random in that it sometimes occurred immediately upon start up and other times occurred after several hours of operation. A Worthington service engineer tested the pump and made several recommendations to alleviate the problem. He concluded that excessive packing box friction, overloading, and shaft unscrewing caused the vibration. He also adjusted the vertical shaft and impeller clearances.

The purpose of this analysis is to examine the shaft bushings for evidence of mechanical or corrosion damage that might have been related to the vibration problem.

The downhole pump is driven by a 200 hp, 3 phase electric motor that operates at 1760 rpm. The shaft is 810 feet long, made from 10 foot lengths of 1 11/16 inch diameter AISI Type 416 stainless steel rod. The pump column is also made from 10 foot lengths of Schedule 30, 8 inch carbon steel pipe. The spider bushings are placed every 10 feet along the column. The base of the column is attached to a nineteen stage bowl and impeller assembly.

The pump is an open water lubricated type, which uses the geothermal well fluid as the lubrication medium. The water temperature is 170°F at the well bottom and 154°F at the well head. An analysis of the geothermal fluid is presented in Table 1. Although this analysis denotes the presence of dissolved oxygen, downhole hydrogen sulfide would act as an oxygen scavenger; therefore, the measured dissolved oxygen is probably a result of post-sampling atmospheric contamination (Reference 1).

This report is part of a continuing DOE effort to gain insight into the service life of component materials employed in geothermal energy utilization. The results of these analyses will be incorporated into an addendum to DOE's Material Selection Guidelines for Geothermal Energy Utilization Systems.

2.0 Visual Examination

The two bushings are shown as received in Figure 1. Each bushing consisted of a cast spider (retainer), with a bearing sleeve press-fitted into the spider. The I.D. surface of each sleeve showed signs of abrasion; however, the bushing that had been placed deep in the well showed signs of more severe abrasion. This bushing was sectioned for analysis.

TABLE 1. CHEMICAL ANALYSIS OF GEOTHERMAL FLUID FROM WARM
SPRINGS STATE HOSPITAL.

	<u>Parameter</u>	<u>Concentration</u>
Key		
Species:	pH (at 158°F)	6.3
	Chloride	5.0 ppm
	Bicarbonate	1.85 ppm
	Sulfate	162 ppm
	Sulfide	0.5 ppm
	Ammonia	15.0 ppm
	Dissolved Oxygen	2.0 ppm
Other	Conductivity (at 70°C)	2.5 m mho/cm
Species:	Total Hardness	6.42 ppm
	Copper	22.0 ppm
	Iron	2.13 ppm
	Silica	13 ppm
	Calcium	149 ppm
	Magnesium	27 ppm
	Nitrate	9.0 ppm

The bushing that was
set deep in the well.
Sleeve I.D. = 1.834 in.

The bushing that was
set near the top of the
well.
Sleeve I.D. = 1.838 in.

Figure 1. Pump bushings from Warm Springs State Hospital
in the as-received condition.

A lip of deformed metal was observed at the top of the deep well bushing sleeve. This is shown in Figure 2. It is typical of a high degree of mechanical abrasion.

3.0 Laboratory Examination

Sections from the deep well bushing sleeve and spider were cut and prepared for microstructural examination using standard laboratory techniques. The microstructures of each are shown in Figures 3 and 4. HRF hardnesses were measured on each polished section. Elemental composition was determined for each sample using inductively-coupled Argon Plasma (ICAP) Emission Spectroscopy and standard analytical chemistry techniques for comparison purposes. The chemical analysis results are given in Table 2.

TABLE 2. CHEMICAL ANALYSIS OF LINE SHAFT PUMP BUSHINGS
FROM WARM SPRINGS HOSPITAL.

	<u>Weight Percent</u>		
	Sleeve	Spider	ASTM B-62 Copper Alloy No. 836
Copper	82	86	84.0 - 86.0
Tin	3.1	2.5	4.0 - 6.0
Lead	9.6	6.4	4.0 - 6.0
Zinc	4.5	4.4	4.0 - 6.0

Figure 2. Lip of cold worked metal observed on the bearing sleeve of the bushing that was set deep in the well (after sectioning). Diameter approx. 2.4 inches.

Magnification: 100X

Magnification: 400X
Black particles are lead;
gray phase is alpha solid
solution.

Figure 3. Microstructure of bearing sleeve; typical of cast leaded red brass. Etchant: 5% NH_4OH aqueous.

Magnification: 100X

Magnification: 400X

Figure 4. Microstructure of the bushing spider. This microstructure indicates slower cooling than that of the sleeve.
Etchant: 5% NH_4OH aqueous

A sample of the bushing sleeve I.D. surface was placed in the scanning electron microscope (SEM) and analyzed for surface chemistry using energy dispersive spectroscopy (EDS). EDS is a fluorescent X-ray technique which detects the presence of elements heavier than neon (atomic number 10); this technique does not determine ionization state or the composition of compounds which may be present. In addition to the base metal elements, major amounts of sulfur and minor amounts of iron and nickel were observed on the I.D. surface.

4.0   Discussion

The chemical composition of the bushings received from Warm Springs Hospital is similar to leaded red brass (copper Alloy nos. 836 and 838). The microstructure of this material indicates that it is cast leaded red brass. However, the chemical composition does not meet the requirements of ASTM specification B 62. The hardness of the spider was measured to be 51.0 HRF; the hardness of the bearing sleeve was measured to be 62.0 HRF. These hardness values correspond to tensile strengths of 34.0 to 37.0 ksi, which is higher than the 30.0 ksi minimum tensile strength of ASTM B 62.

As stated earlier, sulfur was detected on the I.D. bearing sleeve surface by EDS. Leaded red brass has a lower corrosion rate in sulfuric acid than bronzes and other copper alloys, and the presence of an dissolved oxygen does not substantially accelerate this rate (Reference 2). Although copper alloys have been generally unsuccessful in geothermal applications (Reference 1), a recent analysis of line shaft pump components determined that leaded red brass (Alloy 838) impellers and bearings had operated for 24,000 hours in 190°F geothermal fluid with evidence of only slight corrosion damage (Reference 3).

EDS also detected the presence of iron and nickel on the sleeve I.D. surface. SEM examination demonstrated that the iron was concentrated in a scale on the surface. This scale was probably an iron corrosion product; however, the sample lacked sufficient scale for compound identification by X-ray diffraction. The source of the iron-bearing scale was either the line shaft, or the pump column piping.

A thin layer of cold worked metal was observed at the I.D. of the deep well bushing sleeve. Also, microscopic cracks were observed on the I.D. surface (Figure 5). The cracking is probably due to surface contact fatigue (spalling).

The presence of sulfur suggests that this spalling might be corrosion assisted; however, the spalling is insignificant when compared to the purely mechanical damage observed in this sample. Figure 6 is a cross section of the deformed lip observed on this sample. The microstructure in this area is cold worked, and no evidence of corrosion was observed.

Magnification 400X

Figure 5. I.D. surface of bearing sleeve showing layer of cold worked metal and cracking.
Etchant: 5% NH_4OH aqueous

Magnification: 50X

Figure 6. Cross section of lip of deformed metal on bearing sleeve from the deep well bushing.
Etchant: 5% NH_4OH

5.0 Conclusions

- No evidence of corrosion damage was observed in the line shaft pump bushings received from the Warm Springs State Hospital.
- The bushings were manufactured from leaded red brass. From a corrosion standpoint, this appears to be a suitable material for this application.
- A lip of cold worked metal was observed at the top of the bearing sleeve of the bushing that came from deep in the well.
- The damage observed in these bushings was probably a result of the severe vibration problem.

6.0 References

1. Material Selection Guidelines for Geothermal Energy Utilization Systems, Second Edition, Report No. DOE/RA/27026-1, NTIS, 1981.
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3. Anliker, D. M., and Ellis, P. F., Component Analysis Report: Bowls and Impellers of Downhole Lineshaft Pump, Merle West Medical Center, Klamath Falls, Oregon, DCN 81-212-011-05, DOE Contract No. DE-AC03-81SF11503, Radian Corporation, Austin, Texas, March 1981.

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