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Report No. TR-V-MCM-003

6.2

Metallurgical Examination  
of  
Diffuser/R.C.P. Casing Bolts  
Returned from Arizona Unit 2  
(791350)

by

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Report 83-0002

APPENDIX II

# Abstract

Eight broken R.C.P. diffuser/casing bolts were returned from Arizona Unit 2 for examination. One bolt was found to be broken during the de-staking operation. The type of failure was identified as hydrogen induced stress corrosion cracking. The remaining seven were used to pull the diffuser/wedges into position. This operation broke the bolts. All bolts were initially cracked which was attributed to stress corrosion cracking.

All eight bolts originated from the same lot which was examined and discussed in Report TR-MCM-112.

## Introduction and Background

This report is in continuation of Report TR-MCM-112, dated 11-24/82, submitted to CE-KSB with Memo MCM-82-274 on 11-30-1982.

C-E Windsor received from CE-KSB eight broken socket head cap screws (threaded halves only) for examination. These broken bolts were returned from Arizona Unit 2 following recent rework activities. One of the eight cap screws was found to be broken during the de-staking operation (pump S/N1110-2B, identification "8109-200-016-1 Thread"). The remaining seven were used to pull the diffuser/wedges into position prior to installing the new replacement cap screws, and it was this operation which caused the final breakage of the bolts. It was reported by CE-KSB that these bolts were the original new ones which have never been through operation at either CE-KSB or Arizona Unit 2.

A list of the eight bolts with identifications is shown in Attachment (1).

### Examination

All eight bolt samples showed similar fractured surfaces, i.e., an oxidized incipient crack and a clean final fracture (see Fig. 1). Also the surface (shank and thread) of all samples was covered with a dark grey oxide, suggesting that the bolts had been exposed to an oxidizing medium such as, for instance, primary coolant (this would be contrary to information received from CE-KS8; see Introduction of this report).

We selected for the examination bolt sample "8109-200-016-1 Thread" (sample 1) which broke during the de-staking operation, and bolt sample "8109-200-016-3-1 Thread" (sample 3-1) which is representative of all seven bolt samples listed under 2., 3. and 4. in Attachment (1), i.e., rough surface of the final fracture as compared with the fractured surface of sample 1 (Fig. 1)

The bolts came from the same lot discussed in Report TR-MCM-112 and consequently were made from the same grade of steel (Type 410) following the same manufacturing procedure (see Report TR-MCM-112).

Metallographic examination of the samples 1 and 3-1 revealed the microstructure to be tempered martensite with a grain size of about ASTM No. 7 (Fig's 2 and 3) and with clearly distinguishable former, austenitic grain boundaries (see also Fig. 3 in Report TR-MCM-112, the presence of the former, austenitic grain boundary was discussed in this report).

The micro hardness of both samples was found to be DPH 468-470 (500g load), corresponding to about Rc 47.

The fractured surfaces of the two samples were examined on the scanning electron microscope (SEM). The crack which initiated the failure of the two bolts (see Fig. 1) is shown in the left photographs of Fig's 4 and 5. As can be seen the cracks are intergranular and follow the former, austenitic grain boundaries visible in the photomicrographs of Fig's. 2 and 3. The appearance of the crack surface (left, Fig's 4 and 5) is almost identical with that of Fig. 5, Photo A of Report TR-MCM-112, including some secondary cracking between adjacent grains.

The right photographs of Fig's 4 and 5 show the fractured surfaces of the final break of the samples 1 and 3-1, respectively (clean portions of the fractured surface in Fig. 1). The finer appearance of the fracture of sample 1 is believed to be due to the fact that this bolt broke by delayed hydrogen cracking whereas bolt 3-1 broke by overstressing when used to pull the diffuser/wedges into position.

### Conclusions

The initial cracking of all eight bolts occurred by hydrogen induced stress corrosion cracking as discussed in detail in Report TR-MCM-112. Bolt 8109-200-016-3-1 broke finally by delayed hydrogen cracking just as the bolts No. 13 and 15 examined and discussed in Report TR-MCM-112. The remaining seven bolts broke, after initial stress corrosion cracking, when they were used to pull the diffuser/wedges into position. It is believed that they also would have failed sooner or later by delayed hydrogen cracking.

## ATTACHMENT (1)

### Chronology of Arizona Unit 2 RCP Diffuser Ring Segment Bolting

Socket Head Cap Screws, P/N 8109-200-016 were received from the Arizona Unit 2 Site on January 14, 1983. A total of eight (8) broken cap screws were returned from two different pumps - S/N 1110-2A and 1110-2B.

Four major categories have been established as follows:

1. One socket head cap screw was found broken upon de-staking of the locking sleeves from 1110-2B.

Labeled as: 8109-200-016-1 Head; 8109-200-016-1 Thread.

The remaining seven socket head cap screws can be separated into three groups according to the location of the fracture.

2. Three socket head cap screws failed at the head/taper/shank transition.

Labeled as: 8109-200-016-2-1 Head; 8109-200-016-2-1 Thread.  
8109-200-016-2-2 Head; 8109-200-016-2-2 Thread.  
8109-200-016-2-3 Head; 8109-200-016-2-3 Thread.

3. Two socket head cap screws that failed approximately one inch from the head bearing surface.

Labeled as: 8109-200-016-3-1 Head; 8109-200-016-3-1 Thread.  
8109-200-016-3-2 Head; 8109-200-016-3-2 Thread.

4. Two socket head cap screws failed approximately 1-1/8 inch to 1-1/4 inch from head bearing surface.

Labeled as: 8109-200-016-4-1 Head; 8109-200-016-4-1 Thread.  
8109-200-016-4-2 Head; 8109-200-016-4-2 Thread.



59752

500X



59753

1000X

Vilella"s

Fig. 2 Microstructure of Bolt Sample 1



59754

500X



59755

1000X

Vilella's

Fig. 3 Microstructure of Bolt Sample 3-1

59695



Crack

250X

59693



Final Fracture

230X

Fig. 4 SEM Photographs of Fracture Surface of Bolt Sample 1

59691



Crack

300X

59690

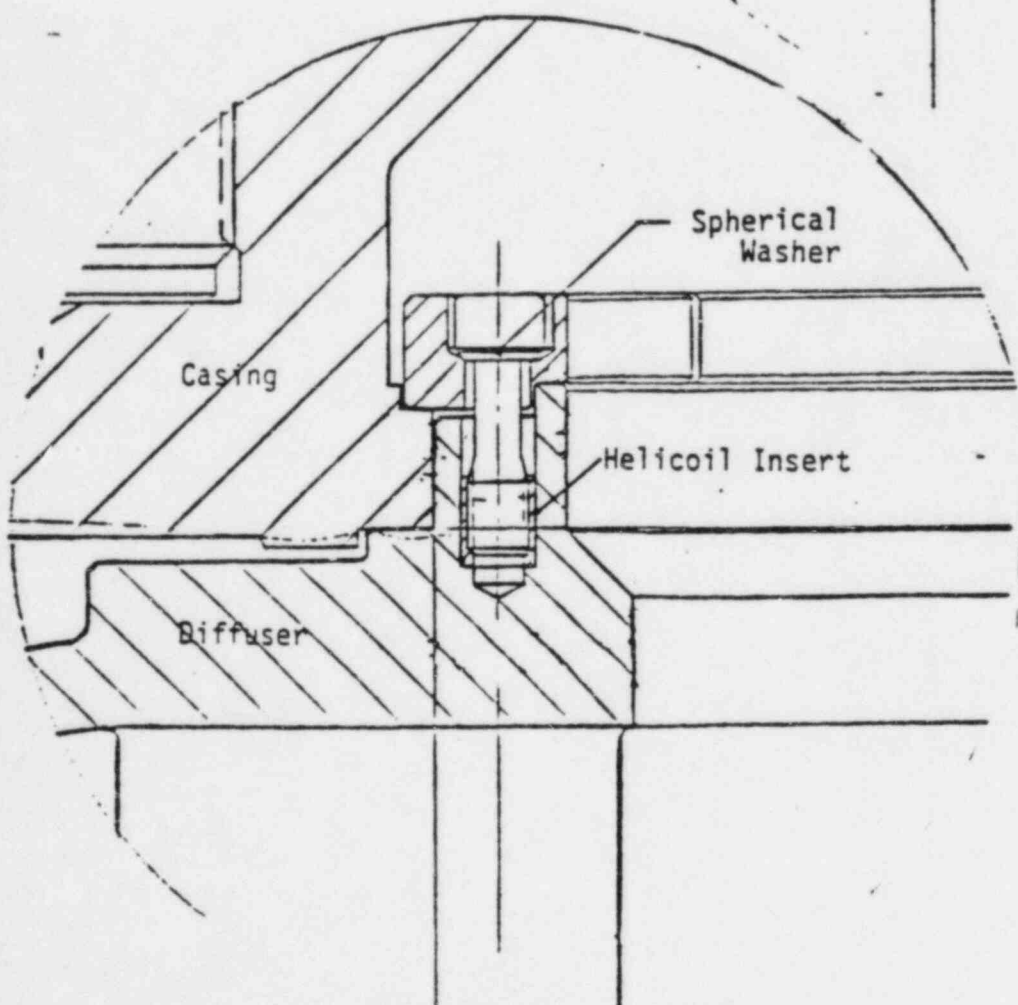
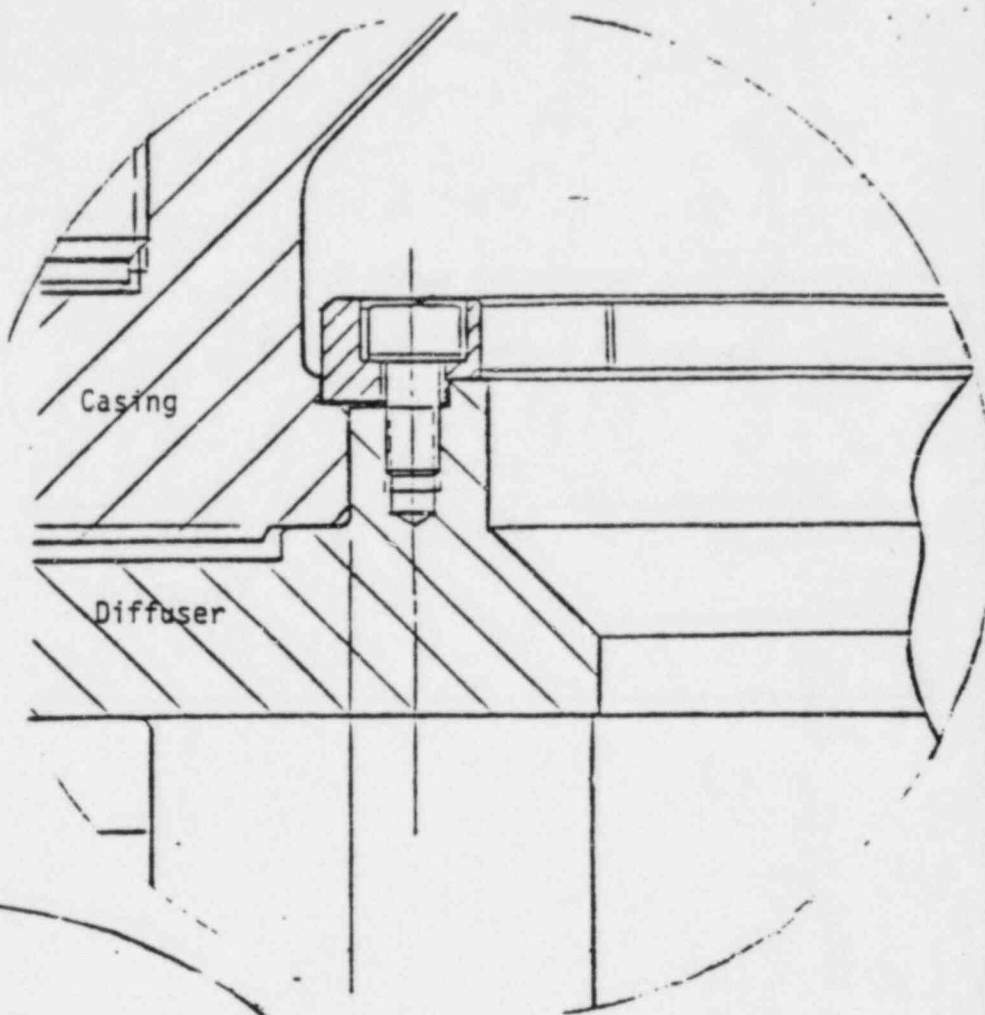


Final Fracture

230X

Fig. 5 SEM Photographs of Fractured Surface of Bolt Sample 3-1

1974  
ORIGINAL  
DESIGN



1979  
REVISED  
DESIGN

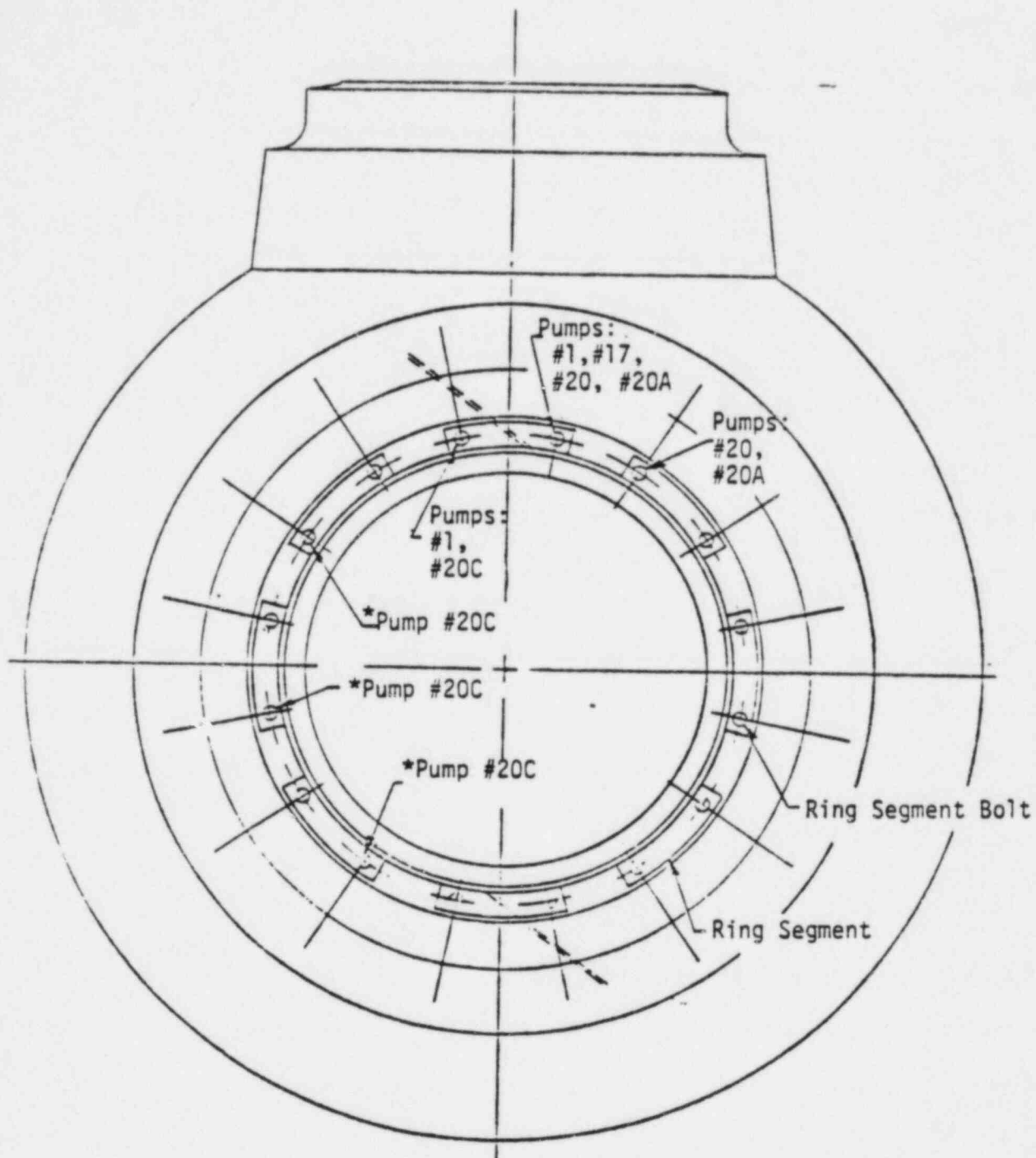
DIFFUSER/CASING  
BOLTED CONNECTION

TABULATED SUMMARY  
DIFFUSER BOLT FAILURES  
DURING MECHANICAL TESTS AT CE-KSB

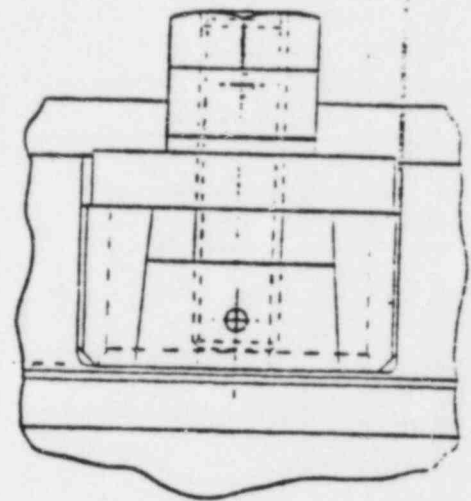
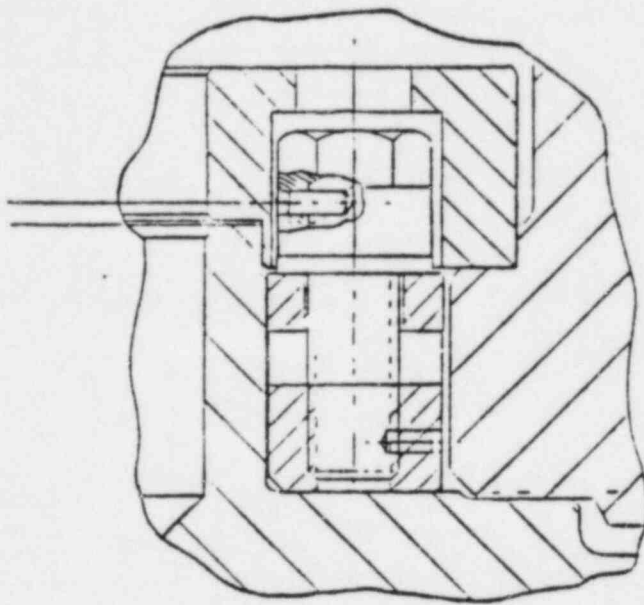
	TEST PUMP NUMBER	TEST DURATION HOURS	NUMBER OF STARTS FROM AMBIENT TEMP.	LOCATION OF SIX* VANE DIFFUSER HALF	NO. OF BOLTS BROKEN	COMMENTS
Random Failures	1 (Test 1 - 3)	500+	3	Right	2	(See Note 1)
	17 (Test 2581,2681)	50	2	Right	1	(See Note 2)
	20 (Test 10182,10282)	50	2	Right	2	(See Note 3)
Controlled Failures	20A (Test 10582,10682)	30	2	Right	2	(See Note 4)
	20B (Test 10782)	30	1	Left	0	
	20C (Test 10882)	30	1	Right	4	(See Note 5)
	20D (Test 10982)	30	1	Left	0	New bolts and Diffuser Wedges.

\*Looking down the discharge, as viewed from behind the casing.

- Note 1: Two bolts were found broken and the ring segment was found sitting on the impeller. The exact location of the broken bolts is not certain, but it is thought that they were the "bolts bridging the gap."
- Note 2: One ring segment bolt found broken on the ring segment "bridging the gap" on the six vane diffuser half.
- Note 3: One bolt was on the ring segment "bridging the gap" on the six vane diffuser half, and the second bolt was on the adjacent ring segment on the six vane diffuser half.
- Note 4: One bolt was on the ring segment "bridging the gap" on the six vane diffuser half, and the second bolt was on the adjacent segment on the six vane diffuser half.
- Note 5: Four ring segment bolts ultimately found cracked on the five vane diffuser half.



\* = Indicated bolt may have been in other hole of the same ring segment.



DIFFUSER WEDGE ASSEMBLY