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C REACTOR FUEL FAILURES

TUBES 2562 & 3361

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C REACTOR FUEL FAILURES - TUBES 2562 & 3361

INTRODUCTION

C Reactor experienced two severe fuel failures, one in process tube 2562 on 10-27-67, and one in process tube 3361 on 12-27-67, both resulting in major efforts to effect their removal. The intent of this document is to present a summary of the action taken for the removal of the failed elements.

SUMMARY

A. Tube 2562 (10-27-67)

At 2058 hours on 10-27-67 C Reactor was manually shut down over a period of 20 minutes due to excessive Panellit pressure increases on tube 2562. Subsequent examination revealed a fuel failure in the thirteenth position from the rear of the fuel charge.

The failure and its companion upstream pieces were stuck in the process tube and required a maximum force of 28,000 pounds to discharge. This represents a force of 12,000 pounds above the force limit as specified by Process Standards.¹

B. Tube 3361 (12-27-67)

At 0330 hours on 12-27-67 the reactor was scrammed by a high trip on Panellit gauge 3361. Examination of the fuel after removal showed a ruptured element in the 14th position from the downstream end. The rupture could not be removed by normal charge-discharge, but was finally removed by applying a force of 22,000 pounds on the upstream fuel. The force required was 6,000 pounds above the force limit as specified by Process Standards.¹

GENERAL DISCUSSION

A. Tube 2562 (10-27-67)

Tube 2562 was charged on March 26, 1967 with I&E natural fuel elements from lot number KJ687Q.

The charge makeup consisted of 19 pieces of bumpered fuel, 12 pieces of nonbumpered fuel and one (1) water mixer in the charge sequence as shown on Figure I.

This column was initially scheduled for a goal exposure of 1450 MWD/Ton, but was authorized to go to 2000 MWD/Ton by PTA-084.² At the time of fuel failure on October 27, 1967 the exposure was approximately 1957 MWD/Ton and the reactor was operating at an equilibrium power level of 2145 MW.

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The tube was operating at a power of 1380 KW, outlet temperature of 118 C with an inlet temperature of 15 C just prior to the shutdown.

The events leading to the reactor shutdown are as follows:

1. At 1930 hours on 10-27-67 a full-scale gamma monitor point was noted on header 25, then it returned to normal.
2. At 2000 hours a water sample was taken, checked and turned out negative.
3. The Panellit pressure on this tube had gradually increased 10 pounds over the previous 16 days of operation. A further increase of 13 pounds was noted prior to the failure with 7 of the 13 pounds occurring in the final 3-1/2 hours before shutdown.
4. The reactor was shutdown at 2058 hours on 10-27-67 due to the large Panellit pressure increase.
5. A survey of the rear nozzle on tube 2562 resulted in a radiation reading of 1.5 R/hour, which was five times that of adjacent tubes.

Attempts were made to remove the fuel column from the tube using the standard charge-discharge procedures with no success. The downstream dummies and 11 downstream fuel elements were then removed by flushing them out the rear of the process tube. A backseating force of 6000 pounds was applied from the rear and resulted with no movement. The ribs were cut up to a distance of 17' 6" from the rear Vanstone flange, a rear dummy gunbarrel was installed and the front Vanstone was removed. A force of 20,000 pounds was applied to the upstream end of the charge which resulted in a movement of 4.5" of the tube and fuel column to the rear. An additional movement of 1.5" of the fuel column only was noted. At this point a borescope examination of the upstream section of the tube was made with the following results:

"An imprint of the push rod, which had a smaller diameter than the fuel piece, was visible in the arc from about 8 o'clock to 10 o'clock on the upstream fuel element in the process tube. No evidence of distortion or mushrooming of the outer circumference could be seen. At the 8 o'clock position, a small amount of cladding material was swaged about 1/16" into the bore of the fuel element."

The above statement was taken from a letter written to E. J. Filip from L. V. Barker.³

An additional 5000 pounds was applied, to make a total force of 25,000 pounds, to the front, but the charge could not be removed. It was backseated with 6500 pounds from the rear. The total force applied to the front was increased to 27,000 pounds and resulted in a very small amount of movement. It was again backseated, this time using 16,000 pounds and moved the charge to the front 7.25". Then a force of 28,000 pounds was applied from the front and was sufficient to remove the fuel from the process tube.

After the removal of the fuel from the process tube steps were taken to remove the tubing from the graphite channel. A large amount of difficulty was experienced during the removal and it was time consuming as is shown by the following summary of activities associated with its removal.

Activities Associated With Tube Removal

10-30-67

1. The process tube (2562) was flushed with water for five minutes to clean the tube before splitting.
2. The tube was split 3.5 feet from front to rear at which point the splitter stuck and was then removed.
3. The tube was split a distance of 19 feet from the rear, then one cutter blade broke.
4. Another splitter was pulled the entire length of the tube before one cutter blade broke. A maximum of 6500 pounds was applied in pulling the splitter out. The tube was not completely split.

10-31-67

1. Inserted a bare push pole from front to rear using a maximum force of 8000 pounds. A splitter was installed on the end of the pole and pulled towards the front of the reactor with a maximum force of 6000 pounds. At 24' the splitter stuck.
2. Pushed splitter to rear and the tube parted approximately 14 feet from the rear.
3. The 14 foot tube section was removed and the splitter and push pole were pulled from the channel.
4. Removed front gunbarrel and a 7'-8" section of tubing came out with the gunbarrel. A dummy gunbarrel was installed in the front.
5. The push pole and splitter was again inserted and resulted in removal of a 16 inch section of tube.
6. A 3000 pound force was applied to the front of the tube but resulted in no movement of the process tube.
7. A 1-inch pole was inserted from the front to the rear end and a splitter attached. The splitter was pulled to the front with a maximum force of 6000 lbs. Both splitter blades were partially broken.
8. Two 12 foot lengths of 3/4 inch pipe were inserted in the front and rear of the tube to keep the tube from collapsing. Pushed on tube with 10,000 pounds and split tube appeared at inner end of rear gunbarrel.

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11-1-67

1. A force of 16,000 pounds moved tube 1'8". Tube collapsed at upstream end. Channel blocked with chunks of graphite at 10'10-1/2" from front. The first piece of tubing is 10'4-1/2" from front.
2. Broken graphite was vacuumed up to 16'6" from rear.

11-2-67

1. Drilling and boring operations were attempted from the front until the drill broke at 13'8" from front. The drill and pieces were removed. Borescoping showed that the drill had gone on top of the tube and 10 inches past the end of the tube.

11-3-67

1. Vacuumed a lot of graphite. Graphite kept falling down and blocking channel.
2. Vacuuming, boring, drilling, and borescoping operations continued.

11-4-67

1. Vacuuming, boring, drilling, and borescoping continued.
2. A 14" section of tube was removed with a push pole.

11-5-67

1. A heavy duty splitter was used to split the tube from rear to front. The tube came out the front and was pulled into a burial can.
2. The graphite in the channel had received quite a bit of damage so the channel was made into an air channel. The final borescope examinations revealed the following:

"The channel was blocked with broken graphite 27'7" from the rear. There was no metallic material visible in the channel. At 22 feet from the rear, a trunion block was broken, but it was possible to get the borescope past the broken graphite. Maintenance personnel examined the front of the channel and reported that the channel was clear to 11 feet at which point it was blocked with broken graphite."

Process Engineering examined the fuel pieces following the discharge and compiled the following notes:

<u>Piece</u>	<u>Description</u>	<u>Relative Weasel Reading</u>
32	Brown film covering	0.17
31	Brown and silver	0.23
30	Brown and silver, slight ledge corrosion	0.33

<u>Piece</u>	<u>Description</u>	<u>Relative Weasel Reading</u>
29	Brown and silver	0.43
28	Brown, heat and rough surface on top of element	0.50
27	High heat on top and rough surface	0.58
26	Brown and silver, mixer piece	0.58
25	High heat on top and rough surface	0.70
24	High heat on top and rough surface	0.80
23	Black, heated appearance	0.86
22	Brown and heated	0.92
21	Dark, silver heavy galled marks, male end cap appears to have started to extrude into the hole of the drilled aluminum piece used for backseating	1.00
20	Bad side-unclassified rupture	0.98
19	Silver, black, heavy galled marks	1.00
18	Heavy galling	0.95
17	Dark grey, heavy galling 80%	0.87
16	Dark brown, heavy galling	0.80
15	Dark brown, heavy galling	0.80
14	Light brown, heavy galling 60%	0.76
13	Dark brown, heavy galling	0.73
12	Light brown, heavy galling 60%	0.73
11	Light brown, heavy galling 70%	0.71
10	Brown, moderate galling 50%	0.69
9	Silver, moderate galling 60%	0.62
8	Silver, heavy galling	0.57
7	Silver, heavy galling 80%	0.50
6	Silver, galled	0.41
5	Silver, heavy galling 80%	0.32
4	Silver, heavy galling 80%	0.26
3	Silver, heavy galling 80%	0.19
2	Silver, heavy galling 80%	0.14
1	Silver, female end cap deformed, element mushroomed slightly on end	0.08

Examples of the mechanical damage occurring to some of the fuel elements during removal is shown on Figure II. Deformation of the upstream fuel element due to the total of 28,000 pounds force needed for removal can be seen on Figure III.

Figures IV and V show the ruptured fuel element removed from tube 2562-C.

B. Tube 3361 (12-27-67)

A Panellit scram occurred on gauge 3361 at 0330 on 12-27-67. A temperature map was being run at the time of the scram. This map indicated that the tube outlet temperature had increased 9 C to 119 C just prior to the scram. Prior to the scram no indication was received on the gamma monitor or on the 107 Basin activity instruments. Gas activity had been going up at a steady rate since 0000 hours. Increases in gas flow or pressure had been unable to stop the activity increase.

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Tube 3361 was charged on March 26, 1967 with I&E Natural fuel elements with Lot Numbers KJ678A. The charge makeup included 19 bumpered pieces located in the downstream section, 12 nonbumpered pieces located in the upstream section, and 1 watermixer piece in the 8th position from the rear of the column as shown on Figure I. This column was initially scheduled for a goal exposure of 1450 MWD/Ton. DUN-2992, "Production Test Authorization-0842," extended the goal to 2000 MWD/Ton. At the time of the fuel element failure on December 27, 1967 the exposure level was approximately 2160 MWD/Ton.

Inlet temperature was averaging 8.0 C prior to the time of the rupture. The reactor was operating at an equilibrium power level of 2380 Mw. Tube 3361 was operating at an average tube power of 1357 Kw during the operating period prior to the rupture.

The fuel column was stuck and could not be removed in the normal manner. The downstream dummies and 13 downstream fuel elements were flushed from the tube. Solid aluminum dummies were inserted and a backseating force of 16,000 pounds resulted in 6" movement of the fuel column. The ribs were then cut up to the ruptured fuel piece. On 12-29-67 the rupture and remaining fuel pieces were removed by applying a force of 22,000 pounds from the front. The tube was split and 16 feet of tube removed out the rear. Loose graphite was noted at 14 feet from rear.

On 12-30-67 a splitter was again pulled from rear to front. The tube could not be held and was eventually completely pulled out the front. Borescope examinations showed a piece of crumpled tube at 23'10" from rear.

On 12-31-67 a borescope examination revealed a piece of process tube 15'5" from the rear and several graphite chunks in the channel. Graphite and tubing was removed with a push pole. A piece of tubing still remained in the channel and broaching was attempted to remove the piece. The broach broke leaving two or three cups of the cutting blade in the channel. These pieces were removed, but a 1/2" by 4" piece of process tube had fallen into a graphite void and could not be removed. On 12-31-67 memorandum of Process Standards Relaxation No. 7-5M Graphite Temperature Control for Uncooled Aluminum in Reactor was obtained verbally. This memorandum was authorization to waiver Process Standard C-040, Section 40.01E concerning uncooled aluminum.

E. R. Marx
Process Engineering Unit
Reactor Engineering Subsection

Fuel Charge Pattern

Tube 2562 & 3361-C

Fuel Charge Sequence

<u>Section</u>	<u>Description</u>
1	Downstream Dummy Pattern (1-5" Perf., 10-8" Perfs, 3-8" Tubulars)
2	7 Pieces of Natural Bumper Fuel (C2NB Fuel Model)
3	1 Water Mixer (O3WB Fuel Model)
4	12 Pieces of Natural Bumper Fuel (C2NB Fuel Model)
5	12 Pieces of Natural Nonbumper Fuel (C2N Fuel Model)
*	Rupture Location in Tube 2562
**	Rupture Location in Tube 3361

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Heavy Gallings

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Heavy Gallings with Uranium Showing

Mechanical Damage to Fuel From 2562

FIGURE II

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FIGURE III

Deformed Upstream Fuel Due to Excessive Discharge Pressure
Tube 2562

Deformed Cap End Resulting From 28,000# Force

Mushrooming Effect Caused By 28,000# Force

View 1

View 2

Ruptured Fuel Element Tube 2562-C

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FIGURE IV

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FIGURE V

Male End of Ruptured Fuel Element
Tube 2562-C

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REFERENCES

1. HW-46000, "Process Standards." (Secret)
2. DUN-2992, "Production Test Authorization-084, Evaluation of Fuel Performance at High Exposure - Supplement A," S. A. Wood, September 15, 1967. (Secret)
3. Letter to E. J. Filip from L. V. Barker, "Results of Borescope Examination of 2562 C," November 21, 1967.

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