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105-C REACTOR

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FRONT-FACE HARDWARE MODIFICATIONS
105-C REACTOR

by

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IRRADIATION PROCESSING DEPARTMENT

September 1, 1965

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FRONT-FACE HARDWARE MODIFICATIONS
105-C REACTOR

BACKGROUND

C reactor installed 425 impact extruded aluminum CGI-558 type nozzles and related front face components in July of 1964. These nozzles complimented an existing 111 CGI-558 type nozzles located in the old operational charge-discharge (OCD) pattern and were authorized under an addendum to Design Change 812. Only 425 component sets were available for immediate use, and it was tentatively planned to complete the installation in late 1964. However, completion of the program was delayed until mid-1965 to better utilize the hardware from the deactivated DR, H, and F reactors. These modifications are now scheduled for completion in October, 1965, and are authorized under Design Change 1026.

OBJECTIVE

The objective of this document is two-fold: first, to discuss the hardware modifications and their effect on reactor operating conditions; and second, to present pertinent hydraulic information. The basis and justification for the hardware modifications are covered in Design Change 1026.

SUMMARY

The planned modifications will improve the front face hardware integrity, reduce the number of front face component types, improve reactor operating limits, and increase reactor flow to approximately 108,000 gpm. The selected venturi and orifices will increase process tube outlet temperature limits, although in some cases, these limits will still be slightly less than the maximum 130°C permitted by Process Standards. In general, reactor power levels should be restricted by the 95°C bulk outlet temperature limit, although graphite limits may be closely approached during the winter months and might be slightly more restrictive than the bulk limit for short periods. It will be necessary to install 25-75 trip span Panellit gauges on all smoothbore process tubes to achieve nonrestrictive tube outlet temperature limits.

DISCUSSION

The document discusses the effects of the front face hardware modifications on reactor operating limits in the following order: first, the new flow measuring devices are presented; next, the process tube outlet temperature limits will be discussed; finally, miscellaneous topics will be reviewed.

1. Venturi and Orifice Design

The CGI-558 venturis from the shutdown reactors will require enlargement for use at C reactor. It is desirable to ream all flow measuring devices to the most flexible size; that is, the size which would give the desired Panellit pressures, increase tube outlet temperature limits, and allow some flexibility for future modifications. Table I, below, shows the selected flow measuring

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devices and sample calculations illustrating the selection basis are contained in Appendix A.

TABLE I
FLOW MEASURING DEVICES

<u>Zone Type</u>	<u>Flow Device and Size</u>
Central zone CG-558 type nozzles on ribbed aluminum tubes	.410 venturi with crosswire
Fringe zone CG-558 type nozzles on ribbed aluminum tubes	.361 primary, .390 secondary double orifice assembly with crosswire
K-type nozzles on small size zirconium smoothbore tubes	.410 venturi with crosswire
Overbore tubes	No scheduled changes

The double orifice assembly selected is a .361 inch I.D. flat plate primary orifice with a 45° taper upstream (this is identical to the D reactor secondary orifice), and a .390 inch I.D. secondary orifice with a 15° taper upstream to the midpoint of the orifice body. This assembly is placed in the standard CG-558 type double orifice cage with a crosswire to minimize upstream plugging.

2. Process Tube Outlet Temperature Limits

At the present time, C reactor is equipped with 10-90 trip span Panellit gauges and must administer a very limited effective range restriction of 35 psi on all ribbed aluminum tubes to obtain reasonable tube outlet temperature limits. Even at this limited effective range, Trip After Instability (TAI) limits are not always the 130°C desired. For this reason, the minimum base limits are normally calculated to give 120°C; thus, the across the board scram limit at C reactor is 120°C.

a. Ribbed Aluminum Tubes

Completion of the front face hardware modifications with the recommended venturis and orifice sizes will allow TAI limits to 130°C for all ribbed aluminum tubes with 10 pump operation.

Figure 1 shows the TAI limit expected for various values of low trip pressure and Panellit gauge dial effective range for both 10-90 and 25-75 trip span Panellit gauges. C reactor will not be able to achieve an unrestricted Panellit gauge dial effective range with TAI limits of 130°C ~~TAI limits~~. The use of 25-75 trip span Panellit gauges would permit 130 TAI limits without requiring restrictions to the dial effective range.

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FIGURE 1

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The Annulus Boiling Limits (ANB) for the central zone ribbed aluminum tubes should increase slightly and will be approximately 130 C. The ANB limits for the fringe tubes will increase but may be as low as 120 C; however, this limit is not expected to restrict reactor power level since C reactor fringe tubes have not been known to operate much over 100 C. In addition, fringe tube flow rates will increase slightly with the use of the double orifice flow measuring device.

b. Smoothbore Tubes

The 62 overbore smoothbore tubes and 68 regular size smoothbore zirconium tubes have slightly different flow instability characteristics with self-support fuel than ribbed aluminum tubes with smooth fuel; thus, Panellit maximum base limits and TAI temperature limits are more restrictive for smoothbore tubes. The maximum Panellit base pressure is restricted by front header pressures and Panellit gauge type as shown in Figure 2. The TAI limit is reduced to 0.92 of the calculated value of a ribbed aluminum tube with a normal fuel charge.

Due to these restrictions, smoothbore tubes with 10-90 trip span Panellit gauges, especially overbore tubes, operate close to both Panellit and tube outlet temperature limits. The highest attainable TAI limits with present loadings and front-face hardware normally calculate slightly over 120 C with 10-90 trip span Panellit gauges. After the front-face hardware modifications are completed, operation will be restricted if 10-90 trip span Panellit gauges remain on smoothbore tubes. Thus, Panellit gauges of 25-75 trip span will have to be installed to monitor pressures for all smoothbore tubes. With 25-75 gauges, Panellit and tube outlet temperature limits will increase over present values and these tubes are not expected to restrict reactor power levels. TAI and ANB limits should calculate at 130 C.

Panellit and tube temperature limits may also be further improved by replacing the flow measuring device. This change may not reduce the possibility that 25-75 trip span Panellit gauges will still have to be used. The 68 regular size zirconium tubes will be equipped with the same venturi size planned for the central zone ribbed aluminum tubes. However, replacement of the flow measuring device on an overbore tube requires a nozzle change and possibly a new overbore zirconium tube. Due to these considerations, overbore hardware modifications have not been considered feasible at this time.

The overbore tubes present the major problem in the smoothbore tube area. There are three different types of front-face hardware on the overbore tubes, each with slightly different flow characteristics. In addition, there are also four tubes with slightly smaller nominal diameters and a different downstream dummy configuration is required to obtain proper pressure drop characteristics. These factors considerably increase the potential for charging errors. The overbore facility is also transitioning to the hot-die-sized fuel model. The R value used in the ANB calculation is 1.33 for the water-quenched hot-die-sized overbore fuel and 1.20 for the oil-quenched hot-die-sized overbore fuel. It is anticipated that the ANB limit for the

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FIGURE 2

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MAXIMUM LIMIT, PSI

water-quenched hot-die-sized overbore fuel element may be as low as 120°C following completion of the front face hardware modifications. This lower ANB temperature limit can be raised by variations in fuel design or by changing the downstream dummy pattern to increase the End of Active Section (EOAS) pressure, or by a combination of both. Oil-quenched hot-die-sized overbore fuel elements are scheduled for all future usage, and all water-quenched hot-die-sized overbore fuel is currently under irradiation. Major changes in overbore fuel design or loading pattern may require major tube and hardware changes to obtain nonrestrictive Panellit pressures and tube outlet temperature limits.

3. Miscellaneous Topics

a. Effluent Piping

The C reactor downcomers have now both been modified in accordance with provisions of Design Change 1001. The far downcomer is now in use, and it has been concluded that either of the modified downcomers will be capable of maintaining the increased flows.² Since downcomer hydraulics are not well defined, data will be required from time to time from the various dip tubes and pressure taps to detect effects of hydraulic changes.

b. Power Level

Figure 3 shows bulk outlet temperature limited power level capabilities for various average inlet water temperatures during each month of the year. Figure 4 plots graphite temperature limits and tube power limits for various gas compositions and indicates that graphite temperatures could be limiting during peak power level months; however, since graphite is not limiting until the gas atmosphere is 100 per cent helium, graphite temperatures are not anticipated to restrict reactor power levels for more than a short period.

Horizontal control rod coolant flows should be adequate, and coolant temperatures should not increase significantly over current values.

Thermal shield temperatures may become high enough to require partial fringe poisoning; however, the alternate product loads - like thorium - should be sufficient to maintain the thermal shield temperatures below the 160°C maximum. Higher helium concentration required for graphite temperature control should also help maintain lower thermal shield temperatures.

c. Last-Ditch Backup Adequacy

Last-ditch backup adequacy is based on 1) an assured high-tank flow at the time of high-tank takeover, and 2) an assured diesel flow at the time the high tanks are empty. The high-tank adequacy is most restrictive on a tube outlet temperature limit basis since initial cooling must be adequate to minimize the probability of flow stoppage due to steam formation. As a reactor remains in a shutdown condition and the graphite and fuel elements cool, less flow is required. On a long-term power

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FIGURE 3

BUK OUTLET LIMITED POWER LEVEL AT INCREASED FLOWS, MW

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level basis, the diesel system adequacy is most restrictive and is based on the time of high-tank emptying and assured diesel system flow. Using references 5 and 6, last-ditch backup adequacy was calculated on the above basis.

Figure 5 presents the maximum allowable tube outlet temperature on a specific crossheader for various high-tank water temperatures over the bulk inlet water temperature. Figure 6 shows the maximum allowable power level for various diesel system inlet water temperatures, and is based on an assured diesel system flow of 6000 gpm. The power level limits are greater than the anticipated bulk outlet temperature limited power level capabilities. Thus, the calculations indicate that the backup coolant system capacities will be adequate after the front-face hardware modifications are complete.

d. Other Considerations

1) Pump Cavitation

190-C pump cavitation is not expected to increase significantly over the present conditions and should not reach such a magnitude as to limit reactor operation.

2) Tube Corrosion

Over-all, essentially no changes in tube corrosion or the tube corrosion program are anticipated.

3) Ruptures

Even at a higher reactor power level, ruptures are not expected to increase appreciable over the present rates. The use of bumpered E-2 metal should also help control ruptures. Recent changes in the overbore charging pattern as well as the use of hot-die-sized fuel model indicate that the high overbore rupture rate may be decreasing somewhat.

CONCLUSIONS

1. The new flow measuring devices improve flexibility and operating limits over the current design.
2. Panellit gauges of 25-75 trip span will be required on all smoothbore tubes.
3. Graphite temperatures may be approached if helium concentrations are not increased. During the cold winter months, graphite temperatures may be limiting for a short period.

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FIGURE 6

MAXIMUM ALLOWABLE POWER LEVEL, MW

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4. The last-ditch coolant system is adequate to support post modification.

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APPENDIX A

Optimum Venturi Calculation

Worst Case Conditions

<u>FHP</u>	<u>10 Pump</u>	<u>9 Pump</u>
Max:	391	371
Min:	375	355

Desired Panellit

Max:	265+	245+
Min:	200+	200+

Tube Flows

Max:	66	64
Min:	54	52

Worst Combinations

Low Flow, High Panellit -

9 Pump: 52 gpm @ 245 psi & 371 FHP ($\Delta P = 126$)
10 Pump: 54 gpm @ 265 psi & 391 FHP ($\Delta P = 126$)

High Flow, Low Panellit -

9 Pump: 64 gpm @ 200 psi & 355 FHP ($\Delta P = 155$)
10 Pump: 66 gpm @ 200 psi & 375 FHP ($\Delta P = 175$)

NOTE: References 7-14 used in Appendix A.

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APPENDIX FIGURE 1

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APPENDIX FIGURE 2

FRONT NOZZLE TO END OF ACTIVE SECTION DELTA P, PSI

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APPENDIX FIXURE 3

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APPENDIX FIGURE 4

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APPENDIX FIGURE 5 **DECLASSIFIED**

APPENDIX FIXURE 6 **CLASSIFIED**

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APPENDIX FIGURE 10

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APPENDIX FIGURE 11

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APPENDIX B

Temperature Calculations¹

$$TAI = T_{in} + \frac{41.45 (FH)^{.709}}{(FH - P_{MRH})^{1/2}} - T_{in} \left(\frac{LT - P_{MRH}}{LT - P_{MRH} + ER} \right)^{1/2}$$

10 Pump Worst Case

$$FH = 375 \text{ psi}$$

$$ER = 60 \text{ psi}$$

$$T_{in} = 18 \text{ C}$$

$$P_{MRH} = 50 \text{ psi}$$

$$LT = 160 \text{ psi}$$

$$TAI = 130 \text{ C}$$

9 Pump Worst Case

$$FH = 355 \text{ psi}$$

$$ER = 40 \text{ psi}$$

$$T_{in} = 18 \text{ C}$$

$$P_{MRH} = 50 \text{ psi}$$

$$LT = 140 \text{ psi}$$

$$TAI = 130 \text{ C}$$

$$ANB = \frac{T_s - T_{in}}{R} + T_{in}$$

$$\text{Worst Case: } R = 1.2$$

$$T_{in} = 5 \text{ C}$$

$$\text{Central Zone: } EOAS \geq 55 \text{ psi}$$

$$T_s \geq 148 \text{ C}$$

$$ANB \geq 125 \text{ C}$$

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Fringe Zone: EOAS = 50 psi

$T_s = 144$

ANB = 121 C

Summary of Central Zone Conditions

10 Pump

Natural: 230 psi Panellit at 57 gpm

E^2 : 200 psi Panellit at 62 gpm

SS Natural: 220 psi Panellit at 58 gpm

TAI = 130 C

ANB $\geq$ 125 C

9 Pump

Natural: 210 psi Panellit at 54 gpm

E^2 : 180 psi Panellit at 58 gpm

Ss Natural: 200 psi Panellit at 55 gpm

TAI = 130 C

ANB $\geq$ 125 C

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October 22, 1965

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Please make the following changes to the above referenced documented:

Page 3 - second sentence from the bottom of the page

Cross out the first two words - "TAI Limits."

Page 19 - Appendix Figure 5

The vertical axis should read: 60.0 to 2.0, not 600 to 20.

Page 21 - Appendix Figure 7

The vertical axis should read: Panellit Pressure, not Front Nozzle
Barrel Pressure.

Page 22 - Appendix Figure 8

The vertical axis should read: Front Nozzle Barrel Pressure, not
Panellit Pressure.

Page 26 - Appendix B

The first equation should read as follows:

$$T_{in} + \left[\text{xxxxxx} - T_{in} \right] \left[\text{xxxxxx} \right]^{-1/2}$$