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TITLE

RESULTS OF TESTS INVESTIGATING PANELLIT
PROTECTION TO "C" AND "K" PROCESS TUBES
WITHOUT REAR PIGTAIL

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PROTECTION TO "C" AND "K" PROCESS TUBES
WITHOUT REAR PIGTAIL

B. R. Cremer, D. E. Fitzsimmons, and G. M. Hesson

September 15, 1959

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RESULTS OF TESTS INVESTIGATING PANELLIT
PROTECTION TO "C" AND "K" PROCESS TUBES
WITHOUT REAR PIGTAIL

Purpose

The purpose of this report is to present the results of a brief experimental program made to determine the adequacy of the panellit protection system to guard against accidental flow reductions to a "C" or "K" geometry process tube which is being operated with a missing rear pigtail.

Introduction

Occasionally a rear pigtail of a reactor fails and is blown free from its connectors. The coolant water then discharges into the rear face area. This in itself is not a particularly hazardous condition and need not necessarily require an immediate reactor shutdown.

A question which does arise, however, if a tube is operated without its rear pigtail, is whether the panellit protection procedures are adequate to guard against accidental coolant flow reductions. The course of events following accidental flow reductions to a normal tube is strongly influenced by critical flow through the rear fittings. If the rear pigtail is missing, the pattern of critical flow might be different.

It is strongly believed, however, that the concepts^(1, 2) developed and the panellit procedures derived⁽³⁾ for normal tubes would apply to the case of a tube with a missing pigtail. This can be substantiated only by transient experimentation and has been done for the "O" geometry case.⁽⁴⁾ This document presents the results of two brief experimental programs covering the "C" and "K" geometry cases.

Summary and Conclusions

Plugs upstream of the panellit tap were simulated by electrically heated mockups of "C" and "K" I & E geometry process tubes operating with a missing rear pigtail.

The results of the tests made evident that use of the present panellit protection procedures provide adequate protection for the cases in question. In particular, the pressurization due to steam formation and critical flow of the discharge fitting on the rear nozzle is so great that in the event of a plug upstream of the panellit tap, sufficient to lead to boiling burnout, a safe high panellit trip would occur should the low panellit trip be missed.

1. HW-56621, "Experimental Results of Tests Simulating Plugging of a 'K' Tube with I & E Slugs", D. E. Fitzsimmons, G. M. Hesson, July 7, 1958.
2. HW-57616, "Experimental Results of Tests Simulating Plugging of a 'C' Tube Charged with I & E Fuel Elements", G. M. Hesson, D. E. Fitzsimmons, J. E. Hammond, October 1, 1958.
3. HW-51659, "Specification A-020, Process Tube Instability Limits", K. W. Hess, July 22, 1957.
4. HW-57867, "Results of Tests Investigating Panellit Protection to a 'O' Process Tube Without a Rear Pigtail", G. M. [REDACTED] Fitzsimmons, October 24, 1958.

For the K reactor case, the course of events following a plug upstream of the panellit tap was found to correspond quite closely to that found previously for the normal case. For the "C" reactor case the pressurization due to steam formation following a plug upstream of the panellit tap was found to be less than was found for the normal case. The conservatism in depending on the high panellit trip backup to guard against plugs upstream of the panellit tap in the event the low panellit trip is missed is therefore reduced if the rear pigtail is missing from a "C" process tube, although it still exists.

Experimental Apparatus and Procedures

The experimental apparatus and procedures used were, with a few minor exceptions, identical to those used for the normal geometry cases (1, 2). The discharge of the tube was from the connector fitting on the rear nozzle into a three-inch pipe. The pressure in the pipe was maintained of values low enough that critical flow conditions existed in the connector fitting. The sudden plugs were simulated by use of an air operated valve which directed the flow through either of two flow channels, one of which provided normal flow to the tube and the other a reduced flow.

Discussion

The loss of a rear pigtail results in the discharge of the coolant water to atmospheric pressure through a reduced resistance to flow than is normal. This causes an increase in the coolant flow rate, and consequently a lower panellit pressure. The lower panellit pressure increases the sensitivity of the high panellit trip, but decreases the sensitivity of a low panellit trip. This argument is valid for all present Hanford reactor geometries, but its effect in the "C" and "K" geometries, where the pressure drop across the rear fittings and pigtail is much smaller, is much less pronounced than it is in "O" geometry.

The question of protection against a plug downstream of the panellit tap is readily answered. With its increased high panellit trip sensitivity, a tube operating with a missing rear pigtail has greater protection against plugs downstream of the panellit tap than does a normal tube.

The converse is true with regard to a low panellit trip in the event of a plug upstream of the panellit tap. However, in the case of a normal tube, critical flow through the rear connector fittings resulted in large pressurization of the tube. This large pressurization carried the panellit pressure to a high trip for all cases except for very large flow reductions. As a result, for any case for which a low panellit trip was not secured, a high panellit trip was; and, in fact, for most cases of operating interest, the panellit pressure passed through both panellit trip pressures, giving double protection. If the rear pigtail should fail, the discharging coolant will pass through the connector fitting on the rear nozzle barrel, but not through the one on the rear header. If the same pressurization occurs as a result of critical flow through the connector fitting on the rear nozzle barrel of a tube with a missing rear pigtail as occurs through the discharge piping of a normal tube, concern about the lower sensitivity to a panellit low trip would disappear.

The experimental results are summarized in Tables I and II for K and C reactor geometries, respectively. In addition, for comparison purposes, in figures 1 through 6 the experimental panellit pressures are plotted against time for both the missing rear pigtail case and the normal case.

1. Op. Cit.

2. Op. Cit.

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These results show that for K reactor geometry there is essentially no difference between the behavior of a normal tube and a tube without a rear pigtail in the event of a plug upstream of the panellit tap.

For the C reactor case, however, the pressurization due to critical flow and/or two phase flow when the rear pigtail is missing is much less than that for the normal case. The data do show, however, that with the rear pigtail missing, a region of double protection exists, although significantly reduced, and either a high or a low trip panellit trip can be assured in the event of a plug upstream of the panellit top.

In conclusion it may be pointed out that Specification A-020 giving process tube instability limits, the possibility of a high panellit trip backup is not considered, and a low panellit trip is required for any plug upstream of the panellit tap. The data shows, then, that the procedures outlined in Specifications A-020 offer adequate protection against plugging incidents to a single tube. Furthermore, the data show that there exists, in addition, a high panellit trip backup to protect against plugs upstream of the panellit tap, although this is reduced for the case of a missing rear pigtail in C reactor geometry from that of normal C reactor geometry.

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TABLE I
EXPERIMENTAL RESULTS FOR K REACTOR

Run No.	Initial Conditions					Panellit Pressure, Psig			3 Sec. Before Scram (a)	Time of Scram, (a) Sec.	Max. Rod Temp., °C
	Tube Power, KW	Flow, GPM	Outlet Water Temp., °C	Rod Temp., °C	Flow After Plug GPM	Initial	Min.	Max.			
1	750	27.1	121	180	14.6	104	56	232	--	b	252
2	750	27.4	125	186	11.1	109	51	253	225	19.1	296
3	750	27.8	124	185	8.1	112	31	199	172	8.9	309
4	750	27.9	124	188	3.9	110	40	161	121	6.5	326
5	750	27.2	123	186	12.6	105	61	301	293	32.	273
6	1250	47.5	126	224	40.4	115	92	321	287	54.5	373
7	1250	48.0	126	224	36.4	120	82	323	289	18.4	398
8	1250	49.9	124	221	31.8	120	72	304	275	11.1	438
9	1250	47.7	125	225	25.9	119	68	299	243	8.5	400
10	1250	47.8	125	225	11.7	124	66	266	166	5.1	384
11	1250	47.1	122	223	7.4	124	67	216	136	4.1	388
12	1250	47.8	122	224	3.4	107	36	195	38	3.2	404
13	500	10.2	118	179	4.3	107	44	177	--	b	217
14	500	13.9	120	182	4.9	100	45	180	--	b	222
15	500	16.2	117	181	2.3	91	3	140	105	10.4	272

a. Time of scram is the time from the insertion of the plug to the time of power reduction.

b. These runs reached a stable, boiling, non-burnout, steady state condition.

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TABLE II

EXPERIMENTAL RESULTS FOR C REACTOR

Run No.	Initial Conditions					Panellit Pressure, Psig			3 Sec. Before Scram (a)	Time of Scram, (a) Sec.	Max. Rod Temp., °C
	Tube Power, KW	Flow, GPM	Outlet Water Temp., °C	Rod Temp., °C	Flow After Plug GPM	Initial	Min.	Max.			
1	1270	47.7	116	168	35.2	194	146	258	220	29.5	272
2	1260	44.5	118	164	33.6	194	143	254	249	44.6	324
3	1280	43.8	128	166	15.2	195	82	175	151	4.4	326
4	1260	39.4	139	173	b	186	177	284	267	45.5	348
5	530	19.3	126	145	7.5	61	46	168	--	c	184
6	520	18.8	118	139	4.0	56	35	118	120	25.0	333
7	525	15.6	136	144	b	66	63	156	154	186.0	321
8	1030	36.6	114	158	26.0	148	105	236	--	c	198
9	1030	36.9	114	159	25.0	147	94	318	--	c	261
10	1030	35.7	117	160	2.0	148	44	154	141	8.4	369
11	1050	34.7	121	162	b	152	135	328	331	135	293

- a. Time of scram is from the time of start of insertion of plug to the time of power reduction.
- b. These runs were gradual plug runs. The flow was slowly reduced until self-induced flow reduction started.
- c. These runs reached a stable, boiling, non-burnout, steady state condition.

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Nomenclature of Tables

Q = Initial tube power, KW

F_i = Initial flow, GPM

F_p = Plugged flow (flow immediately after insertion of the plug), GPM

P_{FH} = Front header pressure, psig

$(P_p)_E$ = Experimentally determined panellit pressure, psig

$(P_p)_C$ = Panellit pressure calculated from normal rear pigtail case

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Figure 2. Typical Comparison of Panellit Pressure for K Reactor

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Figure 1. Typical Comparison of Panellit Pressures for K reactor

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Figure 5. Typical Comparison of Panellit Pressures for C reactor

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