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TITLE

INTERIM REPORT, COCKED-SLUG, FLUSH-CHARGING RELATIONS FOR C-PILE CONDITIONS

AUTHOR

P. B. McCarthy

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INTERIM REPORT, COCKED-SLUG, FLUSH-CHARGING RELATIONS FOR C-PILE CONDITIONS

INTRODUCTION

Pile Engineering Sub-Section has been investigating the causes and effects of cocked slugs in process tubes for the past year(1) because they are suspected to be the cause for some slug ruptures. In Project CG-642 - Continuous Charge-Discharge Equipment - C Reactor it is proposed that slugs be flush charged into the process tubes. This document reports the effect of flush charging slugs on their tendency to cock as discovered in laboratory tests.

SUMMARY AND CONCLUSION

In each of 22 out of 23 process tubes that were flush charged at least one and up to three cocked slugs were observed. The one tube that did not have a cocked slug was charged by maintaining a constant flow of 48 gal/min during charging. Cocked slugs took two basic positions with many degrees of severity. In the most common case, one end of the slug lifted, and in the other case the entire length of the slug was lifted as though it had been rolled up on one rib. In most cases cocking was severe.

No method of flush charging tested to date has shown promise of eliminating cocked slugs.

From tests made to date a few general conclusions can be drawn. Some have been previously commented on(1) but not from a flush charging standpoint. These conclusions are:

1. Flush charged slugs have a high incidence of cocking.

2. Flush charged slugs tend to cock near the end of the column more than the center.

3. Cocked slugs remain cocked regardless of flow conditions once they have been well seated by flow.

4. Slugs cock by lifting one end up or by rolling up on one rib.

5. Slugs cocked with one end up form a short column of lifted slugs. Generally this column includes the slug downstream of the cocked slug and possibly the following slug.

6. The end slug (No. 32) appears to be the only slug that cocks with the downstream end up, when flush charged.

7. The severity of cocking in flush charged slugs is much greater than that of flow seated cocked slugs. Most flush charged cocked slugs appear to touch the tube walls.

8. Slug cocking occurred in straight tubes as well as distorted tubes. In straight tubes cocking seemed to occur at random locations while in distorted tubes cocking was observed to concentrate near the downstream end of the column.

9. No cocked slugs were observed ahead of slug No. 14. However, in most cases x-rays were not taken of the front of the column.

(1) HW-41400, "Slug Cocking and Column Bowing Experiments", S. O. Arneson.

10. Movement of the piston at the end of the charge, simulating differential expansion between aluminum tube and Uranium, did not appreciably effect slugs or column bowing.

DISCUSSION

An investigation has been conducted to determine the relations between flush charged slugs in a process tube and cocked slugs in the process tube. Since cocked slugs in a process tube are considered undesirable, an attempt has been made to determine the cause for slugs cocking and how they can be eliminated. All tests have been conducted in the 189-D Building in a C-Pile process tube.

Description of Equipment

Equipment used in flush charging tests consisted of a C-Pile tube flow mock-up, a standard charging machine and seal, a flapper check valve, and an industrial x-ray. The flow mock-up was equipped with adjustments to allow the tube to be distorted to simulate pile conditions.

A standard BDF charging machine with standard seal was used to charge slugs into the tube. Copper tubing allowed water from the nozzle to pressurize the seal and prevent leakage during slug charging. In place of a ball valve, a flapper check valve(2) made by the Western Gear Co. was used. By using this charging equipment solid slugs could be charged against full header pressure.

A hydraulic piston was installed in the rear nozzle cap so that the column could be moved forward and backwards 1/2 inch if full header pressure was maintained. This movement was used to approximately simulate differential thermal expansion between the uranium charge and the aluminum tube.

Regular metal rejected because of minor imperfections was used for most of the tests although special tests were made with anodized, tru-line, and specially machined slugs.

Procedure

Normal charging of the tube was done by inserting the perf pattern from the rear, setting the cap with piston to the desired position, bringing header pressure up to normal and then charging the metal. The piston was usually moved 1/2 inch back soon after charging the tube to simulate differential thermal expansion caused by power generation in the tube.

The tube was x-rayed after changing each condition to determine the effect on the slugs.

In an attempt to eliminate cocked slugs several different methods of charging slugs were investigated. In tube charge No. 21 and No. 22 (Table 1) the flow was maintained constant while the slugs were charged. In charge No. 20 the ends of the slugs were machined flat, and in tube charge No.'s 23, 24, and 25 tru-line slugs were used.

(2) Drawing H-1-5589

[redacted]

Test Results

Using flush charging methods, cocked slugs appeared in all but 1 of 23 tube charges. The greatest majority of cocked slugs, listed in Table I and II, were located near the downstream end of the column. However, cocked slugs were observed up to slug 15, counting from front to rear.

Two basic types of cocked slugs were observed with considerable variation noted in each type. In one type of cocking the end of the slug (usually the can end) cocked up leaving the other end on or near the ribs. The second type of cocking seemed to come from rolling the slug on one r b or lifting it straight up. The surface of the slug in this case was nearly parallel to the tube wall and very close to it. This latter type of cocking is believed to be the most serious since it reduces water flow between the slug and wall over the greatest area. Figures 2, 3, and 4 show varying degrees of this type of cocking.

Cocking with one end up almost invariably occurred with the can or upstream end up. The exceptions occurred mainly at the last slug and were not badly cocked. Frequently, the cocked slug lifted the adjacent downstream slug slightly. Very little effect could be observed on the second slug downstream of the cocked slug. This is illustrated in Figure 4 slug 28 of the middle section.

As illustrated in Figure 1, cocked slugs appear to be held in a cocked position by water flow until the next slug is charged. In the top section of Figure 1, two slugs were charged and the tube was x-rayed showing a cocked slug. One more slug was charged and the tube was again x-rayed. The cocked slug remained cocked.

Unless a cocked slug is located near the end of the charge, it is almost impossible to seat it flat on the ribs again. As shown in Figure 2, No. 30 and 32 slug were discovered cocked. In the middle section with full tube flow, the piston was moved 1/2 inch back with no results, and in the last section the cap was removed and the column flow-seated 3 1/2 inches. The cocked slugs were eliminated by this action. However, previous(1) tests have shown that flow seating also causes cocked slugs, so this would be a poor method of removing cocked slugs.

In some cases, cocked slugs appear to be held cocked by the weld bead on the slug upstream. This is illustrated in Figure 4, bottom section. However, machining the ends of the slugs to produce a flat surface did not remedy the tendency to cock.

Tru-line slugs cocked much the same as regular slugs. To determine the consequence of charging one slug reversed, slug No. 16 was charged backwards. This caused slug No. 16 to cock with the upstream end up. In another test the slugs were charged with the projection (weld end) upstream. Cocked slugs were observed in all tests.

The only charge that did not result in a cocked slug occurred when the flow rate through the tube was maintained at 48 gal/min during charging. This resulted in a front header pressure of 205 lbs/sq in. for the first slug charged

and a pressure of 495 lbs/sq in. for the last slug charged. In another similar test the flow was held at 43 gal/min and slug 31 cocked. By maintaining a constant flow in the tube, most of the slugs move down the tube much slower, and it seems likely that less cocking would occur.

All 32 slugs in one charge were machined with a flat weld surface and then flush charged. It was hoped that the flat surface would form a cushion as the slugs came together, and that even if a slug did cock it would slide back into position since there would be no weld to hold it up. Cocked slugs were observed in this tube after x-rays were taken.

Future Work

Methods to flush charge slugs in process tubes without introducing cocked slugs will continue to be investigated. The potential of Tru-Line slugs has not been throughly explored and it is entirely possible that a slight change in the geometry of these slugs could eliminate slug cocking.

Anodized slugs appear to be worse than regular slugs although no definite conclusions can be reached until several more tests are run. It may be found that different types of anodized surfaces on slugs will reduce cocking.

Since slugs flush charged at the head of the slug column do not cock as badly or as often as slugs charged to the rear of the column, it may be possible to devise an escapment mechanism in the rear nozzle to allow a slug to discharge every time one is charged. In this manner of charging, slugs would flush down the tube about 1/3 or less of the maximum possible distance.

Ribbed slugs, although still in an early stage of development, offer hope of eliminating cocked slugs.

In order to determine how serious cocked slugs are, it would appear advisable in the near future to initiate an in pile test in which a cocked slug would be inserted into a process tube and irradiated. If from such a test it is found that cocked slugs are not as serious as suspected, many design and development problems could be simplified.

Paul B. McCarthy

Mechanical Equipment Development Unit
Pile Technology Section
ENGINEERING DEPARTMENT

PB McCarthy:cac

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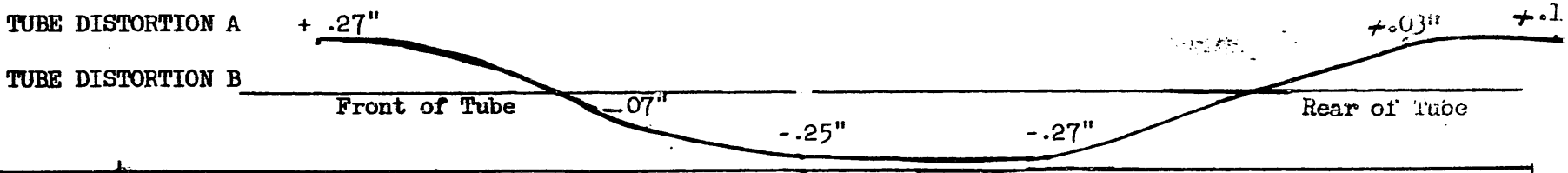
TABLE I

COCKED SLUGS IN A FLUSH CHARGED C-PILE TUBE



CHARGE No.	Metal	TUBE DISTORTION	SLUG NUMBER 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
3	Reg.	A	
4	Reg.	A	
5	Anodized	A	
6	Reg.	A	
7	Reg.	B	
8	Reg.	B	
9	Reg.	B	
10	Reg.	B	
11	Reg.	B	
12	Reg.	B	
13	Reg.	B	
14	Reg.	B	
15	Reg.	B	
16	Reg.	B	
17	Reg.	A	
18	Reg.	A	
19	Reg.	A	
20	Weld Bead Flat	A	
21	Reg.	A	
22	Reg.	A	
23	Tru-Line	A	
24	Tru-Line	A	
25	Tru-Line	A	

(No X-Rays Taken Beyond Arrows)

SYMBOLS:
- - Upstream End (Can) Cocked Up
- - Slug Lifted on Rib
- - Downstream End (Weld) Cocked Up
- - Slug Slightly Lifted Off of Ribs

(1) Very Slight Cocking
(2) Charged with Ends Reversed

TABLE II

FLUSH CHARGED COCKED SLUG DATA

TUBE CHARGE NUMBER(2)	TUBE DISTORTION	FLOW GPM	FRONT HDR. PRESS. PSIG	COCKED SLUG	PISTON(1) 1/2 INCH LOCATIONS	COMMENTS
3	A	78 to 43	410	16,17,29,30	Back	
4	A	" "	"	28,29	Back	
5	A	" "	"	15,16,28,29,32	Back	Anodized Slugs
6	A	" "	"	31,32	Pushed 1/2" Forward	
7	B	" "	"	28,29	" " "	
8	B	" "	"	31,32	Back	X-Rayed after charging-2 slugs Stopped at 8- cut flow Charged, outflow x-rayed)
9	B	" "	"	31,32	Back	
10	B	" "	"	25,26,31	Pushed 1/2" Forward	
11	B	" "	"	22,24,32	Pushed 1/2" Back	
12	B	" "	"	22,29,32	Back	
13	B	" "	"	17,30	Pushed 1/2" Back	
14	B	" "	"	30	Back	
15	B	" "	"	21,32	Pushed 1/2" Back	
16	B	" "	"	23,27,28,31,32	" " "	
17	A	" "	"	31,32	Pushed 1/2" Back	Cut Flow, back 1/2", X-rayed
18	A	" "	"	30,32	" " "	
19	A	" "	"	31	" " Forward	X-rayed after every 1 or 2 slugs
20	A	" "	"	20,21,31,32	" " Back	Welded end Machined flat
21	A	48 to 48	205-495		Back	Constant flow
22	A	43 to 43	172-430	31	Back	Constant flow
23	A	78 to 43	410	32,30,29	"	Tru-Line slugs
24	A	78 to 43	"	32,29,22	"	" " "
25	A	78 to 43	"	32,31,16	"	" " " , slug 16 reversed.

(1) Piston in tube at rear of column could be moved 1/2" forward or back to simulate differential thermal expansion of aluminum tube and uranium charge.

(2) Tube charge No. 1 was not included since an "O" Ring was found in the column after charging. Tube charge No. 2 was not included, since the perf. pattern was not present during charging. Cocked slugs were observed in both charges.

TABLE III

EXPLANATION OF FIGURES

FIGURE	SECTION	COCKED SLUGS	CHARGING	COMMENT
1	Top	31	19	Normal Flush Charge, two slugs charged and tube x-rayed. Full flow during x-rays.
	Bottom	31	19	Same charge after third slug had been charged. Full flow during x-rays.
2	Top	30-32	18	Normal Flush charge. Full flow during x-ray.
	Middle	30-32	18	Same charge. Piston moved back 1/2 inch and the flow was stopped.
	Bottom	-----	18	Same charge. Rear cap removed and column flow seated 3 1/2 inches. Full flow during x-rays.
3	Top	25-26	10	Normal Flush Charge. Column lifting effect on slug No. 26. Full flow during x-ray.
	Bottom	31	10	Same charge and condition.
4	Top	31-32	17	Normal Flush Charge.
	Middle	28	5	Normal Flush charge, anodized slugs.
	Bottom	32	5	Same charge. Anodized slugs.

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