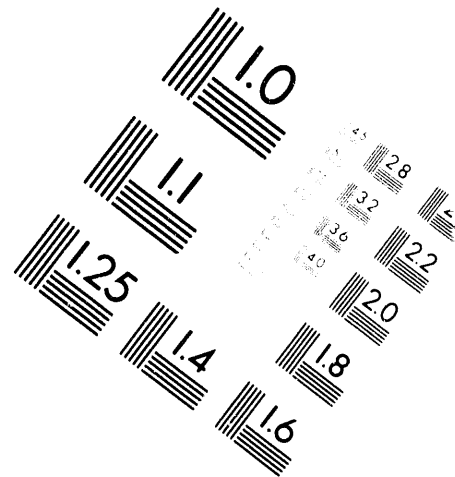
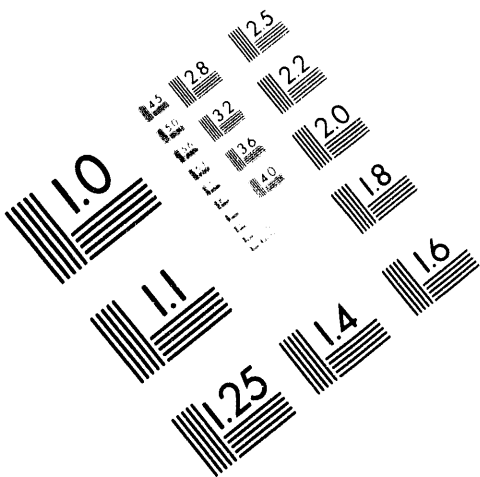




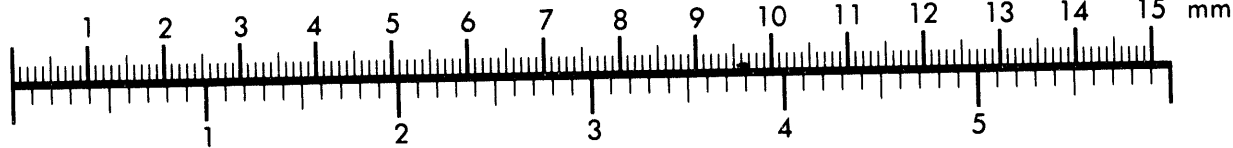
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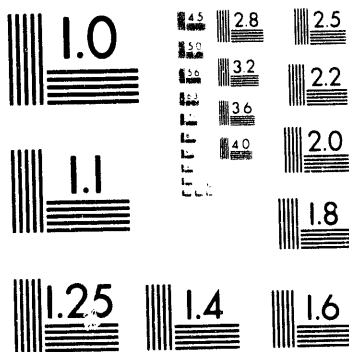
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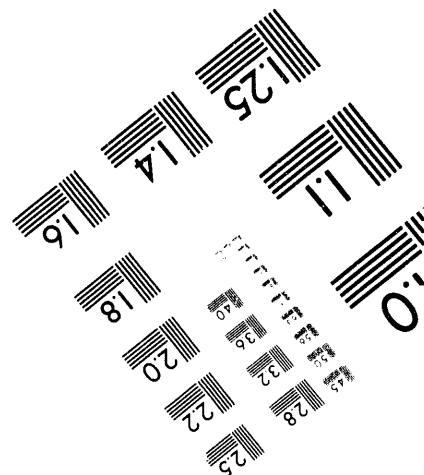
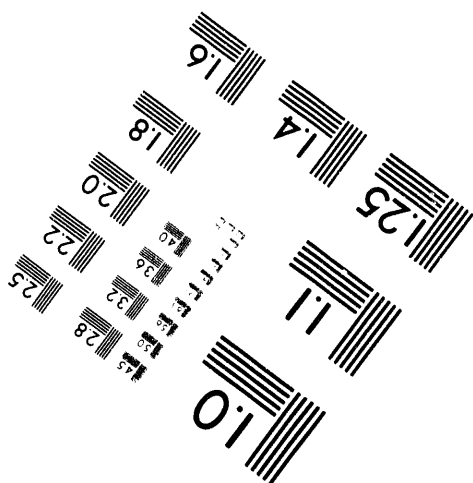
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SLUG COCKING & COLUMN BOWING EXPERIMENTS

AUTHOR
S. O. Arneson

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SLUG COCKING & COLUMN BOWING EXPERIMENTS

INTRODUCTION

A large number of "hot spot" slug failures characterized by intergranular corrosion of the aluminum can have occurred in the past year. The cause of this type of failure may be vertical displacement of one or more slugs in the slug columns. To determine if such displacement may reasonably be expected and to determine the cause and cure of the displacement a set of experiments have been performed in the 189-D laboratory. This document presents data which has been thus far collected.

CONCLUSIONS

1. Slugs which are cocked in a process tube are cause for severe column bowing. Bowing is most severe when the cocked slug is in the downstream portion of the tube. Stopping flow will not realign bowed slugs.
2. Flow seating a slug column can cause slugs to cock and cocked slugs remain cocked even when backseated and the water flow is stopped.
3. When all slugs have undamaged ends and are well aligned with the tube ribs as well as fully seated against the rear nozzle insert, only minor bowing will occur, even when the upstream end of the slug column is restrained.

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4. Anodized pieces behave erratically and in an unexplained manner.
5. Flows as much as 110% of normal do not affect slug column behavior.

BACKGROUND

Many of the slug failures in recent years have been of the "hot spot" type. It has been determined that slug ruptures with the characteristic elliptic film pattern on the can surface, fail through intergranular corrosion of the slug jacket^(1,2). The "hot spot" on most of these failures occurred in the 90° nearest the top of the tube as evidenced by rib marks on the slug can and by corresponding film patterns on the inside of the process tube^(3,4).

A suspected cause for these "hot spots" is, and has been for several years, close proximity of one or more slugs to the wall of the process tube thus reducing cooling water flow in that region, and the attendant reduced heat transfer from the slugs to the coolant water.⁽¹³⁾ It should be noted that process tube slug geometry will allow slug to tube contact only in the top 90° of the tube which is in agreement with rupture examination results. It must be realized that actual contact between slugs and the tube wall may not be a requirement for the "hot spot" failure. The minimum allowable flow annulus adjacent to the slug would logically depend upon 1) the specific slug power, 2) the number of adjacent slugs with reduced flow annulus, and 3) the coolant temperature. Since there are no available data on these questions it must therefore, be assumed that there is a minimum allowable annulus, beyond which intergranular corrosion becomes critical.

The vehicles for the suspected misaligned slugs have been cocked slugs and bowed slug columns. A cocked slug is defined as one which is not in axial alignment with adjacent slugs. A bowed column is one where two or more slugs are lifted from contact with the tube ribs by axial loading of the slug column. A third possible explanation for serious misalignment, discovered by these tests, is in reality a combination of the other two.

Other laboratory tests^(5,6,7), made independently and distinctly different in their method of attack confirm the possibility of both cocking and bowing as likely causes of "hot spot" failures. One of these tests,⁽⁷⁾ reports that the "two separate phenomena existed simultaneously". The tests reported here further confirm their findings.

There has been much evidence that cocking and bowing do occur in pile operation.^(8,9,10) D. E. Strege reports that of seven tubes from C Pile and two tubes from F Pile, all seven C Pile tubes and one F Pile tube showed evidence of cocked slugs. He further states that as many as ten slugs were cocked in one tube. T. L. Deobald reports that in tubes examined from September 1953 to January 1955 sixty-seven per cent of those tubes examined because of ruptures showed evidence of cocked slugs and that thirty-one per cent of those tubes examined for reasons other than ruptures showed evidence of cocked slugs.

On the basis of all the considerations and evidence given above it becomes apparent that cocked slugs may not be serious in themselves but that they may be serious in that they may create situations that are more critical for cooling, i.e. column bowing in any of its forms.

TEST DETAILS

The tests were conducted in a "C" type process tube in the three tube flow mockup

- 3 -

in the 189-D laboratory. The tube was shimmed up every five feet along its length to position: 1) sagging (inadvertantly) a maximum of about 3/16 inch, 2) straight (within 1/32 inch) and, 3) to approximately C Area maximum tube distortion. An industrial type X-ray machine was used to determine slug position (in the vertical plane) in the tube under test conditions. A "C" type rear nozzle insert was modified to form a hydraulic piston behind which water soluble oil was pumped which forced the piston (and slug charge) upstream. Maximum travel was about 5/8 inch. A pressure gage on the oil line enabled calculation of the forces required for movement and the forces exerted on the slug column by process flow.

The mechanism used in those tests where the upstream end was restrained was a 3/4 inch diameter steel rod with a slug diameter button on the downstream end. Two types of buttons were used, one with a flat end and the other with two 1/4 inch long projections on the end and located just above the tube ribs. The latter was intended to simulate unusual rib friction. The upstream end of the rod passed through an O ring seal in a special nozzle fixture and was connected to a load cell. The other end of the load cell was connected by two long bolts to the nozzle fixture. Tightening the bolts increased the axial load on the slug column. The steel rod caused no reduction in tube flow.

A. Sagging Tube Tests

Initial suspension of the tube was by heavy wire from the mockup frame work to allow for film pack placement. The tube was leveled before the tube was loaded with uranium and as a result had a uniform sag of about 3/16 inch maximum when charged. This was not detected until several tests had been run. The tube was hand charged with eight inch regular metal slugs and fully seated against the rear nozzle insert. Cold water flow was then started and increased to 43 gpm, normal "C" Pile flow. The tube was then X-rayed (X-ray beam horizontal). The column was then moved upstream about 1/2" under flow (backseated) and the tube was again X-rayed. Flow was stopped and the tube X-rayed again. This test was repeated several times with tube flows of 43 gpm and with 48 gpm. At no time were any irregularities observed.

The second part of this test was with the upstream end of the charge restrained against forces of up to 1500#. The upstream rod was placed in contact with the slug column and the rear piston was advanced until the front load cell indicated the restraining force. Loading was done under flow (both normal and 48 gpm) and again no misalignment of any kind was observed.

B. Straight Tube Test

As soon as the tube sag was observed the suspension system was changed to one of wooden blocks every five feet along the tube length and the tube was leveled. This method worked satisfactorily and was used throughout the remainder of the test. The tests were repeated exactly as had been done with the sagging tube and again no irregularities of any kind were observed in the slug alignment.

C. Distorted Tube Test

1. Regular Slugs

In this test the tube was blocked to the approximate distortion of tube 4674C (12). As before the tube was hand charged and seated against the rear nozzle insert. The same procedure was followed as in previous tests with regard to flow, backseating and X-raying. The tests were repeated and yielded no bowing except on one run when

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a slug was loaded in the column (Slug No. 7 from the upstream end) with a damaged end cap. The slug had a small projection on the downstream end which was probably caused by striking against another slug as the slugs were flushed from the tube after a previous test. In this instance water flow alone caused severe bowing of the column lifting five downstream slugs off the ribs and causing the damaged slug and the next slug upstream to be raised in a straight line at some angle with the tube axis. Restraining the column axially made both bowing and what was subsequently called the "short column effect" more severe. In this test the small projection on the slug end cap was at 8 o'clock as viewed from the cap end.

Since the damaged end cap resulted in eccentric axial loading of the column the next series of tests was designed to determine the effects of this type of loading from causes suspected to occur in-pile i.e. cocked slugs.

A thick coating of a water soluble glue was smeared one end of a slug which was then charged into the tube in various column positions and the rest of the tube was charged and seated. When the flow was started the glue rapidly dissolved leaving a fully cocked slug as might occur in-pile. The tube was X-rayed under flow with and without backseating.

When the cocked slug was placed in the downstream half of the tube serious column bowing resulted (as much as 0.040 inches where the maximum possible is 0.090 inches) downstream of the cocked slug. This was under conditions of 43 gpm flow and a 1/2 inch backseat during flow. Bowing magnitudes were, in general, independent of which end of the slug was cocked up. With the cocked slug in the upstream portion of the tube there was some bowing but the amount of misalignment was very small in all cases.

In addition, with the cocked slug in the downstream portion of the tube, another phenomenon resulted. Besides downstream column bowing, the cocked slug and one or more adjacent slugs raised up in a straight line bridging between the downstream end of the cocked slug and the next undisturbed upstream slug. (Figure 1-4,6) The resulting annulus above the cocked slug was very nearly zero. It must also be pointed out that since these results were observed from X-rays taken showing only the vertical plane of the tube, it is entirely possible that while some annulus above the slug was visible, the slug might have been in complete contact with the tube wall, lying on only one rib. (Figure 9) The "short column effect" described above became more severe the farther downstream the cocked slug was placed. Backseating under flow was not necessary to produce the effect but it did make it more serious. Restraining the column on the upstream end did not appear to aggravate the lifting. The lifting effect was minor when the cocked slug was in the upstream half of the tube.

A series of tests was run to determine possible causes for slug cocking in the tube. The charge was loaded into the tube in the same manner that is presently employed at the reactors; i.e., the last two to four inches of slug movement is accomplished by increasing water flow and causing the slugs to wash downstream and seat against the rear nozzle insert. The distance flow seated and the rate of flow increase were the variables in question. It was found that cocked slugs resulted from flow seating a distance of three or four inches when flow was started and brought to normal over a period of about 60 seconds. (Figure 5,7,8) Cocking magnitudes were small, (as observed on the X-rays) on the average about .020 inches misalignment and cocking appeared to be randomly distributed in the slug column with as many as 4 or 5 slugs cocked.

The amount, manner and location of cocking varied from one test to the next. Slugs flow seated were cocked, generally, with the can end high, although one test resulted in cocking with the cap end high and causing the same lifting found with

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intentionally cocked slugs. To date 11 tests have been made. In all but 3 of these tests it would appear that the cocking that resulted would have been insufficient to cause slug ruptures. In the other tests cocking was more severe and the resulting reduction in annulus might have been sufficient to cause the slugs to rupture had they occurred in-pile. Although a fully cocked slug was not observed in these tests it would be reasonable to expect that a sufficient number of laboratory tools would produce such effect.

A Development Test⁽¹¹⁾ is now in progress at DR Pile, designed to determine the effect of flow seating on intergranular corrosion type ruptures.

2. Anodized Slugs

Tests similar to those performed with regular slugs in the distorted tube were also made with eight inch anodized pieces to compare their behavior with regular slug behavior under similar conditions. In general, anodized slug behavior was erratic.

It was found that fully seated anodized slugs can bow severely under only the action of process flow. Backseating only makes bowing more severe. The addition of an intentionally cocked slug produces bowing of 60-70 mils. However, anodized slugs were less prone to cock when flow seated.

3. General Results

The tests showed a number of tendencies independent of slug type, i.e.:

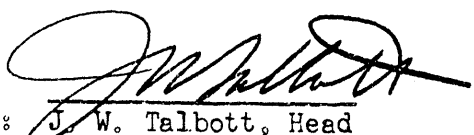
- a) A slug which is cocked remains cocked regardless of any backseating and flow manipulations. Not one cocked slug returned to alignment through backseating and/or flow stoppage.
- b) When column bowing occurs backseating and/or flow stoppage will not correct this form of misalignment.
- c) Flows as much as 110% of normal do not affect slug behavior.
- d) Forces of about 1000# are required to move a regular slug charge upstream under flow, and 400# is required for the same operation without flow. For anodized slugs the corresponding values are about 825# and 300#.



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Development Unit
Pile Technology Section
ENGINEERING DEPARTMENT

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Approved: J. W. Talbott, Head
Mechanical Equipment
Development Unit
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TABLE 1 - BOWING TEST RESULTS

<u>Slug Type</u>	<u>Flow (GPM)</u>	<u>Cocked Slug No.</u>	<u>End Cocked</u>	<u>Amount (Mils.)</u>	<u>Bowed Slug No.</u>	<u>Amount (Mils.)</u>	<u>Lifted Slug No.</u>	<u>Backseat Under flow</u>	<u>Remarks</u>
Regular	43	None	-----	-----	None	-----	None	1/2"	Backseated to upstream restraint of 1500# and repeated several times.
Regular	47	None	-----	-----	None	-----	None	1/2"	Repeated several times.
Anodized	43	17,30	can	20	31,32 4,5,7,8 25,26	40 10 20	None	No	Charge hand loaded and fully seated.
Anodized	43	17,30	can	20	31,32 4, 5 7,8,20-23, 25-29	60 50 20 30	None	1/2"	This is the same test as above after backseating.
Regular	43	7*	cap	90	None	-----	None	1/2"	
Regular	43	13*	cap	90	None	-----	None	1/2"	
Regular	43	17*	can	90	None	-----	None	1/2"	
Regular	43	19*	cap	90	21-30	30	18-19	1/2"	Bowed slugs probably on one rib.
Regular	43	19*	cap	90	20-27	20	16-19	1/2"	Bowed slugs probably on one rib.
Regular	43	19*	cap	90	20-27	40	16-19	1/2"	Backseated to 500# restraint.
Regular	43	22*	can	90	24-26	40	22-23	1/2"	
Regular	43	26*	cap	90	None	-----	23-26	1/2"	
Anodized	43	19*	can	90	None	-----	None	1/2"	
Anodized	43	19*	cap	90	None	-----	None	1/2"	
Anodized	43	23*	cap	90	24-27	40	21-23	1/2"	
Anodized	43	23*	cap	90	4-6,9,10 17,18	20 60	21-23	1/2"	

NOTES: All slugs are numbered from the upstream end of slug charge. Maximum bowing or cocking possible is 90 mils.
* Slug intentionally cocked with water soluble glue.

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TABLE 2 - FLOW SEATING TEST RESULTS

<u>Slug Type</u>	<u>Flow Seat Distance (Inches)</u>	<u>Cocked Slug No.</u>	<u>Amount (Mils.)</u>	<u>End Cocked Up</u>	<u>Bowed Slug Nos.</u>	<u>Amount (Mils.)</u>	<u>Remarks</u>
Regular	1	None	-----	-----	None	-----	
Regular	2	2,9,13,27, 32	10	can	22-24	10	
Regular	3	None	-----	-----	None	-----	Flow started very rapidly.
Regular	3	2	30	can	None	-----	
Regular	3	26 28	30 30	cap can	None None	----- -----	Slugs 25,26 lifted.
Regular	3	3,15,28	10	can	24-27	10	
Regular	3	17,27,28	10	can	None	-----	
	3	17,23 28	10 50	can can	21-23 27,28	20 40	
Regular	4	18,29	20	can	None	-----	
Regular	5	28	5-10	can	None	-----	Cocking almost insignificant.
Regular	8	2,16,29	10	can	26,27	10	Cocking almot insignificant.
Anodized	4	16,28	20	cap	8-10,23-26	20	
Anodized	4	16,24	20	can	3-7,25-28, 31, 32	20	
Anodized	4	18	20	can	4,5 8,9, 24-29 16-18	40 30 20	Backseated $\frac{1}{2}$ " underflow

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1. Groot, C., and Ryan, J. L., "Low Exposure Failures and Intergranular Corrosion", HW-40252, 11/29/55.
2. Groot, C., "Intergranular Corrosion of Fuel Elements", HW-38834, 8/22/55.
3. Jacky, G. F., "Low Exposure Slug Failures: Associated Factors and Hypothesized Causes", HW-38629, 7/29/55.
4. Deobald, T. L., "Process Tube Examination at 108-B Through February 1953", HW-27723, 4/20/53.
5. Call, R. L., "Interim Report, Slug Column Bowing Tests", HW-38809, 7/7/53.
6. Call, R. L., "Final Report - Slug Column Bowing Tests and PT-105-558-A, Determination of Slug Column Forces and Movement", HW-34858, 2/2/55.
7. Morris, W. J., "Final Report, Continuous Charging Studies", HW-29448, 9/25/53.
8. Strege, D. E., "Interim Report, Production Test 105-522-E Examination of Pile Process Tubes Removed from 100-B, 100-D, 100-H and 100-F Piles", HW-38280, 7/25/55.
9. Deobald, T. L., "Evidence of Slug Cocking Observed in Process Tube Examination", HW-35924, 3/25/55.
10. Cooke, J. P., "Slug Cocking at KW, Comments on Results of Sighting Through 600 Tubes", Confidential Undocumented, 2/17/55.
11. Arneson, S. O., and VanWormer, F. W., "Development Test 105-623-A, Relation Between Hand and Flow Seating of Slug Charges as they Affect Slug Rupture Rates", HW-41400, 2/13/56.
12. Personal Communication with J. C. Fox.

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RAISED ↗

RAISED ↗

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19

NO FLOW
"C" TUBE

FIG 1
GLUE
COCKED ↗

19

NORMAL
FLOW →

FIG 2

19

NORMAL FLOW
BACKSEATED $\frac{1}{2}$ "
UNDER FLOW²

FIG. 3

19

FLOW STOPPED

FIG. 4

FLOW
TUBE

FIG 1
GLUE
COCKED ↗

#20

FIG. 1-4
ARE ONE
TEST

ORMAL

FIG 2

#20

W →

ORMAL FLOW
SEATED $\frac{1}{2}$ "
ER FLOW $\frac{1}{2}$ "

FIG. 3

#20

STOPPED

FIG. 4

#20

#26

#27

#22

GLUE COCKED

DECLASSIFIED

#25

#25

#26

#28

3" FLOW

RAISED)

#23

NORMAL FLOW →

↖ SLUG RAISED

DECLASSIFIED

#26

NORMAL FLOW →

3" FLOW SEAT

#27

NORMAL FLOW →

3" FLOW SEAT

#27

LOW SEAT → COCKED 29

#24

#25

DECLASSIFIED

#27

COCKED → #28

PG. 10

COCKED ↗ #29 ↗
BOWED

FIG

COCKED

29

FIG. 5

#25

FIG. 6

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COCKED

#28

FIG. 7

PG. 10

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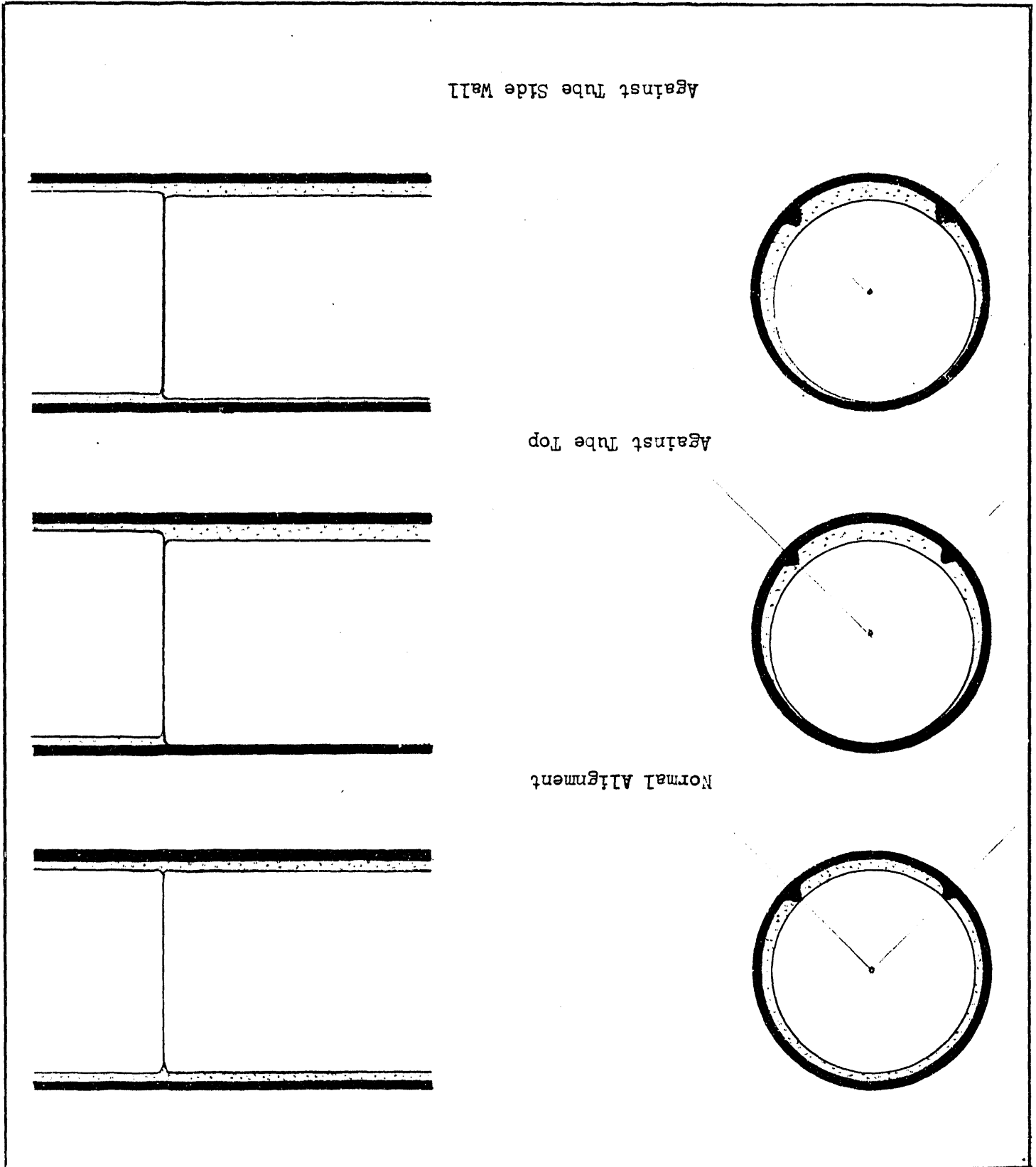
COCKED

#29

BOWED

FIG. 8

Figure 9 - Possible Slug Orientations as Interpreted by X-Rays in the Vertical Plane



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