NORTHEAST UTILITIES

THE CONNECTICUT LIGHT AND POWER COMPANY
THE HARTFORD ELECTRIC LIGHT COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

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March 1, 1982

Docket No. 50-336
B10445

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US NUCLEAR REGULATORY COMMISSION
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Director of Nuclear Reactor Regulation
Attn: Mr. Robert A. Clark
Chief Operating Reactors Branch #3
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

References:
(1) W. G. Counsil letter to R. A. Clark, dated October 15, 1981.
(2) E. J. Mroczka letter to R. C. Haynes, dated December 28, 1981.
(3) W. G. Counsil letter to R. A. Clark, dated January 12, 1982.
(4) W. G. Counsil letter to R. A. Clark, dated February 5, 1982.
(5) W. G. Counsil letter to R. A. Clark, dated February 4, 1982.
(6) W. G. Counsil letter to R. A. Clark, dated February 19, 1982.

Gentlemen:

MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2
STEAM GENERATOR OVERVIEW

A meeting was held with the NRC Staff in the Bethesda Offices on February 16, 1982 to discuss the Millstone Unit No. 2 steam generators. The purpose of this letter is to document the information and conclusions presented during the February 16 meeting as well as to summarize the correspondence to date concerning steam generator inspections and integrity.

In accordance with Technical Specification requirements and those commitments in Reference (1), Northeast Nuclear Energy Company (NNECO) initiated in-service inspections of both steam generators at Millstone Unit No. 2 during the current refueling outage. Preliminary inspection results as reported in Reference (2) indicated an elevated frequency of eddy current indications in the steam generator tubes between the tube sheet and the first support. Eddy-current indications are defined as greater than 20% tube wall degradation. Pursuant to Technical Specification 4.4.5.1.2, NNECO expanded the steam generator tube sample to include all tubes in both steam generators. NNECO provided the Staff

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with an evaluation of the eddy-current indications in Reference (3), concluding that the indications identified at Millstone Unit No. 2 were pits. Included in Reference (3) was a request to amend the Millstone Unit No. 2 Operating License to limit the eddy-current inspections to those areas of the steam generator tube bundle affected by the pitting phenomenon. NNECO performed eddy-current examinations on a representative portion of the steam generator tube bundle which defined the affected area.

NNECO also performed limited eddy-current examinations with an experimental (A600) probe designed to facilitate discrimination between tube imperfections and the effects of the high conductivity deposits known to exist near the tube sheet. The results of these limited inspections enhanced the ability of the eddy-current analysts to identify small volume defects (pits) in the presence of high conductivity sludge. Attachment 1 presents raw data obtained with the experimental A600 probe as compared with data taken with the standard multi-frequency eddy-current probe. Details of the examination and analysis techniques with the A600 probe were provided to the Staff at the February 16 meeting. A comparison between the results obtained with the A600 and standard probes is presented in Attachment 1.

To provide further assurance that the degradation phenomenon has been accurately characterized as well as to confirm the validity of the eddy-current measurements, NNECO pulled three (3) tubes from the cold leg of Steam Generator No. 1. The tubes were selected based on the information which was desired and included various pit sizes and locations as determined by eddy-current measurements.

Preliminary tube examinations have been conducted which confirm the validity of the eddy-current results obtained at Millstone Unit No. 2. A more comprehensive metallurgical analysis and evaluation will be conducted on all three pulled tubes. In addition, sludge samples have been obtained from the secondary side of Steam Generator No. 1. These samples will be analyzed by X-ray fluorescence and X-ray diffraction techniques to determine its composition.

Revised maps of the sludge deposits have been prepared from the eddy-current information. These have been provided to the Staff in Reference (4). The maps illustrate the tendency for the sludge to build up in the interior portions of the tube bundle with lower levels on the periphery. The number and location of defective tubes can be correlated to the existance of sludge.

Steam generator tube maps identifying all indications greater than 20% through wall tube degradation were provided to the Staff in Reference (4). These maps clearly illustrate the area of the tube bundle affected by the pitting phenomenon.

NNECO evaluated several corrective measures for implementation during the current outage. It was decided that all tubes indicating a degradation of greater than or equal to 40% by eddy-current would be removed from service. These tubes have been plugged with a mechanical plug which can be removed at a later time. This affords the opportunity to perform corrective measures at a future date, such as sleeving, which do not render the affected tube inoperable. Details of the mechanical plug utilized were presented to the Staff at the February 16, 1982 meeting.

Analyses as well as tests have been performed to support continued plant operation. Analyses were performed in accordance with the guidance and requirements of Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes." The test program consisted of artificially manufacturing defects, eddy-current testing, burst testing, and in some cases, leak testing tubes equivalent to those used in the steam generators at Millstone Unit No. 2.

Loadings on defective tubes which are considered pursuant to Regulatory Guide 1.121 are:

1. Normal operating loadings
2. Margin between differential pressure across tube wall during normal operation and burst pressure (normally a factor of 3)
3. Concurrent pipe break accidents and safe shutdown earthquake loadings
4. Fatigue effects of cyclic loadings

As an added conservatism for analytical purposes, it was assumed that the steam generator tubes have experienced uniform wall thinning. Individual pit type defects will have a substantially smaller effect on tube strength. The results of these analyses demonstrate that all criteria for safe plant operation including all required factors of safety, as set forth in Section III of the ASME Boiler and Pressure Vessel Code, are maintained for the tubes remaining in service.

Normal operation was determined to be the limiting condition with respect to Code allowable stresses. The tube span between the tubesheet and the first support elevation is not significantly loaded during either pipe break accidents or the safe shutdown earthquake because of the location, geometry and the end support conditions for the steam generator tubes. Only those portions of the tubes in or near the U-bend region of the steam generator are subject to rarefaction wave, centrifugal force or structural response loads caused by LOCA loads, or high flow loads caused by a a steam line break. Seismic loads tend to be small in the lower portion of the steam generator due to the rigidity of the primary coolant pipes at Millstone Unit No. 2. In addition, tube spans in the affected area of the steam generator are very stiff due to the relatively short span length and the method of attachment to the tubesheet. The higher allowables for stress during seismic and accident conditions more than offset the additional mechanical stress contribution of the events.

Since U-tubes are relatively free to expand during thermal transients, no significant thermal cycling stress occurs. Vibratory stresses due to cross-flow are negligible in the area of the tubesheet where the pitting phenomenon has been identified.

Therefore, considering normal operation as the limiting condition a factor of safety of greater than 3 exists between normal operating differential pressure and the calculated burst pressure for tubes remaining in service.

As was noted above, a steam generator tube burst test program was conducted to substantiate the analytical results. The tube burst test matrix and results are provided in Attachment 2. This program was structured to specifically address the type of pitting imperfections identified at Millstone Unit No. 2.

The results of the burst tests demonstrate the conservatism inherent in the analytical approach used to justify the proposed tube plugging limit. The burst tests demonstrate additional operational margin beyond that identified by the conservative analytical results. Burst testing was performed on a tube sample removed during the current refueling outage. The pressure required to induce failure of the tube sample was in excess of 9,000 psi providing futher evidence of the integrity of the steam generator tubes at Millstone Unit No. 2.

Safety analyses have been reviewed in light of the additional plugged steam generator tubes. The results of these reviews were provided to the Staff in Reference (5). The large break LOCA scenario has been reanalyzed. The results of this analysis demonstrate that all acceptance criteria of 10 CFR 50.46 are met. The results of this analysis were provided in Reference (6).

In the event that through wall tube degradation occurs in any tube remaining in service, a pin hole tube leak would result. The consequences of such leakage are readily detectable by existing primary-to-secondary leak detection methods at the plant. Prompt corrective action upon detection of primary-to-secondary leakage (limited to 0.5 gpm per steam generator) is required by Technical Specifications 3/4.4.6.2 and 4.4.5.1.3.c. Primary-to-secondary leakage is detected by monitoring radiation levels in the steam generator blowdown. In addition, condenser air ejector effluent is continuously monitored for radiation which would be indicative of a primary-to-secondary leakage. Leak detection methods can accurately detect primary-to-secondary leakage of 0.01 - 0.05 gpm. per steam generator.

Leak rate tests performed on tubes after experiencing failure pressures demonstrate that potential leak rates in failed tubes remain below Technical Specification allowables. This information is provided in Attachment 2.

In addition, the Attachment 2 information illustrates the leak rates which one would expect for different through-wall pit diameters. This data demonstrates that leakage from large diameter pits (approximately 1/8 inch) at system operating pressures can be adequately handled by plant makeup systems if required. It is noted that the largest diameter pit identified at Millstone Unit No. 2 was approximately 60 mils. The expected leak rate from a pit this size is about 2 gpm. The leak rate tests also demonstrate leak stability. This is expected since the steam generator tube material, Inconel 600, is very resistant to flow induced erosion.

Visual inspections of the steam generator secondary side have been performed. The inspection verified that the gap between the upper tube support plate and the wrapper (which was created by the "rim cut" during the November 1977 outage) was still present. In addition, visual portions of the first egg crate continued to retain their "as built" geometrical appearance, as has been the case in previous outage inspections. In some cases, corrosion products associated with denting, were apparent. Lastly, no loose parts were observed. The visual inspection results confirm the acceptability of the steam generators for continued operation.

NNECO's record to date illustrates its concern for safety with regards to steam generator performance at Millstone Unit No. 2. Efforts to maintain steam generator integrity include the installation of a full flow condensate polisher, profilometry inspections, tube removal, rim cut, and preventive tube plugging. In this instance, however, it is NNECO's assertion that the pitting experienced at Millstone Unit No. 2 is an operational concern and not a safety concern. The analyses results provided herein demonstrate that all Code requirements are maintained including additional operating margin. These analyses were performed pursuant to the guidelines delineated in Regulatory Guide 1.121. Burst test data further substantiate the analytical results and demonstrate that through wall tube degradation up to 88% for axially aligned pits can be tolerated without violating ASME Code guidelines.

In summary, NNECO maintains a high degree of confidence in the adequacy of the eddy-current results obtained during the recent inspections at Millstone Unit No. 2. Prudent measures have been taken to both determine the cause of the steam generator tube degradation and to ensure continued operability of the steam generators. These measures included tube pulling sophisticated eddy-current examinations and tube plugging. All tube plugging, to date at Millstone Unit No. 2 has been preventive. No tubes have been plugged to mitigate primary to secondary leakage. Additional corrective measures are currently being evaluated by NNECO for implementation during future outages. These include sleeving, chemical cleaning, and sludge lancing. NNECO intends to continue its participation in the Steam Generator Owner's Group I and has been instrumental in organizing Steam Generator Owner's Group II.

Currently, NNECO intends to commence plant heatup on or about March 5, 1982. The staff will be promptly apprised of any changes to this schedule as well as any new developments regarding the steam generators through the Millstone Unit No. 2 Project Manager.

We trust you find this information sufficient to concur with our conclusions.

Very truly yours,

NORTHEAST UTILITIES SERVICE COMPANY

W. G. Counsil

W. G. Counsil
Senior Vice President

Table 1

Millstone Unit No. 2

Steam Generator Eddy-Current Test Results

1981/1982

Number of Imperfections	Steam Generator No. 1	Steam Generator No. 2
≥ 40%	424	280
< 40%	250	75
Total	674	355

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Attachment 1

Millstone Nuclear Power Station, Unit No. 2

Additional Handouts Presented on February 16, 1982

March, 1982

MP2, S.G. NO. 1, CL, SPECIAL

PROBE STUDY OF 20 TUBES

TUBE, LINE/ROW	FIRST EXAMINATION (STD. PROBE) DEFECT		A 600 HFWF DEFECT		SECOND EXAMINATION (STD. PROBE) DEFECT	
	%	LOC.	%	LOC.	%	LOC.
63/63	NI	-	NI	-	NI	-
63/61	NI	-	73	4 ATS	62	4 ATS
63/59	56	4 ATS	47	4 ATS	33	4 ATS
64/66	NI	-	NI	-	NI	-
64/62	63	7 ATS	80	6 ATS	71	6 ATS
64/54	DTS	0 ATS	81	5 ATS	84	5 ATS
66/52	DTS	-	81	5 ATS	52	5 ATS
66/50	DTS	-	NI	-	NI	-
67/59	74	6 ATS	73	5 ATS	74	5 ATS
67/57	NI	-	81	5 ATS	85	5 ATS
67/55	58	2 ATS	88	5 ATS	88	5 ATS
67/53	53	5 ATS	66	5 ATS	77	5 ATS
67/51	NI	-	NI	-	NI	-
68/60	95	6 ATS	96	6 ATS	94	6 ATS
68/58	NI	-	83	5-7 ATS	79	5-7 ATS
68/56	NI	-	NI	-	NI	-
68/54	NI	-	83	5 ATS	80	5 ATS
68/52	32	0 ATS	38	0 ATS	29	0 ATS
			79	5 ATS	79	5 ATS
69/53	DTS	-	NI	-	NI	-
71/55	27	0 ATS CL	28	0 ATS	27	0 ATS

ECT DEFECT SUMMARY

FLAWS ALWAYS BELOW CONDUCTIVE "SLUDGE"

NO FLAWS IN LOW "SLUDGE" AREA

FLAWS LOCATED 0-10 IN. ATS

HEAVIEST CONCENTRATION OF FLAWS IN CL

FLAW LOCATION IN ONE AXIAL POSITION

ECT GEOMETRY: ~1/8 INCH PIT

DEFECTED TUBES (≥ 40%)

- 424 S.G. NO. 1
- 280 S.G. NO. 2

SEVEN (7) LARGE DEFECTS TOTAL (≥91%)

~27,500 TUBE TESTS (BY PLENUM)

~13,500 TOTAL TUBE TESTS

CORRELATION OF DT, ECT AND BOROSCOPE RESULTS

TUBE	EDDY CURRENT			DEST. EXAM		BOR. EXAM. SLUDGE HEIGHT, IN. ATS
	%	LOC. IN. ATS	SLUDGE HEIGHT IN. ATS	%	LOC. IN. ATS	
64/54	81	5	6-8	77	5	-
68/58	83	5-7	6	-	5-7	9
109/63	28	4 ATS	6-8	-	4	7
	25	0 ATS	6-8	-	0	7

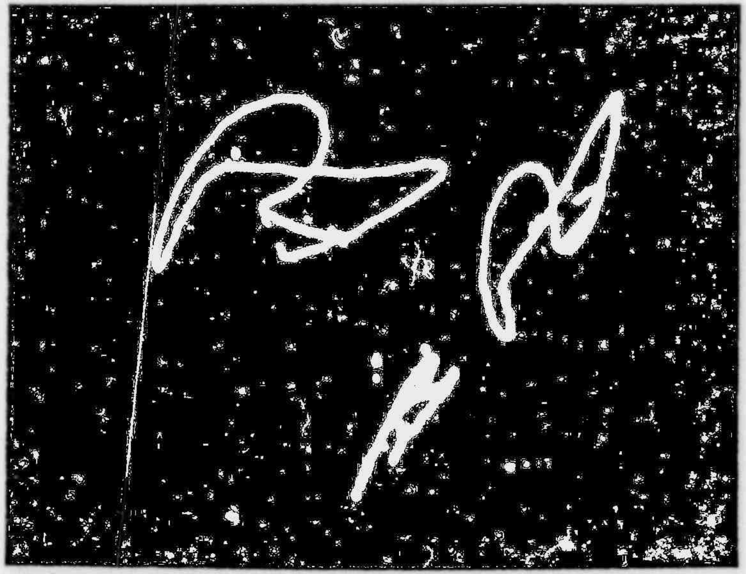
L63R59 C.L. #1 1V/DIV 4"ATS

33% 400K MIX 200K R76C-099

L63R59 C.L. #1 8/6 1V/DIV 4"ATS

U.M. U.M. 131T

R63R59C.L. #1 1V/DIV 4"ATS



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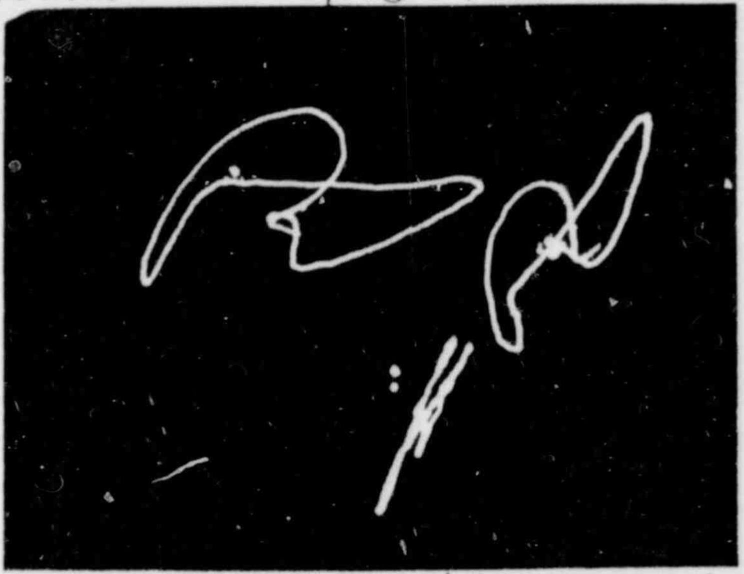

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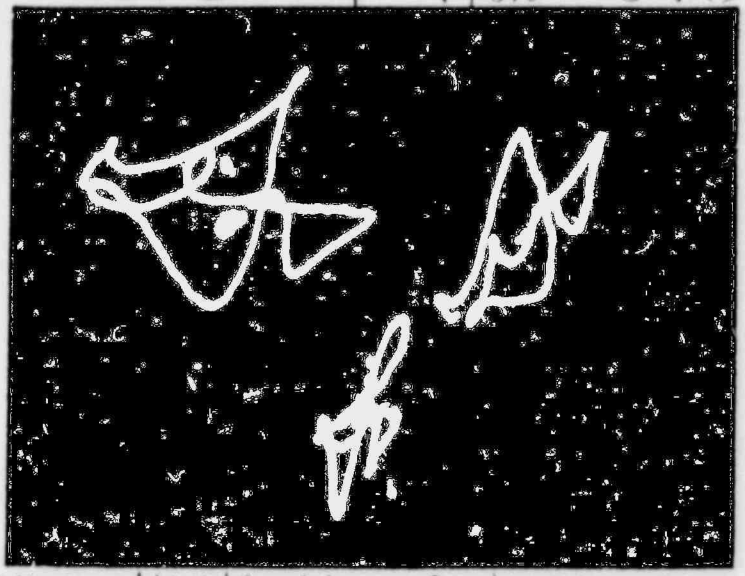

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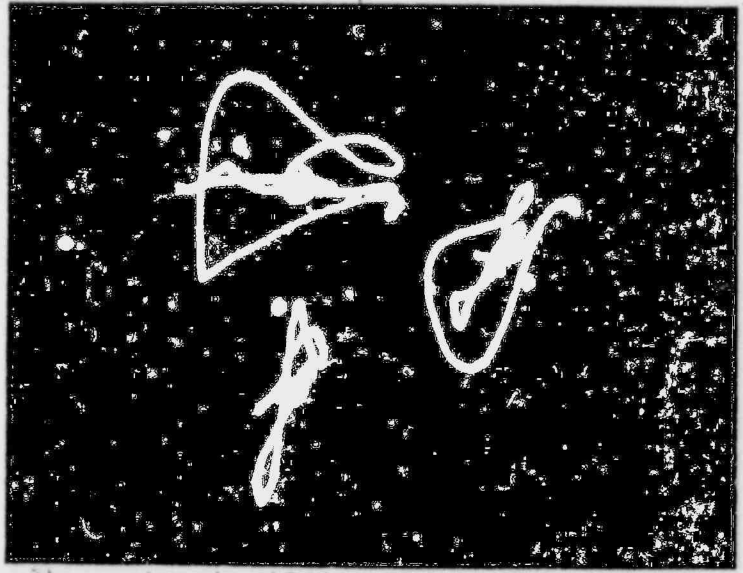

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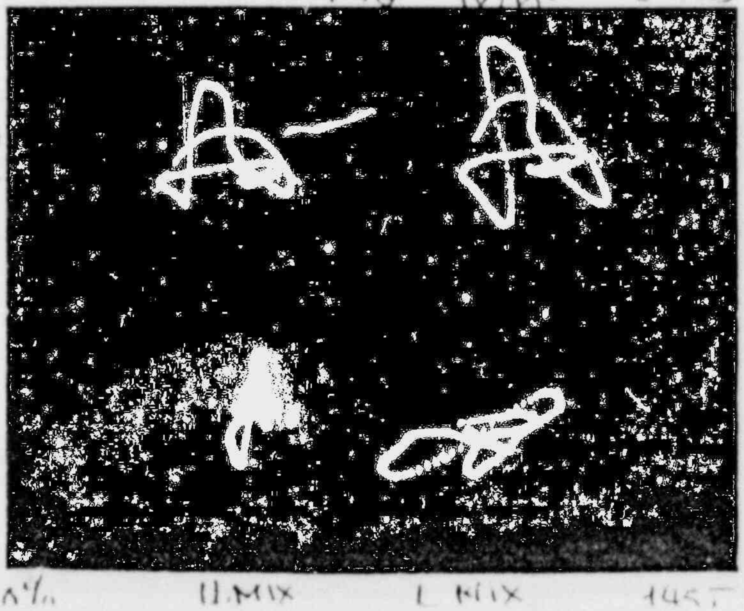
400K



200K

70% H.MIX L MIX 145T

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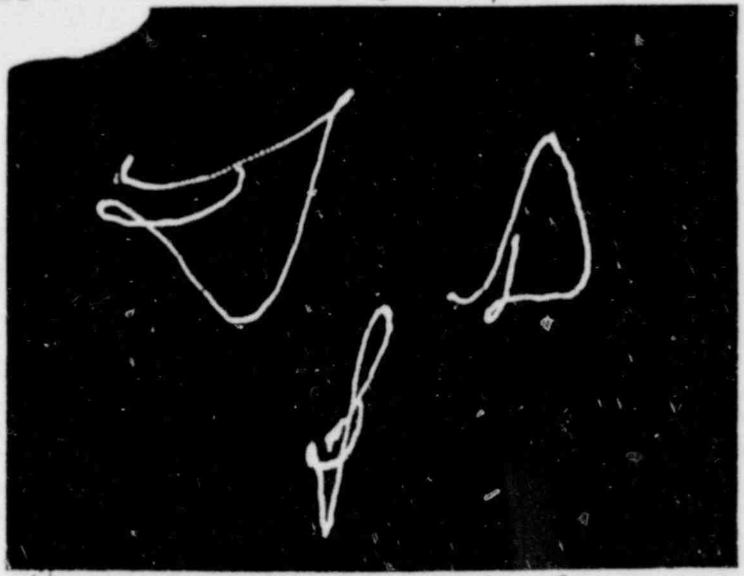

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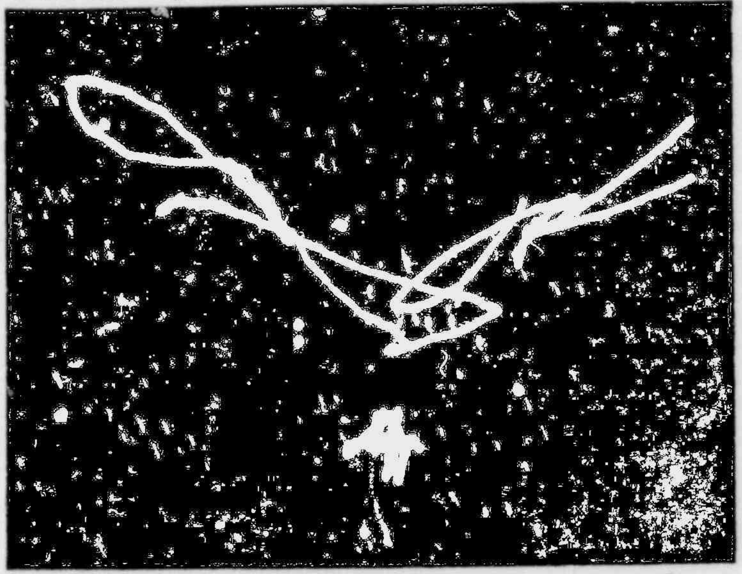

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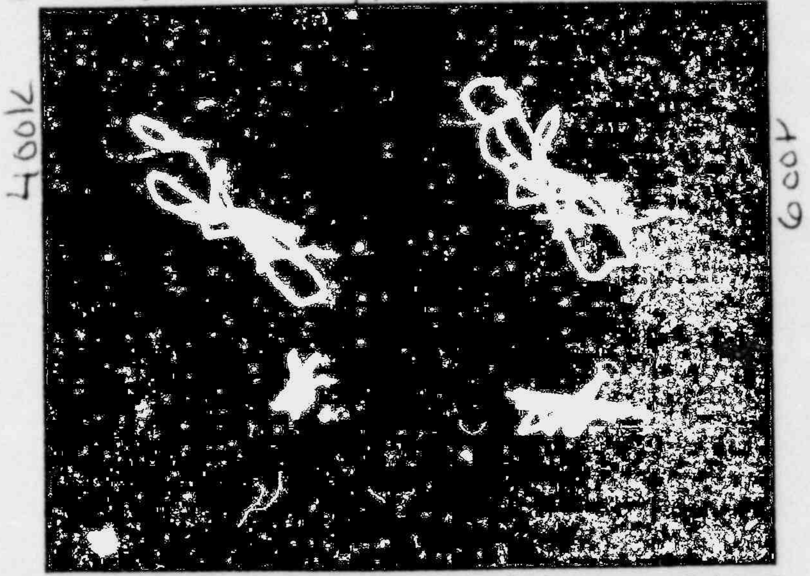

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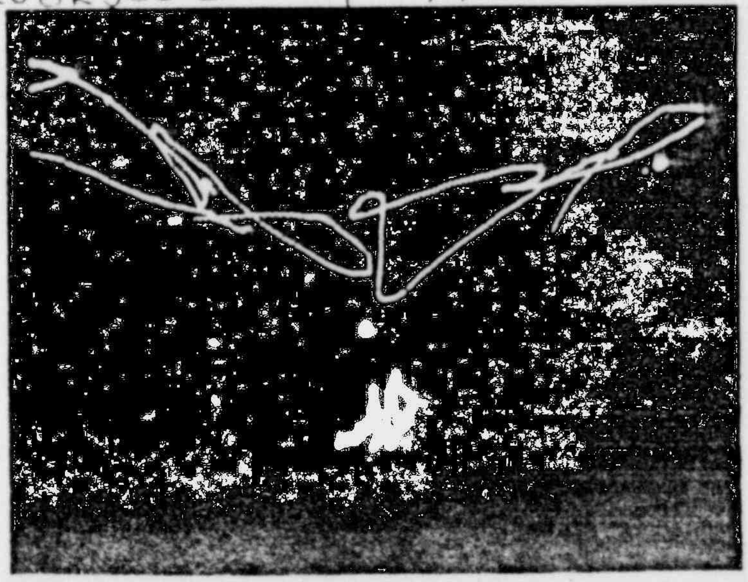

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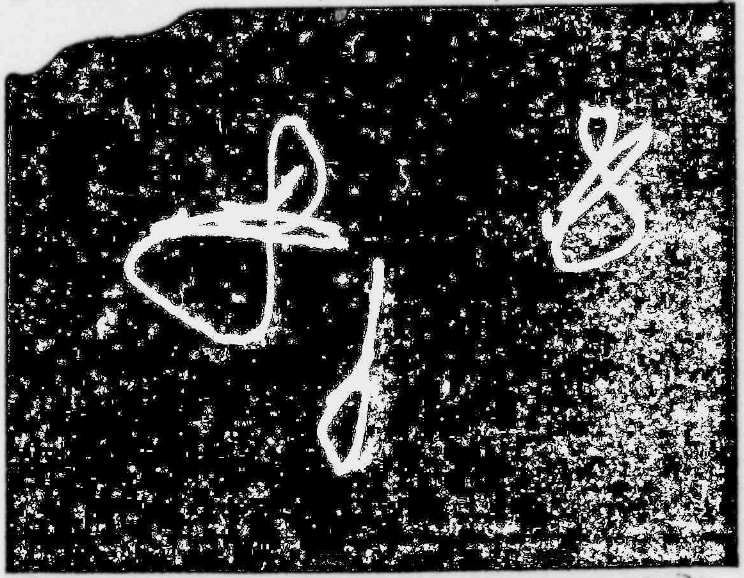

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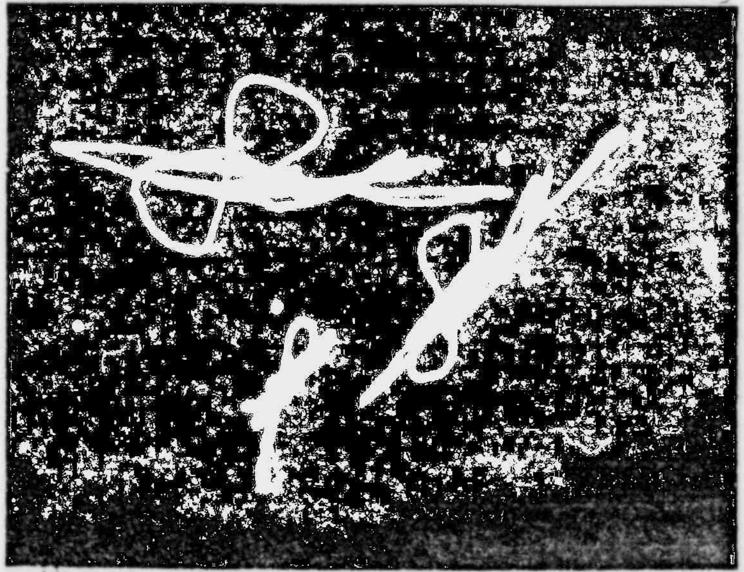

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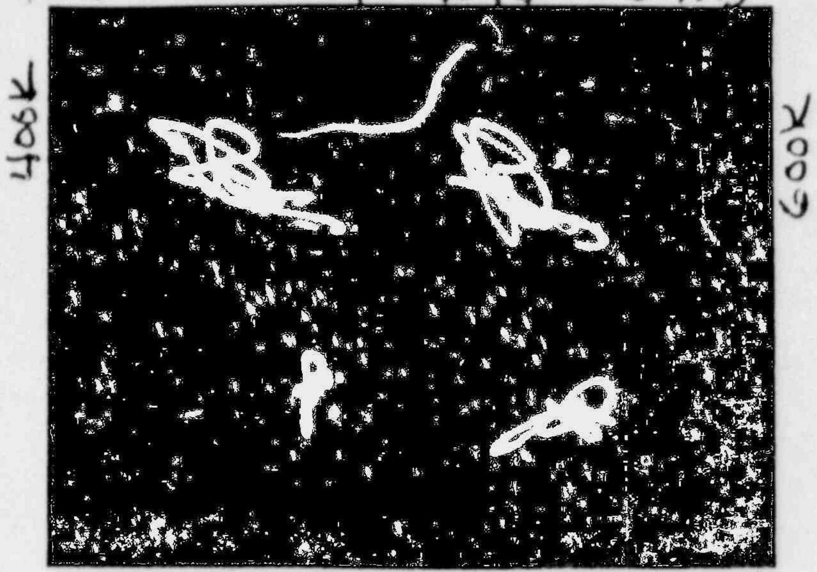

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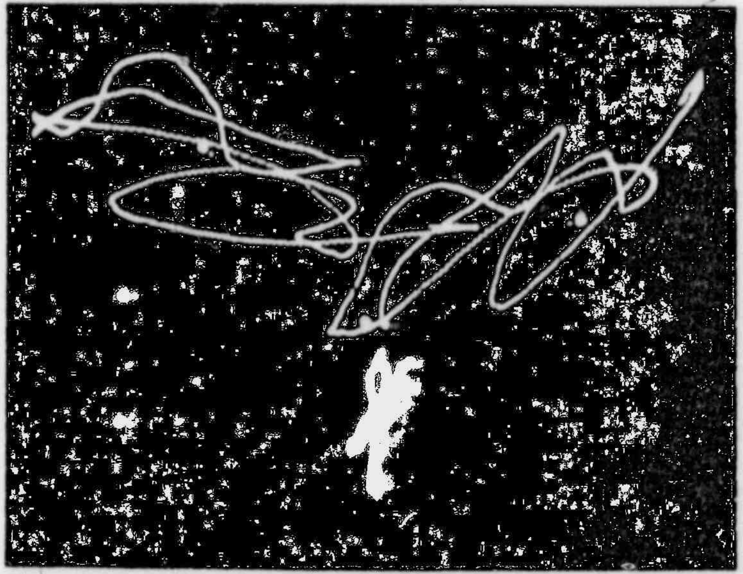

79%Mix 400k MIX 200K R76C-212

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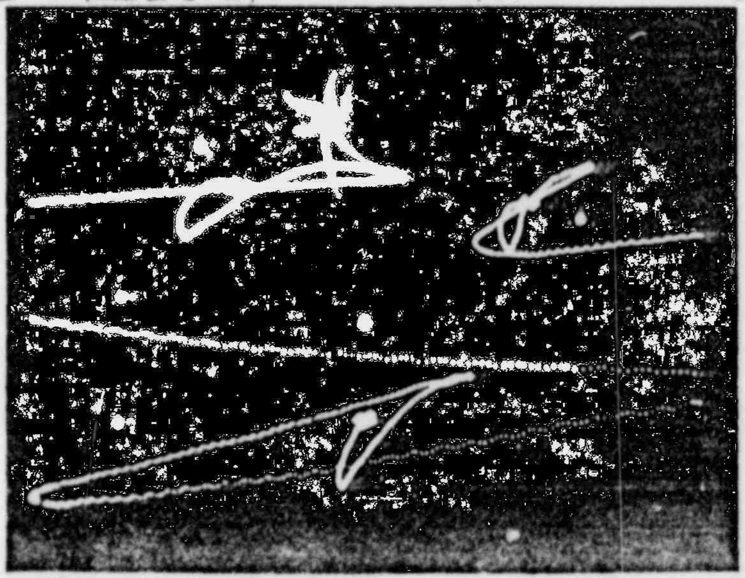

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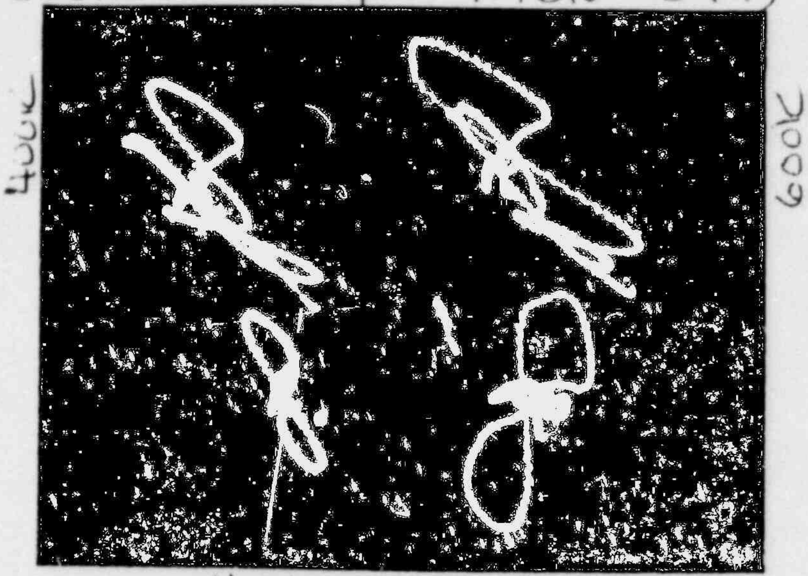

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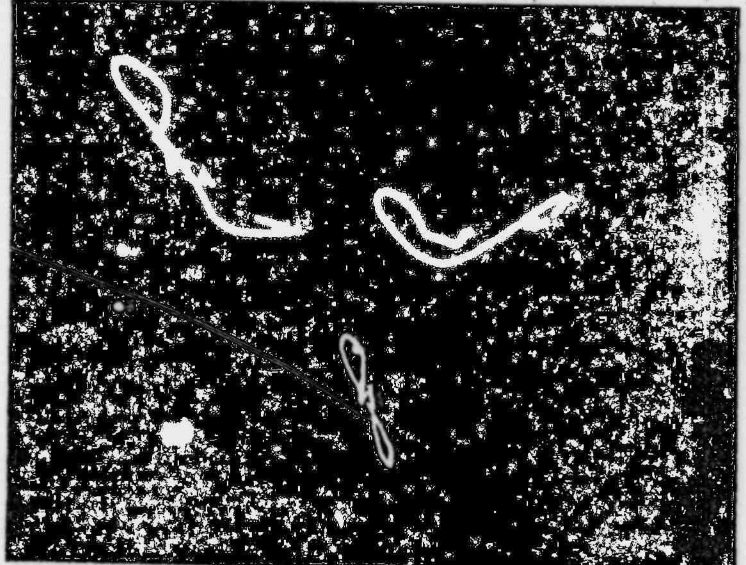

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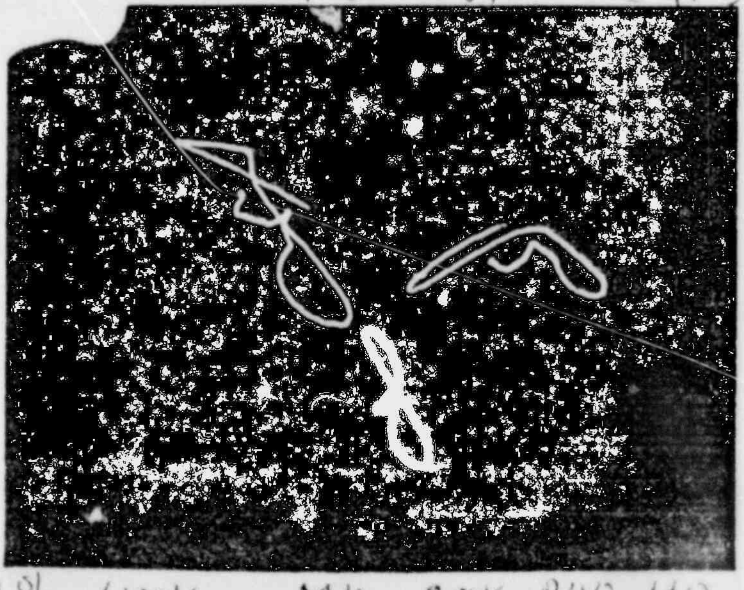

96% 400K MIX 200K R40-110

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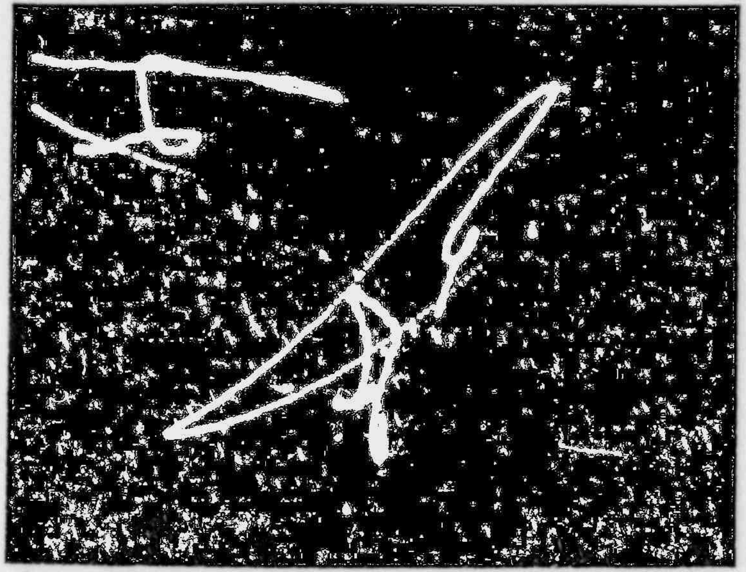

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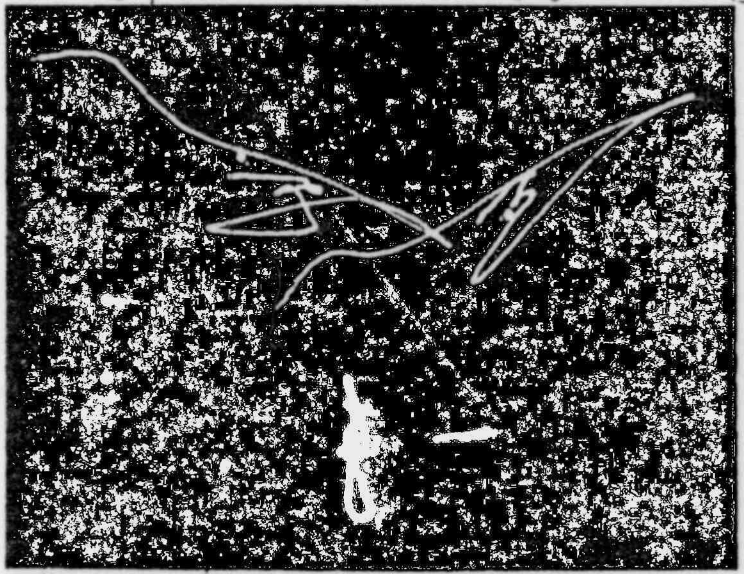

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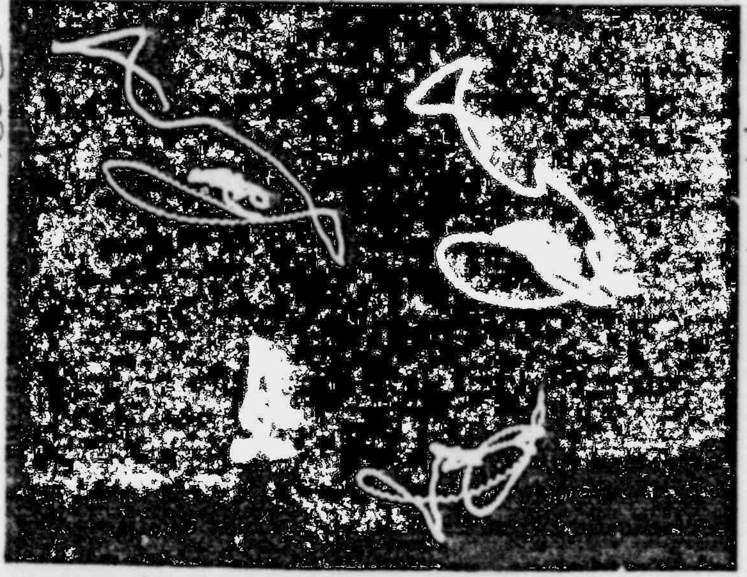

200K

U-Mix L.M 101T

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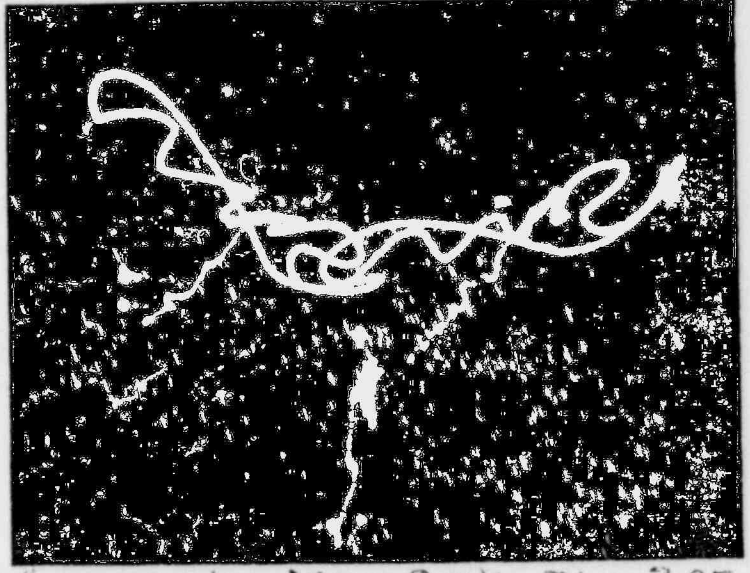

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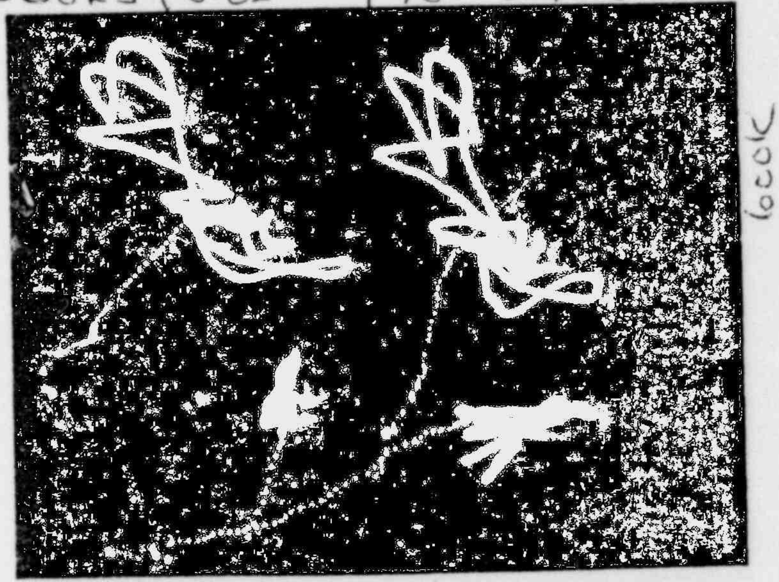

U.MIX L MIX

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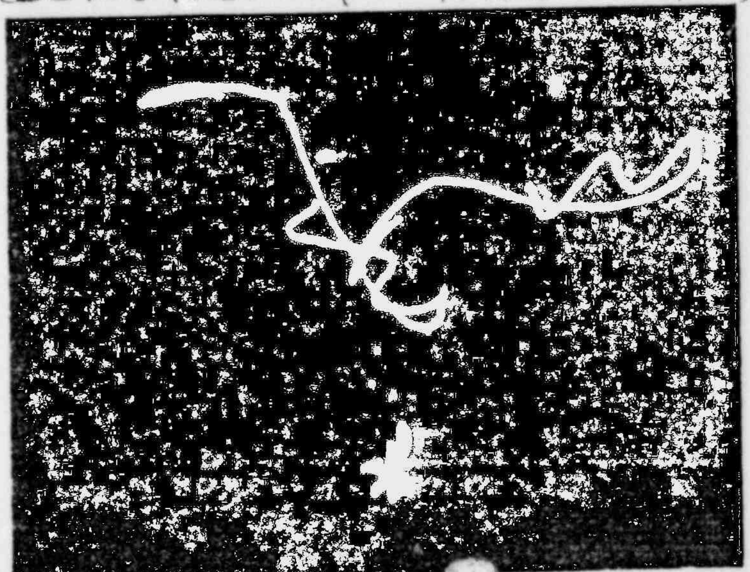

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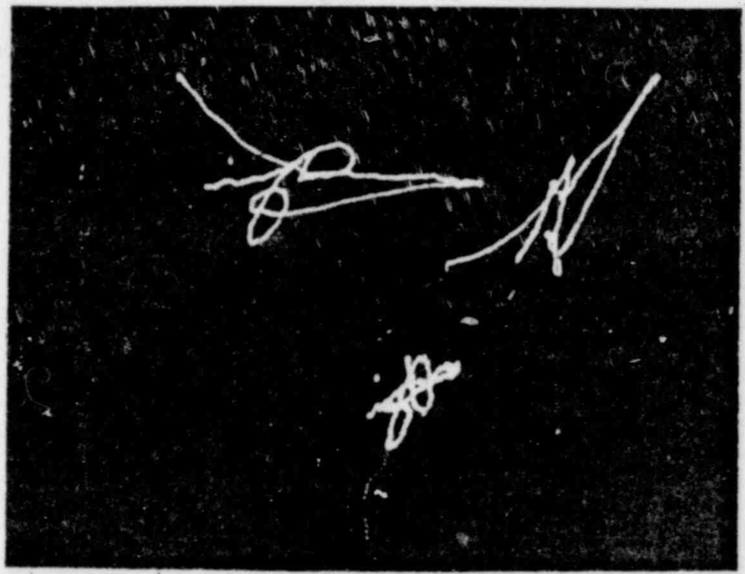

46%MIX 400K MIX 200K R40-1579

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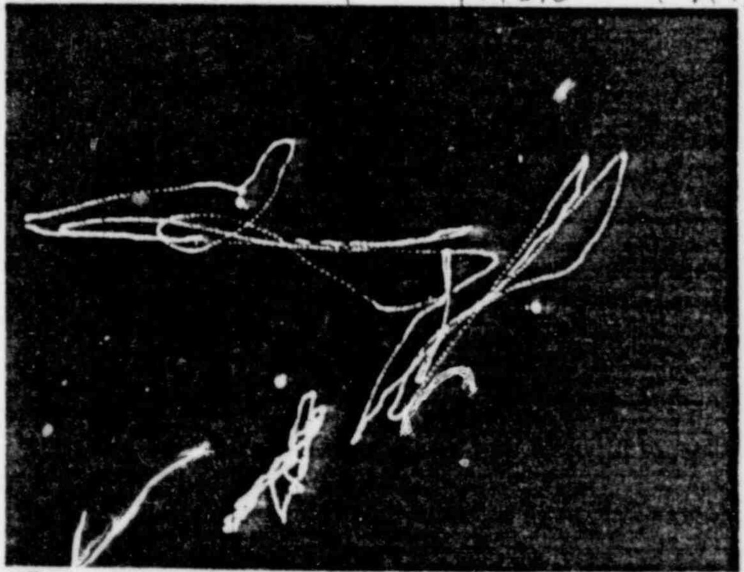

45% 400K MIX 200K R76C-092

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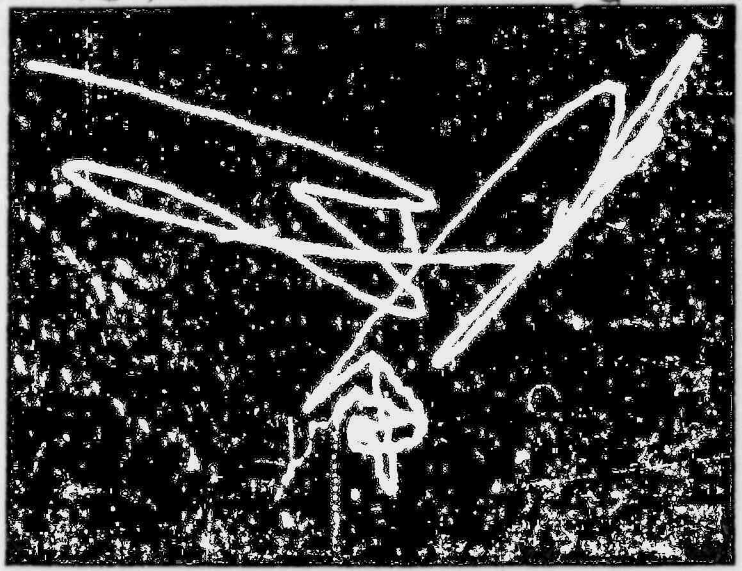

87Mix 400k MIX 200k R40-1320

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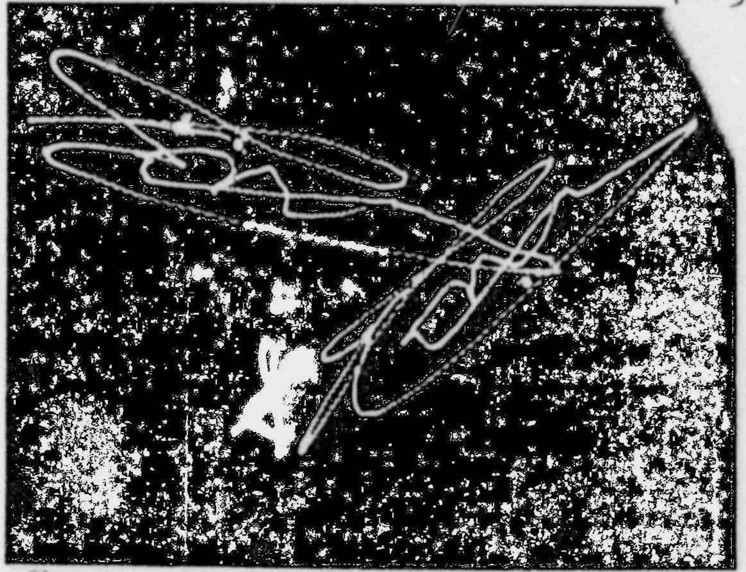

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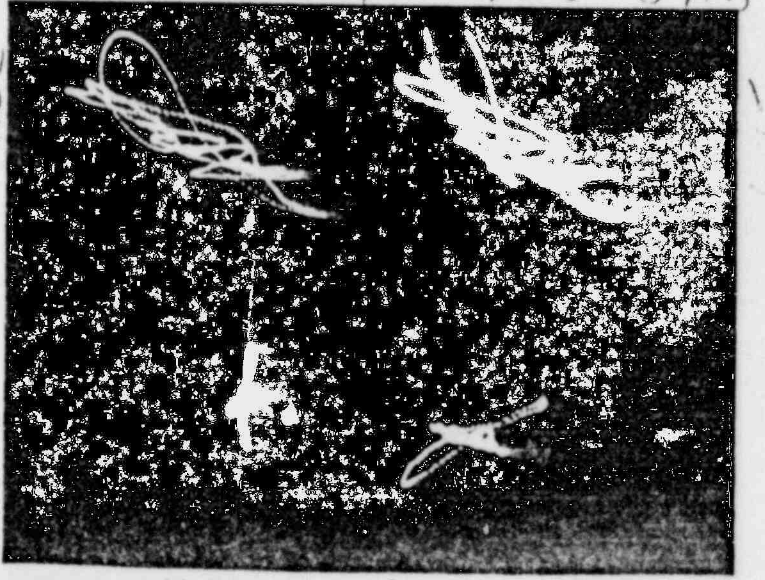
400k



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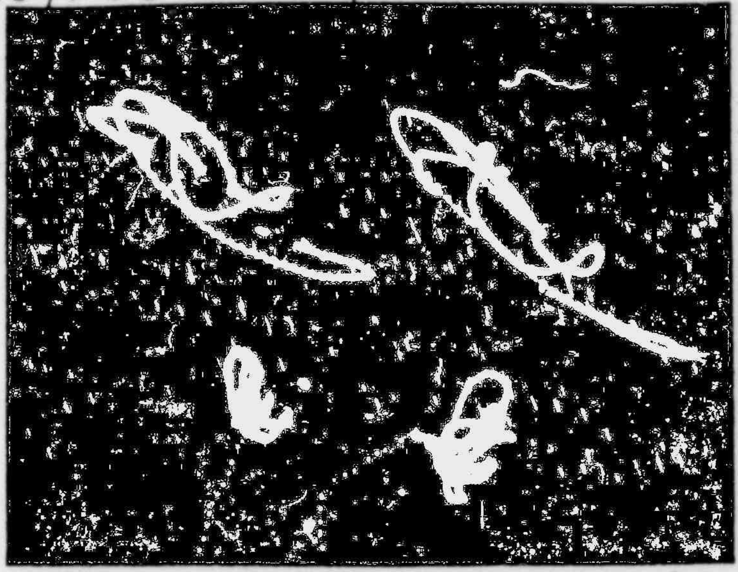
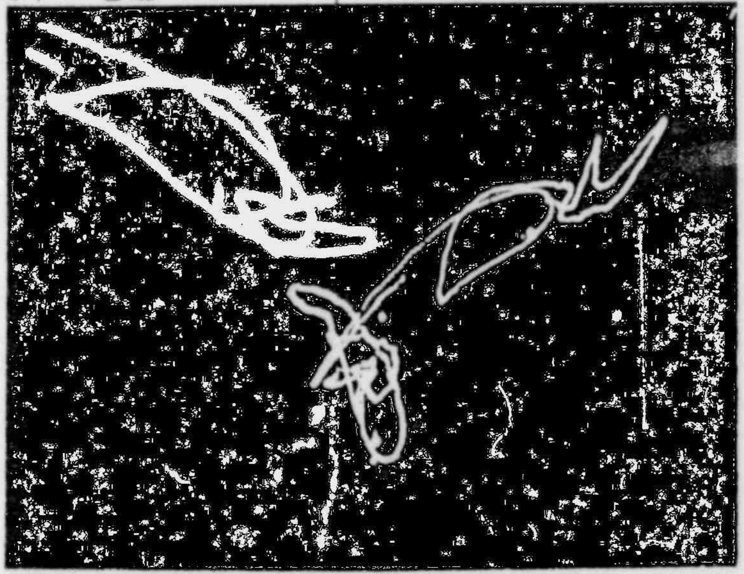


U.M. L.M 187

L67R55C.L. #1 1V/DIV 5"ATS

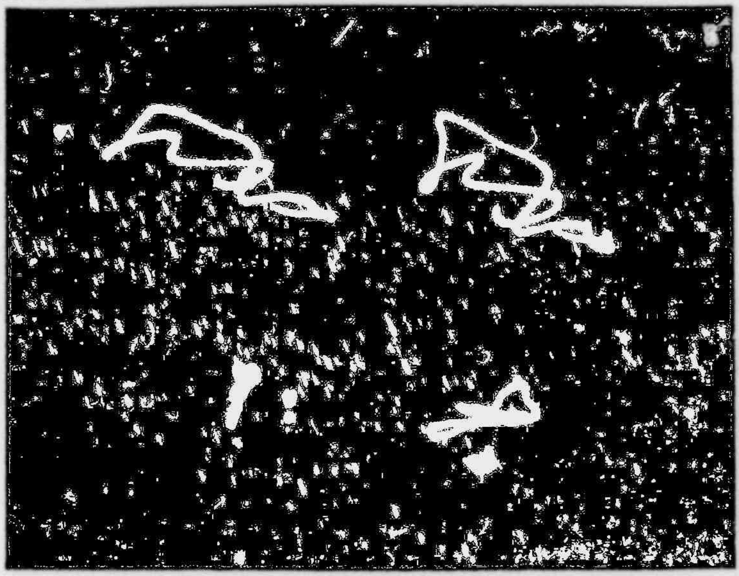


85% MIX 400K MIX 200K R40-596

L67R55C.L #1 1V/DIV 5"ATS

88% MIX 400K MIX 200K [illegible]-116

L66R52 C.L. #13/6 1V/DIV 5"ATS



U-MIX L-MIX 160T

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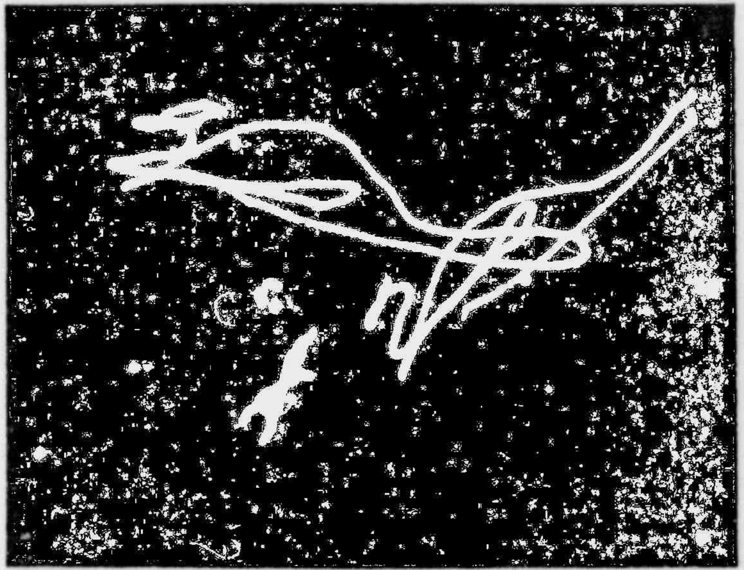
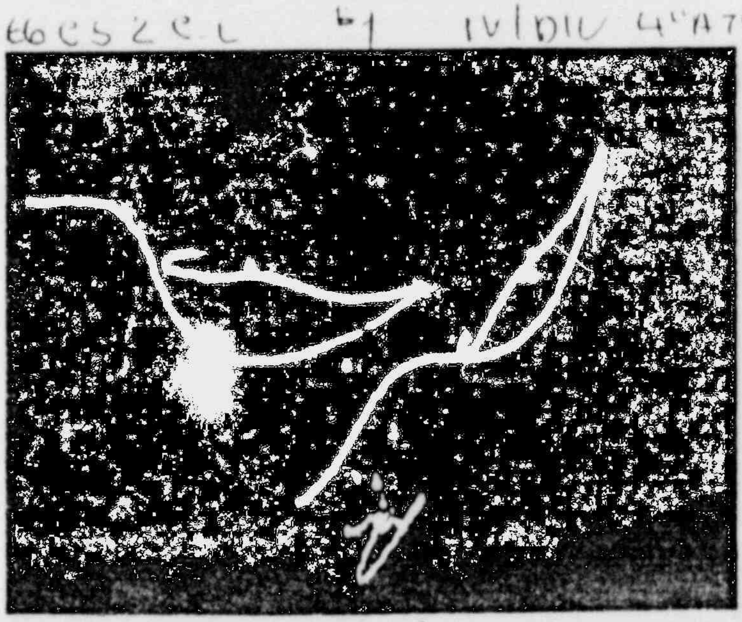


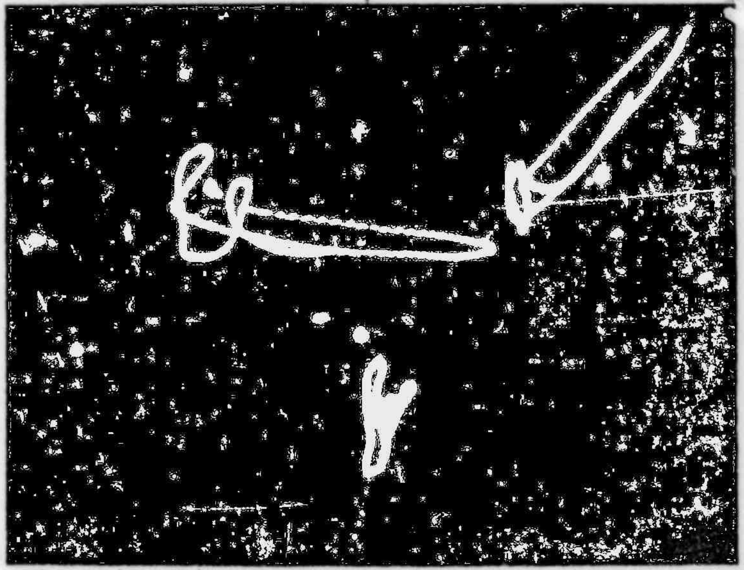
24% 400K MIX 200K R76C-130

R66C52C.L #1 1V/DIV 4"ATS



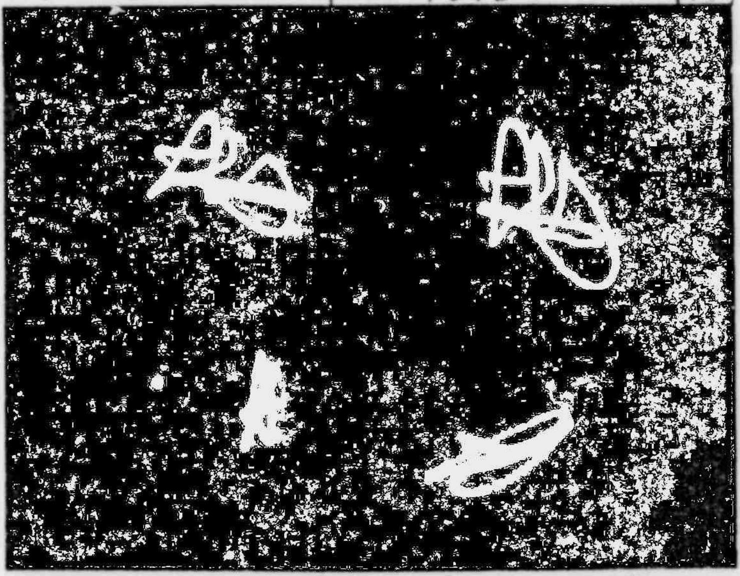
400K MIX 200K R40-770

L67R53C-L #1 1V/DIV 5"ATS



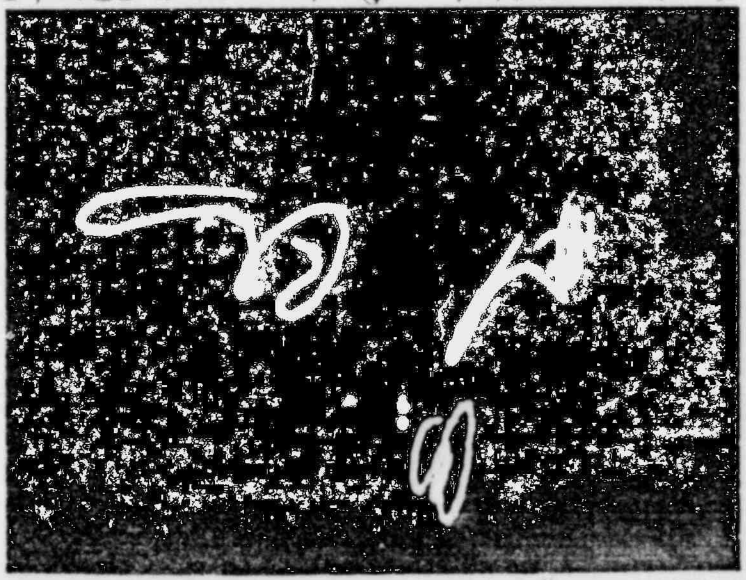
74% 400k MIX 200k R76C-173

R67R53CL #1 1V/DIV 5"ATS

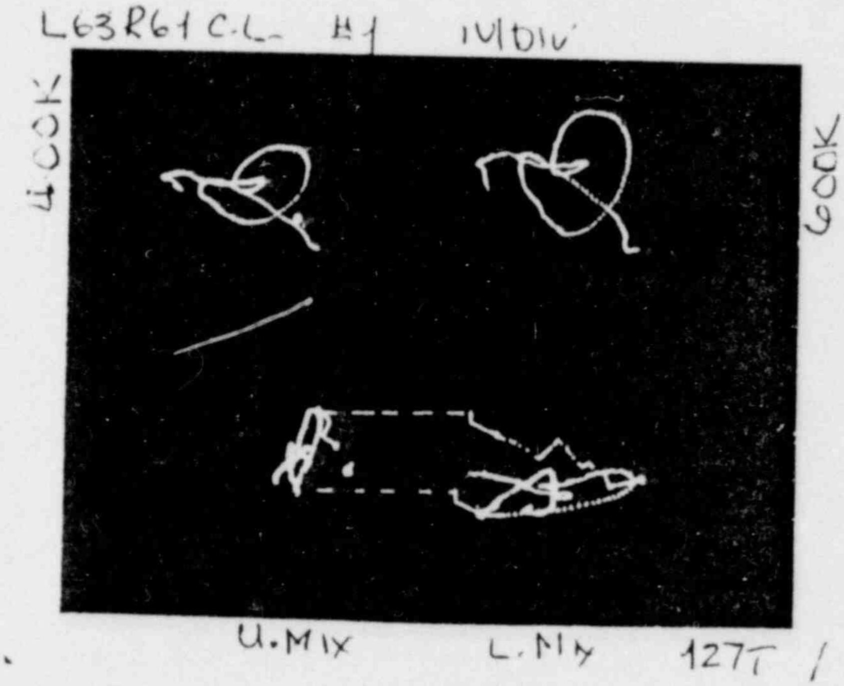


U.M. L.M. 193T

L67R53C-L #13/6 1V/DIV 5"ATS



[illegible] 400k MIX 200k [illegible]


L63R61 C.L. #1
1V/DIV
400K
600K
U.MIX
L.MIX
127T /

Docket No. 50-336

Attachment 2

Millstone Nuclear Power Station, Unit No. 2

Steam Generator Tube Burst and Leak Test Results

March, 1982

TABLE 1

MILLSTONE II S.G. TUBE PITTING

TUBE TEST MATRIX

		DESCRIPTION	QUANTITY	NOMINAL DIMENSIONS IN INCHES			
				DIAMETER	DEPTH	SPACING	RADIUS
I.	1.	Axial Aligned Pits	2	.125	.030	.010	.010-.020
	2.	Axial Aligned Pits	3	.125	.030	.010	.010-.020
	3.	Axial Aligned Pits	4	.125	.030	.010	.010-.020
	4.	Axial Aligned Pits	2	.125	.036	.010	.010-.020
	5.	Axial Aligned Pits	3	.125	.036	.010	.010-.020
	6.	Axial Aligned Pits	4	.125	.036	.010	.010-.020
	21.	Axial Aligned Pits	2	.125	.043	.010	.010-.020
	22.	Axial Aligned Pits	3	.125	.043	.010	.010-.020
	23.	Axial Aligned Pits	4	.125	.043	.010	.010-.020
II.	7.	Single Large Pits	1	.187	.030	NA	.010-.020
	8.	Single Large Pits	1	.187	.036	NA	.010-.020
	9.	Single Large Pits	1	.312	.030	NA	.010-.020
	24.	Single Large Pit	1	.187	.043	NA	.010-.020
III.	10.	Circ. Band Pits	30*	.125	.030	.100	.010-.020
	11.	Circ. Band Pits	30*	.125	.030	.100	.010-.020
	12.	Circ. Band Pits	30*	.125	.043	.100	.010-.020
	13.	Circ. Band Pits	30*	.125	.043	.100	.010-.020
IV.	14.	Chem. Induced Pits	1	.145	.044	NA	NA
	15.	Chem. Induced Pits	13*	.125	.036	.100	NA
	16.	Chem. Induced Pits	14*	.125	.039	.100	NA
	28.	Chem. Induced Pits**	20*	.125	.048	.010	NA
	29.	Chem. Induced Pits**	18*	.125	.048	.010	NA
V.	17.	Thru Wall Pit**	1	.0135	.048	NA	NA
	30.	Thru Wall Pit**	1	.028	.048	NA	NA
	18.	Thru Wall Pit**	1	.052	.048	NA	NA
	19.	Thru Wall Pit**	1	.125	.048	NA	NA
	20.	Thru Wall Pit**	1	.199	.048	NA	NA

Pitted Tube Burst Testing

The test program described in this section consists of artificially manufacturing, ECT testing, burst testing and in some cases leak testing the samples described in the following test matrix. This program was devised to specifically address the type of pitting defects found in the Millstone II steam generators.

TABLE 1 (Cont'd)

MILLSTONE II S.G. TUBE PITTING
TUBE TEST MATRIX

	DESCRIPTION	QUANTITY	DIAMETER	DEPTH	SPACING	RADIUS
VI.	25. Virgin Tube	0	NA	NA	NA	NA
	26. Virgin Tube	0	NA	NA	NA	NA
	27. Virgin Tube	0	NA	NA	NA	NA

Notes: * Extended over 1/4" axial length

** Includes leakage measurement before and after MSLB simulation.

TABLE 2

BURST TESTS

			Actual		ECT Measurement				
		Description	Depth (in)	% Degrad.	Depth (in)	% Degrad.	% Error	Burst Press. (psi)	Sawhill Heat No.
I.	1.	Axial Align. (2)	.030	63	.033	69	+6	7200	NX-4168
	2.	Axial Align. (3)	.030	63	.031	65	+2	6900	NX-4168
	3.	Axial Align. (4)	.030	63	.031	65	+2	6350	NX-4168
	4.	Axial Align. (2)	.036	75	.033	69	-6	6550	NX-4168
	5.	Axial Align. (3)	.036	75	.033	68	-7	5900	NX-4168
	6.	Axial Align. (4)	.036	75	.034	71	-4	5200	NX-4168
	21.	Axial Align. (2)	.041	85	.037	77	-8	6300	NX-05cl
	22.	Axial Align. (3)	.042	88	.037	77	-11	5550	NX-05cl
	23.	Axial Align. (4)	.042	88	.037	77	-11	4300	NX-05cl
II.	7.	Single (.187)	.030	63	.031	66	+3	8900	NX-4168
	8.	Single (.187)	.036	75	.036	76	+1	7500	NX-4168
	9.	Single (.312)	.030	63	.028	60	-3	7700	NX-4168
	24.	Single (.187)	.044	92	.040	84	-8	6500	NX-05cl
III.	10.	Circ. Band	.029	60	.025	52	-8	8150	NX-05cl
	11.	Circ. Band	.030	63	.027	56	-7	7700	NX-05cl
	12.	Circ. Band	.042	88	.034	71	-7	5800	NX-05cl
	13.	Circ. Band	.042	88	.034	71	-7	6300*	NX-05cl
IV.	14.	Chem. Single (E)	.044	92	.039	81	-11	8500	NX-7082
	15.	Chem. Band (A)	.036	75	.033	69	-6	9000	NX-7082
	16.	Chem. Band (B)	.039	81	.033	69	-12	8800	NX-7082
	28.	Chem. T.W. (c)	.048	100	.046	96	-4	NA	NX-7082
	29.	Chem. T.W. (d)	.048	100	.047	98	-2	NA	NX-7082
V.	17.	Thru Wall (.0135)	.048	100	0	0	-100	NA	NX-05cl
	30.	Thru Wall (.028)	.048	100				NA	NX-05cl
	18.	Thru Wall (.052)	.048	100	.048	100	0	NA	NX-05cl
	19.	Thru Wall (.125)	.048	100	.048	100	0	NA	NX-05cl
	20.	Thru Wall (.199)	.048	100	.048	100	0	NA	NX-05cl
VI.	25.	Virgin Tube	0	0	0	0	NA	12100	NX-05cl
	26.	Virgin Tube	0	0	0	0	NA	12200	NX-05cl
	27.	Virgin Tube	0	0	0	0	NA	11300	NX-4168

Note: * Burst line spanned two defects.

TABLE 3

PROPERTIES OF TESTED TUBES

HEAT NO.	AVG. S_y (PSI)	AVG. S_u (PSI)	NO. OF TESTS
NX-05c1	46,100	101,000	10
NX-4168	45,000	103,000	4
NX-7082	41,000	95,200	4

FIGURE 1

PITTING DEFECT BURST TESTING

TEST CONDUCTED AT ROOM TEMPERATURE

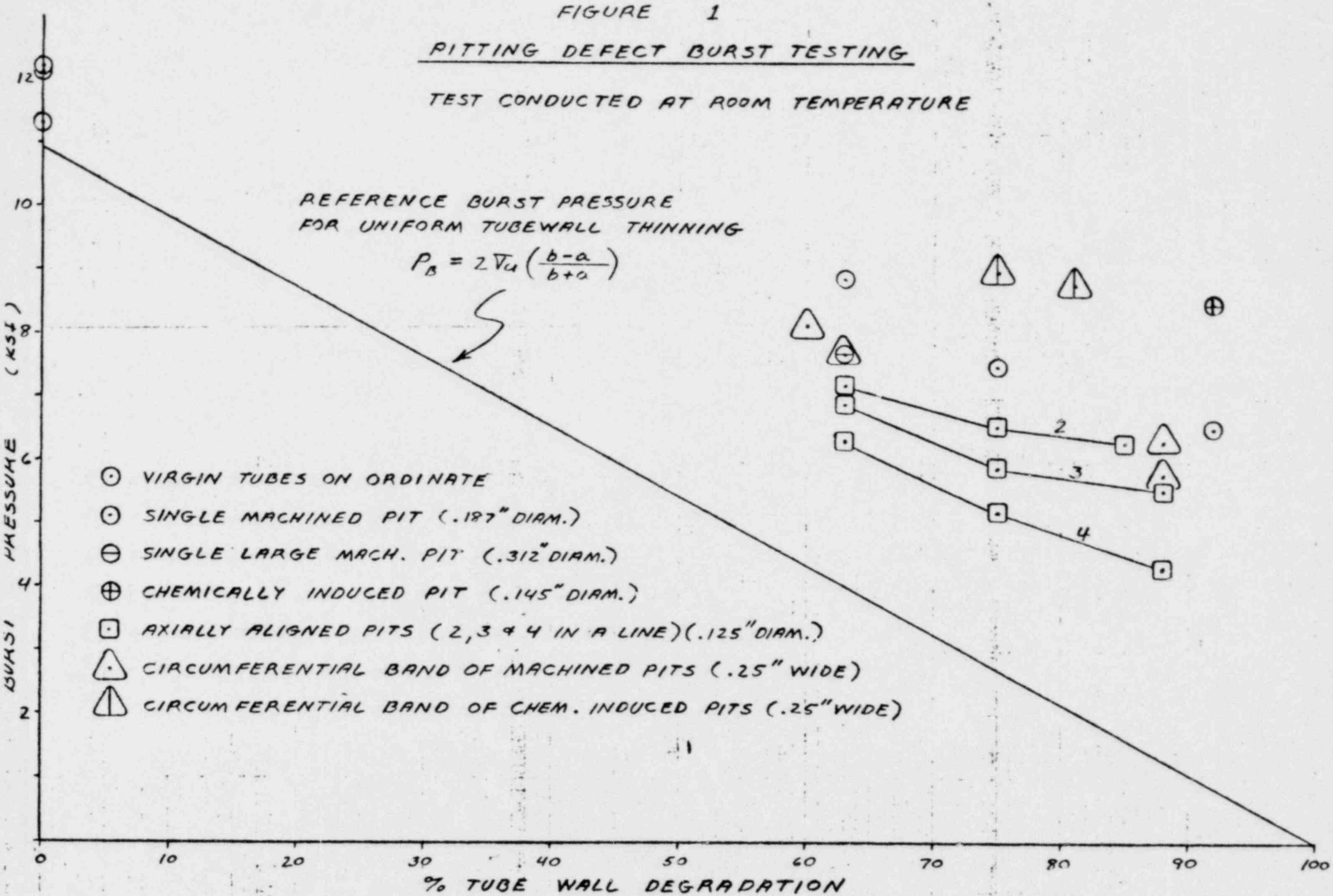
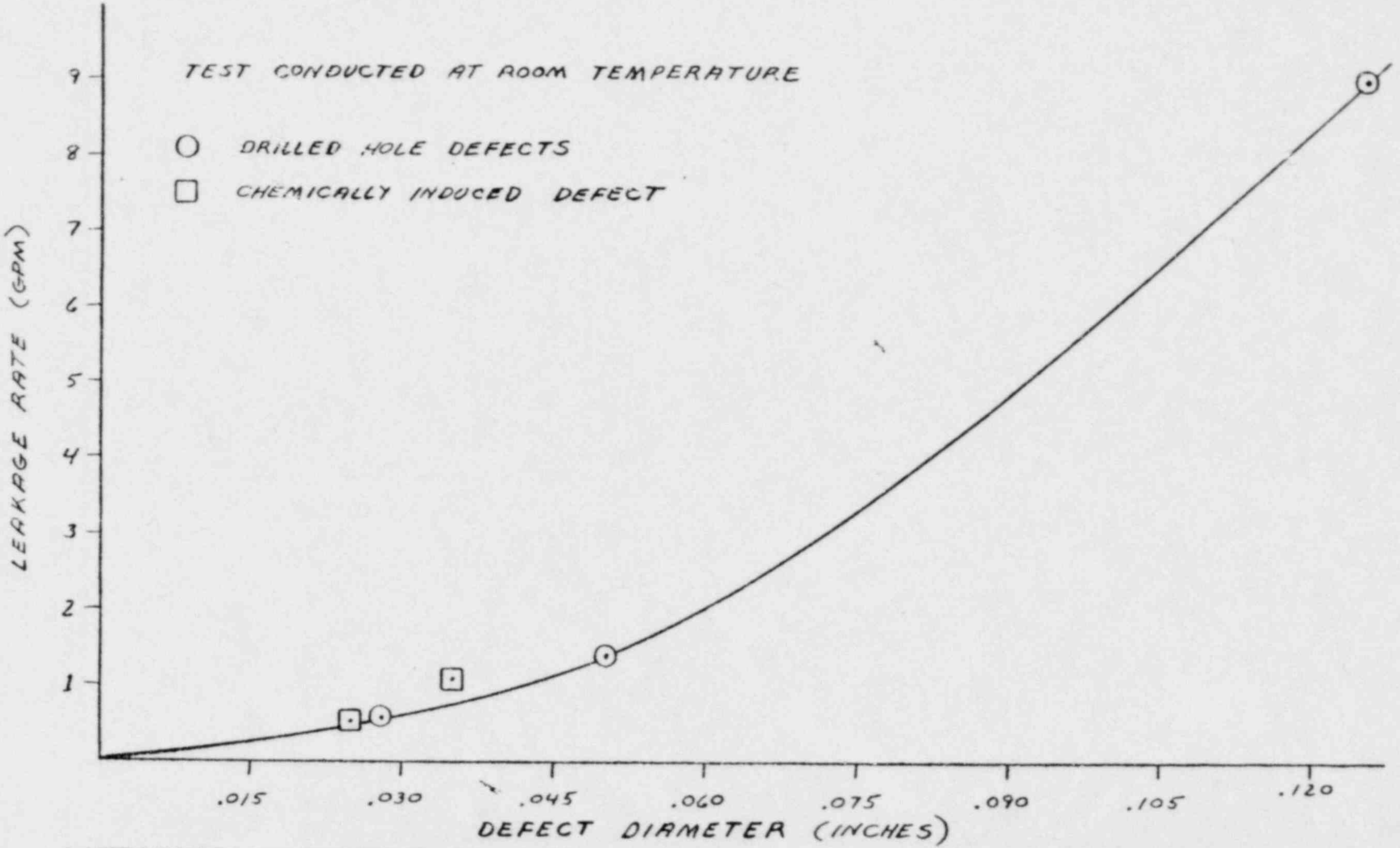


FIGURE 7-1

THROUGH WALL PIT LEAK RATES



LEAKAGE TESTS

	DIAMETER (INCHES)		LEAK RATE (GPM)				
DESCRIPTION	INITIAL	AFTER 3150 PSI	AT 1435 PSI	AT 2250 PSI AFTER 3150 PSI	AT 1435 PSI AFTER 3150 PSI	ENLARGE PRESS. (PSI)	DIAMETER AFTER ENLARGE
29. CHEM. INDUCED	.035	.035	1.09	1.09	1.09	6500	.045
19. DRILLED HOLE	.125	.129	>9.00	>9.00	>9.00	6000	.132