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HANFORD ATOMIC PRODUCTS O[redacted]ION - RICHLAND, WASHINGTON

DATE December 19, 1960

TITLE

CAUSES OF REACTOR SHUTDOWNS

AUTHOR

J. L. Deichman

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CAUSES OF REACTOR SHUTDOWNS

By:

J. L. Deichman
Reactor, Plant Engineering Operation
Facilities Engineering Operation
IRRADIATION PROCESSING DEPARTMENT

December 19, 1960

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CAUSES OF REACTOR SHUTDOWNS

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26.	TH Lyons	1704-B
27.	AR Maguire	1704-B
28.	JS McMahon	762
29.	SL Nelson	1704-K
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31.	RW Reid	1704-D
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CAUSES OF REACTOR SHUTDOWNS

I. INTRODUCTION

A. Purpose

The purpose of this report is to present an analysis of causes of reactor shutdowns as a support to various engineering programs presently under study. Continuing measurement and correlation of these facts can demonstrate the incentives and the necessity for modifying or changing present concepts in reactor safety and control circuits as reactor power levels are continuously increased.

B. Background

Reactor, Plant Engineering Operation has been studying the performance of the safety and control circuits at various intervals during the past 18 months. A report(1) was issued October 1959, classifying into certain catagories the direct and indirect causes of all reactor shutdowns during the 12-month period of FY-1959. As part of this continuing engineering effort to improve operating continuity and at the request of various individuals, it was decided to prepare a second document to update the original report and determine certain performance trends during the past 28 months.

C. Conclusions

1. Production loss charged to reactor shutdowns has increased about 15 per cent from FY-1959.

2. The total number of shutdowns has decreased by approximately 20 per cent from FY-1959.

3. The total number of resultant outages dropped off slightly since FY-1959 but has since returned to the original level.

4. The total number of scrams has dropped nearly 40 per cent, while the number of resultant outages (minimum or longer) has dropped approximately 20 per cent from FY-1959.

5. Ruptures in the old reactors dropped initially but have increased to slightly below the original level.

6. Ruptures in the K Reactors dropped initially but have increased to slightly above the original level.

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(1) HW-62207, "Operating Continuity Analysis of the Hanford Production Reactors", (Confidential)

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7. Average power levels have increased about 15 per cent in all reactors.

9. Poison outages have dropped significantly since the adoption of splines.

10. The production loss caused by water leaks, equipment failures, scheduling, and miscellaneous occurrances has remained almost constant.

D. Recommendations

1. It is suggested that incentive trends be computed similar to those shown in the charts of this document before establishing any project or modifications program for corrective purposes. The lag between the preliminary engineering study and the beneficial use of new equipment is generally two to four years depending upon the size of the program. These programs should be continuously re-evaluated on a systematic basis to make certain that the incentives have not been changed by other programs or revisions to operating standards during the interim period. It should also be important to measure the effectiveness of the modification program after it is installed to see if it, in truth, did perform as predicted and justified.

2. It is suggested that a continuous reporting system be established to show trends in reactor performance. Such information should be issued monthly to engineering and manufacturing management. The foremat of this report should be outlined by an integrated effort of all those interested in such information. Planning and programming will be more effective if it includes feedback from a good measurements system.

II. ANALYSIS OF SHUTDOWN PHILOSOPHY

The period of analysis begins on July 1, 1958 and runs to the present. Data before this period is not significant because of major safety circuit revisions and the increased power levels from various plant improvement programs. The statistical reliability of the analysis and the data is increased by combining the scram information from all eight reactors. This was done for the following reasons:

1. Basically, the design, design function, and components in the control and safety circuits are alike or relatively similar in all reactors in spite of differences in power levels, size, or age. Performance failure in any one area will thus effect all reactors in due time.

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2. The low frequency of occurrence for each type of scram in a single reactor makes data less meaningful than a composite of scram information from all reactors, except to predict similar trends in like equipment at sister reactors.

3. Justification for modifying present equipment or for installing additional equipment is classically based on the previous 12-months' experience. Grouping all reactors together into 12-month periods does show trends and variations in these justifications. This sort of grouping provides the necessary damping to large local fluctuations making a smooth trend curve within certain defined limits.

4. Each reactor encountered different operating problems at various intervals during the 28-month period; however, after a given time, the problems seemed to diminish or change to a different reactor. By grouping all reactors together, the problems will appear in their true magnitude.

Table I shows the four types of shutdowns and the approximate amount of preparation or planning time immediately before the shutdown.

TABLE I - TYPES OF SHUTDOWNS

TYPE OF SHUTDOWN	APPROXIMATE PREPARATION TIME IMMEDIATELY BEFORE SHUTDOWN	METHOD OF SHUTDOWN
1. Instantaneous (Scrams)	None	1XX, 2XX, or 3XX Safety Circuits.
2. Immediate (Ruptures)	0.2-4 hours	Operator controlled over 10 minute period.
3. Semi-Planned (Water Leak)	1 to 4 days	Operator Controlled over 10 minute period.
4. Planned (Scheduled)	1 to 4 weeks	Operator controlled over 10 minute period.

Naturally, the more preparation time that is available immediately before a shutdown, the more effectively and efficiently the resultant outage time can be used.

Table II shows the seven main reasons or categories of reactor shutdown causes. These reasons can be further subdivided, as shown, to provide more specific information. It is more important to know the reasons why instruments initiate scram signals, than it is to know the number of times a particular instrument scrams a reactor. The reason why an instrument scrams

[redacted]

a reactor shows whether or not the instrument is performing according to its design function. If the instrument does perform according to its design function in the safety circuit, it should not be criticized. If it no longer provides the same degree of operating continuity with respect to safety, then the reasons will show the incentives for changing or modifying the system. A good example of this is the four Beckmans. About four years ago, the Beckman scramming circuit was modified to a two-out-of-four coincidence matrix to prevent spurious scrams and improve operating continuity. The octant monitoring theory was developed to achieve better flux protection in the top of the reactor after it was determined that the PCCF tubes and the horizontal control rods could shadow the top of the pile from the Beckmans located in the bottom. The reasons in Table II were designed to show trends in the functional change of instrument and control system requirements, and thus show the incentives for changes in these systems as operating requirements change.

TABLE II
REASONS AND DEFINITIONS OF SHUTDOWNS

I. SCRAMS:	Any instantaneous reactor shutdown regardless of cause or means of shutdown.
A. IMPROPER REACTOR CONDITION:	Any condition which is unsafe to reactor components or personnel demanding an instantaneous shutdown.
1. Faulty Process Equipment:	Failure of a reactor or auxiliary component directly related to production or safety.
2. Non-Standard Process Condition:	Anytime preset limits or standards require a scram.
3. Unusual Situation:	Occurrence of a highly improbable situation.
B. FAULTY INSTRUMENTATION:	Any failure within the process monitoring equipment which directly or indirectly demands a scram.
1. Panellit:	Occurring in pressure monitoring system.
2. Beckman:	Occurring in flux monitoring system.
3. Safety Circuit:	Occurring in safety circuit relay matrix.
4. Temperature:	Occurring in temperature monitoring system.
C. IMPROPER PROCEDURE:	Any error by personnel causing a scram.
1. Instrument:	Caused on instrument systems.
2. Process Equipment:	Caused on process equipment.
3. Unusual Condition:	Any freak or highly improbable mishap cau- [redacted]

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TABLE II (cont.)

	D. UNEXPLAINED:	Scrams which cannot be adequately identified.
	E. RESEARCH AND DEVELOPMENT:	Scrams caused by research and development test facilities attached to reactors.
I.	RUPTURES:	Fuel element failure requiring shutdowns.
I.	PLANNED OUTAGES:	A scheduled outage or outage with a significant amount of pre-shutdown planning.
V.	WATER LEAKS:	Water leaks in process piping requiring a shutdown.
V.	POISON SHUTDOWNS:	Shutdowns required to add or remove poison from reactor.
I.	EQUIPMENT FAILURES:	Shutdowns caused by equipment failures where some degree of advance notice is available before the reactor is manually shut down by the operator.
I.	MISCELLANEOUS:	Category for those rare occurrences not happening in frequency sufficient enough to establish a group or tend by themselves.

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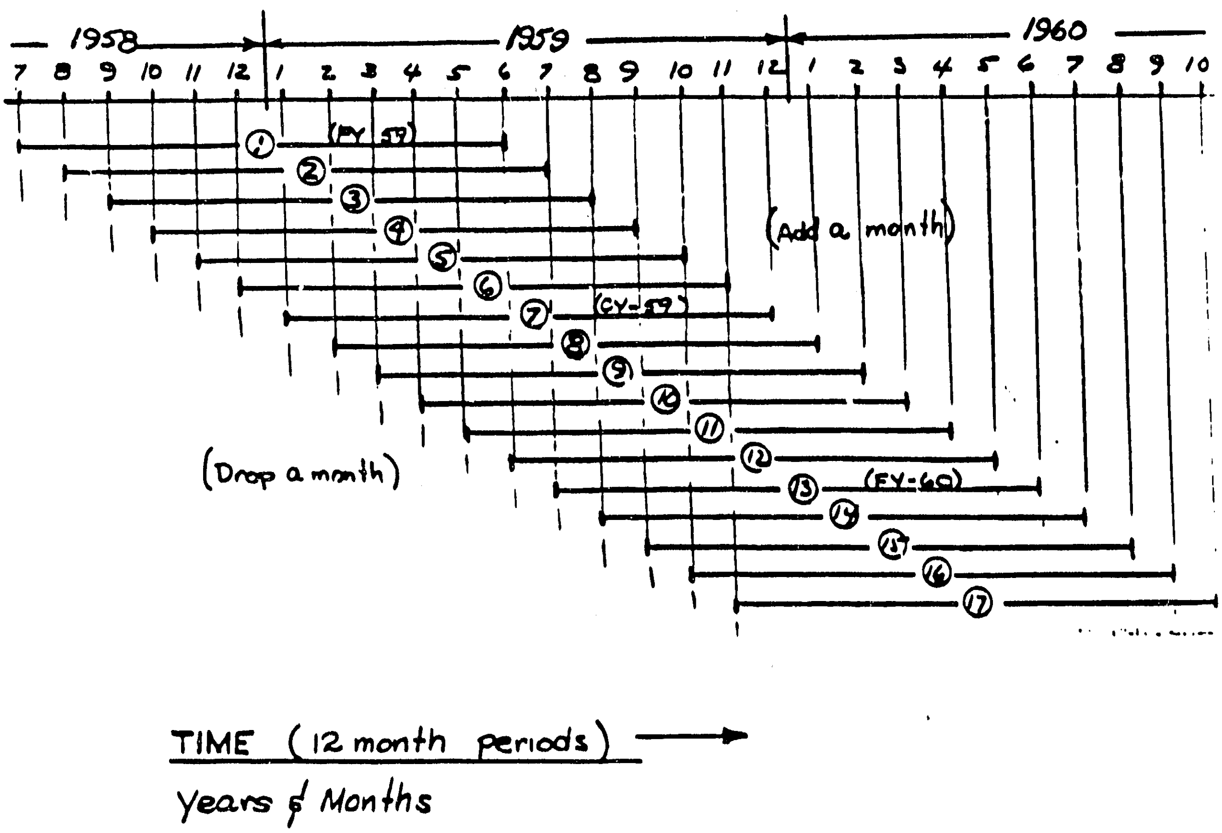
III. PRESENTATION OF DATA

The time base (abscissa) for all graphs is the same. Each point represents a 12-month period as shown in Figure 1, Time Base Chart, and is either defined by point number as indicated in Figure 1, or has the 12-month periods labled on the abscissa of the curve.



TIME BASE CHART

FIGURE I

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The first group of four miscellaneous summary graphs(2) shows:

1. Total number of shutdowns.
2. Total number of resultant outages.
3. Production loss due to shutdowns (#1).
4. Average power level changes during the time period.
5. Relationship of power level increase to main causes of all shutdown production loss.
6. Production loss in the K Reactors due to the main causes of all shutdowns.
7. Production loss in the six old reactors due to the main causes of all shutdowns.
8. Production loss in the K Reactors due to the main types of scram shutdowns only.
9. Production loss in the six old reactors due to the main types of scram shutdowns only.

<u>Graph No. 1</u> shows that while the total number of shutdowns has been decreased by almost 20 per cent, the total number of resultant outages dipped in the beginning but since has returned to the original level to remain about constant. The relative production loss has steadily increased after an initial 20 per cent drop to a point almost 15 per cent higher than at the first point on the graph.

(2) The reader is cautioned to use not less than four points on the graphs and preferably six points to establish the average slope or trend on the graphs.

[redacted]

Graph No. 2 shows the trends in power level with respect to the main causes of production loss; all to the same time base. It is quite apparent that the number of ruptures played an important role in the production loss because all other causes remained relatively constant. There is also a direct similarity between the shape of power level curves, the total production loss curve and the production loss due to rupturescurve. The average slope or trend per curve is approximately a 15 per cent increase on the first three curves. The 15 per cent increase on the total production loss curve results from a 40 per cent increase in rupture loss.

Graph No. 3 shows the principal trends in shutdown causes between the K Reactors and the six old reactors. All trends appeared to be constant during the entire period in the six old reactors except for ruptures. The average slope or rate of the increase between rupture and the total loss is about even. Both ruptures and scrams appear to be rising at the K Reactors. As can be seen in a further breakdown in Graph No. 4, the increase in total scram loss comes primarily from KER.

Graph No. 4 shows a more detailed breakdown of the scram losses shown in Graph No. 3. The main reason scrams are increasing in the K Reactors is KER. KER accounts for approximately 50 per cent of the total scram losses for both KE and KW combined. Improper Reactor Condition is increasing slightly at the K's indicating that they may be tending to become more difficult to operate with present control equipment concepts at the higher power levels. Improper Procedure scrams have been significantly reduced at all reactors. Most everything else has remained generally constant or has varied only slightly indicating no distinct trend or change.

The second group of 12 graphs shows the number of occurrences for:

1. Main Reasons for Shutdowns,
2. Main Reasons for Outages,
3. Causes of Scram Shutdowns Only,
4. Causes of Scram Outages Only,

in all reactors, the K Reactors and the six old reactors.

Graphs No's. 5, 6, and 7 show the ratio in number of shutdowns due to:

1. Scrams,
2. Ruptures,
3. Water Leaks,
4. Planned Outages,

[redacted]

[redacted]

5. Equipment Failure Outages (not from scrams),

6. Poison Outages,

7. Miscellaneous Outages.

Scrams and ruptures have converged while the other causes have remained in an almost constant relative position. This means that scrams dropped nearly 40 per cent while rupture dropped initially, but have since returned to their original level.

Graphs No's 8, 9, and 10 show the same information as above, but only those shutdowns which were not recovered and resulted in an outage (minimum or longer).

Graphs No's, 11, 12 and 13 show the relative ratio of the breakdowns for all scram shutdowns:

1. Improper Reactor Condition,

2. Faulty Instrumentation,

3. Improper Procedure,

4. Scram Source Unknown,

5. Research and Development.

Generally, the trend is downward or constant looking at the overall picture for all reactors. Research and Development scrams from KER, and, on the basis of the last four points, Improper Reactor Condition scrams at all reactors appear to be rising.

Graphs No's. 14, 15, and 16 show the same information as above, but only those shutdowns which were not recovered and resulted in an outage. (minimum or longer). These scrams generally occurred at equilibrium because recoveries are not made due to the fast buildup of the Xenon transient at the higher power levels. Again, most trends are downward or constant with the exception of Research and Development and Improper Reactor Condition scrams. The latter gives evidence that the old reactors, as well as the K Reactors, might be tending to become more difficult to operate with the present control equipment concepts at the higher power levels. The next three or four points on these curves will verify or disprove this theory as the power levels increase for the winter as the river temperature drops.

IV. COMPARISON FY-1959 TO FY-1960

Tables 3, 4, and 5 show the trends of all catagories in six-month steps; that is, the 12-month periods for FY-1959, CY-1959, FY-1960 and the most recent 12-month period. These points correspond to the points on Graphs 5 through 16 and show the full breakdown of the data into all categories and sub-categories.

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V. CONCLUSIONS AND RECOMMENDATIONS

Many conclusions and recommendations can be derived from this set of data. Some of the important ones were listed at the beginning of the report. There are only two additional comments that the author would like to make at the close of this report.

A. Fuel Element Performance

The data has shown the incentive for the Bumper Fuel Element Program. The original drop in the rupture curve can be claimed by the adoption of the I&E fuel element. The following increase in rupture rate meant that the increase of power levels offset the gains in performance by the I&E's. If power levels continue to increase, and it is assumed they will, history would indicate that the Bumper Program may give only temporary relief to this all-important problem of fuel element performance. This gives emphasis to the programs now in the initial thinking stages so that another new fuel element will be ready in the future to replace the Bumper Slug when its performance failures start to increase.

B. Reactor Control and Safety

Reactor control and safety are never-ending problems as power levels increase. Years ago, the reactors were much more sluggish and stable than they are today. Much has been learned about reactor operation in the last several years, and from this, many advances in control and safety circuits have been employed in new reactor construction in the last two or three years. Modern technology has provided many new and wonderful devices which can provide for gains in performance and continuity. It is hoped that an integrated effort to study reactor control will be recognized and established to produce the incentives and means for updating the equipment concepts presently in use today.

VI. ACKNOWLEDGEMENTS AND REFERENCE MATERIAL

The author would like to express his appreciation to all those who assisted him in preparing this report. A special thanks is given to D. L. DeNeal and the Production Operation for supplying the outage information from the following references:

A. CLVI-259-1A, Operating Summary for 100 Areas, CY-58; D. L. DeNeal (TOP SECRET)

B. HW-58863, Operating Summary for 100 Areas, CY-59; D. L. DeNeal, (SECRET)

C. HW-63289, Reactor Outage Time Breakdown, CY-60; D. L. DeNeal, (SECRET)

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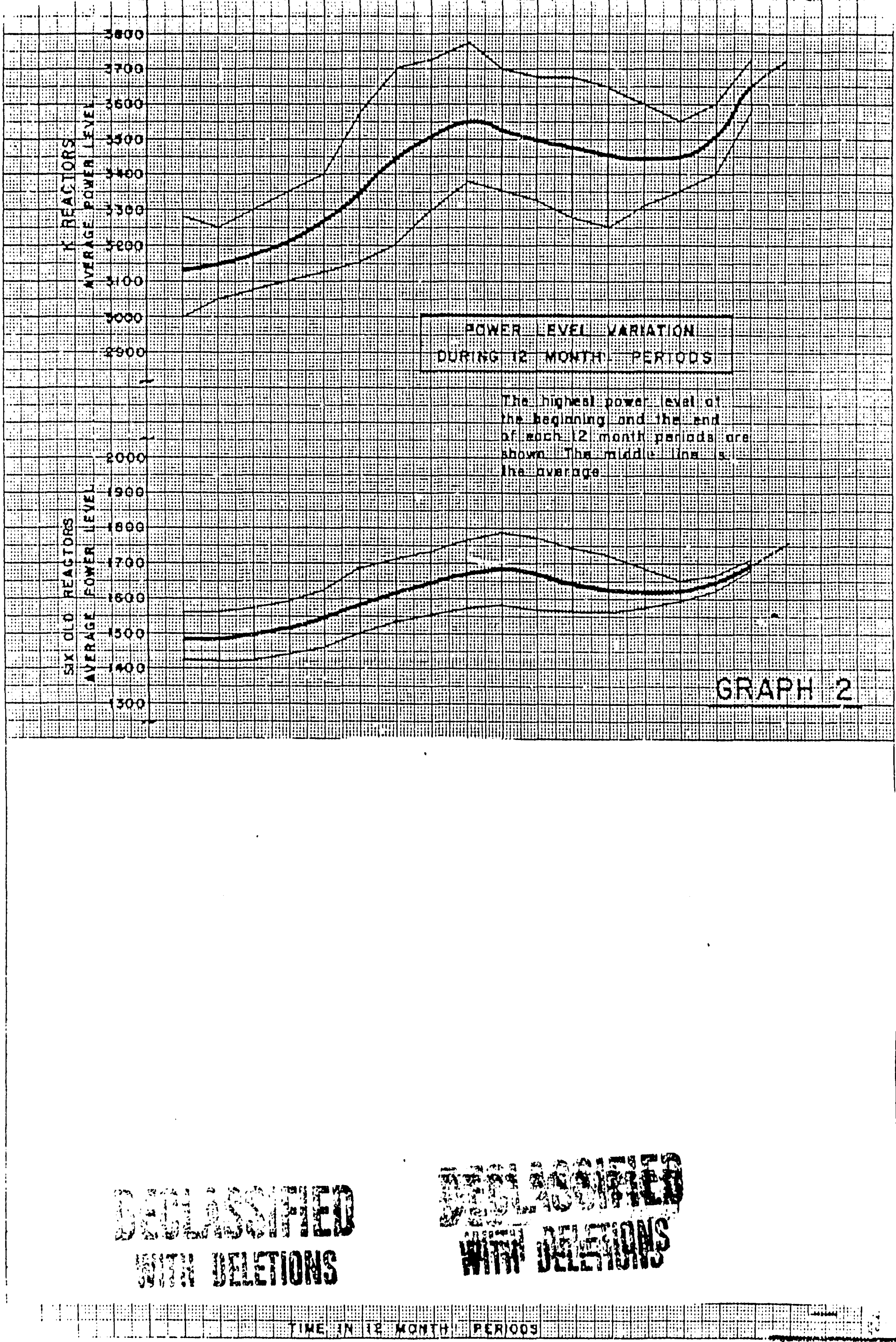
K REACTORS
AVERAGE POWER LEVEL
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
POWER LEVEL VARIATION
DURING 12 MONTH PERIODS
The highest power level at the beginning and the end of each 12 month periods are shown. The middle line is the average
SIX OLD REACTORS
AVERAGE POWER LEVEL
2000
1900
1800
1700
1600
1500
1400
1300
GRAPH 2
TIME IN 12 MONTH PERIODS

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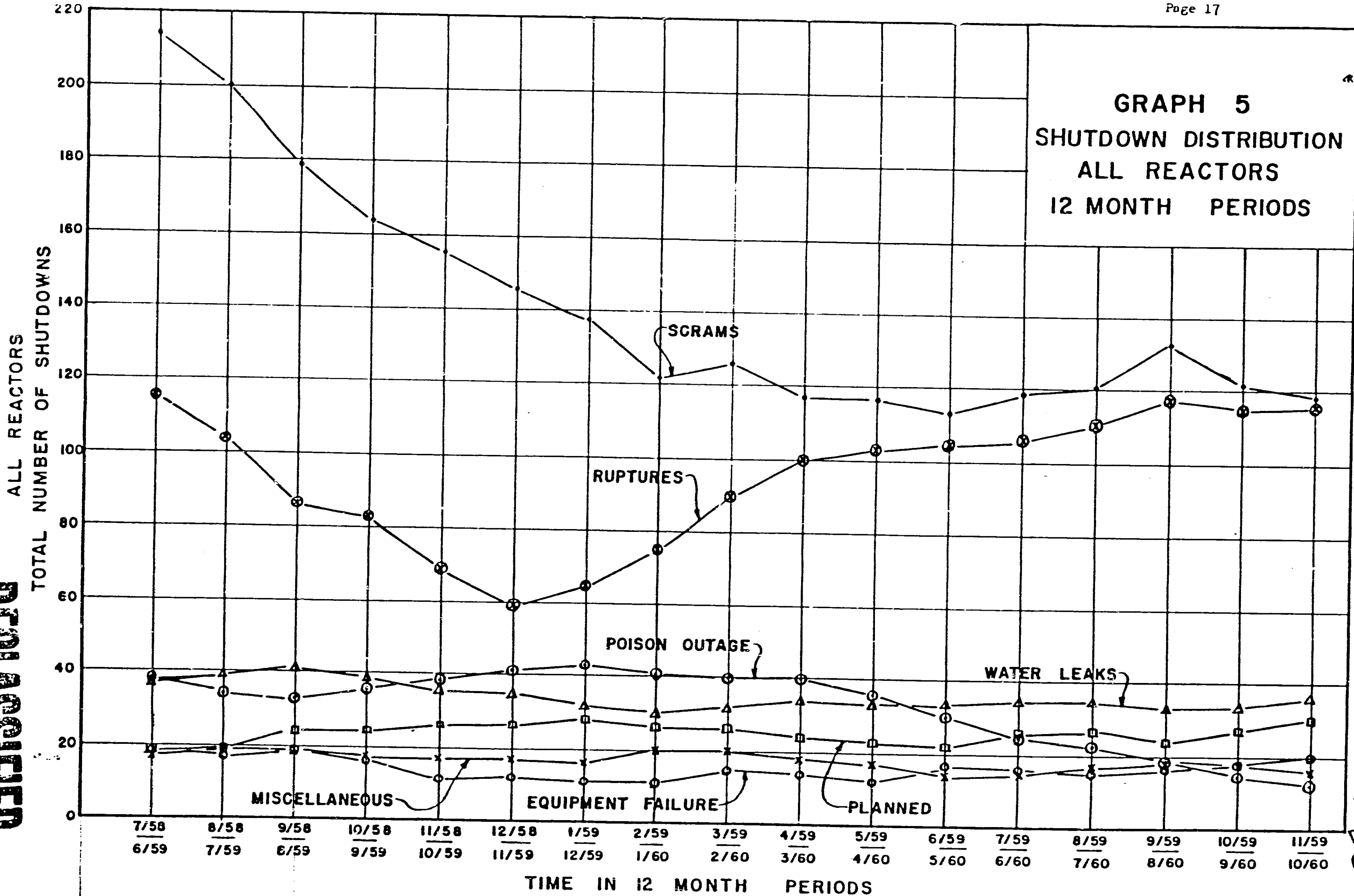

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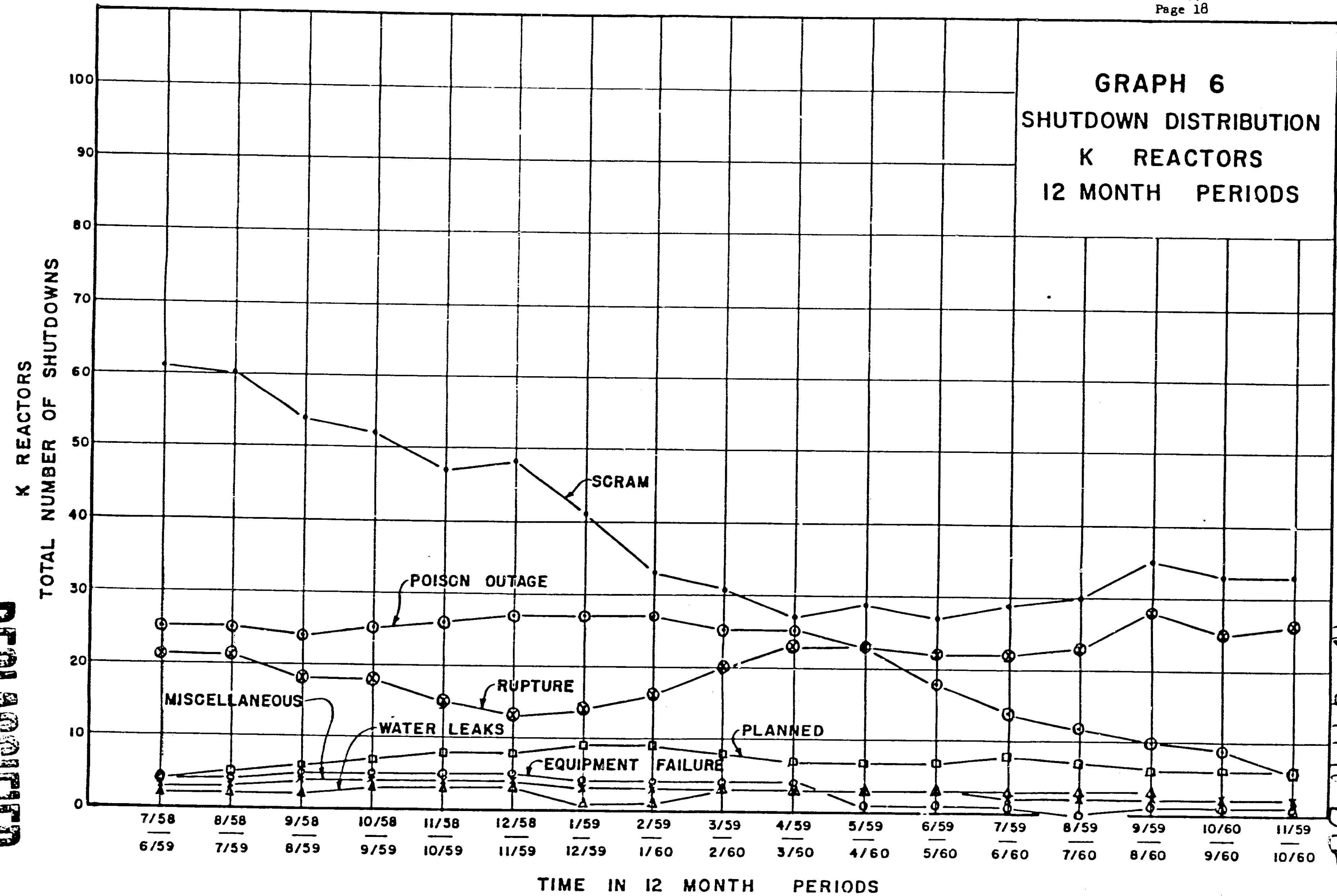
GRAPH 6
SHUTDOWN DISTRIBUTION
K REACTORS
12 MONTH PERIODS
K REACTORS
TOTAL NUMBER OF SHUTDOWNS
100
90
80
70
60
50
40
30
20
10
0
SCRAM
POISON OUTAGE
RUPTURE
MISCELLANEOUS
WATER LEAKS
PLANNED
EQUIPMENT FAILURE
7/58 6/59
8/58 7/59
9/58 8/59
10/58 9/59
11/58 10/59
12/58 11/59
1/59 12/59
2/59 1/60
3/59 2/60
4/59 3/60
5/59 4/60
6/59 5/60
7/59 6/60
8/59 7/60
9/59 8/60
10/60 9/60
11/59 10/60
TIME IN 12 MONTH PERIODS

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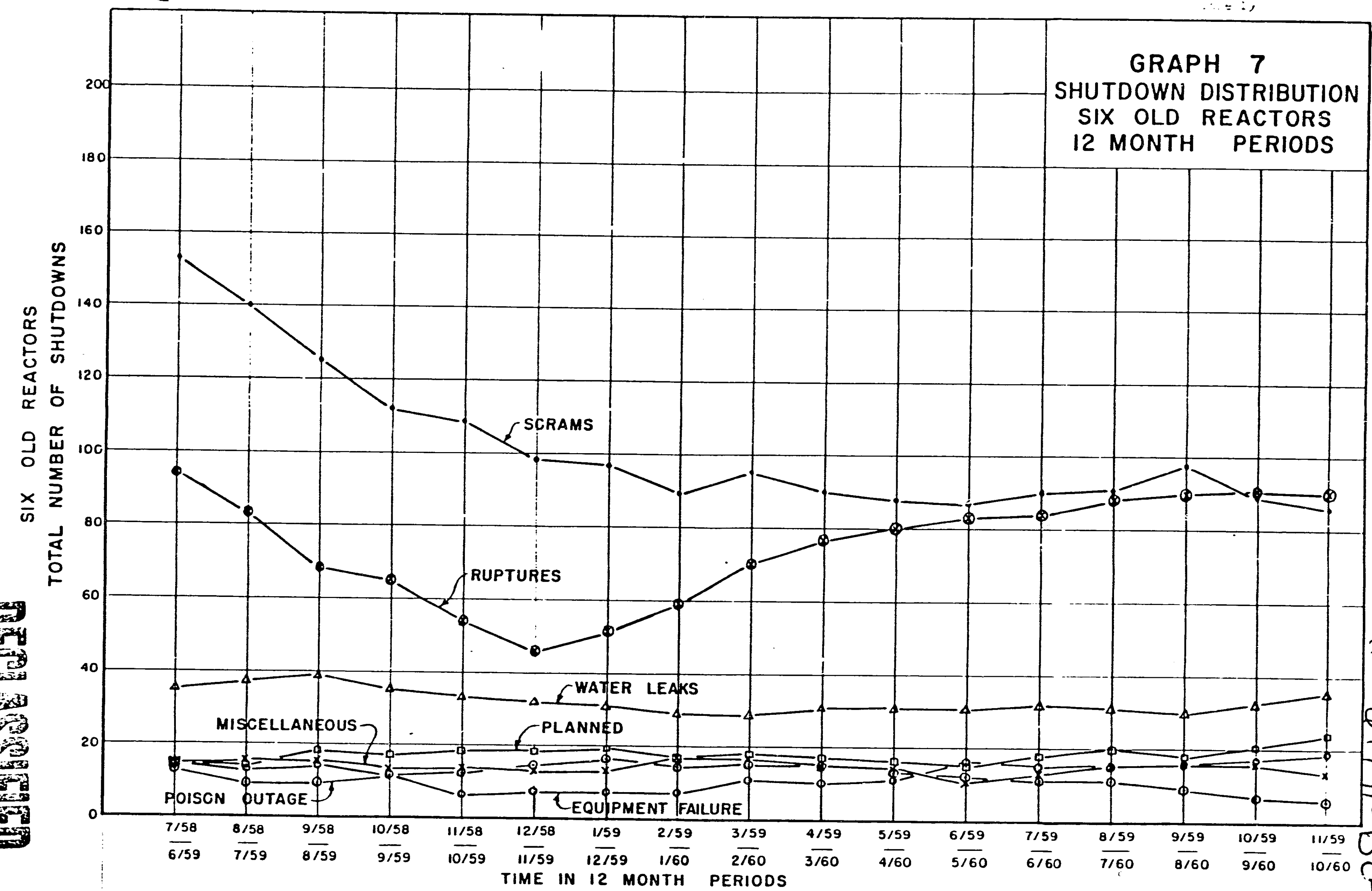

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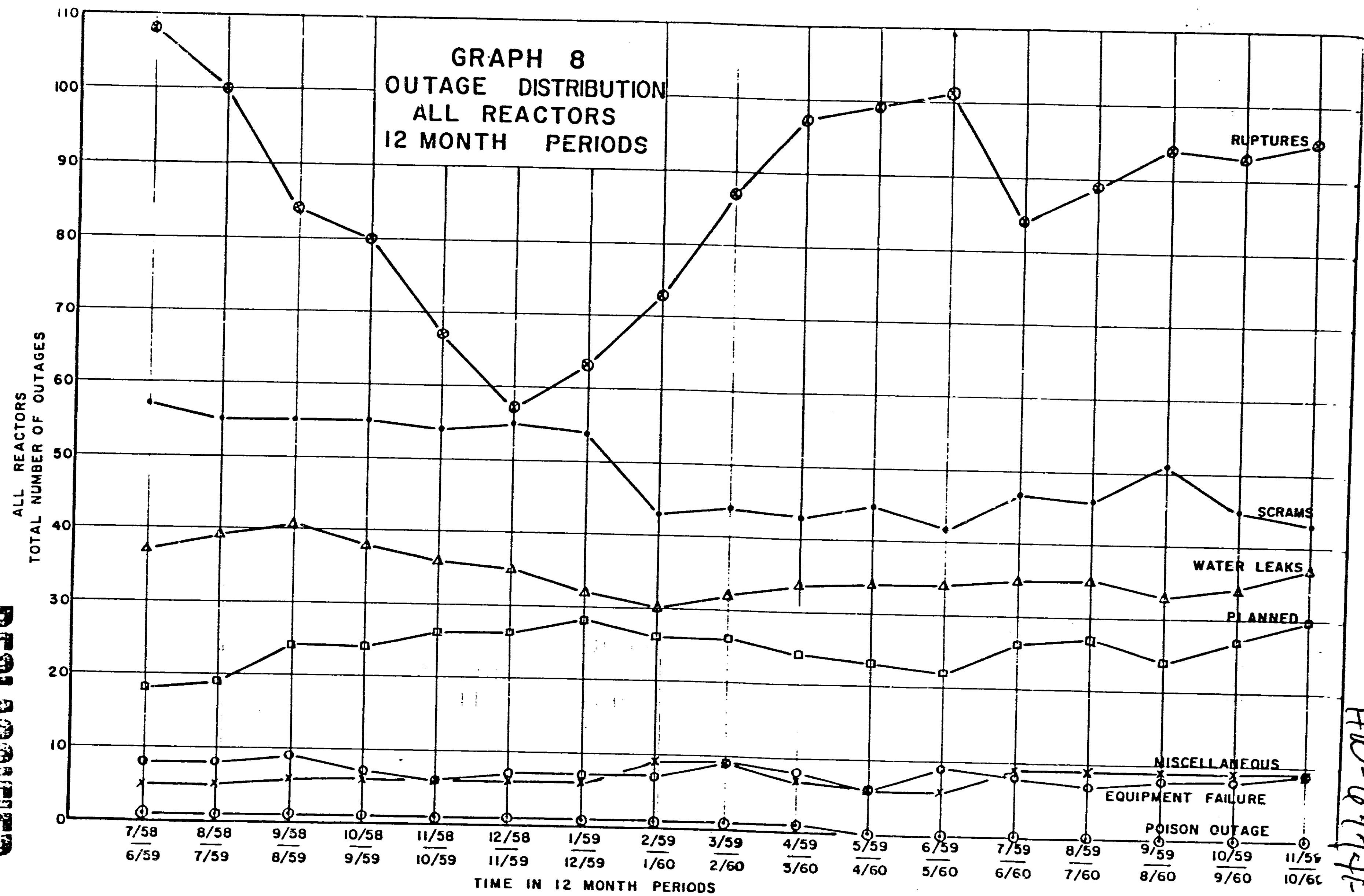

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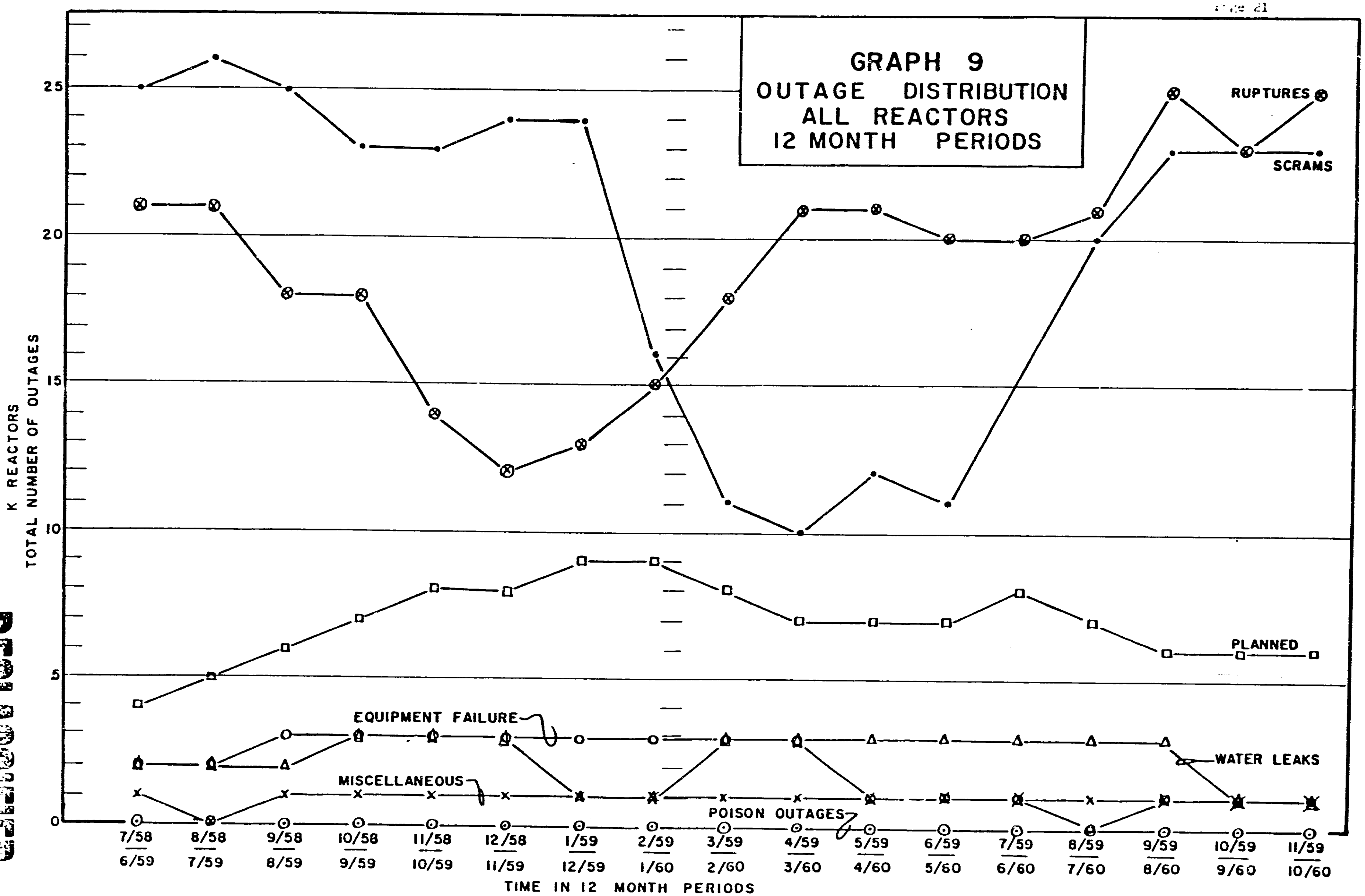

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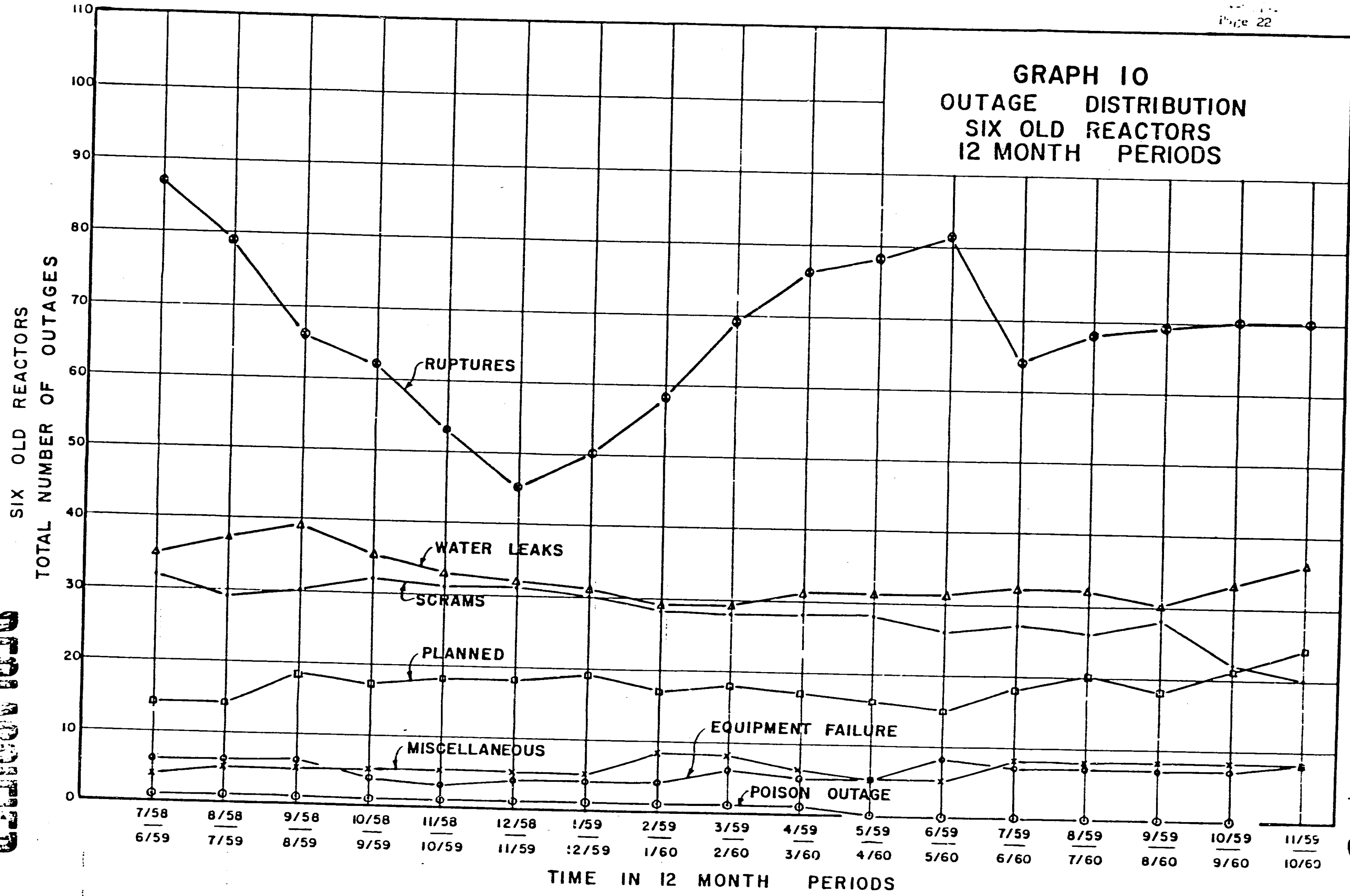

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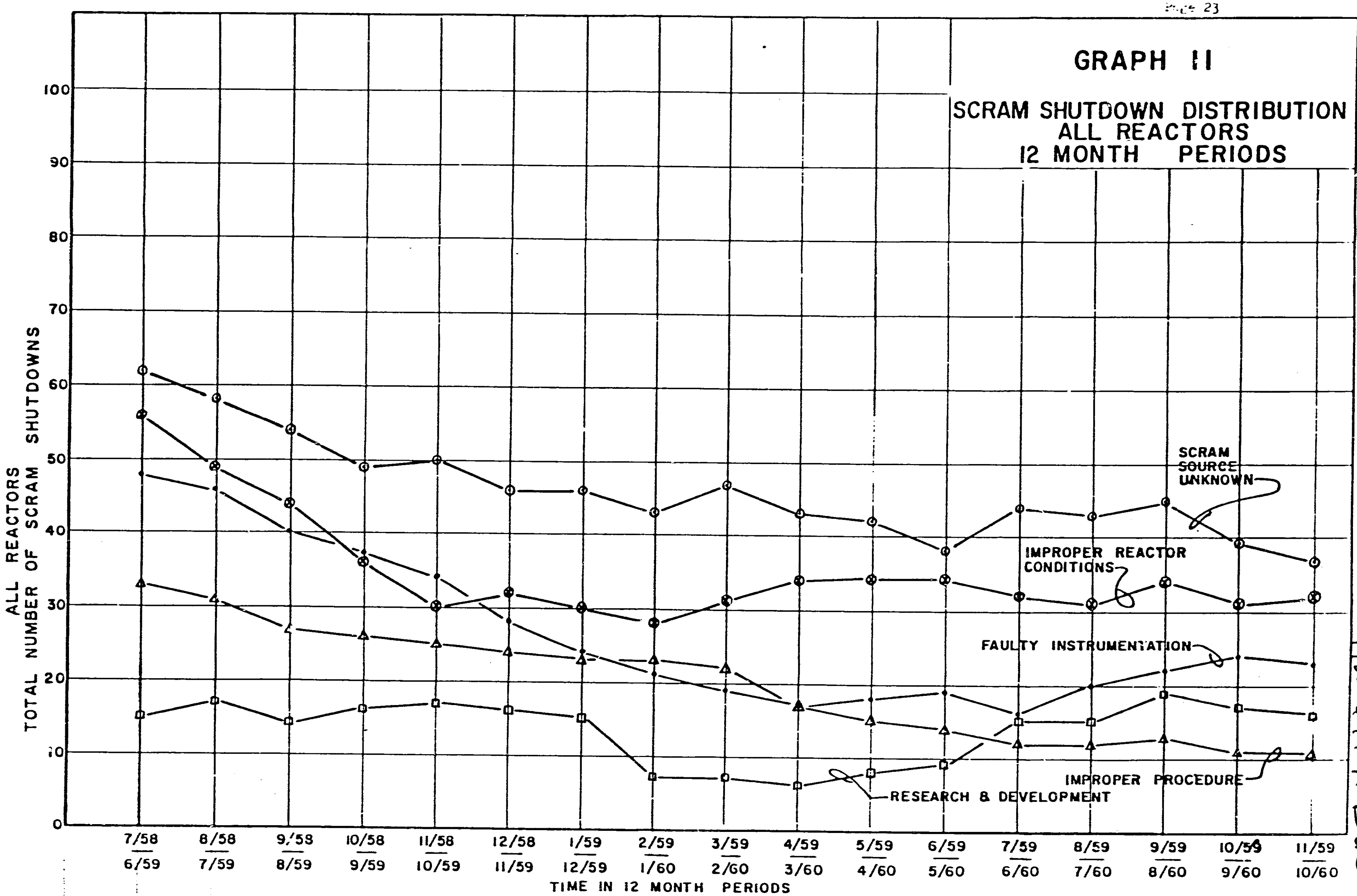
GRAPH II



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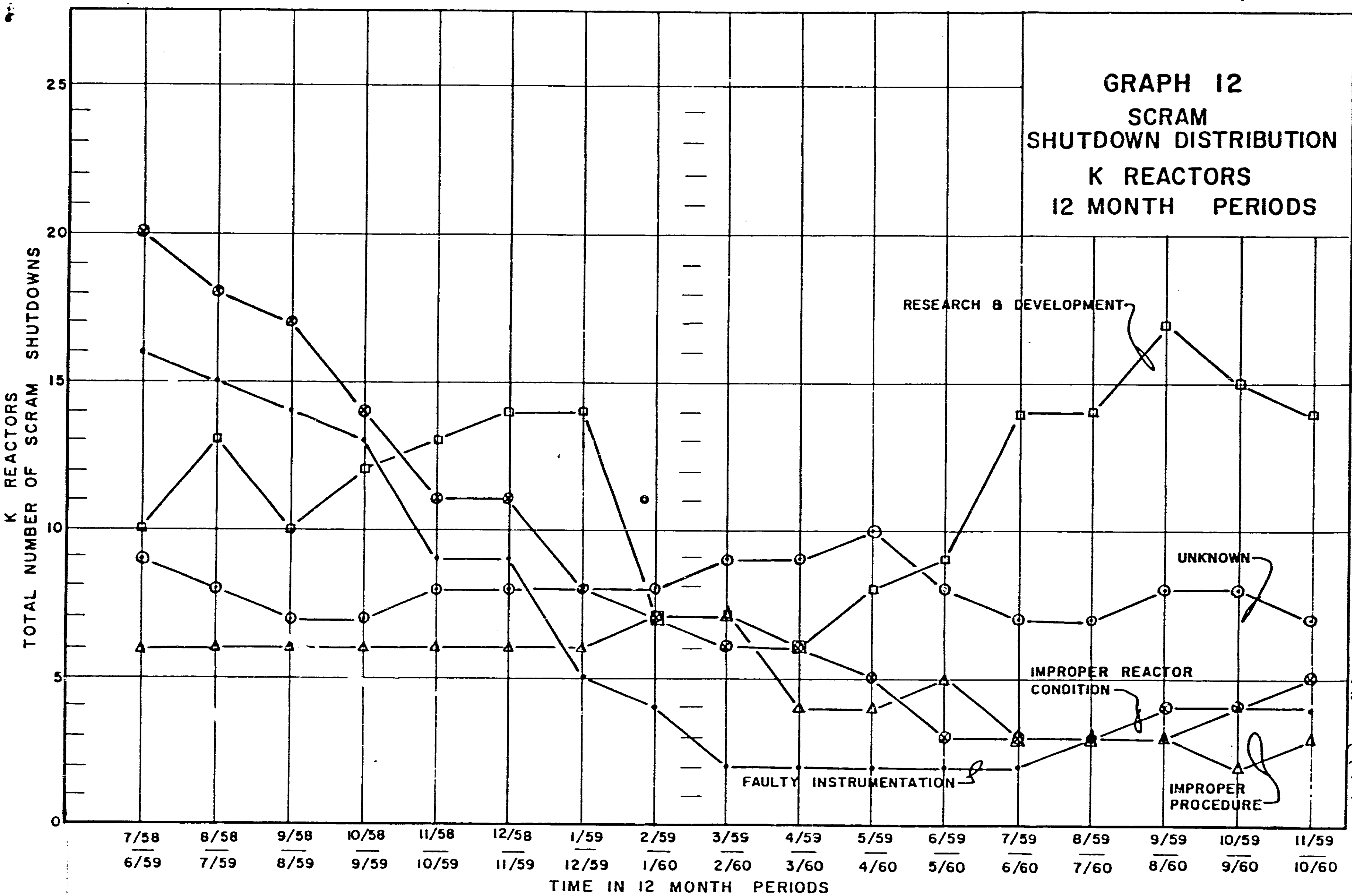

GRAPH 12
SCRAM
SHUTDOWN DISTRIBUTION
K REACTORS
12 MONTH PERIODS
RESEARCH & DEVELOPMENT
UNKNOWN
IMPROPER REACTOR CONDITION
FAULTY INSTRUMENTATION
IMPROPER PROCEDURE
K REACTORS
TOTAL NUMBER OF SCRAM SHUTDOWNS
0
5
10
15
20
25
7/58 6/59
8/58 7/59
9/58 8/59
10/58 9/59
11/58 10/59
12/58 11/59
1/59 12/59
2/59 1/60
3/59 2/60
4/59 3/60
5/59 4/60
6/59 5/60
7/59 6/60
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9/59 8/60
10/59 9/60
11/59 10/60
TIME IN 12 MONTH PERIODS

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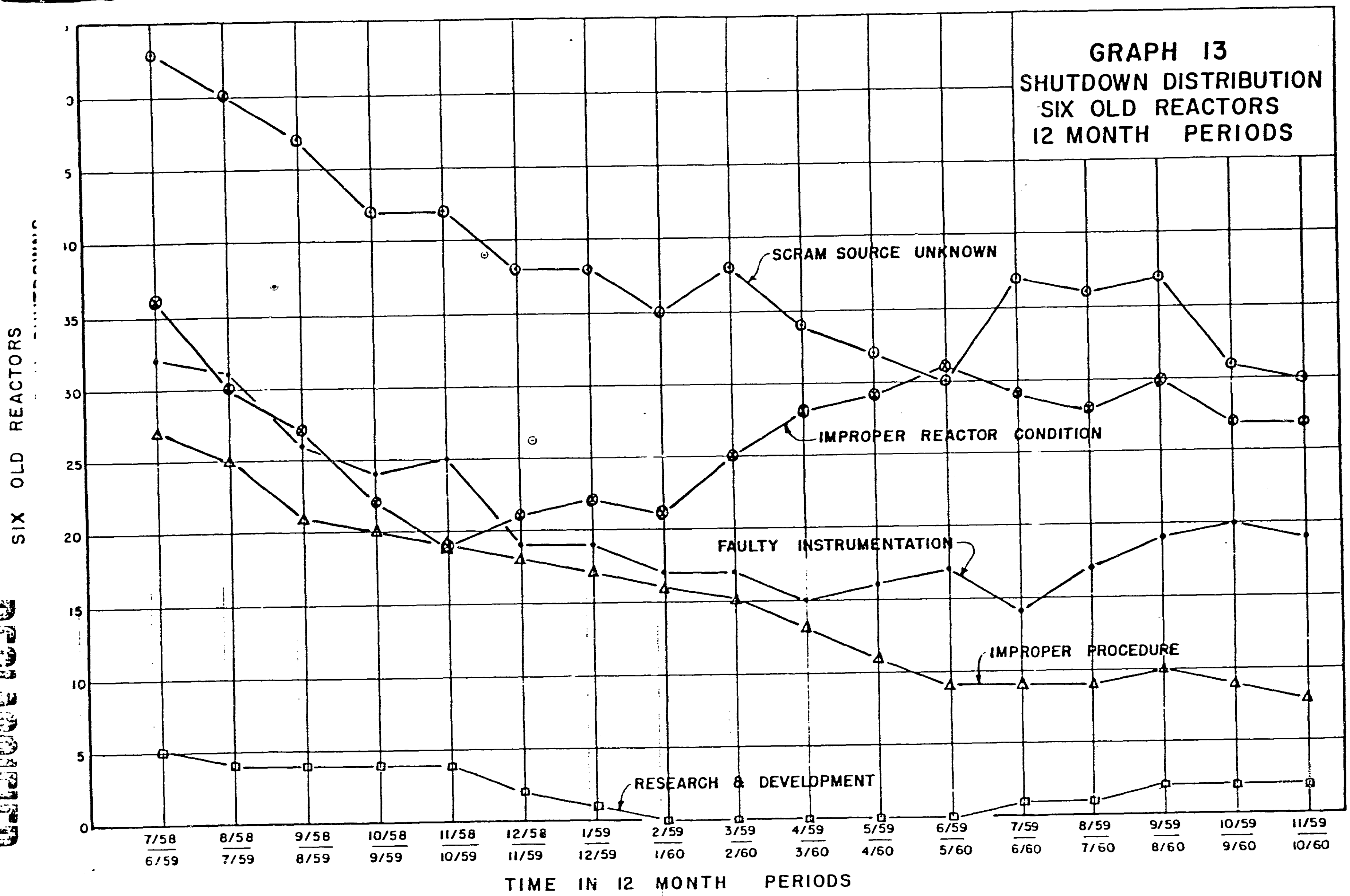

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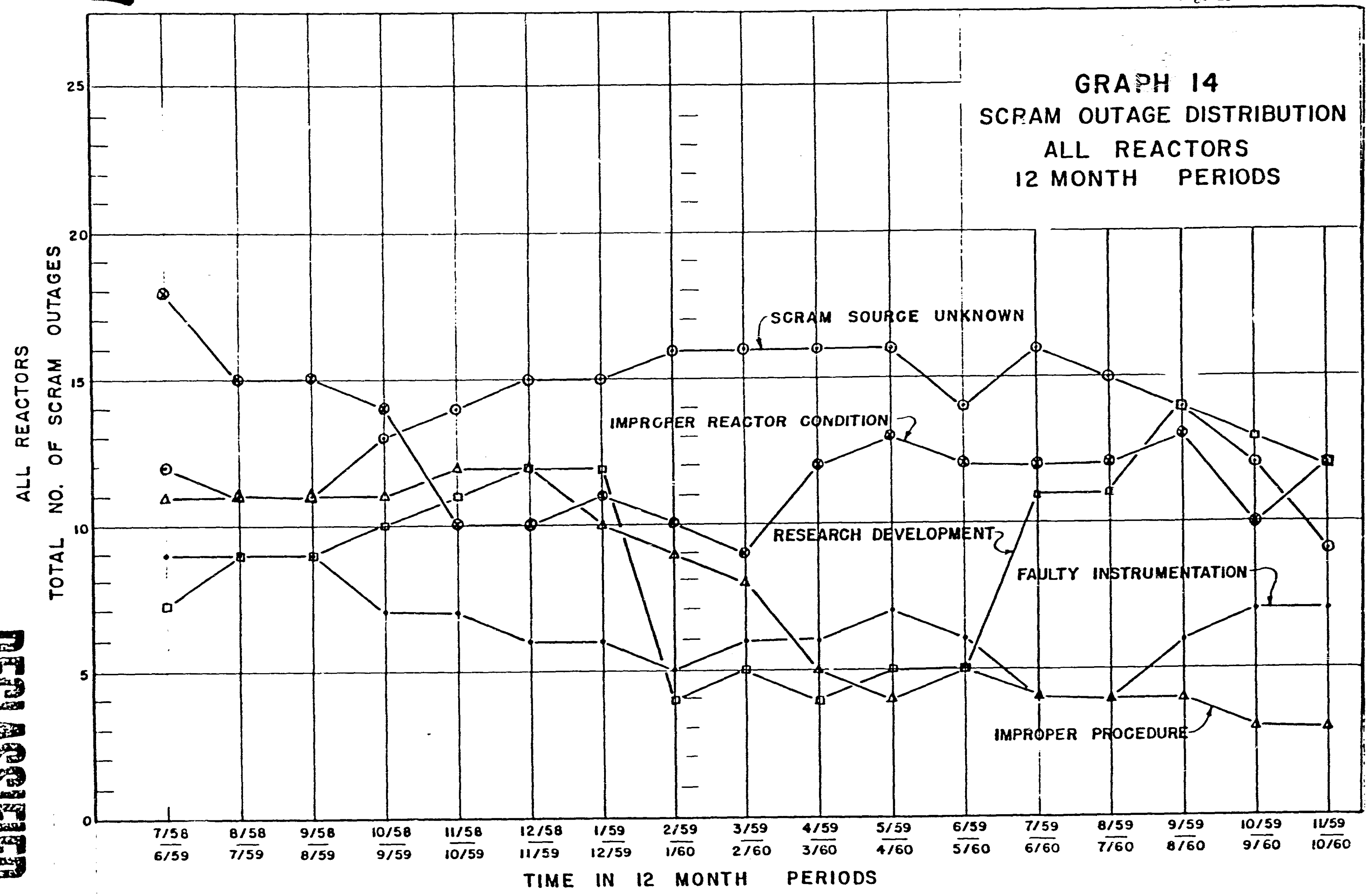

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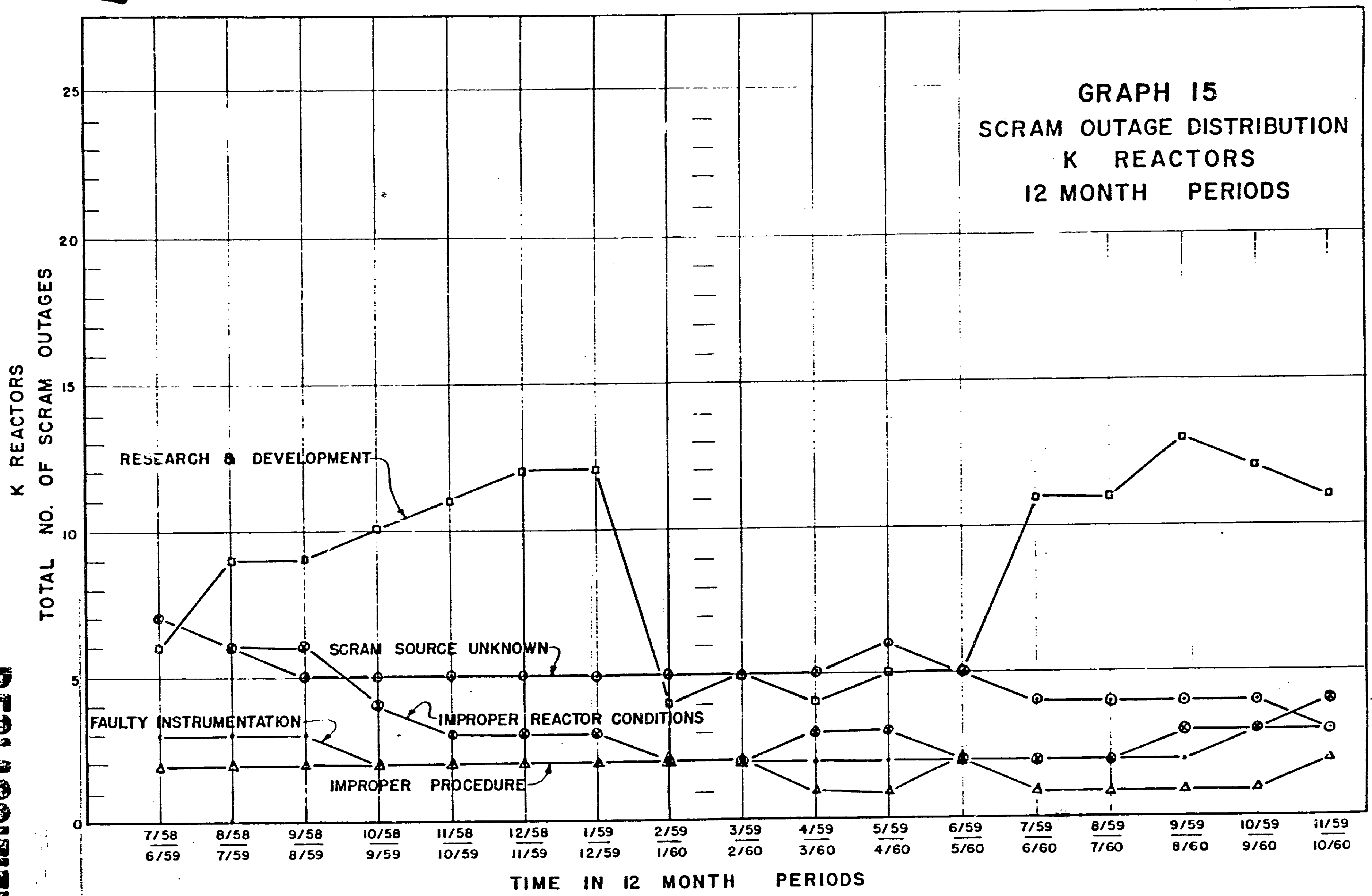

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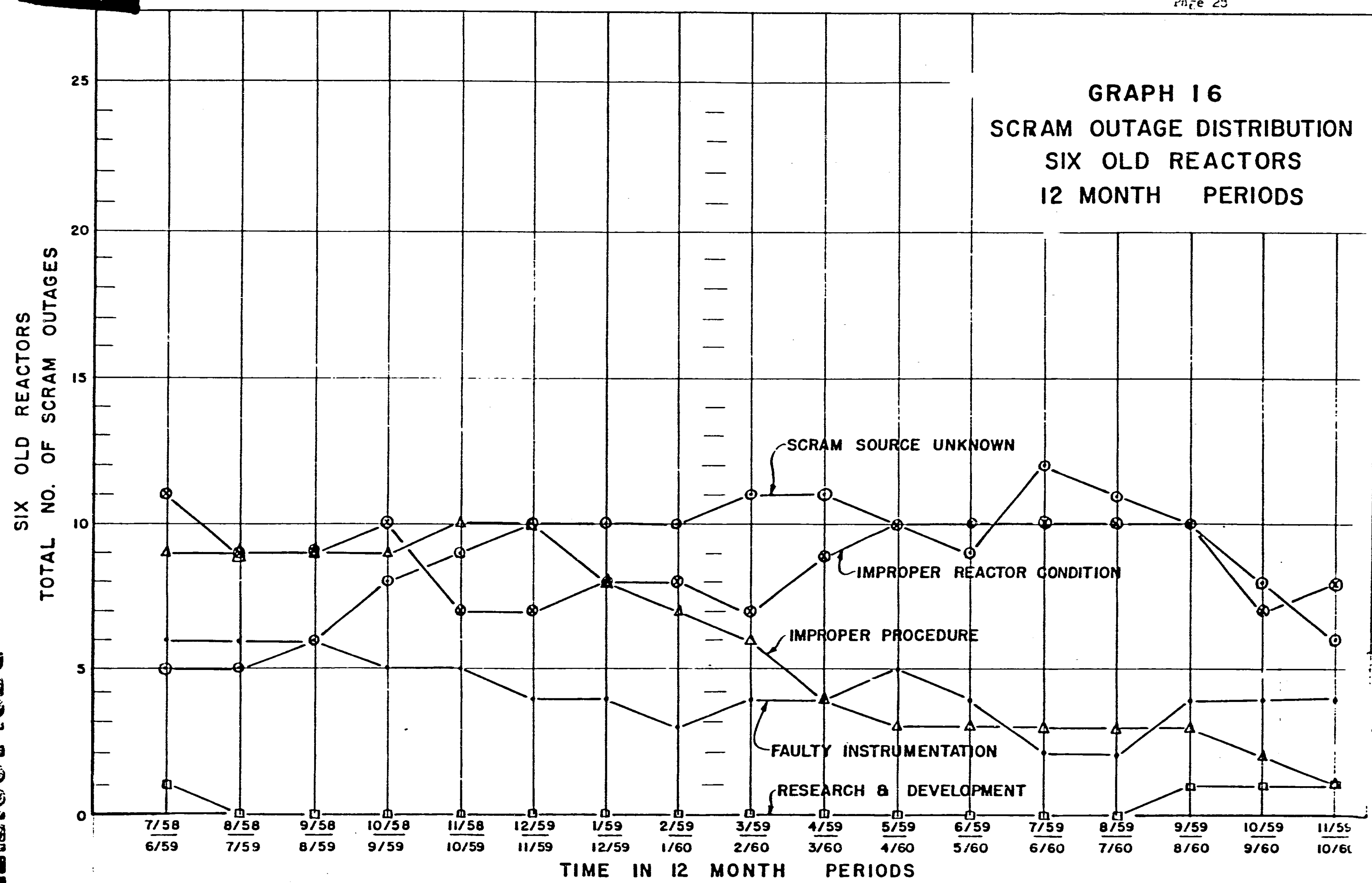

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TABLE 3 - SHUTDOWN DISTRIBUTION - B, C, D, DR, F, & H REACTORS

TYPE OF SHUTDOWN	FY-59			CY-59			FY-60			Nov. 59 through Oct. 60		
	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES
I. SCRAMS												
A. IMPROPER REACTOR CONDITIONS (Subt'l)	36	25	11	22	14	8	29	19	10	27	19	8
1. Faulty Process Equipment	24	17	7	10	5	5	13	7	6	12	9	3
2. Non-Standard Process Condition	9	5	4	7	5	2	7	6	1	8	6	2
3. Unusual Situation	3	3	0	5	4	1	9	6	3	7	4	3
B. FAULTY INSTRUMENTATION (Subt'l)	32	26	6	19	15	4	14	12	2	19	15	4
1. Panellit												
a. Faulty Instruments	11	10	1	5	4	1	5	4	1	10	8	2
b. Oscillating Gauges	17	13	4	11	9	2	7	7	0	5	5	0
2. Beckman	1	1	0	-	-	-	-	-	-	-	-	-
3. Safety Circuit	1	1	0	1	1	0	2	1	1	4	2	2
4. Temperature	2	1	1	2	1	1	-	-	-	-	-	-
C. IMPROPER PROCEDURE (Subt'l)	27	18	9	17	9	8	9	6	3	8	7	1
1. Instruments	16	11	5	11	7	4	5	3	2	5	4	1
2. Process Equipment	10	6	4	4	1	3	1	1	0	1	1	0
3. Unusual Situation	1	1	0	2	1	1	3	2	1	2	2	0
D. SCRAM SOURCE UNKNOWN	53	48	5	38	28	10	37	25	12	30	24	6
E. RESEARCH & DEVELOPMENT	5	4	1	1	1	0	1	1	0	2	1	1
I. TOTAL - SCRAMS	153	121	32	97	67	30	90	63	27	86	66	20
II. RUPTURES	94	7	87	51	1	50	84	20	64	90	20	70
III. PLANNED OUTAGES	14	-	14	19	-	19	18	-	18	24	-	24
IV. WATER LEAKS	35	0	35	31	0	31	32	0	32	36	0	36
V. POISON OUTAGES	13	12	1	16	15	1	11	11	0	6	6	0
VI. EQUIPMENT FAILURE	14	8	6	7	3	4	15	8	7	19	11	8
VII. MISCELLANEOUS	14	10	4	13	8	5	13	5	8	14	6	8
TOTALS	337	158	179	234	94	140	263	107	156	[illegible]	[illegible]	[illegible]

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TABLE 4 - SHUTDOWN DISTRIBUTION - KE AND KW REACTORS

TYPE OF SHUTDOWN	FY-59			CY-59			FY-60			Nov. 59 through Oct. 60		
	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES
I. SCRAMS												
A. IMPROPER REACTOR CONDITIONS (Subt'l)	20	13	7	8	5	3	3	1	2	5	1	4
1. Faulty Process Equipment	2	0	2	2	0	2	1	0	1	3	0	3
2. Non-standard Process Condition	18	13	5	5	4	1	-	-	-	-	-	-
3. Unusual Situation	-	-	-	1	1	0	2		1	2	1	1
B. FAULTY INSTRUMENTATION (Subt'l)	16	13	3	5	3	2	2	0	2	4	1	3
1. Panellit												
a. Faulty Instruments	7	5	2	3	1	2	-	-	-	-	-	-
b. Oscillating Gauges	3	3	0	1	1	0	1	0	1	2	0	2
2. Beckman	1	1	0	-	-	-	1	0	1	1	0	1
3. Safety Circuit	-	-	-	-	-	-	-	-	-	1	1	0
4. Temperature	5	4	1	1	1	0	-	-	-	-	-	-
C. IMPROPER PROCEDURE (Subt'l)	6	4	2	6	4	2	3	2	1	3	1	2
1. Instruments	1	1	0	2	2	0	3	2	1	2	1	1
2. Process Equipment	5	3	2	4	2	2	-	-	-	-	-	-
3. Unusual Situation	-	-	-	-	-	-	-	-	-	1	0	1
D. SCRAM SOURCE UNKNOWN	9	2	7	8	3	5	7	3	4	7	4	3
E. RESEARCH & DEVELOPMENT	10	4	6	14	2	12	14	3	11	14	3	11
I. TOTAL - SCRAMS	61	36	25	41	17	24	29	9	20	33	10	23
II. RUPTURES	21	0	21	14	1	13	22	2	20	26	1	25
III. PLANNED OUTAGES	4	-	4	9	-	9	8	-	8	6	-	6
IV. WATER LEAKS	2	0	2	1	0	1	3	0	3	1	0	1
V. POISON OUTAGES	25	25	-	27	27	0	14	14	0	6	6	0
VI. EQUIPMENT FAILURE	4	2	2	4	1	3	1	0	1	1	0	1
VII. MISCELLANEOUS	3	2	1	3	2	1	2	1	1	2	1	1
TOTALS	120	65	55	[illegible]	[illegible]	[illegible]	[illegible]	26	53	75	19	[illegible]

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TABLE 5 - SHUTDOWN DISTRIBUTION - ALL REACTORS

TYPE OF SHUTDOWN	FY-59			CY-59			FY-60			Nov. 59 through Oct. 60		
	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES	NUMBER	RECOVERIES	OUTAGES
I. SCRAMS												
A. IMPROPER REACTOR CONDITIONS (Subt'l)	56	38	18	30	19	11	32	20	12	32	20	12
1. Faulty Process Equipment	26	17	9	12	5	7	14	7	7	15	9	6
2. Non-standard Process Condition	27	18	9	12	9	3	7	6	1	8	6	2
3. Unusual Situation	3	3	0	6	5	1	11	7	4	9	5	4
B. FAULTY INSTRUMENTATION (Subt'l)	48	39	9	24	18	6	16	12	4	23	16	7
1. Panellit												
a. Faulty Instruments	18	15	3	8	5	3	5	4	1	10	8	2
b. Oscillating Gauges	20	16	4	12	10	2	8	7	1	7	5	2
2. Beckman	2	2	0	-	-	-	1	0	1	1	0	1
3. Safety Circuit	1	1	0	1	1	0	2	1	1	5	3	2
4. Temperature	7	5	2	3	2	1	-	-	-	-	-	-
C. IMPROPER PROCEDURE (Subt'l)	33	22	11	23	13	10	12	8	4	11	8	3
1. Instruments	17	12	5	13	9	4	8	5	3	7	5	2
2. Process Equipment	15	9	6	8	3	5	1	1	0	1	1	0
3. Unusual Situation	1	1	0	2	1	1	3	2	1	3	2	1
D. SCRAM SOURCE UNKNOWN	62	50	12	46	31	15	44	28	16	37	28	9
E. RESEARCH & DEVELOPMENT	15	8	7	15	3	12	15	4	11	16	4	12
I. TOTAL - SCRAMS	214	157	57	138	84	54	119	72	47	119	76	43
II. RUPTURES	115	7	108	65	2	63	106	22	84	116	21	95
III. PLANNED OUTAGES	18	-	18	28	-	28	26	-	26	30	-	30
IV. WATER LEAKS	37	0	37	32	0	32	35	0	35	37	0	37
V. POISON OUTAGES	38	37	1	43	42	1	25	25	0	12	12	0
VI. EQUIPMENT FAILURE	18	10	8	11	4	7	16	8	8	20	11	9
VII. MISCELLANEOUS	17	12	5	16	10	6	15	6	9	16	7	9
TOTALS	457	223	234	333	142	191	342	133	209	350	127	223

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GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

DATE December 19, 1960

TITLE

CAUSES OF REACTOR SHUTDOWNS

AUTHOR

J. L. Deichman

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