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REPORT ON FUEL-PLATE MELTING AT THE OAK RIDGE RESEARCH REACTOR JULY 1, 1963

T. M. Sims
W. H. Tabor

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OPERATIONS DIVISION

REPORT ON FUEL-PLATE MELTING AT THE OAK RIDGE RESEARCH REACTOR JULY 1, 1963

T. M. Sims and W. H. Tabor

OCTOBER 1964

OAK RIDGE NATIONAL LABORATORY
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REPORT ON FUEL-PLATE MELTING AT THE OAK RIDGE RESEARCH REACTOR JULY 1, 1963

T. M. Sims and W. H. Tabor

SUMMARY

During the night of June 30-July 1, 1963, some fission products were released from the Oak Ridge Research Reactor fuel into the water systems. The incident occurred at a power of 24 Mw during a beginning-of-cycle startup. It was discovered later that the fission-product release had been caused by the blocking of one fuel element by a large neoprene gasket. The release from the fuel element was of short duration, probably less than one or two minutes. There is some evidence that a major portion of the release terminated prior to the reduction of the reactor power from 24 Mw.

A preliminary estimate, based on the gross β-γ activity level of the first sample taken from the reactor water system subsequent to the release, indicated a release of the order of 1000 curies. Only volatile fission products escaped in significant quantities from the fuel element into the water system. Diffusion of noble gas isotopes (principally ^{138}Xe and ^{88}Kr) from the water system to the building atmosphere resulted in some contamination of the latter with ^{138}Cs and ^{88}Rb at levels estimated at 10^{-6} to 10^{-7} $\mu c/cm^3$.

Stack monitors indicated that most of the radioactivity discharged from the facility came through the central off-gas system via the primary water degasifier. The integrating sampler in the stack discharge showed that about 150 to 200 mc of iodine were released, although most of the contamination in the off-gas was removed by the filters and scrubber. Contamination in the water was removed by the demineralizers and eventually discharged into the Intermediate-Level Waste System.

Following the reactor shutdown, the building had to be evacuated for approximately 6 1/2 hours because of air contamination. The reactor tank was not opened until about 20 hours after the incident, allowing time for removal of the contamination by the degasifier and ion exchange columns and for decay of short-lived fission products. Before the tank was opened, ∿6000 gallons of the primary water was purged to one of the storage tanks and replaced by less active pool water. No gaseous activity or other contamination was observed when the tank was opened. During this time, an instrument to draw a water sample from each fuel element was built

to aid in locating the faulty element in case the damage could not be observed directly. Once the tank was opened, however, the blocked element was seen almost immediately; and this instrument was not used.

The faulty element was removed without any difficulty and examined in the pool to determine the nature of the blocking material. It was then stored in the pool under off-gas ventilation pending further examination in a hot cell. Except for the blockage, the element appeared perfectly normal.

About 20 hours additional time was spent in searching for the source of the gasket material and in making sure that no other piece of similar material remained in the system. Nothing was found; and, on the evening of July 2, the reactor was brought to full power. Water radioactivity was higher by about a factor of two. The gaseous contamination was slightly higher than normal; however, this disappeared in a few days. No further difficulties were encountered.

CHRONOLOGY OF THE INCIDENT

The official chronology of the principal events of the incident are tabulated below. For the sake of clarity, no details are presented in this tabulation; they are available in other sections of this report.

June 30, 1963

10:35 PM	Rod withdrawal started.
11:16 PM	Power at 330 kw (N_L).
11:22 PM	Power raised to 6 Mw. Visual inspection of reactor core made.
11:32 PM	Power raised to 9 Mw.
11:35 PM	Power raised to 12 Mw. Some agitation of servo and fluctuations of reactor power noticed.

July 1, 1963

12:00 Midnight	Shift change.
12:25 AM	Telephone consultation with instrument engineer about agitated servo and reactor power fluctuations.
12:30 AM	Heat-power calculation.
12:33 AM	Power increase started.
12:37 AM	Power at 24 Mw, intended stop for new heat-power calculation.
12:39 AM	Simultaneously the reactor secondary high-radiation alarm sounded and the ^{16}N instrument went off scale.(^{16}N detector eturned to normal within 2 to 3 minutes). Degasifier high-radiation alarm sounded.
12:43 AM	Power reduced to 21 Mw.
12:46 AM	Power reduced to 12 Mw.
12:48 AM	Subpile room radiation alarm sounded.
12:56 AM	Power reduced to 330 kw (N_L). Building radiation survey initiated.
1:10 AM	Reactor scrammed. Reactor supervisor called.
1:12 AM	Airborne contamination necessitated building evacuation. Building containment manually activated. Area radiation survey initiated.
2:30 AM	First building survey by Health Physics surveyor. Building background was 1 to 2 mr/hr.

3:45 AM	Second building survey.
4:45 AM	Personnel doors opened.
About 6:00 AM	Scrubber shut down. Three roof fans started. West truck door opened.
7:45 AM	Building all clear. Investigation and clean-up procedures started.
About 9:00 PM	Reactor tank opened.
About 9:30 PM	Obstructed element located, removed, and obstruction examined. Started reactor tank inspection, cleanup, etc.
	July 2, 1963
9:01 PM	Reactor power at 30 Mw.

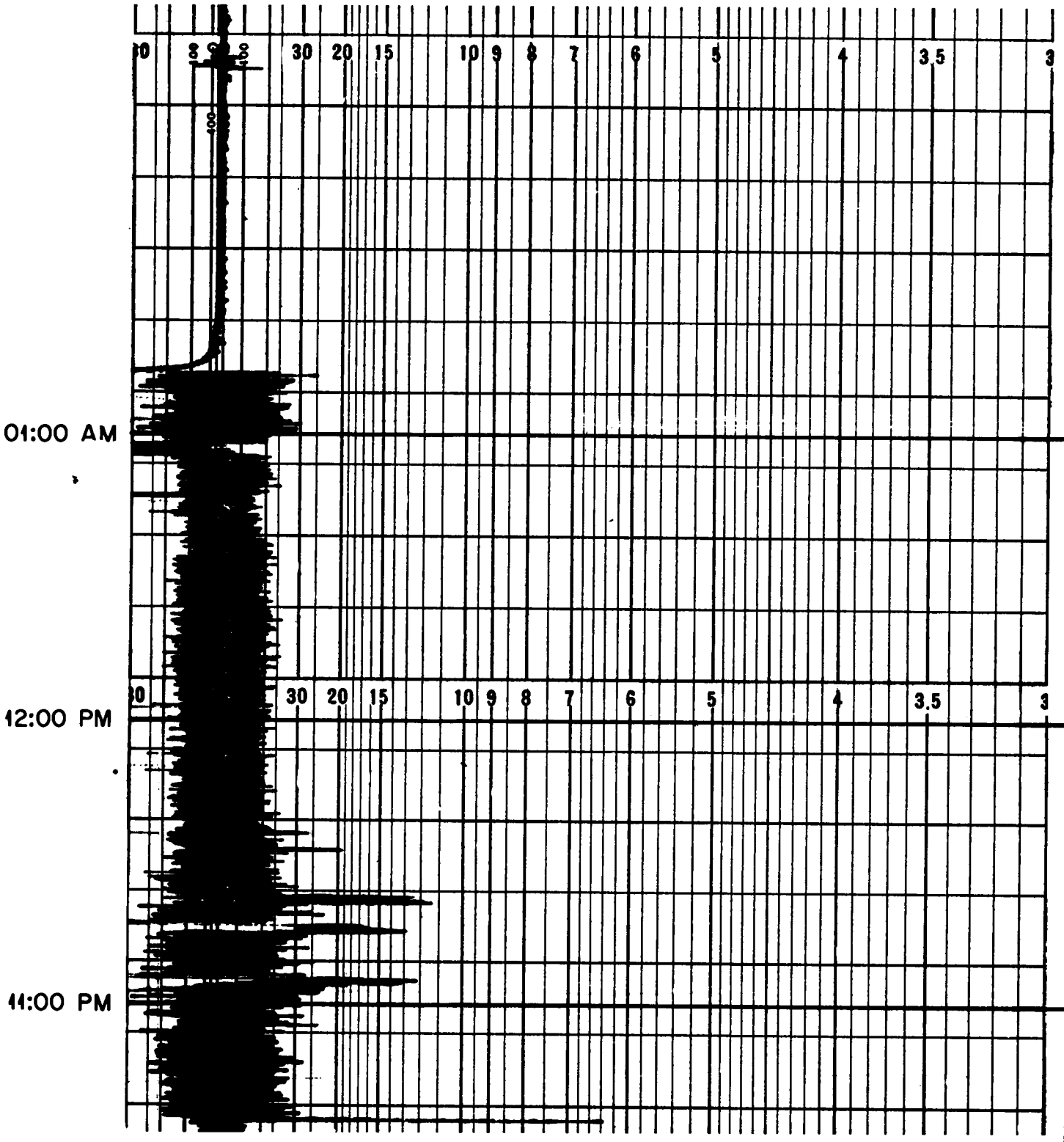
RECONSTRUCTION OF APPROACH TO POWER

Figures 1 and 2 display the recorder charts from the main control and safety instruments. These records were synchronized to facilitate their interpretation. For comparison, two recorder charts from a previous cycle (assumed to be normal) are also shown.

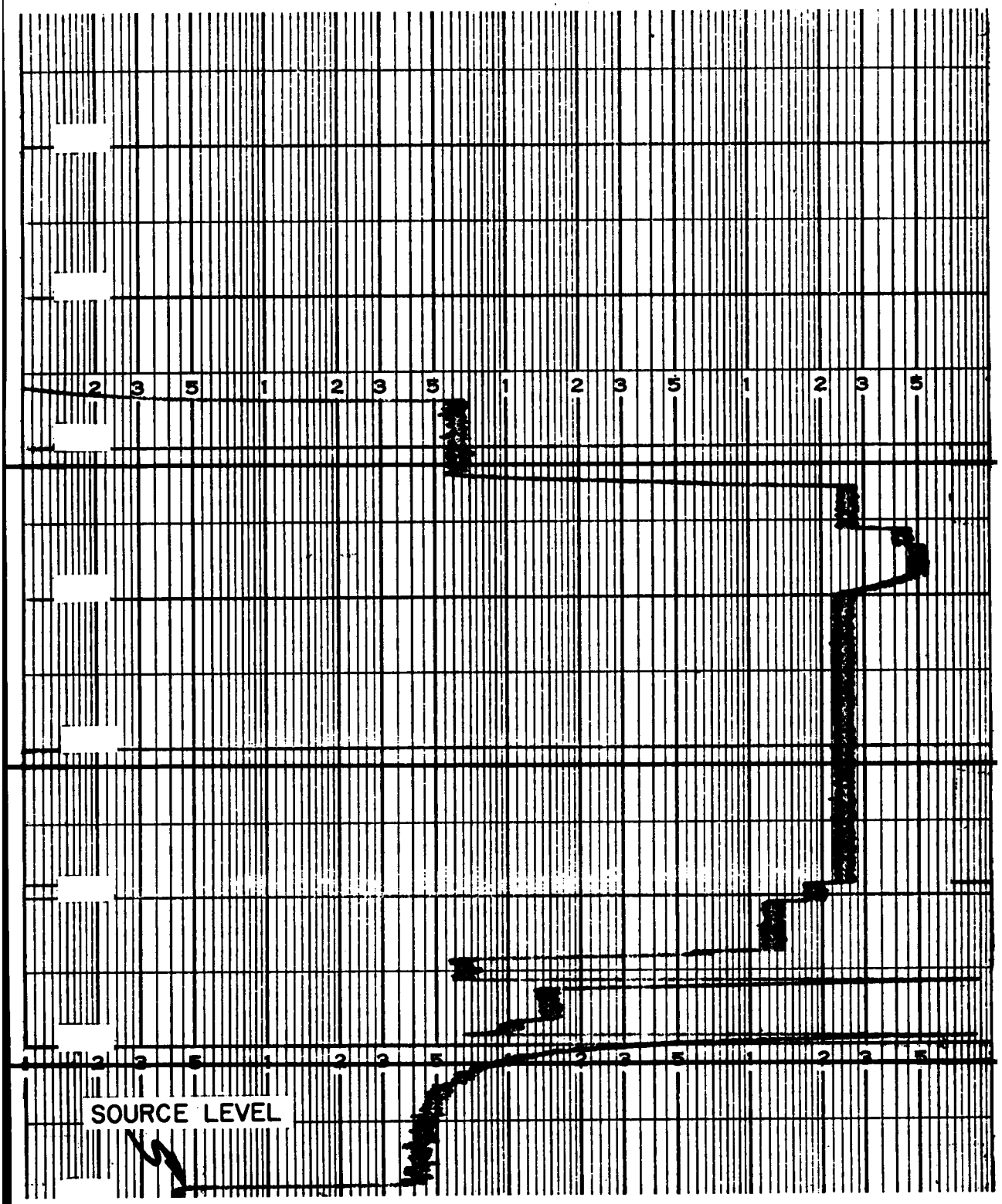
The reactor shim-rods withdrawal was started at 10:35 PM, June 30, 1963. The source level can be observed at the bottom of the No. 1 count-rate-meter chart. The log-N records indicate that the reactor power was stabilized for a few minutes at various levels: 4.4 kw, 330 kw (N_L), and 3, 6, 9, 12, and 24 Mw.

At 6 Mw a visual inspection of the core was performed to determine if any foreign objects were obstructing the coolant flow. A verification of this type was also made before the reactor startup. The first inspection was made with the tank lid open and with an underwater floodlight in the reactor tank. Both visual inspections were made by a shift engineer or the reactor supervisor.

The visual inspection at a power level of a few megawatts should be very effective because an obstructing object lying on the top of the fuel region will intercept the Cerenkov glow and, therefore, appear as a shadow picture. The obstruction which caused the incident reported here was on the extreme south side of the core in position D-1, which could not be observed well through the window. The small size of the viewing hole in the tank lid and its location made it impossible to look



NO. 1 COUNT RATE PERIOD



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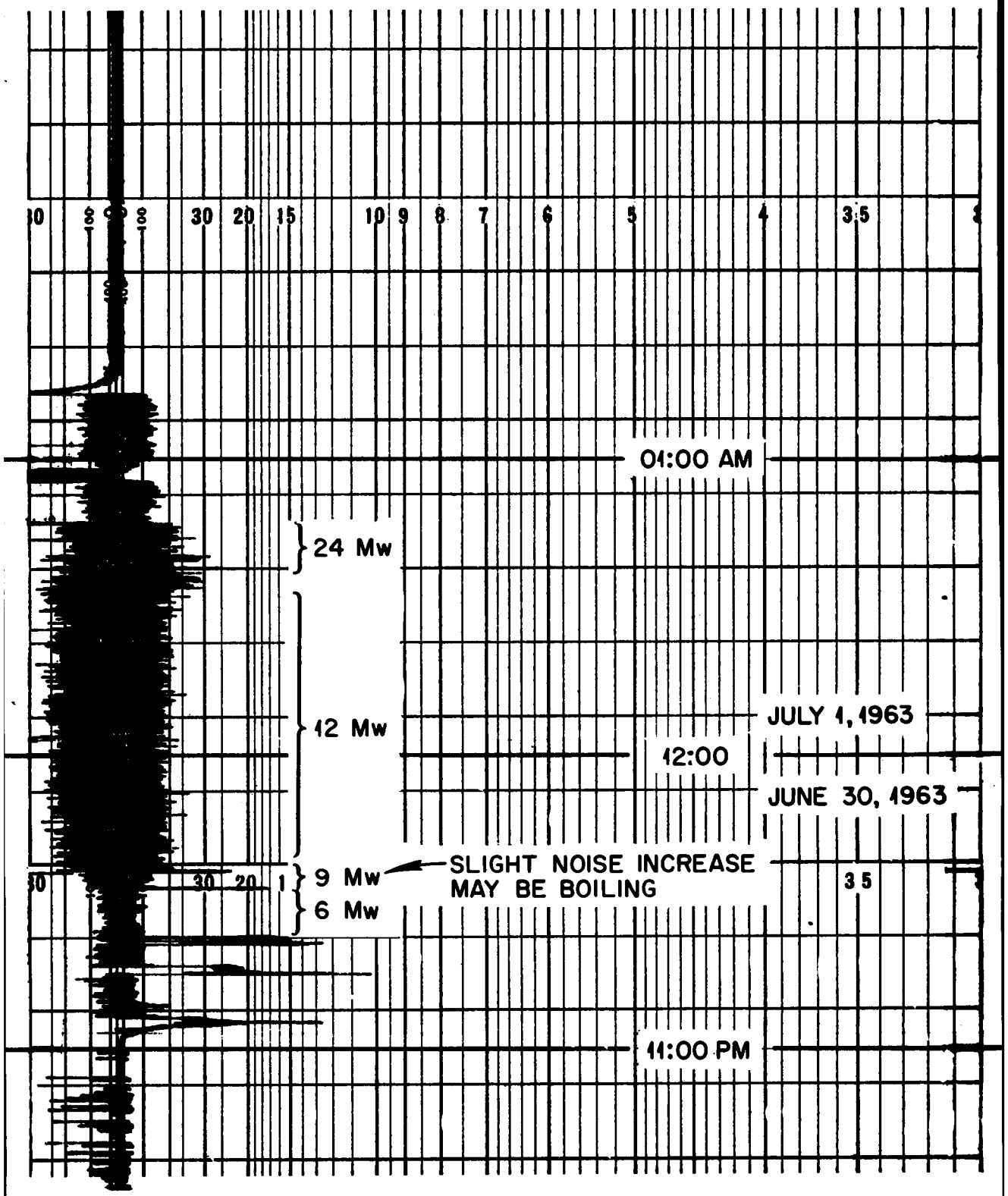
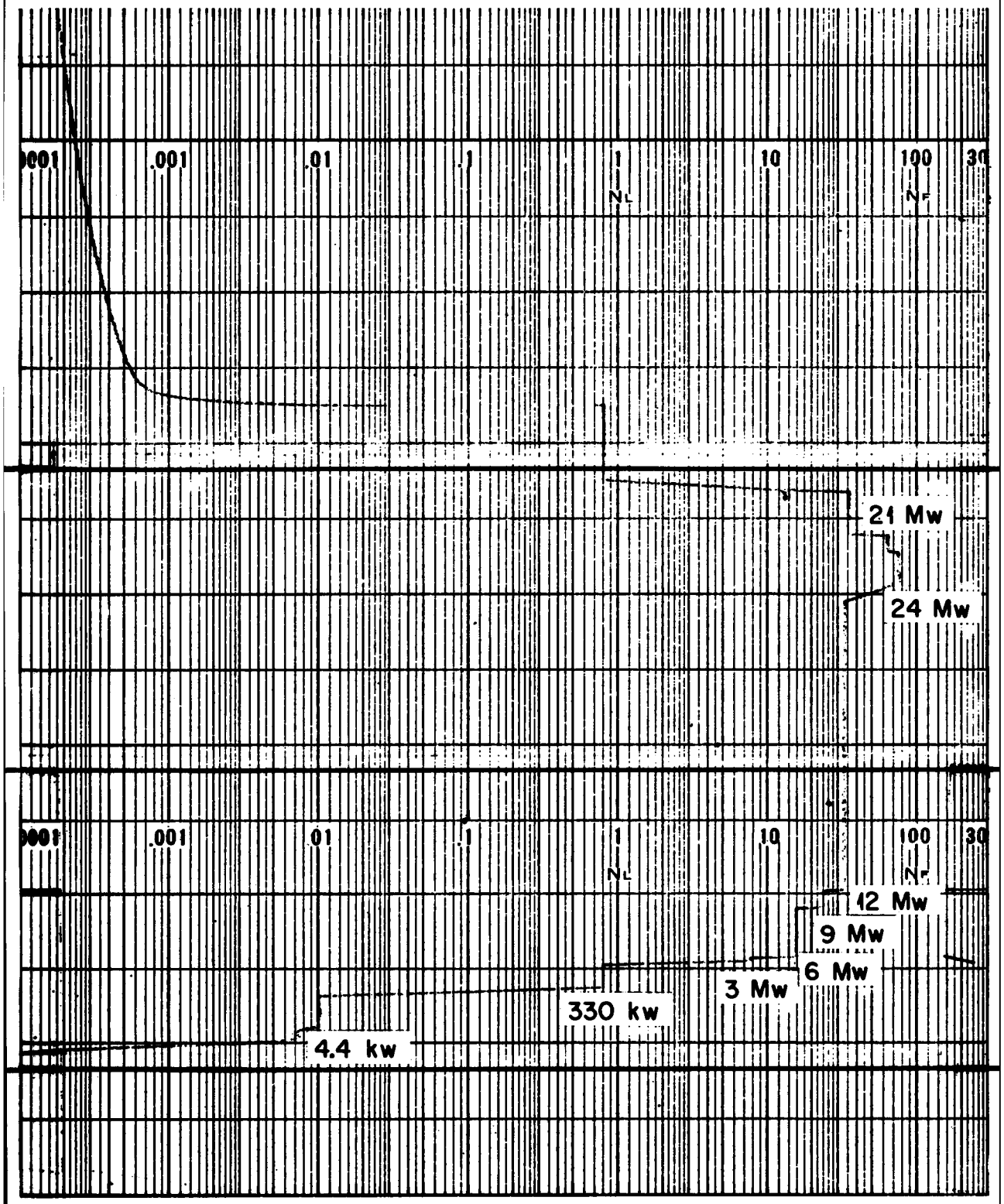


NO. 1 log N PERIOD



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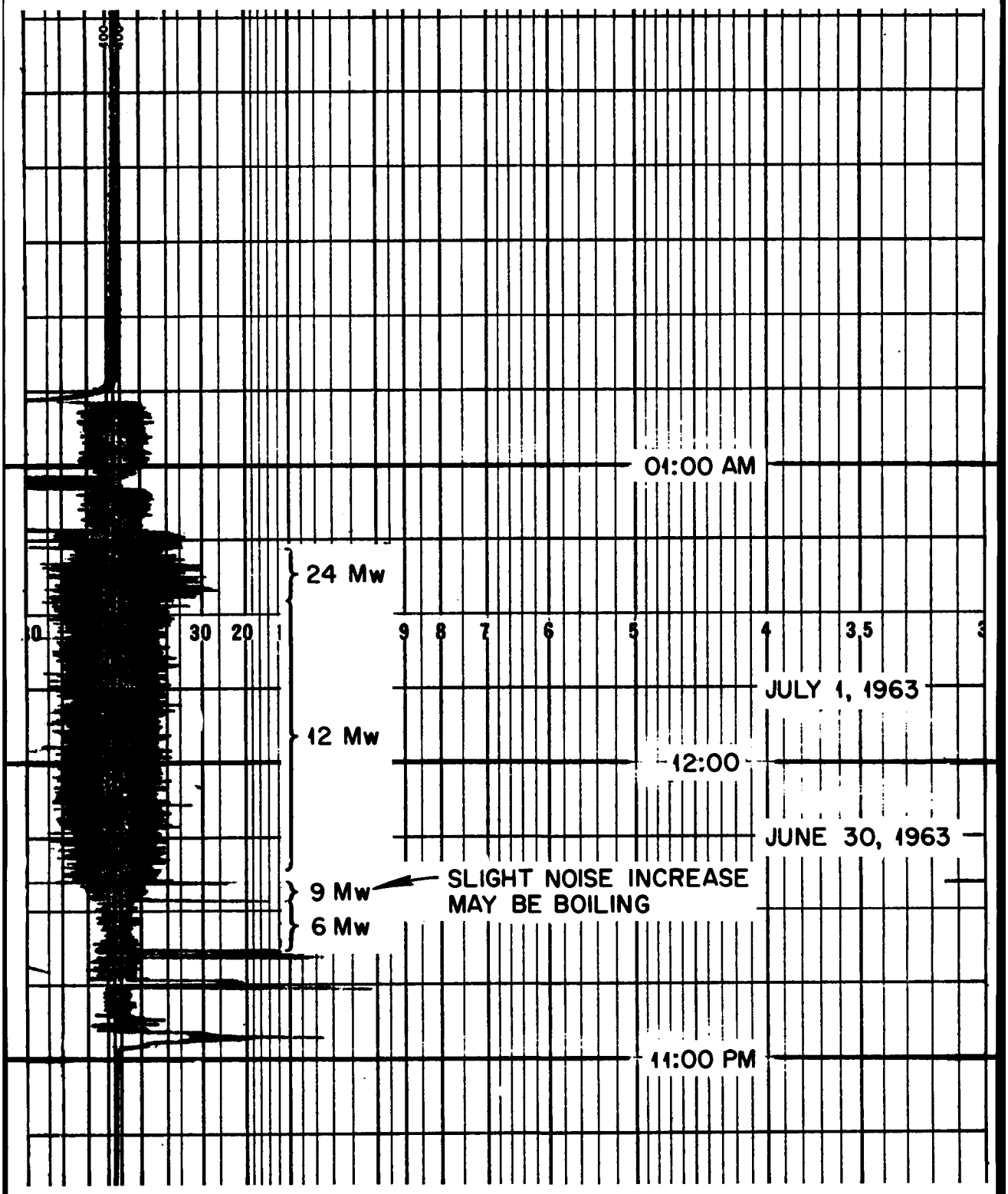
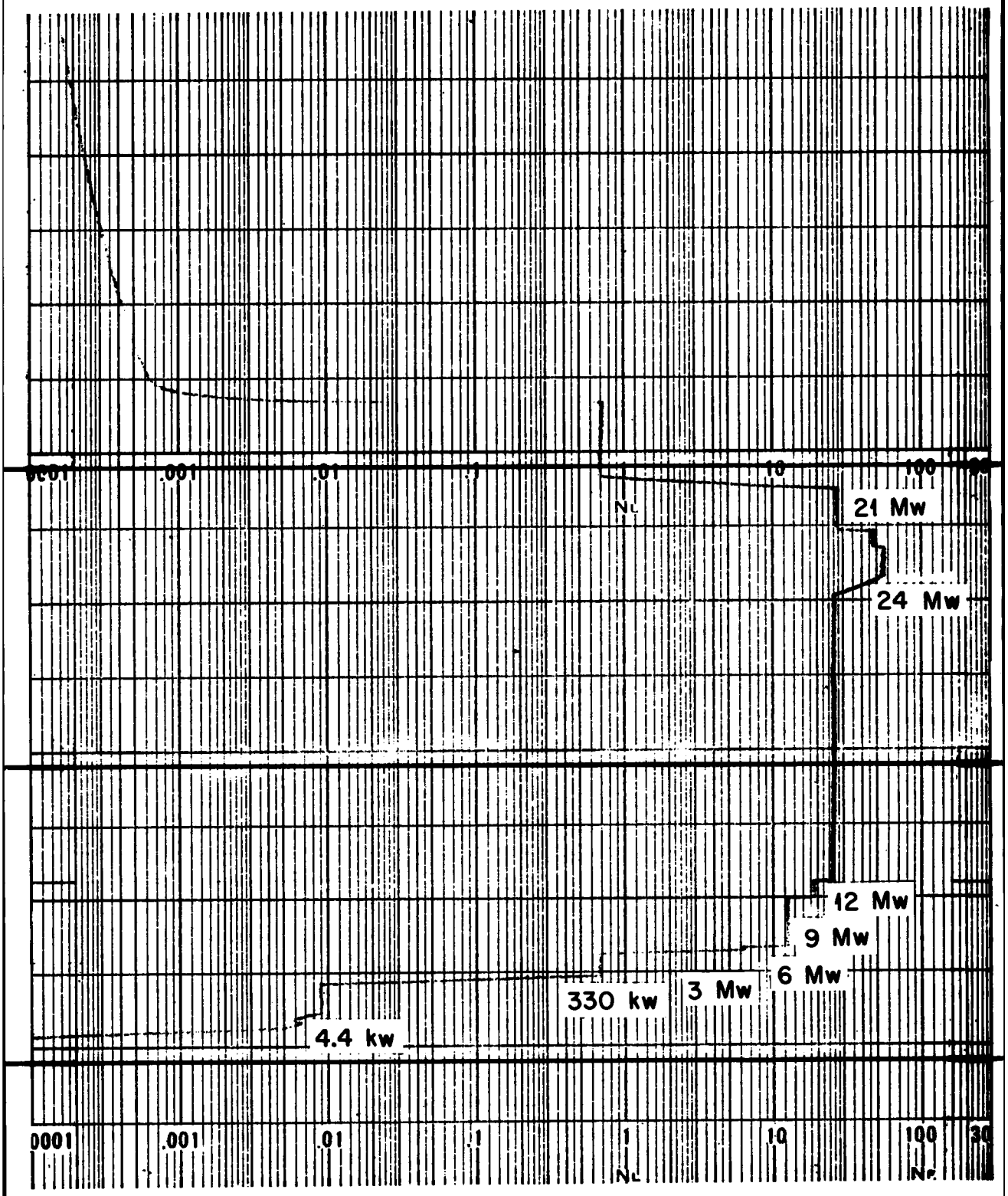


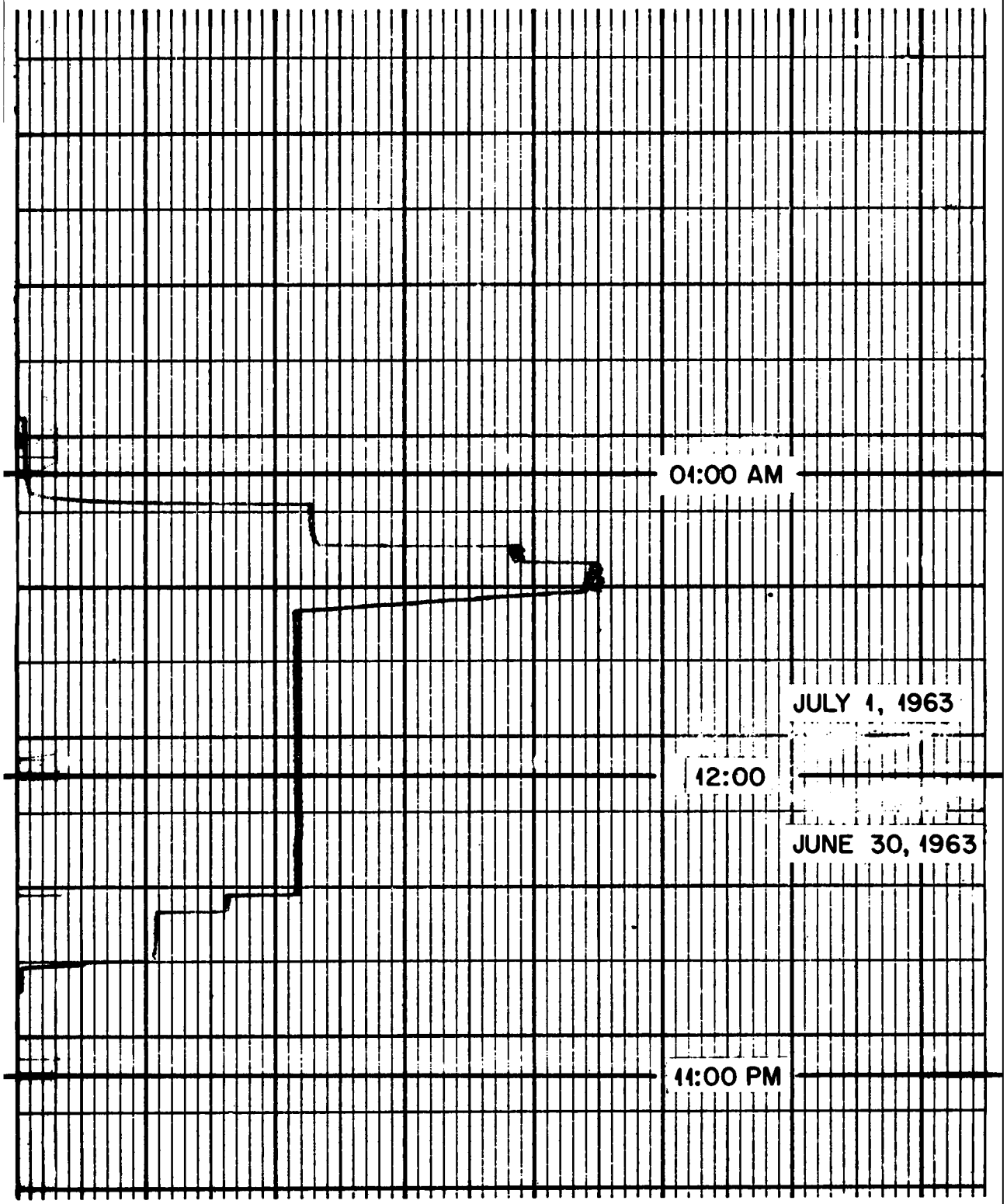
NO. 2 log N PERIOD

Fig. 1. Nuclear Instruments Recorder Charts from 1

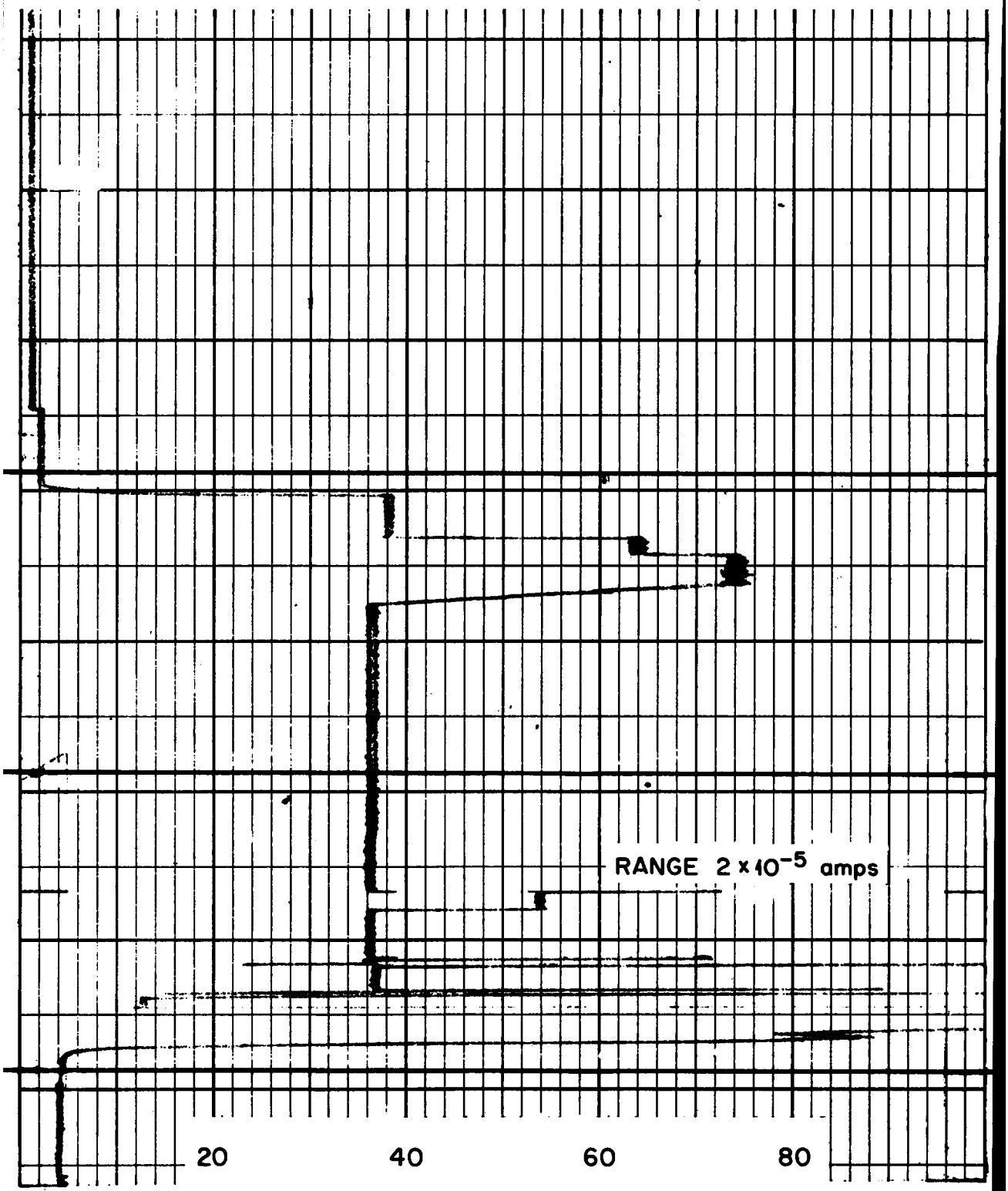


NO. 2 log N

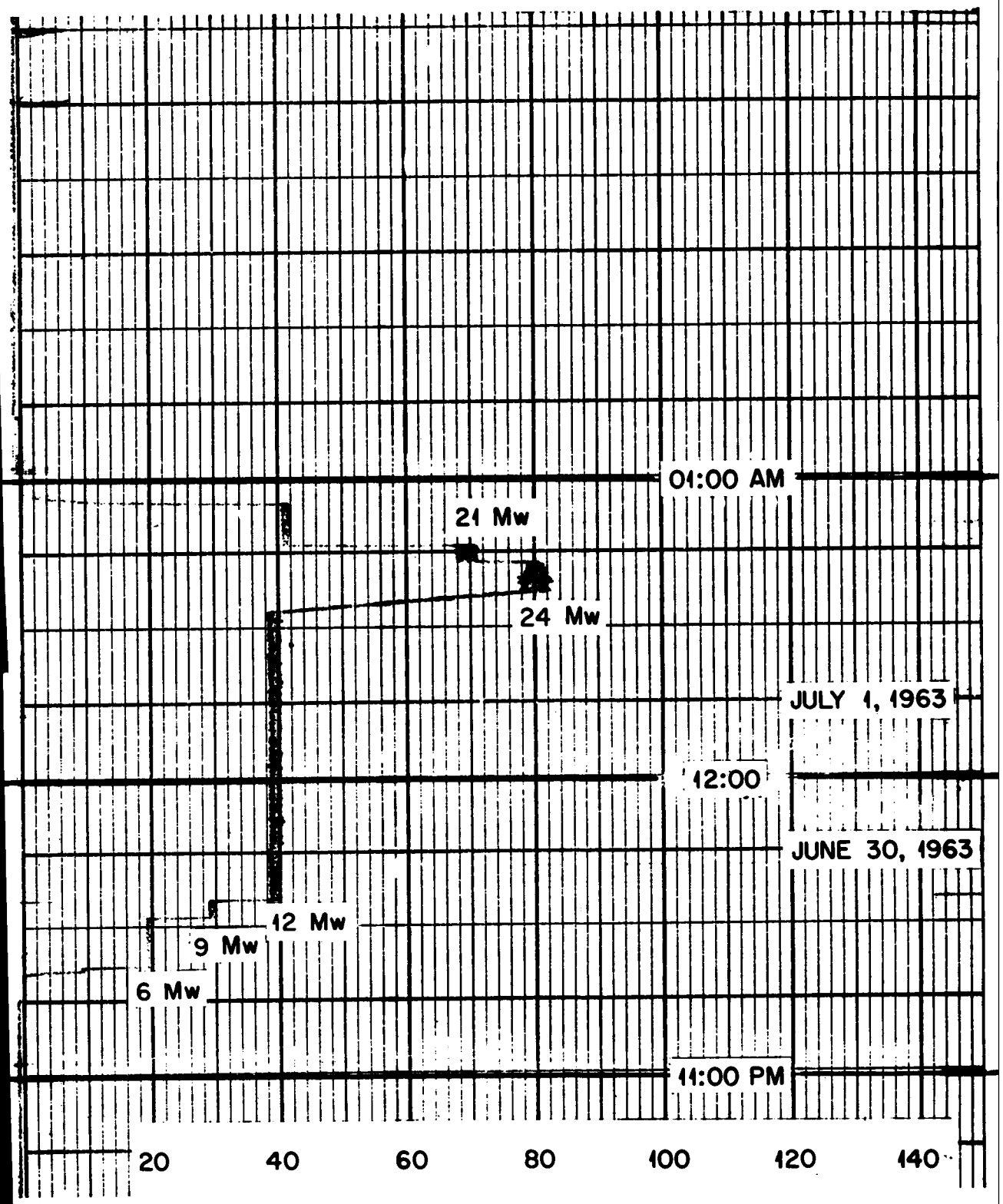
0:30 PM, June 30, 1963, to 02:30 AM, July 1, 1963



NO. 2 GAMMA CHAMBER



PICOAMETER



NO. 1 SAFETY CHANNEL

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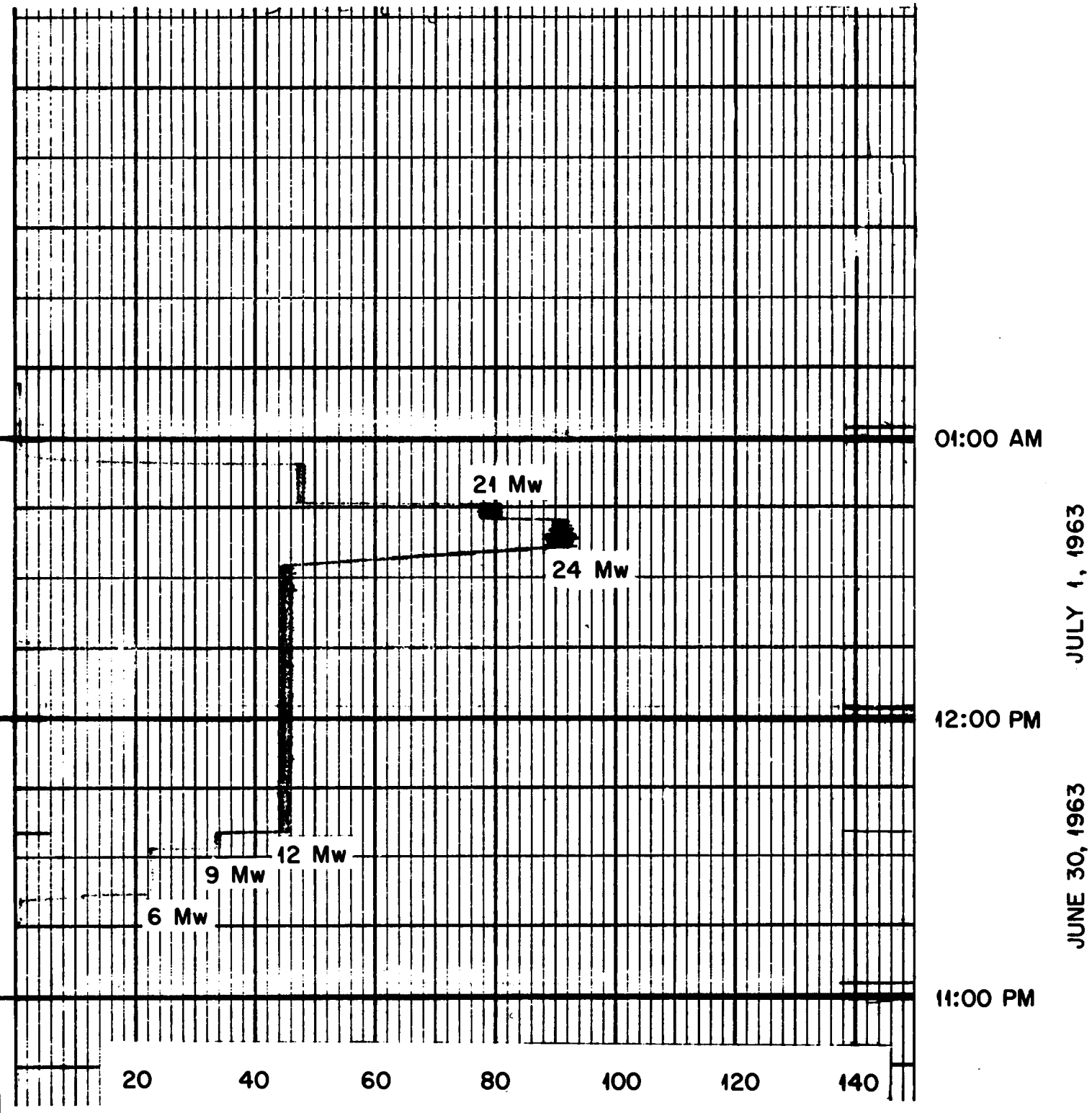

NO. 3 SAFETY CHANNEL

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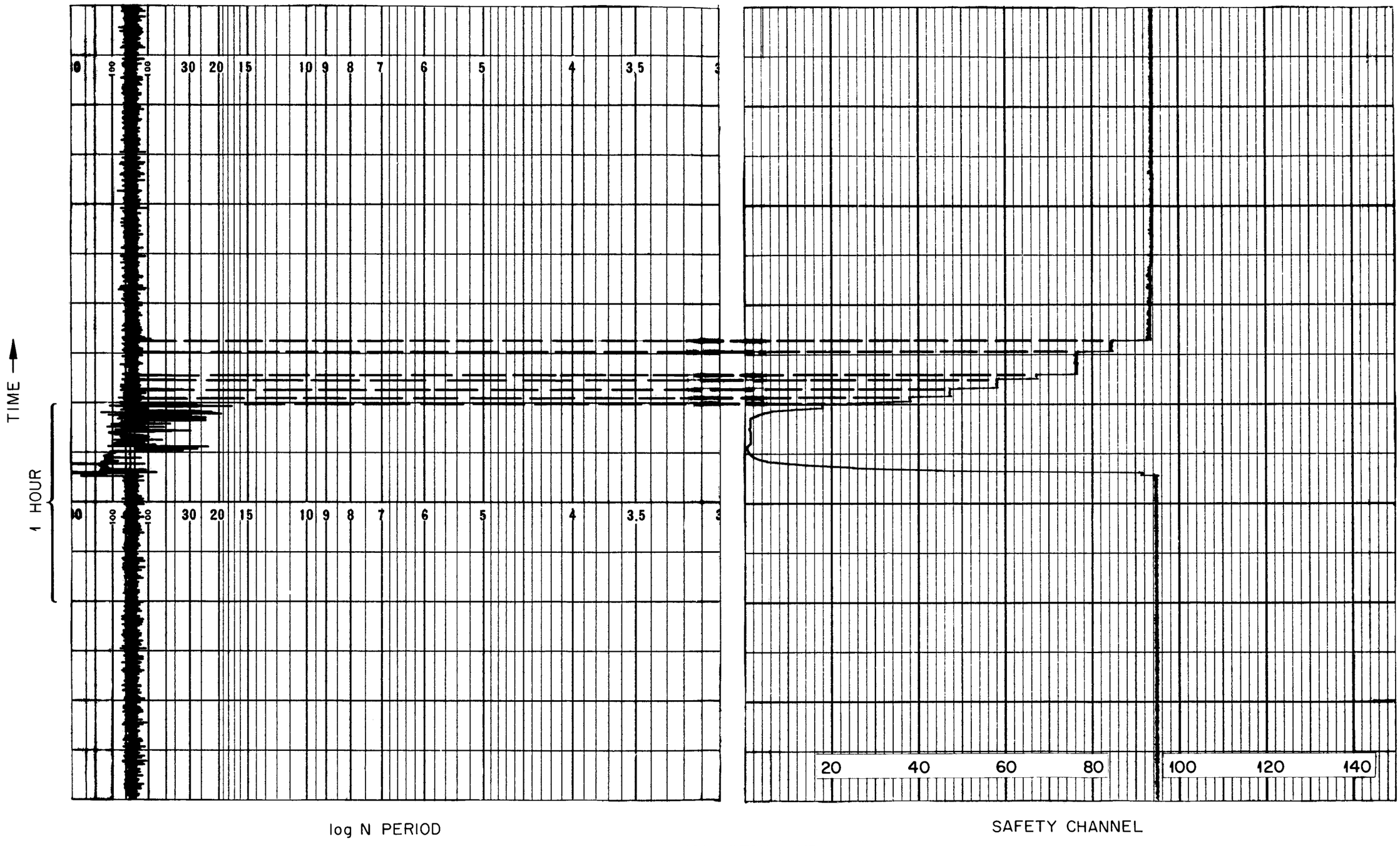

NORMAL START-UP

Fig. 2. Recorder Charts of Normal Startup

straight down every fuel element, so that obstructing material lying on the fuel at the south end of the core is hidden by the end box. This is shown by Figure 3.

In any case, the 6-Mw inspection did not reveal any abnormal condition; and it was decided to bring the reactor to full power at a rate determined by limitations imposed by some of the in-core experiments and with pauses at 12 and 24 Mw to measure the heat power.

At the 9-Mw step, everything seemed normal although postincident examination of the log-N period and safety channel charts indicates a slight increase of the reactor noise. This observation is interesting because, if one assumes that the blocked element started to boil at about 9 Mw, it indicates that it took an increase of a factor of 2.7 in power to damage the element. Accounting for possible variations in coolant flow, this corresponds quite well with heat-transfer predictions.

The power was then increased to 12 Mw, and there all instruments indicated some fluctuations. The servo system was also working harder than usual. These indications could only lead to two conclusions. The first is that the servo was out of adjustment and, therefore, excited the reactor; the second is that the reactor was noisier than usual and that the servo was trying to control the fluctuations. It would, of course, have been possible to decide between these two alternatives by putting the reactor in manual operation. If the noise remained, it could be concluded that the reactor fluctuated more than normally; if it vanished, the servo would have been at fault.

Consultation was held between the 4-12 and 12-8 shift engineers, and later a telephone consultation was held between the 12-8 shift engineer and an instrument engineer. The effect was attributed to the malfunctioning of the servo system. It must be recognized, however, that the amount of noise was not very large and that without comparing this chart with a chart from a previous cycle it is difficult to decide if the condition is really very abnormal.

The reactor power was then increased to 24 Mw, and the amplitude of the noise became considerably larger; but no time was given to the operators to reflect over this phenomenon because radiation monitors

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ORR CORE

CORE LOADING ON 7-1-63

LEGEND:

- AL — ALUMINUM REFLECTOR
- BE — BERYLLIUM REFLECTOR
- Ex — EXPERIMENT
- F — FUEL
- Fs — FUEL (SPECIAL)
- I — ISOTOPE
- SR_F — FUELED SHIM ROD
- SR_R — REFLECTOR SHIM ROD
- [F*] LOCATION WHERE MELTING OCCURRED

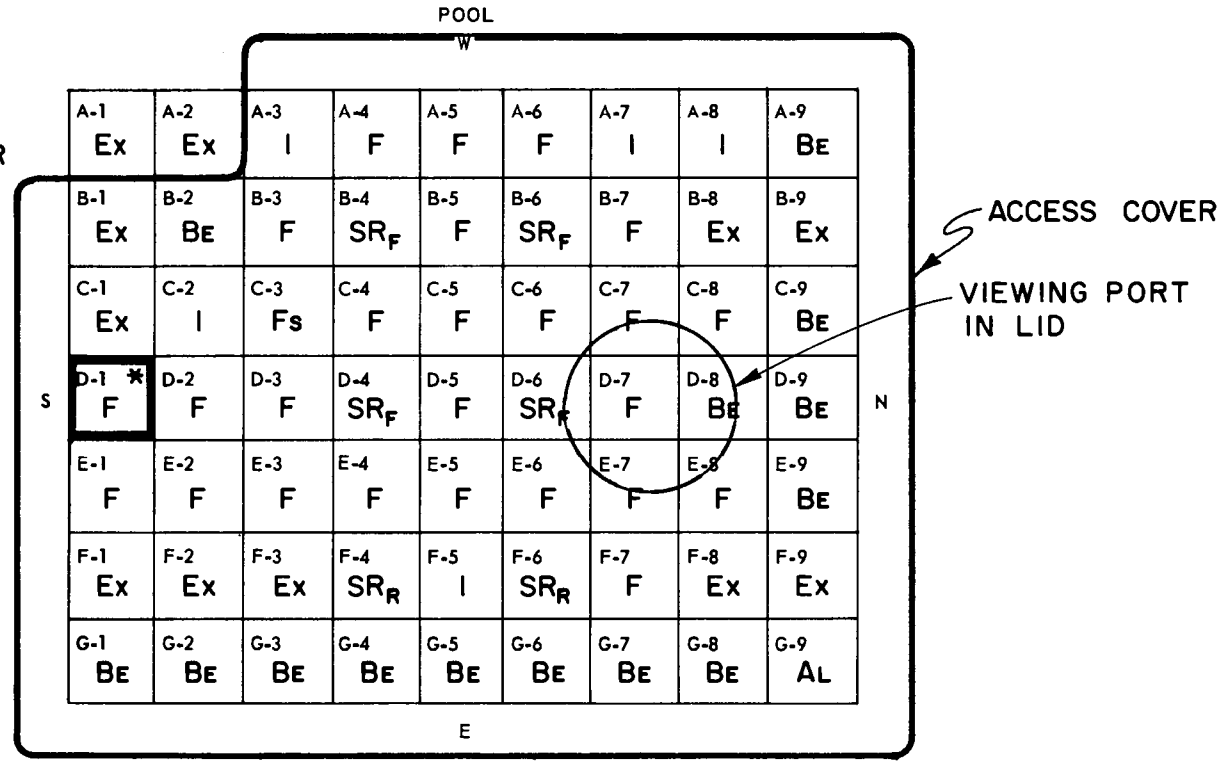


Fig. 3. Access Cover Showing Viewing Port Superimposed Over The Core Loading

started to alarm. Within two minutes, the reactor secondary cooling system high-radiation annunciator alarmed, the ^{16}N detector went off scale, and the degasifier high-radiation annunciator alarmed.

It is worth noticing that the noise amplitude at 24 Mw, as shown by the two safety channel and the gamma chamber charts, remained constant during the first three minutes of the run and then decreased steadily. The various radioactivity monitors (see Figure 4) also indicate that the activity was released during the first two or three minutes of the 24-Mw run. Subsequent inspection of the fuel plates of the damaged element showed that only one plate melted, and it is possible that this occurred in a short time following which the melting stopped and the boiling which caused noise in the instruments became less severe.

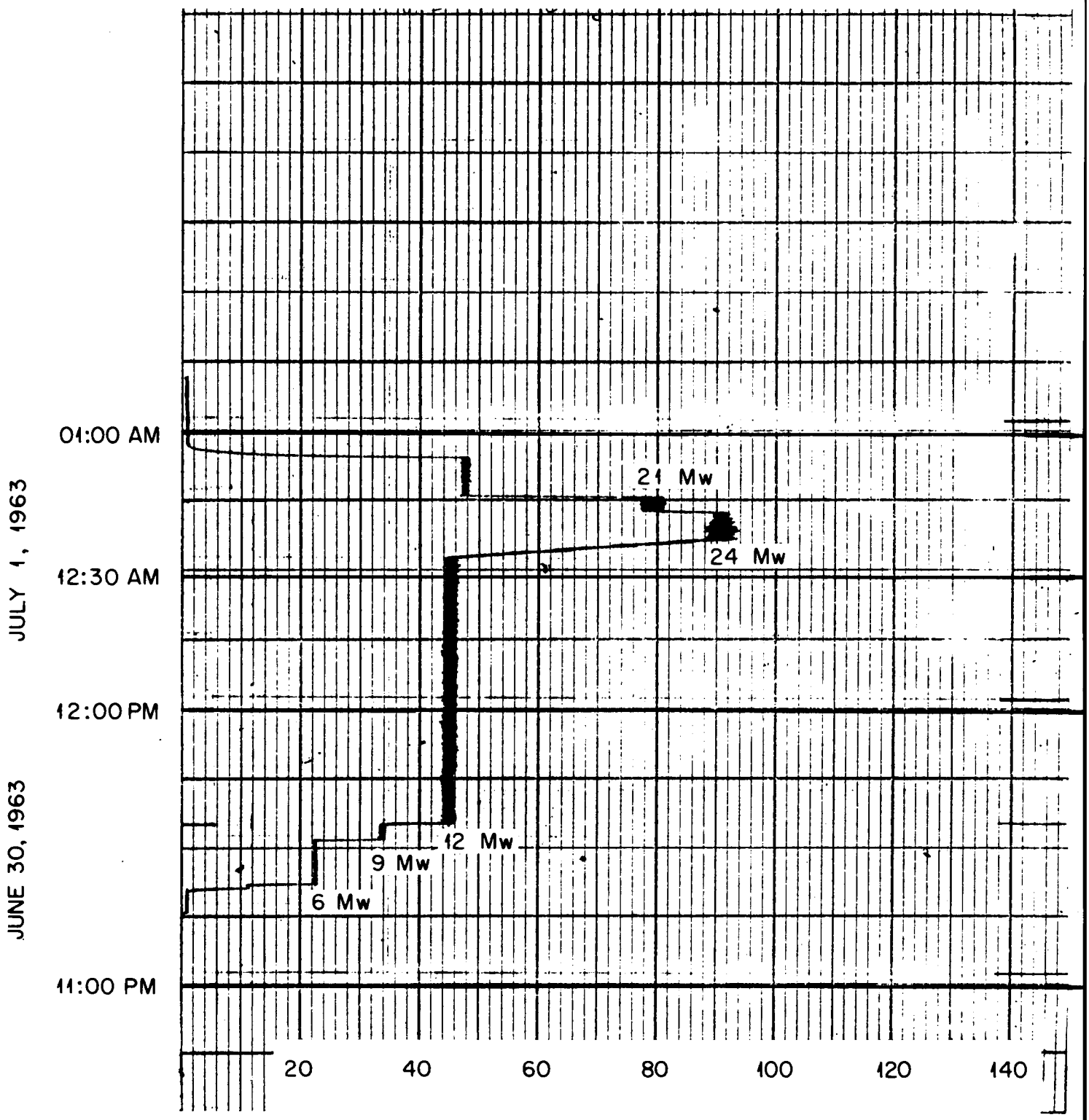
The power remained at 24 Mw for six minutes and then was reduced to 21 Mw. Radiation alarms did not clear, power fluctuations did not disappear, and it was decided to further reduce the power to 12 Mw. At that time, a radiation alarm from the subpile room was received; and the power was reduced to 0.33 Mw (N_L).

A radiation survey was initiated. In the subpile room at the No. 2 rod position, the reading was 2 r/hr; and at the heat-exchanger pit it was 1.4 r/hr. The reactor was then scrammed, and the reactor supervisor was called. Two minutes later air-borne activity reached a level requiring that the building be evacuated.

FISSION-PRODUCT RELEASE AND RADIATION LEVELS

Nature of the Release

Available evidence tends to indicate that the release of fission products from the fuel element to the reactor coolant system was of short duration, probably less than 1 or 2 minutes, and that the major fraction of the release terminated prior to the reduction of reactor power from 24 Mw. These conclusions are drawn in part from Figure 4, a "synchronized" display of the recorder charts from the No. 1 safety channel (showing reactor power level); the reactor secondary water activity instrument channel (showing "shine" from the primary heat exchangers); the reactor water activity instrument channel (showing the



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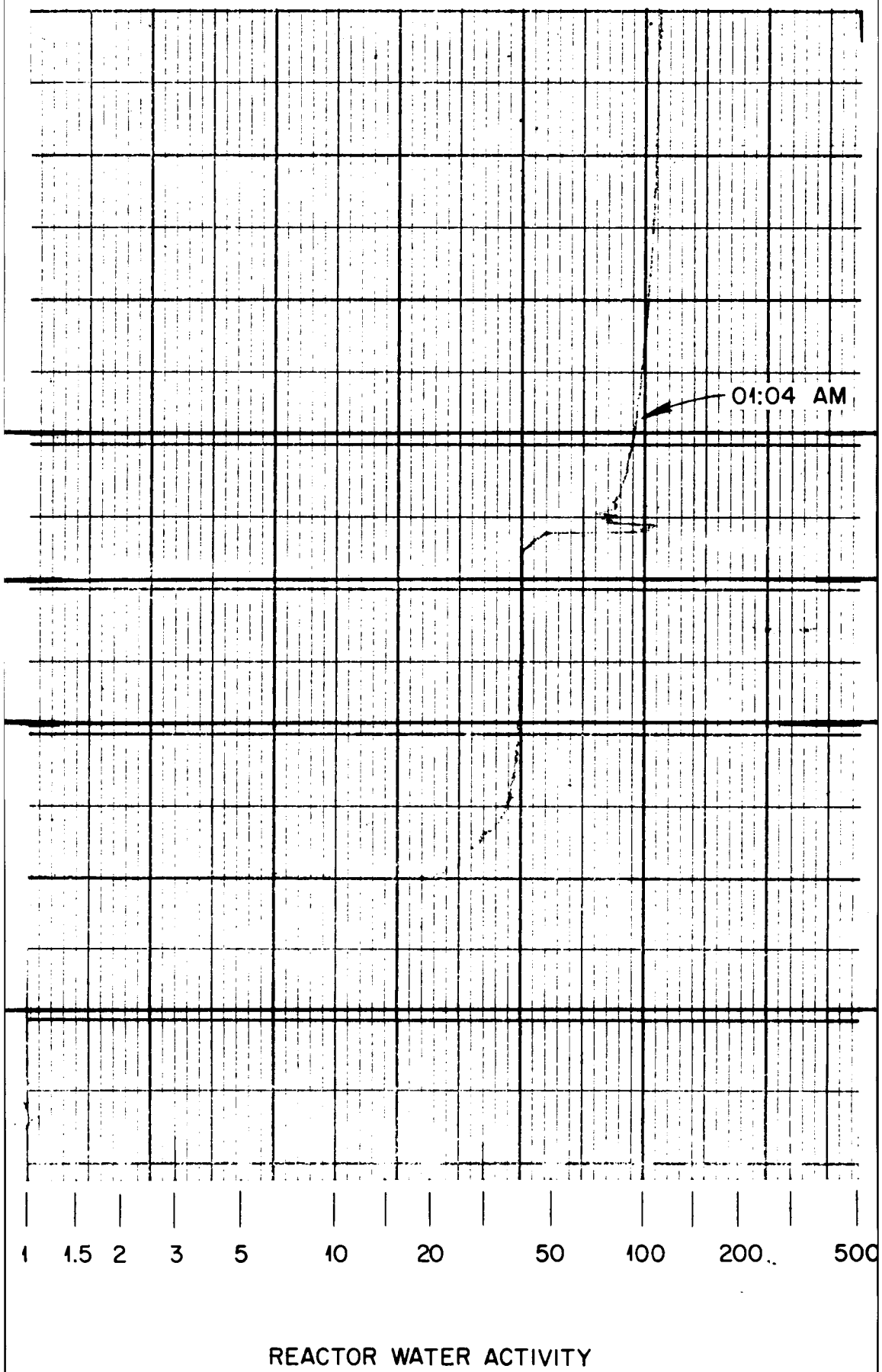
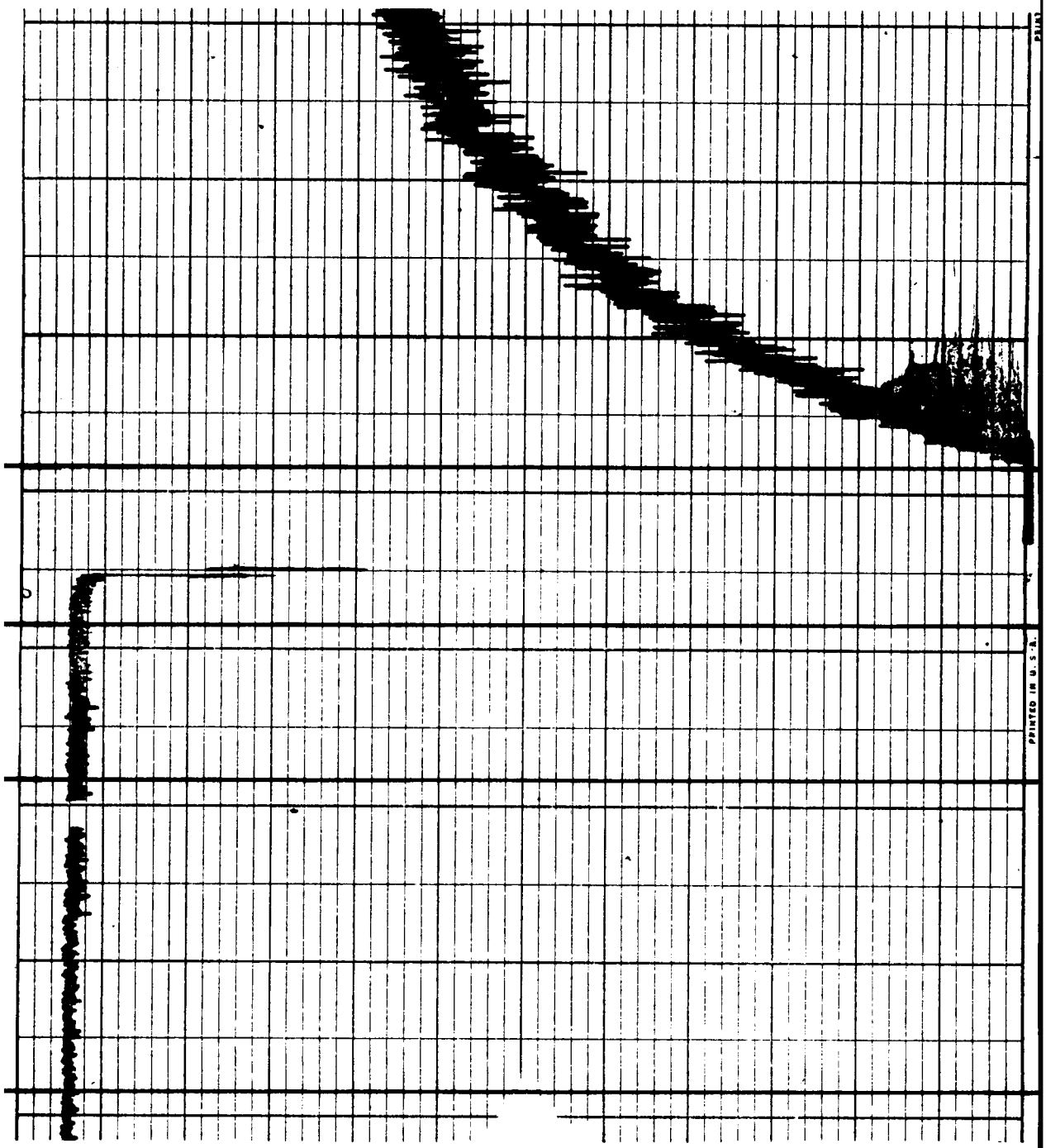


Fig. 4. Radioactivity Monitor Char



REACTOR SECONDARY WATER ACTIVITY
(SHINE FROM PRIMARY HEAT EXCHANGERS)

s Synchronized with Reactor Power Chart

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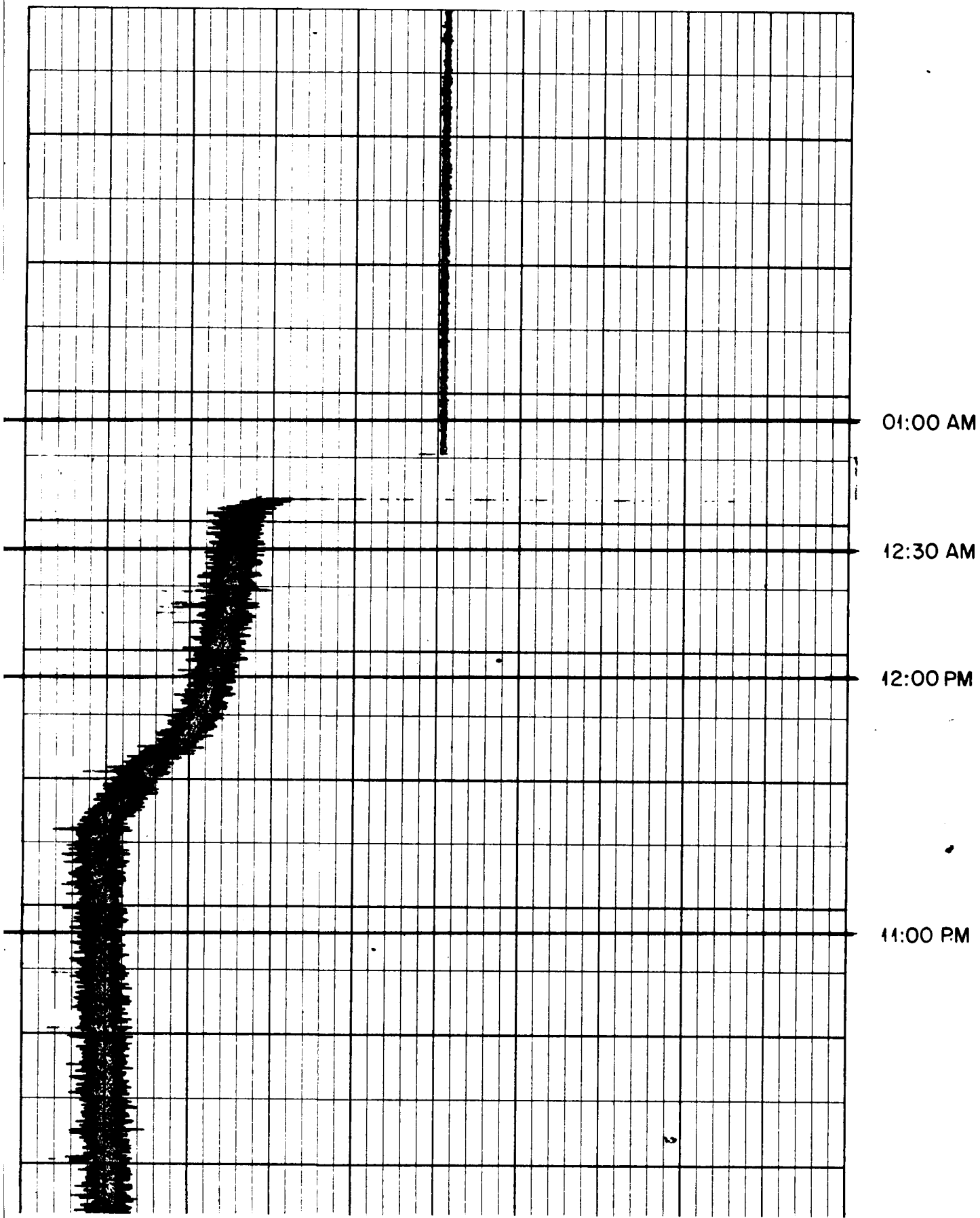


DEGASIFFIER ACTIVITY

response of a radiation detector located adjacent to the reactor coolant system water line downstream from the primary heat exchangers); and the degasifier activity instrument channel. Estimated accuracy of the synchronization of the recorder charts is ±1 minute. If appropriate correction factors, to account for the time lag between an event in the core and its detection by downstream radiation detectors, are applied to the response of these radiation instruments, one concludes that initiation of the release was very nearly coincident with the attainment of 24 Mw. Further, the response of the reactor water activity instrument, together with the behavior of the ^{16}N instrument (which returned "onscale" prior to reactor power reduction from 24 Mw), indicates that the release essentially terminated prior to the reduction of reactor power.

Water-System Contamination

Preliminary estimates, based on the gross β-γ activity of a sample of the reactor water system taken at 1:10 AM and an estimated counter efficiency and geometry factor, indicate a total fission-product inventory of the order of 1000 curies in the coolant system one-half hour after the release. Analyses of reactor water system samples (Figures 5 and 6) on a gamma spectrometer indicated that the principal contaminants were 54-min ^{134}I, 21-hr ^{133}I, 6.7-hr ^{135}I, 32-min ^{138}Cs, and 2.8-hr ^{88}Kr. This, together with other observations subsequently discussed, indicates rather conclusively that only volatile fission products were released from the fuel element into the water in significant quantities. Radiation levels at the south reactor demineralizer anion column (on stream at the time of the release) reached ∿20 r/hr (as compared to levels of ∿100-200 mr/hr normally experienced at 30 Mw) further indicating that a significant portion of the contamination of the water system could be attributed to iodines. The recorded response of a radiation detector seeing "shine" from the column indicated that this radiation level was probably attained within 10 to 30 minutes after the release. Radiation levels at the pool demineralizer anion column reached ∿400 mr/hr. This is of the order of 10 to 20 times the level normally encountered at 30 Mw. No significant increases in the radiation levels at the various demineralizer cation columns were observed.

Fig. 5. γ-Spectra of a Reactor Water Sample

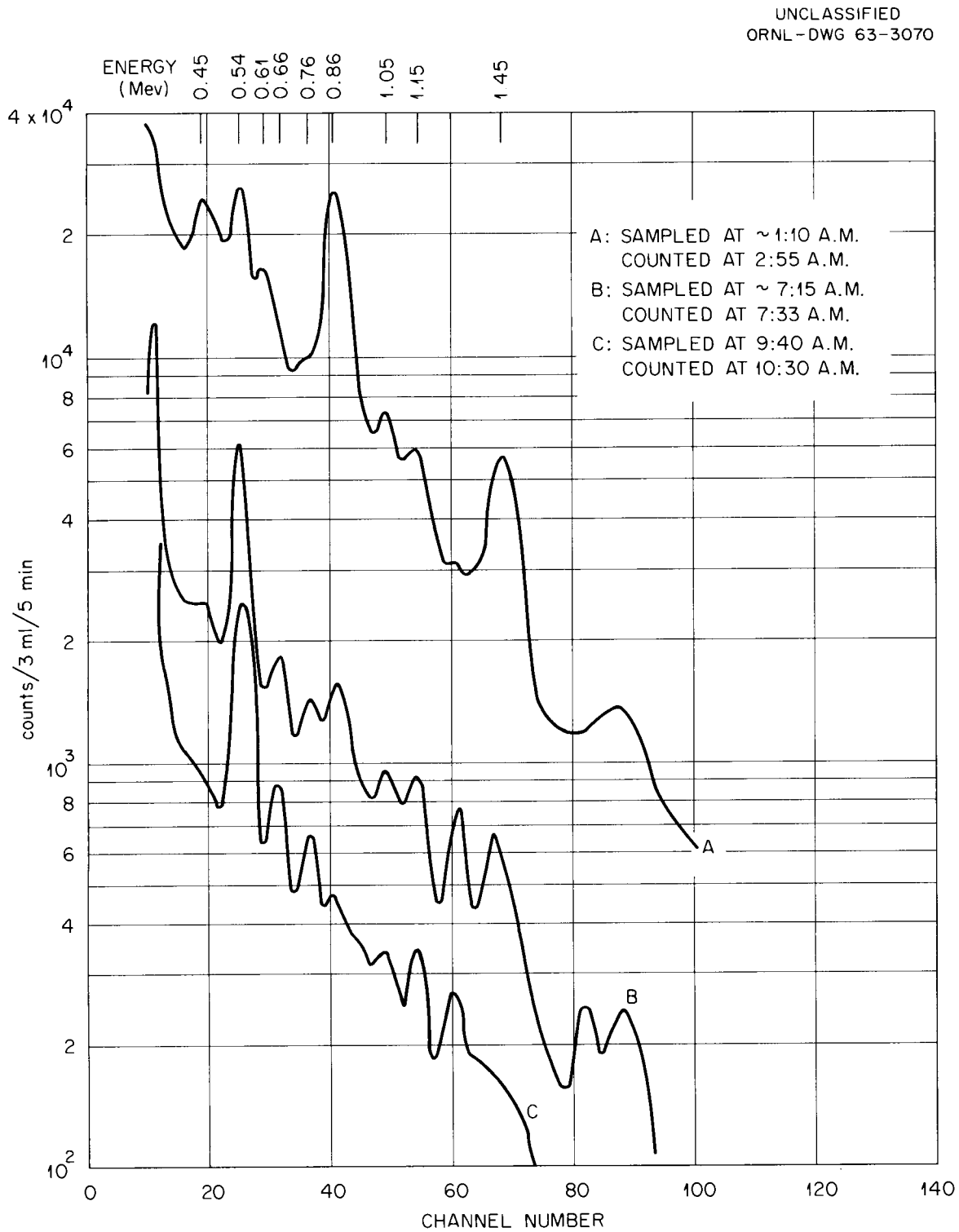


Fig. 6. γ-Spectra of 3 Different Reactor Water Samples

Radiation levels of the order of 1000 mr/hr were observed at 4:30 AM at the degasifier air separator. This is higher than normal by a factor of the order of 100.

An average of radiation levels for the four-month period before and after the incident is listed below.

Degasifier	Before (mr/hr)	After (mr/hr)
Air separator	20	130
Water tank	33	89

Radiation levels at various locations in the reactor primary coolant system outside the reactor building during the period from 1:30 AM to 5:15 AM, July 1, 1963, are shown in Figure 7 and Table 1. Figure 8 indicates the location of these components. Peak radiation levels measured were of the order of 10 to 20 times those normally encountered at 30 Mw.

An analysis, on a gamma spectrometer, of the gases boiled from a 500-cc sample of the reactor system water taken at 9:40 AM (Figure 9) indicates the presence of ^{135}Xe in addition to ^{138}Xe and ^{88}Kr. The apparent preponderance of ^{135}Xe in this sample can probably be attributed to the fact that when the sample was taken most of the ^{88}Kr and ^{138}Xe had decayed.

Figure 10 shows the decay of the gross β-γ contaminant concentration in the reactor water system as a function of time after the release. After four months, the gross gamma radioactivity level in the reactor primary system was about 70% greater than that prior to the incident. Presumably, this is due to small amounts of uranium released from the melted fuel which remain in, or near, the core in a region of high neutron flux. The major activities observed in the reactor water system are listed in Table 2. The radioactivities present in the system prior to July 1, 1963, are listed for comparison.

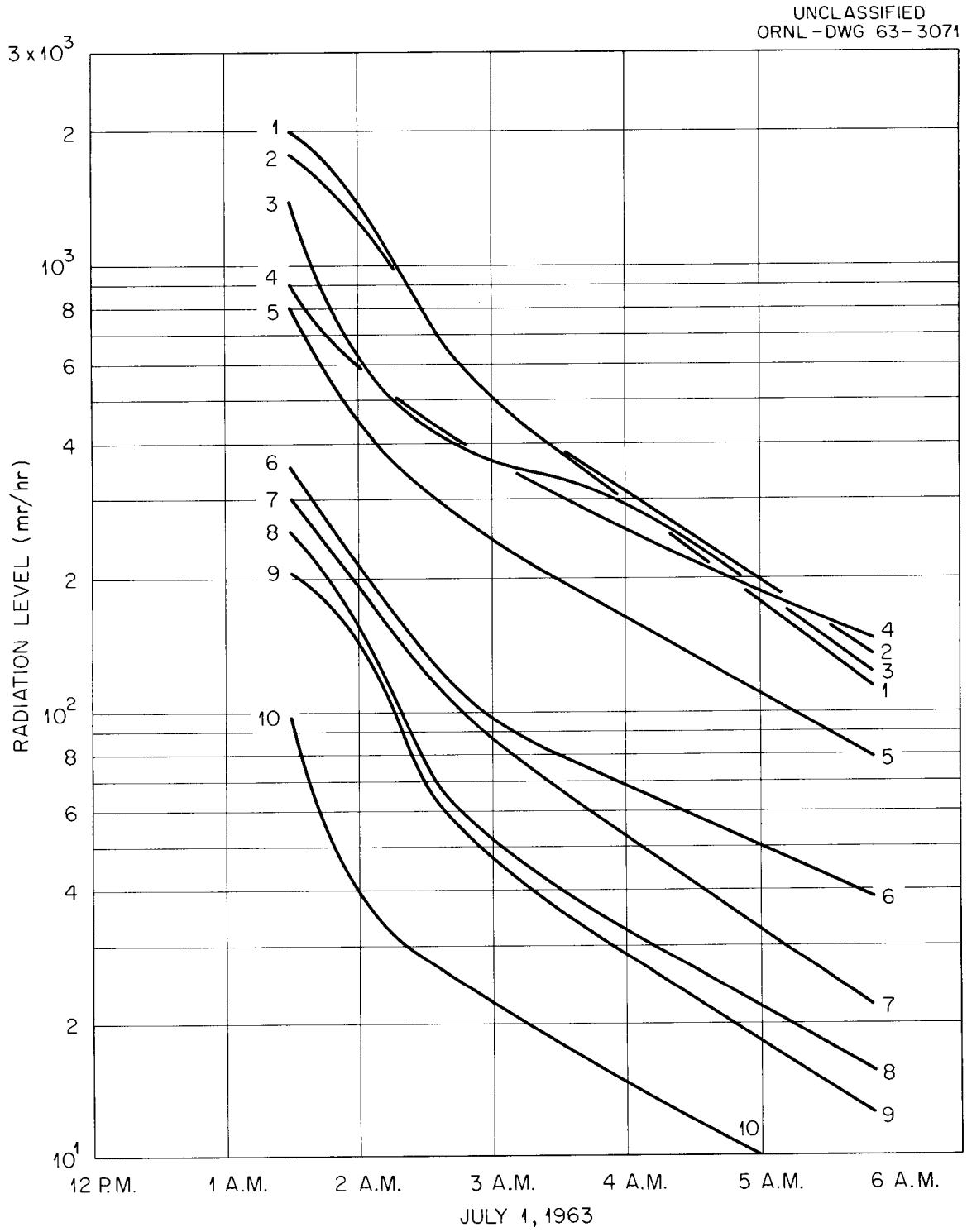


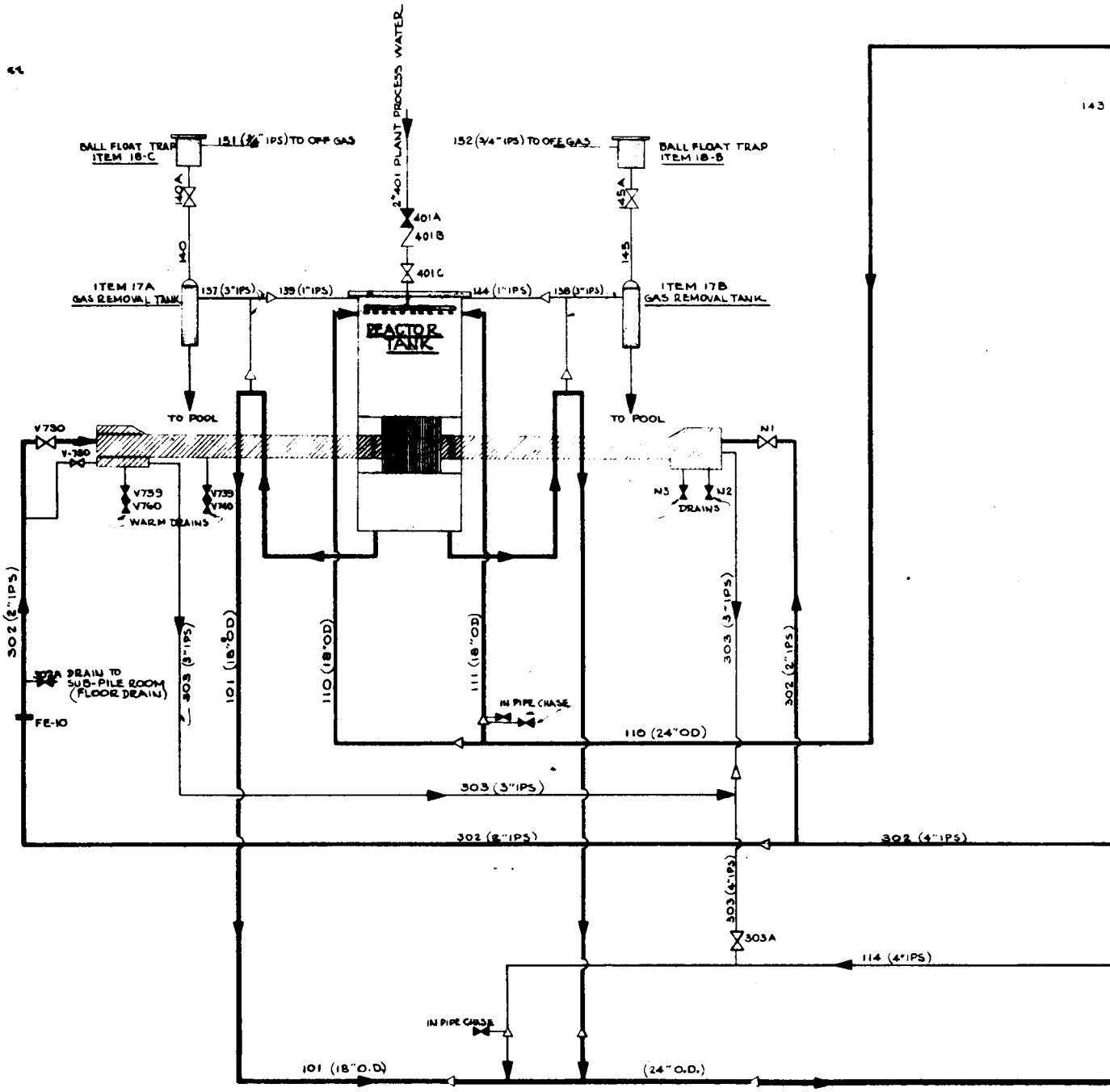
Fig. 7. Radiation Levels at Various Locations in the Reactor Coolant System

Table 1. Radiation Levels at Various Locations on July 1, 1963

Location	Reference Number[a]	Radiation Level (mr/hr)				
		1:30 AM	2:00 AM	2:40 AM	3:30 AM	5:45 AM
No. 3 main pump	1	2,000	1,400	640	400	120
No. 2 main pump	2	1,800	1,300	640	400	140
Top of primary heat-exchanger pit, north side	3	1,400	640	400	360	130
Top of strainer pit	4	900	600	420	300	150
Top of primary heat-exchanger pit, south side	5	800	460	280	200	82
Entrance to heat-exchanger pit	6	350	230	120	80	40
Top of north sump	7	300	210	110	68	24
Top of venturi pit	8	250	160	65	40	16
Primary heat-exchanger bypass control valve	9	200	150	60	35	13
Top of expansion pit	10	100	38	27	18	7
No. 2 Trane heat-exchanger exit line (stagnant line)	11	500	400	200	150	64
No. 6 Trane heat-exchanger exit line (stagnant line)	12	250	200	150	75	40
No. 2 Trane heat-exchanger inlet line (stagnant line)	13		140	40	28	22
Reactor system demineralizers	14	20,000	20,000	20,000	20,000	20,000
Degasifier[b]	15				1,000	

[a]The numbers in this column refer to the corresponding curves (1-8) in Figure 7 and locations in Figure 8.

[b]Measured at about 4:30 AM.


2" 401 PLANT PROCESS WATER
BALL FLOAT TRAP ITEM 18-C
151 (3/4" IPS) TO OFF GAS
152 (3/4" IPS) TO OFF GAS
BALL FLOAT TRAP ITEM 18-B
149A
145A
140
145
401A
401B
401C
ITEM 17A GAS REMOVAL TANK
137 (3" IPS)
139 (1" IPS)
144 (1" IPS)
138 (3" IPS)
ITEM 17B GAS REMOVAL TANK
REACTOR TANK
TO POOL
TO POOL
V730
V-780
V759
V760
V759
V760
WARM DRAINS
N1
N3
N2
DRAINS
302 (2" IPS)
303 (3" IPS)
DRAIN TO SUB-PILE ROOM (FLOOR DRAIN)
FE-10
101 (18" OD)
110 (18" OD)
111 (18" OD)
IN PIPE CHASE
110 (24" OD)
303 (3" IPS)
302 (2" IPS)
302 (4" IPS)
303 (4" IPS)
303A
114 (4" IPS)
IN PIPE CHASE
101 (18" O.D.)
(24" O.D.)
143

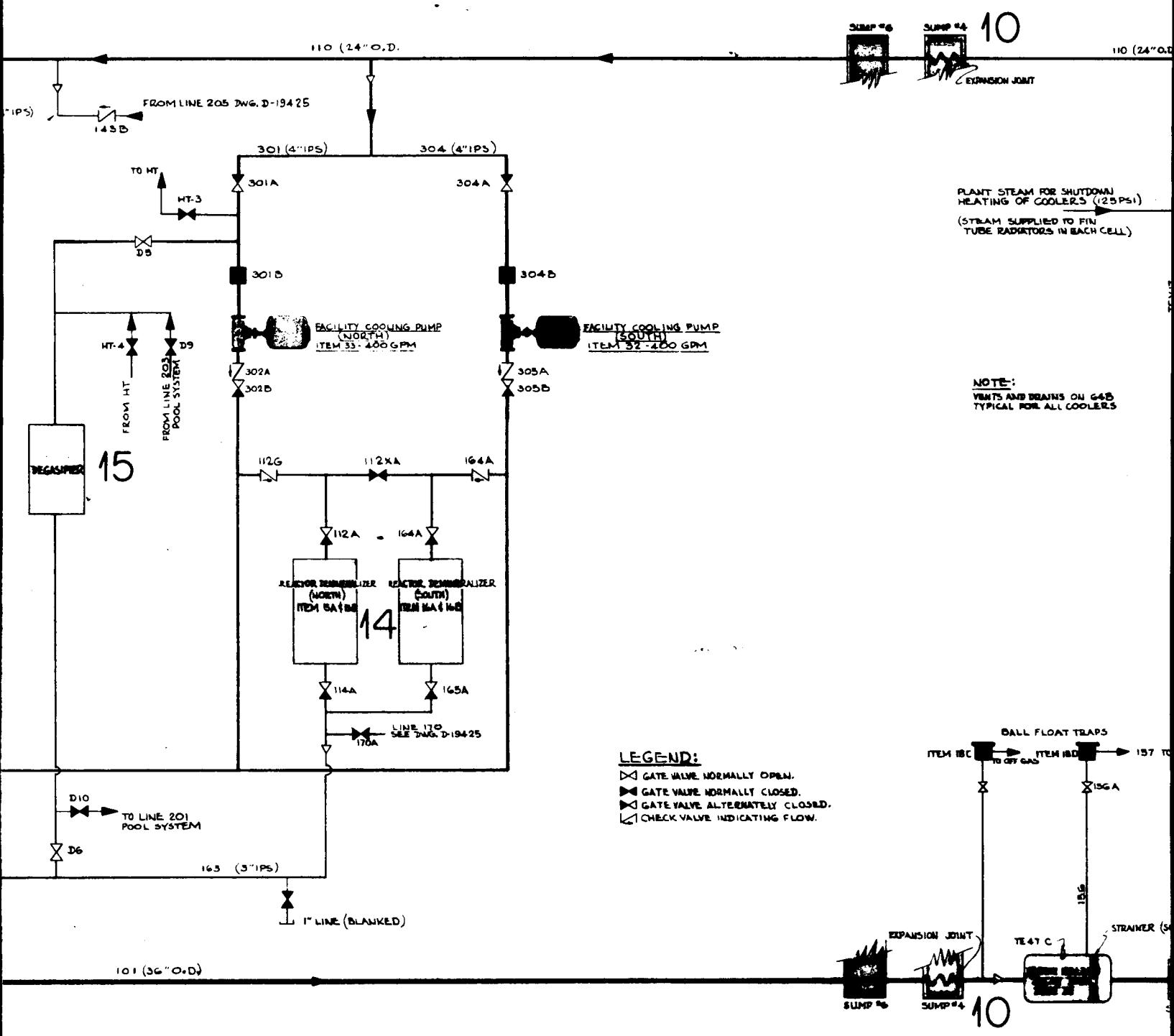


Fig. 8. Schematic Diagram of Reactor Cooling System Showing Location of Radiation M

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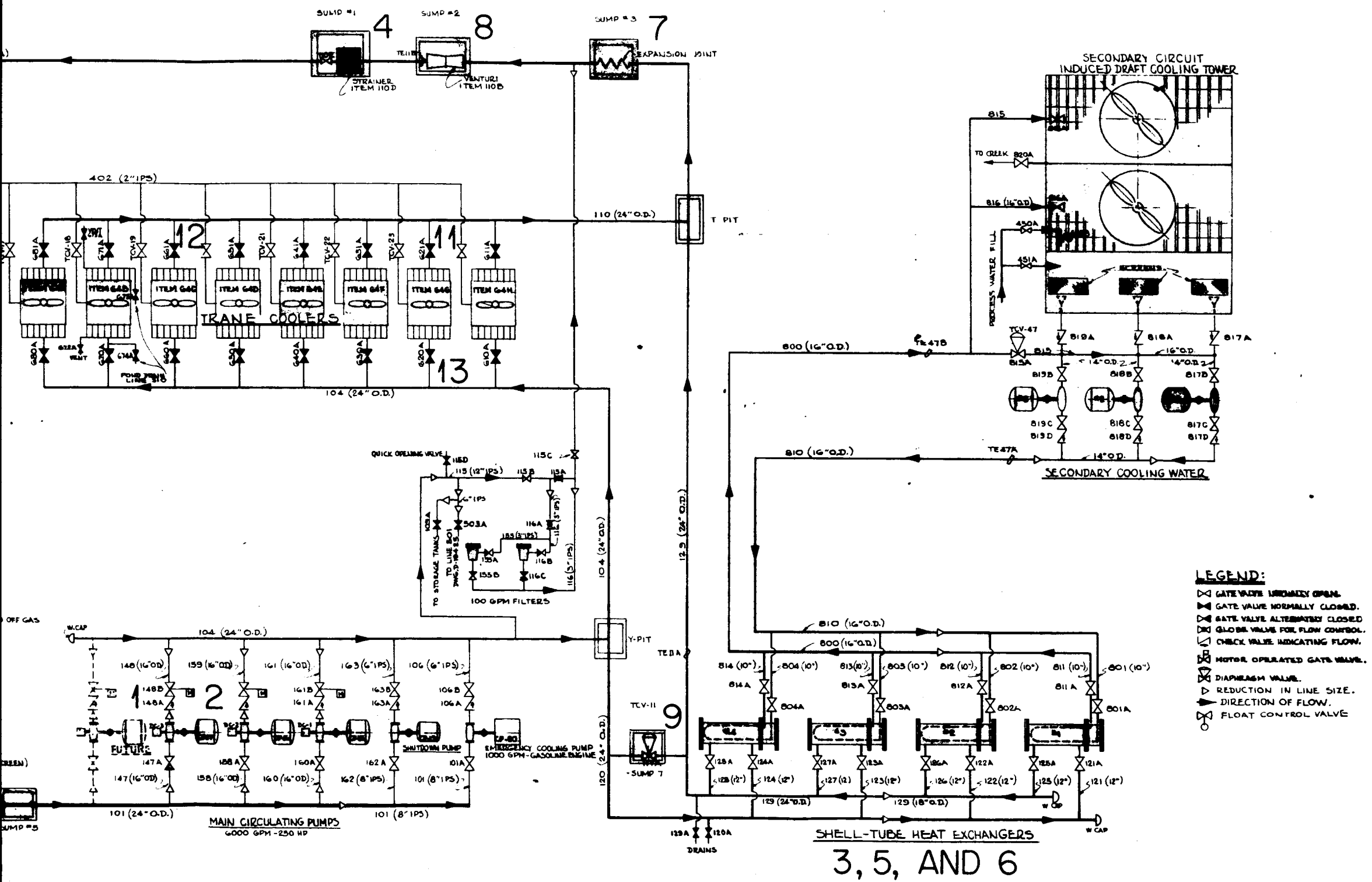

easurements Taken on July 1, 1963

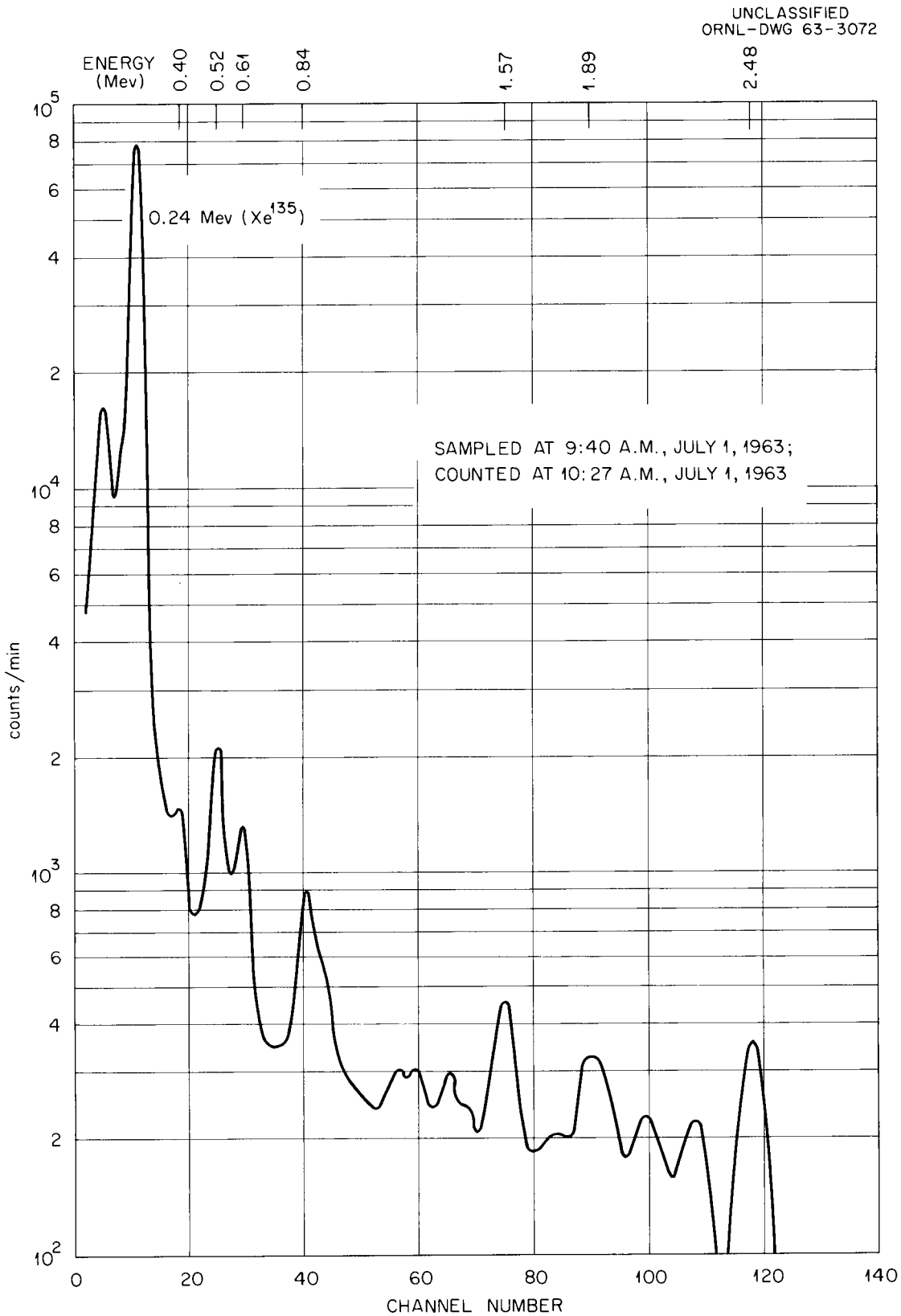

Fig. 9. γ-Spectrum of Gas from 500 cc of Reactor System Water

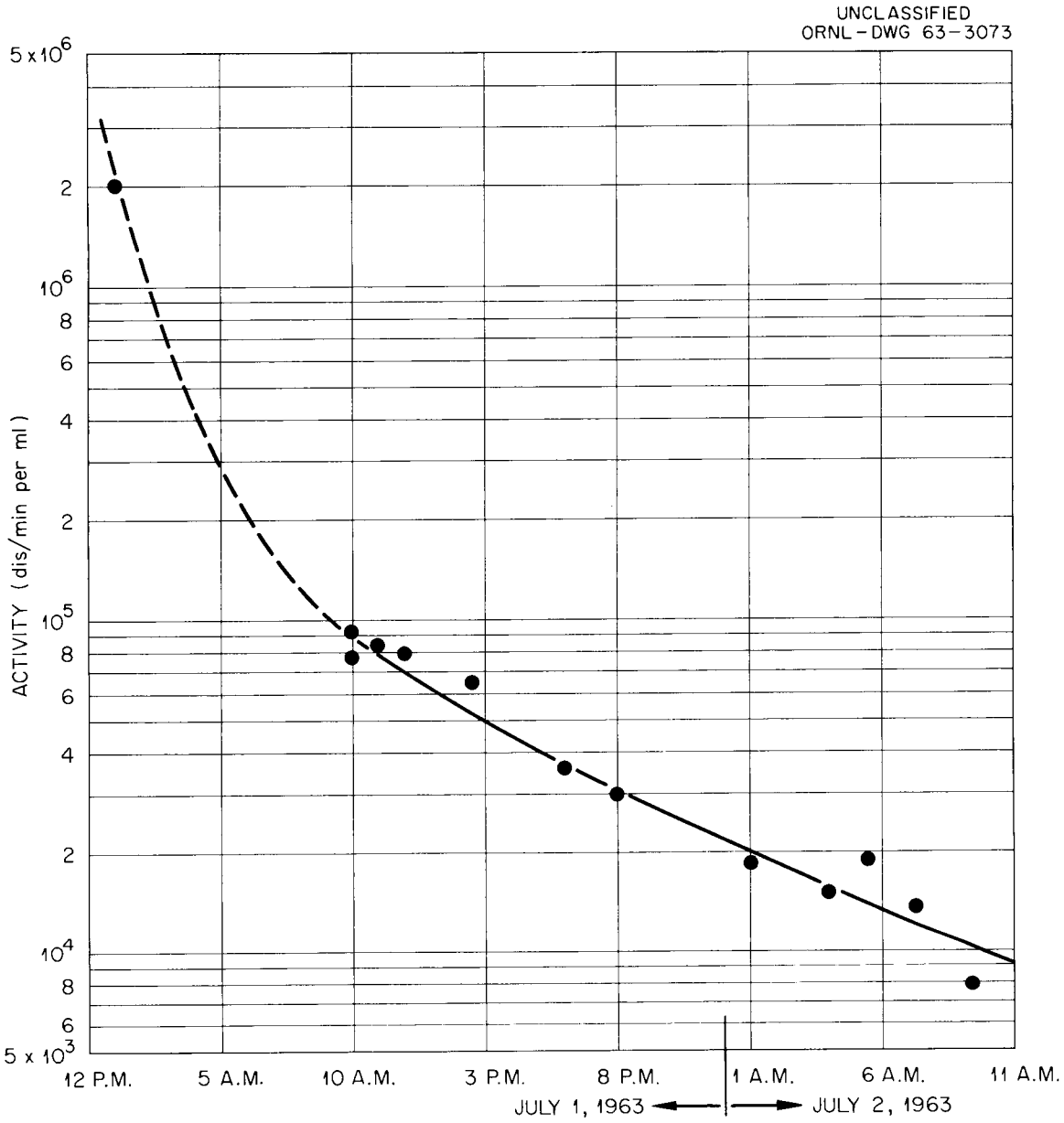

Fig. 10. Gross γ-β Activity Level; ORR Reactor Primary Coolant System

Table 2. Radioactivities in the ORR Reactor Primary System[a]

	5-23-63	7-1-63	9-26-63
^{131}I	∿3	1.0×10^3	∿159
^{133}I	∿31	2.1×10^3	1.4×10^3
^{135}I	No analysis	8.4×10^3	No analysis
^{24}Na	4.2×10^4	No analysis	2.5×10^4
^{239}Np	62	292	No analysis
^{132}Te	No analysis	No analysis	∿166
^{91}Sr	No analysis	No analysis	5×10^3
$^{136-137}Cs$	No analysis	No analysis	<1
$^{103-106}Ru$	No analysis	No analysis	<8.9
Days since last refueling	7	0	2
Gross γ (counts min^{-1} ml^{-1})	25,878	35,887[b]	53,603[c]

[a]All results in dis min^{-1} ml^{-1} unless otherwise specified.

[b]Taken at 5:00 PM. The reactor was shut down at 1:10 AM after accumulating 1.66 Mwd of energy. Previously the reactor was shut down approximately seven days. The reactor water had been cleaned by operating the demineralizer and degasifier for approximately 16 hours prior to sampling.

[c]After the incident, the gross gamma activity doubled. This was apparently due to the deposition of uranium in the lattice structure.

Air-Borne Contamination in the Reactor Building

Some fraction of the noble gases released into the reactor coolant system diffused to the building atmosphere (principally as ^{138}Xe and ^{88}Kr) through the pool-reactor system equalizer to the pool and from the pool to the building atmosphere. Decay of these gases, subsequent to their release from the water system, resulted in air-borne contamination in the building primarily by ^{138}Cs and ^{88}Rb (identified by gamma-spectrometer analysis of the air monitor filter (Figure 11). Peak air concentration of these contaminants is estimated at 10^{-6} to 10^{-7} μc/cc.[1] Estimates of the relative buildup of these isotopes in the building are given in Figure 12. The uncertainty in the levels indicated in the figure is due entirely to the uncertainty in the relative proportions of ^{138}Cs and ^{88}Rb present. Indicated upper limits are based on the assumption of 100% ^{88}Rb and indicated lower limits are based on the assumption of 100% ^{138}Cs.

Figure 13 shows the amount of iodine released per day during the week surrounding the incident. The stack monitoring instruments indicated that approximately 150 mc of radioiodine were released through the stack as a result of the melting of the fuel plate. Most of the radioiodine released in the water system was undoubtedly removed by the demineralizers and by radioactive decay, although a small portion was probably removed by the caustic scrubber and filters in the off-gas system.

Small amounts of particulates, believed to be principally noble gas daughters, were released to the stack through the off-gas system. The main source of this activity was evidently the primary coolant system degasifier where noble gases are removed and subsequently decay to particulate daughters in transit to the stack. Although the isotopes collected by the stack monitors were not positively identified, analysis of the available data indicates half-lives of the principal constituents of the particulate mixture were between 15 and 60 minutes. Corresponding total particulate releases are estimated at between 4×10^{-4} G and 2×10^{-4} G curies, where G is a multiplicative factor estimated at between 10 and 100 to account for detector efficiency and geometry.

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[1]Based on an estimated correction factor of 10 applied to the recorded instrument count rate to account for geometry and detector efficiency for the involved isotopes.

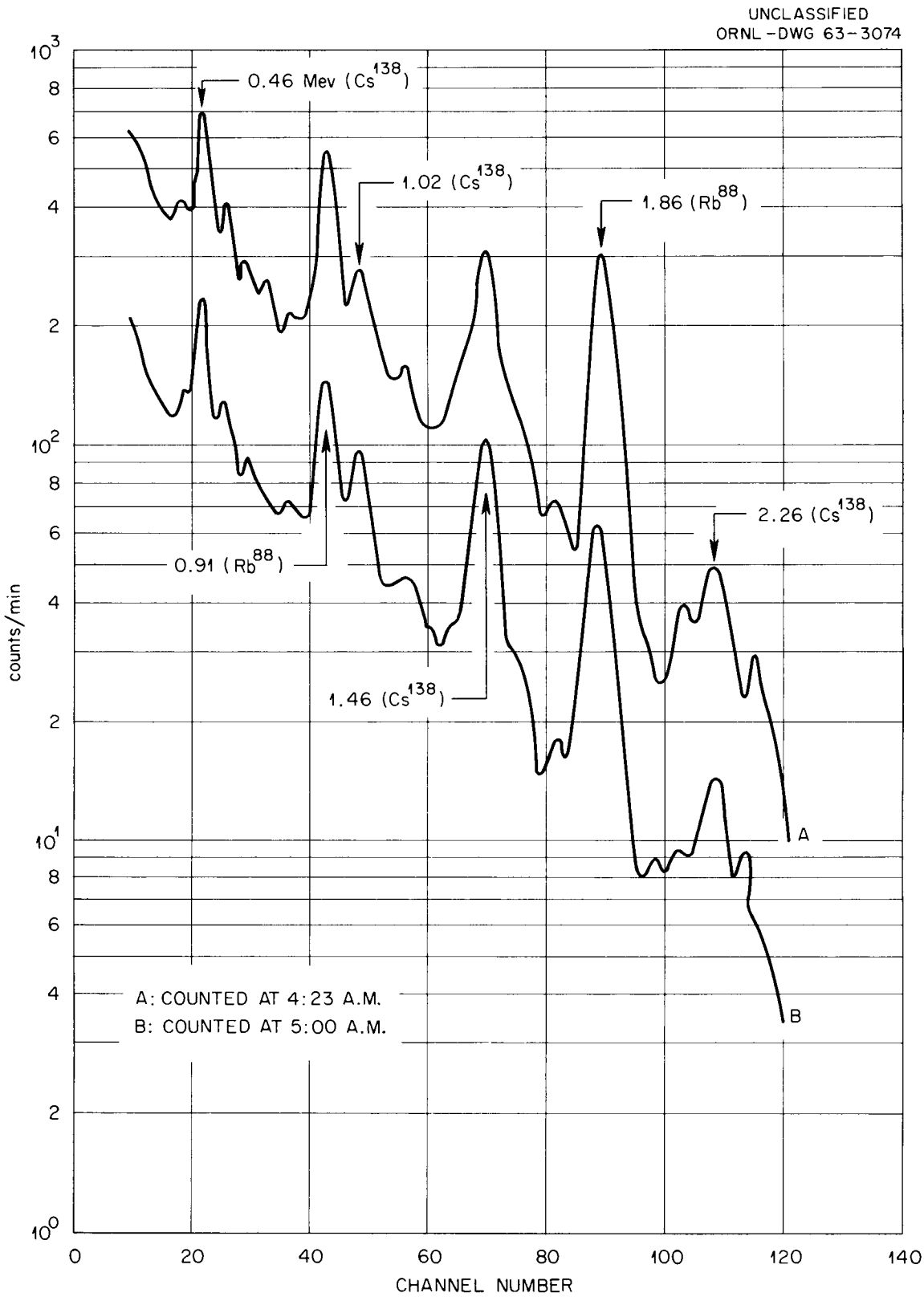

Fig. 11. γ-Spectra of Filter from Air Monitor

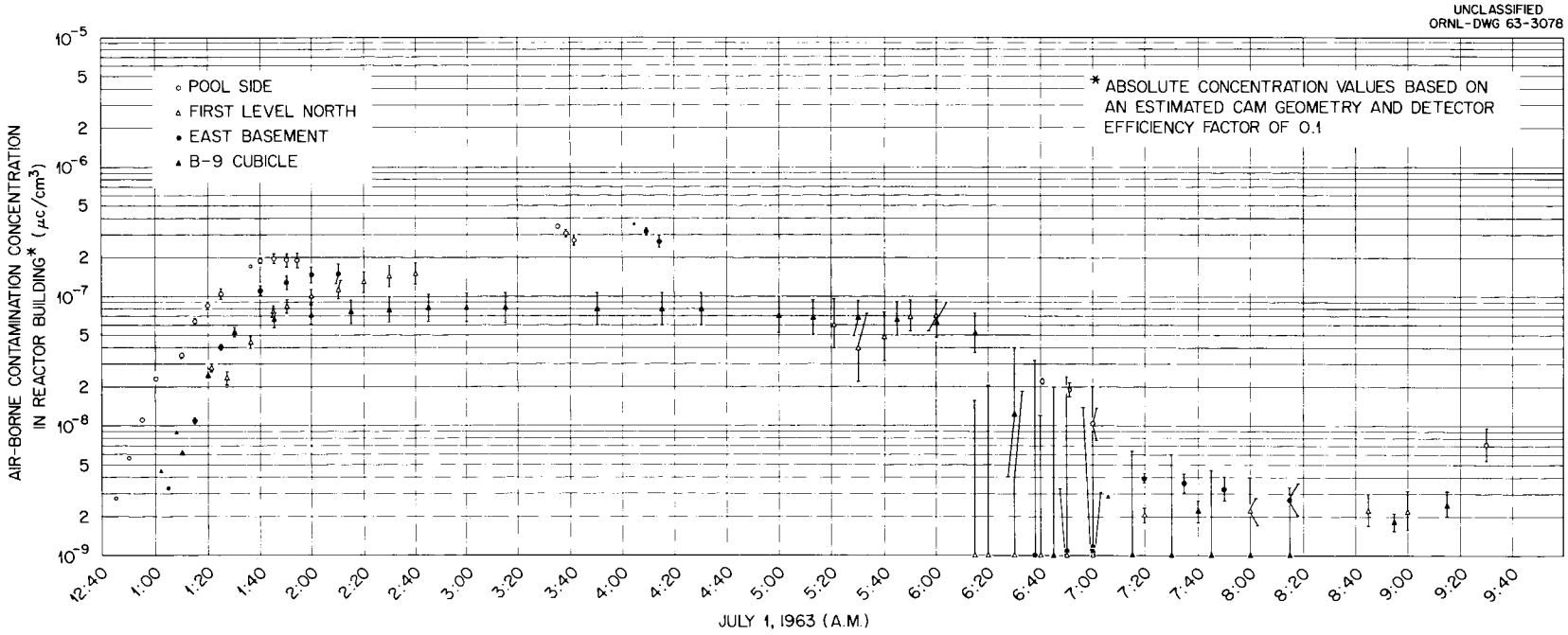

Fig. 12. Air-Borne Contamination Concentration in Reactor Building

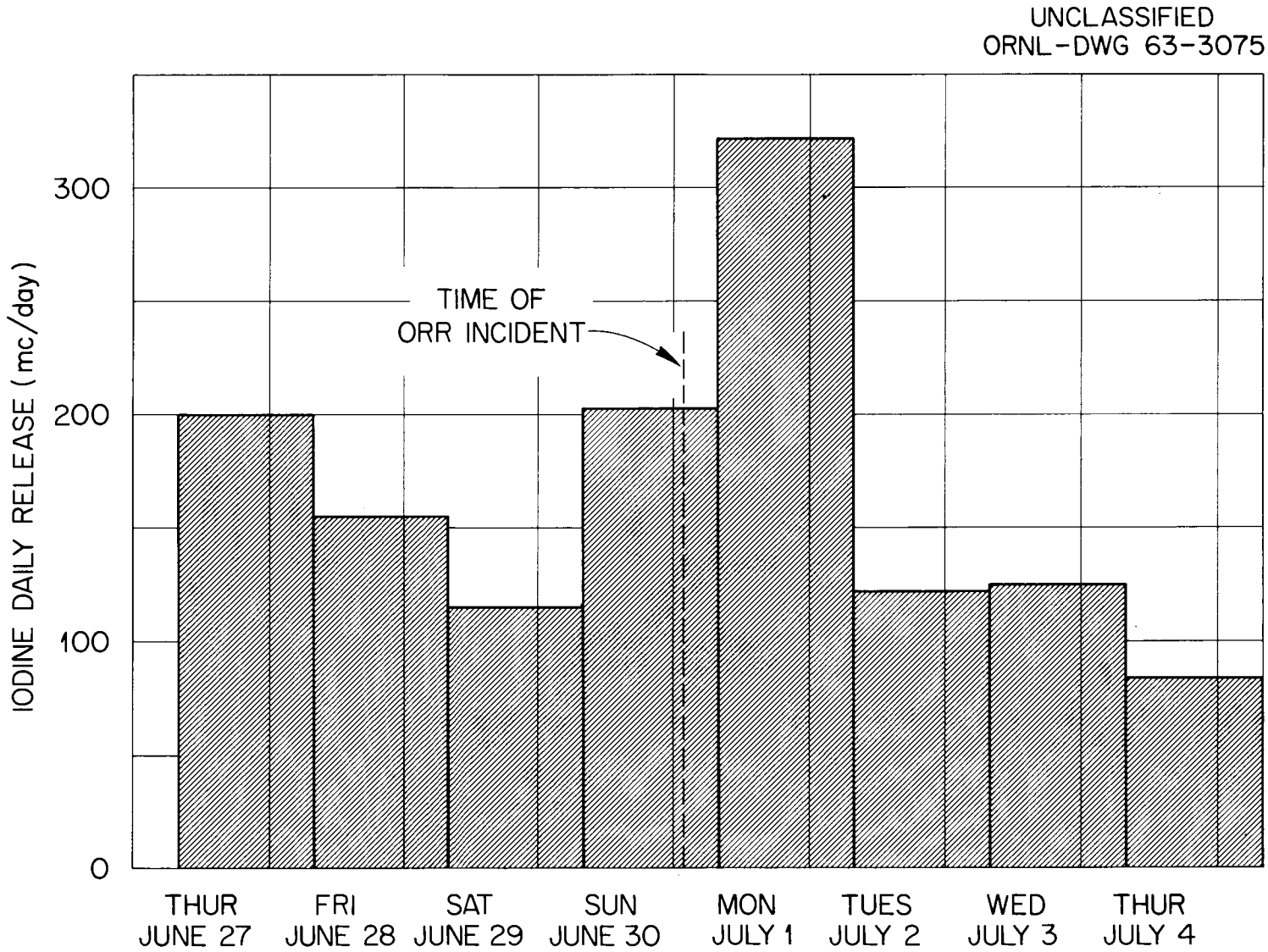

Fig. 13. Daily Iodine Release Through 3039 Stack

Inspection of Fuel Element

The element was transferred into the south ORR hot cell on July 5, 1963, to permit a visual inspection. Figure 14 shows a view of the blockage in the fuel element end box. The end boxes of the element were removed, and Figures 15 and 16 show the bottom of the end box containing the gasket. These view the surface of the gasket which was in contact with the fuel plates. Figure 17 is a photograph of parts of the gasket which were broken apart during its removal from the end-box section.

After the end-box sections were removed from the fueled section, visual inspections were made of the fueled section. Figure 18 is a photograph of the fuel plates taken from the bottom of the element. The darkened section between plates Nos. 2 and 3, and 3 and 4 (from the concave side) indicates the area where the melting occurred. Figure 19 views the fuel plates from the top. The "foreign" particles, with one exception, are cuttings from the disassembly of the end box. The dark material between plates Nos. 1 and 2, on the concave side, is a portion of the gasket material which adhered to the plates.

The fueled section of the element was transferred to a segmenting cell where the plates were removed. Each plate was visually inspected. Figures 20 and 21 show the plates after they were separated from the assembly. The melting occurred in the top section (as oriented in the reactor) of the plate. Visual inspections of the adjacent plates, as well as other plates in the element, did not indicate any surface damage although there was some discoloration.

Analyses have been performed on some of the "beads" of the melted plate and on samples taken from the unmelted portion of the damaged plate. Results are indicated in Table 3.

Further analyses are being made by metallographic examination on sections of the plate to determine the displacement of the alloy and possible temperature gradients.

Fig. 14. View of End Box Showing Blockage in ORR Fuel Element OR-36C

Fig. 15. Separated End Box from ORR Fuel Element OR-36C Showing Gasket Material

Fig. 16. Gasket Material Which was in Contact with Fuel Plates of ORR Element OR-36C

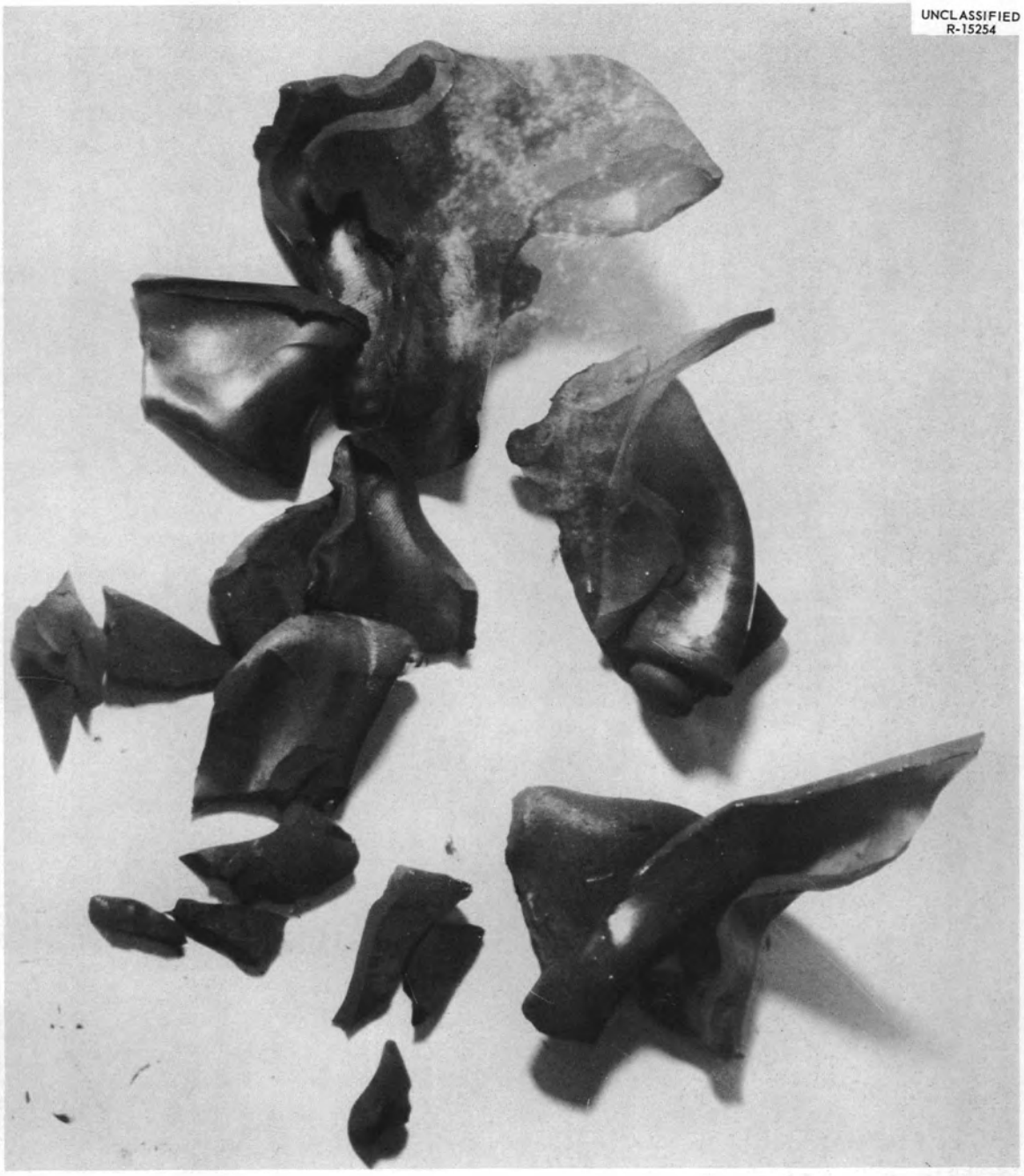

Fig. 17. Parts of Gasket Removed from ORR Fuel Element OR-36C

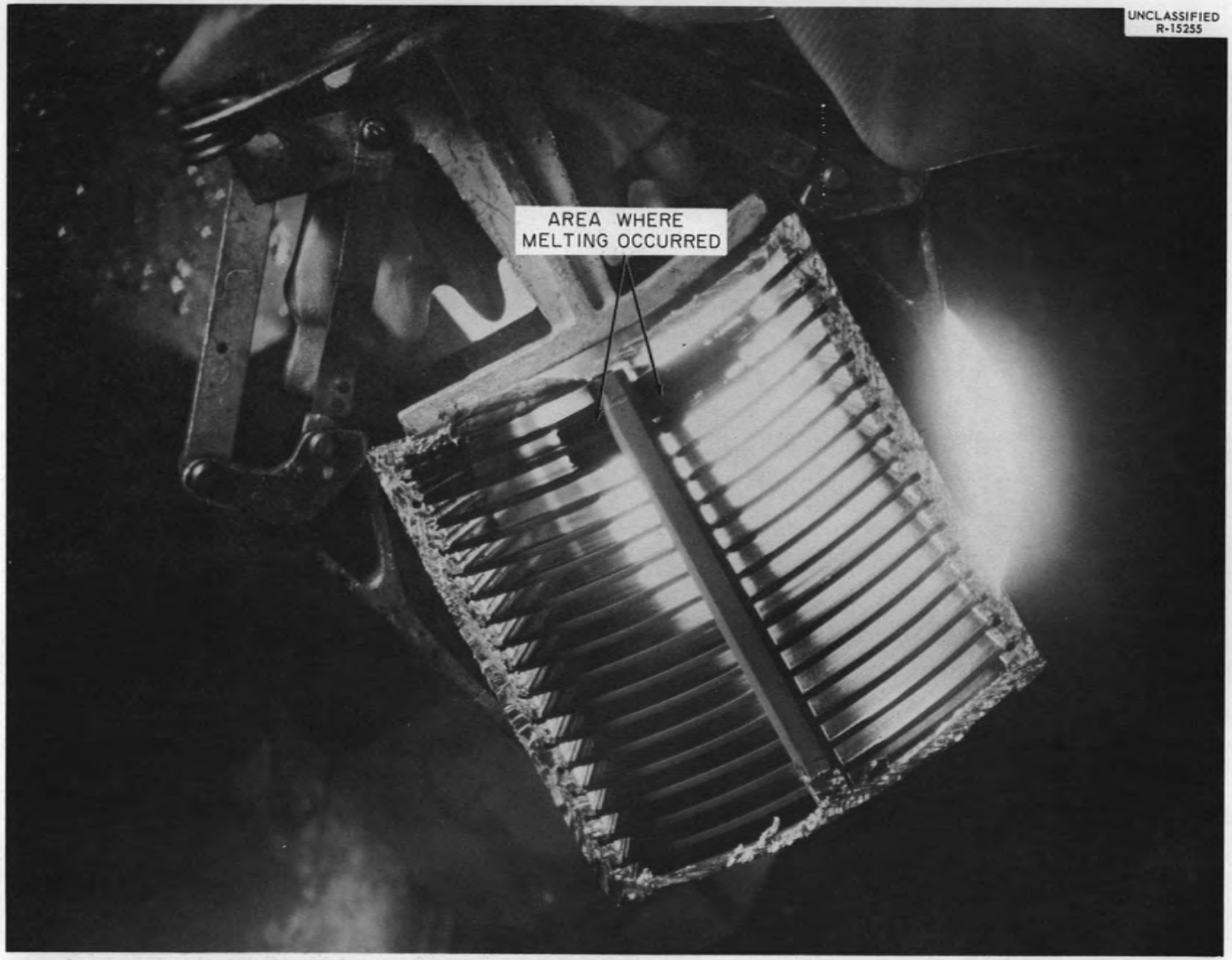

Fig. 18. Bottom View of Fuel Plates of ORR Element OR-36C

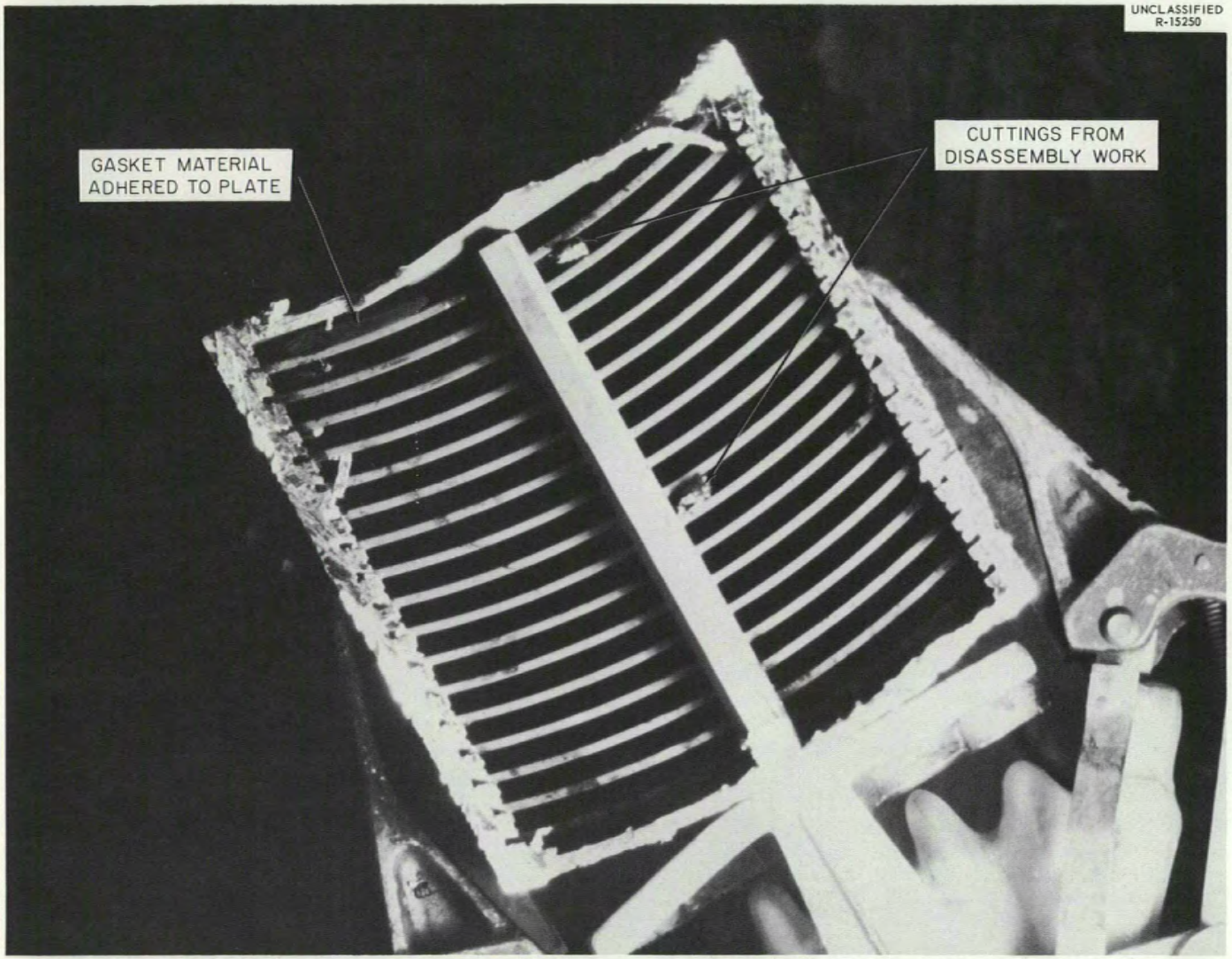

Fig. 19. Top View of Fuel Plates of ORR Element OR-36C

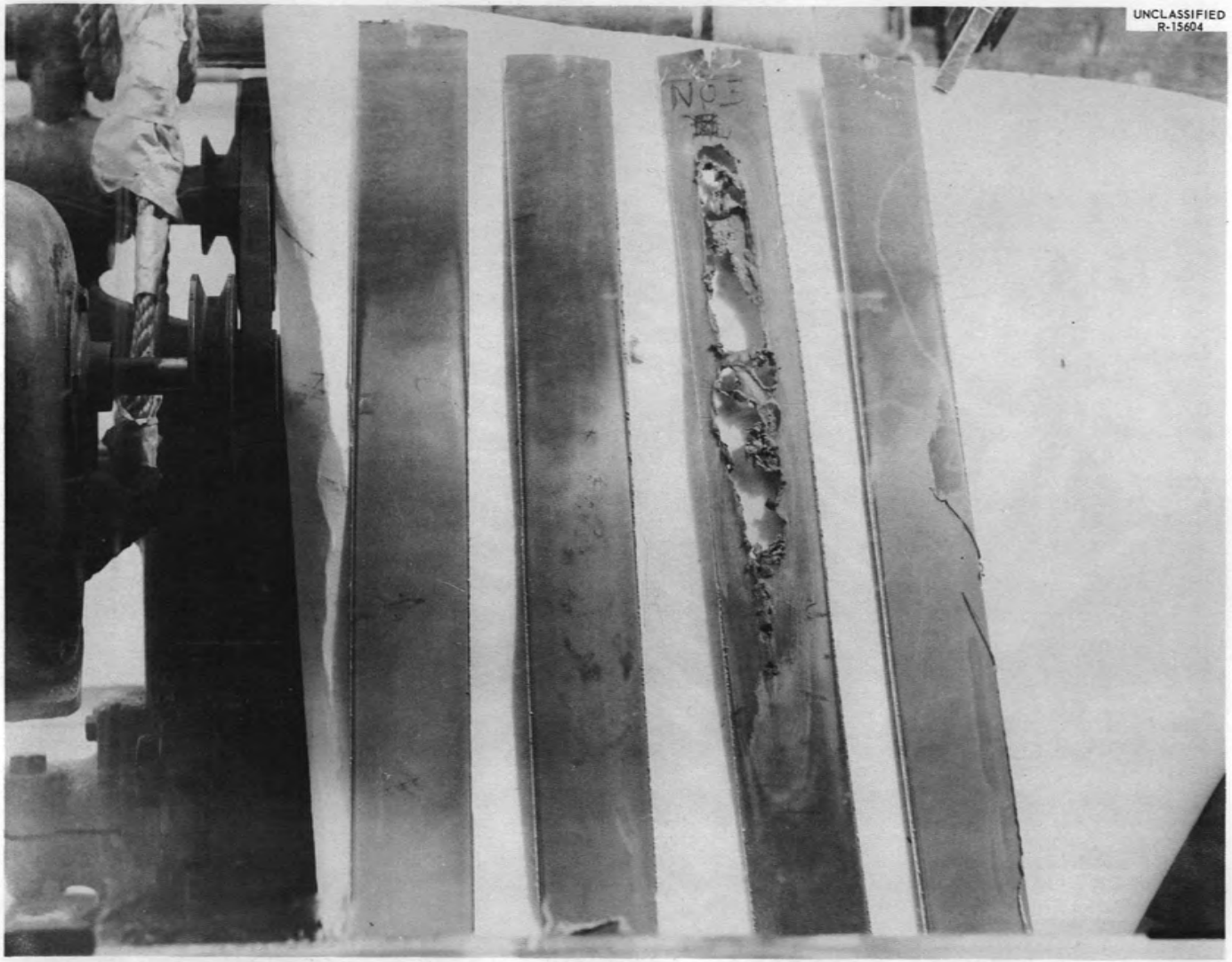

Fig. 20. Convex Side of Plates from ORR Element OR-36C

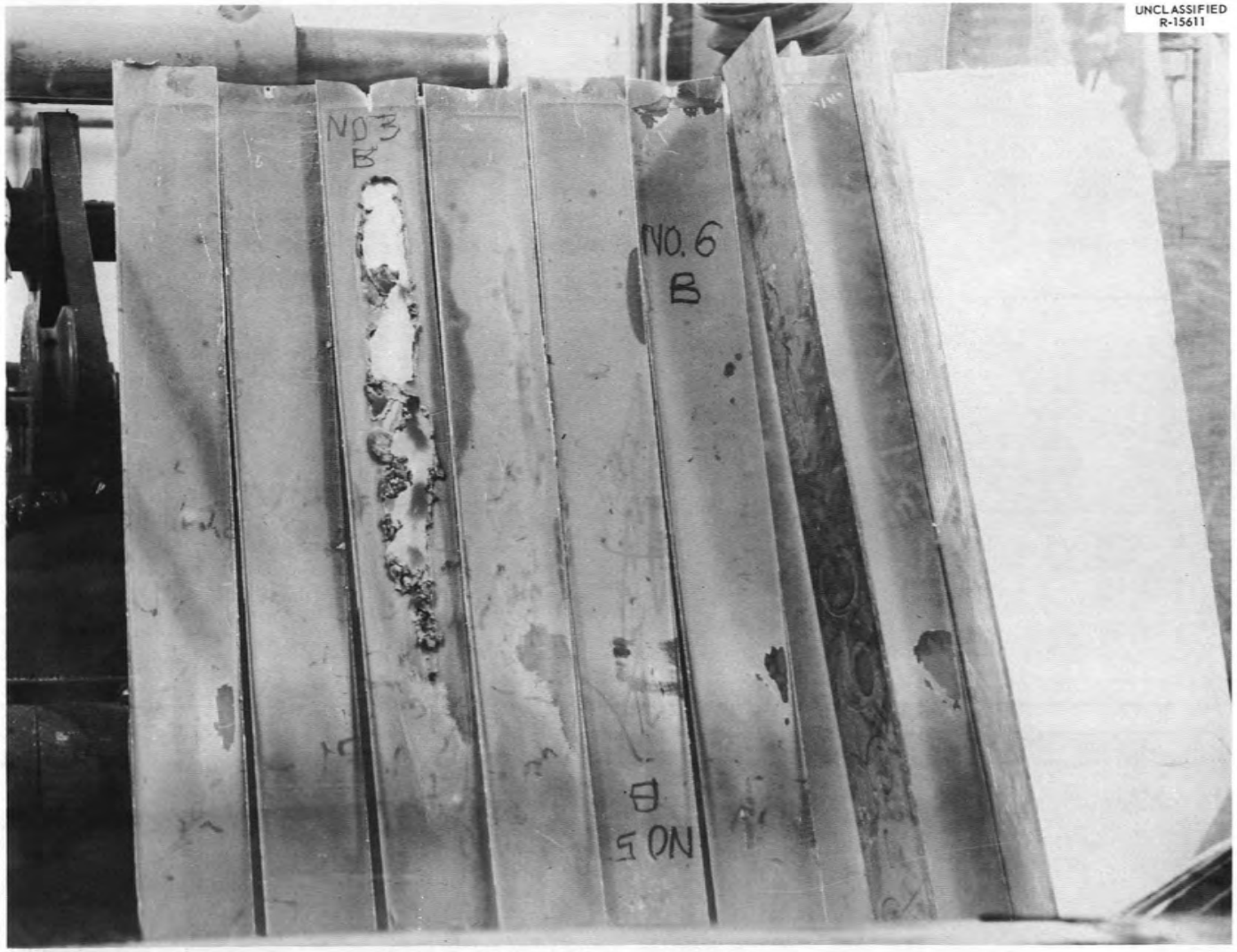

Fig. 21. Concave Side of Plates from ORR Element OR-36C

Table 3. Activities of Samples from Melted Plate

Description of Sample	Rare Gas[a]	Activity in Counts/Min Per Gram of Sample			
		I (γ)	Te (γ)	Cs (γ)	Ru (γ)
		Beads of Melted Plate Selected at Random			
No. 4	279×10^{11}	3.24×10^{7}	4.43×10^{8}	4.84×10^{8}	4.31×10^{10}
No. 6	316×10^{11}	2.32×10^{7}	8.13×10^{8}	9.85×10^{8}	3.67×10^{10}
		Punchings of Plate			
From top of element	234×10^{11}	5.84×10^{7}	1.16×10^{8}	4.6×10^{9}	2.3×10^{10}
From bottom of element	122×10^{11}	1.45×10^{7}	1×10^{8}	2.39×10^{9}	7.43×10^{9}

[a]Numbers are for comparison only.

CONCLUSIONS

This brief description indicates that, as usual, the incident was not caused by a single failure but, rather, by the superposition of various failures, each of which is not by itself sufficient to create the incident. In this case, the gasket fell into the reactor tank, visual inspection did not detect the flow obstruction, and the boiling condition of the reactor was not recognized from the behavior of the instrumentation.

It is interesting to note that the ^{16}N instrument detected the melting of the fuel plate very well. Connecting this or similar instrumentation to the reactor safety system should, to some extent, limit the severity of a future incident, although there would be a delay due to the transit time of the coolant. The connection between the reactor primary cooling system and the pool water resulted in the air-borne activity contamination in the building and the temporary evacuation. This problem could perhaps be diminished if some means could be found to prevent activity release into the pool through this path.

To conclude, it has to be realized that this incident could have been much more serious. The blocked fuel element was located in a position where the flux was only 60% of the reactor average flux. The fuel element itself had only 15 grams burnup and had been out of the reactor for three months before being reloaded into the core and damaged.

This incident prompted immediate action in several areas to improve the operating technique and reduce the probability of a similar incident and to minimize the resulting conditions if one should occur. The following actions have been completed or are being performed.

1. A new access cover which permits visual inspection of each core position has been installed.
2. Written inventories are being used to administratively control all items which are taken into the reactor pool.
3. The scope of core inspection has been increased by using a "check-off" sheet which specifically locates each fuel element in the core. The inspections made before closing the reactor

tank and at a nominal 5-Mw power level are verified by the completion of a "check-off" sheet and the signing of the inspection sheet by the engineer performing the inspection.

4. Modifications in piping have been completed which permit the overflow from the reactor system to the pool, due to thermal expansion, to be routed through the degasifier and a special ion-exchange unit thereby degassing and de-ionizing all reactor water prior to mixing it with the pool water.
5. Access to the pool is limited to personnel experienced in this special work and/or to those who have attended special orientation relative to this type of work.
6. A study is being conducted to determine the advisability of connecting a reliable ^{16}N channel to the reactor safety system.

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