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NEW YORK OPERATIONS OFFICE

410411

RADIOACTIVE DEBRIS FROM OPERATION CASTLE

ISLANDS OF THE MID-PACIFIC

January 18, 1955

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NYO- 4623
Effects of Atomic Weapons

RADIOACTIVE DEBRIS FROM OPERATION CASTLE ISLANDS OF THE MID-PACIFIC

by

Alfred J. Breslin
Melvin E. Cassidy

January 18, 1955

UNITED STATES ATOMIC ENERGY COMMISSION
New York Operations Office
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ABSTRACT

During CASTLE, an offsite monitoring program was conducted in the Central and Southwest Pacific to document and to provide current measurements of the radioactive fallout. Navy patrol aircraft, equipped with gamma radiation instruments, were dispatched over planned routes to measure fallout after its presence had been detected by automatic gamma monitors. Eleven of these were collecting a continuous record on selected atolls in the Marshall, Caroline, and Mariana Islands. Air survey measurements were converted to ground intensities immediately upon receipt by means of suitable curves, permitting appraisal of the radiological situation over a widespread area. Auxiliary stations providing daily gamma measurements were located beyond the network of automatic stations.

Cumulative and peak radiation dosage were measured, or computed from indirect measurements, for all islands in the automatic network and for islands within the two aerial survey patterns east of Bikini in the Marshall Islands.

BRAVO accounted for 89% of the total cumulative radiation measured during the program. The greatest radiation rate, extrapolated from direct measurements, 12.5 r/hr, occurred at Rongelap after BRAVO. Values both greater and lesser than this probably occurred at various islands in the Rongelap atoll. The greatest estimated cumulative radiation occurring from any event until the next following was 190 r at Rongerik after BRAVO. The total cumulative radiation at Rongerik was 206 r.

The monitoring method combined fixed continuous stations and aerial surveys. The advantages of each method was utilized so that they were complementary. Rapid, accurate information about radioactive fallout was provided by a means which probably represents the maximum in economy for such extensive coverage.

The SCINTAMETER, a sensitive, wide range scintillation type gamma meter was demonstrated to be a dependable, very portable, facile instrument for aerial monitoring use.

Increased accuracy, reliability, and precision can be obtained for future surveys of this nature through certain suggested modifications.

I. INTRODUCTION

1. Purpose. At the request of CINCPACFLT the Health and Safety Laboratory of the New York Operations Office organized and directed a program to document radioactive fallout from CASTLE in the Central and Southwest Pacific, exclusive of the proving grounds. Current fallout information was to be made available to CINCPACFLT following each detonation. The program was to be patterned basically on the NYOO monitoring system developed for IVY.

The information derived was used in the immediate estimation of radiological hazards in heavy fallout areas. The documented fallout constitutes a record of cumulative radiation produced during the test series.

2. Organization. The monitoring program was planned and directed by the Health and Safety Laboratory, New York Operations Office and actively supported by several agencies. HASL organized the functions of the participating agencies, developed procedures, and furnished all monitoring instruments employed. The Director, Health and Safety Laboratory, was in over-all charge of the program. The Project Officer (HASL) directed operations in the forward area. Operations were executed in accordance with the operating plan "HASL-154 -Operating Procedure, Fallout Monitoring for CASTLE". Monitoring instrument calibration and maintenance in the forward area was performed by the HASL staff. Joint Task Force-7 Headquarters provided logistic support and made available communications facilities in the forward area.

The instrument monitoring program consisted of the following operational subdivisions:

1. Fixed Instrument Network
    - (a) Automatic monitoring stations
    - (b) Auxiliary monitoring stations
2. Aerial Survey Monitoring

Fixed Instrument Network

The U. S. Weather Bureau, the U. S. Navy, and the USAF Air Weather Service operated fixed automatic gamma monitoring stations on sites selected basically to create a uniformly distributed pattern relative to the test area. The availability of facilities for the operation of monitoring equipment was a factor which limited the number of atolls which could be utilized. Uniform distribution was reasonably well achieved particularly within the Trust Territory.

The nature of the automatic instruments was such that very little attention was required during normal operation. The function of the station personnel was to read and transmit the indicated radiation data. Except for a simple briefing, none of the personnel were pre-trained in the use of these instruments nor in the field of radiation safety.

The sites as originally established[†] were:

Location	Operating Agency
Iwo Jima	AWS
Guam	AWS
Truk	USWB
Yap	USWB
Wake	USWB
Midway	USN
Rongerik	AWS*
Majuro	AWS*
Kusaie	AWS*
Ponape	AWS*
Kwajalein	USN
Ujelang	HASL**

*JTF-7 weather units

**Ujelang was unattended. Data was retrieved periodically by HASL personnel.

AFOAT-1 operated six auxiliary stations in more remote locations which were equipped with portable Geiger-Mueller survey instruments. The six locations were:

Manila, Luzon
Okinawa
Yokota, Japan
Oahu, Hawaiian Islands
Shemya, Aleutian Islands
Anchorage, Alaska

[†] On B + 1 a portable gamma instrument (Scintameter) was placed at Johnston Island AFB to intercept the BRAVO cloud believed to be traveling east from the forward area. This was replaced by an automatic gamma monitor after Rongerik Atoll was evacuated and the automatic monitor removed from that site. Johnston was the only location east of Bikini and approximately in the same latitude as Rongerik with facilities for monitor operation.

Shortly after the first event, the first three listed stations were discontinued.

The locations of all the instrument monitoring stations are plotted in Figure 1.

Aerial Monitoring

Three Navy patrol squadrons were assigned to execute aerial survey missions. These were VW-1 at Barbers Point, Oahu, VP-29 at Kwajalein, M.I., and VW-3 at Agana, Guam. They covered designated Pacific Island groups according to the following patterns:

VP-29

ABLE

1 Kwajalein
2 Lae
3 Ujae
4 Wotho
5 Bikini
6 Ailinginae
7 Rongelap
8 Rongerik
9 Taongi
10 Bikar
11 Utirik
12 Taka
13 Ailuk
14 Jemo
15 Likiep
16 Kwajalein

BAKER

1 Kwajalein
2 Namu
3 Ailinglapalap
4 Namorik
5 Ebon
6 Kili
7 Jaluit
8 Mili
9 Arno
10 Majuro
11 Aur
12 Maloelap
13 Erikub
14 Wotje
15 Kwajalein

CHARLIE

1 Kwajalein
2 Kusaie
3 Pingelap
4 Mokil
5 Ponape
6 Ujelang
7 Kwajalein

VW-3

DOG

1 Guam
2 Rota
3 Agiguan
4 Tinian
5 Saipan
6 Farralon de Medinilla

EASY

1 Guam
2 Namonuito
3 Truk
4 Losap
5 Namoluk
6 Lukunor

FOX

1 Guam
2 Gaferut
3 Faranlep
4 West Fayu
5 Ifalik
6 Woleai

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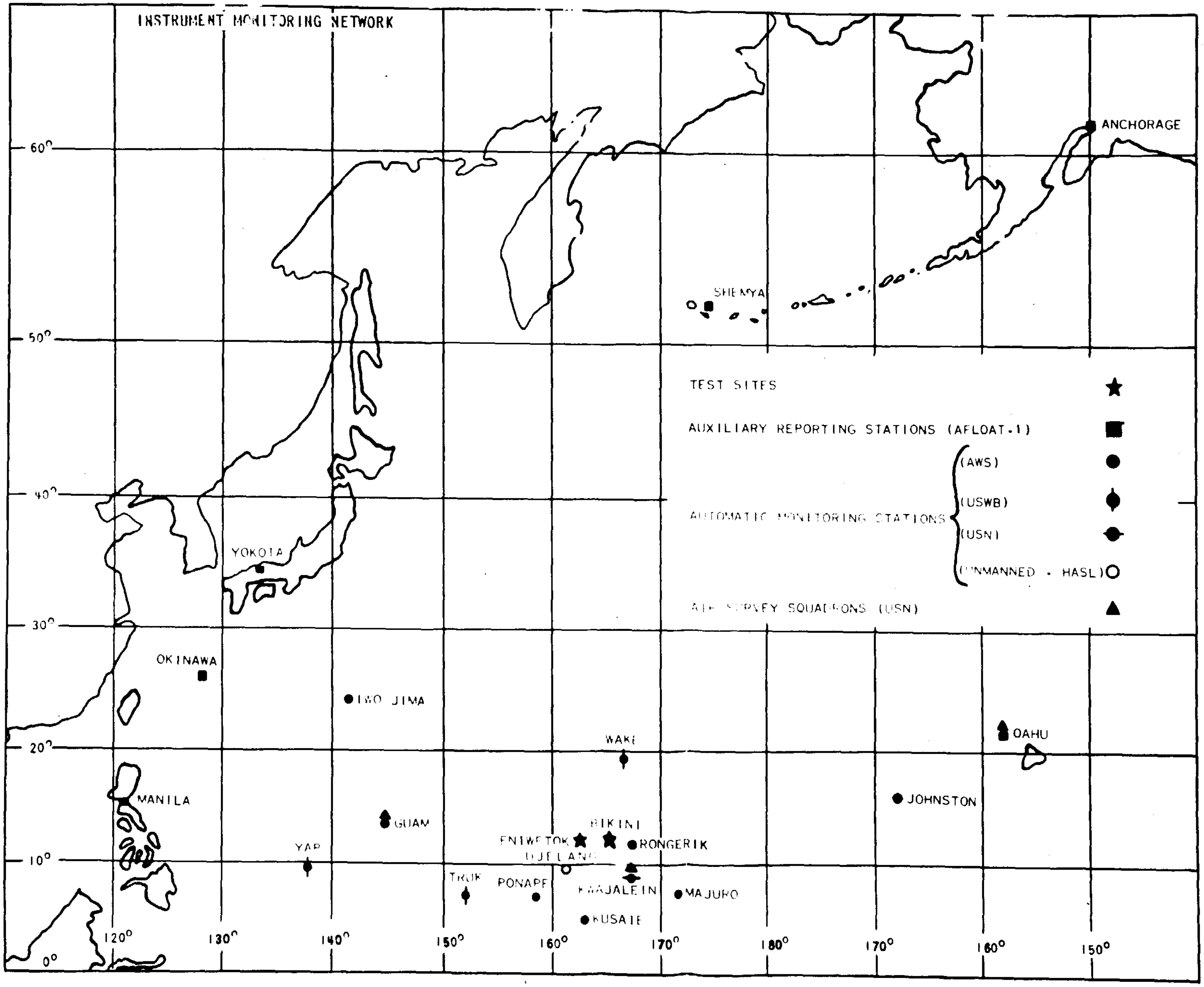
FIG. 1

INSTRUMENT MONITORING NETWORK



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DOG (Cont'd)

7 Anatahan
8 Sariguan
9 Goguan
10 Alamagan
11 Pagan
12 Agrihan
13 Asuncion
14 Maug
15 Farallon de Pajaros
16 Guam

EASY (Cont'd)

7 Satawan
8 Kuop
9 Pulap
10 Guam

FOX (Cont'd)

7 Eauripik
8 Palau
9 Ngulu
10 Yap
11 Ulithi
12 Guam

VW-1

GEORGE

1 Oahu
2 Midway (over south beaches, all isles in chain)

HOW

1 Midway
2 Oahu (over north beaches all isles in chain)

ITEM

1 Oahu
2 Lanai
3 Hawaii
4 Maui
5 Molokai
6 Oahu

Survey patterns are plotted in Figure 2.

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FIG. 17

RECONSTRUCTED GAMMA RADIATION INTENSITY
AT RONGERIK FOLLOWING BRAVO

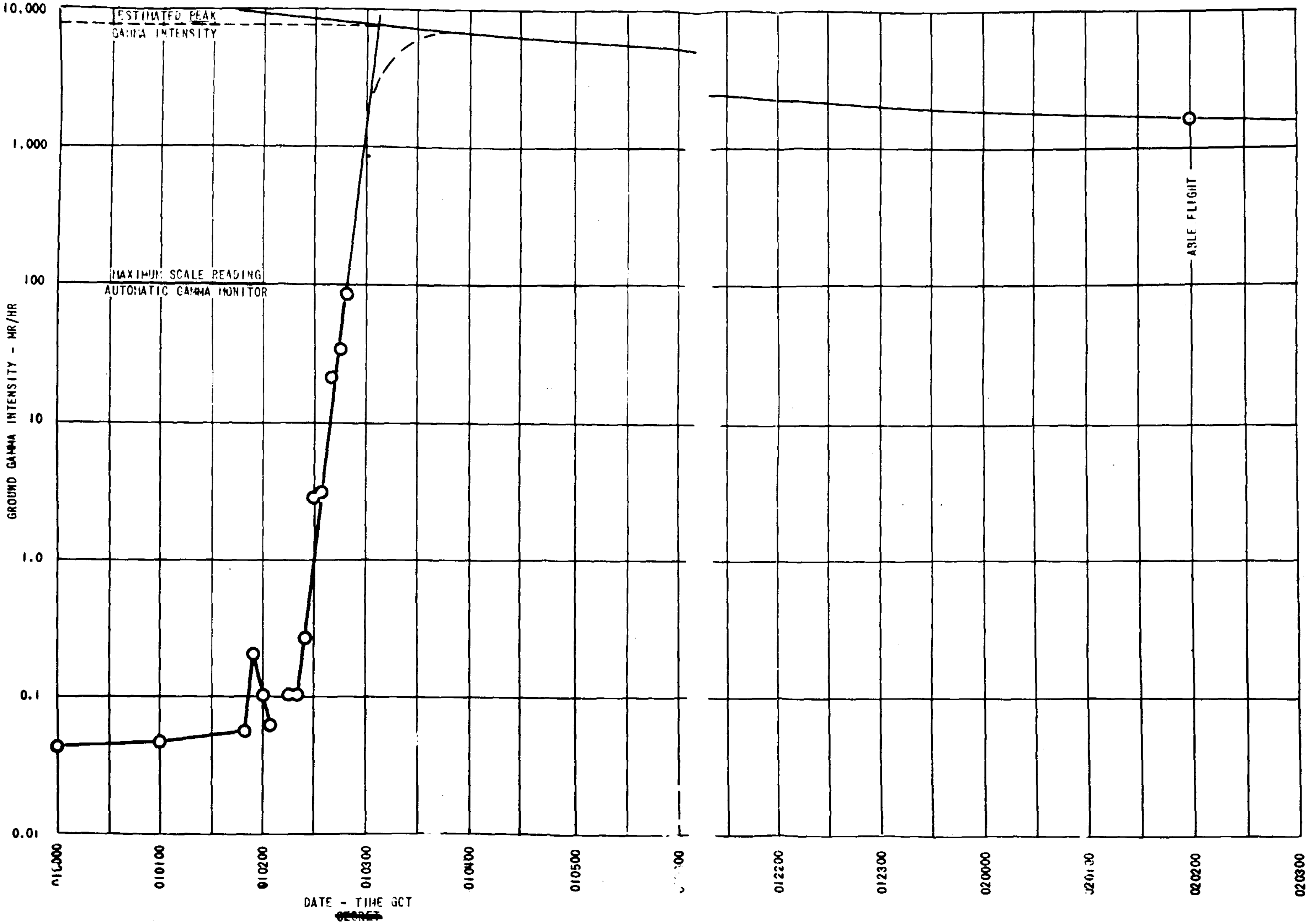

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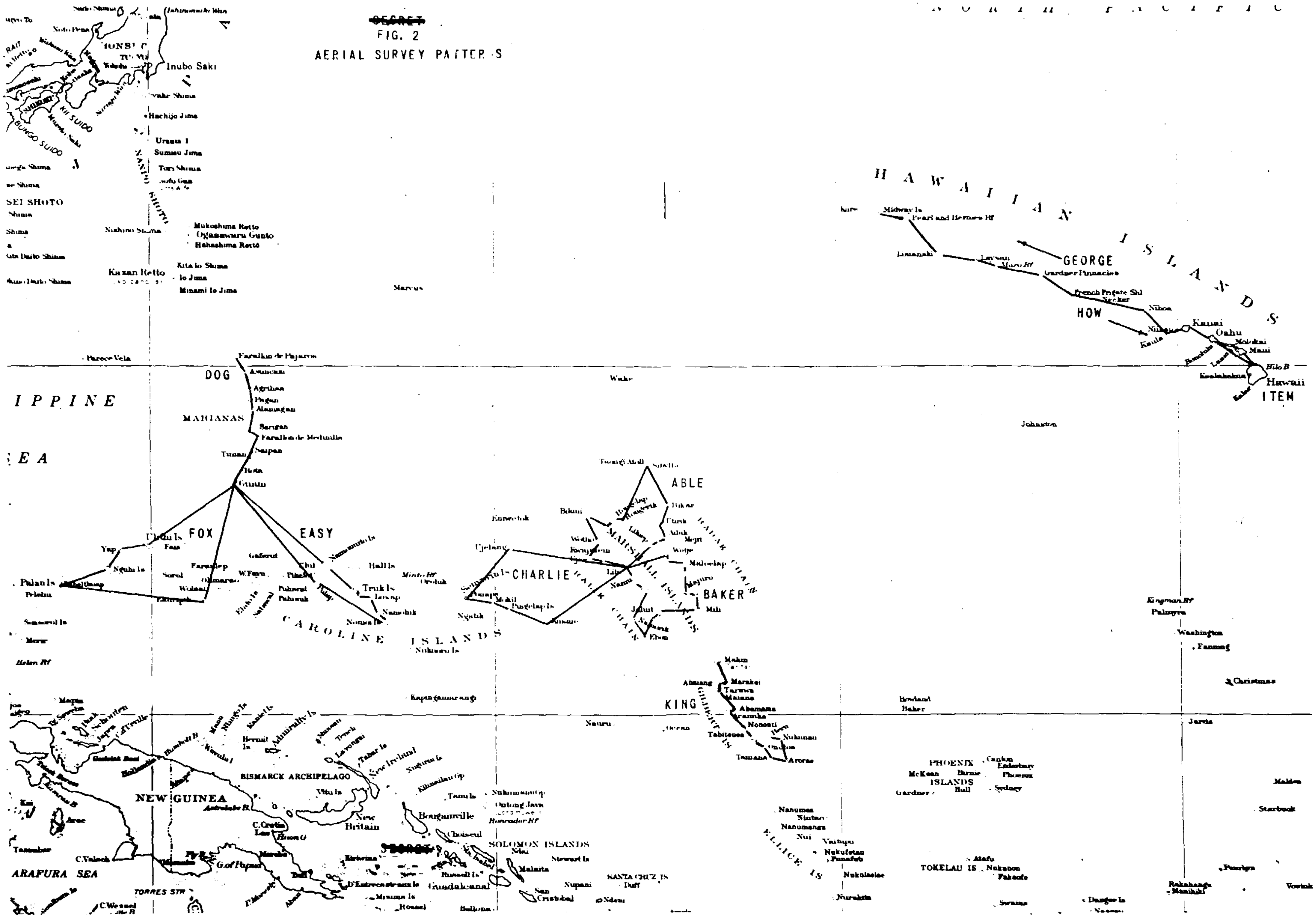
FIG. 2

AERIAL SURVEY PATTERNS



II. METHODS

The program was an integration of two principles of monitoring. The first was a network of fixed monitoring stations reporting data regularly to the Task Force. The second consisted of aerial monitoring flights by Navy patrol squadron aircraft over specified islands following each burst.

1. Fixed Instrument Network

General Description. The fixed network initially consisted of eighteen gamma monitoring stations chiefly in the Marshall, Caroline, and Mariana Islands but extending to the Philippines, Japan, Hawaii, and Alaska. The number and location of the sites were somewhat modified in the course of the test series. The stations, with one exception were manned, and reports of gamma radiation were transmitted regularly to the task force at six, twelve, or twenty-four hour intervals depending on their positions relative to the proving grounds. The twelve stations within 1500 nautical miles of the proving grounds were equipped with 110 v AC automatic continuously recording gamma monitors* having a range of .001 to 100 mr/hr. A battery operated automatic monitor* was placed on one island (Ujelang) where facilities for a manned station were unavailable. Data was recovered from this station after each burst.

Six remote stations beyond 1500 miles were provided with portable GM survey instruments having a range of 0.01 to 20 mr/hr. Twice daily measurements of local gamma activity were transmitted once a day from these stations to the task force.

Data was transmitted by administrative teletype messages from all but four stations which were weather observation posts maintained by the task force. Fallout data from these locations were appended to routine data transmissions to the task force weather central.

Operation. The principle reason for establishing the instrument monitoring network was to provide a reliable fallout detection system by means of which aerial surveys could be selected and timed to produce a minimum of negative flights. Increases in radiation intensities at the automatic monitoring stations were known at Task Force Headquarters within a few hours after their occurrence.

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*Instruments are described in Section VI.

The gamma intensity at each of the automatic stations (except Ujelang) was recorded at 0600, 1200, 1800, and 2400 Z daily by resident operating personnel and transmitted to the HASL representative at Task Force Headquarters.

The instruments were routinely checked each day for proper radiation response. This test, which consisted in observing the meter response to a low intensity button source placed near the GM tube, provided a means of detecting circuit failures. Two HASL technicians, at Guam and Kwajalein, visited the monitoring stations periodically to adjust calibration and to effect repairs as required.

Many of the monitoring units installed were designed to record the beta dust concentration continuously as well as gamma radiation. Unfortunately, all of the beta channels failed as a result of various mechanical and electrical difficulties after short periods of operation.

Twice daily, the ground gamma intensity was measured with the portable GM meters at each of the AFOAT-1 installations. These measurements were obtained by scanning a small ground area from a height of three feet. Meter readings of less than 0.05 mr/hr were attributed to background radiation and were reported as negative values. Data was transmitted daily from each station to Task Force Headquarters.

The instruments were tested each day for correct operation and radiation response in a manner similar to that employed for the automatic monitors. Faulty instruments were replaced after notification of NYOO Project Headquarters thru AFOAT-1 channels.

Receipt and Utilization of Fixed Network Data. Radiation intensity reports were tabulated chronologically by location as they were received at the Task Force Headquarters. When a reported increase was indicative of significant fallout, a survey flight over a pattern which included the island from which the report originated was requested of the appropriate patrol squadron. From the report received upon completion of the survey flight, a comprehensive presentation of fallout intensities within the selected pattern was made available to the task force radsafe officer and other interested task force personnel.

In addition, the continued transmission of radiation data from the monitoring stations provided an accurate measure of potential radiation exposure at these locations. Weekly summaries of cumulative exposures were tabulated for each station.

2. Aerial Monitoring

General Description. Aerial surveys were conducted by Navy patrol planes equipped with SCINTAMETERS*, sensitive, wide range gamma scintillation instruments capable of measuring ground intensities of as little as 0.05 mr/hr from altitudes of 200 ft. or greater. Survey flights were made over pre-determined patterns designed to achieve maximum coverage in selected areas. The patterns included the Marshall, Caroline, Mariana, and Hawaiian Islands. Data was transmitted to the task force occasionally from survey aircraft in flight but more generally from the squadron base at the conclusion of each flight.

Operation. The scintameters were operated in flight by aircraft crew members trained in their use. Usually two instruments were carried, one reserved as a spare. The scintameter operator recorded background reading, position, altitude and radiation intensity for each island in the survey pattern. Background was measured during the approach to each island at a distance of several miles. These data were transmitted to Task Force Headquarters where the intensity at the stated altitude over each island was converted to ground intensity by means of a calibration curve.

Measurements were generally made from an altitude of 200 feet. Where the upper range of the instrument (100 mr/hr) was exceeded at 200 ft., the measurement would be repeated at higher altitudes until a value within the range of the instrument was obtained. Altitude was measured with a radio altimeter. The ratio of ground intensity to the intensity at the operators position within the aircraft at 200 ft. is approximately 4. (Scintameter calibration is described in Section VI). The low end of the scintameter range is 0.003 mr/hr so that theoretically the minimal detectable ground intensity is 0.012 mr/hr. In reality, the minimal detectable value is controlled primarily by the gamma background. This background can be caused by cosmic rays, navigational instruments, aircraft contamination, and possibly residual bomb debris in the air. The practical lower limit during CASTLE was in the order of 0.05 mr/hr.

Following BRAVO, survey parties, put ashore at several atolls in the area of heaviest fallout, recorded large radiation intensity gradients in directions approximately normal to the fallout path. At Rongelap, approximately ninety miles from ground zero, a difference of an order of magnitude in gamma radiation was noted between two opposite ends of the atoll, a distance of about 20 miles. This evidence was substantiated by ABLE flights repeated on B + 3 and B + 18 during which

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*Instruments are described in Section VI.

measurements were made over several islands in each of eight atolls. Tenfold differences between island intensities were measured at Rongelap and four-fold differences at several other atolls.

These large gradients were not anticipated prior to BRAVO and scintameter operators had not been cautioned to identify the individual islands surveyed within each atoll.

To standardize subsequent aerial surveys, a specific island in each atoll was selected for measurement. All radiation reports beginning with ROMEO are in reference to the same island in each atoll.

The planned method of selecting survey flights based on reports from monitoring stations was inapplicable for pattern ABLE after BRAVO due to the evacuation of Rongerik, the only ground station in the ABLE orbit. With upper level winds generally from the west to southwest, pattern ABLE proved to be the most useful and most used of all patterns. It was dispatched routinely on D + 1. Before this was done, air particle trajectory forecasts were reviewed for the possibility of the cloud being over the northern Marshalls on D + 1. The forecasts were reasonably reliable for a period up to H + 24 to H + 36 hours. Usually, the forecasts placed the cloud beyond the Marshalls by H + 24 hours. Surveys on D day were avoided because of the risk of contaminating survey aircraft. The very least result of flying thru the cloud debris would probably have been the elimination of the aircraft from further low intensity measurements. Fallout was generally not forecast to be complete in the northern Marshall's until late on D day or early on D + 1.

III. RESULTS

1. Automatic Monitoring Stations. Twelve automatic monitoring stations were originally installed for CASTLE. Eleven were operated continuously during the series. These were: Iwo Jima, Guam, Truk, Yap, Ponape, Kusaie, Majuro, Kwajalein, Ujelang, Wake, and Johnston.

Gamma intensity versus time after burst is plotted in Figures 3 thru 16, for those locations where significant radiation (generally greater than 0.1 mr/hr) was measured following a particular event.

Rongerik-BRAVO Burst. No monitor data are available after B + 8 hours when the gamma intensity exceeded the upper scale limit (100 mr/hr). Utilizing the ABLE survey measurement at B + 32 hours, an estimation of the peak radiation value may be obtained graphically by extrapolating the automatic gamma monitor curve above 100 mr/hr and extrapolating the ABLE measurement back on a $t^{-1.2}$ decay curve until the two curves intersect. This is shown on Figure 17. Cumulative radiation from BRAVO (Paragraph 4 below) is computed for Rongerik using the peak radiation value obtained from this synthetic graph.

Beta Dust Concentration. No beta dust concentrations were obtained from the manned automatic stations. At Ujelang, the unmanned station, beta dust concentrations were obtained only for ROMEO (Figure 18). Though the eight head dust sampler was serviced prior to each event, a variety of operational and instrumental difficulties generally rendered the instrument ineffectual.

2. Auxiliary Monitoring Stations. Remote stations at Oahu, Shemya, and Anchorage reported gamma radiation daily throughout CASTLE. No significant radiation was detected, i.e. there were no measurements greater than 0.05 mr/hr.

3. Aerial Monitoring. Thirty-three aerial survey missions were flown during CASTLE. Of these, fifteen followed pattern ABLE and seven followed pattern BAKER.

With the exception of pattern KING, all survey patterns were designed prior to the test series. KING was improvised following BRAVO to survey the Gilbert Islands. It was not repeated.

As a result of the widespread and unusually heavy fallout from BRAVO, all survey patterns (except HOW*) were arbitrarily executed to detect any areas of unsuspected fallout. In all of the following events,

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*HOW is identical to GEORGE except for the direction of flight.

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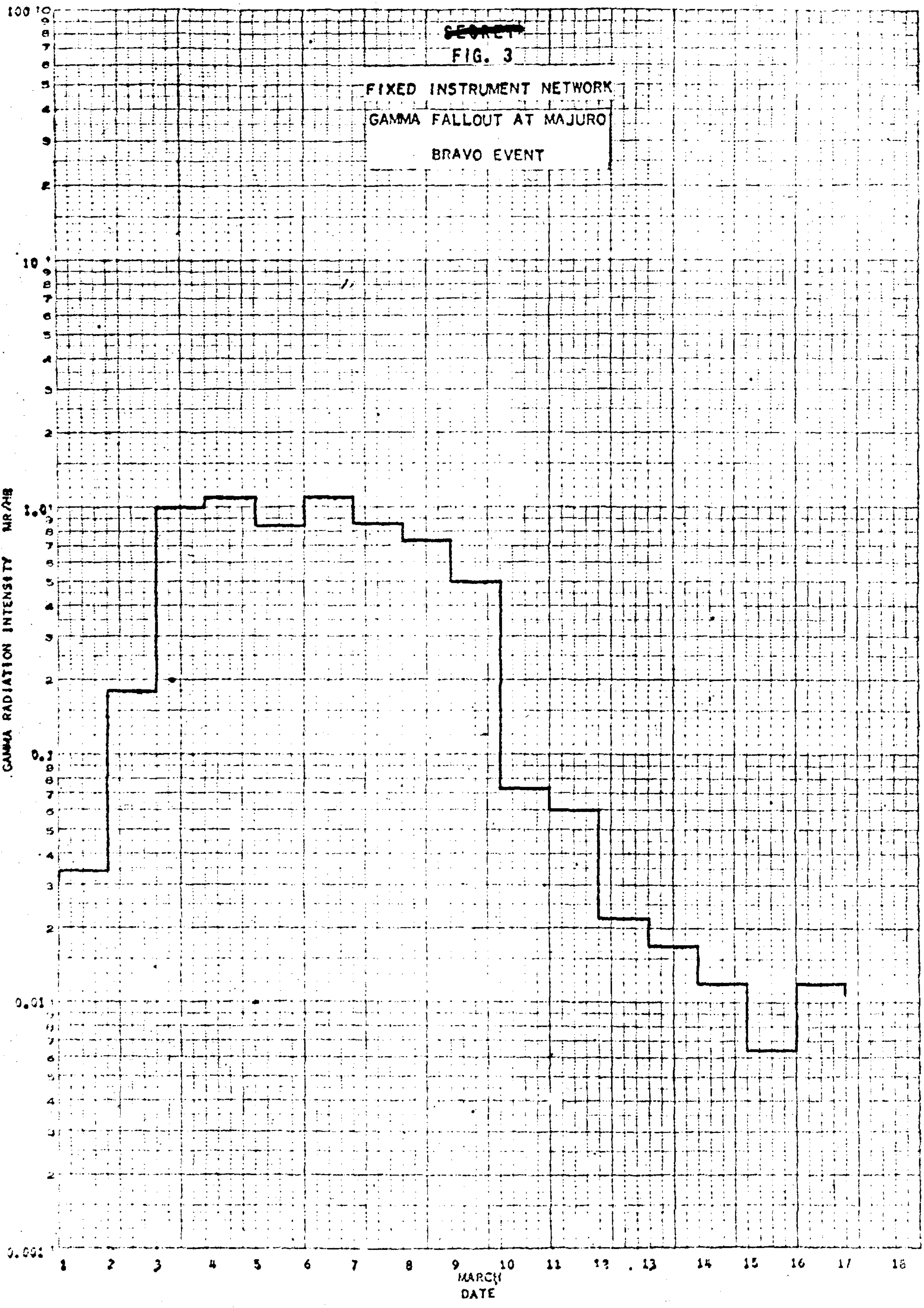

FIG. 3

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT MAJURO

BRAVO EVENT

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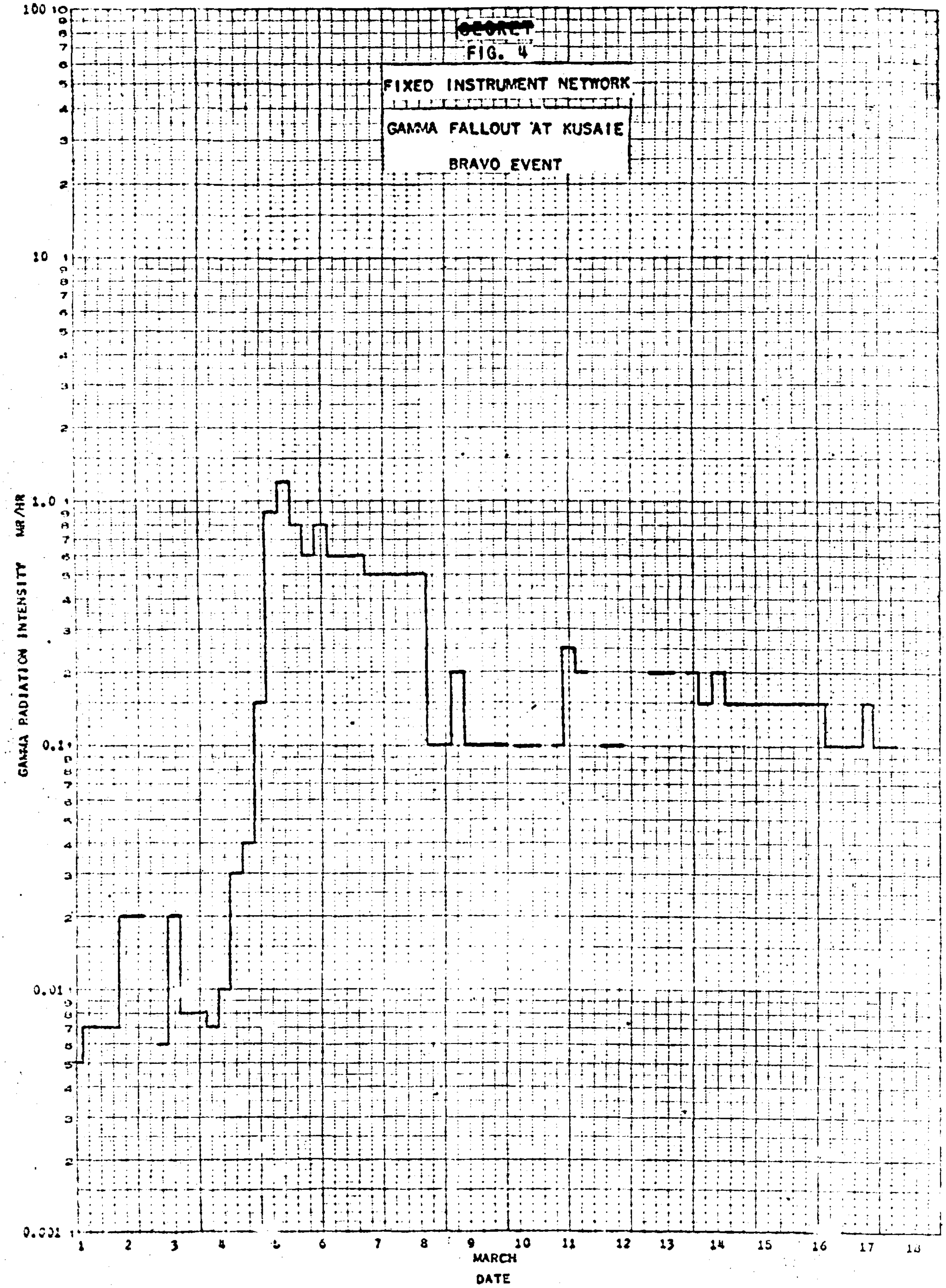
FIG. 4

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT KUSAIE

BRAVO EVENT

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FIG. 5

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT TRUK

BRAVO EVENT

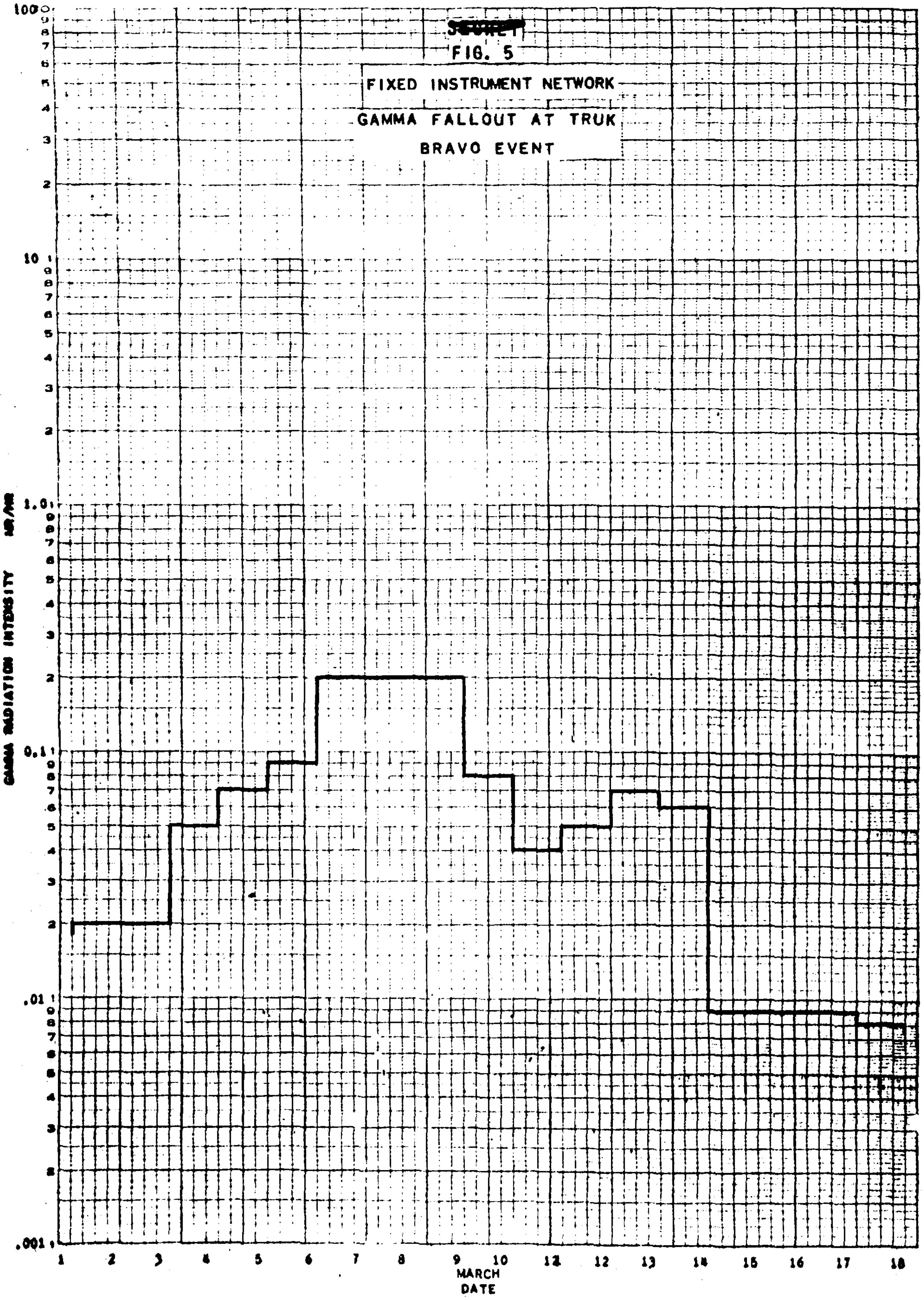

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FIG. 6

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT UJELANG

BRAVO EVENT

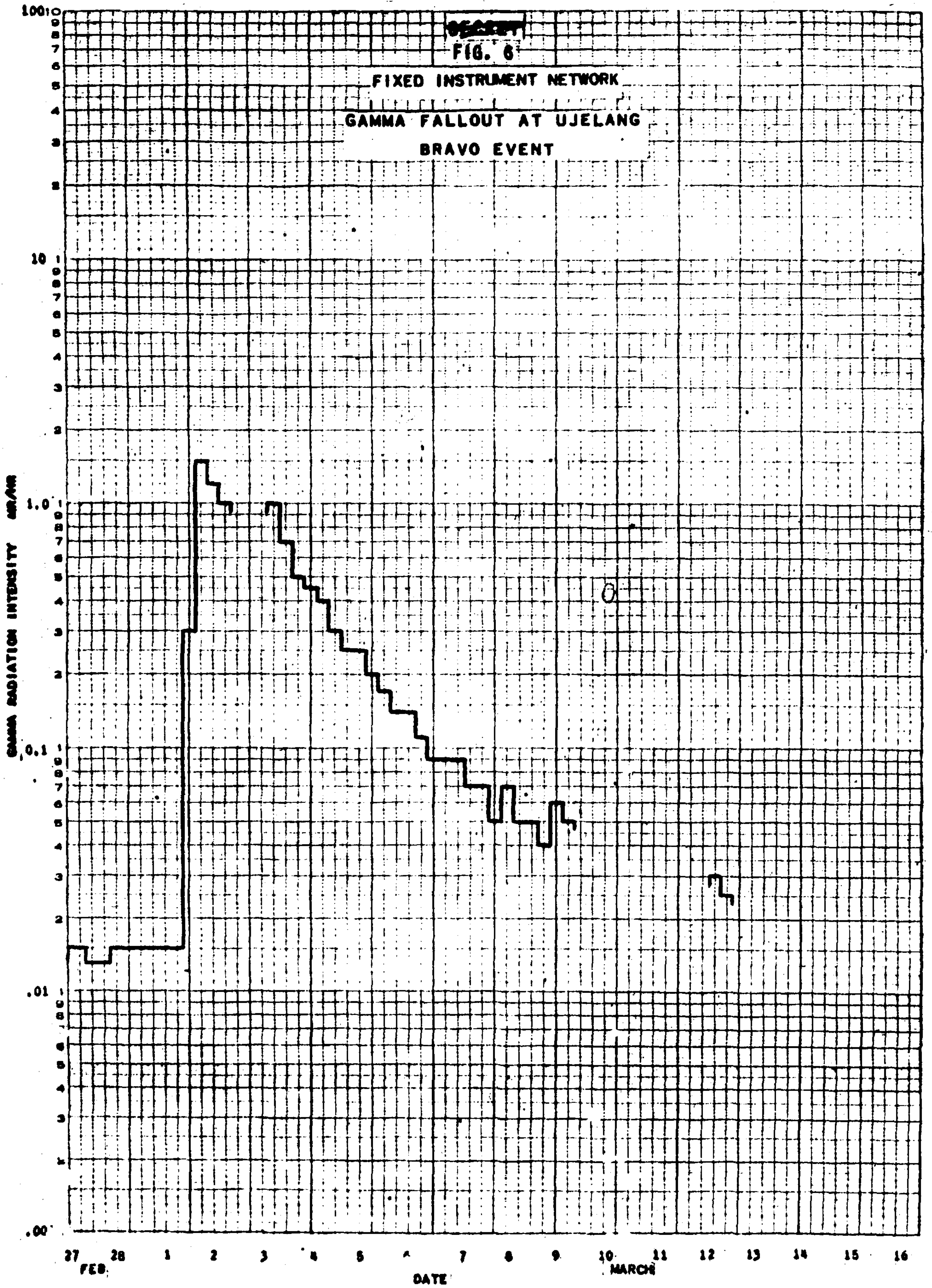

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FIG. 7

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT JOHNSTON

BRAVO EVENT

(SCINTAMETER MEASUREMENT)

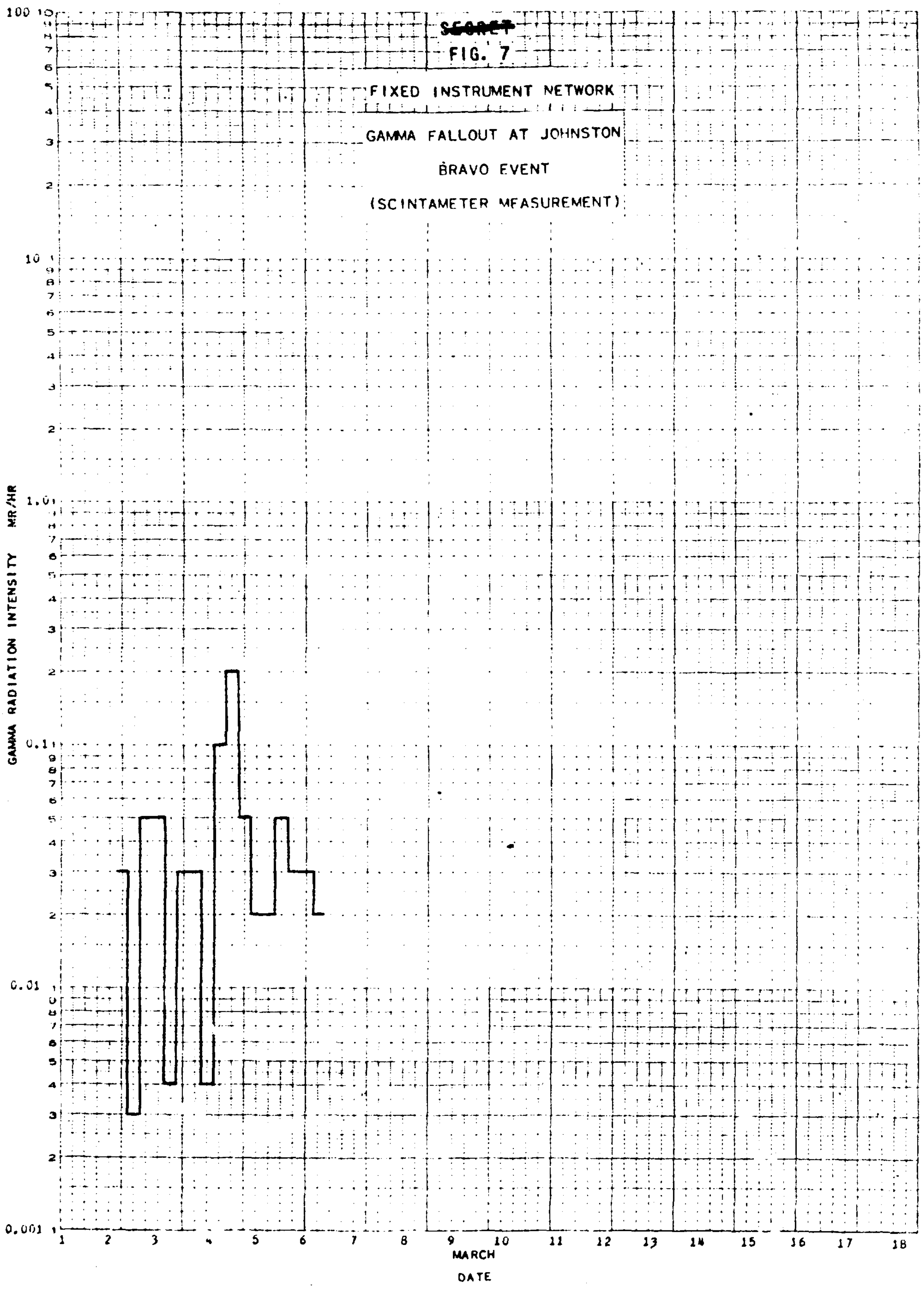

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FIG. 8

FIXED INSTRUMENT NETWORK
GAMMA FALLOUT AT KWAJALEIN

ROMEO AND KOON EVENTS

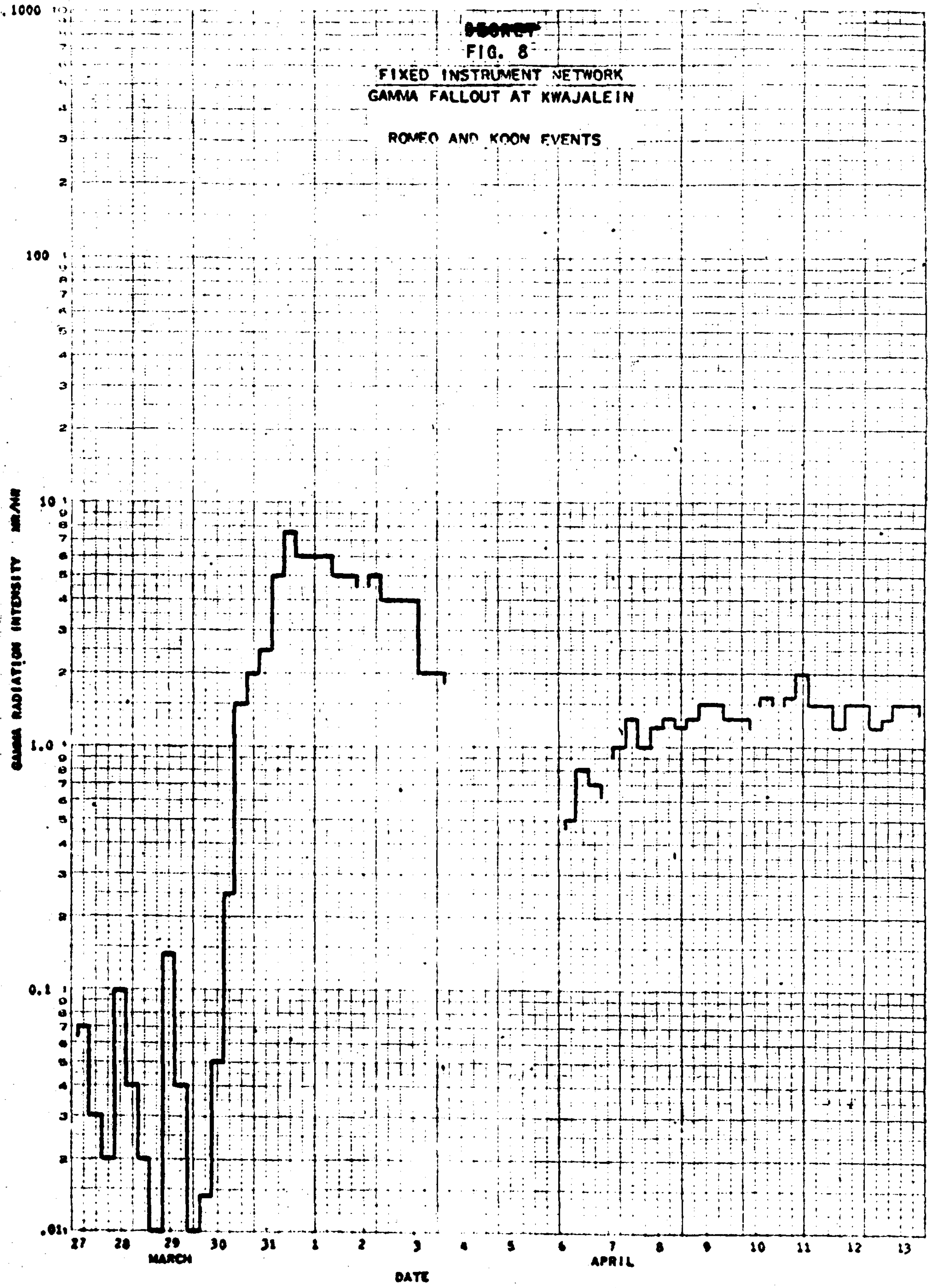

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FIG. 9

FIXED INSTRUMENT NETWORK
GAMMA FALLOUT AT MAJURO

ROMEO AND KOON EVENTS

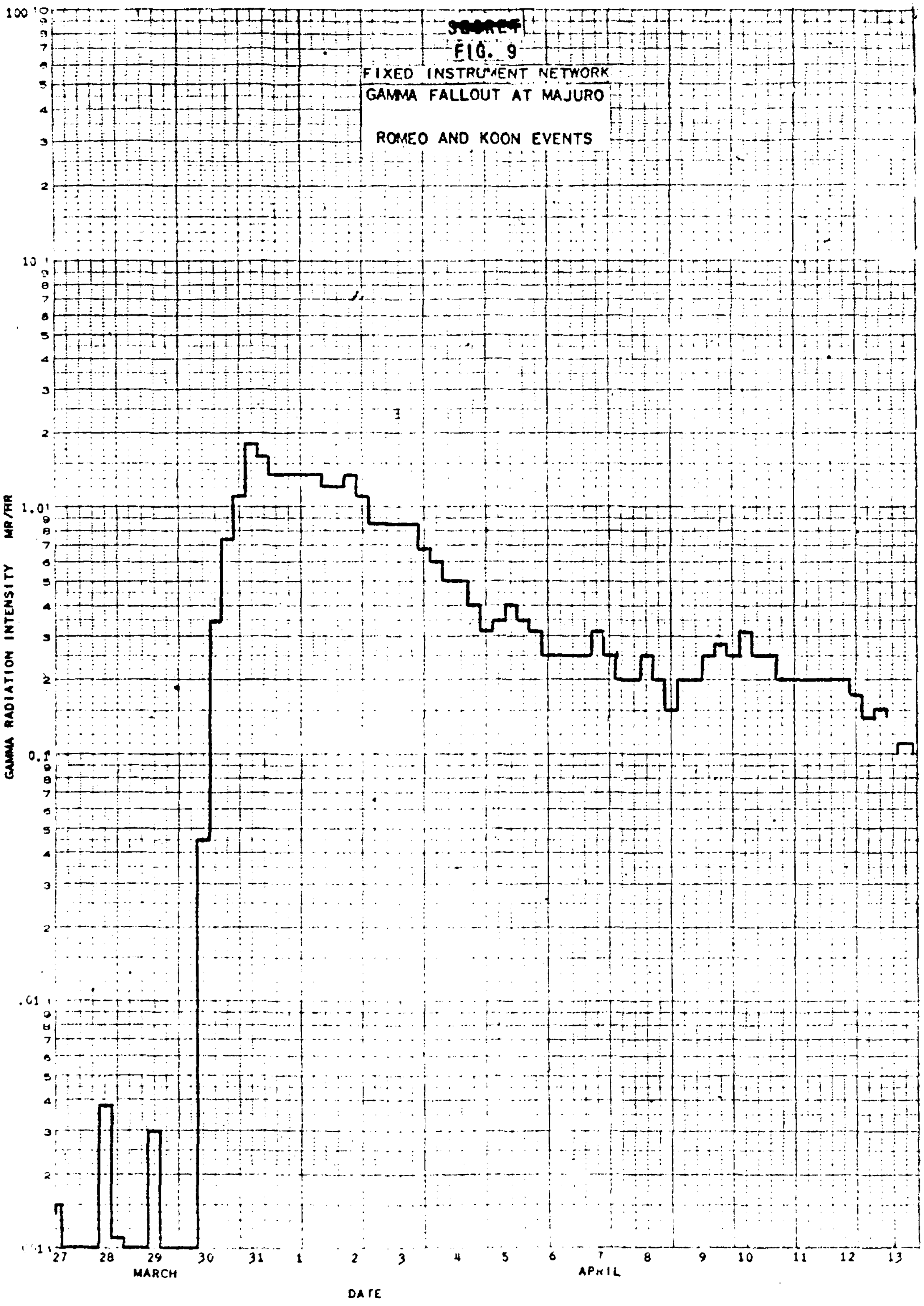

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FIG. 10

FIXED INSTRUMENT NETWORK
GAMMA FALLOUT AT KUSAIE

ROMEO EVENT

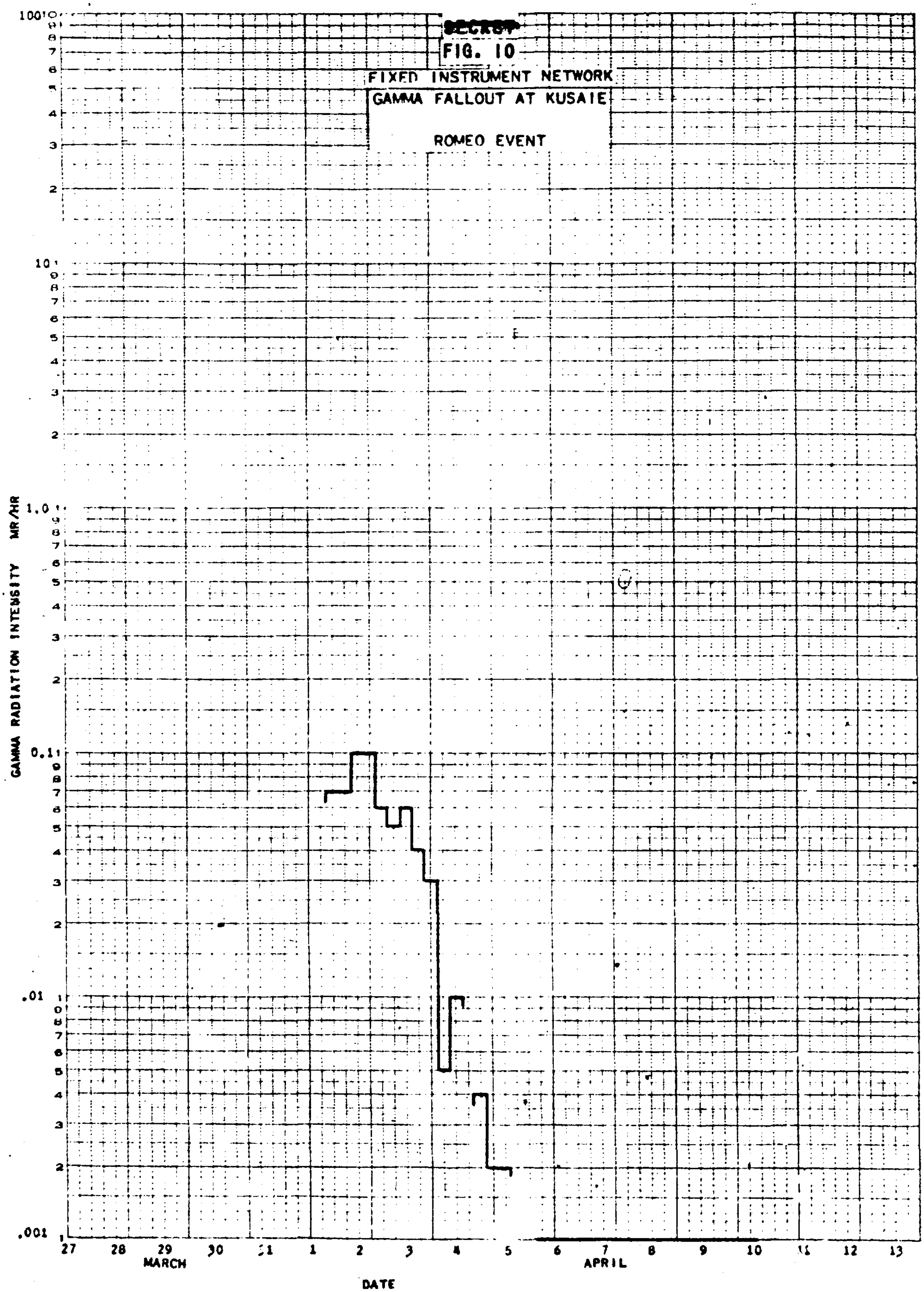

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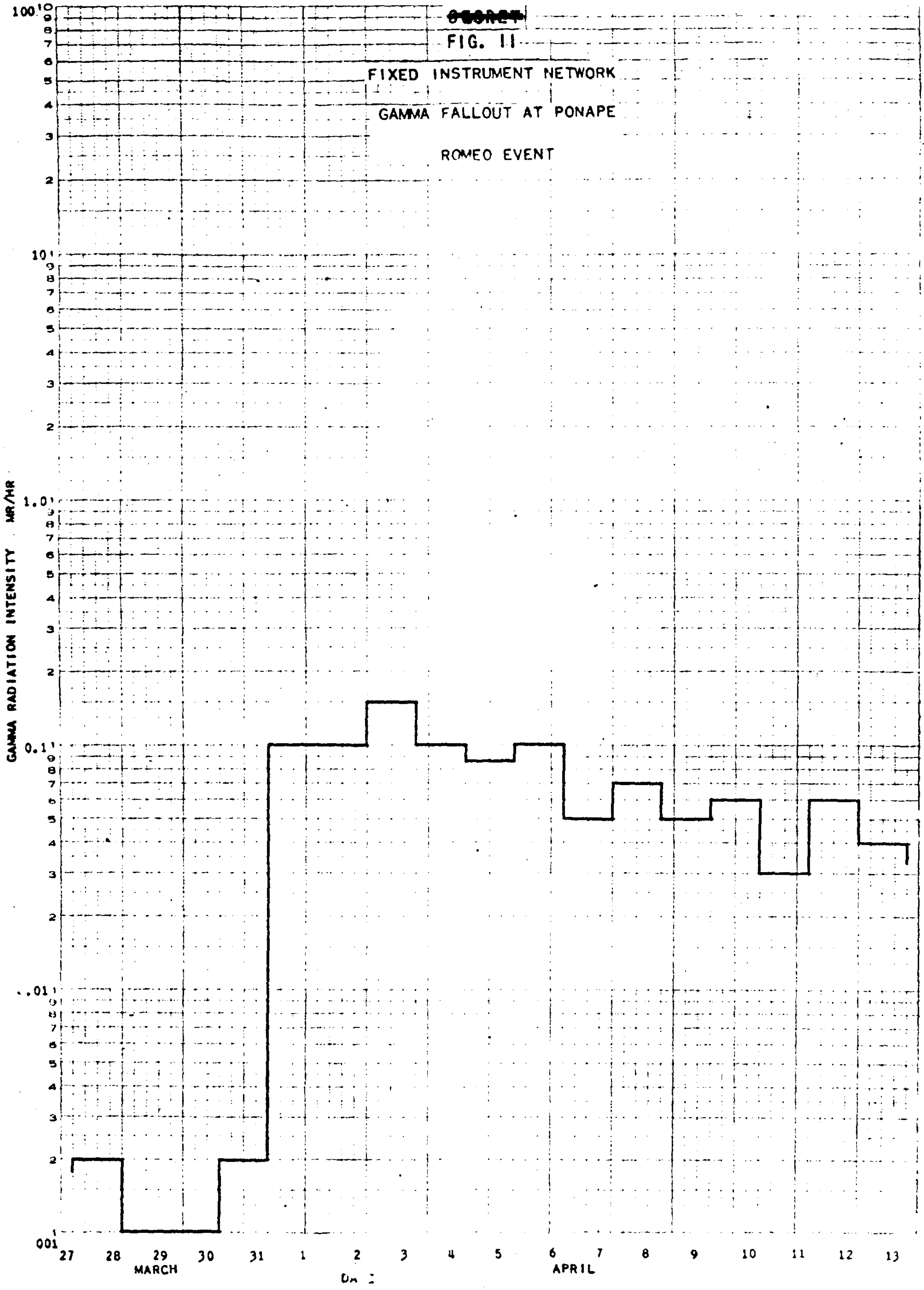
FIG. 11

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT PONAPE

ROMEO EVENT



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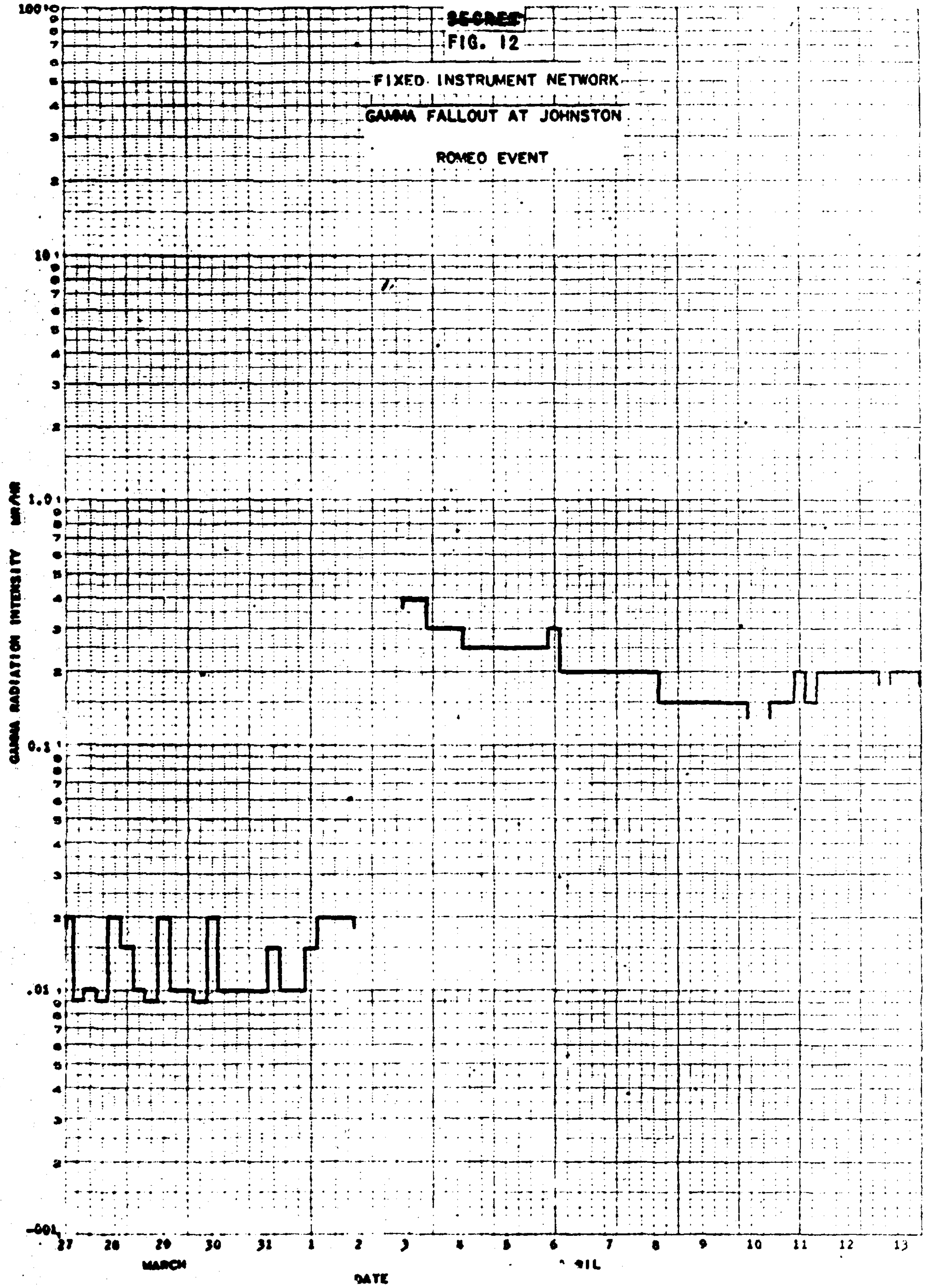

FIG. 12

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT JOHNSTON

ROMEO EVENT

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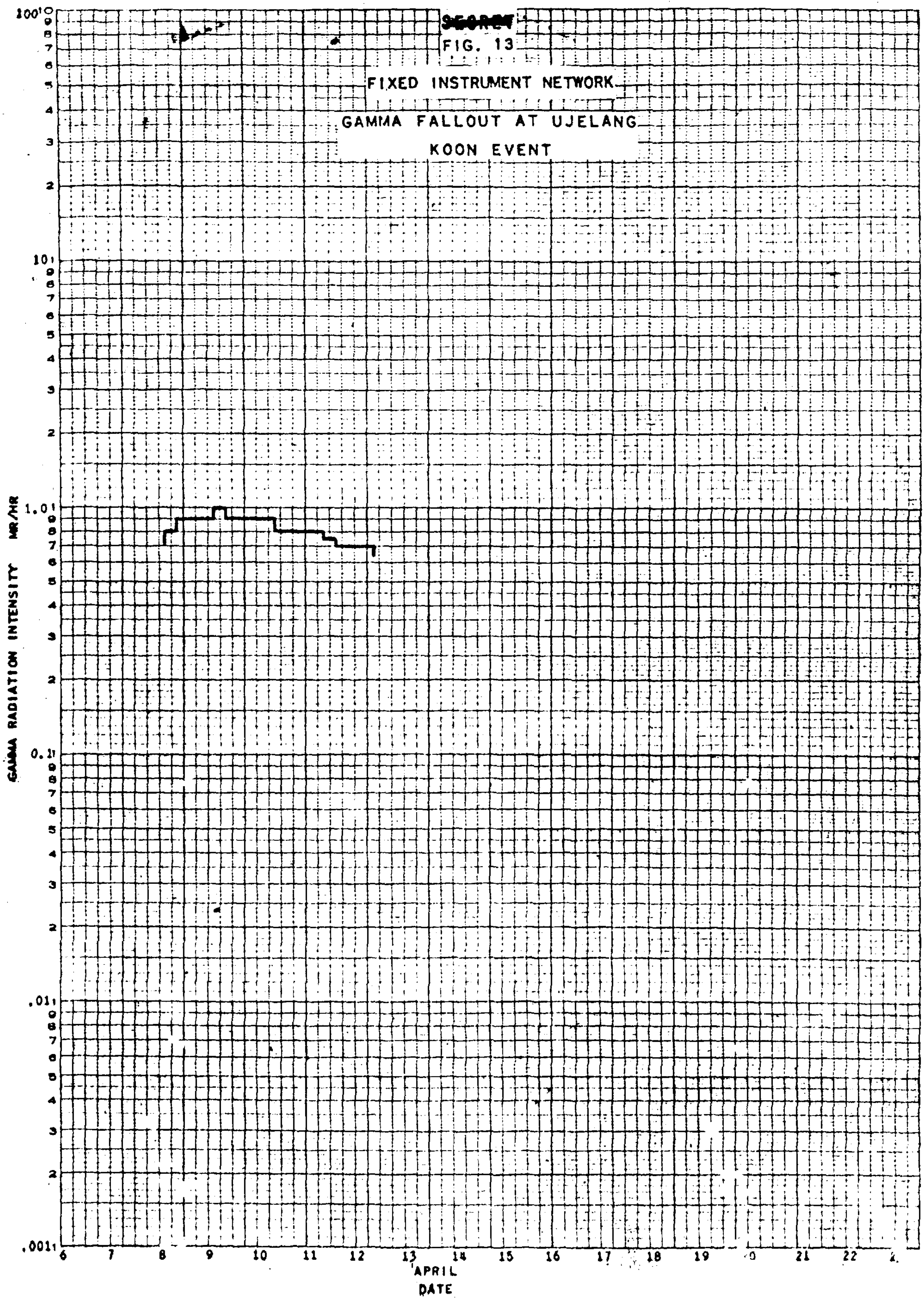

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FIG. 13

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT UJELANG

KOON EVENT

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FIG. 14

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT KWAJALEIN

UNION AND YANKEE EVENTS

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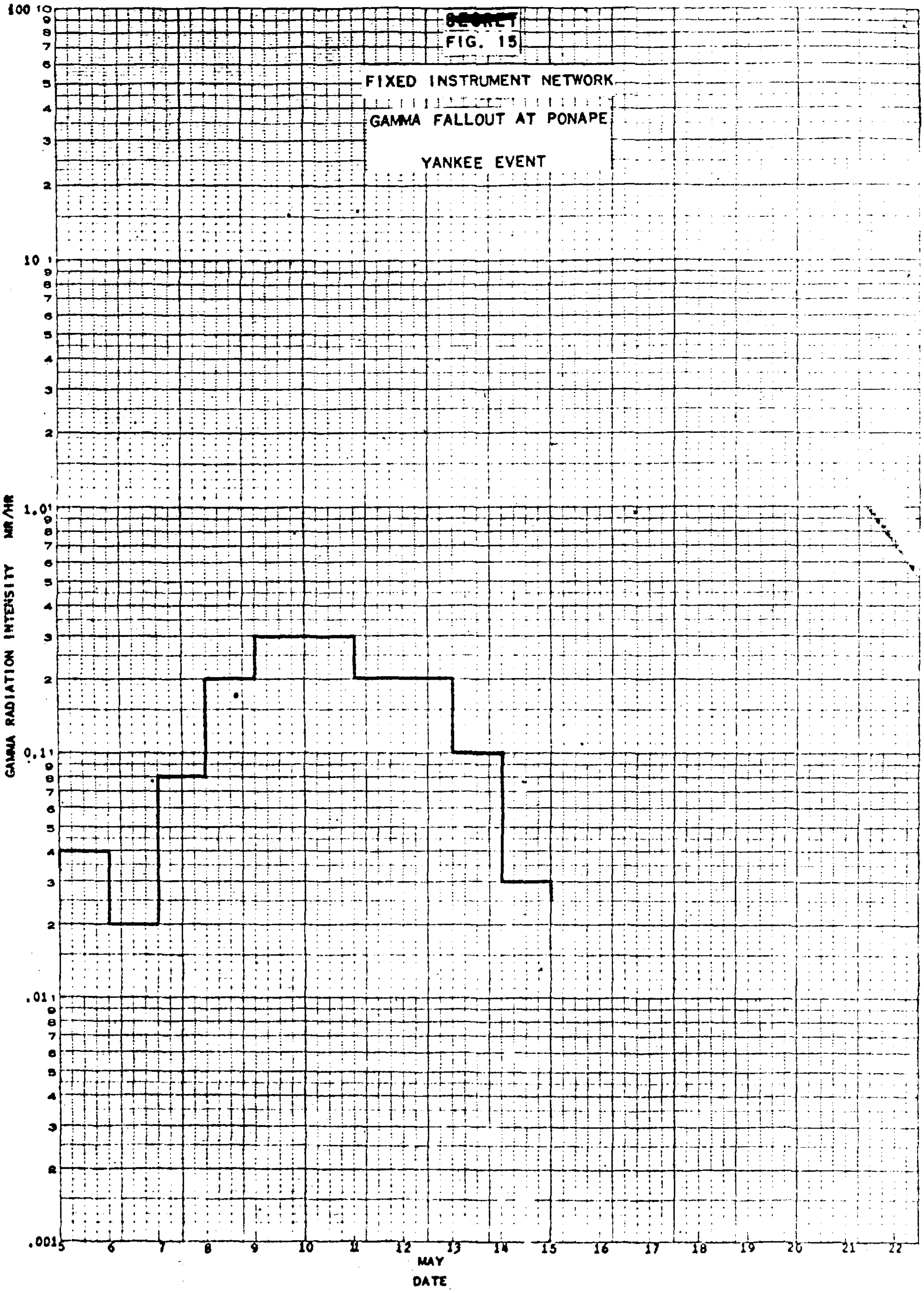
FIG. 15



FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT PONAPE

YANKEE EVENT

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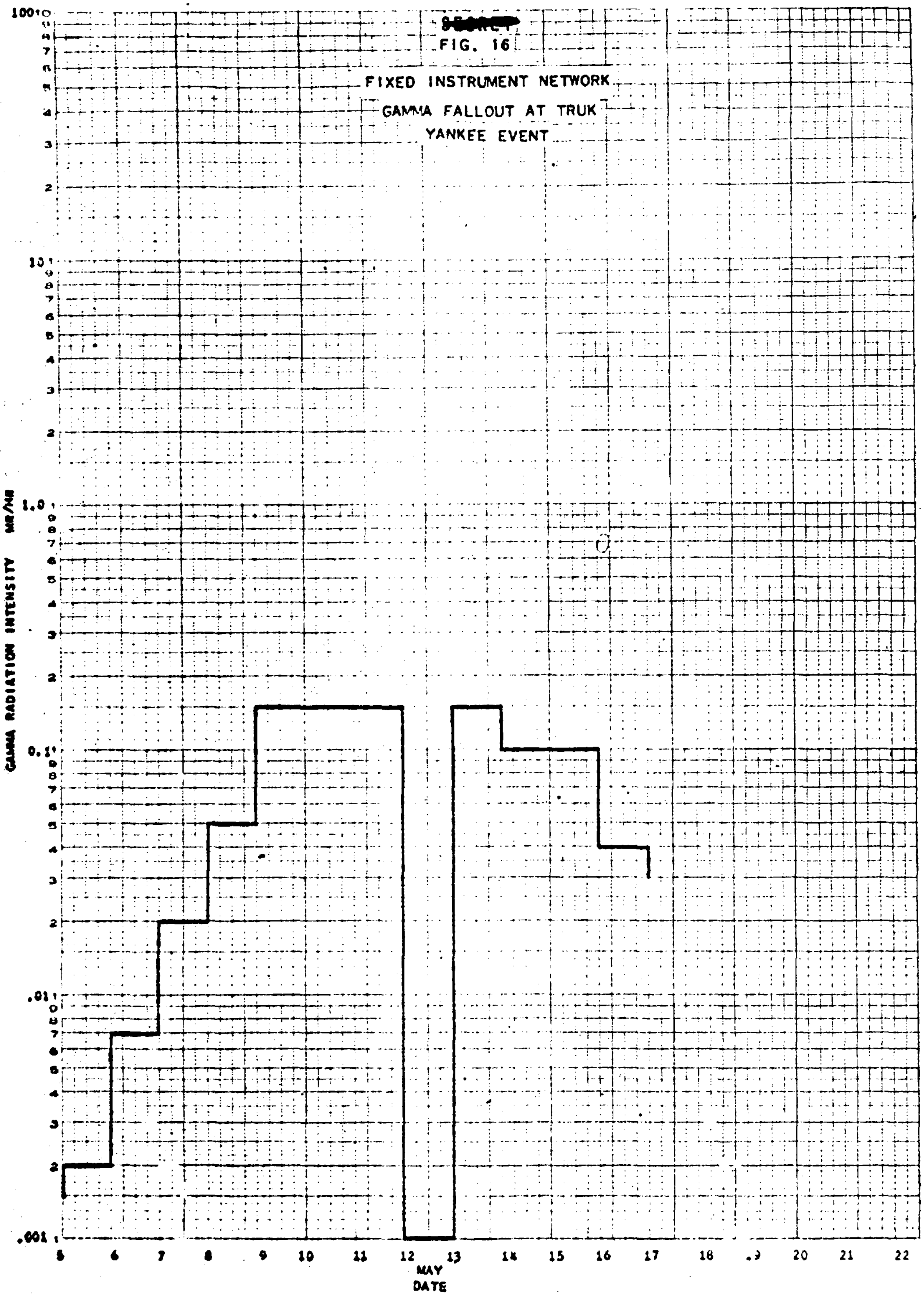

FIG. 16

FIXED INSTRUMENT NETWORK

GAMMA FALLOUT AT TRUK

YANKEE EVENT

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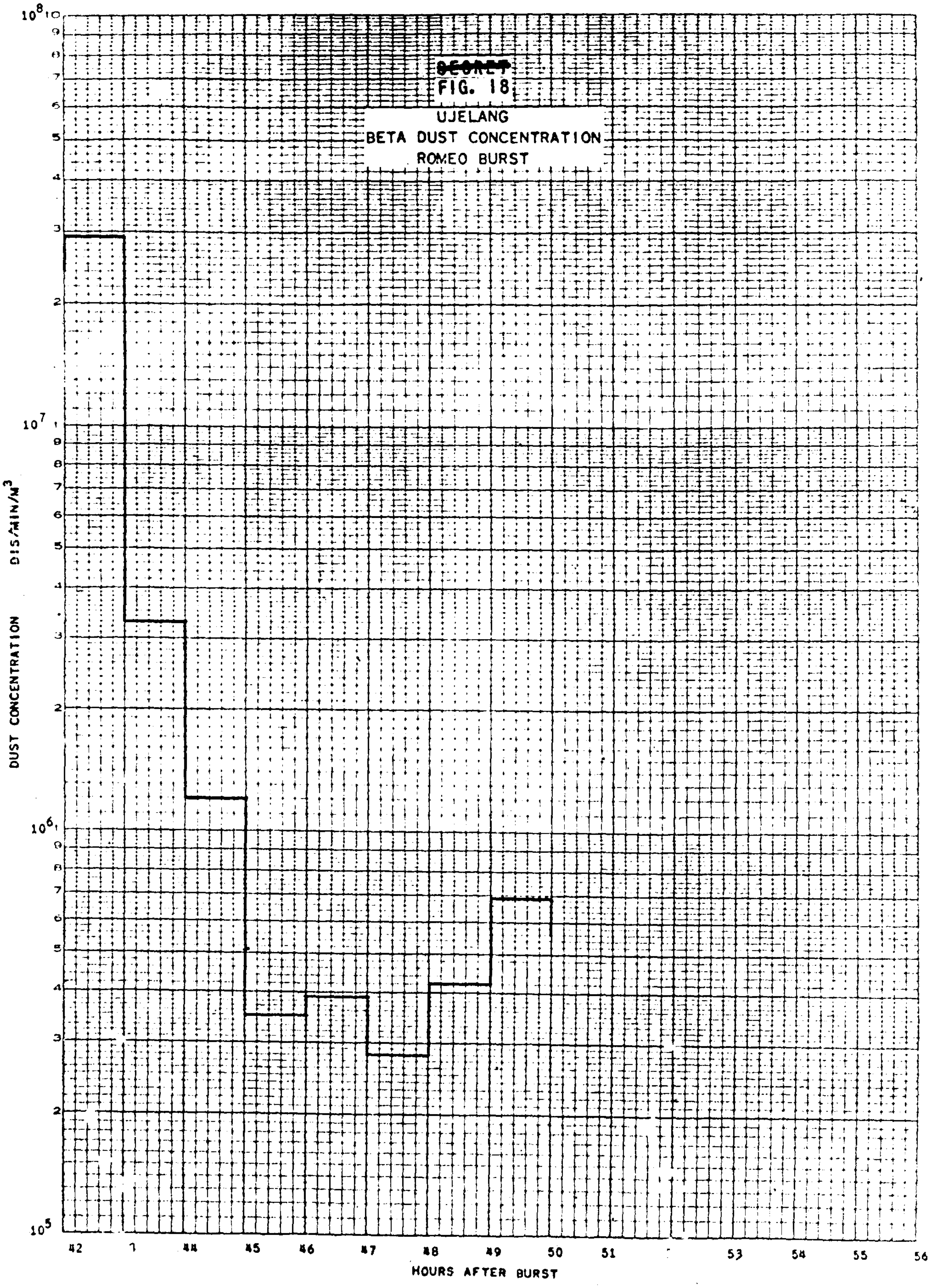
FIG. 18

UJELANG
BETA DUST CONCENTRATION
ROMEO BURST



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monitoring station reports were used as basic criteria in determining the need of flights for all patterns except ABLE. With the elimination of Rongerik after BRAVO, there was no monitoring station in the ABLE pattern. Consequently ABLE was flown on D + 1 after each event. This was necessary because of the consistent upper level westerlies.

The air survey measurements, extrapolated to ground intensities are plotted in Figures 19 thru 26.

4. Cumulative and Peak Radiation. Cumulative radiation is listed in Table I for all atolls in the ABLE and BAKER patterns (all of the Marshall group east of Bikini) and for the islands comprising the automatic monitoring network. The values at atolls within the other survey patterns amounted to so little that they are not included except for those with automatic monitors. (For instance, the total cumulative radiation at Ponape, in the CHARLIE pattern, was less than 5% of the permissible exposure for the test series).

The cumulative values were derived either by integration of direct measurements in the case of the fixed stations or by use of the Way-Wigner decay formula applied to the initial measurements following each burst in the case of aerial monitoring.

The sum of the estimated cumulative gamma at the 40 listed locations for the 26 day period between BRAVO and ROMEO accounts for 89% of the total estimated for the entire series. The approximate contributions from the remaining events are: ROMEO-5.3%, KOON-3.2%, UNION-0.9%, YANKEE-1.2%, and NECTAR-0.2%. These values are computed for the period from the stated event until the next and for this reason undoubtedly include some carry-over of contamination.

The above values should not be interpreted to relate the total effective fallout from each of the devices since the same meteorological conditions did not obtain for each event.

Peak radiation intensities following each burst are listed in Table II. These values apply to one island within each atoll surveyed. Intensities at other islands within the same atoll may have been greater or lesser than stated for any given event.

5. Isodose Chart. Figure 27 is an isodose chart of the Marshall Islands based on total cumulative radiation from CASTLE at each island.

6. Correlation of Gamma Intensity with Fallout Per Unit Area. At many of the automatic gamma monitoring stations, gummed film samples were collected daily as part of the World Wide Monitoring Network.[2] The gummed film analyses are reported as beta dis/min/ft^2. Comparative data from the two monitoring methods are available from these stations

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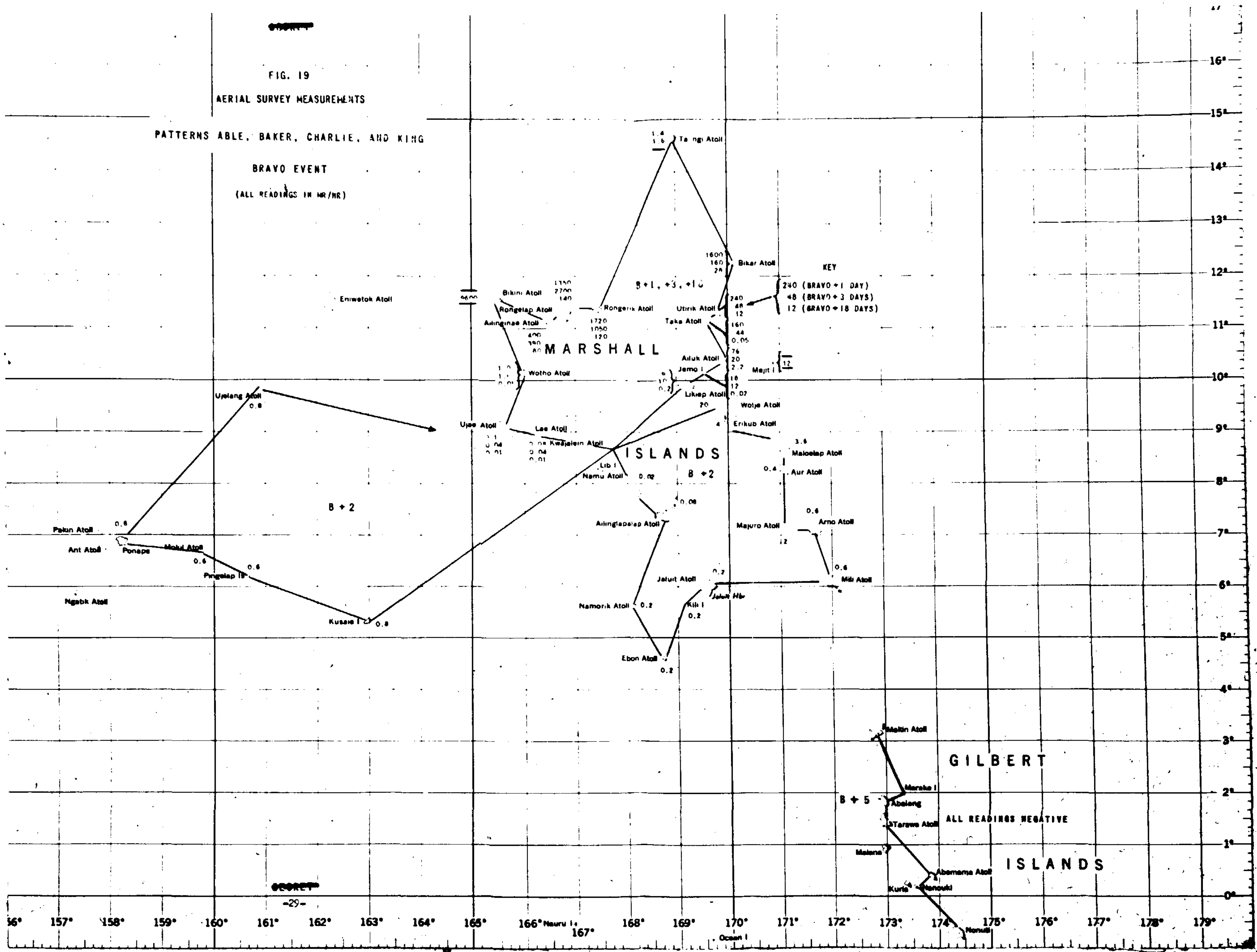
FIG. 19

AERIAL SURVEY MEASUREMENTS

PATTERNS ABLE, BAKER, CHARLIE, AND KING

BRAVO EVENT

(ALL READINGS IN MR/HR)



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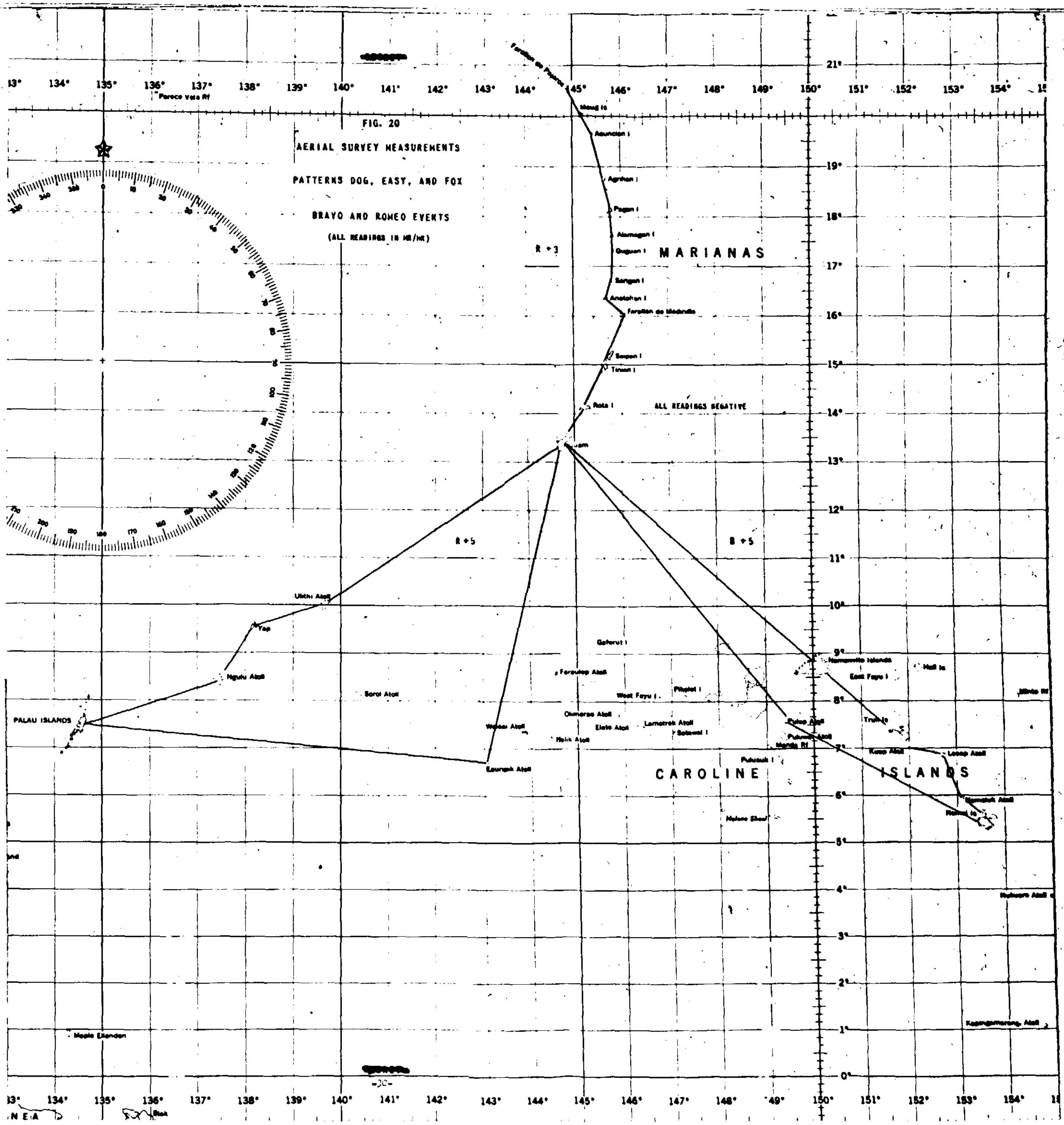


FIG. 20

AERIAL SURVEY MEASUREMENTS

PATTERNS DOG, EASY, AND FOX

BRAVO AND ROMEO EVENTS

(ALL READINGS IN MR/HR)

[redacted]

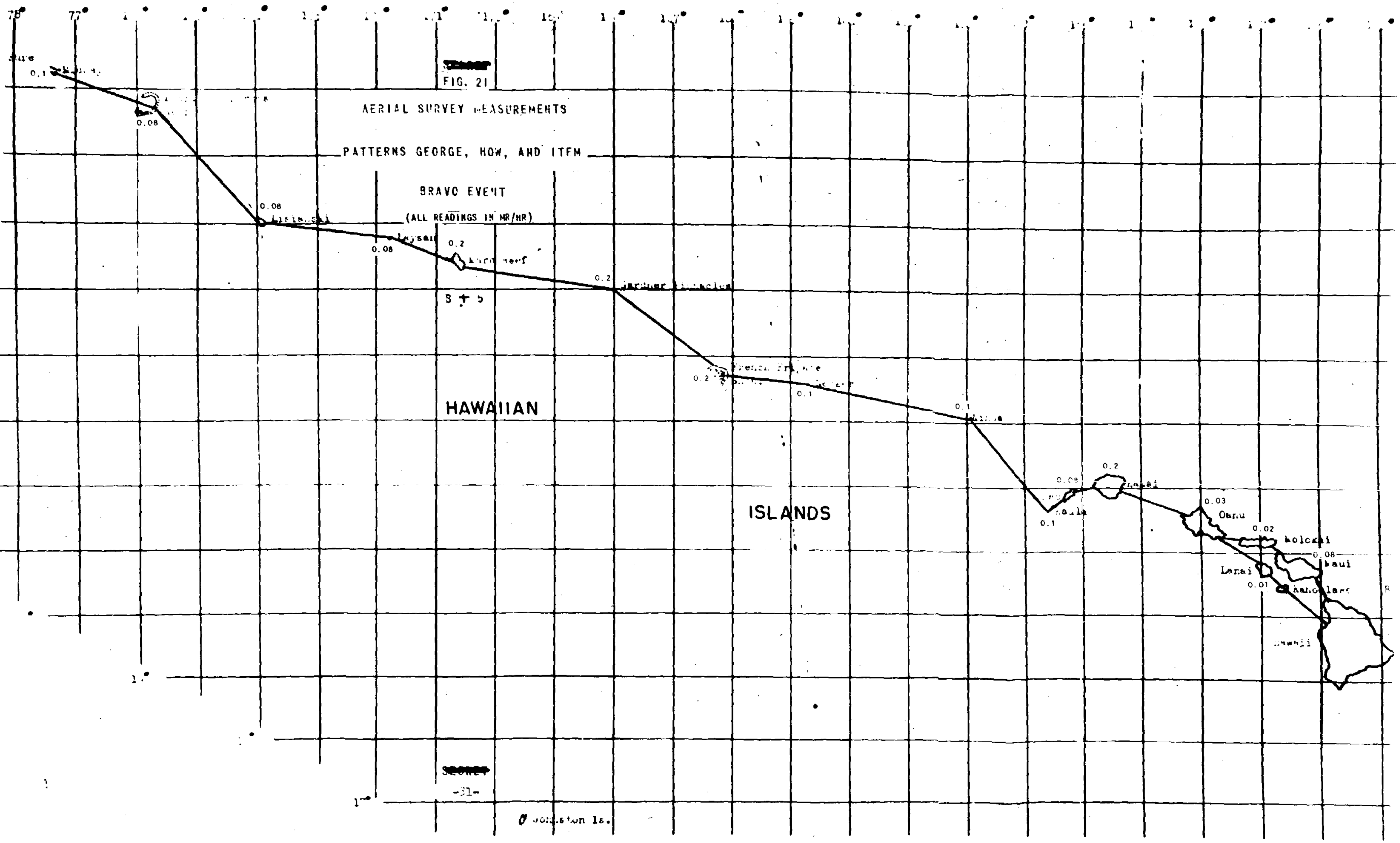
FIG. 21

AERIAL SURVEY MEASUREMENTS

PATTERNS GEORGE, HOW, AND ITEM

BRAVO EVENT

(ALL READINGS IN MR/HR)



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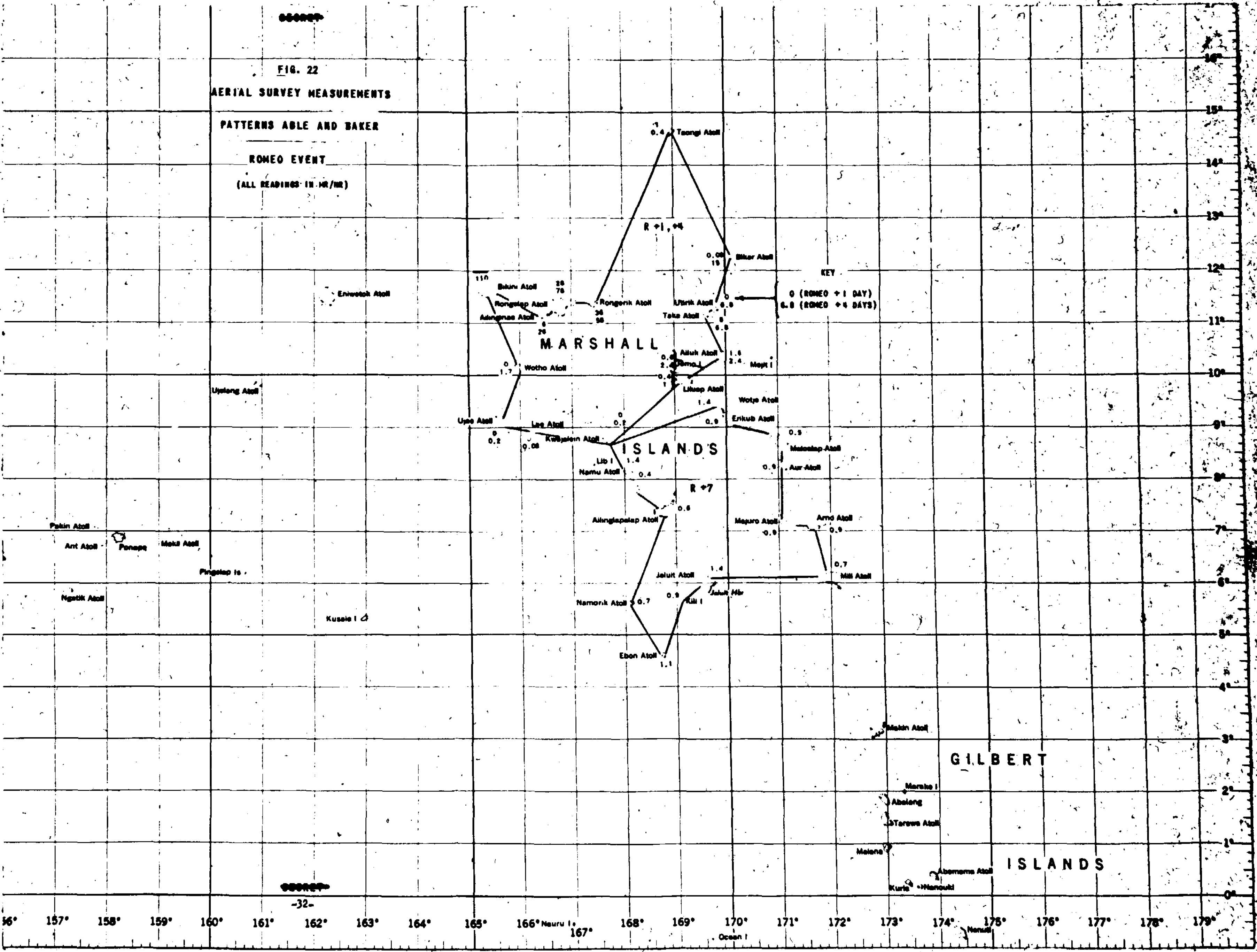

FIG. 22

AERIAL SURVEY MEASUREMENTS

PATTERNS ABLE AND BAKER

ROMEO EVENT

(ALL READINGS IN MR/HR)

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FIG. 23

AERIAL SURVEY MEASUREMENTS

PATTERNS ABLE AND BAKER

KOON EVENT

(ALL READINGS IN MR/HR)

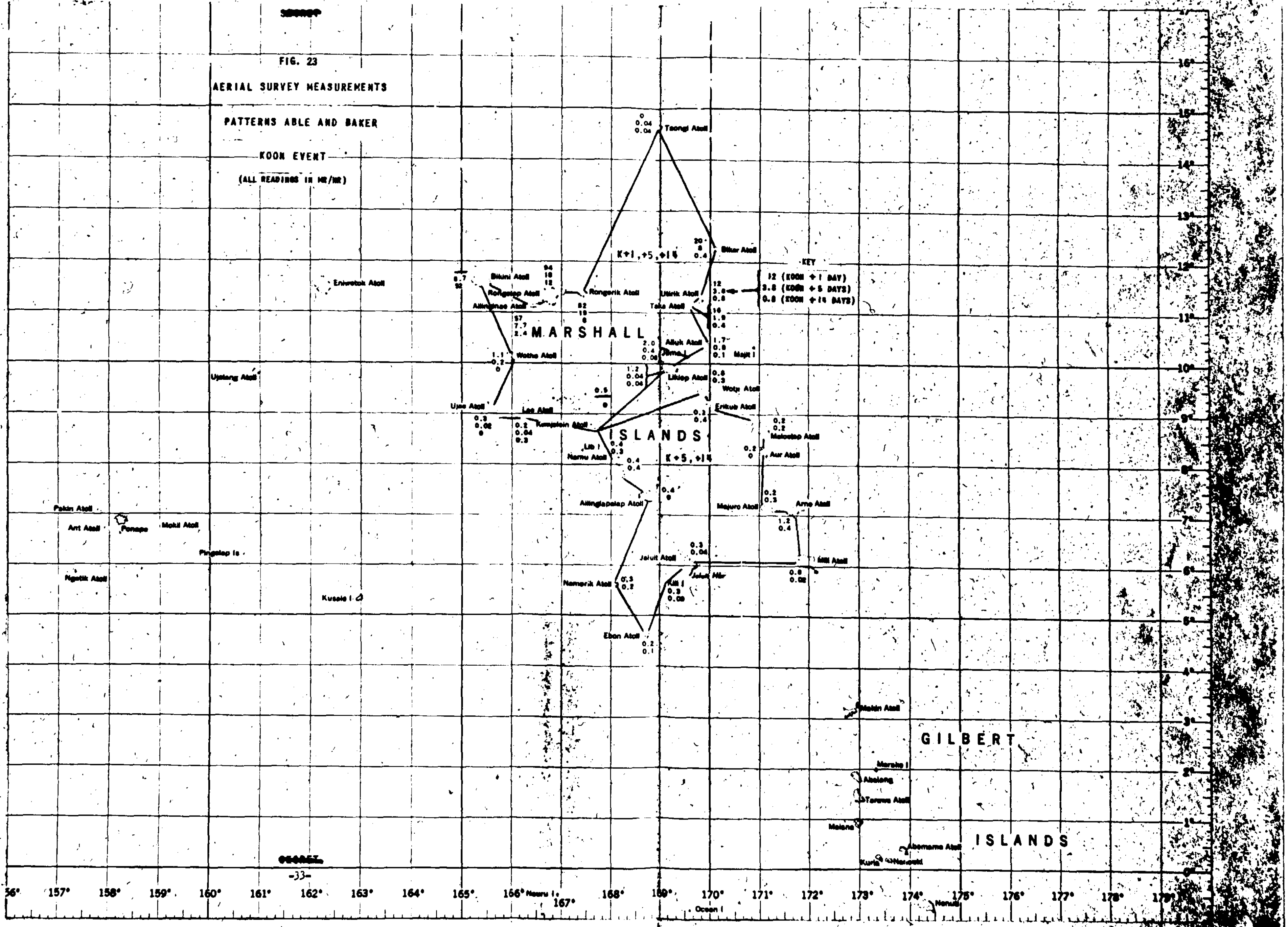

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FIG. 24

AERIAL SURVEY MEASUREMENTS

PATTERNS ABLE, BAKER, AND CHARLIE

UNION EVENT

(ALL READINGS IN MR/HR)

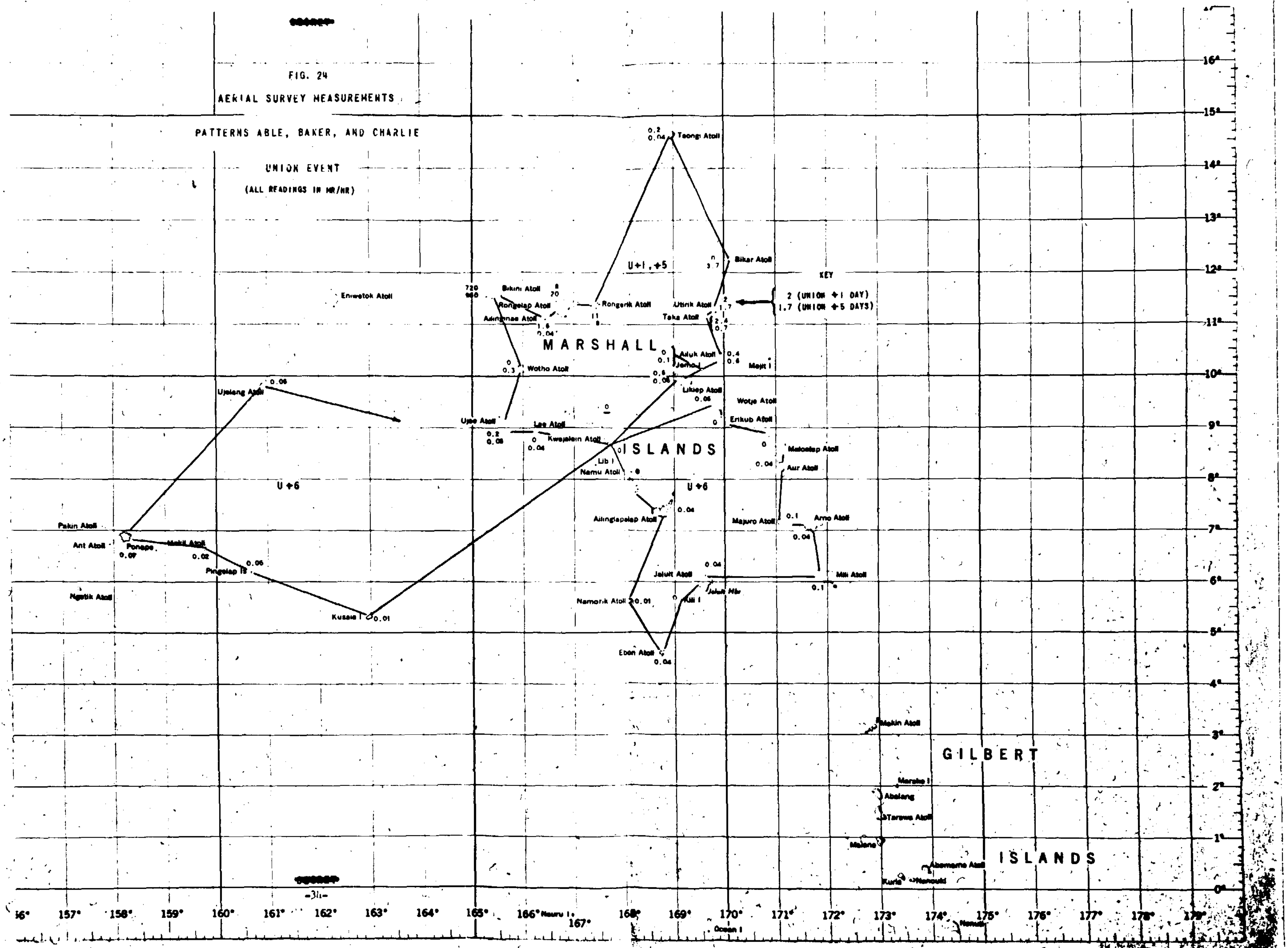

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FIG. 25

AERIAL SURVEY MEASUREMENTS

PATTERNS ABLE, BAKER, AND CHARLIE

YANKEE EVENT

(ALL READINGS IN MR/HR)

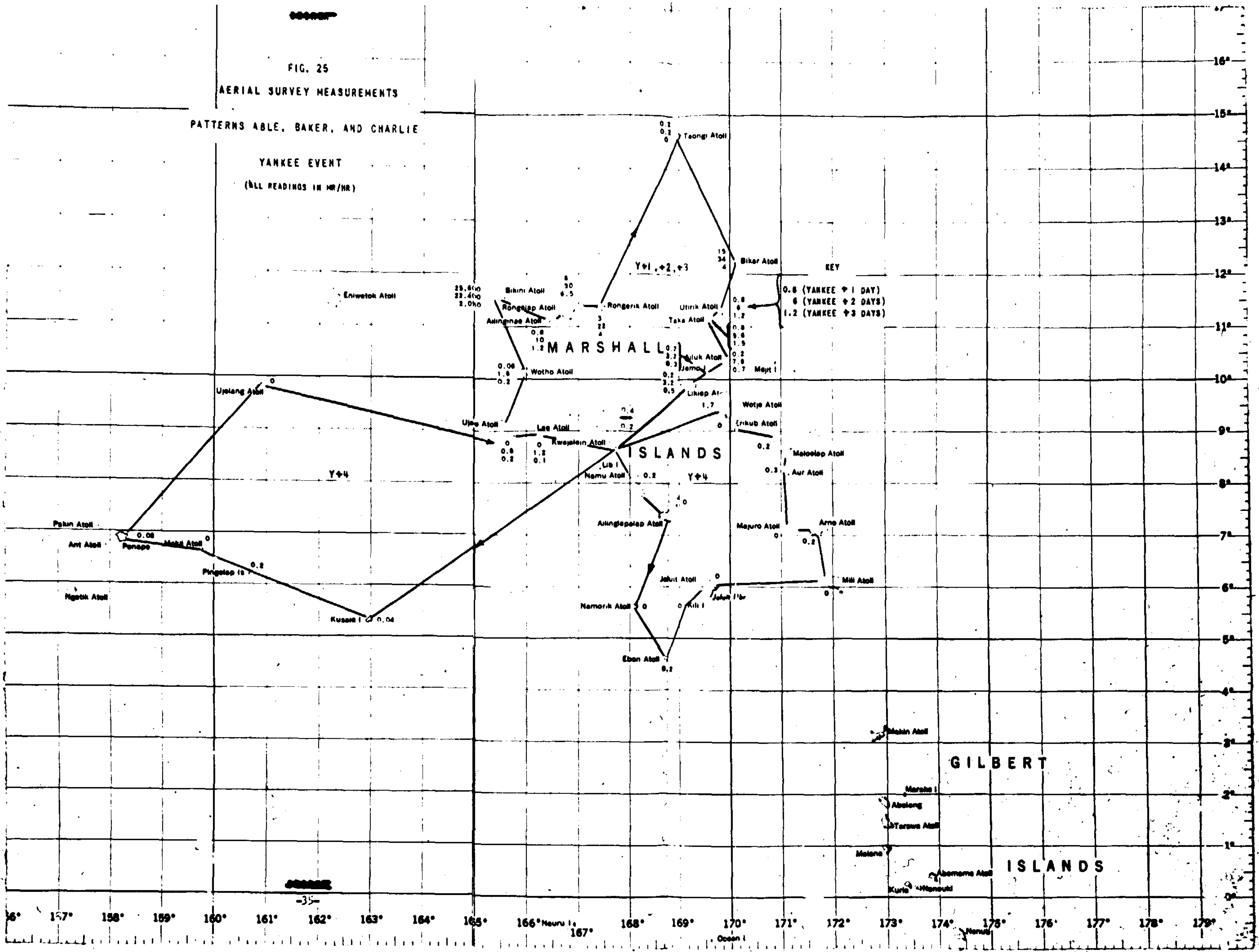

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FIG. 26

AERIAL SURVEY MEASUREMENTS

PATTERNS ABLE, BAKER, AND CHARLIE

NECTAR EVENT

(ALL READINGS IN MR/HR)

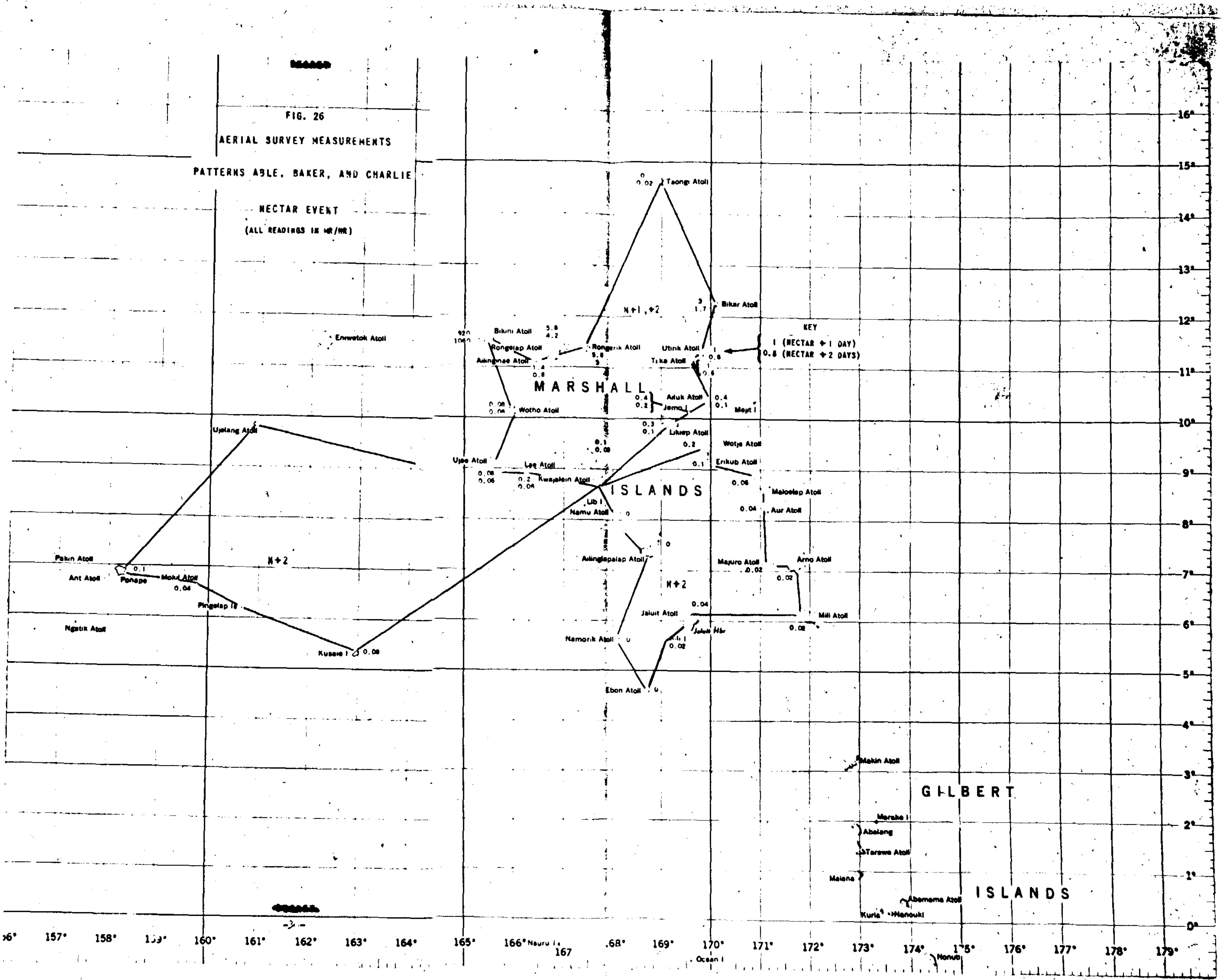

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TABLE I

CUMULATIVE DOSES BY EVENT AND LOCATION
(Finite Dose to Next Event)-mr

EVENT	BRAVO	ROMEO	KOON	UNION	YANKEE	NECTAR	TOTAL
Days between events	26	11	19	9	9	10	
			Aerial Monitoring				
Lae	5.5	12	12	7.5	78	95	125
Ujae	6	32	17	9.5	48	1.4	114
Wotho	250	270	110	55	95	4	784
Ailinginae	60000*	3400	3300	8	600	70	67000
Rongelap	180000*	11000	6000	3400	1700	300	202000
Rongerik	190000*	9000	5000	550	1400	280	206000
Taongi	280	60	9.5	10	10	-	370
Bikar	60000*	3000	1200	650	1700	150	67000
Utirik	22000*	1200	700	100	330	50	24000
Taka	15000*	800	1000	120	380	50	17000
Ailuk	5000	410	110	100	500	20	6140
Jemo	1200	410	130	18	200	20	1978
Likiep	1700	170	80	30	200	16	2196
Namu	1.8	90	100	0	25	0	216
Ailinglapalap	7.2	140	100	8	0	0	255
Namorik	20	160	70	2	0	0	252
Ebon	20	250	50	8	25	0	353
Kili	20	200	70	0	0	1.3	291
Jaluit	20	300	70	8	0	2.6	401
Mili	60	160	200	20	0	1.3	441
Arno	60	200	300	8	25	1.3	594
Majuro	200	200	50	20	0	1.3	471
Aur	40	200	50	8	40	2.6	341
Maledlap	350	120	50	0	25	4.0	549
Erikub	390	200	50	0	0	6.5	647
Wotje	1800	300	200	13	220	10	2543

*Based on arrival estimated from Rongerik data.

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TABLE I (Cont'd)

CUMULATIVE DOSES BY EVENT AND LOCATION
(Finite Dose to Next Event)-mr

EVENT	BRAVO	ROMEO	KOON	UNION	YANKEE	NECTAR	
Days between events	26	11	19	9	9	10	TOTAL
			Fixed Instrument Network				
Kwajalein	150	480	250	12	320	17	1235
Majuro	156	137	53	2	2	0.7	351
Kusaie	85	4.2	0.7	0.2	0.5	0.1	90
Ponape	5.5	20	31	21	38	6.2	122
Truk	29.1	1.3	2.3	0.9	15.1	-	49
Yap	-	-	-	8.7	4.7	4.6	18
Guam	-	-	-	-	-	-	--
Iwo Jima	-	-	-	6.8	12.7	2.0	
Ujelang	85.4	-	176	52	142	-	455
Wake	3.3	1.9	3.0	2.2	1.2	0.7	12
Johnston	110	28	66	-	-	-	
Oahu							<95
Shemya							<95
Anchorage							<95

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TABLE II

PEAK GAMMA INTENSITY BY EVENT AND LOCATION mr/hr

Location	BRAVO	ROMEO	KOON	UNION	YANKEE	NECTAR
			Aerial Monitoring			
Lae	0.08	0.18	0.2	0.12	1.2	0.2
Ujae	0.1	0.5	0.3	0.2	0.8	0.03
Wotho	2.7	4.0	1.1	0.9	1.6	0.03
Alinginae	4600*	55	57	1.6	10	1.4
Rongelap	12500*	155	95	61	30	6
Rongerik	8000*	130	82	11	24	5.8
Taongi	3	1.0	0.12	0.2	0.2	0
Bikar	1200*	37	20	11	34	3
Utirik	490*	17	12	2	6	1.0
Taka	320*	8	16	2.4	5.6	1.0
Ailuk	75	6	1.7	0.4	7.7	0.4
Jemo	18	6	2	0.3	3.4	0.4
Likiep	18	2.5	1.2	0.6	3.2	0.3
Namu	0.02	0.8	0.8	0	0.3	0
Ailinglapalap	0.08	1.2	0.8	0.09	0	0
Namorik	0.2	1.4	0.6	0.02	0	0
Ebon	0.2	2.2	0.4	0.09	0.3	0
Kili	0.2	1.8	0.6	0	0	0.02
Jaluit	0.2	2.8	0.6	0.09	0	0.04
Mili	0.6	1.4	1.5	0.2	0	0.02
Arno	0.6	1.7	2.3	0.09	0.3	0.02
Majuro	2.0	1.7	0.4	0.2	0	0.02
Auk	0.4	1.7	0.4	0.09	0.4	0.04
Malgolap	3.6	0.8	0.4	0	0.3	0.06
Erikub	4	1.7	0.4	0	0	0.1
Wotje	20	2.6	1.6	0.15	2.5	0.15

*Extrapolated to estimated arrival based on Rongerik data.

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[redacted]

TABLE II (Cont'd)

PEAK GAMMA INTENSITY BY EVENT AND LOCATION mr/hr

Fixed Instrument Network

Location	BRAVO	ROMEO	KOON	UNION	YANKEE	NECTAR
Kwajalein	-	7.5	2	0.15	4.5	0.4
Majuro	1.3	1.5	0.3	0.06	0.003	-
Kusaie	1.2	-	0.05	0.003	0.04	-
Ponape	-	0.15	0.07	0.04	0.3	-
Truk	0.2	0.01	0.01	0.009	0.15	-
Yap	0.005	-	-	0.009	0.03	0.03
Guam	-	-	-	-	-	-
Iwo Jima	-	-	-	0.07	0.1	0.03
Ujelang	1.5	-	1.0	1.7	7.0	-
Wake	-	0.02	0.02	0.05	0.007	0.007
Johnston	0.2	0.4	0.25	-	-	-
Oahu	0.05	0.05	0.05	0.05	0.05	0.05
Shemya	0.05	0.05	0.05	0.05	0.05	0.05
Anchorage	0.05	0.05	0.05	0.05	0.05	0.05

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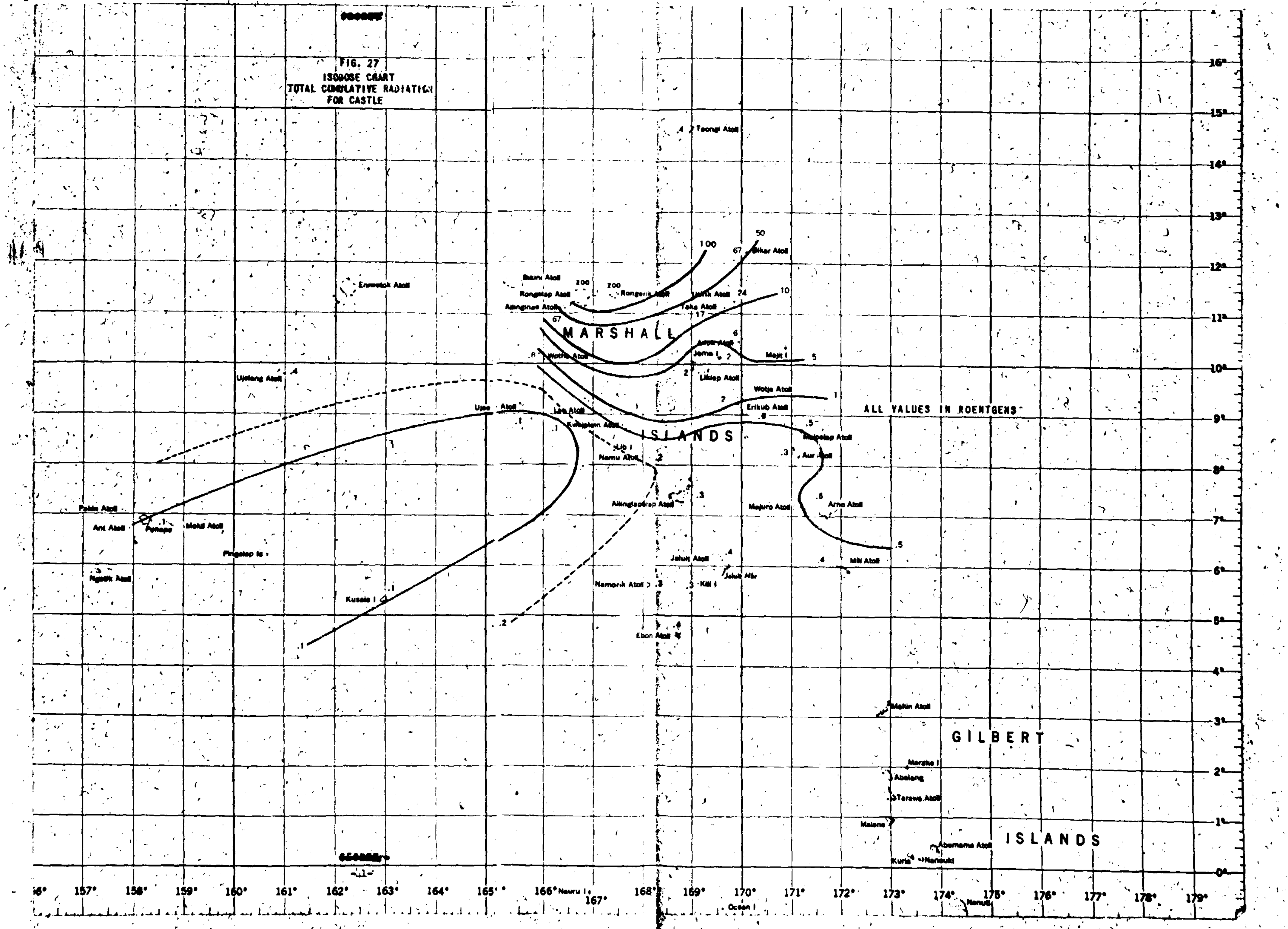
FIG. 27
ISODOSE CHART
TOTAL CUMULATIVE RADIATION
FOR CASTLE



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To establish an empirical relationship between beta dust activity on the ground and gamma radiation intensity at three feet over the ground, selected comparative data have been plotted. (Figure 28). The values selected are limited to the first 24 hour period of significant fallout following a given burst. Beta activity has been extrapolated from counting date to sampling date. The paucity of values is due to incomplete data; dust samples are missing in certain instances and monitor failures occurred at various times.

The values presented are prelininary. Further review of the available data may disclose additional useful comparisons and a refinement of computations may alter the existing values somewhat.

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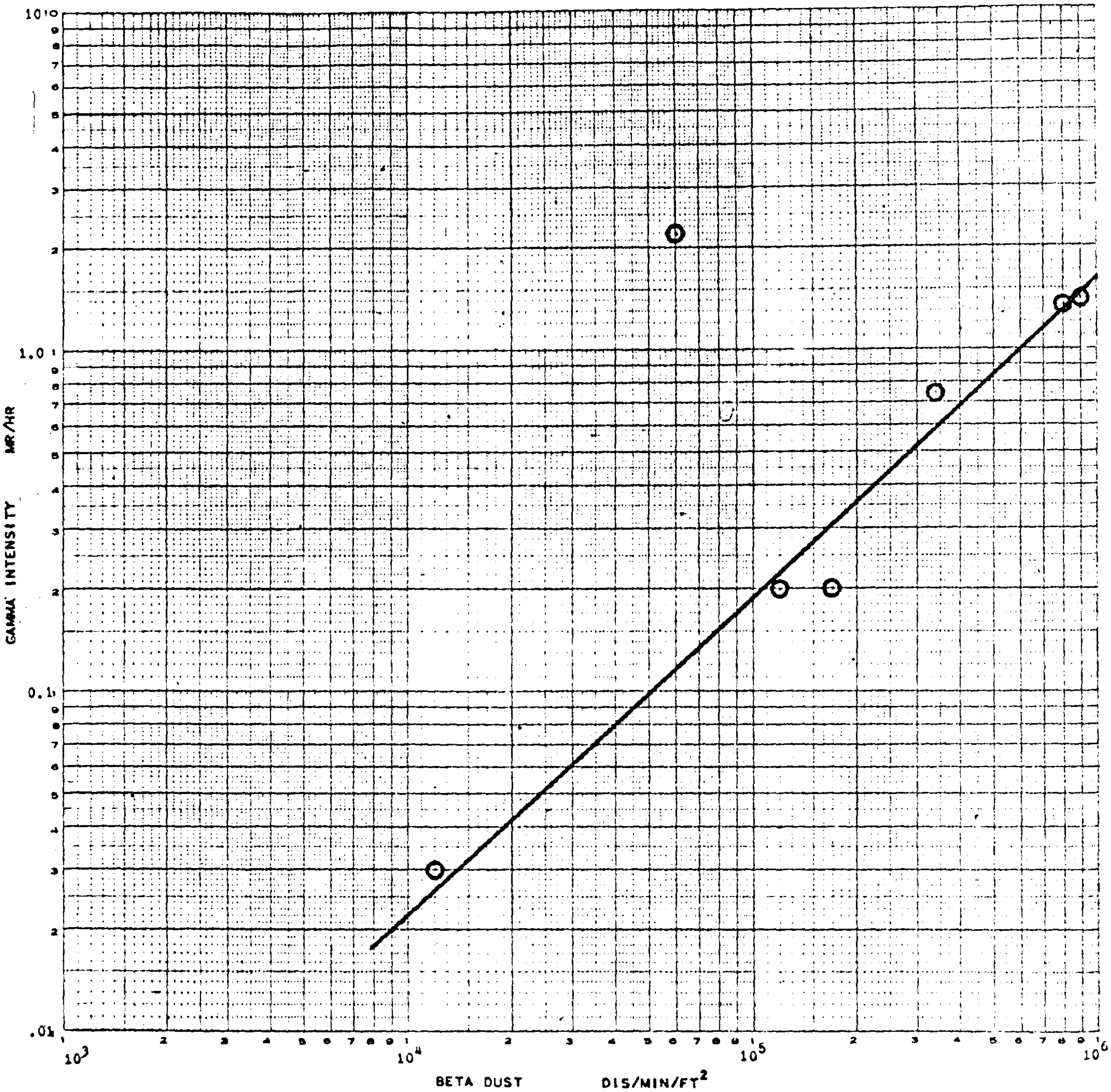
FIG. 28

BETA DUST PER SQUARE FOOT VS GAMMA INTENSITY AT 3 FEET



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IV. FACTORS RELATING TO DATA INTERPRETATION

1. Automatic Monitoring Stations

A. Diurnal Variation. Shortly after their installation, the AC operated automatic monitors displayed a regular diurnal variation apparently due to temperature change, humidity, or both. The variation was as great as an order of magnitude in some instruments. For this reason, the practical lower limit of detection was about 0.1 mr/hr although the design limit was 0.001 mr/hr. Interpretation of radiation intensities less than 0.1 mr/hr was difficult and on one occasion, fallout of low intensity was unnoticed when it occurred. A later, careful analysis of the data revealed that 0.15 mr/hr occurred at Ponape after ROMEO. Had this been known, a CHARLIE survey would have been executed and it is possible that significant fallout may have been detected at other atolls in the area.

A review of the data and the instruments' behaviour has indicated that the late night instrument reading was in most cases a reliable measure of low intensity radiation. In several instances of light fallout, (Ponape-ROMEO, Truk-BRAVO, Truk-YANKEE) only the 1800 Z value was used for plotting time graphs. Similarly, at several stations only the 1800 Z values were used in computing cumulative radiation.

The diurnal variation was consistently so high at Guam that none of those data, all of which are low level, are considered valid.

B. Comparison with Gummed Film. In those instances of suspected fallout where diurnal variation rendered monitor data of questionable validity, the data were compared with the appropriate gummed film analyses from the World Wide Sampling Network.[2] In each case, the gummed film displayed an increase in activity corresponding to the monitor data. Thus, the monitor data was qualitatively substantiated. An example of the comparison of the gummed film results with automatic monitor values is shown in Figure 29.

C. Automatic Monitoring Instruments Down Time. Monitoring stations were out of service for an average of 15% of the time from March 1 to May 20. Fortunately, much of the down time occurred between events so that useful data was lost only at the following stations during the stated fallout periods: BRAVO- Kwajalein, Wake, Ponape and Iwo Jima; ROMEO- Kusaie, Ujelang, Yap, and Iwo Jima; KOON- Yap, and Iwo Jima; UNION, YANKEE, AND NECTAR- Johnston. The presented cumulative radiation values are therefore, in general underestimations. The values are based on the recorded data only which account, on the average, for 85% of the duration of CASTLE.

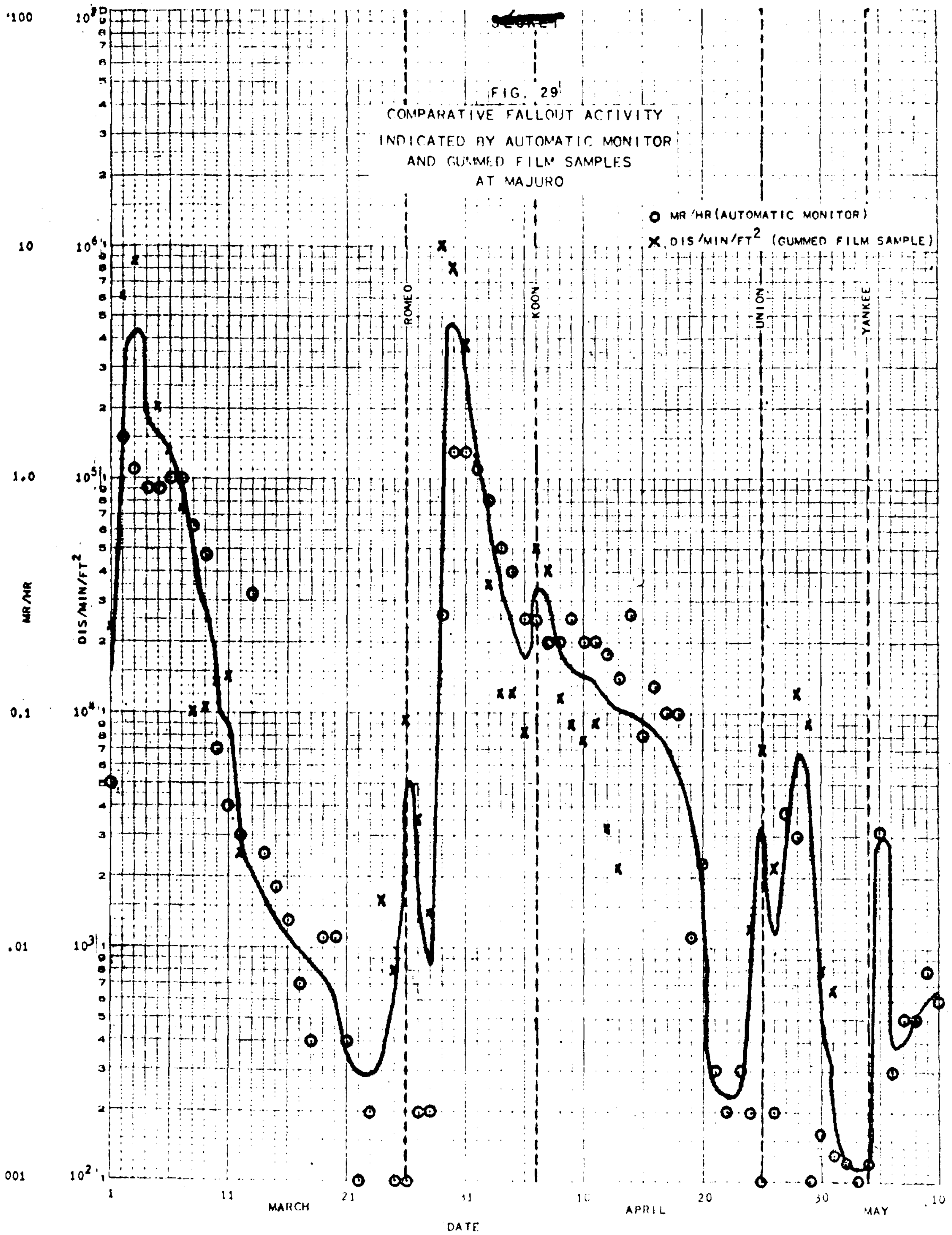

FIG. 29
COMPARATIVE FALLOUT ACTIVITY
INDICATED BY AUTOMATIC MONITOR
AND GUMMED FILM SAMPLES
AT MAJURO

Radiation during down time was not estimated except at Ujelang where down time was in excess of 50%. There the estimate is also low because no data are available for the fallout period ROMEO and NECTAR.

Peak intensities were obtained directly from the monitor data. Where blanks occur in Table II, data are unavailable due to instrument failure or incorrect calibration. The values listed are the greatest intensities following each burst.

2. Aerial Survey Monitoring

A. Fallout Arrival Time Applied to Aerial Monitoring Data- Flight ABLE. Fallout arrival times are not generally known for the islands covered in the aerial surveys. The few exceptions are those which were automatic monitoring installations. Cumulative and peak radiation computations are necessarily based for the most part on estimated arrival times.

For BRAVO, the arrival time at Rongerik is exactly known from the automatic monitor record. For other atolls on the same general bearing as Rongerik from Bikini, the arrival times were arbitrarily assumed to be proportional to the respective distances from Bikini referred to Rongerik. Allowance was made for the initial rapid lateral cloud growth in the first minutes after the burst. Data obtained from Task Unit-1 indicated that at + 10 minutes the cloud diameter had grown to 335,000 feet and the rate of growth had diminished to a relatively slight amount. Peak radiation values were computed by extrapolating the observed intensities to the estimated arrival times.

For the northern Marshall atolls on widely different bearings from Bikini than Rongerik, hence well removed from the direct fallout path, the intensities observed during the aerial survey on B + 1 are the reported peak values in the results. Cumulative radiation computations are based on decay assumed to start from these peak intensities.

For the other events, the peak values are taken as those observed on the D + 1 aerial surveys unless later surveys of the same islands indicated additional fallout after D + 1. In these cases, arrival time was arbitrarily assumed to be D + 2 and the intensities measured on the repeat flight were extrapolated back to D + 2. Cumulative radiation values were computed assuming $t^{-1.2}$ decay from the peak values.

Cumulative values are not corrected for the slower decay rate of residual contamination from previous bursts. The neglect of previous contamination is partially compensated by erosion by wind and rain, a variable factor.

Flight BAKER. Fallout definitely occurred at Majuro during BRAVO and ROMEO and the arrival times were accurately established. But there seems no valid method of relating these to the arrival of fallout at other atolls in the southeast Marhsalls, short of a detailed analysis of the pertinent meteorological situation. However, over Majuro, BAKER flight on B + 2 very nearly coincided with peak fallout there as measured by the automatic monitor. Arbitrarily the peak intensities for all islands covered by that flight are taken as the observed intensities.

For ROMEO, all survey values are extrapolated to R + 4, again to conform with the arrival at Majuro. With the lack of difinitive data for the time of arrival in all remaining events, it is assumed to be D + 3 as a compromise value.

B. Air Survey Background Radiation. Background was recorded prior to each atoll measurement while the aircraft was several miles from the island. In computing atoll radiation intensities, the background value (which varied by as much as an order of magnitude during any one mission) might be attributed to sources such as navigation instruments, aircraft contamination, skyshine, or a combination of these. It has been reasoned that the background could be validly subtracted from the atoll measurement to obtain a net value of ground intensity. Intensities were computed by this means during the test series.

Late in the series, it came to our attention that significant intensities may be emitted from the ocean surface for several days after the burst.[3] This phenomenon may be another factor in the measured background and cannot be disassociated unless an additional background measurement, such as at a different altitude, is available. For any given measurement, there exists the possibility in one extreme that substantially the entire background is due to ocean surface intensity. This value would not be subtracted from the atoll measurement. In the other extreme, the entire value of background must be subtracted as was done in reporting data during the series. In no case did the background value exceed a ground measurement as might hypothetically occur if currents moved contaminated sea water near an uncontaminated island.

The values presented on Figures 3 thru 17 and used in computing cumulative and peak radiation are net radiation values, i.e. background has been subtracted from the observed atoll intensity. It should be noted that low intensity values may be considerably in error where background levels are of the same order as the measured atoll intensity.

C. Relation of Aerial Measurements to Ground Level Intensities. Certainly one intrinsic factor limits the agreement which may be achieved between any particular pair of corresponding aerial and ground measurements. This is the vast difference in the effective areas scanned by the two methods of survey. A single ground level measurement with a portable gamma instrument registers activity emitted from an area of a few square yards while the SCINTAMETER at an altitude of 200 feet or more sees an area of perhaps 10,000 to 15,000 square yards.

It is well known that measurements on the ground will show considerable variation over a relatively small area. This was particularly evident on Eniwetok (Parry) after the late fallout carried back by the low level trades after ROMEO. Gamma intensities in the open over horizontal surfaces were up to two times greater than intensities in the lee of large obstructions. Similarly, measurements near the windward side of vertical surfaces were greater than measurements over open horizontal surfaces.

In the like manner, aerial measurements can be distorted by uneven terrain, scanning the lee or windward side of a mountainous island, and perhaps other factors.

After BRAVO, survey parties reported substantial variations in outside radiation measurements on all of the islands surveyed.

Generally, one aerial measurement should approximate the average of many individual outside ground measurements taken over the same general area, however, the factor of instrumentation must be recognized as a variable. The energy response characteristics of portable instruments commonly used during CASTLE differ from each other somewhat and differ from the SCINTAMETER rather markedly. The response of the T1B, for instance, is nearly flat above 0.1 Mev.[4] The characteristics of the AN/PDR 27C are somewhat less uniform but above 0.3 Mev are reasonably flat. The SCINTAMETER, on the other hand, peaks at about 0.25 Mev and has a uniformly decreasing response from the peak as the gamma energy increases. The characteristics of the three instruments are plotted in Figure 30. If the instruments are all calibrated with Co^{60} or radium source, as in

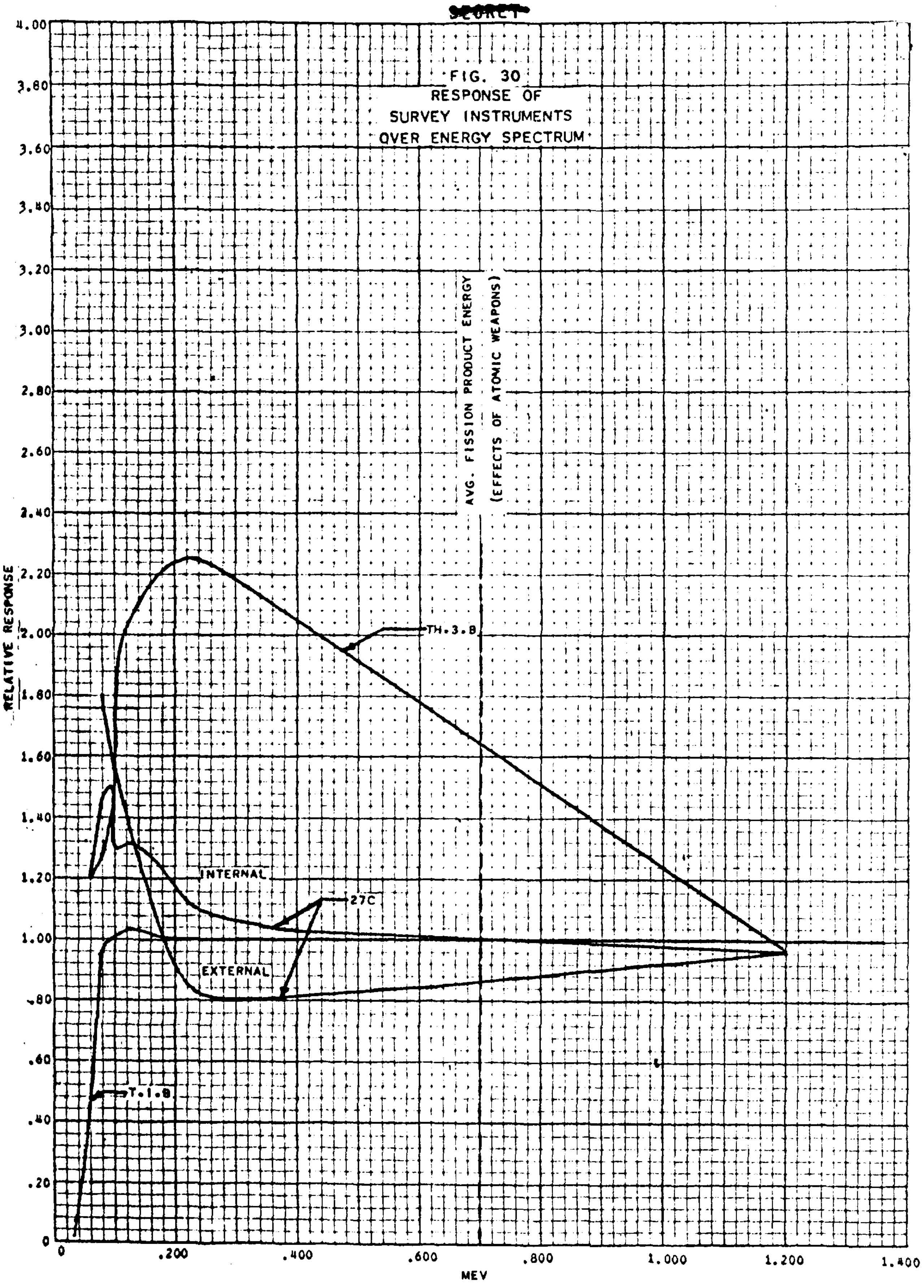

FIG. 30
RESPONSE OF
SURVEY INSTRUMENTS
OVER ENERGY SPECTRUM

Figure 30, the response of the SCINTAMETER at 0.7 Mev,[5] the average of gamma fission product activity, is about 60% greater than both the T1B and the 27C internal probe and about 100% greater than the 27C external probe.

Thus, it can be readily understood that readings of two different instruments in the same gamma field may be different and even two overlapping scales of the same instrument may not agree.

The size of the islands surveyed within the range of this study apparently does not effect the validity of the altitude to ground intensity conversion curve. Calibration for the SCINTAMETERS was performed over areas of various sizes including both small and large islands in the Eniwetok and Bikini atolls. Data from these several locations agreed very closely.

Obviously, judgement is needed in evaluating radiation intensity in terms of potential exposure whether ground measurements or aerial measurements are the source of data.

V. EFFECTIVENESS OF MONITORING PROGRAM

The aerial surveys and the automatic monitoring network must be reviewed together to analyze the effectiveness of the program properly for they were designed to complement each other. The program was a practical compromise between two extreme monitoring methods, one being a monitoring network comprised of stations on each of the islands included in aerial survey patterns (66 in the Marshalls, Carolines, and Marianas) or the other being daily or more frequent flights over each of the survey patterns from D + 1 repetitively for a number of days following each event.

It is believed that the monitoring program did successfully fulfill the basic requirements of providing timely fallout information concerning the Central and Southwest Pacific and of documenting cumulative radiation in those areas. The information developed by this system following the BRAVO burst is an excellent illustration of its effectiveness in performing the former function.*

---

*At 1540 M on B day, the automatic monitor on Rongerik, 130 NM East of Bikini, went off scale. (Maximum scale reading is 100 mr/hr). This information, received at the Task Force Headquarters aboard the Estes at about 1600 M, was the first indication of excessive fallout outside of the ships of the Task Force and Bikini atoll itself. A radsafe monitor was sent with a scheduled island resupply flight on the following morning to clarify the fallout situation which had been indicated by the automatic monitor. At 2000 M on B day, a message to Squadron VP-29 was originated on the Estes requesting the immediate execution of flight ABLE. The request was delayed until that hour to diminish the possibility of the survey aircraft passing thru the radioactive cloud. Due to communications difficulties, the message did not clear the Estes for about twelve hours after it was originated and the flight did not leave Kwajalein until about noon on B + 1 day. At 1535 M on B + 1 the first inflight report was received from the survey aircraft. The report included measurements over Ailinginae, Rongelap, and Rongerik. It confirmed measurements of dangerous radiation made on Rongerik by the radsafe monitor a few hours earlier. On his recommendation, evacuation of Rongerik had begun immediately and was complete when the first inflight message was received. By 2000 M the radiation intensities at all atolls in the ABLE pattern were known and plans were formulated for the evacuation of additional north Marshall atolls. By B + 5 days, all survey patterns had been executed including an improvised pattern to survey the Gilbert Islands and the extent and severity of contamination in the Pacific were clearly defined.

There were two locations from which repetitive practical comparisons between aerial and ground measurements are available during CASTLE. Survey parties visited Rongerik frequently over a period of many weeks after BRAVO and recorded gamma radiation intensities each time. AN/PDR-T1Bs, portable ionization type meters, and other portable gamma meters were employed for the measurements. The averages of those measurements taken outside of buildings agree very closely with aerial survey measurements over Rongerik. These data are plotted on Fig. 31. Certain of the comparative measurements were taken on the same days; others were not. The ground measurements taken on days in between aerial measurements lie very close to the values expected from theoretical decay calculations. Comparative measurements are also plotted for Ailinginae, Utirik, and Ailuk (Figures 32, 33, and 34), although these are locations where only one set of ground measurements were taken. The follow-up survey measurements made after the D + 1 surveys show reasonably close agreement with the theoretical decay curves shown on these figures. For simplicity the decays were computed from each new maximum measurement following each event without regard to residual contamination from previous events. Since there was no method of accounting for the effects of wind and rain in reducing contamination, there seemed no reason for more elaborate theoretical decay computations.

At Majuro, the site of an automatic monitor, there are comparative data for each burst except NECTAR. Here again, the agreement between aerial and ground measurements is good. These data may be found in Table 2.

The significant contamination of sea water following a burst has now been amply demonstrated. The possibility exists that this phenomenon contributed to the background values recorded during the aerial surveys and that those values were incorrectly applied to the atoll measurements in computing net intensities. Suitable procedures must be established to differentiate skyshine, water activity, and aircraft background in future applications of the aerial survey.

Several of the installed automatic monitoring instruments were designed to measure and record beta dust concentrations as well as gamma radiation. All of the beta channels failed within a few days after their installation. The failures resulted from various mechanical and electrical difficulties. No data was obtained regarding beta dust. The desirability of obtaining such measurements has probably increased rather than diminished in light of the renewed interest in offsite fallout. It is desirable that the instruments be perfected for future tests.

In offsite monitoring conducted by this office for previous Nevada tests, the measurement of beta activity in dust collected on filter papers was found to be a more sensitive measure of bomb debris arrival time and

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FIG. 31

AERIAL MONITORING MEASUREMENTS - RONGERIK

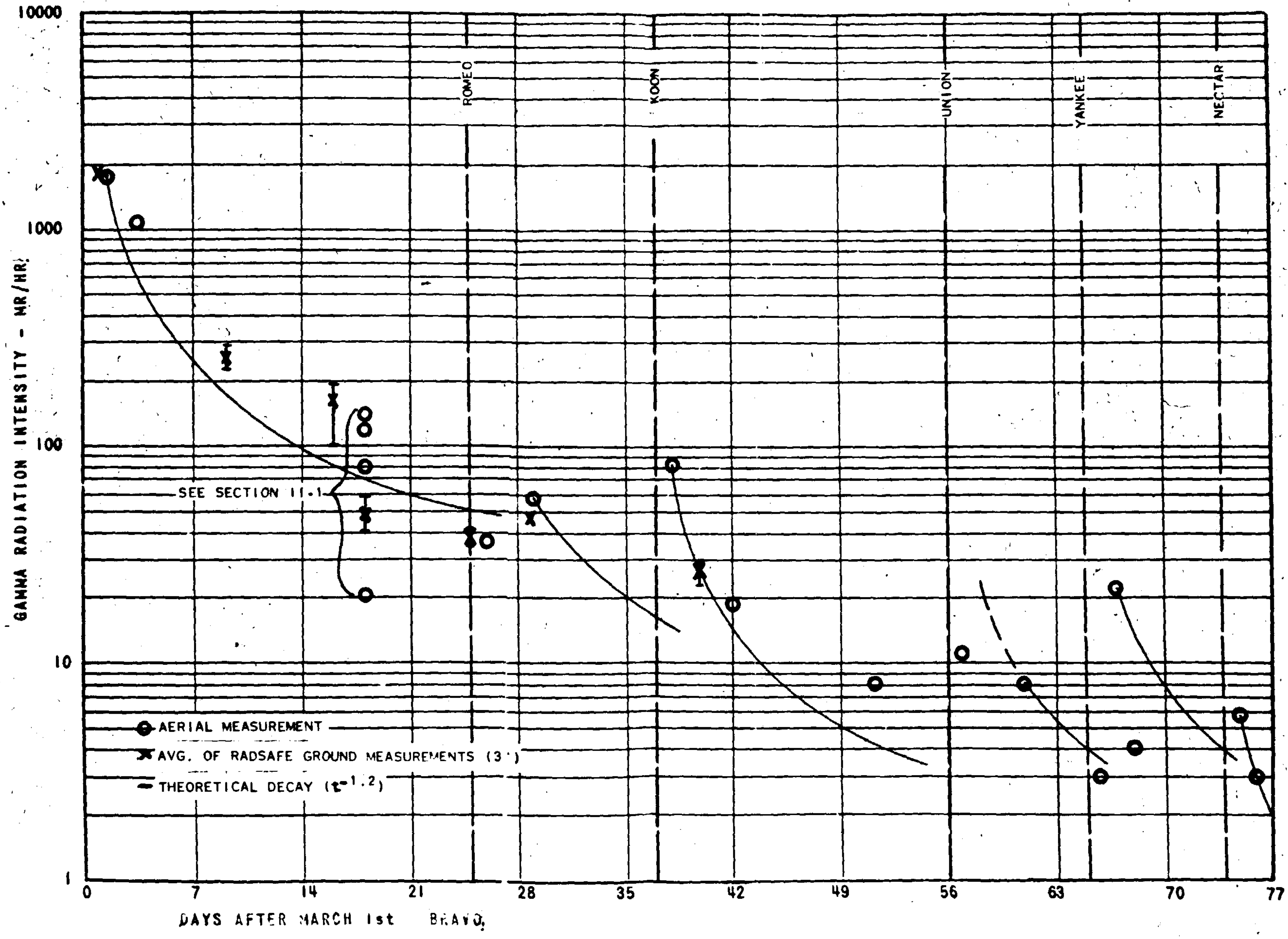

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FIG. 32

AERIAL MONITORING MEASUREMENTS - AILINGINAE

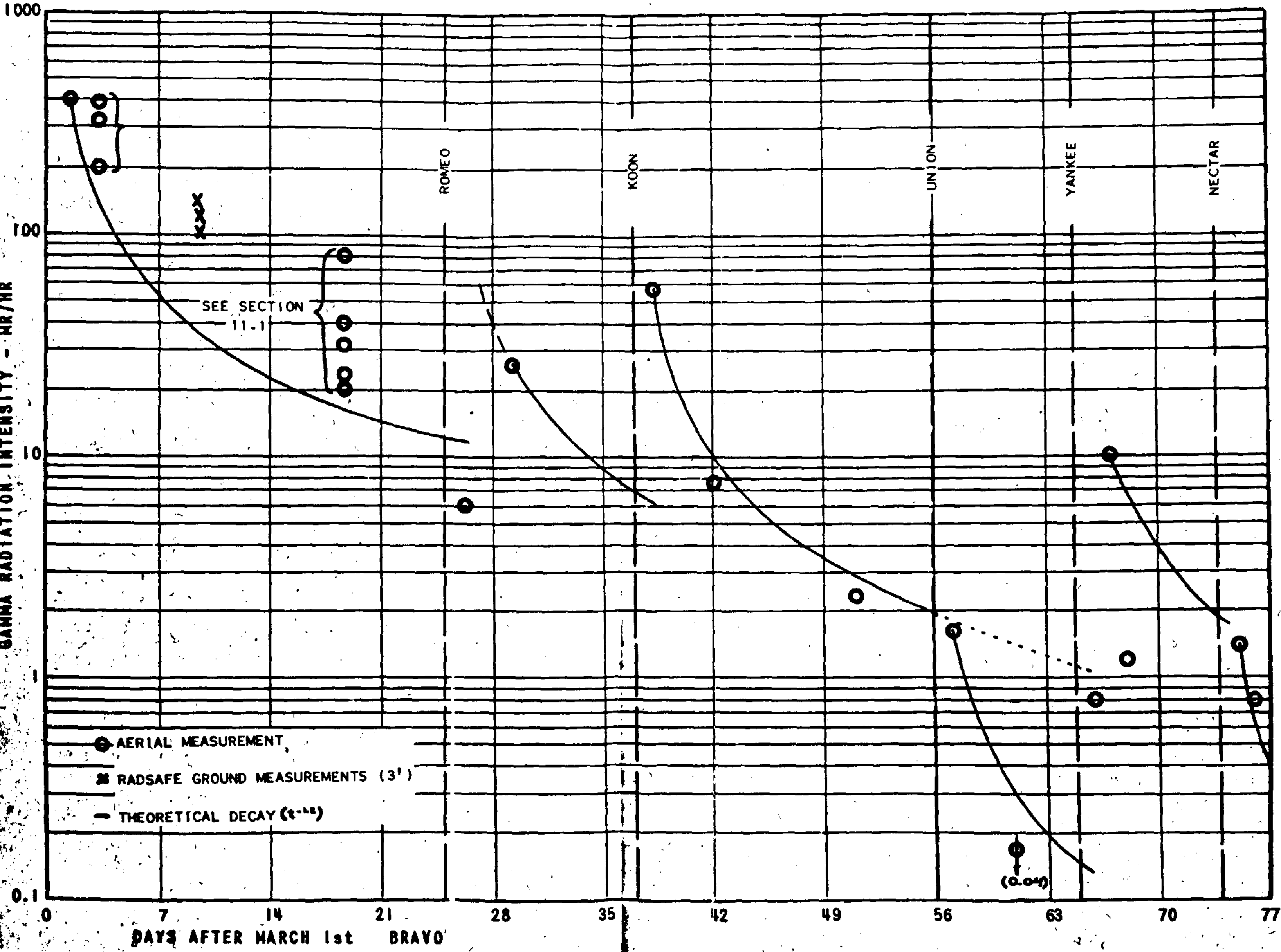

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FIG. 33

AERIAL MONITORING MEASUREMENTS - UTIRIK

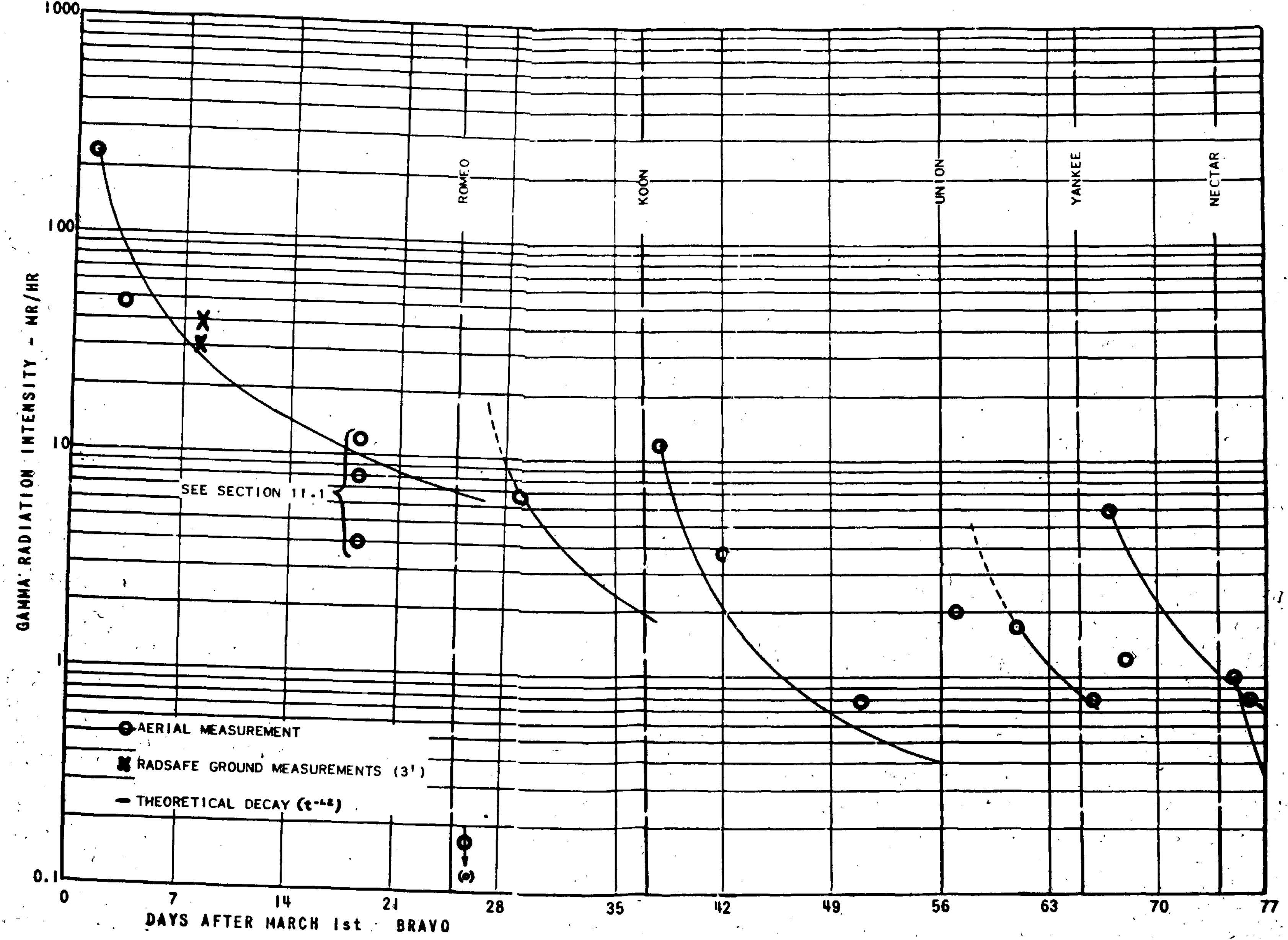

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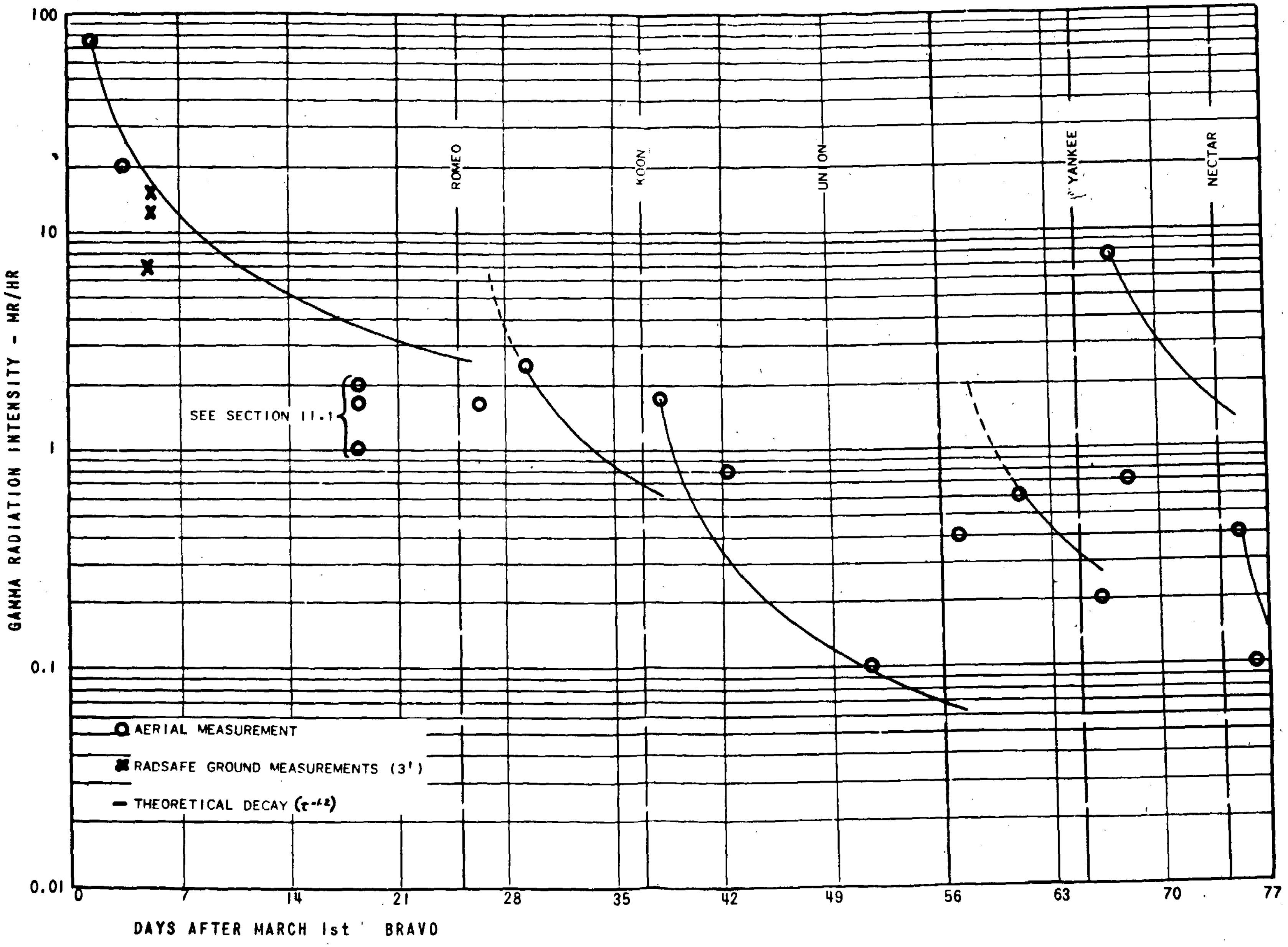
FIG. 34

AERIAL MONITORING MEASUREMENTS - AILUK



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activity than ground gamma measurement, particularly where fallout was of low intensity. It was also found to give earlier indication of arrival, this probably because of its greater sensitivity. There is reason to believe that these characteristics would apply in Pacific tests and might prove useful in warning of fallout arrival.

A particularly gratifying achievement of this program was the utilization of personnel, untrained in radiation instrumentation, for the operation of the automatic monitoring equipment. This represents a tremendous economy in the use of the scarce number of personnel trained in radiation safety techniques. It has been demonstrated that a fairly comprehensive monitoring program can be continued over a protacted period without tying up a large number of trained personnel.

VI. INSTRUMENTATION

1. Aerial Survey Monitoring

A. The SCINTAMETER, General Description.* The SCINTAMETER, a self-contained, waterproof, battery operated scintallation type gamma detector with a fast response time, was used for all aerial surveys. The unit weighs slightly less than five pounds with batteries. The single meter scale is divided logarithmically enabling several decades of radiation intensity to be read without switching arrangements. Two models, the TH-3-B and TH-3-C, have a range from 0.003 to 100 mr/hr and differ only in battery complement. A third model, the TH-7-A, has a range from 0.001 to 10 r/hr. This high level instrument was developed for the use of cloud tracking aircraft and was used extensively on the WILSON flights; it was not utilized in atoll surveys but was serviced by HASL personnel.

B. Conversion of Aerial Measurements to Ground Level Intensities. An air to ground calibration procedure was performed for the SCINTAMETER at Eniwetok in February prior to CASTLE and repeated at Bikini a few days after BRAVO. Similar calibration work had been conducted for the SCINTILOG,[1] predecessor to the SCINTAMETER, prior to its use during IVY.

The calibration procedure consisted first of conducting a thorough survey of the radiation intensity at 3 ft. over an area contaminated by fission products followed by measurements using identical instruments over the same area from an aircraft at altitudes of from 50 to 1000 ft. The ratios of the average ground intensity to values measured at selected altitudes constitute an attenuation curve which may be used in adjusting aerial readings taken over areas of unknown contamination to ground level intensities.

There are several possible errors and variables which may cause variations in the attenuation factors derived. These are: radiation instrument error, (this includes energy dependence which is discussed in Section V), altimeter error, human error, irregular distribution of fission products on the ground, fission product age, and variation in the absorption of different sections within an aircraft and between aircraft. (Both P2V aircraft and helicopters were utilized). Variation in the area of the radioactive source may also be suggested as a cause of variation in attenuation factor, however, although the islands used for calibration sites varied markedly in size and shape, the attenuation factors were not measurably different.

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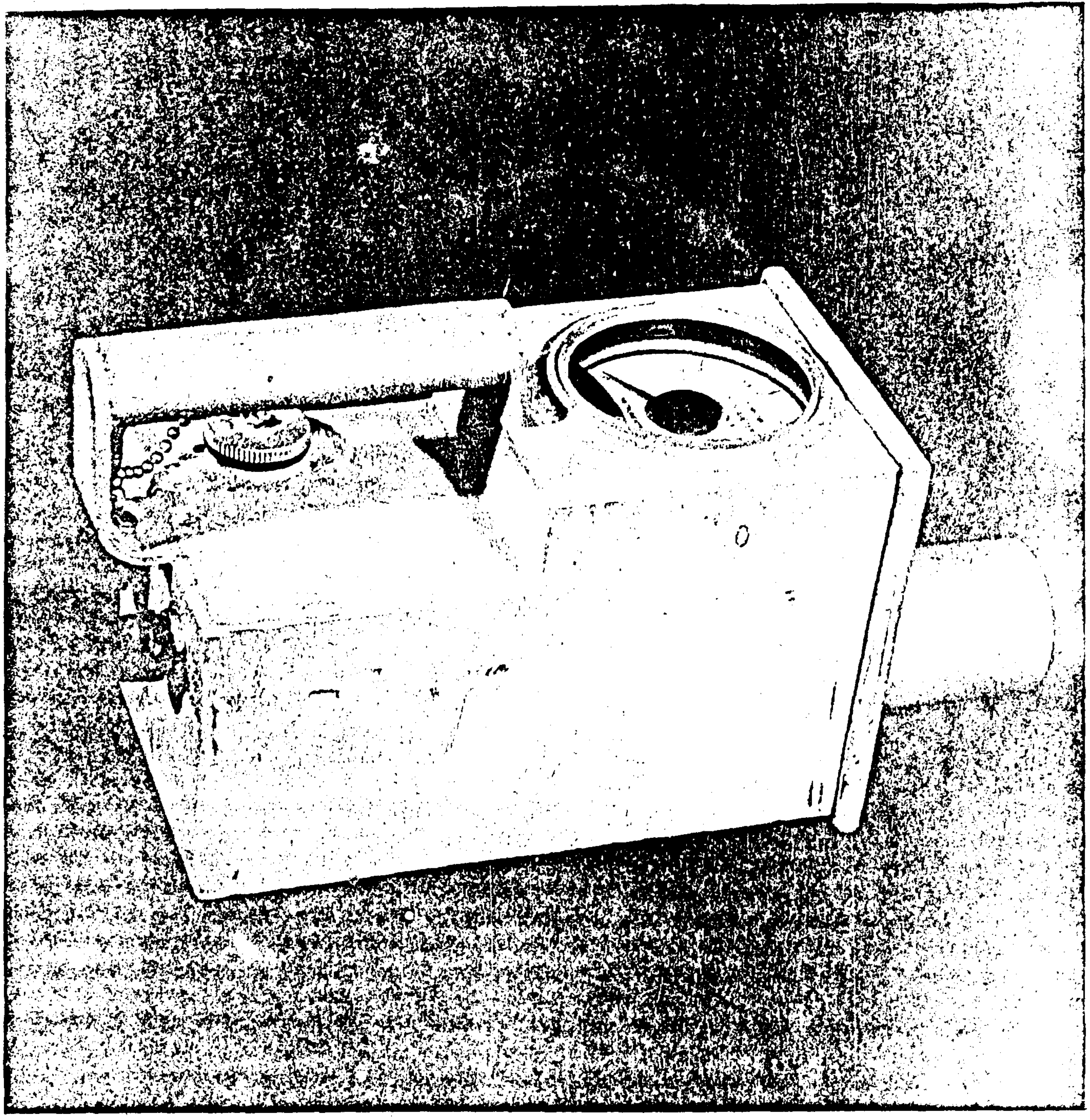
*For detailed description of instruments see "HASL-154, OPERATING PROCEDURES, FALLOUT MONITORING FOR CASTLE."

Fig. 35

SCINTAMETER



The following calibration studies were conducted in connection with CASTLE:

Location and Date	Instrument
Eniwetok, Feb., 1954	
JANET	SCINTAMETER
GENE	SCINTAMETER
GENE	Nuclear Inst. Corp.2610A
Bikini, March, 1954	
WILLIAM	SCINTAMETER
YOKE	SCINTAMETER

In addition, measurements taken by independent survey parties at Rongelap, Rongerik, and Utirik using several different types of survey instruments have been related to corresponding aerial measurements with the SCINTAMETER during the routine execution of the ABLE survey pattern. One other set of factors was obtained by personnel of the Weather Reporting Element with both a SCINTAMETER and T1B. The record of the identity of the atoll where this was obtained has been lost.

Air to ground calibration for the SCINTILOG was performed by HASL personnel in Nevada in 1952, using TUMBLER-SNAPPER test sites as sources. Another set of data, obtained by an independent group using a T1B during the UPSHOT-KNOTHOLE series, is available for comparison.

The attenuation curve applied during CASTLE is shown in Figure 36. This curve is based upon data obtained at JANET then later substantiated by studies performed at WILLIAM and YOKE and by miscellaneous coincidental data obtained during CASTLE. These sites represent a variety of source areas; for instance, YOKE and JANET are 1/8 mile and 5/8 mile across respectively.

There is good agreement among the studies at the three selected islands and between the resultant curve developed from these studies and the miscellaneous data. The extrapolation of the attenuation curve to zero altitude yields a factor of 2 which is approximately equivalent to the aircraft hull absorption.

Individual sets of the GENE attenuation data differ markedly from each other and their average attenuation curve differs markedly from the bulk of the CASTLE data. The two sets of data taken in

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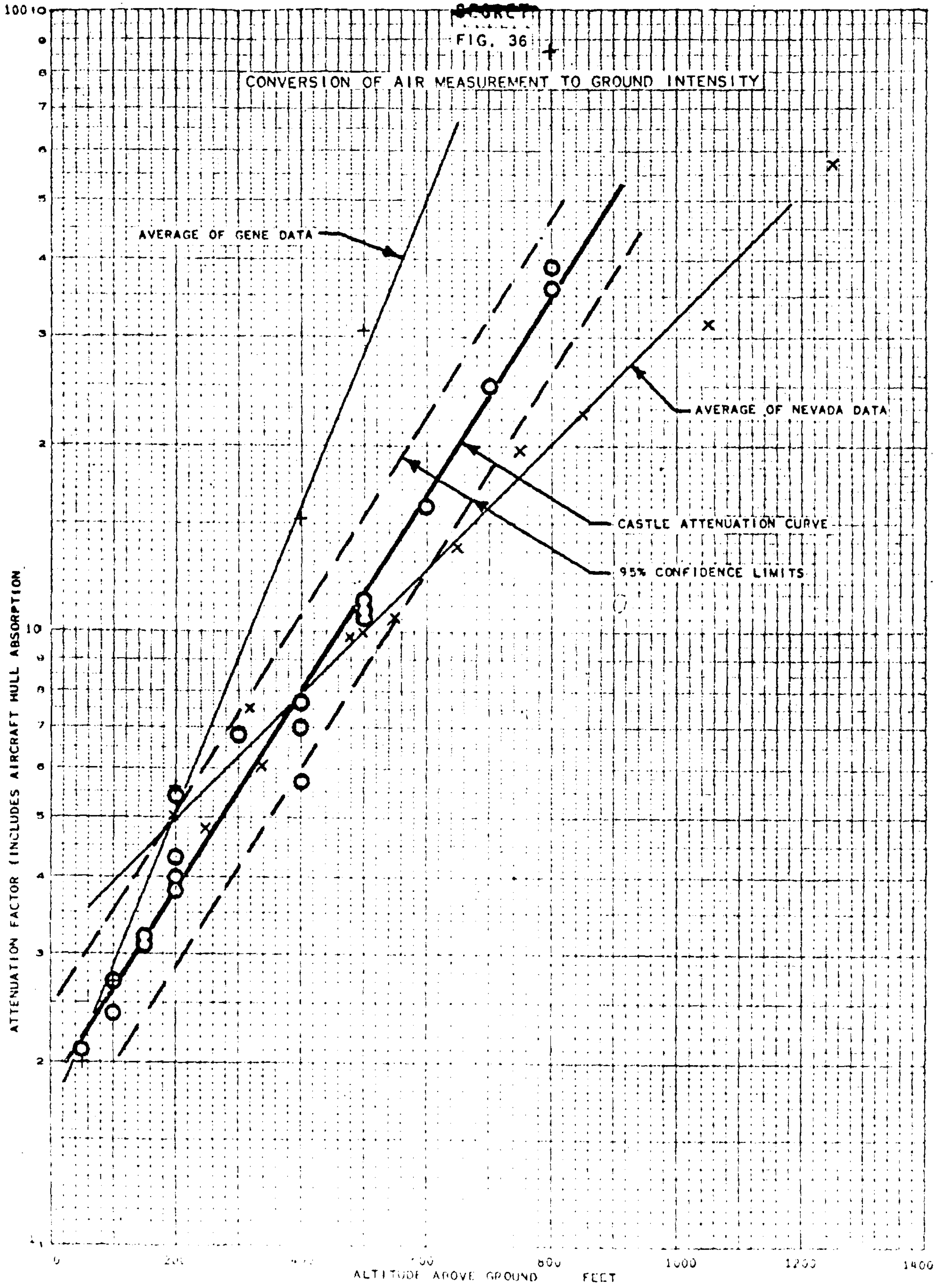
FIG. 36

CONVERSION OF AIR MEASUREMENT TO GROUND INTENSITY



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Nevada on different occasions agree remarkably well with each other but differ from both sets previously mentioned. The averages of the GENE and Nevada data are plotted on Figure 36. The reasons for the discrepancies are not clearly understood. Any combination of the possible errors mentioned above may be responsible. It is felt that the effects of fission product age, type of bomb, and instrument energy dependence are factors which require further investigation.

C. Field Calibration. Radium was used in the calibration of the low level SCINTAMETERS and low end of the high level units, Co^{60} was used for checking the upper end of the TH-7-A scale.

The original meter scale calibration on the TH-3-B and the TH-7-A units remained unchanged throughout CASTLE. The TH-3-C was found to saturate above 20 mr/hr requiring a special calibration curve for correct interpretation of the scale above that value. The latter unit was used only where intensities were expected to be less than 20 mr/hr, i.e., flights originating at Guam and Oahu.

SCINTAMETER calibration was generally checked before each use by VP-29 at Kwajalein and WILSON cloud tracking aircraft at Eniwetok.

D. Field Calibration Difficulties.

Humidity. SCINTAMETER maintenance was performed at Eniwetok, Kwajalein, and Guam. Air conditioned working space was available only at Eniwetok. Because of the high resistances employed in the circuit, the excessive humidity altered their value whenever the SCINTAMETER case was opened.

Setting the float point was accomplished by trial and error. With the instrument out of its case, the float point would be set so that the meter indicated the proper radiation intensity; then the instrument would be reassembled with a package of desicant within the case and after a few hours the error (difference between meter reading and true radiation background) was noted. The case was then reopened and the float point adjusted to compensate for the noted error. The procedure was repeated until agreement of instrument reading with true background was achieved.

Whenever the float point was checked, a reading was taken in a radiation field equivalent to greater than half scale deflection to insure that the remainder of the circuit was operating properly.

Calibration was likewise a tedious procedure because of high humidity. Calibration controls were accessible only by opening the instrument case so that a waiting period was required every time an instrument was resealed to allow the desicant to become effective. Occasionally, calibration of one instrument would require several days because of the waiting periods. Frequently the humidity was so high the package of desicant could not completely absorb all the moisture within the instrument case after it had been sealed.

High Background. The frequent use of several large sources by personnel from other projects in the vicinity of the radsafe building, where the HASL instruments were serviced on Parry, prevented calibration of the low end of the TH-3-B and TH-3-C scales. An increase in background of as much as ten times over the normal of .01 to .015 mr/hr was noted at such times.

Fallout from BRAVO raised the background at Eniwetok so that low end scale calibration was impossible at any time; in order to continue the program, all low level SCINTAMETERS were moved to Kwajalein for servicing. On occasion, the fallout even on Kwajalein was sufficient to prevent low end calibration, although these periods were of relatively short duration.

Background radiation rarely interferred with the calibration of the high level SCINTAMETERS, the minimum scale reading being 1 mr/hr.

E. Field Operation. In field use, the SCINTAMETERS were found to be most satisfactory by task force personnel who used the instruments. Those characteristics which were commented about most frequently are: dependable operation, stable calibration, simple controls, single scale, wide range, and sealed circuit. The last characteristic was particularly helpful for cloud tracking service since the instruments were insensitive to altitude changes.

Position in Aircraft. Our experience has shown that the position of the instrument within the aircraft must be selected so that the radiation from radium dials on navigational instruments is negligible and the absorbing material underneath is minimal and constant. (A position over a gasoline tank is undersirable). If repetitive surveys are planned, the same position within the aircraft should be used each time.

At times either aircraft vibration or rough handling affected the vibrator-transformer (vitran) reed adjustment causing erratic behavior. To correct this, foam rubber pads were provided to cushion the instrument within the survey aircraft.

Operating Difficulties. Minor circuit difficulties became evident shortly after arrival at the forward area but these were easily corrected. Circuit component failures were infrequent. Faulty components were replaced from a stock of spare parts maintained in the forward area.

Battery replacement was necessary on the average after 20 hours of meter operation. Replacement necessitated opening the instrument case. Each time this was done where an air conditioned room was unavailable the instrument remained out of service for up to 24 hours until the moisture had dried.

The vitran in the power supply was the source of two troubles which were corrected after they were discovered. These were: (1) failure of the vitran to start when the instrument was turned on, (2) noise causing erratic meter fluctuations. The first difficulty was easily eliminated by a simple adjustment of the vitran reed. The latter problem required a more critical reed adjustment or cleaning of the contact. It was found that much of this noise was being coupled into the circuit through a common ground from the vitran and filament batteries. Running separate ground leads from these two sets of batteries directly to the connector joining the battery section to the circuit section eliminated the necessity of a fine adjustment of the vitran reed and also stabilized several instruments for which a noise free operating point could not be found by adjusting the reed.

F. Recommended Modifications.

(1) Float point and gain controls should be accessible from outside the sealed circuit case.

(2) Battery changes should be possible without destroying the moisture seal of the circuit case. Greatest utility could be realized if batteries could be integrated in a case that could be plugged into the circuit case such that a spare battery set could be easily interchanged in the field by a non-trained operator.

(3) The vitran should be modified, possibly by shock mounting or eliminated in favor of a more stable power supply if one could be found with comparable high efficiency.

(4) A means should be devised to flatten the energy response characteristics.

2. Fixed Instrument Network

Each automatic monitoring station was equipped with one or two each of four types of automatic gamma monitor. In addition, several stations close to the proving grounds were equipped with AN/PDR-18 Bs, portable gamma survey instruments. The unmanned station, Ujelang, was equipped with an automatic eight head air sampler as well as a battery operated automatic gamma instrument. The auxiliary monitoring stations were each equipped with two Nuclear Instrument Corp. Model 2610A portable gamma survey instruments.

A. Description of Instruments*.

The automatic gamma monitors consisted of:

(1) Two units of NYO type TN-1-A, a 110 volt 60 cycle GM tube gamma monitor with a quasi-logarithmic response allowing a range of 0.01 to 25 mr/hr to be recorded on a linear 0-1 ma recorder.

(2) Ten units of NYO type TN-3-A; a 110 volt, 60 cycle combination monitor alternately measuring (1) the beta radioactivity from dust collected on a filter paper and (2) surrounding gamma intensity is recorded for fifty minutes every hour during which the dust is collected on filter paper. The beta from the dust sample is counted for five minutes and then the background from a clean section of filter paper is counted for the remaining five minutes of the hour. Both channels use GM tubes and the circuits are logarithmic with the gamma range from 0.01 to 100 mr/hr and the beta range from 100 to 10,000,000 dpm. The recorder is a standard 0.1 ma linear recording milliameter.

(3) Two units of NYO type TN-4-A, a 110 volt, 50 cycle GM tube gamma monitor with a logarithmic response allowing a range of 0.1 to 100 mr/hr to be recorded in a linear 0-1 ma. recorder.

(4) Two units of NYO type TN-2-A, a battery operated gamma monitor with a logarithmic response allowing a range of 0.01 to 100 mr/hr. The surrounding gamma intensity is recorded for five minutes each hour on a 0-1 ma. linear recorder.

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*For detailed description of instruments see "HASL-154, OPERATING PROCEDURE, FALLOUT MONITORING FOR CASTLE."

The battery operated eight-head air samplers, NYO type TN-5-A, take eight consecutive one hour dust samples on one inch diameter filter papers. Dust sampling begins automatically when the surrounding gamma radiation exceeds a predetermined value; 0.1 mr/hr was used during CASTLE.

The AN/PDR-18B scintillation type survey meters manufactured for the Navy have full scale ranges of 0.5, 5, 50 and 500 r/hr. These were provided to certain automatic monitoring installations to supplement the automatic units if radiation intensities exceeded 100 mr/hr.

The Nuclear Instrument Corp. Model 2610A survey meter uses a GM tube. Three scales provide maximum readings of 0.2, 2.0, and 20 mr/hr. These instruments were sent from the NYOO via AFOAT-1 channels to the auxiliary stations. No maintenance on these instruments was performed in the forward area.

B. Field Calibration. The automatic monitoring instruments were assembled at Parry Island for maintenance and calibration prior to their distribution to the monitoring stations. The remarks made previously concerning the effects of sources on SCINTAMETER calibration are equally applicable to the automatic units.

C. Field Operation

Diurnal Variation. The TN-2-A, TN-4-A and the gamma channel of TN-3-A exhibited a diurnal variation in radiation reading which adversely affected the dependability of the radiation measurements below 0.1 mr/hr. This was a continuous source of difficulty during CASTLE. Field tests were conducted without success during the monitoring program to determine the cause.

The investigation was continued at HASL, New York, where the resistance of the bakelite insulation on the base of the Anton 310 GM tube was found to change with temperature.

There are other factors likely to contribute to the diurnal variation although specific information is as yet unavailable. The effect of humidity is strongly suspected. The GM tube and certain high resistance components are sealed in a tubular casing which constitutes the probe on the automatic instrument. Since this tube is not disturbed during normal maintenance, the humidity has no immediate effect on calibration as is the case when SCINTAMETERS are opened. However, the daily heating and cooling of moisture which may seep into the probe over a period of time may be partly responsible for erroneous meter indications manifested in the diurnal variation.

High Voltage Boards. A failure common to these units occurred in the high voltage boards. These boards were also bakelite and apparently the high humidity encountered reduced the insulation resistance to the point where sufficient current flowed from high voltage points to ground to burn the board. The leakage reactance of the transformer in the A.C. units (TN-3-A and TN-4-A) was high enough to prevent excessive current in the primary so that the short would burn through without the circuit breaker opening. In the D.C. unit (TN-2-A) the excessive current drawn discharged the battery. Bakelite boards should not be used in the high voltage section of equipment to be used in high humidity areas.

Unregulated Line Voltage. At most of the installations, line voltage and frequency were maintained at standard levels only during the upper level wind observations. Voltages as low as 85 volts were observed during maintenance visits and near the end of the operation conditions may have been worse due to the fuel shortage at several stations.

Water damage caused temporary failure of several instruments. Water entered the instruments due both to heavy wind driven rain and condensation. The former was the greater factor and was eliminated by placing sheds over the units. These sheds were usually constructed with the monitor packing case, supported by four legs, inverted over the instrument. The condensation could not be stopped but this alone did not cause any instrument failures.

TN-2-A. Several mercury batteries (Mallory 308448) went bad long before the expected end of their life and showed signs of leakage. Except for one case, this occurred only in those batteries from which several cells were removed to obtain B+ voltage. Evidently the stress placed on the cells by this operation is excessive and another method of varying B + should be devised. A few of these batteries were received with the polarity, as indicated on the casing, reversed.

The two bars supporting the recorder are not strong enough and under the weight of the recorder, pressed on the batteries cutting their casings. Glyptal paint, which was used to insulate rivets from the metal base plate did not stand up and several shorts occurred.

TN-3-A. The major failures in this type unit occurred in the beta section. The paper drive mechanism broke down in almost every

every unit. The contributing factors here were the tendency of the friction gear to tighten up against the mounting plate and metal corrosion. The former prevented feeding of the filter paper which stalled the drive motor. The overheating of the motor in addition to the rust caused by excessive humidity usually froze the motor shaft putting the dust monitor out of commission until the motor could be replaced.

TN-5-A. Before being placed on Ujelang, the dust samplers were preset to trigger at 0.1 mr/hr. On subsequent visits after bursts, the background was often greater than the trigger setting. In order to ready the instrument for the following event, the trigger setting necessarily had to be raised above the current background value. An existing control on the instrument permitted accurate adjustment only by cumbersome trial and error procedure utilizing a portable source and gamma survey instrument. Generally, there being insufficient time for this procedure, the setting was adjusted to some value, only approximately known, such that the unit would not trigger in the gamma field. Because of this, the sampling time for the next event could not be accurately established.

D. Recommended Modifications.

TN-3-A. The friction clutch should be made with a reversed thread so that it would tend to loosen. The paper drive motor is heavier and faster than required. A smaller motor would allow the paper reel supporting plate to drop lower allowing easier loading of the paper. Also the slower drive motor will eliminate over-running of the detent on the stop can.

A method of stopping the paper after it has traveled three inches would increase the life of a filter paper roll from 8 to approximately 16 days. At present, the amount of paper per sample is controlled by the radius of the takeup reel which increases with the number of samples taken. Since it is necessary to have the drive set so that three inches is traversed with the minimum radius, the open space between samples becomes excessively long as the roll is used. A rubber pinch wheel assembly which would be simple in design could be used to fix the amount of paper travel.

Replacing the beta GM tube or servicing the circuit mounted within the lead shield is difficult, requiring almost a complete dismantling of the monitor which is extremely difficult in the field. This whole section should be mounted to a plug in the rear of the lead shield which is easily removed without disassembling other parts of the unit.

To simplify calibration, the common filament voltage control of the beta and gamma amplifier tubes should be eliminated in favor of individual controls.

TN-5-A. A calibrated control should be provided so that the trigger setting can be changed easily to a different known value in the field.

A device to provide a record of the start of sampling time should be incorporated in the sampler unit.

General. To ease field maintenance and calibration of the continuous monitors, a switch disconnecting high voltage should be incorporated in the circuit and provision made for inserting a portable meter in the output circuit at the monitor. The latter modification would be a convenience because the recorder is usually some distance from the monitor and it is not possible to adjust controls and watch the recorder deflection simultaneously.

VII. RECOMMENDATIONS

On the basis of experience gained during this operation, the following modifications are proposed for use in any further monitoring programs of this nature:

1. In addition to the general pattern of automatic monitoring stations included for CASTLE, provide supplementary stations at several atolls forming a semicircle oriented to the east and within 300 miles of the test site. The most practical installation for these supplemental stations would be automatic, battery operated, unmanned equipment. If possible they should be equipped to telemeter. The locations should be selected on the basis of accessibility by air or surface vessel as well as distribution around the test area.

Weekly or bi-weekly visits would be necessary for maintenance (and data recovery in the event telemetering cannot be utilized).

2. Duplicate instrumentation is essential at unmanned stations and is strongly desirable at manned stations.

3. An alternative to #1 would be more frequent survey flights covering more flight patterns following each event, although this would not provide the same precision of fallout arrival measurements as would be obtained by the ground stations nor would peak values necessarilly be obtained. Daily flights each of the ABLE and BAKER patterns up to five or six days after each event in addition to normal scheduling would suffice to detect late occurring fallout and establish fallout arrival time to within a 24 hour period.

As a minimum requirement, each flight pattern should be executed shortly before each event after the first to measure residual contamination intensities. It is only by this means that the fallout from successive bursts can be accurately computed from measured values. During CASTLE it was found to be impossible to schedule these re-survey flights on D - 1 because of unpredictable delays in detonating the test devices and frequent conflicts with the survey squadron's other commitments which were heaviest prior to D day. Therefore, in cases of long periods between bursts, re-surveys at regular five day intervals are suggested to ensure the currency of residual contamination data.

4. Develop procedures for night survey flights. Such procedures should probably provide for omitting islands with mountainous terrain.

5. Develop procedures for differentiating among the several sources of in-flight radiation to permit proper evaluation of ground intensity

measurements. The sources which may obscure background measurement for correction are skyshine and sea activity. The proper application of shielding at the survey instrument could eliminate substantially all radiation originating in and on the aircraft.

6. Automatic fission product dust measuring instruments should be perfected and utilized at stations within three hundred miles of the test area.

7. A continuing effort should be made to correlate fallout density per unit area of ground with radiation intensity. Sampling by gummed film or equivalent should be done at monitoring stations.

8. The successful measurement of fallout over the open sea from aircraft has been demonstrated.[3] Perfection of this technique holds great promise for accurate evaluation of fallout patterns up to two to three hundred miles downwind from megaton range bursts. Although the aerial survey program described herein was not designed for that particular service, the programs could be coordinated for mutual benefit:

A. Survey aircraft enroute between two atolls can measure sea radiation as a corollary mission. Toward this end, survey patterns could be modified within certain limits to examine areas of particular interest without impairing the atoll survey functions. Wasteful overlapping of survey missions could be avoided in this manner.

B. Atoll radiation data would supplement the sea surface data, broadening the scope of the study.

C. Under suitable circumstances, the atoll data would provide a direct relation between sea measurements and ground activity.

D. Immediate exact knowledge of the fallout path direction, derived from sea surface measurements, would be useful in anticipating appropriate atoll survey requirements.

9. The conversion of radiation measurement from the air to ground intensity should be more accurately defined. Phenomenon necessary to be studied are instrumental energy dependence, effects of fission product age and composition, and the relationship of ground intensities as determined by air measurement to ground intensity measurement by conventional portable survey instruments.

10. Recommendations concerning instrumentation are included in Section VI.

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1. Radioactive Debris From Operation IVY, NYO-4522, April, 1952.
2. Radioactive Debris From Operation CASTLE: Worldwide Fallout. (To be released)
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4. Survey Instrument Characteristics Measured by HASL, Instruments Branch staff.
5. The Effects of Atomic Weapons (Page 258).