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Appendix I to Semiannual Technical Report 2 Covering the Period 1 January to 1 July 1965

# RIOMETER RECORDS OF 18- AND 30- Mc COSMIC NOISE

By: J. C. HODGES

Prepared for:

HEADQUARTERS  
U. S. AIR FORCE  
AIR FORCE TECHNICAL APPLICATIONS CENTER/TD-3  
WASHINGTON, D.C. 20333

CONTRACT AF 33(657)-13727  
AFTAC PROJECT AUTHORIZATION  
NO. T/5060/ASD(59)  
ARPA ORDER NO. 159

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA



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October 1965

Appendix I to Semiannual Technical Report 2 Covering the Period 4 January to 4 July 1965

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SRI Project 5224

This research was supported by the Project VELA office of the Advanced Research Projects Agency and monitored by the Air Force Technical Applications Center.

Approved: RAY L. LEADABRAND, MANAGER  
RADIO PHYSICS LABORATORY

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ELECTRONICS AND RADIO SCIENCES

Copy No. ....20

## ABSTRACT

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Riometer record reproductions of 18-Mc and 30-Mc cosmic noise are presented for the period 4 January 1965 to 4 July 1965. The riometers were located near San Francisco, California.

The riometer and the field site are described briefly and the use of the data is explained. The use of thermoelectric generation of power with propane is detailed.

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## I INTRODUCTION

As part of the experimental studies of ionospheric variations being conducted at SRI, a riometer station has been operated continuously from 11 June 1963 at Nuff Creek--a ranch located in the hills near Half Moon Bay, California.

The riometer records taken at this station for the period 4 January 1965 to 4 July 1965 are reproduced in this volume to make them available to other researchers. These records are useful for comparison with other riometer records or correlation with other data concerning the sun, the earth's ionosphere, and radio astronomy. The riometer records are also useful as a routine source of information on the activity of the sun.\*

---

\*Another source of similar geophysical data is the Monthly CRPL F-series, Part B, "Solar-Geophysical Data," available from the National Bureau of Standards, Boulder, Colorado.

## II RIOMETER

### A. General Description

The word riometer is derived from "relative ionospheric opacity meter." The riometer is an ultra-stable receiver system that records the power level of the cosmic noise impinging on the antenna coming primarily from our galaxy. This radio power, or radio noise, passes through the ionosphere. If the normal ionosphere is bombarded by particles or intense radiations, additional ionization is generated which permits less cosmic noise to pass through the ionosphere, thus producing a noise-level drop on the riometer recording. A drop of the riometer record (usually referred to as absorption) implies that ionizing radiations, generally from the sun, are present.

Long-term stability of the riometer is achieved by using a servo system rather than a simple receiver. The riometer receiver alternately samples the power available from the antenna and from an internal noise generator (called the servo-noise diode) at a sample rate of 340 cps. An electronic servo system continuously adjusts the servo-noise diode power output to be equal to the noise power coming from the antenna. The data are recorded on a strip chart recorder in the form of servo-noise diode plate current, which is proportional to the servo-noise diode power output. Since this servo diode power output is made continuously equal to the antenna noise power, the recording effectively indicates the level of the cosmic signal reaching the antenna.

The noise-power output of a temperature-limited noise diode is directly proportional to the plate current of the diode, which is easily measured or recorded. To convert the plate current to equivalent temperature or power, the following equations are used:

$$T = 5.8 IR + T_r \quad (1)$$

and 
$$F = kTB \quad (2)$$

where

$T$  = equivalent temperature in  $^{\circ}\text{K}$

$I$  = noise-diode plate current in ma

$R$  = resistance of the noise diode load resistor in ohms

$T_r$  = temperature of the noise diode load resistor in  $^{\circ}\text{K}$ ,  
which is approximately equal to room temperature.

A value of  $300^{\circ}\text{K}$  is usually used.

$P$  = noise power

$k$  = Boltzman's constant, and

$B$  = receiver bandwidth.

A useful way to express absorption is in terms of decibels. Since the plate current of the noise diode is proportional to the noise power output, the following equation may be used:

$$\text{db} = 10 \log \frac{I_1}{I_2} \quad (3)$$

where

$I_1$  is the reference current, and

$I_2$  is the current measured during an absorption event.

#### B. Quiet-Day Curve

The ricometer chart recorder will trace out a sine-like curve each day representing the cosmic noise distribution as the antenna rotates with the earth. If the conditions are "normal," the curves of several days are used to determine a quiet-day curve. The usual procedure is to operate the ricometer for several days, and under "normal" circumstances the daily trace on the chart will repeat that of the previous day, shifted forward in time by four minutes. The chart repeats itself because the antenna views the same solid angle of the sky at any given time each sidereal day. The daily 4-minute shift is the difference between sidereal time and solar time, and amounts to exactly one day each sidereal year.

Finally, the daily records can be compared to the quiet-day curve; if the recorded level is less than the quiet-day level, the ionospheric absorption can be measured quantitatively.

C. Important Riometer Operating Parameters

There are many adjustments on riometers that will affect the data quality. Two of the more important of these are adjustments to the receiver bandwidth and the integration time constant. These can be related to the ability of the riometer to measure a given noise power by:

$$\frac{\Delta P}{P} \propto \frac{1}{\sqrt{BT}} \quad (4)$$

where

- $\Delta P$  is the uncertainty in measuring P,
- P is the measured power,
- B is the receiver bandwidth (pre-detection), and
- T is the integration time constant (post-detection).

Practically, this means that the wider the bandwidth and the longer the integration time constant, the smaller the uncertainty or trace width. Unfortunately, with wider bandwidths the riometer is more prone to interference; and with long integration time constants, the riometer is not able to respond to fast variations in absorption. In actual operation, a compromise must be made between these conditions. Two typical modern riometers which were used at the Nuff Creek Station and are described herein have the following available bandwidths and integration time constants:

Riometer Bandwidth	
ARI	EMI
100 kc	60 kc
30 kc	30 kc
15 kc	15 kc
3.5 kc	3.5 kc

Riometer Integration Time Constant	
ARI	EMI
2.5 sec	2 sec
6 sec	7 sec
16 sec	20 sec
27 sec	--

The antenna used with the riometer is another important factor. If the antenna is tilted it will see a different portion of the sky than an antenna looking directly overhead, thereby producing a slightly different quiet-day curve. Rotating an antenna with unequal E and H planes will also result in a different quiet-day curve for the same reason. Finally, the sum of the side lobes of many antennas can contribute almost as much power as the main lobe of the antenna; and, since each lobe looks at a different portion of the sky, a good deal more of the sky is covered than might be expected.

### III NUFF CREEK, CALIFORNIA, SITE

#### A. General Description

The Nuff Creek site, operated by SRI, is located in a steep-sided valley near Half Moon Bay (Lat.  $37^{\circ}30'5''N$ , Long.  $122^{\circ}23.8'W$ ), several miles from any power lines or other sources of interference. The equipment is powered by thermoelectric generators (see Sec. IV) and a stand-by gasoline-powered generator.

The Nuff Creek station is unmanned. A technician services the equipment weekly, spending approximately two hours at the site each visit. During each visit, the technician puts a time mark and calibration on each riometer chart record; this operation is performed manually, usually with the aid of WWV time broadcasts. Errors between time marks and chart time divisions are distributed linearly throughout the chart before the charts are lined up to be photographed.

#### B. 30-Mc Riometer

The 30-Mc EMI riometer is a standard instrument made by EMI Products, Inc. The load resistor for the Type 5845 servo noise diode is  $3320\Omega$ . The recorder used is an Esterline-Angus pen recorder with a chart speed of 3 inches per hour; full-scale deflection is adjusted to 2.9 ma.

This riometer design was originally the Dorsett riometer, then became the EMI riometer, and finally became known as the Western Electrodynamic riometer. Western Electrodynamic has since gone out of business, but some parts are still available.

The antenna used with the EMI riometer is a Hygain three-element Yagi with an E-plane half-power beamwidth of 65 degrees and an H-plane half-power beamwidth of 110 degrees. The impedance of the antenna is 47 ohms. The antenna feedline is RG-8A/U cable with an estimated loss of 1 db. The antenna polarization was parallel to the valley  $N59^{\circ}E$  true ( $N42^{\circ}E$  magnetic).

C. 18-Mc Riometer

The 18-Mc ARI riometer is an Aerospace Research, Inc. Model 100-A instrument modified to have a 50-ohm servo-diode load resistor, which requires attenuation in the antenna lead (see the Chronological Log below). The recorder used is an Esterline-Angus pen recorder with a chart speed of 3 inches per hour; the full-scale deflection is adjusted to 5.0 ma. A 5722 noise diode is used.

The antenna in use with the 18-Mc ARI riometer is a special seven-element ring array designed for low sidelobe response. The antenna polarization is S147°E true. The beamwidth is approximately circular and 40 degrees between the half-power points.\* The antenna impedance is 59 ohms. The antenna feedline is RG-8A/U cable with an estimated loss of 2 db.

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\* R. B. Dyce et al., "Cosmic Noise and Ionosphere Studies--Project VELA," Final Report, Part I, Contract AF 49(638)-989, SRI Project 3498, Stanford Research Institute, Menlo Park, California (December 1963).

#### IV THERMOELECTRIC POWER GENERATION AT NUFF CREEK

As noted in Sec. III, the Nuff Creek site is without commercial electric power; accordingly, various means of generating electricity to run 10- and 35-watt riometers have been tried in the two and a half years the station has been operating. Gasoline-powered generators have been used, the most successful of which was a heavy duty, 1200 rpm, 2-1/2 kw, Navy surplus unit. This generator was operated about 1-1/2 days a week to charge large banks of storage batteries that supplied an inverter, which, in turn, powered the 18-Mc ARI riometer.

The EMI (30-Mc) riometer was operated in similar fashion for a trial period, after which two 3M\* thermoelectric generators were purchased. Each of these units supplies 12v at 12 watts. (The EMI riometer requires only 10 watts, but also requires positive and negative supplies, necessitating the second generator.) Together, the two generators could supply enough power to operate two riometers. The generators have a hot propane flame that heats one thermocouple; another thermocouple is air-cooled by large vanes. The dc current thus generated is converted within the unit from approximately 4 vdc to 12 vdc. Each generator uses one 100-lb bottle of propane per month.

In Fig. 1, the two 12-watt generators can be seen on the shelf at the rear of the trailer, nearest the propane bottles. These two units functioned so satisfactorily that, when a 40-watt unit became available, the 35-watt ARI (18-Mc) riometer was placed on thermoelectrically-generated power. This unit is mounted at the left end of the shelf at the rear of the trailer. A 100-lb bottle of propane will operate this generator for about two weeks.

---

\* Minnesota Mining and Manufacturing Co., Electrical Products Div., Thermoelectric Products, Bldg. 220-5W, 2501 Hudson Road, St. Paul, Minnesota, 55119.

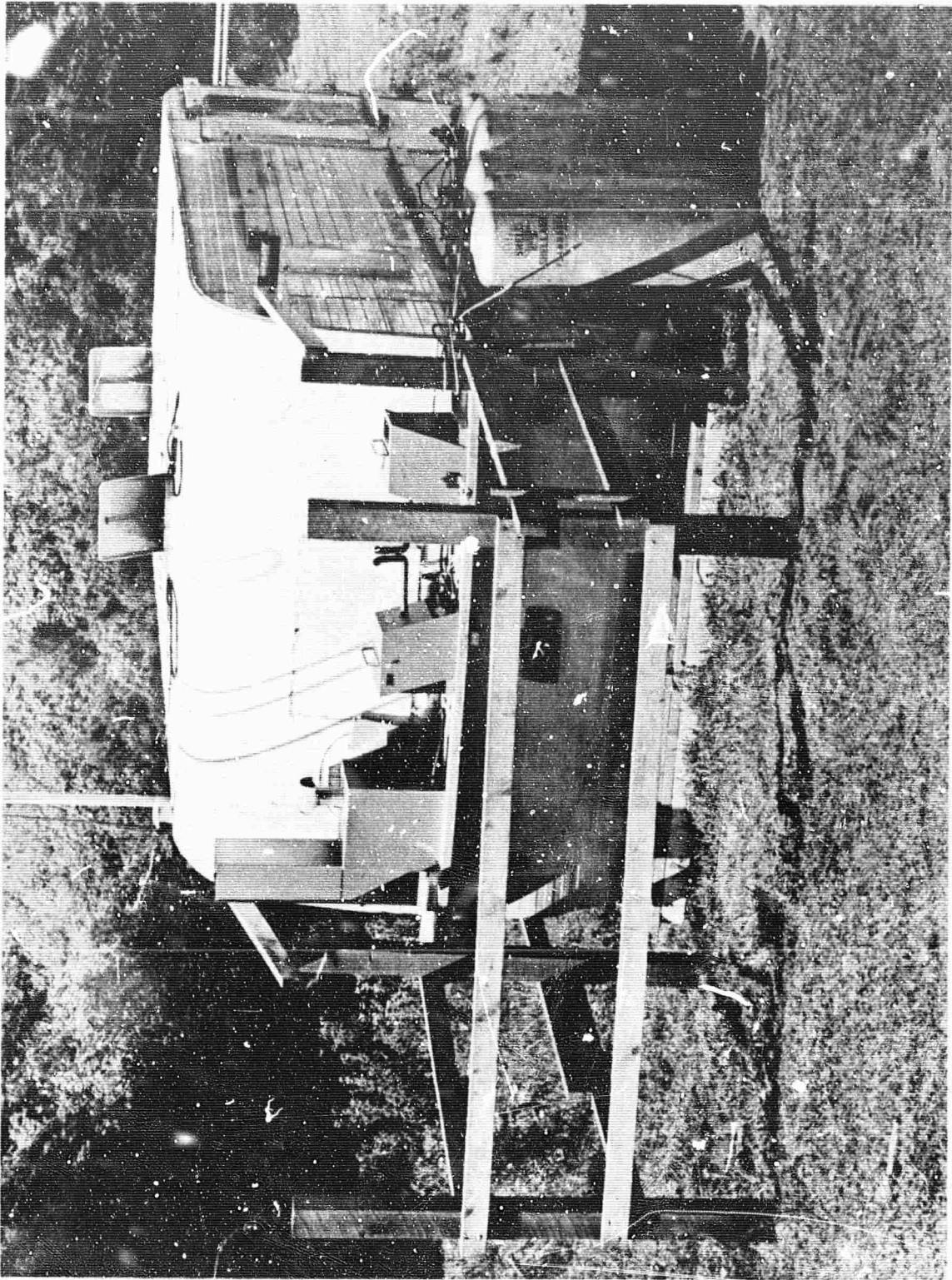


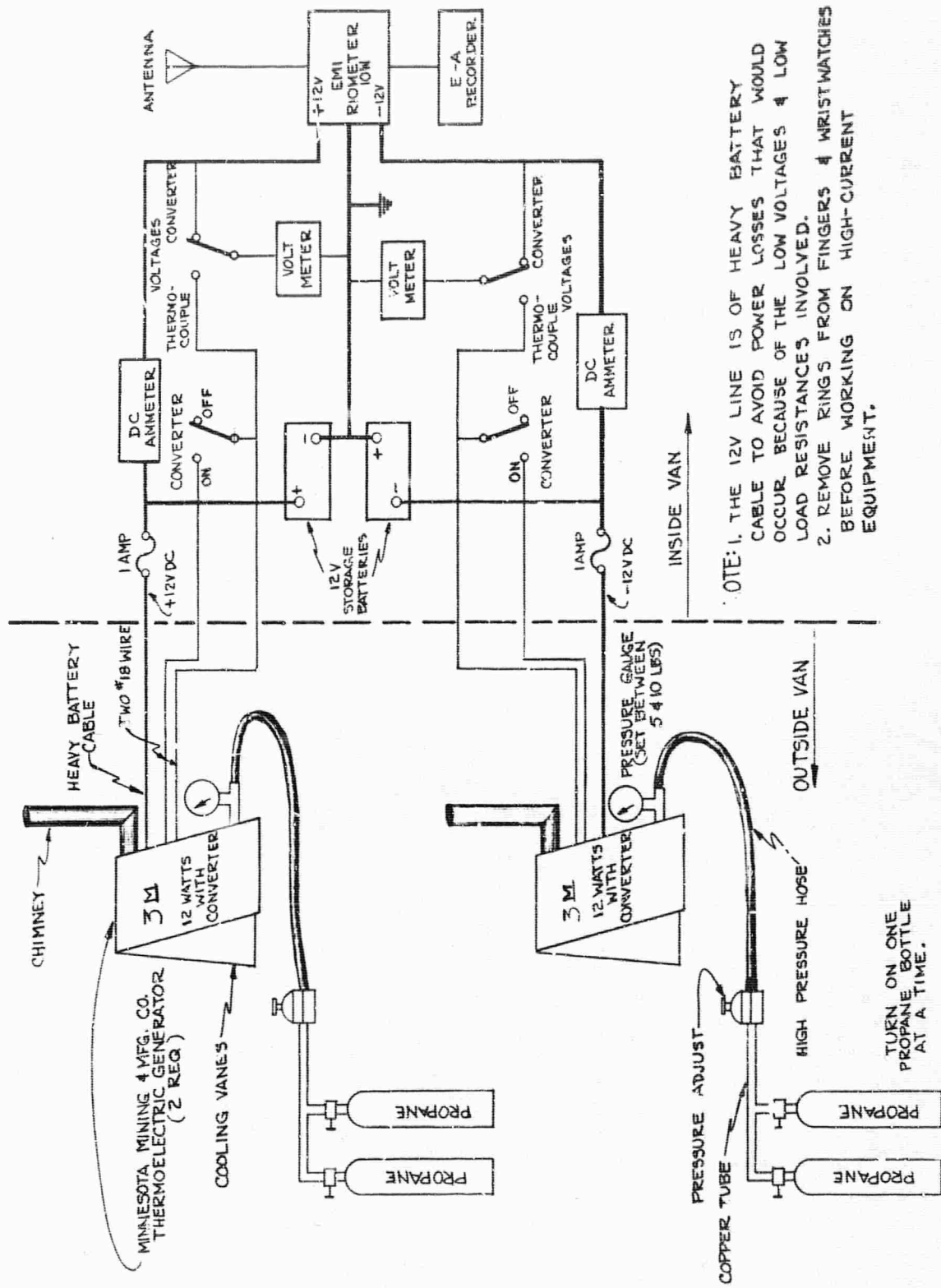
FIG. 1 NUFF CREEK RIOMETER TRAILER, SHOWING THERMOELECTRIC GENERATORS AND PROPANE BOTTLES

The connection of the two 12-watt generators is shown in Fig. 2. The floating batteries are absolutely necessary, since no voltage regulation is provided; under no-load conditions, the voltage may rise to as high as 20 v, which would damage riometer transistors with a turn-on transient. The batteries are charged to some extent during the cool nights and discharge somewhat during the warmer daytime.

The connections to the 40-watt generator are shown in Fig. 3. The generator must operate at full power to keep the 35-watt riometer going; the inefficiency reflected in full-time operation is the 6 vdc-to-115 vac conversion. The batteries that float on the line usually read half charge under this condition, since generator voltage is not high enough to charge them further. Higher-power models (100 and 200 watts) have recently been announced by 3M.

The metering circuits shown in Figs. 2 and 3 are mounted in a rack under the EMI riometer, as shown in Fig. 4. Figure 5 shows the ARI riometer and its companion equipment.

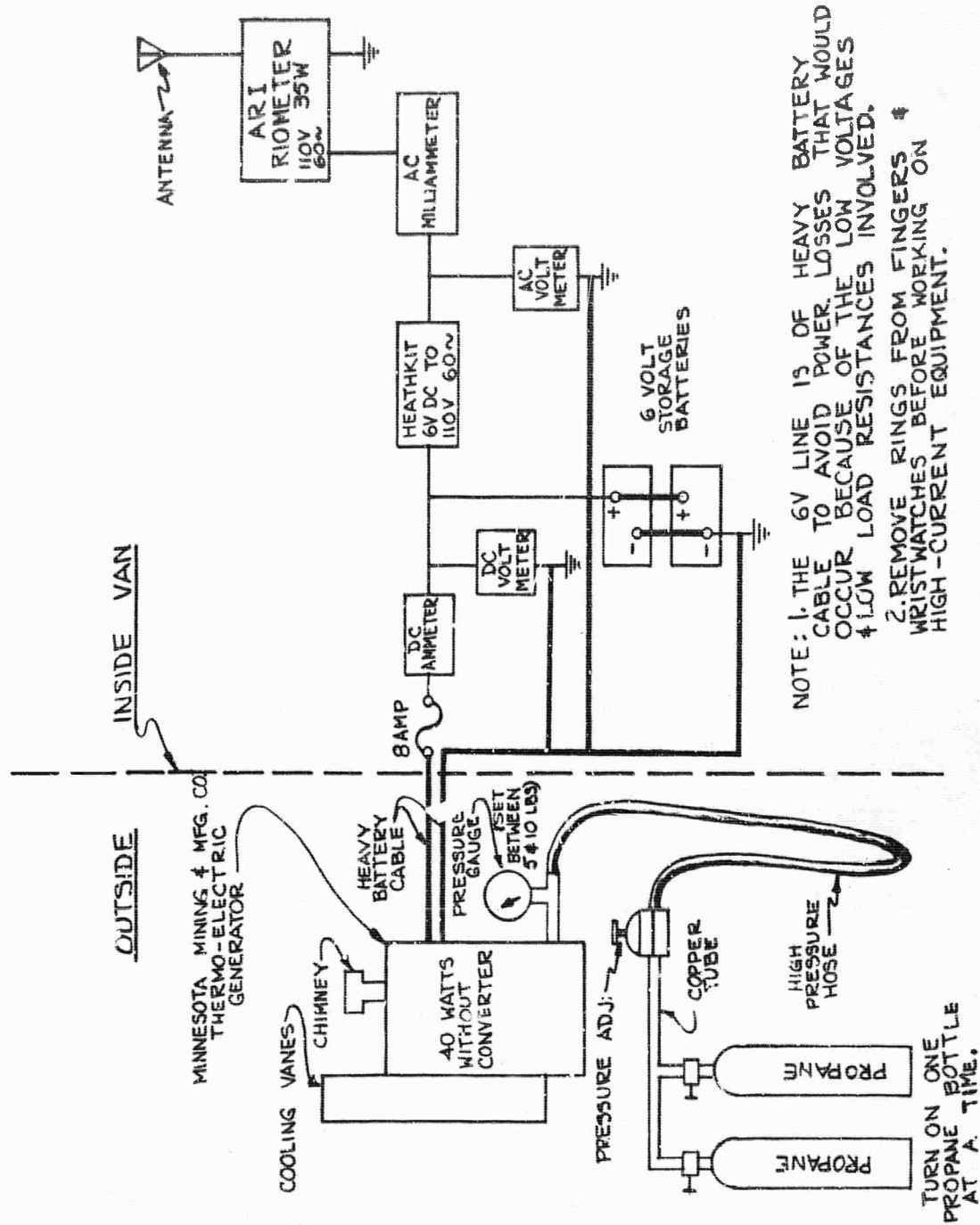
Maintenance on the generators consists of cleaning the orifices in the burner nozzles every few months, supplying gas bottles (delivered free to Nuff Creek by the local distributor), and adjusting gas pressure slightly from week to week. No breakdowns have occurred, although some data have been lost because of improper adjustment of the generators by inexperienced operators.



NOTE: 1. THE 12V LINE IS OF HEAVY BATTERY CABLE TO AVOID POWER LOSSES THAT WOULD OCCUR BECAUSE OF THE LOW VOLTAGES & LOW LOAD RESISTANCES INVOLVED.  
 2. REMOVE RINGS FROM FINGERS & WRISTWATCHES BEFORE WORKING ON HIGH-CURRENT EQUIPMENT.

TURN ON ONE PROpane BOTTLE AT A TIME.

FIG. 2 10-WATT THERMOELECTRIC GENERATOR SYSTEM



NOTE: 1. THE 6V LINE IS OF HEAVY BATTERY CABLE TO AVOID POWER LOSSES THAT WOULD OCCUR BECAUSE OF THE LOW VOLTAGES & LOW LOAD RESISTANCES INVOLVED.  
 2. REMOVE RINGS FROM FINGERS & WRISTWATCHES BEFORE WORKING ON HIGH-CURRENT EQUIPMENT.

FIG. 3 35-WATT THERMOELECTRIC GENERATOR SYSTEM

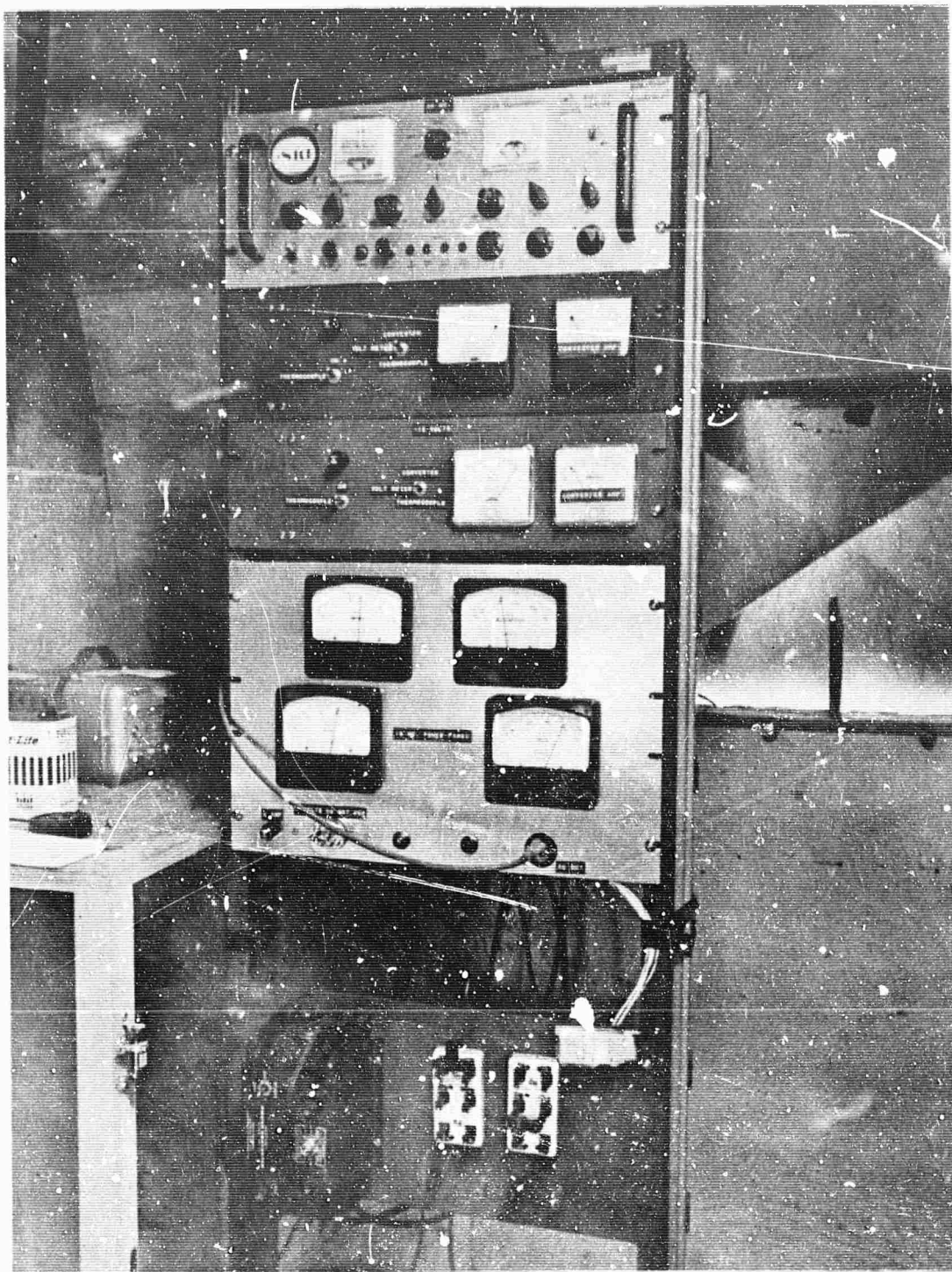


FIG. 4 EMI RIOMETER RACK, SHOWING  
THERMOELECTRIC GENERATOR METERING PANELS

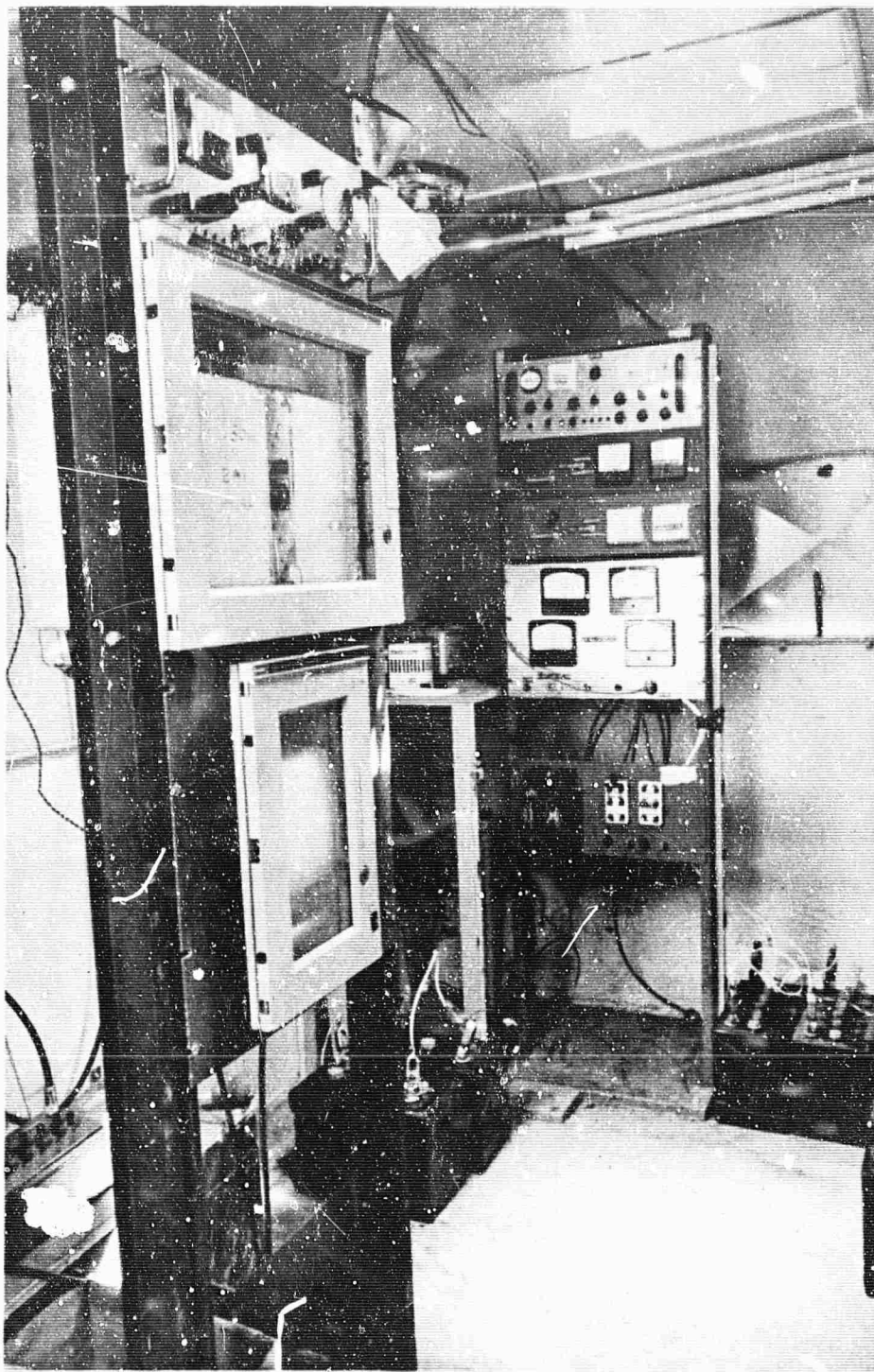


FIG. 5 OVERALL VIEW OF RIOMETER TRAILER INTERIOR

V DATA

A. Chronological Log

1. 30 Mc Riometer Chronology 4 January 1965 to 4 July 1965

Bandwidth 15 kc, Integration 2 sec., Frequency Sweep Off,  
Minimum Detector Off, Antenna Attenuator at Zero

1965

4 January		First chart in this volume.
11 January		Half-hour timing marks evident. From unknown source.
24 January	0330 to 0700	Chart rises probably due to local noise.
30 January and 31 January		Downward spikes probably due to bad antenna connection.
5 February	1800 to 2100	Strong sun noise
15 February	2210	
to		Riometer off
1 March	2400	
5 March	1910	
to		Riometer off or malfunctioning
11 March	2150	
13 March	2250	Possible event
14 March	1300 to 1800	Possible event
15 March	0630 to 0640	Equipmental drop
16 March	0850 to 0900	Equipmental drop
17 March	0635 to 0640	Equipmental drop
27 March	1630	Possible event
29 March	0155 to 0225	Probably bad antenna connection. Continues through 29 March
31 March	0400	
to		Servo diode burned out
5 April	2230	
13 April	0330 to 0355	Probably loose antenna connection
14 April	0950 to 1105	Probably loose antenna connection
18 April	1030 to 2200	Possible event

20 April	1355 to 2150	Possible event
1 May	1200	Jump in record due to man-made noise or equipment malfunction
4 May	0355 to 1745	Servo diode burned out
9 May to	1715	Riometer gradually went off scale and recorder needle hung up on side of recorder
10 May	1715	
17 May	2145 to 2155	Equipmental drop
25 May to	1720	Servo diode behaving erratically. Replaced.
1 June	1800	
10 June to	2400	Servo diode behaving erratically. Replaced again.
14 June	1820	
21 June	1805 to 2020	Testing. Replaced diode.
4 July		Last record in this volume.

2. 18 Mc Riometer Chronology 4 January 1965 to 4 July 1965

Bandwidth 30 kc, Integration 6 sec., Frequency Sweep Off,  
Minimum Detector Off, Antenna Attenuator at 13 db.

1965

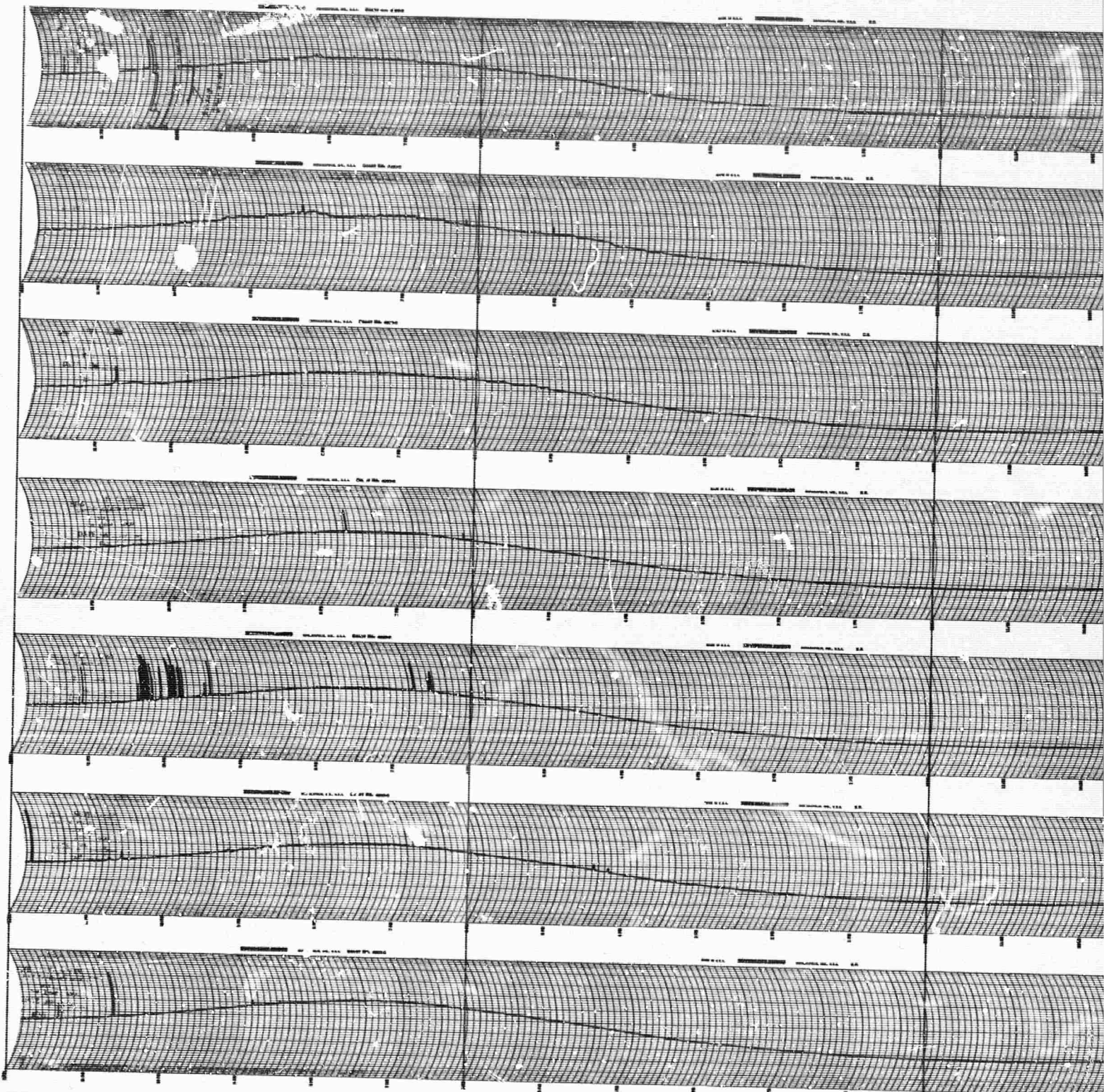
4 January	1300 to 2200	Riometer power limited
11 January	0200 to 2110	Power failure
15 January	1935 to 2240	Test period
17 January	2205	Power failure
to		
19 January	2025	
25 January	2200	Chart 4 minutes fast
1 February	2245	Chart 8 minutes fast
8 February	1545 to 2055	Power failure
	2215	Chart 4 minutes fast
15 February	2030 to 2115	Power failure
		Chart 4 minutes fast
20 February	0730	Power failure
to		
23 February	2000	
25 February	1643	Drop in record due to equipment (corrected in April)
28 February	1255	Power failure. Integration changed from 6 sec to 16 sec
to		
3 March	2300	
4 March	0725 to 0720	Recorder stopped
8 March	0130 to 2155	Power failure. Changed inte- gration from 16 sec to 6 sec
11 March	1955 to 2030	Antenna test
11 March	2045	Integration time constant changed from 6 sec to 16 sec
	2125 to 2150	Test period
12 March	1845 to 2040	Test period
	2105 to 2300	Data questionable
15 March	1850 to 2020	Test period
16 March	0930 to 1205	Equipment malfunction

22 March	2155	
to		Riometer in shop
24 March	2340	
24 March	2340	Test period. Integration time
to		changed from 16 sec to 6 sec
25 March	0130	
27 March	0400	
to		Riometer malfunctioning
29 March	2320	
1 April	0305	Riometer malfunctioning. Data
to		erratic or below normal level.
12 April	2205	(Transformer on antenna array
		disconnected by local bovine.)
21 April	1850 to 2010	Integration changed from 6 sec
		to 2.5 sec and back to 6.
26 April	2030 to 2155	Test period.
1 May	2205	Power failure. Also adjust antenna
to		and install new riometer
5 May	1750	
8 May	0035 to 0045	Equipmental drop
10 May	1130 to 1535	Data questionable. Time error--
		7 min fast.
11 May	0035	Step down due to equipment
	1600	Step up due to equipment
12 May	0755 to 0830	Rise in level could be local man-
		made noise
13 May	2015 to 0810	
14 May	1135	
to		Equipment behaving erratically
17 May	2100	
18 May		Chart level drops gradually
to		
20 May		
19 May	1905 to 2025	Test Period
1 June	1430 to 1755	Power failure
3 June	2025 to 2050	Equipmental drop
4 June	1730 to 1740	Equipmental drop
	1900	Level drops, equipmental
5 June	1810 to 1840	Sunburst and absorption
7 June	1000 to 1910	Rise in record, stops when bat-
		teries changed

9 June	0335 to 0350	Drop due to equipment
	1810 to 1835	Drop due to equipment
10 June	1935 to 2040	Unreliable data
11 June	1815 to 2200	Unreliable data
12 June	1340	
to		
13 June	2400	Data questionable
14 June		
to		
4 July		Drops in the records that appear as sharp steps should be ignored as man-made noise and equipment problems
21 June		New batteries installed
4 July	0855 to 1800	Batteries limiting riometer
4 July		Last record in this volume.

B. Chart Records

The chart records appearing on the following pages are reproduced at 20 percent of their original size. Time goes from right to left, the records begin and end at midnight GMT. The records are in chronological order by frequency; the 30-Mc records are presented first.



2400

1800

NOON

UNIVERSAL TIME  
NUFF CREEK CALIFORNIA

30 mc

JAN.  
1955

4

5

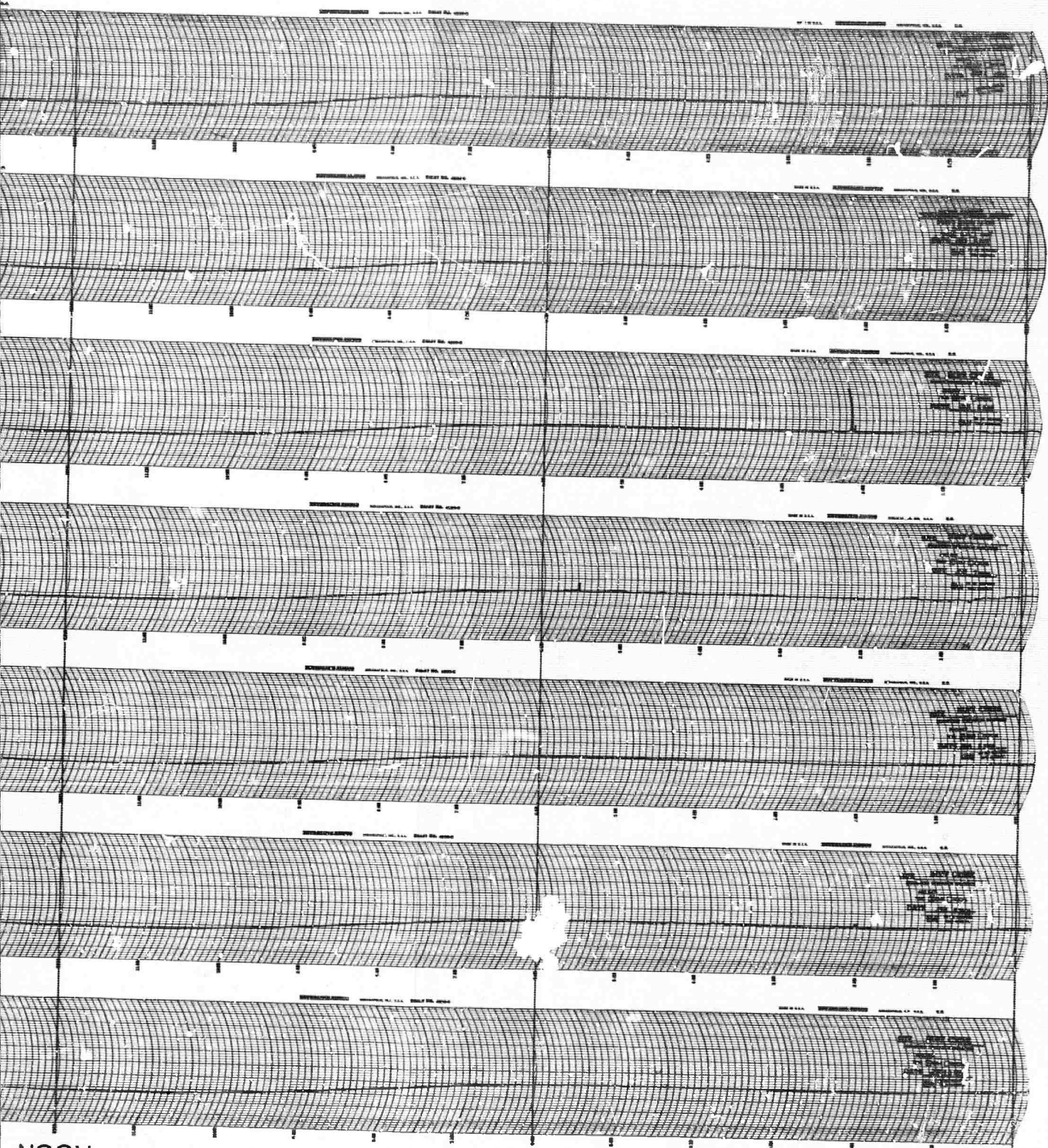
6

7

8

9

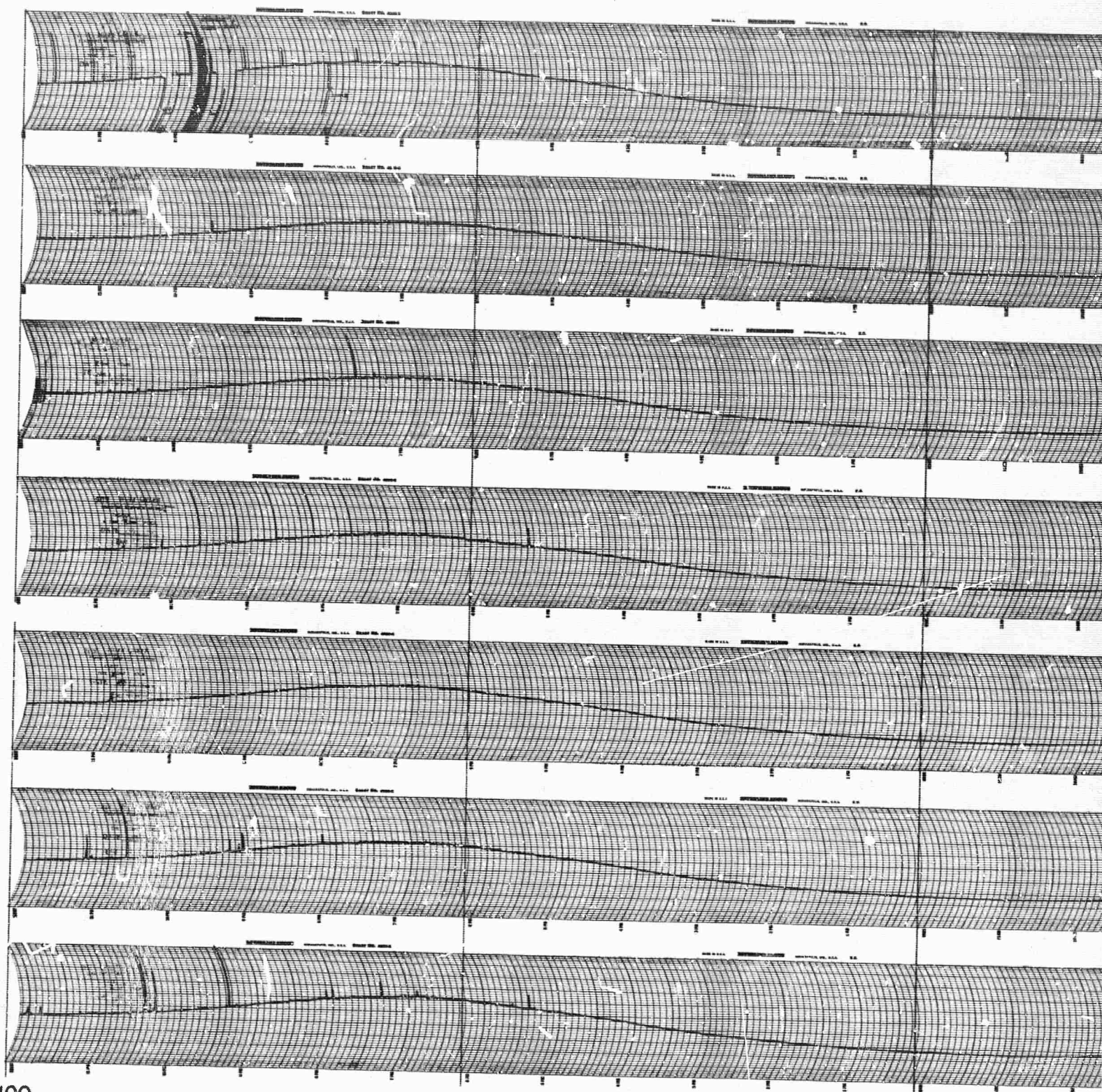
10  
SUNDAY



NOON 0600 0000

UNIVERSAL TIME  
CORNIA 30 mc RIOMETER

2



2400

1800

NOON

NUFF CREEK

UNIVERSAL TIME  
CALIFORNIA

30 mc

1

JAN.  
1965

11

12

13

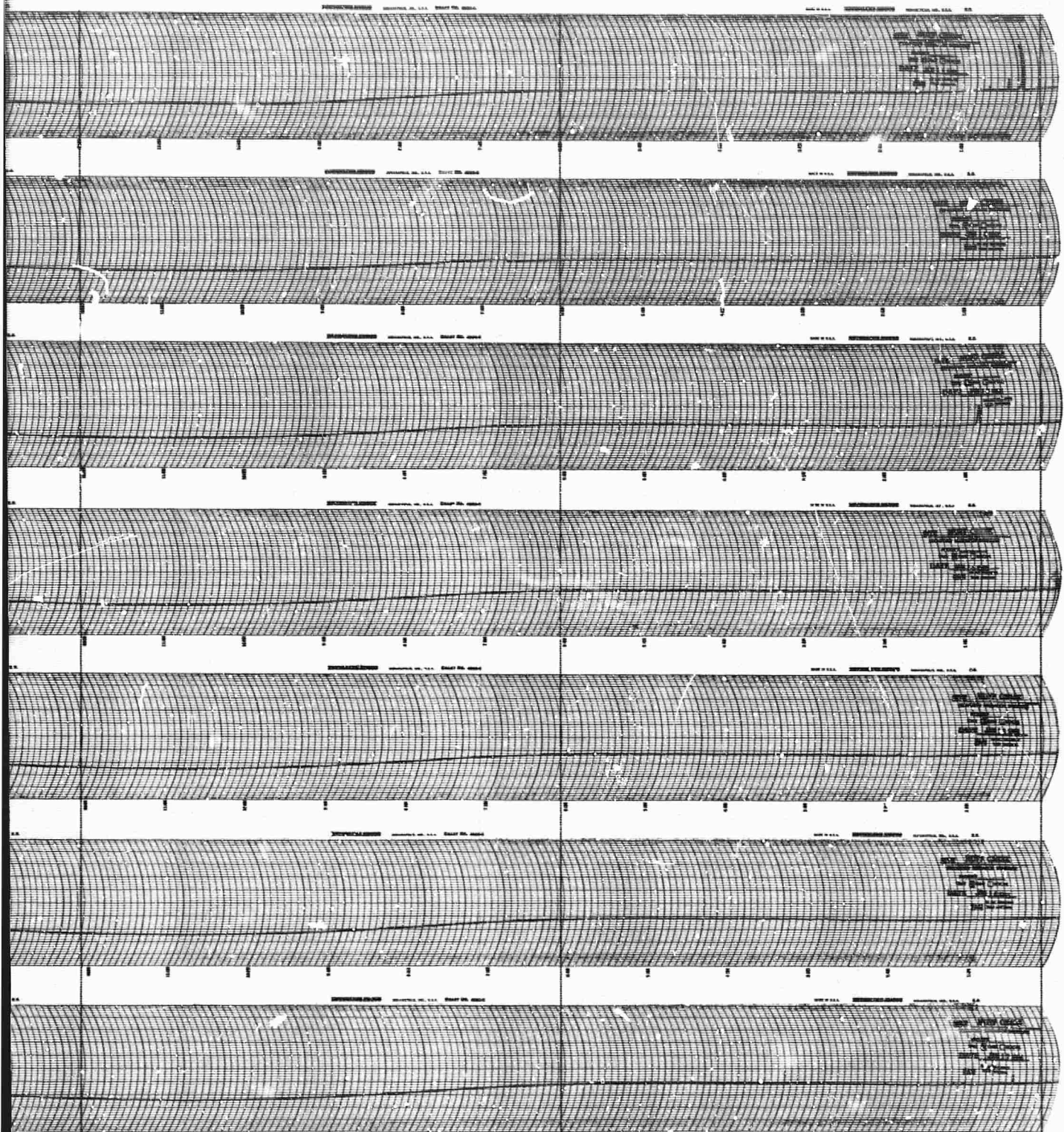
14

15

16

17

SUNDAY



NOON

0600

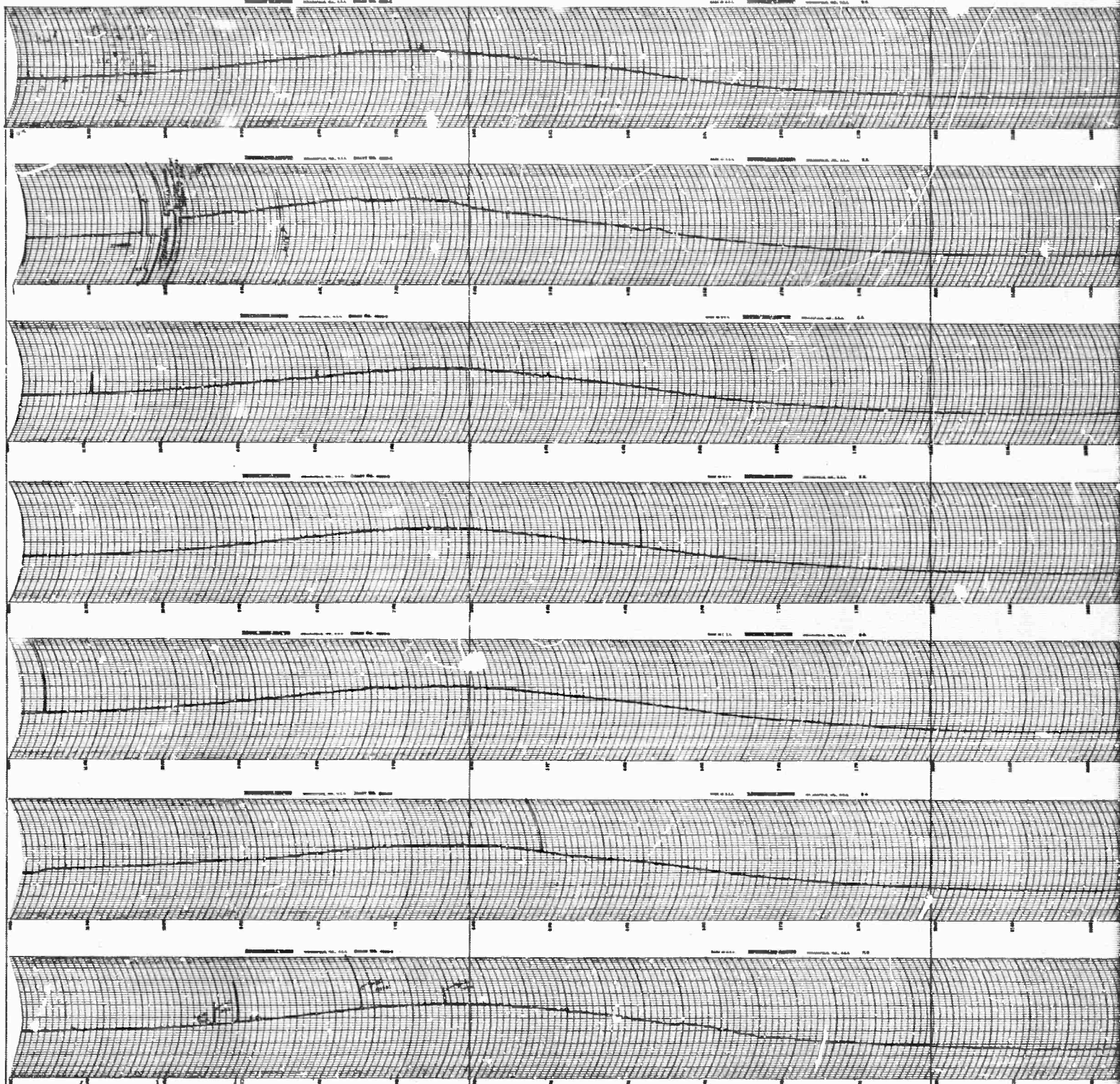
0000

UNIVERSAL TIME

CALIFORNIA

30 mc RIOMETER

2



2400

1800

NOON

UNIVERSAL TIME  
NUFF CREEK CALIFORNIA 30 mc

/

JAN.  
1965

18

19

20

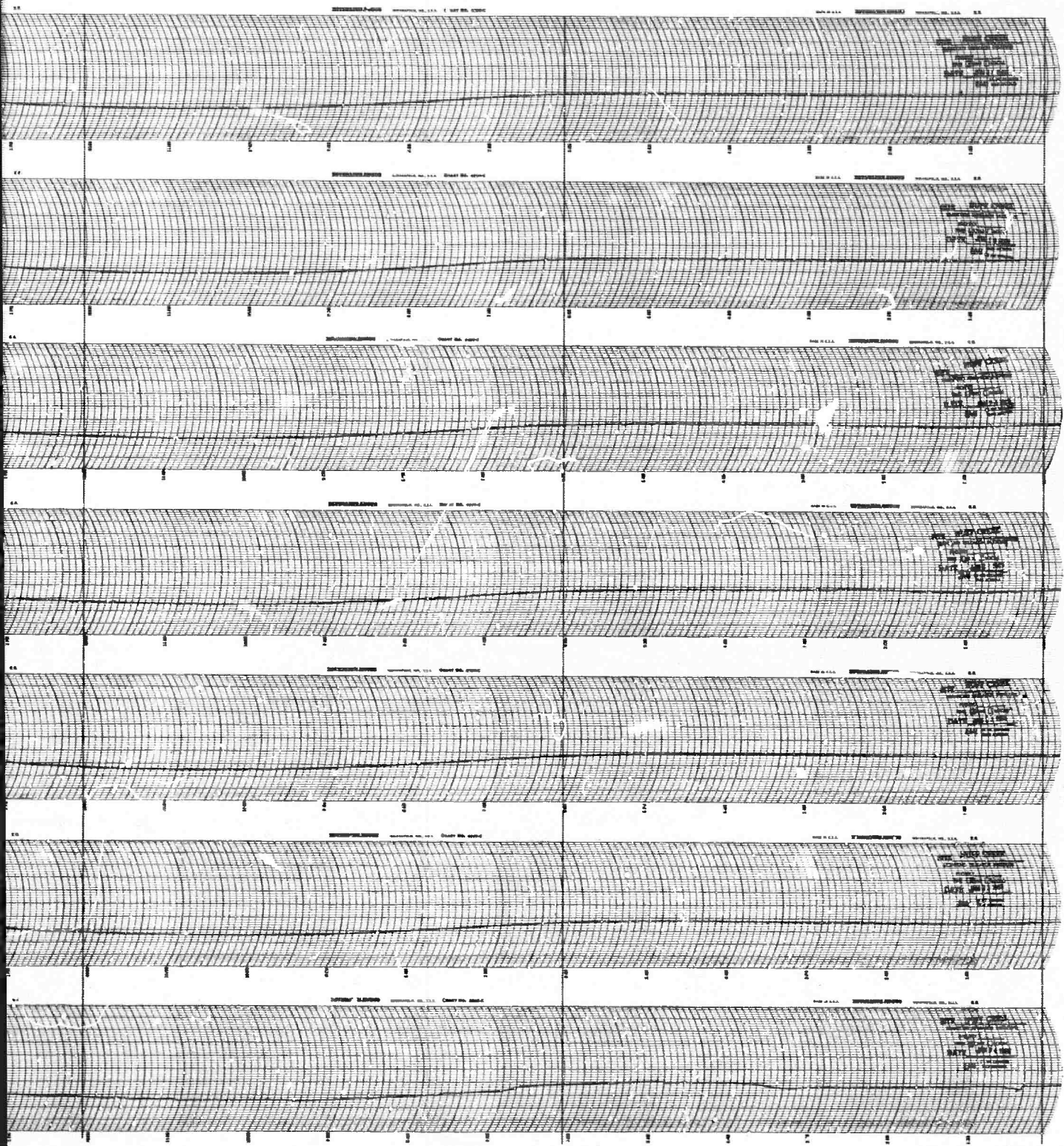
21

22

23

24

SUNDAY



NOON

0600

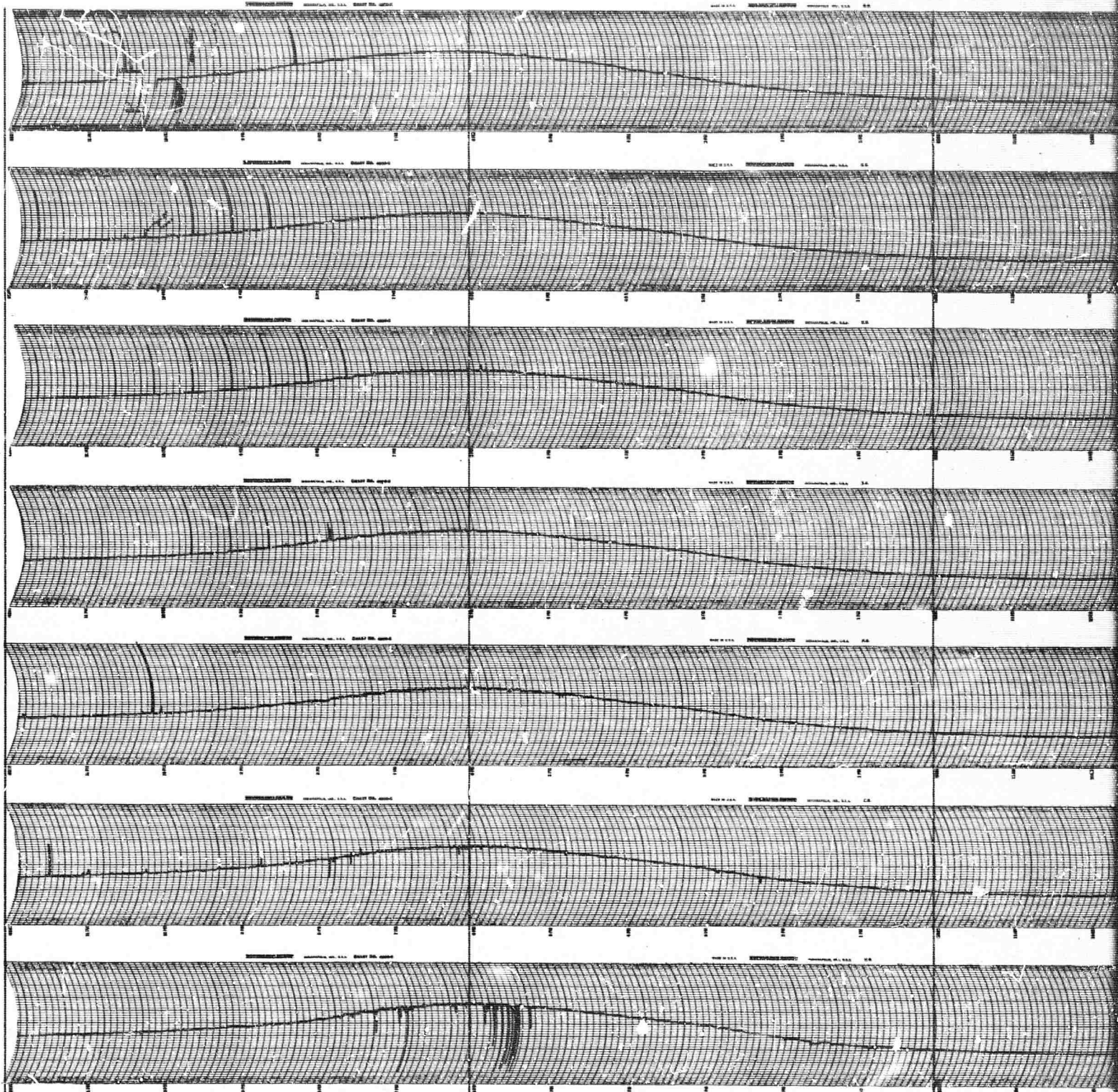
0000

UNIVERSAL TIME

CALIFORNIA

30 mc RIOMETER

2



2400

1800

NOON

UNIVERSAL TIME  
NUFF CREEK CALIFORNIA 30 mc

1

JAN.  
1965

25

26

27

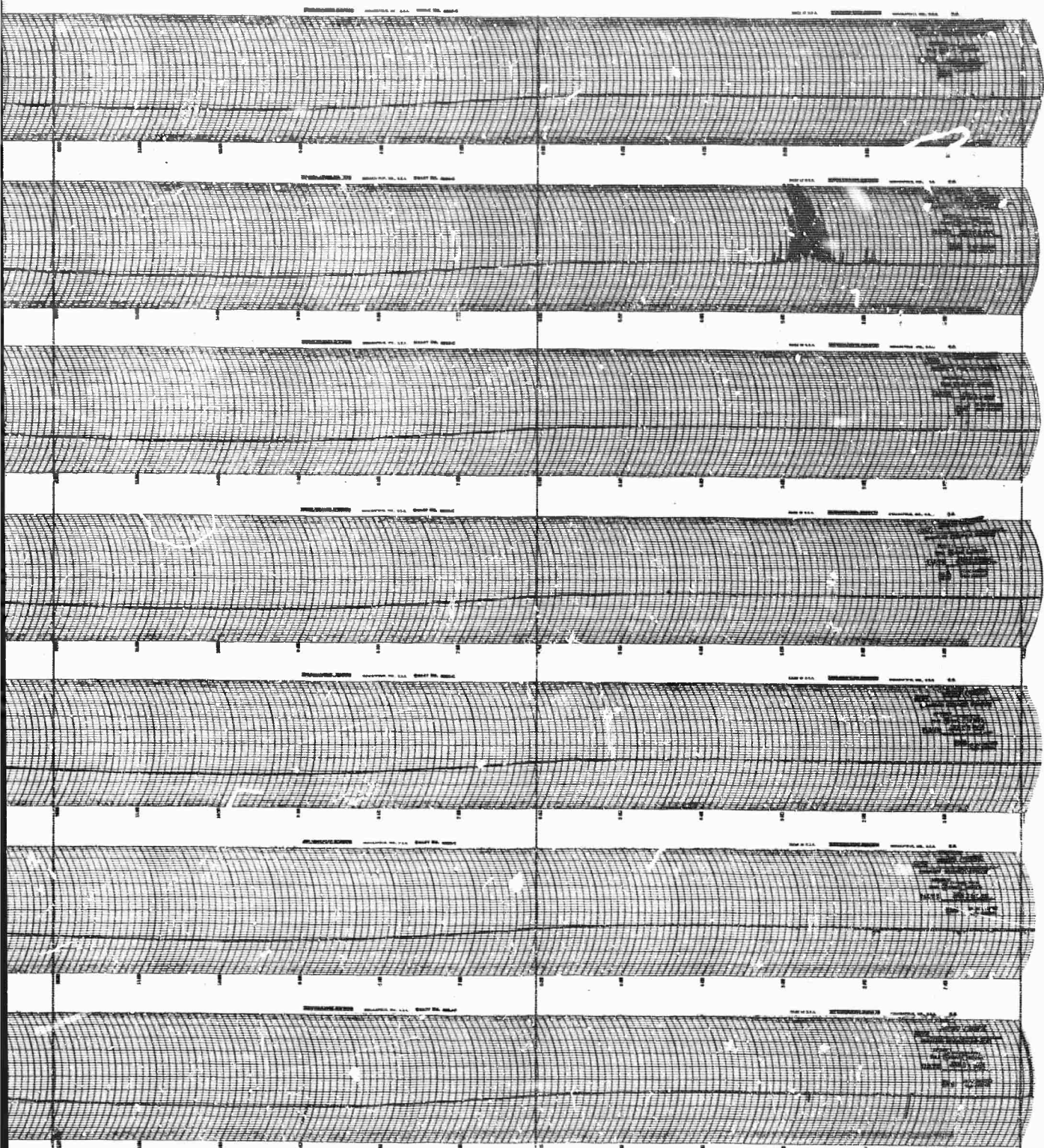
28

29

30

31

SUNDAY



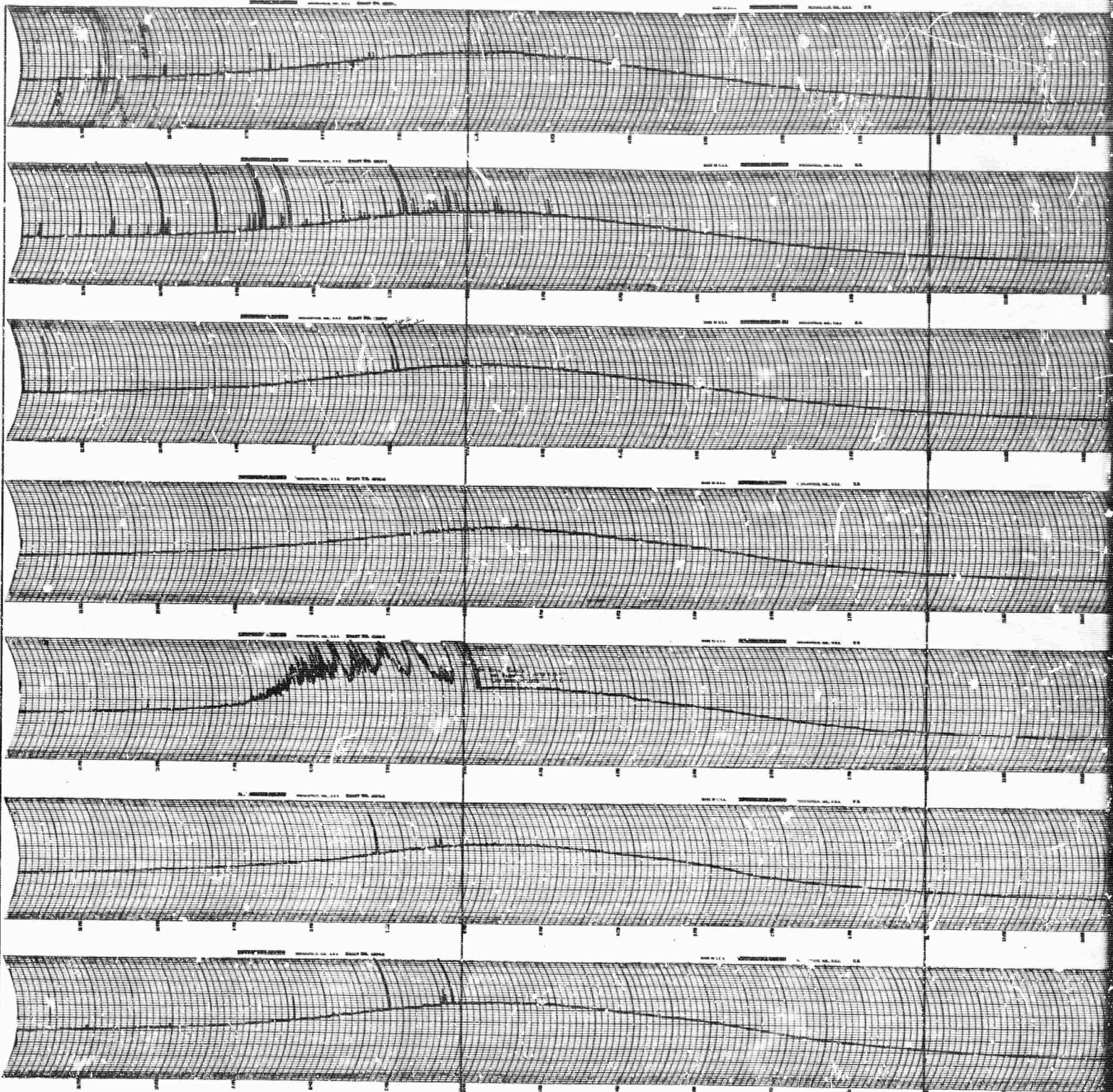
NOON  
UNIVERSAL TIME  
CORNIA

0600

0000

30 mc RIOMETER

2



2400

1800

NOON

NUFF CREEK  
UNIVERSAL TIME  
CALIFORNIA 30 mc

1

FEB.  
1965

1

2

3

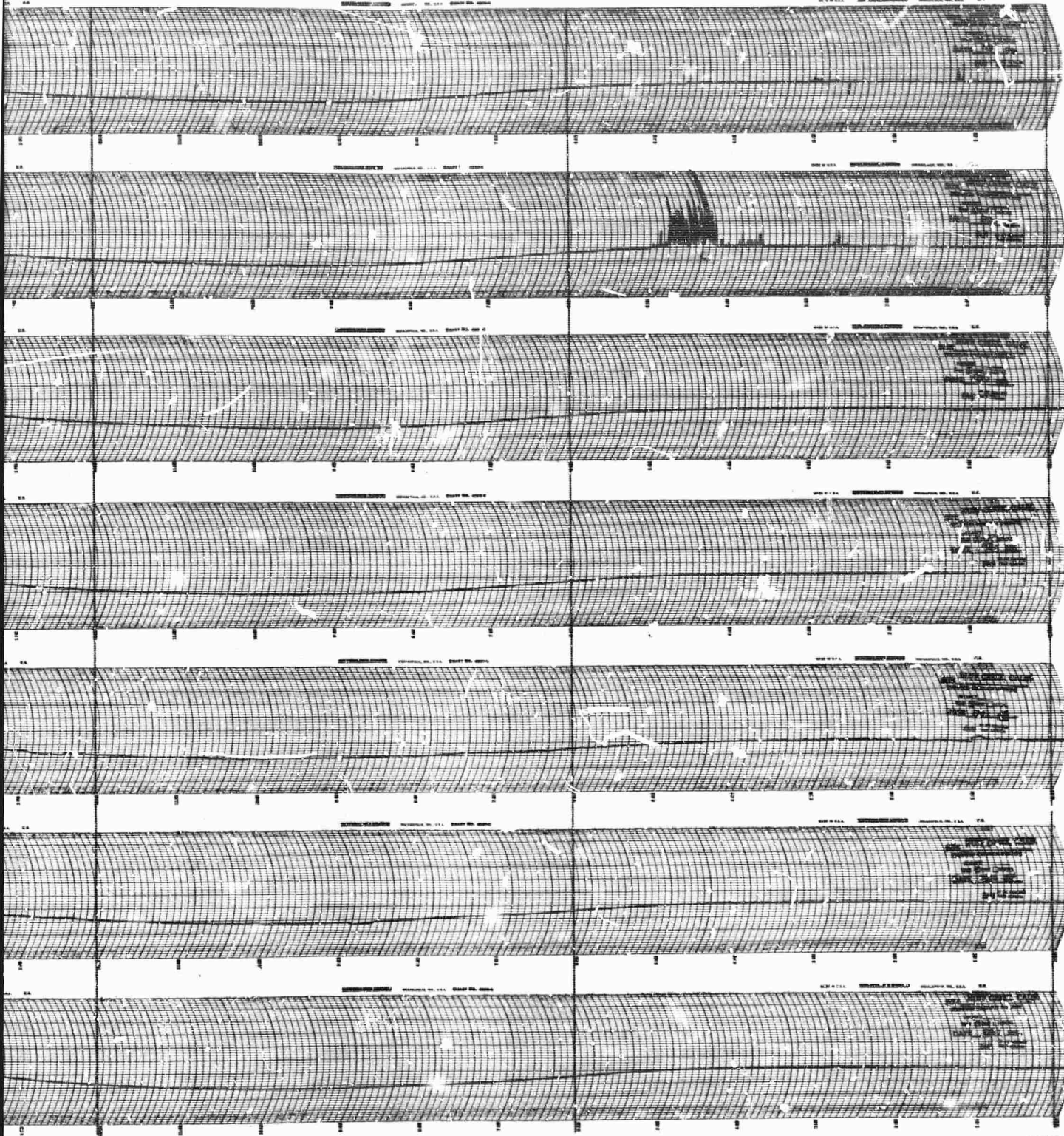
4

5

6

7

SUNDAY



NOON

0600

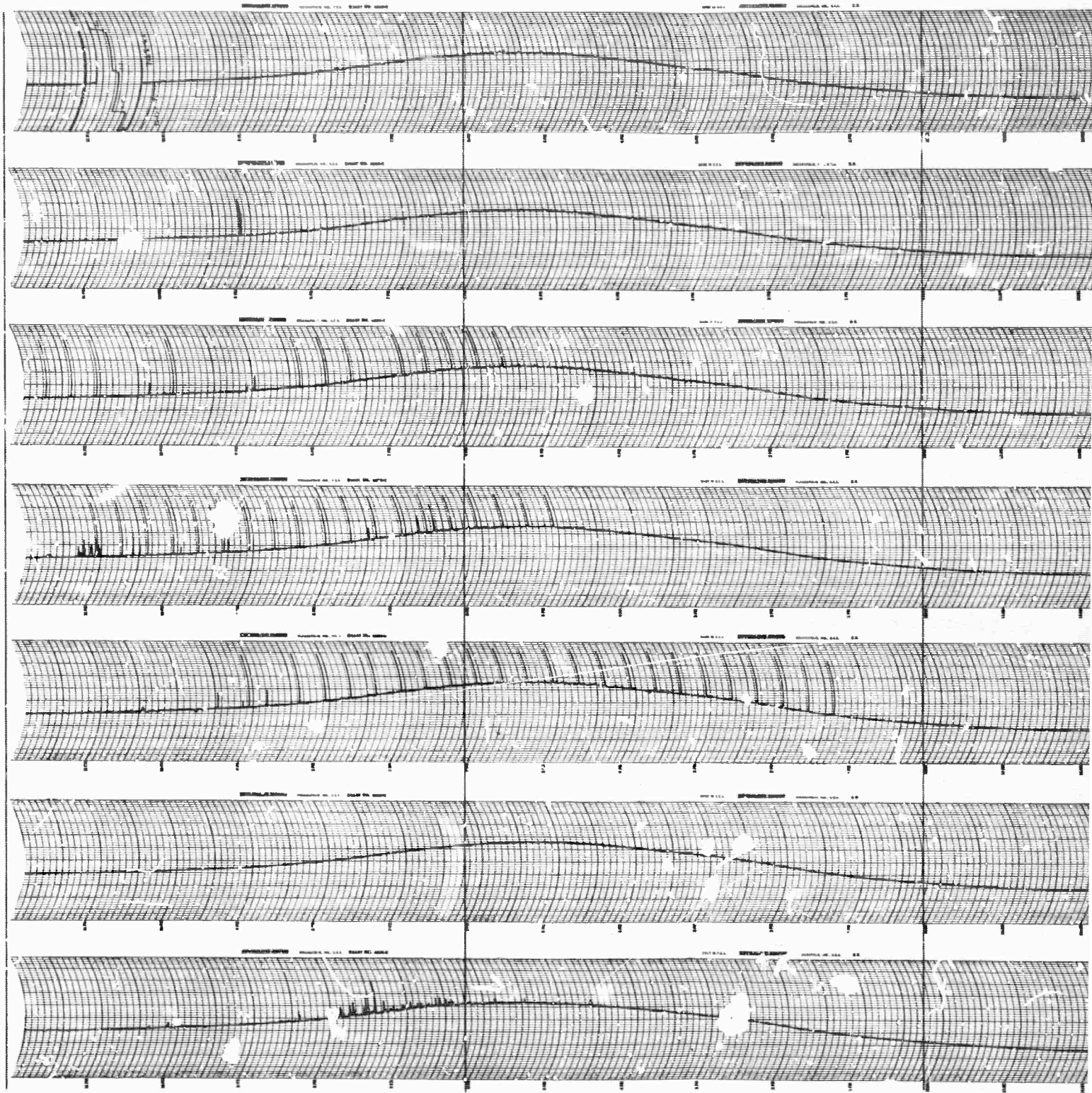
0000

UNIVERSAL TIME

CALIFORNIA

30 mc RIOMETER

2



2400

1800

NOON

UNIVERSAL TIME  
NUFF CREEK CALIFORNIA 30 m

/

FEB.  
1965

8

9

10

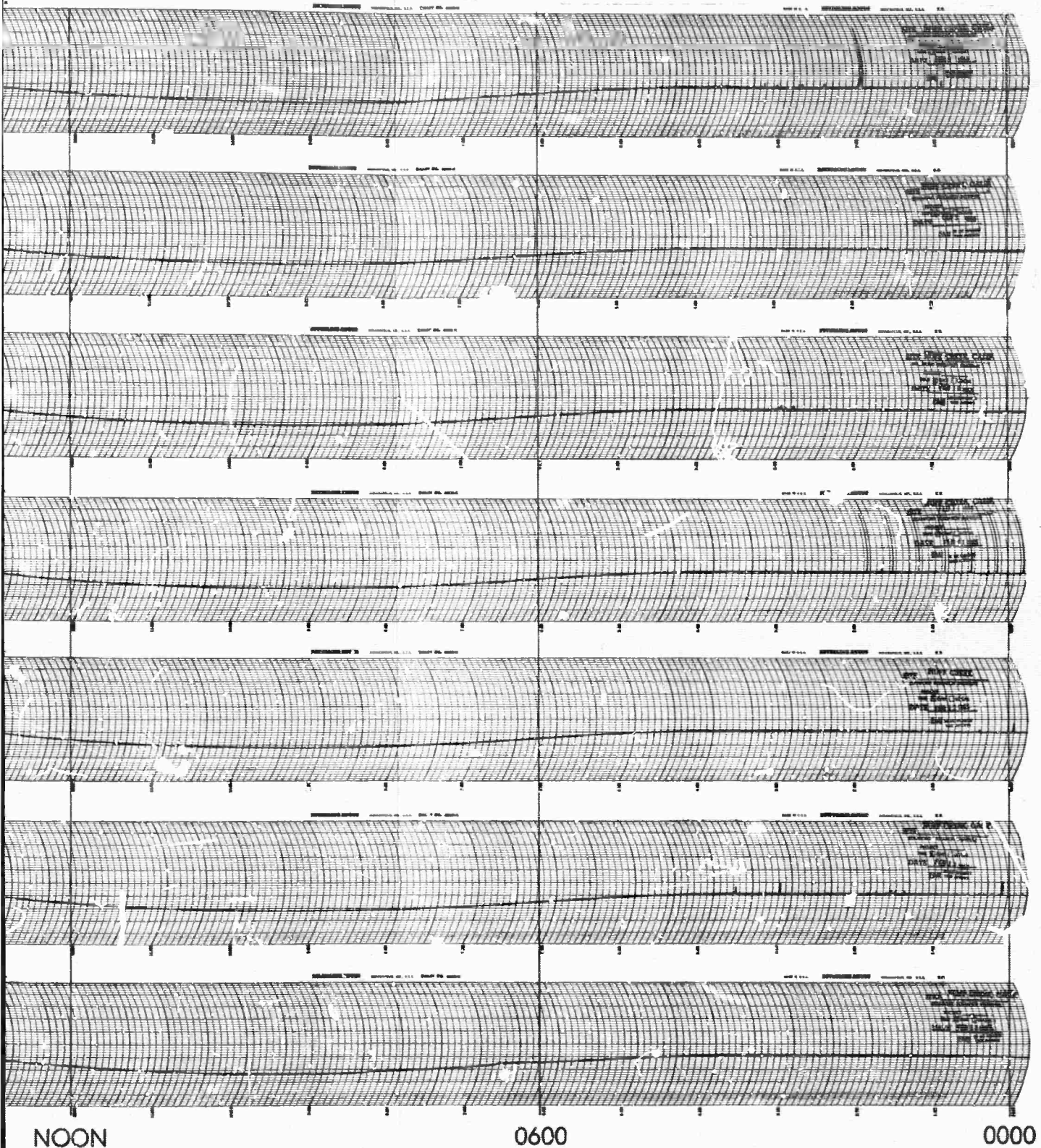
11

12

13

14

SUNDAY



NOON

0600

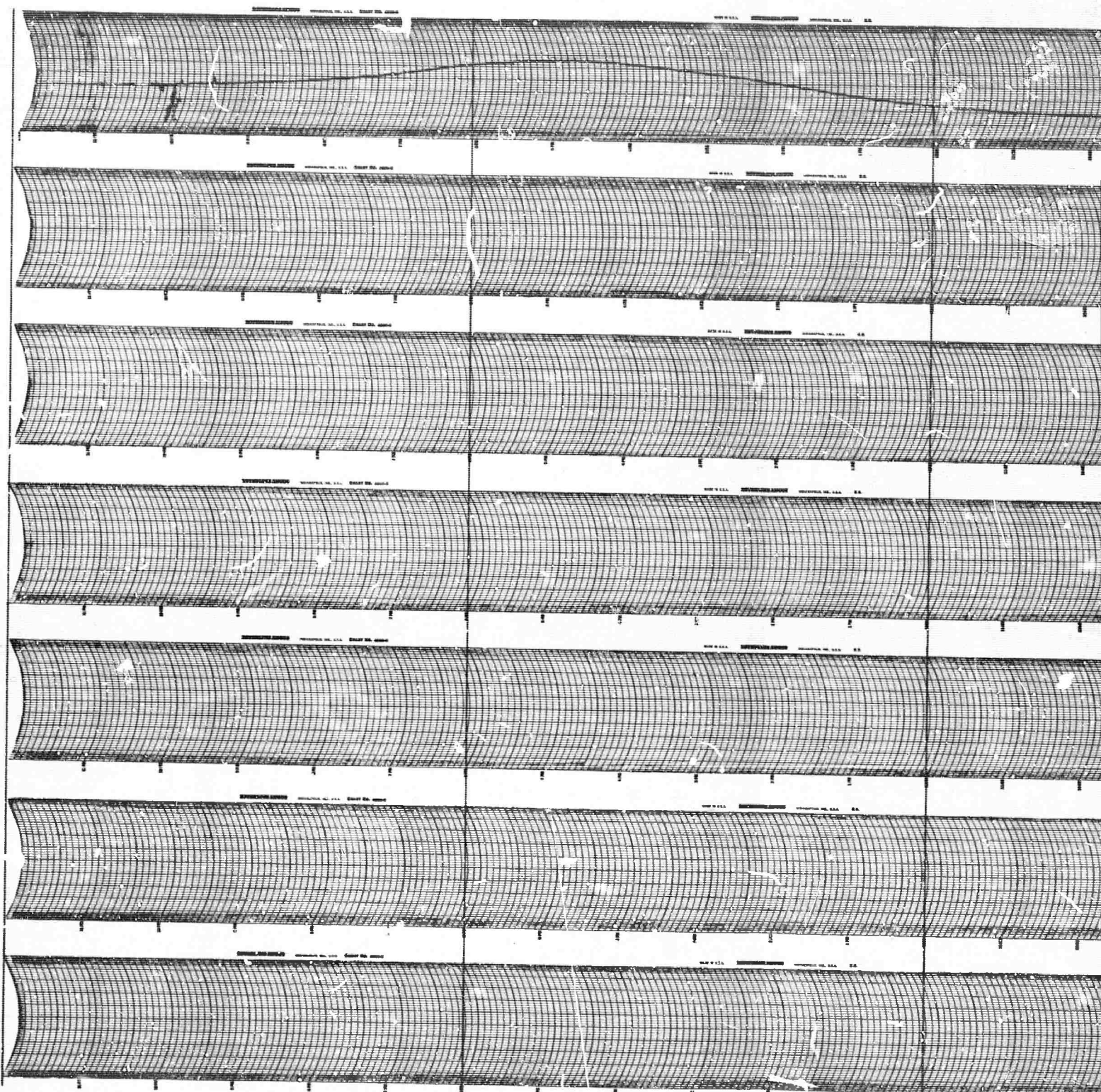
0000

UNIVERSAL TIME

CALIFORNIA

30 mc RIO METER

2



2400

1800

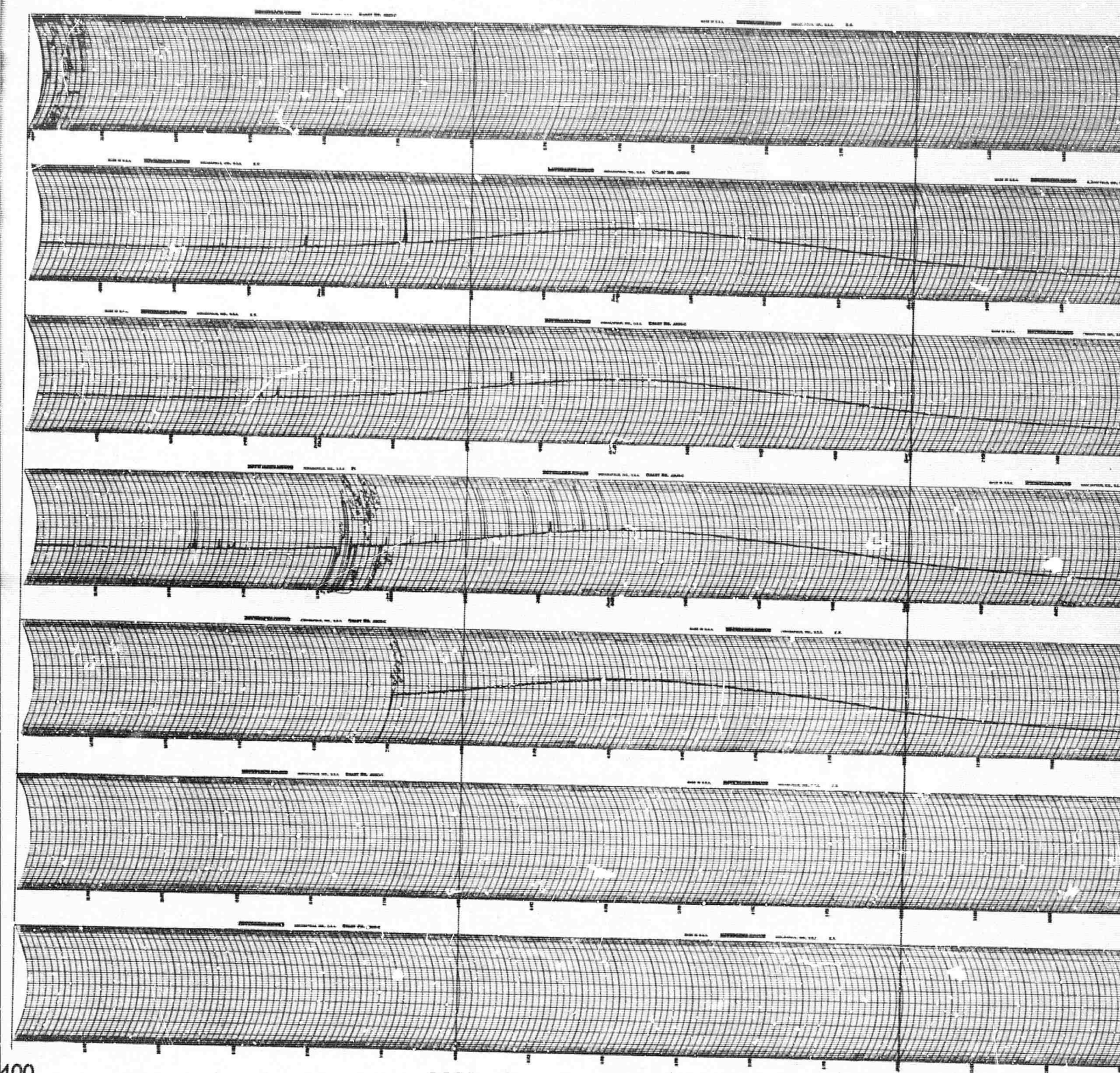
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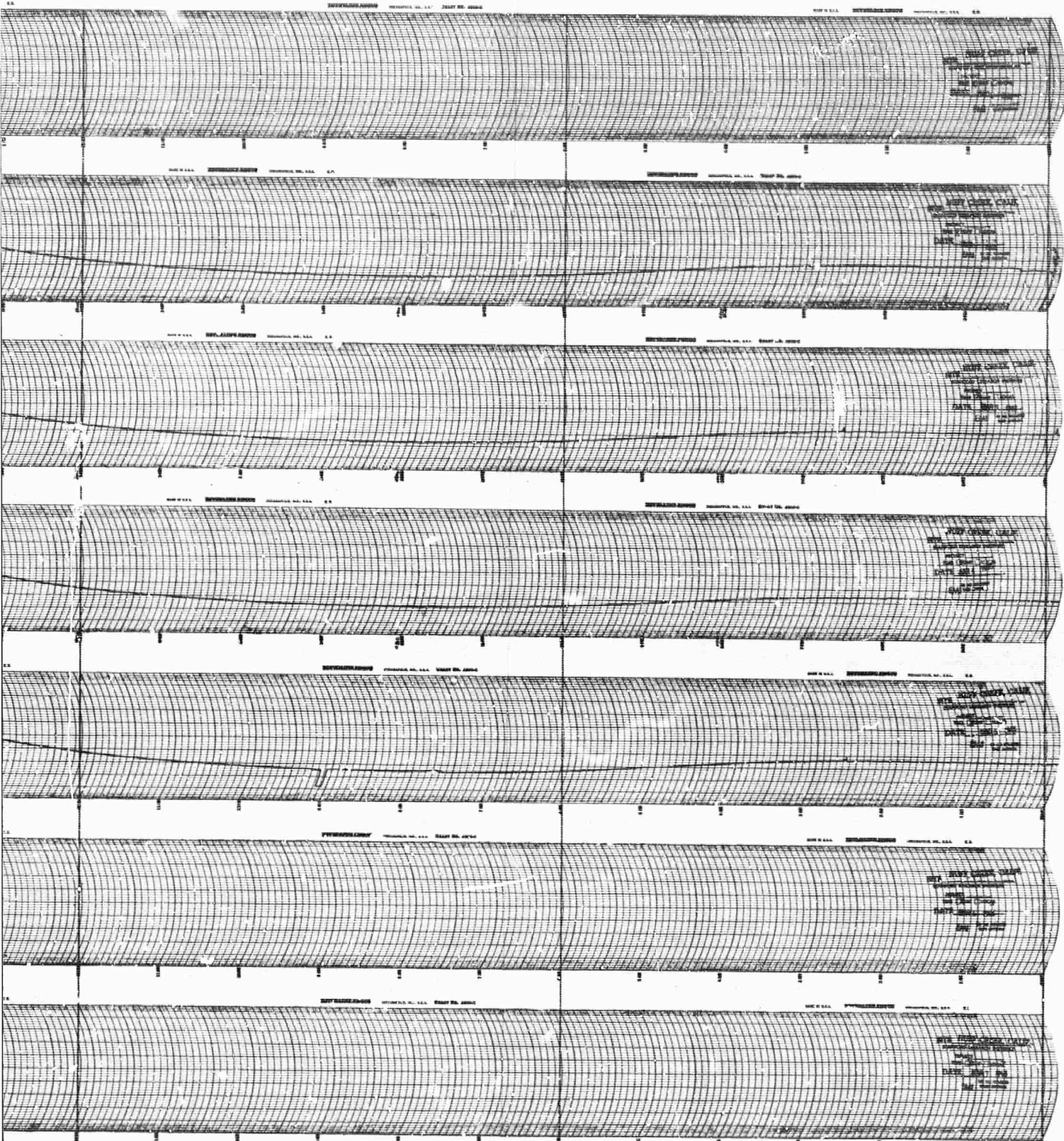
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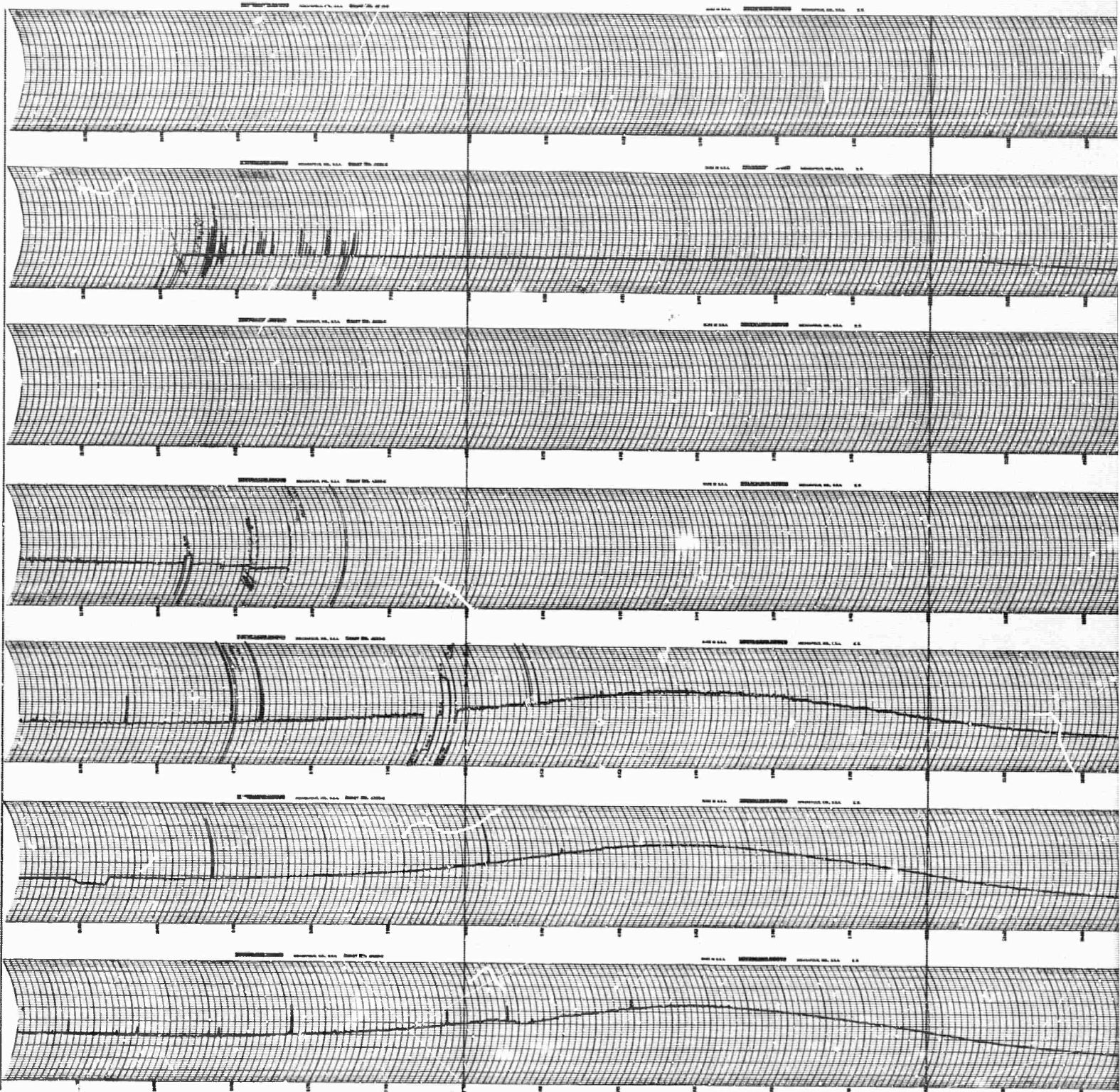
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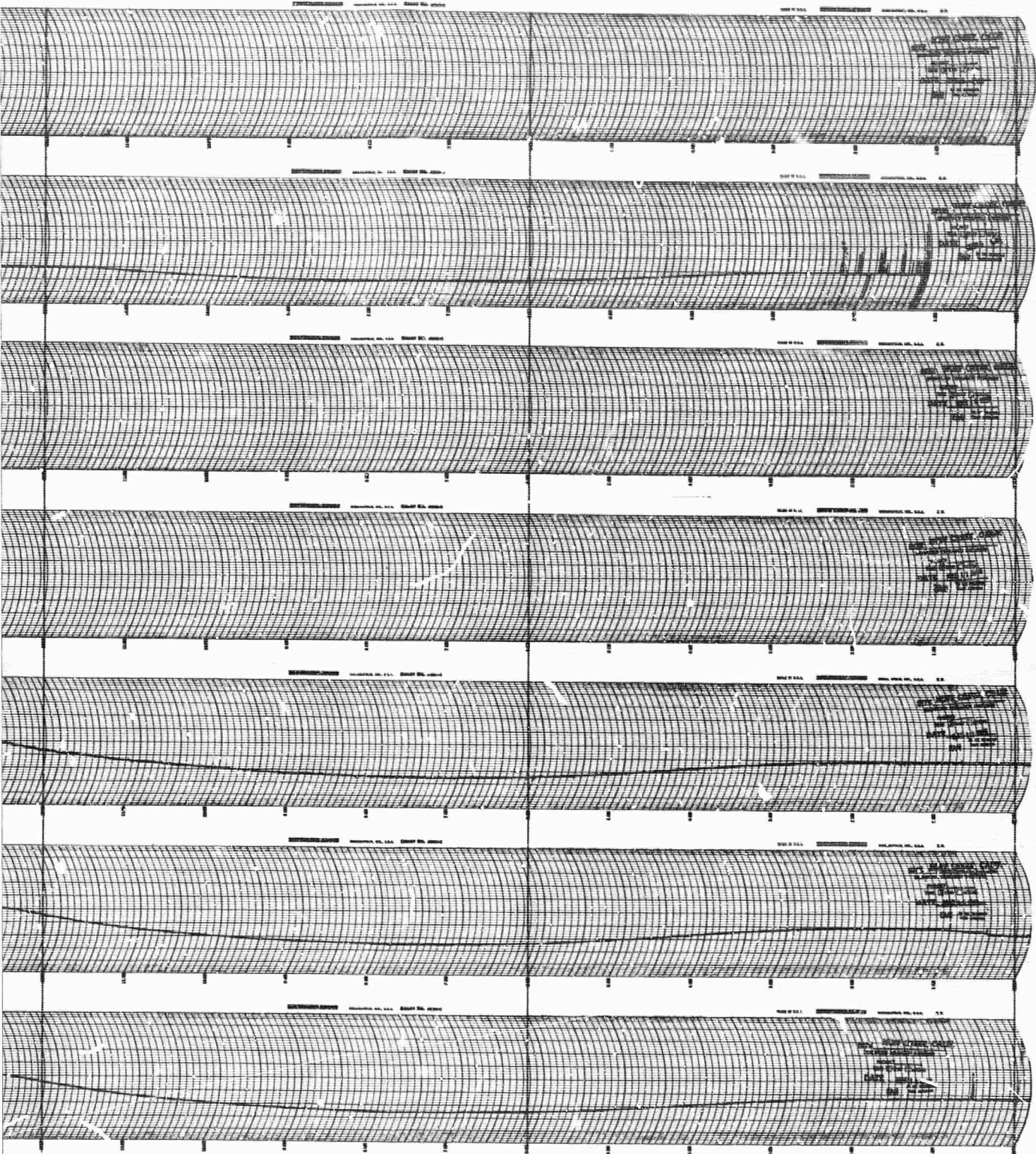
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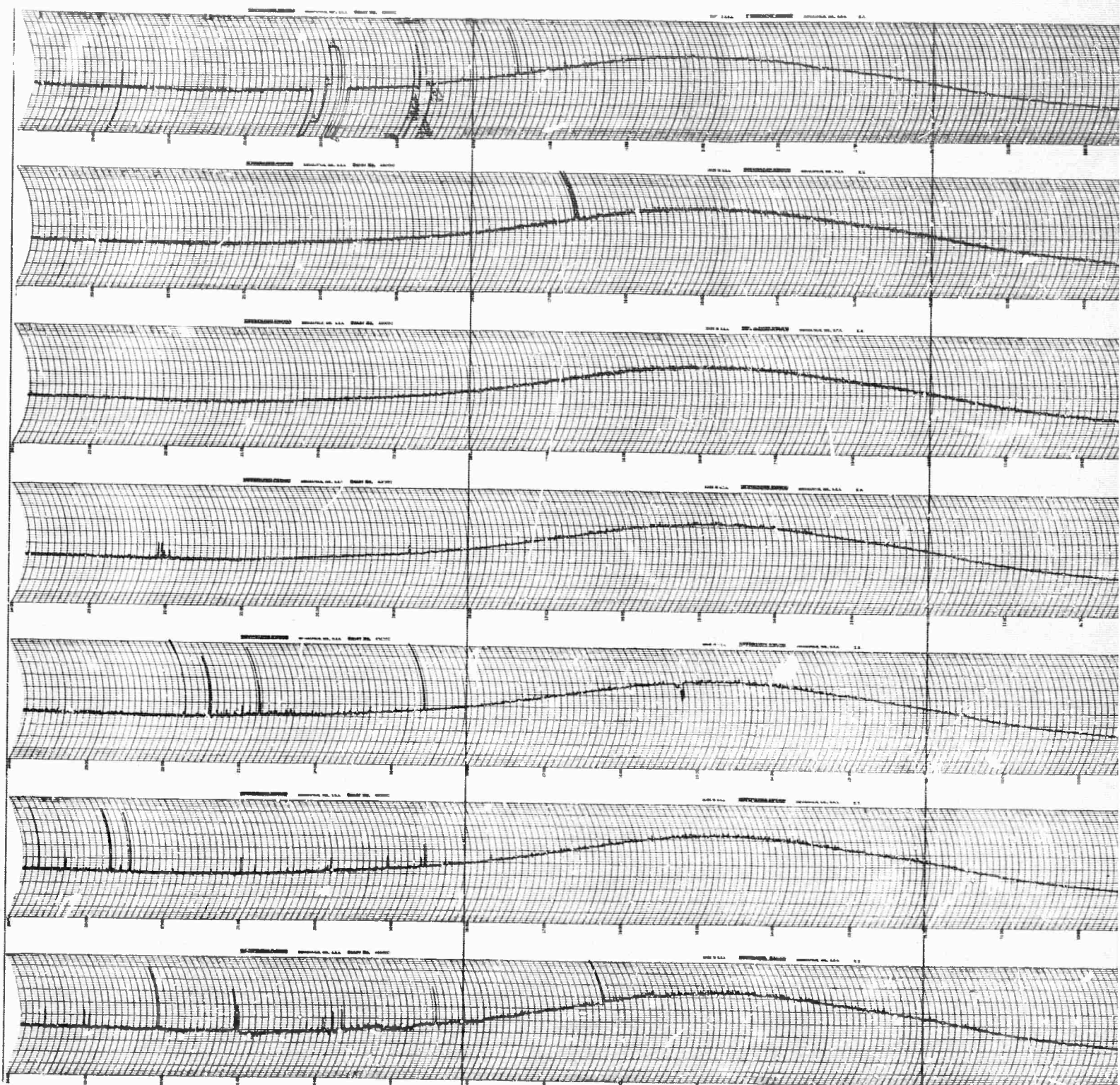


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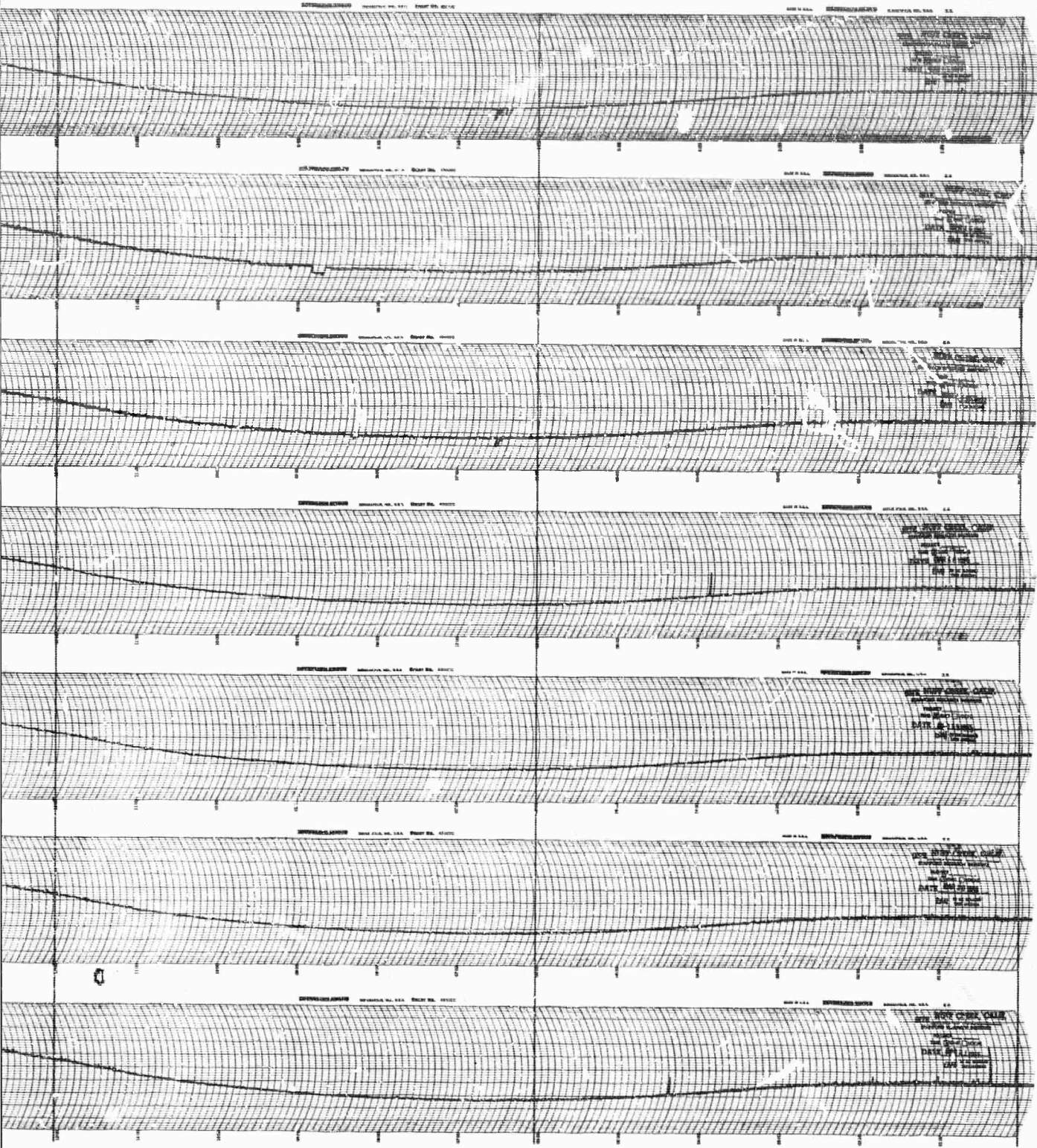
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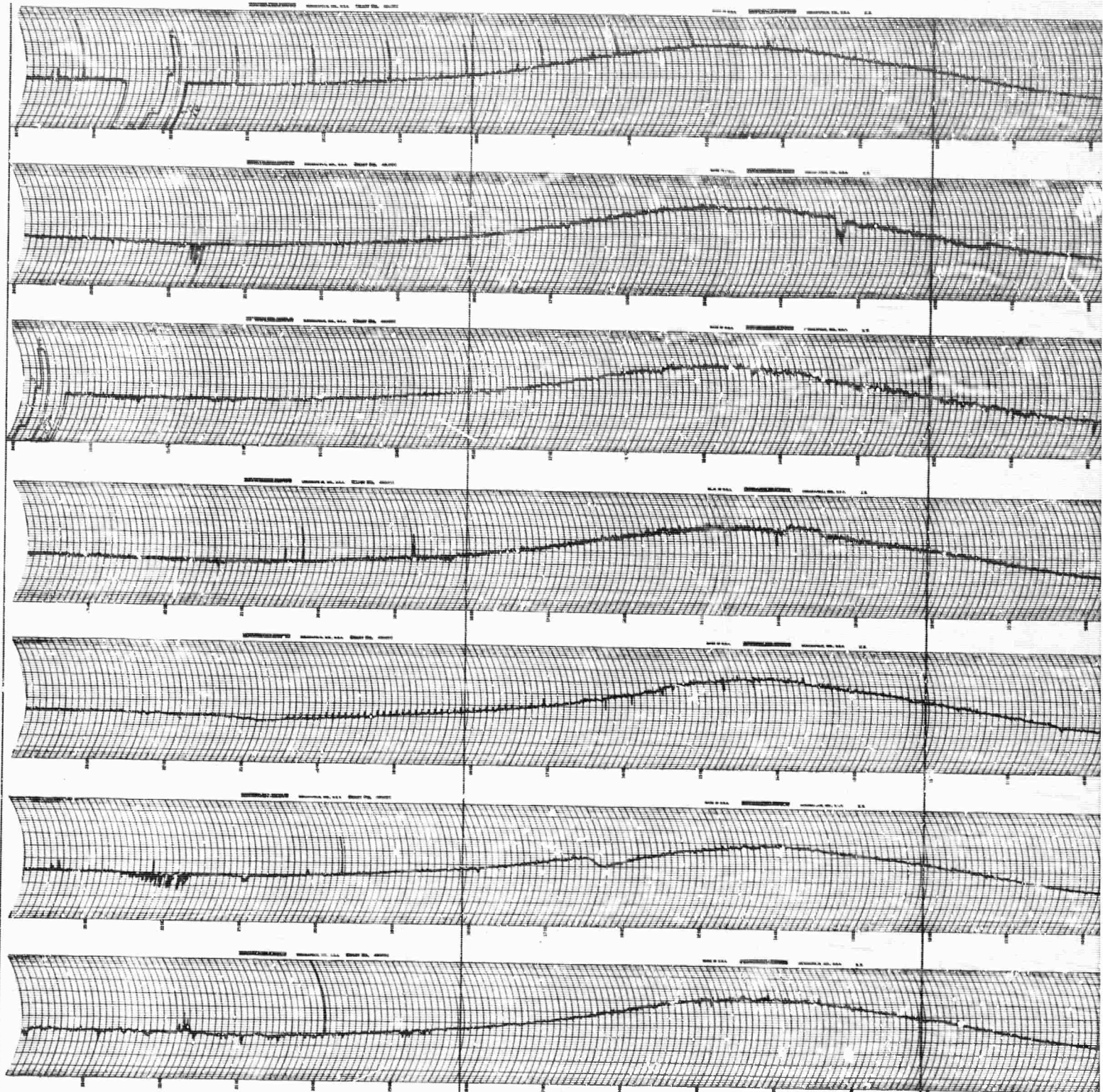
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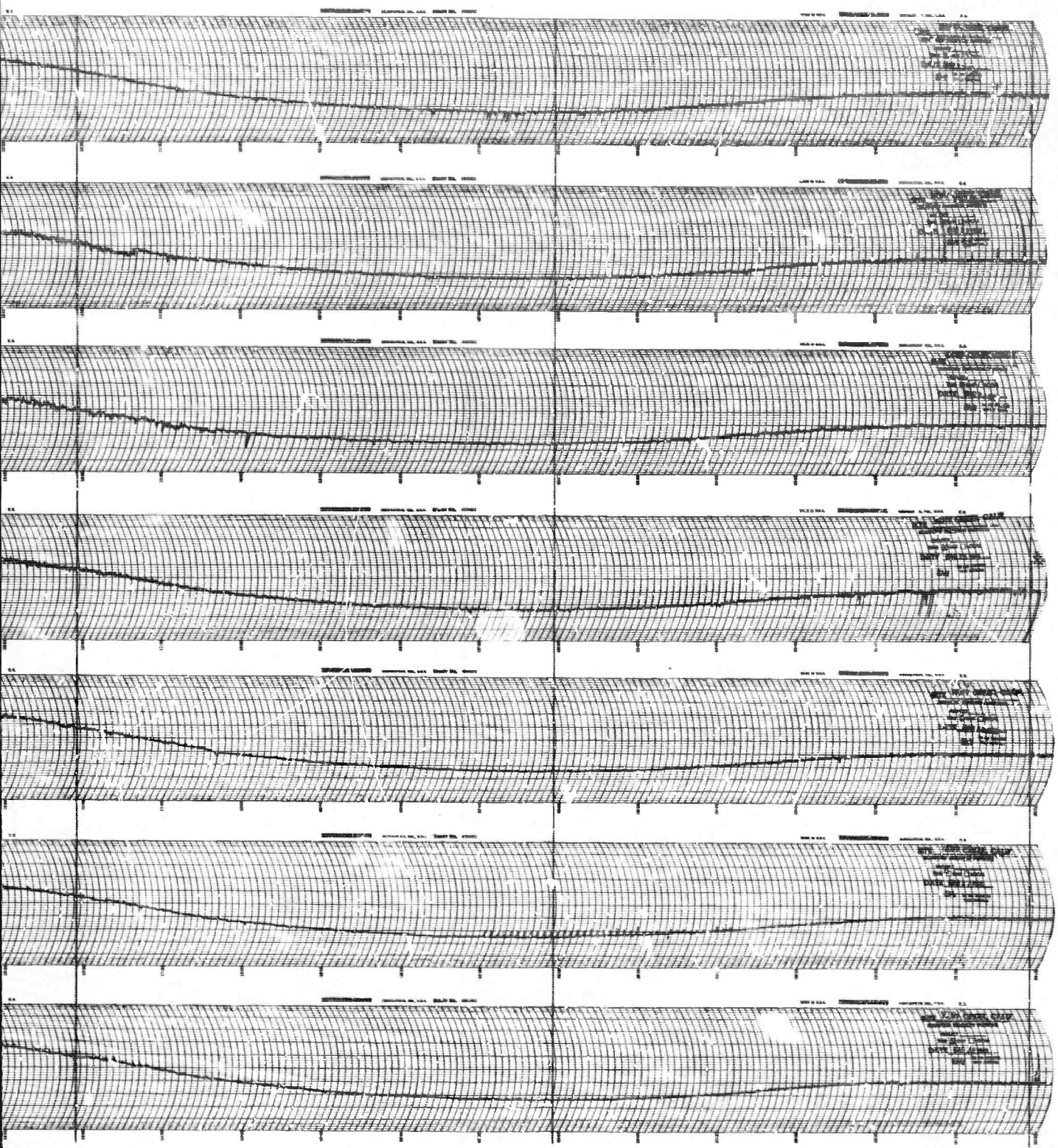
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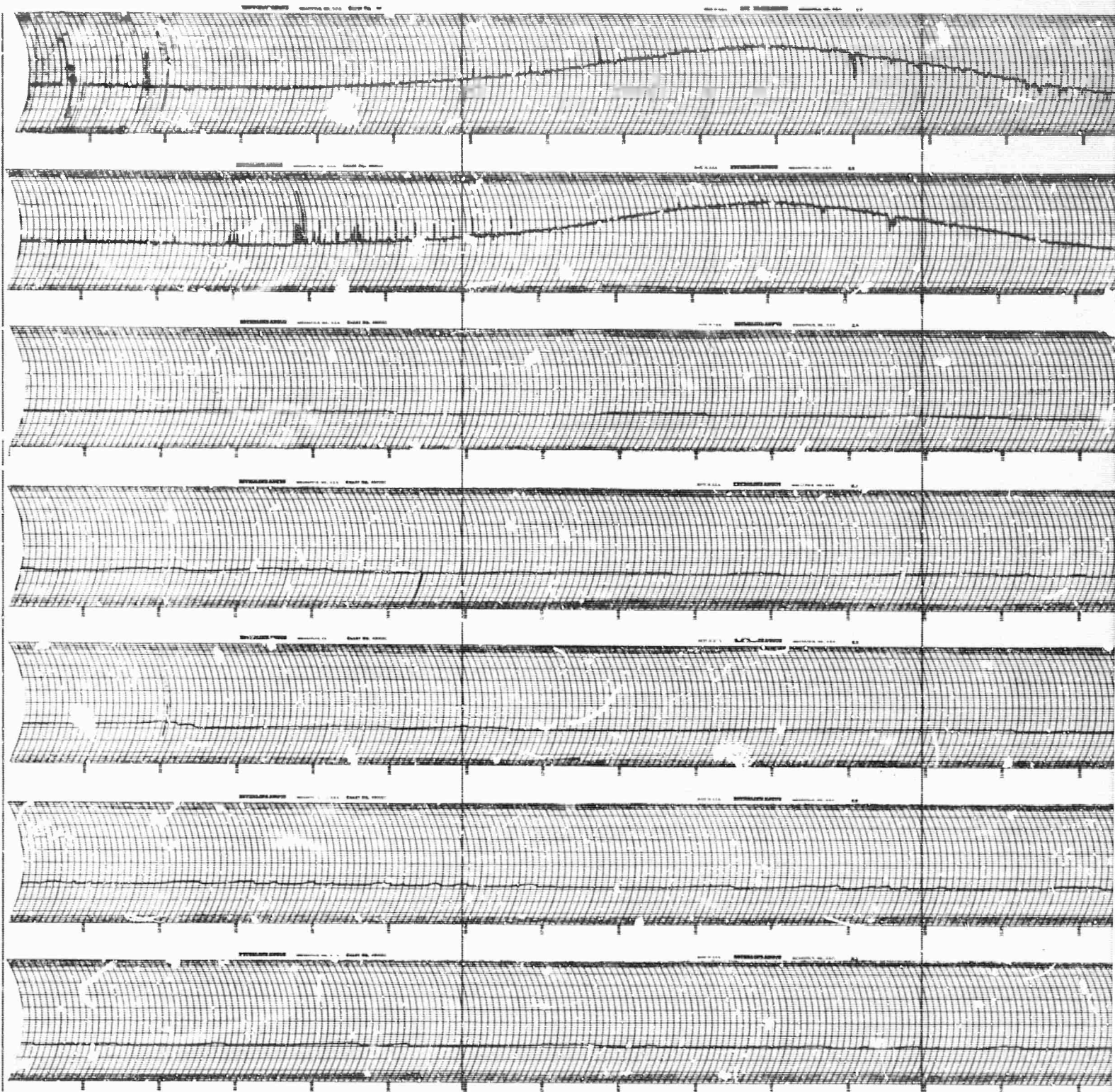
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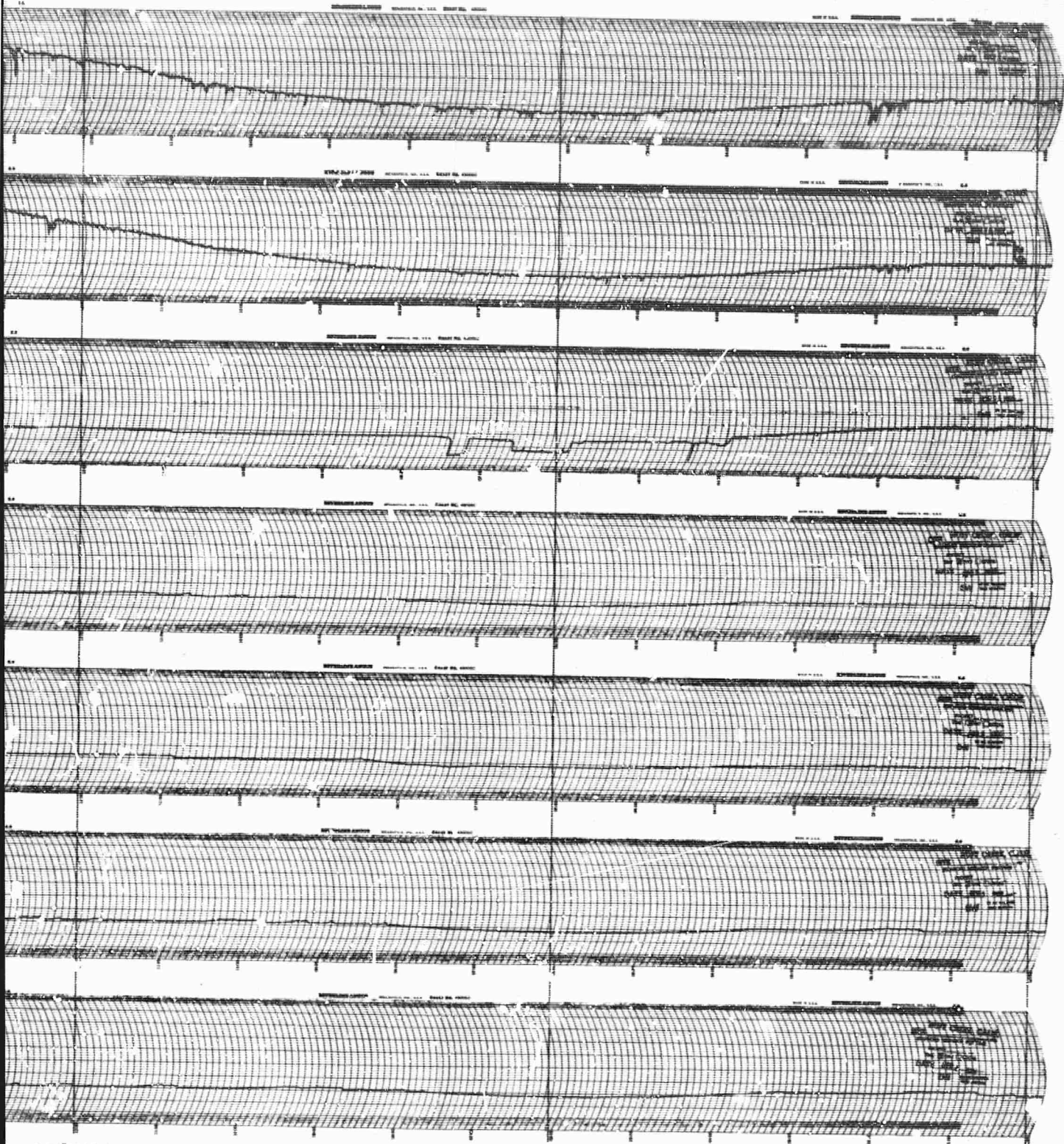
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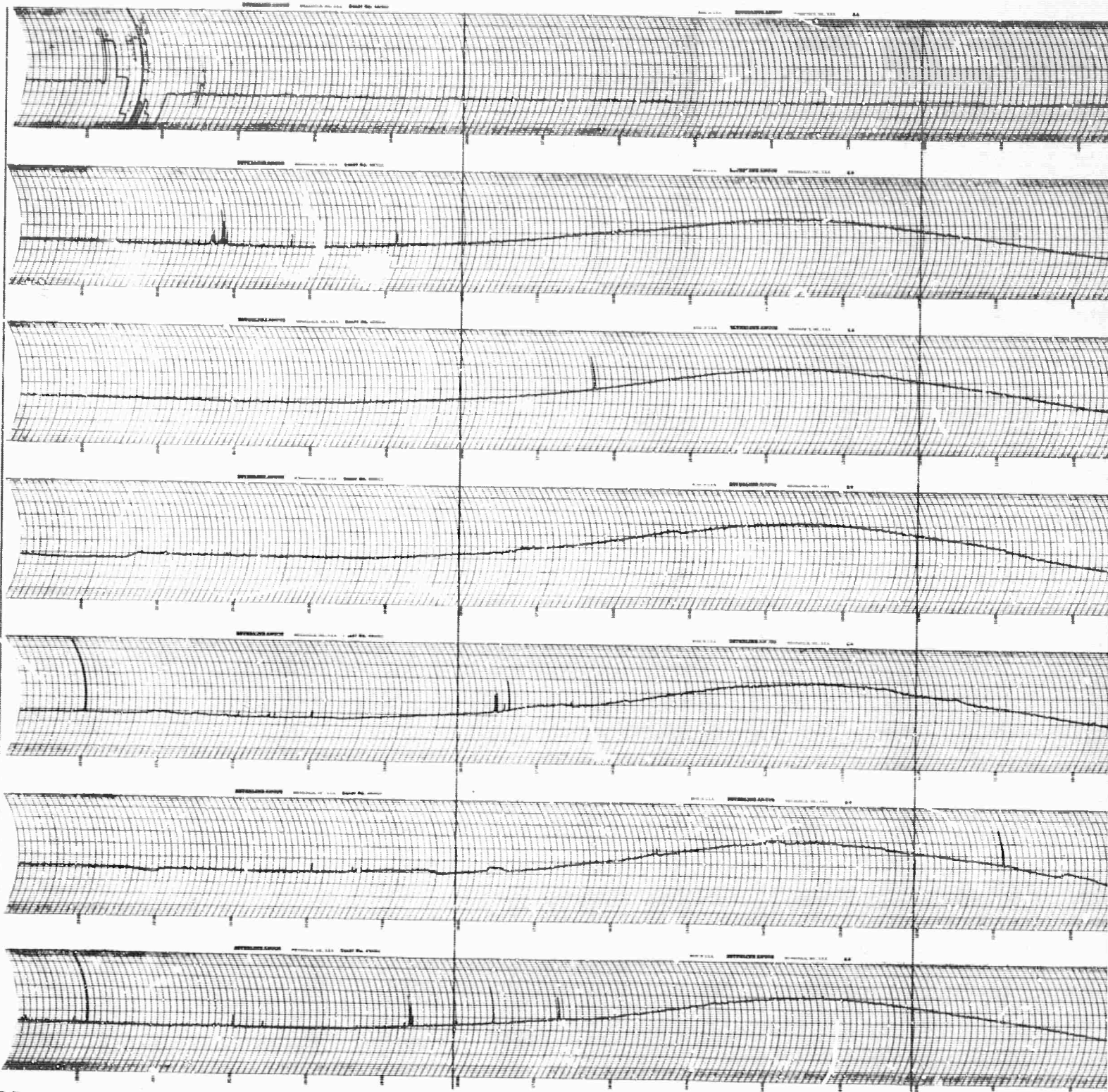
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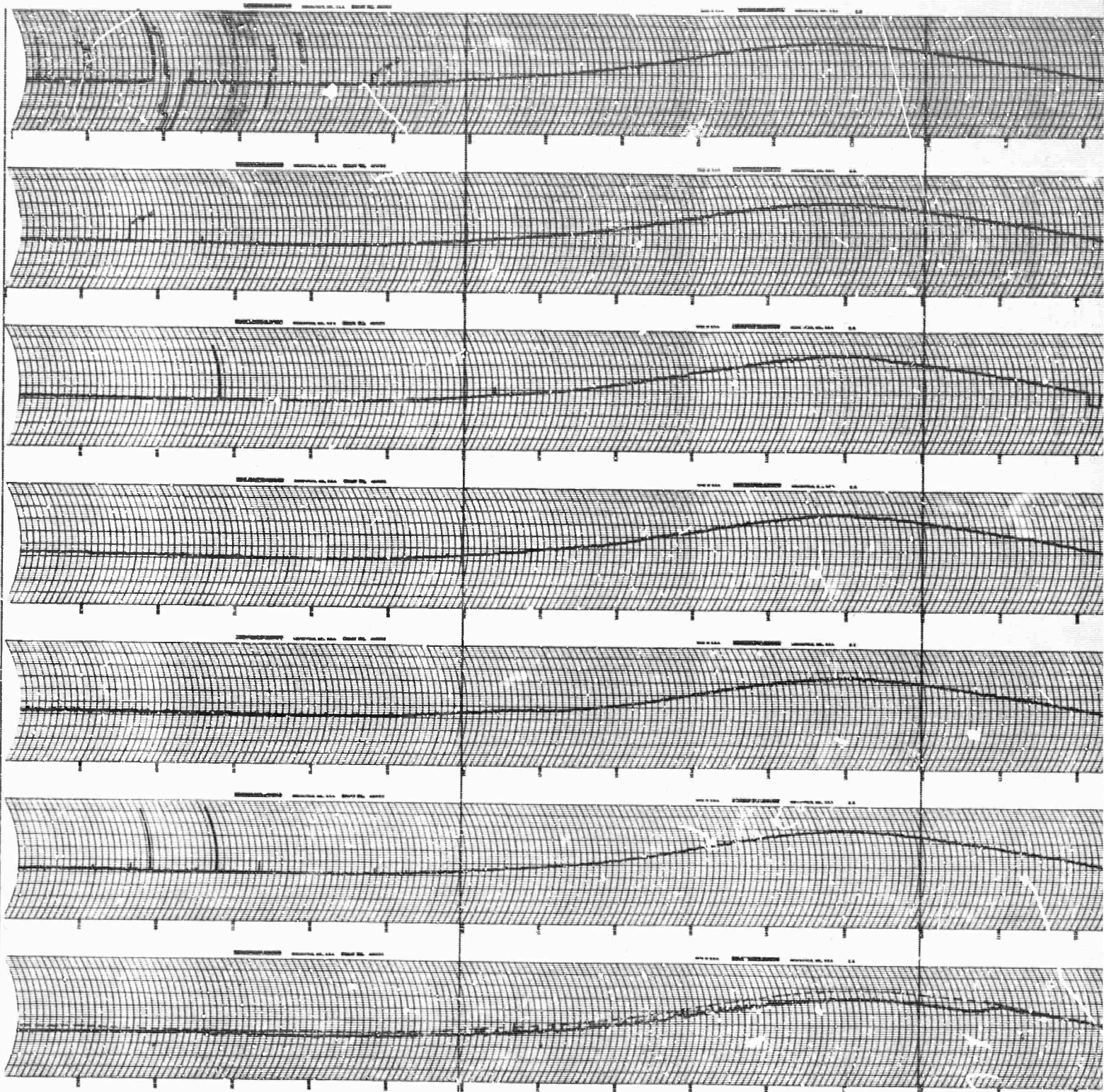
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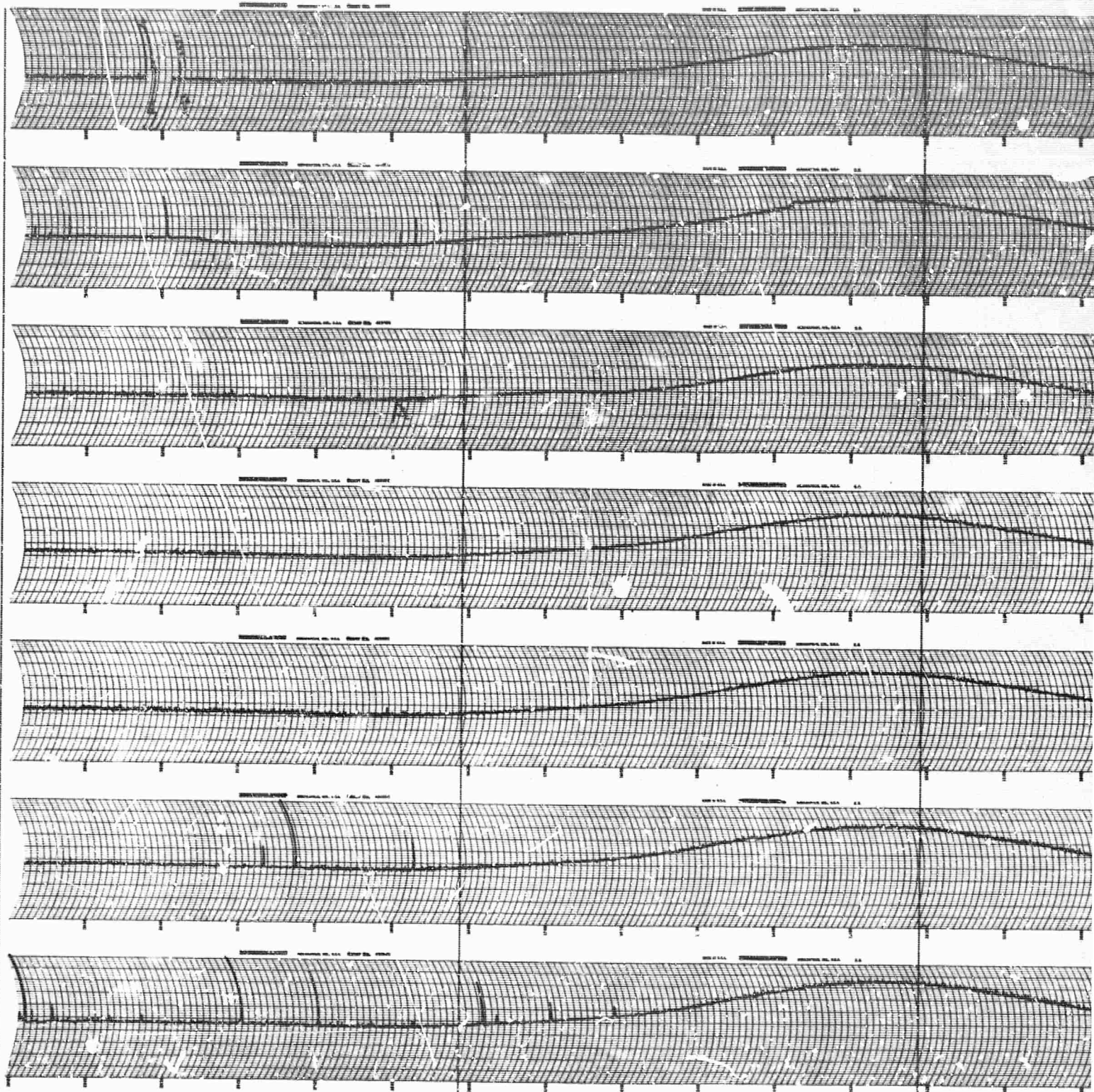
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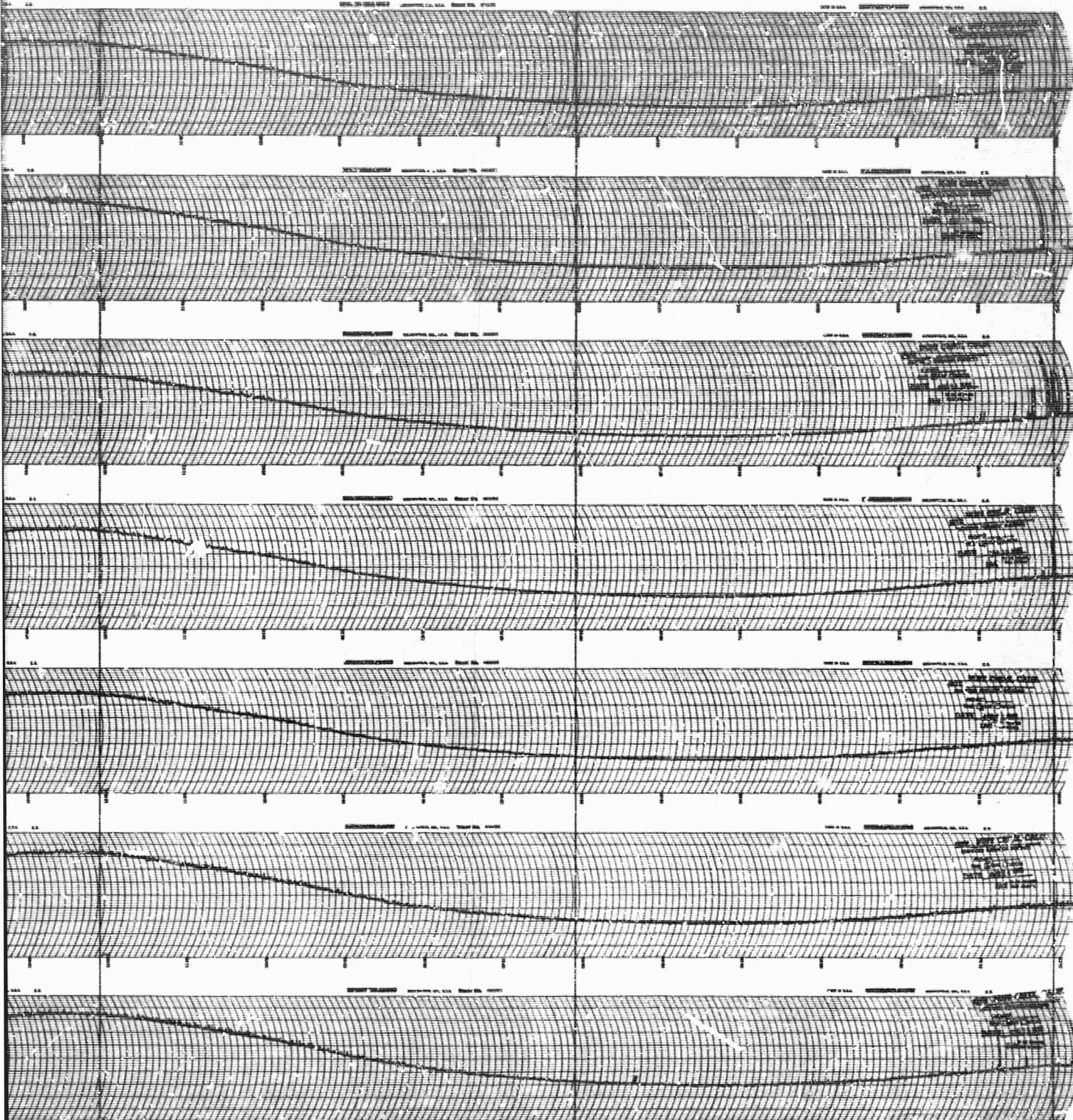
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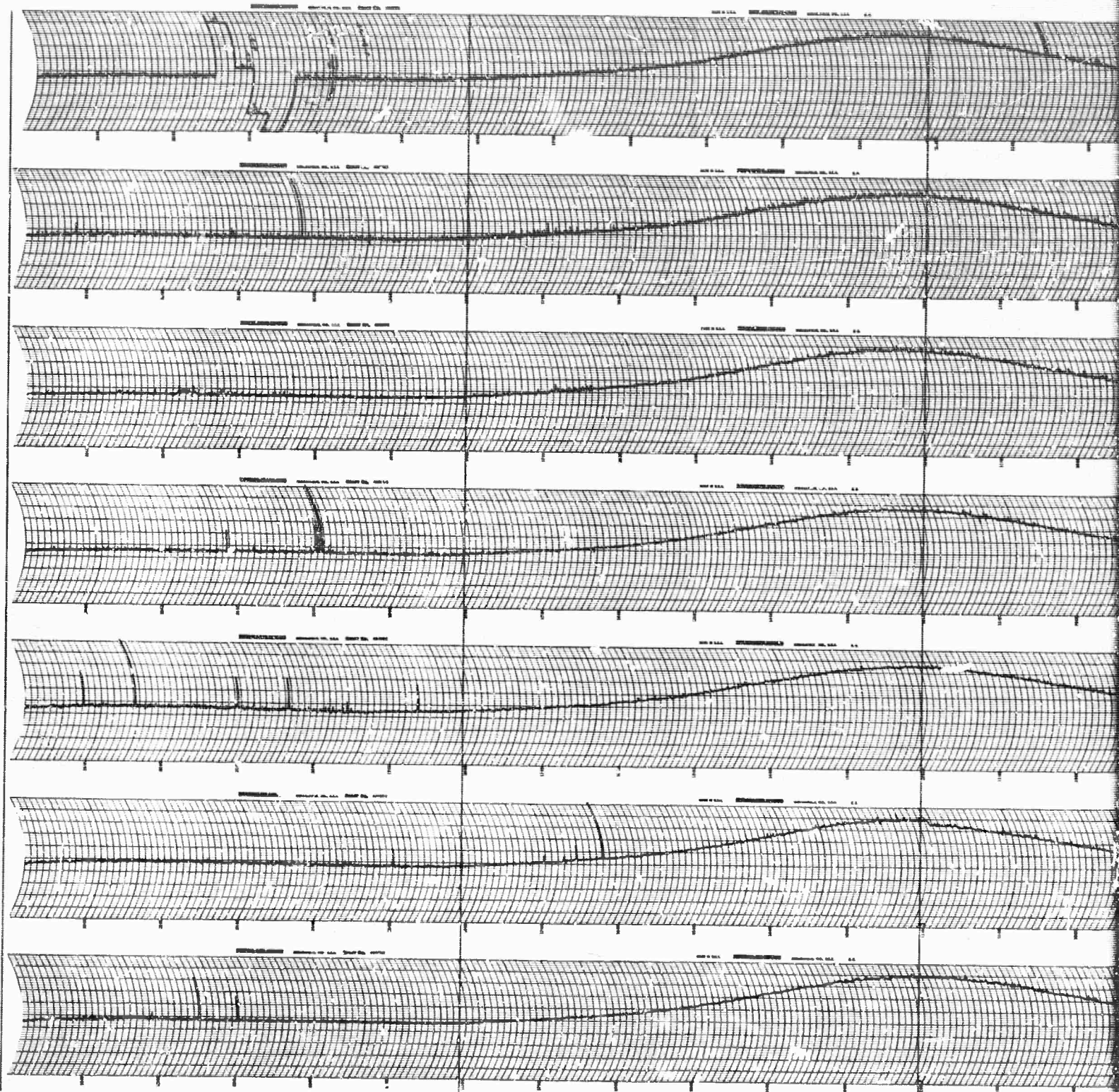
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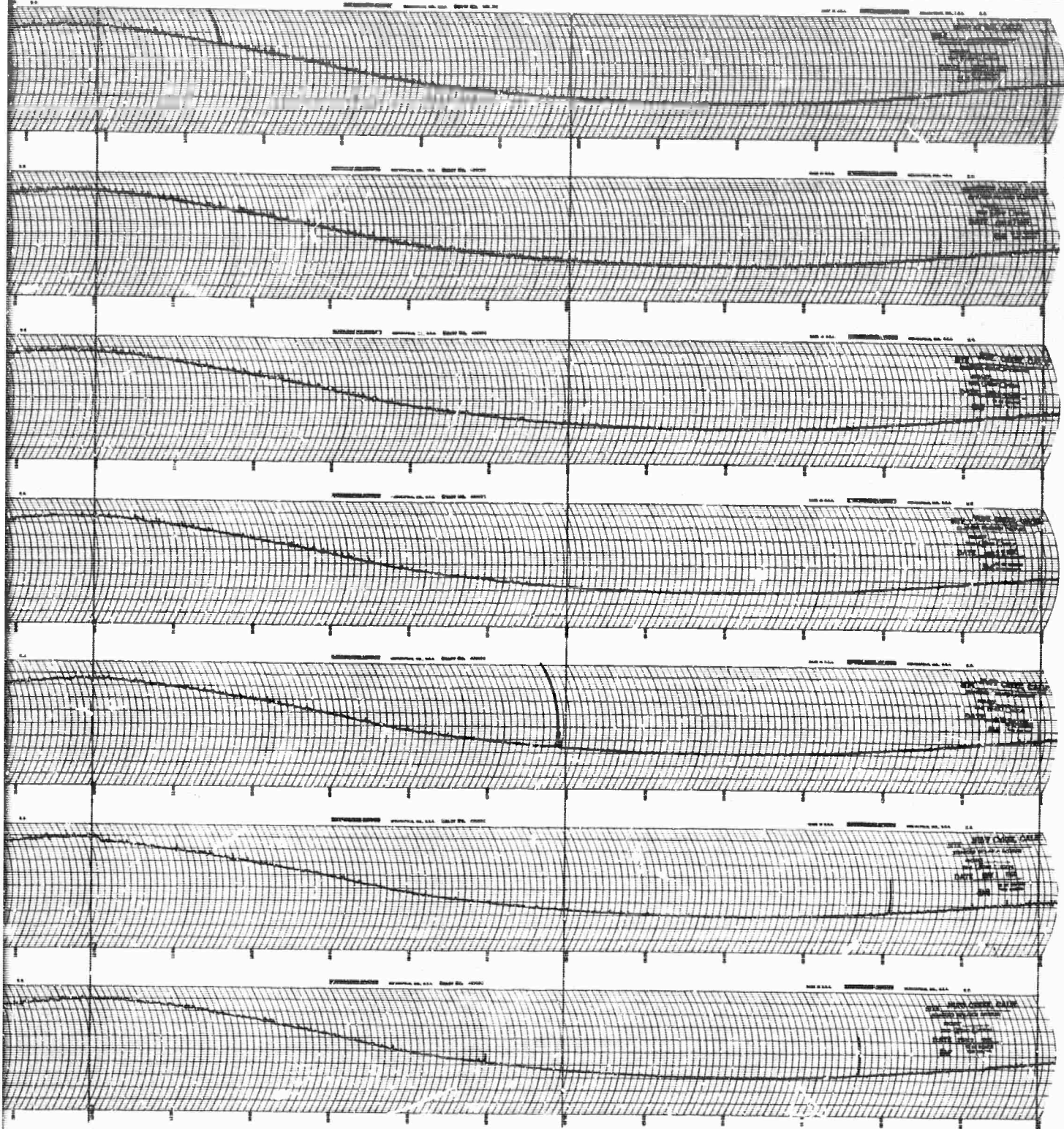
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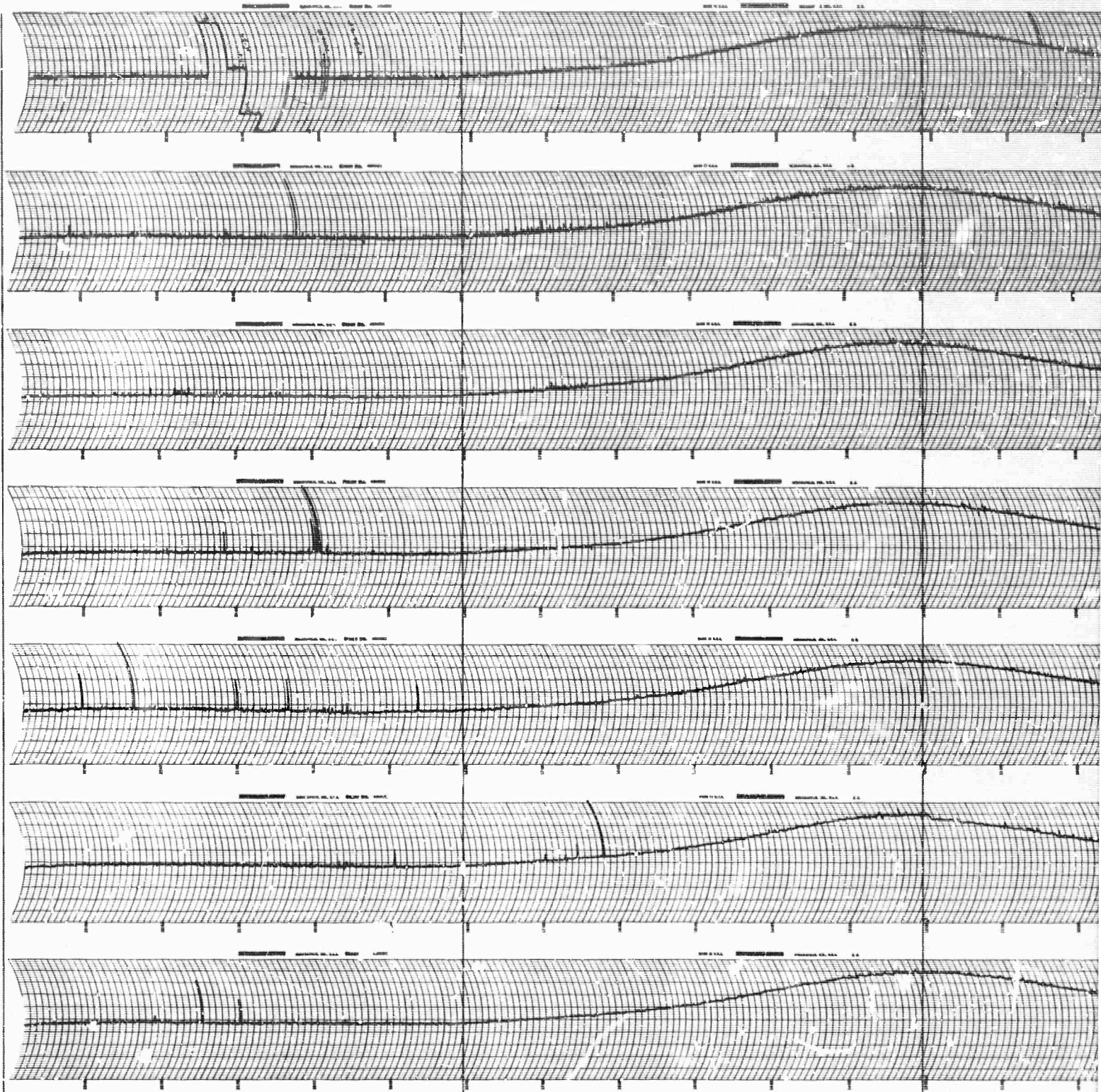
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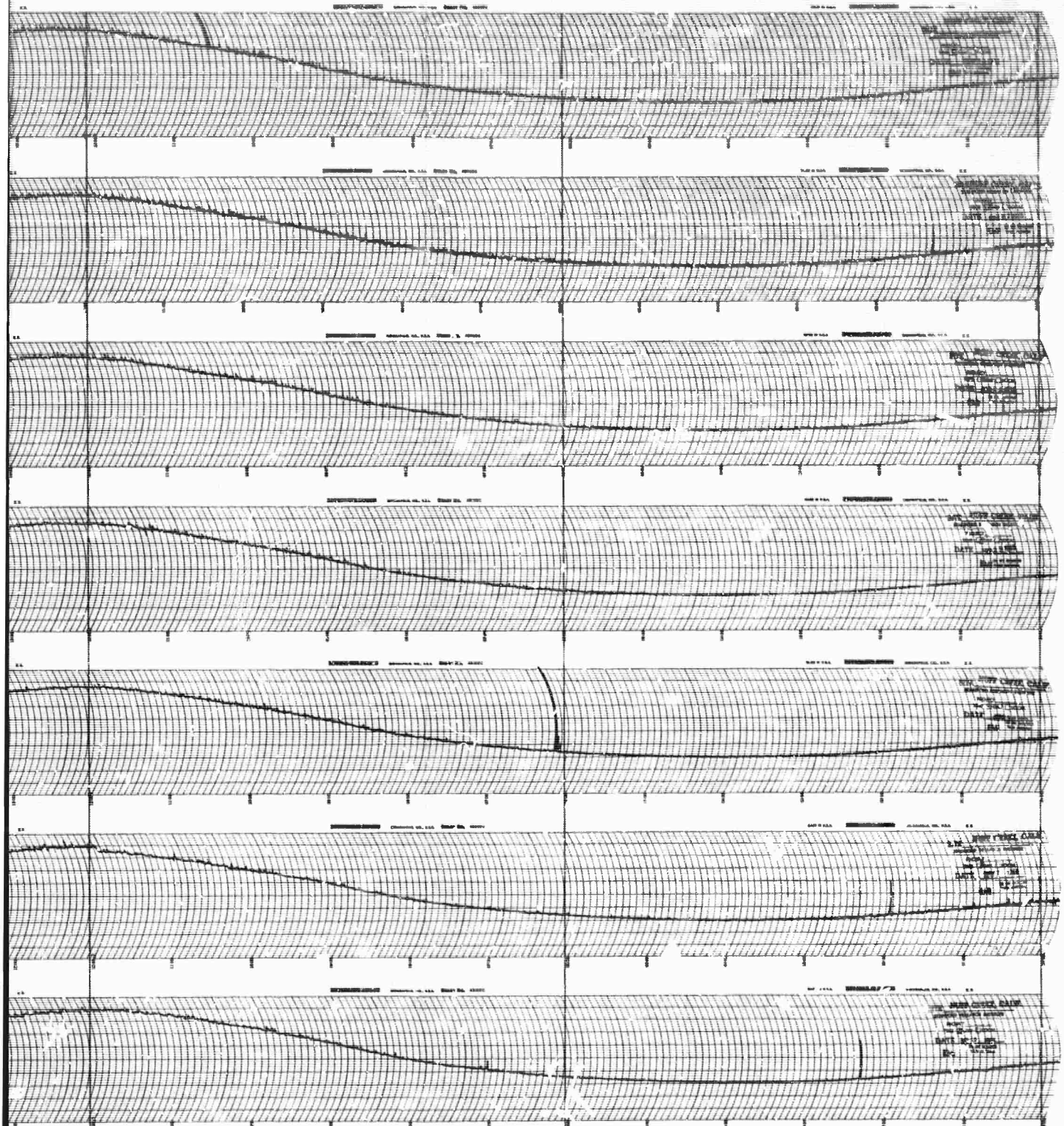
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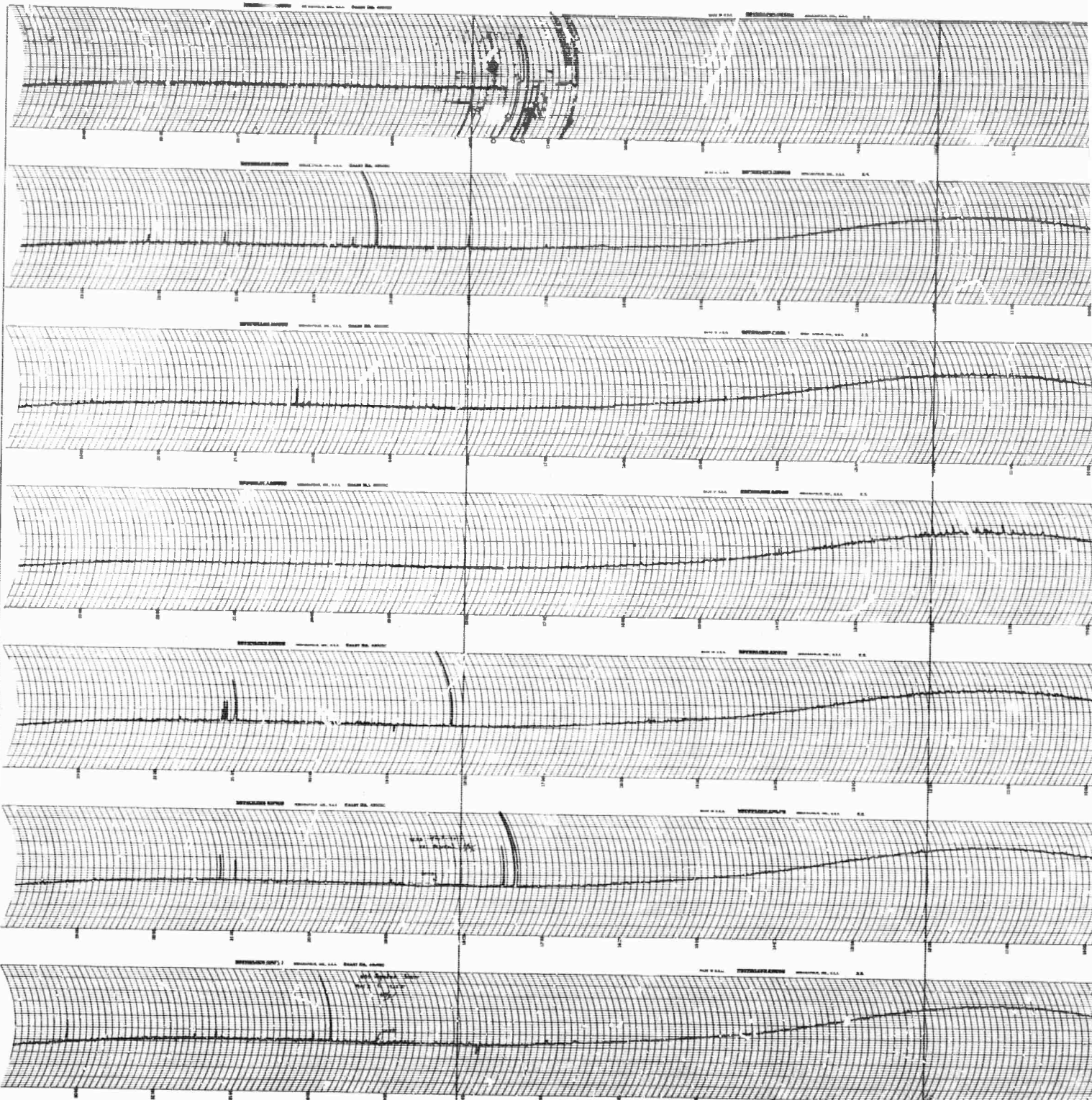
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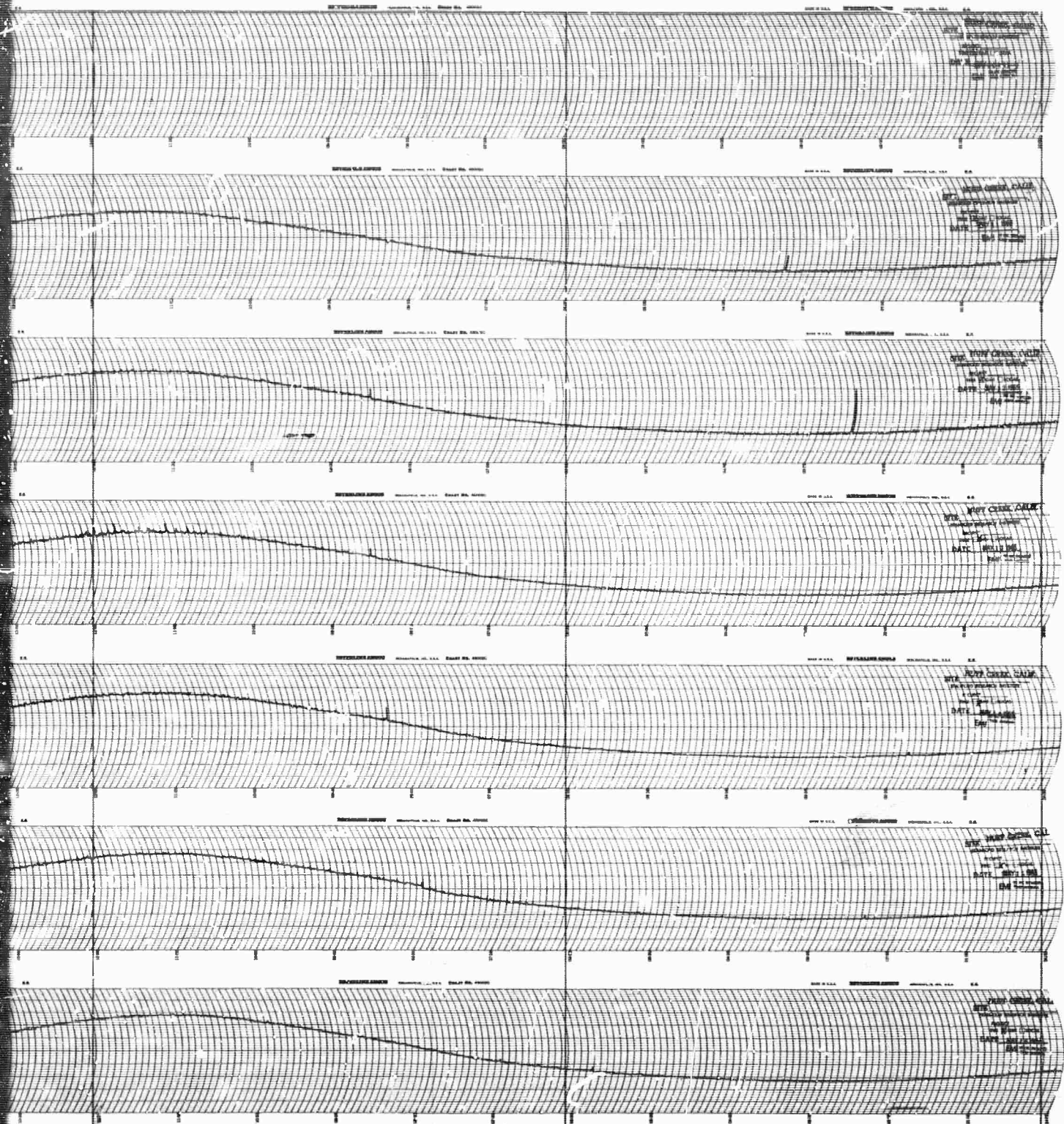
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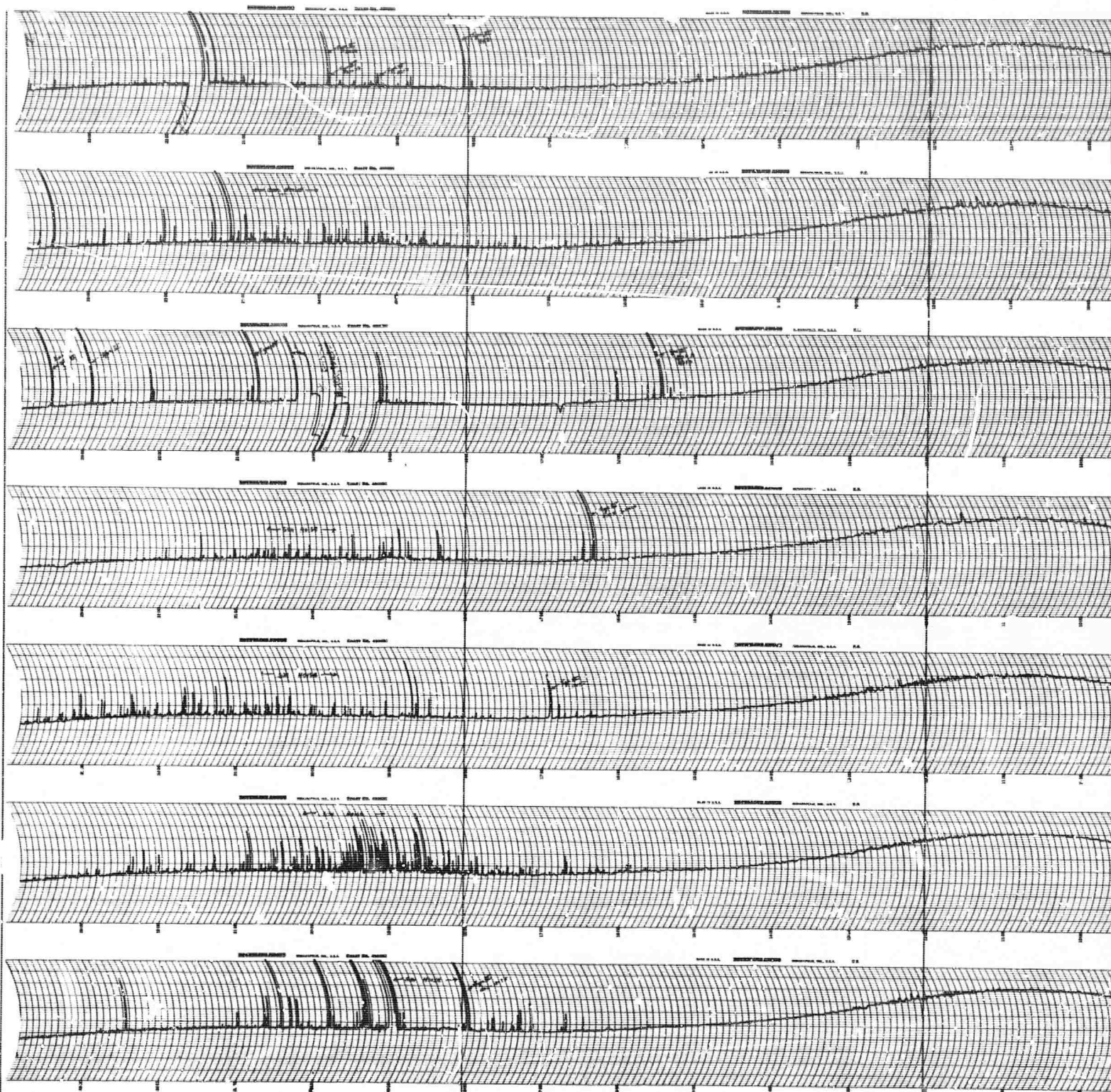
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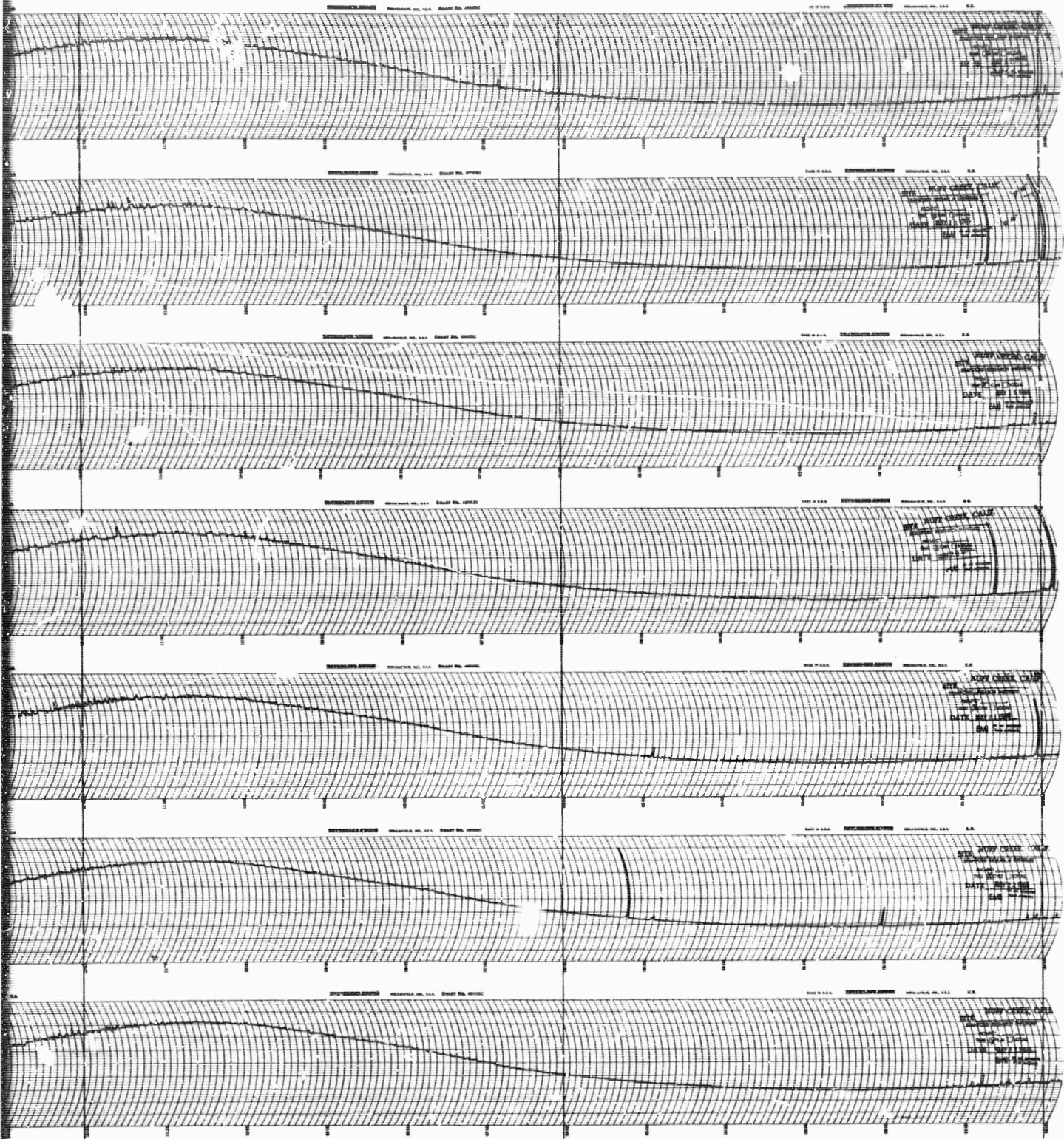
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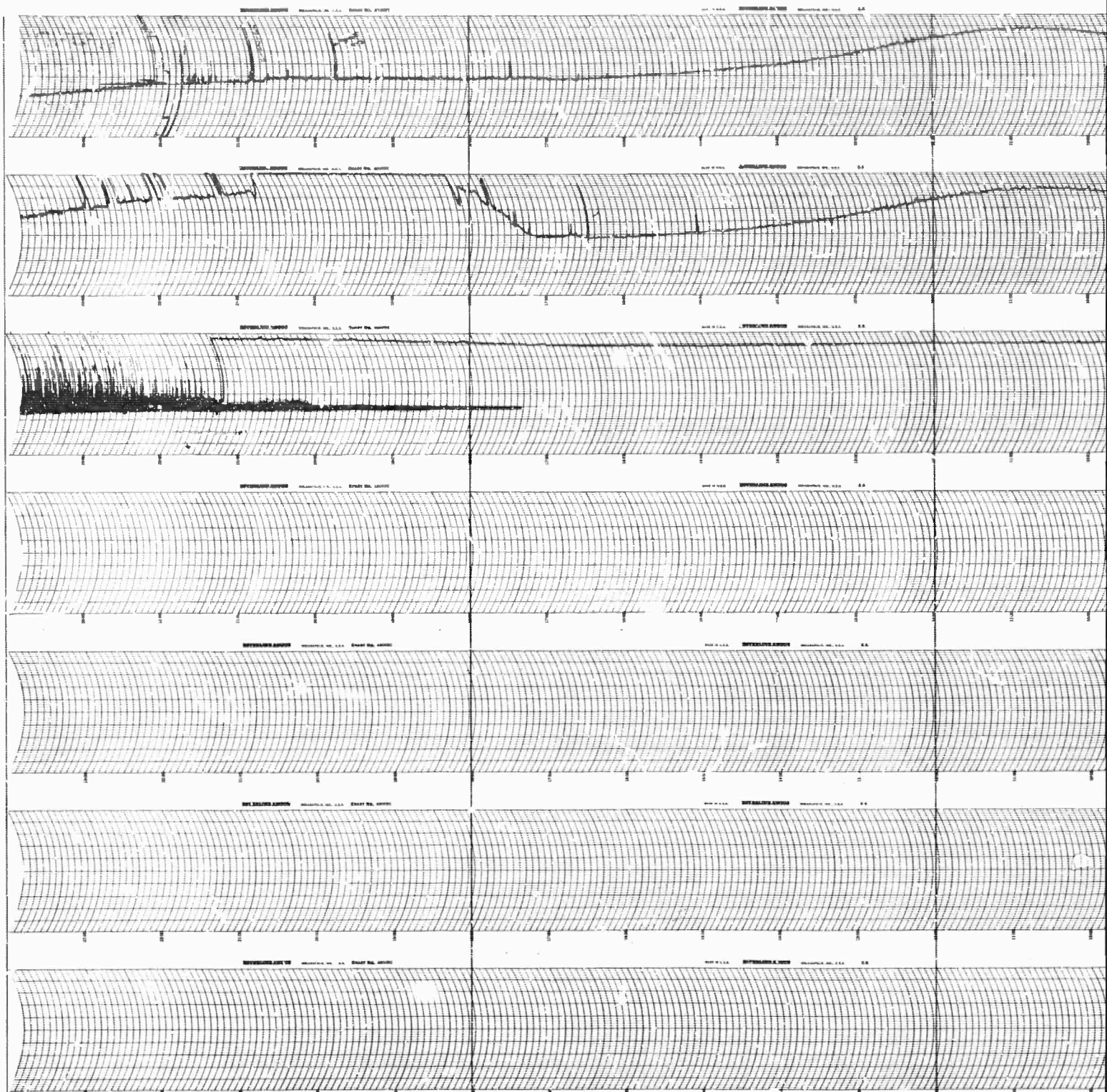
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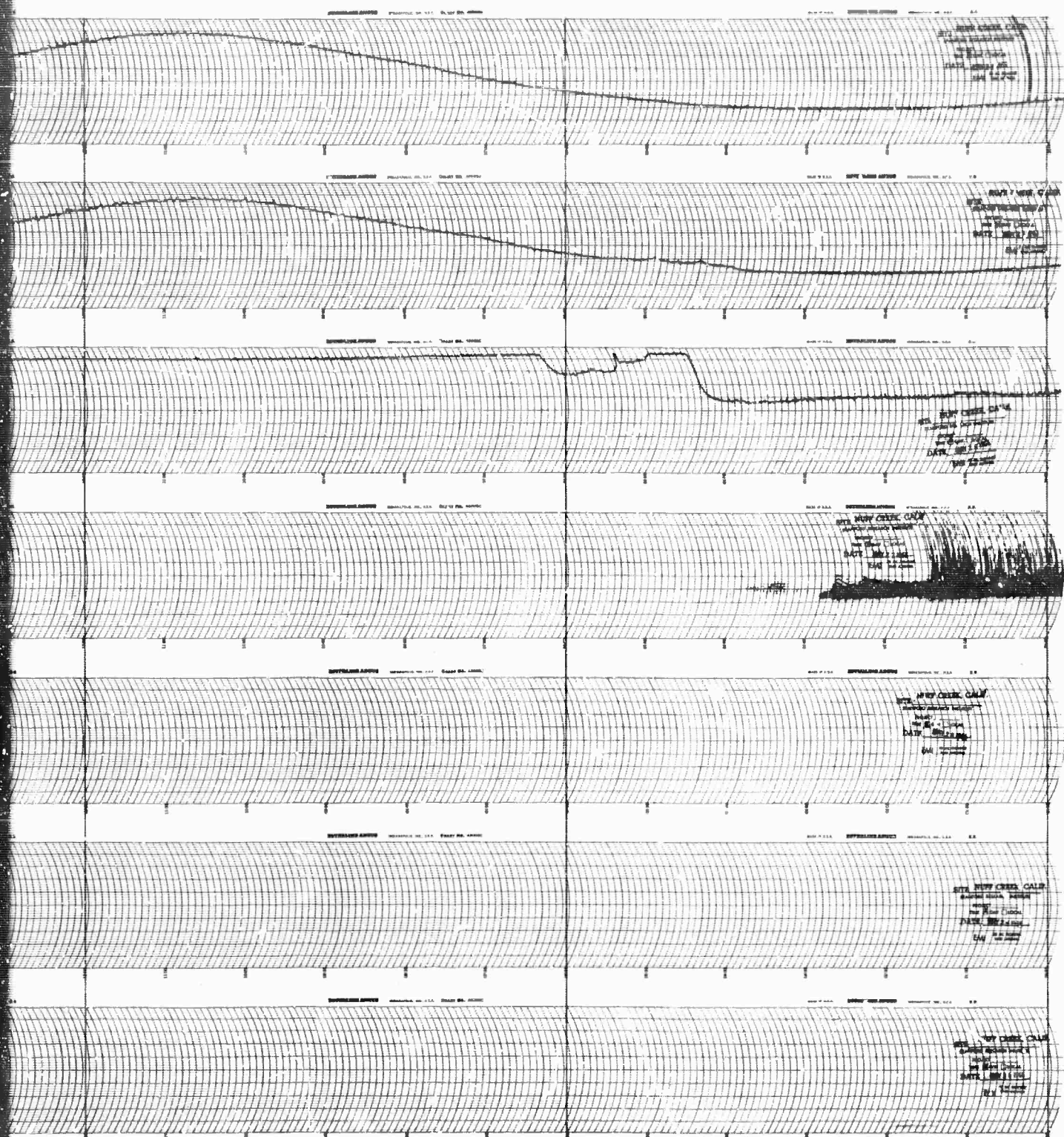
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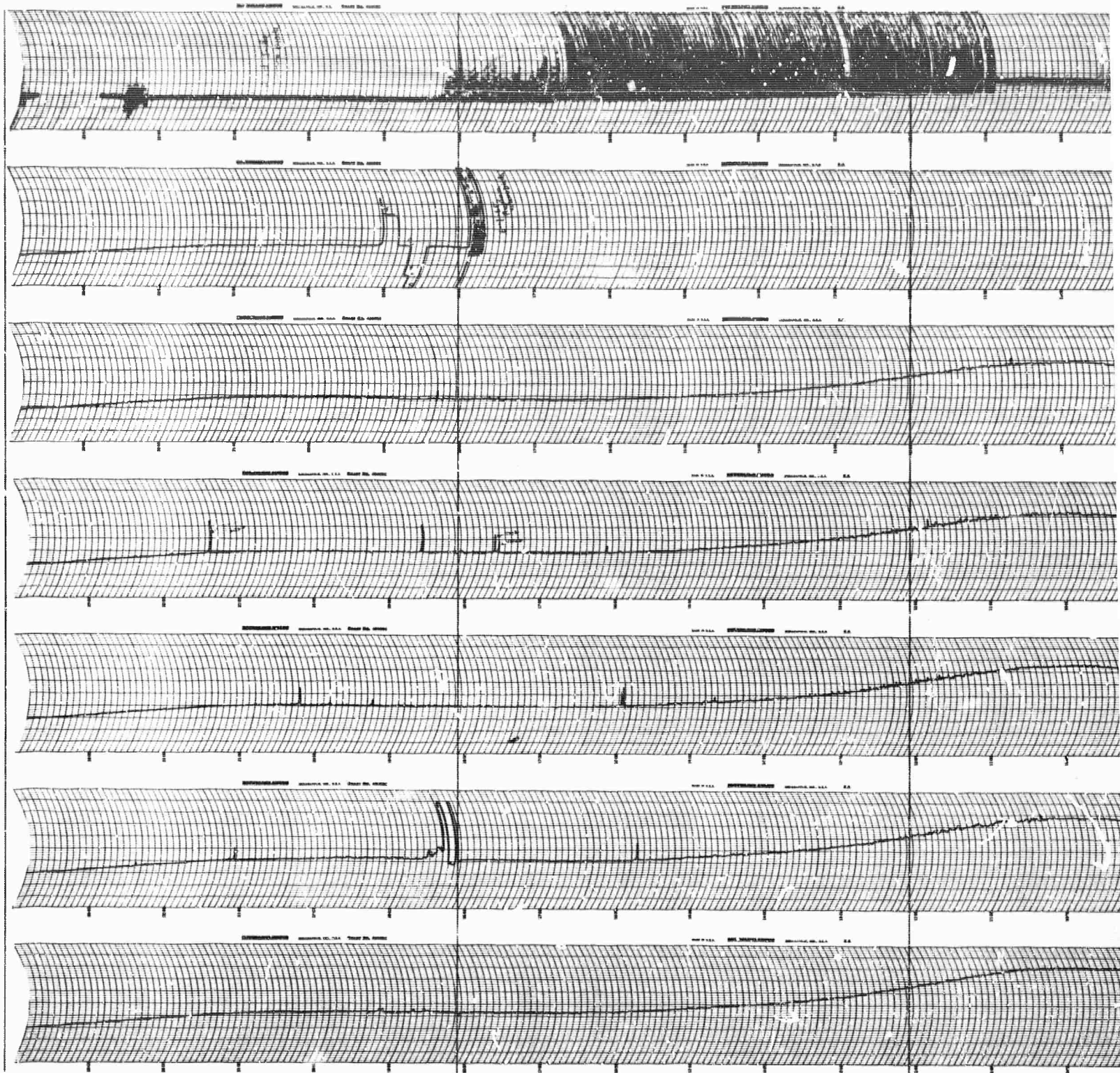
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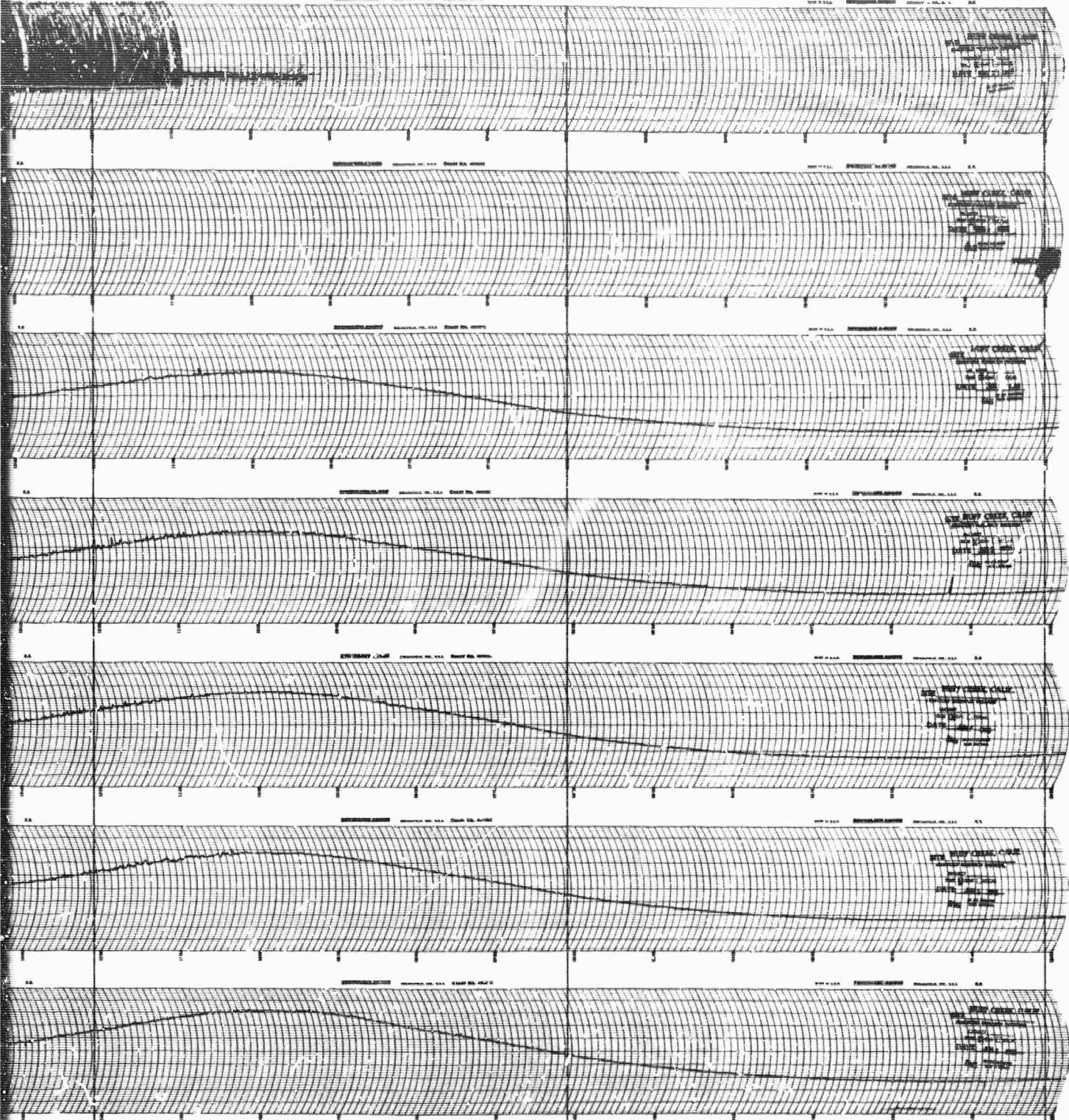
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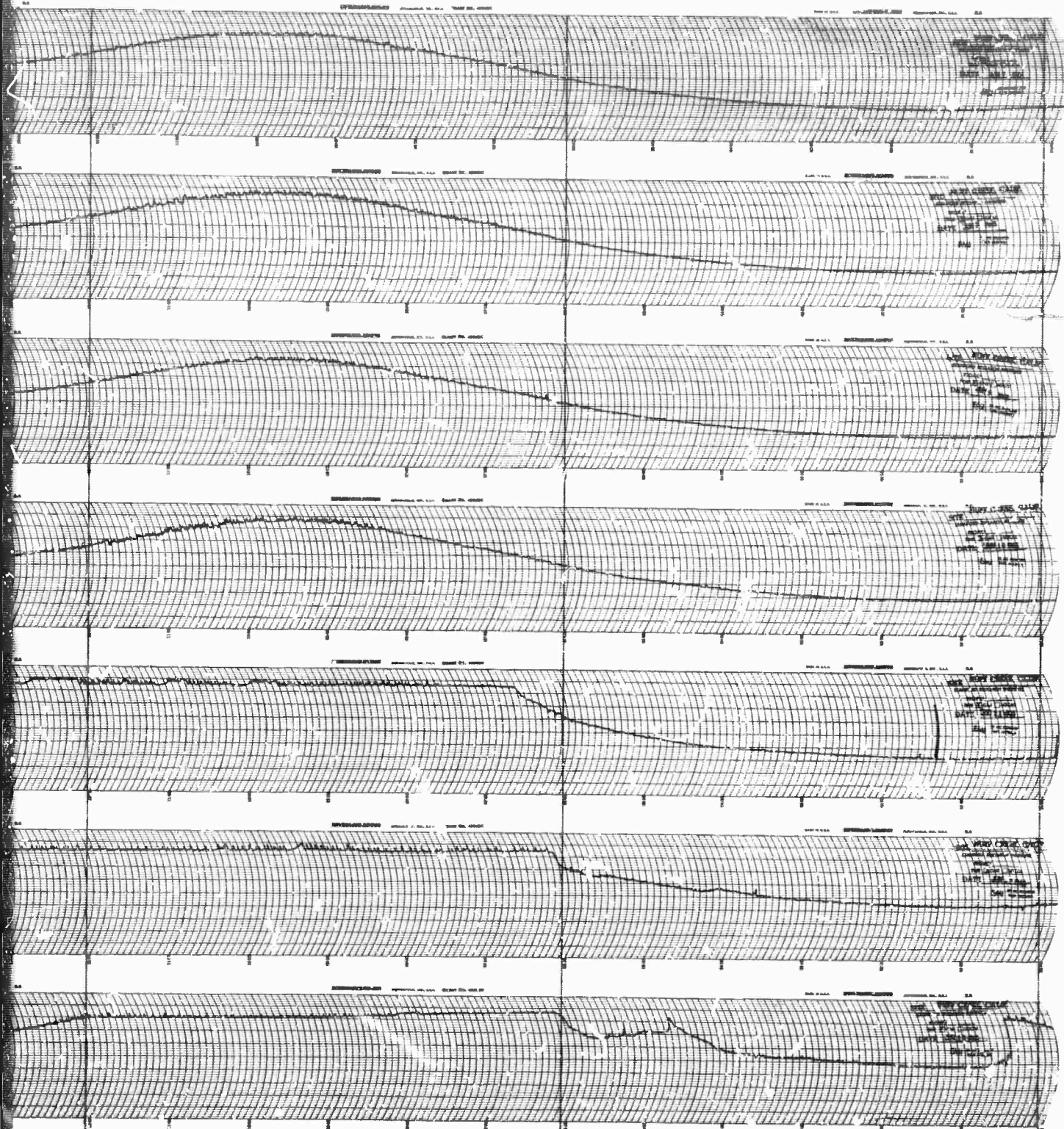
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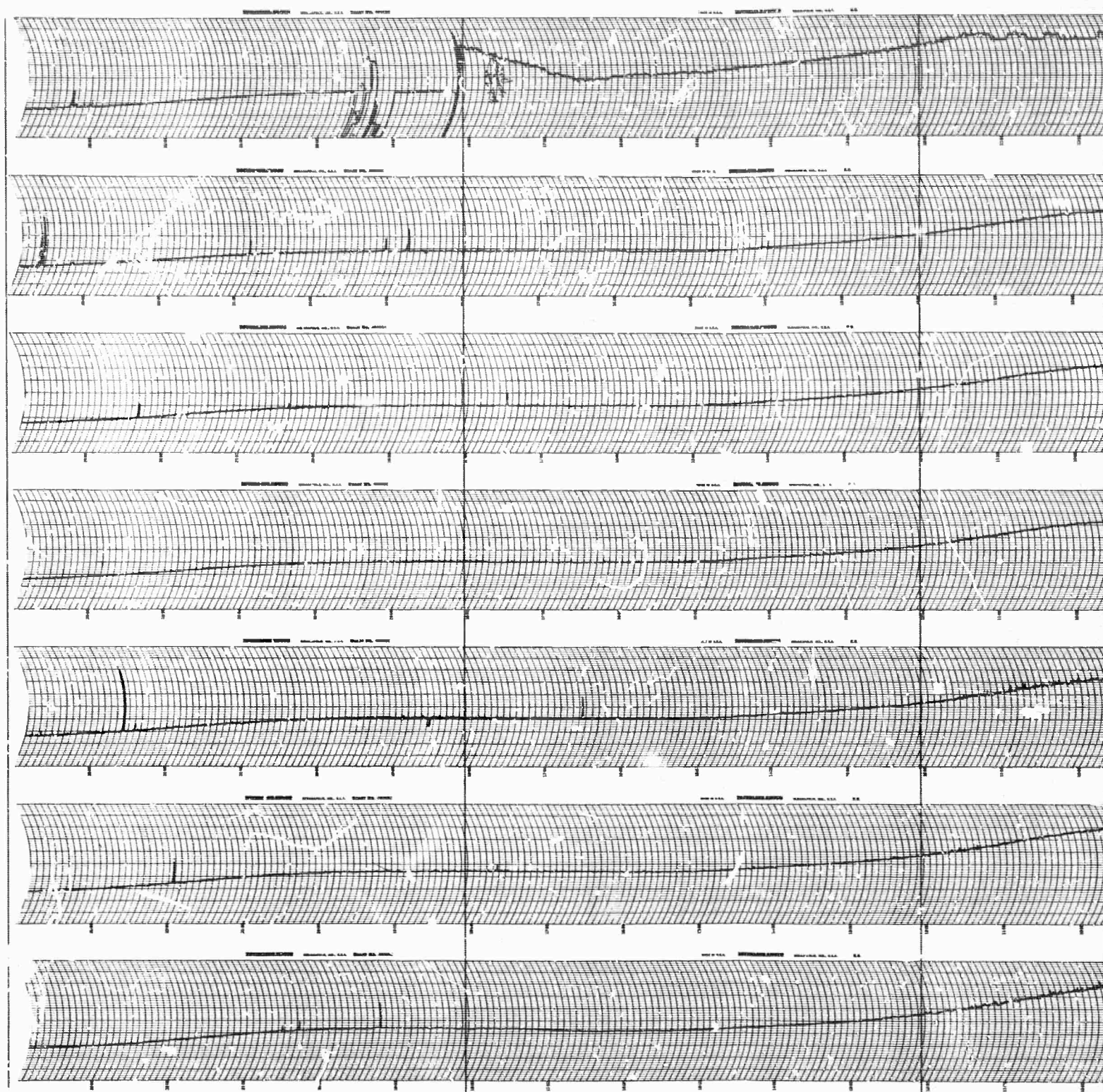
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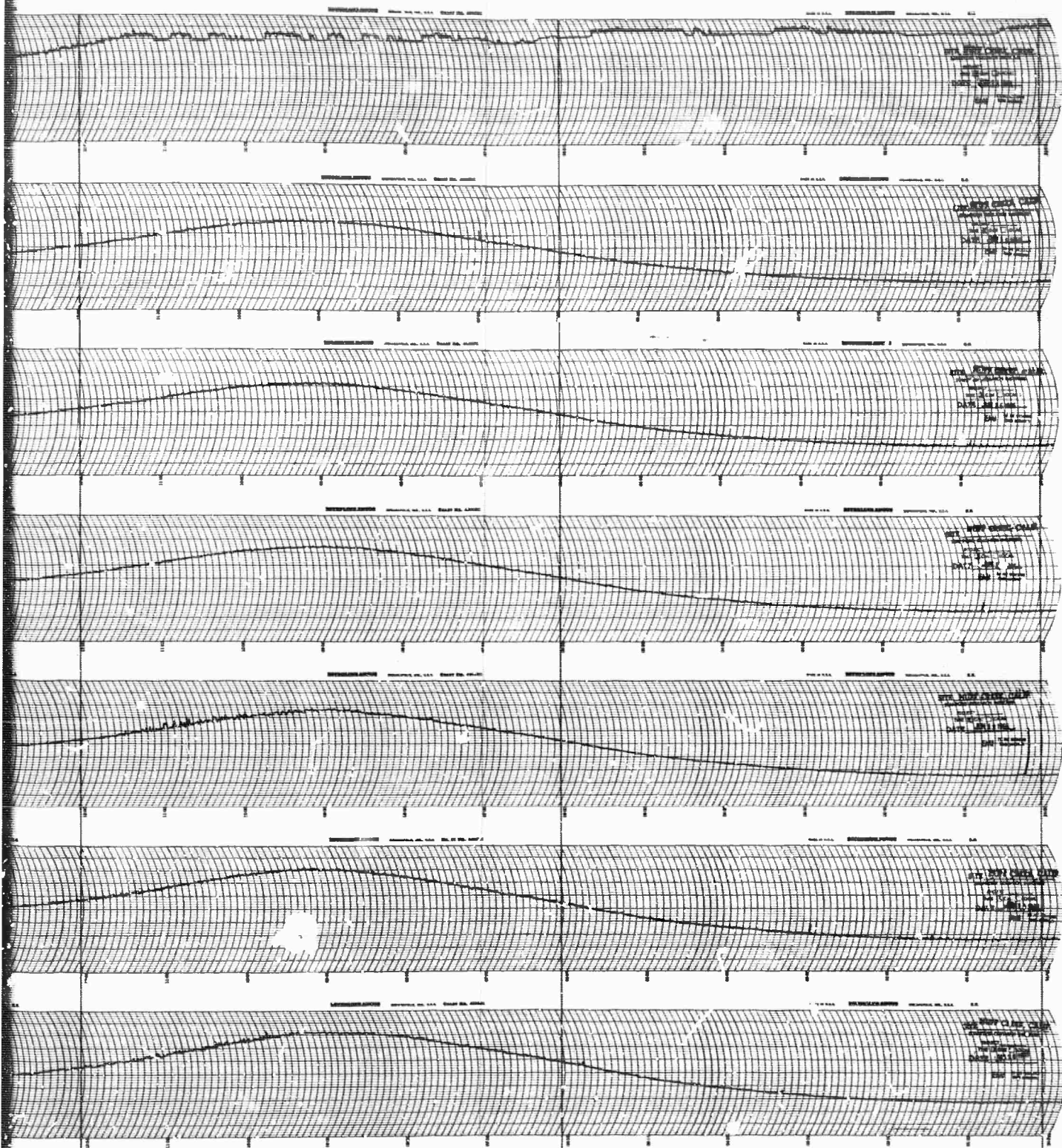
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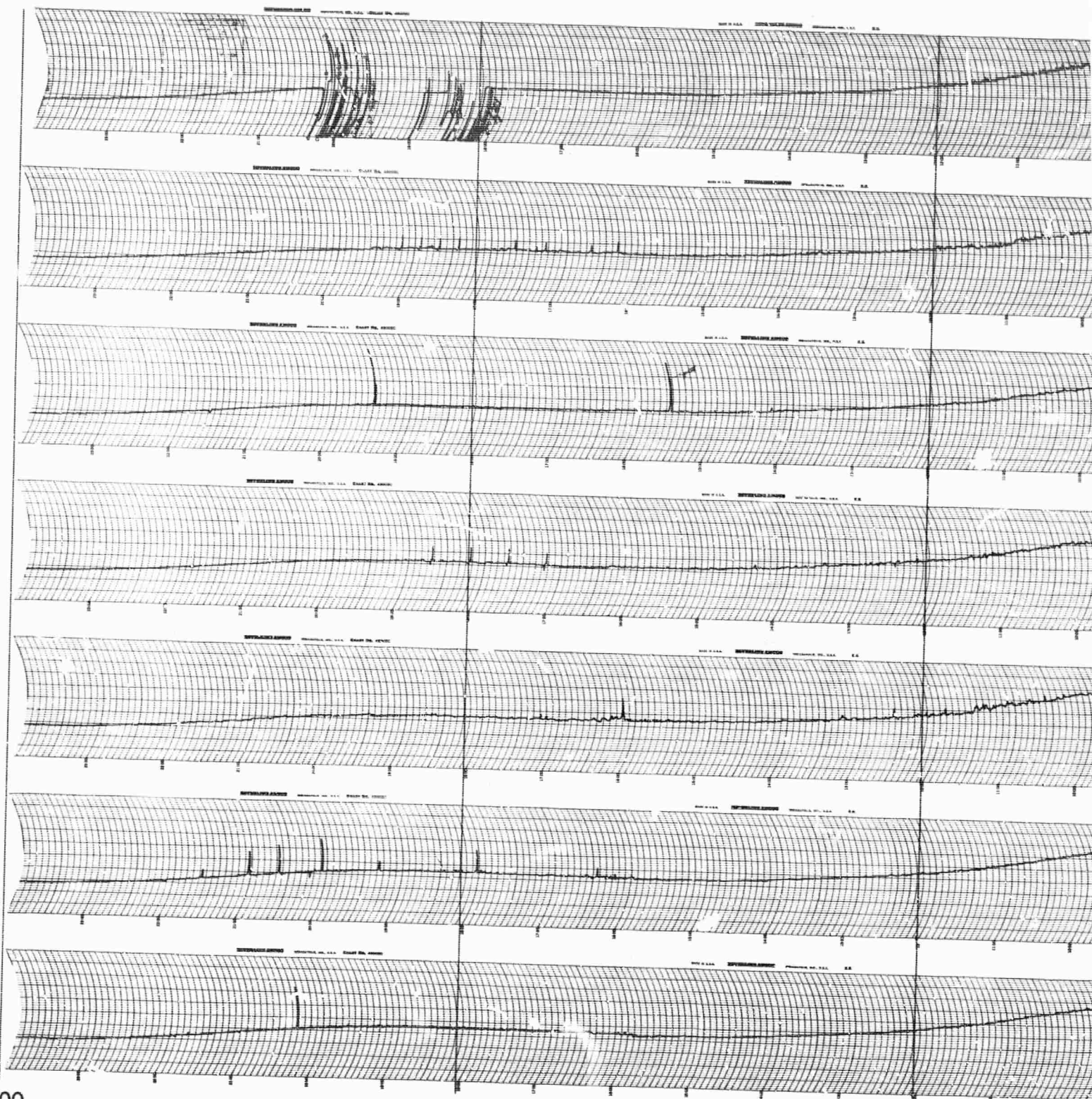
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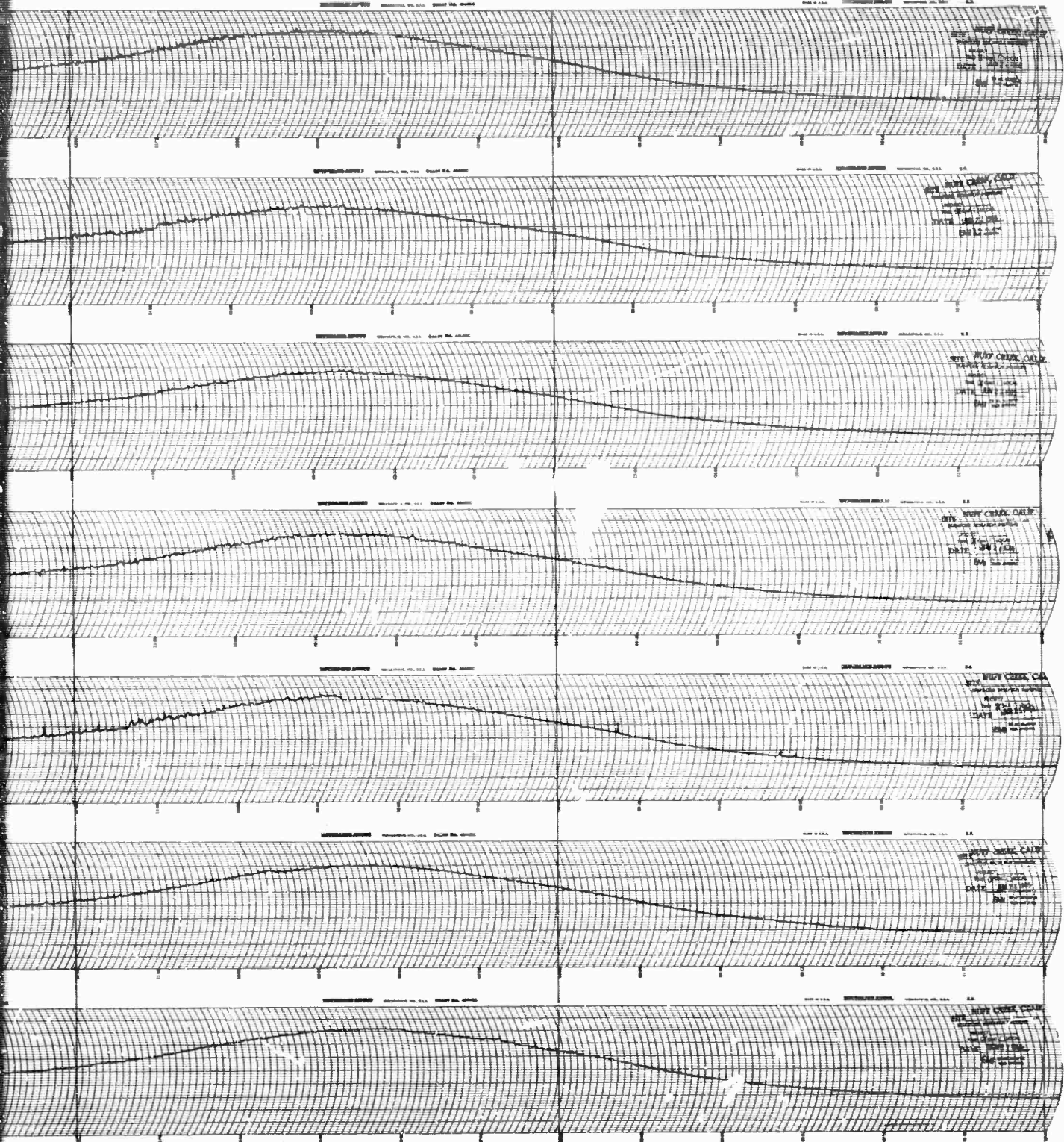
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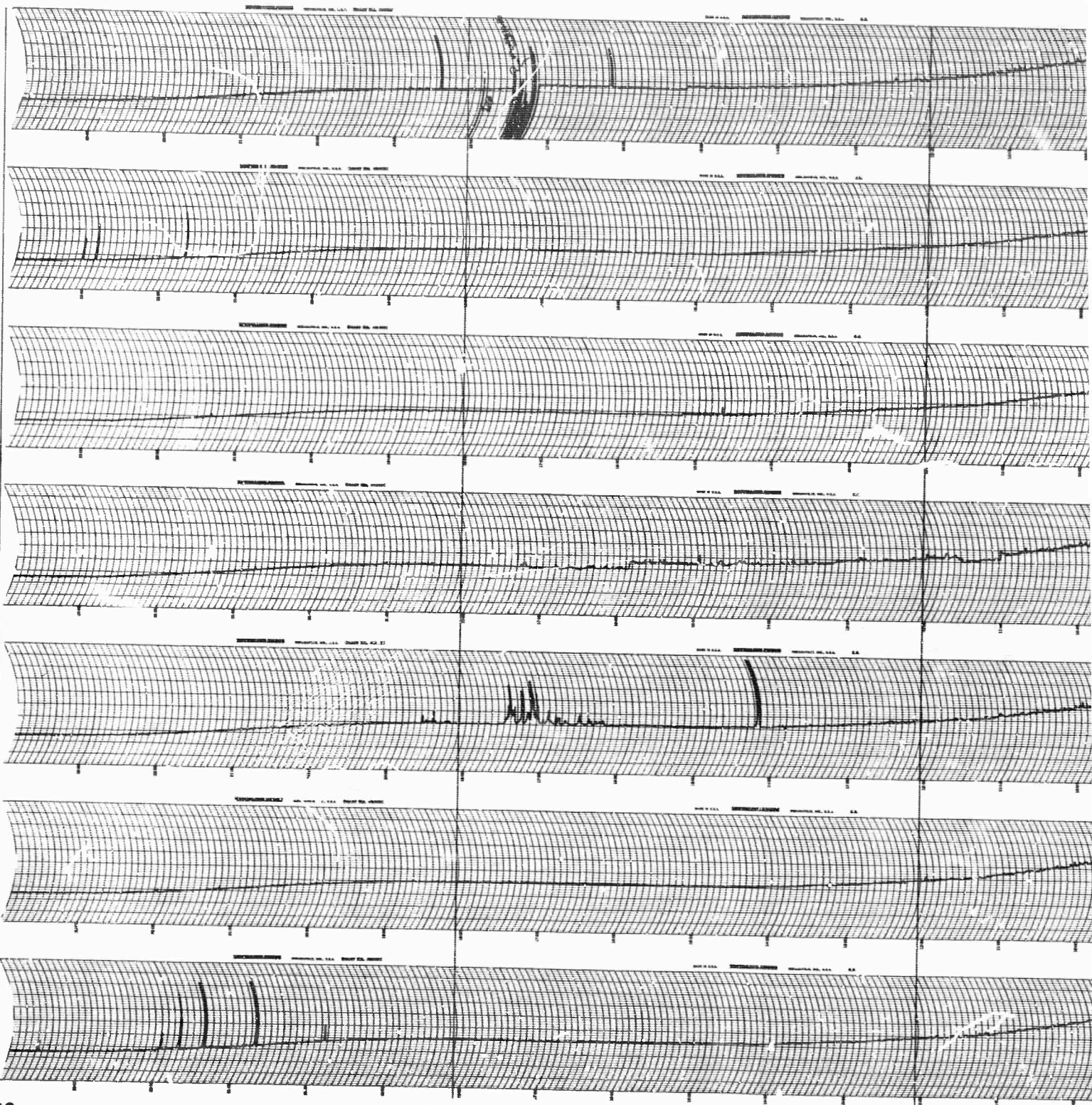
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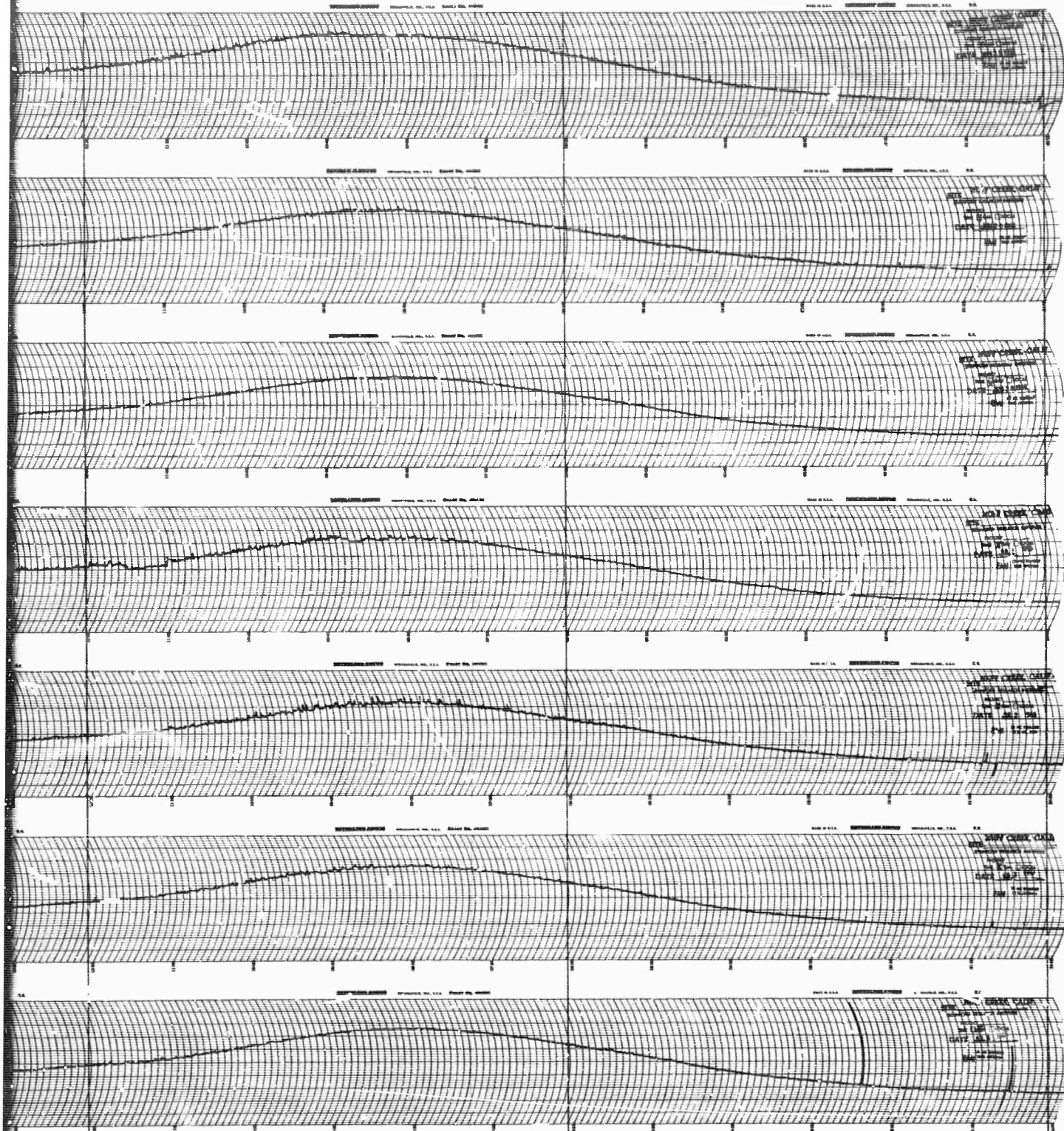
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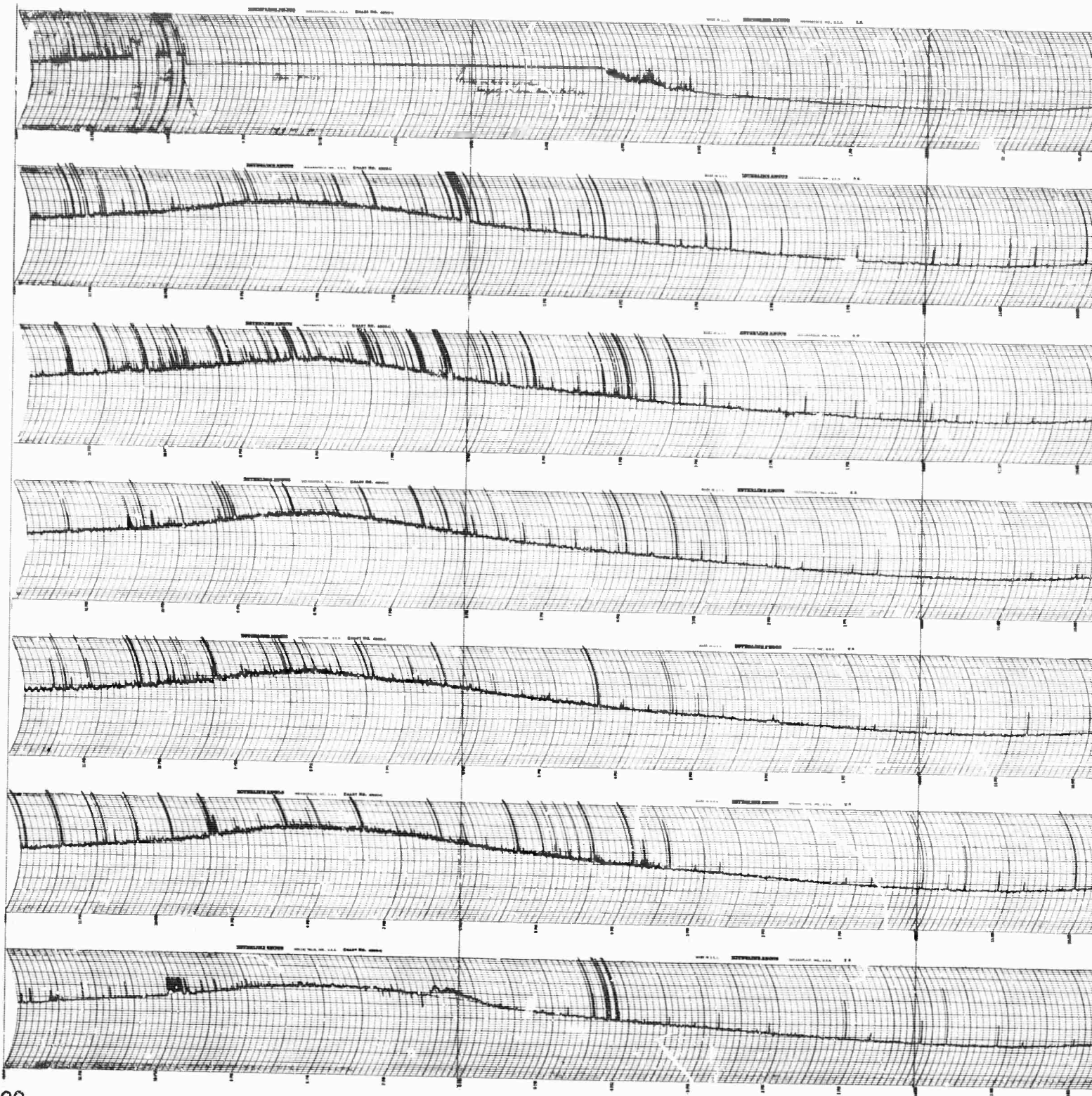
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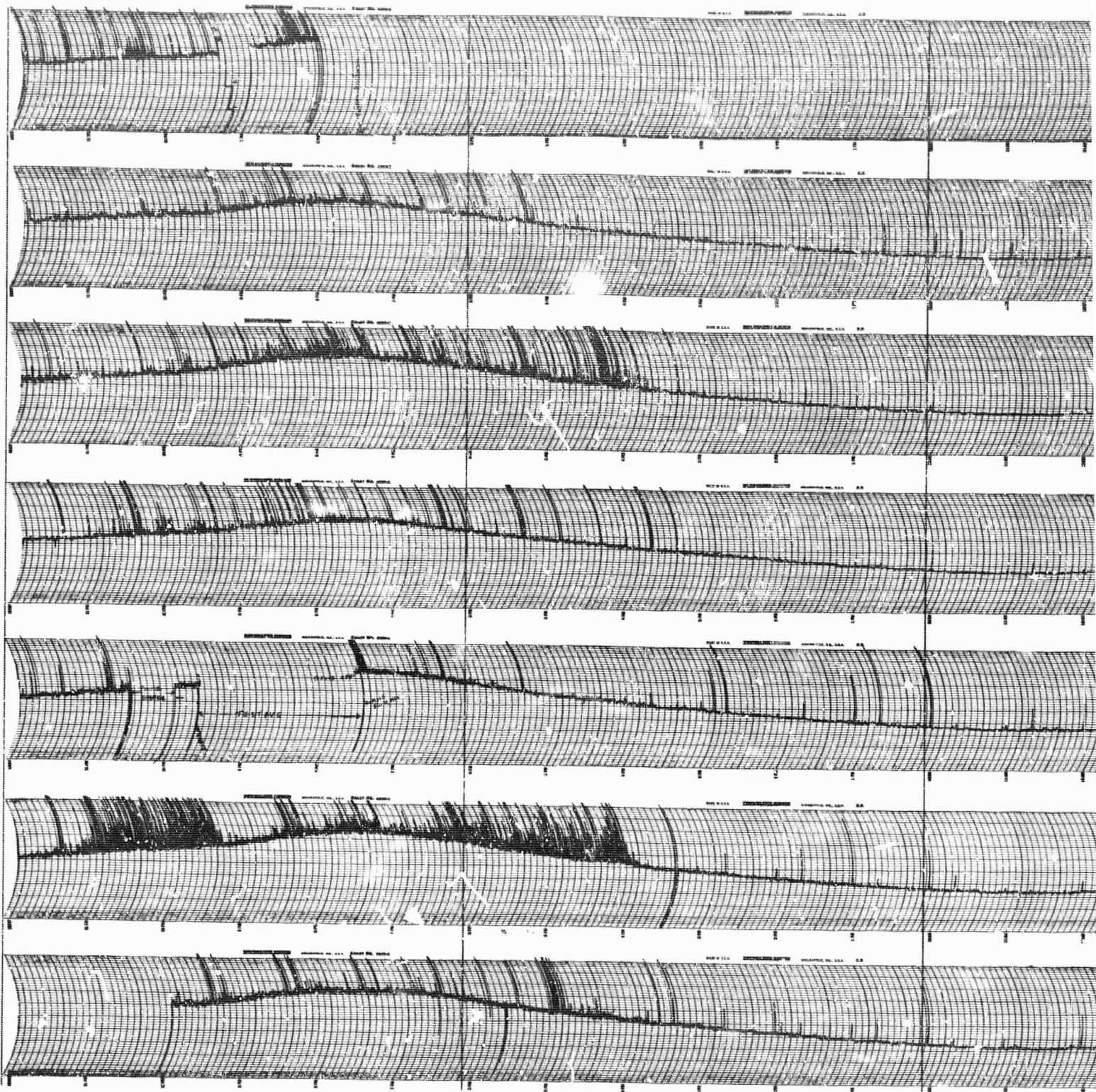
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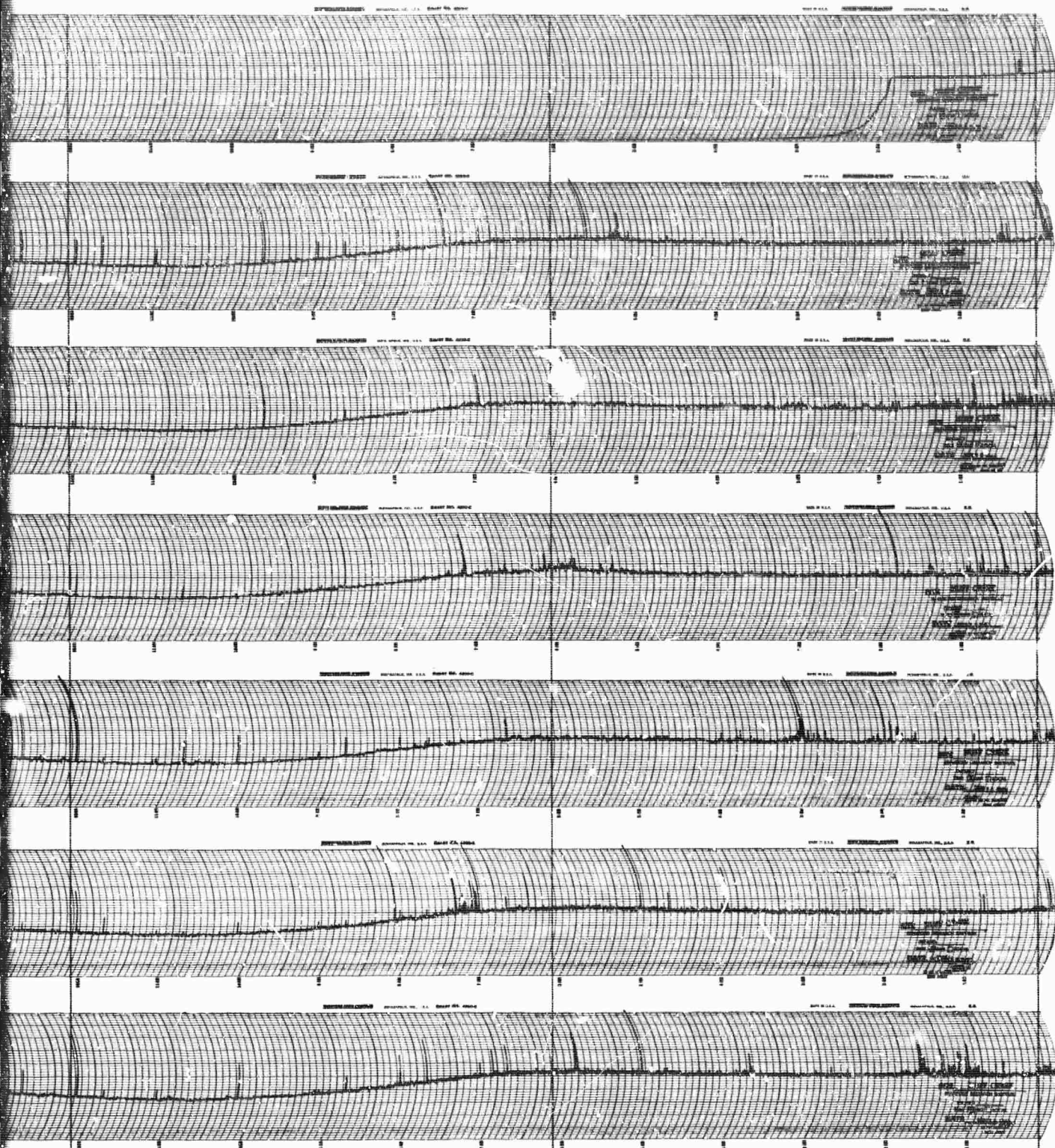
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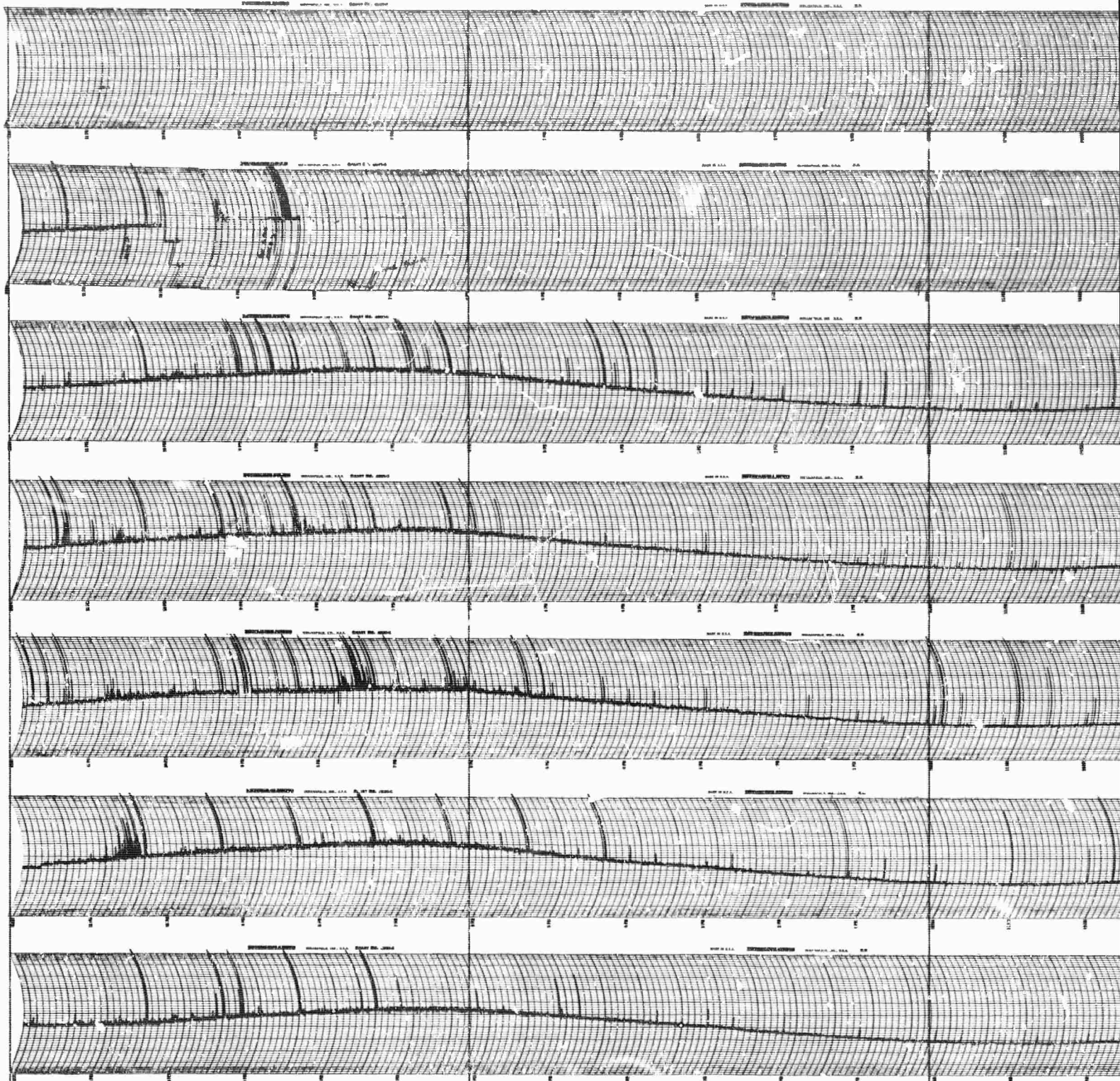
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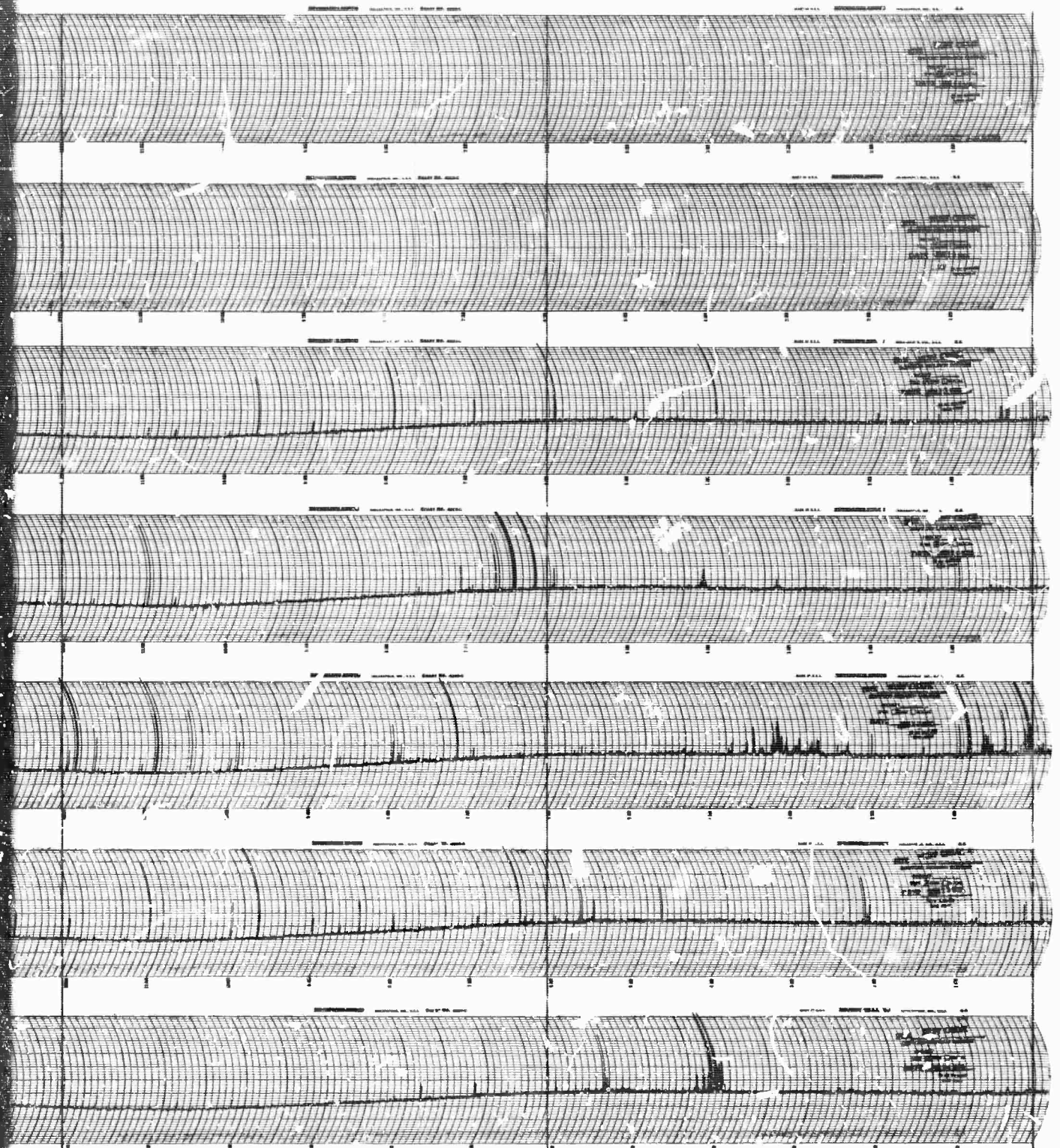
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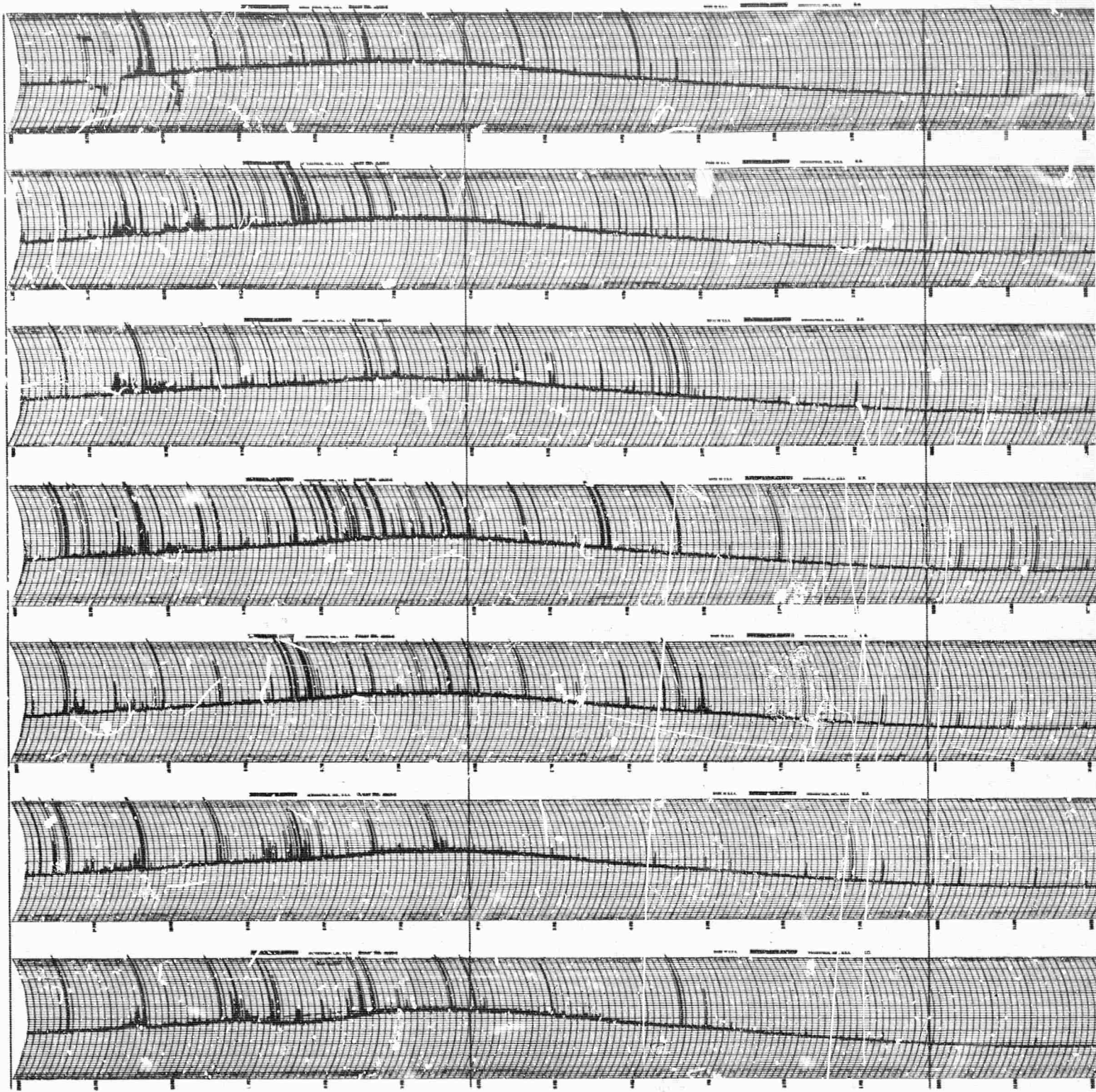
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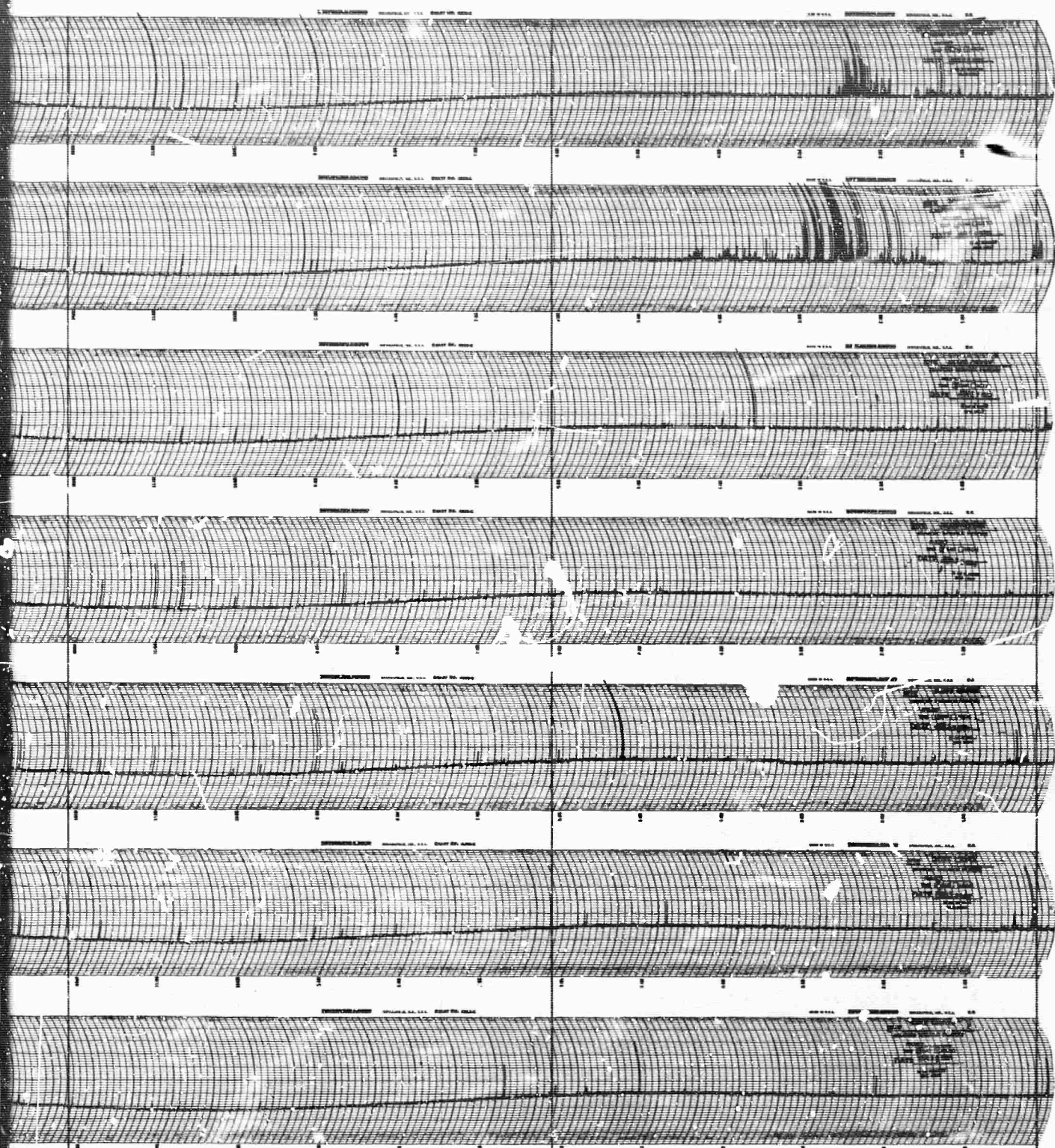
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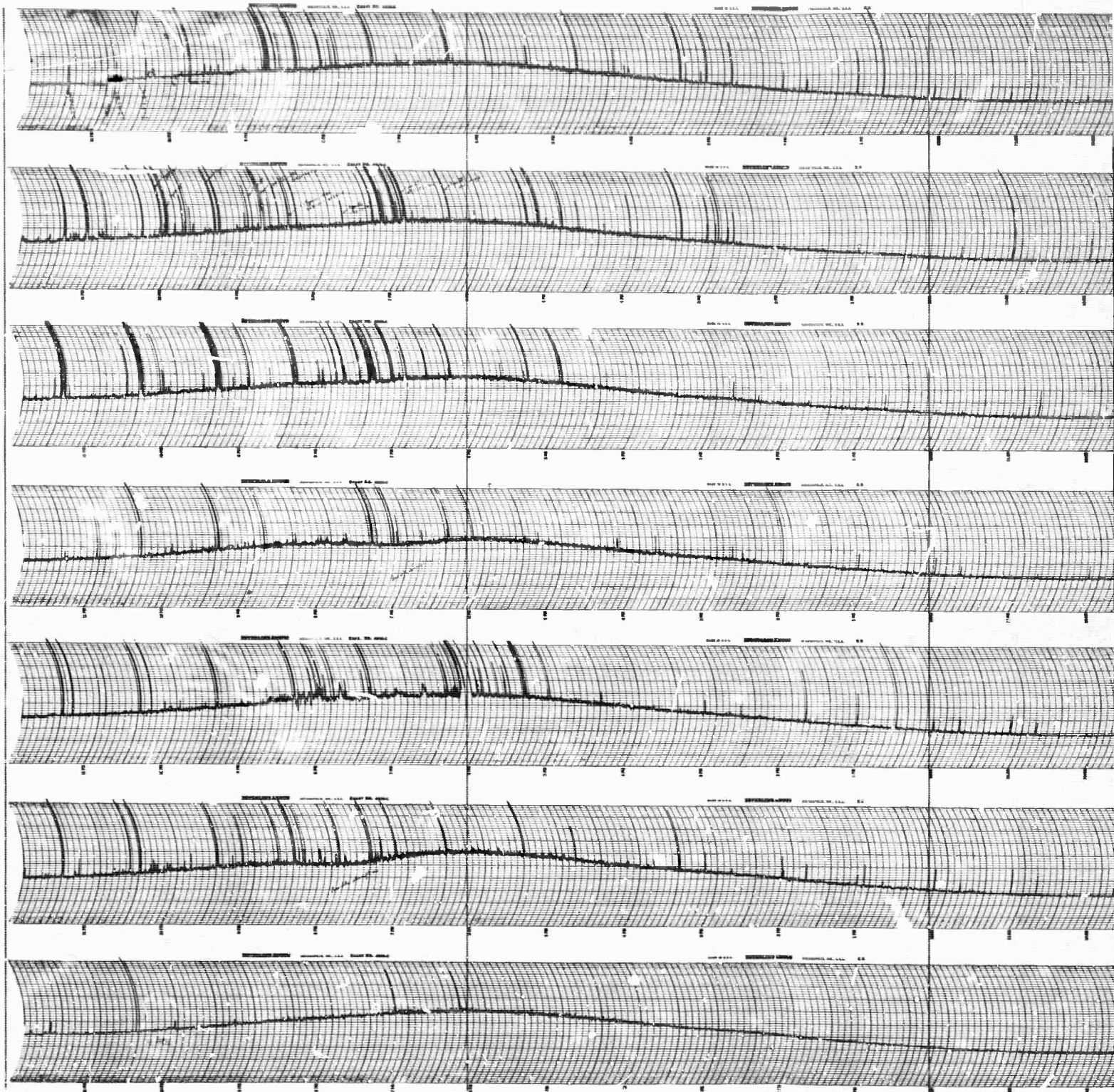
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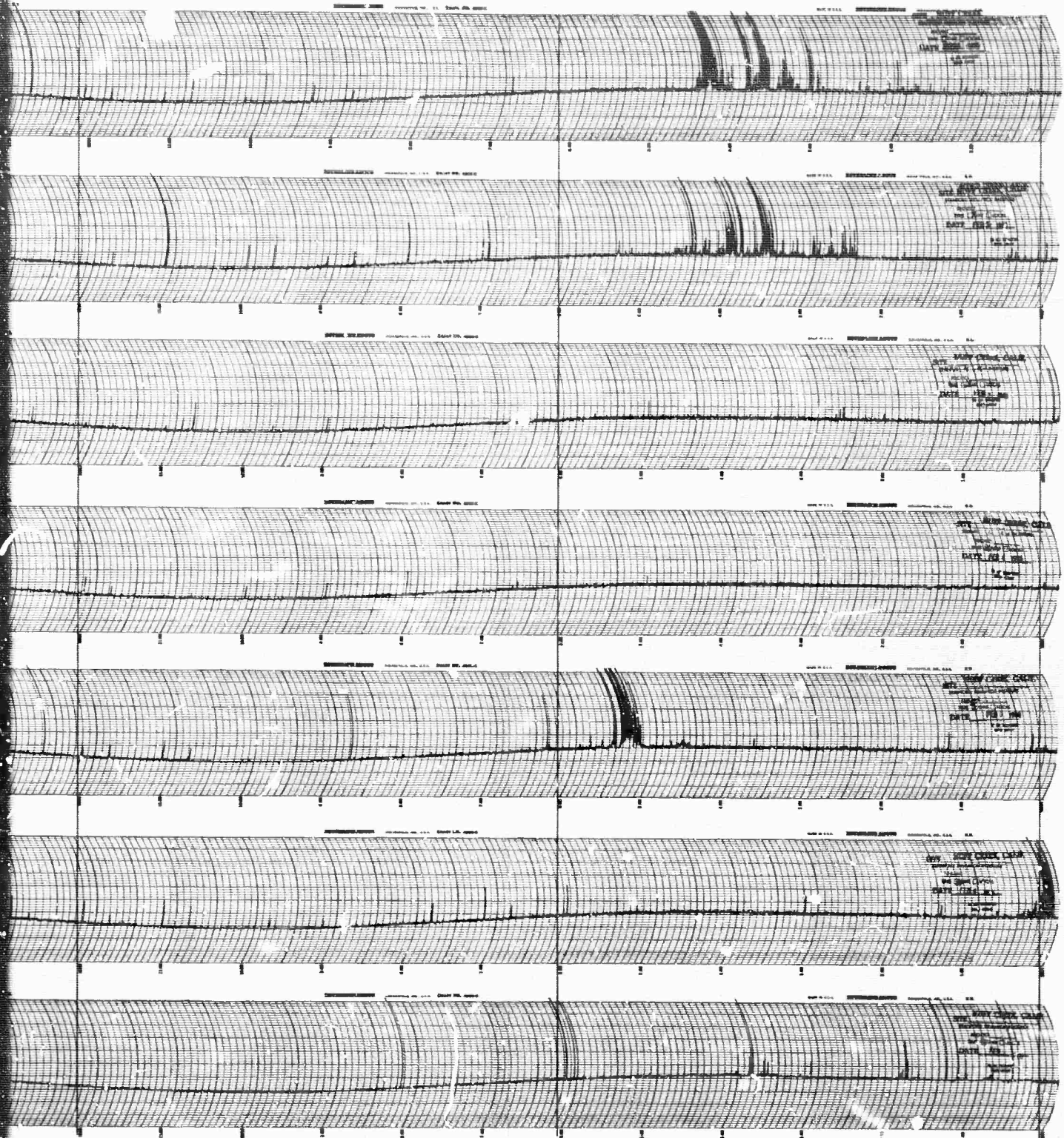
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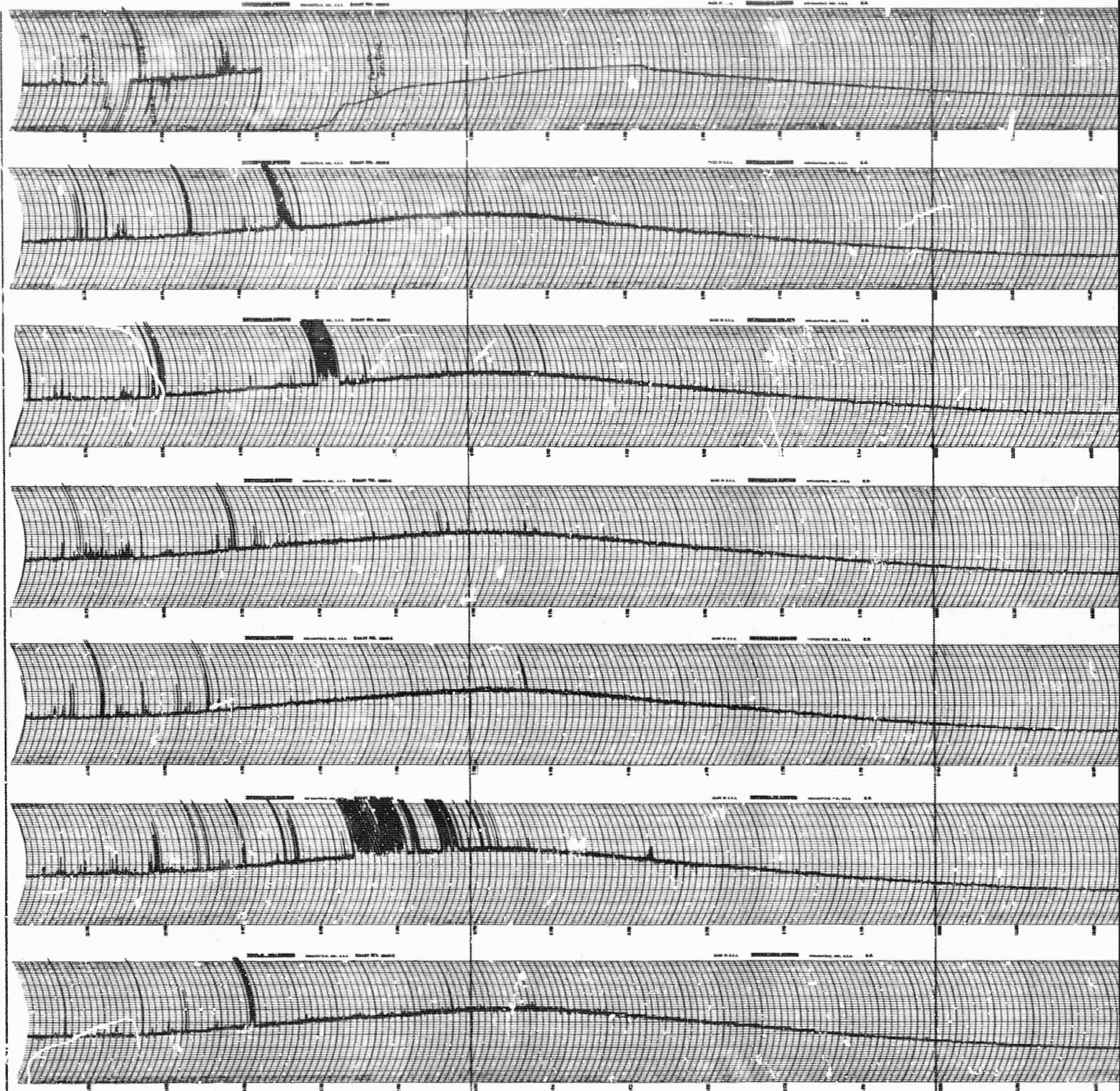
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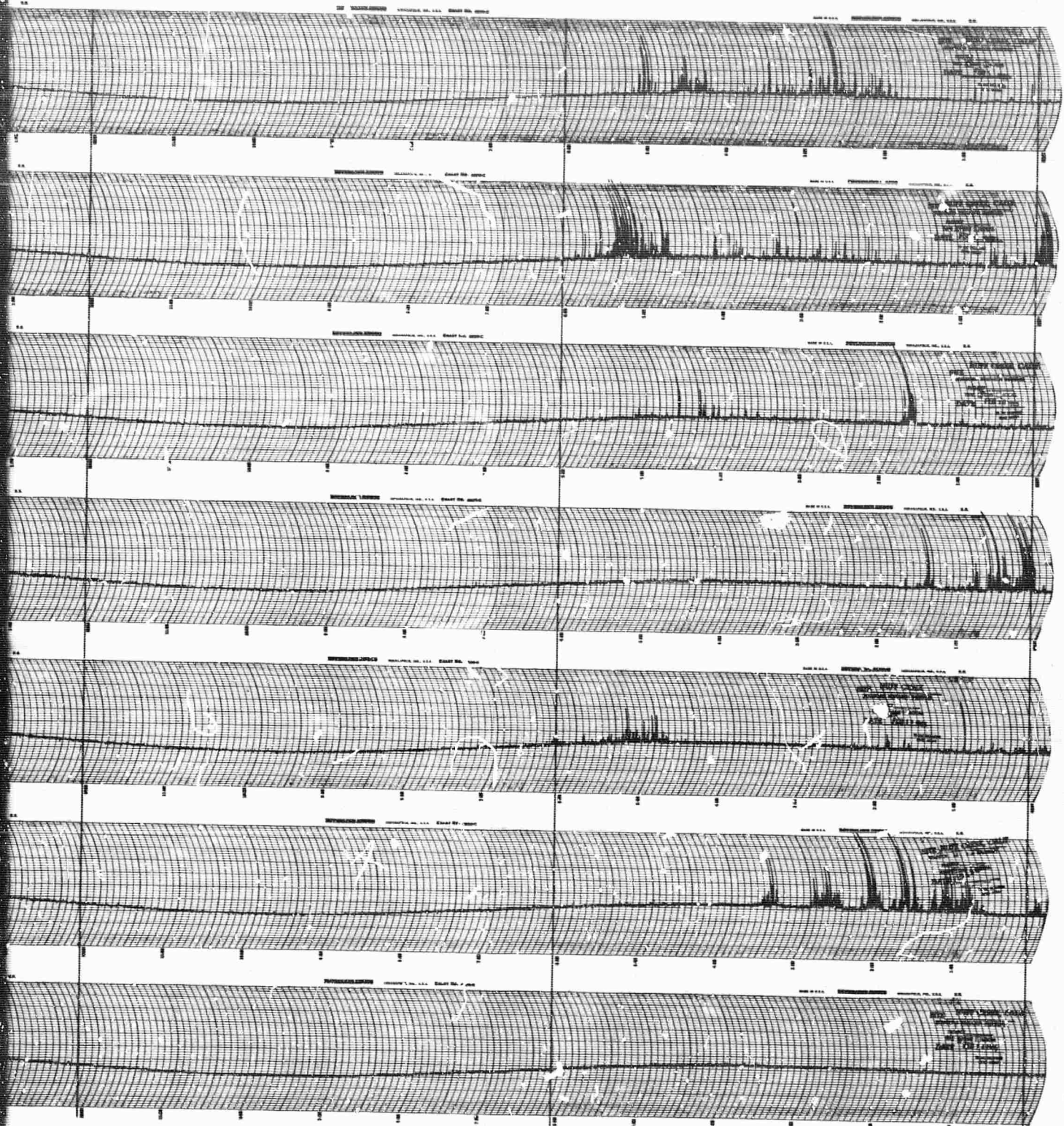
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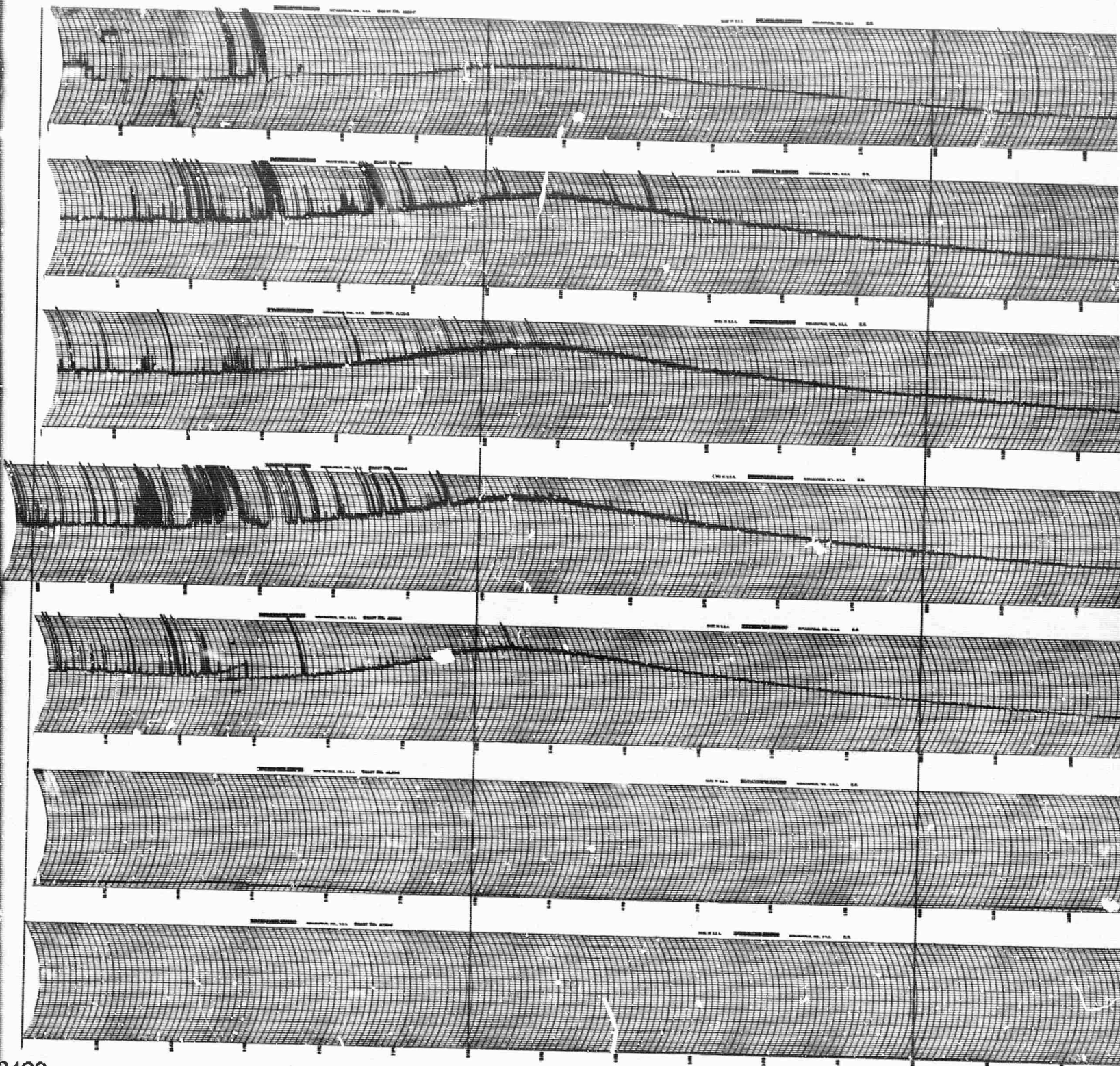
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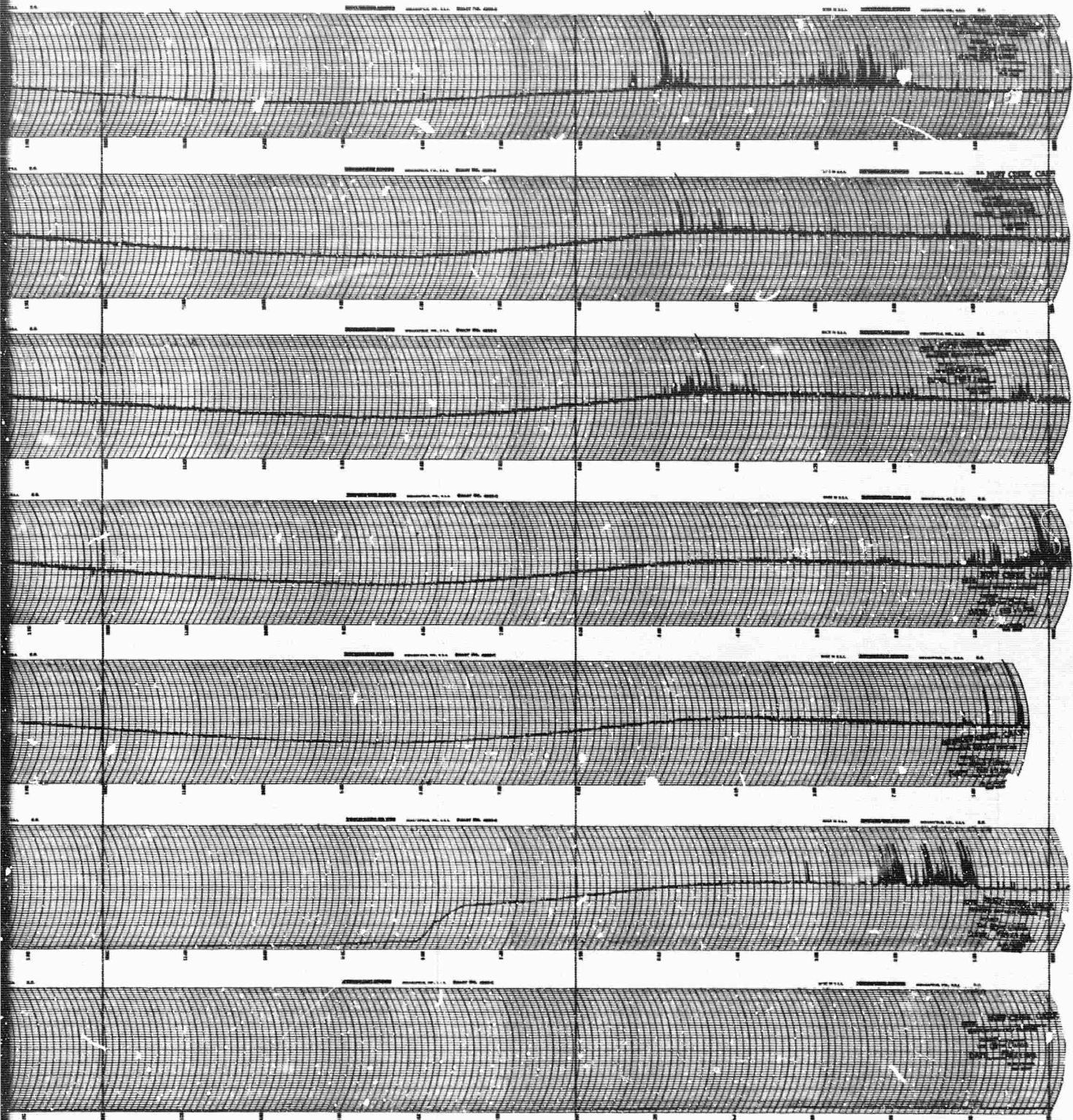
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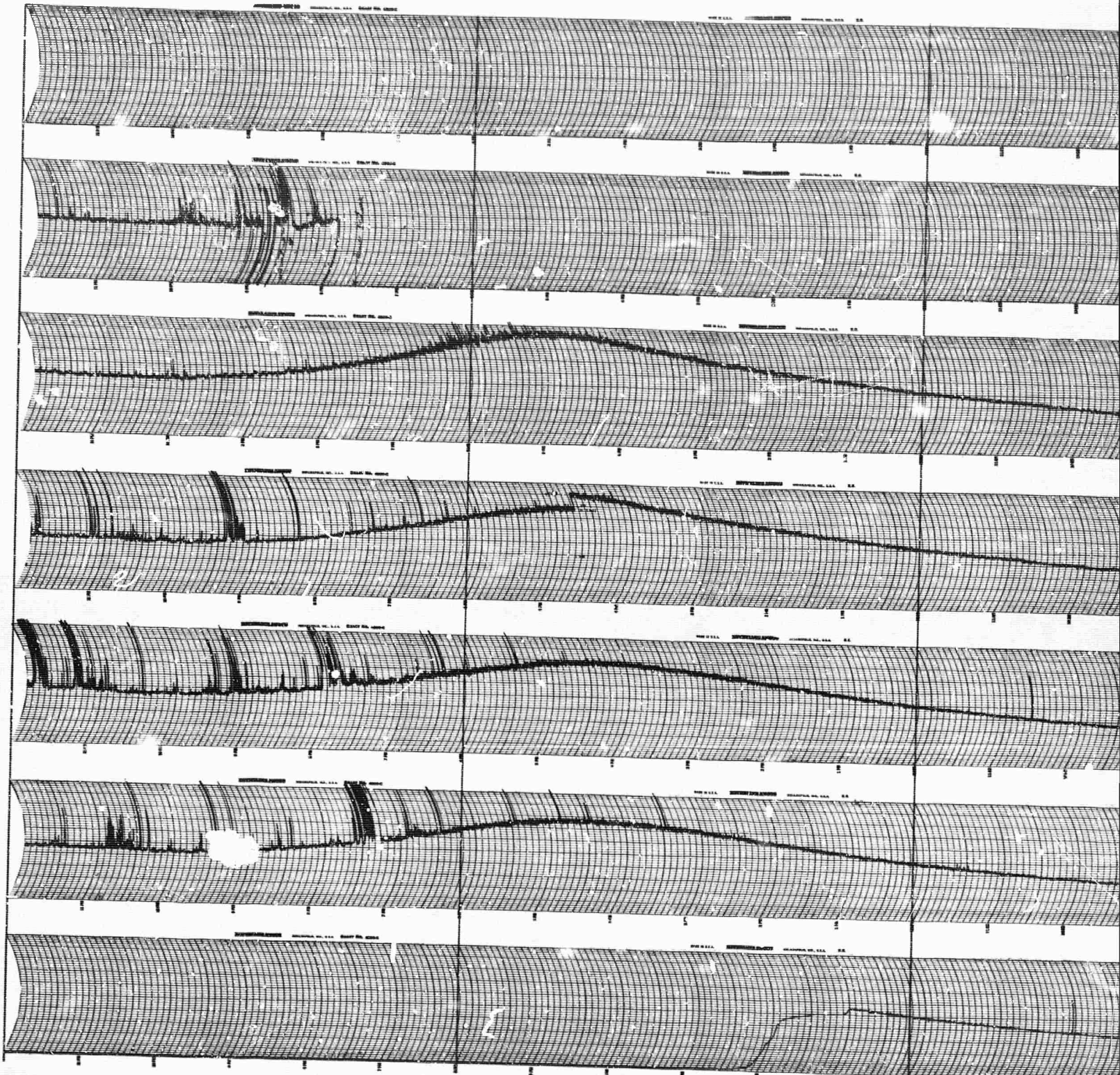
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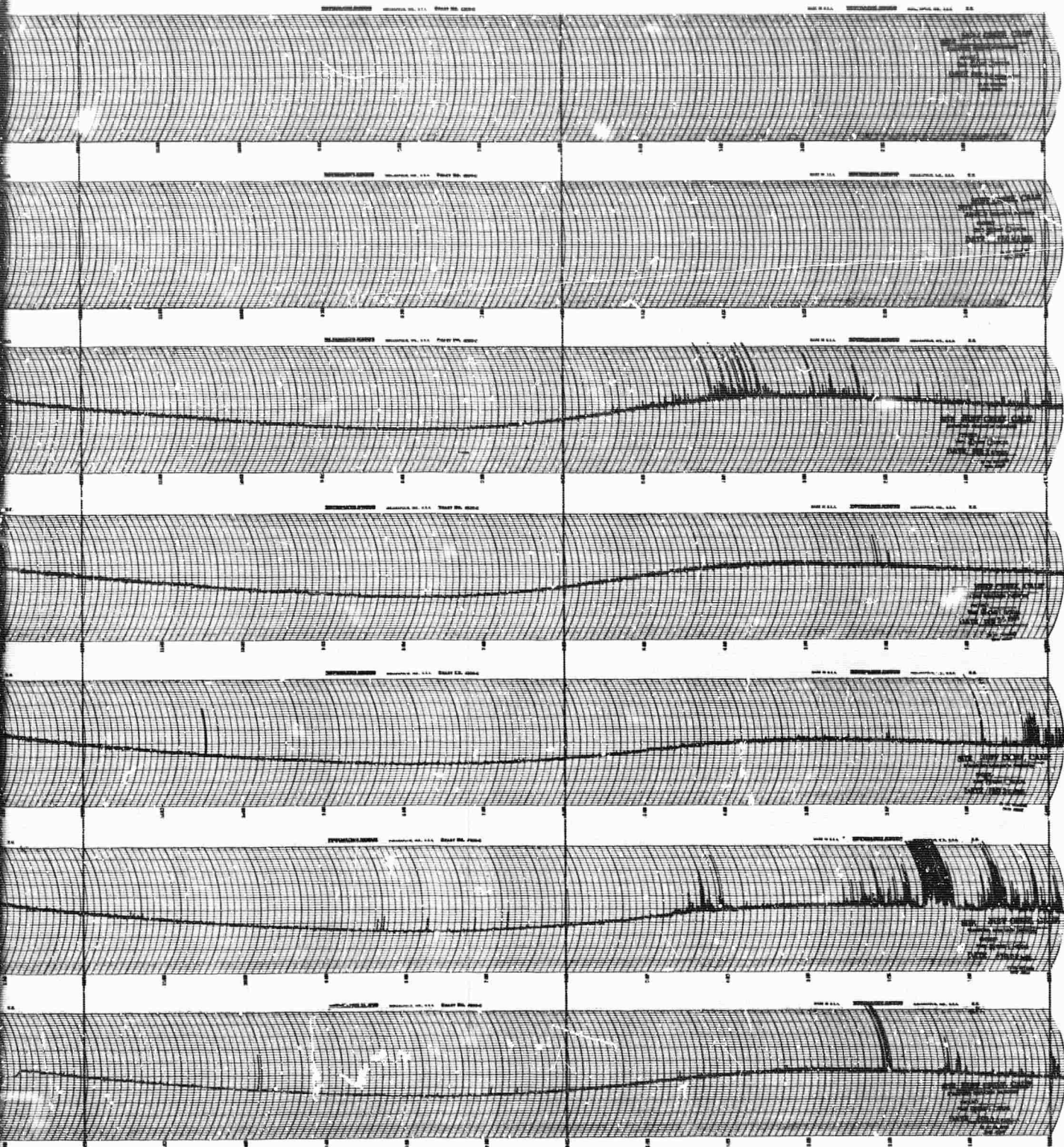
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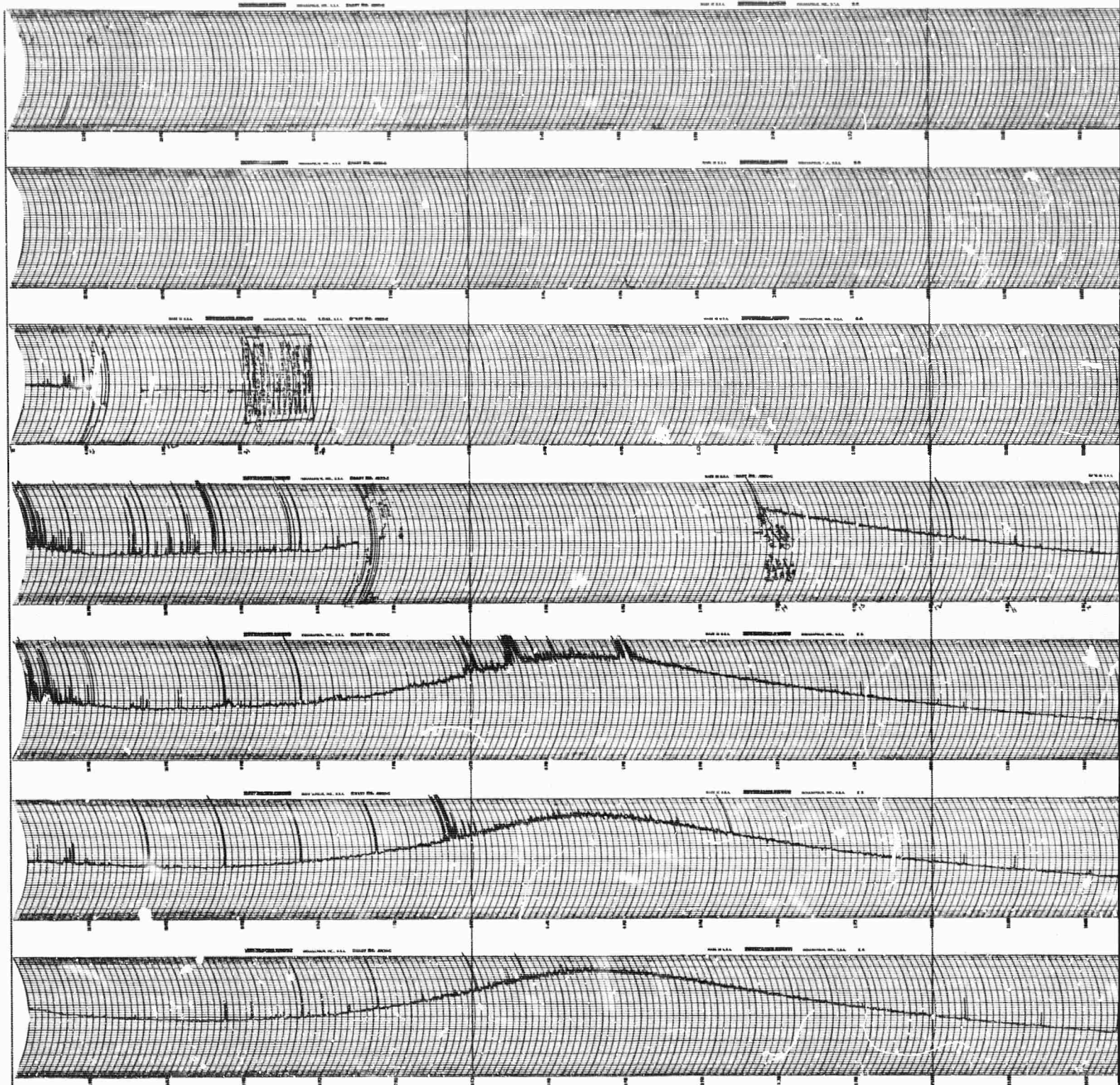
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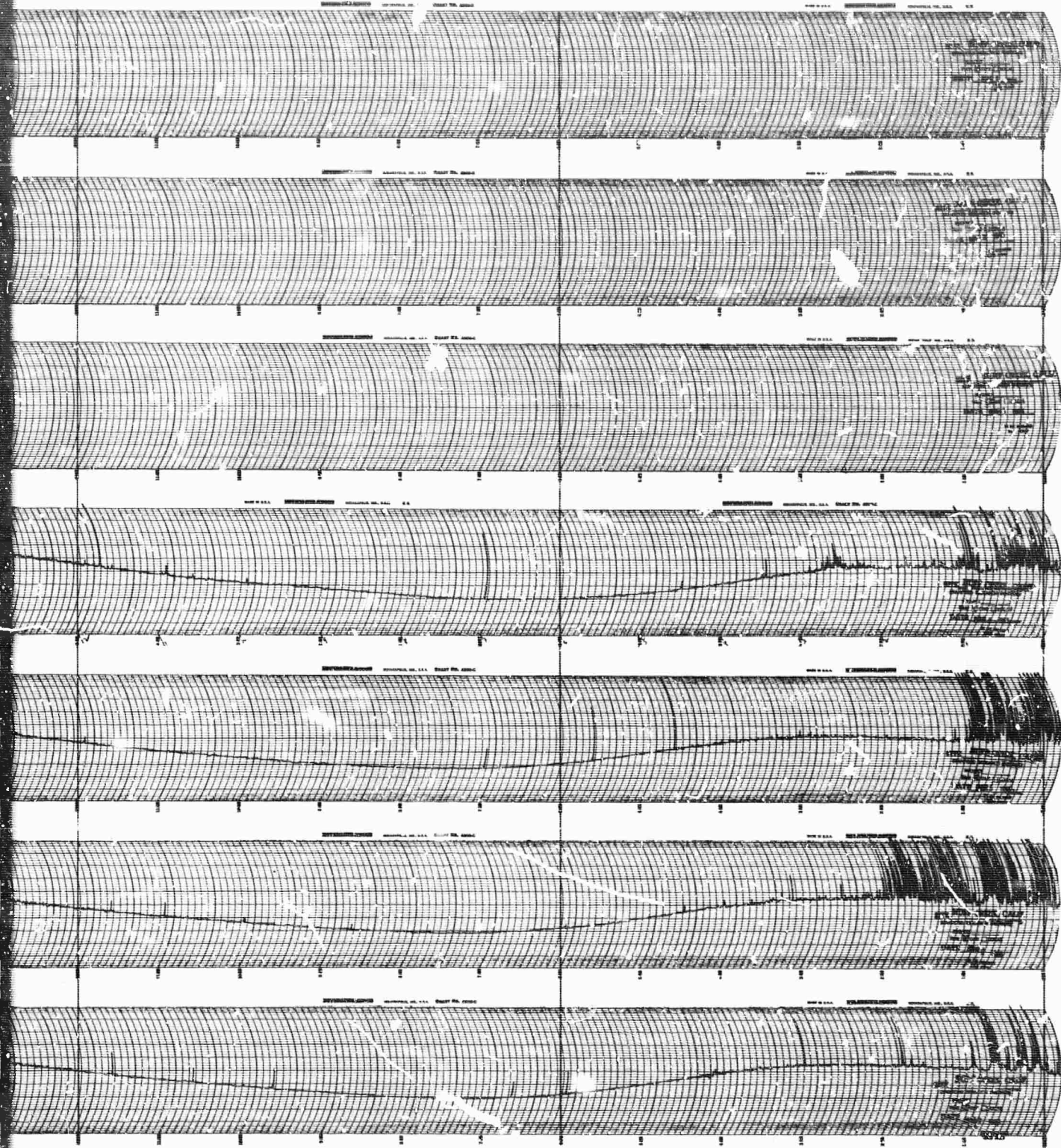
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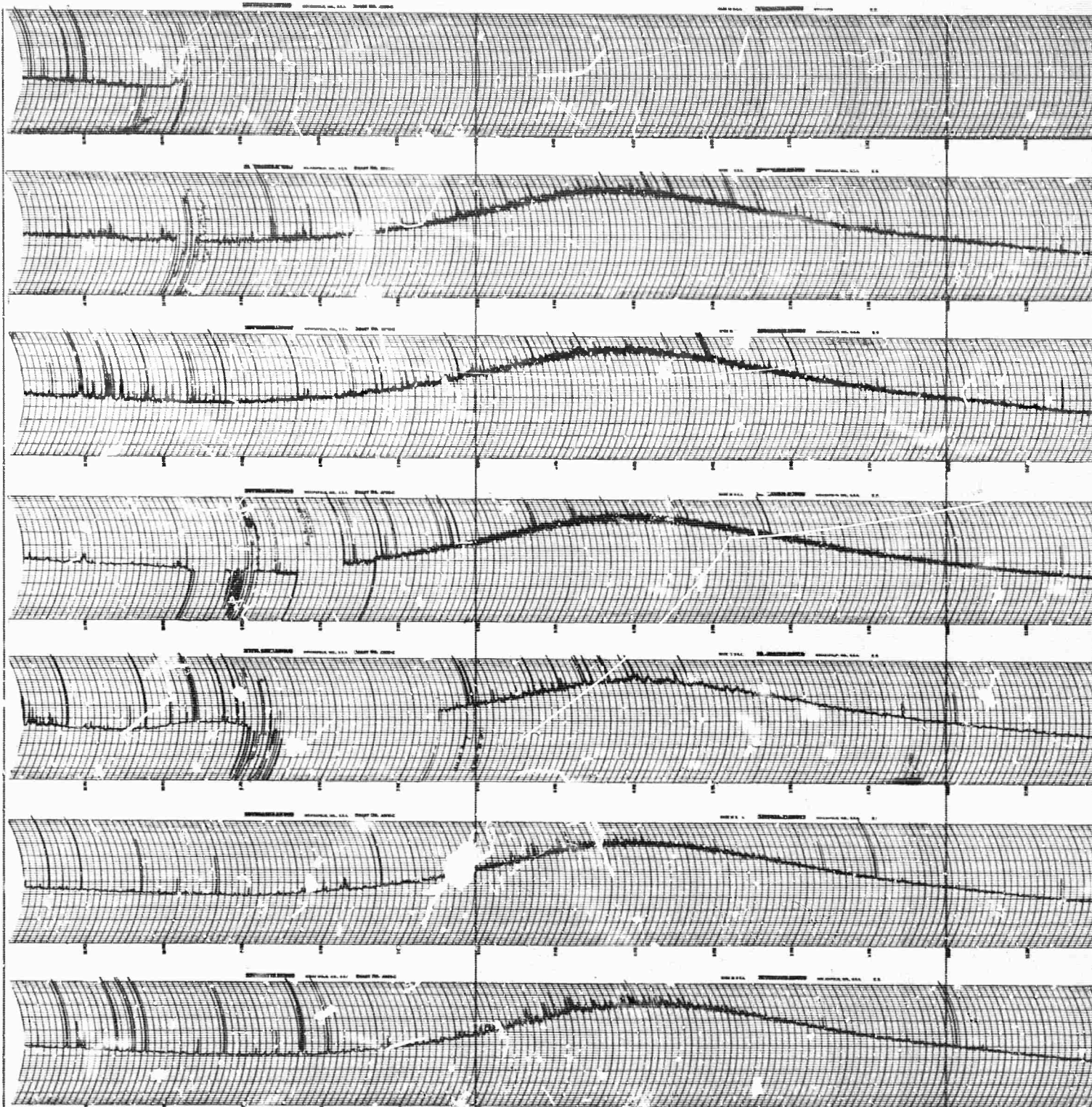
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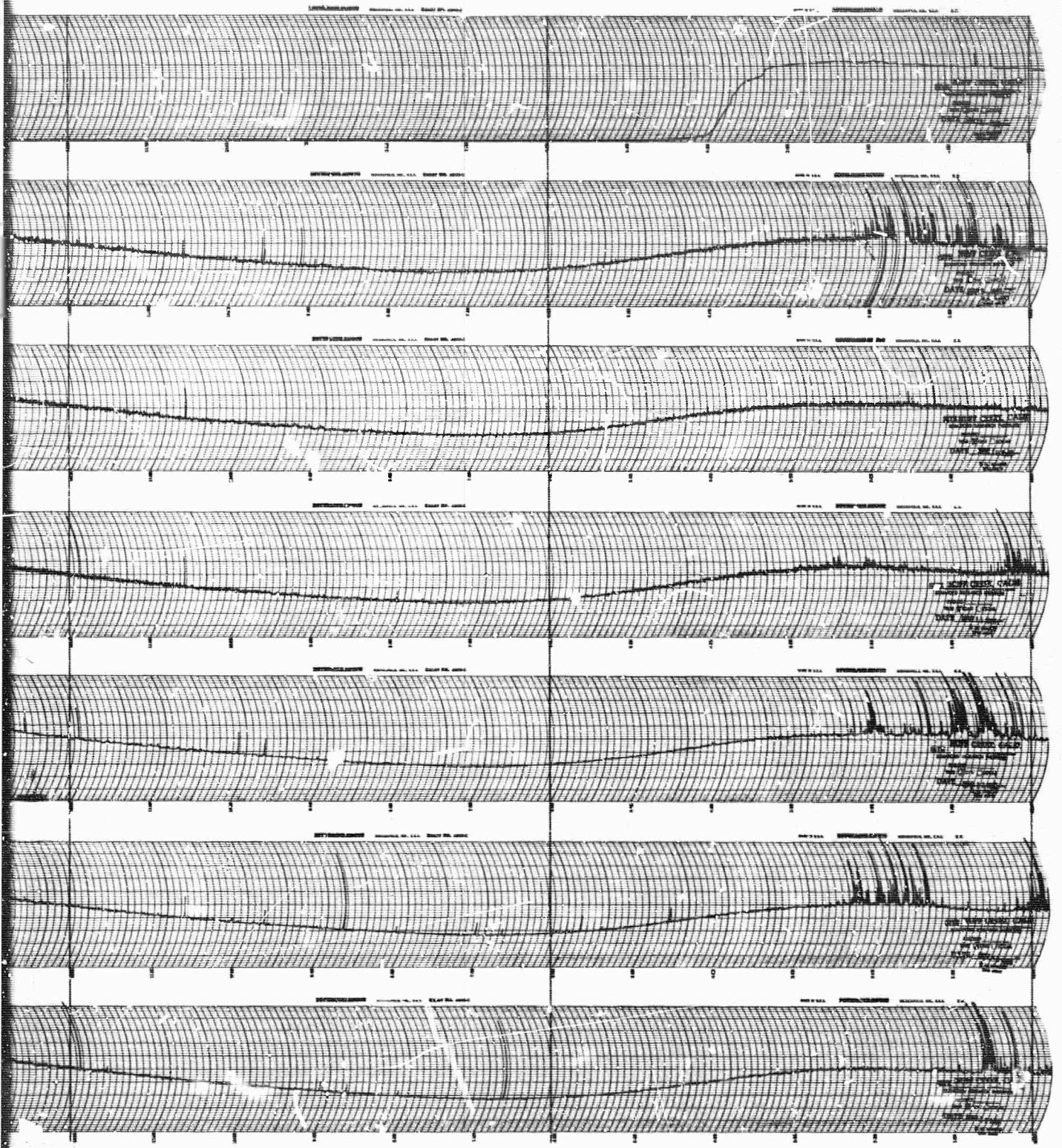
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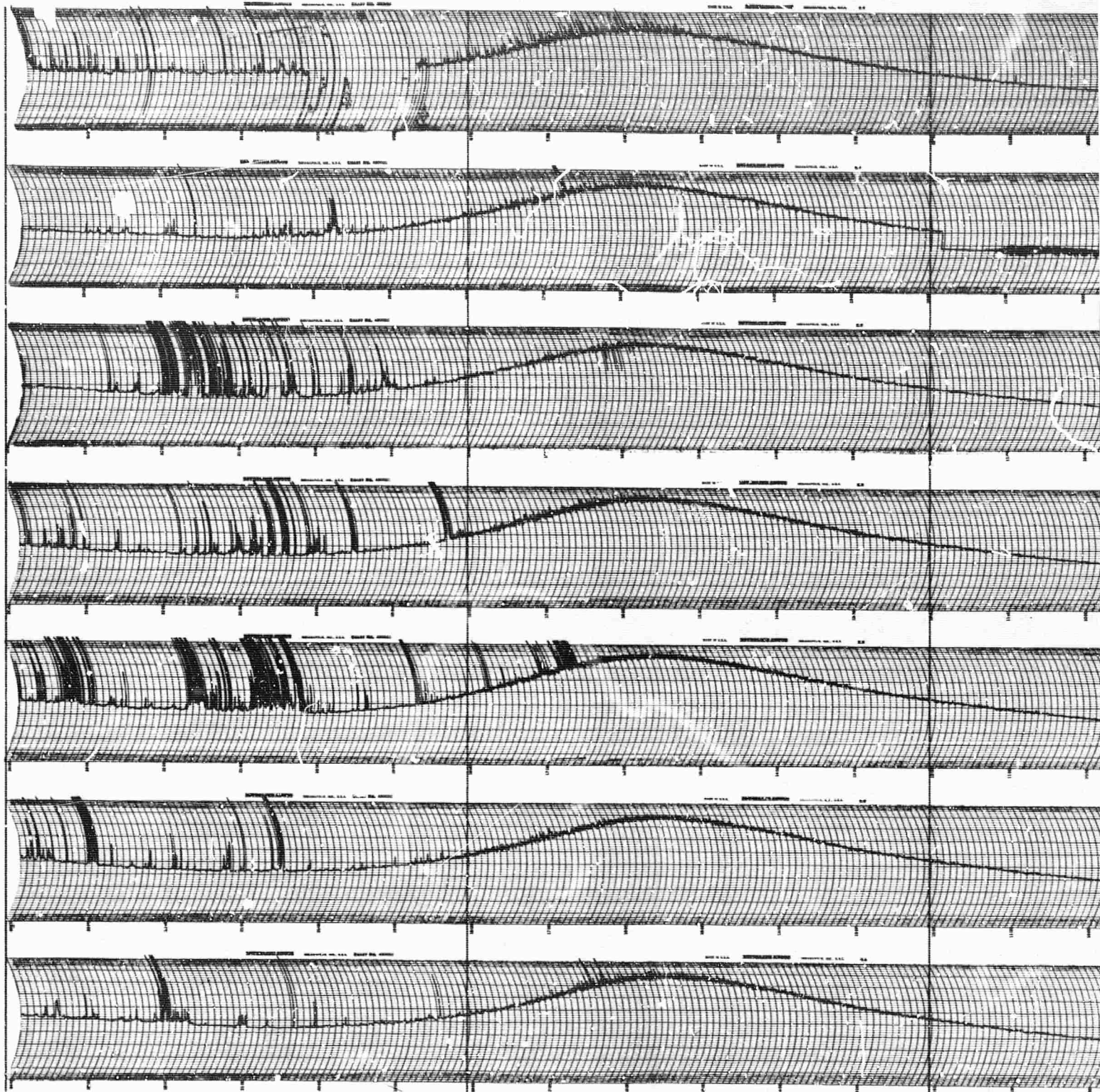
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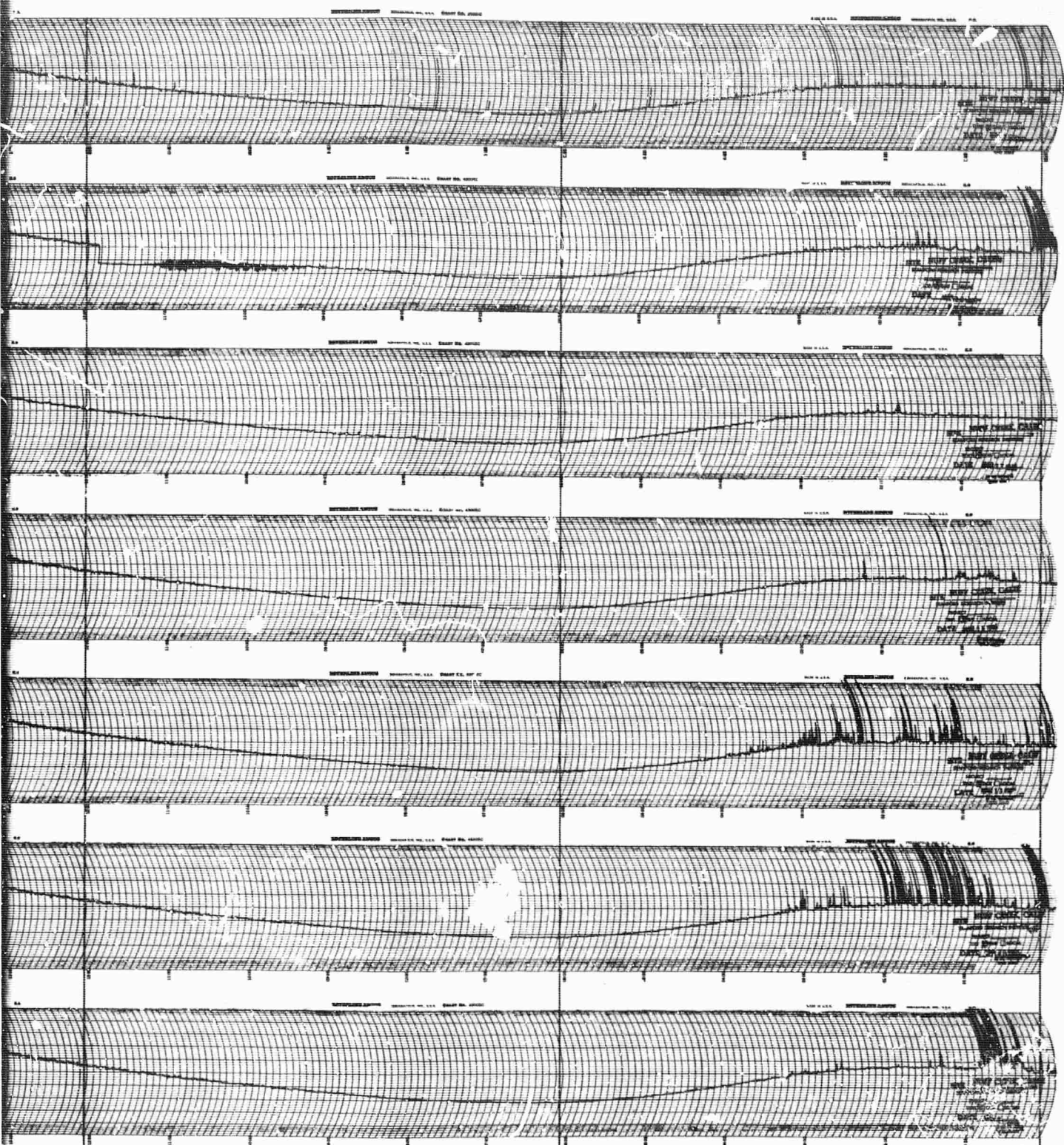
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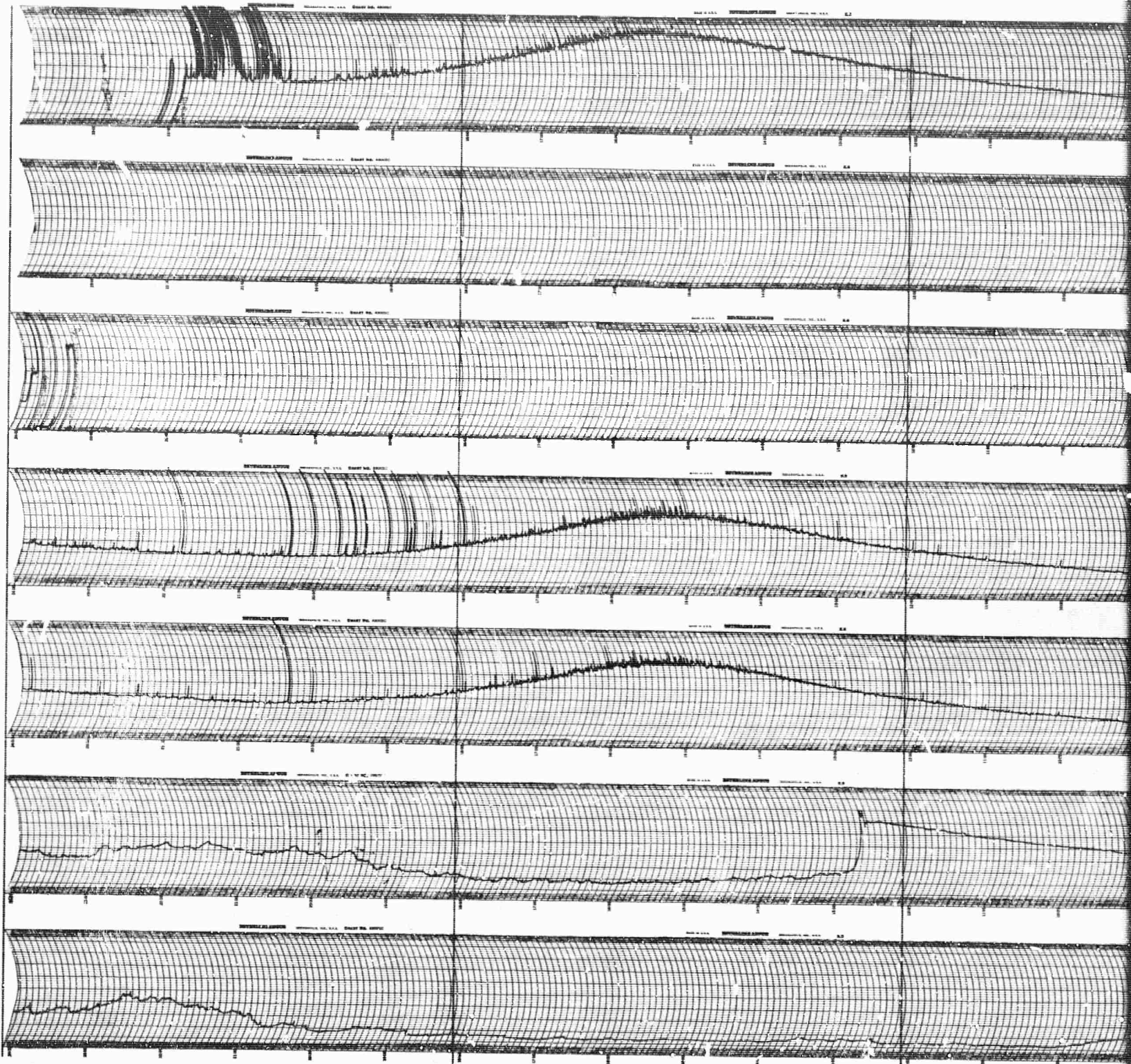
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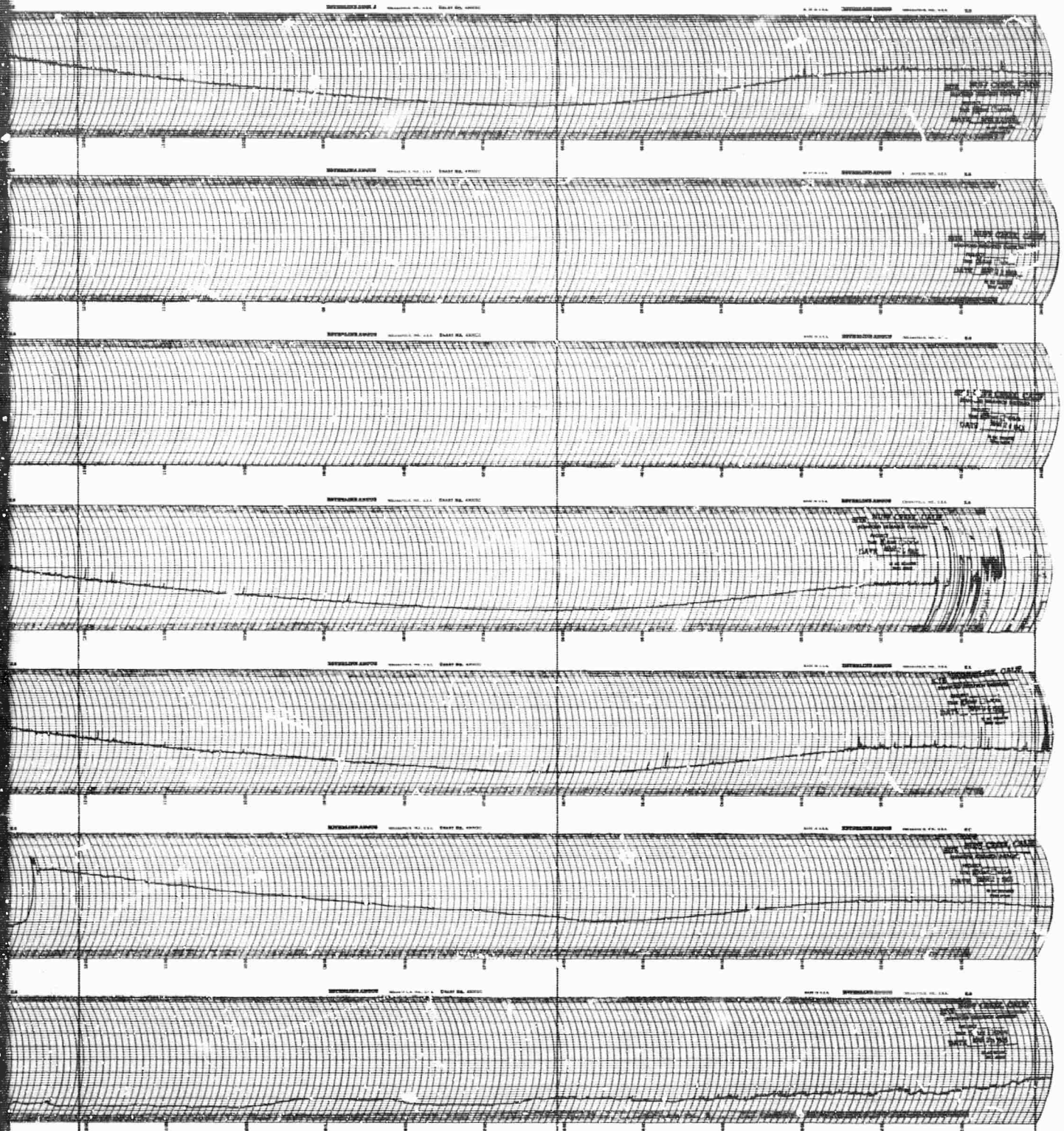
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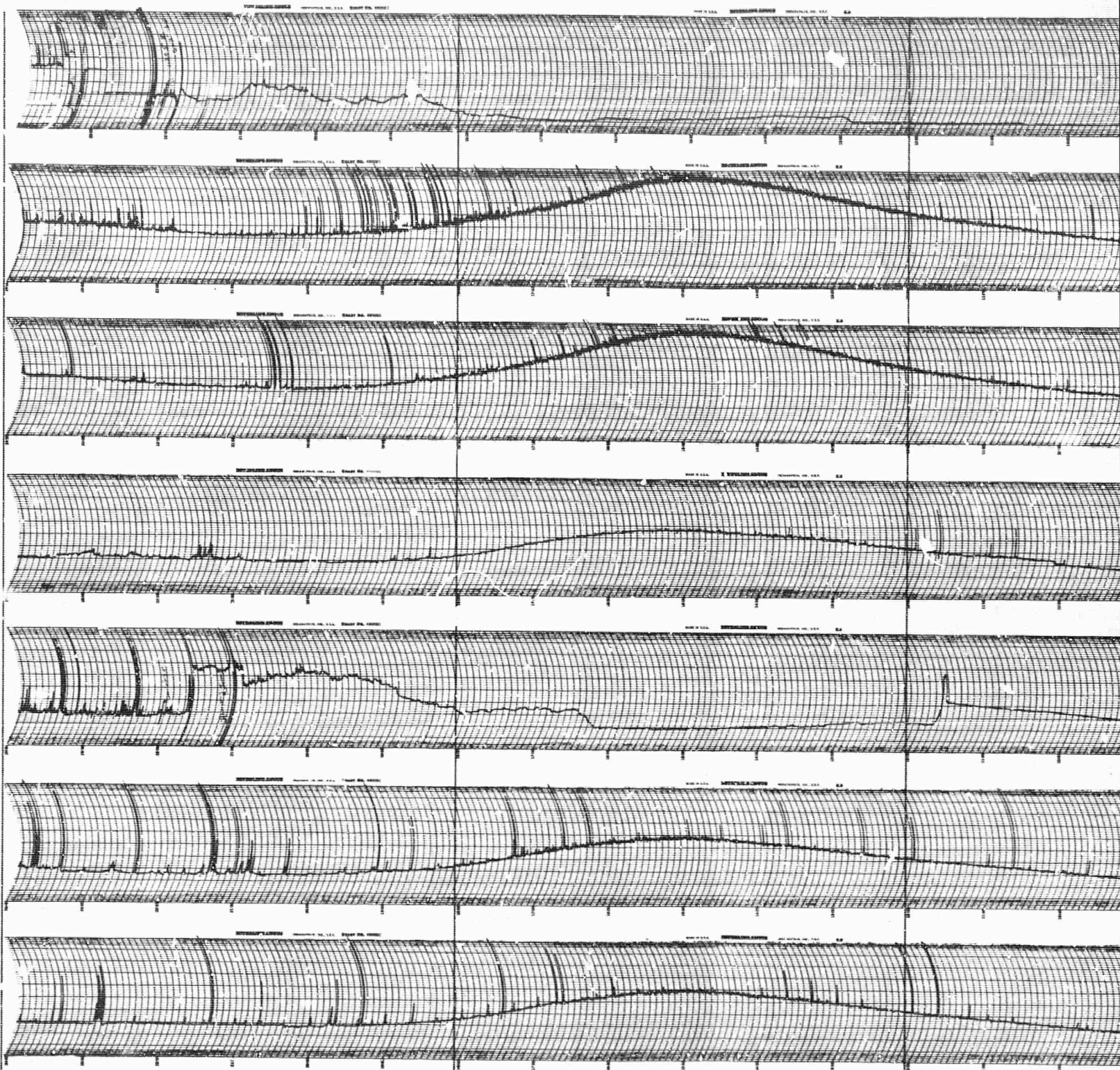
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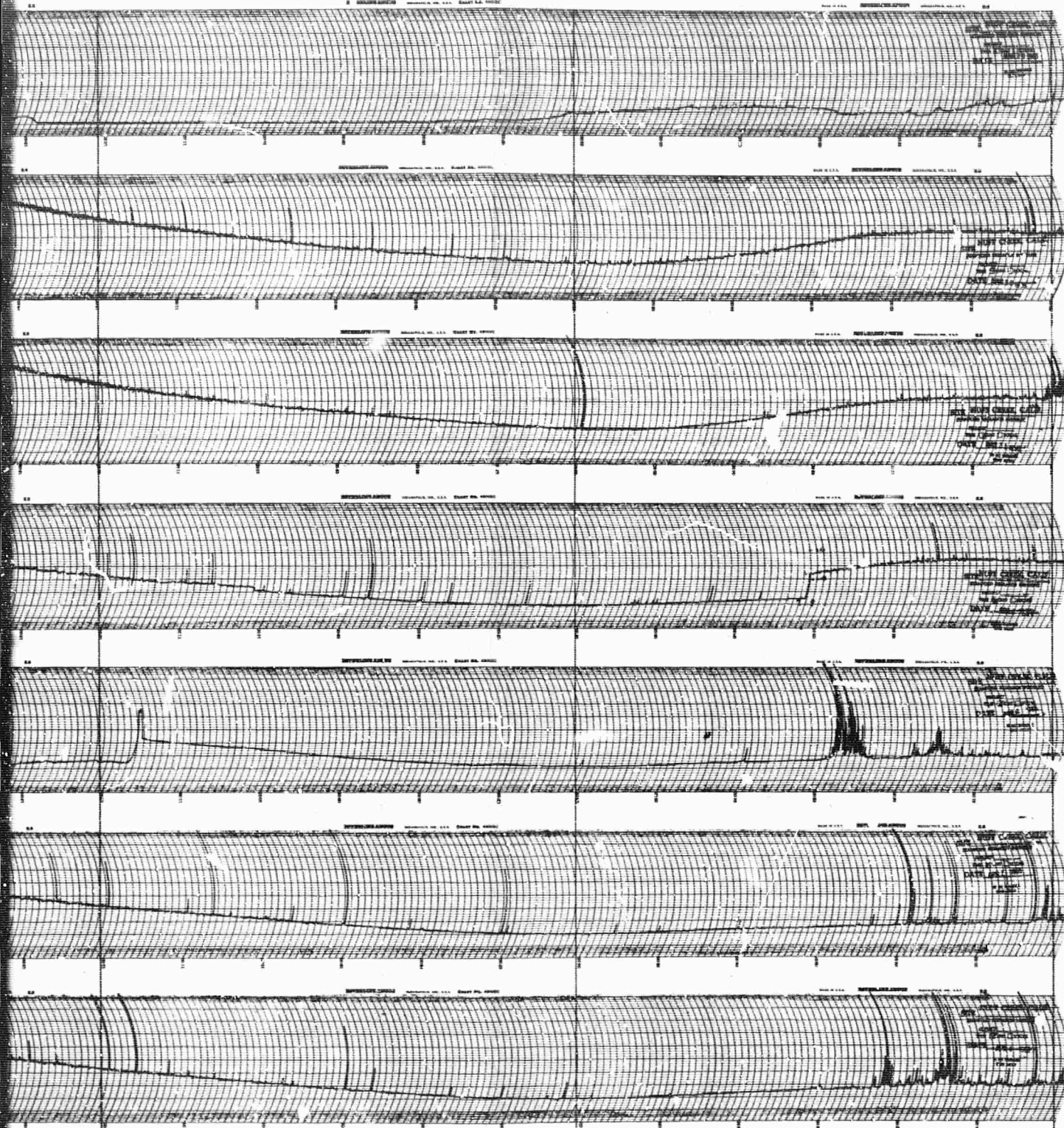
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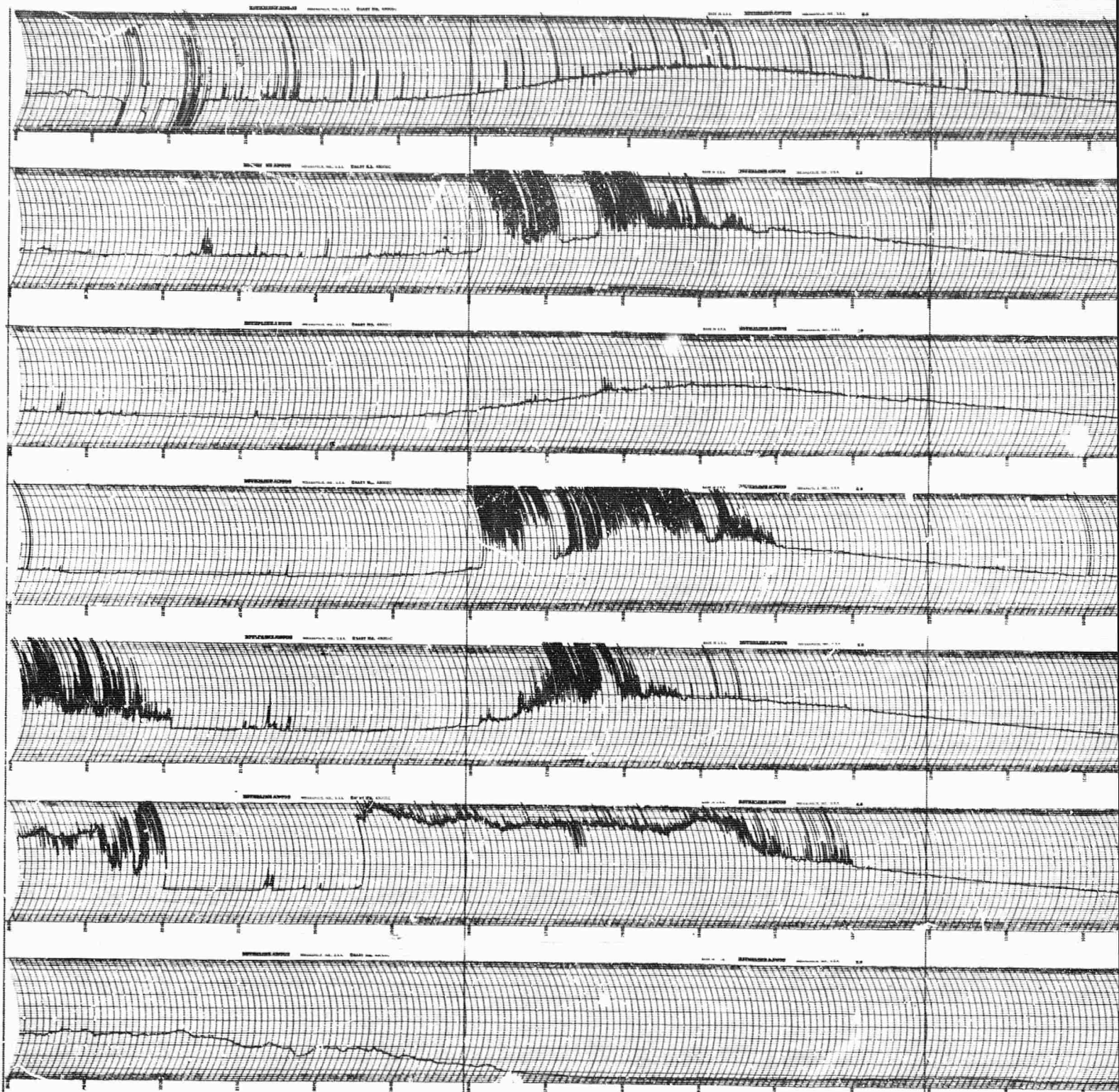
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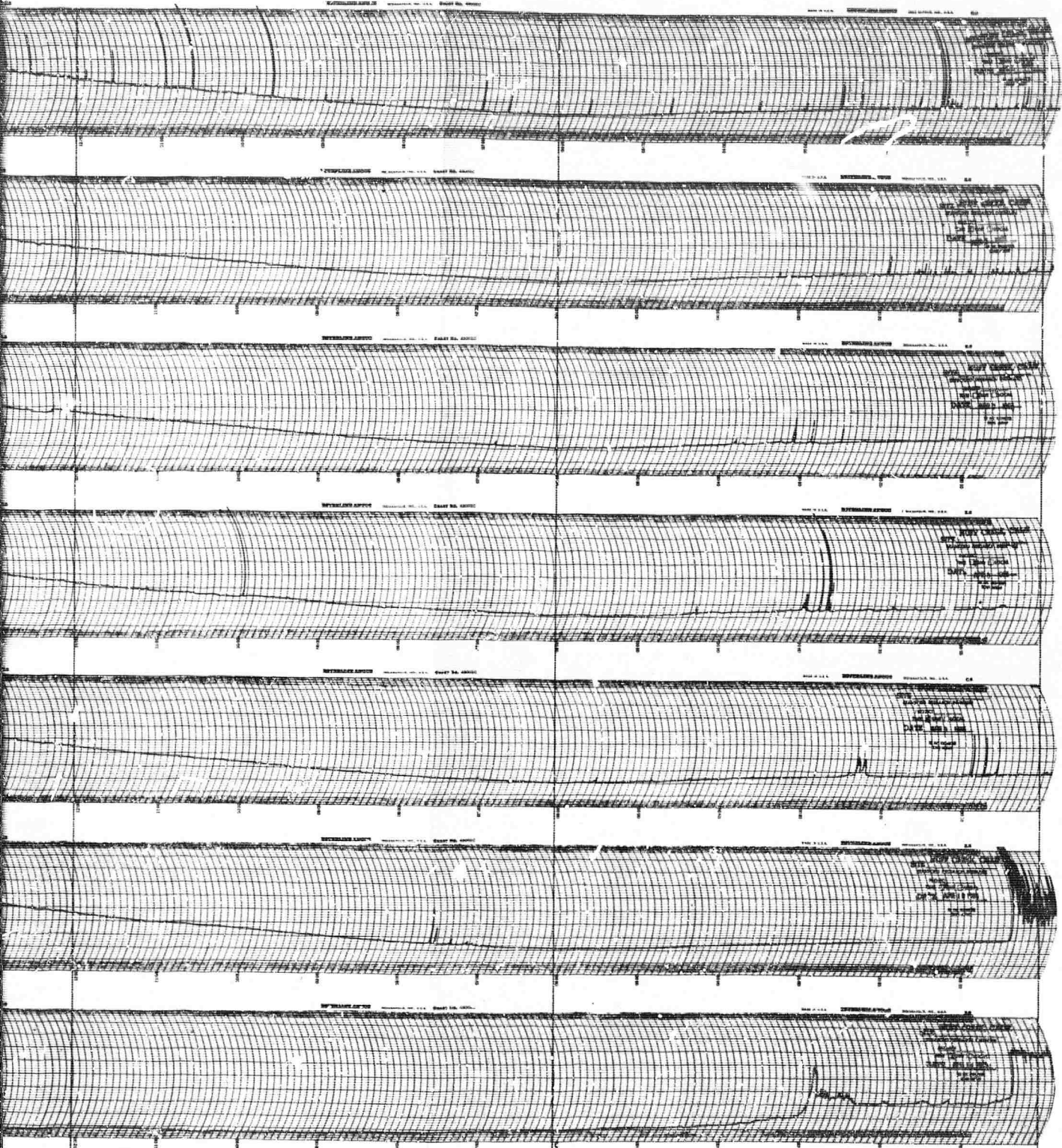
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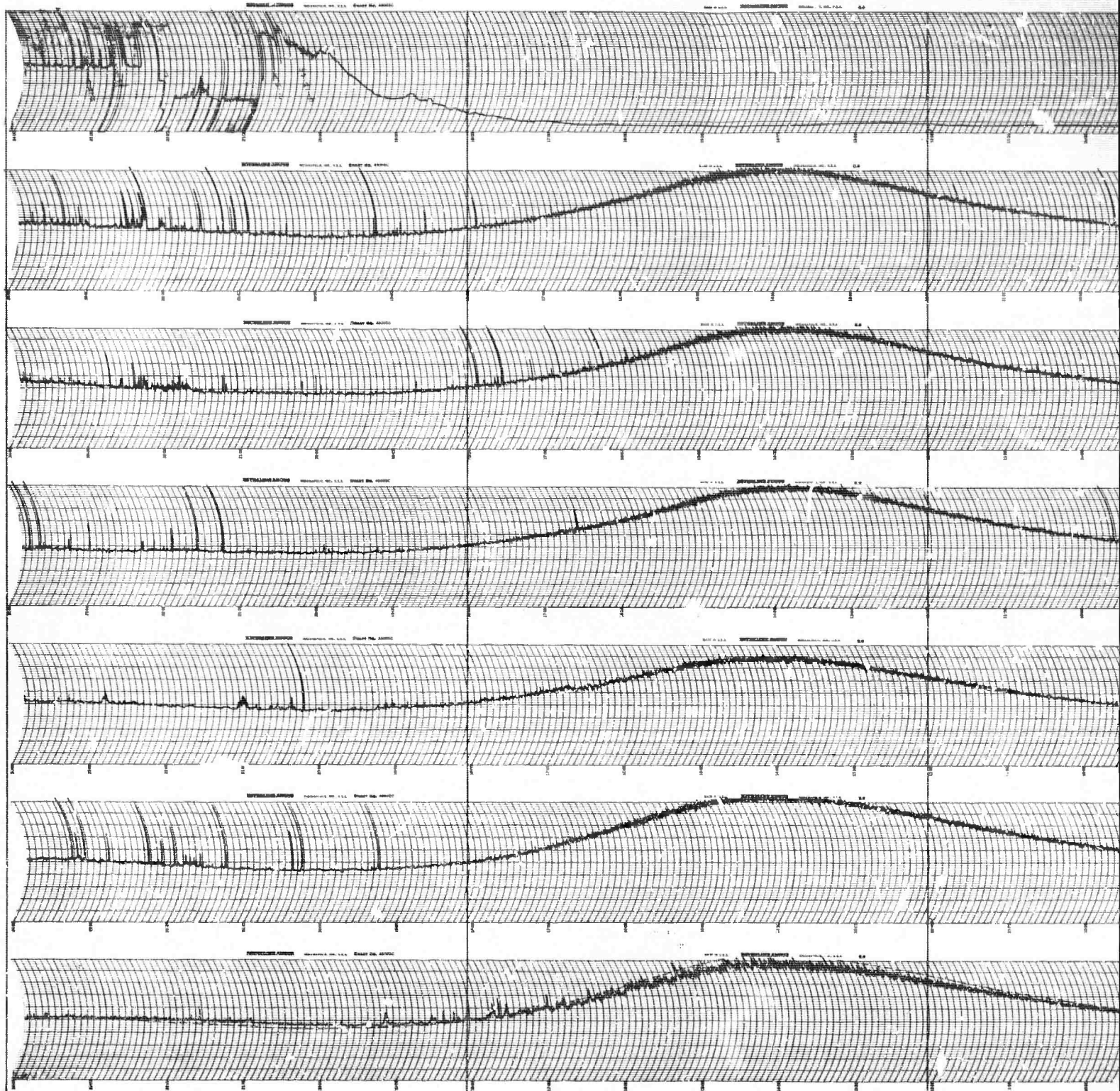
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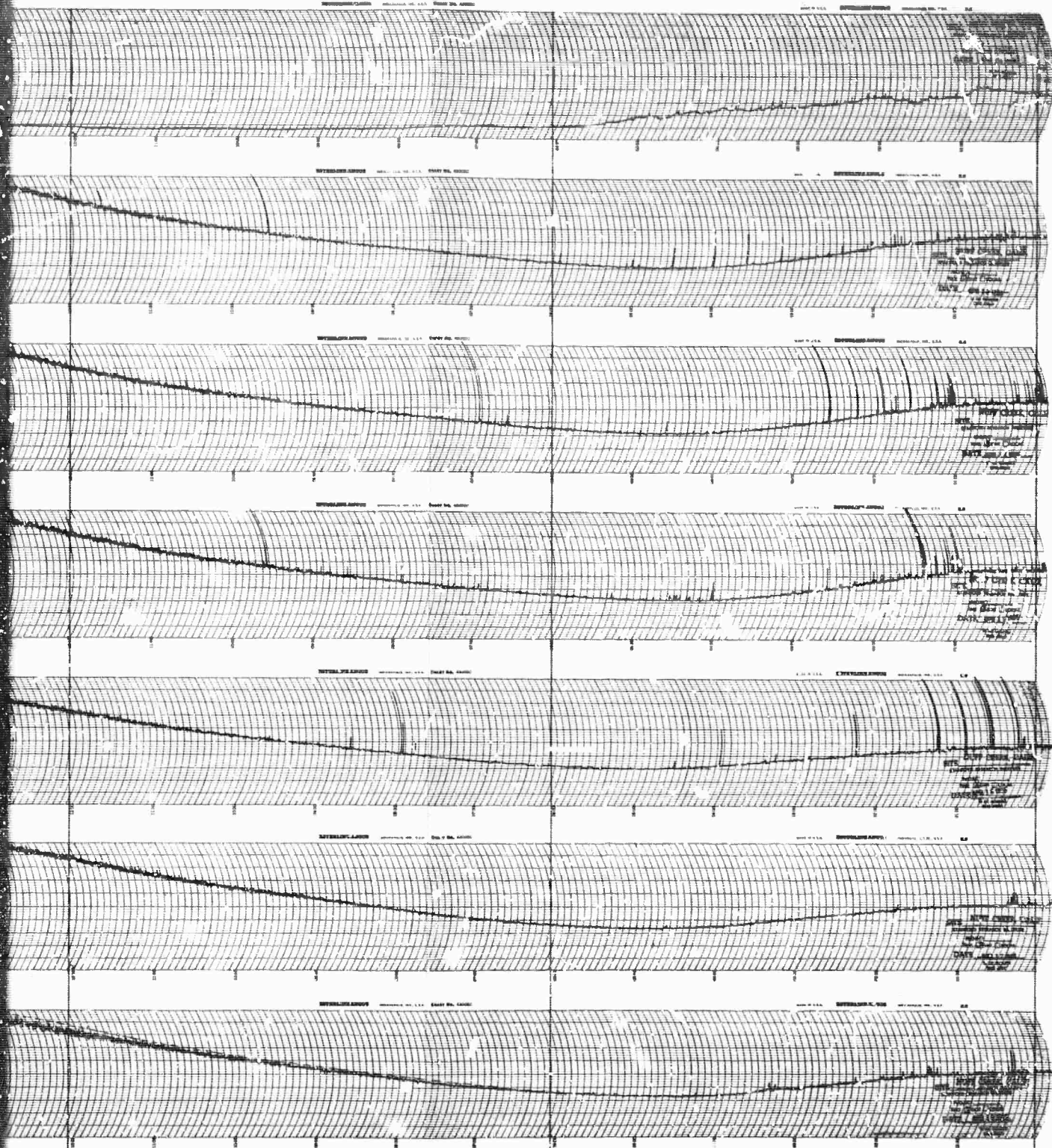
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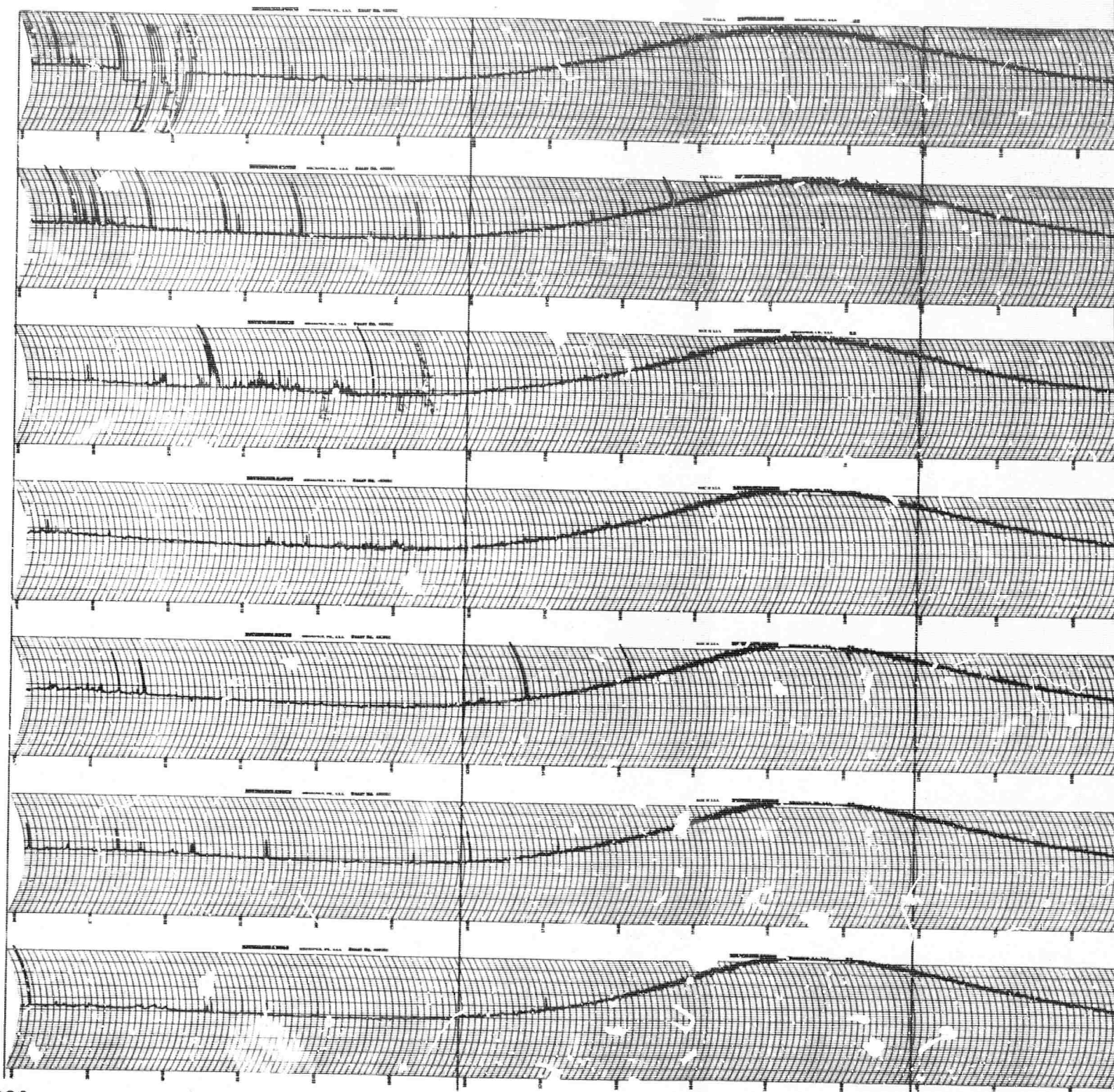
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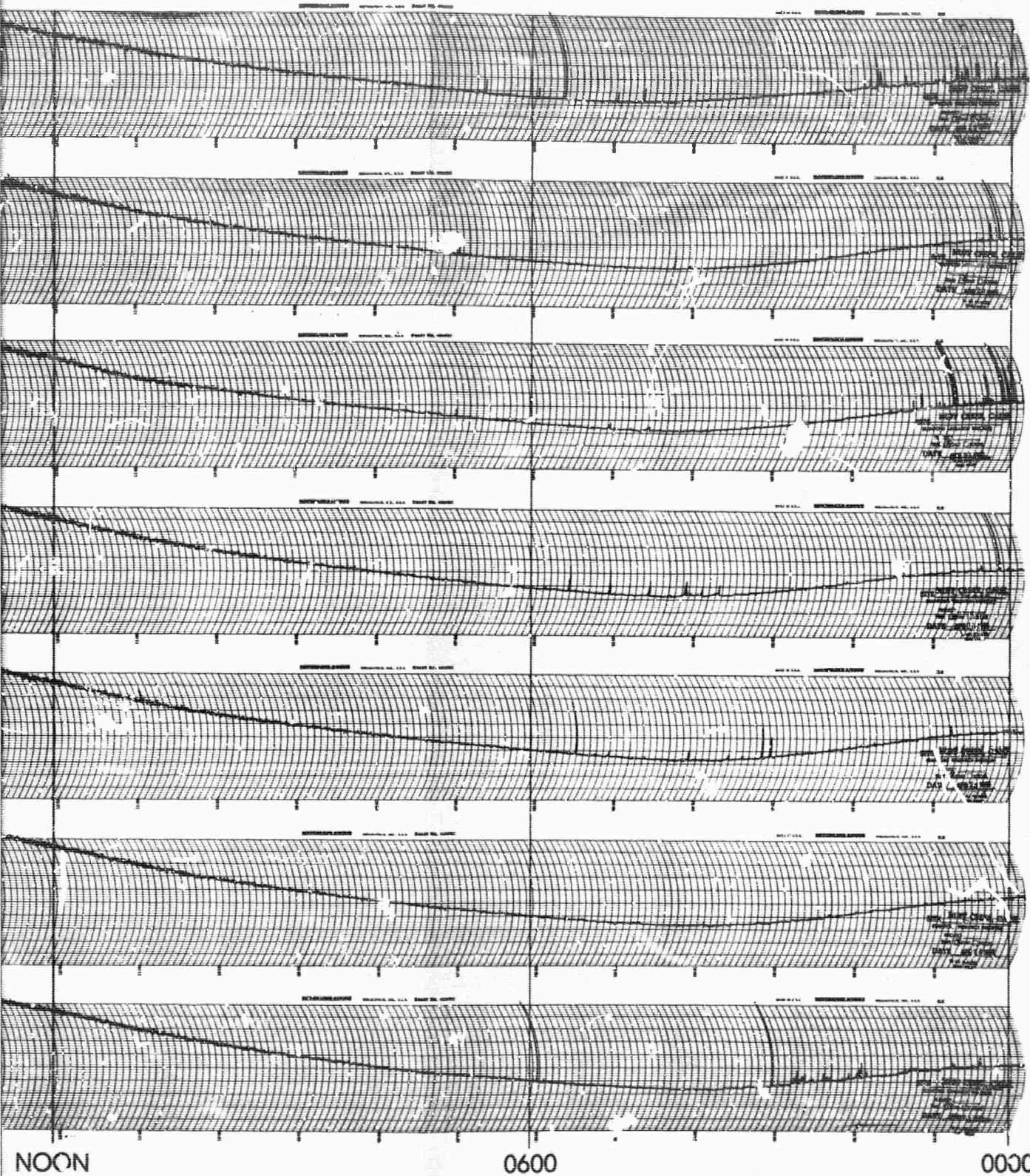
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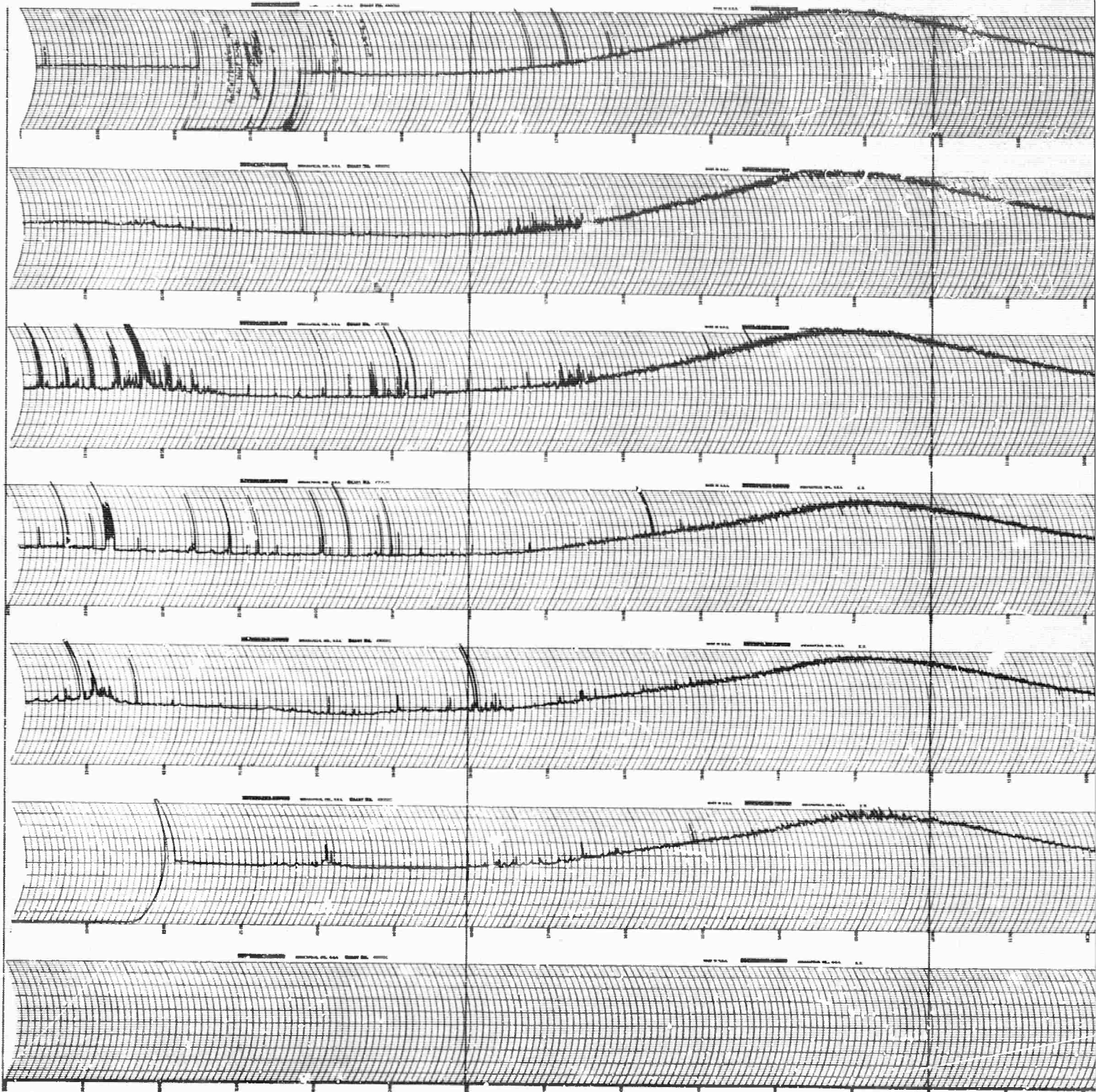


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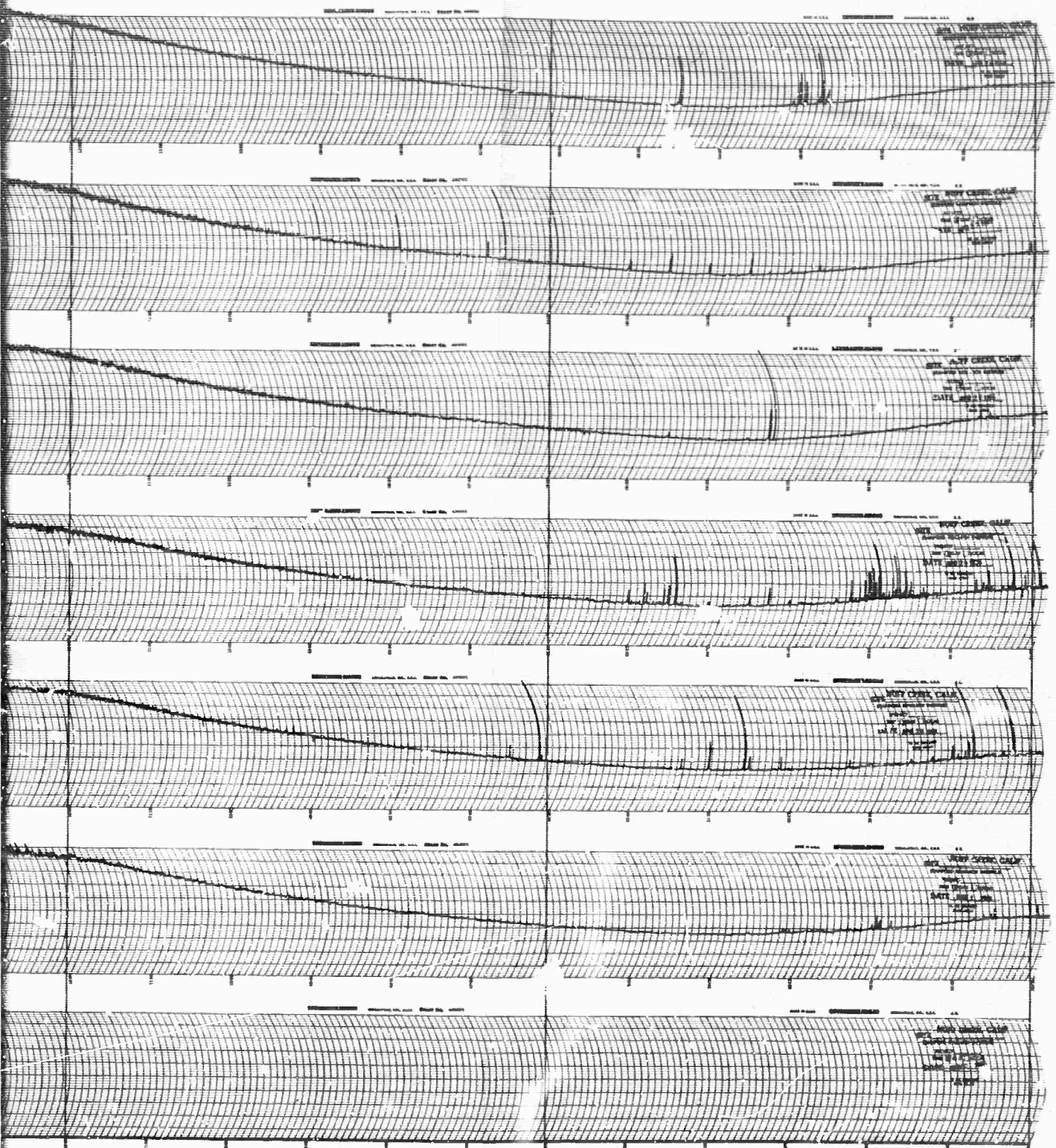
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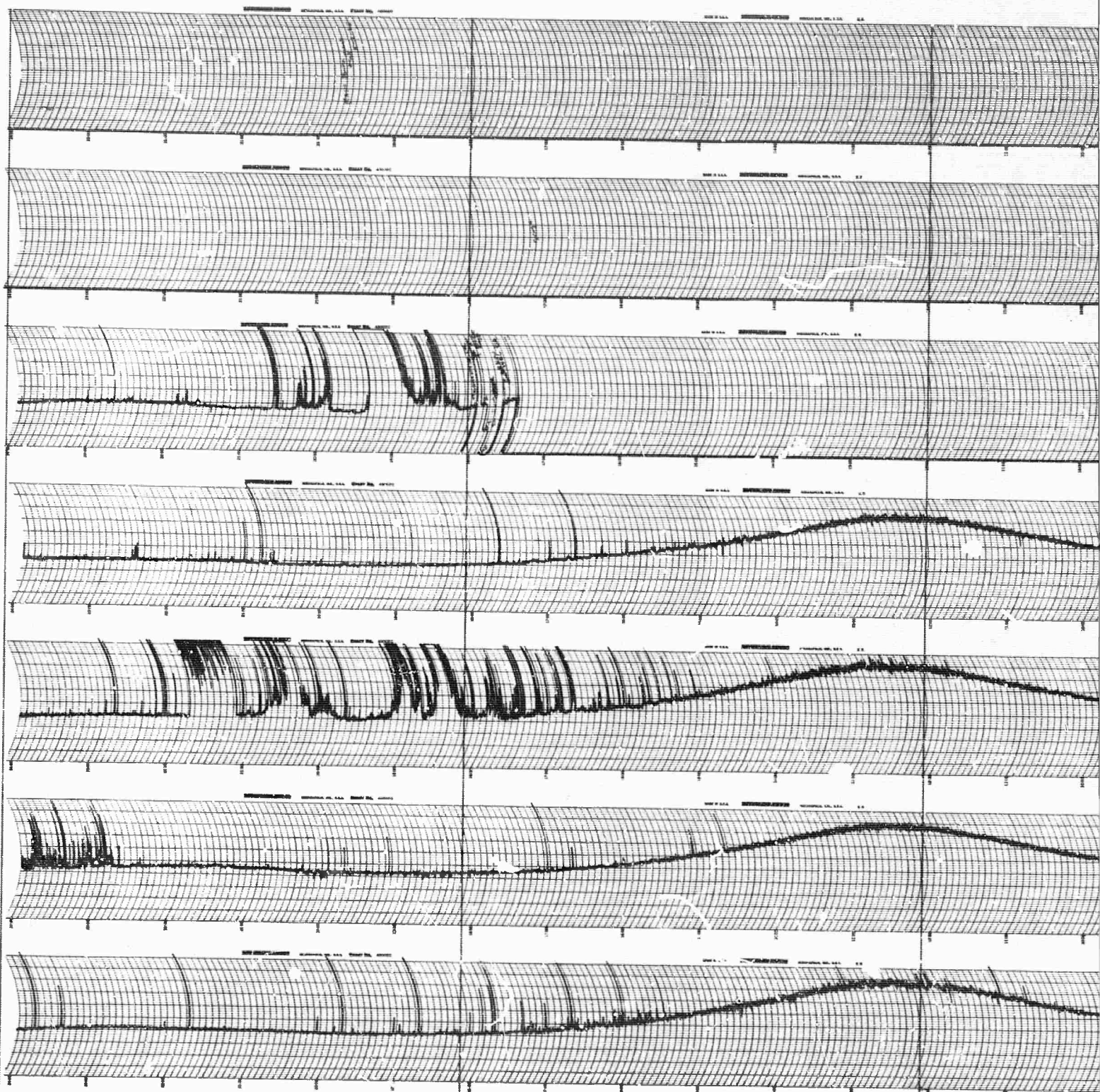
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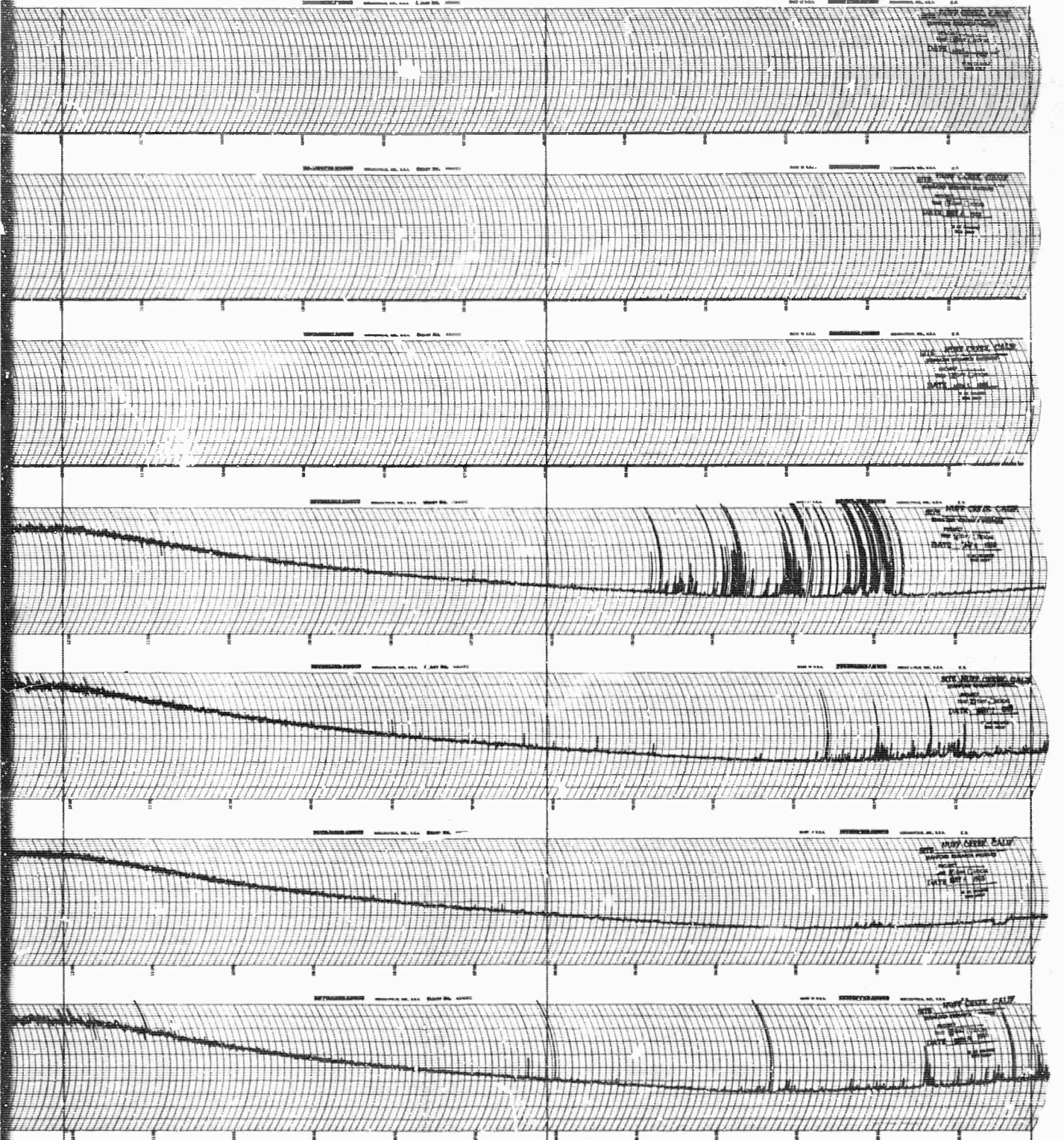
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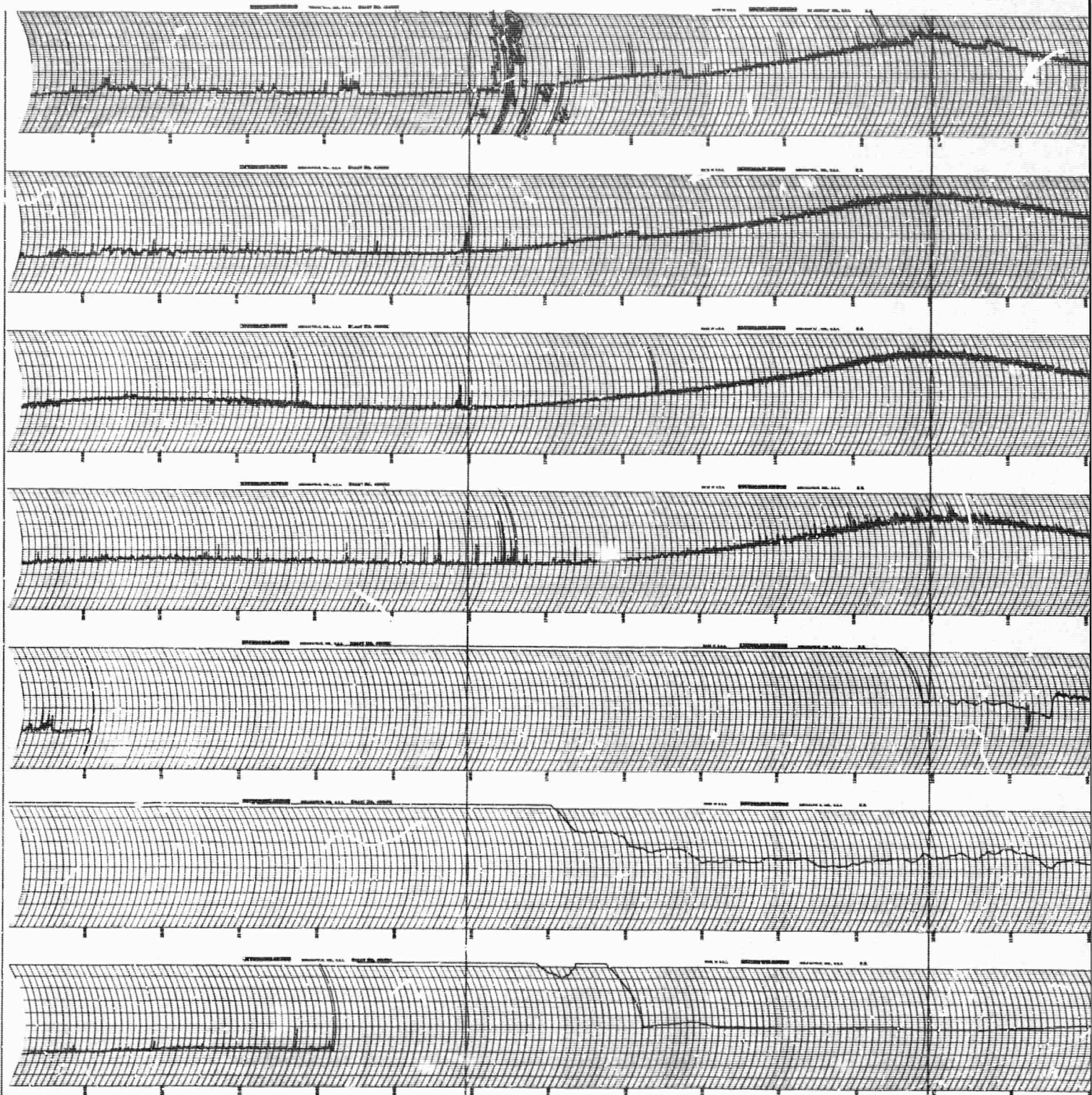


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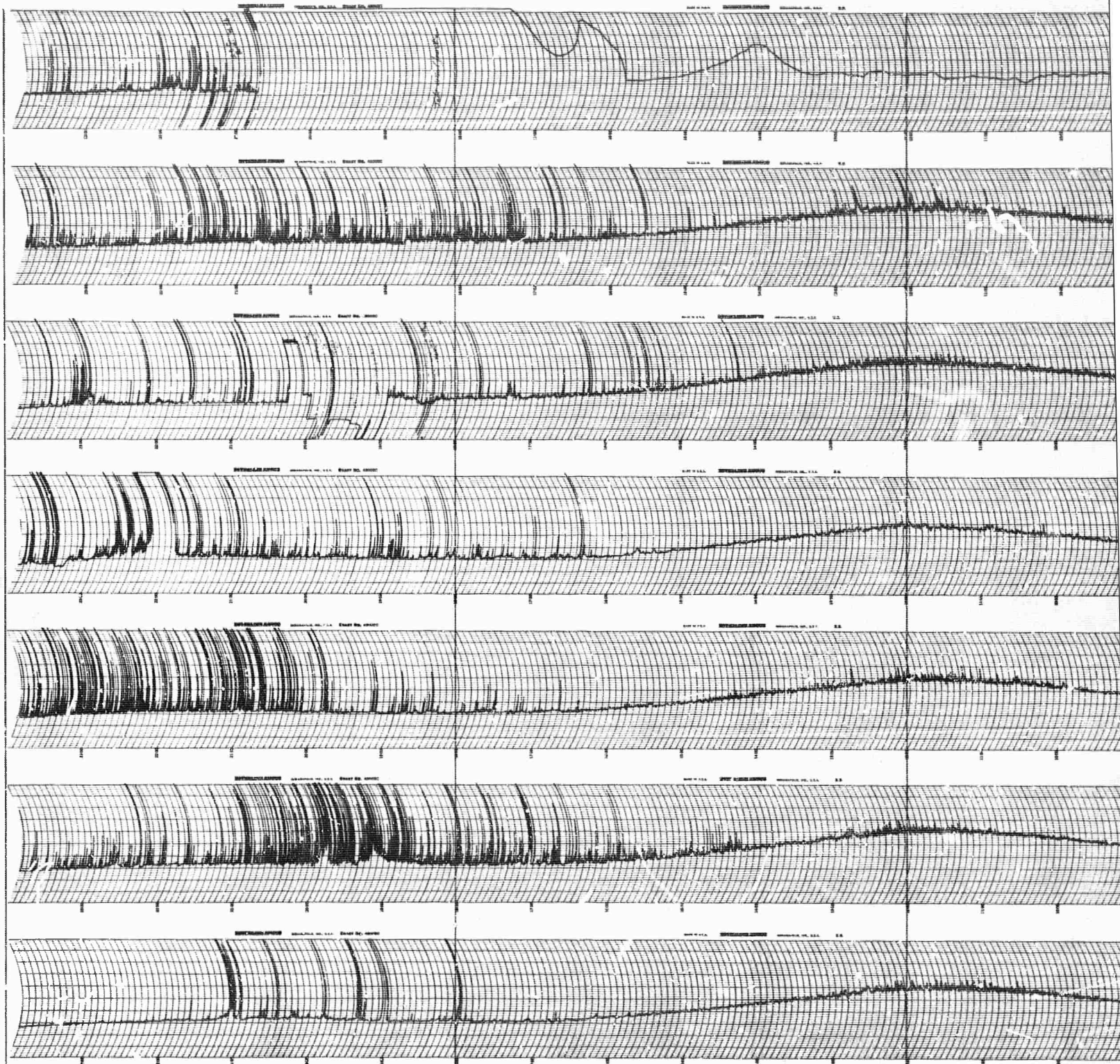
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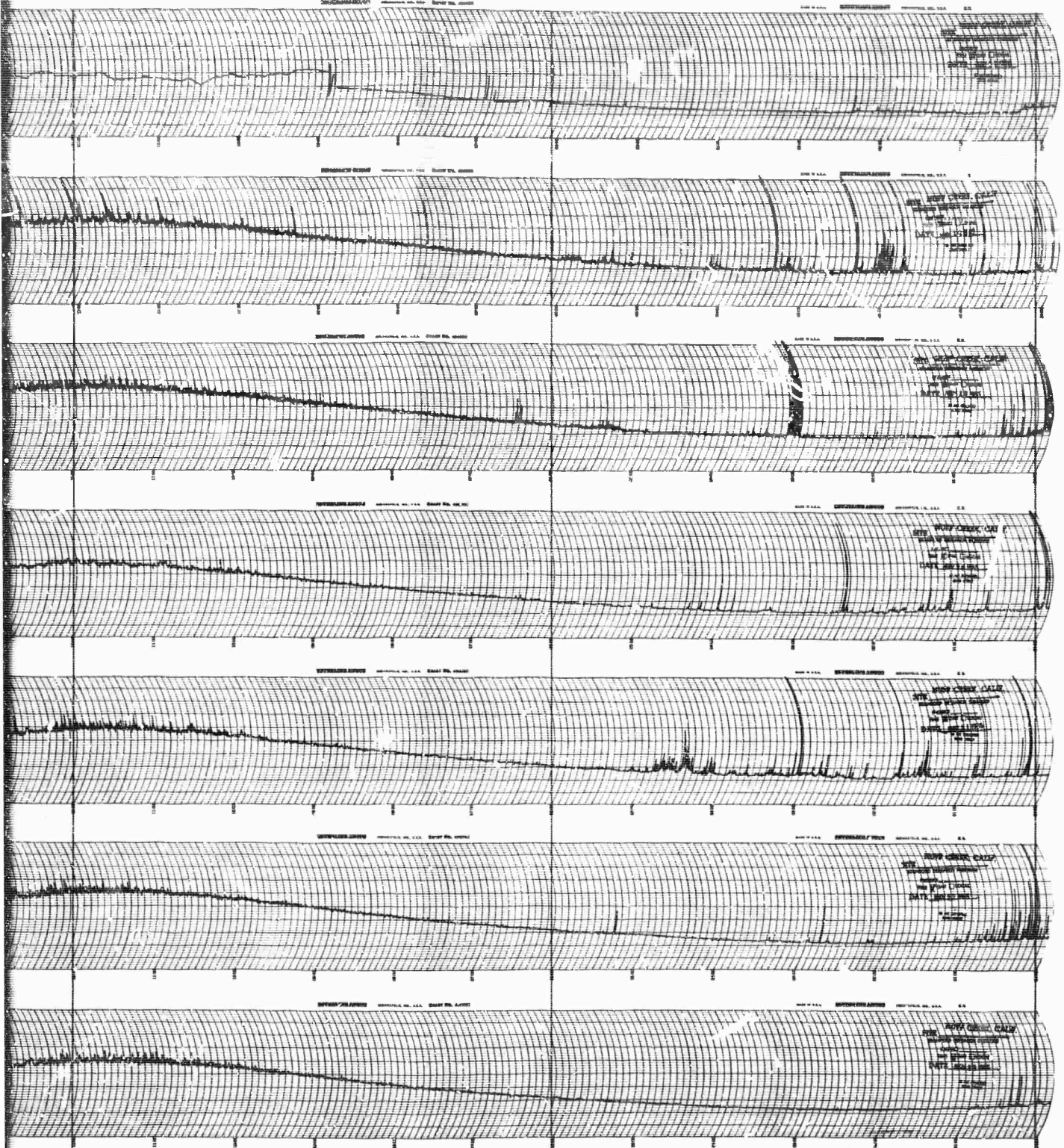
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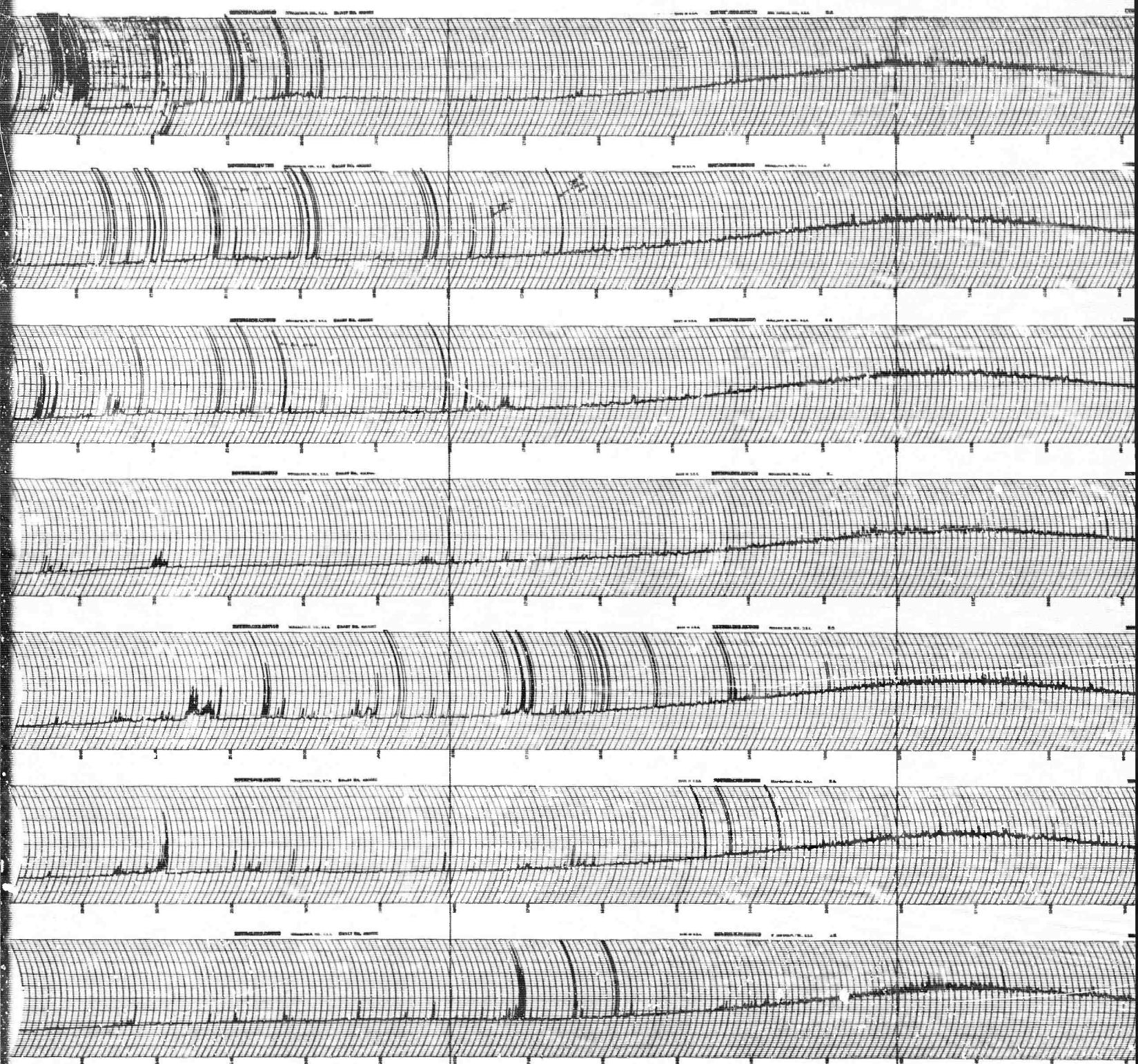
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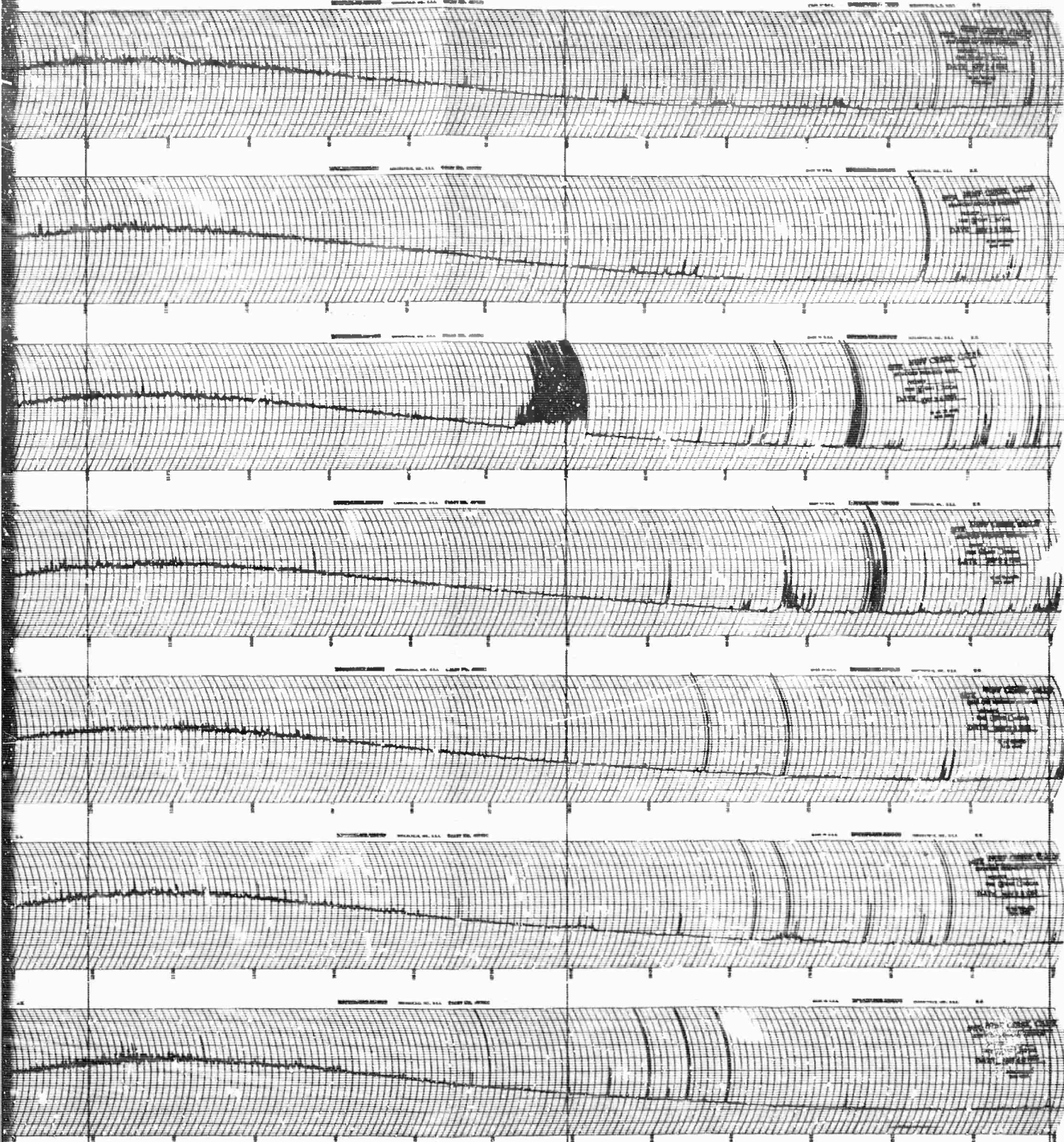
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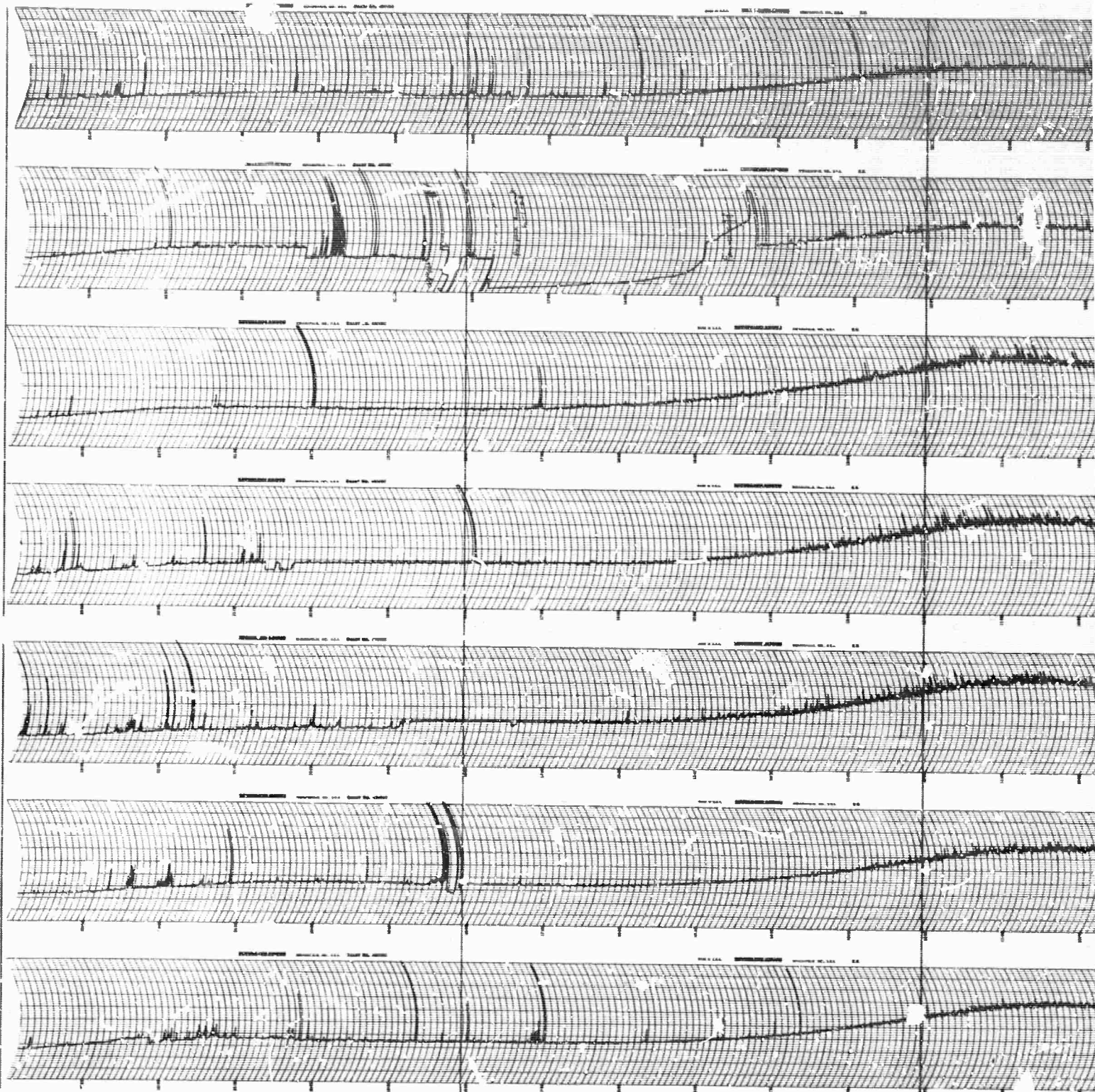
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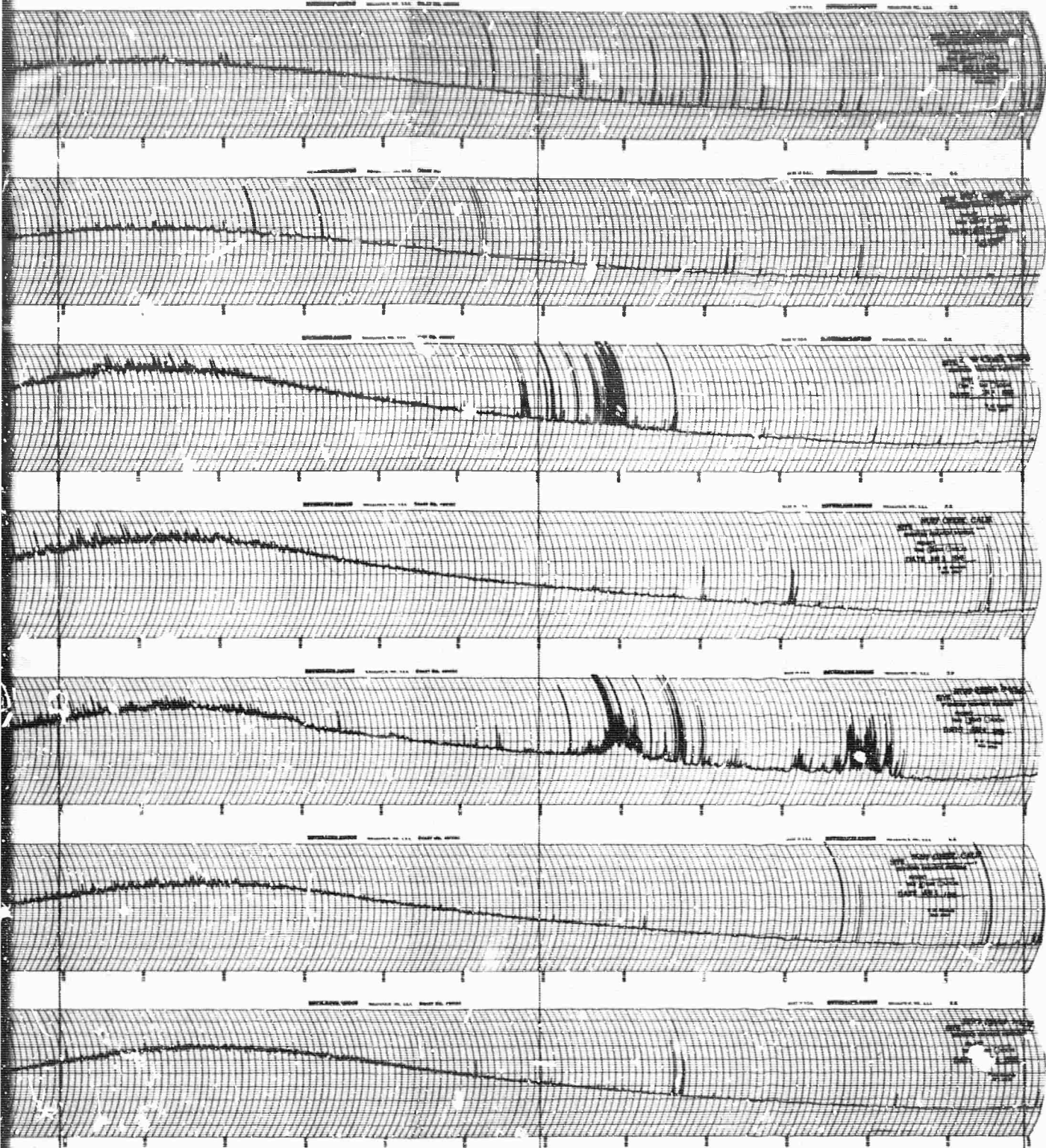
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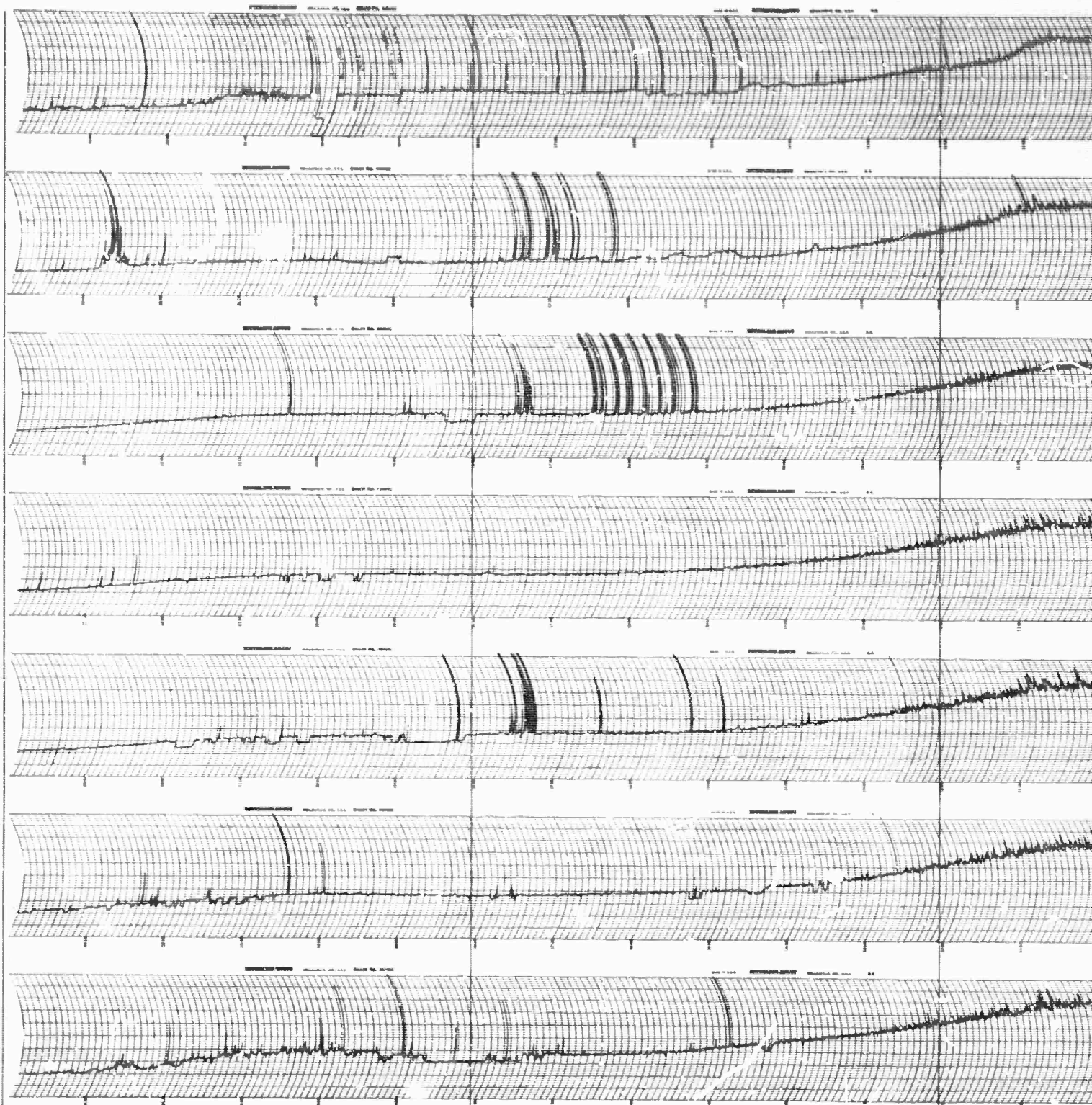
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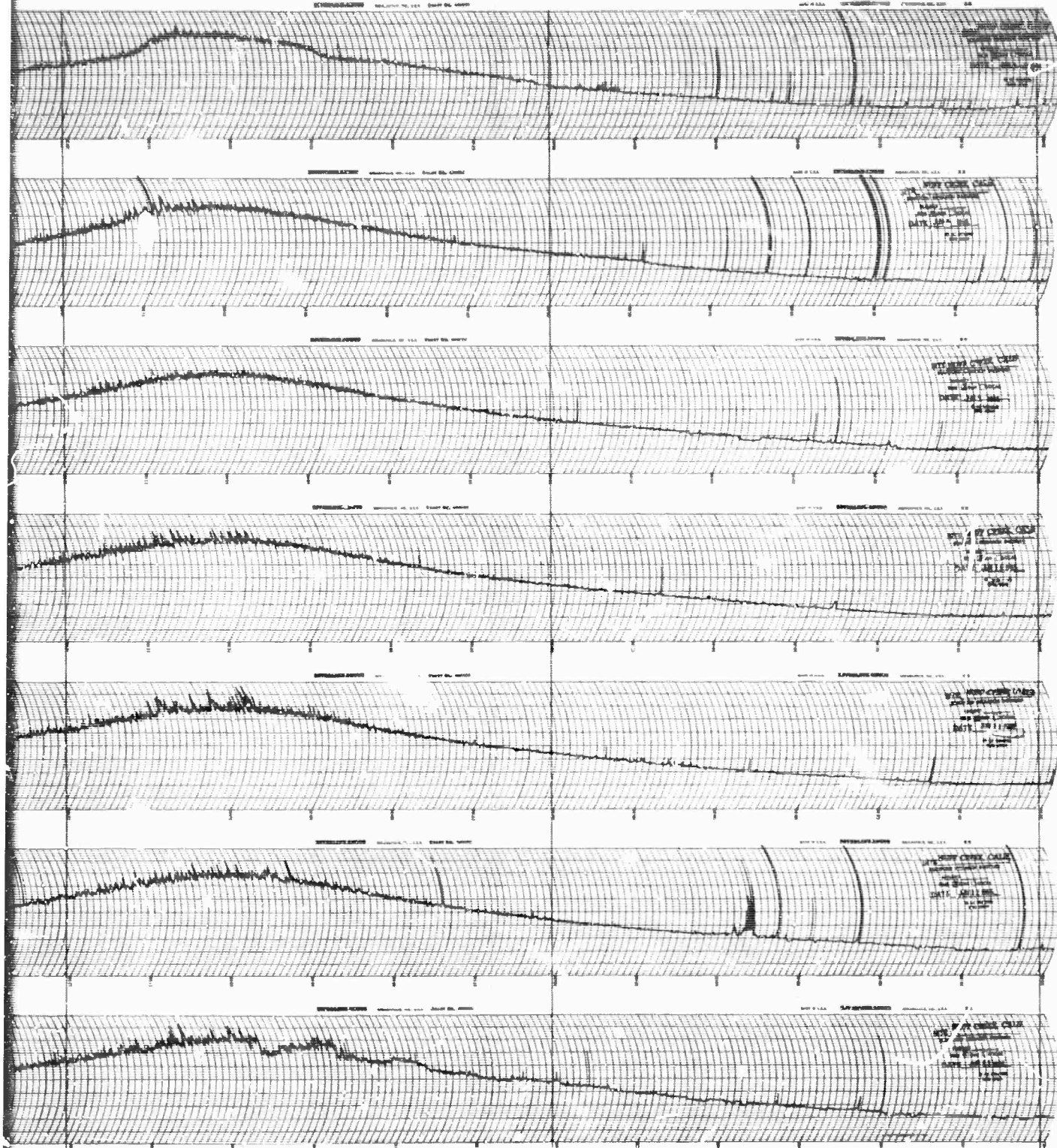
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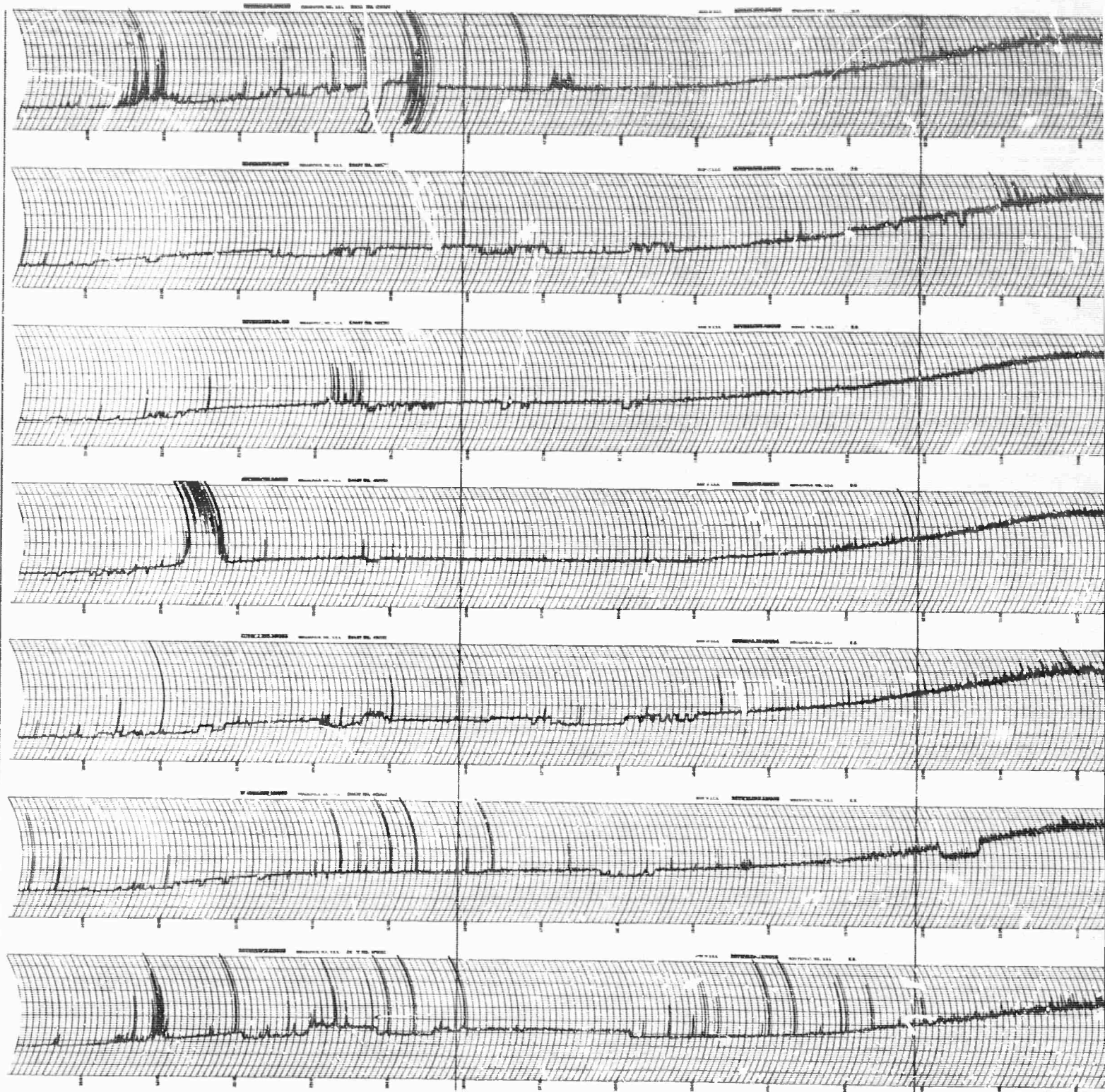
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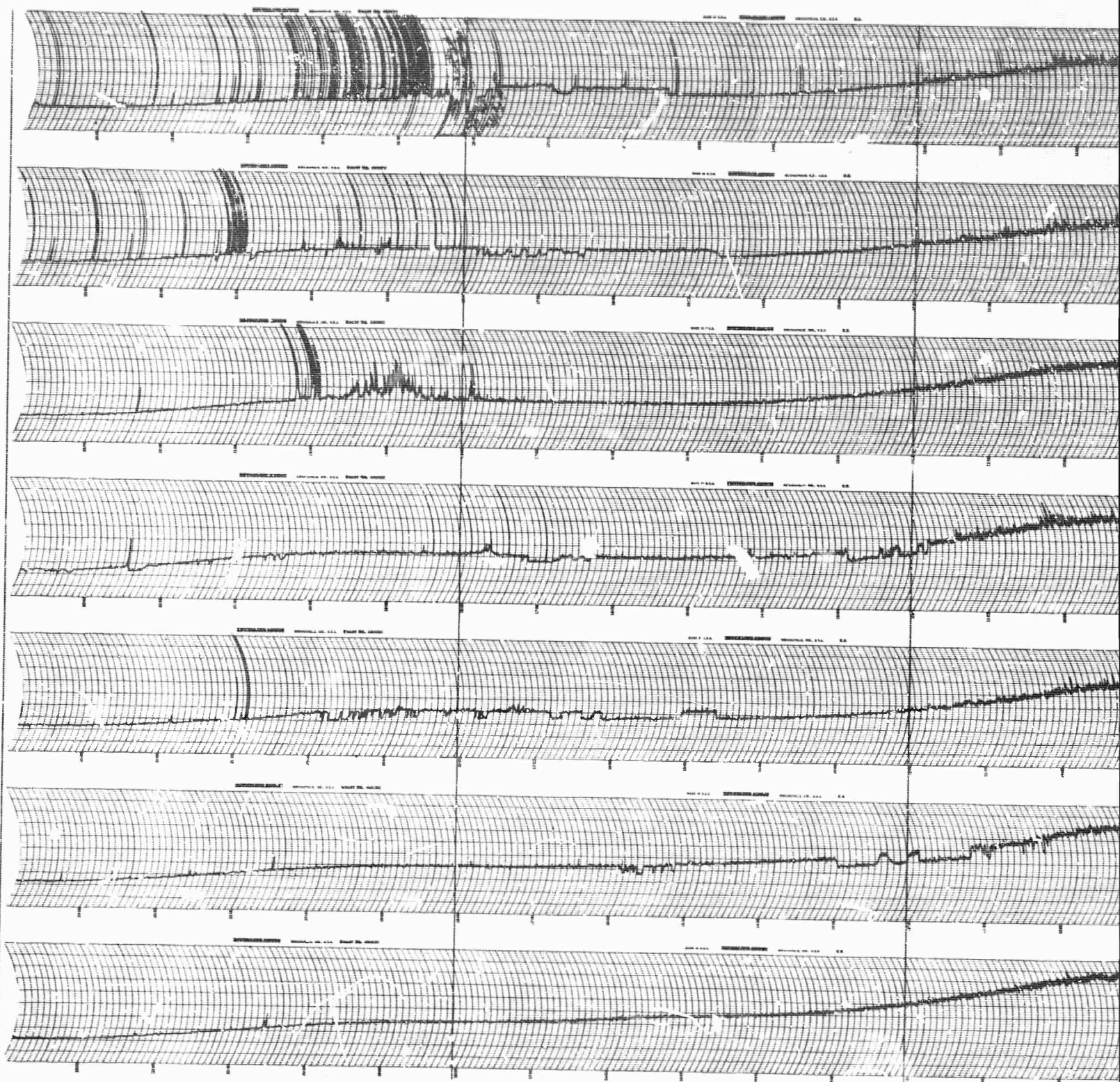
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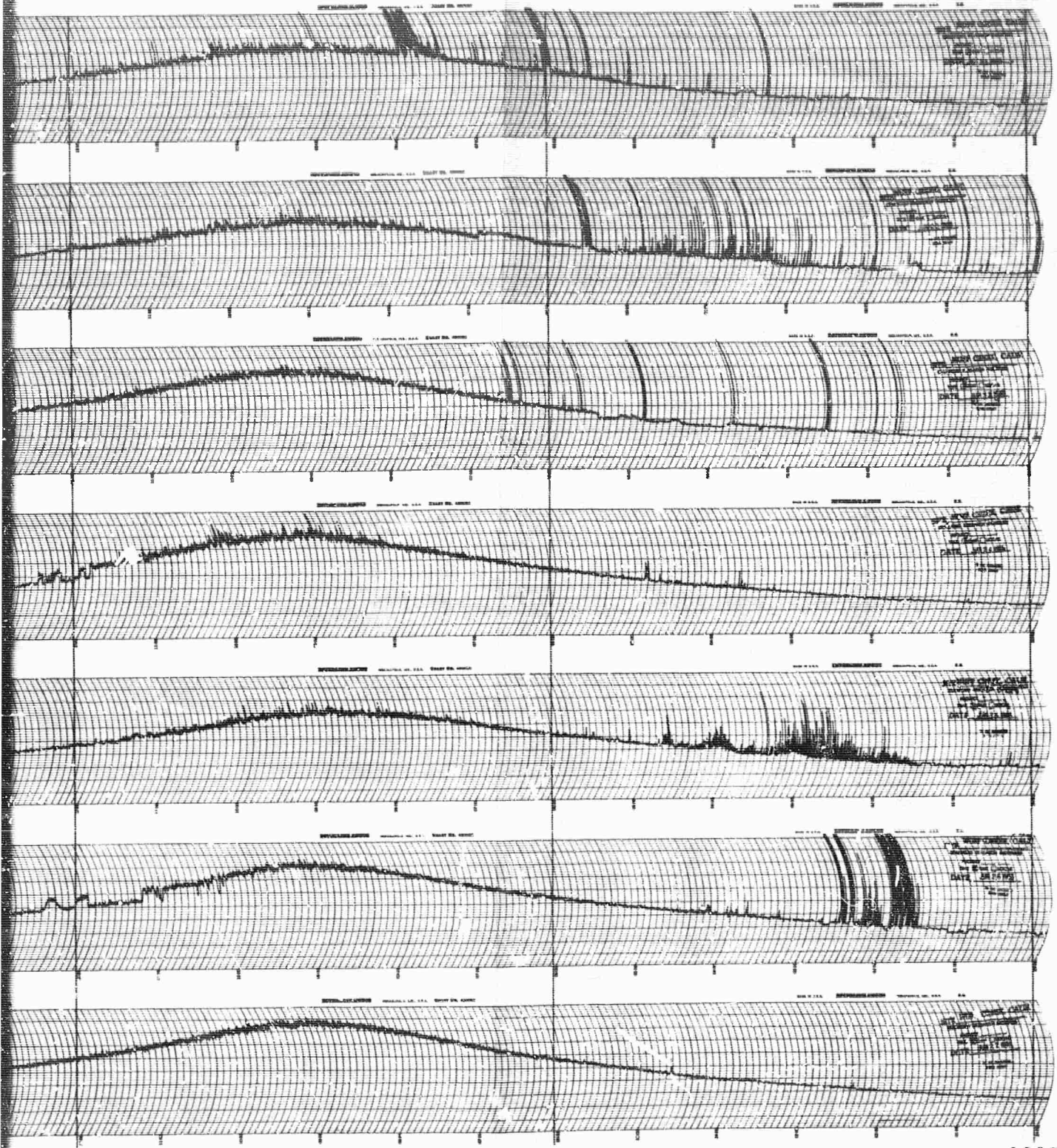
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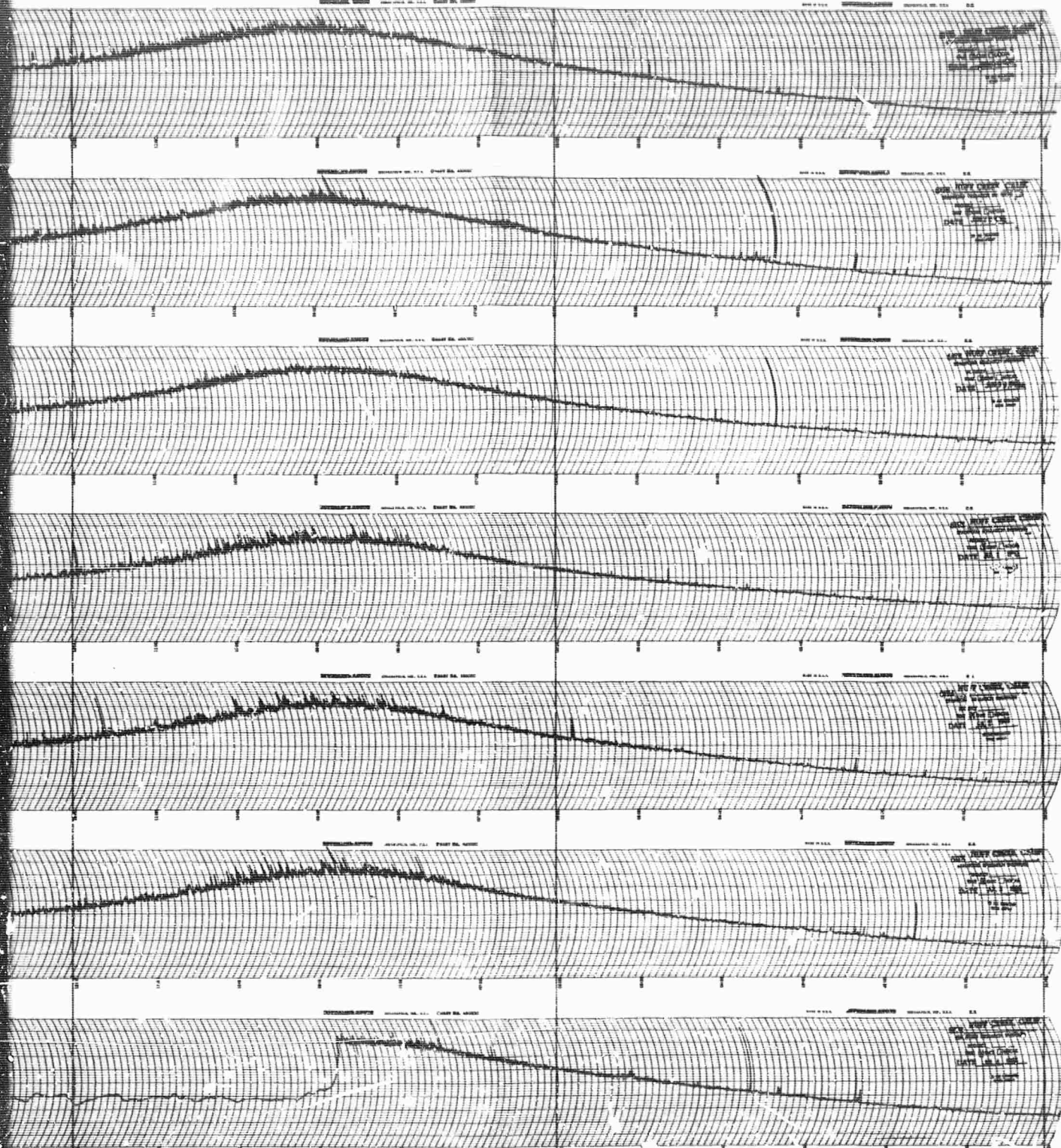
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STANFORD  
RESEARCH  
INSTITUTE

MENLO PARK  
CALIFORNIA

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