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TITLE

KER-4 OPERATING REPORT
TEST K-4-8
PT-IP-300-A

AUTHOR

K. L. Young

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L. V. Barker
Supervisor, Coolant Testing
TESTING SUBSECTION

December 29, 1960

KER-4 OPERATING REPORT
TEST K-4-8
PT-IP-300-A

IRRADIATION OF TWENTY-INCH NATURAL URANIUM TUBE AND TUBE ELEMENTS WITH HOT-HEADED END CLOSURES

A. Test Objective

The objective of the test was to determine and evaluate the behavior of eight 20-inch fuel elements during irradiation using the hot-headed end closures. Only the inner tube of the element employed the hot-headed closure with the outer tube being closed with a normal welded end closure. The adaptation of the hot-headed closure to the outer tubes had not been completed at the start of the test. Details of the hot-headed end closure are available from Drawing Number SK-3-9365.

B. Tube Charge Order

The loop was charged on April 25, 1960 in the following order:

Position	Number of Pieces	Material
1-downstream	1	8-inch stainless steel perf
2-21	20	8-inch carbon steel spacer
22	1	8-inch stainless steel perf
23	1	20-inch tube & tube element
24	1	8-inch stainless steel perf
25	1	20-inch tube & tube element
26	1	8-inch stainless steel perf
27	1	20-inch tube & tube element
28	1	8-inch stainless steel perf
29	1	20-inch tube & tube element
30	1	8-inch stainless steel perf
31	1	20-inch tube & tube element
32	1	8-inch stainless steel perf
33	1	20-inch tube & tube element
34	1	8-inch stainless steel perf
35	1	20-inch tube & tube element
36	1	8-inch stainless steel perf
37	1	20-inch tube & tube element
38	1	8-inch stainless steel perf

[redacted]

C. Mock-Up Exposure

At the start of the test long term testing was being conducted on coupons of stainless steel, carbon steel, Inconel X, Monel X, Titanium, and zirconium. Additional coupons of carbon steel and zirconium were charged during the test. Coupons are to undergo further testing before discharge and examination.

D. Operating Conditions

The following were the desired operating conditions for test K-4-8.

1. Flow - 60 gpm
2. Pressure - 1600 psi at tube outlet
3. Temperature - 288 C at tube outlet
4. pH - 10.0 ± 0.5

E. Termination of Test

The test was terminated on November 11, 1960 after the fuel elements had attained approximately 70 per cent of goal exposure. The test was ended before goal exposure was attained to make room for the testing of fuel elements with brazed end closures. The brazed end closure has been chosen for NPR fuel elements and no testing had been done on this closure at the time of the discharge of K-4-8.

F. Water Quality

1. Control

The loop water quality was maintained primarily by routing a portion of the main loop flow through an ion exchange column charged with XE-154, a high pH mixed-bed resin. An alternate ion exchange column was charged with XE-150, a neutral pH mixed-bed resin. The neutral column was used to "clean up" the loop water when the loop had been drained and refilled. Each column required new resin approximately 45 days after the start of the test. The average clean-up flow during the test was approximately 3 gpm.

Additional pH control was maintained by the addition of lithium hydroxide solution directly into the loop by "bombing". The volume of each bomb was approximately 70 ml. with a lithium hydroxide concentration of 50 gm/l. A total of 128 "bombs" or 8.96 gallons of the lithium hydroxide solution was added to the loop during the test.

The high pH resin was exhausted on May 26, 1960. Water quality and pH control was maintained by feed and bleed until a reactor outage permitted replacement of the ion exchange resin on June 5, 1960. A lithium hydroxide solution was injected into the loop make-up flow with a positive displacement pump equipped with a stroke length control. The regular loop make-up pump operated continuously to maintain the liquid level while water was bled from the loop at the rate of 1 gpm. By varying the stroke length of the lithium hydroxide injection pump the loop water pH was maintained at an average of 10.09 during operation. The feed solution for the injection pump had a concentration of 45 grams of lithium hydroxide per liter of water. A total of 145.7 gallons of solution was added during this period of feed and bleed operation.

2. Water Sample Analysis

Samples of the loop water were taken periodically for laboratory analysis. The concentrations of the metal ions were determined by emission analysis while the chloride, sulfate, and silicate ion concentrations were determined by wet chemical analysis. Also included in the wet chemical analysis was the determination of the hydrogen peroxide and total solid concentrations. Periodic determinations of the loop water turbidity, specific resistance, and pH were also made. Routine determination of the dissolved oxygen content of the loop water was made by the Winkler method.

Table I shows the average impurity concentration in the loop water during test K-4-8. Graphs 2, 3, 4, 5, 6, 7 and 8 show the individual sample results of pH, hydrogen peroxide, chloride ion, total solids, dissolved oxygen, silicate ion, and iron respectively. The concentrations of hydrogen peroxide and the chloride ion were lower than the detectable limits for most of the test. The graphs of these impurities are for that period when there were appreciable concentrations.

The high hydrogen peroxide level occurred during the period when the loop was operating at minimum temperature due to the leak at the primary heat exchanger exit tee. (See second paragraph of G4) The dissolved oxygen content during this period was also high as shown on Graph 6.

The high chloride ion concentration occurred near the end of the test. This was apparently due to depletion of the ion exchange resin used in the clean-up column.

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TABLE I
AVERAGE LOOP WATER IMPURITY CONCENTRATIONS
TEST K-4-8

Iron	75 ppb
Nickel	<10 ppb
Chromium	8 ppb
Copper	10 ppb
Aluminum	242 ppb
Zirconium	< 4 ppb
Manganese	<1 ppb
Cobalt	<10 ppb
Calcium	34 ppb
Chloride Ion	0.053 ppm
Sulphate Ion	<1 ppm
Silicate Ion	0.390 ppm
Hydrogen Peroxide	0.53 ppm
Total Solids	12.5 ppm
Oxygen	3.53 ppm
Turbidity	0.465 ppm (as calculated for silica)
Specific Resistance	30,140 ohm-cm
pH	10.21

[redacted]

G. Equipment Experience

1. Primary Pump Replacement

During an outage on April 29, 1960 it was noted that the loop flow was not normal. The loop remained on single-pass during the next operating period to permit removal of the pumps for examination. Investigation revealed the upper and lower graphitar bearings had grown smaller by approximately 0.0015 inches. It was determined that the bearing growth was due to the graphitar absorbing sodium dichromate which had been used in the loop water during a previous test.[1]

The number 1 primary pump began over heating and drawing a high current during a reactor startup on August 5, 1960. The loop was operated with one pump at reduced temperature and pressure until August 8, 1960 while the pump was replaced and the new pump checked out. The thermal barrier o-ring was found to be leaking when the replaced pump was disassembled for repair.

2. Replacement of Air Operated Valve Plug and Seats

Occasionally air operated valves which should have a tight shut-off are found to be leaking through. The only satisfactory means for stopping the leakage is to replace the valve plug and seat. Listed below are those valves which had their plug and seat replaced during Test K-4-8.

Pressurizer vent valve on April 27, 1960

Loop bleed-off flow valve on June 6, 1960

Loop depressurizing valve on August 19, 1960

Pressurizer vent valve on October 27, 1960

3. Change in System Relief Pressure

Investigation of the pressure differential between the loop pressurizer and the process tube disclosed the process tube to be operating at a higher relative pressure than previously thought. This information made it necessary to lower the relieving pressure of the system rupture disc and relief valve combination located on the pressurizer.

During the outage of July 15 through 18, 1960 new relief valve springs and rupture discs were installed to lower the relieving pressure to 1720 psi.

With the lowering of the rupture disc relieving pressure and not the operating pressure of the loop, the question of rupture disc reliability and the possibility of failure during operation was raised. A program was initiated to replace the rupture discs periodically during the remainder of the tests. Used discs were saved for examination and testing to determine to what extent they are weakened during operation.

4. Replacement of Loop Piping

On August 17, 1960 a leak was discovered in a weld on the piping tee at the confluence of the flows going through and around the primary heat exchanger. The loop was operated at minimum temperature until an outage permitted repair of the weld on August 19, 1960.

On September 12, 1960 a second leak was discovered at the primary heat exchanger tee. This leak was due to a crack in the pipe wall approximately 12 inches downstream of the tee. The loop was operated at minimum temperature until an outage allowed replacement of the tee and approximately 6 feet of pipe on each leg of the tee on October 5, 1960. Investigation of these failures has not been completed as of this writing.

5. Instrumentation

On April 26, 1960 the reactor was scrammed from a high heat exchanger exit temperature trip on KER-4. The operating temperature was approximately 10 C below the trip setting immediately before the reactor was scrammed. The reactor was able to recover from the scram and upon raising the loop temperature several bad "blips" were received on the heat exchanger exit temperature recorder. At that time it was thought the blips might be due to a bad thermocouple converter or to poor mixing of the flows through and around the primary heat exchanger resulting in erratic readings. The loop was reduced to minimum temperature and a Process Change Authorization was received to operate with the heat exchanger exit temperature tripped bypassed at that condition. The heat exchanger exit temperature thermocouple converter was replaced while the trip was bypassed.

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On April 27, 1960 the reactor was scrammed from a heat exchanger exit temperature trip from KER-3. Checking of the instrument wiring disclosed ground loops in the heat exchanger exit temperature control system and the pressurizer liquid level control system on all four KER loops. The ground loops were eliminated with wiring changes on April 28, 1960.[2] During this outage, the heat exchanger exit temperature thermocouple was relocated further downstream to give smoother response. A smoother response was noted during subsequent operation indicating there was a flow mixing problem at the old thermocouple location.

On July 15, 1960 the reactor was again scrammed from a KER-4 heat exchanger trip. This trip was found to be caused by an induced signal in the heat exchanger exit temperature control circuit from the annunciator wiring. This situation was possible since original construction because the 105-KE indicator wiring and annunciator wiring was located in a common duct.[3] Between July 15, 1960 and August 18, 1960 all the signal leads for the control systems on all KER loops were relocated into their own isolated ducts.[4]

H. Operating History

The fuel elements were charged for a total of 4810.50 hours. Table II is a listing of the hours operated at specific conditions and the percentage of the total test at each condition. The daily average tube inlet and tube outlet temperatures are shown on Graph 1.

TABLE II
LOOP OPERATING HISTORY
TEST K-4-8

Condition	Hours	Percentage
At run conditions	2705.7	56.2
Minimum temperature operation reactor operating	637.35	13.2
Raising loop temperature after reactor startup	358.85	7.4
Lowering loop temperature for instrument work or investigation of abnormalities-reactor operating	80.41	1.6

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TABLE II (Con't.)

Condition	Hours	Percentage
Single-pass operation-reactor operating	357.67	7.4
Lowering loop temperature after reactor shutdown	73.76	1.5
Recirculating in reactor-reactor down	391.73	8
Single-pass operation-reactor down	272.3	5.9
Loop recirculating out of reactor reactor operating	343.66	7.1
Out of reactor portion of loop down and cold	237.75	5

K L Young
Engineer, Coolant Testing
Testing Subsection
RESEARCH & ENGINEERING SECTION

KL Young:pb

cc: Distribution

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2. Letter, J. R. Bolliger to M. E. Jackson, "Investigation and Findings of KER-3 Heat Exchanger Exit Temperature Scram of April 27, 1960", May 17, 1960.
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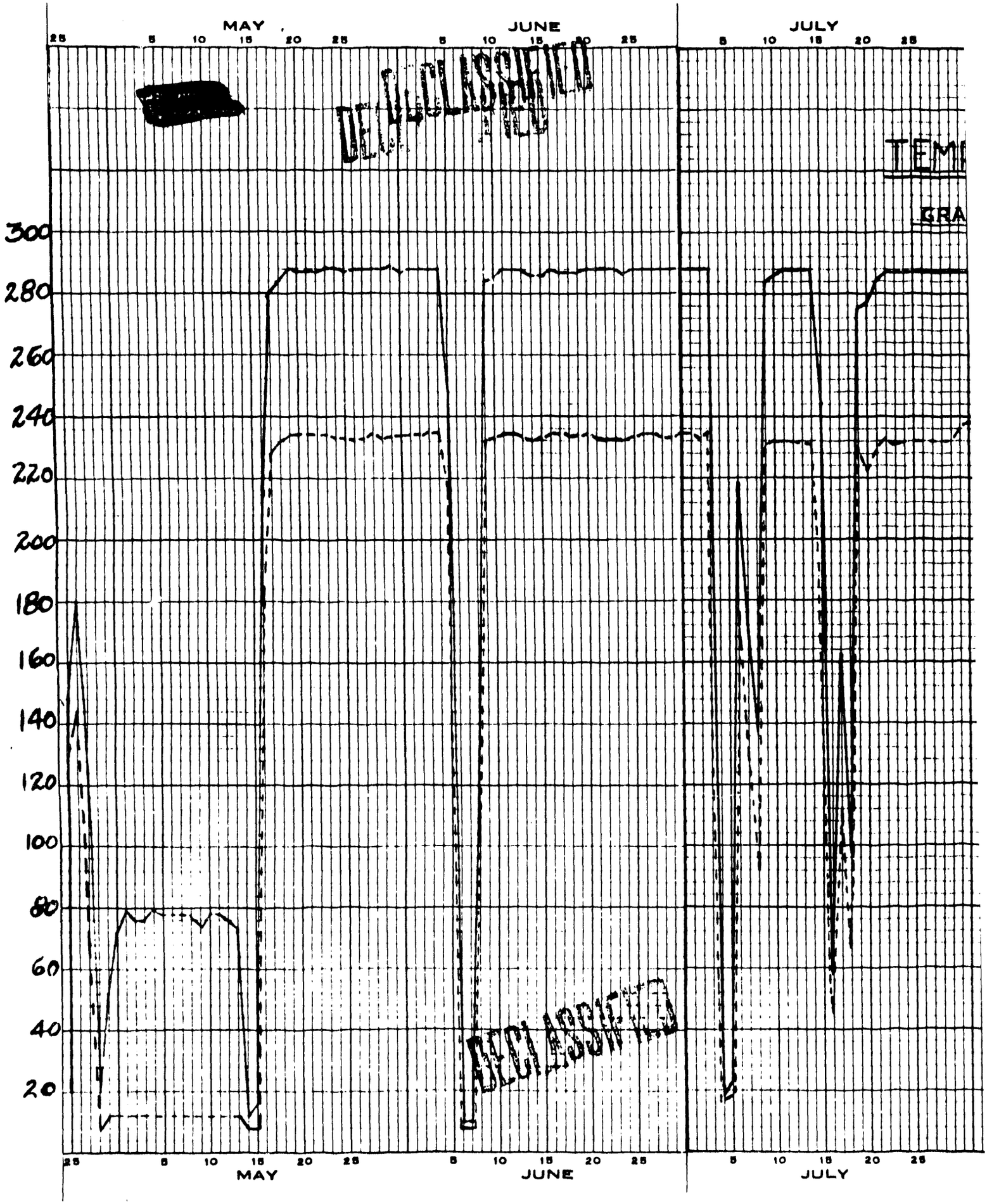
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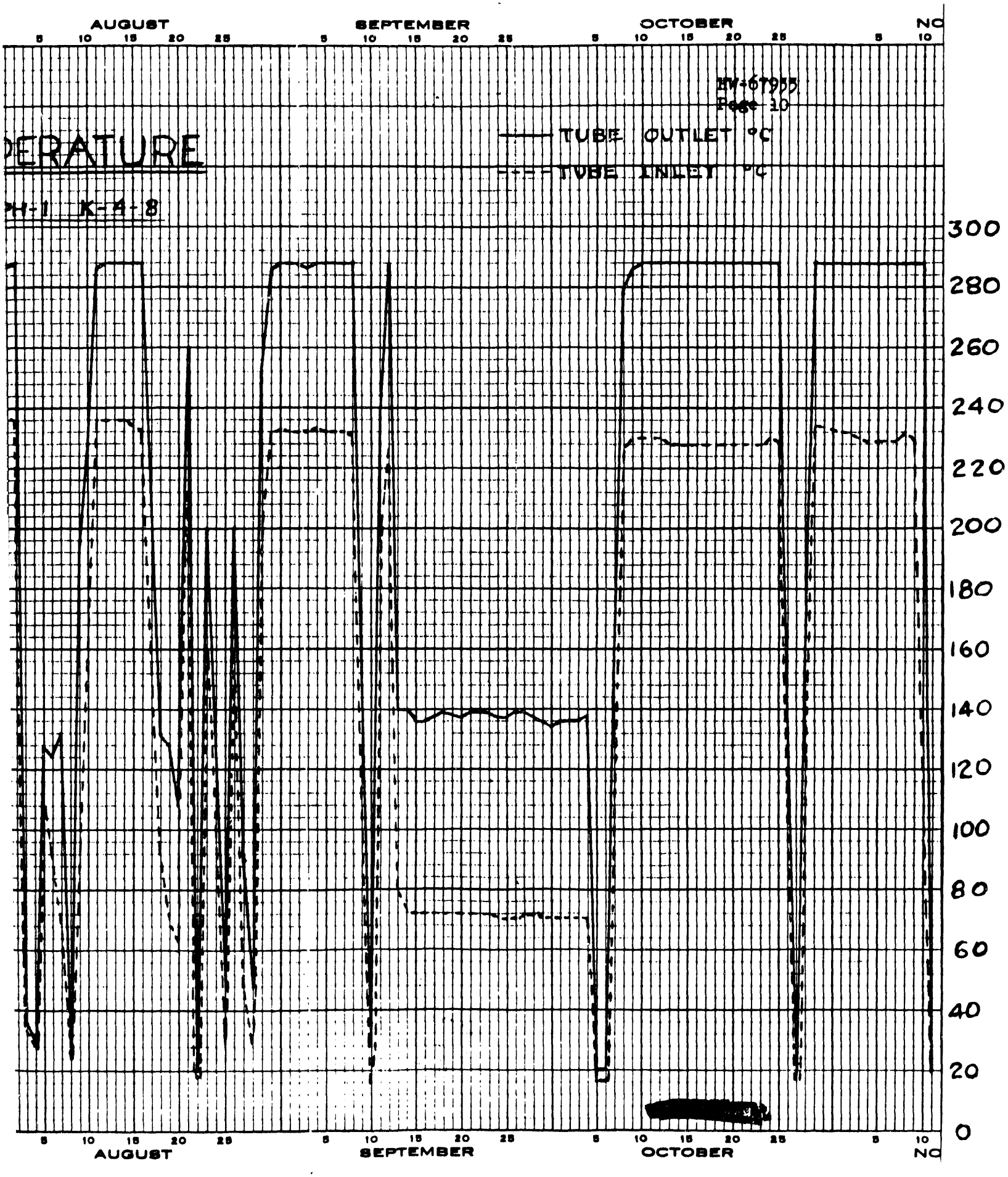
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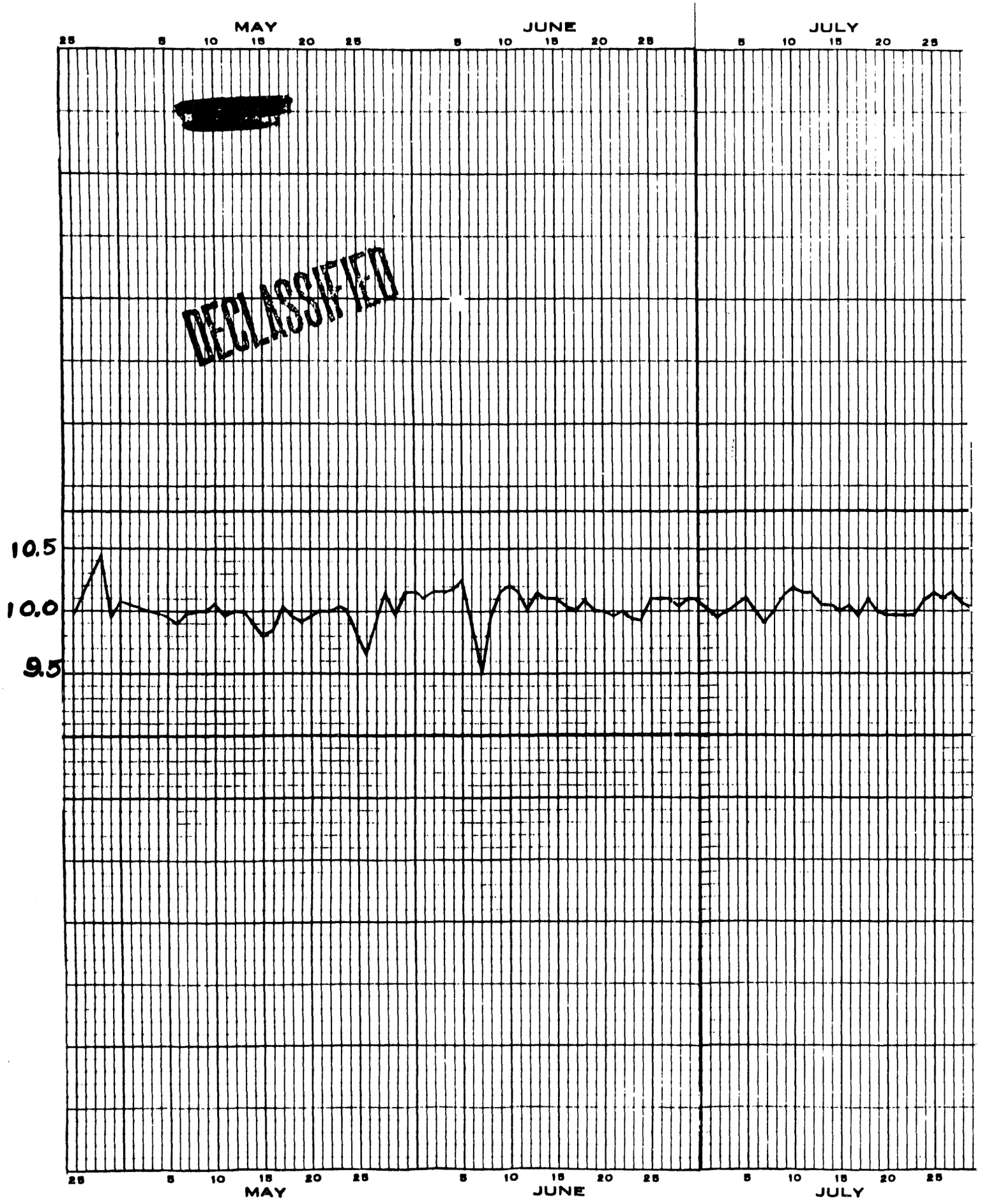
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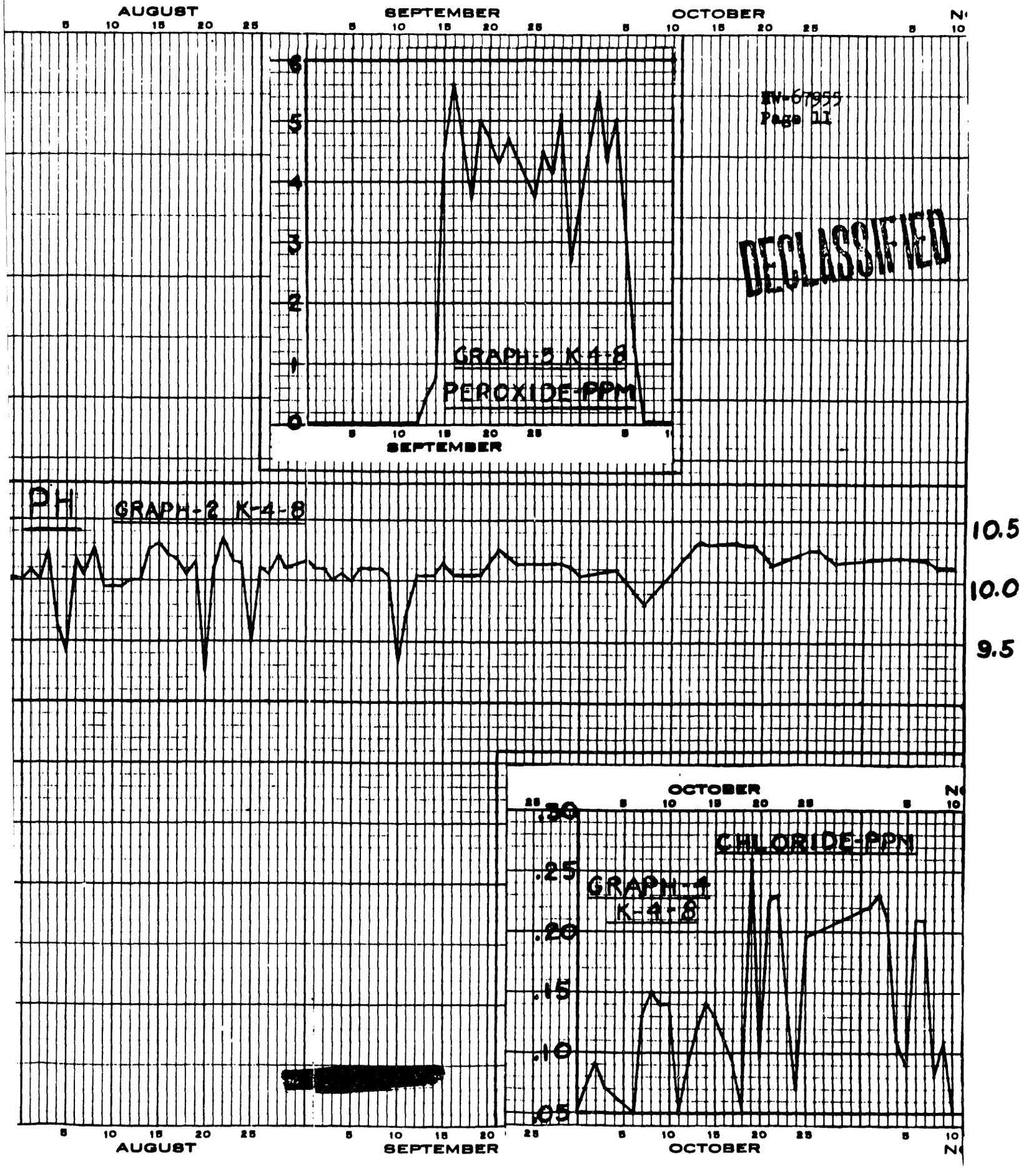

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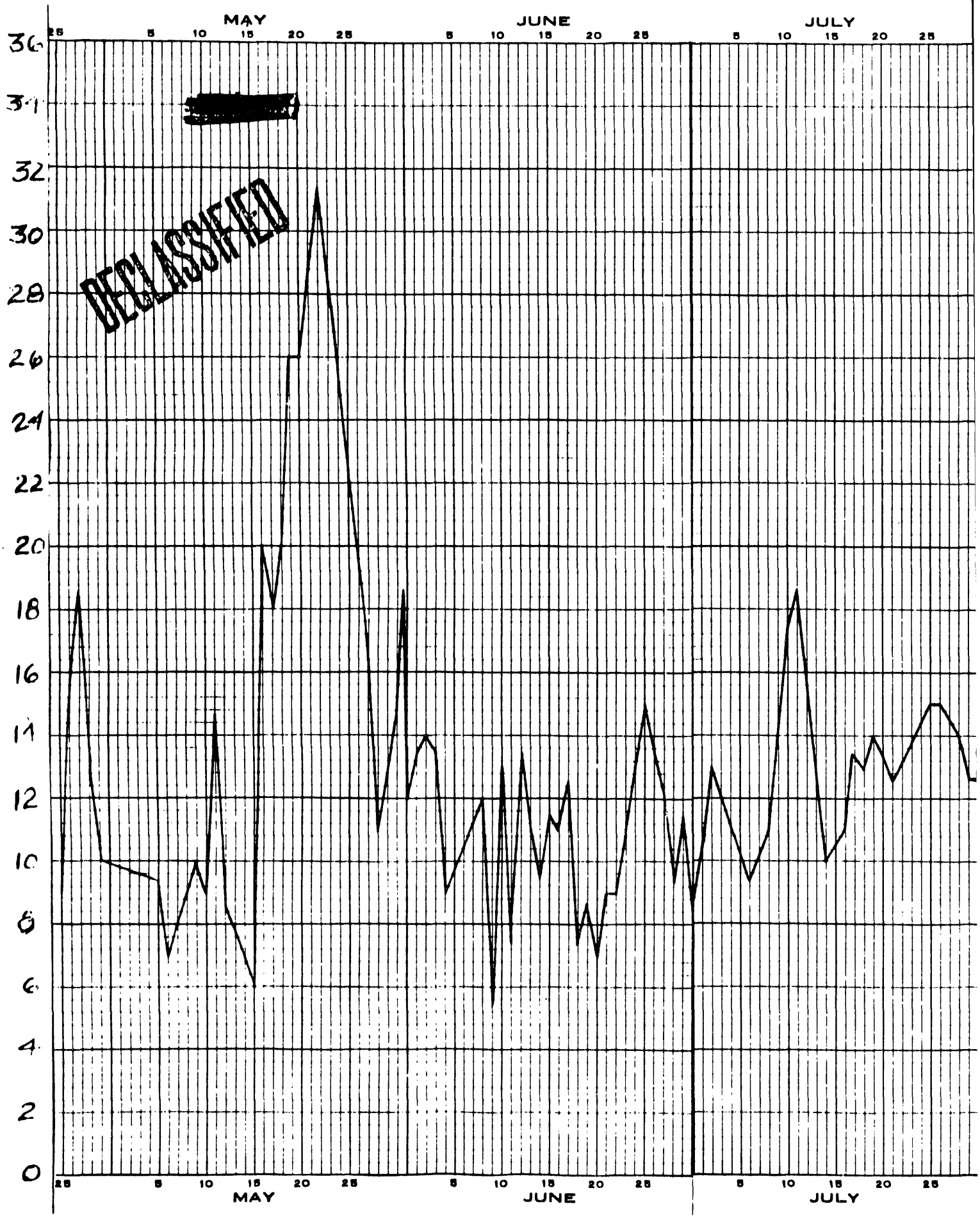
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TOTAL SOLIDS

GRAPH-5 K-4-8

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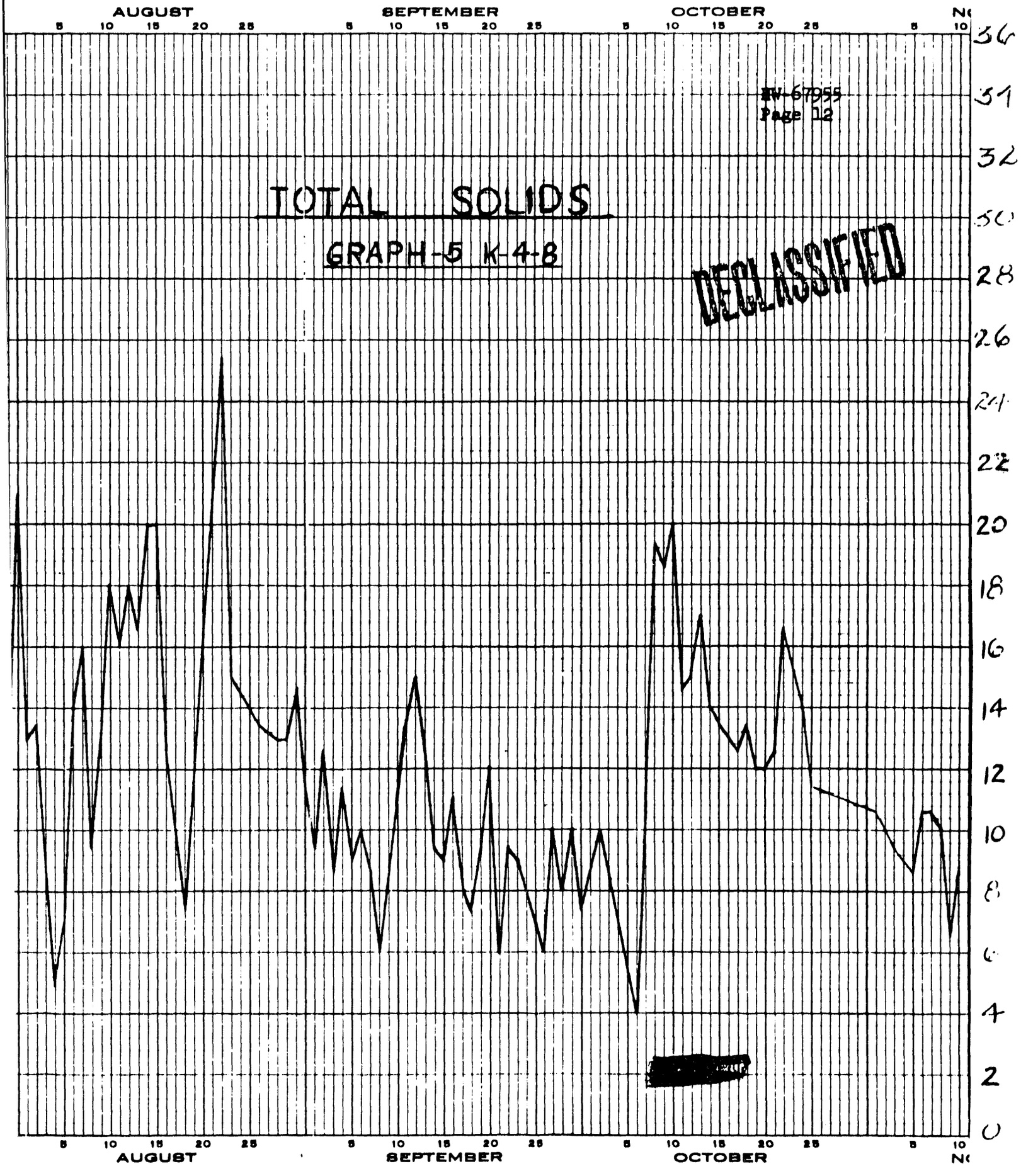

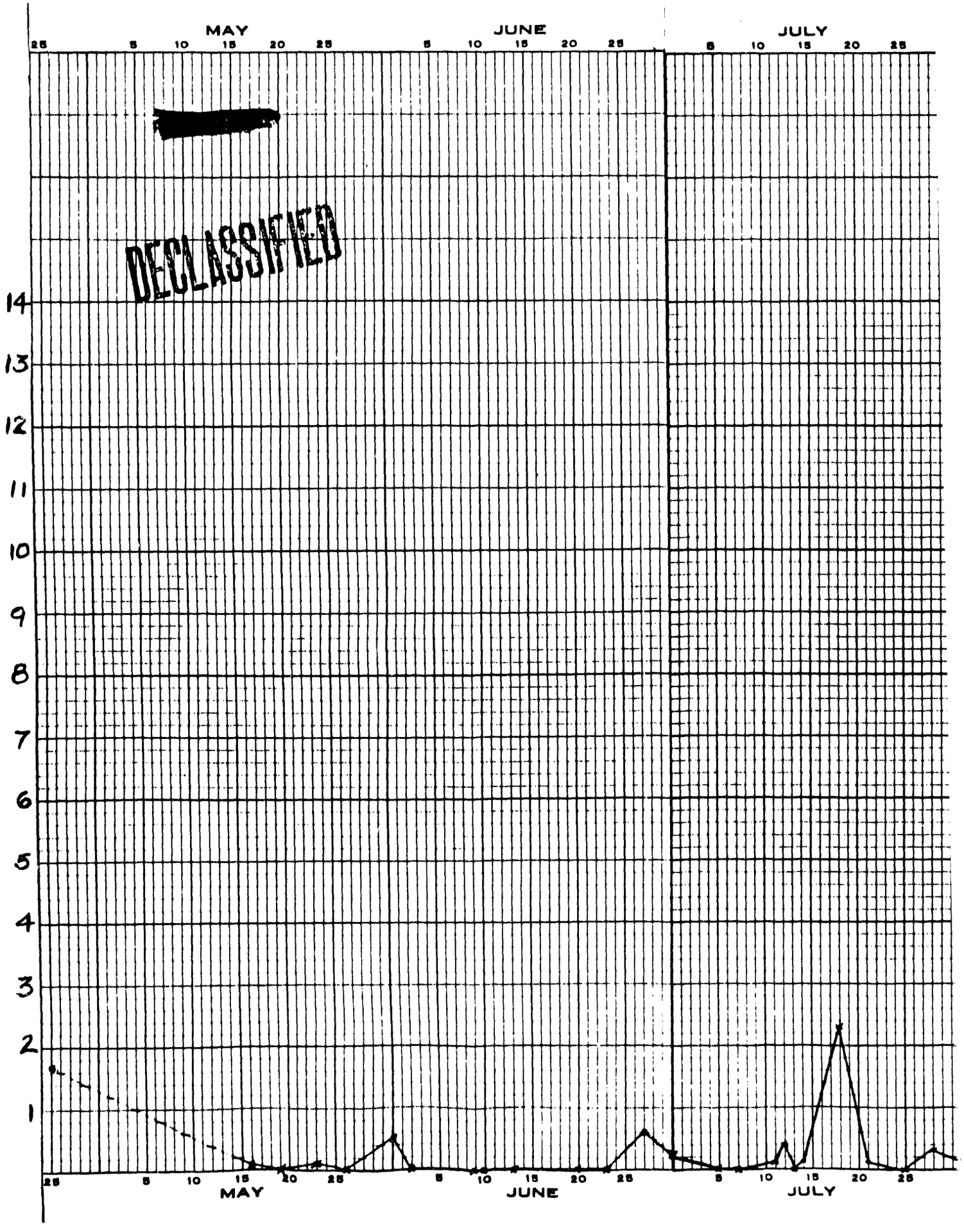
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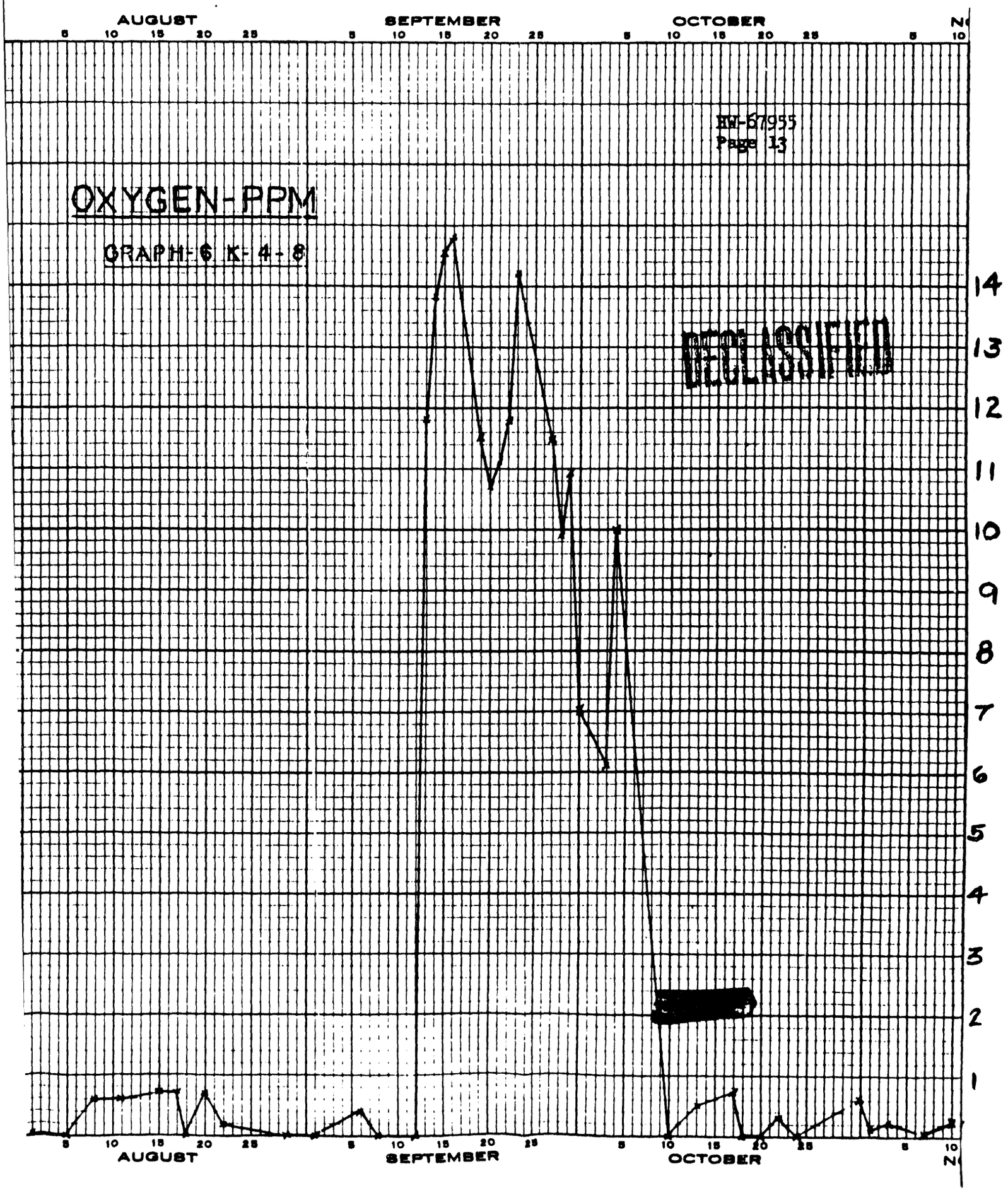

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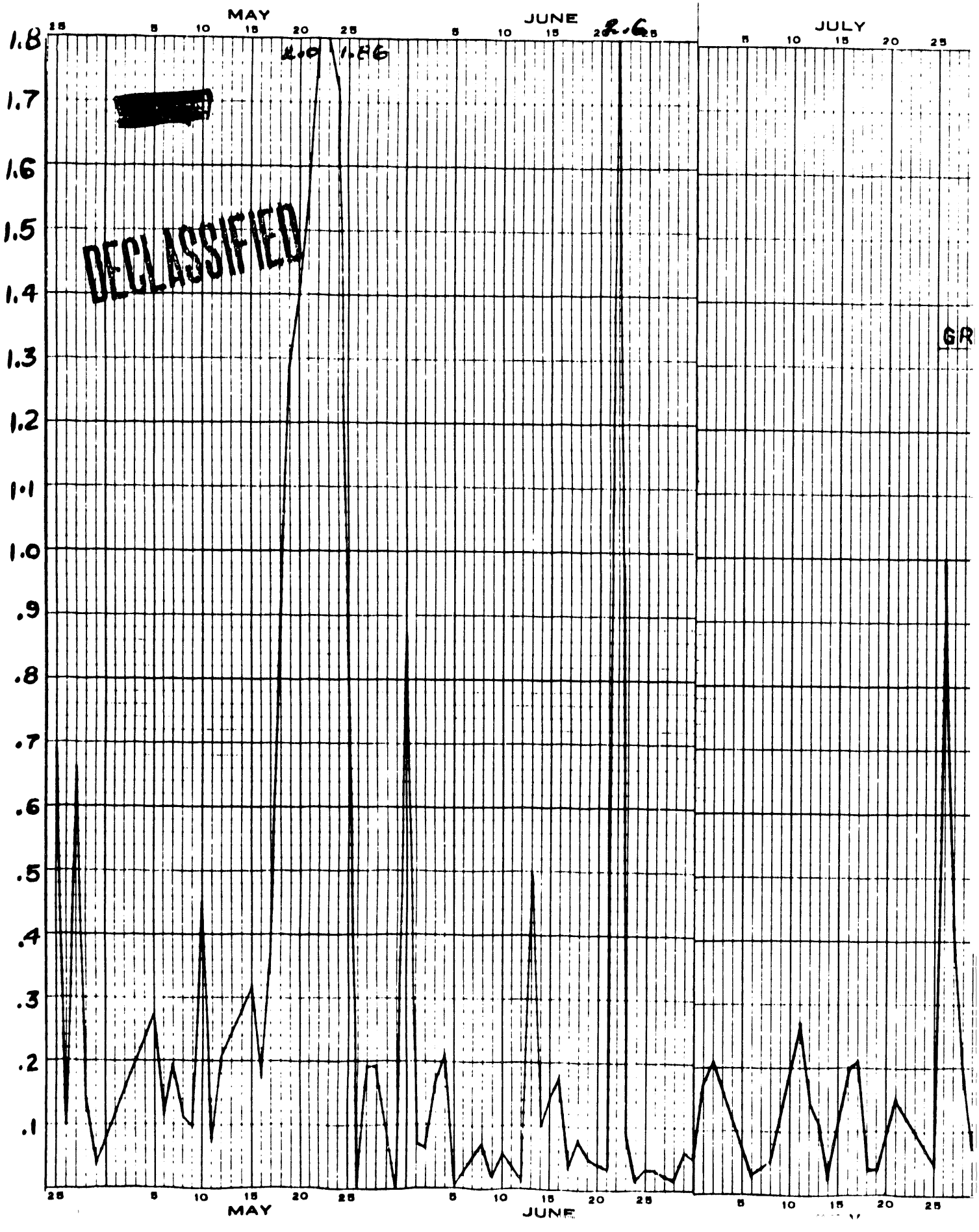
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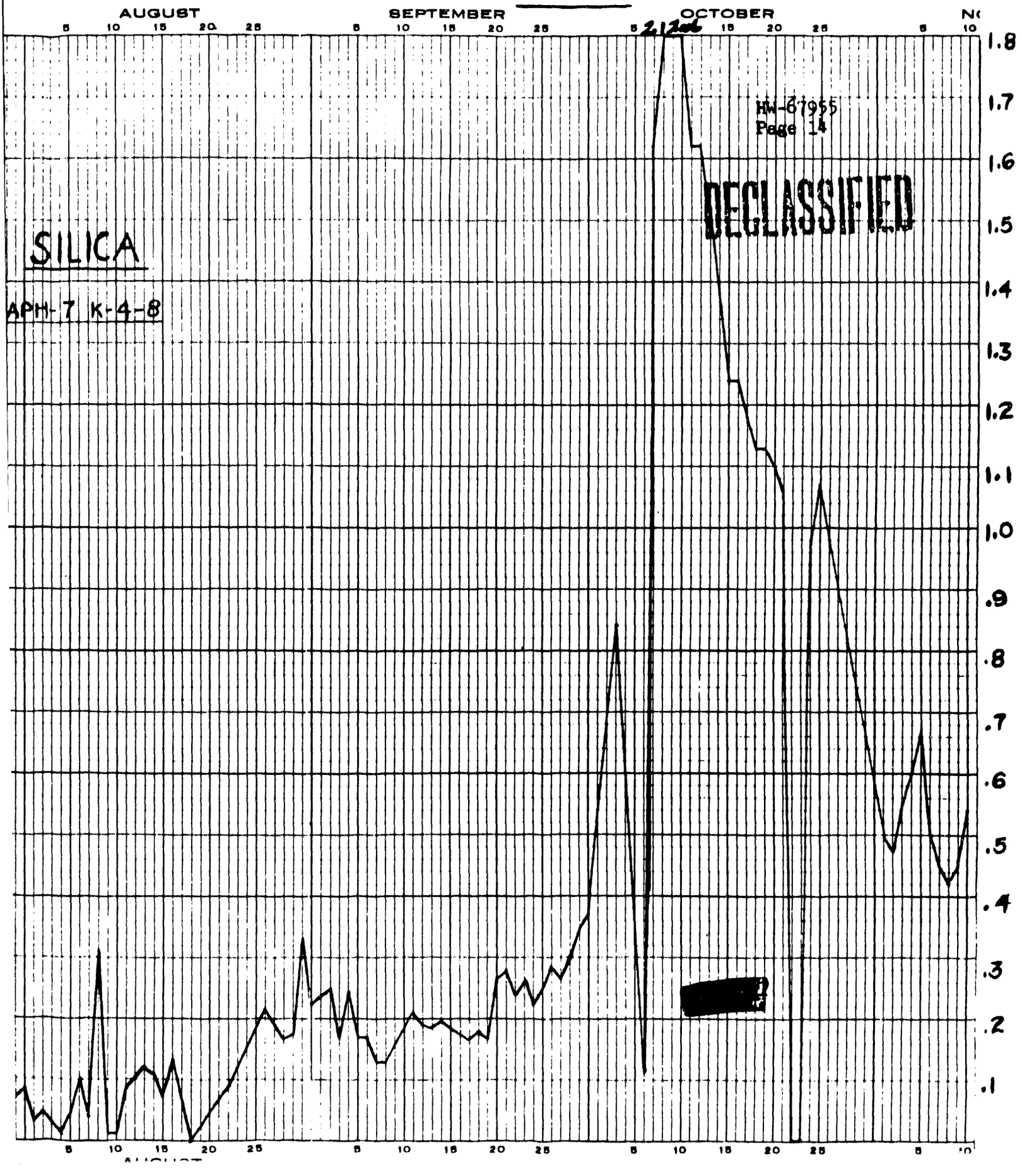

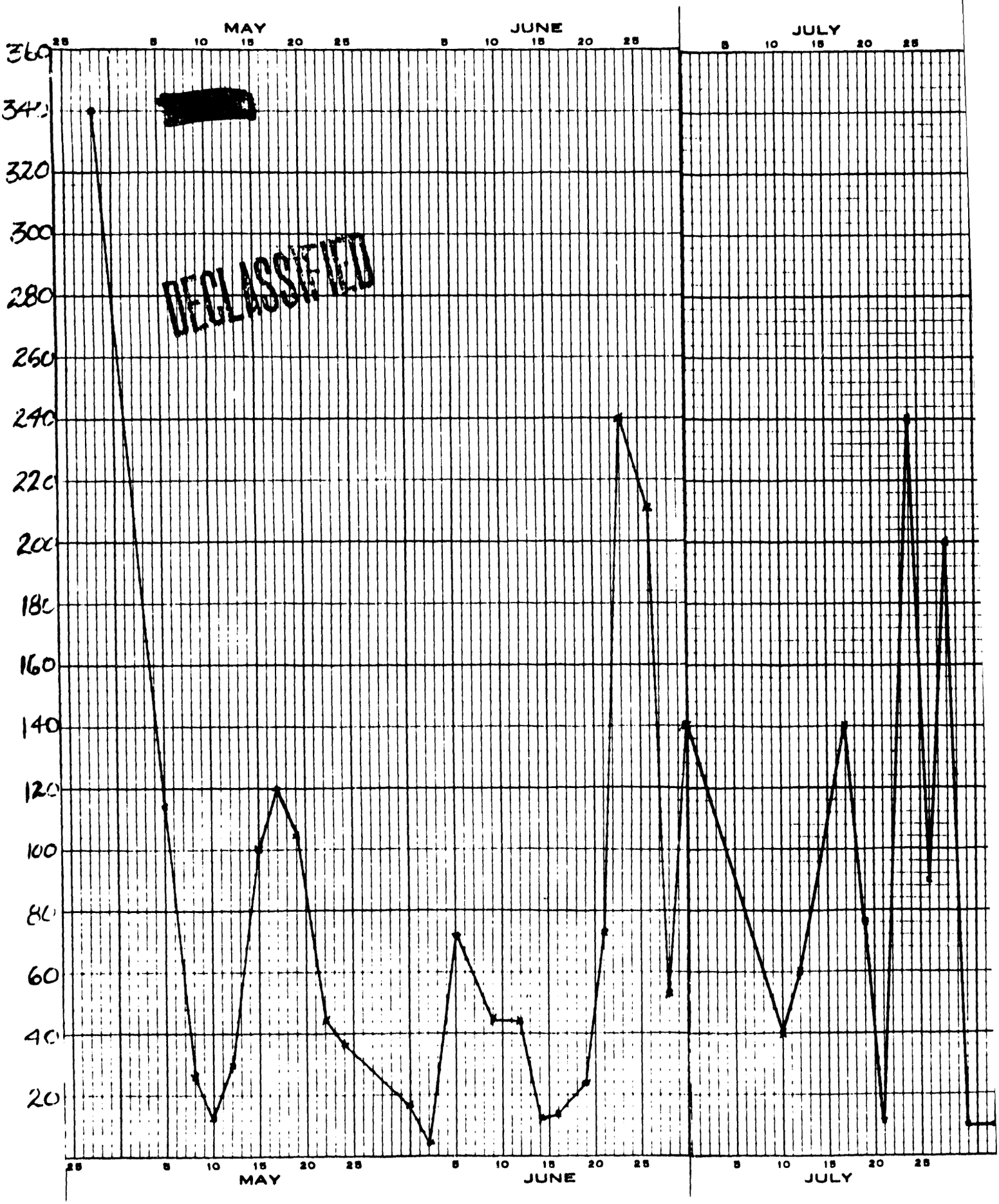
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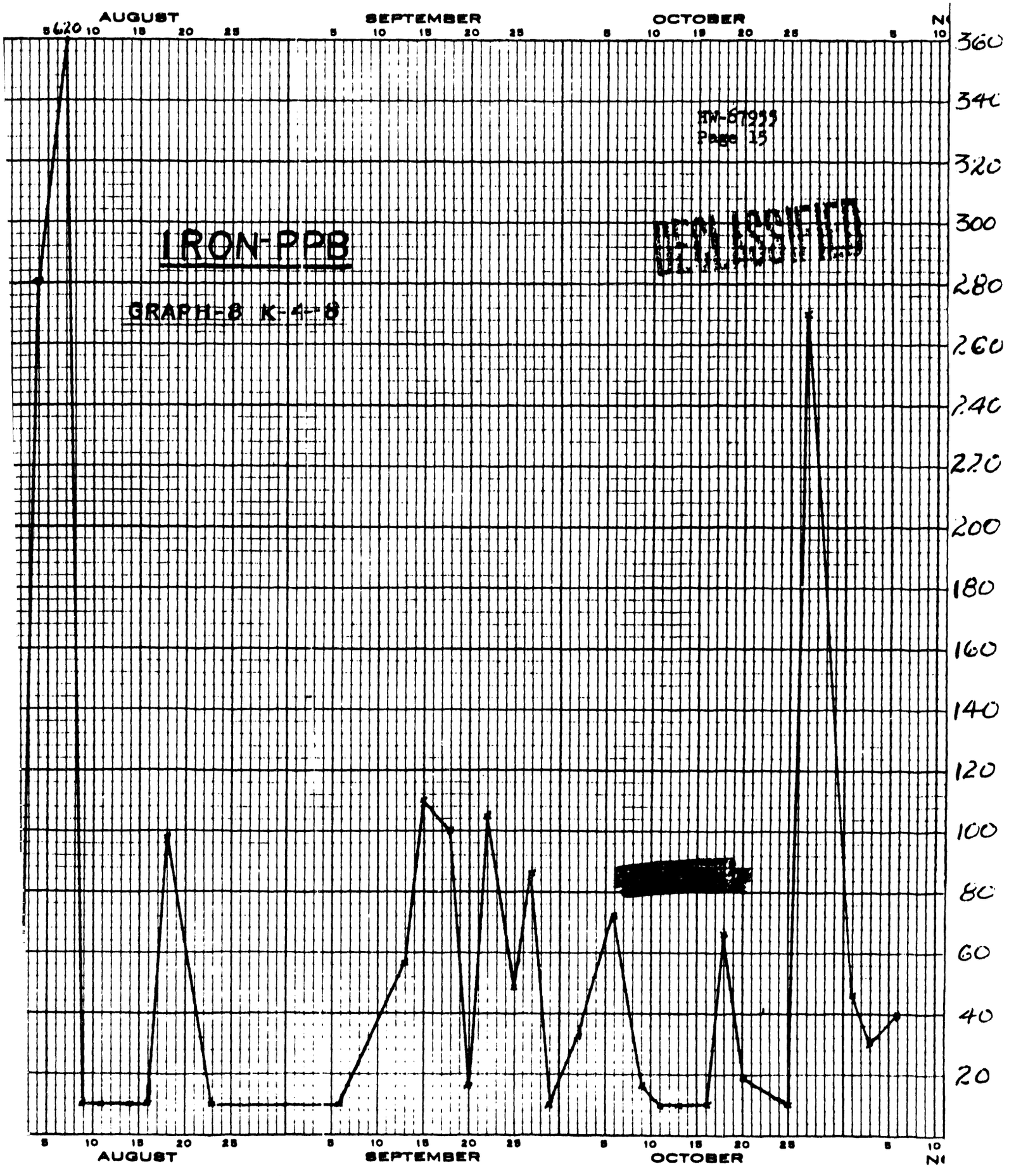
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