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PHYSICS ASPECTS OF OPERATION IN EVENT OF A LARGE REACTIVITY LOSS

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PHYSICS ASPECTS OF OPERATION IN EVENT OF A LARGE REACTIVITY LOSS

MASTER

INTRODUCTION

The following information was prepared to assist the physicist who encounters a large reactivity loss as in a water soaked lattice or a more permanent loss as in the case of balls remaining in the pile after a ball drop. The discussion is based on experience gained during F Reactor's severe water leak of July 27, 1961.

HISTORY

[redacted]

F Reactor scrammed on July 27, 1961, due to a panellit low trip on tube 3063 - top rod bank near side. Inlet and outlet gas pressure went full-scale immediately after scram. Inlet and outlet driplegs began dumping five minutes after the scram. Graphite temperature on stringer 2662 dropped to 30° within 45 minutes. About five hours later, after the flow in the tube was determined, the column was discharged and the water shut off.

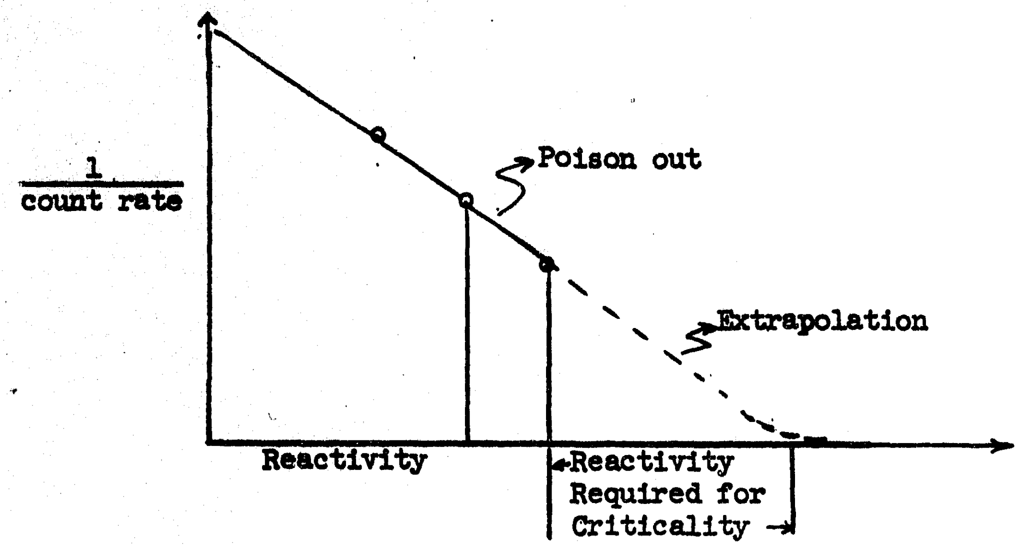
Inspection of the tube showed a large (one square inch) hole nine feet downstream from the front Vanstone and on the top of the tube. An estimated 3,000 to 5,000 gallons of water entered the graphite resulting in a large reactivity loss in the lower two-thirds of the near side of the reactor. The reactivity loss was sufficiently large that the reactor would not become supercritical with all rods out and the xenon decay essentially complete. Operation was eventually achieved by charging about 100 additional tubes of enrichment.

DISCUSSION

I. Reactivity Evaluation and Compensation

A. Determining The Reactivity Status of the Subcritical Reactor

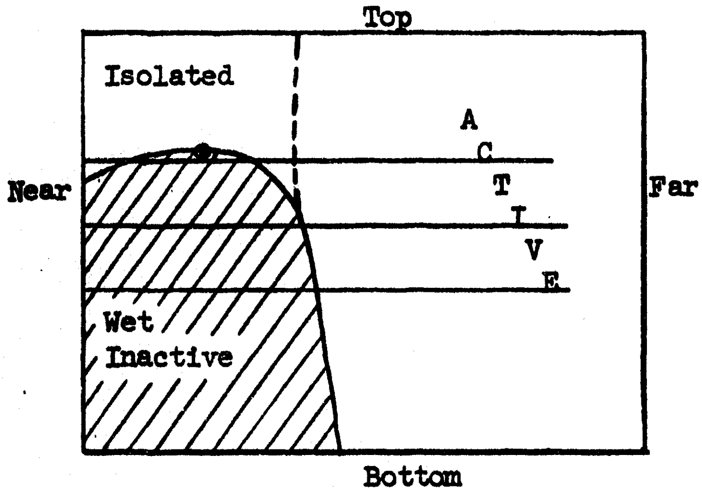
1. If criticality cannot be attained it may be possible to approximate how far subcritical the reactor is by observing the Δ count rate from the subcritical monitor while changing the pile reactivity status with rods, splines, and Pb-Cd poison and plotting a reciprocal count rate graph as shown below. Note that poison in the wet zone of a water soaked reactor will cause no increase in the subcritical count rate and thus should not be considered as "reactivity removed." Note also that if the count rate indicates the reactor is more than 500 c-mk subcritical, the method is inaccurate and the reactivity could be greater than indicated by the extrapolation.



2. When the reactor is very subcritical (so that the subcritical monitor gives no definite indication) it will be necessary to estimate the size of the poisoned areas to determine the reactivity required to become critical.

   In the water leak case the location of the leak will present a fair indication of where most of the water is, but in the ball drop case the situation is more difficult.

   The next step is to determine what percentage of the total pile is inactive. The sketch below illustrates the F Reactor case where it was observed that over 30 per cent of the reactor was completely inactive and the top near side, being somewhat isolated, was considered essentially inactive. This brought the total inactive portion of the reactor to roughly 50 per cent. It is also necessary to consider the front-to-rear distribution of the water soaked lattice when leaks are in the front or rear of a tube.



Note that the water soaked area appears to spread out and form a nearly rectangular inactive region.

After determining the size of the inactive area Figure (1 or 2) may be used to estimate the reduction in pile reactivity. See Part III.

B. Determination of Enrichment Needs and Location

1. When criticality cannot be attained the quantity of enrichment needed to become critical may be estimated by finding the reduction in pile reactivity, see A above, and from this the reactivity required to become critical, and then using Figures (3 or 4) to determine the enrichment requirements to obtain this reactivity.

   Figures (3 and 4) are based on a solid block of enriched metal. A nearly solid block of enrichment will offer the maximum reactivity gain with a minimum number of columns. For reactivity effects of enriched blocks of various densities see /1/.

   It is desirable to place the enrichment in the active portion of the reactor within the HCR region of control and with enough spline caps for complete spline compensation.

   Once criticality is attained and a temperature map shows the fringe of the wet region it may be desirable to shut down and place enrichment along the edge of this inactive area to facilitate drying; however, the gain from this additional step has not been clearly demonstrated.

/1/ HW-71809, "PT IP-467-C, Reducing Minimum Downtime," J.F. Jaklevick, December 6, 1961

2. After criticality is attained and a temperature map is taken it is necessary to evaluate the reactivity status considering the possibility that with continuous operation xenon poison will force a shutdown. This would indicate a need for more enrichment. It has been observed for nearly all water leak cases that once critical is attained the reactivity loss due to xenon between startup and equilibrium is compensated by the reactivity gain rate apparently from the removal of the water around the periphery of the wet zone.

C. Total Control Considerations

1. It may be necessary to acquire an authorization for assuming that the HCR's will scram as total control backup (even though not in the reactor at the time) to allow enrichment to be added without compensating poison. This is deemed necessary if such a quantity of enrichment must be added to become supercritical and maintain a sustained operation. The enrichment should be located within the HCR region of control.

2. HCR's are considered to be worth 60 μb, thus no more than this additional density over and above a normal loading is permitted. Due to this consideration it may be necessary for the enrichment block to be interspersed with natural uranium. For reactivity effects of cores with various densities see /1/.

II. Operation

A. Speed of Control

Unusual conditions enhance the necessity for slow, continuous startups, thus, speed of control which limits power until the graphite heats up should present no major problem. Reactor Physics personnel should be contacted to supply specific speed of control limits based on tube powers.

B. Poison Evaluation

Rods and splines in the block of enrichment will have greater than normal reactivity strengths resulting in the necessity of a modified rod withdrawal order and more cautious use of splines. Rods will need re-evaluation since the portion of rod in the wet region will have no effect on the operating section of the pile.

C. Shadowing on Instrumentation

Operating personnel should fully recognize the fact that many of the flux indicating instruments could be shadowed out by water - of particular importance would be the subcritical monitors, galvanometer, and Beckmans at startup. A plot of graphite stringer thermocouple points will assist in determining the front-to-rear flux distribution along with the use of spline flux traverses.

/1/ Ibid

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D. Biological Shielding

High tube powers in the fringe of the operating portion of the reactor may result in excessively high biological shield temperatures so that particular consideration must be given to this problem. Usage of a significantly greater proportion of low conductivity gas could cause such high shield temperatures.

E. Reactivity

1. Xenon Effects

Split the reactor up into temperature gradient regions and determine the power level at which each region is operating. Each region represents a certain percent of the total pile and the quantity of xenon in each region can thus be easily evaluated. This is valuable in total control considerations as well as in reactivity calculations.

2. Graphite and Low Helium Concentration

To facilitate water removal and for maximum reactivity it is desirable to heat the graphite by operating at as high a level as possible and adjusting the reactor gas atmosphere for minimum conductivity; i.e., minimum helium. Note that graphite temperature limits must not be relaxed with a wet lattice.

3. Initial Power Levels

The limit to be used with regard to initial power levels should be the tube temperatures in the active region of the reactor except that considerably higher concentrations of low conductivity gas graphite limit will restrict the level. Of particular concern will be the region charged with enriched metal.

4. Reactivity Gain with Water Removal

Reactivity will continually be gained as water is removed resulting in a potential danger of having too much rod in the reactor. It will be necessary to place splines in the active area as reactivity is gained thus forcing rod out and forcing the spread of heat to cold areas.

F. Water Removal in Water Leak Case

1. Cycling

It was noted in the F Reactor water leak case that no cycling problems occurred until most of the water was removed. Toward the last a rapid collection rate of water and the resulting rapid reactivity gain presented a very unsteady period of operation. The reactivity gain in the previously wet zone may be very fast - thus considerable rod should be available to put into this region.

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2. Rod Configuration

It will be desirable to establish a rod configuration that will accelerate water removal by forcing the flow of heat toward the inactive region of the pile. Thus a minimum of rods should be in the wet zone.

3. Water Removal

Water collection rate at F Reactor started out rapidly, then slowed to a steady value for a long period and finally increased rapidly toward the last - then stopped suddenly.

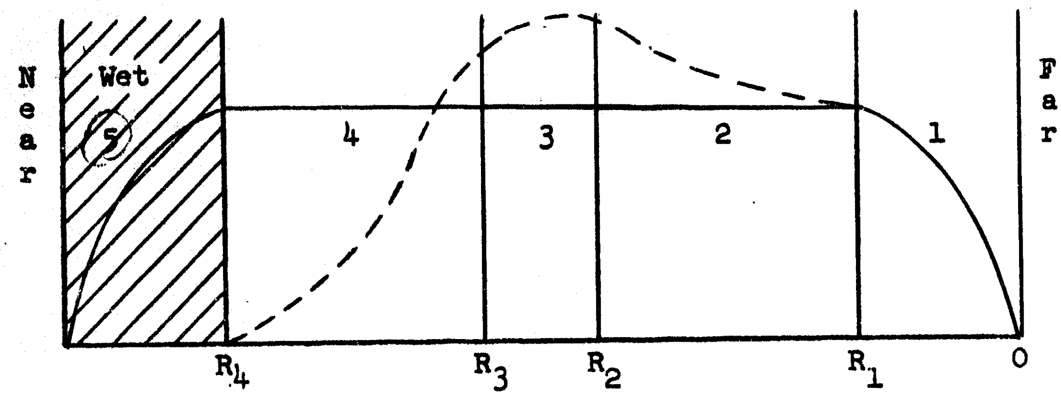
III. Explanation, Justification and Use of Figures (1-4)

A. The infinite number of unique conditions involved in cases of large reactivity losses presents problems in attempting to set down a specific procedure to follow in determining reactivity loss in a reactor. The figures presented are very general and apply only under certain conditions specified below.

B. The data for Figure (1) was determined as follows for an old reactor:

1. A uniformly loaded reactor with the enrichment ring in the 7th lattice from the outside and one lattice thick was assumed.

2. Four region slab buckling calculations from the near side to the far side were performed as the active portion of the reactor was reduced in size to determine the buckling required in one region to become critical.



3. R_4 (radius of region 4) does not include the enrichment ring on the near side - thus the first value for the curve Figure (1) assumes 15 per cent of the reactor inactive including the near side of the enrichment ring. It is therefore not necessary or possible to extrapolate the curve to less than 15 per cent of the reactor inactive. If the reactor is not wet inside the enriched ring the reactivity loss should be small.

[redacted]

4. Region 3, six lattice units in width, represents the region of unknown buckling. As radius R_4 was reduced region 3 was continually slid over to remain in the geometric center of the flat zone.

5. The bucklings of regions 4 and 2 were assumed to be 0 and the buckling in region 1, which includes a 40 cm augmentation distance plus seven lattice units, was determined as follows:

$$B_1^2 = \left[\frac{\pi}{(188.82)^2}\right]^2 = 67.17\ \mu b$$

This is similar to setting $B^2 = 0$ in regions 2, 3, and 4 and finding critical buckling in regions 1 and 5. The water soaked region 5 is then assumed to be completely inactive.

6. Reduction in pile reactivity, determined from region 3, will indicate how much enrichment will be required in that region. Note that in the old reactor case with 15 per cent of the pile inactive the reduction in pile reactivity is 24.5 μb and the actual geometrical buckling normally varies from 28 to 35 μb indicating that no additional reactivity would be required to gain criticality.

C. The data for Figure (3) is from /1/ and for Figure (4) is from calculations performed by R. A. Chitwood. These figures give the reactivity worth of different size blocks of enrichment of density one. Calculations indicated that the variation in reactivity value of this enrichment block with different size active zones of the reactor would be insignificant enough to neglect in determining the amount of enrichment to place in the active portion; i.e., region 3 in the illustration.

D. In applying these curves the above conditions under which they were determined must be considered, since they were prepared using a considerable number of assumptions and simplifications. In the F Reactor water leak case they do apply within a reasonable degree of accuracy to actual conditions. The data for the K Reactor Figure (2) was calculated in a similar manner to that for the old reactors in Figure (1).

IV. Summary

The purpose of this document is to present a procedure to follow in event of a large reactivity loss. It is a very general discussion which certainly does not cover every unique case that may arise, but it may be used as a guide to assist the physicist in improving the "guesstimate" of enrichment requirements in a reactivityless reactor.

R. Bruce Heiple

Pile Physics Unit
Operational Physics Sub-Section
Research and Engineering Section

RB Heiple:gs

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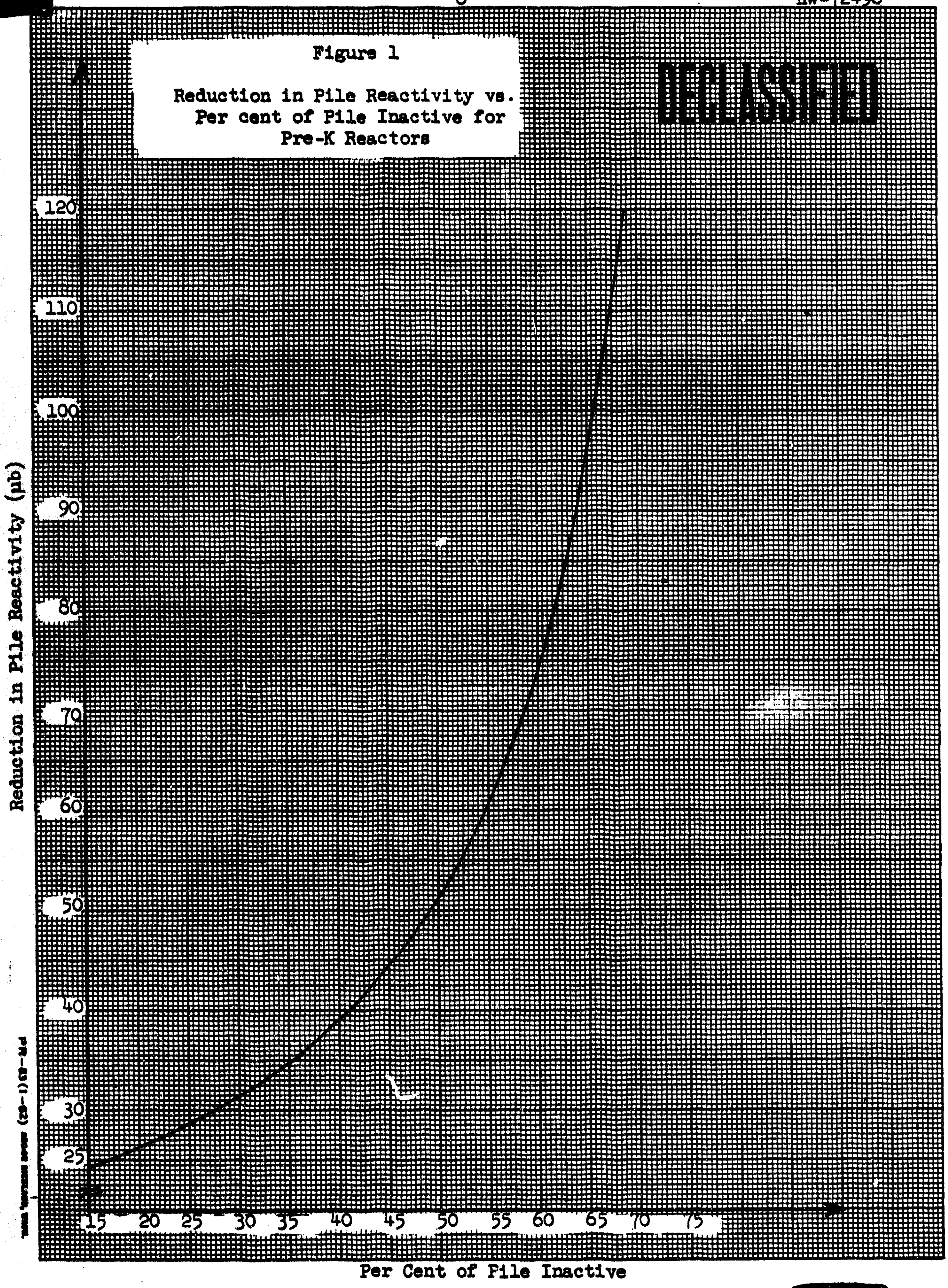

Figure 1

Reduction in Pile Reactivity vs. Per cent of Pile Inactive for Pre-K Reactors

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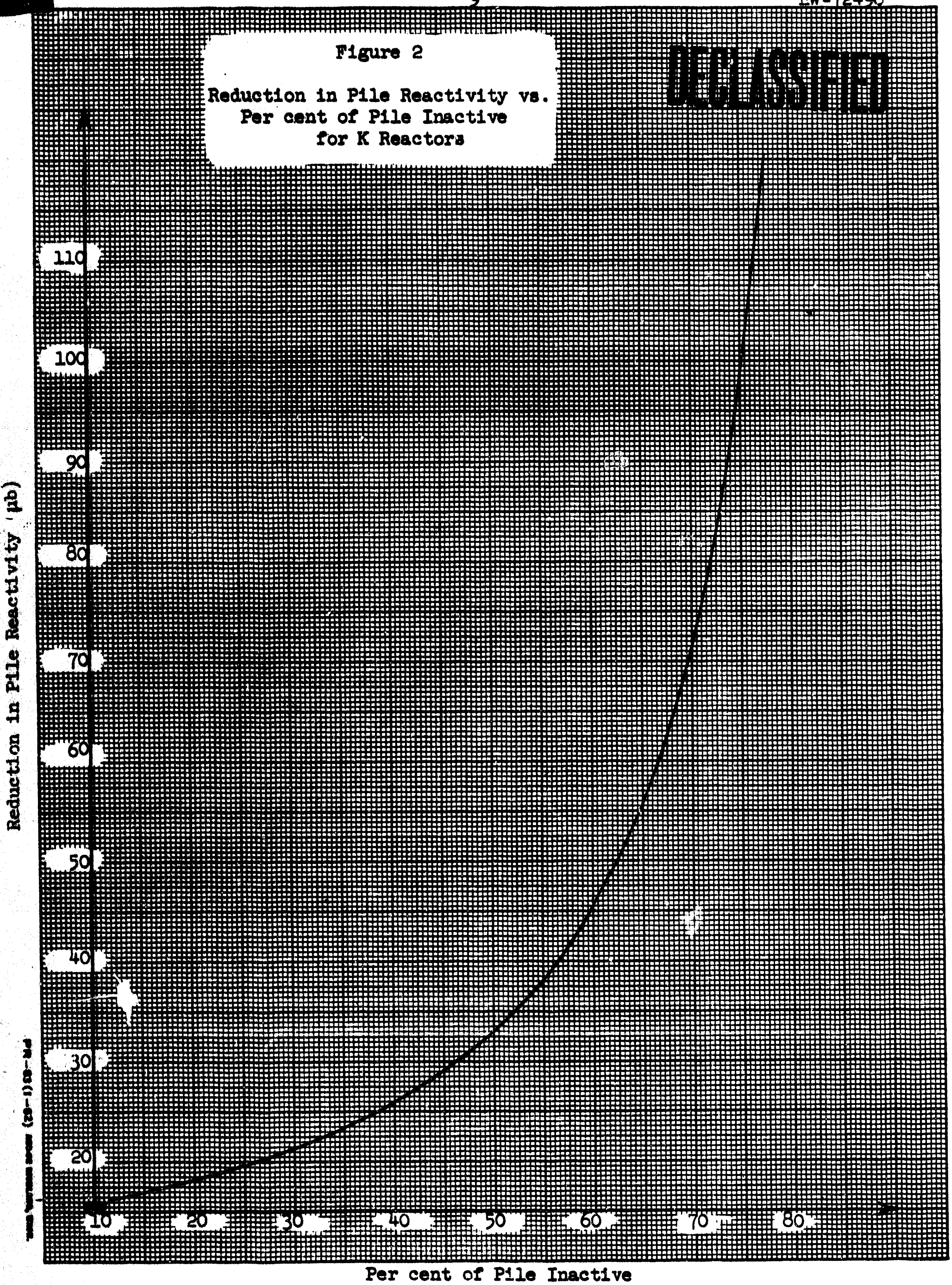

Figure 2

Reduction in Pile Reactivity vs. Per cent of Pile Inactive for K Reactors

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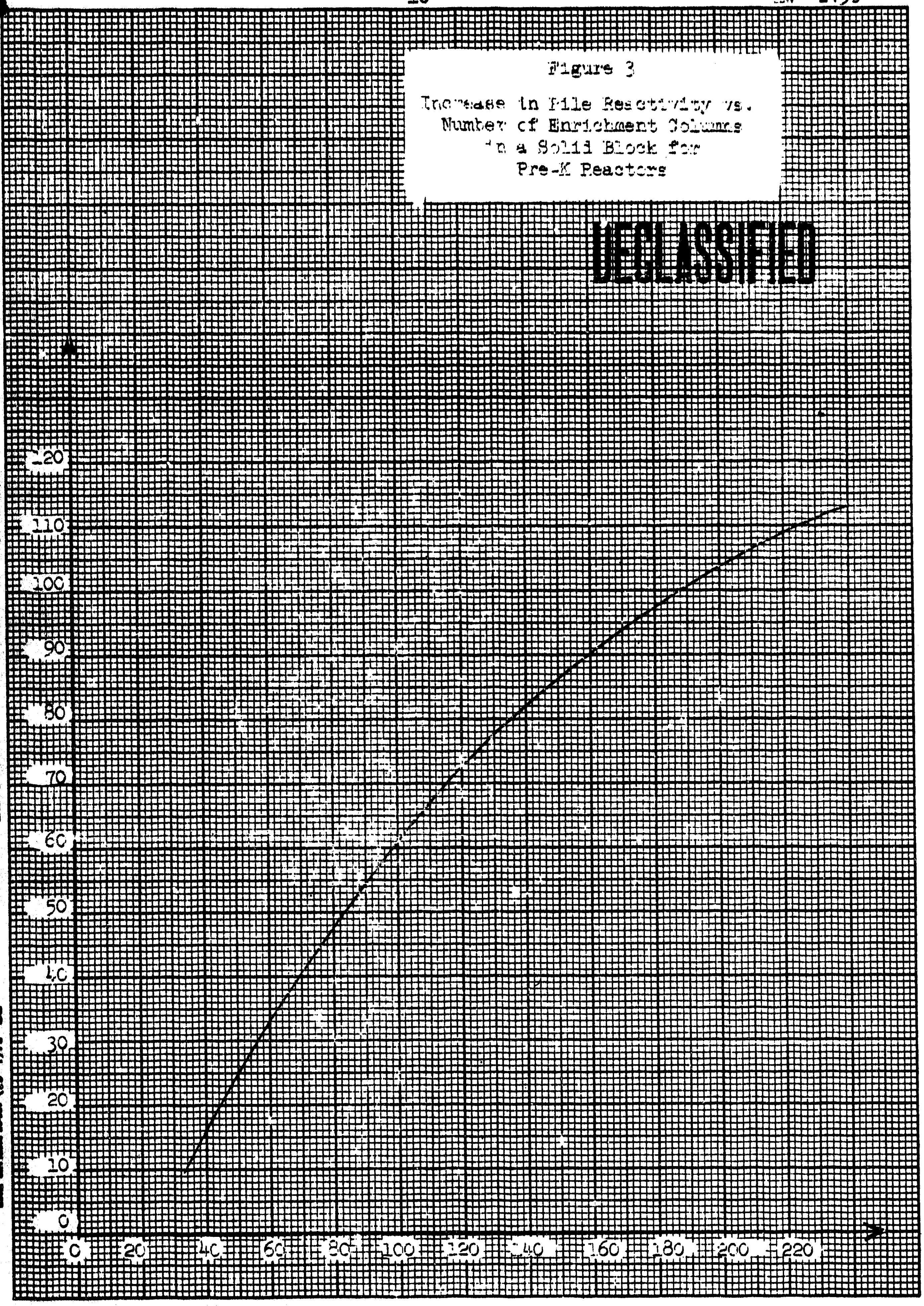

Figure 3

Increase in Pile Reactivity vs. Number of Enrichment Columns in a Solid Block for Pre-K Reactors

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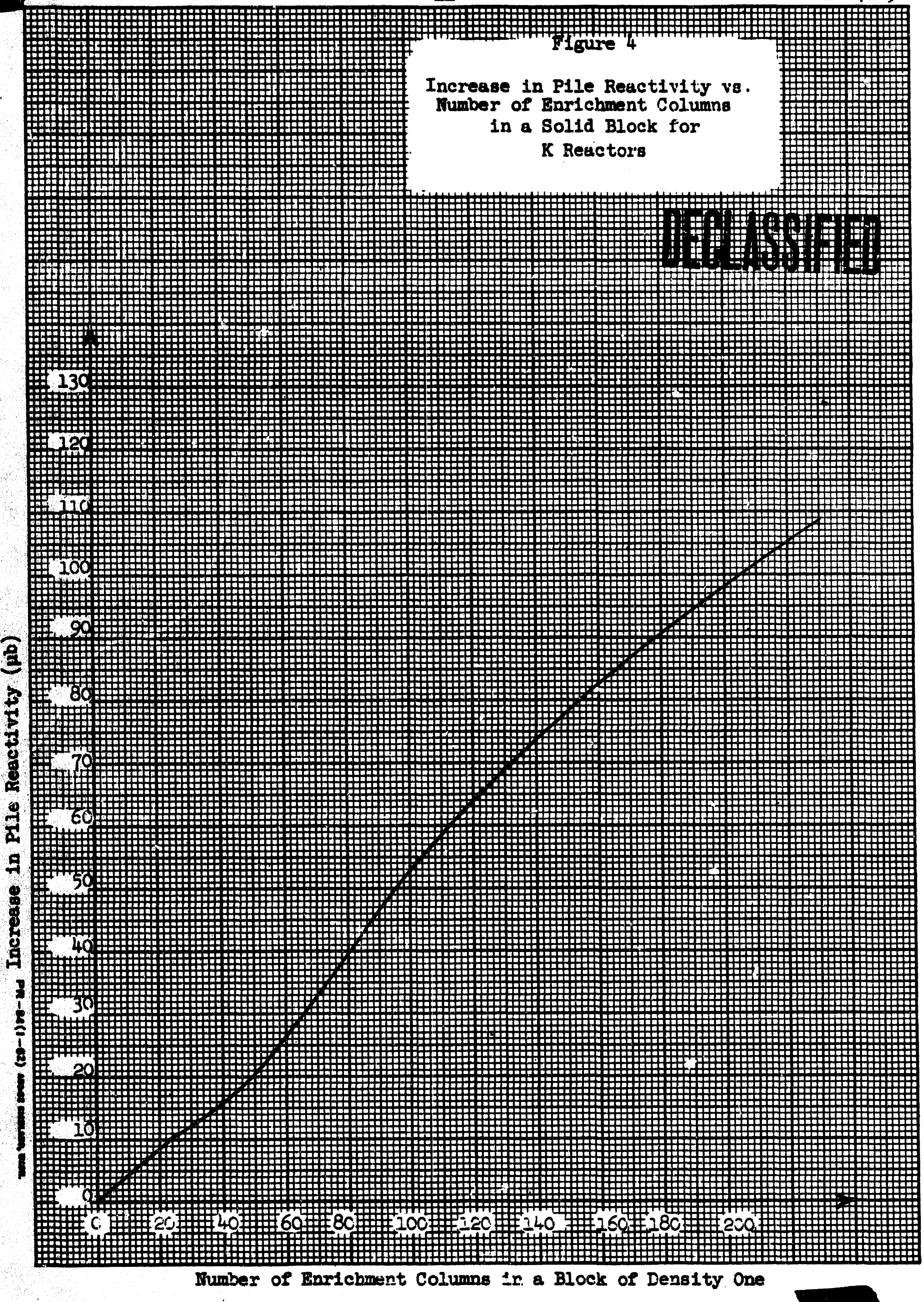

Figure 4

Increase in Pile Reactivity vs. Number of Enrichment Columns in a Solid Block for K Reactors

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