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**Cover Sheet for a Hanford  
Historical Document  
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**Pacific Northwest Laboratory  
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This document consists of 7 pages, [redacted]

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NOTES ON IRRADIATION OF NEODYMIUM

By:

W. K. Woods

June 7, 1966

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FROM W. K. Woods

SUBJECT NOTES ON IRRADIATION OF NEODYMIUM

The fission product, promethium-147, would be much more desirable as a heat-producing radioisotope if it were not in such short supply. C. A. Rohrmann's chart "Characteristics of Radioisotopic Heat Sources" lists the annual availability of Pm-147 as 5.5 kw, corresponding to about 17 kg. Hence, consideration has been given to irradiation of neodymium-146 in order to augment the supply of Pm-147. A method for separating Nd-146 from other neodymium isotopes does not exist today. This memorandum presents the results of a brief look at the irradiation of mixed neodymium isotopes which are available without isotopic separation.

There appears to be no incentive to recover the mixture of stable neodymium isotopes available as waste fission products in preference to using natural neodymium. The concentration of high cross-section Nd-143 in fission product neodymium is about twice as high as that in natural neodymium, doubling the parasitic neutron losses with the same Pm-147 production rate.

Irradiation of natural neodymium in Hanford reactors could reasonably continue until a product concentration of about 500 grams of Pm-147 per ton of neodymium had been obtained. The in-reactor residence time of the neodymium would be about two years (cf Figure 3). To double the quoted supply of Pm-147 available from fission products (17 kg per year) would require irradiating 35 tons of neodymium per year. Assuming that fifteen percent of the rare earths in the nation's stockpile is neodymium, there should be about 1,800 tons of neodymium in excess of stockpile objective available for irradiation.

It is conceivable that one might take another fission product, cerium-144, which decays with a 285-day half-life to Nd-144, and periodically milk the Nd-144 to get a pure neodymium isotope for irradiation. It is doubtful that this would be economical but, if it were, it would be more attractive for a high flux reactor at Savannah River than for Hanford because it would take Hanford so long to build up a reasonable concentration of Pm-147 (cf Figures 1 and 2).



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We conclude that it is feasible to produce Pm-147 by irradiating natural neodymium. However, this would be extremely uneconomical, for most of the neutrons absorbed in such an irradiation will go to convert Nd-143 to Nd-144; isotopic separation to eliminate at least the high cross-section Nd-143 (330 barns) from the neodymium target will be required. In fact, in the absence of isotopic separation and with driver uranium enriched to 0.95 percent U-235, the Hanford plant capability for producing Pm-147 by reactor irradiation would be limited to only 3 kg of Pm-147 per year.

DISCUSSION

Mr. G. D. Guthrie used the computer to calculate Pm-147 yields as a function of exposure when irradiating individual neodymium isotopes. The results of his calculation for two different neutron flux levels are shown in Figures 1 and 2. The following basic constants were used:

<u>Isotope</u>	<u>Half Life</u>	<u>Thermal Cross-Section Barns</u>	<u>0.045 X resonance Cross-Section Barns</u>	<u>Effective Cross-Section Barns</u>
Nd-142	∞	17.	-	17
143	∞	330.	5.5	336
144	<∞	5.0	-	5
145	∞	50.	11.8	62
146	∞	2.0	-	2
147	11.1 days	--	-	--
Pm-147	2.7 years	230.	186	416

We note that irradiating Nd-146 to make Pm-147 is comparable cross-section-wise to irradiating U-238 to make Pu-239, with small target cross-section and large product cross-section.

The data shown in Figure 3 were obtained by adding the product of the Pm-147 yield for each isotope (from Figure 1 or 2) times the fractional abundance of the isotope in a given mixture, as follows:

<u>Isotope</u>	<u>ABUNDANCE, %</u>		
	<u>Natural</u>	<u>Pu-239 Fission</u>	<u>U-235 Fission</u>
Nd-142	27.11	0	0
143	12.17	27.4	28.4
144	23.85	23.0	26.9
145	8.30	18.4	18.8
146	17.22	15.3	14.6
148	5.73	9.9	8.1
150	5.62	6.0	3.2
	<u>100.00</u>	<u>100.0</u>	<u>100.0</u>

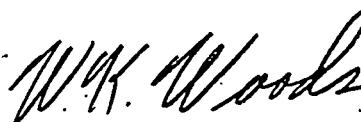
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Finally, for perspective, the effective cross-section of the mixed isotopes was calculated by adding the product of the cross-section for each isotope times the fractional abundance, as follows:

<u>CROSS-SECTION BARNs</u>			
<u>Isotope</u>	<u>Natural</u>	<u>Pu-239 Fission</u>	<u>U-235 Fission</u>
Nd-142	4.6	-	-
143	40.9	92.0	95.4
144	1.2	1.2	1.35
145	5.1	11.4	11.6
146	0.34	.31	0.29
148	0.23	.40	0.32
150	0.09	.09	0.05
	<u>52.5</u>	<u>105.4</u>	<u>109.0</u>

For this table, effective cross-section values for each isotope were as given above, in addition to values of 4.0 barns for Nd-148 and 1.5 barns for Nd-150.

Plant capability was estimated as follows: Total plant capability (excluding N Reactor) is about 3600 kg of Pu-239, or about 15 kg-atomic weights. Twenty percent of this, or 3 kg-atomic weights, can be diverted to other products if 0.95 E-metal is used. If this is all absorbed in Nd isotopes, only 0.34/52.5 goes into making Pm-147. Hence, Pm-147 production initially is (3) (0.34/52.5) (147) kg = 2.8 kg. This rate would increase slowly as Nd-145 is converted to Nd-146.



W. K. Woods, Consulting Engineer  
Advanced Concepts and Planning

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Attachment

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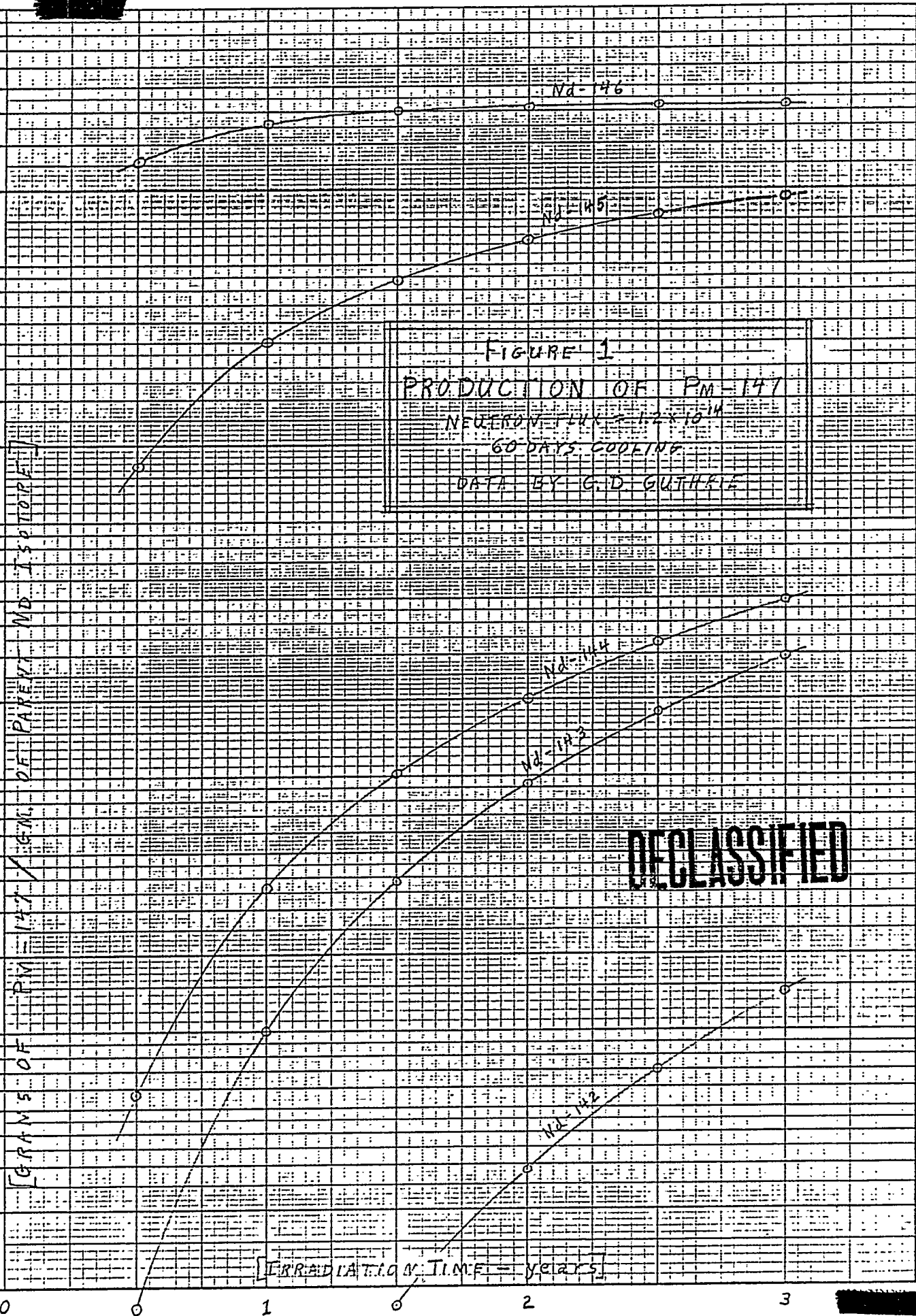
K&E SEMI-LOGARITHMIC 358-91  
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3 CYCLES X 70 DIVISIONS

GRAMS OF PARENT ND ISOTOPE

GRAMS OF PM-147

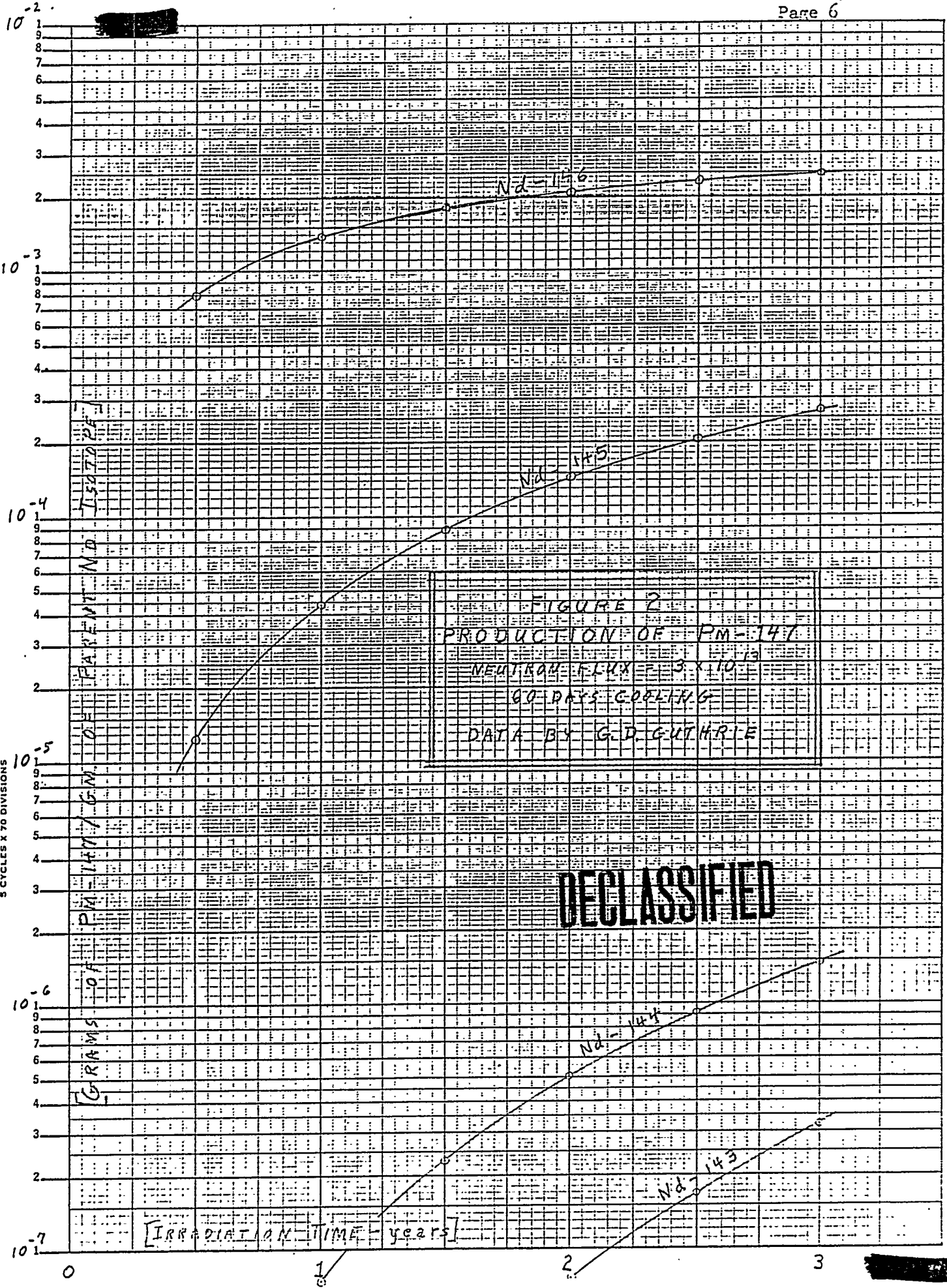
IRRADIATION TIME = years

FIGURE 1  
PRODUCTION OF PM-147  
NEUTRON FLUX =  $1.2 \times 10^{14}$   
60 DAYS COOLING  
DATA BY G.D. GUTHRIE



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KE SEMI-LOGARITHMIC 358-91  
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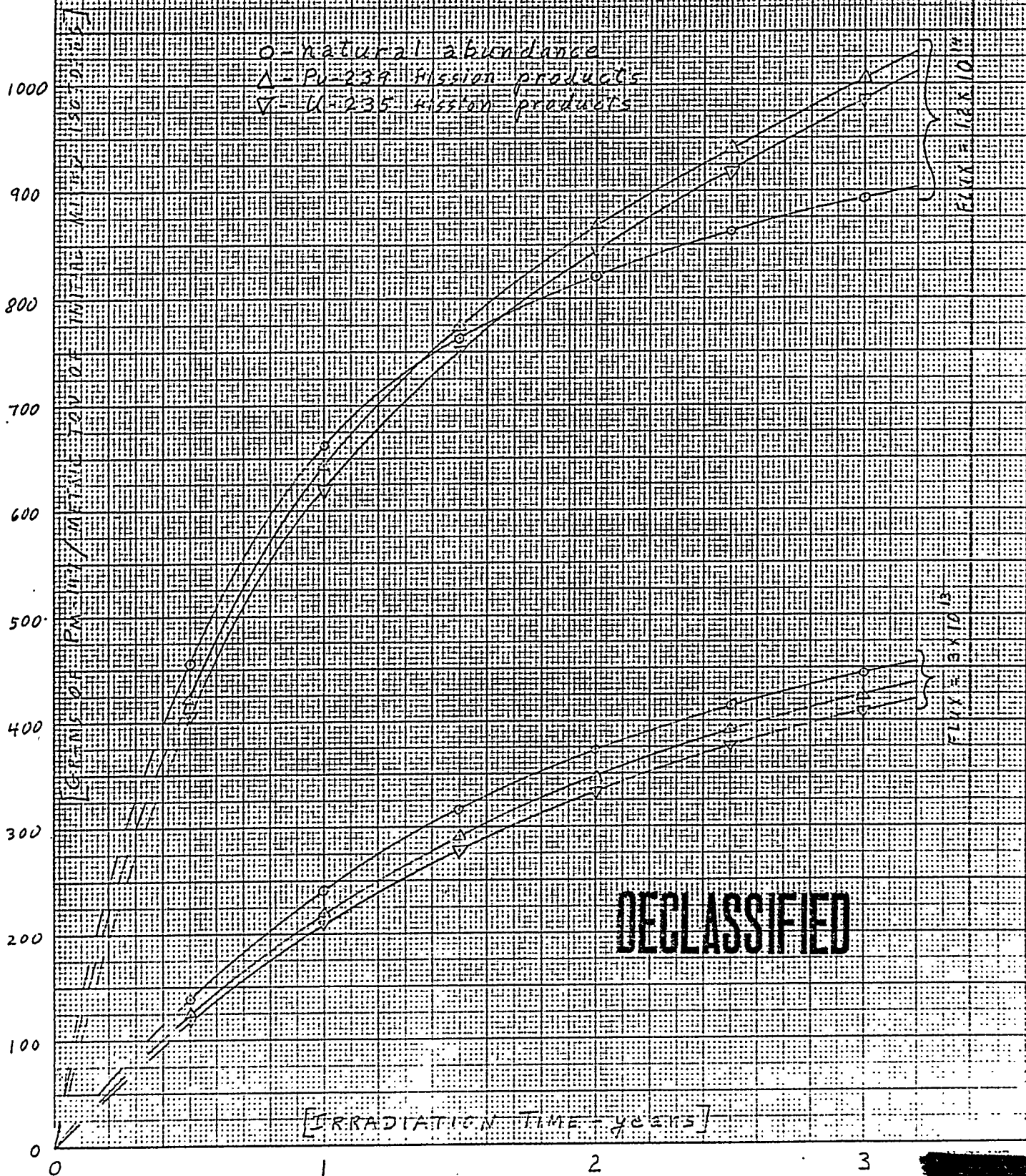


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FIGURE 3

PRODUCTION OF FRENCHMAN-147

BY IRRADIATION OF MIXED MOXIMUM ISOTOPE



10 X 10 TO THE CM. 358-14  
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