

UNCLASSIFIED

CF-54-10-176

Subject Category: ENGINEERING

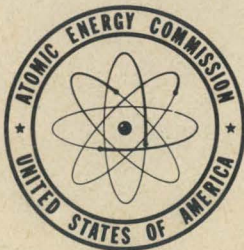
UNITED STATES ATOMIC ENERGY COMMISSION

STAINLESS STEEL UNIVERSITY REACTOR

By
W. E. Kinney

October 30, 1954

Oak Ridge National Laboratory
Oak Ridge, Tennessee



Technical Information Extension, Oak Ridge, Tennessee

UNCLASSIFIED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Date Declassified: November 29, 1955.

— LEGAL NOTICE —

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

This report has been reproduced directly from the best available copy.

Issuance of this document does not constitute authority for declassification of classified material of the same or similar content and title by the same authors.

Printed in USA, Price 15 cents. Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

CF-54-10-176

STAINLESS STEEL UNIVERSITY REACTOR

By W. E. Kinney

October 30, 1954

OAK RIDGE NATIONAL LABORATORY
Operated By
CARBIDE AND CARBON CHEMICALS COMPANY
POST OFFICE BOX P
OAK RIDGE, TENNESSEE

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

STAINLESS STEEL UNIVERSITY REACTOR

I. Statement of the Problem

This study was undertaken to determine the critical mass of a swimming pool type reactor with stainless steel substituted for aluminum in the fuel plates.

Requirements for the reactor are:

- A. Fuel plates be less than 50% by weight UO_2 --a limitation set by fabrication problems.
- B. $k_{eff} \sim 1.05$
- C. Power lie between 0.1 and 1 MW.

II. Heat Transfer

A. General Considerations

Standard swimming pool reactor dimensions* were taken except fuel plates had 5-mil bread and 20-mil meat. A cosine distribution of power was assumed. This yields the following expression for the heat released at 1 MW operation in a region from $-x \rightarrow x$, $-y \rightarrow y$, $0 \rightarrow z$:

$$(1) \quad Q(xyz) = \left\{ 1.795 \times 10^6 \frac{\text{BTU}}{\text{hr}} \right\} \sin \frac{\pi x}{15} \sin \frac{\pi y}{15} \left\{ 1 - \cos \frac{\pi z}{23.6} \right\}$$

where x , y , z are in inches and the origin lies in the center of the reactor base plane.

The central element of the 5×5 loading served as the basis for design. Though the sides of the fuel elements are open, no cross flow of coolant was considered. This should make the design conservative.

The heat output of the central element is, from (1), 3.43×10^5 BTU/hr

B. Natural Convection

Two equations were solved for velocity:

$$(2) \quad Q = p V A c_p \Delta T \times (3.6 \times 10^3 \text{ sec/hr})$$

$$(3) \quad v^2 = \left\{ \frac{p_c}{p} - 1 \right\} \frac{2gr}{f}$$

* ORNL-991

where

Q = heat transferred, BTU/hr
 ρ = weight density of coolant, #/ft³
 V = coolant velocity, ft/sec
 A = area for fluid flow, ft²
 C_p = specific heat at constant pressure, BTU/# - °F = 1 for water
 ΔT = temperature rise of coolant through reactor, °F
 ρ_c = weight density of entering coolant, #/ft³
 $\bar{\rho}$ = average weight density of coolant in reactor, #/ft³
 g = acceleration due to gravity, = 32.2 ft/sec²
 r = hydraulic radius = flow area/wetted perimeter, ft.
 f = average friction factor of fluid in reactor, dimensionless

Note: $f = f\left(\frac{DVP}{\mu}\right)$, a function of Reynold's number.
 See McAdams, "Heat Transmission," p. 118
 μ = average viscosity of coolant

The Dittus-Boelter equation gave the heat transfer coefficient h :

$$(4) \quad \frac{hD}{k} = 0.023(Re)^{0.8}(Pr)^{0.4}$$

where

h = heat transfer coefficient, BTU/hr - ft² - °F
 D = equivalent diameter = $4r$, ft
 k = thermal conductivity, BTU/hr - ft² - °F/ft
 Re = Reynold's number = $\frac{pVD}{\mu}$
 Pr = Prandtl number = $\frac{\mu C_p}{k}$

Finally, plate surface temperature was computed by

$$(5) \quad T_s = \frac{Q}{ha} + T_f$$

where

T_s = surface temperature, °F
 T_f = mean fluid temperature, °F
 a = heat transfer area, ft²

Figure 1 is a plot of central plate surface temperature, assuming non-boiling equations are holding, for 1 MW operation versus the number of plates per element. Note that under 20 feet of water, water boils at 239°F. While obviously non-boiling equations do not hold below 10 plates per element, Figure 1 shows 10 plates per element to be the minimum number for 1 MW operation and natural convection cooling.

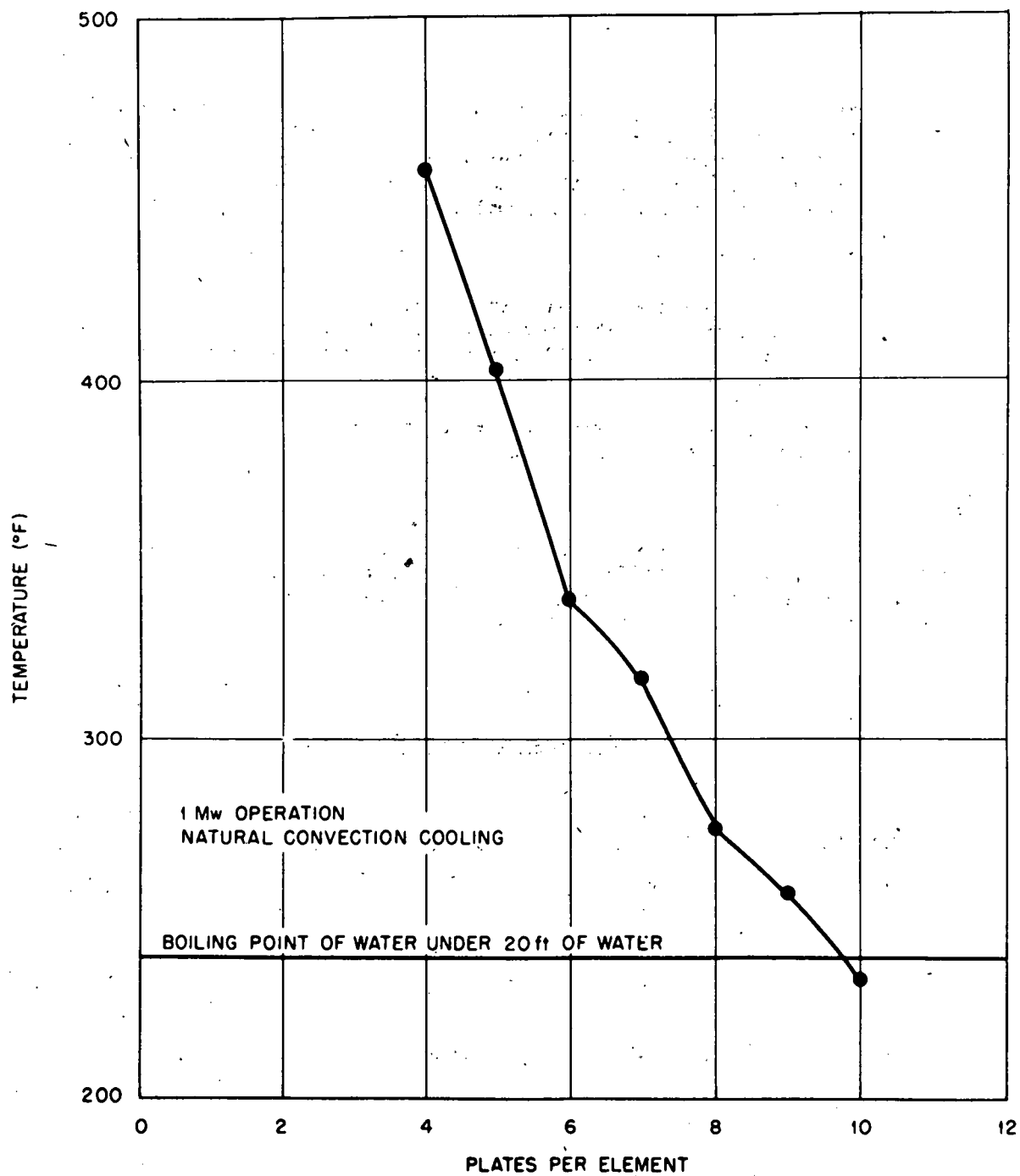


Fig. 1. Central Plate Surface Temperature vs. Number of Plates per Element.

Figure 2 is a plot of maximum power for non-boiling versus number of plates per element. This also shows the effect of adding a 20-foot chimney to the 6 plate system. While the chimney would improve heat transfer, it would also funnel N¹⁶ to the pool surface, creating a health problem.

C. Forced Convection

If coolant is forced through the core, 1 MW operation is possible at low numbers of plates per element. Figure 3 is a plot of required velocity for 230°F central plate surface temperature versus plates per element.

Figure 4 gives the maximum power for non-boiling as a function of velocity for 2 - 6 plate systems.

III. Critical Mass

Calculations were made on the three-group, three-region ORACLE code, cylindrical model 19-cm radius, 66-cm height, light water reflected on the side. Self-shielding was not considered. Figure 5 shows the results, and Table I gives a summary of the results.

Table I

Summary of Results

<u>Plates/element</u>	<u>k = 1</u> <u>gm/plate</u>	<u>k = 1.05</u> <u>gm/plate</u>	<u>k = 1</u> <u>Critical</u> <u>mass, gm</u>	<u>k = 1.05</u> <u>Invested</u> <u>mass, gm</u>
2	46	53	2120	2440
3	34	39	2340	2690
4	27	31	2480	2850
5	24	27	2760	3100
6	20	23	2760	3170

NOTE that 50% by weight of U corresponds to ~ 105 gm 25/plate.

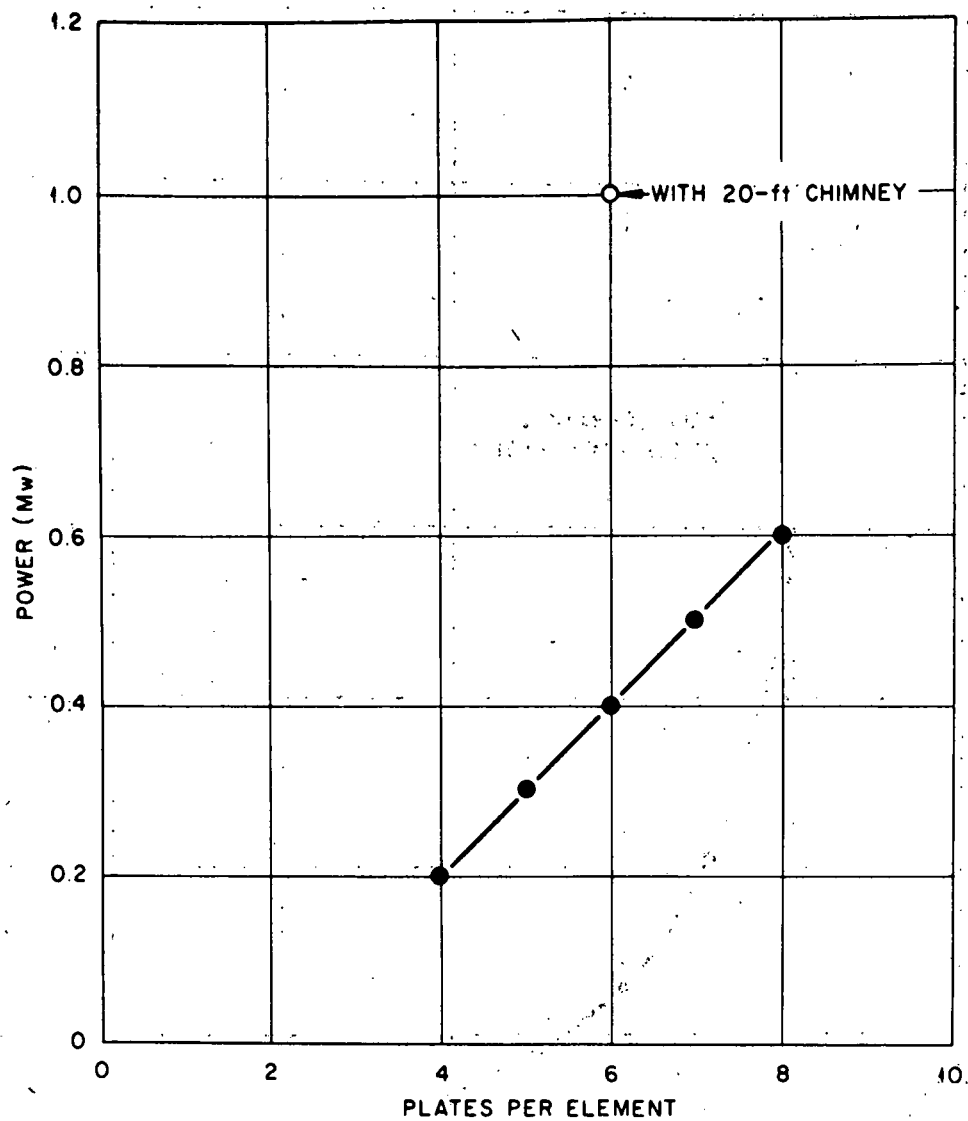


Fig. 2. Maximum Power vs. Number of Plates per Element
(Natural Convection Cooling)

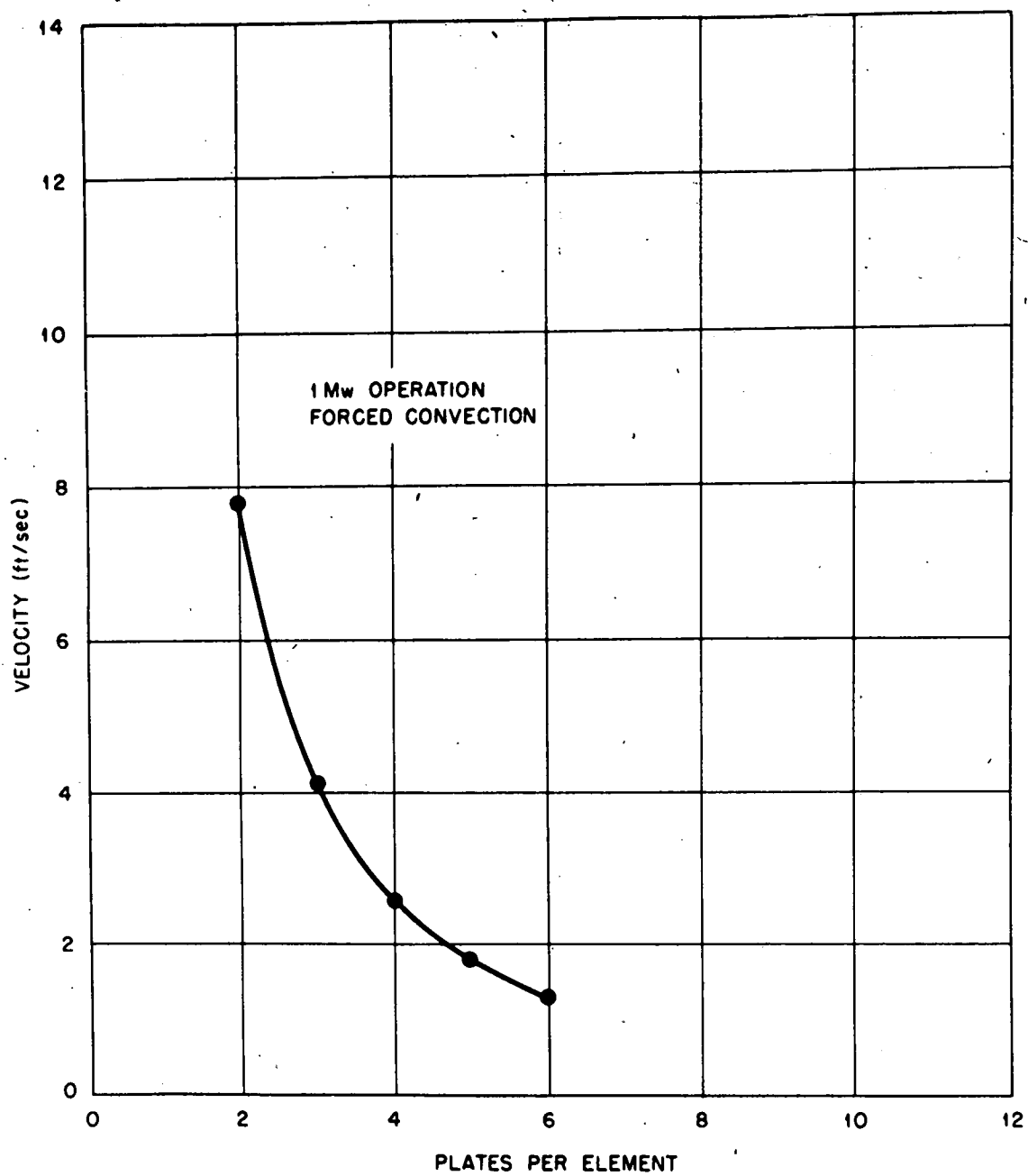


Fig. 3. Velocity for 230°F Central Plate Surface Temperature vs. Number of Plates per Element.

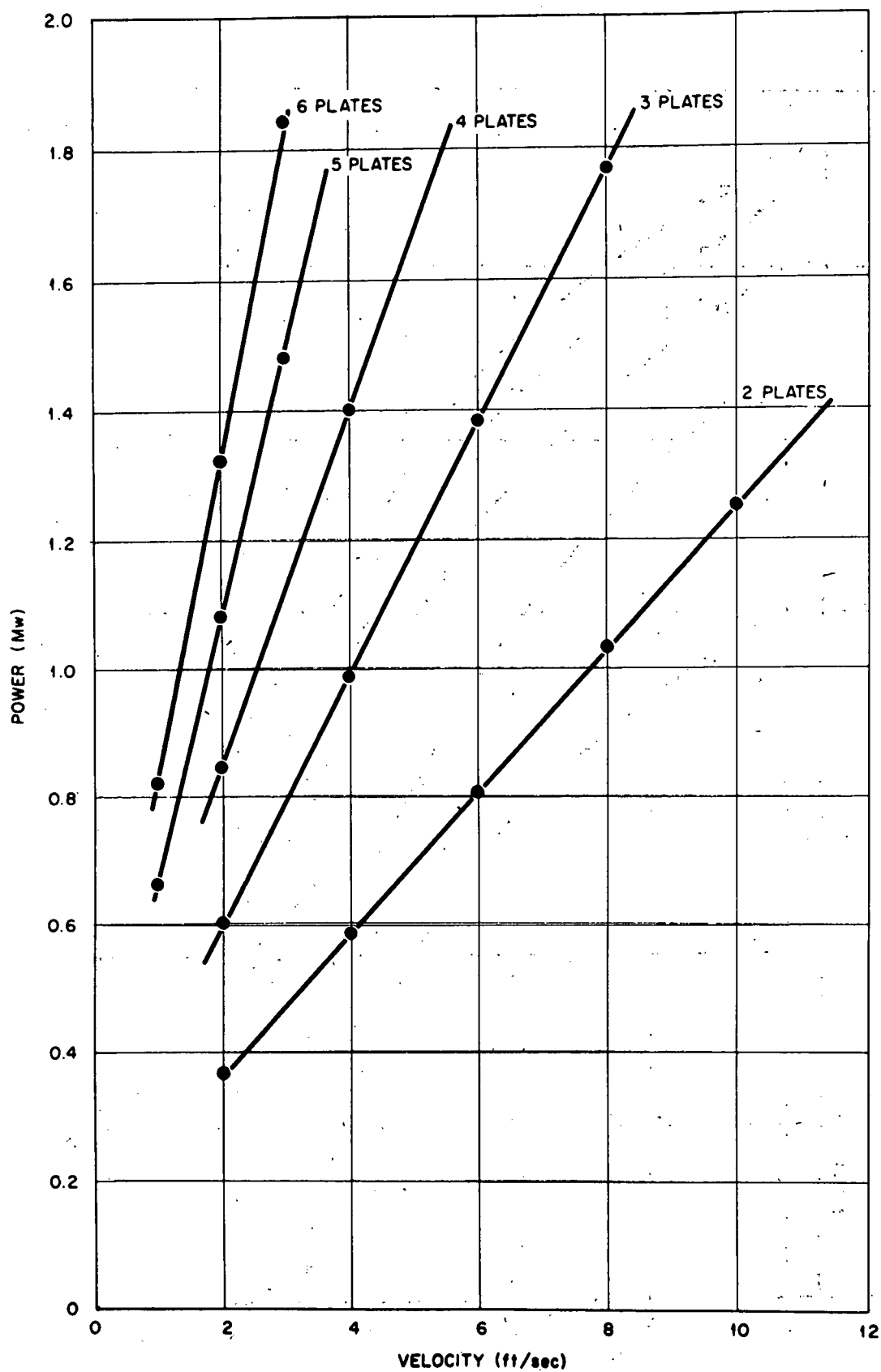


Fig. 4. Maximum Power vs. Velocity (Forced Connection) .

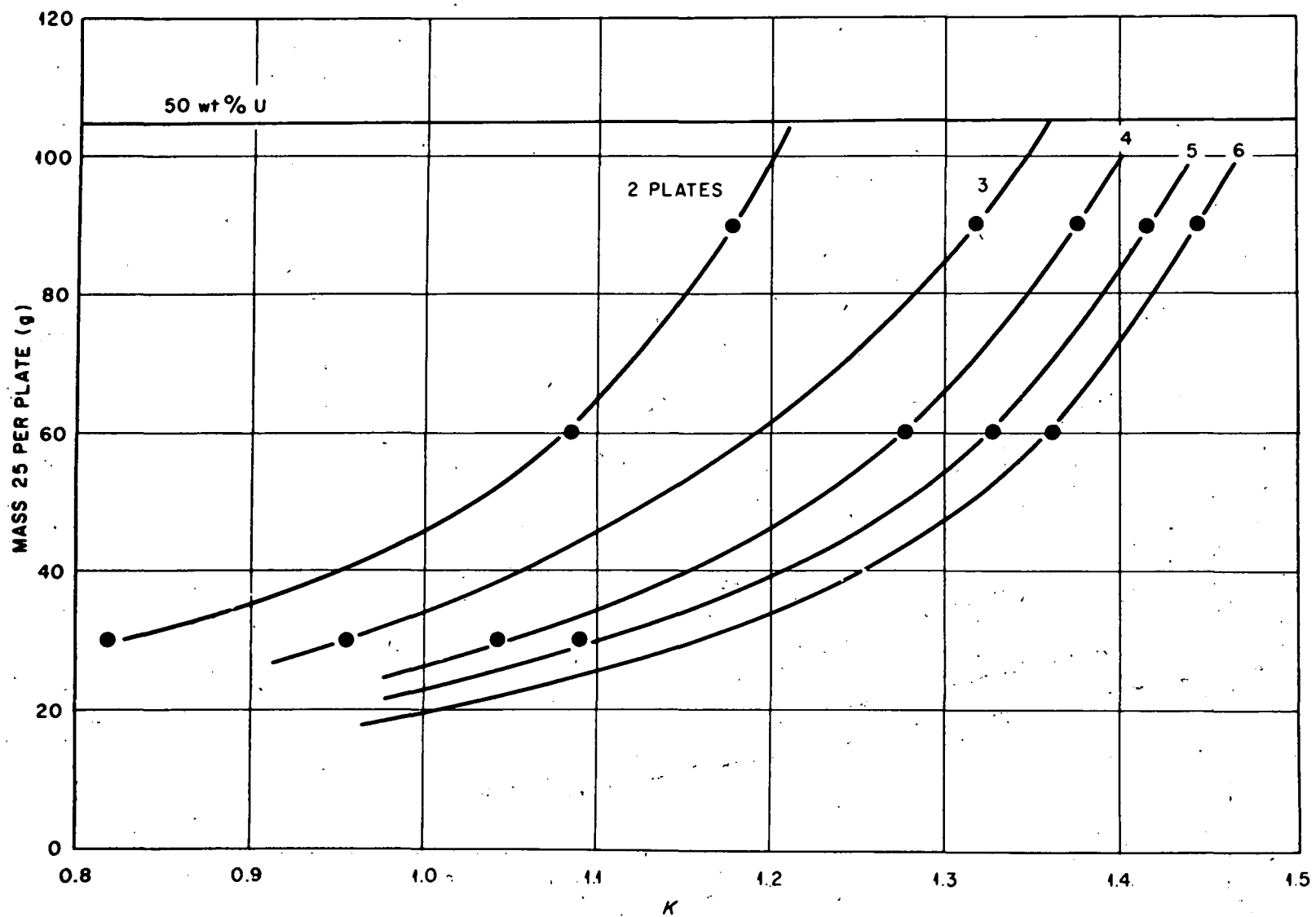


Fig.5. Mass 25 per Plate vs. K ; Cylindrical Model, Light Water Reflected.