UNION CARBIDE

UNION CARBIDE CORPORATION P. O. BOX 324, TUXEDO, NEW YORK 10987
MEDICAL PRODUCTS DIVISION TELEPHONE NUMBER: (914) 351-2131

December 30, 1983

Mr. W. W. Kinney
U. S. Nuclear Regulatory Commission
Region I
Division of Projects and
Resident Programs
631 Park Avenue
King of Purssia, PA 19406

Ref. (a) UCC Letter Dated 11/30/83 to USNRC Region I

Dear Mr. Kinney:

We have reached a conclusion on the cause of the failed uranium targets that were last reported in our letter referenced above. The enclosed report to the Nuclear Safeguards Committee (NSC) is a summary of our investigation and conclusion.

Corrective and preventive measures have proven effective to date. Further work is planned and it will be documented in our NSC minutes.

Please call me if you have further questions on this incident.

Very truly yours,

James J. McGovern
Business Manager
Radiochemicals

JJMcG:js
Enclosure

cc: Mr. H. Bernard, NRC Bethesda

bcc: Mr. H. B. Hill
Mr. R. W. King
Mr. L. Puccini

UC 149-2

UNION CARBIDE INTERNAL CORRESPONDENCE

MEDICAL PRODUCTS DIVISION

P. O. BOX 324, TUXEDO, NEW YORK 109

To (Name) Division Location: Nuclear Safeguards Committee
F. J. Morse (NSC Secretary)

Date: December 12, 1983

Originating Dept.: NUCLEAR OPERATIONS

Answering letter date:

Copy to:
D. J. Gallaher
K. D. George
D. D. Grogan
R. W. King
C. J. Konnerth - (NSC Chairman)
J. J. McGovern
R. A. Strack

Subject: Findings from F.P.M. Target Failure Investigation

Reference (a): Nuclear Operations Memo, 11/29/83

Continued investigation of the F.P. Mo-99 target failures per Ref. (a) revealed the following:

1. All single-pull stringers were gaged to determine the extent of any wear that may have caused the coolant channel gap to change around the target. Several cylindrical gages with O.D.'s that varied from 1.254" (the original I.D. of the positioning lugs within the stringer) up to 1.280" were inserted into each tube of each stringer. The gaging showed that 17 of 32 tubes had worn to an I.D. of greater than 1.270", 1 of 32 had increased to > 1.280", and all but 4 had increased to greater than 1.265". All tubes in the stringer, where the last failed target was irradiated, had worn to an I.D. of at least 1.270" but less than 1.280". Reconstruction of this condition on a drawing of 2:1 scale reveals that the coolant channel was distorted so that the gap on one side was reduced to less than 10 mils in this stringer.

   Therefore, it is concluded that the probable mechanism of failure was as follows:

   (a) The annular coolant channel was distorted to the point where flow in the narrowed portion of the channel was reduced appreciably.

   (b) Local transient film boiling raised the average temperature within the target wall.

(c) Lateral movement of the target caused rapid local cooling from a film boiling condition resulting in an instantaneous high ΔT across the target wall.

(d) The high ΔT ($\geq 170^{\circ}$ F, Ref. (a), page 8) caused excessive thermal stress and consequent tube failure.

The interim corrective measure of using the box stringer will be continued until a permanent correction is worked out.

2. The cause of discoloration of the outer surface of irradiated tubes was investigated further. Some targets were mechanically cleaned by polishing with emery cloth to determine if some residue from the tube drawing mill or the plating process could be the source of the discoloration. Several of these polished targets were examined post irradiation. The degree of discolor was less than the unpolished targets but it was still evident. It is probable that the color varies with the amount of oxidation on the outer tube surface and the heat flux during irradiation but this is not conclusive.

3. The bouyancy effect in narrow channels with coolant flowing down was investigated further. Attachment A provides details of this evaluation. It is concluded that this phenomenon is not significant in the single-pull stringer design.

With the cause of failure identified, it is proposed that further investigation of the uranium target failure be suspended. Operations will propose corrective measures to prevent recurrence in the future.

W. Ruzicka

W. G. Ruzicka

WGR:js

BOUYANCY EFFECT OF HEATED COOLANT IN NARROW CHANNELS

Recent data received from W. R. Gambill on the effect of bouyant forces causing reduction of the burnout heat flux shows that this phenomenon does not affect heat transfer in our system for cooling uranium targets in the single-pull stringer. The data that most closely approximates our system is plotted in three sets of curves. The ratio of the predicted burnout heat flux to the experimental (actual) burnout heat flux is plotted as a function of G_R/K_a.

In order to use this data, it is necessary to calculate the G_R/K_a value for our single-pull stringer, where:

$$G_R/K_a = 0.67\ De\ \beta\ dt/fV^2$$

when:

$De = 0.15$ in.

$B = .0001$ (volumetric expansion H_2O)

$dt = 10^\circ F$ (bulk coolant temp rise)

$f = 16/Re$ (for $Re < 2100$)

$\quad .046/Re^{0.2}$ (for $Re \geq 2100$)

$V = 3.5$ ft./sec.

It is necessary to calculate Re for the single-pull stringer:

$$Re = 4\ RH\ G/U$$

$$RH = \frac{D-d}{4}\ (\text{ft.})$$

G = Mass Flow Rate (lb/ft^2 sec.)

U = Viscosity (lb/ft sec.)

$$Re = 4\ \frac{\left(\frac{.117 - .104}{4}\right) \text{ft} \times \left(\frac{15}{60} \text{ gallons/sec} \times 8.34 \text{ lb/gal} \times \frac{1}{.002 \text{ ft}^2}\right)}{.0046 \text{ lb/ft sec}}$$

$$Re = \frac{.013 \times 1042.5}{.0046}$$

$$Re = 2946 \quad (\geq 2100;\ \therefore\ f = .046/Re^{0.2}$$

G_R/K_a can now be evaluated for the single-pull stringer:

$$G_R/K_a = 0.67 \text{ De } \beta \text{ dt}/fV^2$$

$$= \frac{.67\ (.15 \times .0001 \times 10)}{.046/2946^{0.2} \times 3.5^2}$$

$$= \frac{.0001}{.0093 \times 12.25}$$

$$G_R/K_a = .0009$$

Conclusions: Refer to attached data of Gambill.

1. According to Graph I, the predicted burnout heat flux will be much less than the actual. G_R/K_a for our system is small compared to experimental data, and this suggests bouyant affect does not exist for single-pull stringers, provided the gap remains uniformly constant.

2. In Graph 2, T.S. 7 most closely approximates our system. This indicates that predicted heat flux could be 20 percent high relative to actual burnout conditions. It also suggests that the bouyant affect does not exist in our system.

3. Graph 3 confirms conclusions 1 and 2.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

June 11, 1976

Mr. Ken George
Union Carbide Corporation
P. O. Box 324
Tuxedo, N. Y. 10987

Dear Mr. George:

In response to your inquiry of June 9, I am enclosing copies of four graphs which summarize the work we have done on buoyancy effects on thermal burnout with vertical downflow of water in electrically heated tubes. This material supplements the early data I sent Professors Rust and Meem at the University of Virginia in early 1967 and expands considerably the brief description of the studies in my <u>Nuclear Safety</u> article of Nov.-Dec. 1968. I hope it will be of aid in your updating the technical specifications for the pool reactor at Sterling Forest. Since you have the earlier material and associated notation, I will omit the latter here.

The first experimental study became the focus of a program initiated in Buenos Aires, Argentina, when I was there as a technical assistance expert with the I.A.E.A. in 1966. A. R. Blumenkrantz and I conducted ~ 150 instrumented burnout tests using d_i = 0.118 to 0.354 in., L_h = 2.95 to 11.8 in., L_h/d_i = 16.7 to 33.3, V_{in} = 0.26 to 11.0 ft/sec, and a test section exit pressure of 1.1 atm. abs. These conditions corresponded to ratios of the Grashof to von Kármán moduli (G_r/K_a) at burnout of 0.0035 to 12.3 and yielded burnout (critical) heat fluxes from 95,000 to 2.71 x 10^6 Btu/hr ft^2. The data for $G_r/K_a \leq 1$ are shown in the graph labeled <u>1</u>. For $0.003 < G_r/K_a < 1$:

$$\varphi_{bo\ \text{exptl.}} = \frac{(\varphi_{bo})\ \text{pred., WRG}}{5.87\ (G_r/K_a)^{[illegible]}} \rightarrow \text{[Exp. is 0.40]}$$

with an rms deviation of 23% and a maximum deviation (3 σ level) of ± 40%.

The ratio $G_r/K_a = (g\ D_e/4)(\beta dt/fV^2)$, where dt is the axial temperature rise of the coolant; a dimensional representation is $G_r/K_a = 0.67\ D_e\beta\ dt/fV^2$ when units of in., °F, and ft/sec are used. For Re < 2100, f = 16/Re; for Re ≥ 2100, we used $f = 0.046/Re^{0.2}$. The quantity $[(\varphi_{bo})_{pred.,\ WRG}]$ refers to my generalized superposition (additive) correlation of burnout heat flux for flowing, subcooled, wetting liquids (see my ORNL-TM-2421, Nov. 1968, and the references therein). For calculating $(\varphi_{bo})_{pred.}$, we used the following equations (keyed here to the equation numbers in TM-2421):

Eq. (4) with K = 0.15,

Eq. (9) for F_{sub},

h_{nb} (in Eq. 6) from:

$$h_{nb} = 0.116\ (\frac{k}{D})_b\ (Re_b{}^{2/3} - 125)Pr_b{}^{1/3}\ [1 + \frac{1}{3}\ (\frac{D}{x})^{2/3}],$$

and $(\Delta t_f)_{bo}$ (in Eq. 6) from:

$$(\Delta t_f)_{bo\ °C} = 57\ \ln P - 54\ (\frac{P}{P + 15}) - \frac{V}{4} - (t_b)_{bo}.$$

I conducted an expanded study at ORNL during 1968 - 1969. We obtained 217 burnout measurements using d_i = 0.127 to 0.375 in., L_h = 5.0 to 20.0 in., L_h/d_i = 13.3 to 157, V_{in} = 0.28 to 57.7 ft/sec, and test section exit pressures of 1.8 to 22.2 atm. abs. These extended test conditions resulted in Gr/Ka ratios of 0.00039 to 25.8 and burnout fluxes from 50,000 to 4.36×10^6 Btu/hr ft². The equations used for $(\varphi_{bo})_{pred.} = (\varphi_c)_{pred.}$ and for Gr/Ka were the same as those described above.

The later ORNL data are presented in the graph labeled 2, the test section numbers corresponding to the following dimensions:

T.S. No. →	1	2	3	4	5	6	7	8	9
d_i (in.), →	0.375	0.375	0.375	0.243	0.243	0.243	0.127	0.127	0.127
L_h (in.)[a] →	20	10	5	20	10	5	20	10	5

[a] - within ± 0.02 in.

Curves for the 20 - in. long tubes, which are probably of the most interest to you, are shown separately in the graph labeled 3.

We also conducted upflow burnout tests with test sections 10, 11, and 12, which were nominally identical to downflow test sections 3, 7, and 4, respectively. These data enabled us to plot the experimental ratio of $(\varphi_c)_{up}/(\varphi_c)_{down}$ without relation to any burnout correlation, as in the graph labeled 4. In these terms, there was an inherent buoyancy effect with downflow which decreased burnout fluxes below upflow values for Gr/Ka greater than ~ 1/3.

I will be pleased to provide elaboration as needed.

Very truly yours,

W. R. Gambill

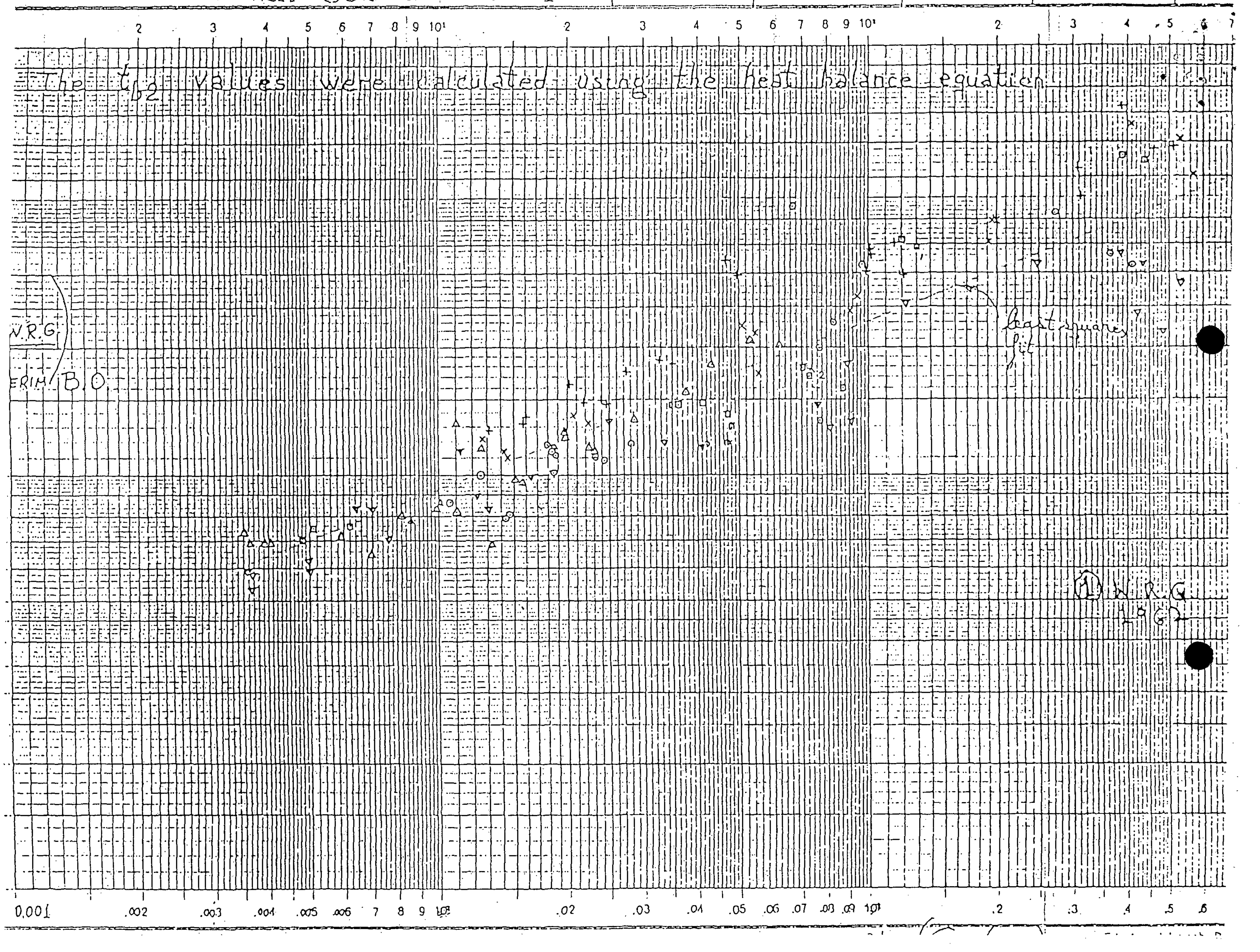
W. R. Gambill
Engineering Coordination and
Analysis Section
Chemical Technology Division

WRG:msb

cc: A. E. Bergles (Iowa State Univ.)

bc: F. T. Binford
R. D. Cheverton
D. E. Ferguson
L. E. McNeese LEMc
✓WRG File (2)
EC&A File

lations based on Heat Balance ○ TS1 | × TS2 | + TS3 | ▽ TS6 | ...



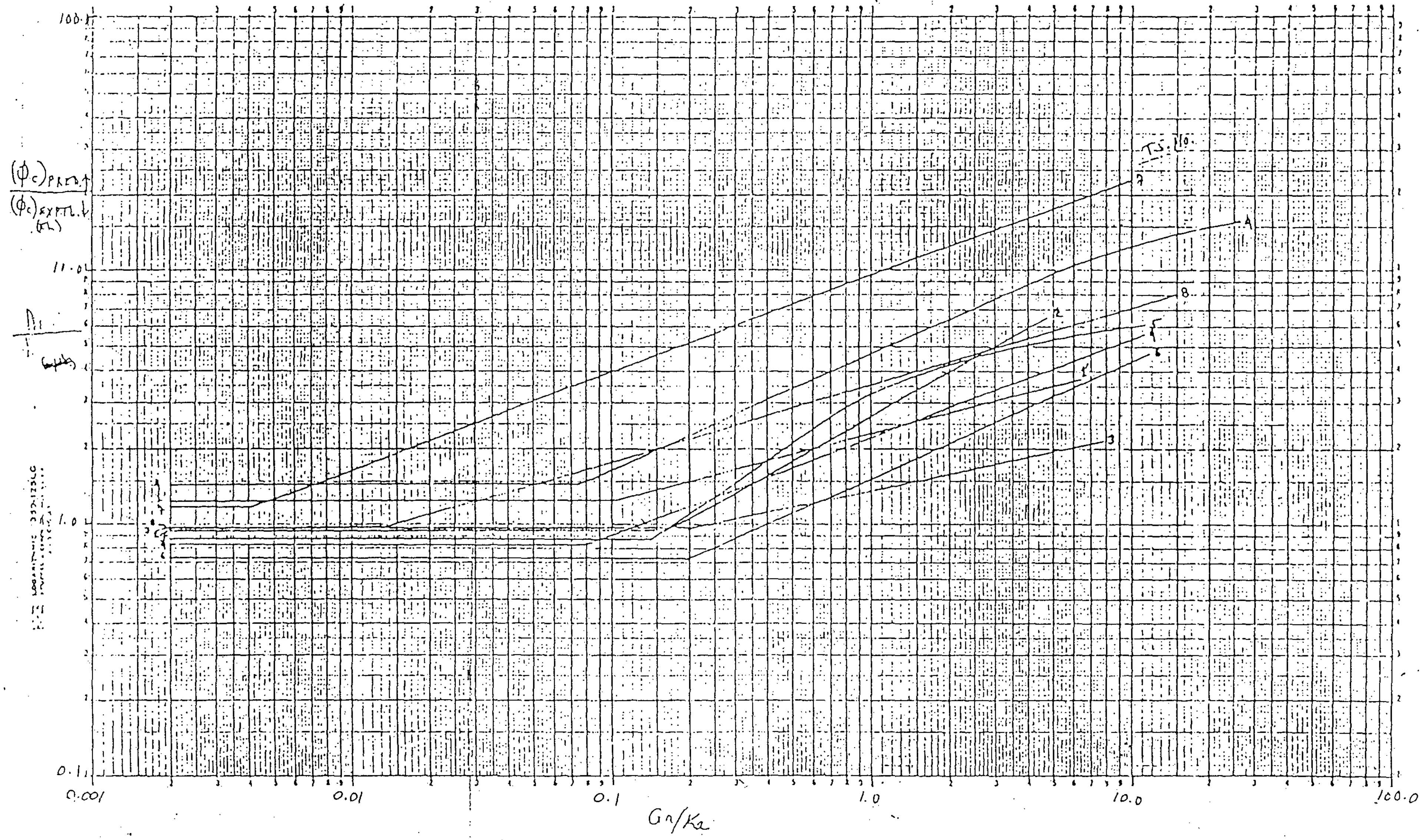
All [illegible] — Steady Data

[illegible] — Avg. Curve

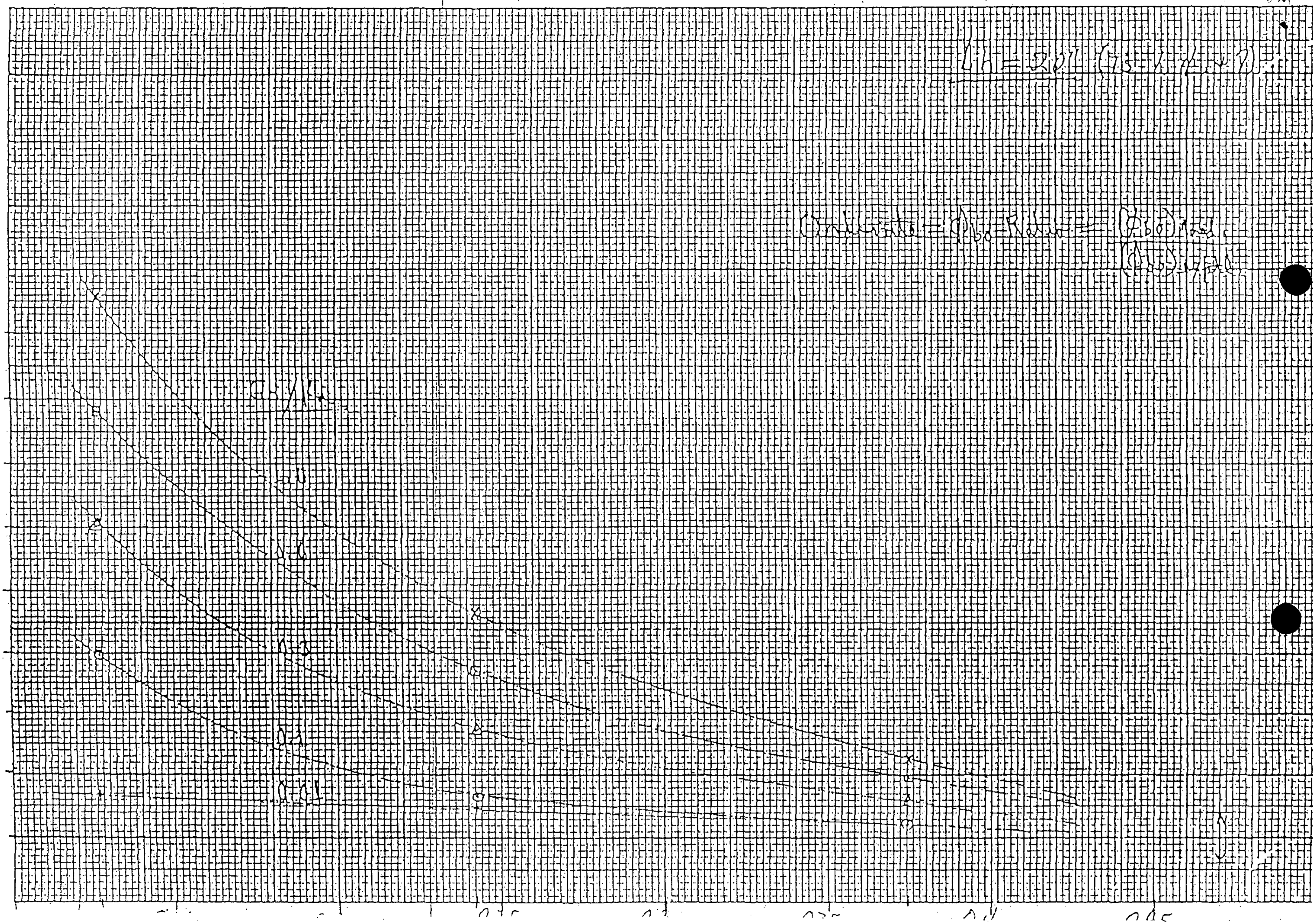
2

10 Oct. '89

W.R.G.



3



Comparison of [illegible] with [illegible] (Exptl. Values)

(4)

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