AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

**Cover Sheet for a Hanford
Historical Document
Released for Public Availability**

Released 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This is a **historical document** that is being released for public availability. This was made from the best available copy. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, 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.** The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DECLASSIFIED

(CLASSIFICATION)

DECLASSIFIED

DOCUMENT NO.

HW-59975

COPY 1 OF 1, SERIES MA

SERIES AND COPY NO.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

DATE

April 13, 1959

☒

RESTRICTED DATA

THIS DOCUMENT CONTAINS RESTRICTED DATA AS DEFINED IN THE ATOMIC ENERGY ACT OF 1954. TRANSMITTAL OF THE DISCLOSURE OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED.

TITLE

POWER RATE METER RESPONSE CHARACTERISTIC

☐

OTHER OFFICIAL CLASSIFIED INFORMATION

THIS MATERIAL CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U. S. C., SECS. 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

AUTHOR

D. E. Simpson

CIRCULATING COPY
RECEIVED 100D AREA

APR 15 1959

RETURN TO

THIS DOCUMENT MUST BE KEPT UNATTENDED OR UNDER THE CLOSE SUPERVISION OF AN AUTHORIZED PERSON. WHEN NOT IN USE, IT MUST BE STORED IN AN APPROVED, LOCKED REPOSITORY WITHIN AN APPROVED SECURED AREA. WHILE IT IS IN POSSESSION AND UNTIL IT HAS BEEN OBTAINED A SIGNED RECEIPT FROM THE ISSUING OFFICE, IT IS THE RESPONSIBILITY OF THE USER TO KEEP IT AND ITS CONTENTS WITHIN THE LIMITS OF THIS PROJECT AND FROM AN UNAUTHORIZED PERSON. ITS TRANSMITTAL TO AND STORAGE IN YOUR PLACE OF RESIDENCE IS PROHIBITED. IT IS NOT TO BE DISSEMINATED. IF ADDITIONAL COPIES ARE REQUIRED, OBTAIN THEM FROM THE RELATED ISDS FILE. AFTER PERSONS READ THIS DOCUMENT ARE REQUESTED TO RETURN THE SP TO THE PROVIDED SOURCE.

TECHNICAL INFORMATION FILE

ROUTE TO:

PAYROLL NO.

LOCATION

FILES ROUTE
DATE

SIGNATURE AND DATE

THIS DOCUMENT IS PUBLICLY
AVAILABLE

DECLASSIFIED

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

HW-59975

DISTRIBUTION

1. ER Astley - DL Condotta
2. JT Baker
3. RS Bell - SL Nelson - EJ Filip
4. CE Bowers
5. JH Brown - ET Hubbard
6. WL Bunch
7. AB Carson
8. RD Carter - GR Parkos
9. RA Chitwood
10. RR Cone
11. RL Dickeman
12. AG Dunbar - WS Nechodom
13. JE Faulkner
14. RL Ferguson
15. FC Franklin
16. GC Fullmer
17. GR Gallagher
18. OH Greager
19. CN Gross - RG Clough
20. WM Harty
21. RT Jessen - DS Lewis
22. JE Kaveckis
23. EH Lockwood - WL Smalley
24. AR Maguire - CG Lewis - JW Baker
25. DI Monnie
26. JF Music
27. R. Nilson
28. GF Owsley - DE Goins
29. RW Reid
30. DE Simpson
31. WR Smit
32. HG Spencer
33. P. Thompson - AK Hardin
34. AD Vaughn
35. 300 Files
36. Record Center

GROUP 1 OF 1, SERIES MA

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of CG-PR-2,

WA Snyder, 1-3-94.

By Jessie Smalley, 4-21-94.

Verified By DK Hanson, 4-21-94

This document consists of
7 pages.

This document classified

by GC Fullmer

April 13, 1959

POWER RATE METER RESPONSE CHARACTERISTICS

INTRODUCTION

Power rate of rise measuring instrumentation is being procured for all of the Hanford piles, and a prototype installation is now in service at D reactor. This instrumentation is expected to provide valuable assistance to the pile operator during the start-up rise to operating power; in order to best utilize the instrument, procedures and limits must be determined on the basis of the relationship between the flux rate of change and the instrument response.

As with any measuring instrument, there is an inherent delay in the power rate meter circuitry; in addition there are greater delays associated with the heat capacity of the metal and water and the transit time of the cooling water. Furthermore, reactivity changes from rod withdrawal and metal coefficient damping are not instantaneous, and the flux is not a simple function of the reactivity changes. Because of the time lags involved the rate meter response cannot be identical to the actual flux rate of change; however, an exact solution for this response in terms of all of the variables would be

DECLASSIFIED

INTRODUCTION (Continued)

inordinately complex. The purpose of this study is to show approximately the changes in power level or rate which might occur in practice relative to the instrument indications, and to point out how the differences may be considered in setting realistic operating standards with neither undue risk nor unwarranted conservatism. This analysis is intended also to provide the technical background for a production test to check the accuracy of the approximate calculations. Together with the results of the intended test and of additional analog calculations, this report will provide the basis for Process Standards governing procedures for pile start-up using the power rate meter.

SUMMARY

Equations characteristic of the power rate meter response for various types of power rate change are presented, and graphical comparisons of actual to indicated rates of rise are shown based on the approximate assumptions made (Figures 1 and 2).

The largest percentage error in the rate indication will occur with exponentially increasing rates with relatively fast periods; this condition could exist at low power levels if the start-up period were allowed to continue unchecked. For example, with a ten second period the indicated rate may be slightly less than half the actual rate. At higher levels, with the slower periods involved, the main concern is a lag in detecting an increase in rate caused by control rod withdrawal. In both cases it is calculated that the instrument will indicate that the pile is exceeding its rate of rise limit before the pile has gained in level the maximum amount permitted by current standards during the ensuing minute. Therefore, the power rate meter system as designed is expected to provide the degree of operator guidance and protection for which it was planned. An in-pile test plus analog studies are desirable, however, to confirm these conclusions which are based on approximate assumptions and calculations.

DISCUSSION

The output of any measuring instrument containing a single delay between input and output is expressed by

$$\frac{dR}{dT} = \lambda(I - R)$$

or
$$\frac{1}{\lambda} \frac{dR}{dT} + R = I$$

where I = input signal (more exactly, the output signal which would give an exact, instantaneous measure of input conditions)

R = output signal

$\frac{1}{\lambda}$ = instrument time constant

The solution of the above equation is

$$R = \left[C + \lambda \int I e^{\lambda t} dt \right] e^{-\lambda t}$$

in which C is the arbitrary constant determined by initial conditions.

DISCUSSION (Continued)

This equation can be solved easily for certain forms of I , notably exponential and linear functions of time. In the first case

$$I_1 = a_1 e^{\lambda t}$$

and

$$R_1 = c_1 e^{-\lambda t} + \frac{a_1 \lambda}{\alpha + \lambda} e^{\lambda t} = c_1 e^{-\lambda t} + \frac{\lambda}{\alpha + \lambda} I_1$$

In the second case

$$I_2 = a_2 t + b_2$$

and

$$R_2 = c_2 e^{-\lambda t} - \frac{a_2}{\lambda} + a_2 t + b_2 = c_2 e^{-\lambda t} - \frac{a_2}{\lambda} + I_2$$

For the still simpler case in which I is constant

$$I_3 = a_3$$

and

$$R_3 = c_3 e^{-\lambda t} + a_3 = c_3 e^{-\lambda t} + I_3$$

After decay of the leading transient term, R approaches the values:

Exponential	$R_1 \rightarrow \frac{\lambda}{\alpha + \lambda} I_1$
Linear	$R_2 \rightarrow I_2 - \frac{a_2}{\lambda}$
Constant	$R_3 \rightarrow I_3$

The time lag between existence of a given input signal and its indication at the instrument output is of interest, particularly for the asymptotic case (after decay of the transient term). This lag is found by setting $R(t^1) = I(t)$ and solving for the time lag, $t^1 - t$.

Input signal	Response time lag (asymptotic case)
Exponential	$-\frac{1}{\alpha} \ln \frac{\lambda}{\alpha + \lambda}$
Linear	$\frac{1}{\lambda}$
Constant	0

It may be noted that the time lag for an exponential input approaches $\frac{1}{\lambda}$ as α goes to zero (period approaching infinity).

DISCUSSION (Continued)

Now, the power rate meter and the associated processes by which the input signal is conveyed include a number of delays rather than one alone. These delays, and the associated time constants, are:

	Time Constant, $\frac{1}{\lambda}$ (Seconds)
1. Metal heating (or cooling) time due to energy absorbed in this process	3.3
2. Water heating (or cooling) time	0.7
3. Water transport time between active zone and RTD	2.1 (Constant lag)
4. RTD response time	1.3
5. Delay in RTD output amplifier	1
6. Delay in power rate meter differentiating circuit	1

Two situations are of concern in which these delays may restrict somewhat the use of the power rate meter:

1. Start-up rising period which is allowed to continue to too high a power.
2. A sudden increase in rate of power rise due to rod withdrawal during the rise to operating power.

Let us consider these in turn.

In the case of the continuing start-up period, the transient terms in the power rate meter response will decay at insignificant power and rates and the asymptotic case will exist in the range of interest. For a particular rising period, an effective value of λ for the instrument may be determined by simply adding the time lag associated with each delay and computing λ_{eff} as

$$\frac{1}{\lambda_{\text{eff}}} = \tau(e^{\Delta t/\tau} - 1)$$

where Δt = sum of all time lags,

and α has been replaced by $\frac{1}{\tau}$, where τ is the rising period.

Neglecting the effect of the negative metal coefficient,

$$W = W_0 e^{t/\tau}$$

and

$$W' = \frac{dW}{dt} = \frac{W_0}{\tau} e^{t/\tau}$$

DECLASSIFIED

HW-59975
Page 5

DISCUSSION (Continued)

Thus, the power rate increases exponentially, and

$$R = \frac{\lambda_{\text{eff}}}{\frac{1}{\tau} + \lambda_{\text{eff}}} W'$$

For a ten-second period, for example, $R = 0.42 W'$. Actually this is conservative because of the effect of the negative metal coefficient of reactivity; Figure 1 shows an estimate of the actual power rate and the indicated power rate resulting from an initial period of ten seconds.

The second case of a sudden rod withdrawal at fairly high power is considerably more complex because the flux is not a simple function of time and the transient delay terms in the instrument response cannot be eliminated. A preliminary estimate of the relationship between flux and instrument response has been made and is discussed below; however, this analysis should be checked by an analog computer calculation.

The maximum possible rate of rod withdrawal for the old piles is about three mk (~ 120 ih) per minute. Since the metal coefficient is about $-.003$ mk/MW, a continuous rod withdrawal would result in a continuous power increase at about 1000 MW/min, or say ~ 20 MW/sec. At powers in the neighborhood of one-half equilibrium power or higher, this rate would be reached in a very few seconds, although the exact power transient is difficult to calculate. If the power rate can be approximated satisfactorily by a step function, the power rate meter will indicate a rate of 10 MW/sec. about eight seconds after the step and a rate of three MW/sec. about five seconds after the step (see Figure 2). It appears, then, that a safety circuit trip upon indication of a 200 MW/min. rate of rise would shut the pile down after a total power increase of roughly 100-150 MW.

Because of the approximate nature of the calculations reported here and because of uncertainties in the various delay times (particularly the metal and water heating and the water transport lag), this analysis is not sufficient to serve as a basis for Process Standards governing pile operating procedures utilizing the power rate meter; however, the accuracy of delay times and the calculated instrument response to a continuing start-up period can be checked with sufficient accuracy by a production pile experiment in which a period is allowed to continue until a specified rate of rise is indicated. The results of such a confirming experiment, plus an analog computation for the case of high level rod withdrawal, should be sufficient to determine Process Standards bases.

DE Simpson

Operational Physics Operation
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

DE Simpson:mwe

Figure 1

POWER RATE AND RATE METER RESPONSE FOR INITIAL
10-SECOND RISING PERIOD

DECLASSIFIED

IM-59575
Page 7

Figure 2

POWER RATE RESPONSE TO STEP CHANGE IN RATE

P_{E-100} / R_{E-100}

Power Rate

$\ln(P_{E-100} / R_{E-100})$

Time (seconds)

DATE

FILMED

6 / 23 / 94

END