AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

(CLASSIFICATION)

RAYFORD CODED 6-5

DOCUMENT NO.

HW-71207

SERIES AND COPY NO.

31

September 29, 1961

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

TITLE

REACTIVITY AND GRAPHITE TEMPERATURE
EFFECTS OF A HELIUM-NITROGEN ATMOSPHERE
FINAL REPORT OF PT IP-385-AC

AUTHOR

G. F. Bailey

ISSUING FILE

CIRCULATING COPY
RECEIVED 100D AREA

OCT 25 1961

RETURN TO

THIS DOCUMENT MUST NOT BE LEFT UNATTENDED WHERE AN UNAUTHORIZED PERSON HAS ACCESS. IF THE DOCUMENT IS NOT IN USE, IT MUST BE KEPT IN AN APPROVED STORAGE REPOSITORY WITHIN AN APPROVED STORAGE AREA. WHILE IT IS IN POSSESSION AND UNDER CONTROL, YOU HAVE OBTAINED A SIGNATURE FROM THE CLASSIFIED FILES, IT IS YOUR RESPONSIBILITY TO PROTECT IT AND ITS CONTENTS WITHIN THE LIMITS OF THIS PROJECT AND TO PREVENT ANY UNAUTHORIZED PERSON FROM TRANSMITTING IT TO, AND USING IT AT YOUR PLACE OF RESIDENCE OR WORK. IT IS NOT TO BE COPIED, REPRODUCED, OR Duplicated. IF ADDITIONAL COPIES ARE REQUIRED, OBTAIN THEM FROM THE RELATED ISSUING OFFICE. ALL PERSONS READING THIS DOCUMENT ARE REQUESTED TO SIGN THE ATTACHED FORM PROVIDED BELOW.

DECLASSIFIED

54-3000-340 (3-57)

AFC-2E RICHLAND, WASH

(CLASSIFICATION)

DISTRIBUTION

1-2. AEC-HOO: Att'n: AT Gifford	22. JF Jaklevick
3. AEC-HOO: Att'n: RL Plum	23. AR Kosmata
4. FW Albaugh	24. CG Lewis
5. TW Ambrose	25. SL Nelson/G Fiorelli
6. GF Bailey	26. DE Newbrough
7. RS Bell	27. R Nilson
8. RW Benoliel	28. GF Owsley
9. JH Brown	29. CA Priode
10. RF Corlett	30. RW Reid
11. RD Carter	31. BA Ryan
12. RA Chitwood	32. OC Schroeder
13. DL Condotta	33. WR Smit
14. DR DeHalas	34. HG Spencer
15. GC Fullmer	35. SL Stewart
16. SM Graves	36. RE Trumble
17. OH Greager	37. FW VanWormer
18. LL Grumme	38. PC Jerman
19. JW Hagan	39. 300 Files
20. AK Hardin	40. Record Center
21. RB Heiple	

This document contains restricted information. Its transmission in any form, by any means, is prohibited.

This document consists of 12 pages, No. 3 of 40 copies.

September 29, 1961

Classification Cancelled and Changed To

DECLASSIFIED

by Authority of WASnyder
CG-PR-2 3-15-94
 by JE Savely 3-15-94
 verified by Dick Hanson, 3-22-94

REACTIVITY AND GRAPHITE TEMPERATURE EFFECTS
OF A HELIUM-NITROGEN ATMOSPHERE

FINAL REPORT OF PT IP-358-AC

INTRODUCTION AND PURPOSE

The purpose of the production test was to "investigate the reactivity and temperature effects and the associated operating problems resulting from the use of nitrogen instead of carbon dioxide as a constituent of the K Reactor atmosphere." /1/ This report summarizes the reactivity and reactivity-associated graphite temperature effects observed during the first four months of the test which was initiated at KE Reactor on December 5, 1960.

SUMMARY

Operation of a K Reactor with a He-N₂ atmosphere does not differ significantly from operation

/1/ HW-66973 - Production Test IP-358-AC, Replacement of Carbon Dioxide with Nitrogen as a Constituent of the K Reactor Atmosphere - RW Benoliel and GF Bailey, 10-3-61

DECLASSIFIED

HW-71207
Page 2

with a He-CO₂ atmosphere. Observed and predicted reactivities and graphite temperatures agreed within the limits of accuracy imposed by the calculational methods.

Under present graphite temperature limits a saving of roughly 15 enrichment columns can be achieved through the use of nitrogen. In addition, Helium losses and gas costs will decrease, as will spline usage. The increased flexibility of control afforded by the variation of the atmosphere composition will decrease the reactor "cycling potential." Although scram recovery time will decrease and minimum downtime will be extended as nitrogen is increased, these should be of minor consequence.

Contingent upon favorable results from corrosion, graphite contraction, and air in leakage monitoring studies, it is recommended that appropriate changes in Process Standards be made to permit the routine use of nitrogen as a constituent of the reactor atmosphere. Since the results of the test apply qualitatively, although not quantitatively, to the older reactors, the recommended changes in Process Standards should apply to all of the Hanford production reactors.

DISCUSSION

I. Direct Reactivity Effects Resulting from the Significant Cross-Section

A. Cold Reactivity

Due to inherent inaccuracies in the present reactivity accounting system no direct measurements of the poisoning effect of Nitrogen in the cold reactor were possible without disrupting normal procedures. Calculations of the cold pile reactivity using a value of six c-mk per percent N₂ were reasonably accurate when used to predict the critical condition at startup. This is in excellent agreement with the theoretically calculated value of 600 c-mk for a 100 per cent N₂ atmosphere. Further substantiation of this could be attempted through analysis of Scram Transient data with and without Nitrogen in the atmosphere.

B. Hot Reactivity

Once again, direct measurement of the poison effect of the nitrogen was impossible because of the uncertainties in other dominant reactivity parameters. Comparison of observed and predicted rod worths at equilibrium tend to indicate the effect is less than 75 c-mk at 25 per cent Nitrogen. The theoretically calculated value was 60 c-mk. In general, the hot reactivity effect is negligible compared to either the cold effect, or the temperature effects. A reasonable prediction of the reactivity effect can be made from the following empirical formula:

$$\Delta R_{N_2} = \frac{600f}{1 + 4.82 W \times 10^{-4} (1 + 1.06f)}$$

where f is the fraction of N₂ in the reactor atmosphere, and W is the power level in megawatts.

II. Indirect (Temperature) Reactivity Effects

Since the moderator temperature coefficient of reactivity is independent of gas composition, the only real result required from the production test insofar as hot reactivity is concerned was substantiation or refutation of theoretical

DECLASSIFIED

HW-71207
Page 3

calculations relating the thermal conductivity of the reactor atmosphere to its composition. Assuming that the moderator power coefficient is accurately known as a function of gas composition in He-CO₂ mixtures, the reactivity effect with He-N₂ mixtures should be predictable, based on comparable thermal conductivity data. For example, from Figure 1, it should be evident that a 25 per cent N₂-75 per cent He gas will have the same conductivity as an 18 per cent CO₂-82 per cent He gas. Therefore, all other things being equal, the moderator power coefficients should be the same for the 75 per cent He-25 per cent N₂ mixture as for the 82 per cent He-18 per cent CO₂ mixture. Stated more simply, the problem is merely to find what nitrogen concentration will produce the same graphite temperature as a given carbon dioxide concentration for some given power level.

Figure 1 shows the relationship predicted by Davidson.^{/2/} Also shown is the magnitude of a ± 10 per cent error in this relationship. Figure 2 shows the relationship between graphite temperatures and per cent CO₂. From this the curve for He-N₂ mixtures was derived and is also shown. Note that the ± 10 per cent error in the thermal conductivity relationship produces only a 1.3 per cent error in the temperature prediction. Note also that the observed temperatures agree fairly well with the predicted ones. The primary reason for the larger deviations in the He-N₂ curve is due to some variation in the spatial flux distribution which was evident when the measurements were made.

Translating this into a more usable form, Figures 3 through 6 illustrate the reactivity and temperature associated effects of using nitrogen instead of carbon dioxide. Figure 3 shows the relationship between power level and gas composition for the condition of limiting graphite temperatures for the present 700C limit. The actual power level at which the limit will be reached will be 3 to 5 per cent lower, due to slight, but continuous "heat movement" or flux oscillations. The comparison, however, is still valid. Note that for the same helium concentration (and hence constant helium losses) the power level with N₂ is several hundred units higher.

Figure 4 illustrates the reactivity gain associated with being limited by graphite temperatures in the He-N₂ system compared to the He-CO₂ system. In effect, this represents the decrease in central zone enrichment (at ~ 4.5 c-mk per charge) requirements. It is also interesting to calculate the increased "flexibility" of the control system. This corresponds to the amount of long-term gains which can be "absorbed" by variation of the reactor atmosphere in the He-N₂ mixture, but which would have to be compensated through the use of supplementary control in the He-CO₂ system. This is virtually independent of power level between 3400 MW and 4600 MW, and corresponds to about 10 or 12 splines on a long (20-30 day) run. This not only implies decreased spline usage, but also more stable and efficient control, since a uniform reactivity decrease (from decreasing the N₂ content) rather than a local "poisoning" (due to a spline) is used to offset a uniform reactivity increase (from long-term gains).

Figure 5 shows helium losses in the He-N₂ system as a fraction of the losses for the He-CO₂ system for typical 20-day operating periods. Figure 6 is a cost comparison on the same basis. Note that the cost comparison does not include any cost for a nitrogen facility.

^{/2/} HW-28766 - Calculated Thermal Conductivities of He-CO₂, He-Ne, and He-N₂ Mixtures, J. M. Davidson, July 30, 1953

DECLASSIFIED

HW-71207
Page 4

III. Impact on Reactor Operation

The main change in routine reactor operation will occur during startups and scram recoveries. Because the nitrogen poison is inversely proportional to the temperature (gas law considerations) scram recovery time will be decreased due to the added "poisoning" transient of the gas cooling. The opposite will be true of reactor startups - that is, an additional positive reactivity transient will exist during the "turnaround." If a startup level is limited by the amount of supplementary control which can be charged between first indication and turnaround (as is the case after a minimum outage) the result of using Nitrogen will be a slightly lower turnaround level. If, on the other hand, the level is limited by the total capacity of the supplementary control system (as after extended outages), a higher turnaround level can be achieved because of the slightly greater amount of Nitrogen poisoning at the turnaround level as compared to the higher equilibrium level. The comparison in these cases is, of course, for equivalent graphite temperatures during turnaround. With splines for supplemental control the impact on operation should be negligible.

IV. Effect of Increased Graphite Temperature Limit

An increase in the graphite temperature limit would further accentuate the benefits of using Nitrogen rather than carbon dioxide. Note, however, that graphite temperatures greatly in excess of the present limits are not feasible in a He-CO₂ system due to graphite burnout considerations. These same temperatures become permissible in the relatively inert He-N₂ system. Consequently, in the following paragraphs and related graphs, it should be kept in mind that a large portion of the benefits discussed could be achieved in a He-CO₂ system with a higher limit, but that such operation is not permitted from pile life consideration.

Figure 7 shows the maximum nitrogen content which would be allowed at various graphite temperature limits. The values at high temperatures are somewhat uncertain due to the fact that they represent extrapolations of the thermal conductivity data.

Figure 8 illustrates the reactivity change which could be achieved (in the hot reactor) by operating with hotter graphite. The nitrogen poisoning effect is virtually negligible, and so the relationship is essentially independent of power level. The present 700C limit was taken as the base case. A word of caution seems appropriate here. Although the reactivity gain can be construed to represent a decrease in enrichment requirements, the magnitude of the change forces another parameter to be considered. For every 125 c-mk of enrichment that are removed, the minimum downtime is extended by roughly one hour. As a result, although operation with a 900° limit would permit removal of about 120 enrichment columns, the removal of these charges would extend the minimum downtime by roughly four and one-half hours. Scram recoveries would probably be virtually impossible after a few hours of operation, but startups to higher levels could be achieved with the same spline usage as is currently considered routine. Obviously, economic analysis of such action is beyond the scope of this document.

St Bailey
Operational Physics Sub-Section
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

DECLASSIFIED

HW-71207
Page 5

Figure 1

Concentrations of N_2 and CO_2
required to achieve equal
thermal conductivities in
helium mixtures.

DECLASSIFIED

HW-71207

Page 6

Figure 2

Graphite Temperature
versus
Gas Composition

DECLASSIFIED

HW-71207
Page 7

3/ HW-6183/4 - Product of PT-IP-312-A; Limiting Graphite Temperature Limit At
100% Helium - P.C. G. 100% Helium, May 20, 1950

DECLASSIFIED

HW-71207
Page 8

Figure 4

Reactivity gain at various power levels. Gain is the result of being limited by 700C limit rather than by the variable limit set in PT IP-312-A

Figure 5

He losses in He-N₂
as a per cent of losses
in He-CO₂

DECLASSIFIED

DECLASSIFIED

Figure 6.

Gas cost with He-N₂
as a per cent of the
cost with He-CO₂

Figure 7
Limiting Gas Composition
Versus
Graphite Temperature Limit

DECLASSIFIED

Figure 8

Change in hot reactivity
vs. graphite temperature
limit

**DATE
FILMED**

9 / 23 / 94

END