Atoms International Division
Rockwell International

U

CLASSIFICATION LEVEL
(S, C OR U)

DOCUMENT NO.

TI-652-240-006

COVER SHEET

DOCUMENT TITLE

Thermal Transient and Deflection Analysis of Internal
Reflector - 5 Kwe Reactor

AUTHOR

E. J. Donovan
C. T. Kudija

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or 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.

THIS IS AN INTERNAL WORKING
DOCUMENT AND MAY BE
EXPANDED, MODIFIED, OR
WITHDRAWN AT ANY TIME.

~~IT IS INTENDED FOR
INTERNAL USE ONLY.~~

CLASSIFICATION TYPE
(RD OR DI)

~~THIS REPORT MAY NOT BE PUBLISHED WITHOUT THE APPROVAL OF THE PATENT BRANCH, AEC~~

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees nor any of their contractors, subcontractors, or 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.

U

CLASSIFICATION LEVEL
(S, C OR U)

MASTER

DO NOT REMOVE THIS SHEET

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

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.

Atomics International
North American Rockwell

SUPPORTING DOCUMENT

NUMBER

TI-652-240-006

REV LTR/CHG NO.

SEE SUMMARY OF CHG

PROGRAM TITLE

5 KWE REACTOR TE SYSTEM

DOCUMENT TYPE

Technical Information

KEY NOUNS

Internal Reflector. Thermal Transient

DOCUMENT TITLE

Thermal Transient and Deflection Analysis of Internal Reflector- 5 Kwe Reactor

ORIGINAL ISSUE DATE

August 2, 1972

PREPARED BY/DATE

E. J. Donovan *EJD*

DEPT

731

MAIL ADDR

LB25

C. T. Kudija *CTK*

731

LB41

IR&D PROGRAM? YES ☐ NO ☐ IF YES, ENTER TPA NO. _____

GO NO.

6531

S/A NO.

20520

PAGE 1 OF

11

TOTAL PAGES

REL. DATE

8.3.72

SECURITY CLASSIFICATION

(CHECK ONE BOX ONLY)

UNCL

CONF.

SECRET

AEC

DOD

RESTRICTED

DATA

DEFENSE

INFO.

☐

☐

☐

AUTHORIZED CLASSIFIER

EJD

DATE

8/2/72

APPROVALS

DATE

EJD

8/2/72

DISTRIBUTION

* NAME	MAIL ADDR
J. Asquith	LB02
E. Donovan	LB25
L. M. Maki	LB03
W. J. Roberts	LB36
H. Rood	LB22
R. F. Wilson	LB01
R. E. Unit (7)	LB25
* P. O. File	LB02
C. T. Kudija	LB41

ABSTRACT

Thermal transient analyses were performed on the stainless steel clad internal reflector of the 5 Kwe reactor. The assumed thermal transient was a linear NaK temperature ramp from 116°F to 260°F at a rate of 2.4°F per second. This approximates the most severe portion of a reactor startup resulting from a 0.0025 cent/sec insertion with a 20 minute hold at 15¢ excess.

Three internal reflector designs were evaluated with the following results:

Type	Free Deflection	Force to Restrain
NaK Filled	0.001 inch	0.72 lb
Helium Backfilled	0.015	10.7
Evacuated	0.018	12.9

Although all designs would probably prove to be acceptable, the benign behavior of the NaK filled design makes it the preferred choice.

RESERVED FOR NR PROPRIETARY/LEGAL NOTICES

* TITLE PAGE ONLY

Introduction and Summary

Two internal reflector (I. R.) geometries are used in the region between the fuel element array and the circular reactor vessel of the 5 Kwe reactor. The thicker type was selected for analysis in this study because of its ability to impose greater loads on the fuel element for given thermal conditions. The principal objective was to study the thermal deflection characteristics of the internal reflector under thermal transient conditions. Three different designs were considered: (1) NaK filled in the annulus between the BeO and its cladding, (2) three psi helium in the annulus and (3) vacuum.

It was determined that the NaK filled design responded very rapidly to the reactor thermal transient and the resulting bowing tendency was negligible. In both the helium backfilled and vacuum designs, the thermal response of the internal reflector was much slower with the result that the bow, if unrestrained, would be 15 and 18 mils respectively. This bowing tendency would be accommodated in the reactor design by a combination of clearance between the fuel elements and the I. R. and contact force between them. Looseness of the I. R. end pins is a less favored design approach because of the desire to have the thin metal core liner fit the core bundle as closely as practical. (Thus negating bow relief afforded by I. R. end pin looseness).

Although all versions are considered satisfactory from the standpoint of potential structural interaction with the fuel elements, the NaK filled design offers a huge margin against temperature induced bowing and is the preferred design approach. The stability of BeO in NaK is discussed in Reference 1. Thermodynamically BeO is stable. In practice, a common grain boundary impurity, SiO_2 , does react with Na_2O and can result in loss of whole grains from the BeO body. It would be expected that high purity and density BeO, sheathed in stainless steel, should not be appreciably affected by the presence of NaK.

Methods and Assumptions

Thermal Analysis- The assumed thermal transient was derived from the NaK inlet plenum transient shown in Figure 1. (Ref 2). The assumed transient is shown in Figure 2.

Ref. 1. IL, R. L. Eichelberger to T. A. Moss, "Interaction with NaK of Zirconium and BeO", September 2, 1970.

Ref. 2. IL, E. J. Donovan to Those Listed, "Startup Transient- 5 Kwe TE System", July 6, 1972 .

FIG. 1

Startup Transient at 0.025 ϵ /sec With 1200 sec Wait at 0.15% Excess Reactivity

FIG. 2

A finite element thermal analysis of the I. R. cross-section was then performed using the DEAP code. In writing this code the following assumptions were made in the interests of both conservative engineering and program simplicity.

1. The temperature at the interface between the core coolant NaK and the stainless steel reflector cladding was assumed to follow the transient of Figure 2 without a lagging due to convection.

2. The reflector was assumed to have good thermal contact with the core can and reactor wall, thus providing a larger sink and colder estimate for those parts of the reflector in contact with the core can.

3. The case of vacuum fill assumed an emissivity of .5 for the BeO and .3 for the 316 stainless.

The effective emissivity of .231 was computed according to the equation

$$E_{\text{eff}} = \frac{1}{\frac{1}{E_1} + \frac{1}{E_2} - 1}$$

4. Radiation heat transfer was left out of the 3 psi helium filler case since it was determined to be of negligible value.

The temperature distributions and nodal array for the three cases analyzed are shown in Figures 3, 4, and 5.

FIGURE 3- NaK DESIGN

3 psi He Filler Between BeO and 316 SS
 2.4°/sec Heating Rate

FIGURE 4 HELIUM DESIGN

FIGURE 5 EVACUATED DESIGN

Structural Analysis- Using the temperature distributions in the cladding wall, computed as described above, the free deflection and required restoring force for each of the three designs was determined. It was assumed that the thermal gradients across the I. R. cross section were invariant with axial location. The BeO was assumed to be segmented so as to be structurally independent from the cladding tube.

The free deflection of the simply supported beam at location "b" from one end was determined using the equation

$$\delta = \frac{M b}{2 EI} [1 - b]$$

The restoring load:

$$P = \frac{3 EI l}{a^2 b^2} \delta$$

The equivalent linear thermal gradient which would cause the calculated deflection was determined by equating the stresses in the restrained beam and solving for ΔT :

$$\sigma = \frac{M_c}{I} = E \alpha \Delta T$$

Results and Conclusions

The temperature at the conclusion of the transient for the three cases studies are shown in Figures 3, 4 and 5. It can be deduced that the

majority of the heating at the vessel side of the cladding is by circumferential conduction within the cladding for the helium and vacuum designs. The NaK filled design, by comparison, has significant conduction through the BeO and hence very low thermal gradients.

The following quantities were determined for use in the structural analysis:

Location of Neutral Axis:	0.2317 inch inward from vessel side
Moment of Inertia:	$2.54 \times 10^{-3} \text{ in}^4$
Beam Length:	17.25 in.
Contact Location:	10.5 in. from inlet end

The thermal moments for each case were determined using the expression:

$$M = \left[\sum AT (y - \bar{y}) \right] E \alpha$$

The calculated free deflection, restoring forces and equivalent linear ΔT are shown in Figure 6.

INTERNAL REFLECTOR RESPONSE TO
2.4 $^{\circ}F$ PER SECOND STARTUP RAMP

FIG. 6