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RADIOISOTOPE TRANSPORT
AND DEPOSITION
IN FLOWING SODIUM

February 1969

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RADIOISOTOPE TRANSPORT AND DEPOSITION
IN FLOWING SODIUM

By

W. F. Brehm, E. A. Kovacevich, and D. W. Shannon

FFTF Development Department
FFTF Project

February 1969

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ABSTRACT

Transport and deposition of radioisotopes released to flowing sodium from corrosion of irradiated stainless steel has been studied. Quantitative measurements of deposition can be made with sensitive counting techniques. The results of the study indicate that ^{51}Cr and ^{60}Co are transported primarily by isotopic exchange, and do not rapidly migrate to lower temperature regions of loop systems. However, ^{54}Mn is released in larger quantities to deposit throughout the test loops. Preferential deposition sites are (1) immediately downstream from the source, (2) at minimum temperature locations, and (3) in oxygen cold traps. These results indicate ^{54}Mn is transported both by exchange and by solution-and-precipitation. Deposited ^{54}Mn migrated rapidly to the cold trap; deposited ^{51}Cr and ^{60}Co migrated slowly by exchange.

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INTRODUCTION

The possibility of high radiation levels arising from transport and deposition of irradiated fuel cladding materials in FFTF primary system piping has been shown.^(1,2) We are investigating the effect of various reactor operating variables on the transport of irradiated stainless steel species through flowing sodium test loops. Our results are of value, not only to FFTF, but to any reactor system where the primary coolant circulates through a heat exchanger system.

This is the first in a series of reports describing our results. The work described herein was presented at the International Conference on Sodium Technology and Large Fast Reactor Design, held at Argonne National Laboratory, November 1968.

SUMMARY

Transport and deposition of radioisotopes released to flowing sodium from corrosion of irradiated stainless steel has been studied. Quantitative measurements of deposition can be made with sensitive counting techniques. The results of the study indicate that ^{51}Cr and ^{60}Co are transported primarily by isotopic exchange, and do not rapidly migrate to lower temperature regions of loop systems. However, ^{54}Mn is released in larger quantities to deposit throughout the test loops. Preferential deposition sites are (1) immediately downstream from the source, (2) at minimum temperature locations, and (3) in oxygen cold traps. These results indicate ^{54}Mn is transported both by exchange and by solution-and-precipitation. Deposited ^{54}Mn migrated rapidly to the cold trap; deposited ^{51}Cr and ^{60}Co migrated slowly by exchange.

The rapid transport of large amounts of ^{54}Mn to low temperature locations can create serious problems for reactor maintenance. Work is continuing to better define the factors which affect this deposition, and to develop methods for trapping radioisotopes in preselected, shielded, low-maintenance locations.

DISCUSSION

In a sodium cooled fast reactor such as the FFTF, material will be lost from the stainless steel fuel cladding by the corrosive action of the flowing sodium coolant. Under ultimate operating conditions (1200 °F bulk coolant temperature, 25 ft/sec sodium velocity, 10 ppm oxygen in sodium) the rate of metal loss is approximately 0.0005 in. (0.0013 cm) per year.^(3,4) For 300 series stainless steel at 1200 °F, this rate of metal loss is acceptable from cladding integrity considerations. More detailed information on all factors affecting metal loss rate is available.^(4,5,6)

However, the material removed from the core will contain large amounts of radioisotopes produced from irradiation of the cladding. A typical inventory is the following:⁽¹⁾

^{51}Cr , 27.8 day half life - 2 Ci/cm³

^{58}Co , 71 day half life - 31 Ci/cm³

^{60}Co , 1913 day half life - 2 Ci/cm³

^{54}Mn , 313 day half life - 10 Ci/cm³

A study based on typical FFTF operation under the conditions described above has shown that about 1100 cm³ of material will be lost from the core and transported to other parts of the heat removal circuit in one year's operation. The isotope inventory will be approximately 10,000 Ci, and the radiation level near heat removal system components may exceed 100 R/hr depending upon deposition conditions.⁽²⁾ Previous studies of transport and deposition of irradiated stainless steel in flowing sodium have shown that activity transport is not necessarily coincident with gross mass transport, but these data are very meager.^(7,8)

Our experimental objective is to study the effect of various reactor operating variables such as temperature,

system temperature gradient (ΔT), velocity, flow perturbations, and impurity level on the transport and deposition of these isotopes in test loops. The ultimate aim of the program is to identify the mechanisms of transport and deposition, and to make a quantitative model to predict deposition behavior in a reactor system. A necessary byproduct of this study will be development of methods to control or trap the isotopes in a shielded preselected location(s).

EXPERIMENTAL PROCEEDINGS

Two types of sodium loops are used: a pumped loop called the Radioisotope Transport Loop (RTL) and small thermal convection (TC) loops. The RTL, constructed of 304 stainless steel, has a 2 gal/min capacity in the primary flow circuit. The primary contains a 40 kW direct resistance heater, a shielded specimen loading port, an isothermal velocity change section in the hot leg, and an airblast heat exchanger. An 0.2 gal/min secondary circuit contains cold trap, plugging meter, and sample removal lines. A schematic of the RTL is shown in Figure 1. The sodium velocity in the primary varies from 0.5 ft/sec in the heat exchanger to 40 ft/sec at the irradiated specimen location. The thermal convection loops are also made of 304 stainless steel; 15 in. high and 8 in. wide. Heat is supplied with a clamshell furnace and trace heating. An irradiated specimen is hung from a wire fastened to the loop cap. Typical velocity estimates are 0.2 to 0.8 ft/sec. A schematic TC loop is shown in Figure 2.

Various irradiated stainless steel specimens are used. They fall into two categories: material irradiated in a thermal flux containing ^{51}Cr , ^{60}Co , and ^{59}Fe , and stock from EBR-II (fast flux) containing ^{54}Mn and small amounts of ^{58}Co . Typical specimen inventories are given in Table 1.

FLOW - PRIMARY 1.7 gal/min., SECONDARY 0.2 gal/min.

FIGURE 1. Schematic Diagram of Radioisotope Transport Loop

$$V^{9/5} = \left(\frac{g\beta}{0.092} \right) \left(\frac{\rho_o}{\mu_o} \right)^{1/5} D^{6/5} \frac{h}{L} \Delta T$$

FROM L.F. EPSTEIN, CORROSION BY LIQUID METALS, PROC. INTERN. CONF. PEACEFUL USES OF ATOMIC ENERGY. 1956, VOL 9, p 311.

$$h = 15 \text{ in.}$$

$$L = 45 \text{ in.}$$

$$D = 0.43 \text{ in.}$$

$$V = 0.2 \text{ TO } 0.8 \text{ ft/sec}$$

$$Re = \frac{D V \rho_o}{\mu_o} = 1500 \text{ TO } 8000$$

FIGURE 2. Schematic Diagram of Thermal Convection Loop

TABLE 1. *Typical Specimen Inventories and Half-Lives*

^{58}Co , 71 days, 60 $\mu\text{Ci/g}$
^{60}Co , 1913 days, 560 $\mu\text{Ci/g}$
^{51}Cr , 278 days, 2×10^5 $\mu\text{Ci/g}$
^{59}Fe , 45 days, 3×10^4 $\mu\text{Ci/g}$
EBR-II stock, out of reactor 18 months
^{58}Co , 1000 $\mu\text{Ci/g}$
^{60}Co , 600 $\mu\text{Ci/g}$
^{54}Mn , 313 days, 3×10^4 $\mu\text{Ci/g}$

The use of radioactive specimens and the counting techniques give us a very powerful tool for observing migration of various elements in a test loop. The loops are scanned either in place with a portable lead-shielded NaI crystal, or sections are cut from the loops and counted in a shielded well with a NaI crystal or a 20 cm³ lithium-drifted germanium diode. Counts are analyzed in a 4096 channel analyzer. Calibration by the first (in-place) method has been achieved by counting radioactive solutions of known inventory in pipes of the same size as loop piping. Thus absolute quantities of radioactive material can be measured in many instances. Further advantages of the in situ method are these: counting can be done quickly and without elaborate preparations, the method is nondestructive, and loop tests can quickly be resumed. Disadvantages include low sensitivity (about 1500 disintegrations/count), poor resolution (10 keV/channel), and Bremsstrahlung generated in the pipe interferes with low-energy gamma ray detection. Counting in the well eliminates these problems, especially when the diode is used, but it is more time consuming and requires either a tab specimen in the loop or a part of the loop which must then be replaced. Counting in the well is usually done to supplement and clarify the data from the more rapid in-place scanning.

RESULTS

The first tests were run in the RTL and TC loops with a thermal-irradiated specimen. The results were similar: ^{51}Cr and ^{60}Co were released from the specimen but migrated only a short distance downstream, as shown in Figure 3. Neither ^{51}Cr nor ^{60}Co was found in the heat exchanger or cold trap of the RTL. The data of Figure 3 are not decay-corrected; the original Cr level was two orders of magnitude higher. This is an example of radioisotope transport by isotopic exchange. Analysis of loop sodium showed ^{60}Co , ^{51}Cr , and traces of ^{54}Mn , indicating higher ^{54}Mn solubility. No ^{59}Fe has ever been identified on loop piping even though substantial amounts of ^{59}Fe are present in the source tab. The first RTL run with an EBR-II irradiated specimen gave quite different results: the amount of manganese released was about 10 times the amount of chromium released in the other test, and ^{54}Mn was found all over the loop. High counting rates were obtained in the following regions immediately downstream of the specimen, in the crossover pipe from heat exchanger outlet to surge tank, and in the cold trap. This shows that some ^{54}Mn is transported by exchange, but the preferential deposition at lower temperature regions suggests transport also occurs by solution and precipitation, possibly assisted in the cold trap by chemical reaction with the Na_2O to form NaMnO_4 .⁽⁹⁾ Specimens showed weight losses that were in approximate agreement with weight losses previously reported.⁽²⁾

Effect of Velocity on Deposition

Deposition of ^{54}Mn in the velocity change section of the RTL varied as shown in Figure 4. Note that the abscissa of the graph is dpm/in.^2 . These measurements can be made with our calibrated counting technique. This part of the loop is isothermal at 1300°F , so the deposition is taking place by exchange. The higher deposition rate at the higher velocity

FIGURE 3. Counting Rate in Original Radioisotope Loop Run

FIGURE 4. Counting Rate of ^{54}Mn in Velocity Section

suggests the rate-limiting step for deposition is diffusion through a boundary layer which decreases in thickness with increasing velocity. Similar indicative results were obtained in the cold leg of the RTL. Cobalt-58 was not found.

Effect of Temperature and Delta-T (ΔT)

Tests in thermal convection loops with ^{54}Mn -bearing specimens gave the following indicative results. In the absence of large temperature gradients (less than 200 °F difference between maximum and minimum temperatures) in a TC loop, ^{54}Mn is also transported chiefly by isotopic exchange. However, at a larger ΔT (400 °F) the segregation of ^{54}Mn to the cold side of the loop occurred (1400 °F specimen temperature and a 1000 °F minimum temperature). Comparison of the two cases is shown in Figure 5. The ratio of counts at the minimum temperature location to counts at maximum temperature location in TCL Number 5 was 5.6; the ratio in another loop with 1230 °F maximum, 1050 °F minimum was 1.4. More than three times as much activity was released from the specimen at 1400 °F as at 1230 °F. These results show that both specimen temperature and loop ΔT affect the transport of ^{54}Mn . Work is in progress to attempt to define the affect of each variable separately.

Activity Migration

One of the most interesting aspects of our work concerns the migration of deposited activity. When the irradiated specimen is removed from the loop and sodium flow is resumed, transport of the deposited radioactive material can be analyzed without the uncertainty as to whether the atoms in question migrated from a previous deposition site, or whether they were released from the source. Such measurements are difficult to make with nonradioactive material.

FIGURE 5. Comparison of Activity in Loops 4 and 5

Limited information available shows that ^{51}Cr migrates very slowly (in thermal convection loops) by isotopic exchange. Figure 6 shows the results of one of these tests. A similar test in which the loop was cut up and well-counted showed a similar profile for ^{60}Co . In this latter test, small amounts of ^{54}Mn were found on the pipe walls. Since only trace amounts of ^{54}Mn are produced in thermal irradiations, this result shows both the sensitivity of the counting technique and the preferential solubility of manganese in sodium. Chromium has also been reported to have preferential (with respect to iron and cobalt) solubility in sodium, but chromium migration similar to that observed has also been reported.⁽¹⁰⁾

The migration of ^{54}Mn in the RTL for two more runs produced a steady decrease in ^{54}Mn activity throughout most of the primary system, and an increase in activity in the cold trap. These results are presented in Table 2.

TABLE 2. *Counting Rates at Selected Areas in Radioisotope ^{54}Mn , Transport Loop as Function of Time. (Isotope - ^{54}Mn , Test conditions - (1) Irradiated specimen in place 351 hr; (2) Exposure 1 plus 416 hr without specimen, (3) Exposure 2 plus 384 hr additional.)*

Location	Temperature, °F	Counts/minute (decay corrected)		
		(1)	(2)	(3)
Specimen holder	1300	5,218	3,102	897
Hot leg 20 in. downstream	1300	944	704	589
Cold side IHX	~850	3,078	2,859	3,051
Crossover between IHX and surge tank	~800	7,482	5,047	*
On surge tank	~800	4,084	5,016	4,621
On cold trap 1 in. above entrance	250 to 300	13,771	15,416	27,951
On cold trap 5 in. above entrance	250 to 300	3,697	13,563	12,112
On heater	1300 to 1350	812	715	*

* Not Counted

FIGURE 6. Comparison of Activity Distribution in TC Loop 1 Before and After Running Loop Without Source Tab. Active Species - ^{51}Cr , 30 min Counts

A graph of ^{54}Mn migration in the hot leg is shown in Figure 7. The peak near 31 in. in the restart data (open circles) is probably the result of some of the atoms migrating from their original deposition location near the source to that location by isotopic exchange. However, note that everywhere else there has been a decrease in activity.

Some of the deposited radioactive atoms diffuse into the pipe wall. Diffusion of ^{51}Cr and ^{54}Mn has been observed. The rate of penetration is roughly that which would be predicted by diffusion theory.

CONCLUSIONS

The obvious conclusions one can draw from this work are that different isotopes are transported in sodium loops by different processes, and each process is dependent on flow, temperature, and chemistry. Much more to the point, however, is a consideration of the implications the results of this work will have on reactor operation. The heat exchanger in the RTL has a radiation field of about 2 mR/hr from deposited ^{54}Mn (remember that it is not the major deposition site). The irradiated specimen lost about 15 mg of material in one month. Predicted weight loss for one year in the FFTF core under ultimate operating conditions is $3 \text{ cm}^3/\text{day}$ or about 8000 g/year.⁽⁶⁾ This material will have a specific activity 100 times that used in our test. If one assumes that the FFTF heat transport system has 1000 times the surface area of the loop, and also assumes that deposition is proportional to surface area for constant temperature profiles, then a crude extrapolation can be made:

$$\frac{8000 \text{ g in FFTF}}{0.015 \text{ g in loop}} \times 100 \text{ factor for specific activity} \times \frac{1}{1000} \text{ factor for area} = 53,333 \text{ factor increase.}$$

FIGURE 7. Migration of ^{54}Mn in Radioisotope Loop

This factor increases the extrapolated radiation level to 106 R/hr, completely intolerable for contact maintenance.

Taken in this light, one can see that either FFTF heat removal system must be designed for remote maintenance (core and probably closed loops) or transport and deposition mechanisms must be identified so that preferential deposition sites can be identified. An ideal situation would be to design the heat removal loops such that areas that may need maintenance would not be preferential deposition sites, and that deposition could be enhanced in low-maintenance areas that could be adequately shielded.

The results of our study show that ^{54}Mn would be trapped just downstream of the heat exchanger and in the cold trap, especially if high velocity, high turbulence flow conditions are present there. Chromium-51 would probably be plated out on the top of the fuel pins just above the core, and may possibly have decayed away by the time the chromium atom is "exchanged" off the top of the fuel pin. Cobalt-58 and ^{60}Co should behave similarly to ^{51}Cr , but not enough data are available to really tell.

FUTURE WORK

The future work on this study will involve redesign of the RTL and TC loops for insertion of more tab and ring specimens to take advantage of the strong points of both counting techniques. The RTL redesign will incorporate coplanar tubing for better detector positioning, and series-flow heat exchanger and cold trap for better determination of (isotope concentration versus temperature) profiles. A high-cobalt stainless steel is being irradiated to introduce enough ^{60}Co into the loops for easier detection.

REFERENCES

1. D. W. Shannon. Fast Reactor Corrosion and Chemistry, Interim Technical Progress Report No. 1, BNWL-483. Battelle-Northwest, Richland, Washington, 1967.
2. W. F. Brehm. Radioactive Mass Transport in FFTF Primary Piping, BNWL-808. Battelle-Northwest, Richland, Washington, 1968.
3. P. T. Nettley et al. "Problems in the Selection and Utilization of Materials in Sodium Cooled Fast Reactors," Fast Breeder Reactors. Pergamon Press, Oxford, 1966.
4. M. C. Rowland et al. Sodium Mass Transfer XV. Behavior of Selected Steels Exposed in Flowing Sodium Test Loops, GEAP-4831. General Electric Company, San Jose, Calif., 1965.
5. E. G. Brush. Sodium Mass Transfer XVI. The Selective Corrosion Component of Steel Exposed to Flowing Sodium, GEAP-4832. General Electric Company, San Jose, Calif., 1965.
6. Alkali Metal Coolants. Proceedings of Symposium in Vienna, November-December 1966. International Atomic Energy Agency, Vienna, 1967.
7. R. W. Lockhart. Sodium Mass Transfer II, Screening Test Data and Analysis. Vol. I Mass Transfer Results, GEAP-3726. General Electric Company, San Jose, Calif., 1962.
8. F. G. Haag. "Material Transport in Sodium Systems," Chem. Eng. Progr., Symp. Ser., vol. 20, no. 53, pp 43-50. 1957.
9. Fast Flux Test Facility Quarterly Progress Report for April-June 1968, BNWL-880. Battelle-Northwest, Richland, Washington, October 1968.
10. G. F. Wozadlo, F. A. Comprelli, and R. S. Young. Mass Transfer Studies and Related Metallurgical Effects for Austenitic Stainless Steel in High-Temperature Pumped Sodium Systems, Paper presented at AEC Corrosion Symposium, Columbus, Ohio, May 1968.

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