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1. INTRODUCTION

To achieve a high breeding gain in the molten-salt breeder reactor, it is necessary to remove rare-earth fission products. If allowed to accumulate, the rare earths absorb neutrons that could otherwise be used to convert thorium-232 into uranium-233. Aside from uranium (which can be removed from the salt by fluorination) the fuel salt contains the valuable components ${}^7\text{LiF}$, BeF_2 , and ThF_4 . Therefore, it is not economically feasible to discard the fuel carrier salt (after uranium removal) as a means of removing the rare earths from the reactor. Two methods have been studied on an engineering scale at Oak Ridge National Laboratory for removing rare earths from fluoride salts. These methods are (1) vacuum distillation at 1000°C , and (2) the metal transfer process by which rare earths are extracted into bismuth solutions and lithium chloride at about 650°C . The metal transfer process is the primary method that is being developed for removal of rare earths from the molten-salt breeder reactor. Vacuum distillation may be useful in recovering LiF and BeF_2 from waste streams in the process, however, it is not being considered as a primary rare-earth removal process for fuel containing thorium since the rare earth fluoride ThF_4 separation is difficult by this method. The work on the metal transfer process will be described first.

2. METAL TRANSFER PROCESS

The distribution coefficients (mole fraction rare earth in metal phase/mole fraction rare earth in salt phase) for the important rare earths between the salt and bismuth phases used in the metal transfer process were measured by L. M. Ferris' group at Oak Ridge National Laboratory.^{1,2} The metal transfer process was developed by L. E. McNeese, L. M. Ferris, and F. J. Smith. Three small engineering experiments have been carried out and an experiment that uses salt and bismuth flow rates that are about 1% of those required for a 1000-MW(e) MSBR is in progress.^{3,4,5} An experiment that uses flow rates that are 5 to 10% of those required is being designed.

2.1 Description of the Metal Transfer Process

A simplified flow diagram of the metal transfer process for a 1000-MW(e) MSBR is shown in Fig. 1. The metal transfer process consists basically of three extraction steps. Fuel salt is processed for rare earth removal after most of the uranium and protactinium have previously been removed. In the first step, rare earths are extracted from the fuel salt by a bismuth stream containing 0.25 mole % thorium and 0.2 mole % lithium. The rare earths removed from the fuel salt are replaced by an equivalent amount of lithium.

In the second step, rare earths are extracted from the bismuth-thorium phase by molten lithium chloride. Very little thorium transfer to the lithium chloride, and this step serves to separate the rare earths from thorium. The thorium-rare earth separation factors are of the order of 10^4 to 10^8 .

In the third step, the rare earths are concentrated by extraction into bismuth containing lithium. The entire lithium chloride stream is contacted

Fig. 1. Simplified Flowsheet for Rare Earth Removal from a Single-Fluid MSBR.

with 5 mole % lithium in bismuth to remove trivalent rare earths. About 2% of the lithium chloride is contacted with 50 mole % lithium-bismuth solution to remove divalent rare earths.

2.2 Metal Transfer Experiment MTE-2

The basic steps of the metal transfer process were demonstrated in a small-scale engineering experiment designated MTE-2. The main objective of the experiment was to demonstrate that the rare earths could be transferred from the fuel salt through the bismuth-thorium phase to the LiCl and then removed from the LiCl and deposited in the Li-Bi solution as the LiCl was circulated without the deposition of an excessive amount of thorium. The system was operated at 650°C.

2.2.1 Equipment

The equipment used for metal transfer experiment MTE-2 is shown in Fig. 2. The vessel was constructed of 6-in.-diam carbon steel pipe and was divided into two compartments by a partition that extends to within 1/2 in. of the bottom. The two compartments are interconnected by a pool of bismuth saturated with thorium. One compartment contained fuel carrier salt to which 0.3 mole % lanthanum fluoride and 7 mCi of neodymium-147 was added as typical trivalent rare earths. The other compartment contained lithium chloride and a cup that contained the lithium-bismuth solution. During operation, the lithium chloride was circulated through the Li-Bi cup using a pump constructed of carbon steel with molten bismuth used as check valves. Argon pressure was used to force LiCl into the pump chamber until the level reached the upper electrode. Then the argon flow was reversed to force LiCl from the pump until the level reached the lower electrode. The procedure was

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Fig. 2. Carbon-Steel Vessel for Use in the Metal Transfer Experiment.

then repeated. Argon pressure was used to circulate the bismuth-thorium phase back and forth between chambers at the rate of 10% of the metal volume every 7 minutes.

The following quantities of materials were used: 0.79 liters (40.7 g moles) of fluoride salt (72-15.7-12-0.3 mole %, LiF, BeF₂, ThF₄, LaF₃ containing 7 mCi ¹⁴⁷NdF₃), 0.80 liters (36.9 g moles) of bismuth saturated with thorium, 1.04 liters (36.6 g moles) of lithium chloride, and 0.16 liters (9.5 g moles) of 35 at. % lithium-bismuth solution. The materials were purified for removal of oxides before being used. The fluoride salt was purified by treatment with HF-H₂. The carbon steel vessel and bismuth were treated with hydrogen at 650°C. The LiCl was dried at 200°C and contacted with bismuth saturated with thorium at 650°C before being introduced into the system. Argon used as a cover gas was passed through molecular sieves and uranium turnings at 600°C.

The run sequence consisted in pumping the LiCl at 25 cc/min through the Li-Bi cup for 3 hr and then allowing 4 hr for the system to approach equilibrium before filtered samples were taken of each phase. The sequence was continued for two weeks. For the remainder of the three-month period, LiCl was circulated only during the day shift and the system was allowed to approach equilibrium during the night and weekends.

2.2.2 Experimental Results

During the experiment the lanthanum and neodymium were removed from the fuel carrier salt and deposited in the Li-Bi solution as expected. Figure 3 shows the rate of removal of lanthanum from the fluoride salt as a function of the volume of LiCl circulated. Greater than 85% of the lanthanum was removed during the run. The removal rate was about 20% of the rate that would have been achieved if the two salt phases in contact with the main bismuth pool had remained in equilibrium, and all of the lanthanum had been removed from the LiCl as it circulated through the

Fig. 3. Rate of Removal of Lanthanum from the Fluoride Salt.

Li-Bi container. The rate of accumulation of lanthanum and neodymium in the Li-Bi solution is shown in Figure 4. There was very little transfer of rare earths until an argon sparge was started in the Li-Bi cup to improve contact between the salt and metal phases after about 50 liters of LiCl had been circulated. Lanthanum transferred at a relatively faster rate because of the more favorable distribution coefficient for lanthanum between the LiCl and bismuth-thorium. After about 400 liters of LiCl had been circulated, or about, two-thirds through the run, about 30% of the neodymium and 50% of the lanthanum had been accumulated in the Li-Bi solution. At this time the concentration of thorium in the Li-Bi solution was less than 10 ppm giving a decontamination factor between thorium and lanthanum of about 10^5 . During this period, from 70 to 100% of the lanthanum and neodymium could be accounted for from filtered samples taken of the system indicating that most of the rare earths had remained in solution. After about two months of operation a leak developed in the Li-Bi cup, which was constructed of thin carbon steel, that allowed about 30% of the Li-Bi to run into the holder surrounding the cup. This caused the later data on concentrations of rare earths in the Li-Bi solution to be higher than would have otherwise been the case.

After the experiment was completed the vessel was cut apart for inspection. The salt and bismuth phases appeared to be clean with no accumulation of material at the interface. Figure 5 shows the LiCl side of the experiment. The bismuth-thorium phase, part of the LiCl, and the lithium-bismuth cup and holder are shown. The only place in the system where a significant deposit of rare earths was found that would not have been detected in filtered samples was a 1/8-in.-thick deposit around the rim of the Li-Bi container. This deposit could account for 5 to 10% of the lanthanum in the system (composition 10% La, 59% Bi, 2% Th, and 23% LiCl) and apparently resulted from the reaction of rare earths with lithium metal in the LiCl or with lithium-bismuth solution on the metal surface.

Fig. 4. Rate of Accumulation of Lanthanum and Neodymium in the Li-Bi Solution.

Fig. 5. View of LiCl Compartment After Removal of Most of the LiCl Following Metal Transfer Experiment MTE-2.

The general condition of the carbon steel vessel was good with little evidence of corrosion. There was evidence of corrosion on components such as the sparge tubes and the Li-Bi cup that were constructed of thin (25 mil) carbon steel. This corrosion is thought to have resulted from mass transfer of iron in the bismuth phase.

While carbon steel is an acceptable material of construction for experiments such as the one described above it is not considered to be suitable for an actual processing plant because of its limited corrosion resistance and low strength at 650°C. Materials such as graphite, molybdenum, and tungsten appear to be suitable materials of construction for processing plant use.

Metal transfer experiment MTE-2 performed as expected with the exception that the lithium concentration in the lithium-bismuth solution decreased more than expected. The lithium concentration decreased from an initial value of 0.35 mole fraction to 0.18 mole fraction after about 570 liters of LiCl had been contacted with the Li-Bi solution. Only a small fraction of this decrease can be accounted for by the reaction of rare earths with lithium. The major portion of the decrease is believed to be associated with the circulation of lithium chloride since little or no decrease occurred during ^{the} period in which LiCl was not circulated. Recently, the equilibrium concentration of metallic lithium and bismuth in LiCl in contact with lithium-bismuth solutions containing from 10 to 50 mole % lithium has been measured.⁶ The lithium and bismuth concentration in the lithium chloride increases markedly as the lithium concentration in the metal phase is increased due to the distribution of a salt-like inter-metallic (Li_3Bi) between the metal and salt. The concentration of lithium in LiCl in equilibrium with a 50 mole % Li-Bi solution is about 420 ppm and the extrapolated concentration in equilibrium with 5 mole % Li-Bi is about 0.02 ppm. A comparison of the rate of decrease of the lithium concentration in the Li-Bi solution during metal transfer experiment MTE-2 with values calculated using the

equilibrium data is shown in Fig. 6. The best agreement between calculated and measured values was obtained by assuming that the concentration of lithium in the LiCl after contact with the lithium-bismuth solution was 95% of the equilibrium value. An additional small-scale experiment (MTE-2B), similar MTE-2, has been operated to determine the rate of transfer of metallic lithium by LiCl in contact with 5 at. % Li-Bi. In this experiment the rate of transfer of lithium by the LiCl was determined to be equivalent to a lithium concentration in the LiCl of less than 0.2 ppm. The distribution of Li_3Bi between the bismuth and the LiCl is not expected to present any serious problems in the operation of the metal transfer process.

2.3 Metal Transfer Experiment MTE-3

A larger metal transfer experiment (MTE-3) is also being operated to measure the rate of transfer of rare earths in the metal transfer process. The experiment uses salt and bismuth salt flow rates that are about 1% of the estimated flow requirements for processing a 1000-MW(e) reactor. Figure 7 is a flow diagram of this experiment.

2.3.1 Equipment

The basic equipment, shown in Fig. 8, consist^A of a 14-in.-diam surge tank that contains fluoride salt, a 10-in.-diam salt-metal contactor, and a 6-in.-diam vessel that contains a 5 at. % Li-Bi solution and LiCl. The vessels are constructed of carbon steel and are coated with nickel aluminide for protection against air oxidation. The experiment contains the following quantities of materials: 36.6 liters of 72-16-12 mole % LiF , BeF_2 , ThF_4 , to which rare earths are added, 6.6 liters of bismuth containing 0.14 wt % thorium, 6.7 liters of LiCl, and 4.6 liters of 5 mole % Li in bismuth. During operation the fluoride salt is circulated at a rate of about $33 \text{ cm}^3/\text{min}$ from the surge tank through one side of the contactor and LiCl is circulated back and forth between the Li-Bi vessel and

Fig. 6. Lithium Concentration in the Lithium-Bismuth Solution.

Fig. 7. Flow Diagram for Metal Transfer Experiment MTE-3.

Fig. 8. Equipment Used for Metal Transfer Experiment
MFE-3. The heaters and insulation have not been installed.

the other side of the contactor at about 1.25 liters/min. The operating temperature of the system is 650°C. Mechanical agitators are used in both compartments of the contactor and in the Li-Bi vessel to improve contact between the salt and bismuth phases. Separate molybdenum paddles having a diameter of 2 7/8-in. and blades having a 45° pitch are located in each phase to contact the salt and bismuth without dispersing the phases. This method of agitation is thought to be less likely to cause entrainment and it is believed that processing systems of this type may be easier to fabricate than systems that use packed column contactors.

2.3.2 Experimental Results

The operation of metal transfer experiment MTE-3 has only recently got under way and only preliminary data has been obtained. Runs have been made using radium, lanthanum, and europium-154 at agitator speeds of from 100 to 200 rpm. Each run has had a duration of approximately 15 hr. Overall mass transfer coefficients have been calculated for the three salt-metal interfaces in the system using the material balance equations shown in Fig. 9. Mass transfer coefficients in a similar type contactor for organic-aqueous systems have been correlated by Lewis⁷ as shown in Fig. 10. The Lewis correlation is based on the two-film model of mass transfer and relates the individual mass transfer coefficient for each film to the physical properties of the two phases in contact. An overall mass transfer coefficient can then be calculated from the individual coefficients by the relationship given. For the systems studied by Lewis, mass transfer was mainly dependent on eddy diffusion. We have extrapolated the Lewis correlation to much higher Reynolds numbers in order to compare the calculated values of the overall mass transfer coefficient with the experimentally determined values. This comparison is shown in Table 1. The values of overall mass transfer coefficient for radium and europium (divalent rare earths) are in reasonable agreement with the Lewis correlation, however, the

$$V_1 \frac{dX_1}{dt} = - F_1 (X_1 - X_2)$$

$$V_2 \frac{dX_2}{dt} = - K_1 A_1 (X_2 - \frac{X_3}{D_A}) + F_1 (X_1 - X_2)$$

$$V_3 \frac{dX_3}{dt} = + K_1 A_1 (X_2 - \frac{X_3}{D_A}) - F_2 (X_3 - X_4)$$

$$V_4 \frac{dX_4}{dt} = - K_2 A_2 (X_4 - D_B X_5) + F_2 (X_3 - X_4)$$

$$V_5 \frac{dX_5}{dt} = K_2 A_2 (X_4 - D_B X_5) - F_3 (X_5 - X_6)$$

$$V_6 \frac{dX_6}{dt} = - K_3 A_3 (X_6 - \frac{X_7}{D_C}) + F_3 (X_5 - X_6)$$

$$V_7 \frac{dX_7}{dt} = + K_3 A_3 (X_6 - \frac{X_7}{D_C})$$

Fig. 9. Equations Used to Calculate Mass Transfer Coefficients for Metal Transfer Experiment MTE-3

Table 1. Overall Mass Transfer Coefficients for Metal Transfer Experiment MTE-3

	Speed of Agitators rpm	K_1 cm/sec		K_2 cm/sec		K_3 cm/sec	
		Observed	Calculated	Observed	Calculated	Observed	Calculated
Radium	100	.000073	.000055	.0291	.0215	.0033	.0024
Radium	200	.000319	.000171	.120	.0673	.0134	.00743
Europium-154	100	.0000473	.000473	.00215	.0215	.000885	.00885
Europium-155	200						

MASS TRANSFER COEFFICIENT EQUATIONS

INDIVIDUAL TRANSFER COEFFICIENTS (LEWIS CORRELATION)

$$\frac{60 k_1}{v_1} = 6.76 \times 10^{-6} \left(\text{Re}_1 + \text{Re}_2 \frac{\mu_2}{\mu_1} \right)^{1.65} + 1$$

OVERALL TRANSFER COEFFICIENTS

$$\frac{1}{K_1} = \frac{1}{k_1} + \frac{1}{D k_2}$$

$$\text{Re} = \frac{d^2 n \rho}{\mu}$$

K_1 = OVERALL TRANSFER COEFFICIENT, cm/sec

k_1 = INDIVIDUAL TRANSFER COEFFICIENT, cm/sec

D = DISTRIBUTION COEFFICIENT, mol/mol

d = PADDLE DIAMETER, cm

n = PADDLE SPEED, rev/sec

v = μ/ρ , cm²/sec

μ = VISCOSITY

ρ = DENSITY

Fig. 10. Mass Transfer Coefficient Correlation by Lewis.

values for lanthanum are considerably lower than that determined from the correlation. Additional runs will be required to substantiate the mass transfer coefficient measurements.

A conceptual design of a contactor for a metal transfer experiment having flow rates about 10% of those needed for processing a 1000-MW(e) MSBR is shown in Fig. 11. The contactor would be machined from a single block of graphite and is similar to the type contactor that might be used in an actual processing plant.

3. VACUUM DISTILLATION

The second method that has been studied at the Oak Ridge National Laboratory for the removal of rare earths from fluoride salts is vacuum distillation at about 1000°C. Under these conditions, materials such as ${}^7\text{LiF}$, BeF_2 , and ZrF_4 (which were the components of the Molten Salt Reactor Experiment fuel carrier salt) can be volatilized and recovered leaving a liquid heel containing the less volatile rare earth fission products. The Molten Salt Breeder Reactor fuel salt will also contain thorium fluoride which is much less volatile than the above components and would be difficult to separate from the rare earth fluoride by vacuum distillation. For this reason vacuum distillation is not being considered as a primary method for removal of rare earths from MSBR fuel salt, however, this method may be useful in processing certain waste streams in the MSBR or could be used for processing a two-fluid MSBR in which the fuel salt would contain no ThF_4 or ZrF_4 . All of the vacuum distillation experiments described in this report were performed using MSRE type fuel salt.

The development program for determining the feasibility of distillation of fluoride salts as a method for separating rare earth fission products from the fuel carrier salt included measurement of the relative volatilities of several rare earth and alkaline earth fluoride mixtures.⁸ Six nonradioactive runs were

Fig. 11. Conceptual Design of a Three-Stage Graphite Contactor for Metal Transfer Experiment MTE-4.

made in engineering-scale equipment,⁹ and finally a demonstration run was made using a portion of the irradiated fuel salt from the ORNL Molten Salt Reactor Experiment (MSRE).¹⁰ In the nonradioactive tests, six 48-liter batches of salt of the MSRE fuel carrier salt (composition, 65 mole % LiF, 30 mole % BeF₂, and 5 mole % ZrF₄) that contained NaF₃ were distilled at condenser pressures below 0.1 torr and a still-pot temperature of 1000°C. A 12-liter batch of radioactive salt (containing no uranium) from the MSRE was also distilled.

3.1 Equipment

The equipment used for the vacuum distillation experiment is shown schematically in Fig. 12. The equipment included a 48-liter feed tank containing the salt to be distilled, a 12-liter still from which the salt was vaporized, a 10-in.-diam by 51-in.-long condenser, and a 48-liter condensate receiver. The still pot consisted of an annular volume between the vapor line and the outer wall, and had a working volume of about 10 liters and an area for vaporization of 75.4 in.². All parts in contact with the fluoride salt were constructed of Hastelloy N.

3.2 Procedure

The operating procedure for the nonradioactive run consisted in filling the still pot to operating level, heating the still pot to operating temperature with the pressure at 10 torr, and then decreasing the pressure to the desired value. Salt was automatically fed to the still pot at the rate required to maintain a constant liquid level in the still pot. Vapor was routed to the condenser and the rare earth fluorides were concentrated in the still pot. The salt condensate drained through a sample reservoir located at the end of the condenser. Samples of condensate were withdrawn periodically using a windless^a to lower copper ladles into the sample reservoir. Only 14 liters of salt was available for the radioactive run and a somewhat different procedure was used. Seven liters of salt was

Fig. 12. Equipment Used for Vacuum Distillation of LiF-BeF₂-ZrF₄.

initially charged to the still pot. Then the remaining 7 liters was fed to the still pot as was done in the nonradioactive runs. After the 7 liters of salt had been fed, the still was then operated batchwise to distill 4 of the remaining 7 liters.

3.3 Experimental Results

3.3.1 Distillation Rates

Distillation rates were determined by observing the rate of rise of liquid level in the condensate receiver. The effect of still temperature on distillation rate for the nonradioactive runs in which the condenser pressure was below 0.1 torr is shown in Fig. 13. The distillation rate is expressed as cubic feet of salt (density 2.2 g/cm^3) distilled per day per square foot of vaporization surface area. In these experiments the distillation rate was limited by the pressure drop at the vapor through the condenser.

3.3.2 Separation Performance

The feed salt for the nonradioactive runs was a mixture of LiF , BeF_2 , and ZrF_4 (65-30-5 mole %) containing 0.3 mole % NdF_3 . In three of the runs, condensate samples were analyzed to determine the effectiveness of the still for separating the fuel carrier salt from NdF_3 which is a typical rare earth fission product. In the nonradioactive run, the effectiveness of the still in separating fuel carrier salt from actual rare earth fission products was determined.

The separation performance of the system is expressed by the effective relative volatility of the rare earth fission products with respect to LiF which was the least volatile of the carrier salt components. The effective relative volatility of component i with respect to LiF is defined as:

$$\alpha_{i-\text{LiF}} = \frac{y_i/x_{i(\text{avg})}}{y_{\text{LiF}}/x_{\text{LiF}(\text{avg})}},$$

Fig. 13. Variation of Distillation Rate with Temperature at Low Condenser Pressure (0.05-0.09 mm Hg).

where the y 's are mole fractions determined from the condensate analyses, and the x 's are mole fractions in the still pot averaged over the entire still pot volume.

Values for the effective relative volatility of NdF_3 during the nonradioactive run are given in Table 2. The equilibrium value for the effective relative volatility of NdF_3 was previously determined to be 1.4×10^{-4} .⁸ The effective relative volatilities for NdF_3 during the nonradioactive run ranged from about two to 40 times the equilibrium value. For the nonradioactive run, effective relative volatilities, with respect to LiF , of the major salt components, BeF_2 and ZrF_4 , and of the fluorides of ^{95}Zr , ^{144}Ce , ^{147}Pm , ^{155}Eu , ^{91}Y , ^{90}Sr , and ^{137}Cs are given in Table 3. The effective relative volatility of $^{144}\text{CeF}_3$ during the radioactive run ranged from 1.5 to 56 times the equilibrium value. No previously measured equilibrium values are available for PmF_3 with which to compare the effective relative volatility of $^{147}\text{PmF}_3$. The effective relative volatility for $^{155}\text{EuF}_2$ was lower than the equilibrium value of 1.1×10^{-3} . However, the accuracy of the ^{155}Eu data is questionable since some difficulty was experienced in making the analyses.

The effective relative volatility of $^{91}\text{YF}_3$ (based on the measured concentration in the feed) had an average value during the run of 4.1×10^{-3} , about 84 times the value measured in recirculating equilibrium stills. The average value of the relative volatility of $^{89}\text{SrF}_2$ (based on a computed concentration in the feed) was 0.193, about 3900 times the value measured in equilibrium stills.

Calculations of the effective relative volatility of ^{137}CsF were based on an estimated feed concentration since the concentration of ^{137}Cs in the feed salt was not measured. The effective relative volatility of ^{137}CsF was found to be no more than 20% of the value for CsF previously measured in $\text{LiF}-\text{BeF}_2$ systems.¹¹ The ef-

Table 2. Effective Relative Volatilities of NdF_3 with Respect to LiF Measured in Nonradioactive Runs*

Run Number	Effective Relative Volatility**
3	$3.3 \times 10^{-4} - 6.8 \times 10^{-4}$
5	$2.2 \times 10^{-4} - 6 \times 10^{-3}$
6	1.4×10^{-3}

* The feed salt composition was 60-30-12 mole % LiF , BeF_2 , ZrF_4 containing 0.3 mole % NdF_3 . The equilibrium effective relative volatility for NdF_3 with respect to LiF is 1.4×10^{-4} .

** Effective relative volatility $\alpha_{\text{NdF}_3-\text{LiF}} = \frac{y_{\text{NdF}_3} / x_{\text{NdF}_3(\text{avg})}}{y_{\text{LiF}} / x_{\text{LiF}(\text{avg})}}$

y = mole fraction in condensate

x = average mole fraction in still pot

Table 3. Effective Relative Volatilities with Respect to LiF
Measured in the Radioactive Run

COMPONENT	EQUILIBRIUM RELATIVE VOLATILITY	EFFECTIVE RELATIVE VOLATILITY
^{144}Ce	1.8×10^{-4}	$6.1 \times 10^{-4} - 1.0 \times 10^{-2}$
^{147}Pm	-	$7.8 \times 10^{-4} - 3.4 \times 10^{-3}$
^{155}Eu	1.1×10^{-3}	$0.86 \times 10^{-4} - 2.2 \times 10^{-4}$
^{91}Y	3.4×10^{-5}	1.4×10^{-2}
^{90}Sr	5.0×10^{-5}	4.1×10^{-3}
^{89}Sr	5.0×10^{-5}	0.193
^{137}Cs	95.1	< 17
^{95}Zr	2.2	4.0 - 1.0
ZrF_4	2.2	4.0 - 1.0
BeF_2	3.9 - 4.7	3.8

THE RELATIVE VOLATILITY OF ThF_4 WITH RESPECT TO LiF

IS 1.4×10^{-2} IN 12 MOLE % ThF_4 .

fective relative volatilities of fission product $^{95}\text{ZrF}_4$ and of ZrF_4 , the carrier salt constituent, were in good agreement with respect to magnitude and variations during the run. The effective relative volatility of BeF_2 was essentially constant during the run at near the equilibrium value.

The most likely explanations for the observed deviations from equilibrium relative volatilities are believed to be the following. The effective relative volatilities of the rare earths are high because of a combination of concentration polarization at the liquid vapor interface in the still pot and entrainment of small amounts of still pot liquid into the vapor stream. The extremely high effective relative volatilities for ^{91}Y , ^{89}Sr , and ^{90}Sr resulted from contamination of the condensate samples in the high-level analytical laboratory. The good agreement of values for ^{95}Zr and the major component ZrF_4 indicates that contamination did not compromise analyses for all fission products. The low effective relative volatility for ^{137}Cs resulted from incomplete condensation of the salt vapor prior to the point where condensate samples were taken.

The equipment performed satisfactorily during the experiments, however, some difficulties were encountered due to plugging of the feed and vacuum lines.

3.3.3 Conclusions

The measured distillation rates are adequate to permit the use of distillation as a processing step. Evidence of concentration polarization and/or entrainment was seen during these experiments. However, even if the effective relative volatilities of the lanthanides are as high as those observed in the radioactive run (~ 0.01), adequate recovery of ^7LiF from waste salt streams by distillation would be possible.

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