K/ETO-144, Part 1

**Quarterly Report
for
Oak Ridge Enrichment Technical Support (ETS)
October through December 1993**

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March 1994

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Oak Ridge, Tennessee 37830
for the
United States Enrichment Corporation
under Contract No. USECHQ-93-C-0001**

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PROCESS EQUIPMENT AND SYSTEM PERFORMANCE

Cascade Coolant Inventory Model - W. P. Gore

An improved model has been developed to compute the CFC-114 inventory in the cooling systems at the GDPs. The new model has been incorporated in a data reduction code called the Refrigerant Inventory Program (RIP), version 1.0 of which is now being used to process Paducah plant coolant inventory data. Traditional methods of inventory calculation do not consider the effect of cascade power level on the liquid levels observed in coolant system sight glasses. Consequently, inventories computed by the traditional techniques often display a spurious power dependence. RIP v1.0 provides a more realistic estimate of the CFC-114 loss rate by applying a power correction that removes the false power dependence exhibited by traditional inventory calculation methods.

The power correction technique employed in the RIP model is based on gas cooler exit quality correlations derived from a comprehensive GDP coolant system analysis code called REHAP (Refrigerant Hydraulic Analysis Program). A thorough discussion of the development of the power correction methodology was presented in KY/L-1657.

The key to the RIP power correction model is a correlation of cooler exit quality as a function of coolant liquid level, coolant temperature, and stage power level. These correlations are derived from hundreds of runs of the REHAP computer code. Version 1.0 of the RIP code includes a power correction for "000" coolant systems without entrainment separators. The power correction model has been modified to include entrainment separators, and new exit quality correlations have been developed for "00" systems and for "000" systems with entrainment separators. However, the addition of these enhancements to the RIP code has been held in abeyance pending thorough analysis of the in-process test cell run at Paducah to obtain data to evaluate a new coolant. These tests provided a wealth of data that are still being analyzed. Some results obtained from the data are discussed in the following paragraphs.

Since the RIP code attempts to correct the coolant inventory for the effects of power changes, the power level must be determined from measurements in the cascade. This is a departure from traditional inventory calculation methods, which do not account for changes in power level and therefore do not require a power measurement. RIP computes the stage power level from the simple linear expression

$$hp = a + b * P_2 \quad (1)$$

where hp is the compressor shaft horsepower, and P_2 is the measured stage 4 high side pressure (psia). The coefficients, a and b , are determined by fitting a straight line to the results of circuit balance calculations for a range of power levels, stage temperature levels, and compressor types. For "000"-size stages, the coefficients are: $a = 56.0$, and $b = 165.6$. Equation (1) was

confirmed during the in-process test in cell C-333-1.9 by carefully measuring the electrical power input to each stage motor and subtracting motor losses computed by an equivalent circuit motor model that predicts motor efficiency as a function of power level and supply voltage. Figure 1 shows that the agreement between the experimental data and equation (1) is remarkably good, which validates the power calculation procedure used in the RIP code.

Observations through a window in the vapor piping at the inlet to the odd condenser of the Paducah in-process test cell (C-333-1.9) suggest that the quality of the coolant is quite low at this point in the system. Since the cooler exit quality computed by REHAP (or by RIP) is usually low, this result is not unexpected. Another factor contributing to the apparent large liquid flow is condensation in the vapor piping resulting from heat loss to the air in the process building. However, an analysis of this heat transfer process, considering both natural convection and radiation, indicates that the effect of condensation in the vapor piping is so small that it can be neglected in the RIP model.

Figure 1 depicts the relationship between the compressor shaft horsepower and the high side pressure. The current production version of the RIP code (RIP v1.0) assumes that all of the power input to the compressor shaft heats the UF_6 passing through the compressor. Moreover, it is assumed that all of the power input to the UF_6 is extracted from the UF_6 by the gas cooler. The power loss in the compressor bearings and heat losses from the UF_6 piping to the surrounding air are ignored. However, it is the rate of heat transfer from the UF_6 to the boiling CFC-114 in the gas cooler that should really be used in RIP's cooler exit quality correlations. Data from the in-process test indicate that the heat losses from the UF_6 piping are significant enough that their effect should be included in the RIP code. Based on heat transfer analyses, an empirical correlation for compressor bearing losses, circuit balance calculations, and the experimental data from the in-process circuit balance calculations, and the experimental data from the in-process test in cell C-333-1.9, a simple model has been developed to predict the fraction of the compressor shaft power that is rejected to the RCW flowing through the condenser. The model is compared with the in-process test data in Fig. 2. Since the scatter in the data is large, the model is considered to be a reasonable representation of the behavior of real GDP systems. This model has been implemented in the RIP power correction scheme.

Another new mathematical model has been developed to enable the RIP code to account for the effect of vapor piping length on the cooler exit quality. The original cooler exit quality correlations were developed by running hundreds of REHAP cases over widely ranging values of stage horsepower, coolant temperature, and liquid level. This was done for a single cooling system because it is impractical to make so many REHAP runs for all of the major cooling system configurations. However, there are substantial variations in cooling system size, and there has been some concern that these differences may have a significant effect on cooler exit quality. (The obvious direct effect of system volume is taken into account in RIP v1.0). For example, the "000"-size cooling systems at Paducah vary in volume from about 610 cubic feet to about 830 cubic feet. The RIP correlations for "000"-size cooling systems at Paducah were derived from REHAP calculations for a system with an intermediate volume of about 720 cubic feet. Most of the variation in volume is due to differences in the vapor piping. As the length

Fig. 1. Relationship between compressor shaft horsepower and high side pressure.

Fig. 2. Condenser heat load as a function of compressor shaft power. Data points from PGDP in-process test conducted in cell C-333-1.9 (odd coolant system).

of the vapor piping changes, the cooler exit quality changes due to the change in pressure drop. In order to assess the importance of this effect, a series of REHAP cases was run with different vapor piping lengths. The results show that the effect is relatively small (± 10 percent in cooler exit quality at worst, but the impact of such a change on the inventory is much smaller, about $2\frac{1}{2}$ percent). Nevertheless, the effect is deemed important enough to include in the RIP code. Therefore, a correlation for the change in cooler exit quality with system size has been developed and implemented in the RIP power correction model.

After the in-process test was completed in cell C-333-1.9, special inventory data were obtained from the odd coolant system of the in-process test cell. This data has been used to refine the RIP power correction model by allowing for the effects of condenser flooding. The provisional flooding model is very empirical, making use of data from a special sight glass that was installed to provide an indication of the liquid level in the bottom of the C-333-1.9 odd condenser.

The new flooding model, the allowance for compressor bearing losses and heat losses from the UF₆ piping, and the correction for the length of the coolant vapor piping have been incorporated in a QuickBasic computer code that is used for RIP code development. These models have been checked and are currently being implemented in a RIP upgrade that will be designated RIP v1.3. Figures 3, 4, and 5 compare results computed by the improved inventory model (RIP v1.3) with calculations based on the traditional method and with the model used in version 1.0 of the RIP code. As shown in Fig. 3, the inventory computed by the traditional method drops as the high side pressure increases from 0 psia (cell evacuated of its UF₆ inventory) to about 6 psia. In addition, the traditional inventory exhibits the characteristic increase as the high side pressure increases above 6 psia. The positive slope is an indication of the power dependence that has been observed in inventory data for many years. On the other hand, RIP v1.0 overcorrects for the power effect. RIP v1.3 produces a relatively flat curve, which is the physically correct behavior since the coolant inventory was not changed during the test.

The condenser flooding model was developed from the same data that were used to prepare Fig. 3. Therefore, it is not surprising that RIP 1.3 gives sensible results when applied to that data. However, Figs. 4 and 5 also show that RIP 1.3 performs much better than RIP 1.0 or the traditional inventory model. The data upon which Fig. 4 is based were obtained in cell C-333-1.9 during a shakedown test prior to the in-process test. The data presented in Fig. 3 were obtained in the same cell shortly after the in-process test. Figure 5 was generated using data obtained during a psi-test of a different cell (C-333-1.4) two years before the in-process test. The results shown in Figs. 3, 4, and 5 are very encouraging, suggesting that RIP v1.3 will also reduce the scatter in plant inventory data. When it has been demonstrated that Paducah plant inventories computed by RIP v1.3 exhibit logical behavior, the new code will be adopted for routine inventory calculations. Then attention will be directed toward accounting for entrainment separators in Portsmouth "000" size stages and also toward completing work on the "00" inventory code.

Fig. 3. Inventory calculated for special in-process inventory data.

Fig. 4. Inventory calculated for shakedown test data.

Fig. 5. Inventory calculated for psi-test.

Analysis of Paducah Recycle Cooler Performance Test Data Operating with C_4F_{10} - A. J. Szady

During the Paducah off-stream cell testing with alternate coolant C_4F_{10} , the recycle cooler experienced difficulty in maintaining temperature when attempting to raise the stage temperature from 265°F to 290°F. The cell was operating satisfactorily at 2400 HP with a coolant temperature of 145°F when the operator raised the coolant system set point in order to increase the stage temperature. As the coolant temperature exceeded 150°F the stage 1B outlet temperature showed a sharp raise within a 40 minute period that did not appear to be reaching a steady state condition. When the B outlet temperature reached approximately 283°F the operator reduced the cell inventory.

In order to analyze what might have taken place, the 3D cooler performance code and the REHAP cell model were used to simulate the test conditions. The models were first used to simulate the steady state operating point of 2400 HP at 265°F stage temperature and 145°F coolant. Two unknowns needed to be determined at the start of the analysis: 1) the gas side performance of the recycle cooler, and 2) the hydraulic driving head. The original recycle cooler core test data was used as a starting point. However, it was acknowledged when the coolers were installed that the flow distribution within the shell was poor, and therefore that the actual performance would be below that of the test core samples. For this analysis a factor of 0.75 of the core results gives good agreement with the Paducah data. The coolant piping to the recycle cooler is more restricted than to the other coolers. Therefore, it is not clear what was the driving head for the cooler during the testing. Consequently, a range of driving heads was explored.

Figure 6 shows the computed power removal capability of the recycle cooler as a function of driving head, and the coolant and stage temperatures. The bottom curve is for the starting condition. It is clear that for driving heads as low as 3.5 ft the cooler can handle 2400 hp. At lower heads performance starts to drop off rapidly. A separate analysis with the REHAP model showed that with a cell coolant level of 9 ft, the recycle cooler had a driving head of 3.7 ft. These conditions calibrate the model to the actual test data. The remaining two curves show computed performance for increasing both coolant and stage temperature. These results indicate that the cooler would be expected to easily handle the increased temperatures, provided the actual driving head was above approximately 2.5 ft. (In a separate calculation the model predicts that the cooler temperature could be raised to 167°F for a 290°F stage at 2400 hp.)

There is no indication that the coolant level was dropped when the coolant temperature was raised; therefore, the above computational results do not agree with the test data. The analysis is based on steady state conditions. The cooler and the REHAP models do not have the capability to handle transient conditions. Perhaps if the operators let the condition go longer it may have settled out. The flow restrictions in the smaller recycle coolant piping may have caused a temporary interruption in the coolant flow which may have resolved itself with time. The C_4F_{10} coolant has the lowest latent heat of the candidate fluids, therefore more liquid must be circulated and consequently the smaller recycle piping will have a greater effect. Clearly,

Fig. 6 Recycle cooler performance.

more test data is needed to resolve what physically is taking place. As a continuation of our analysis effort we will be using the stability code developed by M. Z. Podowski to see if we can find an interaction between the cooler and the piping.

Estimated Portsmouth In-Process Test Cell Coolant System Performance - S. T. Baker

During the first quarter of FY 1994, numerical analysis was provided on the expected Portsmouth in-process test cell coolant system performance. Using the numerical code, REHAP, the thermal performance of cell X-333-6.9 was calculated using C_4F_{10} and compared to the thermal performance calculated using CFC-114. In addition to coolant types, the following parameters were varied to investigate the impact on performance; coolant liquid level (10' to 14') stage horsepower (1000 hp to 3300 hp) and condenser tube-side fouling factor (0.001 to 0.0034°F-h-ft²/BTU). Heat transfer coefficients for C_4F_{10} were calculated using the latest A. J. Szady correlation based on CUDO Technologies, Ltd. pool and flow boiling results.

Results showed that C_4F_{10} liquid levels must be at least 12' to avoid excessively high gas cooler dryout at high stage horsepower levels (due to the lower latent heat of vaporization of C_4F_{10} compared to CFC-114). A coolant liquid level of 14' would further reduce gas cooler dryout, increase coolant vapor temperatures, reduce RCW flow requirements, and provide an overall thermal performance very comparable to that calculated for CFC-114. RCW requirements at 3300 hp using C_4F_{10} are calculated to be 18 percent higher than that required at 3300 hp using CFC-114. By reducing the RCW inlet temperature 6°F (from 92°F to 86°F), the RCW flow requirements using C_4F_{10} at 3300 hp are reduced to the same as required by CFC-114 at 3300 hp. However, these flow requirements are all based on clean condenser tubes (i.e., a fouling factor of 0.001°F-h-ft²/BTU).

The numerical results further illustrated the impact of fouled condenser tubes on the overall thermal performance of the cell. Substantial fouling of condenser tubes causes a large decrease in the condenser overall heat transfer coefficient and a corresponding increase in RCW flow requirements (which increases dramatically at high stage horsepower levels). For a tube fouling factor of 0.0034°F-h-ft²/BTU (corresponding to a condenser overall heat transfer coefficient of approximately 60 BTU/h-ft²-°F), the RCW flow requirements would exceed the X-333 building rated capacity if all 80 "000" cells were onstream and operating at a stage horsepower level of 2600 hp or higher. However, for clean condenser tubes, RCW flow requirements would not exceed the maximum building capacity at stage horsepower levels up to 3300 hp using C_4F_{10} and a liquid level of 14'. Results from this numerical analysis were presented at a Technical Information Exchange meeting at Paducah in November.

Cascade Equipment Reliability - D. E. Hendrix

Up-rated compressor failures during FY 1993 totalled 22 (nine "00" and nine "000" sizes at Portsmouth; two of each size at Paducah). These totals for FY 1993 are more nearly comparable to those for FY 1991 and are higher than for FY 1992, which was unusually low. The failure rate for converters was also approximately equal to the FY 1991 average while

exceeding that of FY 1992. Motor failures stand at 32 ("00" and "000"), a consistent increase from the two preceding years. Seal failures also exceeded those in both previous years, although still comparable to the FY 1991 level. A concerted effort was expended at the Portsmouth plant in the latter part of the year in the study of their seal failures and steps taken to reduce them have been largely successful.

Failures for these major equipment items for the past three fiscal years are tabulated below.

FY 1993 Portsmouth and Paducah Equipment Failures

	Compressors		Converters		Motors		Seals	
	"00"	"000"	"00"	"000"	"00"	"000"	"00"	"000"
FY 93	11	11	4	12	7	25	115	280
FY 92	5	9	1	8	3	20	74	142
FY 91	8	14	6	12	4	16	127	235

Area load levels for the quarter were only slightly lower at Paducah than in the preceding year, but significantly lower at Portsmouth (compared with the four prior years). No significant change in failure rates would be expected as a result of unusual loading. A summary report of FY 1993 equipment reliability observations is in preparation.

During the first quarter of FY 1994, one "000" and two "00" compressor failures have been reported at Portsmouth, all in December. On December 1, 1993, Paducah suffered a failure in C-337-4.3.1 in which both bearing rockers were fractured, resulting in complete seal destruction, wet air inleakage, and eventual coupling failure (with the spoolpiece being thrown a few feet). The resulting cascade disturbance led to four other compressor failures, three "000" and one "00" size. Investigation is still in progress.

Failure data acquisition at Paducah is currently hampered by the absence of key personnel.

BARRIER

Separation Measurements in the Single Stage Separation System - T. W. Selby

In early FY 1992, the Single Stage Separation System was inoperative for an extended period for modification of the oil heating system in the Normatex compressor, necessitated by carbonization of the pump oil by "hot spots" on the calrod heaters previously used to heat the

oil.¹ After completing these modifications, attempts were made to reactivate the system in February 1992; at that time it was found that, while the system had been inoperative, a water leak in one of the system heat exchangers had filled the system with liquid water. To prevent recurrence of this type of water inleakage, it was decided to install new heat exchangers employing double-walled tubes.

After removing nearly 30 gallons of water from the system by draining followed by extensive evacuation and cold trapping, it was found that the Normatex compressor had developed a leak in the inner bellows, presumably from exposure to aqueous HF formed when the system was filled with water as a result of the heat exchanger leak. This necessitated return of the compressor to the Eurodif plant in France for repairs. These repairs have been completed, and the repaired compressor was received on 12/8/93; the compressor is currently being reinstalled in the system.

The new heat exchangers have been fabricated and tested, and should be received sometime in January. When these have been installed, return of the system to operation will permit checkout of other auxiliary equipment and instrumentation prior to resuming separation measurements.

MATERIALS AND CHEMISTRY

SOLGAS User's Manual - L. D. Trowbridge and J. M. Leitnaker

A multi-component computational thermodynamics program of long lineage named SOLGAS had been modified to ease the mechanics of its use, correct programming errors, and expand the types of calculations for which it can be utilized. A more extensive "user's manual", L. D. Trowbridge and J. M. Leitnaker, *SOLGAS Refined - A Computerized Thermodynamic Equilibrium Calculation Tool*, K/ETO-140, Martin Marietta Utility Services, Inc., Oak Ridge, Tennessee, November 1993, has been written. Undertaken to improve the availability of computational thermodynamics as a tool for the scientific and technical support staff in uranium enrichment, SOLGAS has already proven useful in a number of chemical problems, including estimation of fluorine-fluorocarbon flame temperatures and composition boundaries (for safety analyses), tabulation of HF gas densities (for criticality studies), and prediction of the specific chemical form contaminants are likely to take (during plant troubleshooting analyses).

Conversion of Waste Gases - L. D. Trowbridge and D. H. Bunch

At the request of Paducah GDP Operations Engineering, assistance is being provided to a project involving chemical conversion of waste gases to more readily disposable forms. Our part of the effort is to produce a computer simulation of the gas transport, chemical kinetics, and

¹Gaseous Diffusion Technical Support Review for October, November, December 1991 (U), K/ETO-90, Part 1, Uranium Enrichment Organization, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, May 1992. CONFIDENTIAL-RD.

thermodynamics of the system. This simulation will be used to evaluate the feasibility of the proposed process. Available chemical kinetic and thermodynamic data has been assembled and a kinetic simulation has been formulated. An existing gas transport model is in the process of being customized to the current problem. As part of this effort a report, L. D. Trowbridge, *Reinterpretation of Rate Data for the Reaction of ClF and F₂*, K/TCD-1091, Martin Marietta Energy Systems, Inc., K-25 Site, Oak Ridge, Tennessee, January 1994, elucidating the surface-mediated reaction kinetics of the ClF and F₂ has been written and is in reproduction.

Recycle of HF - L. D. Trowbridge

At the request of USEC Headquarters, a brief analysis was conducted of scenarios related to recycle of HF derived from conversion of UF₆ tails to uranium oxides. The quantities of HF generated by such a conversion campaign would be much larger than the needs of a manufacturer of replacement coolant for the GDPs, but much smaller than the national HF market as a whole.

Replacement Coolants Containing Iodine - L. D. Trowbridge

There have been news reports lately suggesting that "FICs" (Fluoro-Iodo-Carbons) might be useful as substitutes for CFCs or halons in certain applications. These reports suggest that the atmospheric reactivity of FICs is sufficiently high that they would be removed in the troposphere, and not significantly contribute to global warming or ozone depletion. A brief re-examination of such compounds was conducted. As a class, they tend to be irritants (i.e., more toxic than CFCs or PFCs); they are much more prone to hydrolysis; their reaction products in the cascade would likely lead to a new variety of materials compatibility problems. Further, only one such compound has physical properties remotely close to those of CFC-114. We are considering obtaining a small sample of this compound for reactivity testing (and welcome advice on this question, pro or con, from those interested in the CFC replacement issue). To summarize, the outcome of the examination was not preemptively negative, but one must say that FICs do not look promising for GDP use.

Article Publication - D. P. Armstrong

An article entitled, *Multiphoton Ionization of Uranium Hexafluoride*, authored by D. P. Armstrong, D. A. Harkins, R. N. Compton (ORNL) and D. Ding (ORNL), was recently accepted for publication in an upcoming volume of the Journal of Chemical Physics (JCP). JCP is generally regarded as one of the premier forums for the presentation of cutting edge developments in the areas of laser chemistry and physics, quantum mechanics, and theoretical chemistry. The submitted article describes the applied research results which led to the development of the Portsmouth Minor Isotope Detector, currently being constructed and tested by this group.

Desublimation of UF_6 from Gaseous Mixtures of UF_6 , CFC-114 and HF - E. J. Barber

The UF_6 -HF, the (CFC-114) - UF_6 and the (CFC-114) -HF binary phase equilibria were examined and a set of operating temperatures and pressures were developed for freezer-sublimers (F/S's) which would allow only the desublimation of solid UF_6 while limiting the amount of UF_6 passing through the F/S in the other gas and vapor to quantities acceptable for trapping with sodium fluoride or alumina. The recommended maximum pressure was 2.9 psia over the temperature range of 1.9° to 20°F. Below 1.9°F HF-rich solution can potentially condense if the pressure is 2.9 psia and above 20°F the exhaust vapor contains too much UF_6 for the effective use of traps.

Examination of the HF- ClF_3 and ClF_3 -(CFC-114) binary phase systems shows that condensation of a liquid phase containing ClF_3 will not occur if the set of operating conditions recommended above is employed in the F/S operation. Maintenance of these conditions assures nuclear criticality safety in a F/S of unsafe geometry as long as no significant inleakage of atmospheric air occurs.

Properties of (CFC-114)-(n- C_4F_{10}) and (CFC-114)-(c C_4F_8) Solutions - D. A. Harkins and E. J. Barber

In measuring the effect of mixing CFC-114 and perfluoro-n-butane (n- C_4F_{10}) on the heat transport properties, some information as to the expected behavior of the system is useful in setting up the experimental study. Based on the methods of estimating the free energies of mixing of solutions of two components developed by Hildebrand and Scott, the activity coefficients of CFC-114 and c- C_4F_{10} were calculated as functions of the composition and temperature assuming that the densities of the liquid mixtures are adequately predicted by the additivity rule. The activity coefficients were then used to estimate the pressure-temperature liquid composition relationships, the liquid-vapor equilibria, and the heats of vaporization of the liquid as functions of composition and temperature. This information was given to CUDO Technologies who reported that the information supplied fit the experimental results quite well.

A similar treatment was used to estimate the same data for the CFC-114-perfluorocyclobutane (c C_4F_8) system. As anticipated from the slightly higher critical temperature for perfluorocyclobutane than for perfluoro-n-butane, the deviations from ideality are smaller for the CFC-114-perfluorocyclobutane system at the higher temperatures. A report is in preparation.

The Phase Equilibria in the Binary Systems UF_6 -(n- C_4F_{10}) and UF_6 -c C_4F_8 - E. J. Barber

The perfluoro-n-butane [n- C_4F_{10} or FC-31(10)] and perfluorocyclobutane (c C_4F_8 or FC-c318) are the primary principal and alternate substitute coolants for the gaseous diffusion plants. Since inleakage to the cascades is inevitable, knowledge of the phase equilibria are important to the development of separation processes for removal of the coolants from the UF_6 . In the absence of any phase data on mixtures of UF_6 and these coolants, the methods of Hildebrand and Scott are being used with the data on the pure components to develop the condensed phase and liquid-

vapor phase equilibria for mixtures of UF_6 with $\text{n-C}_4\text{F}_{10}$ and with cC_4F_8 . The normal temperature-composition plots for the condensed systems are shown for these two systems in Figs. 7 and 8. Both of these systems have similar features, are nonideal, and exhibit large positive deviation from Raoult's law as demonstrated by the existence of two liquid phases in equilibrium and significantly less solubility of solid UF_6 in the liquid fluorocarbon than is predicted for an ideal solution. In both cases the nonideality becomes worse as the temperature is increased; however, the deviations from ideality are greater for the $\text{n-C}_4\text{F}_{10}$ solutions as would be expected because of the slightly lower critical temperature of $\text{n-C}_4\text{F}_{10}$. The existence of two liquid phases of different compositions at all temperatures of interest above the triple point of UF_6 indicates that distillation alone will not offer an useful approach to the removal of the substitute coolants from UF_6 vapor. However, the currently used compression-liquefaction method or a freezer-sublimar method should be workable. Solid UF_6 is less soluble in either of these substitute coolants than in CFC-114. The UF_6 is least soluble in $\text{n-C}_4\text{F}_{10}$. These solubility relationships are shown in Fig. 9.

Reactions of UF_6 Vapor and Hydrocarbon Oil in Exhaust Pumps - E. J. Barber and R. G. Russell

The use of large amounts of hydrocarbon oil in pumps of unsafe geometry for handling gases containing LEU (low enrichment assay) UF_6 raises questions about the nuclear criticality safety of such operations. A review of the chemistry of the reaction between UF_6 vapor and the hydrocarbon oils used in these pumps is in progress to determine if the characteristics of the reaction offer a basis for prevention of such incidents.

The review to date indicates that the reaction between UF_6 vapor and oil causes large increases in the viscosity of the oil and formation of very slow-to-settle agglomerates containing uranium probably as the tetrafluoride which together cause pump failures before the uranium content of the oil reaches 30 weight percent uranium. These factors suggest that, in any given incident, pump failure and thus stoppage of further uranium accumulation will occur before sufficient uranium accumulates to produce a nuclear safety problem. The questions of sludge accumulation or its prevention if the pumps are not cleaned after each incident are under study. When the investigation is finished and the proper technical communities satisfied, a report will be issued.

Flammability Limit for Replacement CFCs - F. W. Nehring

The refrigerant currently used in the GDPs, CFC-114, is environmentally unacceptable due to its effect on the atmosphere's ozone layer. Accordingly, we seek a second generation of refrigerants that will have little impact on the ozone content of the atmosphere. However, the replacement candidates identified thus far are a short term solution, since they will contribute to global warming. A long term solution with a third generation of refrigerants is under investigation.

Fig. 7 . Temperature - composition diagram for the system $(n\text{-C}_4\text{F}_{10}) - \text{UF}_6$

Fig. 8. Temperature - composition diagram for the system $(c\text{-C}_4\text{F}_8) - \text{UF}_6$

Fig. 9. Solubility of UF_6 in Three Cascade Coolants

The refrigerant chosen to replace CFC-114 must not lead to the support of a flame should an ignition source become present. Flammability limits for the second generation of refrigerants have been calculated, but reliable calculations for the third generation of refrigerants have not been made. Therefore, we are assembling the equipment needed to measure the flammability limit of mixtures of gases found within the GDPs with the refrigerants chosen to replace CFC-114. These experiments will provide a valuable check on the calculations already made for the second generation of refrigerants, and will lead to a better understanding of the chemistry of the third generation refrigerants.

INSTRUMENTATION

Assay Monitoring at Portsmouth Withdrawal Stations - K. N. Castleberry, D. E. Smith, and J. H. Draher

In FY 1991 an instrumentation system, which was intended to improve assay monitoring and control at a Portsmouth compression/liquification withdrawal facility, was developed by Oak Ridge Enrichment Technical Support (ETS) personnel and installed by both Oak Ridge and Portsmouth ETS personnel in X-330. That prototype system, currently in use, monitors assay readings and cylinder weights to maintain an accurate calculation of the weighted assay of material accumulated in tails cylinders. The system obtains assay readings from either of two existing mass spectrometers and can read weights from electronic scales at any of three scale positions, although only position number two at the tails stations is presently equipped with an electronic scale. The acquired information is displayed in both graphics and text formats for operators in ACR-2, where cascade controls are located that allow the tails assay to be manipulated. Assay and weight of material withdrawn from the cascade is printed on an hourly basis, and the final statistics for each cylinder filled are printed as required.

At the request of Portsmouth Operations, further development of the tails system is underway to provide the expanded capabilities that will be required for product withdrawal monitoring. A copy of the new system is to be installed during this fiscal year at both LAW and ERP, and the system at Tails will be upgraded so that, except for specific set-up conditions at each facility, the systems will be identical. Installations will also include electronic scales at up to four scale positions in each facility.

During the quarter most development effort went into system software improvements, which should provide enough flexibility to satisfy the operational requirements of all three withdrawal stations. All of the computer hardware for both the LAW and ERP systems was also procured.

Secondary Surge Monitoring in X-330 - K. N. Castleberry, S. F. Smith, and J. T. Hollback

Under an FY 1993 Enrichment Technical Support (formerly P&LRTS) project, a monitoring system, developed and installed in X-330 to detect secondary surge operation in all "00"-size compressors, was improved and expanded to monitor all 50 stage-one compressors. The system

provides this detection by monitoring for specific frequency components which are induced into the motor current during secondary. The motor currents are measured from the panel meter loops in ACR-2 using special clamp-on current transducers (CTs).

Only ten compressors in X-330 are currently being monitored by the system because the manufacturer of the CTs, used in this system as well as those used in a monitoring system in X-326, went out of business in early 1993. A subsequent search for an off-the-shelf replacement CT proved unsuccessful, so another vendor, who agreed to design a new CT to our specifications, was found. That vendor has finally completed the new design and has sent a prototype for our evaluation. Following a positive evaluation, the 40 additional CTs needed in X-330 could be procured and installed within the next quarter.

A recurring problem with the monitoring system has been that the system computer tends to crash periodically for an unknown reason. Several software modifications were made to try and correct the condition, but none were successful. Attempts to duplicate the problem on an identical development system at K-25 have also been unsuccessful. We have therefore concluded that the office-type personal computer used in the system has internal problems and should be replaced. To accomplish this and to improve the overall integrity of the hardware, the computer and operator interface in ACR-2 is being upgraded to a more appropriate rack-mounted industrial-grade system.

Control System Improvements in the Portsmouth Purge Cascade - S. F. Smith and K. N. Castleberry

During a Enrichment Technical Support (ETS) project last fiscal year, a methodology was developed for estimating the average molecular weight of the gas at various points in the Portsmouth top purge cascade. This concept, which was to be incorporated into an existing prototype stage motor monitoring system previously developed by ETS and installed in X-326, would display the locations and movements of the interfaces or "fronts" between pockets of gases having different molecular weights. In on-site meetings with Operations and Engineering personnel, it was agreed that, although gas front monitoring would be very beneficial to purge operators, the most pressing problem is presently the control of the position of the UF₆-Freon front. Since ETS personnel had already examined the control problem, we proposed that the control monitoring point be moved back to the desired position of the front and that a stage delta-pressure over inlet-pressure measurement be used as the control variable. X-326 personnel were convinced that a test of the revised control scheme would be the logical way to proceed with improving control, and subsequent phone conversations seem to have gained Engineering support. Pneumatic control equipment needed to do this has now been ordered, and plans are being made to test the recommended control system modifications.

UF₆ Outleakage Detection Instrumentation - D. A. Branam

Activities undertaken this quarter relating to the possible replacement of the UF₆ outleakage detection instruments included hardware vendor searches, laboratory equipment preparation for

evaluation of replacement candidates, test site location search and evaluation for possible UF₆ testing, and investigation of requirements for conducting evaluations with UF₆.

Vendor search efforts concentrated on hydrogen fluoride (HF) gas detection equipment and alternative smoke detection hardware. Efforts will continue toward finding suitable hardware candidates and obtaining them for evaluation. No additional candidates for evaluation were identified during this reporting period.

Initial laboratory evaluation of the International Sensor Technology (IST) HF detector, conducted by W. L. Maddox in late 1992, indicated that it was worthy of further examination. Continued laboratory evaluation of this instrument was delayed due to Dr. Maddox's retirement and by commitments to other high priority tasks by ETS staff. A laboratory set-up is currently being arranged which should permit the evaluation of this instrument to continue soon.

A search is underway for an available and appropriate test chamber which could be used for UF₆ and UF₆ surrogate sensitivity testing of candidate replacement instrumentation. If a suitable location is identified and a test program approved, actual UF₆ could be used to evaluate and compare the performance of both the current detectors and the best replacement candidates, including HF detectors. A few potential locations have been identified and are being evaluated for this purpose.

Meetings and conversations were held with Industrial Hygiene personnel concerning the applicable requirements and safety precautions relating to possible instrumentation testing which could involve use of HF and/or UF₆.

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