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(UTRC R94-970566-3)

INVESTIGATION INTO THE FRACTIONATION OF REFRIGERANT BLENDS

**Quarterly Technical Report
1 October 1994 - 31 December 1994**

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R&D Quarterly Status Report**

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The Investigation into the Fractionation of Refrigerant Blends program contract was awarded to United Technologies Research Center (UTRC) on March 28, 1994. The four-technical task program was outlined in the ARTI RFP of Nov. 1993 and final agreement on task content, deliverables and schedule was reached in a precontract program review at UTRC on Feb. 23, 1994.

Background

The Heating, Ventilation, Air Conditioning and Refrigeration (HVAC) industry is vigorously evaluating and testing refrigerant blends as a means of complying with impending national and international environment regulations restricting CFC and HCFC usage and disposal.

While the use of refrigerant blends both from analytical predictions and system test results appear to offer certain performance, capacity, design and operational advantages, there are significant possible service and operational issues that are raised by the use of blends. Many of these issues occur due to the fractionation of the blends. Fractionation can result in increased safety hazards if during leakage the more volatile components are flammable, and must be considered in the design of the heat exchanger, expansion valves and other system components. Fractionation can occur during charging of the system or during leakage in selected two-phase components, as well as due to the different miscibility of the blend component refrigerants and the selected compressor lubricant.

Objective

The objective of this ARTI-sponsored program is to conduct analytical and laboratory tests aimed at understanding these issues, developing approaches or techniques to predict these effects and/or overcome these potential problems, and conveying to the industry safe and reliable approaches.

Scope

UTRC has defined a four-technical task program to conduct the necessary analyses and confirming experimental tests to understand and describe fractionation effects in blends and produce useful analytical models and explanations of the physical phenomena. The program activities are organized into the following, including a preprogram project review and development of detailed work plan, (Task 0), four technical tasks, (Tasks 1.0 through 4.0) and a separate report, presentation and program management task (Task 5.0).

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<u>Task 0.0</u>	<u>Project Review and Detailed Work Plan</u>
<u>Task 1.0</u>	<u>Lubricant Solubility Effects on Fractionation of Blends</u>
1A	Model Development and Review of Prior Activity/Results
1B	Experimental Verifications
<u>Task 2.0</u>	<u>Fractionation Effects from Successive Charges</u>
2A	Model Preparation
2B	Bench Scale Verification Testing
<u>Task 3.0</u>	<u>Fractionation Effects within System Components</u>
3A	Model Development and Revisions
3B	Experimental Verification
<u>Task 4.0</u>	<u>Fractionation Effects During System Leaks</u>
4A	Dynamic Model Development and Enhancements
4B	Experimental Verification
<u>Task 5.0</u>	<u>Reports, Presentation and Program Management</u>

Quarterly Summary

Task 0.0 - Project Review and Detailed Work Plan

A detailed work plan, schedule and description of approach to each task was presented previously (see Figure 1 and Tables I and II).

Task 1.0 - Lubricant Solubility Effects on Fractionation of Blends

Both the model development (Subtask 1A) and experimental verification efforts (Subtask 1B) are essentially complete and the fractionation effects of the reference blend (R34/R134a) due to the presence of lubricant have been predicted using solution theory modeling. The experimental results confirm the model results especially for high concentrations of refrigerant/lubricant mixtures, [approximately 40% to 90% by wt of refrigerant in mixture] over a range of temperatures for selected POE. At lower refrigerant concentrations, the model is less accurate in predicting the trends, but is within 10 to 20% of the test data.

The solution theory model has been used to predict the solubility for the reference refrigerant blend/POE oil mixture over a wide range of operating temperature and pressure conditions for various compositions of lubricant and refrigerant.

The results were then used in Task 3 and 4 models to more accurately predict the conditions in the compressor sump and, where appropriate, the system accumulator. Sample charts are shown in this progress report depicting the solubility range for the reference blend.

Task 2.0 - Fractionation Effects from Successive Charges

Both subtasks under this task effort, the development of static and dynamic models (subtask 2A) and the experimental verification of the models (subtask 2B) have

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been completed. The experimental results for both slow and rapid liquid withdrawal from a tank of R32/R134a fluid match very closely the model results. Parametric studies of the impact of tank size, ambient temperature, and tank liquid level were conducted and fractionation effects noted.

The model procedure was found to very accurately predict the fractionation during liquid discharging from a tank. Where appropriate, this tank discharge model can be used in the larger system models (Tasks 3 and 4).

Task 3.0 - Fractionation Effects within System Components

The dynamic models to describe the fractionation effects within system components have been developed and typical model results were generated and described in the 2nd quarter report. The model is capable of predicting the start up transients of the system, including concentration of refrigerant constituents in the evaporator, condenser, expansion valve and compressor, and the steady state refrigerant concentrations effects in each component.

The initial dynamic model did not include the fractionation effects which occur in the compressor due to oil/refrigerant solubility effects. The latest dynamic model includes this effect and procedures to model the impact of having the accumulator in the system were also initiated in this quarter.

Task 4.0 - Evaluation of Fractionation Effects During System Leaks

The same dynamic model will be used to predict fractionation effects during system leaks (Task 4.0).

The UTRC laboratory to be used for the fractionation tests was modified to accept the 2-1/2 ton residential split system heat pump. Locations of instrumentation, data acquisition, and the composition measurement system were completed. A mobile gas chromatograph was purchased (under UTRC capital) and also incorporated in the laboratory test set up to perform rapid gas sampling during the tests. A test plan was developed for the Task 3 and 4 efforts.

Quarterly Technical Progress

Task 0.0 - Project Review and Detailed Work Statement Prepared

On Feb. 23, 1994, the ARTI Program Manager, Mr. Steven Szymurski lead a review committee to visit UTRC and discuss the planned program activities. Included in the discussions were: (1) level of detail in each task analysis, (2) model approach to be undertaken and (3) number of experiments to be conducted in Tasks 1 through 4. The proposed program schedule, blend composition, and size of the heat pump test vehicle for Tasks 3.0 and 4.0 were discussed and agreement reached on these issues.

The schedule agreed upon is shown in Fig. 1 and the task scopes and program deliverables are shown in Tables 1 and 2. A separate handout brochure summarizing the meeting was prepared and submitted after the meeting to ARTI. The current status of each task is also indicated on the Fig. 1 schedule. (A request for a contract time

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extension has been made to allow completion of Task 3 and 4 efforts and final report draft.)

Task 1.0 - Solubility Effects on Fractionation Due to the Presence of a Lubricant

The objective of this task is to determine, via modeling (subtask 1A) and experimentation (subtask 1B), refrigerant concentration shifts and pressure changes due to the presence of a lubricant; i.e. refrigerant/lubricant solubility. Concentration shifting or fractionation within HVAC systems can have serious consequences regarding operating performance, reliability, safety, etc., as described above.

Subtask 1A - Model Development and Experimental Verification

The solubility and thermodynamic behavior of the system R32/R134a/Castrol SW68 was modeled using non-ideal solution theory. The model predictions were compared to experimental data from program tests. The agreement in the refrigerant rich region (90% refrigerant/10% lubricant) is excellent over the temperature range that was examined. Agreement in other regions was good to adequate for various reasons.

However, the theoretical model appears to be a useful tool for predicting the solubility and thermodynamic behavior of the ternary system represented by a two component refrigerant blend and a lubricant. Other refrigerant blend/lubricant mixtures incorporating a third refrigerant component such as R134a could be developed and would be useful for the HVAC industry since it is a blend being considered for R22 replacement and drop-in applications.

Figure 2 shows sample thermodynamic data developed using the solution theory model at typical system temperature and operating conditions. Figure 2a, for example, illustrates the vapor pressure of the R32/R134a mixture (25%/75%) above the oil sump for a range of sump temperature, and oil fractions in the sump. Figure 2b, illustrates the R32 vapor mass fraction for the same mixture as a function of sump temperature and mass fraction in the sump. The data illustrate high R32 vapor mass fraction at low temperatures and mass fractions of oil in the sump.

The three charts shown at the bottom of Figure 2, also illustrate three different temperature slices (0°C, 30°C, and 60°C) and the R32 vapor pressure overlayed with vapor mass fraction. The shaded areas in Figures 2c, 2d and 2e show the dual solutions predicted for vapor pressure at liquid concentration levels of 25% R32 and above between mass fractions of oil in the sump between a few percent and approximately 50% depending upon temperature level.

Task 2.0 - Evaluation of Fractionation Effects from Successive Charges

The objectives of this task are to determine the fractionation of a refrigerant blend when discharged from a storage tank. The task was composed of two parts, analytical and experimental. The analytical portion of the task involved building two models, one static (no thermal effects) and one transient. The experimental part involved discharging a two gallon tank at different rates and different thermal conditions in order to verify the analytical models.

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Subtasks 2A and 2B - Analytical Evaluations and Experimental Verification

Two models were constructed to determine the fractionation properties of the 25/75 weight percent blend of R32/R134a. The first model, a static model, was used to determine the composition shift under slow leak conditions. The second model was used to determine the fractionation under fast discharge conditions.

Both the model predictions and the best results were described in the previous quarterly progress report. The models very accurately predicted the liquid discharge behavior of the blend measured in the tests.

The experimental procedure used to obtain these results were also described in previous reports and could be of interest to HVAC industry service and manufacturing personnel.

Task 3.0 - Evaluation of Fractionation Effects within System Components

The objective of this task is to determine the composition shifts in the two phase components of the refrigeration system during operation, start up and after shut-off. The two-phase components of the system are the evaporator, condenser, expansion valve, and accumulator. In addition, the effect of composition shifts (estimated in Task 2 due to charging scenarios) on the performance of the individual components and overall system will be estimated and verified in system test.

Subtask 3A - Model Development

The requirement for this model is to predict fractionation effects for the representative zeotrope blend in typical heat pump applications. This requires the calculation of mass, energy and composition as a function of time for each heat pump component. The initial model developed included evaporator, condenser, compressor, and expansion valve. The heat exchangers are modeled as single volumes, though they are partitioned by refrigerant state (superheated, saturated, and subcooled) according to total mass and volume. Overall heat transfer coefficients for each state are based on cross-flow air-cooled heat exchanger configurations. A log-mean temperature difference is used to calculate heat transfer performance.

The pressure in each heat exchanger is calculated from the energy, refrigerant component mass and total volume. Both constant temperature and constant mass fraction conditions are calculated. These represent the two extreme operating conditions. These extreme conditions are depicted in Figure 3. Conditions between the two are specified by a percent of maximum glide. Additional energy exchange is calculated for subcooling in the condenser and superheating in the evaporator.

The condenser and evaporator refrigerant compositions depend on the percent of glide in the evaporator and condenser respectively. Zero glide implies constant temperature and pressure fractionation of the gas and liquid phases, while 100 percent glide implies temperature dependent fractionation with constant overall composition. (These conditions are depicted in Figure 3a and 3b, respectively).

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Initial Conditions

As a starting condition from system off and long time shut down, all the refrigerant liquid charge is assumed to be in the colder coil, typically the evaporator. Proper operation requires most of the charge to be in the condenser. In the model this is accomplished by closing the expansion valve until enough charge is pumped from the evaporator to permit 10 degrees of superheat to the compressor inlet. The compressor is able to move refrigerant by lowering the evaporator pressure to a point where boiling is sufficient to meet the compressor flow demands. The evaporator is sized such that an entering overall quality of 20 to 30 percent results in 10 degrees of superheat at the evaporator exit at system design conditions. The expansion valve is then controlled to maintain this condition. The overall quality in the condenser depends on the total refrigerant charge. With the addition of an accumulator, expansion valve control will not be necessary, but a longer time will likely be needed to reach steady state operation.

Oil Sump Model

During the third quarter, the sump model was added to the dynamic simulation. The approach was to assume that all oil and refrigerant mixture fractionates but all of the oil remains in the sump and there is no carryover to other components. In reality some oil carryover occurs due to system and component design conditions but the zero oil carry over situation can be modeled at a later date to include a specified quantity of oil in circulation and deposited in the various components based on measured concentrations. However, such data is not currently available. The oil solubility model developed under Task 1A requires the specification of sump temperature, pressure, and the liquid or gas phase R32 refrigerant concentration. From this model (shown in Fig. 2), oil and refrigerant mass fractions are calculated. For the dynamic model, it is assumed that the refrigerant gas phase mass concentration is set by the compressor inlet mass concentration. This assumption is valid when the sump is not contributing to the mass flow, and approximately correct when the sump mass flow is small relative to the compressor mass flow. If, in addition, the oil mass in the sump is assumed constant, the calculated liquid phase mass concentrations can be used to determine the mass of liquid refrigerant in the sump. This can be conceptualized by considering the oil sump as a large mass of oil at known pressure and temperature and when exposed to a constant gas phase refrigerant concentration will absorb a calculable quantity of refrigerant.

Results with Sump Model Included

The model predictions when the sump is included in the dynamic simulation are shown in Figures 4 and 5 for the DOE E heating condition with the assumption of zero (no) glide in the heat exchangers. Total system refrigerant mass is set at 1.5 kg. (25% R32) and the oil mass at 0.5 kg. Initially, the mass fraction of R32 in the sump lies about mid-way between evaporator and condenser concentrations (Figure 4). About 15% of the refrigerant is in the sump (Figure 5). When the compressor is started, and the expansion valve closed, the concentration of R32 in the sump decreases as does the total refrigerant mass in the sump. This is in part due to an increase in sump temperature which is assumed to be the average of the compressor inlet and exit temperatures. At about 45 seconds, superheat in the evaporator is sufficient to allow the expansion valve to open. The R32 mass fraction in the sump increases, but remains below the condenser, which now has most of the refrigerant, and well above the

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evaporator which has about 30% of its mass in the gas phase. The results shown in Figures 4 and 5 can be compared with that shown in the Second Quarterly report (Figure 13) and indicate some 2% to 3% higher R32 composition in the condenser with the oil sump in the model.

If maximum glide (100%) is assumed, the sump results change considerably (Figures 6 and 7). The compressor inlet R32 mass fraction is considerably reduced for this assumption and as a consequence, so is the sump R32 mass fraction. Also, a greater fraction of the refrigerant mass is initially in the sump. This trend remains during steady state with the sump R32 mass fraction about 2 points lower than in the other components.

The accumulator model is being added to the dynamic simulation. The accumulator will be modeled in the same manner as the evaporator. It will be treated as a single volume with mass and energy balances. Initially, all liquid refrigerant will be in the colder coil, typically the evaporator. When the compressor starts, the resulting lower pressure in the accumulator will draw two phase refrigerant from the evaporator. This mass flow through the suction line will lead to a pressure difference between the evaporator and accumulator. The accumulator will accumulate evaporator liquid and provide the compressor with gas flow due to low pressure boiling. As with the evaporator, varying glide may be specified, however, zero glide is anticipated for the accumulator. Since fixed orifices are typical for systems with an accumulator, the evaporator may operate with two phase discharge under some operating conditions. This will increase the pressure drop between the evaporator and accumulator and lead to some steady state boiling in the accumulator. The consequence will be reduced mass flow and capacity in the system.

Subtask 3B - Experimental Verification

With the dynamic model available, the experimental validation steps can proceed to determine the extent of glide in the heat exchangers, and expansion valve and the impact of system composition change during cooling, heating, operating and non-operating conditions. The experimental facility to complete these tests, the UTRC Advanced Refrigerant Laboratory, is being prepared to conduct tests on a selected heat pump. The overall setup is shown in Figure 8.

Experimental Facilities

To verify the dynamic fractionation model, a Carrier 38YCA 2.5 ton heat pump with a scroll compressor was instrumented and will be run at heating and cooling conditions. The indoor and outdoor units of the heat pump were placed into separate Indoor Environmental Chambers (IECs), which provide precise temperature, humidity, and airflow conditions for simulation of various environmental conditions. During the course of each test, transient pressure and temperature data will be taken, as well as steady state composition data.

Indoor Environmental Chambers (IECs)

The experimental facility includes two IECs, a 2.5 ton capacity and a 5 ton capacity system. The IECs can provide exact control of supply temperature from 47 F to 150 F, relative humidity from ambient to 100%, and airflow up to 3000 cfm. The supply air side of the indoor unit of the heat pump was connected directly to the 2.5

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ton IEC. In contrast, the outdoor unit was placed in a large chamber which was connected to the 5 ton IEC. This is shown schematically in Figure 9.

Pressure and Temperature Data Acquisition

Eight thermocouples and six pressure transducers were installed in the system to provide an accurate determination of refrigerant state throughout the cycle. Type J thermocouples were selected for their good low temperature response. Figure 10 shows the instrumentation locations as installed in the system. The thermocouple and pressure transducer data will be sampled once a second by a dedicated PC (PC2 on Figure 9). Labtech Notebook, a commercially available software package, will be used to display and record the data.

Composition Measurement and Data Acquisition

Refrigerant will be sampled from four locations in the system to determine the steady state composition at various conditions. In addition, during the course of the tests, refrigerant will be removed from various parts of the system to simulate leaks. Finally, a gas cylinder with a known composition will also be periodically sampled to confirm the consistency of the results.

The refrigerant sampling locations are shown in Figure 10. The basic sampling concept is simple: a small diameter, long capillary tube is connected directly to the refrigerant system at one end, and a Tee at the other. One side of the Tee is directed through a bubbler, and the other fed through a series of filters to the Gas Chromatograph (GC). The refrigerant entered the capillary tube and gradually expanded to near atmospheric pressure as it flows through the tube. This ensures that the sample entering the GC is fully vaporized.

In actuality, each of the sampling ports will be arranged somewhat differently, depending on the conditions expected during testing. Sample ports 1 and 4 will be connected to a 27 foot long section of 0.01" diameter line. These lines will be attached to shutoff valves to trap any liquid in this section while the lines are not being sampled. Another 20 foot long section of 0.02" diameter line follows the first section and are attached to a six position selector valve. After the selector valve, a two foot section of 0.04" diameter line leads to the Tee in the line. One end of the Tee is connected to a bubbler, to both ensure that gas is flowing through the line and to determine the flowrate of the gas. The other end of the Tee passes through an oil filter and a particulate filter before entering the GC. These two sample ports have the longest length because liquid is expected and at least one port will be exposed to a high pressure. Sample port 2 will be connected to a 27 foot section of 0.01" line which feeds directly to the selector valve. High pressure is expected here, but no liquid. Sample port 4 will be connected to a 10 foot section of 0.01" line connected directly to the selector valve. This port will be exposed to the low pressure side of the system, with the possibility of liquid being present. The known sample will be connected to a 27 foot section of 0.01" line attached to the selector valve. The long length here is to minimize the flowrate in order to increase the total number of samples possible.

The GC measures the peak location and area for each component in the sample. This information is used to determine refrigerant mass composition using two different methods. The first method uses a calibration curve of the area count for a number of known samples versus the known sample composition. The second method uses a

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calibration curve of the ratio of area counts versus the known sample composition. The second method is currently deemed more reliable after a number of preliminary tests.

The test plan to be used for both Task 3 and 4 experimental results is described in the following section.

Task 4.0 - Evaluation of Fractionation Effects During System Leaks

The objectives of this task are: (1) to conduct analytical evaluations through the use of transient simulation techniques of the effects of various leak scenarios within selected components and (2) to conduct experimental verification test of these components within a representative refrigeration system.

Subtask 4A - Analytical Simulation of Leakage Scenarios

The dynamic models described in Task 3.0 above will be used to conduct assessments of leakage effects during operation, shut down and non-operating conditions and to determine refrigerant composition changes.

Subtask 4B - Experimental Verification

The experimental hardware from Subtask 3B will be used to determine performance and composition changes during leaks from each of the two phase components in the next quarter. The test plans to be used for Tasks 3 and 4 are described below.

Test Plan

The test plan developed will examine two to three different environmental conditions using two different leak scenarios. Before the system is tested, the old refrigerant and oil will be removed from the system. The oil will be replaced with a POE compatible with the blend: Castrol SW-68. In order to ensure the removal of all of the old oil, the oil sump will be drained, refilled with SW-68, and run with R134a. This procedure will be repeated three times.

This test plan will require six full blend charges. The oil will not be changed between runs. The system is run to the environmental conditions specified below. When the system reaches steady state for each condition, four samples (two liquid, one vapor, and one unknown) are taken and analyzed in the GC. The test plan is shown below (runs 5 and 6 are optional)

	<u>Indoor Conditions</u>		<u>Outdoor Conditions</u>	
Run 1: Run DOE A Cooling test (100% charge)	80F DB	67F WB	95F DB	75F WB
Shut down system & remove 25% charge from vapor side				
Run DOE A Cooling test (75% charge)	80F DB	67F WB	95F DB	75F WB
Shut down system & remove 25% charge from vapor side				
Run DOE A Cooling test (50% charge)	80F DB	67F WB	95F DB	75F WB
Purge system				
Run 2: Refill system with Blend				
Run DOE A Cooling test (100% charge)	80F DB	67F WB	95F DB	75F WB
Remove 25% charge from two-phase port while running system				

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	Run DOE A Cooling test (75% charge)	80F DB	67F WB	95F DB	75F WB
	Remove 25% charge from two-phase port while running system				
	Run DOE A Cooling test (50% charge)	80F DB	67F WB	95F DB	75F WB
	Purge system				
Run 3:	Refill system with Blend				
	Run DOE E Heating test (100% charge)	70F DB	<60F WB	47F DB	43F WB
	Shut down system & remove 25% charge from vapor side				
	Run DOE E Heating test (75% charge)	70F DB	<60F WB	47F DB	43F WB
	Shut down system & remove 25% charge from vapor side				
	Run DOE E Heating test (50% charge)	70F DB	<60F WB	47F DB	43F WB
	Purge system				
Run 4:	Refill system with Blend				
	Run DOE E Heating test (100% charge)	70F DB	<60F WB	47F DB	43F WB
	Remove 25% charge from two-phase port while running system				
	Run DOE E Heating test (75% charge)	70F DB	<60F WB	47F DB	43F WB
	Remove 25% charge from two-phase port while running system				
	Run DOE E Heating test (50% charge)	70F DB	<60F WB	47F DB	43F WB
	Purge system				
Run 5:	Refill system with Blend				
	Run Minimum Temp. Heating test (100% charge)	70F DB	<60F WB	Minimum Temp.	
	Shut down system & remove 25% charge from vapor side				
	Run Minimum Temp. Heating test (75% charge)	70F DB	<60F WB	Minimum Temp.	
	Shut down system & remove 25% charge from vapor side				
	Run Minimum Temp. Heating test (50% charge)	70F DB	<60F WB	Minimum Temp.	
	Purge system				
Run 6:	Refill system with Blend				
	Run Minimum Temp. Heating test (100% charge)	70F DB	<60F WB	Minimum Temp.	
	Remove 25% charge from two-phase port while running system				
	Run Minimum Temp. Heating test (75% charge)	70F DB	<60F WB	Minimum Temp.	
	Remove 25% charge from two-phase port while running system				
	Run Minimum Temp. Heating test (50% charge)	70F DB	<60F WB	Minimum Temp.	
	Purge system				

PROGRAMS AND EQUIPMENT

The Task 1.0 and 2.0 computer programs were completed during previous reporting period. Small quantities of refrigerants, lubricants and sample bottles were purchased during the first four months of the program. Task 2.0 is a new computer program. Task 3.0 and 4.0 computer programs are almost complete.

KEY PERSONNEL

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The key personnel for this program remained the same as stated in the UTRC proposal and during the Feb. 23, 1994 meeting. Mr. Frank R. Biancardi, remains the UTRC Program Manager with Dr. H. Michaels, (Task 1.0), Mr. Tobias Sienel (Task 2.0) and Mr. Dennis Pandy (Task 3.0 and 4.0) being the key task managers for the effort.

TRIPS, MEETINGS AND CONFERENCES

Various discussions, in person and teleconference, have been held with lubricant and refrigerant suppliers and government agencies (NIST) and numerous representatives to secure the needed data and information for analytical and experimental program elements. Most of these discussions have occurred at the ASHRAE meetings and other refrigerant conferences.

A presentation of the program results and status at the AREP meetings prior to the ASHRAE Semi-Annual Meeting and Conference is scheduled for Chicago in late January 1995.

F. R. Biancardi

TABLE I
SCOPE OF PROGRAM WORK

TASK 1 - Solubility Effects on Fractionation

- Develop model
- Experimental verification of model
 - Use binary blend HFC-32/HFC-134a (25/75%) and a polyester lubricant

TASK 2 - Evaluation of Fractionation Effects from Successive Charges

- Determine composition shift and pressure shift from large shipping container
- Determine power and capacity shifts in typical HVAC system due to change differences *[moved to Task 3]

TASK 3 - Evaluation of Fractionation Effects within System Components*

- Conduct analytical study to determine composition shifts in two-phase components during operating mode, during non-operating mode
- Experimental verification of results for azeotropic blend (same as above)

TASK 4 - Evaluation of Fractionation Effects During System Leaks

- Conduct model development to predict composition shifts during slow and rapid leaks; with and without lubricant
- Experimental verification (with lubricant)
- Determine blend composition shift with blend and compare results

*In typical one-to-three-ton heat pump system with accumulator at ARI conditions

TABLE II

Deliverables

ARTI MCLR CONTRACT NO. 660-52300

- One-day progress review at UTRC
- Quarterly technical progress reports
- Final report that documents the development and experimental verification of fractionation model (s)
- Presentation of final results at ARTI - selected US conference (including technical paper)
- Computer software version of fractionation model(s) (stand alone or able to run together with commercial software)
- License to use software developed under agreement

ARTI Program Manager
Mr. Steven R. Szymurski

PROGRAM SCHEDULE FOR

DOE-CE/23810-51C

Figure 1

■ - Region of two liquid phases

THS 11-18-94

Figure 2

ARTI TASK 3 & 4 MODELING

IS THERE COMPOSITION SHIFT IN 2-PHASE COMPONENTS?

R32 CONCENTRATION BY COMPONENT

EVAP AIR TEMP 47F COND AIR TEMP 70F

DOE HEATING CONDITION
25% R32/75% R134A, 1.5 Kg Refrigerant/0.5 Kg Lubricant

REFRIGERANT LOCATION

EVAP AIR TEMP 47F COND AIR TEMP 70F

DOE E HEATING CONDITION
[25% R32/75% R134a]

R32 CONCENTRATION BY COMPONENT

EVAP AIR TEMP 47F, COND AIR TEMP 70F

DOE E HEATING CONDITION
[25% R32/75% R134a]

REFRIGERANT LOCATION

EVAP AIR TEMP 47F, COND AIR TEMP 70F

ADVANCED HVAC SYSTEMS LAB

DOE/CE23810-51C
 UTRC R94-970566-3
 Figure 8