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**ANALYSIS OF ADVANCED CONCEPTUAL DESIGNS FOR
SINGLE-FAMILY-SIZED ABSORPTION CHILLERS**

Semi-Annual Report

April 5, 1978

Work Performed Under Contract No. EG-77-C-03-1586

**Southern Research Institute
Birmingham, Alabama**

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U.S. Department of Energy

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Solar Energy

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SINGLE-FAMILY-SIZED ABSORPTION CHILLERS

Semi-Annual Report to

DEPARTMENT OF ENERGY

Contract EC-77-C-03-1586

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ANALYSIS OF ADVANCED CONCEPTUAL DESIGNS FOR SINGLE-FAMILY-SIZED ABSORPTION CHILLERS

I. INTRODUCTION AND OBJECTIVE

This is the semi-annual Technical Progress Report under Contract EC-77-C-03-1586. It covers the work between September 28, 1977, the date of initiation of work, and February 28, 1978. The objective of the research is to develop and analyze new refrigerant-absorbent pairs, new additives to presently used refrigerant-absorbent pairs, and modifications to the absorption cycle, which can improve performance or reduce the cost of a solar-powered absorption chiller in the size range of 3 tons.

II. TECHNICAL DISCUSSION

Air conditioning is a particularly attractive application for solar energy because the peak cooling loads effectively coincide with the peak solar insolation. Moreover, the absorption air-conditioning cycles, which appear to be the most promising for this application, are mechanically simple and well advanced in development. However, lithium bromide-water and ammonia-water, which are used most often as refrigerant-absorbent (R/A) pairs in fuel-fired absorption cycles, may not be best for solar energy. Both of these R/A systems have certain features that limit utility, and better systems are needed.

The objective of our research program is to develop and analyze new concepts for absorption cycles to improve the performance or reduce the cost (or both) of a 3-ton absorption chiller that can be used with solar-collected heat. We are investigating new refrigerant-absorbent pairs, additives to currently used refrigerant-absorbent pairs, and modifications to the cycle. For the initial analyses we are assuming the use of a fluid at 160 to 230°F from a solar collector as a heating source. In the initial analyses the chiller is to provide chilled water at 45°F at full load; alternatively, if a new refrigerant-absorbent pair appears to be amenable for direct cooling of the occupied space, the temperature of the evaporator is to be 45°F. We are studying both water cooling and air cooling of the absorber and the condenser. The use of ambient air at 95°F dry bulb and 75°F wet bulb temperatures is assumed. With the water-cooled cycles, we will include the initial and operating costs of a properly sized cooling tower.

The research to meet the above objective consists of five principal tasks: (a) acquisition of information for analysis, (b) definition of criteria for selection of promising refrigerant-absorbent pairs, additives for currently used pairs, or cycle modifications, (c) preparation and analysis of conceptual designs, (d) comparison and selection of the promising new systems that warrant further study, and (e) recommendations for further research for each promising new system. Before describing our progress on each of these tasks we will present a discussion of the basic absorption cycle as operated with solar energy to aid in understanding the approaches we took on each task.

A. Absorption Cycle Used With Solar-Collected Heat

Figure 1 is a diagram showing the basic components of an absorption cooling system. The working fluid for the system is a solution of refrigerant and absorbent. These have a strong affinity for each other. When heat is added to this solution in the generator the refrigerant is vaporized and a mixture weak in refrigerant is left behind. Heat is subsequently removed from the vapor as it is liquefied in the condenser. Both the generator and the condenser operate at high pressure. Thus the liquid refrigerant is available for expansion into the evaporator which is at a lower pressure. It is the vaporization of the refrigerant that effects cooling. The vaporized refrigerant recombines exothermally with the weak absorbent mixture in the absorber, which is cooled to enhance refrigerant solubility. The solution in the absorber, now rich in refrigerant, is pumped back into the generator to complete the cycle. Since the solution weak in refrigerant must be circulated continuously from the generator at high temperature to the absorber at low temperature, and since the strong solution must circulate in the opposite direction, a heat exchanger is used to minimize heat losses between the two.

As depicted in Figure 1, the heat that is needed to vaporize refrigerant in the evaporator is obtained from water. The water thus chilled can then be used for space cooling. However, a better refrigerant-absorbent pair would allow direct cooling of occupied spaces and would provide a simpler and less costly system.

A meaningful comparison of new refrigerant-absorbent pairs requires an analysis of a complete solar-absorption cooler, which includes the components shown in Figure 2 in addition to the absorption chiller. Solar energy is received by a collector and stored at a temperature high enough to provide sustained cooling despite the intermittent absorption of energy. For low-cost solar collectors, the probable temperature range will be 160 to 230°F.

Heat-transfer fluid is withdrawn from the high-temperature storage device to heat the generator in the absorption chiller. An auxiliary heater is needed to heat the generator for sustained cooling when solar insolation is inadequate.

Figure 1. Basic Components of an Absorption Cooling System.

Figure 2 . Block Diagram of Components to be Considered in a Solar-Absorption Chiller.

A complete and detailed comparison of refrigerant cycles with new refrigerant-absorbent pairs, with new additives to existing pairs, or with new modifications to the cycle requires a rigorous analysis of each system. Each system should be optimized for comparison.

Before detailed analyses can be made, accurate information is needed on the heat capacity, vapor pressure, heat of vaporization, density, viscosity, and thermal conductivity of the refrigerant, the absorbent, and the refrigerant-absorbent solutions. Information is needed about heats of mixing and heats of dilution as a function of the concentration of refrigerant in the absorbent. Data on the rates of solution and disassociation of refrigerant and absorbent and on the stabilities and corrosiveness of R/A pairs is desirable. We have found that not all of the required information is available; and for many of the combinations, almost none of the information required is available. Therefore, obtaining or accurately estimating the needed properties has been an important part of our program.

B. Acquisition of Information

1. Literature search

We have searched the literature to obtain information about refrigerant-absorbent pairs and additives to existing pairs that is required for the analysis of absorption cycles. The literature search also included obtaining information pertinent to new cycle modifications. In addition, we have obtained information from vendors and manufacturers of refrigerants and equipment. This information has been categorized in tabular form to aid in use of the various references. Table I gives references on properties of refrigerants, and Table II gives references on refrigerant-absorbent pairs.

In the literature search we have also found several articles describing the toxicity of refrigerants. Toxicological data for refrigerants of potential interest, as taken from the excellent review articles by P. H. Howard⁵⁸, and J. W. Clayton⁵⁹, are presented in Tables III, IV, V and VI.

Tables III, IV, and V give data on acute inhalation toxicity of halo-unsaturated methanes, ethanes, and bromofluoroethanes, respectively. In Table III, it can be seen that toxic effects decrease with an increasing number of fluorine atoms on the carbon atom. The same general trend for the ethane compounds can be observed in Table IV. Table V shows that the bromofluoroethanes are, in general, more toxic than the chlorofluoroethanes.

Table VI gives the results of chronic inhalation toxicity studies of fluorocarbons, as taken from the review by Howard. For the compounds of interest as possible refrigerants listed in

TABLE I. LITERATURE ON SPECIFIC REFRIGERANT PROPERTIES
(The numbers in the table are bibliographic references)

Code	Formula	Heat capacity	Vapor pressure	Enthalpy, (f) temp.	Entropy, (f) temp.	Heat of vaporization	Liquid density	Vapor density	Liquid viscosity	Vapor viscosity	Liq. thermal conductivity	Vapor thermal conductivity	Critical temp.	Critical volume	Critical pressure
22	CHCl ₂ F	1, 9, 17, 8	6, 2, 17, 10, 8	1, 10, 7, 8	1, 10, 8	15, 17, 8, 1	1, 10, 8	1, 2, 10, 8	7, 9, 10, 8	7, 9, 10, 8	7, 9, 8	7, 9, 8	6, 1, 2, 10	1, 10	6, 10, 1, 3
124a	CHClF ₂	17	5, 17	5	5	5, 17	5	5					5		5
134	C ₂ H ₂ F ₄	16, 17	17, 18, 16	16	16	17, 16	16	13, 16	16	16	16	16	18, 16	16	16
142b	C ₂ H ₃ F ₃	9, 16	4, 16	10, 16	10, 16	4, 16	4, 16	4, 16	4, 9,	9, 16	9, 16	9, 16	16	16	16
152a	C ₂ H ₃ F ₃	9	3, 10	10	10	3	3, 10	3, 10	3, 9	9	9	9			
245	C ₂ H ₃ F ₃	13	13, 10	13, 10	13, 10, 16	13, 16	13, 10, 16	13, 10					13	13	13
500	CCl ₂ F and CH ₂ -CHF ₂ ^a	9, 8	12, 6, 8	8	8	8	8	8	9, 8	9, 8	14, 9, 8	8	6, 12	12	6, 12, 8
502	CHClF ₂ CClF-CF ₃ ^a	11, 9, 8	11, 6, 12, 8	11, 8	11, 8	8	11, 12, 8	8	14, 14, 8	9, 8	9, 8	9, 8	6, 11	11	11, 6, 8
503	CHF ₃ + CClF ₃	9, 8	8	8	8	8	8	8	14, 9, 8	9, 8	9, 8	9, 7	8	8	8
718	H ₂ O	10	10	10	10	10	10	10	10	10	10	10	10	10	10

a. Azeotrope

TABLE II. PARTIAL LIST OF REFRIGERANT-ABSORBENT
PAIRS AND ADDITIVES FOUND IN THE LITERATURE

Refrigerant	Absorbent	Additives	References
Methanol, ethanol <u>n</u> -propanol	Ethylene Glycol 2 alcohols, 5 polyamines	LiBr	30
<u>n</u> -propanol	LiBr, ZnCl ₂ , ZnI ₂ , ZnBr ₂		
Ethylene diamine	ZnBr	Ethylene Glycol	
<u>n</u> amylamine	LiBr LiBr	Ethylene Glycol ZnBr	
Methylene bromide, 1,2-dibromoethylene, 1-chloro 1-bromo- ethylene, trichloro- ethylene, triethyl- amine, propylene dibromide, propylene dichloride, ethylene chlorhydrin, nitro- ethane	Dimethyl ether of tetraethylene glycol		
1,1,2-trichloroethene	Triglycol dichloride, diethylene glycol diacetate, dibutyl phthalate, tributyl- phosphate, acetonyl acetate		
Water	12 organic "donor" solvents-some in combination with LiBr, zinc halides, lithium acetate, H ₃ PO ₄ , glycerol, amines and polyamines		
	Zinc chloride	KCl, LiCl, CaCl ₂	
	Potassium acetate	Potassium formate	
	Calcium nitrate	CaCl ₂	
	LiBr	LiI	

TABLE II. (continued)

Refrigerant	Absorbent	Additives	References
Methylene chloride	10 alcohols, 4 ethers or polyethers, 9 esters or ether-esters, 5 aldehydes, 7 halo- genated aromatics		
Chlorform, Ethyl iodide	Diethylene glycol		
Pyridine	Tetrachlororesorcinol		
CHFC1 ₂ , CH ₃ Cl, CCl ₂ F ₂ , CH ₂ Cl ₂ , CFCl ₃ , C ₂ H ₅ Cl, C ₂ Cl ₂ F ₄	7 polyethers, 5 ether- esters, 2 halogenated ethers, 2 halogenated aromatics, 1 halogenated aliphatic		19
CHCl ₂ F	19 ethers and thioethers including ring ethers, and halogenated ethers, 12 esters, 29 ether- esters, 1 ketone (1- menthone), 2 aldehydes, 7 alcohols, 4 aromatic amines, nitrobenzene, 4 hydrocarbons and halogenated hydrocarbons		21
CCl ₂ F ₂ , CCl ₃ F, CHCl ₂ F, CH ₂ Cl ₂	5 alcohols, 3 ethers, 2 carboxylic acids, 2 esters, 3 ketones, 1 aldehyde, 2 secondary amines (1 aliphatic; one aromatic), 3 tertiary amines (1 sat'd cyclic; 2 aromatic), 2 nitriles (1 aliphatic; 1 aromatic), 2 nitro-compounds (1 aliphatic; 1 aromatic), 4 hydrocarbons, and halogenated hydrocarbons		17
CH ₂ Cl ₂ , CHCl ₂ F	4 aliphatic nitriles 1 aromatic nitriles		30

TABLE II. (continued)

Refrigerant	Absorbent	Additives	References
CCl_2F_2 , CHCl_2F , CHClF_2	4 aliphatic esters, 2 aromatic esters, 3 alcohols, 2 aldehydes, 2 ketones, 1 polyether		27
CCl_2F_2 , CHCl_2F , CHClF_2	3 amides, 3 primary amines, 1 tertiary amine, 1 nitrile, nitrobenzene		32
Methanol	LiBr		33
CHClF_2	Dibutyl phthalate		34
Water	LiBr	Fluorinated Alcohols	35
Methyl alcohol	H_2O	Alkali metal and alkaline earth halides	36
CHCl_2F	Dimethyl formamide		37
Methanol	LiI	ZnBr_2	38
Ethanol	LiBr		39
NH_3	H_2O , NaSCN		40
H_2O	LiBr	LiCl, Ethylene glycol	20
Methylamine	NaSCN	other thiocyanates	41
H_2O	LiBr	Zn or Ca halides	42
H_2O	LiBr	Mono-butyl ether of ethylene glycol	43
NH_3	NaSCN, NH_4I	Thiourea	44
H_2O	LiBr	CO_2	45
H_2O	LiBr	LiMoO_4	46

TABLE II. (continued)

Refrigerant	Absorbent	Additives	References
CHCl ₂ F	19 ethers and thioethers, 12 esters, 27 ether- esters, 3 ketones, 7 alcohols, 4 amines, 3 amides, 4 hydrocarbons		47
CHClF ₂	Dibutyl phthalate		48
CH ₃ NH ₂	LiSCN		49
NH ₃	LiSCN		50
Ethylenediamine, Monoethanalamine, or Ethylene glycol	NaI, NaClO ₄ , LiBr, LiI, BaCl ₂ , CaCl ₂ , SrCl ₂		51
NH ₃	1,4-butanediol, 2,3-butanediol, tetraethylene glycol, tetraethylene glycol- dimethylether, triethylene glycol- dimethylether		52
CHClF ₂	Dimethylformamide, dimethylacetamide, diethylformamide, tetraethyleneglycol- dimethylether		
CHCl ₂ F	Tetraethylene glycol- dimethyl ether, triethylene glycol- dimethyl ether, ethyl laurate, diethyloxalate, diethyladipate diethylformamide		
CHCl ₂ F	Dibutyl phthalate, diethyl phthalate, dibutyl oxalate, butyl butyrate, diethylene glycol methyl ethyl ether, ethylene glycol ethyl ether acetate, p-ethoxyethyl acetate		53

TABLE II. (continued)

Refrigerant	Absorbent	Additives	References
NH ₃	Water, NaSCN		54
CHCl ₂ F CHClF ₂	Tetraethylene glycol dimethyl ether		55
H ₂ O	LiBr		56
CHCl ₂ F	2-(t-butoxymethyl) tetrahydrofuran		57

TABLE III. ACUTE INHALATION TOXICITY OF HALO-UNSATURATED
METHANES IN LABORATORY ANIMALS

Fluorocarbon	Code	Animal	ALC ^a	LC ₅₀	Anesth.	Tremors	Non-lethal	Duration
CHCl ₂ F	F-21	Guinea Pig	5% ^b					<2 hr
			10%					1 hr
		Higher Vertebrates	10%		1-2%			brief
								several minutes
CHClF ₂	F-22	Guinea Pigs				10%		2 hr
		Dogs	70%		40%		20%	2 hr
		Mice	40%					<90 min
								2 hr
CHF ₃	F-23	Rat					20%	2 hr
		Dogs					80%	<90 min

a. Approximate lethal concentration (ALC) is the minimum concentration causing death in any of the animals.

b. Percent by volume in air.

TABLE IV. ACUTE INHALATION TOXICITY OF HALO-UNSATURATED
ETHANES IN LABORATORY MAMMALS

Fluorocarbon	Code	Animal	ALC ^a	LC ₅₀	Anesth.	Tremors	Non-lethal	Duration
CF ₂ Cl-CH ₂ Cl	F-132	Mice		4.3% ^b 4.9%	1.3%[delayed death in 24-28 hrs] 1.29%[no delayed death noted in 15 days]		3% [lung lesions]	10 min
CClF ₂ -CH ₃	F-142b	Mice	12.8% ^b 20%					4 hr
CHF ₂ -CH ₃	F-152a	Rats	50-55% <45% 6.4%					10-25 min 4 hr
CF ₃ -CHCl ₃	F-123a	Mice		7.4% 7.7%		2.4% 2.7%		30 min 10 min 30 min 10 min
CClF ₂ -CHClF	F-123	Dog Mice			7% 4%	none none		15 min 30 min 1 hr
							7%	
CF ₃ -CH ₂ Cl	F-133			25% 15%	8% 4.3%			10 min 30 min
CF ₃ -CH ₃	F-143	Mice		50%				10 min
CClF ₂ -CHF ₂	F-124	Guinea Pig					20%	2 hr
CF ₃ -CHClF	F-124a	Dog			40%			2 min
CHF ₂ -CF ₃	F-125	Rats Dog					10%	4 hr rapid onset
				[80%-long lasting excitement stage]				

a. Approximate lethal concentration (ALC) is the minimum concentration causing death in any of the animals.

b. Percent by volume in air.

TABLE V. ACUTE INHALATION TOXICITY OF BROMOFLUOROETHANES
IN LABORATORY MAMMALS

Fluorocarbon	Code	Animal	ALC ^a	LC ₅₀	Anesth.	Tremors	Non-lethal	Duration
CH ₂ Br-CF ₂ Br	H-2207	Rats	0.5% ^b		0.25% ^b			18 hr 18 hr
CH ₂ Br-CHF ₂	H-2201	Rats		4.6%	1.3%			10 min
CHBr ₂ -CF ₃	H-2302	Mice	1.2%		0.53			30 min
		Mice	2.0%		0.42			10 min
CH ₂ Br-CF ₃	H-2301	Mice		9.76% 11.7%	2.51% 2.8%			30 min 10 min
CBrF ₂ -CBrF ₂	H-2402	Rats	17.3%				13.1	4 hr 4 hr
CHBrF-CF ₃	H-2401	Dogs			25%			rapid

a. Approximate lethal concentration (ALC) is the minimum concentration causing death in any of the animals.

b. Percent by volume in air.

TABLE VI. CHRONIC INHALATION TOXICITY OF VARIOUS FLUOROCARBONS

Fluoro-carbon	Code	Acute ALC ^a	Animal	% (V/V) Conc.	Hr/Day	Days	Mortality	Comments
CCl ₃ F	F-11	6% x 4 hr Rats	Rats	1.025%	8	30	0/15	No outward signs of toxicity
			G. Pigs				0/15	
			Dogs				0/2	
		0.1%	Monkeys				0/9	
			Rats		24	90	0/15	
			G. Pigs				0/15	
			Dogs				0/2	
			Monkeys				1/9	Hemorrhagic lesions on surface of lung not directly attributable to compound.
CCl ₂ F ₂	F-12	80%, Rats, G. Pigs, Rabbits	Dogs	20%	7-8	52	0/2	Dogs and monkeys apparently developed tolerance to exposure, tremors disappearing after first two weeks.
			Monkeys	20%	7-8	35-52	0/2	Deaths in Guinea pigs not related to exposure.
			G. Pigs	20%	7-8	35-56	10/26	
			Rats	0.0840%	8*	30	2/15	Guinea Pigs-several showed focal necrosis or fatty infiltration of liver. Monkey-heavy pigment deposits in liver, spleen, and kidney.
			Rats	0.0810%	24	90	1/15	Guinea pigs-all showed slight to extensive fatty infiltration of liver and several had focal or submassive necrosis of liver.
			G. Pigs				0/15	
			Rabbits				0/3	
			Dogs				0/2	
			Monkeys				0/3	

-15-

- continued -

TABLE VI. CHRONIC INHALATION TOXICITY OF VARIOUS FLUOROCARBONS - continued -

Fluoro-carbon	Code	Acute ALC ^a	Animal	% (V/V) Conc.	Hr/Day	Days	Mortality	Comments
CHClF ₂	F-22	70%, Rats	Rabbits Rats Mice	1.42	6	300		No toxic effects.
			Rats Mice	0.198%	6	300		No toxic effects.
CBrF ₃	H-1301	85% x 2 hr, Mice G. Pigs	Rats	2.3%	5	90	0/30 0/3	No signs of toxicity.
CCl ₂ F- CCl ₂ F	F-112	1.3% x 4 hr, Rats	Rats Mice G. Pigs Rabbit	0.1%	6	31	0/16 0/10 0/2 0/1	Female rats (8): significant decrease in leukocyte count. Male Rats: liver and kidney weights greater than control. Transient liver reactions in rats.
CCl ₂ F- CClF ₂	F-113	5.5% x 4 hr, Rats	Rats Rats	0.0232% 0.5%	7 7	30 30	0/21 0/12	No signs of toxicity. Three rats showed slightly pale livers.
CClF ₂ - CF ₃	F-115	80% x 4 hr, Rats	Rats Mice Rabbits Dogs	10%	6*	90	0/20 0/10 0/4 0/4	No signs of toxicity.
CH ₃ - CHF ₂	F-152a	6.4% x 4 hr, Rats	Rats	10%	16	60	0/8	No signs of toxicity. Mild chronic irritation of lungs in five rats.
CH ₃ - CClF ₂	F-142a	12.8% x 4 hr, Rats	Rats	1%	16	60	0/6	No signs of toxicity. Mild chronic irritation of lungs in two rats.

* 5 days/week

Table VI (CHClF_2 , $\text{CH}_3\text{-CHF}_2$, and $\text{CH}_3\text{-CClF}_2$), no signs of toxicity were observed, although there were indications of mild irritation of the lungs in some of the rats used in the studies made with $\text{CH}_3\text{-CHF}_2$ and $\text{CH}_3\text{-CClF}_2$.

The Underwriters Laboratories have developed a classification for the toxicities of compounds that have been used as refrigerants. The potential toxicity of compounds ranges from Classification 1 (toxic) through Classification 6 (little toxicity evidenced). Table VII shows the Underwriters classification for some fluorocarbons and other compounds. In contrast to SO_2 and NH_3 , which are rated as relatively toxic compounds and have ratings of 1 and 2, fluorocarbons of potential interest (CHCl_2F , CHClF_2 , $\text{CH}_3\text{-CClF}$, and $\text{CH}_3\text{-CHF}_2$) are rated "between 4 and 5" and as 5a or 6, which indicates low toxicities.

On the basis of the evidence and references cited, we believe the fluorocarbon refrigerants of interest in absorption refrigeration are of low enough toxicity for further consideration. However, in a recent hearing before the Environmental Hazards Committee of the EPA⁶⁰, a Du Pont representative reported that fluorocarbon 21 (CHCl_2F) was too toxic to be acceptable for use as an aerosol propellant, and that fluorocarbon 22 (CHClF_2) was found to be weakly mutagenic in a 72-hr Ames (bacterial) test. It was stated that "While the significance of the Ames test as a predictor of hazard to humans is far from established, pending completion of a long-term animal test, we consider it imprudent to develop fluorocarbon 22 for aerosol uses that involve direct application of the chemical to humans".

We have been told by Du Pont that the results of their animal tests will begin to be available this summer. We will have our pathologists review the results to obtain an opinion on the safety of R22 for use in refrigeration.

The Ansul Company, Marinette, Wisconsin, which manufactures the polyglycol ethers of potential interest as absorbents, furnished some data on toxicity of these ethers. The di-, tri-, and tetra-ethylene glycol dimethyl ethers had an acute oral LD_{50} of approximately 7 g/kg in tests conducted on adult albino male rats. Primary skin irritation studies on adult rabbits indicate these three ethers to be non-irritating. They report that diethylene glycol dibutyl ether is moderately toxic when swallowed and can cause irritation to the skin. However, breathing the vapors should not be harmful under ordinary circumstances.

According to the manufacturer's technical brochures, some of the refrigerants of potential interest are flammable (e.g. $\text{CH}_3\text{-CClF}_3$, and $\text{CH}_3\text{-CHF}_2$). However, based on their flammability limits, there appears to be only slight hazard associated with the use of these compounds. In contrast, NH_3 from refrigeration systems has exploded.⁶¹

TABLE VII. UNDERWRITERS' LABORATORIES CLASSIFICATION

<u>Group</u>	<u>Criteria</u>	<u>Fluorocarbons in this class</u>	<u>Other chemicals in this class</u>
1	1/2-1% for $\leq$ 5 min. causes injury or death		SO ₂
2	1/2-1% for $\leq$ 30 min. causes injury or death		NH ₃
3	2-2 1/2% for $\leq$ 60 min. causes injury or death		CHCl ₃
4	2-2 1/2% for $\leq$ 120 min. causes injury or death		CH ₃ Cl
Between 4 & 5	Apparently less toxic than 4	CCl ₂ F-CCl ₂ F, CHCl ₂ F	CH ₂ Cl ₂
5a	Less toxic than 4; more toxic than 6	CCL ₃ F, CCl ₂ F ₂ , CHClF ₂	CO ₂
5b	Available (Non-Underwriters') data indicate either 5a or 6		Ethane
6	20% for 120 min. causes no injury	CClF ₂ -CClF ₂ , CClF ₂ -CF ₃ CClF ₂ -CClF ₂ CH ₃ -CClF ₂ CH ₃ -CHF ₂	

In discussions with a representative of a company that makes refrigerants, we learned that no manufacturer of refrigeration equipment that the refrigerant manufacturer had talked with would consider making an ammonia-based household air-conditioning unit because of the possibility of liability suits.

Because of the known tendency for ethers to auto-oxidize and form peroxides that can explode, we asked the manufacturer of high-boiling ethers that are candidates for use as absorbents, such as tetraethylene glycol dimethyl ether, about their propensity for auto-oxidation and peroxide formation. These ethers are typical in that they are subject to auto-oxidation. However, they have been used for a variety of applications including absorption refrigeration without explosive decomposition when a small amount of a reducing agent (e.g. hydroquinone) is added to inhibit peroxide formation. Alkaline materials also inhibit auto-oxidation. We see nothing in the known behavior of such ethers to prohibit their use in absorption refrigeration systems when proper precautions against auto-oxidation are taken.

2. Experimental data

Refrigerant-absorbent pairs with the highest heats of mixing should have the largest negative deviations from Raoult's law, and refrigerant-absorbent pairs with large negative deviations from Raoult's law have been found to be suitable for absorption refrigeration. We have devised a simple screening test to determine relative values of the heats of mixing of candidate refrigerants and absorbents. In this test, which was adapted from one developed by Eiseman¹⁷, the temperature rise from mixing pre-weighed amounts of a refrigerant and an absorbent is measured. The apparatus used has a standard rate of heat loss that does not vary from measurement to measurement. Thus, the refrigerant-absorbent pair with the highest heat of mixing will result in the highest temperature rise.

Analysis of data in the literature indicated we could screen and select the better absorbents by heats of mixing tests performed with methylene chloride. This permitted the initial screening to be performed at atmospheric pressure.

Results of the screening of absorbents against methylene chloride are presented in Figure 3 and Table VIII. Figure 3 shows typical shapes of the heats of mixing curves*. In all instances there was a maximum in the curves, and the maximums were not necessarily at or near the 1:1 ratio of absorbent and refrigerant used by Eiseman.

* Although we call these measured quantities "heats of mixing", it should be recognized that the values are only approximate because the screening measurements were not made with the degree of precision needed for exacting calorimetry.

Figure 3. Approximate Heats of Mixing of Three High-Molecular-Weight Ethers with Methylene Chloride.

TABLE VIII. APPROXIMATE MAXIMUM HEATS OF MIXING
[METHYLENE CHLORIDE REFRIGERANT]

Absorbent	Maximum heat of mixing per mole of solution ^a Cal/mole	Change in heat of mixing per mole of refrigerant Cal/mole	Mole fraction of absorbent ^b	Weight percent of absorbent ^b
Tetraethylene glycol dimethyl ether	1775	2275	0.22	41
Triethylene glycol dimethyl ether	1725	2425	0.29	47
2-Methoxyethyl ether	1225	1750	0.31	41
Diethylene glycol dimethyl ether	1100	1875	0.41	52
Diethylene glycol dibutyl ether	950	2275	0.59	45
1,1,3,3-tetramethylurea	875	1575	0.44	52
N,N,N',N'-tetramethylenediamine	850	1325	0.64	44
Tripropylene glycol monomethyl ether	675	1175	0.42	64
N,N,N',N'-tetramethyl-1,3-propanediamine	625	1775	0.64	73
2,2-Methoxypropane	500	825	0.39	44
Dipropylene glycol monomethyl ether	500	825	0.40	54
N,N,N',N'-tetramethyldiaminomethane	250	450	0.43	48
Propylene glycol monomethyl ether	250	875	0.72	73
Ethanesulfonic acid	50	75	0.34	45
Pentaerythritol tetraacetate (solid)	Heat absorbed			
Sodium 5-formyl-2-furansulfonate (solid)	Insoluble			
Tetrahydrofuran-2,3,4,5-tetracarboxylic acid (solid)	Insoluble			

a. Moles solution = final number of [moles A + moles R].

b. At the maximum heat of mixing.

Therefore, we believe the values given here represent a better screening of absorbents than those given by Eiseman.

Table VIII shows the maximum heats of mixing and the mole fractions at which the maxima occurred for 17 selected absorbents as screened against methylene chloride. We have arranged the absorbents in descending order of the maximum heats of mixing. Since large heats of mixing are related to large negative deviations from Raoult's law, the absorbents in Table VIII are thus arranged in descending order of the emphasis we will place on them in future studies.

We also screened several candidate absorbents against water as a refrigerant. Typical curves are shown in Figure 4; the maximum values of heats of mixing and the mole fractions at which the maxima occurred are given in Table IX for 7 absorbents screened against water. In Table IX the absorbents are again arranged in descending order of the maximum heat of mixing, and thus represent the order of emphasis we will place on the absorbents in future work.

The solids listed in Tables VIII and IX (Pentaerythritol tetracetate, sodium-5-formyl-2-furansulfonate, tetrahydrofuran-2,3,4,5-tetracarboxylic acid and sodium ethanesulfonate) were either insoluble absorbed heat, or gave very small exothermic heats of mixing because of the effects of the heat needed to overcome the energy of crystallization when they dissolved. The heats of dilution of saturated solutions will be measured for these compounds.

Several candidate absorbents listed in Table VIII will be tested with water as the refrigerant compound, including the sodium salt of ethanesulfonic acid and sodium 5-formyl-2-furansulfonate. In addition, we have 9 selected candidate absorbents on hand that have not been tested. We plan to determine the approximate heats of mixing of these compounds with methylene chloride and water.

We have designed an experimental apparatus for determining the relationships between vapor pressure, temperature, and composition of selected refrigerant-absorbent pairs. We have ordered all necessary components and many of them have been received. We have encountered a delay in shipment of a high precision compound (vacuum-pressure) gage to be used, but we plan to start assembling the apparatus soon and use a less precise gage until the precision gage is received.

C. Criteria and Guidelines for Selection of Promising Refrigerant-Absorbent Pairs

Based on theory and our study of the information found in the literature, we developed the following criteria and desirable features of refrigerants and absorbents to serve as guidelines in selecting refrigerant-absorbent pairs.

Figure 4. Approximate Heats of Mixing of Three High-Molecular-Weight Ethers with Water.

TABLE IX. APPROXIMATE MAXIMUM HEATS OF MIXING
[WATER REFRIGERANT]

Absorbent	Maximum heat of mixing per mole of solution ^a Cal/mole	Change in heat of mixing per mole of refrigerant Cal/mole	Mole fraction of absorbent ^b	Weight percent of absorbent ^b
Ethanesulfonic acid	1600	2575	0.38	79
Tetraethylene glycol dimethyl ether	525	650	0.17	72
Triethylene glycol dimethyl ether	400	550	0.27	79
Diethylene glycol dimethyl ether	375	500	0.25	71
Methanedisulfonic acid	50	50	0.04	31
Tetrahydrofuran-2,3,4,5-tetracarboxylic acid	25	225	0.02	23
Sodium ethanedisulfonate (solid)	Heat absorbed			

a. Moles solutions = final number of [moles A + moles R].

b. At the maximum heat of mixing.

1. Desirable properties of refrigerants

- The refrigerant should be highly associated in the liquid state. This association may be a result of hydrogen bonding, or other dipole-dipole attractions. In the vaporization of associated liquids the heat of dissociation must be supplied as well as the heat needed to overcome Van der Waals forces that tend to hold molecules together. For this reason, an associated liquid has a higher molal latent heat of vaporization than a less associated liquid of equal molecular weight. For example, ammonia, which is highly associated, with a molecular weight of 17, has a latent heat of vaporization of 5580 cal/mole at its normal boiling point; but methane, which is not associated, with almost the same molecular weight, 16, has a latent heat of vaporization of 1950 cal/mole at its normal boiling point.
- Qualitative information about the degree of association of potential refrigerants can be obtained by a comparison of boiling points of the potential refrigerant and nonassociated compounds of equal, or nearly equal, molecular weights, as illustrated in Figures 5 and 6. In Figure 5 (methane series), if a line is drawn to the right from the trend line of the fully halogenated compounds (CX_4) along a constant molecular weight, the line will first intersect the trend line for compounds with three halogens and one hydrogen atom attached to the carbon (CHX_3). This is an indication that the CHX_3 compounds are more associated than the CX_4 compounds. If the constant molecular weight line is extended further to the right, it will intersect the trend line for the CH_2X_2 compounds. This further increase in boiling point at constant molecular weight indicates the CH_2X_2 compounds are more associated than the CHX_3 compounds. The latent heats of vaporization for the CH_2X_2 compounds should therefore be higher than those for the CHX_3 compounds. In turn, the latent heats of vaporization of CHX_3 compounds should be higher than those of CX_4 compounds.

Similar information can be obtained about the ethane series of halogenated compounds as shown in Figure 6.

- Since for refrigeration purposes, the primary interest is in the heat of vaporization on the basis of cal/g (or Btu/lb), the latent heats of vaporization of potential refrigerants should be compared on the basis of equal weights and not on the basis of molal latent heats. For example, ethanol has a molal latent heat of vaporization of 9396 cal, and methanol has a molal latent heat of 7881 cal. However, on a weight basis the latent heat of ethanol is 204 cal/g and that of methanol is 263 cal/g.

Figure 5 . Relationship between molecular weights and normal boiling points of fully halogenated and hydro-halogenated refrigerants in the methane series.

Figure 6 . Relationship between molecular weights and normal boiling points of fully halogenated and hydro-halogenated refrigerants in the ethane series.

- The normal boiling points of refrigerants should be in the range of -35°C to $+100^{\circ}\text{C}$. For example, ammonia, which might represent the upper limit of desirable pressures, has a normal boiling point of -33.4°C ; water, which represents the lower limit of pressure, has a boiling point of 100°C .
- The refrigerant should be nonflammable, nontoxic, and chemically stable under conditions of use (*i.e.*, in contact with absorbent, lubricating oils, and materials used for fabricating the air-conditioning systems).
- Refrigerants with high values of surface tension should be avoided, if possible, because surface tension of refrigerants could represent a "kinetic" barrier to the quick attainment of equilibrium. A search for additives that might lower surface tension appears to be worthwhile.
- Refrigerants with high values of viscosity should be avoided, if possible. High viscosities make both heat transfer and diffusion more difficult.
- Consideration should be given to additives to minimize the corrosiveness of refrigerants that might otherwise be good for use in solar-heated refrigeration cycles.

2. Desirable characteristics of absorbents

- The absorbent should be a substance with low volatility with moieties that have either high electron density to act as donors to the positive regions of polar refrigerant molecules or that are strong acceptors for the negative regions of polar refrigerant molecules.
- The absorbent should not be associated or be only slightly associated. In his studies of haloform refrigerants and absorbents, Zellhoeffer^{4,7} found that the solubility of CHCl_2F was much higher in compounds in which there was only a slight propensity for association, such as ethers, esters, ketones, tertiary amines, and amides, than in associated compounds, such as alcohols or primary and secondary amines. The difference in solubilities was because hydrogen bonding of the hydrogen in CHCl_2F with donor atoms is weaker than the hydrogen bonding of alcohol or amine molecules with themselves. Thus, the weaker $\text{C-H}\cdots\text{O}$ bonds cannot disrupt $\text{O-H}\cdots\text{O}$ or $\text{N-H}\cdots\text{N}$ bonds.
- Solvents with the greatest number of "active" (*i.e.*, donor or acceptor) atoms per unit of molecular weight will dissolve the most refrigerant on a pound-per-pound basis, other factors being equal.

- With ethers, oxygen atoms in a ring (e.g., dioxane) or attached by one bond to a benzene ring (e.g., resorcinol diethyl ether) are less effective solvents than aliphatic ethers. Although Zellhoeffer studied no aliphatic amines, by inference the same trends between ring compounds, aromatic compounds, and aliphatic compounds should be true for tertiary amines.
- On the basis of moles of refrigerant dissolved at a given pressure per mole of solvent, ethers, esters, ketones, amides, and tertiary amines appear to be approximately equal in their effectiveness as solvents for hydrogen bonded refrigerants. Fully alkylated amides (dimethyl formamide and dimethyl acetamide) are good solvents for hydrogen-containing haloform refrigerants. In such compounds, the amide nitrogen appears to be superior in its hydrogen-bonding capabilities to the singly-bonded oxygen in esters. In nonalkylated amides the solubilities of hydrogen-containing haloforms are lower because the solvents are hydrogen bonded, and there is competition between solvent-solvent and solvent-haloform hydrogen bonds. In their solvent behavior, nitriles and dinitriles also appear to be hydrogen bonded, and haloform refrigerants have lower solubilities in these solvents because of the competition between hydrogen bonds.
- The active sites should not be too close together in solvents with multiple active sites. In his studies of polyethylene glycol ethers, Zellhoeffer found that only alternate oxygen atoms were effective in complexing because of steric effects. Zellhoeffer's work was primarily with haloform refrigerants, which are relatively large molecules. Steric effects would be expected to be less important with smaller refrigerant molecules, but they will still be a factor.
- Ion-dipole interactions are stronger than dipole-dipole interactions. Ion-exchange resins have been used as desiccants.²² In this use the attraction between ions and water molecules is stronger than the hydrogen bonds between water molecules. In the study of ion-exchange resins as desiccants, the lithium form was found to sorb the most water at equilibrium, but the potassium form of the resin sorbed water faster. If linear oligomers of polyacids are used (as Li^+ or K^+ salts) instead of crosslinked ion-exchange resins, they should have a strong attraction for hydrogen-bonded molecules, and also have low volatility.

- In selecting ions as candidates for use in absorbent solutions, a high ratio of charge to size is desirable for both the cation and anion being considered. The cations and anions should also be as disparate in size as practicable, since "mismatching" of ion sizes contributes to the attraction of the compound for water or other hydrogen-bonded solvents.

3. Desirable features of refrigerant-absorbent combinations

Certain desirable features of refrigerant-absorbent pairs are characteristic of the combination of refrigerant and absorbent and not of either compound by itself. These are discussed below.

- In previous analyses of absorption-refrigeration cycles, it was found that it is highly desirable to have only a small amount of absorbing liquid per Btu of cooling. To accomplish this, the difference between the solubility of refrigerant at the generator conditions and the absorber conditions should be as large as possible. This factor is perhaps the most important characteristic of a refrigerant-absorbent pair.
- It was found in prior work¹⁷ that although hydrogen-containing haloform refrigerants and triethylene glycol dimethyl ether (TGDE) are only very slightly corrosive to common materials of construction (aluminum, copper, and mild steel) when each is in contact with the materials by itself, certain haloform refrigerants are highly corrosive when combined with TGDE and exposed to the metals. The most corrosive refrigerants are those which contain both hydrogen and chloride atoms on the same carbon atom (e.g., CH_2Cl_2). The next most corrosive refrigerants are those which contain one hydrogen, one fluoride, and two chloride atoms on a carbon atom (e.g., CHCl_2F). However, refrigerants which contain one hydrogen atom, one chloride atom, and two fluoride atoms on a carbon atom (e.g., CHClF_2) are much less corrosive. These corrosion data were obtained with haloform refrigerants of the methane series and with TGDE. We believe the following generalization can be inferred, however. From the viewpoint of corrosion of aluminum, copper, and low-carbon steel, haloform refrigerants that contain two chlorine atoms and hydrogen on the same carbon atom should be avoided if the haloforms are to be used in conjunction with ethers as absorbents. Haloforms with two fluorine atoms on a carbon atom that also has hydrogen attached to it are much less corrosive in such use.

- With refrigerant-absorbent pairs in which metal ammines are formed, the metals should not form stable hydrides which would diminish activity or possibly create hazards, since some metal hydrides can be explosive.
- Solutions with high values of surface tension should be avoided, if possible, because surface tension of refrigerant-absorbent solutions in the absorber and generator could represent a "kinetic" barrier to the quick attainment of equilibrium. A search for additives that might lower surface tension may be worthwhile.
- To minimize heat transfer area in the liquid heat exchanger, the solutions of refrigerant and absorbent, which circulate between the absorber and generator, should have high values of thermal conductivity and low values of viscosity and specific heat.
- For ion-dipole refrigerant-absorbent pairs, the ionic component should be dissociated as much as possible under the conditions of use.

D. Analysis of Conceptual Designs

We are developing a computer model for use in analyzing conceptual designs of solar-powered absorption cycles. The overall model, which is nearing completion, will not only be capable of analyzing the basic absorption cycle but will also provide the ability to analyze variants to the basic cycle, such as compression of refrigerant vapors from the generator before introducing them to the condenser or decreasing the pressure in the evaporator by a compression device installed between the evaporator and absorber. Many of the properties of refrigerants and absorbents required for the analyses are not available in the literature. Therefore, we have developed and debugged programs to estimate the following physical properties: density of liquids, viscosity of liquids, viscosity of binary liquid mixtures, thermal conductivity of binary liquid mixtures, thermal conductivity of gases, viscosity of gases, and specific heats of gases and liquids. The procedures used to develop the computer sub-routines were selected from methods given by Reid, Prausnitz, and Sherwood.⁶¹ We have also developed sub-routines for calculating the coefficients of heat transfer needed for the analyses. Examples of the printouts for each sub-routine are given in the Appendix. When the overall model is complete, debugged, and tested, we will describe the program in more detail.

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APPENDIX

Examples of Computer Printouts
for the Sub-routines

I. SUB-ROUTINE THERMAL CONDUCTIVITY, SINGLE GAS

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001      REAL LAMGTR
002      REAL LAMGIN
003      REAL LAMBDA
004      REAL NAME
005      REAL NAME2
006      C THIS PROGRAM TESTS OUT A SUBROUTINE FOR DETERMINING THE THERMAL
007      C CONDUCTIVITY OF A SINGLE GAS
008      COMMON TC(100),XMW(100),PC(100),C(100),THMCON(100,11),TE(100),
009      * NAME(100),NAME2(100)
010      READ(2,50) N
011      READ(2,100) (TC(J),XMW(J),PC(J),C(J),NAME(J),NAME2(J),J=1,N)
012      50  FORMAT(I2)
013      100  FORMAT(4F10.5,A3,A3)
014      WRITE(3,)(TC(J),XMW(J),PC(J),C(J),J=1,N)
015      C THE TEMPERATURE IS SET AT 273 KELVIN AND WILL INCREMENT EVERY 10
016      C DEGREES
017      DO 800 I=1,N
018      T=273.0
019      DO 900 J=1,11
020      C THERM IS THE SUBROUTINE THAT DETERMINES THE THERMAL
021      C CONDUCTIVITY OF A SINGLE GAS
022      CALL THERM(T,TR,FTR,LAMGIN,LAMBDA,LAMGTR,I)
023      THMCON(I,J)=LAMBDA
024      TE(J)=T
025      T=T+10.
026      900  CONTINUE
027      800  CONTINUE
028      WRITE(3,400) ((NAME(K),NAME2(K),TE(L),THMCON(K,L),L=1,11),K=1,N)
029      400  FORMAT('0',' THE THERMAL CONDUCTIVITY OF ',A3,A3,' AT ',F5.1,
030      * ' DEGREES KELVIN IS ',F10.5,' CAL/CM S K ')
031      STOP
032      END

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001      SUBROUTINE THERM(T,TR,FTR,LAMGIN,LAMBDA,LAMGTR,I)
002      REAL LAMGTR
003      REAL LAMGIN
004      REAL LAMBDA
005      REAL NAME
006      REAL NAME2
007      C THIS IS THE ROY-THODOS ESTIMATION TECHNIQUE FOR
008      C THERMAL CONDUCTIVITY OF A SINGLE GAS AS FOUND ON P.481 OF
009      C REID ET AL.
010      COMMON TC(100),XMW(100),PC(100),C(100),THMCON(100,11),TE(100),
011      * NAME(100),NAME2(100)
012      TR=T/TC(I)
013      GAMMA=(TC(I))**(.1/.6)*XMW(I)**.5/PC(I)**(.2/.3)
014      LAMGTR=99.6*10.**(-6)*(EXP(0.0454*TR)-EXP(-0.2412*TR))
015      C FTR CHANGES IF THE GAS IS NOT A HA-IDE
016      FTR=0.107*TR+1.33*TR**2+0.223*TR**3
017      LAMGIN=C(I)*FTR
018      C LAMBDA IS THE THERMAL CONDUCTIVITY FOR A SINGLE GAS
019      LAMBDA=(LAMGTR+LAMGIN)/GAMMA
020      WRITE(3,)(GAMMA,LAMGTR,FTR,LAMGIN,LAMBDA,TR
021      RETURN
022      END

```

'TC(1)'= 385.00000
'XMW(1)'= 120.91400
'PC(1)'= 40.700000
'C(1)'= 5.380000
'TC(2)'= 302.00000
'XMW(2)'= 104.45900
'PC(2)'= 38.700000
'C(2)'= 3.4800000

'GAMMA'= 2.5066026
'LANGTR'= 0.18989244E=04
'PTR'= 0.51335651
'LANGIN'= 2.7618580
'LAMBDA'= 1.1018408
'TR'= 0.70909090

'GAMMA'= 2.5066026
'LANGTR'= 0.19637613E=04
'PTR'= 0.55140524
'LANGIN'= 2.9665602
'LAMBDA'= 1.1835063
'TR'= 0.73564494

'GAMMA'= 2.5066026
'LANGTR'= 0.20282871E=04
'PTR'= 0.59058498
'LANGIN'= 3.1773472
'LAMBDA'= 1.2675992
'TR'= 0.76103896

'GAMMA'= 2.5066026
'LANGTR'= 0.20925016E=04
'PTR'= 0.63087234
'LANGIN'= 3.3940932
'LAMBDA'= 1.3540695
'TR'= 0.78701299

'GAMMA'= 2.5066026
'LANGTR'= 0.21564082E=04
'PTR'= 0.67224380
'LANGIN'= 3.6166717
'LAMBDA'= 1.4428666
'TR'= 0.81298701

'GAMMA'= 2.5066026
'LANGTR'= 0.22200084E=04
'PTR'= 0.71467599
'LANGIN'= 3.8449568
'LAMBDA'= 1.5339404
'TR'= 0.83896104

'GAMMA'= 2.5066026
'LANGTR'= 0.22833041E=04
'PTR'= 0.75814545
'LANGIN'= 4.0788225
'LAMBDA'= 1.6272405
'TR'= 0.86493507

'GAMMA'= 2.5066026
'LANGTR'= 0.23462979E=04

'PTR'= 0.80262870
'LANGIN'= 4.3181424
'LAMBDA'= 1.7227166
'TR'= 0.89090909

'GAMMA'= 2.5066026
'LANGTR'= 0.24089912E=04
'PTR'= 0.84810229
'LANGIN'= 4.5627903
'LAMBDA'= 1.8203182
'TR'= 0.91688311

'GAMMA'= 2.5066026
'LANGTR'= 0.24713866E=04
'PTR'= 0.89454286
'LANGIN'= 4.8126405
'LAMBDA'= 1.9199953
'TR'= 0.94285715

'GAMMA'= 2.5066026
'LANGTR'= 0.25334851E=04
'PTR'= 0.94192685
'LANGIN'= 5.0675665
'LAMBDA'= 2.0216973
'TR'= 0.96883117

'GAMMA'= 2.3138407
'LANGTR'= 0.23778687E=04
'PTR'= 0.82517869
'LANGIN'= 2.8723178
'LAMBDA'= 1.2413739
'TR'= 0.90397350

'GAMMA'= 2.3138407
'LANGTR'= 0.24575494E=04
'PTR'= 0.88414209
'LANGIN'= 3.0768144
'LAMBDA'= 1.3297540
'TR'= 0.93708609

'GAMMA'= 2.3138407
'LANGTR'= 0.25367465E=04
'PTR'= 0.94444728
'LANGIN'= 3.2866765
'LAMBDA'= 1.4204529
'TR'= 0.97019968

'GAMMA'= 2.3138407
'LANGTR'= 0.26154660E=04
'PTR'= 1.0062456
'LANGIN'= 3.5017348
'LAMBDA'= 1.5133976
'TR'= 1.0033112

'GAMMA'= 2.3138407
'LANGTR'= 0.26937114E=04
'PTR'= 1.0694887
'LANGIN'= 3.7218205
'LAMBDA'= 1.6085150
'TR'= 1.0364238

'GAMMA'= 2.3138407
'LANGTR'= 0.27714868E=04
'PTR'= 1.1341278
'LANGIN'= 3.9467646
'LAMBDA'= 1.7057320
'TR'= 1.0695364

'GAMMA'= 2.3138407
'LANGTR'= 0.28487962E=04
'PTR'= 1.2001144
'LANGIN'= 4.1763980
'LAMBDA'= 1.8049758
'TR'= 1.1026490

'GAMMA'= 2.3138407
'LANGTR'= 0.29256428E=04
'PTR'= 1.2673999
'LANGIN'= 4.4105515
'LAMBDA'= 1.9061730
'TR'= 1.1357616

'GAMMA'= 2.3138407
'LANGTR'= 0.30020319E=04
'PTR'= 1.3359357
'LANGIN'= 4.6490562
'LAMBDA'= 2.0092508
'TR'= 1.1688742

'GAMMA'= 2.3138407
'LANGTR'= 0.30779658E=04
'PTR'= 1.4056733
'LANGIN'= 4.8917431
'LAMBDA'= 2.1141359
'TR'= 1.2019668

'GAMMA'= 2.3138407
'LANGTR'= 0.31534490E=04
'PTR'= 1.4765640
'LANGIN'= 5.1384429
'LAMBDA'= 2.2207555
'TR'= 1.2350993

THE THERMAL CONDUCTIVITY OF CCL2F2 AT 273.0 DEGREES KELVIN IS	1.10184 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 283.0 DEGREES KELVIN IS	1.18351 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 293.0 DEGREES KELVIN IS	1.26760 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 303.0 DEGREES KELVIN IS	1.35407 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 313.0 DEGREES KELVIN IS	1.44287 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 323.0 DEGREES KELVIN IS	1.53394 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 333.0 DEGREES KELVIN IS	1.62724 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 343.0 DEGREES KELVIN IS	1.72272 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 353.0 DEGREES KELVIN IS	1.82032 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 363.0 DEGREES KELVIN IS	1.92000 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCL2F2 AT 373.0 DEGREES KELVIN IS	2.02170 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 273.0 DEGREES KELVIN IS	1.24137 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 283.0 DEGREES KELVIN IS	1.32975 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 293.0 DEGREES KELVIN IS	1.42045 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 303.0 DEGREES KELVIN IS	1.51340 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 313.0 DEGREES KELVIN IS	1.60851 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 323.0 DEGREES KELVIN IS	1.70573 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 333.0 DEGREES KELVIN IS	1.80498 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 343.0 DEGREES KELVIN IS	1.90617 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 353.0 DEGREES KELVIN IS	2.00925 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 363.0 DEGREES KELVIN IS	2.11414 CAL/CM S K
THE THERMAL CONDUCTIVITY OF CCLF3 AT 373.0 DEGREES KELVIN IS	2.22076 CAL/CM S K
STOP 000000	

II. SUB-ROUTINE THERMAL CONDUCTIVITY, BINARY LIQUIDS

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001 C THIS PROGRAM IS DESIGNED TO TEST OUT A SUBROUTINE
002 C WHICH FIGURES OUT THE THERMAL CONDUCTIVITY OF TWO
003 C LIQUIDS MIXED TOGETHER.
004 REAL NAME, NAME1, NUMBER
005 COMMON DELTAH(100), TB(100), H(100), TC(100), RHO(100), CPT(100),
006 * TCLMX(100,11), DELTA S(100), THMIQ(100), TR(100), WF(100), TE(100),
007 * NAME(100), NAME1(100), NUMBER(100)
008 READ(2,50) N
009 READ(2,100) (DELTAH(J), TB(J), H(J), TC(J), RHO(J), CPT(J), NUMBER(J),
010 * WF(J), NAME(J), NAME1(J), J=1, N)
011 100 FORMAT(7F10.3/F10.3,2A5)
012 50 FORMAT(I2)
013 C DELTAH=MOLAL HEAT OF VAPORIZATION AT NORMAL BOILING
014 C POINT, CAL/G-MOL
015 C TB=NORMAL BOILING POINT, K
016 C H=PARAMETER DEPENDENT ON MOLECULAR STRUCTURE
017 C TC=CRITICAL TEMPERATURE, K
018 C RHO=MOLAL LIQUID DENSITY, G-MOL/CM3
019 C CPT=MOLAL HEAT CAPACITY, CAL/G-MOL K
020 C NUMBER=PARAMETER DEPENDENT ON LIQUID DENSITY AT 20 C
021 C WF=WEIGHT FRACTION
022 WRITE(3,)(DELTAH(J), TB(J), H(J), TC(J), RHO(J), CPT(J), NUMBER(J),
023 * WF(J), J=1, N)
024 DO 2500 I=1, N, 2
025 T=273.0
026 DO 2500 J=1, 11
027 C TCLMX IS THE SUBROUTINE
028 CALL TCLMX (I, CMGLAM, TCLMX, T)
029 TCLMX(I, J)=TCLMX
030 TE(J)=T
031 T=T+10.
032 2500 CONTINUE
033 2600 CONTINUE
034 WRITE(3,500) ( (NAME(K), NAME1(K), NAME(K+1), NAME1(K+1), TCLMX(K, L),
035 * TE(L), L=1, 11), K=1, N, 2)
036 500 FORMAT('0', 'THE THERMAL CONDUCTIVITY OF ', 2A5, ' AND ', 2A5, ' IS ',
037 * F10.3, ' CAL/CM S K AT ', F4.2, ' DEGREES KELVIN')
038 STOP
039 END

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001      SUBROUTINE TCLIMX(I,CHGLAM,TCLMIX,T)
002      C THIS SUBROUTINE FIGURES OUT THE THERMAL CONDUCTIVITY OF
003      C TWO LIQUIDS TOGETHER
004      C ALL EQUATIONS COME FROM REID ET AL.
005      REAL NAME,NAME1,NUMBER
006      COMMON DELTAH(100),TB(100),H(100),TC(100),RHO(100),CPT(100),
007      * TCLMX(100,11),DELTAS(100),THMLIQ(100),TR(100),WF(100),TE(100),
008      * NAME(100),NAME1(100),NUMBER(100)
009      C DELTAS IS A PARAMETER OF ROBBINS AND KINGREA'S EQUATION FOR
010      C THERMAL CONDUCTIVITY OF A SINGLE LIQUID, (10=9.2)
011      DELTAS(I)=DELTAM(I)/TR(I)+1.987*ALOG(273./TR(I))
012      DELTAS(I+1)=DELTAM(I+1)/TR(I+1)+1.987*ALOG(273./TR(I+1))
013      C TR IS THE REDUCED TEMPERATURE
014      TR(I)=T/TC(I)
015      TR(I+1)=T/TC(I+1)
016      C THMLIQ IS ROBBINS AND KINGREA'S EQUATION (10=9.1)
017      THMLIQ(I)=(88.0+4.94*H(I))*(10.**(-3))/DELTAS(I)*((0.55/TR(I))
018      * **NUMBER(I))*(CPT(I)*RHO(I)**(4./3.))
019      THMLIQ(I+1)=(88.0+4.94*H(I+1))*(10.**(-3))/DELTAS(I+1)*((0.55/
020      * TR(I+1))*NUMBER(I+1))*(CPT(I+1)*RHO(I+1)**(4./3.))
021      C JORDAN-COATES EQUATION FOR BINARY LIQUID THERMAL CONDUCTIVITY
022      C EQUATION (10=12.3)
023      CHGLAM=ABS(THMLIQ(I+1)-THMLIQ(I))
024      TCLMIX=(EXP(13.8+CHGLAM)-0.5+13.8*(THMLIQ(I+1)+THMLIQ(I)))*
025      * (WF(I)+WF(I+1))*(THMLIQ(I)+WF(I)*THMLIQ(I+1)+WF(I+1))
026      RETURN
027      END

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*DELTAH(1)*= 7352.0000
*TB(1)*= 353.30000
*H(1)*= 0.00000000
*TC(1)*= 562.09999
*RH0(1)*= 0.88499999
*CPT(1)*= 32.400000
*NUMBER(1)*= 0.00000000
*WF(1)*= 0.59999999
*DELTAH(2)*= 8426.0000
*TB(2)*= 337.80000
*H(2)*= 1.0000000
*TC(2)*= 512.59999
*RH0(2)*= 0.79099999
*CPT(2)*= 19.500000
*NUMBER(2)*= 1.0000000
*WF(2)*= 0.40000000

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THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.092 CAL/CM S K AT 273.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.092 CAL/CM S K AT 283.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.091 CAL/CM S K AT 293.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.091 CAL/CM S K AT 303.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.091 CAL/CM S K AT 313.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.090 CAL/CM S K AT 323.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.090 CAL/CM S K AT 333.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.090 CAL/CM S K AT 343.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.089 CAL/CM S K AT 353.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.089 CAL/CM S K AT 363.00 DEGREES KELVIN
THE THERMAL CONDUCTIVITY OF BENZENE	AND METHANOL IS	0.088 CAL/CM S K AT 373.00 DEGREES KELVIN
STOP 000000		

III. SUB-ROUTINE SPECIFIC HEAT, SINGLE COMPOUND

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001      REAL NAME
002      REAL NAME1
003      C THIS PROGRAM DETERMINES THE SPECIFIC HEAT, CP, FOR VARIOUS COMPOUNDS
004      C THE COMPOUNDS DETERMINED HERE ARE CCLF3 AND CCL2F2, RESPECTIVELY
005      C THE FORMULA FOR CP IS FOUND ON PAGE 629 OF REID ET AL. AND THE "CPC"
006      C WHICH PLUG INTO THE FORMULA IS FOUND ON PAGE 631 IN A CHART
007      COMMON CPC(100,4), TE(11), CPA(100,12), NAME(100), NAME1(100)
008      READ (2,200) N
009      200  FORMAT(12)
010      READ(2,300) (NAME(J), NAME1(J), CPC(J,1), CPC(J,2), CPC(J,3), CPC(J,4),
011      * J=1,N)
012      300  FORMAT(2A5,4E10,5)
013      WRITE(3,1) (NAME(J), NAME1(J), J=1,N)
014      1    FORMAT(1X,2A5)
015      WRITE(3, ) ((CPC(J,K), K=1,4), J=1,N)
016      ID=1
017      DO 2500 I=1,N
018      C INCREMENT TEMPERATURE FROM 273 DEGREES TO 283 DEGREES BY 10 DEGREES
019      T=273.00
020      DO 2600 K=1,11
021      C ACTUAL SUBROUTINE USED TO CALCULATE SPECIFIC HEATS
022      C FROM A FORMULA ON PAGE 629 OF REID ET AL.
023      CALL CP(ID,T,CPT)
024      CPA(I,K) = CPT
025      TE(K)=T
026      T=T+10.0
027      2600 CONTINUE
028      ID=ID+1
029      2500 CONTINUE
030      WRITE(3,700)
031      700  FORMAT(' ',25X,'SPECIFIC HEATS AT VARIOUS TEMPERATURES DEGREE K')
032      WRITE(3,800) (TE(I), I=1,11)
033      800  FORMAT(' ',11F12.2)
034      DO 2700 I=1,N
035      WRITE(3,890) NAME(I), NAME1(I)
036      890  FORMAT('0', ' THE COMPOUND IS ',2A5)
037      WRITE(3,900) (CPA(I,J), J=1,11)
038      900  FORMAT(' ',11E12.5)
039      2700 CONTINUE
040      STOP
041      END

001      SUBROUTINE CP(ID,T,CPT)
002      COMMON CPC(100,4), TE(11), CPA(100,12), NAME(100), NAME1(100)
003      CPT=CPC(ID,1)+CPC(ID,2)*T+(CPC(ID,3))*T**2+
004      * (CPC(ID,4))*T**3
005      RETURN
006      END

```

CCLF3
 CCL2F2
 CPC(1,1)# 54.490000
 CPC(1,2)# 0.45650000E-01
 CPC(1,3)# -0.37649999E-04
 CPC(1,4)# 0.10650000E-07
 CPC(2,1)# 75.469959
 CPC(2,2)# 0.42570000E-01
 CPC(2,3)# -0.36029999E-04
 CPC(2,4)# 0.10370000E-07

SPECIFIC HEATS AT VARIOUS TEMPERATURES DEGREE K										
273.00	283.00	293.00	303.00	313.00	323.00	333.00	343.00	353.00	363.00	373.00
THE COMPOUND IS CCLF3										
0.64363E+02	0.64635E+02	0.64901E+02	0.65162E+02	0.65416E+02	0.65666E+02	0.65910E+02	0.66148E+02	0.66381E+02	0.66609E+02	0.66832E+02
THE COMPOUND IS CCL2F2										
0.84617E+02	0.84867E+02	0.85111E+02	0.85349E+02	0.85583E+02	0.85811E+02	0.86033E+02	0.86251E+02	0.86464E+02	0.86671E+02	0.86874E+02
STOP 000000										

IV. SUB-ROUTINE DENSITY, SINGLE LIQUID

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001 C PLEASE NOTE, THIS PROGRAM SUBROUTINE WILL NOT WORK FOR
002 C REDUCED TEMPERATURES OF 1.0 OR GREATER OR COMPONENTS
003 C WITH CRITICAL TEMPERATURES OF 373 K OR LESS.
004     REAL NAME,NAME1,NAME2,NAME3,NAME4
005     COMMON TC(100),OMEGA(100),PC(100),TE(100),NAME(100),
006            * NAME1(100),NAME2(100),NAME3(100),NAME4(100),
007            * SNGDEN(100,11),TRR(100,11)
008 C THIS PROGRAM IS DESIGNED TO CALCULATE THE DENSITY OF
009 C A PURE LIQUID USING THE GUNN AND YAMADA METHOD.
010 C
011 C
012 C TC=CRITICAL TEMPERATURE
013 C OMEGA=PITZER'S ACENTRIC FACTOR
014 C PC=CRITICAL PRESSURE
015     READ(2,100) N
016 100  FORMAT(I2)
017     READ(2,150) (TC(J),OMEGA(J),PC(J),NAME(J),NAME1(J),NAME2(J),
018            $ NAME3(J),NAME4(J),J=1,N)
019 150  FORMAT(3F10,4,5A5)
020     WRITE(3,)(TC(J),OMEGA(J),PC(J),J=1,N)
021     DO 2500 I=1,N
022         T=273.
023 C TEMPERATURE INCREMENTS EVERY 10 DEGREES
024         DO 2600 J=1,11
025             CALL LSDEN(I,T,RHO,TR)
026             TRR(I,J)=TR
027             SNGDEN(I,J)=RHO
028             TE(J)=T
029             T=T+10.
030 2600  CONTINUE
031 2500  CONTINUE
032         DO 6000 I=1,N
033             DO 5000 J=1,11
034                 WRITE(3,500) NAME(I),NAME1(I),NAME2(I),NAME3(I),
035                    $NAME4(I),SNGDEN(I,J),TE(J)
036                 IF (TRR(I,J).GE.1.00) GO TO 600
037 500  FORMAT('0',' THE LIQUID DENSITY OF ',5A5,' IS ',
038            $ F10.5,' AT ',F5.1,' DEGREES KELVIN')
039 5000  CONTINUE
040 6000  CONTINUE
041 600  STOP
042     END

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001      SUBROUTINE LSDEN(I,T,RHO,TR)
002      C PLEASE NOTE, THIS PROGRAM SUBROUTINE WILL NOT WORK FOR
003      C REDUCED TEMPERATURES OF 1.0 OR GREATER OR COMPONENTS
004      C WITH CRITICAL TEMPERATURES OF 373 K OR LESS.
005      C THIS SUBROUTINE CALCULATES THE DENSITY OF A PURE LIQUID.
006      C ALL EQUATIONS ARE FROM RIED ET AL, PP. 60-61.
007      COMMON TC(100),OMEGA(100),PC(100),TE(100),NAME(100),
008      * NAME1(100),NAME2(100),NAME3(100),NAME4(100),
009      * SNGDEN(100,11),TRR(100,11)
010      C      TR=REDUCED TEMPERATURE
011      TR=T/TC(I)
012      IF (TR.GT.1.0) GO TO 990
013      IF ((0.2.LE.TR).AND.(TR.LE.0.8)) GO TO 800
014      C      VRO=FUNCTION OF REDUCED TEMPERATURE
015      C      EQ.(3-15.5)
016      VRO=1.0+1.3*(1.-TR)**.5*ALOG10(1.-TR)-0.50879*
017      * (1.-TR)=0.91534*(1.-TR)**2
018      GO TO 900
019      C      EQ.(3-15.4)
020      800      VRO=0.33593+0.33953*TR+1.51941*TR**2
021      * -2.02512*TR**3+1.11422*TR**4
022      C      VSC=SCALING PARAMETER
023      C      EQ.(3-15.3)
024      900      VSC=1.987*TC(I)*(0.292+0.0967*OMEGA(I))/PC(I)
025      C      TAU=FUNCTION OF REDUCED TEMPERATURE
026      C      EQ.(3-15.6)
027      TAU=0.29607+0.09045*TR+0.04842*TR**2
028      C      RHO=LIQUID DENSITY
029      C      EQ.(3-15.1)
030      RHO=1./(VRO*(1.-OMEGA(I)*TAU)*VSC)
031      WRITE(3,1) TR
032      WRITE(3,2) VRO
033      WRITE(3,3) VSC
034      WRITE(3,4) TAU
035      WRITE(3,5) RHO
036      990      RETURN
037      END

```

'TC(1)'= 499.00000	'VSC'= 5.0056224
'OMEGA(1)'= 0.19000000	'TAU'= 0.21723470
'PC(1)'= 54.200000	'RHO'= 0.52205732
'TC(2)'= 302.00000	'TR'= 0.54709418
'OMEGA(2)'= 0.18000000	'VRD'= 0.37315603
'PC(2)'= 38.700000	'VSC'= 5.0056224
	'TAU'= 0.23209264
	'RHO'= 0.56006430
	'TR'= 0.56713426
	'VRD'= 0.37793559
	'VSC'= 5.0056224
	'TAU'= 0.22919884
	'RHO'= 0.55266358
	'TR'= 0.58717436
	'VRD'= 0.38289552
	'VSC'= 5.0056224
	'TAU'= 0.22626614
	'RHO'= 0.54518689
	'TR'= 0.60721444
	'VRD'= 0.38806229
	'VSC'= 5.0056224
	'TAU'= 0.22329455
	'RHO'= 0.53761096
	'TR'= 0.62725452
	'VRD'= 0.39346661
	'VSC'= 5.0056224
	'TAU'= 0.22028407
	'RHO'= 0.52991027
	'TR'= 0.64729460
	'VRD'= 0.39914351
	'VSC'= 5.0056224
	'TAU'= 0.21414644
	'RHO'= 0.51402588
	'TR'= 0.68737476
	'VRD'= 0.41147690
	'VSC'= 5.0056224
	'TAU'= 0.21101928
	'RHO'= 0.50578691
	'TR'= 0.70741484
	'VRD'= 0.41822503
	'VSC'= 5.0056224
	'TAU'= 0.20785323
	'RHO'= 0.49731432
	'TR'= 0.72745492
	'VRD'= 0.42542910
	'VSC'= 5.0056224
	'TAU'= 0.20464829
	'RHO'= 0.48858321
	'TR'= 0.74749500
	'VRD'= 0.43314569
	'VSC'= 5.0056224
	'TAU'= 0.20140446
	'RHO'= 0.47957145
	'TR'= 0.90397350
	'VRD'= 0.53276271

'VSC' 4.2577964
 'TAU' 0.17473832
 'RHO' 0.45515629
 'TR' 0.93708609
 'VRD' 0.57266892
 'VSC' 4.2577964
 'TAU' 0.16879150
 'RHO' 0.42297143
 'TR' 0.97019868
 'VRD' 0.64161272
 'VSC' 4.2577964
 'TAU' 0.16273849
 'RHO' 0.37709776

THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.56006 AT 273.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.55266 AT 283.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.54519 AT 293.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.53761 AT 303.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.52991 AT 313.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.52206 AT 323.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.51403 AT 333.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.50579 AT 343.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.49731 AT 353.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.48858 AT 363.0 DEGREES KELVIN
THE LIQUID DENSITY OF ETHYL MERCAPTAN	IS	0.47957 AT 373.0 DEGREES KELVIN
THE LIQUID DENSITY OF CHLOROTRIFLUOROMETHANE	IS	0.45516 AT 273.0 DEGREES KELVIN
THE LIQUID DENSITY OF CHLOROTRIFLUOROMETHANE	IS	0.42297 AT 283.0 DEGREES KELVIN
THE LIQUID DENSITY OF CHLOROTRIFLUOROMETHANE	IS	0.37710 AT 293.0 DEGREES KELVIN
THE LIQUID DENSITY OF CHLOROTRIFLUOROMETHANE	IS	0.37710 AT 303.0 DEGREES KELVIN
STOP 000000		

V. SUB-ROUTINE VISCOSITY, SINGLE GAS

```

001      REAL NAME
002      COMMON VISC(100,11), XMW(100), EK(100), DEL(100), XMF(100),
003      * NAME(100), VISMV(100,11), TE(100), TC(100), XNC(100)
004      C THIS PROGRAM IS DESIGNED TO TEST A SUBROUTINE WHICH CALCULATES
005      C VISCOSITY FOR A SINGLE GAS
006      C THE GASES USED HERE ARE CH3CL AND SO2
007      C TC=CRITICAL TEMPERATURE
008      C XMW=MOLECULAR WEIGHT
009      C XNC=SUMMATION OF THE NUMBER OF THE SAME ATOMIC GROUPS TIMES THE
010      C VALUE OF THE GROUP CONTRIBUTION
011      C VISC=VISCOSITY
012      C NAME=THE NAME OF THE COMPOUND
013      C TE=TEMPERATURE OF THE GAS
014      READ (2,300) N
015      300 FORMAT (I2)
016      READ (2,200) (NAME(J), XMW(J), TC(J), XNC(J), J=1, N)
017      200 FORMAT (A5, 2X, 3E12.5)
018      DO 2500 I=1, N
019      T=374.
020      DO 2600 K=1, 11
021      CALL VISCOS(N, VIS, T, I)
022      VISC(I, K)=VIS
023      TE(K)=T
024      T=T+10.0
025      2600 CONTINUE
026      2500 CONTINUE
027      WRITE(3, 350)
028      350 FORMAT(' ', 'VISCOSITY OF VARIOUS GASES')
029      WRITE(3, 450) (TE(K), K=1, 11)
030      450 FORMAT(' ', 11F12.2)
031      DO 5000 I=1, N
032      WRITE(3, 550) NAME(I)
033      550 FORMAT(A6)
034      WRITE(3, 650) (VISC(I, K), K=1, 11)
035      650 FORMAT(' ', 11E12.5)
036      5000 CONTINUE
037      STOP
038      END

```

```

001      SUBROUTINE VISCOS (N, VIS, T, I)
002      REAL NAME
003      COMMON VISC(100,11), XMW(100), EK(100), DEL(100), XMF(100),
004      * NAME(100), VISMV(100,11), TE(100), TC(100), XNC(100)
005      WRITE(3, ) TC(I), T, XMW(I), XNC(I)
006      TR=T/TC(I)
007      C EQUATION (9-4, 22) FROM REID ET AL.
008      STA=XMW(I)**.5*TC(I)/XNC(I)
009      WRITE(3, ) TR, STA
010      C EQUATION (9-4, 21)
011      VIS=(STA*TR)/(1+.36*TR*(TR-1.))**.167
012      WRITE(3, 4) NAME(I), VIS
013      4 FORMAT(' ', ' THE VISCOSITY FOR ', A5, ' IS ', F10.5, ' MICROPOISE')
014      RETURN
015      END

```

TC(1)= 416.30000
T= 374.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.89839059
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 139.91225 MICROPOISE

TC(1)= 416.30000
T= 384.00000
XMW(1)= 50.488000
XNC(1)= 19.108000

TR= 0.92241174
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 143.47791 MICROPOISE

TC(1)= 416.30000
T= 394.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.94643287
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 147.02557 MICROPOISE

TC(1)= 416.30000
T= 404.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.97045401
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 150.55479 MICROPOISE

TC(1)= 416.30000
T= 414.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.99447516
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 154.06523 MICROPOISE

TC(1)= 416.30000
T= 424.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 1.0184963
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 157.55651 MICROPOISE

TC(1)= 416.30000
T= 434.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.0425174

STA= 154.86993

THE VISCOSITY FOR CH3CL IS 161.02832 MICROPOISE

TC(1)= 416.30000
T= 444.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 1.0665386
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 164.48037 MICROPOISE

TC(1)= 416.30000
T= 454.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 1.0905597
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 167.91239 MICROPOISE

TC(1)= 416.30000
T= 464.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 1.1145808
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 171.32416 MICROPOISE

TC(1)= 416.30000
T= 474.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 1.1386020
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 174.71549 MICROPOISE

TC(2)= 430.80000
T= 374.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.86815229
STA= 214.96857

THE VISCOSITY FOR SO2 IS 187.94157 MICROPOISE

TC(2)= 430.80000
T= 384.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.89136492
STA= 214.96857

THE VISCOSITY FOR SO2 IS 192.75423 MICROPOISE

TC(2)= 430.80000
T= 394.00000
XMW(2)= 64.063000

XNC(2)= 16.040000

TR= 0.91457754
STA= 214.96857

THE VISCOSITY FOR 802 IS 197.54433 MICROPOISE
TC(2)= 430.80000
T= 404.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.93779017
STA= 214.96857

THE VISCOSITY FOR 802 IS 202.31128 MICROPOISE
TC(2)= 430.80000
T= 414.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.96100280
STA= 214.96857

THE VISCOSITY FOR 802 IS 207.05455 MICROPOISE
TC(2)= 430.80000
T= 424.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.98481342
STA= 214.96857

THE VISCOSITY FOR 802 IS 211.77364 MICROPOISE
TC(2)= 430.80000
T= 434.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 1.0074281
STA= 214.96857

THE VISCOSITY FOR 802 IS 216.46810 MICROPOISE
TC(2)= 430.80000
T= 444.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 1.0306407
STA= 214.96857

THE VISCOSITY FOR 802 IS 221.13750 MICROPOISE
TC(2)= 430.80000
T= 454.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 1.0538533
STA= 214.96857

THE VISCOSITY FOR 802 IS 225.78145 MICROPOISE

TC(2)= 430.80000
 T= 464.00000
 XMM(2)= 64.063000
 XNC(2)= 16.040000

TR= 1.0770659
 STA= 214.96857

THE VISCOSITY FOR SO2 IS 230.39964 MICROPOISE
 TC(2)= 430.80000
 T= 474.00000
 XMM(2)= 64.063000
 XNC(2)= 16.040000

TR= 1.1002786
 STA= 214.96857

THE VISCOSITY FOR SO2 IS 234.99173 MICROPOISE
 VISCOSITY OF VARIOUS GASES

	374.00	384.00	394.00	404.00	414.00	424.00	434.00	444.00	454.00	464.00	474.00
CH3CL	0.13991E+03	0.14348E+03	0.14703E+03	0.15059E+03	0.15407E+03	0.15756E+03	0.16103E+03	0.16448E+03	0.16791E+03	0.17132E+03	0.17472E+03
SO2	0.18794E+03	0.19275E+03	0.19754E+03	0.20231E+03	0.20705E+03	0.21177E+03	0.21647E+03	0.22114E+03	0.22578E+03	0.23040E+03	0.23499E+03
STOP	000000										

VI. SUB-ROUTINE VISCOSITY, BINARY GAS

```

001 C THIS PROGRAM IS DESIGNED TO TEST A SUBROUTINE FOR GAS MIXTURE
002 C VISCOSITY
003 C A SUBROUTINE FOR VISCOSITY FOR SINGLE COMPONENTS IS
004 C INCORPORATED IN THIS PROGRAM ALONG WITH A SUBROUTINE FOR
005 C THE VISCOSITY OF A GAS MIXTURE
006 REAL NAME
007 COMMON VISC(100,11), XHW(100), EK(100), DEL(100), XMF(100),
008 * NAME(100), VISMX(100,11), TE(100), TC(100), XNC(100)
009 C VISC=VISCOSITY
010 C EK=K/EPSILON
011 C DEL=DELTA
012 C NAME=NUMERICAL REPRESENTATION OF A GAS
013 C VISMX=VISCOSITY FOR GAS MIXTURE
014 C N IS THE NUMBER OF CARDS OR COMPOUNDS
015 READ(2,200)N
016 200 FORMAT(I2)
017 C GIVEN IN THE CARD LIST IS THE NAME OF THE COMPOUND, IT'S
018 C MOLECULAR WEIGHT, CRITICAL TEMP., A FUNCTION OF THE EQUATION
019 C FOR VISCOSITY OF SINGLE COMPONENTS, K/EPSILON, DELTA, AND THE
020 C MOLECULAR FRACTION
021 READ (2,400) (NAME(J),XHW(J), TC(J),XNC(J),J=1,N)
022 400 FORMAT( A5,1X,3E12,5)
023 READ(2,300)(EK(J), DEL(J), XMF(J), J=1,N)
024 300 FORMAT(3E12,5)
025 C THE TEMPERATURE IS SET AT SOME ARBITRARY DEGREE, SAY 273 K,
026 C AND SHOULD INCREMENT EVERY 10 DEGREES
027 DO 2400 I=1,N
028 T=273
029 DO 2300 K=1,11
030 CALL VISCOS(N,VIS,T,I)
031 VISC(I,K)=VIS
032 T=T+10.0
033 2300 CONTINUE
034 2400 CONTINUE
035 DO 2600 I=1,N,2
036 T=273.
037 DO 2500 K=1,11
038 CALL VISMIX (T,VISM,I,K)
039 VISMX(I,K)=VISM
040 TE(K)=T
041 T=T+10.
042 2500 CONTINUE
043 2600 CONTINUE
044 WRITE(3,500) (TE(K),K=1,11)
045 500 FORMAT(11F12,2)
046 DO 2700 I=1,N
047 WRITE(3,600) NAME(I), NAME(I+1)
048 600 FORMAT(' ', ' VISCOSITY MIXTURE FOR ',A5,' AND ',A5,' IN
049 * MICROPOISE')
050 WRITE(3,700) (VISMX(I,K),K=1,11)
051 700 FORMAT(11E12,5)
052 2700 CONTINUE
053 STOP
054 END

```

```

001 SUBROUTINE VISCOS (N,VIS,T,I)
002 REAL NAME
003 COMMON VISC(100,11), XMW(100), EK(100), DEL(100), XMF(100),
004 * NAME(100), VISM(100,11), TE(100), TC(100), XNC(100)
005 WRITE(3,1) TC(I),T,XMW(I),XNC(I)
006 TR=T/TC(I)
007 C EQUATION (9=4,22) FROM REID ET AL.
008 STA=XMW(I)**.5*TC(I)/XNC(I)
009 WRITE(3,1)TR,STA
010 C EQUATION (9=4,21)
011 VIS=(STA*TR)/(1.+0.36*TR*(TR-1.))**.167
012 WRITE(3,4) NAME(I),VIS
013 4 FORMAT(' ', ' THE VISCOSITY FOR ',A5,' IS ',F10.5)
014 RETURN
015 END

001 SUBROUTINE VISMIX (T,VISM,I,K)
002 REAL NAME
003 C THIS IS THE ACTUAL SUBROUTINE THAT WILL CALCULATE THE VISCOSITY
004 C FOR A GAS MIXTURE
005 DIMENSION TSTR(100)
006 COMMON VISC(100,11), XMW(100), EK(100), DEL(100), XMF(100),
007 * NAME(100), VISM(100,11), TE(100), TC(100), XNC(100)
008 C THE FOLLOWING EQUATIONS ARE FROM REID,ET AL. P. 416-417 FOR USE
009 C IN DETERMINING THE VISCOSITY OF GAS MIXTURES
010 C THESE EQUATIONS ARE THOSE SUGGESTED BY BROKAW IN THE BOOK
011 C TEMPERATURE IS IN DEGREES KELVIN
012 C XMF = MOLE FRACTION
013 C XMW = MOLECULAR WEIGHT
014 C TSTR = TEMPERATURE X BOLTZMANN'S CONST./ CHARACTERISTIC ENERGY
015 C VISC = VISCOSITY FOR THE SINGLE COMPOUNDS
016 TSTR(I) = EK(I) * T
017 TSTR(I+1) = EK(I+1) * T
018 C EQ. (9=5,12)
019 SIJ=(1.+(TSTR(I) * TSTR(I+1))**.5+(DEL(I) * DEL(I+1)/4.))/
020 * ((1.+TSTR(I) )+(DEL(I) **2/4.))**.5*(1.+TSTR(I+1)+
021 * (DEL(I+1)**2/4.))**.5)
022 C EQ. (9=5,10)
023 XMIJ=XMW(I) /XMW(I+1)
024 C EQ. (9=5,9)
025 XLMIJ=(4./((1.+XMIJ**(-1))*(1.+XMIJ)))**.25
026 C EQ. (9=5,8)
027 AIJ=XLMIJ*(XMIJ**(-.5))*(1.+(XMIJ-XMIJ**.45)/(2.*(1.+XMIJ)
028 * +(1.+XMIJ**.45)*XLMIJ**(-.5)/(1.+XLMIJ)))
029 C EQ. (9=5,7)
030 XPHIJ=((VISC(I,K)/VISC(I+1,K))**.5)*SIJ*AIJ
031 C THESE NEXT EQUATIONS ARE WHERE THE TWO COMPOUNDS HAVE SWITCHED
032 C POSITIONS FOR THE SUMMATION OF THE VISCOSITY MIXTURE EQUATION
033 XMIJ=XMW(I+1)/XMW(I)
034 XLMIJ=(4./((1.+XMIJ**(-1))*(1.+XMIJ)))**.25
035 AIJ=XLMIJ*(XMIJ**(-.5))*(1.+(XMIJ-XMIJ**.45)/(2.*(1.+XMIJ)
036 * +(1.+XMIJ**.45)*XLMIJ**(-.5)/(1.+XLMIJ)))
037 XPHIJ=((VISC(I+1,K)/VISC(I,K))**.5)*SIJ*AIJ
038 C THE VISCOSITY EQUATION (9=5,1) , VISM IN MICRO POISE
039 WRITE(3,1)T,TSTR(I) ,TSTR(I+1),SIJ,XMIJ,XLMIJ,AIJ,XPHIJ,XMIJ,
040 * XLMIJ,AIJ,XPHIJ
041 VISM=XMF(I) *VISC(I,K)/(XMF(I) +XMF(I+1)*XPHIJ)+XMF(I+1)*
042 * VISC(I+1,K)/(XMF(I) *XPHIJ+XMF(I+1))
043 WRITE(3,1) XMF(I) ,VISC(I,K),XMF(I+1), XPHIJ, VISC(I+1,K),XPHIJ,
044 * VISM
045 10 FORMAT(7F10.4)
046 RETURN
047 END

```

TC(1)= 416.30000
T= 273.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.65577710
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 103.00789
TC(1)= 416.30000
T= 283.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.67979823
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 106.72485
TC(1)= 416.30000
T= 293.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.70381936
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 110.42977
TC(1)= 416.30000
T= 303.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.72784051
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 114.12192
TC(1)= 416.30000
T= 313.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.75186165
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 117.80060
TC(1)= 416.30000
T= 323.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.77588278
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 121.46517
TC(1)= 416.30000
T= 333.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.79990393

STA= 154.86993

THE VISCOSITY FOR CH3CL IS 125.11496
TC(1)= 416.30000
T= 343.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.82392506
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 128.74937
TC(1)= 416.30000
T= 353.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.84794620
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 132.36783
TC(1)= 416.30000
T= 363.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.87196735
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 135.96978
TC(1)= 416.30000
T= 373.00000
XMW(1)= 50.488000
XNC(1)= 19.100000

TR= 0.89598848
STA= 154.86993

THE VISCOSITY FOR CH3CL IS 139.55472
TC(2)= 430.80000
T= 273.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.63370474
STA= 214.96857

THE VISCOSITY FOR SO2 IS 138.22637
TC(2)= 430.80000
T= 283.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.65691736
STA= 214.96857

THE VISCOSITY FOR SO2 IS 143.22628
TC(2)= 430.80000
T= 293.00000
XMW(2)= 64.063000

XNC(2)= 16.040000

TR= 0.68013000
STA= 214.96857

THE VISCOSITY FOR SO2 IS 148.21151
TC(2)= 430.80000
T= 303.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.70334263
STA= 214.96857

THE VISCOSITY FOR SO2 IS 153.18112
TC(2)= 430.80000
T= 313.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.72655526
STA= 214.96857

THE VISCOSITY FOR SO2 IS 158.13419
TC(2)= 430.80000
T= 323.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.74976788
STA= 214.96857

THE VISCOSITY FOR SO2 IS 163.06986
TC(2)= 430.80000
T= 333.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.77298051
STA= 214.96857

THE VISCOSITY FOR SO2 IS 167.98729
TC(2)= 430.80000
T= 343.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.79619314
STA= 214.96857

THE VISCOSITY FOR SO2 IS 172.88568
TC(2)= 430.80000
T= 353.00000
XMW(2)= 64.063000
XNC(2)= 16.040000

TR= 0.81940576
STA= 214.96857

THE VISCOSITY FOR SO2 IS 177.76425

*TC(2)'= 430.80000
*T'= 363.00000
*XHW(2)'= 64.063000
*XNC(2)'= 16.040000

*TR'= 0.84261839
*STA'= 214.96857

THE VISCOSITY FOR SO2 IS 182.62228

*TC(2)'= 430.80000
*T'= 373.00000
*XHW(2)'= 64.063000
*XNC(2)'= 16.040000

*TR'= 0.86583102
*STA'= 214.96857

THE VISCOSITY FOR SO2 IS 187.45908

*T'= 273.00000
*TSTR(1)'= 113022.00
*TSTR(2)'= 94731.000
*SIJ'= 1.0000001
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94538140
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0532967

*XMF(1)'= 0.49400000
*VISC(1,1)'= 103.00789
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94538140
*VISC(2,1)'= 138.22637
*XPHJI'= 1.0532967
*VISM'= 114.90090

*T'= 283.00000
*TSTR(1)'= 117162.00
*TSTR(2)'= 98201.000
*SIJ'= 0.99999988
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94534118
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0533010

*XMF(1)'= 0.49400000
*VISC(1,2)'= 106.72485
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94534118
*VISC(2,2)'= 143.22628
*XPHJI'= 1.0533010
*VISM'= 119.05074

*T'= 293.00000
*TSTR(1)'= 121302.00
*TSTR(2)'= 101671.00
*SIJ'= 0.99999990
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94529916
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0533479

*XMF(1)'= 0.49400000
*VISC(1,3)'= 110.42977
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94529916
*VISC(2,3)'= 148.21151
*XPHJI'= 1.0533479
*VISM'= 123.18758

*T'= 303.00000
*TSTR(1)'= 129442.00
*TSTR(2)'= 105141.00
*SIJ'= 1.0000002
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94525549
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0533972

*XMF(1)'= 0.49400000
*VISC(1,4)'= 114.12192
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94525549
*VISC(2,4)'= 153.18112
*XPHJI'= 1.0533972
*VISM'= 127.31063

*T'= 313.00000
*TSTR(1)'= 129582.00
*TSTR(2)'= 108611.00
*SIJ'= 0.99999991
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94520940
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0534479

*XMF(1)'= 0.49400000
*VISC(1,5)'= 117.80060
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94520940
*VISC(2,5)'= 158.13419

*XPHJI'= 1.0534479
*VISM'= 131.41916

*T'= 323.00000
*TSTR(1)'= 133722.00
*TSTR(2)'= 112081.00
*SIJ'= 0.99999981
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94516177
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0535008

*XMF(1)'= 0.49400000
*VISC(1,6)'= 121.46517
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94516177
*VISC(2,6)'= 163.06986
*XPHJI'= 1.0535008
*VISM'= 135.51241

*T'= 333.00000
*TSTR(1)'= 137862.00
*TSTR(2)'= 115551.00
*SIJ'= 1.0000000
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94511272
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0535558

*XMF(1)'= 0.49400000
*VISC(1,7)'= 125.11496
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94511272
*VISC(2,7)'= 167.98729
*XPHJI'= 1.0535558
*VISM'= 139.58964

*T'= 343.00000
*TSTR(1)'= 142002.00
*TSTR(2)'= 119021.00
*SIJ'= 0.99999990
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94506180
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0536124

*XMF(1)'= 0.49400000
*VISC(1,8)'= 128.74937

*XMF(2)'= 0.26199999
*XPHIJ'= 0.94506180
*VISC(2,8)'= 172.88468
*XPHJI'= 1.0536124
*VISM'= 143.65022

*T'= 353.00000
*TSTR(1)'= 146142.00
*TSTR(2)'= 122491.00
*SIJ'= 1.0000001
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94500963
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0536709

*XMF(1)'= 0.49400000
*VISC(1,9)'= 132.36783
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94500963
*VISC(2,9)'= 177.76425
*XPHJI'= 1.0536709
*VISM'= 147.69348

*T'= 363.00000
*TSTR(1)'= 150282.00
*TSTR(2)'= 129961.00
*SIJ'= 0.99999990
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94495575
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0537306

*XMF(1)'= 0.49400000
*VISC(1,10)'= 135.96978
*XMF(2)'= 0.26199999
*XPHIJ'= 0.94495575
*VISC(2,10)'= 182.62228
*XPHJI'= 1.0537306
*VISM'= 151.71884

*T'= 373.00000
*TSTR(1)'= 154422.00
*TSTR(2)'= 129431.00
*SIJ'= 1.0000000
*XMIJ'= 0.78809921
*XLMIJ'= 0.99647047
*AIJ'= 1.0951338
*XPHIJ'= 0.94490089
*XMJI'= 1.2688758
*XLMJI'= 0.99647047
*AJI'= 0.90923049
*XPHJI'= 1.0537921

```
*XMF(1)*= 0.49400000
*VISC(1,1)*= 139.55472
*XMF(2)*= 0.26199999
*XPWIJ*= 0.94490089
*VISC(2,1)*= 187.45909
*XPWJI*= 1.0537921
*VISM*= 155.72559
```

```
273.00 283.00 293.00 303.00 313.00 323.00 333.00 343.00 353.00 363.00 373.00
VISCOSITY MIXTURE FOR CH3CL AND SO2 IN MICROPOISE
0.11490E+03 0.11905E+03 0.12319E+03 0.12731E+03 0.13142E+03 0.13551E+03 0.13959E+03 0.14365E+03 0.14769E+03 0.15172E+03 0.15573E+03
VISCOSITY MIXTURE FOR SO2 AND IN MICROPOISE
0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
STOP 000000
```


VII. SUB-ROUTINE VISCOSITY, SINGLE LIQUID

```

001      COMMON      VISC(100,11),DELRI(100), DELNI(100),XNCARB(100)
002 C THIS PROGRAM TESTS OUT A SUBROUTINE DESIGNED TO CALCULATE THE
003 C VISCOSITY OF A SINGLE LIQUID
004 C THE EQUATIONS USED ARE FROM "PROPERTIES OF A GAS AND LIQUIDS" BY
005 C REID ET AL.
006 C DELBI=CONSTANT CALCULATED FROM TABLE 9-11
007 C DELNI=CONSTANT CALCULATED FROM TABLE 9-11
008 C XNCARB=NUMBER OF CARBONS
009 C THE PROGRAM WILL INCREMENT TEMPERATURE BY 10 DEGREES
010      READ(2,50) N
011      50      FORMAT(I2)
012      READ(2,100) (DELRI(J),DELNI(J),XNCARB(J),J=1,N)
013      100     FORMAT(3F10,4)
014      WRITE(3,)(DELBI(J),DELNI(J),XNCARB(J),J=1,N)
015      DO 2600 I=1,N
016      T=229.44
017      DO 2500 J=1,11
018 C VISILI IS THE PROGRAM FOR LIQUID VISCOSITY
019      CALL VISILI(XNST=,BA,TO,B,VISGAS,T,I)
020      VISC(I,J)=VISGAS
021      WRITE(3,400) VISC(I,J),T
022      400     FORMAT('0', ' THE LIQUID VISCOSITY IS ',F10.5, ' CENTIPOISE AT ',IX,
023      * F6.2, ' DEGREES')
024      T=T+10.
025      2500    CONTINUE
026      2600    CONTINUE
027      STOP
028      END

```

```

001      SUBROUTINE VISILI(XNSTR,BA,TO,B,VISGAS,T,I)
002      COMMON      VISC(100,11),DELBI(100), DELNI(100),XNCARB(100)
003      XNSTR=XNCARB(I)+DELNI(I)
004 C EQ. (9-11.6)
005      IF(XNSTR.GT.20.) GO TO 200
006      BA=24.79+66.885*XNSTR      =1.3173*XNSTR**2+00.00377*XNSTR**3
007 C EQ. (9-11.10)
008      TO=28.86+37.439*XNSTR-1.3547*XNSTR**2+0.02076*XNSTR**3
009 C EQ. (9-11.7)
010      GO TO 300
011      200     TO=8.164*XNSTR+238.59
012 C EQ. (9-11.8)
013      BA=530.59+13.740*XNSTR
014 C EQ. (9-11.11)
015      300     B=BA+DELBI(I)
016 C EQ. (9-11.9)
017      VISGAS      =10.*(B*(1./T-1./TO))
018 C EQ. (9-11.5)
019      WRITE(3, ) XNSTR,DELNI(I),XNCARB(I),DELRI(I),BA,B,VISGAS
020      RETURN
021      END

```

DELBI(1) 452.62000
DELNI(1) 7.0799999
XNCARB(1) 13.000000
DELBI(2) 179.34768
DELNI(2) 4.4699999
XNCARB(2) 13.000000

XNSTR 20.080000
DELNI(1) 7.0799999
XNCARB(1) 13.000000
DELBI(1) 452.62000
BA 806.48920
B 1259.1092
VISGAS 286.46857

THE FOLLOWING 11 VISCOSITIES ARE FOR BENZOPHENONE

THE LIQUID VISCOSITY IS 286.46857 CENTIPOISE AT 229.44 DEGREES

XNSTR 20.080000
DELNI(1) 7.0799999
XNCARB(1) 13.000000
DELBI(1) 452.62000
BA 806.48920
B 1259.1092
VISGAS 165.90388

THE LIQUID VISCOSITY IS 165.90388 CENTIPOISE AT 235.44 DEGREES

XNSTR 20.080000
DELNI(1) 7.0799999
XNCARB(1) 13.000000
DELBI(1) 452.62000
BA 806.48920
B 1259.1092
VISGAS 100.45376

THE LIQUID VISCOSITY IS 100.45376 CENTIPOISE AT 245.44 DEGREES

XNSTR 20.080000
DELNI(1) 7.0799999
XNCARB(1) 13.000000
DELBI(1) 452.62000
BA 806.48920
B 1259.1092
VISGAS 63.260971

THE LIQUID VISCOSITY IS 63.26097 CENTIPOISE AT 255.44 DEGREES

XNSTR 20.080000
DELNI(1) 7.0799999
XNCARB(1) 13.000000
DELBI(1) 452.62000
BA 806.48920
B 1259.1092
VISGAS 41.251287

THE LIQUID VISCOSITY IS 41.25129 CENTIPOISE AT 265.44 DEGREES

XNSTR 20.080000
DELNI(1) 7.0799999
XNCARB(1) 13.000000

*DELBI(1)'= 452.62000
*BA'= 806.48920
*B'= 1259.1092
*VISGAS'= 27.747437

THE LIQUID VISCOSITY IS 27.74744 CENTIPOISE AT 275.44 DEGREES

*XNSTR'= 20.080000
*DELNI(1)'= 7.0799999
*XNCARB(1)'= 13.000000
*DELBI(1)'= 452.62000
*BA'= 806.48920
*B'= 1259.1092
*VISGAS'= 19.189993

THE LIQUID VISCOSITY IS 19.18999 CENTIPOISE AT 285.44 DEGREES

*XNSTR'= 20.080000
*DELNI(1)'= 7.0799999
*XNCARB(1)'= 13.000000
*DELBI(1)'= 452.62000
*BA'= 806.48920
*B'= 1259.1092
*VISGAS'= 13.607182

THE LIQUID VISCOSITY IS 13.60718 CENTIPOISE AT 295.44 DEGREES

*XNSTR'= 20.080000
*DELNI(1)'= 7.0799999
*XNCARB(1)'= 13.000000
*DELBI(1)'= 452.62000
*BA'= 806.48920
*B'= 1259.1092
*VISGAS'= 9.8682008

THE LIQUID VISCOSITY IS 9.86820 CENTIPOISE AT 305.44 DEGREES

*XNSTR'= 20.080000
*DELNI(1)'= 7.0799999
*XNCARB(1)'= 13.000000
*DELBI(1)'= 452.62000
*BA'= 806.48920
*B'= 1259.1092
*VISGAS'= 7.3038937

THE LIQUID VISCOSITY IS 7.30389 CENTIPOISE AT 315.44 DEGREES

*XNSTR'= 20.080000
*DELNI(1)'= 7.0799999
*XNCARB(1)'= 13.000000
*DELBI(1)'= 452.62000
*BA'= 806.48920
*B'= 1259.1092
*VISGAS'= 5.5068364

THE LIQUID VISCOSITY IS 5.50684 CENTIPOISE AT 325.44 DEGREES

*XNSTR'= 17.470000
*DELNI(2)'= 4.4699999
*XNCARB(2)'= 13.000000

DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISGAS 51.981450

THE FOLLOWING 11 VISCOSITIES ARE FOR D-METHYLDIPHENYLAMIDE

THE LIQUID VISCOSITY IS
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISGAS 34.417189

51.98145 CENTIPOISE AT 225.44 DEGREES

THE LIQUID VISCOSITY IS
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISGAS 23.566461

34.41719 CENTIPOISE AT 235.44 DEGREES

THE LIQUID VISCOSITY IS
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISGAS 16.622317

23.56646 CENTIPOISE AT 245.44 DEGREES

THE LIQUID VISCOSITY IS
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISGAS 12.036814

16.62232 CENTIPOISE AT 255.44 DEGREES

THE LIQUID VISCOSITY IS
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISGAS 8.9229848

12.03681 CENTIPOISE AT 265.44 DEGREES

THE LIQUID VISCOSITY IS
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000

8.92298 CENTIPOISE AT 275.44 DEGREES

DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISCAS 6.7548792

THE LIQUID VISCOSITY IS 6.75488 CENTIPOISE AT 285.44 DEGREES
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISCAS 5.2108554

THE LIQUID VISCOSITY IS 5.21086 CENTIPOISE AT 295.44 DEGREES
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISCAS 4.0886545

THE LIQUID VISCOSITY IS 4.08865 CENTIPOISE AT 305.44 DEGREES
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISCAS 3.2578422

THE LIQUID VISCOSITY IS 3.25784 CENTIPOISE AT 315.44 DEGREES
XNSTR 17.470000
DELNI(2) 4.4699999
XNCARB(2) 13.000000
DELBI(2) 179.34768
BA 771.12871
B 950.47639
VISCAS 2.6323419

THE LIQUID VISCOSITY IS 2.63234 CENTIPOISE AT 325.44 DEGREES
STOP 000000

VIII. SUB-ROUTINE VISCOSITY, BINARY LIQUID

```

001      REAL KLVISM,NAME1
002      REAL NAME,NSTR
003      C THIS PROGRAM TESTS OUT A SUBROUTINE FOR A LIQUID MIXTURE VISCOSITY
004      C THE COMPOUNDS USED HERE ARE METHYLENE CHLORIDE AND TETRAETHYLENE-
005      C GLYCOLDIMETHYLETHYER, RESPECTIVELY
006      COMMON XKVISC(100,11),VISC(100,11),RHO(100),ASTR(100,11),
007      *XMF(100),XMV(100),TE(100),NAME(100),DELB(100),DELNI(100),
008      *XNCARB(100),XPHI(100,11),KLIVSM(100,11),NSTR(100),NAME1(100)
009      READ(2,100) N
010      100  FORMAT(I2)
011      READ(2,300) (DELB(I),DELNI(I),XNCARB(I),NSTR(I),RHO(I),XMF(I),
012      * XMV(I),NAME(I),NAME1(I),J=1,N)
013      300  FORMAT(4F10.4/3F10.4,A5,A5)
014      WRITE(3,1) (DELB(I),DELNI(I),XNCARB(I),NSTR(I),RHO(I),XMF(I),
015      * XMV(I),J=1,N)
016      C NAME=NAME OF COMPOUND
017      DO 2000 I=1,N
018      C TEMPERATURE WILL START AT 225.44 KELVIN AND INCREMENT 10 DEGREES
019      T=225.44
020      DO 2500 J=1,11
021      C VISILI IS THE PROGRAM FOR LIQUID VISCOSITY
022      CALL VISILI(XNSTR,BA,TD,B,VISCAS,T,I)
023      VISC(I,J)=VISCAS
024      TE(J)=T
025      T=T+10.
026      2500 CONTINUE
027      2600 CONTINUE
028      WRITE(3,2)((VISC(K,L),L=1,11),K=1,N)
029      DO 2050 I=1,N,2
030      DO 2060 J=1,11
031      C LIMXVS IS THE LIQUID MIXTURE VISCOSITY SUBROUTINE
032      CALL LIMXVS(N,XKVISM,I,J)
033      KLIVSM(I,J)=XKVISM
034      2060 CONTINUE
035      2050 CONTINUE
036      DO 3000 I=1,N,2
037      DO 3001 J=1,11
038      WRITE(3,400) NAME(I),NAME1(I),NAME(I+1),NAME1(I+1),
039      * KLIVSM(I,J),TE(J)
040      400  FORMAT('0','THE MIXTURE VISCOSITY FOR ',A5,A5,' AND ',A5,A5,' IS
041      * ',F10.4,' CENTISTOKES AT ',F10.4,' DEGREES KELVIN')
042      3001 CONTINUE
043      3000 CONTINUE
044      STOP
045      END

```



```

001      SUBROUTINE VISILI(XNSTR,BA,TO,R,VISGAS,T,I)
002      REAL KLIVSM,NAME1
003      REAL NAME,NSTR
004      C THIS SUBROUTINE CALCULATES THE VISCOSITY FOR A SINGLE GAS LIQUID
005      C THESE EQUATIONS ARE FROM 'PROPERTIES OF GASES AND LIQUIDS' BY REID
006      C ET AL. AND ARE FOUND ON PAGES 443-449
007      COMMON XKVISC(100,11),VISC(100,11),RHO(100),ASTR(100,11),
008      *XMF(100),XMV(100),TE(100),NAME(100),DELB(100),DELNI(100),
009      *XNCARB(100),XPHI(100,11),KLIVSM(100,11),NSTR(100),NAMF(100)
010      C XNSTR=PART OF EQUIVALENT CHAIN LENGTH
011      C DELBI=PART OF VISCOSITY PARAMETER
012      C DELNI=STRUCTURAL CONTRIBUTION IN EQUIVALENT CHAIN LENGTH
013      C XNCARB=NO. OF CARBONS
014      XNSTR=NSTR(I)
015      C EQ. (9-11.6)
016      IF(XNSTR.GT.20.) GO TO 200
017      BA=24.79+66.865*XNSTR -1.3173*XNSTR**2+0.00377*XNSTR**3
018      C EQ. (9-11.10)
019      TO=28.86+37.439*XNSTR-1.3547*XNSTR**2+0.02076*XNSTR**3
020      C EQ. (9-11.7)
021      GO TO 300
022      200 TO=8.164*XNSTR+238.59
023      C EQ. (9-11.8)
024      BA=530.59+13.740*XNSTR
025      C EQ. (9-11.11)
026      300 B=BA+DELB(I)
027      C EQ. (9-11.9)
028      VISGAS =10.**(B*(1./T-1./TO))
029      C EQ. (9-11.5)
030      WRITE(3,1) XNSTR,DELNI(I),XNCARB(I),DELB(I),BA,R,VISGAS
031      RETURN
032      END

```

```

001 SUBROUTINE LIMXVS(N,XKVISM,I,J)
002 REAL KLIVSM,NAME1
003 REAL NAME,NSTR
004 C THIS SUBROUTINE CALCULATES THE VISCOSITY FOR A BINARY LIQUID MIXTURE
005 C THESE EQUATIONS ARE FOUND ON PAGE 461 OF REID ET AL.
006 C COMPONENT 'I' MUST HAVE THE LESSER PURE LIQUID VISCOSITY AND THE
007 C MIXTURE KINEMATIC VISCOSITY MUST VARY MONOTONICALLY
008 C WITH COMPOSITION
009 COMMON XKVISC(100,11),VISC(100,11),RHO(100),ASTR(100,11),
010 *XMF(100),XMV(100),TE(100),NAME(100),DELBI(100),DELNI(100),
011 *XNCARB(100),XPHI(100,11),KLIVSM(100,11),NSTR(100),NAME1(100)
012 C VISC=STATIC VISCOSITY OF SINGLE LIQUID
013 C XKVISC=KINEMATIC VISCOSITY OF SINGLE LIQUID
014 C RHO=DENSITY,G/CM3
015 C XMF=MOLE FRACTION
016 C XMV=MOLAL VOLUME,CM3/G-MOL
017 C ASTR=CHARACTERISTIC VISCOSITY PARAMETER
018 C XPHI=VOLUME FRACTION
019 C XKVISM=VISCOSITY OF MIXTURE OF TWO LIQUIDS
020 C CHANGING STATIC VISCOSITY TO KINEMATIC VISCOSITY
021 XKVISC(I,J)=VISC(I,J)/RHO(I)
022 WRITE(3,1)XKVISC(I,J)
023 XKVISC(I+1,J)=VISC(I+1,J)/RHO(I+1)
024 WRITE(3,1)XKVISC(I+1,J)
025 C EQ.(9-13,11)
026 ASTR(I,J)=1.7+ALOG(XKVISC(I+1,J)/XKVISC(I,J))
027 WRITE(3,1)ASTR(I,J)
028 C EQ.(9-13,12)
029 ASTR(I+1,J)=0.27+ALOG(XKVISC(I+1,J)/XKVISC(I,J))+
030 * (1.3+ALOG(XKVISC(I+1,J)/XKVISC(I,J)))*.5
031 WRITE(3,1)ASTR(I+1,J)
032 C EQ.(9-13,10)
033 XPHI(I,J)=XMF(I)*XMV(I)/(XMF(I)*XMV(I)+XMF(I+1)*XMV(I+1))
034 WRITE(3,1)XPHI(I,J)
035 XPHI(I+1,J)=1.-XPHI(I,J)
036 WRITE(3,1)XPHI(I+1,J)
037 XKVISM=XPHI(I,J)*XKVISC(I,J)+EXP(XPHI(I+1,J)*ASTR(I+1,J))+
038 * XPHI(I+1,J)*XKVISC(I+1,J)+EXP(XPHI(I,J)*ASTR(I,J))
039 WRITE(3,1)XKVISM
040 WRITE(3,1)XKVISC(I,J),XKVISC(I+1,J),ASTR(I,J),ASTR(I+1,J),
041 * XPHI(I,J),XPHI(I+1,J),XKVISM
042 RETURN
043 END

```

*DELBI = -17.030000
 *DELNI = 3.2100000
 *XNCARB(1) = 1.0000000
 *NSTR(1) = 4.2099999
 *RHO(1) = 1.3250000
 *XMF(1) = 0.7500000
 *XMV(1) = 64.080000
 *DELBI(2) = 53.094999
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *NSTR(2) = 21.940000
 *RHO(2) = 1.0130000
 *XMF(2) = 0.2500000
 *XMV(2) = 219.45000
 *DELBI(3) = -17.030000
 *DELNI(3) = 3.2100000
 *XNCARB(3) = 1.0000000
 *NSTR(3) = 4.2099999
 *RHO(3) = 1.3250000
 *XMF(3) = 0.5000000
 *XMV(3) = 64.080000
 *DELBI(4) = 35.835999
 *DELNI(4) = 1.9700000
 *XNCARB(4) = 8.0000000
 *NSTR(4) = 15.880000
 *RHO(4) = 0.9859999
 *XMF(4) = 0.5000000
 *XMV(4) = 180.53000
 *DELBI(5) = -17.030000
 *DELNI(5) = 3.2100000
 *XNCARB(5) = 1.0000000
 *NSTR(5) = 4.2099999
 *RHO(5) = 1.3250000
 *XMF(5) = 0.1900000
 *XMV(5) = 64.080000
 *DELBI(6) = 20.958000
 *DELNI(6) = 1.5520000
 *XNCARB(6) = 6.0000000
 *NSTR(6) = 10.656000
 *RHO(6) = 0.9449999
 *XMF(6) = 0.8499999
 *XMV(6) = 142.01000

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.36190695

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.32250392

*XNSTR = 4.2099999

*DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.29010317
 *XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.26312989

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.24042588

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.22112500

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.20456952

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.19025319

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.17778132

*XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658

*B = 265.71658
 *VISGAS = 0.16684273
 *XNSTR = 4.2099999
 *DELNI(1) = 3.2100000
 *XNCARB(1) = 1.0000000
 *DELBI(1) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.15718942

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 64.156326

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 43.699449

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 30.711521

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 22.188081

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 16.427660

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 12.431131

*XNSTR = 21.940000

*DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 9.5924218

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 7.5329869

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 6.0100621

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 4.8641821

*XNSTR = 21.940000
 *DELNI(2) = 2.3880000
 *XNCARB(2) = 10.000000
 *DELBI(2) = 53.094999
 *BA = 832.04559
 *B = 885.14059
 *VISGAS = 3.9882876

*XNSTR = 4.2099999
 *DELNI(3) = 3.2100000
 *XNCARB(3) = 1.0000000
 *DELBI(3) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.36190695

*XNSTR = 4.2099999
 *DELNI(3) = 3.2100000
 *XNCARB(3) = 1.0000000
 *DELBI(3) = -17.030000
 *BA = 282.74658
 *B = 265.71658
 *VISGAS = 0.32250392

*XNSTR = 4.2099999
 *DELNI(3) = 3.2100000
 *XNCARB(3) = 1.0000000
 *DELBI(3) = -17.030000
 *BA = 282.74658

•XNSTR• 4.2099999

```

'XNSTR' = 15.880000
'DELNI(4)' = 1.9700000
'XNCAR(4)' = 8.0000000
'DELRI(4)' = 35.815499
'BA' = 739.63739

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INSTR 4.2099999

```
*XNSTR' = 4.2099999
*DELNI(5)' = 3.2100000
*XNCARR(5)' = 1.0000000
*DELBI(5)' = -17.030000
*BA' = 282.74658
```

B 265.71658	*DELNI(6)* 1.5520000	*VISC(3,8)* 0.19025319	*XKVISC(1,2)* 0.24339918
VISCAS 0.15718942	*XNCARB(6)* 6.0000000	*VISC(3,9)* 0.17778132	
	DELBI(6) 20.958000	*VISC(3,10)* 0.16684273	*XKVISC(2,2)* 43.138647
XNSTR 10.656000	*BA* 583.37503	*VISC(3,11)* 0.15718942	
DELNI(6) 1.5520000	*B* 604.33302	*VISC(4,1)* 20.638690	*ASTR(1,2)* -8.8017018
XNCARB(6) 6.0000000	*VISCAS* 1.0593742	*VISC(4,2)* 14.742810	*ASTR(2,2)* 3.9922792
DELBI(6) 20.958000		*VISC(4,3)* 10.823899	
BA 583.37503	*XNSTR* 10.656000	*VISC(4,4)* 8.1413093	*XPHI(1,2)* 0.46695329
B 604.33302	*DELNI(6)* 1.5520000	*VISC(4,5)* 6.2563981	*XPHI(2,2)* 0.53304671
VISCAS 4.5729476	*XNCARB(6)* 6.0000000	*VISC(4,6)* 4.9007105	
	DELBI(6) 20.958000	*VISC(4,7)* 3.9050385	
	BA 583.37503	*VISC(4,8)* 3.1598672	
	B 604.33302	*VISC(4,9)* 2.5925879	*XKVISM* 1.3318592
	VISCAS 0.90798625	*VISC(4,10)* 2.1540053	
		VISC(4,11) 1.8101158	*XKVISC(1,2)* 0.24339918
XNSTR 10.656000	*XNSTR* 10.656000	*VISC(5,1)* 0.36190695	*XKVISC(2,2)* 43.138647
DELNI(6) 1.5520000	*DELNI(6)* 1.5520000	*VISC(5,2)* 0.32250392	*ASTR(1,2)* -8.8017018
XNCARB(6) 6.0000000	*XNCARB(6)* 6.0000000	*VISC(5,3)* 0.29010317	*ASTR(2,2)* 3.9922792
DELBI(6) 20.958000	*DELBI(6)* 20.958000	*VISC(5,4)* 0.26312989	*XPHI(1,2)* 0.46695329
BA 583.37503	*BA* 583.37503	*VISC(5,5)* 0.24042588	*XPHI(2,2)* 0.53304671
B 604.33302	*B* 604.33302	*VISC(5,6)* 0.22112500	*XKVISM* 1.3318592
VISCAS 3.5183401	*VISCAS* 0.78587832	*VISC(5,7)* 0.20456952	
		VISC(5,8) 0.19025319	*XKVISC(1,3)* 0.21894579
		VISC(5,9) 0.17778132	
		VISC(5,10) 0.16684273	*XKVISC(2,3)* 30.317396
		VISC(5,11) 0.15718942	
		VISC(6,1) 4.5729476	*ASTR(1,3)* -8.3821096
		VISC(6,2) 3.5183401	*ASTR(2,3)* 3.8630441
		VISC(6,3) 2.7653958	
		VISC(6,4) 2.2149556	*XPHI(1,3)* 0.46695329
		VISC(6,5) 1.8039960	*XPHI(2,3)* 0.53304671
		VISC(6,6) 1.4913445	
		VISC(6,7) 1.2494300	
		VISC(6,8) 1.0593742	*XKVISM* 1.1240529
		VISC(6,9) 0.90798625	
		VISC(6,10) 0.78587832	*XKVISC(1,3)* 0.21894579
		VISC(6,11) 0.68625580	*XKVISC(2,3)* 30.317396
			ASTR(1,3) -8.3821096
		XKVISC(1,1) 0.27313732	*ASTR(2,3)* 3.8630441
			XPHI(1,3) 0.46695329
		XKVISC(2,1) 63.332998	*XPHI(2,3)* 0.53304671
			XKVISM 1.1240529
		ASTR(1,1) -9.2585180	
		ASTR(2,1) 4.1313056	*XKVISC(1,4)* 0.19858860
		XPHI(1,1) 0.46695329	*XKVISC(2,4)* 21.903338
		XPHI(2,1) 0.53304671	
			ASTR(1,4) -7.9953703
		XKVISM 1.6011018	*ASTR(2,4)* 3.7425249
		XKVISC(1,1) 0.27313732	*XPHI(1,4)* 0.46695329
		XKVISC(2,1) 63.332998	*XPHI(2,4)* 0.53304671
		ASTR(1,1) -9.2585180	
		ASTR(2,1) 4.1313056	*XKVISM* 0.96090062
		XPHI(1,1) 0.46695329	
		XPHI(2,1) 0.53304671	*XKVISC(1,4)* 0.19858860
		XKVISM 1.6011018	*XKVISC(2,4)* 21.903338

*ASTR(1,4) = 7.9953703	*XPHI(2,7) = 0.53304671	*ASTR(1,10) = -6.1898674	*XKVISM = 3.2173356
*ASTR(2,4) = 3.7425249	*XKVISM = 0.63971090	*ASTR(2,10) = 3.1587409	*XKVISC(3,2) = 0.24339918
*XPHI(1,4) = 0.46695329	*XKVISC(1,7) = 0.15439209	*XPHI(1,10) = 0.46695329	*XKVISC(4,2) = 14.952140
*XPHI(2,4) = 0.53304671	*XKVISC(2,7) = 9.4693208	*XPHI(2,10) = 0.53304671	*ASTR(3,2) = -7.0004418
*XKVISM = 0.96090062	*ASTR(1,7) = -6.9977390	*XKVISM = 0.45886984	*ASTR(4,2) = 3.4255502
*XKVISC(1,5) = 0.18145350	*ASTR(2,7) = 3.4246742	*XKVISC(1,10) = 0.12591904	*XPHI(3,2) = 0.26196803
*XKVISC(2,5) = 16.216841	*XPHI(1,7) = 0.46695329	*XKVISC(2,10) = 4.8017594	*XPHI(4,2) = 0.73803197
*ASTR(1,5) = -7.6377704	*XPHI(2,7) = 0.53304671	*ASTR(1,10) = -6.1898674	*XKVISM = 2.5622927
*ASTR(2,5) = 3.6298009	*XKVISM = 0.63971090	*ASTR(2,10) = 3.1587409	*XKVISC(3,2) = 0.24339918
*XPHI(1,5) = 0.46695329	*XKVISC(1,8) = 0.14358731	*XPHI(1,10) = 0.46695329	*XKVISC(4,2) = 14.952140
*XPHI(2,5) = 0.53304671	*XKVISC(2,8) = 7.4363149	*XPHI(2,10) = 0.53304671	*ASTR(3,2) = -7.0004418
*XKVISM = 0.83083670	*ASTR(1,8) = -6.7102185	*XKVISM = 0.45886984	*ASTR(4,2) = 3.4255502
*XKVISC(1,5) = 0.18145350	*ASTR(2,8) = 3.3309875	*XKVISC(1,11) = 0.11863352	*XPHI(3,2) = 0.26196803
*XKVISC(2,5) = 16.216841	*XPHI(1,8) = 0.46695329	*XKVISC(2,11) = 3.9371053	*XPHI(4,2) = 0.73803197
*ASTR(1,5) = -7.6377704	*XPHI(2,8) = 0.53304671	*ASTR(1,11) = -5.9536753	*XKVISM = 2.5622927
*ASTR(2,5) = 3.6298009	*XKVISM = 0.56854378	*ASTR(2,11) = 3.0793153	*XKVISC(3,3) = 0.21894579
*XPHI(1,5) = 0.46695329	*XKVISC(1,8) = 0.14358731	*XPHI(1,11) = 0.46695329	*XKVISC(4,3) = 10.977586
*XPHI(2,5) = 0.53304671	*XKVISC(2,8) = 7.4363149	*XPHI(2,11) = 0.53304671	*ASTR(3,3) = -6.6551373
*XKVISM = 0.83083670	*ASTR(1,8) = -6.7102185	*XKVISM = 0.41616919	*ASTR(4,3) = 3.3129229
*XKVISC(1,6) = 0.16688679	*ASTR(2,8) = 3.3309875	*XKVISC(1,11) = 0.11863352	*XPHI(3,3) = 0.26196803
*XKVISC(2,6) = 12.271601	*XPHI(1,8) = 0.46695329	*XKVISC(2,11) = 3.9371053	*XPHI(4,3) = 0.73803197
*ASTR(1,6) = -7.3061365	*XPHI(2,8) = 0.53304671	*ASTR(1,11) = -5.9536753	*XKVISM = 2.0785429
*ASTR(2,6) = 3.5240795	*XKVISM = 0.56854378	*ASTR(2,11) = 3.0793153	*XKVISC(3,3) = 0.21894579
*XPHI(1,6) = 0.46695329	*XKVISC(1,9) = 0.13417458	*XPHI(1,11) = 0.46695329	*XKVISC(4,3) = 10.977586
*XPHI(2,6) = 0.53304671	*XKVISC(2,9) = 5.9329340	*XPHI(2,11) = 0.53304671	*ASTR(3,3) = -6.6551373
*XKVISM = 0.72572052	*ASTR(1,9) = -6.4415250	*XKVISM = 0.41616919	*ASTR(4,3) = 3.3129229
*XKVISC(1,6) = 0.16688679	*ASTR(2,9) = 3.2424963	*XKVISC(3,11) = 0.27313732	*XPHI(3,3) = 0.26196803
*XKVISC(2,6) = 12.271601	*XPHI(1,9) = 0.46695329	*XKVISC(4,11) = 20.931734	*XPHI(4,3) = 0.73803197
*ASTR(1,6) = -7.3061365	*XPHI(2,9) = 0.53304671	*ASTR(3,11) = -7.3763798	*XKVISM = 2.0785429
*ASTR(2,6) = 3.5240795	*XKVISM = 0.50905658	*ASTR(4,11) = 3.5465713	*XKVISC(3,4) = 0.19898860
*XPHI(1,6) = 0.46695329	*XKVISC(1,9) = 0.13417458	*XPHI(3,11) = 0.26196803	*XKVISC(4,4) = 8.2569060
*XPHI(2,6) = 0.53304671	*XKVISC(2,9) = 5.9329340	*XPHI(4,11) = 0.73803197	*ASTR(3,4) = -6.3368688
*XKVISM = 0.72572052	*ASTR(1,9) = -6.4415250	*XKVISM = 3.2173356	*ASTR(4,4) = 3.2077709
*XKVISC(1,7) = 0.15439209	*ASTR(2,9) = 3.2424963	*XKVISC(3,11) = 0.27313732	*XPHI(3,4) = 0.26196803
*XKVISC(2,7) = 9.4693208	*XPHI(1,9) = 0.46695329	*XKVISC(4,11) = 20.931734	*XPHI(4,4) = 0.73803197
*ASTR(1,7) = -6.9977390	*XPHI(2,9) = 0.53304671	*ASTR(3,11) = -7.3763798	*XKVISM = 1.7137098
*ASTR(2,7) = 3.4246742	*XKVISM = 0.50905658	*ASTR(4,11) = 3.5465713	
*XPHI(1,7) = 0.46695329	*XKVISC(1,10) = 0.12591904	*XPHI(3,11) = 0.26196803	
	*XKVISC(2,10) = 4.8017594	*XPHI(4,11) = 0.73803197	

*XKVI8C(3,4)'= 0.19858860	*XPHI(3,7)'= 0.26196803	*XKVI8C(4,10)'= 2.1845896	*XPHI(5,1)'= 0.73756624E-01
*XKVI8C(4,4)'= 8.2569060	*XPHI(4,7)'= 0.73803197	*ASTR(3,10)'= -4.8510249	*XPHI(6,1)'= 0.92624338
*ASTR(3,4)'= -6.3368688	*XKVI8M'= 1.0406124	*ASTR(4,10)'= 2.6964908	*XKVI8M'= 3.3735278
*ASTR(4,4)'= 3.2077709	*XKVI8C(3,7)'= 0.15439209	*XPHI(3,10)'= 0.26196803	*XKVI8C(5,2)'= 0.24339918
*XPHI(3,4)'= 0.26196803	*XKVI8C(4,7)'= 3.9604854	*XPHI(4,10)'= 0.73803197	*XKVI8C(6,2)'= 3.7231112
*XPHI(4,4)'= 0.73803197	*ASTR(3,7)'= -5.5158650	*XKVI8M'= 0.69375487	*ASTR(5,2)'= -4.6369406
*XKVI8M'= 1.7137098	*ASTR(4,7)'= 2.9298295	*XKVI8C(3,10)'= 0.12591904	*ASTR(6,2)'= 2.6195099
*XKVI8C(3,5)'= 0.18145350	*XPHI(3,7)'= 0.26196803	*XKVI8C(4,10)'= 2.1845896	*XPHI(5,2)'= 0.73756624E-01
*XKVI8C(4,5)'= 6.3452314	*XPHI(4,7)'= 0.73803197	*ASTR(3,10)'= -4.8510249	*XPHI(6,2)'= 0.92624338
*ASTR(3,5)'= -6.0425811	*XKVI8M'= 1.0406124	*ASTR(4,10)'= 2.6964908	*XKVI8M'= 2.6527942
*ASTR(4,5)'= 3.1093080	*XKVI8C(3,8)'= 0.14358731	*XPHI(3,10)'= 0.26196803	*XKVI8C(5,2)'= 0.24339918
*XPHI(3,5)'= 0.26196803	*XKVI8C(4,8)'= 3.2047336	*XPHI(4,10)'= 0.73803197	*XKVI8C(6,2)'= 3.7231112
*XPHI(4,5)'= 0.73803197	*ASTR(3,8)'= -5.2792495	*XKVI8M'= 0.69375487	*ASTR(5,2)'= -4.6369406
*XKVI8M'= 1.4333732	*ASTR(4,8)'= 2.8477159	*XKVI8C(3,11)'= 0.11863352	*ASTR(6,2)'= 2.6195099
*XKVI8C(3,5)'= 0.18145350	*XPHI(3,8)'= 0.26196803	*XKVI8C(4,11)'= 1.8358172	*XPHI(5,2)'= 0.73756624E-01
*XKVI8C(4,5)'= 6.3452314	*XPHI(4,8)'= 0.73803197	*ASTR(3,11)'= -4.6566501	*XPHI(6,2)'= 0.92624338
*ASTR(3,5)'= -6.0425811	*XKVI8M'= 0.90095051	*ASTR(4,11)'= 2.6266380	*XKVI8M'= 2.6527942
*ASTR(4,5)'= 3.1093080	*XKVI8C(3,8)'= 0.14358731	*XPHI(3,11)'= 0.26196803	*XKVI8C(5,3)'= 0.21894579
*XPHI(3,5)'= 0.26196803	*XKVI8C(4,8)'= 3.2047336	*XPHI(4,11)'= 0.73803197	*XKVI8C(6,3)'= 2.9263448
*XPHI(4,5)'= 0.73803197	*ASTR(3,8)'= -5.2792495	*XKVI8M'= 0.61599803	*ASTR(5,3)'= -4.4075649
*XKVI8M'= 1.4333732	*ASTR(4,8)'= 2.8477159	*XKVI8C(3,11)'= 0.11863352	*ASTR(6,3)'= 2.5359145
*XKVI8C(3,6)'= 0.16688679	*XPHI(3,8)'= 0.26196803	*XKVI8C(4,11)'= 1.8358172	*XPHI(5,3)'= 0.73756624E-01
*XKVI8C(4,6)'= 4.9702947	*XPHI(4,8)'= 0.73803197	*ASTR(3,11)'= -4.6566501	*XPHI(6,3)'= 0.92624338
*ASTR(3,6)'= -5.7696618	*XKVI8M'= 0.90095051	*ASTR(4,11)'= 2.6266380	*XKVI8M'= 2.1273831
*ASTR(4,6)'= 3.0168567	*XKVI8C(3,9)'= 0.13417458	*XPHI(3,11)'= 0.26196803	*XKVI8C(5,3)'= 0.21894579
*XPHI(3,6)'= 0.26196803	*XKVI8C(4,9)'= 2.6293996	*XPHI(4,11)'= 0.73803197	*XKVI8C(6,3)'= 2.9263448
*XPHI(4,6)'= 0.73803197	*ASTR(3,9)'= -5.0581273	*XKVI8M'= 0.61599803	*ASTR(5,3)'= -4.4075649
*XKVI8M'= 1.2143373	*ASTR(4,9)'= 2.7700673	*XKVI8C(3,11)'= 0.11863352	*ASTR(6,3)'= 2.5359145
*XKVI8C(3,6)'= 0.16688679	*XPHI(3,9)'= 0.26196803	*XKVI8C(4,11)'= 1.8358172	*XPHI(5,3)'= 0.73756624E-01
*XKVI8C(4,6)'= 4.9702947	*XPHI(4,9)'= 0.73803197	*ASTR(3,11)'= -4.6566501	*XPHI(6,3)'= 0.92624338
*ASTR(3,6)'= -5.7696618	*XKVI8M'= 0.78728953	*ASTR(4,11)'= 2.6266380	*XKVI8M'= 2.1273831
*ASTR(4,6)'= 3.0168567	*XKVI8C(3,9)'= 0.13417458	*XPHI(3,11)'= 0.26196803	*XKVI8C(5,4)'= 0.19858860
*XPHI(3,6)'= 0.26196803	*XKVI8C(4,9)'= 2.6293996	*XPHI(4,11)'= 0.73803197	*XKVI8C(6,4)'= 2.3438684
*XPHI(4,6)'= 0.73803197	*ASTR(3,9)'= -5.0581273	*XKVI8M'= 0.61599803	*ASTR(5,4)'= -4.1961485
*XKVI8M'= 1.2143373	*ASTR(4,9)'= 2.7700673	*XKVI8C(3,11)'= 0.11863352	*ASTR(6,4)'= 2.4577648
*XKVI8C(3,7)'= 0.15439209	*XPHI(3,9)'= 0.26196803	*XKVI8C(4,11)'= 1.8358172	*XPHI(5,4)'= 0.73756624E-01
*XKVI8C(4,7)'= 3.9604854	*XPHI(4,9)'= 0.73803197	*ASTR(3,11)'= -4.6566501	*XPHI(6,4)'= 0.92624338
*ASTR(3,7)'= -5.5158650	*XKVI8M'= 0.78728953	*ASTR(4,11)'= 2.6266380	
*ASTR(4,7)'= 2.9298295	*XKVI8C(3,10)'= 0.12591904	*XPHI(3,11)'= 0.26196803	
		*XPHI(4,11)'= 0.73803197	
		*XKVI8M'= 0.61599803	
		*XKVI8C(5,1)'= 0.27313732	
		*XKVI8C(6,1)'= 4.8390981	
		*ASTR(5,1)'= -4.8866652	
		*ASTR(6,1)'= 2.7092136	
		*XPHI(5,1)'= 0.73756624E-01	
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		*XKVI8M'= 3.3735278	
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		*ASTR(5,1)'= -4.8866652	
		*ASTR(6,1)'= 2.7092136	

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 *XKVISC(5,4)" 0.19898860 *XPHI(5,7)" 0.73756624E-01
 *XKVISC(6,4)" 2.3438684 *XPHI(6,7)" 0.92624338
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 *XKVISM" 1.7358135 *XKVISC(5,7)" 0.15439209
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 *XKVISM" 1.4382052 *ASTR(6,8)" 2.1893629
 *XKVISC(5,5)" 0.8145350 *XPHI(5,8)" 0.73756624E-01
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 *ASTR(6,5)" 2.3844931
 *XPHI(5,5)" 0.73756624E-01
 *XPHI(6,5)" 0.92624338
 *XKVISM" 1.4382052 *XKVISC(5,8)" 0.14358731
 *XKVISC(5,6)" 0.16688679 *XKVISC(6,8)" 1.1210309
 *ASTR(5,8)" -3.4936032
 *XKVISC(6,6)" 1.5781423 *ASTR(6,8)" 2.1893629
 *XPHI(5,8)" 0.73756624E-01
 *XPHI(6,8)" 0.92624338
 *ASTR(5,6)" -3.8193696 *XKVISM" 0.88294853
 *ASTR(6,6)" 2.3156096 *XKVISC(5,9)" 0.13417458
 *XPHI(5,6)" 0.73756624E-01 *XKVISC(6,9)" 0.96083201
 *XPHI(6,6)" 0.92624338 *ASTR(5,9)" -3.3467183
 *XKVISM" 1.2080065 *ASTR(6,9)" 2.1313048
 *XKVISC(5,6)" 0.16688679 *XPHI(5,9)" 0.73756624E-01
 *XKVISC(6,6)" 1.5781423 *XPHI(6,9)" 0.92624338
 *ASTR(5,6)" -3.8193696
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 *XPHI(5,6)" 0.73756624E-01 *XKVISM" 0.76655169
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 *XKVISM" 1.2080065 *XKVISC(5,9)" 0.13417458
 *XKVISC(5,7)" 0.15439209 *XKVISC(6,9)" 0.96083201
 *ASTR(5,9)" -3.3467183
 *ASTR(6,9)" 2.1313048
 *XKVISC(6,7)" 1.3221481 *XPHI(5,9)" 0.73756624E-01
 *XPHI(6,9)" 0.92624338
 *ASTR(5,7)" -3.6507800 *XKVISM" 0.76655169

XKVIS(5,10)= 0.12591904
 XKVIS(6,10)= 0.83161727
 ASTR(5,10)= -3.2091463
 ASTR(6,10)= 2.0762297
 XPHI(5,10)= 0.73756624E-01
 XPHI(6,10)= 0.92624338
 XKVISM= 0.67147416
 XKVIS(5,10)= 0.12591904
 XKVIS(6,10)= 0.83161727
 ASTR(5,10)= -3.2091463
 ASTR(6,10)= 2.0762297
 XPHI(5,10)= 0.73756624E-01
 XPHI(6,10)= 0.92624338
 XKVISM= 0.67147416
 XKVIS(5,11)= 0.11863352
 XKVIS(6,11)= 0.72619662
 ASTR(5,11)= -3.0800290
 ASTR(6,11)= 2.0238850
 XPHI(5,11)= 0.73756624E-01
 XPHI(6,11)= 0.92624338
 XKVISM= 0.59297916
 XKVIS(5,11)= 0.11863352
 XKVIS(6,11)= 0.72619662
 ASTR(5,11)= -3.0800290
 ASTR(6,11)= 2.0238850
 XPHI(5,11)= 0.73756624E-01
 XPHI(6,11)= 0.92624338
 XKVISM= 0.59297916

THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	1.6011 CENTISTOKES AT	225.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	1.3319 CENTISTOKES AT	235.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	1.1241 CENTISTOKES AT	245.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.9609 CENTISTOKES AT	255.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.8308 CENTISTOKES AT	265.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.7257 CENTISTOKES AT	275.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.6397 CENTISTOKES AT	285.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.5685 CENTISTOKES AT	295.4400 DEGREES KELVIN

THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.5091 CENTISTOKES AT	305.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.4589 CENTISTOKES AT	315.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TEGDM	IS	0.4162 CENTISTOKES AT	325.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	3.2173 CENTISTOKES AT	225.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	2.5623 CENTISTOKES AT	235.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	2.0785 CENTISTOKES AT	245.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	1.7137 CENTISTOKES AT	255.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	1.4334 CENTISTOKES AT	265.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	1.2143 CENTISTOKES AT	275.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	1.0406 CENTISTOKES AT	285.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	0.9010 CENTISTOKES AT	295.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	0.7873 CENTISTOKES AT	305.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	0.6938 CENTISTOKES AT	315.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND TREGDM	IS	0.6160 CENTISTOKES AT	325.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	3.3735 CENTISTOKES AT	225.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	2.6528 CENTISTOKES AT	235.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	2.1274 CENTISTOKES AT	245.4400 DEGREES KELVIN
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THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	1.4382 CENTISTOKES AT	265.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	1.2080 CENTISTOKES AT	275.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	1.0271 CENTISTOKES AT	285.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	0.8829 CENTISTOKES AT	295.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	0.7666 CENTISTOKES AT	305.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	0.6719 CENTISTOKES AT	315.4400 DEGREES KELVIN
THE MIXTURE VISCOSITY FOR MECL	AND DEGDM	IS	0.5930 CENTISTOKES AT	325.4400 DEGREES KELVIN
STOP 000000				