OPTIMAL DESIGN OF ORGANIC REFRIGERANT REVERSE CYCLE ABSORPTION AIR CONDITIONING SYSTEMS.

A thesis submitted in fulfilment of the requirement for a Master of Engineering Science Degree at the Chemical Engineering Department of the University of Adelaide.

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ABSTRACT

Currently there is a small market in absorption refrigeration equipment which is dominated by Lithium Bromide-Water and Water-Ammonia systems. To overcome some of the problems associated this equipment an organic fluid cycle has been proposed.

A computer model for a single stage absorption cycle has been written which provides for optional selection of internal heat exchangers, a choice of working fluid pairs and the selection of system operating parameters. Fluid properties are calculated using the Peng-Robinson cubic equation of state. Tables of pure and mixture fluid properties can be generated as well as system analyses from both the First and Second Laws of thermodynamics.

In the working range of the cycle fluid properties, other than liquid entropy, were generally within 5 percent of published data. The second law analysis revealed that absorber mixing and the distillation column availability losses (irreversibilities) were large and unavoidable.

Coefficient of Performance (COP) was used to assess system performance and 0.35 can be taken as a typical COP value for a cooling cycle under Adelaide conditions. When compared with a commercially available Lithium Bromide system the organic cycle COP was 15 percent lower. In the heat pump mode heating COP's of 1.3 and above were predicted.

These results are considered encouraging enough to warrant investing the additional time required to exhaustively investigate the cycle and optimise its design.

STATEMENT OF ORIGINALITY

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and to the best of the author's knowledge and belief contains no material previously published or written by another person, except where due reference is made in the text. The author consents to this thesis being made available for photocopying and loan.

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INTRODUCTION

Currently two types of equipment dominate the established absorption refrigeration technology. For evaporator applications below 0 deg C water ammonia systems are used. Usually, for domestic systems, heat is rejected through a refrigerant to air heat exchanger. Forty years ago in Australia these systems were common as household refrigerators whereas nowadays their application is largely confined to the leisure industry eg gas/electric powered caravan refrigerator where portability and flexibility of energy supply is important. The Lithium Bromide - Water system is used in air conditioning applications where evaporator temperatures are usually in the range 3 deg C to 8 deg C. However, here heat is usually rejected via a water cooled condenser and absorber. Chilled water is produced in the evaporator to effect the air conditioning function and cooling water is required to remove the rejected heat. These requirements generally confine the use of lithium bromide - water equipment to larger commercial systems. Examples include the use of exhaust and cooling water heat from gas and diesel generating sets and the use of off peak or off season steam. A few solar powered systems have been installed (5).

When assessing the viability of this equipment compared with mechanical vapour compression machines it is necessary to account for all costs over a lifespan and not just costs based on coefficient of performance (COP).

For cooling the coefficient of performance (COP) is defined as

$$\text{COP} = \frac{\text{Useful cooling effect}}{\text{Heat input}}$$

However, as this report is concerned with fundamental technical aspects of the cycle COP has been chosen as the prime measure for comparison rather than life cycle cost. A typical lithium - bromide based air conditioning system COP is 0.5 (22) whilst less than this can be expected of an ammonia water system operating with a low temperature evaporator eg -10 deg C. Other factors which serve to limit the application of this type of equipment are, in the case of lithium - bromide the possibility of solidification and, for ammonia - water, toxicity, flammability, corrosion and high manufacturing costs.

As early as 1949 (8) researchers were investigating the characteristics of alternative binary mixtures in an effort to improve system performance but despite this the two abovementioned systems remain dominant. During the late 1970's Dr J. R. Roach of the Chemical Engineering Department of the University of Adelaide (17) began experimenting with organic based binary mixture systems because they offered low toxicity, freedom from the crystallization problems of lithium bromide and the possibility of sub-zero operation either for low temperature refrigeration or for use in a heat-pump mode. In addition they can use the existing well established materials and methods used for conventional mechanical vapour compression systems.

Early experimentation demonstrated that these organic systems could be used in an absorption cycle and this project was founded with a view to detailing cycle performance. The aims of the project have been grouped under three broad headings viz:

Fluid property estimation

a) To represent in a computer thermodynamic and other relevant properties for combinations of organic fluids considered as candidate working fluids for the absorption cycle.

b) To produce enthalpy concentration diagrams for these fluids.

Absorption system analysis

a) To create a computer model of the system with the ability to nominate a range of operating parameters, operating fluids, and combinations of internal heat exchangers.

b) To provide a first law energy balances for the system and to determine performance data such as power input and COP.

c) To provide second law analyses which illustrate the energy efficiency of the various components.

Optimum design

To establish a system configuration and associated mixture which approaches optimum performance given the normal constraints applying to such equipment.

Three methods were considered for the generation of fluid property data namely, tables, specific empirical equations and a generalized equation approach. The Peng-Robinson cubic equation of state was finally selected because it offered acceptable accuracy and manageable programming for both pure substance and mixture properties. Most pure and mixture property values calculated for vapour were within 5 percent of published data but liquid property values, in particular liquid entropy, sometimes exhibited errors around 10 percent. Both enthalpy and entropy data were generated so that the thermodynamic property of availability (exergy) could be calculated for use in a 'second law analysis'.

The absorption refrigeration cycle computer model was developed and the property data utilized was derived from the Peng-Robinson equation referred to above. Traditionally analysis of such systems has been conducted using the first law of thermodynamics although two references were found which used the second law for a single set of operating conditions (21,7). It was decided that a second law analysis should be a part of the model in an effort to establish which components or aspects of the system were the most wasteful of energy. This was achieved and in addition to being able to select working fluids, heat exchangers and system operating parameters, it is possible to calculate the availability losses through the various cycle elements.

Experimental data from an early model prototype test was used to check the program and, for 1.5kW of cooling, the computed power input to the reboiler was 2.53kW while the measured value was 2.4kW. The resulting COP values of 0.58 (predicted) and 0.61 (measured) respectively were considered an encouraging result.

Using equations developed by Teja and Roach (35) and the first law concept of COP it is possible to derive the expression

$$COP = COP_{CARNOT} - \frac{\frac{D}{Q_G}}{\frac{T_O}{T_E} - 1}$$

where D = Availability loss (or irreversibility)

Q_G = Absorption system input

T_O = Temperature of the environment

T_E = Temperature of the evaporator

Using this equation it is possible to calculate the system COP by subtracting the sum of the irreversibility components from the Carnot COP. The smaller the irreversiblity values are, the closer the actual COP is to the Carnot value. Taking this to the limit, if D is zero, then the operating COP equals the Carnot COP. Of course in practice there must always be some availability loss and therefore the COP can never equal the Carnot COP. By separating this availability loss into avoidable and unavoidable components an assessment of the potential for COP improvement is possible. For example, the availability loss which occurs in a heat exchanger due to the temperature difference between the streams is, in theory at least, avoidable by virtue of heat exchanger design whereas the availability loss through mixing of streams is not.

For all the systems tested the sum of the distillation column irreversibilities and the irreversibility of mixing in the absorber was always dominant, even though adding internal heat exchangers produced some reductions overall these two losses remained dominant. An extensive investigation of the topology of all possible systems including multistage evaporator-absorber combinations and multiple column combinations is considered to be beyond the scope of this thesis.

Aside from assessing the importance of system variables such as heat exchanger approaches the computer model offers the possibility of investigating the cycle performance with a large number of working fluid pairs. Only two mixtures have been considered here :-

Dichlorodifluoromethane (R12) -

Trichlorotrifluoroethane (R113)

and Chlorodifluoromethane (R22) -

Trichlorofluoromethane (R11).

Their performances were found to be significantly different. This suggests that an examination of other pairs could lead to system improvement. The R12-R113 combination consistently produced higher COP values for the same ambient and evaporator conditions because it has a higher Carnot COP capability. Despite this higher value the R12-R113 system cooling COP was still 15% lower than a commercially available lithium bromide-water air conditioning chiller for a typical single stage system.

Both cooling and heat pump systems have been considered and, for the heating mode, if all the heat rejected from the system is used for heating the COP can be significantly greater than one (about 1.3).

It should be noted that the boiler heat input values used throughout this report are nett values and do not include a heating source efficiency (eg a gas combustion efficiency).

It is not possible to optimize the overall system design based on COP alone. Whether or not these absorption systems are economically viable can only be determined by an appraisal which takes into account such factors as fuel costs, manufacturing costs and the COP variation due to changing load requirements. Ambient temperature changes significantly affect the COP and therefore the importance of temperature variations should not be under-estimated. For an evaporator temperature of approximately 7 deg C the COP for cooling varied from approximately 0.3 for an air cooled condenser operating at a condensing temperature of 48 deg C (ambient air temperature of 38 deg C) to above 0.6 for a system using condenser cooling water at 30 deg C. To make a meaningful assessment of the situation it is proposed that further work include driving the modelling program by some optimization program which takes account of these seasonal variations as well as considering economic criteria.

Even though this work has not conclusively shown the viability or otherwise of the organic absorption system it has demonstrated a method of system analysis and that prototype modelling by computer is feasible. Further work is recommended and it is suggested that it be divided into four broad areas:-

1) Investigation of an extended range of binary mixtures.
2) Simulation of prototype performance.
3) Investigation of alternative system configurations including multistage evaporator/absorber combinations and multiple columns.
4) Optimization of design by assessing costs and performance.

For the mixtures tested the COP was lower than for existing Lithium Bromide - water systems and therefore, on a COP only basis it is considered unlikely that these would be able to capture the existing cooling market. But it is possible that a market exists, particularly for heating, for systems which can use low grade heat with refrigerant to air heat exchangers as well as offering low toxicity, subzero operation and construction from components already extensively used in mechanical vapour compression equipment.

CHAPTER 1

Nomenclature

A = Peng Robinson constant
a = Peng Robinson constant
B = Peng Robinson constant
b = Peng Robinson constant
c = constants
C_p = Isobaric specific heat
f = fugacity
H = enthalpy
h = enthalpy
n = number of unknowns
P = pressure
R = universal gas constant
S = entropy
T = temperature
v = specific volume
x = concentration
Z = compressiblity

κ = Peng Robinson constant
δ = Peng Robinson interaction coefficient
ω = Acentric factor

Subscripts

c = critical
R = reduced
i = component
j = component

Superscripts

o = ideal gas state

FLUID PROPERTIES

1.1 Property calculation methods

Three methods were considered for the generation of the following pure and mixture properties:

Enthalpy
Entropy
Density
Fugacity
Availability (exergy)
Compressibility

Method 1: Published data and tables

The use of interpolation or curve fitting on published thermodynamic tables was dismissed through lack of comprehensive data. For pure refrigerants some 35 tables were found (3) but only 2 references were found for non-azeotropic binary mixtures. One for refrigerants 13B1& 152a (10) and the other for Ammonia & water (2). A search for equations used to generate data yielded a similar result. A family of equations by Downing (14) included pure refrigerants 11, 12, 13, 14, 21, 22, 23, 113, 114, 500, 502 and C318 but no suitable equations were found for mixtures.

Method 2: Hybrid of published pure substance data and the Van Laar equations for mixture vapour-liquid equilibrium.

This evolved from method 1 in that it was thought that the lack of mixture data could be overcome by using some generalized approach. Using the published pure substance data and the activity coefficient approach discussed by Null (26) vapour-liquid equilibrium data was found. This method was pursued (Appendix B) and some enthalpy concentration diagrams for R12-R113 were produced using the Van Laar equations for liquid phase activity coefficients and the Peng-Robinson equation of state for the other thermodynamic properties based on P-V-T data. This method was abandoned because data was restricted to substances with detailed thermodynamic tables (properties at low pressures were used in Van Laar equations) and the program required inconveniently large input files.

Method 3: Generalized Equation of State

By using an equation of state for all properties including vapour-liquid equilibrium a consistent approach could be obtained for a large range of substances with minimal input data. Reid et al (31) claimed good accuracy from the Benedict-Webb-Rubin equation, however, its use was rejected on the basis of lack of data for some refrigerants and its complexity for programming. Cubic equations of state were considered next because it had been demonstrated by Asselineau et al (4) that the Soave Redlich Kwong (SRK) equation gave acceptable engineering data for refrigerants. This approach was reinforced in an article (11) on cubic equations of state in which it was concluded that " A practical balance must be struck between accuracy on the one hand, and simplicity and generalizability on the other. The cubic equations, despite their short comings, meet this requirement ".

It was decided to try the newer Peng-Robinson equation (28) rather than the SRK because the authors claimed that " it (the equation) performs as well as or better than the SRK equation in all cases tested and shows its greatest advantages in the prediction of liquid phase densities ". At the time, 1981, no publications could be found on PR generated data for organic refrigerants thus making it an opportunity to test the Peng Robinson claim by checking PR results against the Asselineaus SRK data. It is interesting to note that other researchers had similar ideas. Meskel-Lesavre et al (24) published (before this work was complete) PR data and described the equations performance as "fair". Also Otakake et al (27) claim that of the SRK, Redlich Kwong Soave Fuller, Benidict Webb Rubin Nishiumi, The Combination and the PR equations "the PR is the most suitable for superheated vapours as well as pressurized liquids".

Conclusion

Of the 3 methods the equation of state approach used the least and most general input data, as well as offering an acceptable accuracy overall. Appendix F shows final tables of calculated pure substance data while appendix E shows comparisons with published values. The accuracy is considered to be acceptable and as good as that which Asselineau et al gained from the SRK equation. (See Appendix D for a comparison)

1.2 Pure substance:

Dichlorodifluoromethane (R12) was used to prove the pure substance calculations.

The Peng Robinson equation of state is

$$P = \frac{RT}{v - b(T)} - \frac{a(T)}{v(v + b(T)) + b(T)(v - b(T))} \qquad (1.1)$$

This basic equation (28) expressed in terms of compressibility factor is

$$Z^3 - (1 - B)Z^2 + (A - 3B^2 - 2B)Z - (AB - B^2 - B^3) = 0 \qquad (1.2)$$

where

$$A = \frac{a(T)P}{(RT)^2} \qquad (1.3)$$

$$B = \frac{b(T)P}{RT} \qquad (1.4)$$

$$Z = \frac{Pv}{RT} \qquad (1.5)$$

$$a(T) = a(T_c)\alpha \qquad (1.6)$$

$$\alpha = 1 + \kappa\left(1 - \sqrt{T_r}\right)^2 \qquad (1.7)$$

$$b(T) = b(T_c)$$

(1.8)

In equation 1.7 K is a constant for each substance and may be determined from

$$\kappa = 0.37464 + 1.54226\omega - 0.26992\omega^2 \qquad (1.9)$$

where ω is the acentric factor.

This correlation, by Peng & Robinson, between K and acentric factor was determined by establishing vapour-liquid equilibrium using $f_L = \bar{f}_V$. Initially a range of K was determined for each substance by comparing experimental and calculated saturated pressure values for a given temperature. Peng & Robinson then used equation 1.7 to linearize the relationship. This in turn established K. Finally, to generalize the application of the equation, K was correlated to the acentric factor which yielded equation 1.9 .

Initially equation 1.9 was used to generate saturated data, however, it was reasoned that by using the Peng -Robinson approach and minimising the error between calculated and selected experimental data a value of K could be generated for each substance rather than rely on the acentric factor correlation. (Note Meskel-Leasavre (24) did this too) This was done and equation 1.11 was discarded. Figure 1.1 illustrates how the prediction of saturated data is affected by K. Convergence for the selection of K was based on pressure by minimizing

$$\text{SD1} = \sqrt{\frac{\sum_1^n (calcd - publd)^2}{(n-1)}} \qquad (1.10)$$

for a range of temperatures between the higher of -40 deg C or the freezing point and the lower of T critical or 200 deg C. See Appendix A for detail.

The a(Tc) and b(Tc) values of equations 1.6 and 1.8 are generated by substituting critical conditions in equation 1.1 thus

$$a(T_c) = 0.457252\frac{R^2T_c^2}{P_c} \qquad (1.11)$$

$$b(T_c) = 0.0778\frac{RT_c}{P_c} \qquad (1.12)$$

$$Z_c = 0.3074 \qquad (1.13)$$

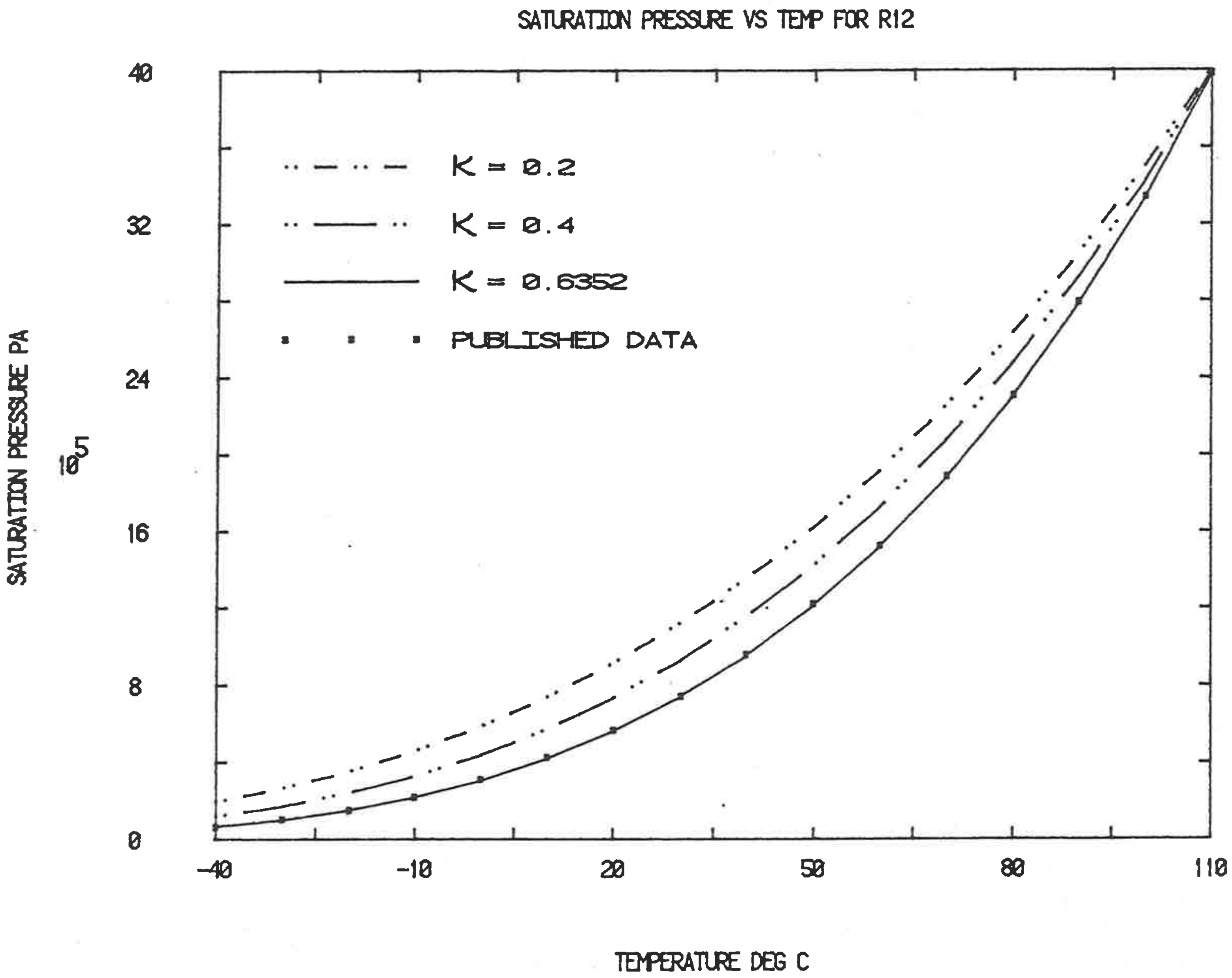

SATURATION PRESSURE VS TEMP FOR R12
K = 0.2
K = 0.4
K = 0.6352
PUBLISHED DATA
SATURATION PRESSURE PA
10^5
40
32
24
16
8
0
-40
-10
20
50
80
110
TEMPERATURE DEG C

Fig 1.1

These critical constants may be checked by equating the second derivative of equation 1.2 (corresponding to the point of inflextion at the critical condition) to zero.

From equation 1.2 $$B = 1 - 3Z \qquad (1.14)$$

Substituting Zc = 0.3074 in equation 1.14 yields

B = 0.0778

Rearranging 1.2

$$A = \frac{-Z^3 + (1 - B)Z^2 + Z(3B^2 + 2B) - (B^2 + B^3)}{(Z - B)}$$

Substituting for B and Zc yields

A = 0.457252

It is worth noting that the set of constants given in the original PR publication of Zc = 0.307, B = 0.0778 and A = 0.45724 did not satisfy the above equations and that later publications (11) used the same set as was derived here.

One of the features of cubic equations of state is their fixed critical condition. This PR Z value of 0.3074 seldom coincides with the actual value (viz R12 = 0.276) and therefore must be in error. No attempt was made to substitute the correct value because the small latent heat value near the critical region made refrigeration system operation in this area undesirable. It was essential though that the algorithm operate up to and through this critical region. Occasionally a "guess" generated in an iteration was quite close to the critical point, well away from the system operating condition. This sometimes led to computational difficulties. When the cubic yielded 3 roots but only 1 was real, program execution terminated. This failure to get both a liquid and a vapour root was overcome by the definition of a "dead zone" around the critical point. Inside this zone, which was specified in terms of Celsius degrees, the critical properties were used. The largest zone width was 0.7 Celsius degrees.

Figure 1.2 illustrates the nature of the equation. A wide flat zone develops as the cubic approaches the point of inflexion. The following points 1.2.1 to 1.2.6 outline the basis used for the calculation of each property.

1.2.1 Saturation pressure

For a given temperature the saturation pressure was determined by the convergence of the vapour and liquid fugacity values.

1.2.2 Compressiblity

Knowing P and T compressibility is evaluated directly from equation 1.5 using the specific volume value from the PR equation.

1.2.3 Fugacity

Appendix A shows the derivation of

$$ln\frac{f}{P} = Z - 1 - ln(Z - B) - \frac{A}{2\sqrt{2}B} ln\left(\frac{Z + 2.414B}{Z - 0.414B}\right) \qquad (1.15)$$

By substituting known values of P and T and a calculated value of Z into equation 1.15 the fugacity can be found.

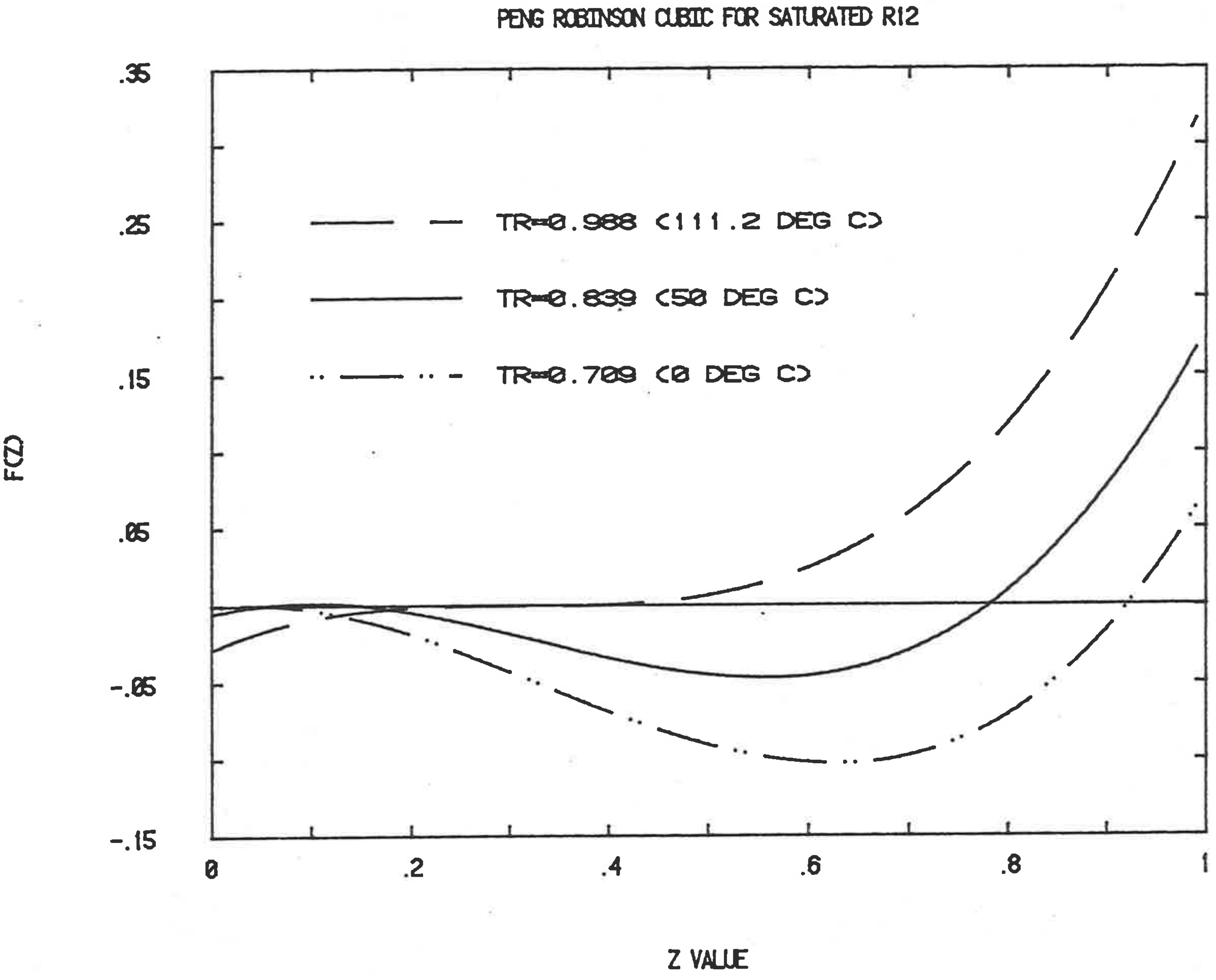

PENG ROBINSON CUBIC FOR SATURATED R12
TR=0.988 (111.2 DEG C)
TR=0.839 (50 DEG C)
TR=0.709 (0 DEG C)
F(Z)
.35
.25
.15
.05
-.05
-.15
0
.2
.4
.6
.8
1
Z VALUE

Fig 1.2

1.2.4 Enthalpy

Reid et al (31) propose a 3 stage calculation for enthalpy

Stage 1

Evaluate enthalpy departure at T_{datum} (equation 1.16) from saturated liquid to ideal gas state.

$$H - H^{\circ} = RT(Z-1) + \frac{T\frac{da(T)}{dT} - a(T)}{2\sqrt{2}\,b(T)} ln\left(\frac{Z + 2.414B}{Z - 0.414B}\right) \qquad (1.16)$$

(See appendix A for all departure derivations)

Stage 2

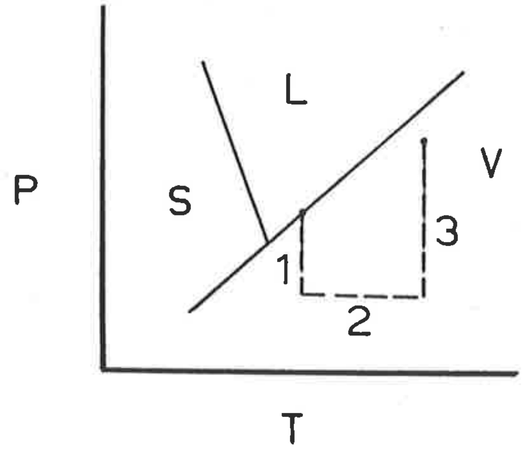
Integrate, with respect to temperature, the specific heat capacity expression for the ideal gas state. A cubic specific heat capacity equation (equn 1.17) was taken from Reid (31) with constants from the same reference as well as some derived from data in ASHRAE (2).

$$C_p^o = c4 + c3\,T + c2\,T^2 + c1\,T^3 \qquad (1.17)$$

$$\int_T^{T_{ref}} C_p^o\,dT = \left[\frac{c1\,T^4}{4} + \frac{c2\,T^3}{3} + \frac{c3\,T^2}{2} + c4\,T\right]_{T_{ref}}^{T} \qquad (1.18)$$

Stage 3

At T = T_{system} evaluate the enthalpy departure from the ideal gas state up to the system pressure. Graphically on a P − T diagram these 3 stages may be represented thus;



1.2.5 Entropy

As with enthalpy a 3 stage process with saturated liquid as the datum was used. The departure was given by

$$S - S^o = \frac{\frac{da}{dT}}{2\sqrt{2}\, b(T)} \ln\frac{Z + 2.414\,B}{Z - 0.414\,B} - R \ln\frac{Z}{Z - B} + R \ln\frac{V}{V^o} \qquad (1.19)$$

and by the specific heat equation integration for the ideal gas state

$$\Delta S = \int_{T_{ref}}^{T} \frac{C_p^o}{T}\, dT \qquad (1.20)$$

$$\Delta S = \left[\frac{c1\,T^3}{3} + \frac{c2\,T^2}{2} + c3\,T^2 + c4 \ln T\right]_{T_{ref}}^{T}.$$

1.2.6 Latent Heat

For a given temperature the latent heat was taken as the difference between the liquid and vapour isothermal enthalpy departure from the ideal gas state to the pressure under consideration as computed using the PR equation.

1.3 Binary Mixtures

Like most cubic equations of state the PR equation copes with mixtures via mixing rules and a coefficient which is peculiar to a pair of substances. Mixture properties are sensitive to the value of the coefficient and therefore care should be taken in its evaluation. Values for the Feng-Robinson constants a(T) and b(T) were taken directly from the original publication (28). Applying these rules to a binary mixture yields

$$a_{mix} = x_1^2\, a(T)_1 + 2\, x_1\, x_2\, a(T)_{12} + x_2^2\, a(T)_2 \tag{1.21}$$

$$b_{mix} = x_1\, b(T)_1 + x_2\, b(T)_2 \tag{1.22}$$

where

$$a(T)_{12} = (1 - \delta_{12})\, \sqrt{a(T)_1\, a(T)_2} \tag{1.23}$$

For the mixtures listed below the binary interaction coefficient δ was determined by minimizing the error between calculated and published data

mixture	reference
R13B1 - R152a	(10)
R11 - R22	(24)
R12 - R152a	(29)
R12 - R13	(25)
R12 - R22	(16)

No experimental data could be found for an R12 R113 mixture and so the regular solution data shown in Appendix B was used. For all mixtures the saturation pressure data generated from a given temperature and liquid concentration was compared to published data using

$$SD2 = \sqrt{\frac{\Sigma_1^n \left(\frac{calcd-publd}{publd}\right)^2}{(n-1)}}$$

Table 1.1 shows the δ values whilst appendix E shows all data.

Mixture		SD2	No Pts	δ
R13B1	R152a	0.014	19	0.079
R11	R22	0.016	22	0.0495
R12	R152a	0.011	18	0.081
R12	R13	0.033	10	0.011
R12	R22	0.013	22	0.047
R12	R113	0.069	14	0.04525

Table 1.1

(Note: SD2 is based on saturation pressure)

For saturation pressure, compressibility, enthalpy, entropy and latent heat calculations the pure property equations were used but with mixture values of Z. In the case of the specific heat capacity integration for enthalpy (and entropy) a simple molar proportion of the pure values was used.

$$\int_{T_{ref}}^{T} (C_p^o)_{mix}\, dt = x_1 \int_{T_{ref}}^{T} (C_p^o)_1\, dt + x_2 \int_{T_{ref}}^{T} (C_p^o)_2\, dt$$

The fugacity coefficient was evaluated after configuring the published equation for a binary mixture viz;

$$ln \frac{f_1}{x_1\, P} = \frac{b(T)_1\,(Z-1)}{b(T)} - ln(Z-B) - \frac{A}{2\sqrt{2}\,B} \left(\frac{2(x_1\, a(T)_1 + x_2\, a(T)_{12})}{a(T)} - \frac{b(T)_1}{b(T)}\right) \; ln\left(\frac{Z+2.414\,B}{Z-0.414\,B}\right) \qquad (1.24)$$

Note: In equation 1.24 properties without a subscript are mixture properties calculated from the main PR equation but with the pure a and b constant values replaced with the mixture values determined from the mixing rules (equations 1.21 and 1.22).

1.4 Subcooled liquid properties

For subcooled liquid conditions the PR equation sometimes yields a meaningless negative root instead of a valid liquid value. To overcome this discrepancy in the calculation all subcooled liquid calcuations were treated as saturated condition calculations at the temperature in question. The error introduced by this was considered insignificant. For example the error in enthalpy between R12 liquid at saturation pressure and 60 deg C and liquid at the same pressure and 40 deg C is less than one percent.

1.5 Superheated Vapours

A vapour root was found from the PR cubic for all superheated values tested. No detailed check on superheated vapour points was conducted, however, all pure refrigerant tables in Appendix F show these data and spot checks on enthalpy revealed a typical accuracy of around 3 percent. For example Dupont data gives 231 kJ/kg for R12 at 959 kPa and 30 degrees of superheat and the calculated value was 224.6 kJ/kg.

CHAPTER 2

Nomenclature

a = activity
B = availability
D = irreversibility
F = flow
f = fugacity
H = enthalpy
Q = energy
n = mols
S = entropy

Subscript

A = absorber
B = bottom
C = condenser
D = distillate
E = evaporator
F = feed
G = generator (boiler)
i = component
i = internal
L = liquid
o = datum
p = pump
q = energy across boundary
R = reflux
V = vapour
y = relates to internal subsystem
z = relates to external system

Superscript

- = partial molar property

Availability, the Second Law and the Absorption cycle.

2.1 The second law and the closed system

By using the approach to second law system analysis developed by Teja and Roach (35) it is possible to write an availability balance equation for an absorption cycle where only heat and work cross the system boundary.

Consider the absorption refrigeration cycle shown in figure 2.1;

- Heat input to the boiler (Q_G) powers the distillation column.
- Heat is rejected from the condenser (Q_C) to the surroundings.
- After throttling to a lower pressure heat (Q_E) is transferred from the medium being cooled to the boiling low temperature refrigerant.
- Heat is rejected from the absorber (Q_A) to condense the two phase mixture formed when the refrigerant vapour from the evaporator is mixed with the bottom product from the distillation column.
- A work input (W_P) is required to pump the feed flow into the column.

Several internal heat exchangers may be employed but only one, the preheater, is shown here. If a boundary is drawn around this system the availability balance equation may be written thus;

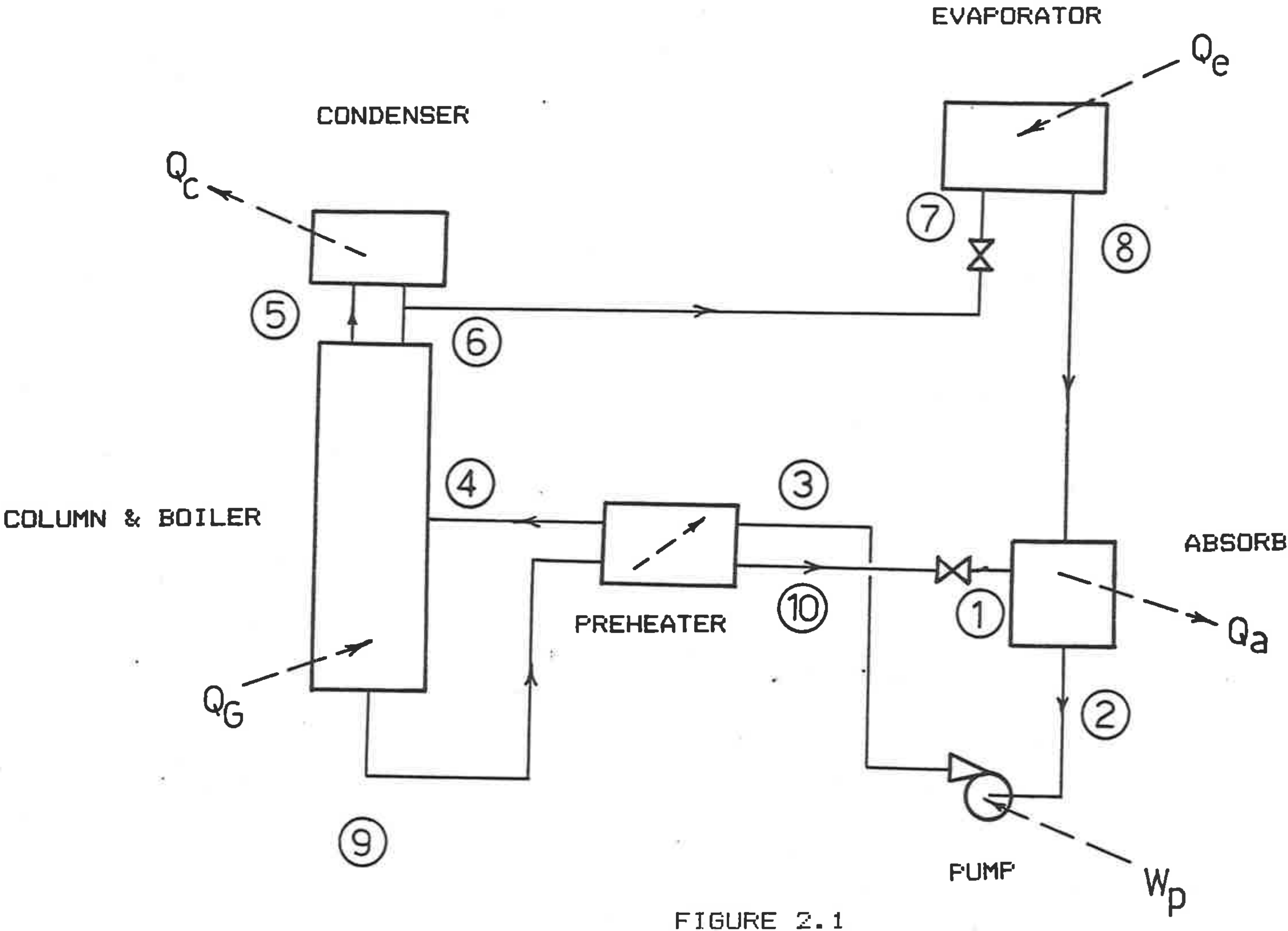
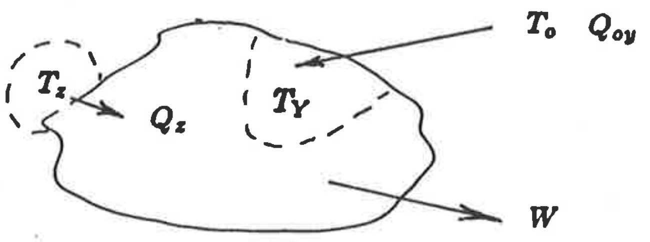

EVAPORATOR
Q_e
CONDENSER
Q_c
⑦
⑧
⑤
⑥
④
③
COLUMN & BOILER
ABSORBER
PREHEATER
⑩
①
Q_a
Q_G
②
⑨
PUMP
W_p

FIGURE 2.1



$$\Sigma Q_z\left(1-\frac{T_o}{T_z}\right)-W \quad = \quad D \qquad (2.1)$$

$-W$ = work supplied to the system

$\Sigma Q_z\left(1-\frac{T_o}{T_z}\right)$ = the Carnot work equivalent across the boundary due to the transfer of Q_z from an adjacent system at temperature T_z with respect to datum T_O. If the boiler heat Q_G is transferred at boiler temperature T_G and the evaporator heat Q_E at T_E then

$$= \qquad Q_E\left(1-\frac{T_O}{T_E}\right)-Q_G\left(1-\frac{T_O}{T_G}\right)$$

D = total system irreversibilities.

Note: If heat is transferred across the boundary at the datum temperature there is no Carnot work associated with it. Assuming Q_C and Q_A have been transferred at T_O, then

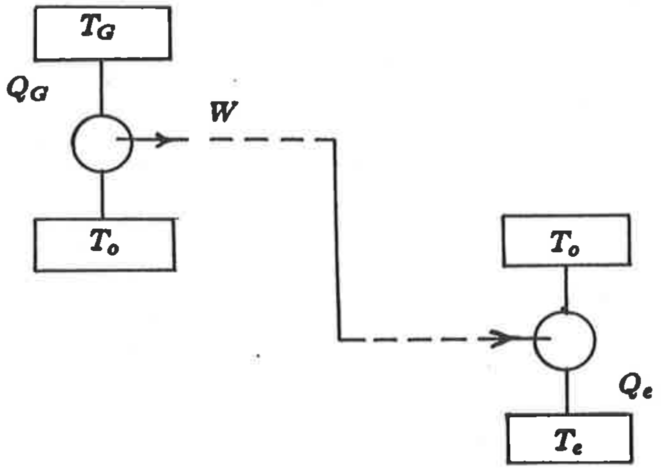
$$Q_C\left(1-\frac{T_O}{T_O}\right)-Q_G\left(1-\frac{T_O}{T_O}\right) \quad = \quad 0$$

If irreversibilities are considered as available work which has been degraded to thermal energy at T_O without producing useful work then equation 2.1 states that the total available work minus the useful work done must equal the total system irreversibility.

2.2 The absorption system and the Carnot cycle

It is possible to represent the ideal absorption cycle as a

Carnot engine driving a Carnot heat pump (36)



According to the second law the maximum possible output of the Carnot engine (W) operating between T_G and T_O is given by (36)

$$W = Q_G\left(1 - \frac{T_O}{T_G}\right) \tag{2.2}$$

Similarly the minimum work required by the heat pump to raise Q_E from T_E to T_O is the carnot work

$$W = Q_E\left(\frac{T_O}{T_E} - 1\right) \tag{2.3}$$

Defining coefficient of performance as

$$COP = \frac{Energy \quad transferred}{Energy \quad input} = \frac{Q_E}{Q_G} \tag{2.4}$$

Substituting equations 2.2 and 2.3 in the COP expression yields

$$COP = \frac{\left(1 - \frac{T_O}{T_G}\right)}{\left(\frac{T_O}{T_E} - 1\right)}$$

$$COP_{CARNOT} = \frac{T_E\,(T_G - T_O)}{T_G\,(T_O - T_E)} \tag{2.5}$$

Equation 2.5 represents the maximum COP possible from an absorption system.

2.3 A relationship between Carnot and actual COP

Rewriting equation 2.1

$$Q_E\left(1-\frac{T_O}{T_E}\right)-Q_G\left(1-\frac{T_O}{T_G}\right)-W_p \quad = \quad D$$

Dividing through by Q_G and substituting from 2.4 gives

$$COP\left(1-\frac{T_O}{T_E}\right)-\left(1-\frac{T_O}{T_G}\right)-\frac{W_P}{Q_G} \quad = \quad \frac{D}{Q_G}$$

Therefore

$$COP \quad = \quad \frac{\frac{W_P}{Q_G}+\frac{D}{Q_G}+\left(1-\frac{T_O}{T_G}\right)}{\left(1-\frac{T_o}{T_E}\right)} \qquad (2.6)$$

$$COP \quad = \quad \frac{\frac{W_P}{Q_G}+\frac{D}{Q_G}}{\left(1-\frac{T_o}{T_E}\right)}-\frac{T_E\,(T_G-T_O)}{T_G\,(T_O-T_E)}$$

Ignoring the work term because it is typically a second order effect

$$= \quad \frac{T_E\,(T_G-T_O)}{T_G\,(T_O-T_E)}-\frac{D}{Q_G\left(\frac{T_O}{T_E}-1\right)}$$

Substituting from equation 2.5

$$COP \quad = \quad COP_{CARNOT}-\frac{\frac{D}{Q_G}}{\frac{T_O}{T_E}-1} \qquad (2.7)$$

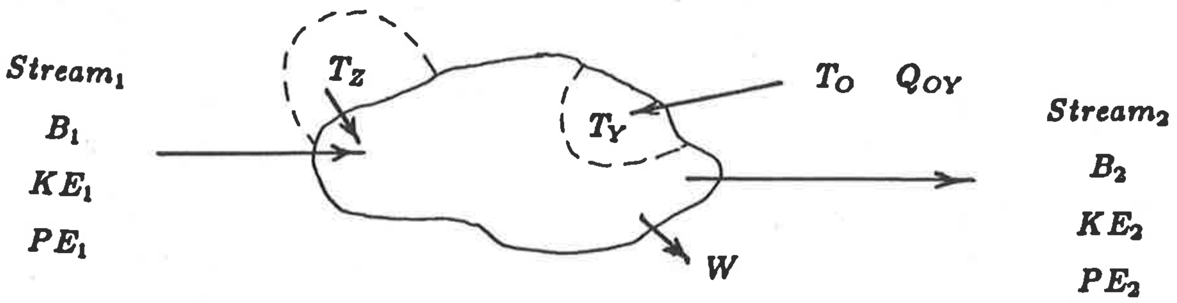
This means that a system COP may be calculated two ways, either by a first law energy balance approach or by subtracting the system irreversibility from the Carnot COP. The two results may be compared and by examining the individual irreversibility terms in equation 2.7 it is possible to establish which processes causes the largest departure from the Carnot value.

2.4 System irreversibilities

For convenience system irreversibilities may divided into two types, boundary and subsystem.

In 2.1 the overall system was defined such that only thermal energy and work crossed the boundary. If losses associated with the work transfer (the mechanical pump) are ignored then the availability losses associated with the boundary will be Carnot work lost due to thermal energy passing across the boundary from one temperature to another with no useful work output. (see equation 2.1) For this analysis it has been assumed that all boundary heat exchange takes place at constant temperature. If this was not the case an integration along the heat exchanger surface would be necessary.

Irreversibilities occuring internally may be dealt with by defining internal subsystems. Many of these subsystems involve streams as well as heat transfer. Using the same representation as 2.1 and including streams yields the equation



$$-\Delta B + \Sigma Q_Z\left(1 - \frac{T_O}{T_Z}\right) - W - \Delta(KE + PE) \quad = \quad D \qquad (2.8)$$

where B is the stream availability function which may be evaluated by selecting a datum and applying the following (35) equation

$$B\{T, P, x_i\} \quad = \quad (H - H_O) - T_O\,(S - S_O) + \Sigma n_i\,(RT_O ln a_i^o) \qquad (2.9)$$

By replacing the activity term with a fugacity expression it is possible to evaluate 2.9 with data from the Peng-Robinson equation. The following fugacity terms were developed for the 3 possible binary mixture conditions.

Liquid phase only

$$RT_o\left[x_1 ln\left(\frac{\bar{f}_{1L}}{f^o_{1L}}\right) + x_2 ln\left(\frac{\bar{f}_{2L}}{f^o_{2L}}\right)\right]$$

Vapour phase only

$$RT_o\left[x_1 ln\left(\frac{\bar{f}_{1V}}{f^o_{1V}}\right) + x_2 ln\left(\frac{\bar{f}_{2V}}{f^o_{2V}}\right)\right]$$

Two phase

$$RT_o\left[x_1 ln\left(\frac{\bar{f}_{1V}}{f^o_{1V}}\right) + x_2 ln\left(\frac{\bar{f}_{2L}}{f^o_{2L}}\right)\right]$$

Appendix F shows availability values for pure refrigerants. Due to the absence of published data no checking was possible. All that can be said is that accuracy is dependent on the data generated by the Peng-Robinson equation. No doubt the liquid property values would contribute the greatest error, in particular liquid entropy.

It should be noted that availability changes across a given process are dependent on the datum conditions. Consider some arbitrary heat exchange process using a pure substance.

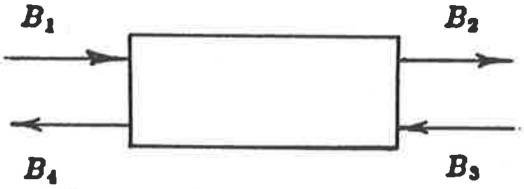
$$\Delta B_{process} = B_2 - B_1$$

from equation 2.1

$$\begin{aligned} B_1 &= (h_1 - T_oS_1) - (h_o - T_oS_o) \\ B_2 &= (h_2 - T_oS_2) - (h_o - T_oS_o) \\ \Delta B &= (h_2 - T_oS_2) - (h_1 - T_oS_1) \end{aligned}$$

Here the datum $h_0 - T_0\ S_0$ values cancel and ΔB depends only on the enthalpy and entropy at the two conditions and the datum temperature. Therefore if the same process is considered (same h_1 ,h_2 viz same temperatures and pressures) for two different availability datum temperatures (same datum pressure) ΔB will have different values. This means that it is not possible to produce a single general table of availability values as it is for say enthalpy; there has to be a separate table for each T_0 value.

An example of a subsystem irreversibility is the loss in availability through the streams entering and leaving a heat exchanger. The contra-flow heat exchanger example is treated in many texts (6)



An irreversibility occurs when the availability lost by the hot stream (B1-B2) is greater than the availability gained

(B4-B3) by the cold stream. In terms of a temperature profile for zero availability loss to occur both profiles would have to be coincident ie matching profiles with no approach. In summary all the internal heat exchangers have the possiblity of incurring irreversibilities.

Now applying equation 2.8 to find the individual subsystem irreversibilities:

Evaporator

Consider that the superheating at the evaporator exit is negligible and therefore the refrigerant temperature/pressure will be constant at saturation conditions (T_E). On this basis the Carnot term can be written

$$Q_E\left(1-\frac{T_o}{T_E}\right)$$

This represents the Carnot work required to lift Q_E from T_E to T_O. Applying equation 2.8 to the evaporator in figure 2.1 we get

$$D_{EVAP} \quad = \quad Q_E\left(1-\frac{T_o}{T_E}\right)-F_D(B_7-B_8)$$

where D_{EVAP} is the total evaporator irreversibility and for cooling the temperature of the adjacent system T_z is T_E.

Condenser

Assume subcooling and superheating to be zero and that the fluid is at the datum temperature.

$$D_{COND} \quad = \quad -(F_D+F_R)(B_5-B_6))$$

where the subsystem temperature T_y adjacent to the boundary is T_O.

Absorber

In the case of the absorber usually a two phase mixture results from the mixing of the bottoms and distillate streams. The feed concentration is far from being a pure substance and therefore a temperature change can be expected through the heat exchanger. However, if the mixing and heat exchange process are combined it can be argued that the heat of mixing may be removed as it forms with an isothermal process resulting. Using this and applying equation 2.8

$$D_{ABS} \quad = \quad -(F_D B_8 + F_B B_1 - F_F B_2)$$

where the subsystem temperature T_y adjacent to the boundary is T_0 .

Generator

Both the generator temperature and the temperature of the external system supplying heat have been assumed to be the same. This means that the generator Carnot term in equation 2.1 gives the total work available to the fluid in the system. In practice of course substantial irreversibilities may occur during the heat exchange process eg gas flame to fluid, and therefore care should be taken when comparing this data with actual systems. For the generator and column, from equation 2.8

$$D_{GEN} \quad = \quad -Q_G\left(1 - \frac{T_o}{T_G}\right) - (F_F B_4 + F_R B_6 - (F_D + F_R)B_5 - F_B - B_9)$$

where the external adjacent system temperature T_z is T_G .

Pump

If some of the pump work which crossed the boundary was lost in the efficiency of the pump there would be an irreversibility. For this analysis it will be assumed that all work crossing the boundary is imparted to the fluid and therefore applying 2.8 gives

$$W_p \quad = \quad -\Delta B \quad = \quad -F_F(B_2 - B_3)$$

Distillate throttling

$$D_{DE} \quad = \quad -F_D(B_6 - B_7)$$

Bottoms throttling

$$D_{BE} \quad = \quad -F_B(B_{10} - B_1)$$

Preheater

$$D_{PH} \quad = \quad -(F_F B_3 + F_B B_9 - F_F B_4 - F_B B_{10})$$

These system irreversibilities may be summed and used in equation 2.7 to determine COP or, in equation 2.1, to compile an availability balance around the cycle viz;

$$\begin{aligned} D \quad = \quad & Q_E\left(1 - \frac{T_o}{T_E}\right) - F_D(B_7 - B_8) \; -(F_D + F_R)(B_5 - B_6) \\ & -Q_G\left(1 - \frac{T_o}{T_G}\right) - (F_F B_4 + F_R B_6 - (F_D + F_R)B_5 - F_B - B_9) \\ & -(F_D B_8 + F_B B_1 - F_F B_2) \\ & -F_D(B_6 - B_7) \quad -F_B(B_{10} - B_1) \\ & -(F_F B_3 + F_B B_9 - F_4 B_4 - F_B B_{10}) \end{aligned}$$

$$= \quad Q_E\left(1-\frac{T_O}{T_E}\right) + F_F B_2 - F_F B_3 \quad - Q_G\left(1-\frac{T_O}{T_G}\right)$$

$$D \quad = \quad Q_E\left(1-\frac{T_O}{T_E}\right) - W_p \quad - Q_G\left(1-\frac{T_O}{T_G}\right)$$

This checks with equation 2.1 ie the availability changes around the internal circuit sum to zero.

2.5 Avoidable and unavoidable irreversibilities

For this system there is no way of deriving work from the mixing process and therefore there will always be unavoidable mixing irreversibilities.

The only way this loss can be minimised is to change the stream compositions and not the actual mixing process. By keeping the availabilty of the streams being mixed as close as possible the losses are minimized. In the case of mixing the distillate and bottom flows minimising of the mixing loss is done by changing the stream availabilities with internal heat exchangers. (see chapter 3) The column and its mixing may be assesed by taking an overall view. If the minimum work of separation is taken as the increase in availability between the products (12) and the feed then

Column loss = equivalent Carnot input
- minimum work of separation

An example of a theoretically avoidable irreversibility occurs in the contra flow heat exchanger. If there is no approach and the temperature profiles of the two streams are coincident then the loss is zero.

CHAPTER 3

Nomenclature

D = irreversibility
Q = heat
T = temperature

Subscript

E = evaporator
C = condenser
G = generator (boiler)
o = datum

ABSORPTION SYSTEM

3.1 Introduction

Chapter 3 deals with the application of the computer model to an ideal system, a practical system and a prototype system with an emphasis on second law analyses. The sections in the chapter and their objectives are as follows:

Second law and Carnot performance

- To configure the second law COP expression (equation 2.7) for use with the absorption cycle.

The ideal System

- To model an ideal system, ie one in which all avoidable irreversibilites are removed so that the COP predicted is the maximum possible.
- To investigate the effect of internal heat exchangers on COP for an ideal system via second law analyses.
- To assess the effect of performance variables such as mixture concentrations and operating temperature on COP for the ideal system.

Practical cycle

- To model an air cooled system and show a typical cooling COP using conditions encountered in practice.
- Model a heat pump mode to predict a heating COP for a practical air to air system.
- Model an organic system using published performance data for a commercially available Lithium Bromide plant and compare COP values for the two systems.

Prototype performance

- Model an existing prototype system and compare the measured and predicted COP's.

For this analysis Coefficient of Performance (COP) has been selected as the measure of performance. It is recognised that in the application of this equipment many other factors, in addition to COP, should be considered, however, since this work is confined to the thermodynamics of the internal system COP alone has been used.

3.2 Ideal cycle and second law analysis

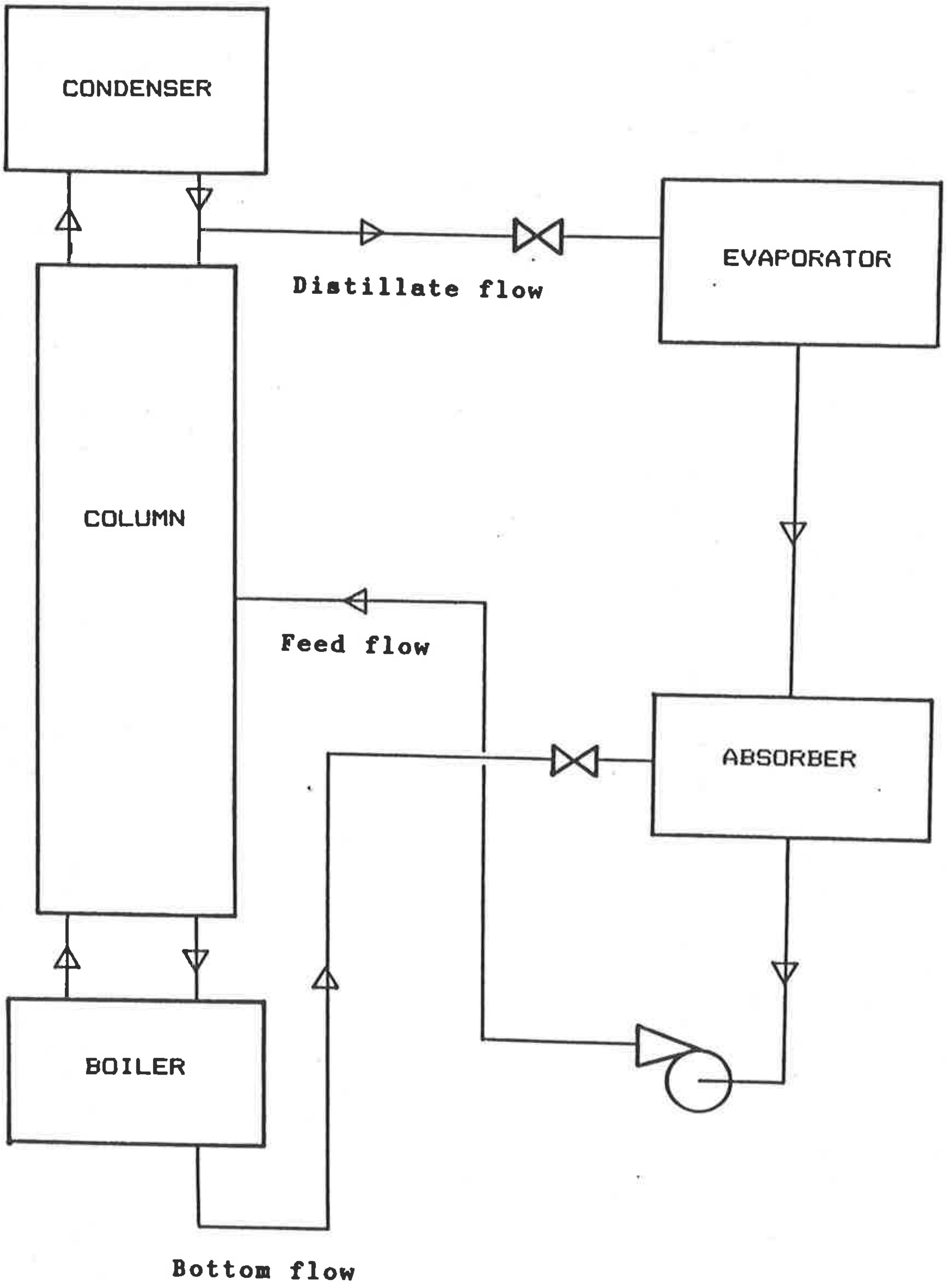
By using a second law analysis (equation 2.7) it is possible to assess the effect of the various irreversibilities on COP. Further to this by distinguishing between avoidable and unavoidable irreversibilities it should be possible to establish a maximum achievable COP. Using the computer model it is possible to eliminate some avoidable irreversibilites by

- Selecting a zero approach on all heat exchangers which means rejecting all heat at ambient conditions, transferring all heat to the evaporator at T_E and supplying the boiler heat at T_G.

- Ignoring friction as well as heat and "cold" losses for the system pipework.

System performance may then be analysed by substituting the remaining irreversibilities in equation 2.7 . For example using the cycle shown in figure 3.1 and the conditions listed above equation 2.7 yields

$$\text{COP} = \text{Carnot COP} - \frac{(D1+D2+D3+D4)}{Q_g\left(\frac{T_o}{T_E} - 1\right)} \quad \ldots \; (3.1)$$



BASIC CYCLE

FIGURE 3.1

where the irreversibilities are

D1 = column

D2 = absorber mixing

D3 = Throttling of bottom flow

D4 = Throttling of distillate flow

The Carnot COP expression derived in section 2.2 is

$$\text{Carnot COP} = \frac{T_E\ (T_G - T_o)}{(T_o - T_E)\ T_G} \qquad \ldots\ldots \qquad (3.2)$$

In equation 3.2 the the boiler temperature (T_G) is dependent on the ambient temperature (T_o) and so this relationship may be plotted for a specified evaporator temperature (T_E). In the system (figure 3.1) the distillation column pressure is determined by the condensing condition, which in turn, is established by the heat rejection temperature. Assuming heat is rejected to the environment and not to some other system then the heat rejection temperature (T_o) determines the generator pressure and therefore its temperature (T_G).

This relationship between T_o and T_G is determined by both mixture properties and by the system operating parameters. It should be noted that an ideal case will be considered and therefore the condensing temperature (T_C) will be assumed to be the ambient temperature (T_o). Figure 3.2 shows T_C versus T_o for 3 mixtures where the distillate and bottoms mass concentrations are 0.99 and 0.05 respectively. Therefore for a given ambient temperature the Carnot COP can be calculated for a range of T_E values (figure 3.3). This then defines the maximum thermodynamically possible COP.

It is interesting to note that even though the ammonia-water cycle (R717 R718) Carnot COP is much higher than the organic

PARAMETERS FOR FIGURE 3.2

Distillate mass concentration 0.99

Bottom mass concentration 0.05

Assume column at constant pressure

Tg Deg C : Saturation temperature of bottom composition corresponding to saturation pressure of distillate at Tc

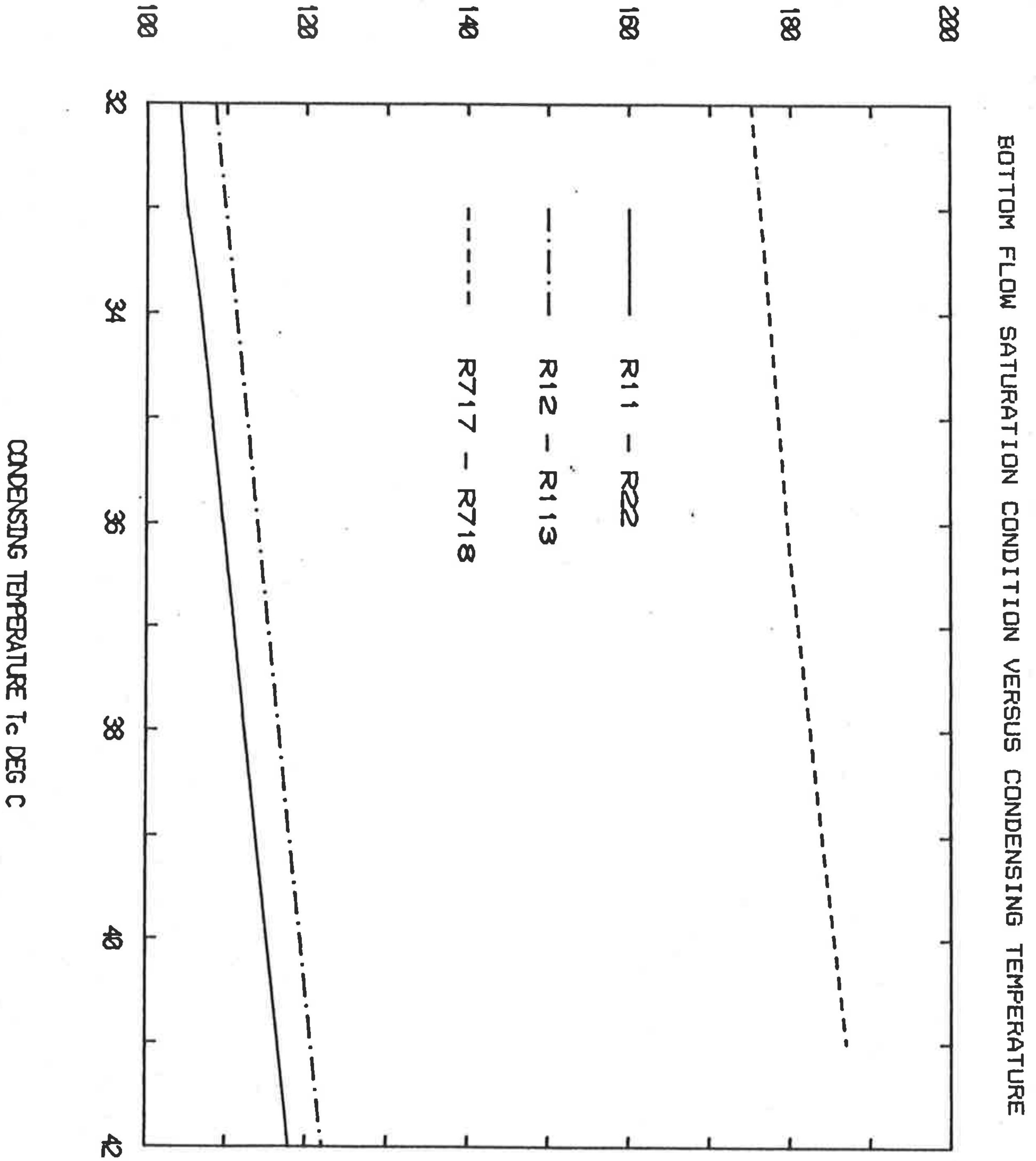


Fig 3.2

PARAMETERS FOR FIGURE 3.3

Data was derived from equation 3.2

Distillate mass concentration 0.99

Bottom mass concentration 0.05

T_G = Saturation temperature of bottom composition corresponding to saturation pressure of distillate at 30 deg C.

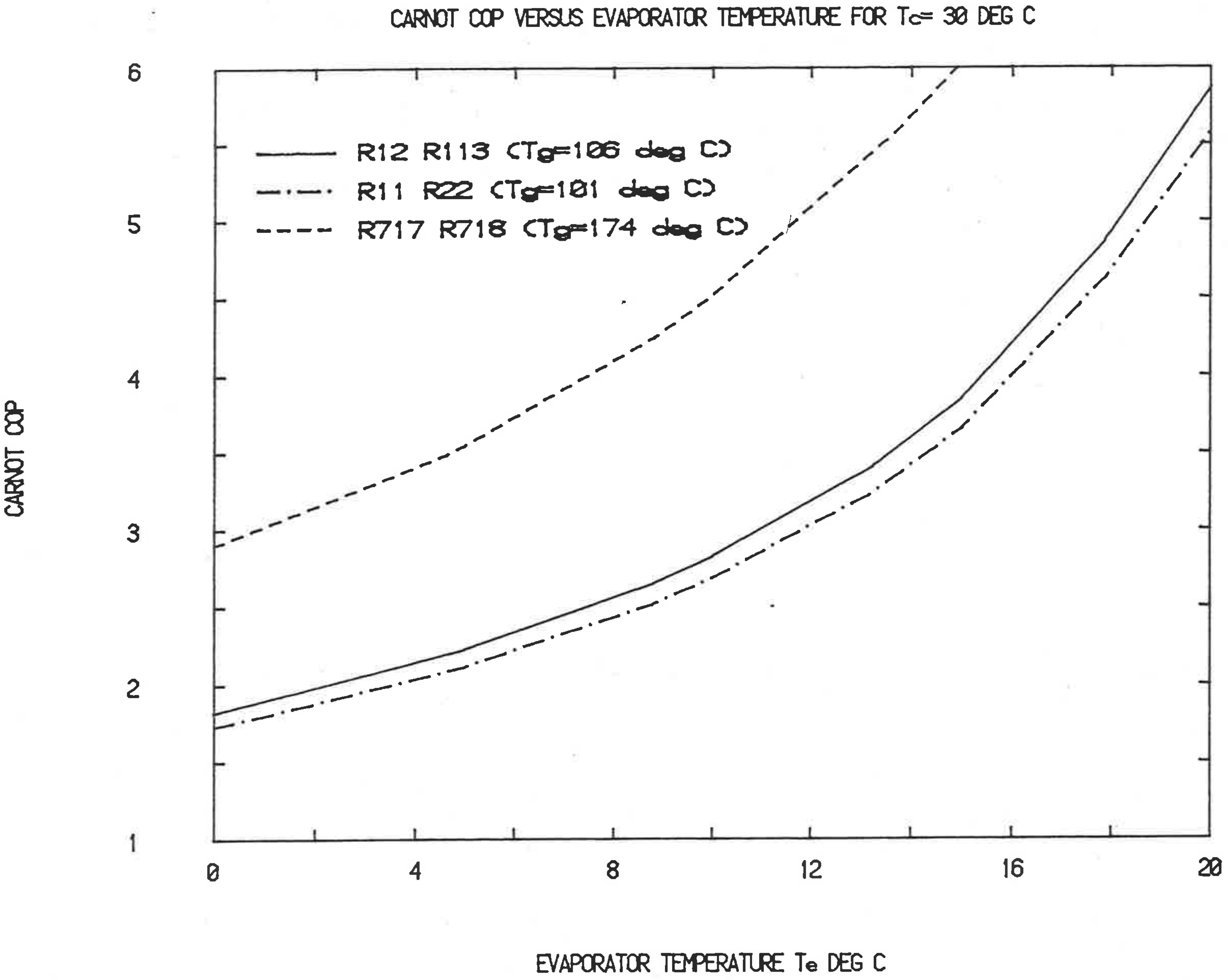

CARNOT COP VERSUS EVAPORATOR TEMPERATURE FOR Tc= 30 DEG C
R12 R113 (Tg=106 deg C)
R11 R22 (Tg=101 deg C)
R717 R718 (Tg=174 deg C)
CARNOT COP
1
2
3
4
5
6
0
4
8
12
16
20
EVAPORATOR TEMPERATURE Te DEG C

Fig 3.3

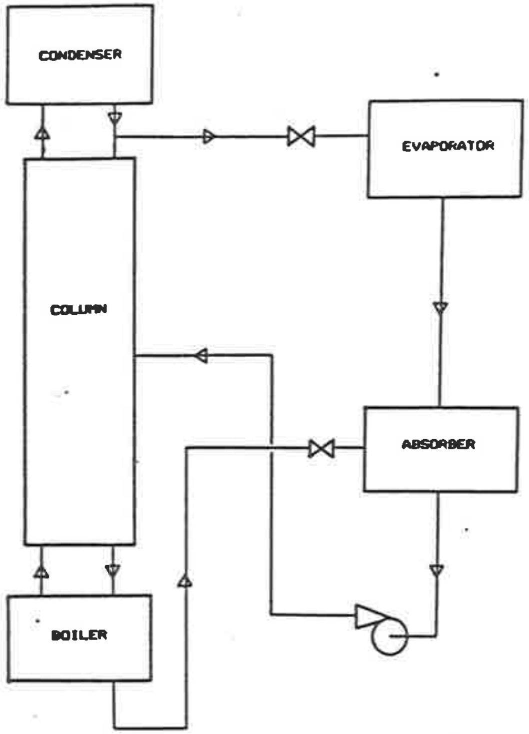
cycles the actual practical COP's are of the same order (7) because of the large heat of mixing value. In terms of equation 3.1 this means a large D2 value.

To establish the importance of the various irreversibilities a cycle with a range of evaporator temperatures will be considered. This range was chosen so as to cover typical comfort air conditioning operation for Adelaide (see section 3.3). Various internal heat exchangers will be added later in an effort to reduce irreversibilities but firstly consider the basic cycle.

3.2.1 Basic Cycle

Equation 3.1 was applied to the basic cycle for a range of evaporator temperatures (table 3.1) so that the effects of the various irreversibilities could be assessed. For example in figure 3.4, which is a plot of the data in table 3.1, the distance between the Carnot COP line and the case A line is an indication of the effect of the column irreversibilities. Similarly the effect of the absorber mixing losses is indicated by the distance between case A and case B. Only the two irreversibilities have been considered here because the effect of both the distillate and bottom flow throttling processes was negligible.

If all of the irreversibilities were unavoidable then the final plot (case B) would represent the maximum COP theoretically possible. For example the absorber mixing irreversibilities are unavoidable because no useful work can be derived from the mixing process. However, this is not the case for the column.



PARAMETERS FOR FIGURE 3.4 AND TABLE 3.1

Ambient air temperature (To) 30 deg C
Boiler temperature (Tg) 101 deg C
Bottom mass concentration 0.05
Distillate mass concentration 0.99
R11 & R22 mixture

	Irreversiblity terms included in equation 3.1
Case A	Column
Case B	Column and absorber mixing

TABLE 3.1: COP VALUES FROM EQUATION 3.1

evap temp deg C	0	5	10	15	20
Carnot	1.73	2.11	2.69	3.65	5.57
Case A	0.73	0.90	1.14	1.42	1.79
Case B	0.16	0.19	0.26	0.33	0.43

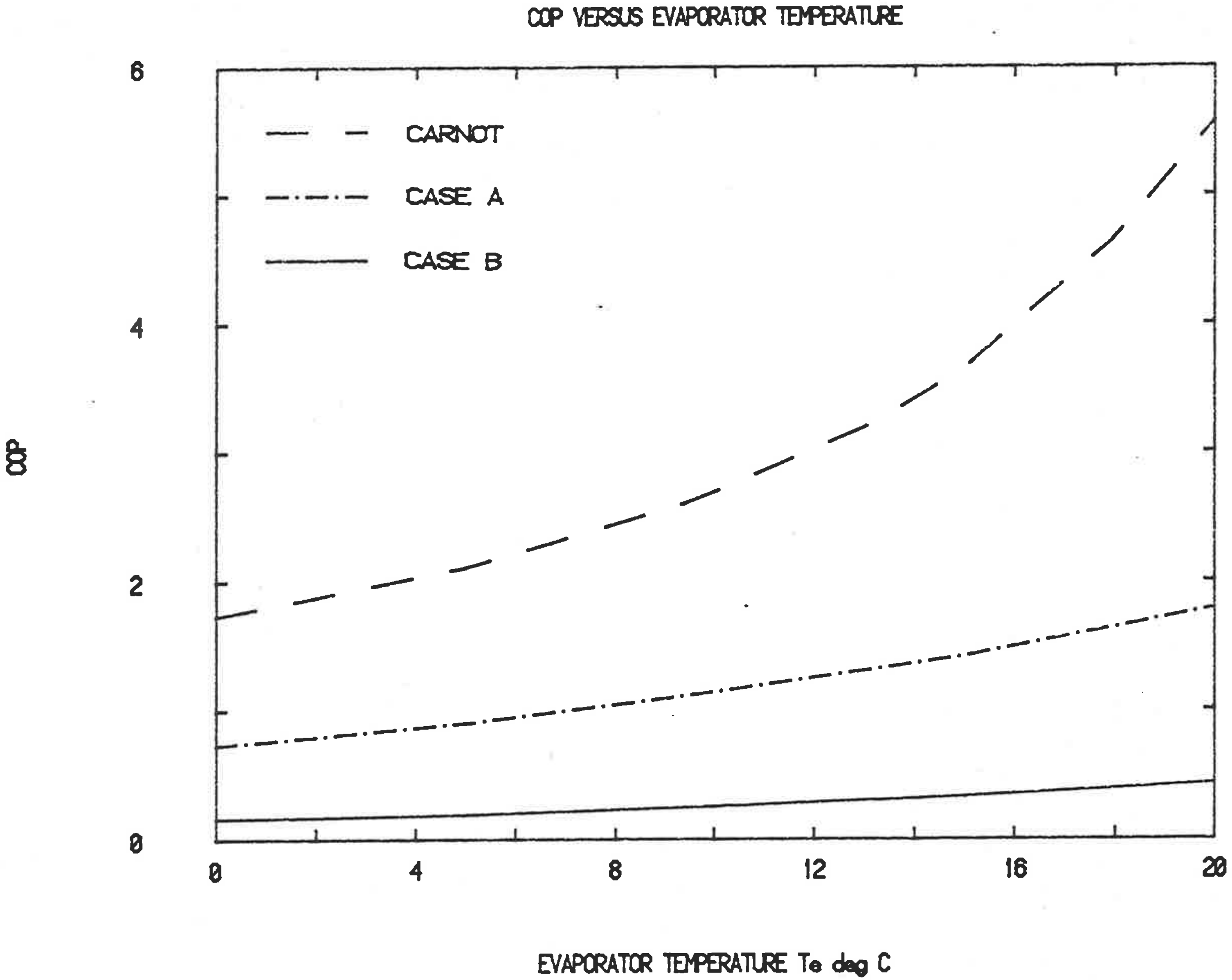

COP VERSUS EVAPORATOR TEMPERATURE
CARNOT
CASE A
CASE B
COP
0
2
4
6
0
4
8
12
16
20
EVAPORATOR TEMPERATURE Te deg C

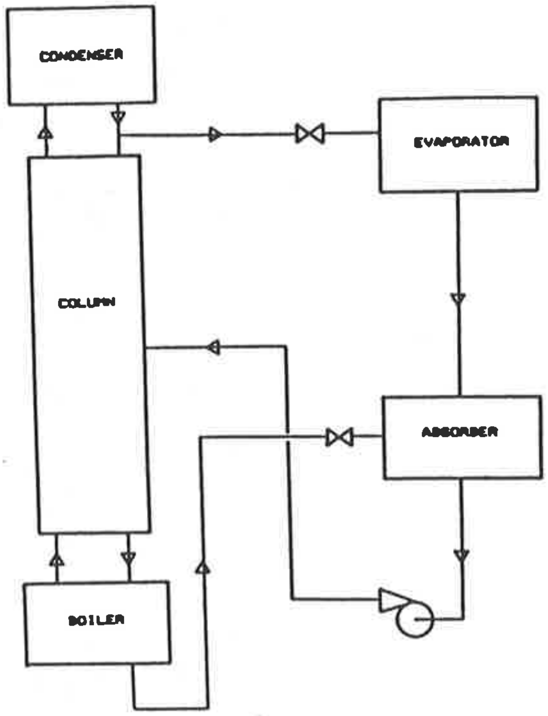
FIGURE 3.4

The column requires a minimum reflux flow to operate and irreversibilities associated with the production of this minimum flow are unavoidable. Irreversibilities created by the production of reflux flow in excess of the minimum are theoretically avoidable in a column of infinite stages. The computer model does not separate the two and therefore it is not possible to quantify the avoidable value but it is possible to estimate it. Later, in section 3.2.7, it is shown that for a 30 deg C ambient a reduction in reflux ratio from around 1.15 to 1.00 results in a COP increase of approximately 7 percent. Since the column irreversibilities account for in excess of 50 percent the avoidables are small in comparison with the unavoidables and therefore case B is within say 10 percent of being the maximum attainable COP.

All the irreversibilities being discussed here are due to the mixing of streams. This is illustrated in the column analysis print out (Appendix H, fig H1) which shows large feed plate and stripping section losses. If the feed stream availability could be brought closer to the feed plate value then at least the feed plate losses would be reduced!

To improve the maximum possible COP a reduction in one or more of the irreversibilities is necessary. Since the column and mixing values together represent approximately 90 percent of the total (fig 3.6) they invite close inspection. Unfortunately, other than the reduction of the reflux flow to the minimum it is not possible to eliminate irreversibilities. A change in the cycle is necessary to realize an improvement and two possibilities are;

- reduction of feed-plate availability loss by increasing the feed availability towards that



PARAMETERS FOR FIGURE 3.6

Ambient (T_0) 30 deg C

Boiler temp (T_G) 101.1 deg C

Bottom mass concn. 0.05

Distillate mass concn. 0.99

R11 and R22 mixture

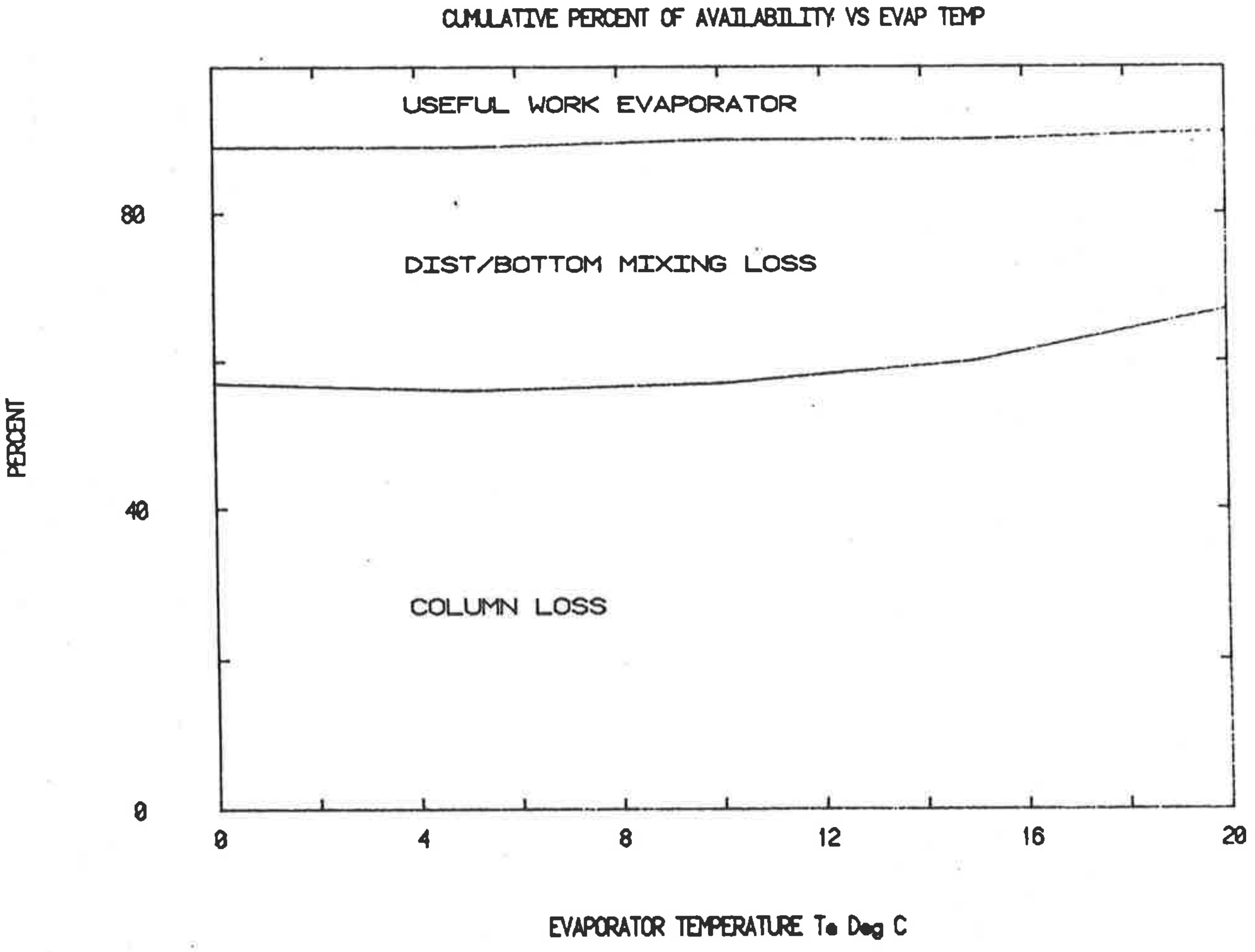


FIGURE 3.6

of the feed-plate liquid

- making use of the availability in the bottoms stream instead of 'losing' it to the mixing process in the absorber.

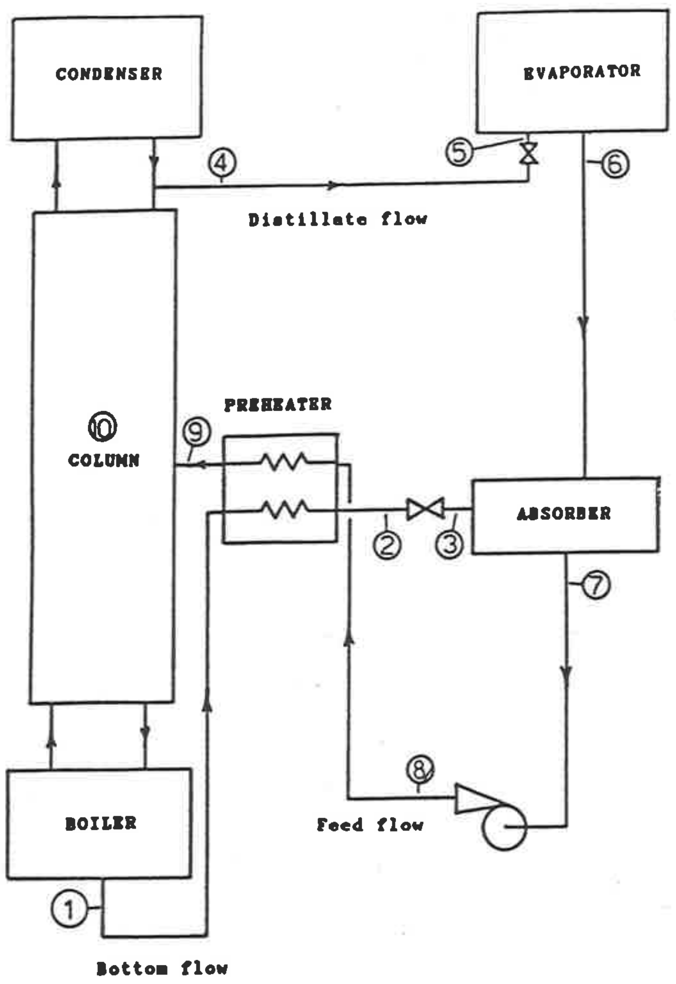
The common practice of preheating the feed flow with the hot bottoms stream achieves both of the above.

3.2.2 Cycle with preheater

Figure 3.7 shows typical data for this system at a 5 deg evaporator temperature (see appendix H, figure H2 for complete computer model print out) while table 3.2 is a precis of the data for the full range of evaporator temperatures.

For this preheater cycle data has been tabulated to illustrate typical trends in performance. For example the absorber output reflects the evaporator capacity and varies little whilst the condenser kW follow the boiler input. The evaporator temperature determines the low side pressure in the system which, together with the ambient temperature, determines the liquid concentration leaving the absorber. Therefore as the evaporator temperature drops the feed concentration is reduced to achieve the required lower evaporator temperature and, in order to maintain a constant bottom concentration of 0.05, the feed/distillate ratio is increased.

Figure 3.8 includes both first law COP values from table 3.2 as well as a plot of the second law data. Here again the final COP, case D, is not the maximum possible value because the column irreversibility contains an avoidable reflux flow component.



PREHEATER CYCLE

FIGURE 3.7

PARAMETERS FOR FIG 3.7,FIG 3.8 AND TABLE 3.2

Ambient air temperature (To) 30 deg C
Boiler temperature (Tg) 101 deg C
Bottom mass concentration 0.05
Distillate mass concentration 0.99
R11 & R22 mixture

	Irreversibility terms included in equation 3.1
CASE A	Column
CASE B	Column and absorber mixing
CASE C	Column, absorber mixing and precooler
CASE D	All losses

SYSTEM DATA

№	Temp Deg C	Avbty kJ/kg	
1	101.1	5.8	
2	30.0	2.9	
3	30.0	2.5	
4	30.0	65.6	
5	5.0	63.8	
6	5.8	50.6	
7	30.0	9.0	
8	29.9	9.4	
9	66.4	11.5	
10	68.3	6.8	liquid
	68.3	40.0	vapour

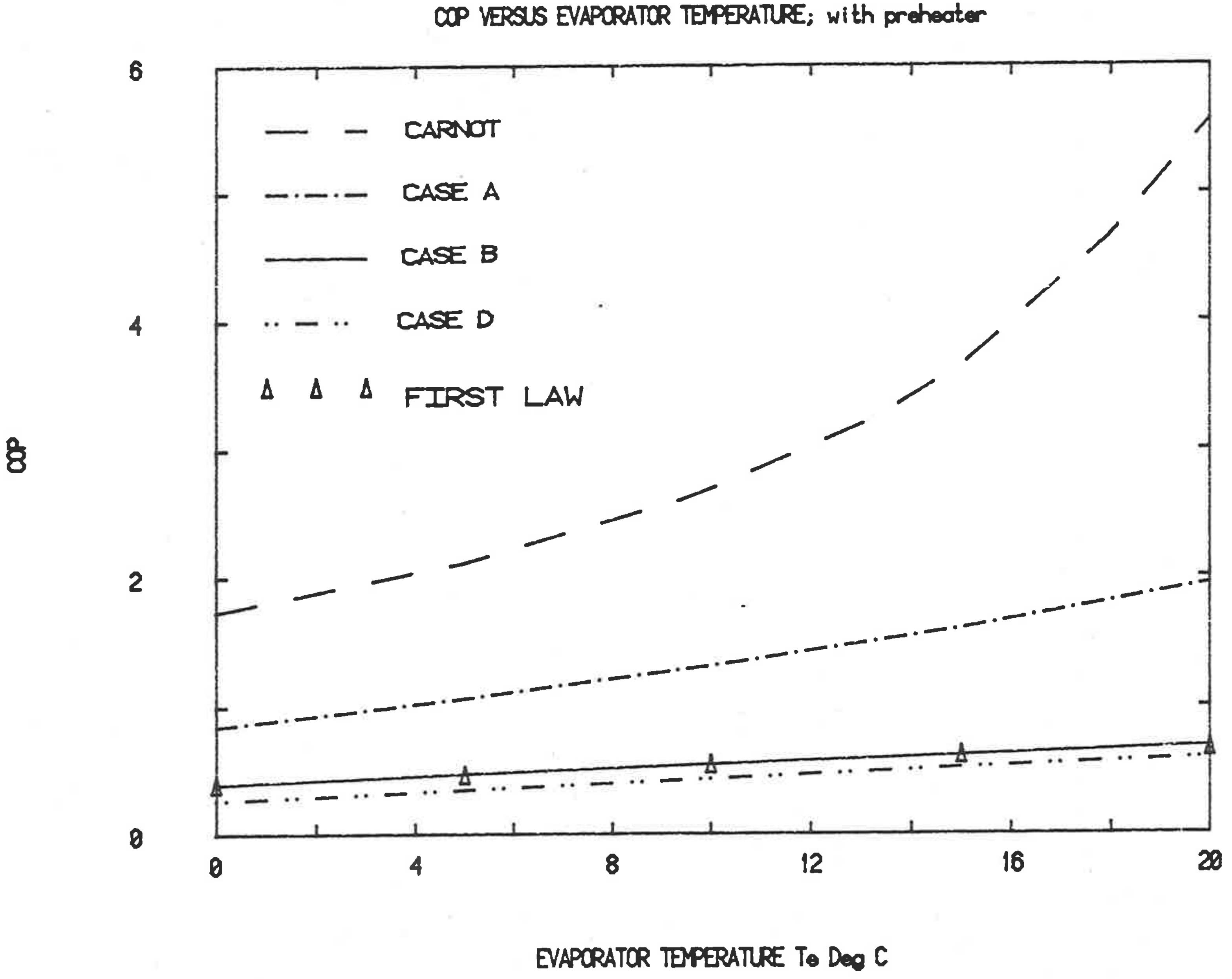

COP VERSUS EVAPORATOR TEMPERATURE; with preheater
CARNOT
CASE A
CASE B
CASE D
FIRST LAW
COP
0
2
4
6
0
4
8
12
16
20
EVAPORATOR TEMPERATURE Te Deg C

FIGURE 3.8

TABLE 3.2: PREHEATER SYSTEM DATA

evap temp deg C	0	5	10	15	20
Pump kW	0.173	0.107	0.066	0.039	0.021
Boil kW	25.19	21.18	18.26	16.17	14.88
Cond kW	24.87	20.91	18.03	15.97	14.75
Evap kW	10.00	10.00	10.00	10.00	10.00
Abs kW	10.3	10.26	10.22	10.18	10.13
Reflux✱ ratio	1.17	1.15	1.14	1.14	1.18
Plates	11	12	13	14	14
Dist kg/s	0.059	0.058	0.057	0.057	0.056
FOD ratio†	6.3	4.41	3.17	2.31	1.71
Feed conc	0.199	0.263	0.346	0.457	0.601
	kJ/s				
Boiler Work input	4.788	4.024	3.469	3.071	2.827
Losses					
Column	4.453	1.993	1.773	1.724	1.84
Mixing	1.248	1.129	0.991	0.831	0.639
Dist. exp	0.172	0.101	0.048	0.012	--
Bottom exp	0.144	0.08	0.043	0.02	0.007
Preheater	0.032	0.057	0.054	0.047	0.046
Useful Evap work	1.066	0.868	0.677	0.493	0.315
	COP				
Carnot	1.73	2.114	2.69	3.65	5.57
CASE A	0.843	1.067	1.315	1.601	1.944
CASE B	0.392	0.474	0.547	0.614	0.685
CASE C	0.278	0.378	0.476	0.576	0.685
CASE D	0.266	0.349	0.434	0.519	0.595
First law	0.394	0.47	0.546	0.617	0.671

✱ Reflux ratio = actual reflux / minimim reflux

† FOD = feed flow rate / distillate flow rate

For all these tests a reflux value approximately 20 percent greater than the minimum was used to achieve manageable computing times and to avoid the accuracy problems associated with a large number of plates (see chapter 4). In practice a reflux flow less than this would be desirable but since the effect of reflux can be estimated the value used for calculation is not critical.

Other than this reflux component all the other irreversibilities are considered unavoidable. In the case of the preheater even though a zero approach was used for the controlling end an irreversibility occurred because the stream temperature profiles did not match. The differing stream flow rates and specific heat capacities resulted in a temperature difference at the other end of the heat exchanger. For example the difference for the system shown in figure 3.7 is 101.1 - 66.4 = 34.7 degrees.

Care should be taken when making comparisons between the first and second law COP's. Theoretically the first law COP value should equal the second law calculation with all the irreversibilities taken into account. Unfortunately, due to inaccuracy in the availability values (see chapter1), this is not the case.

For example, in table 3.2 for a 5 deg C evaporator the first and second law calculations yielded COP's of 0.47 and 0.349 respectively and, using the first law value as a basis, this represents a -25% variation. The second law value was arrived at by subtracting all the individual components, each with their own error, from the Carnot value of 2.1 and the accumulation of the errors has resulted in this variation. Consequently in figure 3.8 the plot D and the first law values do not coincide.

Despite these inaccuracies the improvement in COP of the preheater cycle over the basic cycle is obvious. For example at a 5 deg C evaporator temperature the first law COP value changed from 0.32 (table 3.1) to 0.47 (table 3.2) a 47% increase.

By pursuing the concept of reducing mixing losses a further COP improvement may be had by making as much use as possible of the high availability leaving the evaporator before it is lost during mixing in the absorber. For example in figure 3.7 the distillate vapour leaves the evaporator with an availabilty of 51 kJ/kg and is mixed in the absorber with a bottom stream having an availability of 2.5 kJ/kg. Since the heat of mixing is rejected this availability is lost as heat in the absorber.

3.2.3 Cycle with preheater and precooler

Figure 3.9 illustrates the cycle and shows data extracted from the 5 deg C evaporator example in Appendix H (figure H3) whilst table 3.3 summarizes the results for a range of evaporator temperatures. This data may be compared with table 3.2 to assess the effect of the precooler. Firstly comparing case B only, the improvement in COP is 0.09 ie 0.474 to 0.564 however, when all the irreversibilities are considered (in case D) the gain is of the order 0.07; from 0.349 to 0.423, a 20% increase. One reason for the reduction from 0.09 to 0.07 is the introduction of an irreversiblity in the new precooler heat exchanger.

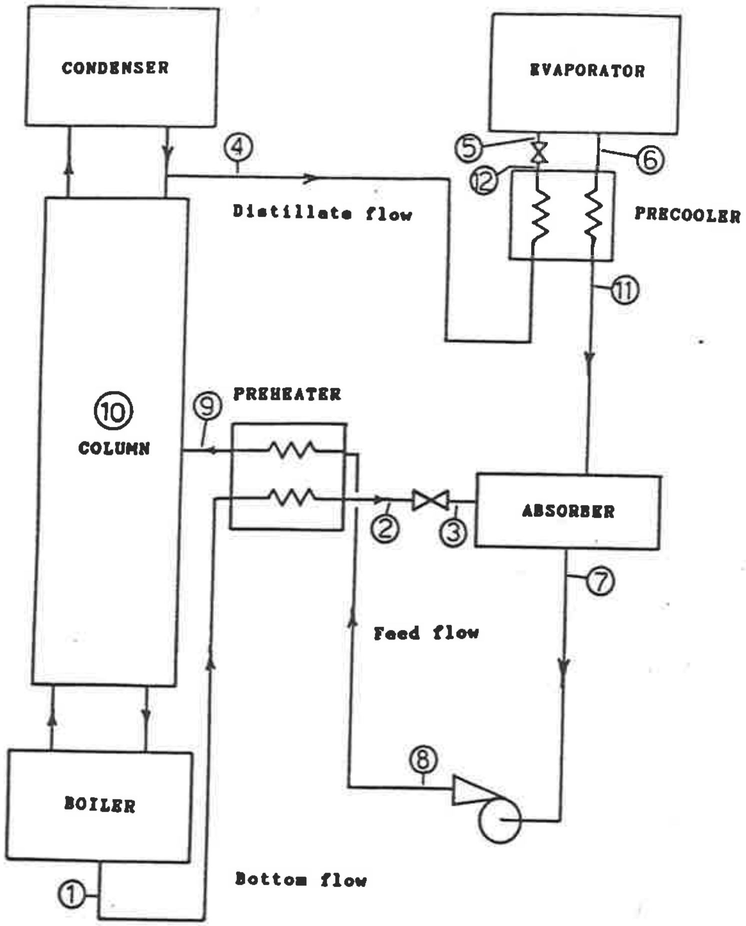
PARAMETERS FOR FIGURE 3.9 AND TABLE 3.3

Ambient air temperature 30 deg C
Boiler temperature 101 deg C
Bottom mass concentration 0.05
Distillate mass concentration 0.99
Reflux nominally 20% above minimim
R11&R22 mixture

	Irreversibility terms included in equation 3.1
CASE A	Column
CASE B	Column and absorber mixing
CASE C	Column, absorber mixing, precooler and preheater
CASE D	All losses

TABLE 3.3: COP VALUES FOR A RANGE OF EVAP TEMPERATURES

evap temp deg C	0	5	10	15	20
Carnot	1.73	2.11	2.69	3.65	5.57
Case A	0.84	1.063	1.315	1.6	1.95
Case B	0.475	0.564	0.649	0.723	0.796
Case C	0.396	0.497	0.598	0.687	0.796
Case D	0.344	0.423	0.508	0.583	0.659
1st law	0.44	0.515	0.588	0.653	0.697



PREHEATER-PRECOOLER CYCLE

FIGURE 3.9

SYSTEM DATA

№	Temp Deg C	Avbty kJ/kg	
1	101.1	5.8	
2	30.0	2.9	
3	30.0	2.5	
4	30.0	65.6	
5	5.0	66.4	
6	5.8	50.6	
7	30.0	9.0	
8	29.9	9.4	
9	66.4	11.5	
10	68.3	6.8	liquid
	68.3	40.0	vapour
11	30.0	47.6	
12	17.2	67.2	

COLUMN DATA

Plate No.	Temp Deg C	Avbty Change kJ/s *	Comment
1	30.0	-0.006	Condenser
2	30.7	-0.018	
3	32.0	-0.026	
4	34.6	-0.043	
5	39.7	-0.078	
6	48.5	-0.105	
7	58.3	-0.069	
8	65	-0.027	
9	68.3	-0.251	Feedplate
10	74.1	-0.175	
11	85.6	-0.493	
12	101.1	3.137	Boiler 19.3kW

* Negative indicates an availability loss

An inspection of the column data in figure 3.9 reveals that the greatest availability losses occur on the stripping section plates. In figure 3.9 the boiler plate shows a gain in availability but in fact there is an availability loss of 0.534 kJ/s incurred. This loss value is calculated by subtracting the nett increase of 3.137 kJ/s for the plate from the equivalent Carnot work input of 3.671 kJ/s.

The next section demonstrates the effect of an internal column heat exchanger on these stripping section losses.

3.2.4 Cycle with preheater, precooler and column heat exchanger.

For this system no attempt has been made to model a heat exchanger on each individual plate but rather a whole section approach has been taken with equal heat exchange per plate. Figure 3.10 shows COP data extracted from the computer model print out figure H4 (appendix H) while table 3.4 shows COP data for a range of evaporator temperatures.

The addition of the column heat exchanger produces an improvement in the COP which is greatest at the lower evaporator temperatures. As T_E drops the feed/distillate ratio increases and the larger bottom flow contributes more heat to the column. For example at a 5 deg C evaporator temperature the improvement in COP over the precooler/preheater system was 0.029 (0.515 to 0.544) but at a 20 deg C evaporator the increase was only 0.008 (0.697 to 0.705).

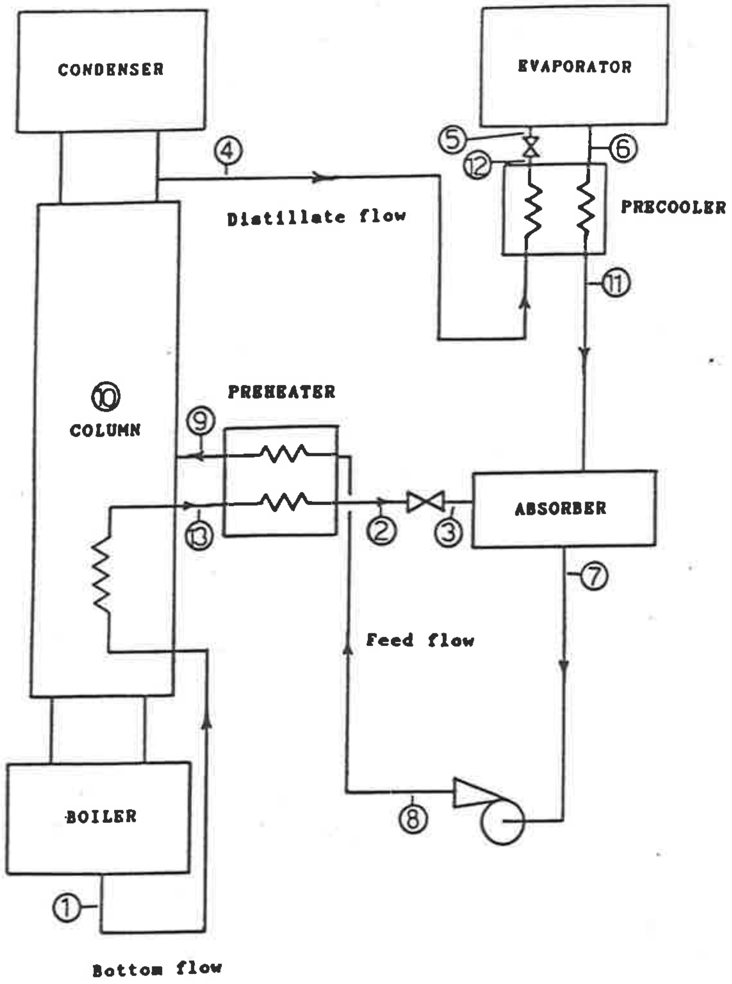
PARAMETERS FOR FIGURE 3.10 AND TABLE 3.4

Ambient air temperature (To) 30 deg C
Boiler temperature (Tg) 101 deg C
Bottom mass concentration 0.05
Distillate mass concentration 0.99
Reflux nominally 20% above the minimum
R11 & R22 mixture

	Irreversibility terms included in equation 3.1
CASE A	Column
CASE B	Column and absorber mixing
CASE C	All losses

TABLE 3.4: COP VALUES FROM EQUATION 3.1

evap temp deg C	0	5	10	15	20
Carnot	1.73	2.11	2.69	3.65	5.57
CASE A	0.996	1.172	1.387	1.62	1.88
CASE B	0.582	0.645	0.689	0.721	0.725
CASE C	0.386	0.449	0.527	0.593	0.643
1st law	0.494	0.544	0.615	0.669	0.705



PREHEATER-PRECOOLER-BOTTOM HX CYCLE

FIGURE 3.10

SYSTEM DATA

№	Temp Deg C	Avbty kJ/kg	
1	101.1	5.8	
2	29.9	2.9	
3	30.1	2.5	
4	30.0	65.6	
5	5.0	66.4	
6	5.8	50.6	
7	30.0	9.0	
8	29.9	9.4	
9	57.9	8.8	
10*	64.5	7.8	liquid
	64.5	41.8	vapour
11	30.0	47.6	
12	17.2	67.2	
13	69.5	2.7	

*Feedplate

COLUMN DATA

Plate No.	Temp Deg C	Avbty Change kJ/s	Comment
1	30.0	-0.006	Condenser
2	30.7	-0.016	
3	31.9	-0.02	
4	34.2	-0.029	
5	38.5	-0.049	
6	45.7	-0.069	
7	54.3	-0.054	
8	61.0	-0.022	
9	64.5	-0.133	Feedplate
10	73.2	0.02	2.79kW
11	86.1	-0.119	2.79kW
12	101.1	2.98	Boiler 18.3kW

Overall the improvement comes about because availability from the bottom stream is being used to vapourize some of the downward liquid flow before it gets to the generator. Therefore the generator heat input is reduced and a COP improvement results.

It may be argued that use of the stripping section heat exchanger is unnecessary since this bottom stream availability can be recovered in the preheater and returned to the column via the feed flow anyway. A comparison of figures 3.9 and 3.10 reveals that the the availability of the bottom flow leaving the preheater is the same (2.9 kJ/kg) for both configurations. However, this is not the case because the column heat exchanger system shows a superior COP. This is because the availability transfer via the preheater and feed flow path incurs greater irreversibilities than the more direct route via the column heat exchanger.

This choice of path is fundamental to optimum design. In the case of the absorption cycle we are seeking to transfer the work potential, which is input as heat to the boiler, to the evaporator via a path of least loss or degredation. Indeed the transfer of work input to the point of application via a path of minimum loss most often determines the design of thermodynamic systems.

Despite the use of the stripping section heat exchanger an irreversibility still remains in the preheater due to the mismatch of temperature profiles. Whilst it is not possible to modify the specific heat capacities of the streams it is possible to change the flow rates by splitting the feed stream. By reducing the feed flow it is theoretically possible to match the temperature profiles of the two streams. The proportion of the feed flow diverted away from the preheater may be directed to a heat exchanger in the rectification section of the column.

3.2.5 Cycle with preheater/precooler and both stripping and rectification heat exchangers

Initially 2 percent of the feed flow was directed through the rectification heat exchanger (figure 3.11) and at a 5 deg C evaporator temperature this resulted in a COP improvement over the stripping heat exchanger system of 0.07, ie from 0.544 (table 3.4) to 0.616 (table 3.5) ie a 12% increase.

This improvement in COP can be attributed to reduced irreversibilities in the column and in the preheater. Here part of the total reflux requirement is generated (condensed) internally in the column by the cooler feed stream. This incurs a penalty in column size. A comparison of plate numbers in figures 3.10 and 3.11 bears this out; the dual heat exchanger column has 13 plates while the single only 12, an 8% increase in column size. The feed and feed plate availabilities are still close, 8.68 kJ/kg and 9.81 kJ/kg respectively, thus losses here are minimal.

By reducing the flow through the feed side of the preheater the temperature profile of this stream can be brought closer to that of the bottom flow. In an effort to establish an optimum proportion for the feed split tests were conducted for 1,2,4 and 6 percent of the feed flow through the rectification section heat exchanger and the results plotted

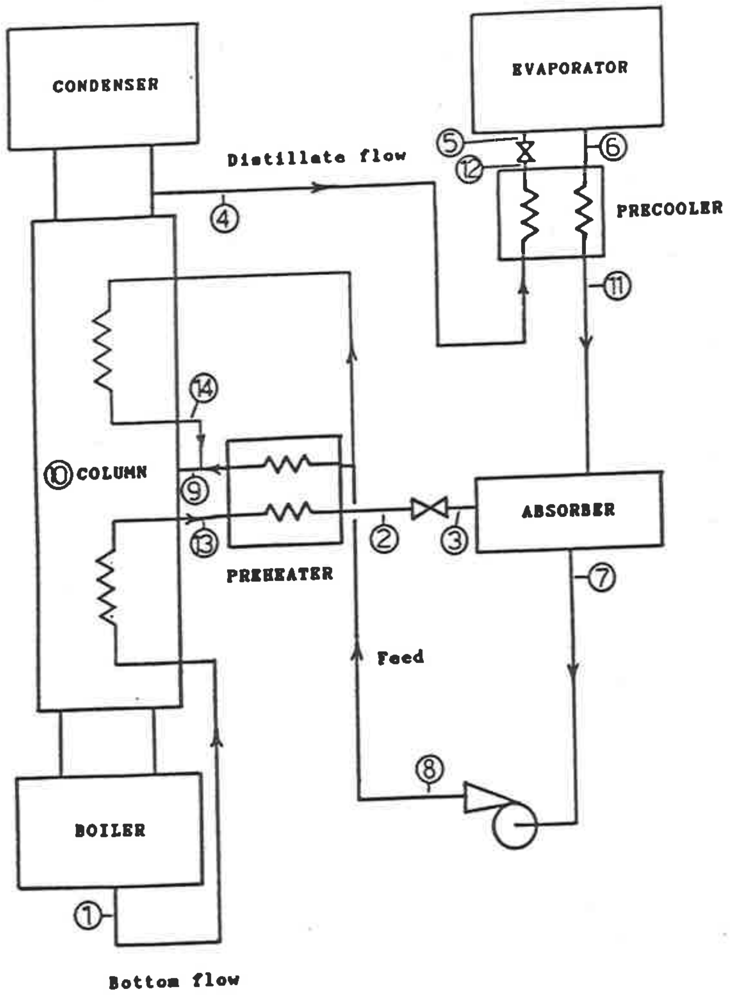
PARAMETERS FOR FIGURE 3.11 AND TABLE 3.5

Ambient air temperature 30 deg C
Boiler temperature 101 deg C
Bottom mass concentration 0.05
Distillate mass concentration 0.99
2 percent feed flow thru rectification heat exchanger
R11 & R22 mixture

	Irreversibility terms included in equation 3.1
CASE A	Column
CASE B	Column and absorber mixing

TABLE 3.5: COP VALUES FROM EQUATION 3.1

evap temp deg C	0	5	10	15	20
Carnot	1.73	2.11	2.69	3.65	5.57
CASE A	1.098	1.299	1.468	1.687	
CASE B	0.644	0.7	0.729	0.75	
1st law	0.541	0.616	0.653	0.696	



PREHEATER-PRECOOLER-BOTTOM-RECTIFICATION HX CYCLE

FIGURE 3.11

SYSTEM DATA

	Temp Deg C	Avbty kJ/kg	
1	101.1	5.8	
2	29.9	2.9	
3	30.1	2.5	
4	30.0	65.6	
5	5.0	66.4	
6	5.8	50.6	
7	30.0	9.0	
8	29.9	9.4	
9	53.0	8.7	
10*	61.0	9.2	liquid
	61.0	43.5	vapour
11	30.0	47.6	
12	17.2	67.2	
13	62.2	2.4	
14	60.2	8.8	

*Feedplate

COLUMN DATA

Plate No.	Temp Deg C	Avbty Change kJ/s	Comment
1	30.0	-0.005	Condenser
2	30.7	-0.007	0.01kW
3	31.7	-0.001	0.01kW
4	33.6	0.006	0.01kW
5	36.8	0.014	0.01kW
6	42.0	0.022	0.01kW
7	49.2	0.031	0.01kW
8	56.4	0.016	0.01kW
9	61.0	-0.107	Feedplate
10	65.9	0.095	2.27kW
11	74.0	-0.011	2.27kW
12	86.4	-0.153	2.27kW
13	101.1	2.598	Boiler 16.1kW

in figure 3.12 indicate an optimum around one percent.

For most of the tests the heat exchanged in the rectification section was approximately one tenth of that transferred in the stripping section.

For the column, even with heat exchangers fitted, the feed plate, boiler and bottom plate irreversibilities remained dominant. At the feed plate the availability loss can be attributed, in part, to the mixing of the column and feed flows which have different temperatures and concentrations. The remaining loss is due to the difference between the availabilities of vapour and liquid in equilibrium. This is the main reason for the large loss in the boiler too.

The total loss can be minimised by

- having a mixture where the equilibrium availability values for liquid and vapour are closer together. Support for this appears towards the top of the column. Condensing is taking place at the datum temperature and therefore the difference in availability between liquid and vapour is due only to the non-datum pressure. (at datum temperature and pressure liquid and vapour availability are equal, see section 2.2) At the condenser and on the top few plates, (see figure 3.11) availability losses are negligible in comparison with the boiler losses.
- reducing the system flow rate. Mixing irreversibilities are a function of both specific availability values of the streams and of the stream flow rates. This explains why the lower flows of a system with minimal reflux and with a high latent heat refrigerant are an advantage.

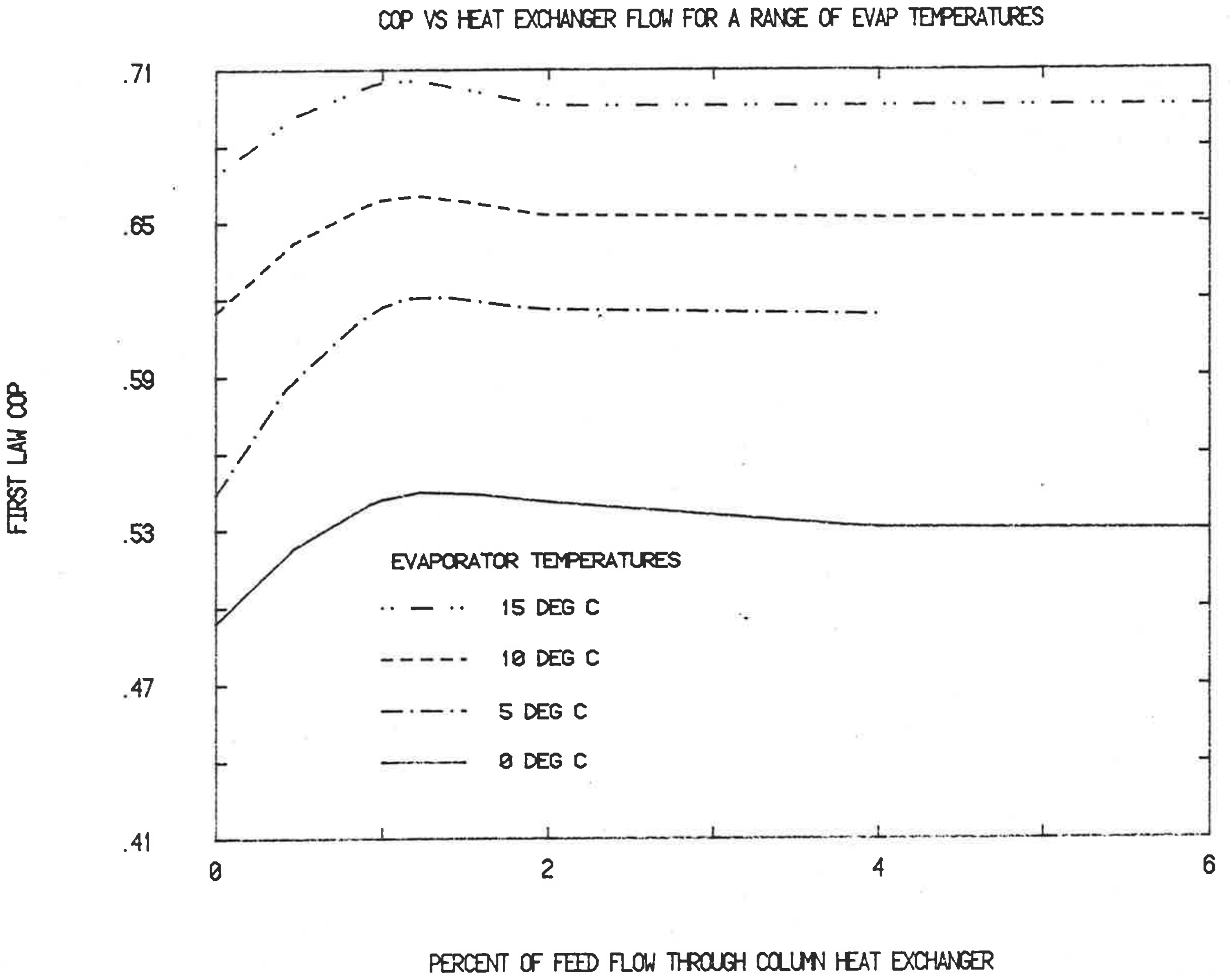
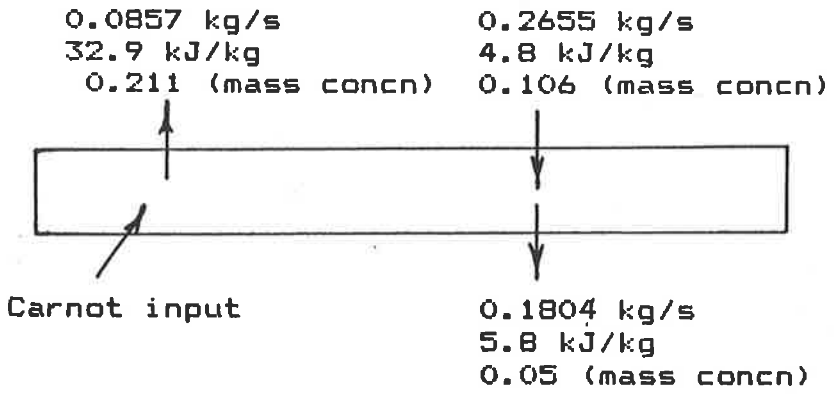

COP VS HEAT EXCHANGER FLOW FOR A RANGE OF EVAP TEMPERATURES
FIRST LAW COP
.71
.65
.59
.53
.47
.41
0
2
4
6
EVAPORATOR TEMPERATURES
15 DEG C
10 DEG C
5 DEG C
0 DEG C
PERCENT OF FEED FLOW THROUGH COLUMN HEAT EXCHANGER

FIGURE 3.12

These low flows minimise the effect of the unavoidable irreversiblities.

Another important factor is the relationship, for a given mixture, between temperature and availability. Consider both the minimum work of separation and the Carnot input for the system shown in figure 3.11 . These two are related via the characteristics of the fluid properties. Using data from the column analysis of figure H5 the following may be compiled for the boiler.



$$\text{Carnot input} = Q_G\left(1 - \frac{T_o}{T_G}\right)$$

$= 3.477$ kJ/s

Therefore availability entering the boiler is

$3.477 + (0.2655 \times 4.8) = 4.75$ kJ/kg

and availability leaving is

$(0.1804 \times 5.8) + (0.0857 \times 32.9) = 3.87$ kJ/kg

Total availability loss is

$4.75 - 3.87 = 0.88$ kJ/kg

Minimum work of separation = the availability difference of the streams entering and leaving = $3.87 - (0.2655 \times 4.8) =$ 2.59 kJ/s

For these conditions the theoretical minimum work of separation (12) is 2.59 kJ/s but at the same time the equilibrium temperature of 101.1 deg C requires, via the Carnot term, an input of 3.477 kJ/s. The difference is the 0.88 kJ/s availability loss. If the temperature required had been 89 deg C for example then the Carnot requirement would have equalled the separation work required and the loss would have been zero. Examination of other pairs of working fluids may reveal a combination with more favourable characteristics.

As far as the usefulness of the rectification heat exchanger is concerned it is suggested that the feed split option be tried on a prototype to establish if the magnitude of the COP improvement justifies the additional complexity in control and manufacture.

3.2.6 Variations in ambient conditions.

COP variations due to ambient temperature changes have been considered on the ideal preheater/precooler/bottom system only. Table 3.6 and figure 3.13 show 38 deg C results while figure 3.14 compares the Carnot and first law COP's for ambients of 30 deg C (table 3.4)and 38 deg C (table 3.6).

For example at a 5 deg C evaporator temperature the ambient temperature increase from 30 deg C to 38 deg C caused a reduction in the First Law COP of 0.12 which is significant but small in comparison with the corresponding Carnot COP drop of 0.49. Referring to equation 3.1 if the irreversibility term had decreased at the same rate as the Carnot COP then the first law values would have differed by 0.49 too. The fact that the first law COP variation was smaller indicates that as the ambient temperature increases the irreversibility term in equation 3.1

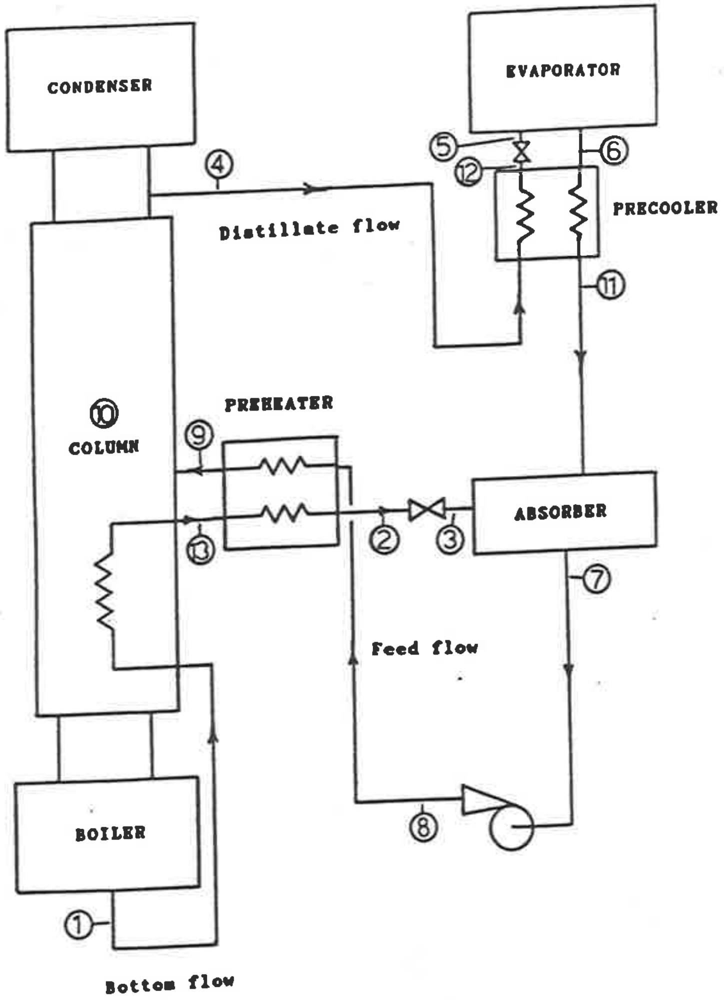
PARMETERS FOR FIGURE 3.13 AND FIGURE 3.14 PLUS TABLE 3.6

Ambient air temperature (To) 38 deg C
Boiler temperature (Tg) 112.4 deg C
Bottom mass concentration 0.05
Distillate mass concentration 0.99
Reflux nominally 20 percent above minimum
R11 and R22 mixture

	Irreversibility terms included in equation 3.1
CASE A	Column
CASE B	Column and absorber mixing

TABLE 3.6: COP for a 38 deg C ambient

evap temp deg C	0	5	10	15	20
Carnot	1.386	1.626	1.95	2.416	3.143
CASE A	0.78	0.914	1.109	1.312	
CASE B	0.492	0.544	0.61	0.661	
1st law	0.375	0.428	0.505	0.573	



PREHEATER-PRECOOLER-BOTTOM HX CYCLE

FIGURE 3.13

SYSTEM DATA

No	Temp Deg C	Avbty kJ/kg	
1	112.4	11.3	
2	37.8	7.9	
3	38.1	7.3	
4	38.0	72.6	
5	5.0	73.1	
6	5.8	53.4	
7	38.0	10.7	
8	37.8	11.3	
9	79.3	11.1	
10*	84.8	11.0	liquid
	84.8	41.9	vapour
11	38.0	49.0	
12	21.4	74.8	
13	89.3	8.5	

* Feedplate

COLUMN DATA

Plate No.	Temp Deg C	Avbty Change kJ/s	Comment
1	38.0	-0.007	Condenser
2	38.6	-0.025	
3	40.0	-0.043	
4	42.8	-0.083	
5	49.0	-0.167	
6	60.1	-0.234	
7	72.7	-0.153	
8	81.0	-0.056	
9	84.8	-0.161	Feedplate
10	91.9	0.23	3.76kW
11	101.1	0.142	3.76kW
12	112.4	3.95	Boiler 23.2kW

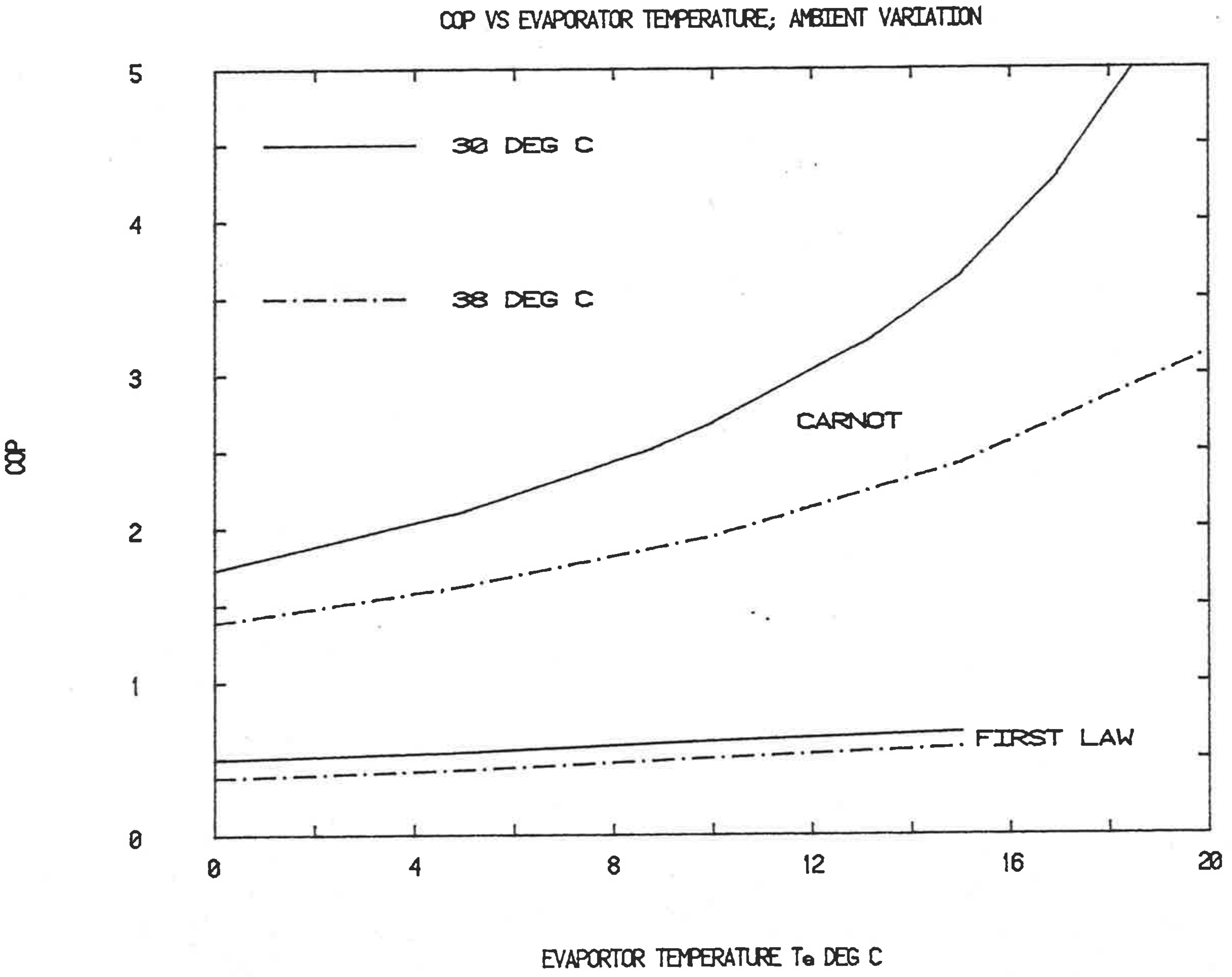

COP VS EVAPORATOR TEMPERATURE; AMBIENT VARIATION
30 DEG C
38 DEG C
CARNOT
FIRST LAW
COP
0
1
2
3
4
5
0
4
8
12
16
20
EVAPORTOR TEMPERATURE Te DEG C

FIGURE 3.14

$$COP = COP_{CARNOT} - \frac{\frac{D}{Q_G}}{\frac{T_O}{T_E} - 1}$$

diminishes more rapidly than the Carnot term. In terms of figure 3.14 this means that the distance between the Carnot and first law plots is less for 38 Deg C than it is for the 30 deg C ones. Therefore it is the relationship between the irreversibilities and boiler input which is important. A study of the relationship between D and Q_G for various mixtures and temperature conditions could be used to establish desirable characteristics for these mixtures.

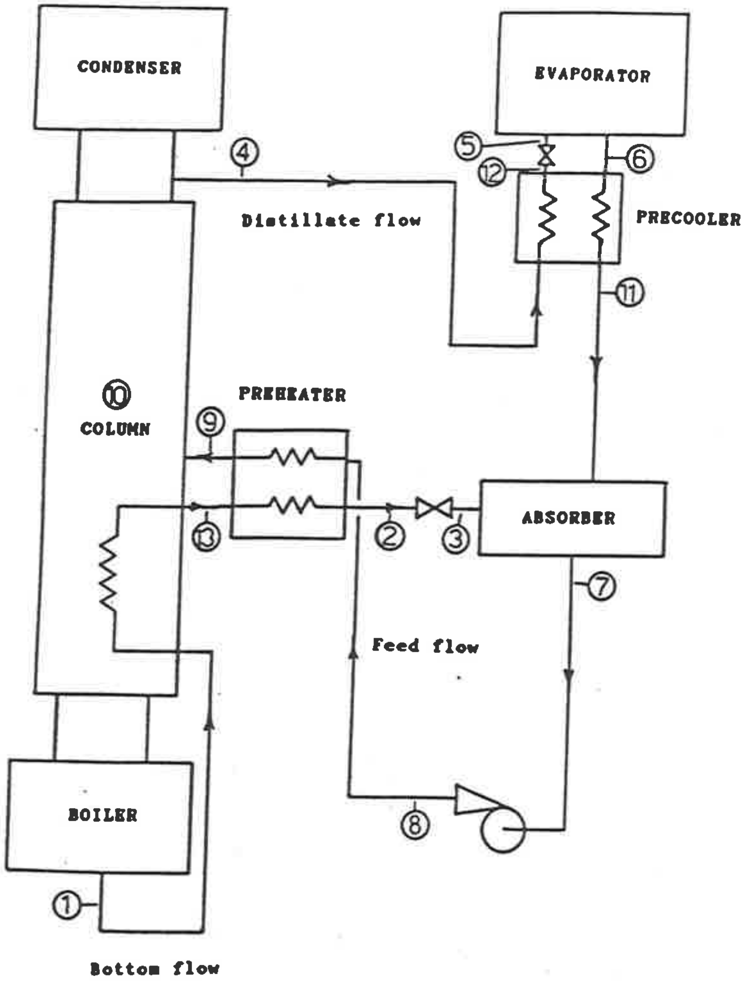
3.2.7 Variations in Reflux Ratio

Reflux ratio was varied for the precooler/preheater/bottoms cycle at both 30 deg C and 38 deg C ambients for a 5 deg C evaporator. Figure 3.16 shows increasing COP with diminishing reflux while figure 3.15 shows data extracted from appendix H, figure H7.

For a given set of conditions reducing the reflux ratio reduces the availability loss in the column whilst, apart from an insignificant change at the preheater, all the other losses remain constant. Obviously from the point of view of maximizing COP a low reflux ratio is desirable but since the column size/cost increases as reflux ratio decreases economics will determine the optimum.

3.2.8 Variation of bottom concentration

By increasing the ratio of feed flow to distillate flow it is possible to change the concentration of the bottom product. This was done for the preheater/precooler/bottom



PREHEATER-PRECOOLER-BOTTOM HX CYCLE

FIGURE 3.15

PARMETERS FOR FIGURE 3.15 AND FIGURE 3.16

Bottom mass concentration 0.05
Distillate mass concentration 0.99
Reflux nominally 20 percent above minimum
R11 and R22 mixture

SYSTEM DATA

(No)	Temp Deg C	Avbty kJ/kg	
1	101.1	5.8	
2	29.9	2.9	
3	30.1	2.5	
4	30.0	65.6	
5	5.0	66.4	
6	5.8	50.6	
7	30.0	9.0	
8	29.9	9.4	
9	58.5	8.8	
10*	65.3	7.6	liquid
	65.3	41.4	vapour
11	30.0	47.6	
12	17.2	67.2	
13	70.4	2.7	

*Feedplate

COLUMN DATA

Plate No.	Temp Deg C	Avbty Change kJ/s	Comment
1	30.0	-0.009	Condenser
2	30.7	-0.039	
3	32.3	-0.085	
4	36.8	-0.219	
5	47.9	-0.475	

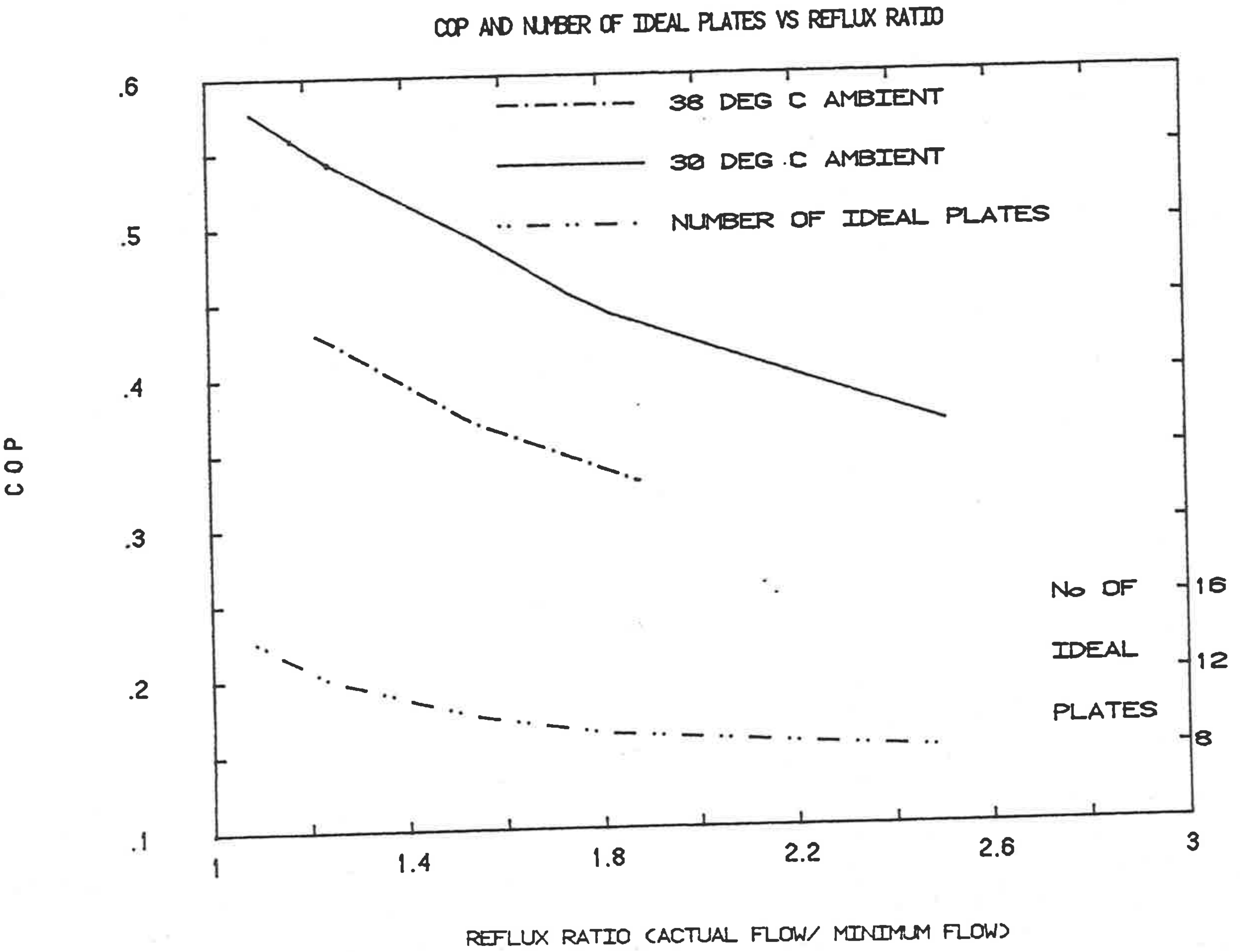

COP AND NUMBER OF IDEAL PLATES VS REFLUX RATIO
38 DEG C AMBIENT
30 DEG C AMBIENT
NUMBER OF IDEAL PLATES
COP
.6
.5
.4
.3
.2
.1
No OF
IDEAL
PLATES
16
12
8
1
1.4
1.8
2.2
2.6
3
REFLUX RATIO (ACTUAL FLOW/ MINIMUM FLOW)

Fig 3.16

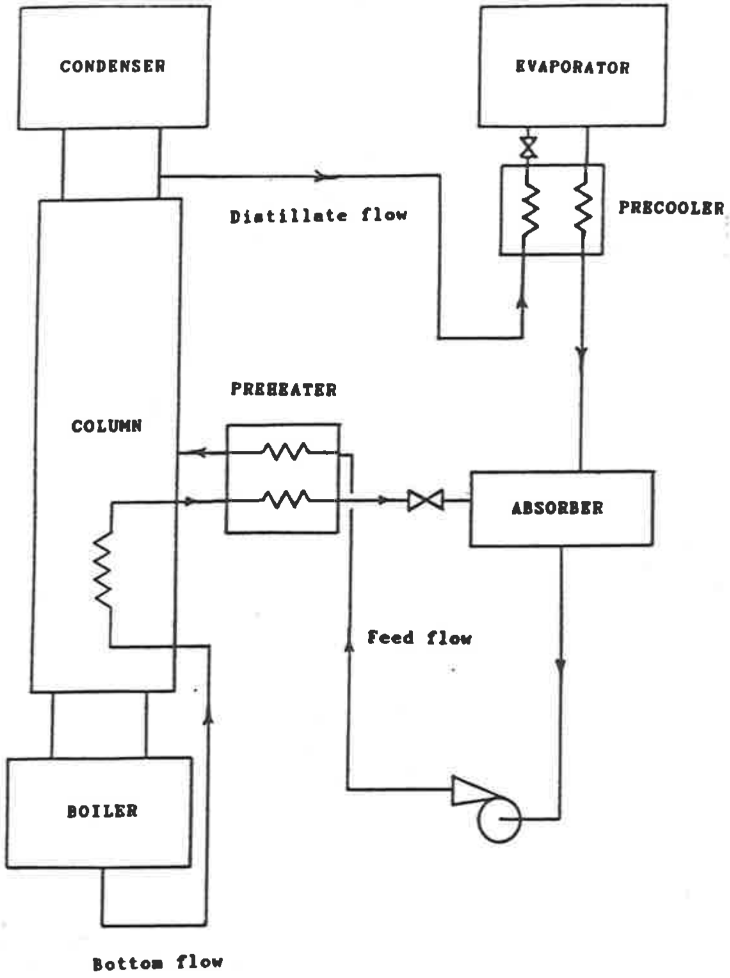
heat exchanger cycle shown in figure 3.17, a sample program output is shown in Appendix H figure H8.

Since the computer model establishes the number of plates required in the column for each evaporator condition it was difficult to assess the effect of bottom concentration without a change in the number of plates and a variation in reflux ratio. In figure 3.18 the dislocation between FOD values of 5.2 and 5.3 is caused by a change in the number of plates from 12 to 11.

Ignoring the discontinuity for the moment and considering a feed/distillate range from 4.4 to 5 there is an increase in bottom concentration from 0.05 to 0.08 together with a 0.02 COP increase. However, at the same time there was a reflux ratio reduction from 1.24 to 1.155 which, according to section 3.2.7, represents a COP increase of 0.02 approximately. Consequently it is assumed that the effect of bottom concentration on COP is negligible. Of greater significance is the fact that a bottom concentration increase from 0.05 to 0.13 decreased the boiler temperature from 101 deg C to 82 deg C thus making the system more attractive for use with low grade heat.

3.2.9 Variation of distillate concentration

One of the effects of reducing the distillate concentration is to produce a temperature gradient across the evaporator surface. Within reason this is not considered detrimental to performance, in fact Connon et al (10) consider this an advantage for heating situations. For this work a gradient of 5 degrees, approximately half of that allowed by Connon et al, has been selected as tolerable where typical air



PREHEATER-PRECOOLER-BOTTOM HX CYCLE

FIGURE 3.17

PARMETERS FOR FIGURE 3.17 AND FIGURE 3.18

Ambient temperature (To) 30 deg C
Evaporator temperature (Te) 5 deg C
Distillate mass concentration 0.99
R11 and R22 mixture

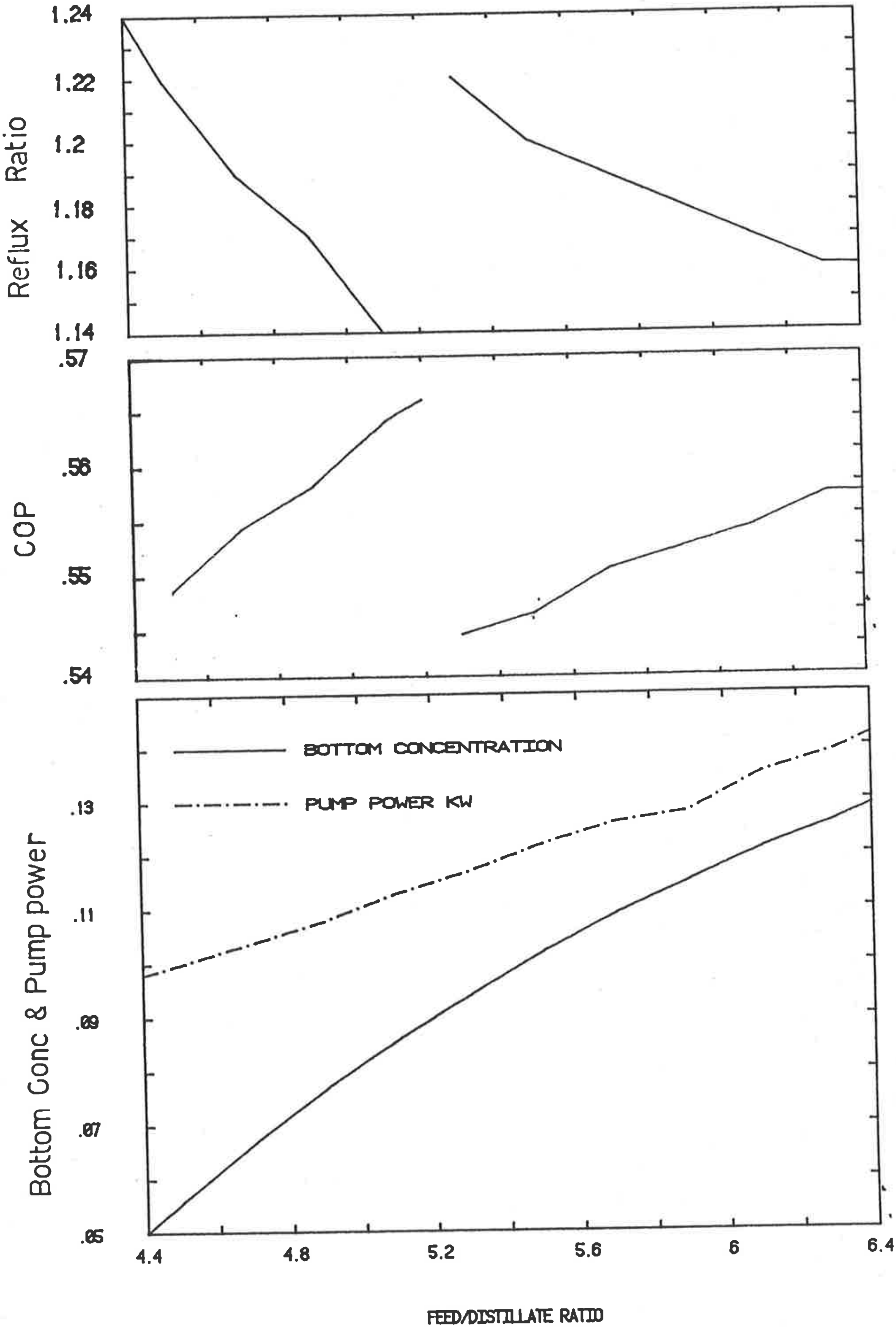

Reflux Ratio
1.24
1.22
1.2
1.18
1.16
1.14
COP
.57
.56
.55
.54
Bottom Conc & Pump power
.13
.11
.09
.07
.05
BOTTOM CONCENTRATION
PUMP POWER KW
4.4
4.8
5.2
5.6
6
6.4
FEED/DISTILLATE RATIO

Fig 3.18

temperatures might be 24 deg C approaching the evaporator and 15 deg C leaving.

In terms of a second law consideration a contra flow refrigerant to air heat exchanger could benefit from the closer matching of temperature gradients via a reduction in availability loss. Also the work required to raise the heat from the evaporator condition to the reference condition would be less because part of the surface is warmer. It was thought that this reduction in work as well as less effort required for distillate and absorbant separation would improve the COP.

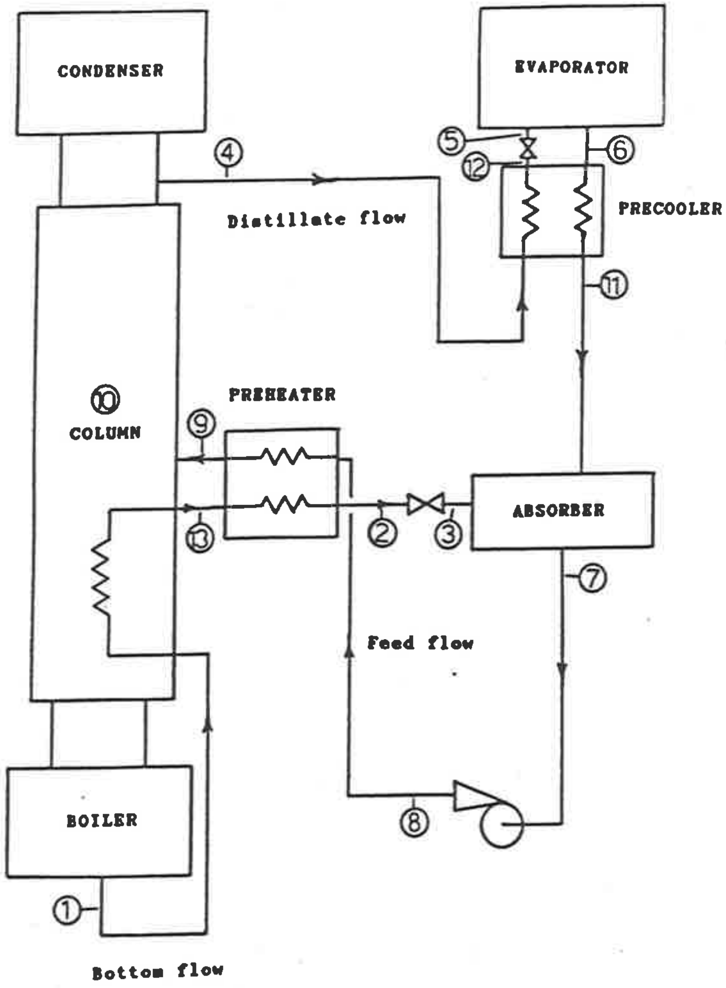
At ambients of both 30 deg C and 38 deg a 7 percent increase in COP resulted from a reduction in distillate concentration from 0.99 to 0.93 (figure 3.20).

It is suggested that this approach is worth investigating on a prototype. A distillate concentration of 0.93 resulted in a 5.9 degree evaporator gradient. (see figure 3.19 or, for a complete output, appendix H,figure H9)

3.2.10 Mixture variations

Even though an extensive investigation of binary mixtures suitable for use in absorption refrigerators is beyond the scope of this report it was decided to test an R12 R113 mixture as well as R11 R22.

This was prompted by the fact that the former showed Carnot COP values approximately 10 percent higher than the latter. The precooler/preheater/bottom heat exchanger combination (figure 3.21) was tested and the results are shown in table



PREHEATER-PRECOOLER-BOTTOM HX CYCLE

FIGURE 3.19

PARAMETERS FOR FIGURES 3.19 AND 3.20

Ambient temperature (To) 30 deg C
Bottom mass concentration 0.05
Reflux nominally 20 percent above minimum
R11 and R22 mixture

SYSTEM DATA

№	Temp Deg C	Avbty kJ/kg	
1	99.2	5.5	
2	29.9	2.9	
3	30.1	2.5	
4	30.0	58.0	
5	5.0	58.8	
6	10.9	43.6	
7	30.0	8.2	
8	29.9	8.6	
9	52.9	7.9	
10*	60.7	5.3	liquid
	60.7	36.8	vapour
11	30.0	41.3	
12	19.7	59.4	
13	62.0	2.4	

* Feedplate

COLUMN DATA

Plate No.	Temp Deg C	Avbty Change kJ/s	Comment
1	30.0	-0.036	Condenser
2	35.1	-0.109	
3	43.8	-0.101	
4	53.8	-0.062	
5	60.7	-0.150	Feedplate
6	65.4	0.107	2.2kW

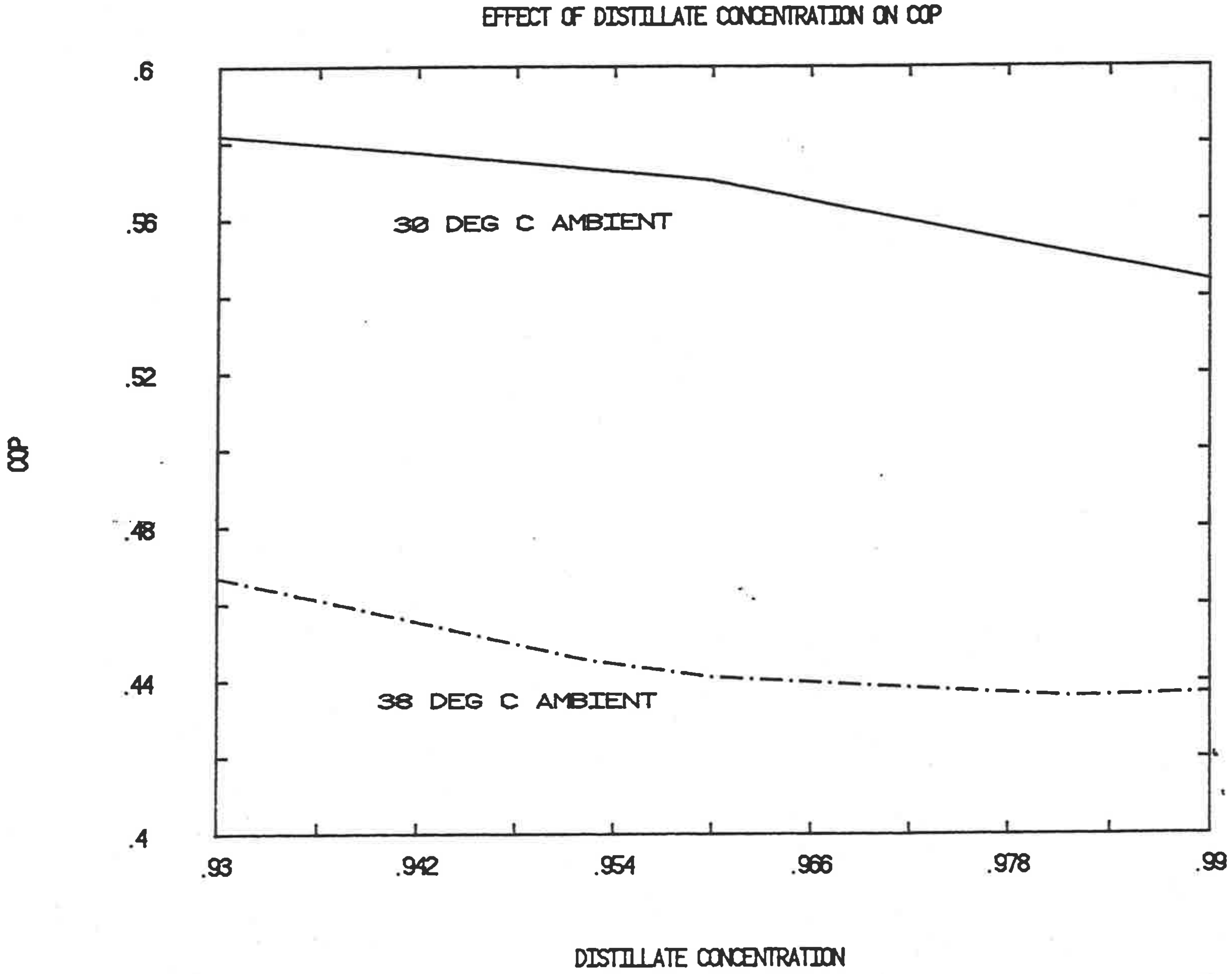

EFFECT OF DISTILLATE CONCENTRATION ON COP
.6
.56
.52
.48
.44
.4
COP
30 DEG C AMBIENT
38 DEG C AMBIENT
.93
.942
.954
.966
.978
.99
DISTILLATE CONCENTRATION

Fig 3.20

3.7 (Complete print out Appendix H, figure H10).

First law COP values from tables 3.4 and 3.7 plotted in figure 3.22 indicate that the R12 R113 COP values are higher for all conditions tested. Taking a specific case at a 5 deg C evaporator temperature and a 30 deg C ambient temperature the R12 R113 Carnot COP was higher by 0.113 (2.227-2.114) but this dropped to 0.087 (0.536-0.449) for the final COP value. This full Carnot improvement of 0.113 was not carried through to the final value because the R12 R113 system had higher column and absorber irreversibilities than the R11 R22 combination. Nevertheless this 0.087 represents a worthwhile improvement in the maximum achievable COP. It should be noted that this Carnot COP increase was achieved at the expense of a boiler temperature increase from 101.1 deg C to 105.9 deg C.

Examination of a large number of mixtures may reveal a relationship between fluid properties and COP and lead to an even greater improvement in COP than the one shown here.

3.2.11 Summary of the ideal cycle

For all of the system configurations considered the column and absorber mixing irreversibilities dominate and therefore appear to offer the largest potential for COP improvement. However, a closer investigation reveals that these column irreversibilities are unavoidable and therefore, other than with a structual change, system improvement is difficult. Overall these unavoidable irreversibilities result in a maximum attainable COP far below the Carnot value. This is illustrated in figure 3.23 where, other than a minor variation due to reflux in excess of the minimum, the plot

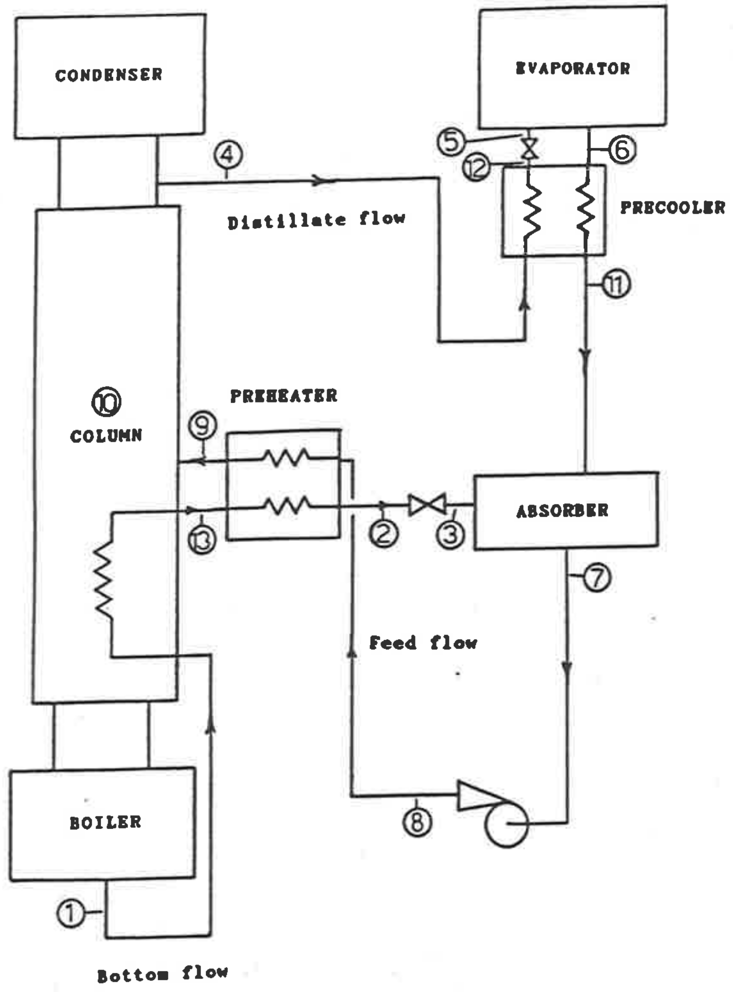
PARAMETERS FOR FIGURES 3.21 AND 3.22 PLUS TABLE 3.7

Ambient air temperature 30 deg C
Boiler temperature 105 deg C
Bottom mass concentration 0.05
Distillate mass concentration 0.99
Reflux ratio nominally 20% above the minimum
R12 and R113 mixture

	Irreversibility terms included in equation 3.1
CASE A	Column
CASE B	Column and absorber mixing
CASE C	All losses

TABLE 3.7: COP values for R12 & R113

evap temp deg C	0	5	10	15	20
Carnot	1.822	2.227	2.833	3.845	5.867
CASE A	1.082	1.265	1.413	1.62	1.95
CASE B	0.653	0.713	0.748	0.773	0.808
CASE C	0.45	0.536	0.602	0.627	0.732
1st law	0.536	0.616	0.672	0.720	0.779



PREHEATER-PRECOOLER-BOTTOM HX CYCLE

FIGURE 3.21

SYSTEM DATA

№	Temp Deg C	Avbty kJ/kg	
1	105.9	3.7	
2	29.9	-1.0	
3	30.1	-1.2	
4	30.0	37.9	
5	5.0	38.8	
6	6.4	26.9	
7	30.0	2.4	
8	29.9	2.6	
9	53.3	2.2	
10*	60.9	2.7	liquid
	60.9	27.7	vapour
11	30.0	24.6	
12	15.2	39.3	
13	61.8	-1.0	

*Feedplate

COLUMN DATA

Plate No.	Temp Deg C	Avbty Change kJ/s	Comment
1	30.0	-0.006	Condenser
2	31.1	-0.018	
3	33.6	-0.024	
4	38.7	-0.042	
5	47.1	-0.049	
6	55.7	-0.028	
7	60.9	-0.122	Feedplate
8	66.8	0.157	3kW
9	76.0	0.108	3kW
10	89.7	0.048	3kW
11	106.0	2.814	Boiler 16.2kW

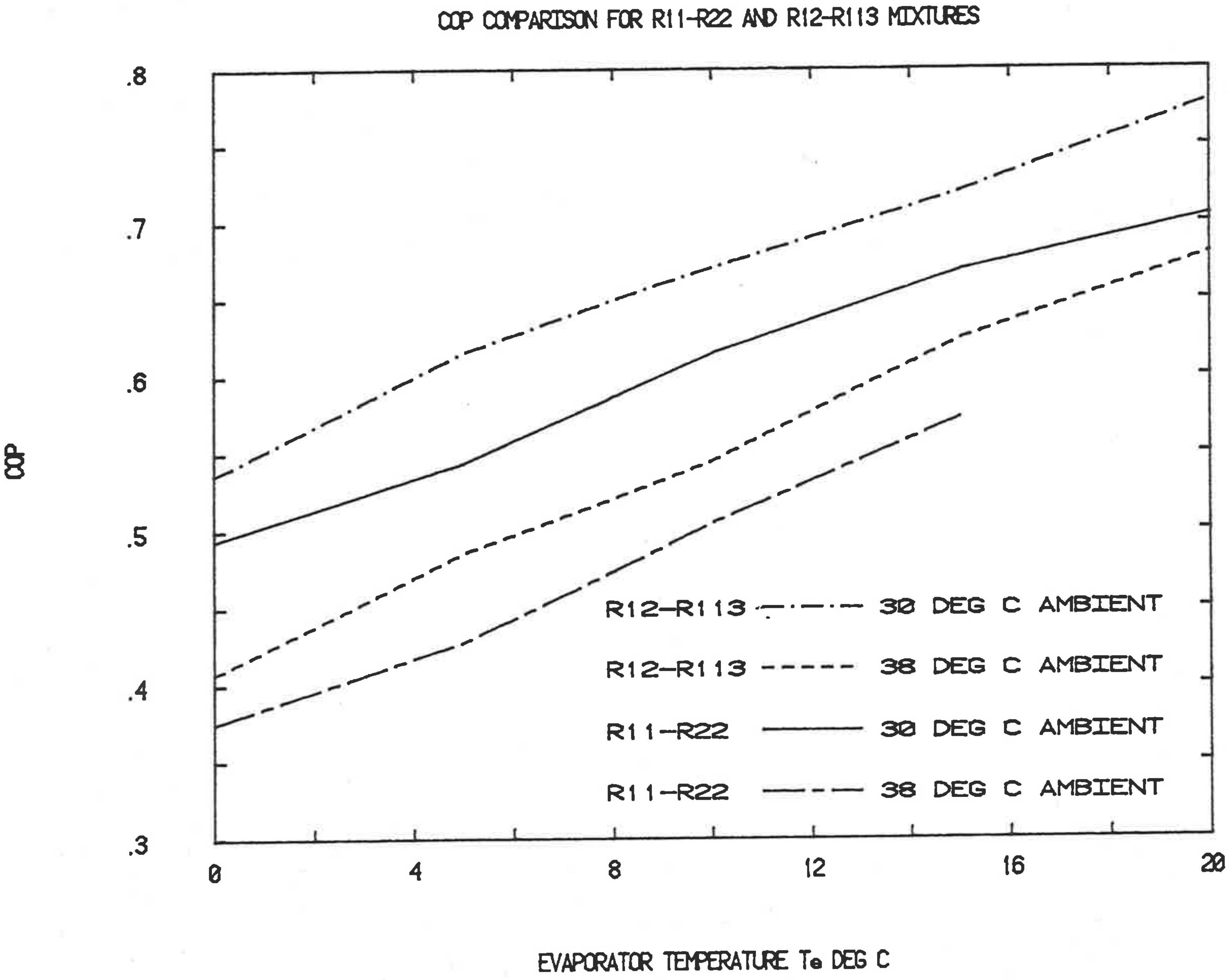

COP COMPARISON FOR R11-R22 AND R12-R113 MIXTURES
COP
.8
.7
.6
.5
.4
.3
0
4
8
12
16
20
R12–R113 30 DEG C AMBIENT
R12–R113 38 DEG C AMBIENT
R11–R22 30 DEG C AMBIENT
R11–R22 38 DEG C AMBIENT
EVAPORATOR TEMPERATURE Te DEG C

Fig 3.22

for each system represents the maximum COP theoretically attainable for a specified set of parameters.

Primarily the unavoidable minimum reflux losses are brought about by mixing losses which depend on the column flow rates and the difference between liquid and vapour availability values. Therefore not only system configuration but also operating parameters have an effect on COP and two such parameters are reflux ratio and distillate concentration.

The minimum reflux flow is determined by fluid properties and the feed condition but the excess flow above the minimum is determined by allowable column size. As the excess reflux is reduced column size increases. The distillate concentration limit is usually determined by the temperature gradient in the evaporator. For an R11 R22 mixture a reflux ratio of 1.15 gave 14 ideal plates whilst a distillate concentration of 0.93 resulted in a 5 degree evaporator gradient. Whilst COP gains from variations in distillate concentration and reflux flow are worthwhile, say of the order of 10 percent, they do not significantly reduce the gap between the attainable COP and the Carnot COP.

From the COP point of view increasing the bottom concentration from 0.05 to 0.13 for the R11 R22 system made no measurable difference and therefore 0.05 was adopted as the standard test concentration. Bottom concentrations below 0.05 were not investigated.

The heat rejection temperature, or in this case the ambient temperature, has a significant effect on performance. For example a change in ambient temperature from 30 deg C to 38

LEGEND FOR FIGURE 3.23

·· — ·· — ·	Carnot
—·—·—·—	Basic cycle
— —	Basic+preheater
————	Basic+preheater+precooler
--------	Basic+preheater+precooler +bottom column
——— —	Basic+preheater+precooler +bottom column+top column

PARMETERS FOR FIGURE 3.23

30 deg C ambient

101 deg C boiler

0.05 bottom concentration

0.99 distillate concentration

R11/R22

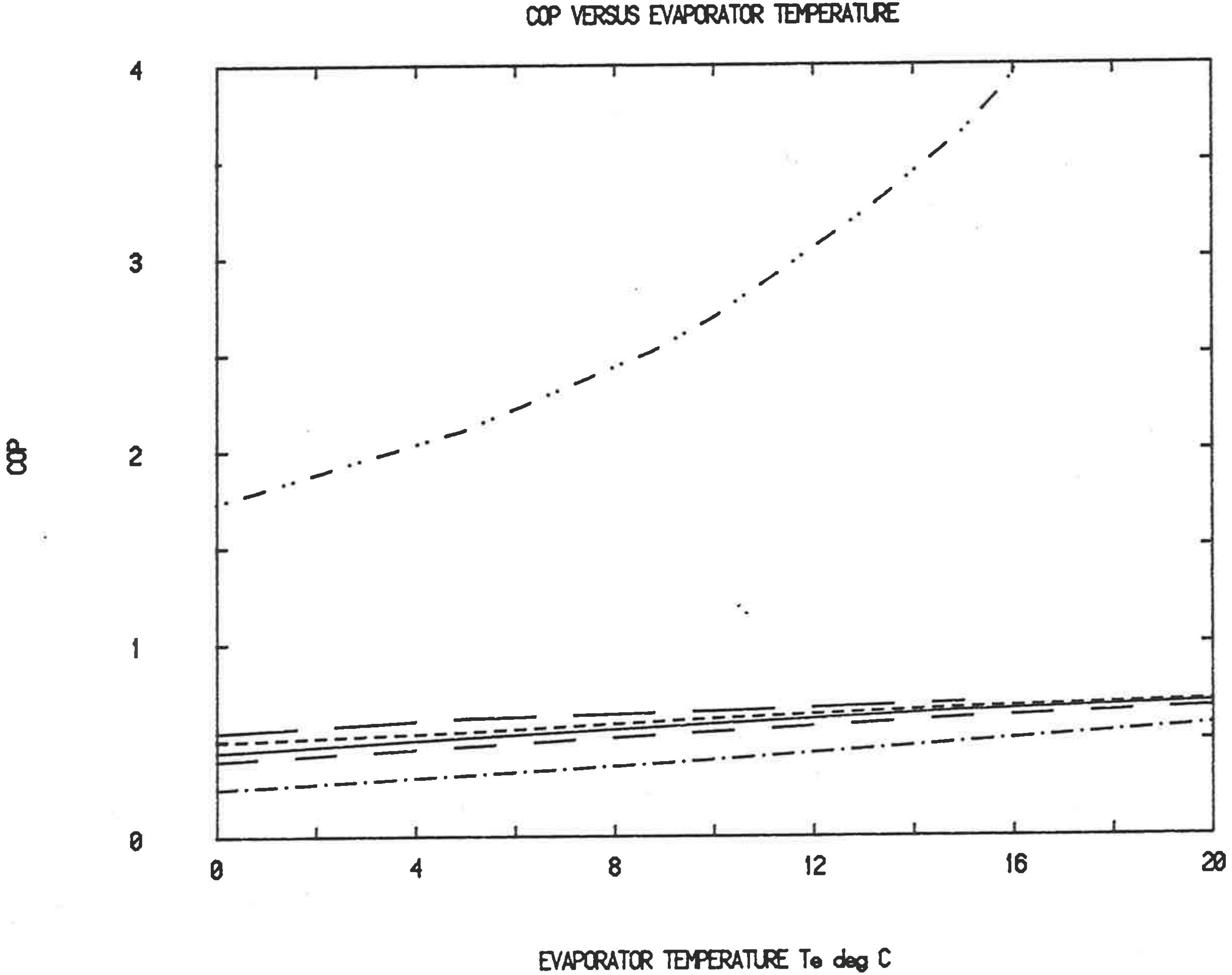

COP VERSUS EVAPORATOR TEMPERATURE
COP
0
1
2
3
4
0
4
8
12
16
20
EVAPORATOR TEMPERATURE Te deg C

FIGURE 3.23

deg C for an R11 R22 system at an evaporator temperature of 5 deg C reduced the COP from 0.54 to 0.43, a 20 percent reduction.

The 10 percent COP improvement of R12 R113 over R11 R22 suggests that mixture properties are important and that more combinations should be considered.

3.3 A practical cycle

Having considered an ideal cycle it is now opportune to establish both ambient and internal system conditions for a practical cycle.

Using design data from the Australian Institute of Refrigeration Air-conditioning and Heating (AIRAH) for Adelaide the following design conditions have been chosen

Summer outdoor design dry bulb temperature	38 deg C
Winter outdoor design dry bulb temperature	3.5 deg C
Indoor design air dry bulb temperature	24.0 deg C

3.3.1 Cooling

Ten kilowatts has been arbitrarily selected as the system cooling capacity but the 15 deg C air temperature leaving the cooling coil has been based on AIRAH data (1). Allowing an 8 degree approach between distillate into the evaporator and air leaving (33) results in a distillate evaporator entry temperature of 7 deg C. Often, for mechanical vapour compression systems using the common refigerants, approximately 4 degrees of superheat at the evaporator exit is required by the refrigerant flow control device. However, for this absorption system a more sophisticated control system is expected and therefore only 1 degree of superheat will be used. This allows maximum use of the high heat transfer coefficients experienced with boiling fluids.

Therefore, by assuming a distillate concentration of 0.99 with 1 degree of superheat, a 1 degree gradient and a 7 deg C entering temperature the vapour leaving the evaporator would be at 9 deg C. This is considered workable for an air temperature entering at 24 deg C and leaving at 15 deg C. (Assuming percent relative humidity requirements can be met by coil selection).
Pressure drop, and for that matter operating temperature, is selected largely on an economic basis and therefore the optimum for mechanical vapour compression systems may not be applicable to absorption systems. Because of this instead of selecting a pressure drop based on mechanical compression systems a range of values was tested.

No facility has been programmed to allow for condenser pressure drop. With regard to condensing temperature a 10 degree approach between air entering and distillate leaving was used. Mechanical vapour compression systems may use a 15 degree condenser approach but in this case, based on prototype performance (see section 3.4), it was limited to 10 degrees with one degree of subcooling.

In an effort to avoid cavitation at the pump 5 degrees of subcooling was allowed at the absorber out and, as a starting point, an initial approach value of 5 degrees was used between air entering and the feed flow. Again this selection was influenced by prototype performance.

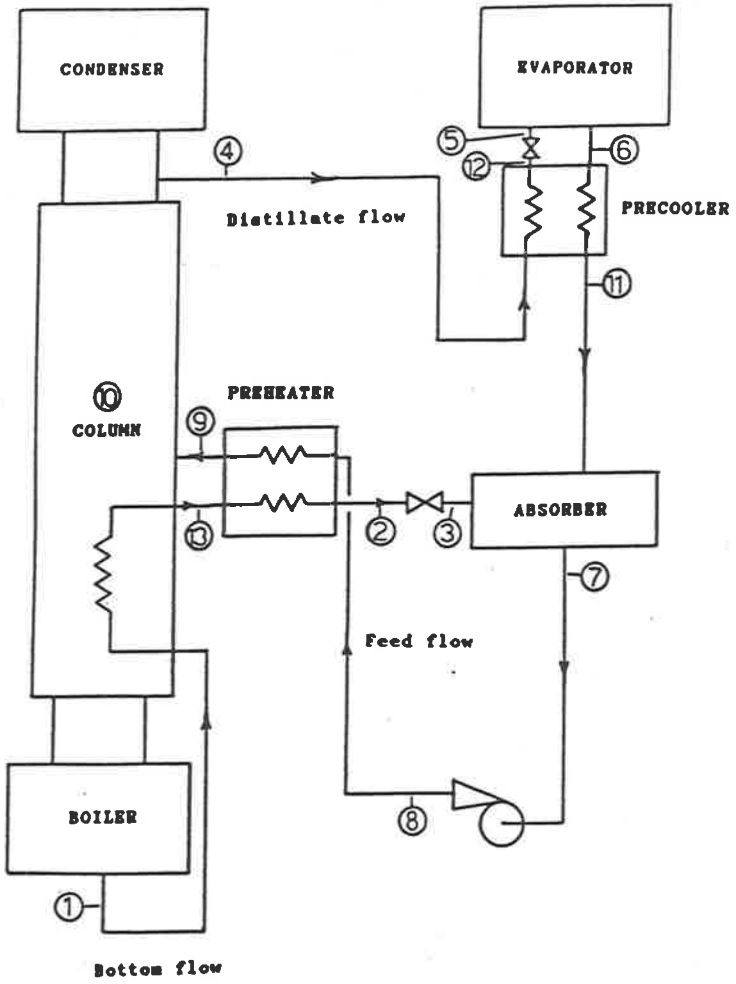
Similarly 5 degree approaches were allowed on all other heat exchangers. It should be noted that the column heat exchangers are specified by setting values between the end of the heat exchanger and the adjacent column plate and not by an approach setting for each plate.

In the first instance all pressure drops were set to zero and figure 3.24 shows the result for an R11 R22 mixture with preheater, precooler and stripping section heat exchangers. Appendix H, figure H11 shows a complete computer model print out. If the 38 deg C COP value of 0.428 from table 3.6 is used for a comparison between the ideal and practical cycle then there is a 30 percent drop to 0.3 for this practical system.

To test the sensitivity of COP to some of the parameters each was varied with the others constant and the results are presented graphically in figure 3.25. All the temperature variations have been plotted such that the slope represents the COP change per degree.

The variation in the evaporator approach plot is caused by a change in the number of column plates from 14, for the 0 to 4 degrees span, to 13 for the 5 to 8 degree section.

Ambient temperature was found to be the most important variable (steepest slope) and the precooler approach the least. The variation in the evaporator plot makes it difficult to assess its slope, however, it can be said to be approaching that of the ambient. This suggests that variables which change the pressure ratio of the system are of equal importance. eg ambient or evaporator approach. Maintaining the condenser condition and reducing the



PREHEATER-PRECOOLER-BOTTOM HX CYCLE

FIGURE 3.24

PARAMETERS FOR FIGURE 3.24

Ambient temperature 38 deg C
Bottom concentration 0.05
Distillate concentration 0.99
R11 and R22 mixture
Air entering evaporator 24 deg C
Air leaving evaporator 15 deg C
Evaporator superheat 1 degree
Condenser subcooling 1 degree
Absorber subcooling 5 degrees
Heat exchanger approaches
    Evaporator 8 degrees
    Condenser 10 degrees
    Absorber 5 degrees
    Preheater 5 degrees
    Precooler 5 degrees
    Stripping section 5 degees

SYSTEM DATA

Ⓝⓞ	TEMP DEG C
1	127.9
2	47.7
3	48.1
4	48.0
5	7.0
6	8.7
7	43.0
8	42.7
9	96.7
10	103.9
11	43.0
12	31.3
13	109.0

LEGEND FOR FIGURE 3.25

——————— Approach evaporator: Air off evaporator to refrigerant in.

Each degree represents a degree of approach For example at zero degrees, air off and refrigerant in are at the same temperature

·—·—·—·—·— Approach absorber: Air on absorber to feed leaving.

Each degree represents a degree of approach

··—··—··— Ambient temperature variation:

The 10 degree value represents a 38 deg C ambient, therefore 4 degree represents 32 deg C.

---------- Approach Preheater: Feed flow in to bottom flow out.

Each degree represents a degree of approach.

— — — Approach Precooler: Liquid in to vapour out.

Each degree represents a degree of approach.

NOTE: The X axis represents the chosen conditions for the practical cycle viz;

10 deg approach on evaporator
8 deg approach on absorber
5 deg approach on all other heat exchangers
5 deg C evaporator
38 deg C ambient

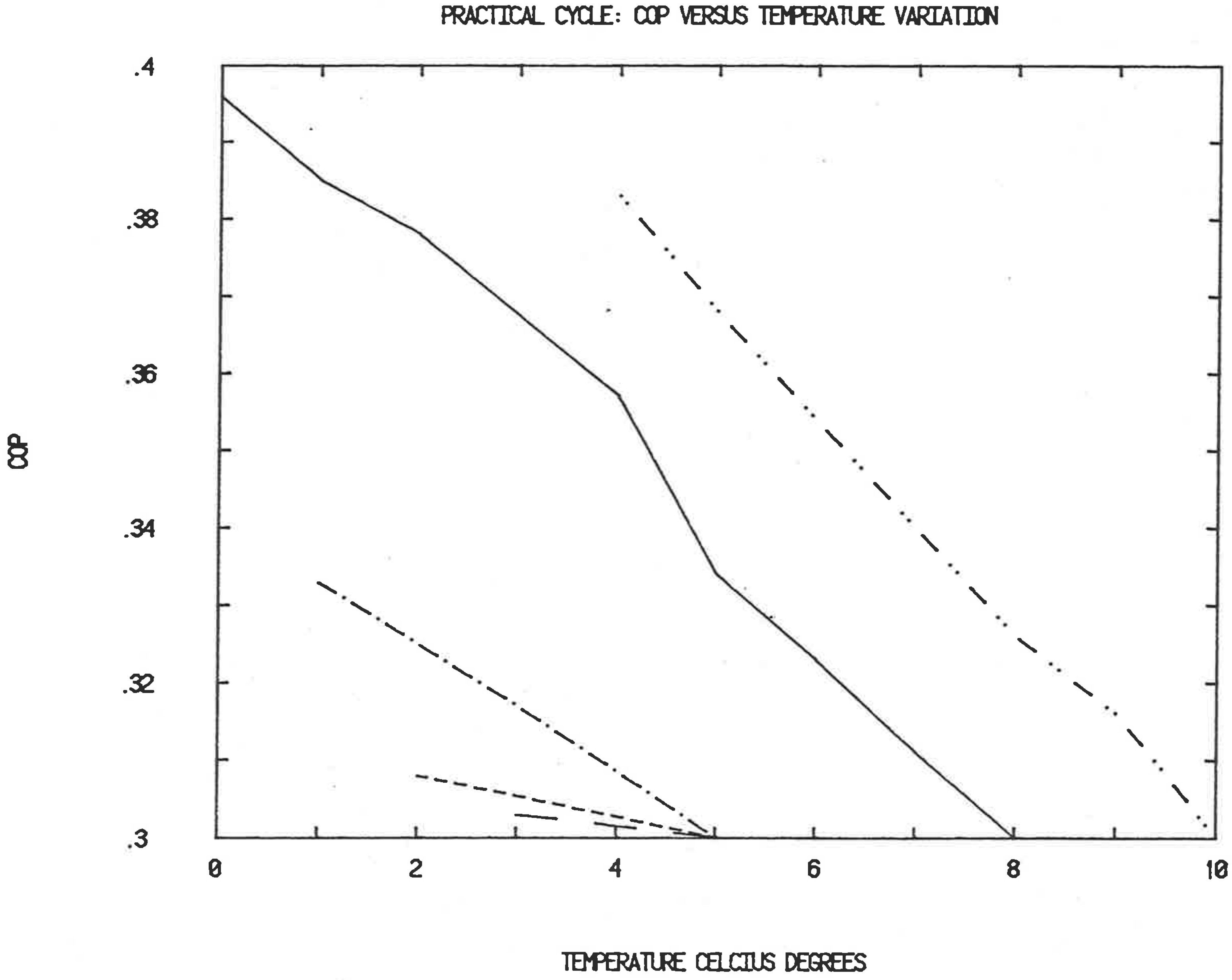

PRACTICAL CYCLE: COP VERSUS TEMPERATURE VARIATION
COP
.4
.38
.36
.34
.32
.3
0
2
4
6
8
10
TEMPERATURE CELCIUS DEGREES

FIGURE 3.25

absorber temperature results in an increase in COP but at a lesser rate than for the overall ambient reduction.

Pressure drops were tested on the evaporator, absorber and feed pipework. Of these the evaporator was the most important with a COP reduction of 0.001 for each 1 kPa drop.

A variation of 0.09 in COP can be expected per 0.1 change in the reflux ratio (figure 3.26). This is considered significant and highlights the importance of controlling reflux flow.

Using the R12 R113 mixture on the practical cycle gave a COP of 0.327 which is a 9 percent improvement on the 0.3 value of R11 R22.

Use of the rectification heat exchanger with the practical cycle increased the R11 R22 COP from 0.3 to 0.32 and for the R12 R113 value from 0.327 to 0.366, both increases are considered significant. On this basis testing of the rectification heat exchanger is recommended.

In summary the effect of preheater and precooler approaches is small in comparison with temperature variations which cause a change in the difference between condensing and evaporator conditions. For example, with R11 R22 at a given evaporator condition a COP change of approximately 0.015 can be expected for each degree change in ambient. Optimum pressure drops are best established on an economic basis and the same can be said for reflux ratio. Mixture selection is important and use of the rectification heat exchanger is recommended.

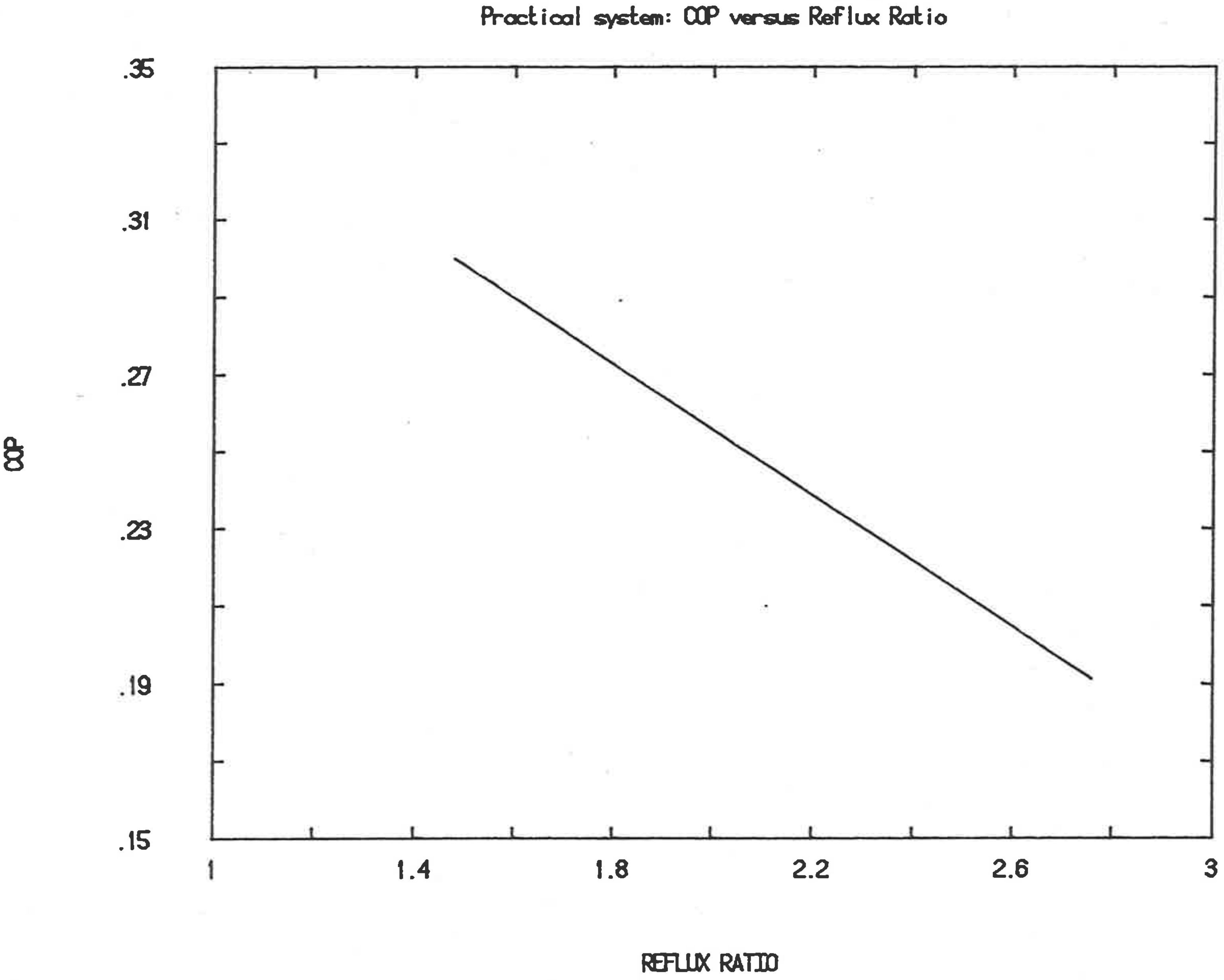
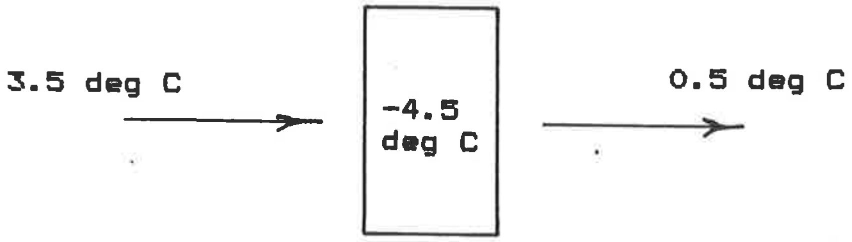

Practical system: COP versus Reflux Ratio
COP
.35
.31
.27
.23
.19
.15
1
1.4
1.8
2.2
2.6
3
REFLUX RATIO

FIGURE 3.26

3.3.2 Heating

Some of the practical cooling cycle parameters were varied for the heating cycle. For the sake of uniformity the evaporator capacity was maintained at 10 kW with one degree of superheating but the approach was reduced because one of the problems encountered with air to air heat pumps is the fouling of the outdoor heat exchanger with ice. Selecting a large heat transfer surface is therefore desirable and so if a 5 degree approach is allowed with an ambient of 3.5 deg c, an air leaving temperature of 0.5 deg C results if the evaporator temperature is -4.5 deg C.



It is envisaged that the heat rejected from both the condenser and the absorber will be used for heating purposes and so the air entering these heat exchangers will be at the return air condition of 24 deg C. If a 10 degree approach is allowed with 1 degree of subcooling a condenser (and absorber) temperature of 35 deg C results. This allows for an air leaving temperature of say 32 deg C which is considered adequate for a comfort heating situation.

In addition to zero pressure drops throughout a 5 degree approach was used for the precooler, preheater, and both column heat exchangers.

For these conditions a heating COP of 1.32 (Cooling COP = 0.336) was obtained for R11 R22 and 1.39 (0.402) for R12

R113. Whether or not these systems are viable at these COP's depends on economic considerations which should include such factors as fuel costs, manufacturing costs, boiler input efficiency and the COP variation due to changing load requirements on the plant. It should be noted that for Adelaide a heating plant would spend a significant proportion of its time operating at less demanding conditions than have been chosen here and therefore an annual average COP could well be higher than the 'spot' values shown.

3.4 Prototype simulation

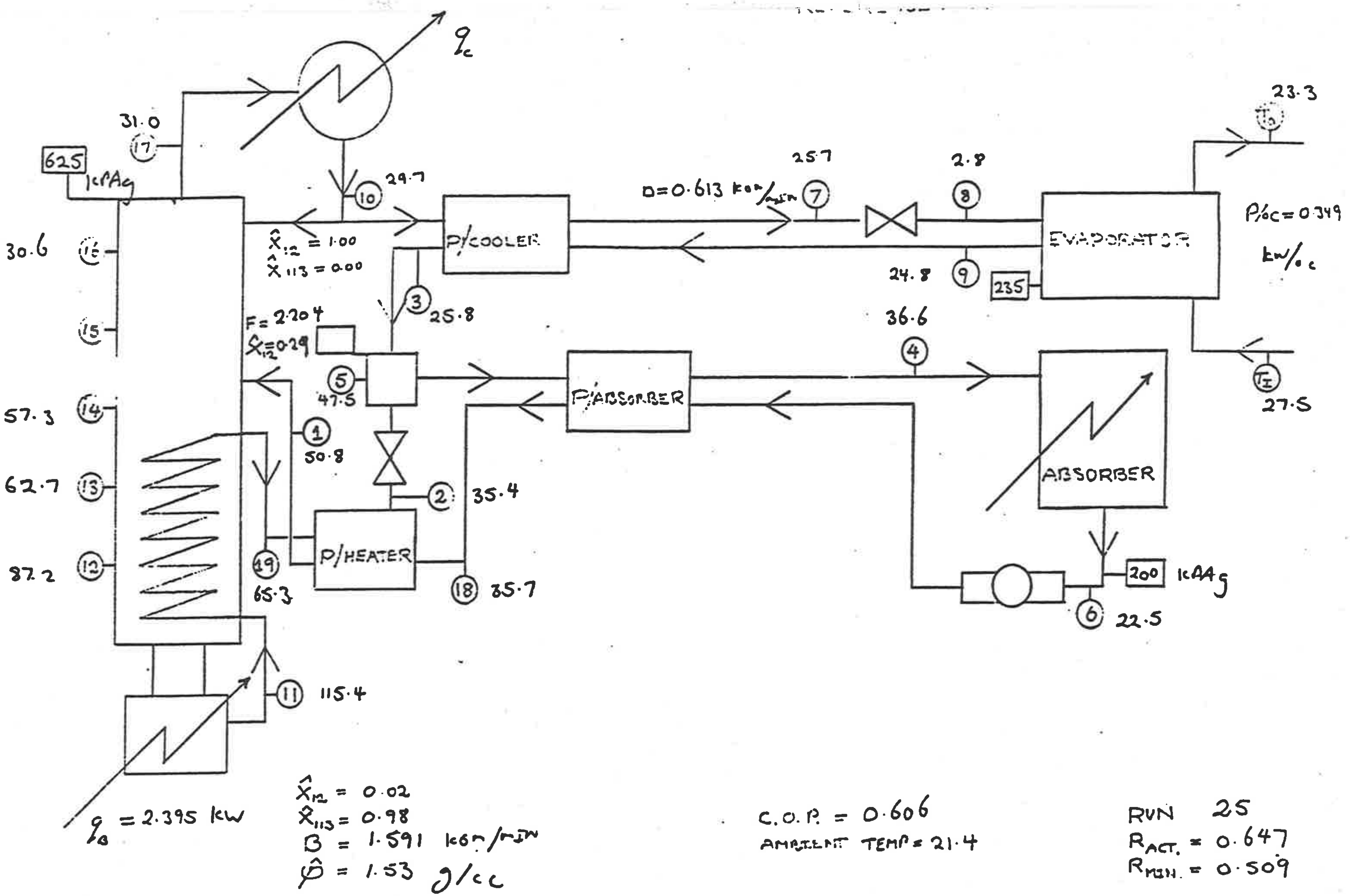
In the late 1970's Dr J. R. Roach built and tested the first prototype R12 R113 organic absorption cycle with a circuit as shown on the work sheet in figure 3.27. Currently the computer model is not designed to simulate this cycle which included a preabsorber heat exchanger. However, if the mixing/preheater/preabsorber/absorber is considered collectively then an approximate simulation is possible. Data for the program was set up as follows:

Pressure drop

- Evaporator out to absorber out was 35 kPa total. In the absence of detail about the components the following was assumed

Evaporator to precooler	zero
Precooler	6 kPa
Precooler to mixing	10 kPa
Mixing	zero
Mixing out to absorber in	10 kPa
Absorber	9 kpa

(Note: pressures on test sheet are gauge)



q_B = 2.395 kW

$\hat{X}_{12}$ = 0.02
$\hat{X}_{113}$ = 0.98
B = 1.591 kgm/min
$\hat{\rho}$ = 1.53 g/cc

C.O.P. = 0.606
AMBIENT TEMP = 21.4

RUN 25
$R_{ACT.}$ = 0.647
$R_{MIN.}$ = 0.509

FIGURE 3.27

Subcooling and superheating

- Values on the actual cycle were estimated by comparing the measured temperatures with saturation temperatures corresponding to the measured pressure.

Absorber 301 kPa at 0.29 gives 24.7 deg C

Subcooling = 24.7-22.4 allow 2 degrees

Condenser 726 kPa for R12 gives 29.5 deg C

Subcooling = 29.7-29.5 allow 0 degrees

Evaporator 336 kPa for R12 gives 2.8 deg C

Superheating = 24.8 - 3.8 = 21 deg
(allow for a one degree gradient)

Approach values

Absorber 22.5 - 21.4 = 1.1 degree

Condenser 29.7 - 21.4 = 8.3 degrees

Evaporator 23.3 - 2.8 = 20.5 degrees

Precooler 25.7 - 24.8 allow 1 degree

Preheater 35.7 - 35.4 allow 1 degree

Column, Bottom heat exchanger

Feed plate to heat exchanger out

assume 3 degrees

Bottom plate to heat exchanger in

assume 8 degrees

Evaporator capacity = (27.5 - 23.3) x 0.349 = 1.466 kW

Given the above parameters the computer model was run so that the boiler temperatures coincided with the measured value of 115.4 deg C. For ease of comparison the data below have been taken from appendix H, figure H12:

	measured	predicted
Power input kW	2.395	2.528
Condensing pressure kPa	726	733
Feed temperature deg C	50.8	53.5
Bottom Heat Exchanger leaving column deg C	65.3	65.1
Precooler liquid out deg C	25.7	29.3
Bottom flow kg/s	0.0265	0.0312
Feed flow kg/s	0.0367	0.0417
Distillate flow kg/s	0.0102	0.0105
COP	0.606	0.577

Even though these results are considered encouraging checks with other tests have not been conducted because of the different system configuations.

This first prototype has now been dismantled and a second, with the same configuation as the program, has just been completed.

3.5 Comparison with a Lithium Bromide/water system.

Yazaki Australia Pty Ltd market a range of absorption chillers including a gas fired unit model CH600, the typical operating characteristics (37) of which are given in the table below. The R12 R113 system was modelled using all the Yazaki operating conditions except for the preheater and absorber approaches. It was considered reasonable to have an absorber approach of the same order as the condenser and evaporator and so the preheater approach was reduced from 15.1 degrees to 5 degrees. The Yazaki absorber approach was reduced from 6.6 degrees to the prototype value of 2.0 degrees.

	Yazaki	R12-R113
Cooling capacity kW	6.87	6.87
Chilled water in deg C	11.9	11.9
Chilled water out deg C	6.8	6.8
Evaporator temperature deg C	4.5	4.5
Cooling water deg C	29.2	29.2
Condenser approach degrees	2.4	2.4
Absorber approach degrees	6.6	2.0
Evaporator approach degrees	2.3	2.3
Precooler approach degrees	-	2.0
Preheater approach degrees	15.1	5.0
All column HX approach degrees	5.0	5.0
COP	0.745	0.635
Heat input to generator kW	9.22	10.757
Feed flow/distillate flow ratio	14.5	4.42
Distillate flow rate kg/s	0.0029	0.0493
Column feed flow rate kg/s	0.0421	0.2177
Heat rejected in condenser kW	7.45	10.349
Heat rejected in absorber kW	8.64	7.298
Pump power kW	0.0	0.058
Distillate mass concentration	1.0	0.99
Feed mass concentration	0.58	0.263
Bottom mass concentration	0.54	0.05
Feed temperature deg C	70.6	59.1
Bottom temperature deg C	87.0	108.0
Pressure ratio	11.75	2.17
Highside pressure kPa	9.87	770.8
Lowside pressure kPa	0.84	355.0

Compared with the Lithium Bromide/water system the R12 R113 variation is:

COP	15%	lower
Distillate flow	1600%	higher
Feed flow	417%	higher

Two factors contributing to the superior performance of Lithium Bromide are

- The high latent heat value of water. It is 1600% higher than R12. (See section 3.2.5)
- Reduced difference between high and low pressure sides of the system.

For the R12 R113 system COP to rival the Lithium Bromide/water system under these conditions a reduction in column and/or absorber irreversibilities is necessary. A preliminary investigation indicates that these reductions may be achieved with a multistage cycle. If the organic system is significantly cheaper to produce it may be competitive from an economic point of view even with the lower COP and/or a more complex cycle.

Space heating for the Lithium Bromide system is achieved not by using the system as a fluid to fluid heat pump but by boiling refrigerant out of solution with the gas flame and then condensing it in what was previously the evaporator. The condenser and absorber are rendered inoperative and the condensed refigerant is absorbed and circulated back to the boiler. Unlike the organic system this mode of operation cannot produce a COP greater than one and therefore no attempt has been made to compare heating cycle performance.

CHAPTER 4

Nomenclature

a,b,c = constants
f = fugacity
O = pressure
R = residual
T = temperature
N = number of distillate column plates
Z = compressibility
τ = convergence criterion

Subscripts

i and j = component
k = iteration number
l = liquid
v = vapour
c = critical

COMPUTER MODEL

To analyse the absorption refrigeration cycle it was decided to write a VAX 11 Fortran computer model which provided the following:

- A comparison between calculated and published fluid properties for a range of working fluids.
- Easy selection of working fluids.
- Tables of fluid properties for both pure substances and binary mixtures.
- Optional use of various internal heat exchangers in the refrigeration cycle.
- Specification of refrigeration cycle operating variables such as evaporator temperature.
- A system analysis showing fluid properties at various points in the cycle as well as cycle operating characteristics such as COP.

The program was written in stages, firstly the fluid property calculation section, then the property checking section and finally the absorption cycle model hence the extensive use of subroutines. These subroutines allowed sections of the program to be run independently and also simplified the location of errors. Consequently the main program contains only an input facility and some minor calculations followed by the appropriate subroutine calls.

4.1 Program structure and ancilliary programs

A single input file contains variables for selecting program options such as tables of fluid properties and also for specifying system model values such as temperatures and heat exchanger options. As shown in the file structure in Appendix C it is in this file that the two operating fluids are specified by ASHRAE number. Once the two fluids are specified their properties are read from individual data files. Therefore, prior to running the system model separate input files must exist for each pure substance and a value for the Peng-Robinson equation interaction coefficient must have been entered into the program.

The program may be imagined to have 3 levels, the first being the main program which reads and checks input data and also calculates various Peng-Robinson constants. Next are the system and property table subroutines and, finally, the individual calculation subroutines. The system and property table subroutines contain the information required for the writing of the output files such as the system layouts shown in Appendix H and, in the case of the mixture properties, a plot file is written for the enthalpy concentration diagrams as shown in appendix G.

In all there are three ancilliary programs which support the main program but these are not essential for its operation viz: a plotting program (32), a batch program and an interactive program for writing the main input file.

The plot program may use the file generated by the main program as an input to generate enthalpy concentration diagrams. All graphics are produced using external IGL subroutines.

No keyboard input is required during execution of the main program and therefore it can be run in the batch processing mode. In fact most of the system modelling used in chapter 3 was done via an overnight batch program which modified the main input file after each run and then returned the program to the queue for the next execution.

For single runs of the main program an interactive program which reads the current input file, prompts for the changes required and then writes a new version has been created. This avoids having to memorise the input file structure.

For portability the main program was written to stand alone and therefore numerical method subroutines were included. Overall the program occupies 240K bytes and execution on the VAX 11/780 varies between 2 and 5 minutes of processing time depending on the number of heat exchangers in the circuit.

4.2 Numerical Methods

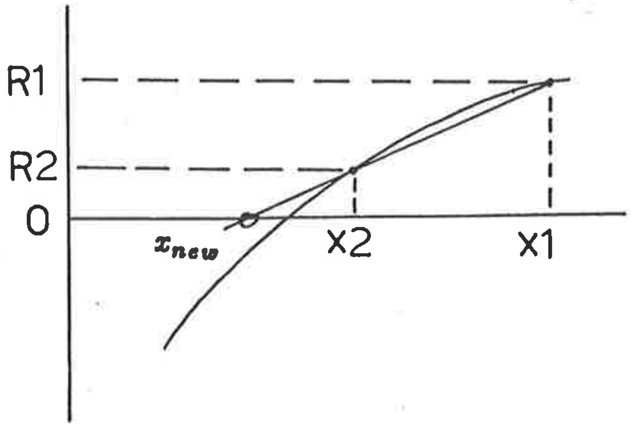
Early in the development of the program it was found to be necessary to write some standard subroutines for numerical methods for the solution of equations and so the solution of the Peng-Robinson cubic was used as a test case. The methods considered were direct substitution, half interval, regula falsi (or linear inverse interpolation) and Newton's method (9). Three were tried and typical results for the cubic solution were

Half interval	20 - 30 iterations
Regula falsi	6 - 9 iterations
Newton	3 - 5 iterations

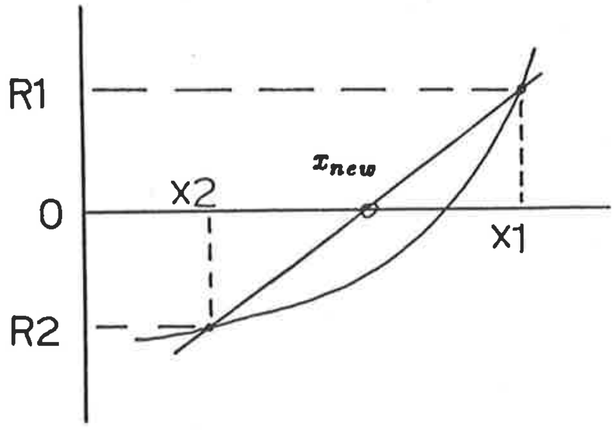
From this a set of priorities for methods was developed which rated Newton's method first, but of course this was only available for analytically differentiable functions, followed by regula falsi, half interval and direct substitution. It transpired that Newton's method was confined to the solution of the Peng-Robinson cubic because it was the only analytic function and elsewhere, because of speed and reliability, the regula falsi method was used. In some cases two methods were combined. For example it is possible to obtain the two guesses required to start the regula falsi method by supplying one guess and using direct substitution to find the second.

A robust subroutine was written for the regula falsi method by incorporating a similar method called false position and by storing three successive values of the function. False postion was included because the positive and negative residual required by regula falsi for the first two guesses could not always be guaranteed. In the case of false position both residuals can have the same sign but during computation one of the guesses remains stationary while the other is updated. For true regula falsi (9) the two initial guesses must have different signs and then both are updated. The equation used for both methods is:-

$$x_{new} = \frac{x_1 R_2 - x_2 R_1}{R_2 - R_1} \qquad (4.1)$$

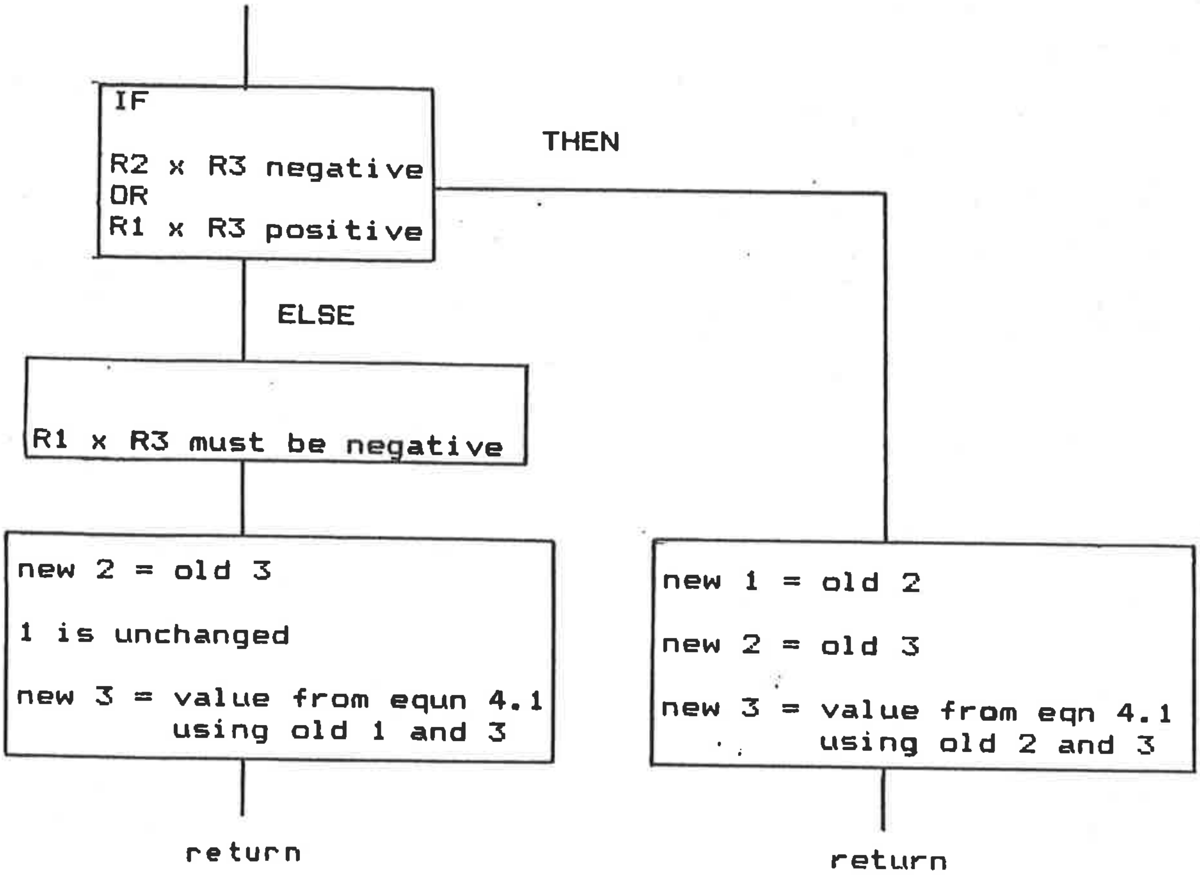


False position



Regula falsi

Three values of x and their corresponding residual values are required by the subroutine. The flow chart is as follows:



For the first call, which involved the two initial guesses, values X1 and X2 were made equal to guess one and X3 equal to guess two. This procedure will run for initial pairs of residuals with either the same signs or opposite signs.

4.3 Fluid properties

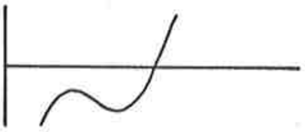
Peng-Robinson equation subroutines were written to generate basic data such as pure and mixture enthalpy values and then these in turn are called by the subroutines which establish working fluid conditions like vapour-liquid equilibrium.

4.3.1 Peng-Robinson equation

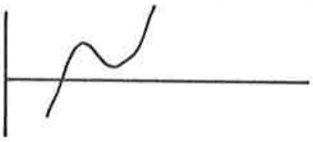
A section in the main program calculates all constants for the Peng-Robinson (chapter 1) equation of state, including those sections of the enthalpy, entropy and availability computation which remain constant throughout. These values are transmitted via a common block.

The solution of the Peng-Robinson cubic in Z (eqn 1.2) involves three meaningful possibilities :-

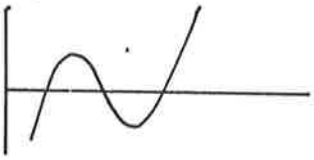
vapour only .... one real root



liquid only .... one real root



Two phase .... three real roots, the smallest for liquid and the largest for vapour.



For a given temperature and pressure the number of roots and the stationary points are determined by setting the first derivative of equation 1.2 to zero. The form of the equation is

$$aZ^2 + bZ + c = 0$$

The number of real roots can be obtained by evaluating the discriminant of the quadratic formula

$$Z = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$discriminant = \sqrt{b^2 - 4ac}$$

If the discriminant is

> zero = 3 real roots

= zero = 2 real and equal roots

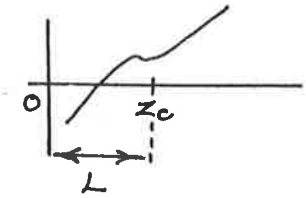
< zero = 1 real root

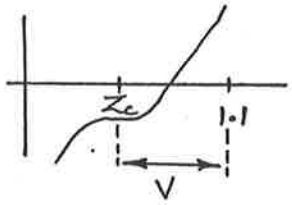
Knowing the stationary points and the number of solutions a single half interval calculation using two limiting values is used to find a starting value for Newton's method. The limiting values are:-

One root

Liquid root only: zero and Z_c

Vapour root only: Z_c and 1.1

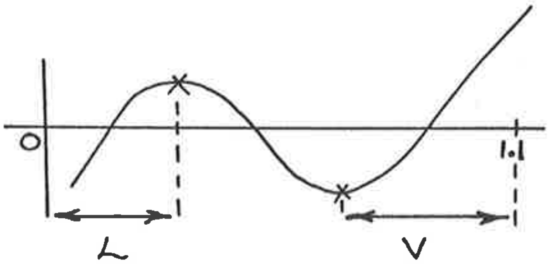




Two roots

Liquid: zero and the lower stationary point

Vapour: Upper stationary point and 1.1



For the solution of the cubic a residual of less than 1×10^{-12} is required. The program terminates if the number of iterations exceeds 10 or if Newton's method yields a guess outside the starting limits. Generally this method was found reliable although even with calculations in double precision it can fail near the critical point if the value of the slope approaches the accuracy limit of the machine. However, this is not a problem because failure always occurs inside the 'dead zone' (see chapter 1, end of section 1.2).

This solution of the cubic is the most frequently used section of the program and therefore a reduction in its computation time could represent a significant reduction overall. Further development of the program should include a comparison with an analytical method.

4.3.2 Pure Substance Vapour-liquid equilibrium

For a given temperature and substance the saturation pressure is established by the convergence of

$$\text{absolute value} = \left|P_{guess}\left(1-\frac{f_v}{f_L}\right)\right| < 5Pa$$

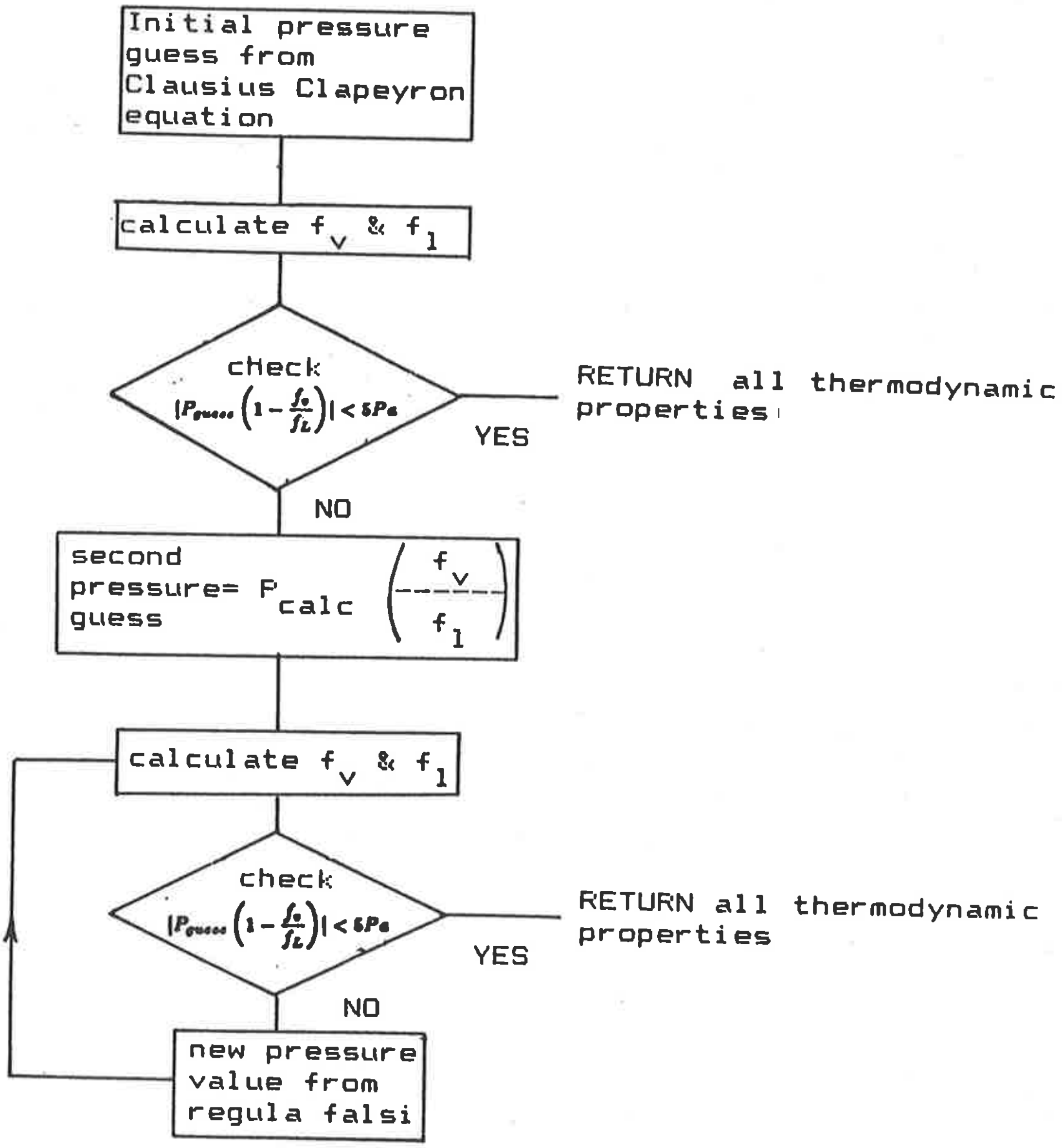


Fig 4.2

4.3.3 Mixture vapour-liquid equilibrium

Given two properties the vapour liquid equilibrium data for a mixture can be established. Several subroutines have been written which establish mixture vapour-liquid equilibrium and for these the input variable combinations are:-

- temperature and pressure
- pressure and liquid mole concentration
- temperature and liquid mole concentration
- pressure and vapour mole concentration
- temperature and vapour mole concentration

These subroutines all follow a similar pattern and are based on the equilibrium requirement that the fugacity of a component in the liquid phase must be equal to the fugacity of that component in the vapour phase. Typically the convergence criterion used in these subroutines is based on

$$1 = x_1 \frac{\bar{f}_{v1}}{f_{L1}} + x_2 \frac{\bar{f}_{v2}}{f_{L2}} \qquad (4.2)$$

ie. when the pure liquid and vapour fugacities are equal then the sum of the mole fractions of the components equals one. Only the flow diagram for the temperature/pressure subroutine is shown in figure 4.3 because the other combinations follow a similar pattern. In this case the convergence criterion for the liquid mixture is based on the difference between the guessed and calculated mole fractions of the components. Equation 4.3 forms the basis of the liquid mole fraction calculation:

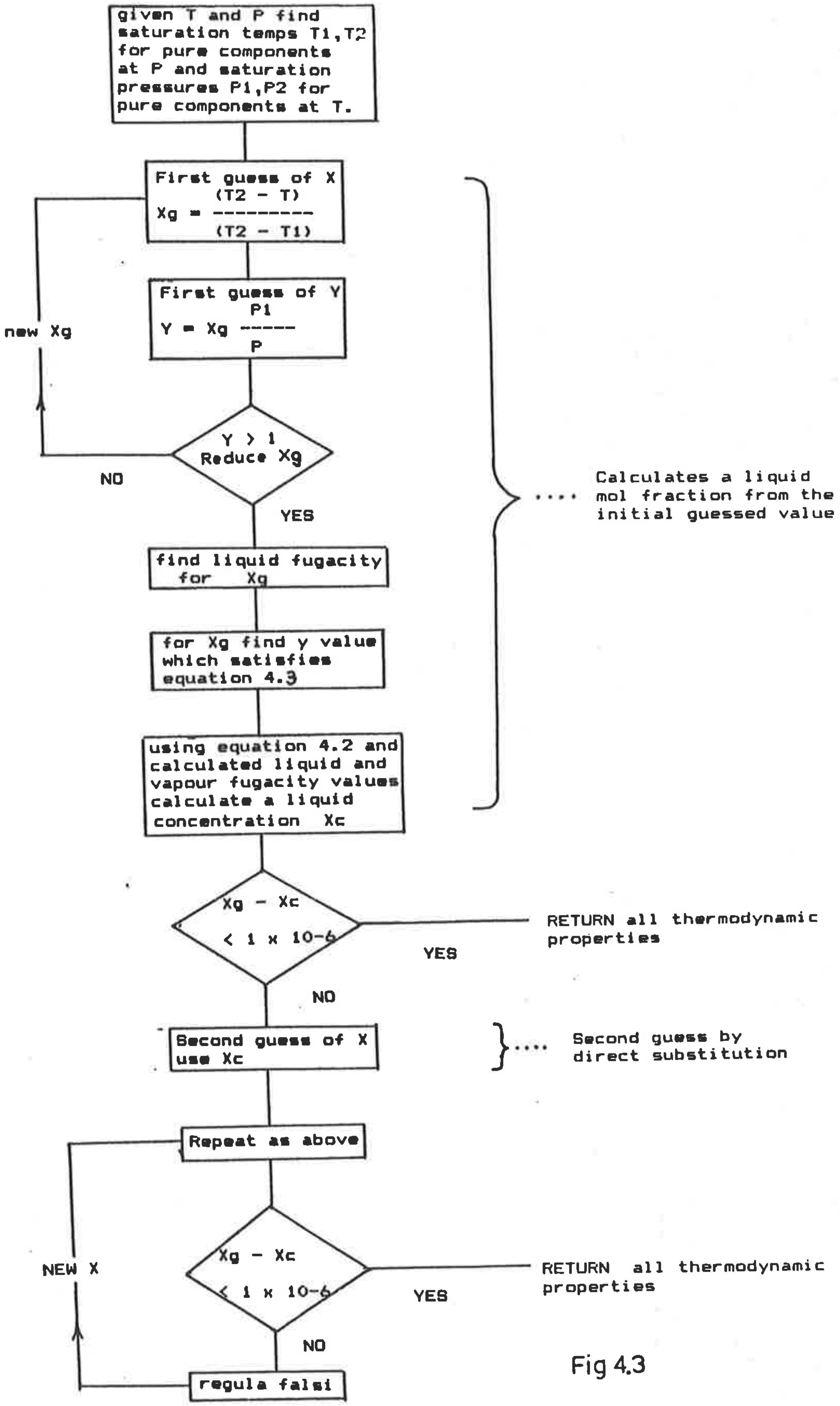


Fig 4.3

Flow diagram for determination of mixture vapour-liquid equilibrium

$$\frac{y_i}{x_i} = \frac{\frac{f_{iL}}{x_i}}{\frac{f_{iV}}{y_i}} \qquad (4.3)$$

Checks, not shown in the flow chart, include

- that the temperature specified lies between the pure component saturation temperature for that pressure.
- that the temperature does not exceed the critical temperature of either of the components.
- the number of iterations does not exceed 30.

4.3.4 General mixture subroutines

Two subroutines have been written which generate mixture properties for any state given three variables. One requires inputs of pressure, concentration and enthalpy and the other pressure, concentration and availability. These two subroutines call various combinations of the mixture subroutines mentioned in section 4.3.3 and also follow the same flow pattern of an initial guess from the program, a second guess from direct substitution and all subsequent predictions from regula falsi.

4.4 Fluid property tables

Since the refrigeration system model's accuracy depended on fluid property data the production of fluid property data tables was a secondary consideration to the checking of calculated data against published values.

4.4.1 Pure property tables

Saturated temperature values are calculated at 10 degree intervals between the nominated enthalpy datum and the critical condition. Variables to specify are

- Substance: nominated by refrigerant number eg R12
- Units : SI or Imperial

and the output is in tabular form as shown in appendix F. Options include superheated vapour data at 10,20,30 and 40 degrees of superheat from each of the saturated values and a comparison between calculated and published values from the input file (appendix E).

4.4.2 Mixture properties and enthalpy concentration diagrams

Calculation of mixture data is centred around the production of enthalpy concentration diagrams. At the pressure in question equilibrium data is calculated at 10 degree intervals between the saturation temperatures of the two pure components. Superheated values are calculated along isotherms using the vapour solution of the Peng-Robinson equation at the temperature and pressure in question. No subcooled solutions for the Peng-Robinson equation are used. All subcooled calculations are treated as saturated ones at the temperature and concentration in question but at a different pressure. It has been assumed that liquid properties are independent of pressure because the Peng-Robinson equation fails at varying distances (depending on temperature) out into the subcooled region. ie the effect of small pressure changes on liquid enthalpy is ignored.

Variables to specify:-

- Components : by refigerant number

- Pressure : either by a pressure value or by the saturation temperature for the most volatile component in its pure state.
- Concentration : Intervals for calculation, down to 0.01
- Number of isotherms : Number of isotherms above and below the equilibrium lines.

Output is in tabular and graphic form although only the graphics of the enthalpy concentration diagram are shown in appendix G.

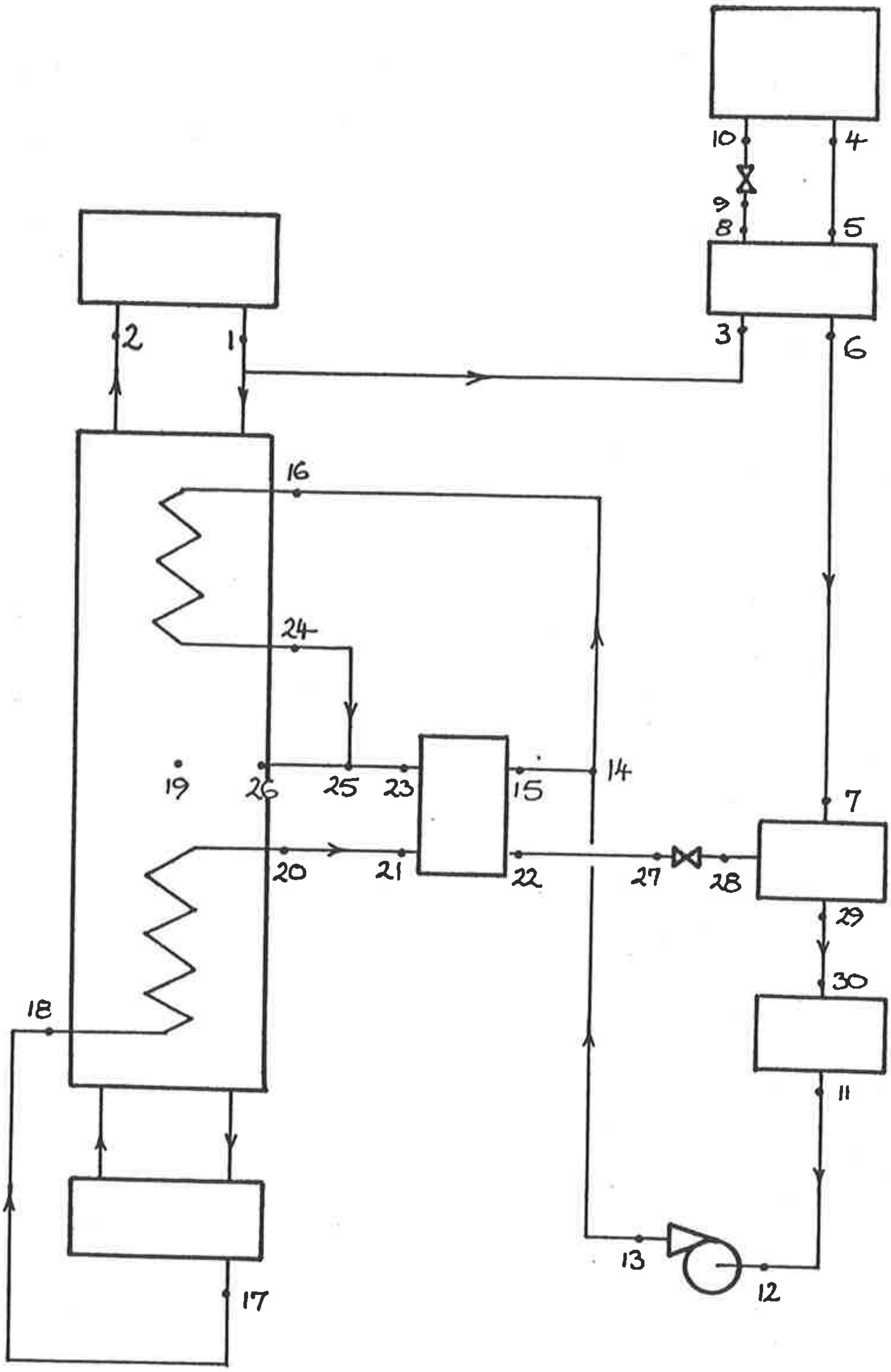
4.5 Absorption system

4.5.1 Overall sequence

A sequential modular approach (9) was used to analyse the absorption cycle and the sequence used along with the corresponding listing is shown in figures 4.4 and 4.5 respectively. Iterative procedures were necessary in the evaporator and column sequences as shown.

Consider the evaporator. Here two factors interacting make a loop necessary. The pressure in this section of the system is determined by the saturation condition in the evaporator. Guessing the evaporator outlet condition allows the evaporator inlet condition to be calculated via the precooler energy balance. This inlet condition must then agree with the temperature calculated from air leaving the evaporator minus the evaporator approach value.

The column loop is necessary because at the outset the program has too many constraints. It was decided to adopt the approach of specifying too many variables and then modifying one to suit so that program would yield the nearest possible solution to the overall requirement. In



10
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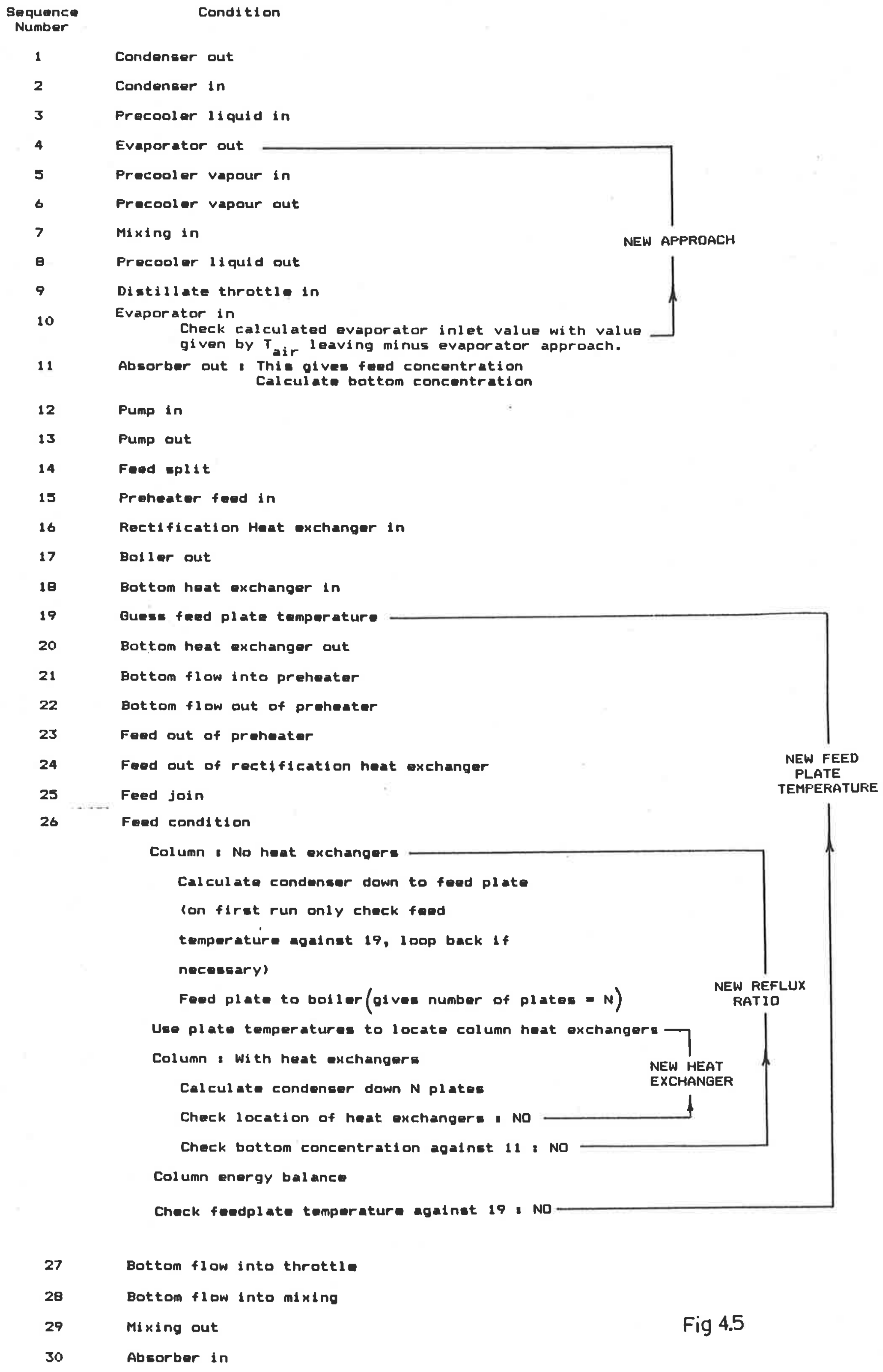
FIG 4.4



Sequence Number	Condition
1	Condenser out
2	Condenser in
3	Precooler liquid in
4	Evaporator out
5	Precooler vapour in
6	Precooler vapour out
7	Mixing in
8	Precooler liquid out
9	Distillate throttle in
10	Evaporator in Check calculated evaporator inlet value with value given by T_{air} leaving minus evaporator approach.
11	Absorber out : This gives feed concentration Calculate bottom concentration
12	Pump in
13	Pump out
14	Feed split
15	Preheater feed in
16	Rectification Heat exchanger in
17	Boiler out
18	Bottom heat exchanger in
19	Guess feed plate temperature
20	Bottom heat exchanger out
21	Bottom flow into preheater
22	Bottom flow out of preheater
23	Feed out of preheater
24	Feed out of rectification heat exchanger
25	Feed join
26	Feed condition Column : No heat exchangers Calculate condenser down to feed plate (on first run only check feed temperature against 19, loop back if necessary) Feed plate to boiler (gives number of plates = N) Use plate temperatures to locate column heat exchangers Column : With heat exchangers Calculate condenser down N plates Check location of heat exchangers : NO Check bottom concentration against 11 : NO Column energy balance Check feedplate temperature against 19 : NO
27	Bottom flow into throttle
28	Bottom flow into mixing
29	Mixing out
30	Absorber in

Fig 4.5

keeping with this the bottom concentration was calculated via a specified feed flow/distillate flow ratio and then again from the reflux flow via the column analysis. The reflux flow was modified until the two bottom concentration values converged and generally this modified the original value of the order of five percent. The explanatory notes relate to the sequence numbers in figure 4.5:

No	comment
10	Required residual is < 0.1 degrees. The first guess for the approach is a fixed value, the second is from direct substitution and finally regula falsi is used.
13	Constant enthalpy assumed across the pump.
19	Initial feed temperature guess uses a simple linear interpolation between the saturation temperatures of the two pure components and is based on the bottom, feed and distillate mass concentrations. viz $\dfrac{\text{feed concentration} - \text{bottom concentration}}{\text{distillate concentration} - \text{bottom concentration}}$
26	First time through the calculated feedplate temperature is checked against the first guess. If the difference is > 0.5 degrees control is returned to 19 and the new calculated value is used. From then on only the full column loop can modify the feedplate temperature value. Reflux ratio is varied so that the bottom concentration calculated from the column coincides with the concentration from 11 by <= 0.0005 . Plate temperatures determine column heat exchanger location and heat transfer. Adding the heat exchanger modifies the plate temperatures making a check of new plate conditions necessary.

All input variables required for modelling are contained in a single input file (appendix C). Data required includes

- Substances
- Enthalpy temperature datum
- Availability pressure datum
- Availability temperature datum
- Cooling fluid temperature onto condenser
- Condenser subcooling
- Approach: distillate out to fluid temperature on
- Cooling fluid temperature onto absorber
- Absorber subcooling
- Approach: feed out to cooling fluid temperature entering
- Evaporator capacity
- Fluid temperature leaving evaporator
- Evaporator superheating of distillate
- Approach: Fluid temp leaving to distillate entering
- Distillate mass concentration
- Feed flow/distillate flow ratio
- Ratio of actual to minimum reflux flow
- Pressure drops (various)
- Precooler approach: liquid in to vapour out
- Preheater approach : feed flow in to bottom flow out
- Bottom heat exchanger approach: HXr out to feed plate
- Bottom heat exchanger approach: Bottom plate to HXr out
- Rectification HXr approach: HXr out to feed plate
- Rectification HXr approach: Top plate to HXr
- Percentage of feed flow through preheater

Program control data specifies system configuration by allowing independent selection of heat exchangers *:

Preheater
Precooler
Column heat exchanger, stripping section
Column heat exchanger, rectification section

and also output by controlling the amount of data in the print out.

* A feed boost heat exchanger was programmed but not tested.

Typical print outs are shown in Appendix H.

4.5.2 Column calculations

Two methods were tried for the solution of the column, a rigorous approach by Henly et al (19) and a computer model of the Ponchon Savarit construction. Henly's method for column analysis is based on equation partitioning and tearing methods. This method requires an initial guess of temperature and vapour flow rate for each plate and then, for subsequent guesses, Henley recommends direct substitution with damping. With regard to damping a 10 percent maximum variation in temperature and flow was suggested. The method was easy to program but it was too sensitive to the initial guesses to be reliable.

The initial guess for the vapour flow rates on each stage was set equal to the flow entering the condenser (as suggested in the text). Linear interpolation between condenser and boiler temperatures was used for the plate temperature guesses but after unreliable performance these were replaced with Ponchon Savarit values. Even then the method occasionally failed. Damping did not guarantee success and when regula falsi was used to predict subsequent plate temperatures the method failed completely.

Difficulty was also experienced with the convergence criterion. Henley suggested that a criterion based on temperature and vapour flow was unnecessarily complicated and that the following expression, based on temperature alone, would suffice.

$$\tau = \Sigma_{j=1}^{N}\left[T_j^k - T_j^{k-1}\right]^2 \leq 0.01N \qquad (4.4)$$

Indeed this was found to be the case. The vapour flow values did converge more quickly than the plate temperatures and so equation 4.4 was used. However, it was discovered that this limit of 0.01N demanded a convergence between subsequent temperatures calculated for each plate of less than one degree. Assuming the number of plates (N) is 12 then the sum of the squares of the temperature differences between iterations k and k-1 must be <= 0.12. If this difference is assumed equal for all plates then this criterion requires a difference in temperature between successive guesses of 0.1 degrees. This means that loops used to find fluid properties must have a convergence criterion less than 0.1 otherwise variations in fluid properties cause unstable operation. The overall accuracy of the program does not warrant such a tolerance on temperature and so the criterion was increased to 1.0N. However, by relaxing the value to 1.0N (a 1 degree difference per plate) allowed a convergence situation where values were within a fraction of one degree on most plates but 2 or 3 degrees for another. It was not possible to embark on an detailed investigation of this method and so it was replaced with the Ponchon Savarit method.

Despite the failure of this method two benefits did result from this work. One was a check on the Ponchon Savarit column calculations. When plate temperatures from successful runs of Henley's method were checked against Ponchon Savarit values they were at most two degrees different. Secondly it was found that by using Ponchon Savarit temperatures and enthalpies in an adapted version of Henley's method plate flow rates could be easily calculated.

Column temperatures and concentrations are determined using a Ponchon Savarit construction procedure (figs 4.6 and 4.7). In the case of the column with heat exchange the same procedure is used except that the difference point c (and d) is progressively stepped down (d goes up) for each plate with a heat exchanger. Protection in the procedure includes checks for

- Excessive number of plates (100 maximum)
- Azeotrope
- Excessive heat exchange in the column
- Excessive number of iterations (most are set at 30)

By knowing plate temperatures as well as liquid and vapour concentrations it is possible to calculate plate flow rates. As mentioned Henley's rigorous method required the adjustment of two variables, temperature and vapour flow rate. It was found that by using Ponchon Savarit temperatures and varying only vapour flow rate all the flows could be determined. The sequence starts with all the vapour flows being set at the condenser flow

PONCHON SAVARIT PROCEDURE

Number	Operation	Known values	method
1	Calculate minimum difference point (b)	Feed concentration Feed enthalpy Distillate concn	Guess temperatures and compare slopes F-b1 and b2-b1
2	Actual difference point (c)	Ratio of actual to minimum reflux flow	
3	Stripping section difference point (d) (Principle operating line)	Bottom concentration difference point Feed point	
4	Locate isotherm e-f	Distillate concn Pressure Temperature	
5	Locate g (vapour leaving stage)	difference point Liquid condition (f)	Guess temperature & use ratio of sides of triangles to compare c-f1/c-g1 to f-f1/g-g1
6	Repeat 4 & 5 until the isotherm crosses the principle operating line g1-h1 (No attempt has been made to find the optimum feed plate)		
7	Repeat 4 & 5 using d instead of c until j concentration is less than or equal to bottom concentration.		

FIGURE 4.6

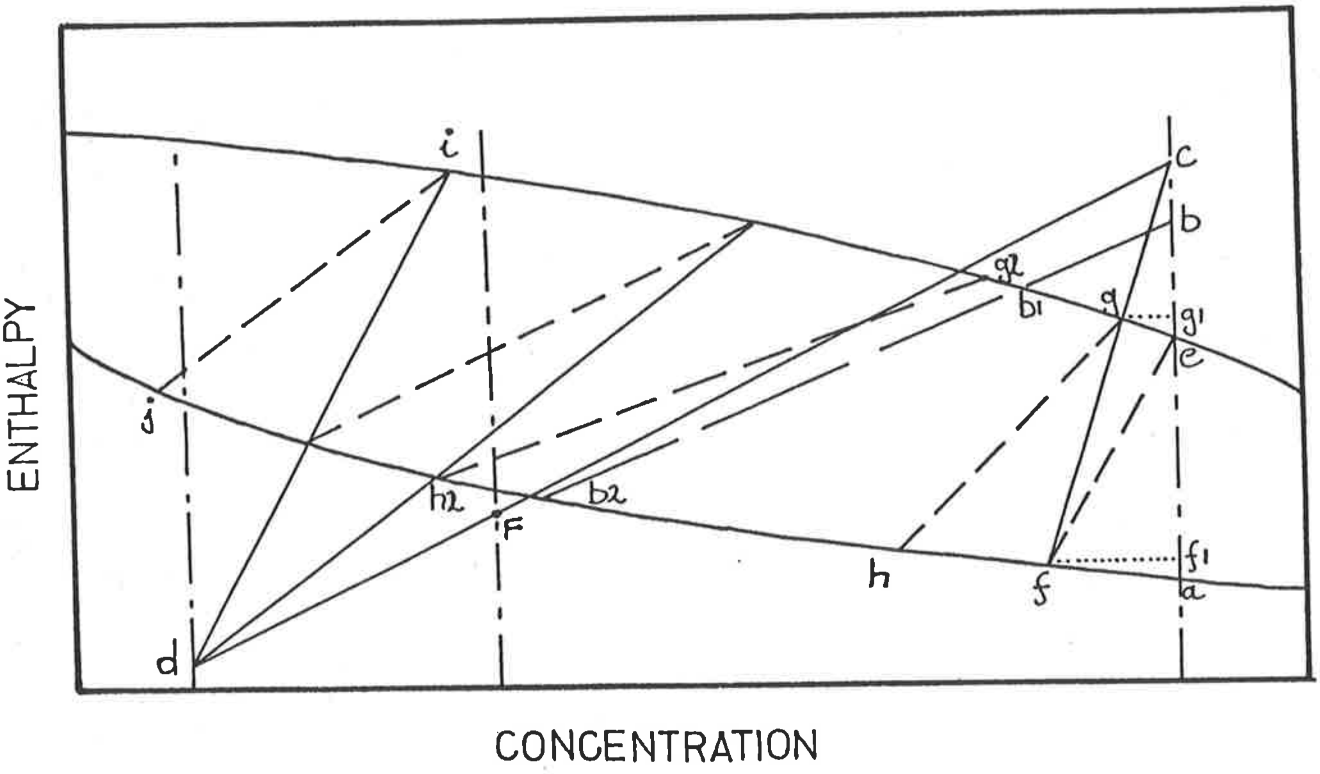


FIGURE 4.7

value, then uses direct substitution and finally terminates when the largest difference between successive vapour flow calculations for any plate is less than one percent.

CHAPTER 5

GENERAL CONCLUSIONS

This chapter is divided in the same way that the project aims were grouped in the introduction; viz fluid property estimation, absorption system analysis and optimisation of system design. The requirements of the aims for the first two headings were fulfilled but the system optimization aspect was not pursued. After a substantial time investment in the areas of fluid properties and system analysis it was realized that the course requirements could be fulfilled on this basis and that an effort of similar magnitude in the optimization area could not be justified. Consequently this work provides a basis for an exhaustive investigation of absorption refrigeration cycles and their working fluids by supplying the method, in terms of the second law analysis, and the means, by way of the computer model.

Information contained in this chapter is a collection of the conclusions stated in various parts of this report.

5.1 Mixture properties

Both pure and mixture fluid properties have been predicted satisfactorily for a range of organic fluids.

From this work it can be concluded that

a) The Peng-Robinson equation of state (section 1.2) can be used to predict fluid properties with sufficient accuracy for engineering calculations. Typically calculated values were within ± 5 percent of the published data although liquid entropy values did show larger deviations. Appendix E shows a comparison between Peng-Robinson and published data while appendix D illustrates that the Peng-

Robinson equation performs as well as, and in some cases better, than the widely used Soave-Redlich-Kwong cubic equation.

b) Property prediction can be improved by fitting the Peng-Robinson constant K value to published data for each substance rather than using the generalised Peng-Robinson correlation based on acentric factor.

c) For the mixtures tested the effect of the Peng-Robinson binary interaction coefficient on properties was significant. Assuming zero for this constant is not recommended as errors between calculated and published values of between 20 and 40 percent may result. This coefficient was determined by substituting published vapour-liquid equilibrium data in the Peng-Robinson equation and then working "backwards" through the calculation. In the absence of published data for mixtures the activity coefficient approach of Van Laar can be used to estimate vapour-liquid data. These values can then be substitued in the Peng-Robinson equation to establish the interaction coefficient. This was done for the R12 R113 mixture and the method is discussed in appendix B.

5.2 Absorption refrigeration cycle analysis

A computer model has been written which executes successfully for evaporator temperatures between 0 deg C and 20 deg C and for ambient temperatures between 25 deg C and 38 deg C. The model has facilities to predict and check fluid properties as well as model an organic absorption refrigeration cycle.

5.2.1 Computer model options and performance

Input variables allow selection of heat exchanger approaches, ambient temperatures, mixture concentrations, evaporator capacity and working fluids as well as individual selection of four internal heat exchangers. Output from the program includes fluid property tables and pressure enthalpy diagrams as well refrigeration cycle details. Modelling of the refrigeration cycle has produced:

a) A simulation of an R12 R113 system prototype which gives comparable results to experimental test data. For example the measured and predicted COP values were 0.606 and 0.577 respectively.

c) A Second Law of Thermodynamics analysis of the system (chapter 3) which shows that

   - the column and absorber mixing processes are the least energy efficient.
   - energy utilization may be improved by the use of internal heat exchangers.
   - After fitting internal heat exchangers the column irreversibilities mainly occur on the feed plate and in the boiler. For the boiler it is due to the difference in availabilities of the vapour and liquid streams in equilibrium and in the case of the feed plate there is an added loss due to the introduction of another stream with a different availability. Overall the greater this vapour liquid difference, and the higher the column flow rates, the greater is the irreversibility loss. For this reason external reflux flow to the column should be minimised to the

extent justified by economics of distillation column size. These unavoidable irreversibilities due to mixing set the maximum achievable COP at a value well below the Carnot value. These achievable COP's are closest to the Carnot values at the lower evaporator temperatures: for example for an R11 R22 system with all the internal heat exchangers, ideal conditions and a 0 deg C evaporator the achievable COP is approximately one third of the Carnot value.

- Fluid selection is important. Both the Carnot COP and the irreversibilities depend on this. The R12-R113 mixture consistently produced COP values 10% higher than those for R11-R22, mainly because of its higher Carnot COP.

d) A First Law of Thermodynamics analysis shows that

- The system COP is most sensitive to variables which affect the pressure ratio (such as ambient temperature) and least sensitive to preheater and precooler heat exchanger approaches. For example with an R11 R22 mixture and a constant evaporator temperature of 5 deg C a change of 0.015 in COP can be expected for each degree change in ambient.
- As the column reflux flow reduces, the COP increases, but with a corresponding increase in column size.
- Reducing distillate concentration provides an increase in COP whilst introducting a temperature gradient across the evaporator. For R11-R22 reducing the concentration from 0.99 to 0.93 introduced a 6 degree gradient and a 7% COP increase.

- Increasing the bottom concentration significantly reduces the generator temperature but has little effect on COP and pump power. For an R12 R113 system of 10kW capacity an increase in bottom concentration from 0.05 to 0.13 reduced the generator temperature from 101 deg C to 82 deg C with a corresponding pump power change from 0.1kW to 0.14kW.

e) A comparison with a commercially available Yazaki gas fired Lithium Bromide water system commonly used for air conditioning revealed a 15% lower COP for the R12-R113 system. This comparison was made at the Yazaki rating conditions for cooling which included heat rejection to cooling water at 29.2 deg C and an evaporator temperature of 4.5 deg C.

f) Modelling of a practical heating cycle revealed COP's of the order of 1.3 for R11 R22 system operating with an evaporator temperature of -4.5 deg C. This suggests that further work is worthwhile.

5.2.2 Computer model methods

With regard to computational procedures (section 4.2) Newton's method has been used successfully to solve for the Peng-Robinson equation cubic roots. For non-differentiable functions the regula falsi method has proved to be far more robust and faster than both the direct substitution and the half interval methods.

For the distillation column analysis (section 4.5.2) a programmed representation of the Ponchion Savarit method has been used in preference to the equation partitioning and tearing variable method proposed by Henley et al (19).

Henley's method failed often because it was too sensitive to initial guesses and also it required a fluid property accuracy greater than that which was possible with the Peng-Robinson equation.

Execution for one set of refrigerant cycle conditions required 2 to 5 minutes of central processing unit time on the VAX 11/780 computer. These relatively long run times are often inconvenient when using the computer interactively and so the input was configured to enable multiple runs in the batch processing mode.

5.3 Optimum system design

An optimum design procedure has not been established because to effectively optimise absorption system design both cost and performance must be considered, not just COP as has been the case here. For example even though the organic unit COP is 15% less than for the Yazaki design it may still be cost competitive because of lower production costs. Also, unlike the Yazaki units, the organic system is capable of heat pump operation and therefore has a wider market potential. It is considered that the organic COP is sufficiently close to the already commercial Yazaki equipment to warrant further investigation

5.4 Future work

Further work is recommended and it is suggested that it be divided into four broad areas:-

1) Investigation of a range of binary mixtures with a

view to establishing relationships between fluid properties and COP. This should include a comparison with existing systems.

2) Simulation of prototype performance. Checks should be conducted against test measurements to establish if trends predicted by the program occur in pratice.

3) Investigation of multistage evaporator/absorber combinations in conjunction with two or more separate column sections is warranted. These systems offer the possiblity of reducing the column and absorber mixing irreversibilities and therefore may offer significant improvements.

4) Optimization of design by assessing both costs and performance.

APPENDIX A

PENG–ROBINSON EQUATION OF STATE

Nomenclature

A = Peng Robinson constant
a = Peng Robinson constant
B = Peng Robinson constant
b = Peng Robinson constant
f = fucacity
P = pressure
R = universal gas constant
S = entropy
T = temperature
U = Helmholtz function
v = volume
Z = compressibility

Subscript

L = liquid
V = vapour

Superscript

o = ideal gas state

PENG ROBINSON EQUATION

A.1 Optimization of κ equation 1.7

To optimize κ a decision had to be made on the comparison with experimental data with respect to :

a) Temperature range.

b) Convergence criterion for f_v and f_l.

c) Deviation parameter.

d) Property to be used as a basis for selection.

A.1.1 Temperatures

For the absorbtion cycle under consideration temperatures can range from subzero in the evaporator to in excess of 100 deg C in the distillation column. As most thermodynamic tables (3) use saturated liquid at -40 deg C as the enthalpy and entropy datum condition this was chosen as the lower limit. Also it was below the lowest evaporator temperature expected. From ambient temperature considerations it was not unreasonable to expect 120-150 deg C in the distillation column. Using this data a range for the selection of κ was chosen from the higher of -40 deg C and the freezing point to the lower of 200 deg C and the critical temperature. It should be noted that property data computation is not restricted to this range.

A.1.2 Convergence

A saturated liquid-vapour fugacity convergence criterion of 5x10-3 kPa was selected because further reduction increased computing time with no change in the property values generated.

A.1.3 Deviation

Figure A1 illustrates that, based on pressure, minimums occur for equation A1 at 0.6352 and for equation A2 at 0.6381. This variation is typical for these refrigerants.

$$SD1 = \sqrt{\frac{\sum_1^n (calcd - publd)^2}{(n-1)}} \tag{A.1}$$

$$SD2 = \sqrt{\frac{\sum_1^n \left(\frac{calcd-publd}{publd}\right)^2}{(n-1)}} \tag{A.2}$$

Equation A1 was selected as the optimization criterion on the basis that it was biased toward the higher working end, and not the low useage end, of the temperature range. At the low temperature even though the absolute errors are small the relative error is large which increases the importance of this section for equation A2. For example, compare the two pressure percentage error curves in figure A2. Equation A1 allows the greater

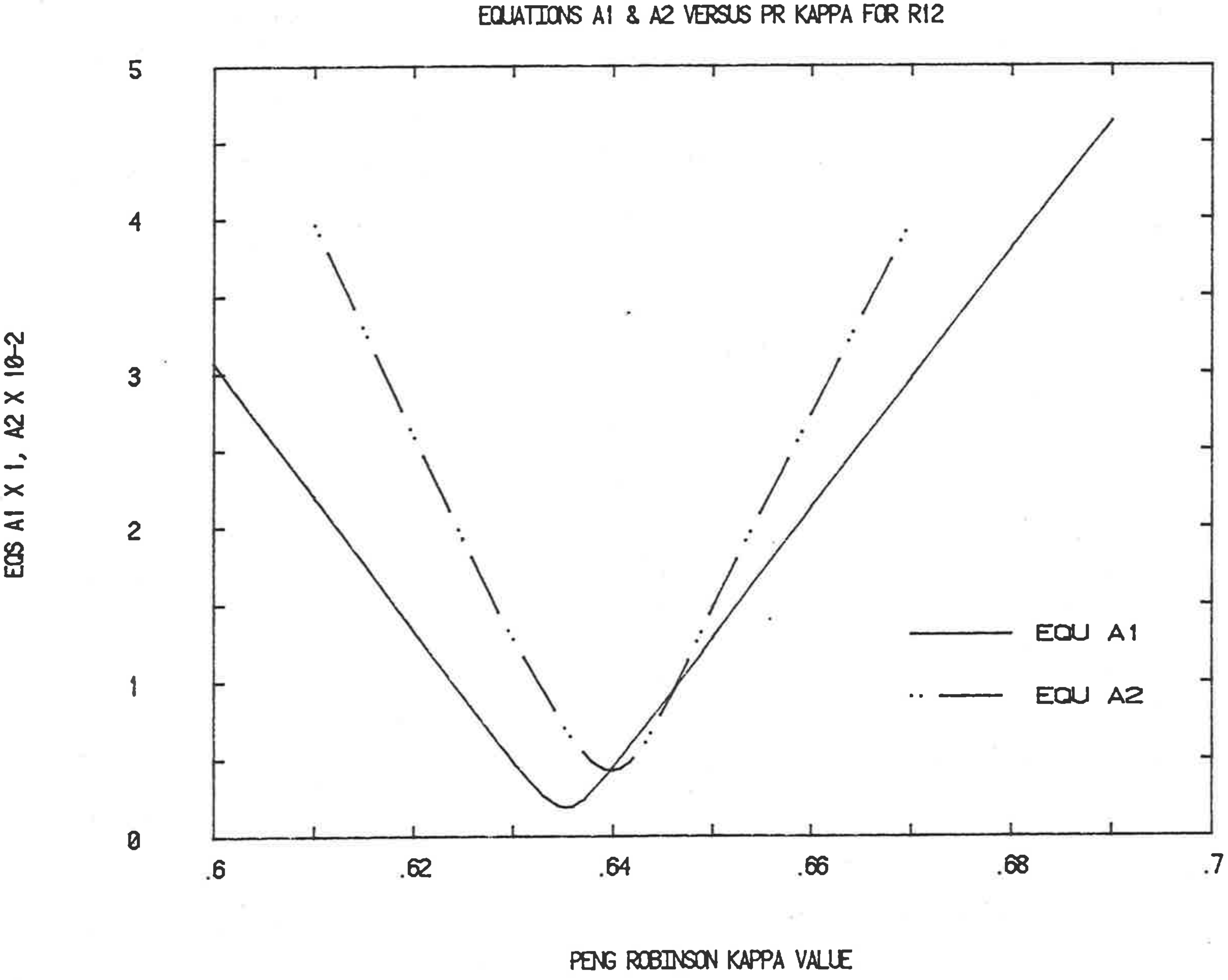

EQUATIONS A1 & A2 VERSUS PR KAPPA FOR R12
EQS A1 X 1, A2 X 10-2
5
4
3
2
1
0
.6
.62
.64
.66
.68
.7
PENG ROBINSON KAPPA VALUE
EQU A1
EQU A2

Fig A1

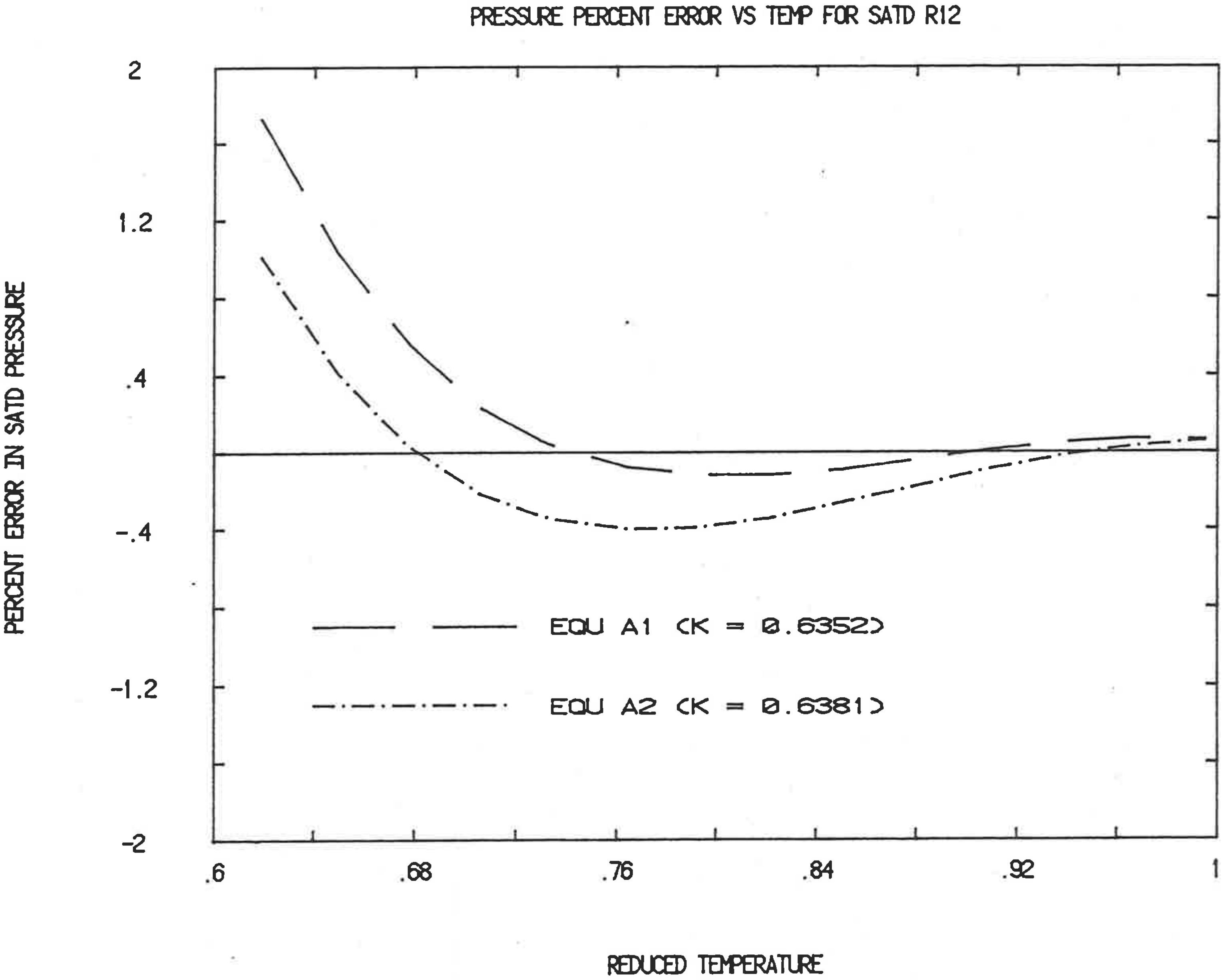

PRESSURE PERCENT ERROR VS TEMP FOR SATD R12
PERCENT ERROR IN SATD PRESSURE
2
1.2
.4
-.4
-1.2
-2
.6
.68
.76
.84
.92
1
REDUCED TEMPERATURE
EQU A1 (K = 0.6352)
EQU A2 (K = 0.6381)

Fig A2

error at the lower end but maintains better accuracy for Tr greater than approximately 0.7 . Appendix E2 shows, at 10 Fahrenheit degree intervals, both the values calculated from equation A.1 and the published (3) R12 saturation pressure data.

A denominator of n-1 was chosen for equation A1 to allow for the smaller sample sizes which occured when the temperature range was small.

A.1.4 Property

Equation A.3 is an indication of the relative deviation between published and calculated values (Average absolute value of relative percent deviation) making it an ideal basis for a direct comparison between properties.

$$AAD = \frac{\sum_1^n \left|\left(\frac{calcd-publd}{publd}\right)\right| 100}{n} \qquad (A.3)$$

Figure A3 ((a)=liquid (b)= vapour) shows R12 saturated propety AAD values for a range of κ . Typically the largest errors occured in the liquid properties. With κ at 0.6352 the largest deviation of 6.1 was for liquid entropy. To improve accuracy it was proposed that liquid entropy be used for optimization. However, to optimize on a minimum for this property causes unacceptable errors. Even at the graph lower limit of κ = 0.58 the error in pressure is in excess of the original maximum of 6.1 and the liquid entropy minimum has not yet been reached. Also entropy (and enthalpy) accuracy is

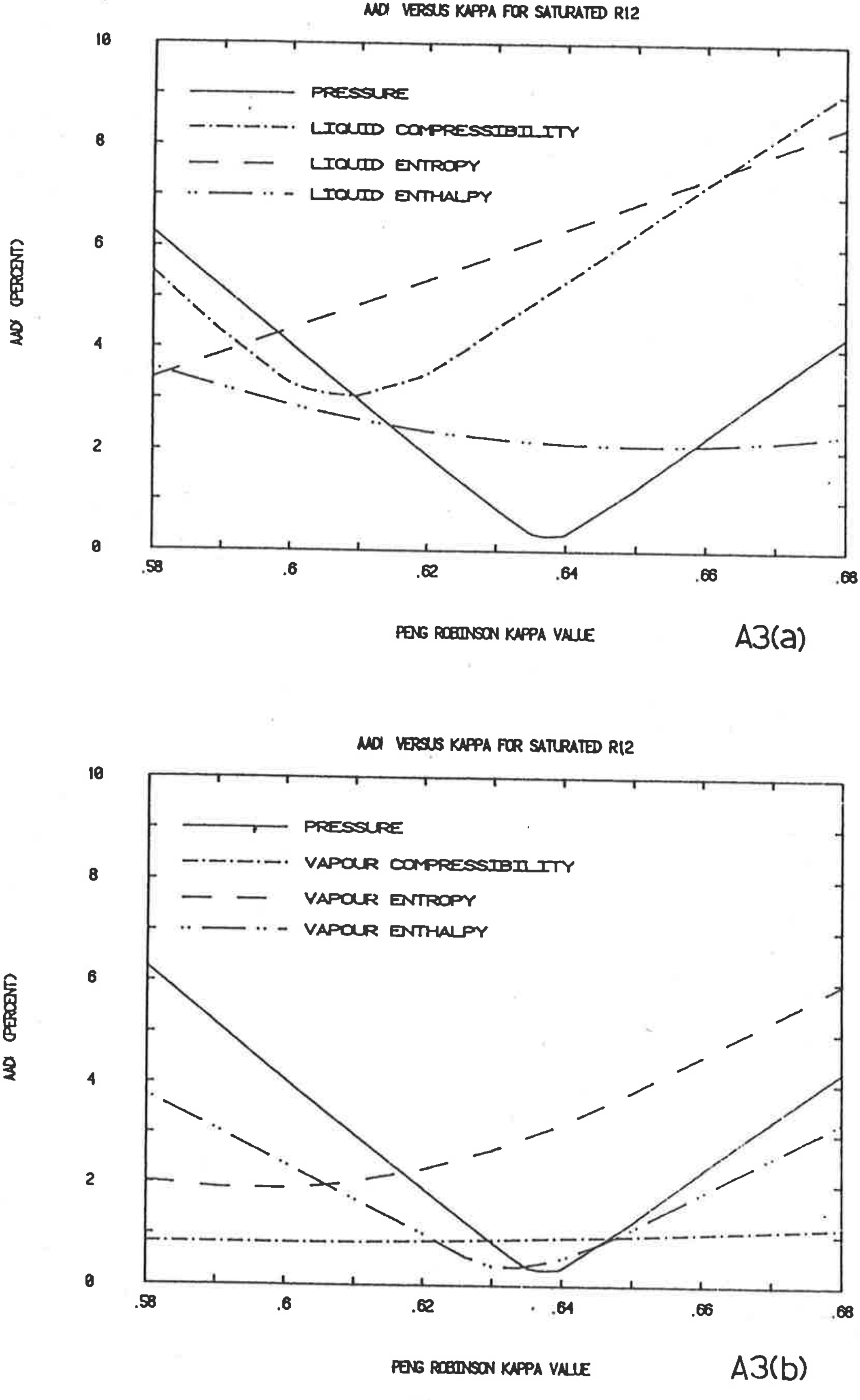

AAD% VERSUS KAPPA FOR SATURATED R12
10
8
6
4
2
0
AAD% (PERCENT)
PRESSURE
LIQUID COMPRESSIBILITY
LIQUID ENTROPY
LIQUID ENTHALPY
.58
.6
.62
.64
.66
.68
PENG ROBINSON KAPPA VALUE
A3(a)
AAD% VERSUS KAPPA FOR SATURATED R12
10
8
6
4
2
0
AAD% (PERCENT)
PRESSURE
VAPOUR COMPRESSIBILITY
VAPOUR ENTROPY
VAPOUR ENTHALPY
.58
.6
.62
.64
.66
.68
PENG ROBINSON KAPPA VALUE
A3(b)

Fig A3

influenced by two features:- liquid compressiblity and Specific Heat Capacity data. Since liquid compressiblity is determined by the fundamental accuracy of the PR equation any change in liquid entropy would have to come from the Specific Heat Capacity equation constants. It was not possible to embark on an investigation into the accuracy of this data and so the constants were used as published. (31)

Since enthalpy is the basis for the first law analysis of systems it was given a higher priority than entropy. Liquid and vapour enthalpy minima occured either side of the pressure minimum making pressure an acceptable comprimise. On this basis pressure was retained as the K selection property.

Table A.2 is a resume of the SD1 and AAD values. A full data set are given in appendix E.

Reft no.	Formula	K	SD1 Pressure psi	AAD								Tr limits		No. Points
				Density	Compressiblity		Enthalpy		Entropy		Latent Heat	Lower	upper	
				liq	liq	vap	liq	vap	liq	vap				
11	$C\ Cl_3\ F$	0.6654	0.5112	5.65	5.99	1.07	3.4	0.59	3.70	2.36	2.15	0.495	0.990	43
12	$C\ Cl_2\ F$	0.6352	0.1826	5.11	4.89	0.91	2.15	0.39	6.11	2.93	1.76	0.605	0.995	28
13	$C\ Cl\ F_3$	0.6321	0.4361	4.85	5.25	1.47	3.45	0.51	10.5	2.69	3.72	0.772	0.993	13
13B1	$C\ Br\ F_3$	0.6319	0.3541	5.03	5.37	2.24	2.18	0.99	7.15	1.74	4.42	0.685	0.996	20
22	$CH\ Cl\ F_2$	0.7072	1.25	3.98	4.48	0.88	2.37	0.64	8.41	3.37	2.45	0.632	0.993	25
113	$C\ Cl_2\ F\text{-}C\ CL\ F_2$	0.7514	0.4079	5.76	5.2	1.17	5.43	8.04	2.33	1.94	2.18	0.479	0.992	46
152a	$CH_3\ CH\ F_2$	0.7608	0.552	8.74	9.27	1.40	4.73	2.55	7.53	2.72	2.13	0.603	0.962	26
			kPa											
718	H_2O	0.8502	111.7									0.422	0.994	38
-	$C_2\ Cl_4$	0.7511	70.4		No thermodynamic data for Perchloroethlyene							0.376	1.000	40

Table A2

A.2 Departure function and fugacity derivation

Reid et al (1977) expresses all the departure functions in terms of the Helmholtz energy (U).

$$U - U^\circ = -\int_\infty^V \left(P - \frac{RT}{V}\right) dV - RT\,ln\frac{V}{V^\circ} \qquad (A4)$$

$$S - S^\circ = -\frac{\partial (U - U^\circ)_v}{\partial T} \qquad (A5)$$

$$H - H^\circ = (U - U^\circ) + T\,(S - S^\circ) + RT(Z - 1) \qquad (A6)$$

nd

$$ln\frac{f}{P} = \frac{U - U^\circ}{RT} + ln\frac{V}{V^\circ} + (Z - 1) - ln\,Z \qquad (A7)$$

substituting equation 1.1 into equation A4

$$U - U^\circ = \int_\infty^V \frac{RT}{V - b(T)} - \frac{a(T)}{V(V + b(T)) + b(T)(V - b(T))} - \frac{RT}{V}\,dV$$

$$= -\int_\infty^V \frac{RT\,b(T)}{V^2 - V\,b(T)} - \frac{a(T)}{-(b(T))^2 + 2\,b(T)V + V^2}$$

(Note; The integral of the second term was taken from Hodgeman) (20)

$$= RT\,ln\frac{V}{V - b(T)} + \frac{a(T)}{2\sqrt{2}\,b(T)}\,ln\frac{V - 0.414\,b(T)}{V + 2.414\,b(T)} - RT\,ln\frac{V}{V^\circ}$$

substituting in equation A5

using

$$b(T) = \frac{BRT}{P}$$

$$a(T) = \frac{AR^2T^2}{P}$$

$$V = \frac{RTZ}{P}$$

ives

$$S - S^\circ = \frac{\frac{da}{dT}}{2\sqrt{2}\,b(T)}\,ln\frac{Z + 2.414\,B}{Z - 0.414\,B} - R\,ln\frac{Z}{Z - B} + R\,ln\frac{V}{V^\circ}$$

substituting in equation A6

$$H - H^\circ = RT\,ln\frac{V}{V - b(T)} + \frac{a(T)}{2\sqrt{2}\,b(T)}\,ln\frac{V - 0.414\,b(T)}{V + 2.414\,b(T)} - RT\,ln\frac{V}{V^\circ}$$

$$+RT\,ln\frac{V}{V^o} - RT\,ln\frac{V}{V-b(T)} - \frac{T\frac{da}{dT}}{2\sqrt{2}\,b(T)}\,ln\frac{V-0.414\,b(T)}{V+2.414\,b(T)}$$
$$+RT(Z-1)$$

Therefore

$$H - H^o = RT(Z-1) + \frac{T\frac{da}{dT} - a(T)}{2\sqrt{2}\,b(T)}\,ln\frac{Z+2.414\,B}{Z-0.414\,B}$$

Substituting in equation A7

$$ln\frac{f}{P} = ln\frac{V}{V-b(T)} + \frac{a(T)}{2\sqrt{2}\,b(T)}\,ln\frac{V-0.414\,b(T)}{V+2.414\,b(T)} - ln\frac{V}{V^o} + ln\frac{V}{V^o} + (Z-1)$$

$$= Z - 1 - ln(Z-B) - \frac{A}{2\sqrt{2}\,B}\,ln\frac{Z+2.414\,B}{Z-0.414\,B}$$

APPENDIX B

REGULAR SOLUTION THEORY CALCULATION USING THE VAN LAAR EQUATIONS

Nomenclature

A = Van Laar constant
B = Van Laar constant
f = fugacity
h = enthalpy
P = pressure
R = universal gas constant
S = entropy
T = temperature
v = volume
Z = compressibility

μ = free energy
γ = acitivity coefficient
η = fugacity coefficent
δ = solubility coefficient

Subscript
i = component

Superscript
o = datum
- = partial molar

R12 R113 ENTHALPY CONCENTRATION DIAGRAM theory and calculations using liquid activity coefficients from the Van Laar equations and some thermodynamic properties from the PR equation.

B.1 Vapour Liquid equilibrium

Null (26) states that three conditions are required for vapour liquid equilibrium.

$$P_{iL} = P_{iV} \tag{B.1}$$

$$T_{iL} = T_{iV} \tag{B.2}$$

$$\mu_{iL} = \mu_{iV} \tag{B.3}$$

If
$$\mu_i = \mu_i^o + \Delta\mu_i \tag{B.4}$$

where $\Delta\mu_i$ is the partial molar free energy of mixing

μ_i^o is the pure substance free energy for that state at standard conditions.

Standard conditions for all subsequent calculations are system pressure and the temperature under consideration.

Using
$$\Delta\mu_i = RTln(\gamma_i x_i) \tag{B.5}$$

Null shows that

$$\frac{\gamma_{iL} x_{iL}}{\gamma_{iV} x_{iV}} = exp\left(\frac{\mu_{iV}^o - \mu_{iL}^o}{RT}\right) \tag{B.6}$$

where

$$\gamma_i = \frac{f_i}{x_i f_i^o} \tag{B.7}$$

Null's equation for fugacity of a component in a mixture is

$$f_i = f_i^o x_i exp\left[\frac{1}{RT}\int_0^p (v_i - v_i^o)dp\right] \qquad (B.8)$$

The affect of the mixture is related through concentration and the fugacity at the reference state. Null evaluates the chemical potential difference term using a 3 step path between liquid and vapour based on

$$d\mu_i = -s_i dT + v_i dP \qquad (B.9)$$

Step 1: Increase pressure from P_{psat} to P on an incompressible liquid at constant temperature.

Step 2: Change of state at constant temperature and pressure.

Step 3: Compression of vapour at constant temperature.

Summing these steps and substituting in equation B6 gives

$$\frac{y_i}{x_i} = \frac{\gamma_{iL} P_{isat}}{\gamma_{iV} P} exp\left[\frac{v_{iL}(P - P_{isat})}{RT}\right] exp\left[\frac{1}{RT}\int_{P_{isat}}^{P}\left(\frac{RT}{P} - v_{iL}\right)\right] \qquad (B.10)$$

B.1.1 Activity Coefficients

B1.1.1 Vapour

Null suggests that assuming an ideal gas phase for a mixture is often an acceptable assumption. To test this the PR equation with a mixture interaction coefficient of

0.0 was used to generate fugacity values for the components in both the pure state and in the mixture. It was considered that if the variation in the evaluation of equation B10 attributable to the vapour activity coefficients was less that 1% then the coefficient could be considered to be unity. Table B1 shows that with the exception of the two lower mol fractions of R12 (0.4 and 0.5) which had temperatures close to the critical point of R12 (112 deg C), all variations were less than 1%. Based on this, and the fact that for the diagram at 423.3 kPa all R12 vapour activity coefficients were between 1.0 and 1.01, Null's assumption was considered acceptable.

Temp deg C	50	60	70	80	90	100	110
Mol fraction of R12							
0.4							1.017
0.5						1.012	1.011
0.6					1.008	1.008	
0.7			1.006	1.005	1.005		
0.8		1.003	1.003	1.002			
0.9	1.0008	1.0007					
1.0	1.0						

Table B1 Typical activity coefficients for R12 vapour in and R12 R113 mixture at 1009 kPa.

B.1.1.2 Liquid

Null expresses reservations about the ability of an equation of state and its mixing rules to accurately predict liquid molar volumes. He suggests that some of the "empirical or, at best semitheoretical approaches " available might be adequate. Of the methods discussed by him it was decided that the two constant binary equations of Van Laar were a good comprimise between accuracy and complexity. Edmister (15) gives the Van Laar equations in the form

$$ln\gamma_1 = \frac{A}{\left[\frac{Ax_1}{Bx_2}+1\right]^2} \qquad \text{(B.11)}$$

$$ln\gamma_2 = \frac{B}{\left[\frac{Bx_1}{Ax_2}+1\right]^2} \qquad \text{(B.14)}$$

where

$$A = \frac{v_1}{RT}(\delta_1-\delta_2)^2 \qquad \text{(B.13)}$$

$$B = \frac{v_2}{RT}(\delta_1-\delta_2)^2 \qquad \text{(B.14)}$$

and

$$\delta = \sqrt{\frac{internal\ \ energy\ \ change\ \ from\ \ saturated\ \ liquid\ \ to\ \ ideal\ \ gas}{molar\ \ volume}}$$

$$= \sqrt{\left[\frac{(h^o - RT) - (h_{sat} - RTZ_{sat})}{v_s}\right]} \qquad \text{(B.15)}$$

Note that this evaluation of the solubility coefficient δ assumes a constant temperature. Edmister discusses this and concludes "A constant value of the solubility coefficient δ at all temperatures is satisfactory and much simpler". In this case the reference state, ideal gas, was assumed to be vapour at zero pressure and the temperature under consideration. Reference state enthalpy was taken at the lowest pressure shown (for the required temperature) in published data. For example Dupont R12 (14) shows data down to 965 Pa. By calculating the molar volumes for A and B from the data, finding the solubility coefficient as above and knowing X1 and X2 the liquid activity coefficients were evaluated. Figure B1 shows that as the temperature approaches the critical value for R12 (112 deg C) the activity coefficient increases rapidly.

B.1.2 Evaluation of equation B10

Using published data and calculating activity coefficients as above all of equation B10 may be evaluated except the expression

$$exp\left[\frac{1}{RT}\int_{P_{isat}}^{P}\left(\frac{RT}{P-V_{iV}}\right)dP\right] \qquad (B.16)$$

This may be done by rewriting this as two integrations

$$exp\left[\frac{1}{RT}\int_{0}^{P}\left(\frac{RT}{P-V_{iV}}\right)dP-\frac{1}{RT}\int_{0}^{P_{isat}}\left(\frac{RT}{P-V_{iV}}\right)dP\right]$$

$$=\frac{exp\left[\frac{1}{RT}\int_{0}^{P}\left(\frac{RT}{P-V_{iV}}\right)dP\right]}{exp\left[\frac{1}{RT}\int_{0}^{P_{isat}}\left(\frac{RT}{P-V_{iV}}\right)dP\right]}$$

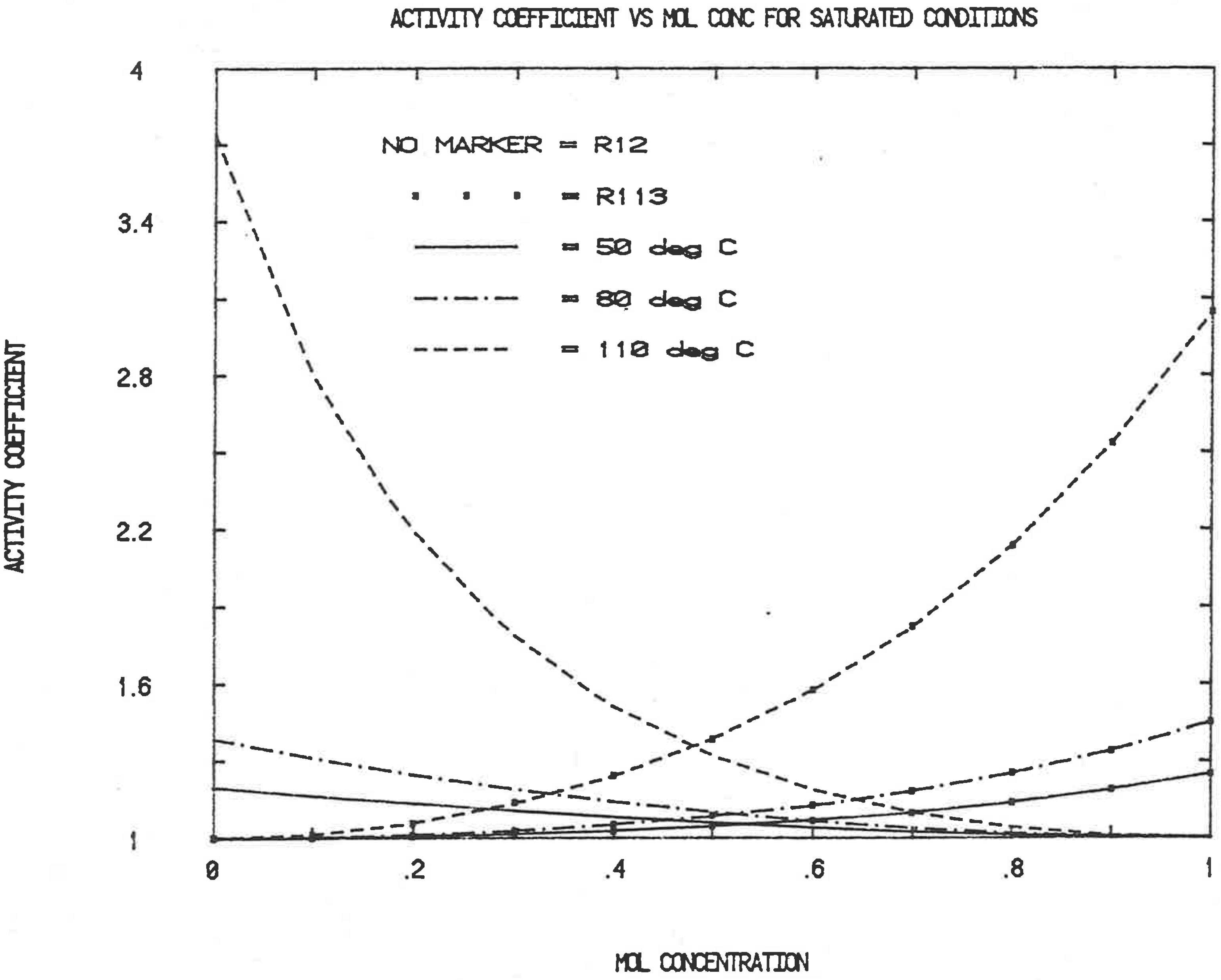

ACTIVITY COEFFICIENT VS MOL CONC FOR SATURATED CONDITIONS
NO MARKER = R12
▪ ▪ ▪ = R113
= 50 deg C
= 80 deg C
= 110 deg C
ACTIVITY COEFFICIENT
4
3.4
2.8
2.2
1.6
1
0
.2
.4
.6
.8
1
MOL CONCENTRATION

Fig B1

And expressing the fugacity coefficient of a pure substance as

$$\eta_i = \frac{f_i}{P} = exp\left[\frac{1}{RT}\int_0^P v_i^o - \frac{RT}{P}dp\right]$$

Equation B16 becomes

$$\frac{\eta_{iPsat}}{\eta_{iP}} = \frac{fugacity\ \ coeff\ \ at\ \ saturation\ \ pressure}{fugacity\ \ coeff\ \ at\ \ system\ \ pressure} \qquad (B.17)$$

These fugacities were obtained from the PR equation. Table B2 shows some typical values.

Temperature		R12		R113	
C	K	system	satd	system	satd
50	323.16	0.8497	0.8187	0.596	0.9605
60	333.16	0.8621	0.7928	0.64	0.9501
70	343.16	0.8732	0.765	0.675	0.9379
80	353.16	0.8832	0.738	0.7118	0.9246
90	363.16	0.8923	0.7086	0.7367	0.9097
100	373.16	0.9009	0.6798	0.7576	0.8939
110	383.16	0.9080	0.6496	0.7760	0.8752

TABLE B2: Fugacity coefficients for pure vapour

In summary a combination of pure published data, the Van Laar equations and the PR equation was used to evaluate equation B10.

B.1.3 Total system pressure calculation

Rewriting equation B.10 using equation B.17 gives

$$y_i = \frac{x_i \gamma_{iL} P_{isat} \eta_{isat}}{\gamma_{iV} P \eta} exp\left[\frac{v_{iL}(P - P_{isat})}{RT}\right]$$

A mass balance for a binary system yields

$$1 = y_1 + y_2$$

but

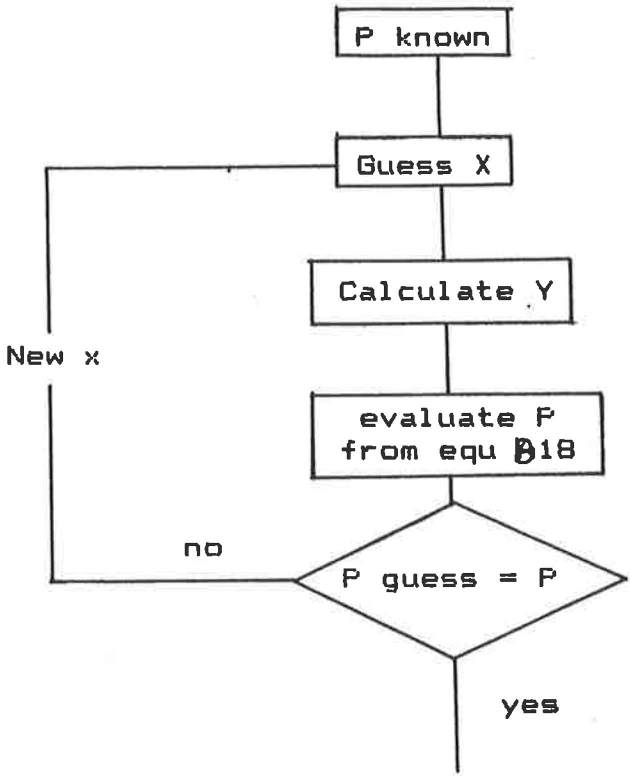
$$P = P(y_1 + y_2)$$

Substituting for Y1 and Y2

$$P = \frac{x_1 \gamma_{1L} P_{1sat} \eta_{1sat}}{\gamma_{1V} P \eta} exp\left[\frac{v_{1L}(P - P_{1sat})}{RT}\right]$$

$$+ \frac{x_2 \gamma_{2L} P_{2sat} \eta_{2sat}}{\gamma_{2V} P \eta} exp\left[\frac{v_{2L}(P - P_{2sat})}{RT}\right] \quad (B.18)$$

Knowing P and assuming vapour activity coefficients to be 1.0 the system equilibrium may be found by



B.1.4 Sample calculation for R12 - R113 mixture

P = 1.009 x 10^6 Pa (Satn pressure of R12 at 42 deg C)

T = 50 deg C

Evaluating the terms in equation A10

	R12	R113
$Part1 = exp\left[\frac{v_{iL}(P - P_{isat})}{RT}\right]$	0.9922	1.0427
$Part2 = \frac{P}{P_{isat}}$	1.2091	0.109
$Part3 = \frac{\eta_{isat}}{\eta_P}$	0.9635	1.612

Substituting in B10 for R12

$$y = x\frac{\gamma_L}{\gamma_V}1.2091 \quad 0.9922 \quad 0.9635$$

Assuming vapour activity coefficient to be one then

$$y = x\gamma_L \quad 1.1559$$

Try X1 = 0.8

Using the Van Laar equations

$$\delta_1 = 11939$$

$$\delta_2 = 14130$$

A = 0.1784

B = 0.223

$$\gamma_L = 1.01$$

$$Y = 0.8\ 1.01\ 1.1559$$

$$= 0.933$$

Check system pressure using equation B18

$$P = 0.8\ \frac{1.01}{1.0}\ 1.22 \times 10^{6}\ 0.9635\ 0.9922 +$$

$$0.2\ \frac{1.138}{1.0}\ 1.1 \times 10^{5}\ 1.612\ 1.0427$$

$$P = 0.984 \times 10^{6}\ \mathrm{Pa}$$

Residual = -2.4%

Using a second guess and a graphical approach the final result was

X1 = 0.83 and Y1 = 0.97 with a residual of -0.3%

B.2 Subcooled liquid mixture enthalpies

An ideal liquid mixture was assumed, the effects of pressure were ignored and mixture enthalpies were taken as molar proportions of the pure saturated values for that temperature.

$$h = x_1 h_{1sat} + x_2 h_{2sat}$$

B.3 Superheated vapour enthalpies

Instead of assuming an ideal mixture for the vapour phase it was decided to try a 4 part process which included enthalpy departure values from the PR equations. The process parts were:

Part1: Evaluate latent heat of mixture at datum temperature based on molar proportions of the pure latent heats.

Part2: Calculate enthalpy departure at datum temperature, from pressure corresponding to reference condition to zero pressure.

Part3: At zero pressure integrate the specific heat capacity function from T_{datum} to T.

Part4: Calculate enthalpy departure, at T from zero pressure to system pressure.

Table B3 shows some typical values for pure R12

Temp deg C	State	kJ/Kg						Percent Error
		Part1	Part2	Part3	Part4	Calcd	Publd	
42	satd	169.6	0.98	47.4	-11.7	206.3	204.3	0.9
70	s/heat	169.6	0.98	64.9	-9.8	225.7	225.4	0.1
100	s/heat	169.6	0.98	84.3	-8.3	246.6	247.5	-0.4

Table B3 Enthalpy calculation data

B.4 Enthalpy concentration diagram

Note that the rapid change in the near critical activity coefficients for R12 produce a steep slope in the boiling point equilibrium line in Figure B3.

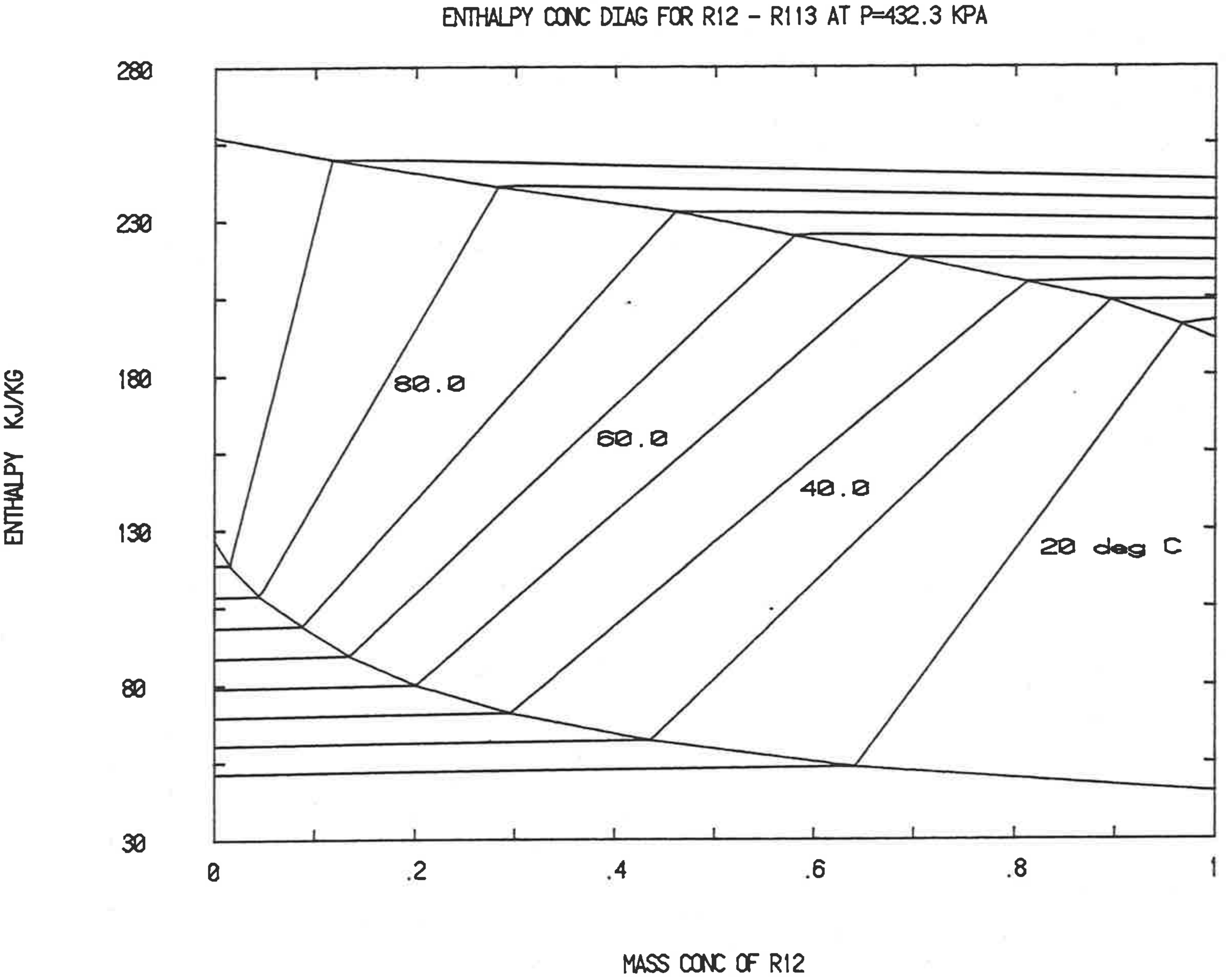

ENTHALPY CONC DIAG FOR R12 - R113 AT P=432.3 KPA
ENTHALPY KJ/KG
280
230
180
130
80
30
0
.2
.4
.6
.8
1
80.0
60.0
40.0
20 deg C
MASS CONC OF R12

Fig B2

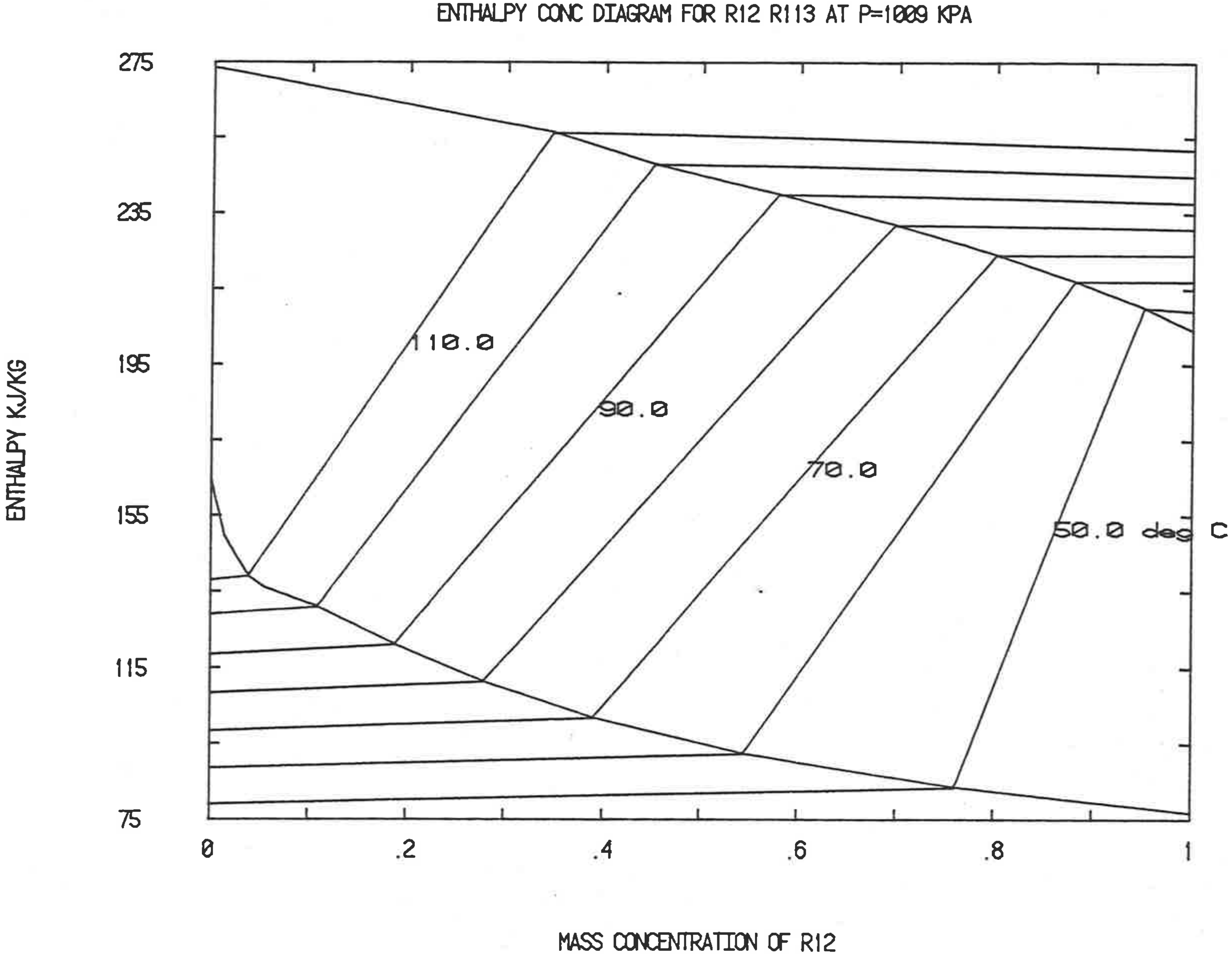

ENTHALPY CONC DIAGRAM FOR R12 R113 AT P=1009 KPA
ENTHALPY KJ/KG
275
235
195
155
115
75
0
.2
.4
.6
.8
1
110.0
90.0
70.0
50.0 deg C
MASS CONCENTRATION OF R12

Fig B3

This method of producing enthalpy concentration data was abandoned because it relied too much on published thermodynamic data and was difficult to program.

APPENDIX C

COMPUTER MODEL INPUT FILES

C.1 Main input file

One input file was used for both program control and for the refrigeration system model input data. The following file structure layout illustrates that the variables ME to JC inclusive relate to program options and their associated data while variables RN(1) to TD(14) detail data for working fluids and the refrigeration system model.

VARIABLE	COMMENT
ME	0 Interactive mode 2 Batch mode
MF	0 Supresses all program comments to screen other than error messages 1 During run gives indication of progress
MH	Table of pure properties. 0 No table 1 Saturated values only 2 Saturated and superheat
MHH	compare with published data 1 pressure 2 all properties 3 all+ integral of Cp data 4 optimize kappa on liquid z value 5 optimize kappa on pressure
MHI	0 SI 1 Imperial
MK	Mixture data 0 No table 1 calculate for mixture data given 2 compare with data from mixture property file
MKK	Compare single calc with 1 Pressure (PMK) 2 Mass concentration (XMK) 3 Mol concentration (XMMK)
TMK	Temperature in deg C for single calc
PMK	Pressure in Pa for single calc
XMK	Mass conc of component 1 for single calc
XMMK	Mol conc of component 1 for single calc
MJ	Enthalpy concentration diagram 0 No diagram 1 Equilbrium only 2 Complete diagram
MO	Plot files 0 Table only 1 Table plus plot file
TMI	temperature in deg C. Saturation temperature for most volatile component
PMI	Pressure in Pa. Diagram pressure NOTE;Of TMI and PMI the one not used must be negative TMI (deg c) here diag pressure is satn pressure corresponding to TMI for component 1 PMI (Pa)is pressure of diagram
ADD	Molar increment (minimum 0.01)
VALUE	How many degrees of isotherm above and below saturation

MG	Pure data detail 0 No data 2 Data for plot of fugacity vs pressure 3 Data for Peng-Robinson cubic plot
MG1	Input for Peng-Robinson cubic plot 1 Use refrigerant 1 2 Use refrigerant 2 3 Use mixture
TEMPMG	Temperature for Peng-Robinson cubic plot
PRESSMG	Pressure for Peng-Robinson cubic plot
CONCMG	Mass concentration for Peng-Robinson cubic plot
ML	Refrigeration system calculation 0 No system calculation 1 System calc
JJ	Saturation pressure calculation method 0 Peng Robinson equation 1 Dupont equation 2 Clausius Clapeyron equation
JL	Pressure calculation at enthalpy datum 0 Simple molar proportion at datum temperature 1 Does equilibrium calc at datum temperature
JC	Peng Robinson Kappa value calc method 0 Standard K calc based single K for whole program 1 Uses cubic in TR for K values
RN(1)	Refrigerant number
RN(2)	Refrigerant number Order does not matter. Program will put most volatile in position 1 Refrigerants available are R11,R12,R13,R13B1,R22,R23,R113,RPERC,R718,R152A R500
TD	Temperature datum for enthalpy and entropy deg C
BT	Temperature datum for availability deg C
BP	Pressure datum for availability Pa
TONE	Fluid temperature entering evaporator deg C
TOFFE	Fluid temperature leaving evaporator deg C
SUPHE	Distillate superheat at evaporator out Celcius degrees
EVAPCAP	Evaporator capacity kW
TONA	Fluid temperature onto absorber deg C
SUBCA	Feed subcooling at absorber out Celcius degrees
TONC	Fluid temperature onto condenser deg C
SUBCC	Distillate subcooling at evaporator out Celcius degrees
DCONCMASS	Mass concentration of distillate
FOD	Mass ratio of feed to distillate flow
TFEED	Temperature after feed boost heater
MTFEED	Feed boost heater selection 0 No 1 Yes
MPRECOOL	Precooler heat exchanger 0 No 1 Yes
MRECTHX	Rectification heat exchanger 0 No 1 Yes
MPREHEAT	Preheater heat exchanger 0 No 1 Yes
PHPROP	Proportion of feed flow through preheater ie 0 to 1.0
MBOTHX	Bottoms heat exchanger 0 No 1 Yes
RR	Reflux ratio (Ratio of actual reflux flow to minimum flow)
MPCONTROL	Print out control 1 System layout only 2 System plus column analysis 3 System plus column analysis plus Second Law analysis

	Refrigeration system approach values
A(1)	Evap out to fluid on evap
2	Condenser out to fluid onto absorber
3	Absorber out to fluid onto absorber
4	Precooler liquid in to precooler vapour out
5	Preheater feed in to preheater bottoms out (mixture end)
6	Preheater feed out to preheater bottoms in (column end)
7	Rectifier HX out to feed plate
8	Stripping HX out to feed plate
9	Rectifier HX in to plate temperature
10	Stripping HX in to plate temperature
	Refrigeration system pressure drops
PD(1)	Absorber out to pump in
2	Pump out to feed split
3	Feed split to feed PH in
4	Feed split to Rectification HX in
5	Rectification HX in to out
6	Rectification HX out to feed join
7	Feed feed PH in to out
8	Feed PH out to feed join
9	Feed join to column in
10	Bottoms out to bottom HX in
11	Bottom HX in to out
12	Bottom HX out to preheater in
13	Bottom feed preheat out to expansion in
14	Condernser out to precooer liquid in
15	Precooler liquid in to out
16	Precooler liquid out to expansion in
17	Evaporator in to out
18	Evaporator out to precooler vapour in
19	Precooler vapour in to out
20	Precooler vapour out to mix in
21	Mix out to absorber in
22	Absorber in to out
23	Bottom feed preheat in to out
24	Condenser in to out
	Refrigeration system temperature changes
TD(1)	Absorber out to pump in
2	Pump out to feed split
3	Feed split to feed HX in
4	Feed split to Rectification HX in
5	Rectification HX out to feed mix
6	Feed PH out to feed mix
7	Feed boost HX to column in
8	Bottoms out to bottom HX in
9	Bottom HX out to feed PH in
10	Feed PH out to bottom exp in
11	Condenser out to precooler liquid in
12	Precooler liquid out to distillate expansion
13	Evaporator out to PC vapour in
14	Precooler vapour out to mixing in

NOTE: The following abbreviations have been used

Heat exchanger to HX
Precooler to PC
Preheater to PH
Peng-Robinson to PR

C.2 Pure substance input files

C.2.1 File structure and units

In addition to tabulating the values of constants used for all the pure substance data derivation this section shows the layout of the program data files.

Item	Symbol	Units	comment
name			
formula			
Critical pressure	Pc	Pa	
Critical temp	Tc	Deg K	
Molecular Wt	MW		
Pr K constant	K		Chap. 1 & appendix A
Dead zone		Deg	Chap. 1 section 1.2
Specific heat capacity const.			
4 lines	C4		Chap. 1 equ 1.17
	C3		"
	C2		"
	C1		"
Clausius equn const.			
2 lines	AR		Clausius Clapeyron equation constants
	BR		
4 lines (See Note 1 below)			
7 lines (See Note 2 below)			
n lines (See note 3 below)			

Note 1:

These constants are for a cubic equation which fits the Peng-Robinson constant K as a function of temperature.

This feature, which was suggested by Dr J. R. Roach, was programmed as an alternative to the single K value approach discussed in chapter 1. It was hoped that fitting K as a function of temperature would improve the Peng-Robinson equation's accuracy. Time did not permit the calculation of these constants.

Note 2:

These constants are for the Dupont vapour pressure equation. If these constants were available this equation was used to check the published data.

Note 3:

Each of the next n lines contains published saturation values of temperature, pressure, liquid density, liquid enthalpy, latent heat, vapour enthalpy, liquid entropy, vapour entropy, liquid compressiblity and vapour compressiblity. These values appear as the published values of the respective properties shown in Appendix E. All compressiblity values shown were calculated from the published tables.

C.2.2 File content

The ASHRAE refrigerant number shown in the following table is not part of the data file it has just been included for convenience.

R12	R22	R23
'DICHLORODIFLUOROMETHANE'	'CHLORODIFLUOROMETHANE'	'TRIFLUOROMETHANE'
'CCL2F2'	'CHCLF2'	'CHF3'
4.1155E+06	4.9773128E+06	4.836013E+06
385.16	369.16	298.77
120.9	86.48	70.00
0.6352	0.7020	0.7822
0.6	0.7	0.4
7.547	6.035167	5.339472
0.04257	2.128E-02	0.020029
-0.3603E-04	2.2E-05	1.8E-05
0.1037E-07	-3.739705E-08	-2.443922E-08
9.36195982	9.567632	9.62552
1.0581307E+03	1.060095E+03	881.3117
0	0	0
0	0	0
0	0	0
0	0	0
39.88381727	29.35754453	328.90853
-3.43663223E+03	-38.45193152E+02	-7952.76913
-12.47152228	-7.86103122	-144.51423
4.73044244E-03	2.190939E-03	0.24211502
0.0	4.45746403E-01	-2.1280665E-04
0.0	6.861E+02	9.434955E-08
459.7	459.69	459.69

R11	R13B1	R718
'TRICHLOROFLUOROMETHANE'	'BROMOTRIFLUOROMETHANE'	'WATER'
'CCL3F'	'CBRF3'	'H2O'
4.409199E+06	3.964487E+06	22048000.0
471.16	340.16	647.3
137.38	148.93	18.015
0.6654	0.6319	0.8508
0.7	0.4	0.9
9.789	5.22741862	7.701
3.893E-02	0.04851168	4.595E-04
-3.383E-05	-3.557E-05	2.521E-06
9.903E-09	7.14402592E-10	-8.59E-10
9.51930112	9.32427949	10.461
1.35459E+03	928.499988	2020.097
0	0	0
0	0	0
0	0	0
0	0	0
42.14702865	0.0	0
-4344.343807	0.0	0
-12.84596753	0.0	0
0.0040083725	0.0	0
0.0313605356	0.0	0
862.07	0.0	0
459.67	0.0	0

R13

```
'CHLOROTRIFLUOROMETHANE'
'CCLF3'
  3.867983E+06
301.99
104.47
  0.6321
  0.4
 -4.662728E+01
 0.54353
 -1.62E-03
  1.6836E-06
  9.35722
  8.3659361E+02
0
0
0
0
 25.967975
 -2.70953822E+03
 -7.17234391
  2.545154E-03
  2.80301091E-01
  5.46E+02
459.67
```

*****

```
'TETRACHLOROETHYLENE'
'C2CL4'
4.7640E+06
620.0
165.83
0.7511
0.8000
10.98
0.05387
-5.478E-05
2.002E-08
9.8098831
1912.83397
0
0
0
0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
```

R152a

```
'DIFLUOROETHANE'
'CH3CHF2'
  4.49537050E+06
386.66
 66.05
 0.7608
 0.5
 -6.37682450E+01
  6.67859200E-01
 -2.11450000E-03
  2.40000000E-06
  9.60311
  1.14085525E+03
0
0
0
0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
```

R113

```
'TRICHLOROTRIFLUOROETHANE'
'CCL2F-CCLF2'
3.4397858E+06
487.27
187.39
0.751400
0.6
2.4401721
1.182996E-01
-1.243E-04
4.1417751E-08
9.48006088
1.43562224E+03
0
0
0
0
33.0655
-4.33098E+03
-9.2635
2.0539E-03
0.0
0.0
459.6
```

R500

```
'73.8% CCL2F2 26.2% CH3CHF2'
'R12 & R152A'
4425707.9
378.66
99.31
0.6887
0.6
33.462211
-0.189143
0.000652294
-6.66E-07
9.435097
1058.3573
0
0
0
0
17.780935
-3422.69717
-3.63691
0.00050272207
0.4629401
695.57
459.67
```

* No number

APPENDIX D

COMPARISON WITH SIMILAR DATA DERIVED FROM SOAVE-REDLICH-KWONG (SRK) EQUATION

Comparison with Asselineau et al (4)

Asselineau used 21 points to check the SRK equation saturation data with published data. Five points were checked in each of the intervals

$0.6 <= Tr < 0.7$

$0.7 <= Tr < 0.8$

$0.8 <= Tr < 0.9$

and three in each of the ranges

$0.9 <= Tr < 0.95$

$0.95 <= Tr <= 1$

The deviation parameter used was

$$SD2 = \sqrt{\frac{\sum_1^n \left(\frac{calcd-publd}{publd}\right)^2}{(n-1)}}$$

Table D1 shows the SD2 values calculated here and those for Asselineau's method three.

Reft No	This work				Asselineau SRK SD2
	PR SD2	Tr		No. pts	
		lower	upper		
11	0.0077	0.495	0.99	43	0.0126
12	0.0066	0.605	0.995	28	0.0069
13	0.002	0.772	0.993	13	0.0078
22	0.0037	0.632	0.993	25	0.0103
113	0.040	0.479	0.992	46	0.0078
152a	0.0141	0.603	0.962	26	0.0224

Table D1: Saturation Pressure data

Even though the distribution of points is not the same for each case, with the exception of R13, the range considered was approximately equal to or larger than that of Assenleau. Other than for R113 the PR equation values showed the lesser deviation from the published data.

APPENDIX E

CALCULATED VERSUS PUBLISHED REFRIGERANT DATA

Table	Fluid	Data
E.1	R11	abridged
E.2	R12	complete
E.3	R13	abridged
E.4	R13B1	"
E.5	R22	"
E.6	R113	"
E.7	R152a	"
E.8	R718	"
E.9	R500	"
E.10	Perchloroethylene	"
E.11	R13B1 - R152a	complete
E.12	R11 - R22	"
E.13	R12 - R152a	"
E.14	R12 - R13	"
E.15	R12 - R22	"
E.16	R12 - R113	"

<u>Equations</u> (for definitions see Appendix A)

$$AAD = \frac{\sum_1^n \left|\left(\frac{calcd - publd}{publd}\right)\right| 100}{n}$$

$$SD1 = \sqrt{\frac{\sum_1^n (calcd - publd)^2}{(n-1)}}$$

$$SD2 = \sqrt{\frac{\sum_1^n \left(\frac{calcd - publd}{publd}\right)^2}{(n-1)}}$$

R11

TABLE E1

```
*******************
PRESSURE COMPARISON
*******************

----------------------------------------------------------------------------------------------
TEMP       PRESSURE  PSIA         ABS          PERCENT       N          TR            PR
DEG F      CALCD     PUBLD        ERROR        ERROR
----------------------------------------------------------------------------------------------
-40.00   0.752E+00  0.743E+00   0.915E-02      1.23         1        0.4949        0.0012
-30.00   0.105E+01  0.104E+01   0.635E-02      0.61         2        0.5067        0.0016
-20.00   0.143E+01  0.143E+01   0.304E-02      0.21         3        0.5184        0.0022
-10.00   0.192E+01  0.192E+01  -0.209E-02     -0.11         4        0.5302        0.0030
  0.00   0.255E+01  0.256E+01  -0.112E-01     -0.44         5        0.5420        0.0040
 10.00   0.334E+01  0.336E+01  -0.228E-01     -0.68         6        0.5538        0.0052
 20.00   0.431E+01  0.436E+01  -0.477E-01     -1.10         7        0.5656        0.0067
 30.00   0.550E+01  0.556E+01  -0.563E-01     -1.01         8        0.5774        0.0086
 40.00   0.694E+01  0.702E+01  -0.783E-01     -1.11         9        0.5892        0.0109
 50.00   0.868E+01  0.878E+01  -0.106E+00     -1.20        10        0.6010        0.0136
 60.00   0.107E+02  0.109E+02  -0.136E+00     -1.25        11        0.6128        0.0168
 70.00   0.132E+02  0.133E+02  -0.171E+00     -1.28        12        0.6246        0.0206
 80.00   0.160E+02  0.162E+02  -0.209E+00     -1.29        13        0.6364        0.0251
 90.00   0.193E+02  0.196E+02  -0.251E+00     -1.28        14        0.6481        0.0302
100.00   0.232E+02  0.235E+02  -0.294E+00     -1.25        15        0.6599        0.0362
110.00   0.276E+02  0.279E+02  -0.338E+00     -1.21        16        0.6717        0.0431
120.00   0.326E+02  0.329E+02  -0.384E+00     -1.16        17        0.6835        0.0509
130.00   0.382E+02  0.387E+02  -0.427E+00     -1.10        18        0.6953        0.0598
140.00   0.447E+02  0.451E+02  -0.468E+00     -1.04        19        0.7071        0.0698
150.00   0.519E+02  0.524E+02  -0.505E+00     -0.96        20        0.7189        0.0811
160.00   0.599E+02  0.605E+02  -0.534E+00     -0.88        21        0.7307        0.0937
170.00   0.689E+02  0.694E+02  -0.556E+00     -0.80        22        0.7425        0.1077
180.00   0.788E+02  0.794E+02  -0.568E+00     -0.71        23        0.7543        0.1233
190.00   0.898E+02  0.904E+02  -0.567E+00     -0.63        24        0.7661        0.1405
200.00   0.102E+03  0.103E+03  -0.552E+00     -0.54        25        0.7779        0.1594
210.00   0.115E+03  0.116E+03  -0.518E+00     -0.45        26        0.7896        0.1803
220.00   0.130E+03  0.130E+03  -0.477E+00     -0.37        27        0.8014        0.2030
230.00   0.146E+03  0.146E+03  -0.415E+00     -0.28        28        0.8132        0.2279
240.00   0.163E+03  0.163E+03  -0.329E+00     -0.20        29        0.8250        0.2549
250.00   0.182E+03  0.182E+03  -0.231E+00     -0.13        30        0.8368        0.2843
260.00   0.202E+03  0.202E+03  -0.104E+00     -0.05        31        0.8486        0.3161
270.00   0.224E+03  0.224E+03   0.228E-01      0.01        32        0.8604        0.3504
280.00   0.248E+03  0.248E+03   0.181E+00      0.07        33        0.8722        0.3875
290.00   0.273E+03  0.273E+03   0.335E+00      0.12        34        0.8840        0.4274
300.00   0.301E+03  0.300E+03   0.500E+00      0.17        35        0.8958        0.4702
310.00   0.330E+03  0.329E+03   0.665E+00      0.20        36        0.9076        0.5162
320.00   0.362E+03  0.361E+03   0.821E+00      0.23        37        0.9193        0.5653
330.00   0.395E+03  0.394E+03   0.951E+00      0.24        38        0.9311        0.6179
340.00   0.431E+03  0.430E+03   0.105E+01      0.24        39        0.9429        0.6740
350.00   0.469E+03  0.468E+03   0.110E+01      0.24        40        0.9547        0.7338
360.00   0.510E+03  0.509E+03   0.109E+01      0.21        41        0.9665        0.7974
370.00   0.553E+03  0.552E+03   0.980E+00      0.18        42        0.9783        0.8650
380.00   0.599E+03  0.598E+03   0.725E+00      0.12        43        0.9901        0.9369

AAD=    0.6190972
SD1=    0.5112267
SD2=    7.7368235E-03
```

```
***************
VAPOUR ENTHALPY                                                     TABLE E1  CONTINUED
***************

---------------------------------------------------------------------------------------------
TEMP       BTU/LB                        ABS          PERCENT       N          TR          PR
DEG F      CALCD      PUBLD              ERROR        ERROR
---------------------------------------------------------------------------------------------
-40.00   0.859E+02  0.872E+02  -0.134E+01   -1.53       1       0.4949      0.001
-30.00   0.871E+02  0.884E+02  -0.128E+01   -1.45       2       0.5067      0.001
-20.00   0.883E+02  0.896E+02  -0.123E+01   -1.37       3       0.5184      0.002
-10.00   0.896E+02  0.908E+02  -0.118E+01   -1.30       4       0.5302      0.003
  0.00   0.908E+02  0.920E+02  -0.113E+01   -1.23       5       0.5420      0.004
 10.00   0.921E+02  0.932E+02  -0.108E+01   -1.16       6       0.5538      0.005
 20.00   0.934E+02  0.944E+02  -0.103E+01   -1.09       7       0.5656      0.006
 30.00   0.946E+02  0.956E+02  -0.976E+00   -1.02       8       0.5774      0.008
 40.00   0.959E+02  0.968E+02  -0.924E+00   -0.95       9       0.5892      0.010
 50.00   0.971E+02  0.980E+02  -0.872E+00   -0.89      10       0.6010      0.013
 60.00   0.984E+02  0.992E+02  -0.818E+00   -0.82      11       0.6128      0.016
 70.00   0.996E+02  0.100E+03  -0.763E+00   -0.76      12       0.6246      0.020
 80.00   0.101E+03  0.102E+03  -0.709E+00   -0.70      13       0.6364      0.025
 90.00   0.102E+03  0.103E+03  -0.654E+00   -0.64      14       0.6481      0.030
100.00   0.103E+03  0.104E+03  -0.599E+00   -0.58      15       0.6599      0.036
110.00   0.105E+03  0.105E+03  -0.545E+00   -0.52      16       0.6717      0.043
120.00   0.106E+03  0.106E+03  -0.491E+00   -0.46      17       0.6835      0.050
130.00   0.107E+03  0.107E+03  -0.440E+00   -0.41      18       0.6953      0.059
140.00   0.108E+03  0.109E+03  -0.390E+00   -0.36      19       0.7071      0.069
150.00   0.109E+03  0.110E+03  -0.344E+00   -0.31      20       0.7189      0.081
160.00   0.110E+03  0.111E+03  -0.299E+00   -0.27      21       0.7307      0.093
170.00   0.112E+03  0.112E+03  -0.259E+00   -0.23      22       0.7425      0.107
180.00   0.113E+03  0.113E+03  -0.223E+00   -0.20      23       0.7543      0.123
190.00   0.114E+03  0.114E+03  -0.193E+00   -0.17      24       0.7661      0.140
200.00   0.115E+03  0.115E+03  -0.169E+00   -0.15      25       0.7779      0.159
210.00   0.116E+03  0.116E+03  -0.150E+00   -0.13      26       0.7896      0.180
220.00   0.117E+03  0.117E+03  -0.139E+00   -0.12      27       0.8014      0.203
230.00   0.118E+03  0.118E+03  -0.136E+00   -0.11      28       0.8132      0.227
240.00   0.119E+03  0.119E+03  -0.141E+00   -0.12      29       0.8250      0.254
250.00   0.120E+03  0.120E+03  -0.155E+00   -0.13      30       0.8368      0.284
260.00   0.120E+03  0.121E+03  -0.179E+00   -0.15      31       0.8486      0.316
270.00   0.121E+03  0.121E+03  -0.213E+00   -0.18      32       0.8604      0.350
280.00   0.122E+03  0.122E+03  -0.258E+00   -0.21      33       0.8722      0.387
290.00   0.122E+03  0.123E+03  -0.314E+00   -0.26      34       0.8840      0.427
300.00   0.123E+03  0.123E+03  -0.381E+00   -0.31      35       0.8958      0.470
310.00   0.123E+03  0.124E+03  -0.461E+00   -0.37      36       0.9076      0.516
320.00   0.124E+03  0.124E+03  -0.552E+00   -0.44      37       0.9193      0.565
330.00   0.124E+03  0.125E+03  -0.655E+00   -0.53      38       0.9311      0.617
340.00   0.124E+03  0.125E+03  -0.767E+00   -0.61      39       0.9429      0.674
350.00   0.124E+03  0.125E+03  -0.885E+00   -0.71      40       0.9547      0.733
360.00   0.123E+03  0.124E+03  -0.100E+01   -0.81      41       0.9665      0.797
370.00   0.122E+03  0.123E+03  -0.109E+01   -0.88      42       0.9783      0.865
380.00   0.120E+03  0.121E+03  -0.105E+01   -0.86      43       0.9901      0.936

AAD=    0.5929967
SD1=    0.7286715
SD2=    7.2999690E-03
```

TABLE E2 R12

```
********************
PRESSURE COMPARISON
********************

---------------------------------------------------------------------------------------------------------------
TEMP         PRESSURE   PSIA            ABS          PERCENT          N              TR                 PR
DEG F         CALCD     PUBLD          ERROR          ERROR
---------------------------------------------------------------------------------------------------------------
40.00     0.951E+01  0.931E+01  0.201E+00       2.16           1            0.6054             0.0159
30.00     0.122E+02  0.120E+02  0.208E+00       1.73           2            0.6198             0.0205
20.00     0.155E+02  0.153E+02  0.207E+00       1.36           3            0.6342             0.0259
10.00     0.194E+02  0.192E+02  0.200E+00       1.04           4            0.6486             0.0325
 0.00     0.240E+02  0.238E+02  0.186E+00       0.78           5            0.6631             0.0403
10.00     0.295E+02  0.293E+02  0.164E+00       0.56           6            0.6775             0.0494
20.00     0.359E+02  0.357E+02  0.136E+00       0.38           7            0.6919             0.0601
30.00     0.432E+02  0.431E+02  0.101E+00       0.23           8            0.7063             0.0725
40.00     0.517E+02  0.517E+02  0.617E-01       0.12           9            0.7208             0.0867
50.00     0.614E+02  0.614E+02  0.193E-01       0.03          10            0.7352             0.1029
60.00     0.724E+02  0.724E+02 -0.253E-01      -0.03          11            0.7496             0.1213
70.00     0.848E+02  0.849E+02 -0.674E-01      -0.08          12            0.7640             0.1421
80.00     0.988E+02  0.989E+02 -0.107E+00      -0.11          13            0.7784             0.1655
90.00     0.114E+03  0.114E+03 -0.140E+00      -0.12          14            0.7929             0.1916
00.00     0.132E+03  0.132E+03 -0.161E+00      -0.12          15            0.8073             0.2206
10.00     0.151E+03  0.151E+03 -0.180E+00      -0.12          16            0.8217             0.2529
20.00     0.172E+03  0.172E+03 -0.182E+00      -0.11          17            0.8361             0.2884
30.00     0.196E+03  0.196E+03 -0.171E+00      -0.09          18            0.8506             0.3276
40.00     0.221E+03  0.221E+03 -0.145E+00      -0.07          19            0.8650             0.3705
50.00     0.249E+03  0.249E+03 -0.102E+00      -0.04          20            0.8794             0.4175
60.00     0.280E+03  0.280E+03 -0.415E-01      -0.01          21            0.8938             0.4687
70.00     0.313E+03  0.313E+03  0.280E-01       0.01          22            0.9083             0.5244
80.00     0.349E+03  0.349E+03  0.103E+00       0.03          23            0.9227             0.5849
90.00     0.388E+03  0.388E+03  0.176E+00       0.05          24            0.9371             0.6503
00.00     0.430E+03  0.430E+03  0.254E+00       0.06          25            0.9515             0.7210
10.00     0.476E+03  0.476E+03  0.309E+00       0.07          26            0.9660             0.7972
20.00     0.525E+03  0.524E+03  0.352E+00       0.07          27            0.9804             0.8792
30.00     0.577E+03  0.577E+03  0.351E+00       0.06          28            0.9948             0.9673

AD=     0.3438416
D1=     0.1826097
D2=     6.6197840E-03
*************************
LIQUID DENSITY COMPARISON
*************************
```

TABLE E2 CONTINUED

```
---------------------------------------------------------------------------------------------------------------
TEMP           DENS  IN  LB/FT3           ABS         PERCENT          N              TR                 PR
DEG F          CALCD      PUBLD           ERROR        ERROR
---------------------------------------------------------------------------------------------------------------
0.00      0.101E+03  0.947E+02  0.605E+01       6.39           1            0.6054             0.0159
0.00      0.997E+02  0.937E+02  0.598E+01       6.38           2            0.6198             0.0205
0.00      0.986E+02  0.927E+02  0.590E+01       6.36           3            0.6342             0.0259
0.00      0.975E+02  0.917E+02  0.580E+01       6.32           4            0.6486             0.0325
0.00      0.963E+02  0.907E+02  0.567E+01       6.26           5            0.6631             0.0403
0.00      0.951E+02  0.896E+02  0.553E+01       6.17           6            0.6775             0.0494
0.00      0.939E+02  0.885E+02  0.536E+01       6.06           7            0.6919             0.0601
0.00      0.926E+02  0.874E+02  0.517E+01       5.91           8            0.7063             0.0725
0.00      0.912E+02  0.863E+02  0.495E+01       5.74           9            0.7208             0.0867
0.00      0.898E+02  0.851E+02  0.471E+01       5.53          10            0.7352             0.1029
0.00      0.884E+02  0.840E+02  0.439E+01       5.22          11            0.7496             0.1213
0.00      0.869E+02  0.827E+02  0.414E+01       5.00          12            0.7640             0.1421
0.00      0.853E+02  0.814E+02  0.380E+01       4.67          13            0.7784             0.1655
0.00      0.836E+02  0.801E+02  0.343E+01       4.28          14            0.7929             0.1916
0.00      0.818E+02  0.788E+02  0.303E+01       3.84          15            0.8073             0.2206
0.00      0.800E+02  0.774E+02  0.258E+01       3.34          16            0.8217             0.2529
0.00      0.780E+02  0.759E+02  0.210E+01       2.76          17            0.8361             0.2884
0.00      0.759E+02  0.744E+02  0.157E+01       2.11          18            0.8506             0.3276
0.00      0.737E+02  0.727E+02  0.990E+00       1.36          19            0.8650             0.3705
0.00      0.714E+02  0.710E+02  0.360E+00       0.51          20            0.8794             0.4175
0.00      0.689E+02  0.692E+02 -0.326E+00      -0.47          21            0.8938             0.4687
0.00      0.662E+02  0.672E+02 -0.107E+01      -1.59          22            0.9083             0.5244
0.00      0.632E+02  0.651E+02 -0.188E+01      -2.89          23            0.9227             0.5849
0.00      0.600E+02  0.627E+02 -0.276E+01      -4.40          24            0.9371             0.6503
0.00      0.563E+02  0.600E+02 -0.371E+01      -6.18          25            0.9515             0.7210
0.00      0.521E+02  0.568E+02 -0.473E+01      -8.32          26            0.9660             0.7972
0.00      0.469E+02  0:527E+02 -0.577E+01     -10.96          27            0.9804             0.8792
0.00      0.393E+02  0.458E+02 -0.644E+01     -14.07          28            0.9948             0.9673

D=       5.111201
1=       4.369181
2=      5.9726264E-02
```

```
***************
LIQUID ENTHALPY                                                          TABLE E2  CONTINUED
***************

------------------------------------------------------------------------------------------------
TEMP        H  IN  BTU/LB           ABS         PERCENT       N          TR           PR
DEG F      CALCD     PUBLD         ERROR         ERROR
------------------------------------------------------------------------------------------------
40.00   0.000E+00  0.000E+00  0.000E+00       0.00         1        0.6054       0.0159
30.00   0.201E+01  0.211E+01 -0.107E+00      -5.07         2        0.6198       0.0205
20.00   0.403E+01  0.424E+01 -0.202E+00      -4.76         3        0.6342       0.0259
10.00   0.609E+01  0.637E+01 -0.283E+00      -4.45         4        0.6486       0.0325
 0.00   0.817E+01  0.852E+01 -0.352E+00      -4.13         5        0.6631       0.0403
10.00   0.103E+02  0.107E+02 -0.406E+00      -3.80         6        0.6775       0.0494
20.00   0.124E+02  0.129E+02 -0.447E+00      -3.48         7        0.6919       0.0601
30.00   0.146E+02  0.151E+02 -0.473E+00      -3.14         8        0.7063       0.0725
40.00   0.168E+02  0.173E+02 -0.486E+00      -2.81         9        0.7208       0.0867
50.00   0.190E+02  0.195E+02 -0.482E+00      -2.47        10        0.7352       0.1029
60.00   0.213E+02  0.218E+02 -0.466E+00      -2.14        11        0.7496       0.1213
70.00   0.236E+02  0.240E+02 -0.434E+00      -1.80        12        0.7640       0.1421
80.00   0.260E+02  0.264E+02 -0.389E+00      -1.48        13        0.7784       0.1655
90.00   0.284E+02  0.287E+02 -0.330E+00      -1.15        14        0.7929       0.1916
00.00   0.308E+02  0.311E+02 -0.258E+00      -0.83        15        0.8073       0.2206
10.00   0.334E+02  0.335E+02 -0.172E+00      -0.51        16        0.8217       0.2529
20.00   0.359E+02  0.360E+02 -0.746E-01      -0.21        17        0.8361       0.2884
30.00   0.386E+02  0.386E+02  0.358E-01       0.09        18        0.8506       0.3276
40.00   0.413E+02  0.412E+02  0.157E+00       0.38        19        0.8650       0.3705
50.00   0.441E+02  0.438E+02  0.292E+00       0.67        20        0.8794       0.4175
60.00   0.471E+02  0.466E+02  0.439E+00       0.94        21        0.8938       0.4687
70.00   0.501E+02  0.495E+02  0.601E+00       1.21        22        0.9083       0.5244
80.00   0.533E+02  0.526E+02  0.784E+00       1.49        23        0.9227       0.5849
90.00   0.568E+02  0.558E+02  0.992E+00       1.78        24        0.9371       0.6503
00.00   0.604E+02  0.592E+02  0.124E+01       2.10        25        0.9515       0.7210
10.00   0.645E+02  0.630E+02  0.156E+01       2.48        26        0.9660       0.7972
20.00   0.693E+02  0.672E+02  0.202E+01       3.01        27        0.9804       0.8792
30.00   0.757E+02  0.729E+02  0.282E+01       3.88        28        0.9948       0.9673

D=     2.152249
1=    0.8692907
2=    2.6591945E-02

***************
APOUR ENTHALPY                                                          TABLE E2  CONTINUED
***************

------------------------------------------------------------------------------------------------
EMP          BTU/LB                ABS         PERCENT       N          TR           PR
EG F       CALCD      PUBLD        ERROR         ERROR
------------------------------------------------------------------------------------------------
0.00    0.722E+02  0.729E+02 -0.725E+00      -0.99         1        0.6054       0.0159
0.00    0.734E+02  0.740E+02 -0.633E+00      -0.86         2        0.6198       0.0205
0.00    0.746E+02  0.751E+02 -0.541E+00      -0.72         3        0.6342       0.0259
0.00    0.757E+02  0.762E+02 -0.449E+00      -0.59         4        0.6486       0.0325
0.00    0.769E+02  0.773E+02 -0.357E+00      -0.46         5        0.6631       0.0403
0.00    0.781E+02  0.783E+02 -0.268E+00      -0.34         6        0.6775       0.0494
0.00    0.792E+02  0.794E+02 -0.180E+00      -0.23         7        0.6919       0.0601
0.00    0.803E+02  0.804E+02 -0.955E-01      -0.12         8        0.7063       0.0725
0.00    0.814E+02  0.814E+02 -0.156E-01      -0.02         9        0.7208       0.0867
0.00    0.825E+02  0.824E+02  0.597E-01       0.07        10        0.7352       0.1029
0.00    0.835E+02  0.834E+02  0.128E+00       0.15        11        0.7496       0.1213
0.00    0.845E+02  0.844E+02  0.191E+00       0.23        12        0.7640       0.1421
0.00    0.855E+02  0.853E+02  0.244E+00       0.29        13        0.7784       0.1655
0.00    0.865E+02  0.862E+02  0.289E+00       0.34        14        0.7929       0.1916
0.00    0.874E+02  0.870E+02  0.326E+00       0.37        15        0.8073       0.2206
0.00    0.882E+02  0.878E+02  0.351E+00       0.40        16        0.8217       0.2529
0.00    0.890E+02  0.886E+02  0.367E+00       0.41        17        0.8361       0.2884
0.00    0.897E+02  0.893E+02  0.371E+00       0.42        18        0.8506       0.3276
0.00    0.903E+02  0.900E+02  0.365E+00       0.41        19        0.8650       0.3705
0.00    0.909E+02  0.905E+02  0.348E+00       0.38        20        0.8794       0.4175
0.00    0.913E+02  0.910E+02  0.321E+00       0.35        21        0.8938       0.4687
0.00    0.916E+02  0.914E+02  0.287E+00       0.31        22        0.9083       0.5244
0.00    0.918E+02  0.916E+02  0.247E+00       0.27        23        0.9227       0.5849
0.00    0.918E+02  0.916E+02  0.209E+00       0.23        24        0.9371       0.6503
0.00    0.915E+02  0.913E+02  0.183E+00       0.20        25        0.9515       0.7210
0.00    0.908E+02  0.906E+02  0.195E+00       0.22        26        0.9660       0.7972
0.00    0.894E+02  0.890E+02  0.320E+00       0.36        27        0.9804       0.8792
0.00    0.861E+02  0.851E+02  0.969E+00       1.14        28        0.9948       0.9673

=     0.3883371
=     0.3858528
=     4.7423360E-03
```

```
***********************
LATENT HEAT COMPARISON                                                    TABLE E2  CONTINUED
***********************

-----------------------------------------------------------------------------------------------
TEMP        LH IN BTU/LB             ABS          PERCENT       N          TR            PR
DEG F     CALCD      PUBLD          ERROR          ERROR
-----------------------------------------------------------------------------------------------
40.00   0.722E+02  0.729E+02  -0.725E+00      -0.99         1        0.6054        0.0159
30.00   0.714E+02  0.719E+02  -0.526E+00      -0.73         2        0.6198        0.0205
20.00   0.705E+02  0.709E+02  -0.339E+00      -0.48         3        0.6342        0.0259
10.00   0.697E+02  0.698E+02  -0.165E+00      -0.24         4        0.6486        0.0325
 0.00   0.687E+02  0.688E+02  -0.500E-02      -0.01         5        0.6631        0.0403
10.00   0.678E+02  0.677E+02   0.139E+00       0.21         6        0.6775        0.0494
20.00   0.668E+02  0.665E+02   0.267E+00       0.40         7        0.6919        0.0601
30.00   0.657E+02  0.654E+02   0.378E+00       0.58         8        0.7063        0.0725
40.00   0.646E+02  0.642E+02   0.470E+00       0.73         9        0.7208        0.0867
50.00   0.635E+02  0.629E+02   0.542E+00       0.86        10        0.7352        0.1029
60.00   0.622E+02  0.616E+02   0.594E+00       0.96        11        0.7496        0.1213
70.00   0.609E+02  0.603E+02   0.625E+00       1.04        12        0.7640        0.1421
80.00   0.596E+02  0.589E+02   0.634E+00       1.08        13        0.7784        0.1655
90.00   0.581E+02  0.575E+02   0.619E+00       1.08        14        0.7929        0.1916
00.00   0.565E+02  0.559E+02   0.583E+00       1.04        15        0.8073        0.2206
10.00   0.548E+02  0.543E+02   0.523E+00       0.96        16        0.8217        0.2529
20.00   0.530E+02  0.526E+02   0.441E+00       0.84        17        0.8361        0.2884
30.00   0.511E+02  0.508E+02   0.336E+00       0.66        18        0.8506        0.3276
40.00   0.490E+02  0.488E+02   0.207E+00       0.42        19        0.8650        0.3705
50.00   0.467E+02  0.467E+02   0.558E-01       0.12        20        0.8794        0.4175
60.00   0.443E+02  0.444E+02  -0.118E+00      -0.27        21        0.8938        0.4687
70.00   0.415E+02  0.418E+02  -0.315E+00      -0.75        22        0.9083        0.5244
80.00   0.385E+02  0.390E+02  -0.537E+00      -1.38        23        0.9227        0.5849
90.00   0.350E+02  0.358E+02  -0.783E+00      -2.19        24        0.9371        0.6503
00.00   0.310E+02  0.321E+02  -0.106E+01      -3.30        25        0.9515        0.7210
10.00   0.262E+02  0.276E+02  -0.137E+01      -4.95        26        0.9660        0.7972
20.00   0.201E+02  0.218E+02  -0.170E+01      -7.82        27        0.9804        0.8792
30.00   0.104E+02  0.122E+02  -0.186E+01     -15.17        28        0.9948        0.9673

AD=      1.759213
D1=    0.7337487
D2=    3.5766512E-02
```

```
**************************
LIQUID ENTROPY COMPARISON                                          TABLE E2  CONTINUED
**************************

----------------------------------------------------------------------------------------------------------
TEMP          BTU/LB F              ABS          PERCENT         N           TR              PR
DEG F     CALCD       PUBLD         ERROR         ERROR
----------------------------------------------------------------------------------------------------------
40.00   0.000E+00  0.000E+00  0.000E+00        0.00          1         0.6054          0.0159
30.00   0.510E-02  0.496E-02  0.140E-03        2.82          2         0.6198          0.0205
20.00   0.101E-01  0.983E-02  0.306E-03        3.11          3         0.6342          0.0259
10.00   0.151E-01  0.146E-01  0.491E-03        3.36          4         0.6486          0.0325
 0.00   0.200E-01  0.193E-01  0.713E-03        3.69          5         0.6631          0.0403
10.00   0.249E-01  0.239E-01  0.955E-03        3.99          6         0.6775          0.0494
20.00   0.297E-01  0.285E-01  0.121E-02        4.25          7         0.6919          0.0601
30.00   0.345E-01  0.330E-01  0.151E-02        4.57          8         0.7063          0.0725
40.00   0.393E-01  0.375E-01  0.182E-02        4.87          9         0.7208          0.0867
50.00   0.440E-01  0.418E-01  0.216E-02        5.15         10         0.7352          0.1029
60.00   0.487E-01  0.462E-01  0.252E-02        5.45         11         0.7496          0.1213
70.00   0.534E-01  0.505E-01  0.290E-02        5.74         12         0.7640          0.1421
80.00   0.580E-01  0.547E-01  0.329E-02        6.02         13         0.7784          0.1655
90.00   0.627E-01  0.590E-01  0.372E-02        6.30         14         0.7929          0.1916
00.00   0.674E-01  0.632E-01  0.414E-02        6.55         15         0.8073          0.2206
10.00   0.720E-01  0.675E-01  0.459E-02        6.81         16         0.8217          0.2529
20.00   0.767E-01  0.717E-01  0.505E-02        7.05         17         0.8361          0.2884
30.00   0.815E-01  0.759E-01  0.552E-02        7.28         18         0.8506          0.3276
40.00   0.862E-01  0.802E-01  0.601E-02        7.49         19         0.8650          0.3705
50.00   0.910E-01  0.845E-01  0.651E-02        7.71         20         0.8794          0.4175
60.00   0.960E-01  0.889E-01  0.702E-02        7.89         21         0.8938          0.4687
70.00   0.101E+00  0.934E-01  0.755E-02        8.08         22         0.9083          0.5244
80.00   0.106E+00  0.980E-01  0.809E-02        8.25         23         0.9227          0.5849
90.00   0.112E+00  0.103E+00  0.867E-02        8.43         24         0.9371          0.6503
00.00   0.117E+00  0.108E+00  0.929E-02        8.61         25         0.9515          0.7210
10.00   0.123E+00  0.113E+00  0.100E-01        8.84         26         0.9660          0.7972
20.00   0.130E+00  0.119E+00  0.109E-01        9.14         27         0.9804          0.8792
30.00   0.140E+00  0.127E+00  0.123E-01        9.65         28         0.9948          0.9673

AD=     6.110417
D1=    5.8668796E-03
D2=    6.6365361E-02
**************************
VAPOUR ENTROPY COMPARISON                                          TABLE E2  CONTINUED
**************************

----------------------------------------------------------------------------------------------------------
TEMP          BTU/LB F              ABS          PERCENT         N           TR              PR
DEG F     CALCD       PUBLD         ERROR         ERROR
----------------------------------------------------------------------------------------------------------
-40.00  0.172E+00  0.174E+00 -0.161E-02       -0.93          1         0.6054          0.0159
-30.00  0.171E+00  0.172E+00 -0.965E-03       -0.56          2         0.6198          0.0205
-20.00  0.171E+00  0.171E+00 -0.356E-03       -0.21          3         0.6342          0.0259
-10.00  0.170E+00  0.170E+00  0.231E-03        0.14          4         0.6486          0.0325
  0.00  0.170E+00  0.169E+00  0.801E-03        0.47          5         0.6631          0.0403
 10.00  0.169E+00  0.168E+00  0.135E-02        0.80          6         0.6775          0.0494
 20.00  0.169E+00  0.167E+00  0.187E-02        1.12          7         0.6919          0.0601
 30.00  0.169E+00  0.166E+00  0.238E-02        1.43          8         0.7063          0.0725
 40.00  0.169E+00  0.166E+00  0.285E-02        1.72          9         0.7208          0.0867
 50.00  0.169E+00  0.165E+00  0.330E-02        2.00         10         0.7352          0.1029
 60.00  0.169E+00  0.165E+00  0.374E-02        2.27         11         0.7496          0.1213
 70.00  0.168E+00  0.164E+00  0.415E-02        2.53         12         0.7640          0.1421
 80.00  0.168E+00  0.164E+00  0.454E-02        2.77         13         0.7784          0.1655
 90.00  0.168E+00  0.164E+00  0.491E-02        3.00         14         0.7929          0.1916
 00.00  0.168E+00  0.163E+00  0.526E-02        3.22         15         0.8073          0.2206
 10.00  0.168E+00  0.163E+00  0.557E-02        3.42         16         0.8217          0.2529
 20.00  0.168E+00  0.162E+00  0.588E-02        3.62         17         0.8361          0.2884
 30.00  0.168E+00  0.162E+00  0.616E-02        3.80         18         0.8506          0.3276
 40.00  0.168E+00  0.162E+00  0.641E-02        3.97         19         0.8650          0.3705
 50.00  0.168E+00  0.161E+00  0.666E-02        4.13         20         0.8794          0.4175
 60.00  0.167E+00  0.161E+00  0.688E-02        4.29         21         0.8938          0.4687
 70.00  0.167E+00  0.160E+00  0.709E-02        4.44         22         0.9083          0.5244
 80.00  0.166E+00  0.160E+00  0.677E-02        4.24         23         0.9227          0.5849
 90.00  0.165E+00  0.158E+00  0.750E-02        4.75         24         0.9371          0.6503
 00.00  0.164E+00  0.157E+00  0.772E-02        4.93         25         0.9515          0.7210
 10.00  0.163E+00  0.155E+00  0.800E-02        5.18         26         0.9660          0.7972
 20.00  0.160E+00  0.151E+00  0.843E-02        5.56         27         0.9804          0.8792
 30.00  0.155E+00  0.145E+00  0.961E-02        6.62         28         0.9948          0.9673

AD=      2.932905
D1=    5.4896330E-03
D2=    3.4833509E-02
```

```
**********************
LIQUID COMPRESSIBILITY                                               TABLE E2 CONTINUED
**********************

------------------------------------------------------------------------------------------
TEMP              Z                    ABS       PERCENT       N         TR           PR
DEG F     CALCD      PUBLD            ERROR      ERROR
------------------------------------------------------------------------------------------
40.00  0.253E-02  0.264E-02 -0.106E-03   -4.00         1       0.6054       0.0159
30.00  0.321E-02  0.336E-02 -0.149E-03   -4.44         2       0.6198       0.0205
20.00  0.402E-02  0.422E-02 -0.199E-03   -4.72         3       0.6342       0.0259
10.00  0.498E-02  0.524E-02 -0.258E-03   -4.92         4       0.6486       0.0325
 0.00  0.611E-02  0.645E-02 -0.336E-03   -5.21         5       0.6631       0.0403
10.00  0.744E-02  0.785E-02 -0.413E-03   -5.26         6       0.6775       0.0494
20.00  0.897E-02  0.948E-02 -0.508E-03   -5.36         7       0.6919       0.0601
30.00  0.107E-01  0.114E-01 -0.615E-03   -5.42         8       0.7063       0.0725
40.00  0.128E-01  0.135E-01 -0.720E-03   -5.33         9       0.7208       0.0867
50.00  0.151E-01  0.159E-01 -0.833E-03   -5.22        10       0.7352       0.1029
60.00  0.178E-01  0.187E-01 -0.951E-03   -5.08        11       0.7496       0.1213
70.00  0.208E-01  0.218E-01 -0.106E-02   -4.86        12       0.7640       0.1421
80.00  0.242E-01  0.253E-01 -0.116E-02   -4.57        13       0.7784       0.1655
90.00  0.280E-01  0.293E-01 -0.124E-02   -4.23        14       0.7929       0.1916
00.00  0.324E-01  0.337E-01 -0.129E-02   -3.83        15       0.8073       0.2206
10.00  0.373E-01  0.386E-01 -0.130E-02   -3.38        16       0.8217       0.2529
20.00  0.429E-01  0.441E-01 -0.124E-02   -2.81        17       0.8361       0.2884
30.00  0.492E-01  0.503E-01 -0.110E-02   -2.18        18       0.8506       0.3276
40.00  0.563E-01  0.572E-01 -0.815E-03   -1.43        19       0.8650       0.3705
50.00  0.645E-01  0.649E-01 -0.366E-03   -0.56        20       0.8794       0.4175
60.00  0.738E-01  0.735E-01  0.324E-03    0.44        21       0.8938       0.4687
70.00  0.846E-01  0.833E-01  0.134E-02    1.61        22       0.9083       0.5244
80.00  0.972E-01  0.944E-01  0.282E-02    2.99        23       0.9227       0.5849
90.00  0.112E+00  0.107E+00  0.494E-02    4.61        24       0.9371       0.6503
00.00  0.130E+00  0.122E+00  0.811E-02    6.63        25       0.9515       0.7210
10.00  0.154E+00  0.141E+00  0.128E-01    9.12        26       0.9660       0.7972
20.00  0.185E+00  0.165E+00  0.204E-01   12.36        27       0.9804       0.8792
30.00  0.240E+00  0.206E+00  0.338E-01   16.42        28       0.9948       0.9673

AD=     4.892306
D1=    8.2559334E-03
D2=    5.9710901E-02
**********************
VAPOUR COMPRESSIBILITY                                               TABLE E2 CONTINUED
**********************

------------------------------------------------------------------------------------------
TEMP              Z                    ABS       PERCENT       N         TR           PR
DEG F     CALCD      PUBLD            ERROR      ERROR
------------------------------------------------------------------------------------------
40.00  0.976E+00  0.968E+00  0.739E-02    0.76         1       0.6054       0.0159
30.00  0.971E+00  0.962E+00  0.816E-02    0.85         2       0.6198       0.0205
20.00  0.965E+00  0.956E+00  0.885E-02    0.93         3       0.6342       0.0259
10.00  0.958E+00  0.948E+00  0.945E-02    1.00         4       0.6486       0.0325
 0.00  0.950E+00  0.941E+00  0.996E-02    1.06         5       0.6631       0.0403
10.00  0.942E+00  0.932E+00  0.104E-01    1.11         6       0.6775       0.0494
20.00  0.933E+00  0.922E+00  0.106E-01    1.15         7       0.6919       0.0601
30.00  0.923E+00  0.912E+00  0.107E-01    1.18         8       0.7063       0.0725
40.00  0.912E+00  0.901E+00  0.107E-01    1.18         9       0.7208       0.0867
50.00  0.900E+00  0.889E+00  0.104E-01    1.17        10       0.7352       0.1029
60.00  0.887E+00  0.877E+00  0.999E-02    1.14        11       0.7496       0.1213
70.00  0.873E+00  0.863E+00  0.938E-02    1.09        12       0.7640       0.1421
80.00  0.858E+00  0.849E+00  0.859E-02    1.01        13       0.7784       0.1655
90.00  0.841E+00  0.834E+00  0.761E-02    0.91        14       0.7929       0.1916
00.00  0.824E+00  0.817E+00  0.647E-02    0.79        15       0.8073       0.2206
10.00  0.805E+00  0.800E+00  0.513E-02    0.64        16       0.8217       0.2529
20.00  0.785E+00  0.781E+00  0.368E-02    0.47        17       0.8361       0.2884
30.00  0.764E+00  0.761E+00  0.217E-02    0.28        18       0.8506       0.3276
40.00  0.741E+00  0.740E+00  0.389E-03    0.05        19       0.8650       0.3705
50.00  0.716E+00  0.717E+00 -0.130E-02   -0.18        20       0.8794       0.4175
60.00  0.689E+00  0.692E+00 -0.298E-02   -0.43        21       0.8938       0.4687
70.00  0.660E+00  0.665E+00 -0.459E-02   -0.69        22       0.9083       0.5244
80.00  0.629E+00  0.635E+00 -0.593E-02   -0.93        23       0.9227       0.5849
90.00  0.595E+00  0.602E+00 -0.696E-02   -1.16        24       0.9371       0.6503
00.00  0.556E+00  0.564E+00 -0.722E-02   -1.28        25       0.9515       0.7210
10.00  0.512E+00  0.519E+00 -0.655E-02   -1.26        26       0.9660       0.7972
20.00  0.459E+00  0.462E+00 -0.340E-02   -0.74        27       0.9804       0.8792
30.00  0.379E+00  0.372E+00  0.760E-02    2.04        28       0.9948       0.9673

AD=    0.9106935
D1=    7.7746701E-03
D2=    1.0100145E-02
```

TABLE E3 R13

```
********************
PRESSURE COMPARISON
********************

-----------------------------------------------------------------------------------------------------------
TEMP        PRESSURE   PSIA        ABS          PERCENT       N         TR             PR
DEG F       CALCD      PUBLD       ERROR        ERROR
-----------------------------------------------------------------------------------------------------------
-40.00    0.871E+02  0.874E+02  -0.291E+00     -0.33         1       0.7721         0.1553
-30.00    0.105E+03  0.106E+03  -0.366E+00     -0.35         2       0.7905         0.1876
-20.00    0.126E+03  0.126E+03  -0.410E+00     -0.32         3       0.8089         0.2246
-10.00    0.150E+03  0.150E+03  -0.460E+00     -0.31         4       0.8273         0.2667
  0.00    0.176E+03  0.177E+03  -0.374E+00     -0.21         5       0.8457         0.3145
 10.00    0.207E+03  0.207E+03  -0.201E+00     -0.10         6       0.8641         0.3683
 20.00    0.240E+03  0.240E+03   0.172E-01      0.01         7       0.8825         0.4285
 30.00    0.278E+03  0.278E+03   0.250E+00      0.09         8       0.9009         0.4958
 40.00    0.320E+03  0.320E+03   0.476E+00      0.15         9       0.9193         0.5705
 50.00    0.366E+03  0.366E+03   0.586E+00      0.16        10       0.9376         0.6533
 60.00    0.418E+03  0.417E+03   0.684E+00      0.16        11       0.9560         0.7445
 70.00    0.474E+03  0.473E+03   0.588E+00      0.12        12       0.9744         0.8449
 80.00    0.536E+03  0.536E+03   0.234E+00      0.04        13       0.9928         0.9549

AAD=    0.1813645
SD1=    0.4360734
SD2=    2.2072275E-03
```

TABLE E3 CONTINUED

```
**************************
LIQUID DENSITY COMPARISON
**************************

-----------------------------------------------------------------------------------------------------------
TEMP        DENS  IN  LB/FT3       ABS          PERCENT       N         TR             PR
DEG F       CALCD      PUBLD       ERROR        ERROR
-----------------------------------------------------------------------------------------------------------
-40.00    0.890E+02  0.841E+02   0.490E+01      5.83         1       0.7721         0.1553
-30.00    0.868E+02  0.824E+02   0.438E+01      5.31         2       0.7905         0.1876
-20.00    0.845E+02  0.807E+02   0.379E+01      4.69         3       0.8089         0.2246
-10.00    0.820E+02  0.789E+02   0.316E+01      4.00         4       0.8273         0.2667
  0.00    0.794E+02  0.770E+02   0.238E+01      3.09         5       0.8457         0.3145
 10.00    0.765E+02  0.749E+02   0.158E+01      2.11         6       0.8641         0.3683
 20.00    0.734E+02  0.727E+02   0.652E+00      0.90         7       0.8825         0.4285
 30.00    0.700E+02  0.703E+02  -0.342E+00     -0.49         8       0.9009         0.4958
 40.00    0.662E+02  0.677E+02  -0.149E+01     -2.20         9       0.9193         0.5705
 50.00    0.620E+02  0.647E+02  -0.273E+01     -4.21        10       0.9376         0.6533
 60.00    0.570E+02  0.611E+02  -0.408E+01     -6.67        11       0.9560         0.7445
 70.00    0.509E+02  0.565E+02  -0.552E+01     -9.78        12       0.9744         0.8449
 80.00    0.421E+02  0.488E+02  -0.674E+01    -13.79        13       0.9928         0.9549

AAD=    4.852096
SD1=    3.855265
SD2=  6.2464975E-02
```

TABLE E3 CONTINUED

```
**********************
LATENT HEAT COMPARISON
**********************

-----------------------------------------------------------------------------------------------------------
TEMP        LH  IN  BTU/LB         ABS          PERCENT       N         TR             PR
DEG F       CALCD      PUBLD       ERROR        ERROR
-----------------------------------------------------------------------------------------------------------
-40.00    0.545E+02  0.540E+02   0.439E+00      0.81         1       0.7721         0.1553
-30.00    0.528E+02  0.524E+02   0.380E+00      0.73         2       0.7905         0.1876
-20.00    0.510E+02  0.507E+02   0.321E+00      0.63         3       0.8089         0.2246
-10.00    0.490E+02  0.486E+02   0.391E+00      0.80         4       0.8273         0.2667
  0.00    0.469E+02  0.466E+02   0.227E+00      0.49         5       0.8457         0.3145
 10.00    0.445E+02  0.445E+02   0.928E-02      0.02         6       0.8641         0.3683
 20.00    0.418E+02  0.421E+02  -0.253E+00     -0.60         7       0.8825         0.4285
 30.00    0.389E+02  0.395E+02  -0.591E+00     -1.50         8       0.9009         0.4958
 40.00    0.355E+02  0.365E+02  -0.950E+00     -2.61         9       0.9193         0.5705
 50.00    0.316E+02  0.330E+02  -0.140E+01     -4.24        10       0.9376         0.6533
 60.00    0.268E+02  0.287E+02  -0.187E+01     -6.51        11       0.9560         0.7445
 70.00    0.207E+02  0.232E+02  -0.251E+01    -10.84        12       0.9744         0.8449
 80.00    0.110E+02  0.136E+02  -0.253E+01    -18.62        13       0.9928         0.9549

AAD=    3.722181
SD1=    1.293864
SD2=  6.6852726E-02
```

R13B1

TABLE E4

```
*******************
PRESSURE COMPARISON
*******************

--------------------------------------------------------------------------------------------
TEMP      PRESSURE  PSIA        ABS       PERCENT      N         TR           PR
DEG F      CALCD    PUBLD      ERROR       ERROR
--------------------------------------------------------------------------------------------
40.00  0.319E+02  0.319E+02 -0.591E-02    -0.02        1       0.6854       0.0554
30.00  0.395E+02  0.396E+02 -0.541E-01    -0.14        2       0.7018       0.0687
20.00  0.485E+02  0.486E+02 -0.988E-01    -0.20        3       0.7181       0.0843
10.00  0.589E+02  0.591E+02 -0.159E+00    -0.27        4       0.7344       0.1025
 0.00  0.710E+02  0.712E+02 -0.209E+00    -0.29        5       0.7508       0.1234
10.00  0.848E+02  0.850E+02 -0.246E+00    -0.29        6       0.7671       0.1474
20.00  0.100E+03  0.101E+03 -0.327E+00    -0.32        7       0.7834       0.1747
30.00  0.118E+03  0.119E+03 -0.330E+00    -0.28        8       0.7998       0.2057
40.00  0.138E+03  0.139E+03 -0.289E+00    -0.21        9       0.8161       0.2405
50.00  0.161E+03  0.161E+03 -0.234E+00    -0.15       10       0.8324       0.2796
60.00  0.186E+03  0.186E+03 -0.190E+00    -0.10       11       0.8488       0.3231
70.00  0.214E+03  0.214E+03 -0.755E-01    -0.04       12       0.8651       0.3715
80.00  0.244E+03  0.244E+03 -0.465E-02     0.00       13       0.8814       0.4250
90.00  0.278E+03  0.278E+03  0.215E+00     0.08       14       0.8978       0.4840
00.00  0.316E+03  0.315E+03  0.383E+00     0.12       15       0.9141       0.5488
10.00  0.356E+03  0.356E+03  0.505E+00     0.14       16       0.9304       0.6198
20.00  0.401E+03  0.400E+03  0.597E+00     0.15       17       0.9468       0.6974
30.00  0.450E+03  0.449E+03  0.682E+00     0.15       18       0.9631       0.7819
40.00  0.502E+03  0.502E+03  0.592E+00     0.12       19       0.9794       0.8737
50.00  0.560E+03  0.559E+03  0.473E+00     0.08       20       0.9958       0.9733

AD=     0.1575302
D1=     0.3540626
D2=     1.8763094E-03
```

TABLE E4 CONTINUED

```
**************************
LIQUID DENSITY COMPARISON
**************************

--------------------------------------------------------------------------------------------
TEMP      DENS  IN  LB/FT3       ABS      PERCENT      N         TR           PR
DEG F      CALCD     PUBLD      ERROR      ERROR
--------------------------------------------------------------------------------------------
40.00  0.127E+03  0.119E+03  0.750E+01     6.29        1       0.6854       0.0554
30.00  0.125E+03  0.118E+03  0.721E+01     6.13        2       0.7018       0.0687
20.00  0.123E+03  0.116E+03  0.688E+01     5.93        3       0.7181       0.0843
10.00  0.121E+03  0.114E+03  0.649E+01     5.68        4       0.7344       0.1025
 0.00  0.119E+03  0.112E+03  0.605E+01     5.38        5       0.7508       0.1234
10.00  0.116E+03  0.111E+03  0.556E+01     5.03        6       0.7671       0.1474
20.00  0.114E+03  0.109E+03  0.501E+01     4.61        7       0.7834       0.1747
30.00  0.111E+03  0.107E+03  0.439E+01     4.11        8       0.7998       0.2057
40.00  0.108E+03  0.105E+03  0.373E+01     3.56        9       0.8161       0.2405
50.00  0.105E+03  0.102E+03  0.295E+01     2.88       10       0.8324       0.2796
60.00  0.102E+03  0.100E+03  0.213E+01     2.13       11       0.8488       0.3231
70.00  0.990E+02  0.978E+02  0.121E+01     1.24       12       0.8651       0.3715
80.00  0.954E+02  0.952E+02  0.202E+00     0.21       13       0.8814       0.4250
90.00  0.915E+02  0.924E+02 -0.905E+00    -0.98       14       0.8978       0.4840
00.00  0.873E+02  0.894E+02 -0.211E+01    -2.36       15       0.9141       0.5488
10.00  0.826E+02  0.861E+02 -0.344E+01    -4.00       16       0.9304       0.6198
20.00  0.773E+02  0.822E+02 -0.489E+01    -5.95       17       0.9468       0.6974
30.00  0.712E+02  0.776E+02 -0.645E+01    -8.30       18       0.9631       0.7819
40.00  0.635E+02  0.716E+02 -0.805E+01   -11.25       19       0.9794       0.8737
50.00  0.519E+02  0.607E+02 -0.886E+01   -14.59       20       0.9958       0.9733

AD=     5.030906
D1=     5.449911
D2=    6.2005714E-02
```

```
********************
PRESSURE COMPARISON                                                          TABLE E5
********************

------------------------------------------------------------------------------------------------
TEMP       PRESSURE  PSIA          ABS         PERCENT       N           TR              PR
DEG F      CALCD     PUBLD         ERROR       ERROR
------------------------------------------------------------------------------------------------
-40.00   0.154E+02  0.152E+02  0.135E+00      0.89         1         0.6316          0.0213
-30.00   0.197E+02  0.196E+02  0.126E+00      0.64         2         0.6466          0.0273
-20.00   0.250E+02  0.248E+02  0.107E+00      0.43         3         0.6617          0.0346
-10.00   0.312E+02  0.312E+02  0.773E-01      0.25         4         0.6767          0.0433
  0.00   0.387E+02  0.387E+02  0.355E-01      0.09         5         0.6918          0.0536
 10.00   0.474E+02  0.475E+02 -0.151E-01     -0.03         6         0.7068          0.0657
 20.00   0.577E+02  0.577E+02 -0.747E-01     -0.13         7         0.7219          0.0799
 30.00   0.695E+02  0.696E+02 -0.137E+00     -0.20         8         0.7369          0.0962
 40.00   0.830E+02  0.832E+02 -0.198E+00     -0.24         9         0.7520          0.1150
 50.00   0.985E+02  0.987E+02 -0.250E+00     -0.25        10         0.7670          0.1364
 60.00   0.116E+03  0.116E+03 -0.282E+00     -0.24        11         0.7821          0.1607
 70.00   0.136E+03  0.136E+03 -0.286E+00     -0.21        12         0.7971          0.1882
 80.00   0.158E+03  0.158E+03 -0.259E+00     -0.16        13         0.8122          0.2190
 90.00   0.183E+03  0.183E+03 -0.165E+00     -0.09        14         0.8272          0.2534
100.00   0.211E+03  0.211E+03 -0.160E-01     -0.01        15         0.8423          0.2917
110.00   0.241E+03  0.241E+03  0.204E+00      0.08        16         0.8573          0.3342
120.00   0.275E+03  0.275E+03  0.505E+00      0.18        17         0.8724          0.3811
130.00   0.312E+03  0.312E+03  0.877E+00      0.28        18         0.8874          0.4327
140.00   0.353E+03  0.352E+03  0.134E+01      0.38        19         0.9025          0.4894
150.00   0.398E+03  0.396E+03  0.183E+01      0.46        20         0.9175          0.5513
160.00   0.447E+03  0.445E+03  0.232E+01      0.52        21         0.9326          0.6190
170.00   0.500E+03  0.497E+03  0.274E+01      0.55        22         0.9476          0.6926
180.00   0.558E+03  0.555E+03  0.294E+01      0.53        23         0.9627          0.7726
190.00   0.620E+03  0.618E+03  0.268E+01      0.43        24         0.9777          0.8592
200.00   0.688E+03  0.686E+03  0.157E+01      0.23        25         0.9928          0.9529

AAD=    0.3008717
SD1=      1.254800
SD2=    3.7347944E-03
```

```
**************************
LIQUID DENSITY COMPARISON                                                    TABLE E5  CONTINUED
**************************

------------------------------------------------------------------------------------------------
TEMP       DENS  IN  LB/FT3        ABS         PERCENT       N           TR              PR
DEG F      CALCD     PUBLD         ERROR       ERROR
------------------------------------------------------------------------------------------------
-40.00   0.899E+02  0.880E+02  0.187E+01      2.12         1         0.6316          0.0213
-30.00   0.888E+02  0.870E+02  0.185E+01      2.13         2         0.6466          0.0273
-20.00   0.878E+02  0.860E+02  0.181E+01      2.11         3         0.6617          0.0346
-10.00   0.867E+02  0.849E+02  0.175E+01      2.06         4         0.6767          0.0433
  0.00   0.855E+02  0.838E+02  0.166E+01      1.99         5         0.6918          0.0536
 10.00   0.843E+02  0.827E+02  0.155E+01      1.88         6         0.7068          0.0657
 20.00   0.830E+02  0.816E+02  0.141E+01      1.73         7         0.7219          0.0799
 30.00   0.817E+02  0.804E+02  0.125E+01      1.55         8         0.7369          0.0962
 40.00   0.803E+02  0.793E+02  0.105E+01      1.32         9         0.7520          0.1150
 50.00   0.788E+02  0.780E+02  0.816E+00      1.05        10         0.7670          0.1364
 60.00   0.773E+02  0.768E+02  0.551E+00      0.72        11         0.7821          0.1607
 70.00   0.757E+02  0.755E+02  0.250E+00      0.33        12         0.7971          0.1882
 80.00   0.740E+02  0.741E+02 -0.898E-01     -0.12        13         0.8122          0.2190
 90.00   0.722E+02  0.727E+02 -0.471E+00     -0.65        14         0.8272          0.2534
100.00   0.703E+02  0.712E+02 -0.895E+00     -1.26        15         0.8423          0.2917
110.00   0.683E+02  0.697E+02 -0.137E+01     -1.96        16         0.8573          0.3342
120.00   0.662E+02  0.681E+02 -0.189E+01     -2.77        17         0.8724          0.3811
130.00   0.639E+02  0.663E+02 -0.246E+01     -3.71        18         0.8874          0.4327
 40.00   0.614E+02  0.644E+02 -0.309E+01     -4.79        19         0.9025          0.4894
 50.00   0.586E+02  0.624E+02 -0.378E+01     -6.05        20         0.9175          0.5513
 60.00   0.556E+02  0.601E+02 -0.453E+01     -7.53        21         0.9326          0.6190
 70.00   0.522E+02  0.576E+02 -0.534E+01     -9.27        22         0.9476          0.6926
 80.00   0.483E+02  0.545E+02 -0.620E+01    -11.37        23         0.9627          0.7726
 90.00   0.436E+02  0.507E+02 -0.708E+01    -13.97        24         0.9777          0.8592
 00.00   0.369E+02  0.446E+02 -0.766E+01    -17.19        25         0.9928          0.9529

AD=      3.984774
D1=      3.270701
D2=     6.0678329E-02
```

```
**************************
LIQUID ENTROPY COMPARISON                                          TABLE E5  CONTINUED
**************************

------------------------------------------------------------------------------------------
TEMP          BTU/LB F              ABS        PERCENT       N          TR            PR
DEG F      CALCD      PUBLD        ERROR       ERROR
------------------------------------------------------------------------------------------
-40.00   0.000E+00  0.000E+00  0.000E+00      0.00         1        0.6316        0.0213
-30.00   0.637E-02  0.598E-02  0.389E-03      6.50         2        0.6466        0.0273
-20.00   0.127E-01  0.119E-01  0.781E-03      6.57         3        0.6617        0.0346
-10.00   0.189E-01  0.178E-01  0.116E-02      6.51         4        0.6767        0.0433
  0.00   0.251E-01  0.236E-01  0.154E-02      6.53         5        0.6918        0.0536
 10.00   0.313E-01  0.293E-01  0.194E-02      6.62         6        0.7068        0.0657
 20.00   0.374E-01  0.350E-01  0.235E-02      6.70         7        0.7219        0.0799
 30.00   0.435E-01  0.407E-01  0.277E-02      6.80         8        0.7369        0.0962
 40.00   0.495E-01  0.463E-01  0.322E-02      6.95         9        0.7520        0.1150
 50.00   0.556E-01  0.519E-01  0.370E-02      7.13        10        0.7670        0.1364
 60.00   0.617E-01  0.575E-01  0.421E-02      7.34        11        0.7821        0.1607
 70.00   0.677E-01  0.630E-01  0.478E-02      7.59        12        0.7971        0.1882
 80.00   0.738E-01  0.685E-01  0.538E-02      7.86        13        0.8122        0.2190
 90.00   0.800E-01  0.739E-01  0.603E-02      8.16        14        0.8272        0.2534
100.00   0.862E-01  0.794E-01  0.674E-02      8.49        15        0.8423        0.2917
110.00   0.924E-01  0.849E-01  0.752E-02      8.86        16        0.8573        0.3342
120.00   0.988E-01  0.904E-01  0.837E-02      9.26        17        0.8724        0.3811
130.00   0.105E+00  0.960E-01  0.931E-02      9.70        18        0.8874        0.4327
140.00   0.112E+00  0.102E+00  0.103E-01     10.15        19        0.9025        0.4894
150.00   0.119E+00  0.107E+00  0.115E-01     10.66        20        0.9175        0.5513
160.00   0.126E+00  0.113E+00  0.127E-01     11.21        21        0.9326        0.6190
170.00   0.134E+00  0.120E+00  0.141E-01     11.79        22        0.9476        0.6926
180.00   0.142E+00  0.126E+00  0.157E-01     12.41        23        0.9627        0.7726
190.00   0.152E+00  0.134E+00  0.175E-01     13.04        24        0.9777        0.8592
200.00   0.164E+00  0.145E+00  0.195E-01     13.49        25        0.9928        0.9529

AAD=     8.412169
SD1=    8.9903465E-03
SD2=    9.0413079E-02
**************************
VAPOUR ENTROPY COMPARISON                                          TABLE E5  CONTINUED
**************************

------------------------------------------------------------------------------------------
TEMP          BTU/LB F              ABS        PERCENT       N          TR            PR
DEG F      CALCD      PUBLD        ERROR       ERROR
------------------------------------------------------------------------------------------
-40.00   0.238E+00  0.239E+00 -0.511E-03     -0.21         1        0.6316        0.0213
-30.00   0.236E+00  0.236E+00  0.235E-03      0.10         2        0.6466        0.0273
-20.00   0.234E+00  0.233E+00  0.973E-03      0.42         3        0.6617        0.0346
-10.00   0.232E+00  0.231E+00  0.170E-02      0.74         4        0.6767        0.0433
  0.00   0.231E+00  0.228E+00  0.242E-02      1.06         5        0.6918        0.0536
 10.00   0.229E+00  0.226E+00  0.312E-02      1.38         6        0.7068        0.0657
 20.00   0.228E+00  0.224E+00  0.381E-02      1.70         7        0.7219        0.0799
 30.00   0.226E+00  0.222E+00  0.447E-02      2.02         8        0.7369        0.0962
 40.00   0.225E+00  0.220E+00  0.513E-02      2.33         9        0.7520        0.1150
 50.00   0.224E+00  0.218E+00  0.576E-02      2.64        10        0.7670        0.1364
 60.00   0.223E+00  0.216E+00  0.636E-02      2.94        11        0.7821        0.1607
 70.00   0.221E+00  0.215E+00  0.693E-02      3.23        12        0.7971        0.1882
 80.00   0.220E+00  0.213E+00  0.749E-02      3.52        13        0.8122        0.2190
 90.00   0.219E+00  0.211E+00  0.801E-02      3.79        14        0.8272        0.2534
 00.00   0.218E+00  0.210E+00  0.850E-02      4.06        15        0.8423        0.2917
 10.00   0.217E+00  0.208E+00  0.896E-02      4.31        16        0.8573        0.3342
 20.00   0.216E+00  0.206E+00  0.939E-02      4.56        17        0.8724        0.3811
 30.00   0.214E+00  0.204E+00  0.978E-02      4.79        18        0.8874        0.4327
 40.00   0.212E+00  0.202E+00  0.101E-01      5.01        19        0.9025        0.4894
 50.00   0.211E+00  0.200E+00  0.105E-01      5.23        20        0.9175        0.5513
 60.00   0.209E+00  0.198E+00  0.108E-01      5.44        21        0.9326        0.6190
 70.00   0.206E+00  0.195E+00  0.110E-01      5.66        22        0.9476        0.6926
 80.00   0.203E+00  0.191E+00  0.113E-01      5.91        23        0.9627        0.7726
 90.00   0.198E+00  0.186E+00  0.117E-01      6.25        24        0.9777        0.8592
 00.00   0.190E+00  0.178E+00  0.124E-01      6.99        25        0.9928        0.9529

AD=     3.371461
D1=    7.9773273E-03
D2=    4.0038630E-02
```

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****
PRESSURE COMPARISON
****

TABLE E6

TEMP	PRESSURE	PSIA	ABS	PERCENT	N	TR	PR
DEG F	CALCD	PUBLD	ERROR	ERROR			
-40.00	0.231E+00	0.206E+00	0.250E-01	12.14	1	0.4785	0.0005
-30.00	0.334E+00	0.299E+00	0.350E-01	11.70	2	0.4899	0.0007
-20.00	0.474E+00	0.429E+00	0.449E-01	10.46	3	0.5013	0.0009
-10.00	0.661E+00	0.605E+00	0.556E-01	9.19	4	0.5127	0.0013
0.00	0.906E+00	0.838E+00	0.678E-01	8.09	5	0.5241	0.0018
10.00	0.122E+01	0.114E+01	0.811E-01	7.10	6	0.5355	0.0025
20.00	0.163E+01	0.153E+01	0.940E-01	6.13	7	0.5469	0.0033
30.00	0.214E+01	0.203E+01	0.107E+00	5.27	8	0.5583	0.0043
40.00	0.277E+01	0.265E+01	0.118E+00	4.43	9	0.5697	0.0056
50.00	0.355E+01	0.343E+01	0.128E+00	3.72	10	0.5811	0.0071
60.00	0.451E+01	0.437E+01	0.133E+00	3.05	11	0.5925	0.0090
70.00	0.566E+01	0.552E+01	0.134E+00	2.42	12	0.6039	0.0113
80.00	0.703E+01	0.690E+01	0.129E+00	1.88	13	0.6153	0.0141
90.00	0.866E+01	0.855E+01	0.117E+00	1.37	14	0.6267	0.0174
100.00	0.106E+02	0.105E+02	0.101E+00	0.97	15	0.6381	0.0212
110.00	0.128E+02	0.128E+02	0.630E-01	0.49	16	0.6495	0.0257
120.00	0.154E+02	0.154E+02	0.239E-01	0.16	17	0.6609	0.0309
130.00	0.184E+02	0.185E+02	-0.275E-01	-0.15	18	0.6723	0.0369
140.00	0.219E+02	0.219E+02	-0.711E-01	-0.32	19	0.6837	0.0438
150.00	0.258E+02	0.259E+02	-0.155E+00	-0.60	20	0.6951	0.0517
160.00	0.302E+02	0.304E+02	-0.225E+00	-0.74	21	0.7065	0.0606
170.00	0.352E+02	0.355E+02	-0.307E+00	-0.86	22	0.7179	0.0706
180.00	0.408E+02	0.412E+02	-0.373E+00	-0.91	23	0.7293	0.0819
190.00	0.471E+02	0.476E+02	-0.465E+00	-0.98	24	0.7407	0.0945
200.00	0.541E+02	0.547E+02	-0.523E+00	-0.96	25	0.7521	0.1085
210.00	0.619E+02	0.625E+02	-0.596E+00	-0.95	26	0.7635	0.1241
220.00	0.705E+02	0.711E+02	-0.580E+00	-0.82	27	0.7749	0.1413
230.00	0.799E+02	0.813E+02	-0.132E+01	-1.63	28	0.7863	0.1602
240.00	0.903E+02	0.915E+02	-0.113E+01	-1.24	29	0.7977	0.1811
250.00	0.102E+03	0.102E+03	-0.918E-01	-0.09	30	0.8091	0.2039
260.00	0.114E+03	0.114E+03	0.566E+00	0.50	31	0.8205	0.2288
270.00	0.128E+03	0.127E+03	0.328E+00	0.26	32	0.8319	0.2559
280.00	0.142E+03	0.142E+03	0.257E+00	0.18	33	0.8433	0.2853
290.00	0.158E+03	0.158E+03	0.416E+00	0.26	34	0.8547	0.3172
300.00	0.175E+03	0.176E+03	-0.131E+00	-0.07	35	0.8661	0.3517
310.00	0.194E+03	0.193E+03	0.905E+00	0.47	36	0.8776	0.3889
320.00	0.214E+03	0.214E+03	0.371E+00	0.17	37	0.8890	0.4290
330.00	0.236E+03	0.235E+03	0.339E+00	0.14	38	0.9004	0.4722
340.00	0.259E+03	0.258E+03	0.879E+00	0.34	39	0.9118	0.5184
350.00	0.283E+03	0.283E+03	0.681E-01	0.02	40	0.9232	0.5680
360.00	0.310E+03	0.310E+03	0.227E-01	0.01	41	0.9346	0.6210
370.00	0.338E+03	0.338E+03	0.819E-01	0.02	42	0.9460	0.6777
380.00	0.368E+03	0.368E+03	0.129E+00	0.04	43	0.9574	0.7381
390.00	0.400E+03	0.400E+03	0.348E+00	0.09	44	0.9688	0.8025
400.00	0.435E+03	0.434E+03	0.228E+00	0.05	45	0.9802	0.8710
410.00	0.471E+03	0.471E+03	0.261E+00	0.06	46	0.9916	0.9438

AAD= 2.206517
SD1= 0.4079235
SD2= 4.0156055E-02

TABLE E7

```
********************
PRESSURE COMPARISON
********************

-------------------------------------------------------------------------------------------------------
TEMP      PRESSURE  PSIA          ABS          PERCENT        N          TR            PR
DEG F     CALCD     PUBLD         ERROR        ERROR
-------------------------------------------------------------------------------------------------------
-40.00   0.708E+01  0.744E+01  -0.362E+00     -4.86          1        0.6030        0.0109
-30.00   0.932E+01  0.967E+01  -0.347E+00     -3.59          2        0.6174        0.0143
-20.00   0.121E+02  0.124E+02  -0.315E+00     -2.54          3        0.6317        0.0186
-10.00   0.155E+02  0.158E+02  -0.263E+00     -1.67          4        0.6461        0.0238
  0.00   0.196E+02  0.198E+02  -0.192E+00     -0.97          5        0.6605        0.0301
 10.00   0.246E+02  0.247E+02  -0.104E+00     -0.42          6        0.6749        0.0377
 20.00   0.304E+02  0.304E+02  -0.126E-02      0.00          7        0.6892        0.0467
 30.00   0.374E+02  0.372E+02   0.113E+00      0.30          8        0.7036        0.0573
 40.00   0.454E+02  0.452E+02   0.230E+00      0.51          9        0.7180        0.0696
 50.00   0.547E+02  0.544E+02   0.348E+00      0.64         10        0.7323        0.0840
 60.00   0.655E+02  0.650E+02   0.456E+00      0.70         11        0.7467        0.1004
 70.00   0.778E+02  0.772E+02   0.547E+00      0.71         12        0.7611        0.1193
 80.00   0.917E+02  0.911E+02   0.613E+00      0.67         13        0.7754        0.1407
 90.00   0.107E+03  0.107E+03   0.645E+00      0.60         14        0.7898        0.1649
100.00   0.125E+03  0.125E+03   0.638E+00      0.51         15        0.8042        0.1921
110.00   0.145E+03  0.145E+03   0.585E+00      0.40         16        0.8185        0.2226
120.00   0.167E+03  0.167E+03   0.483E+00      0.29         17        0.8329        0.2565
130.00   0.192E+03  0.192E+03   0.333E+00      0.17         18        0.8473        0.2942
140.00   0.219E+03  0.219E+03   0.136E+00      0.06         19        0.8616        0.3360
150.00   0.249E+03  0.249E+03  -0.968E-01     -0.04         20        0.8760        0.3820
160.00   0.282E+03  0.282E+03  -0.355E+00     -0.13         21        0.8904        0.4325
170.00   0.318E+03  0.319E+03  -0.616E+00     -0.19         22        0.9047        0.4879
180.00   0.358E+03  0.358E+03  -0.854E+00     -0.24         23        0.9191        0.5484
190.00   0.401E+03  0.402E+03  -0.103E+01     -0.26         24        0.9335        0.6144
200.00   0.447E+03  0.448E+03  -0.110E+01     -0.25         25        0.9478        0.6862
210.00   0.498E+03  0.499E+03  -0.101E+01     -0.20         26        0.9622        0.7640

AAD=    0.8051299
SD1=    0.5522523
SD2=    1.4181199E-02
```

```
**************************
LIQUID DENSITY COMPARISON
**************************
```

TABLE E7 CONTINUED

```
-------------------------------------------------------------------------------------------------------
TEMP      DENS IN LB/FT3          ABS          PERCENT        N          TR            PR
DEG F     CALCD     PUBLD         ERROR        ERROR
-------------------------------------------------------------------------------------------------------
-40.00   0.608E+02  0.649E+02  -0.416E+01     -6.40          1        0.6030        0.0109
-30.00   0.602E+02  0.643E+02  -0.408E+01     -6.35          2        0.6174        0.0143
-20.00   0.596E+02  0.636E+02  -0.402E+01     -6.33          3        0.6317        0.0186
-10.00   0.589E+02  0.629E+02  -0.397E+01     -6.32          4        0.6461        0.0238
  0.00   0.583E+02  0.622E+02  -0.393E+01     -6.33          5        0.6605        0.0301
 10.00   0.576E+02  0.615E+02  -0.391E+01     -6.36          6        0.6749        0.0377
 20.00   0.568E+02  0.607E+02  -0.389E+01     -6.41          7        0.6892        0.0467
 30.00   0.561E+02  0.600E+02  -0.389E+01     -6.48          8        0.7036        0.0573
 40.00   0.553E+02  0.592E+02  -0.390E+01     -6.58          9        0.7180        0.0696
 50.00   0.545E+02  0.584E+02  -0.392E+01     -6.71         10        0.7323        0.0840
 60.00   0.536E+02  0.576E+02  -0.396E+01     -6.87         11        0.7467        0.1004
 70.00   0.527E+02  0.567E+02  -0.401E+01     -7.07         12        0.7611        0.1193
 80.00   0.518E+02  0.559E+02  -0.408E+01     -7.30         13        0.7754        0.1407
 90.00   0.508E+02  0.550E+02  -0.416E+01     -7.56         14        0.7898        0.1649
100.00   0.498E+02  0.540E+02  -0.426E+01     -7.88         15        0.8042        0.1921
110.00   0.487E+02  0.530E+02  -0.437E+01     -8.24         16        0.8185        0.2226
120.00   0.475E+02  0.520E+02  -0.450E+01     -8.65         17        0.8329        0.2565
130.00   0.463E+02  0.509E+02  -0.465E+01     -9.13         18        0.8473        0.2942
140.00   0.450E+02  0.498E+02  -0.481E+01     -9.66         19        0.8616        0.3360
150.00   0.436E+02  0.486E+02  -0.499E+01    -10.28         20        0.8760        0.3820
160.00   0.421E+02  0.473E+02  -0.519E+01    -10.98         21        0.8904        0.4325
170.00   0.405E+02  0.459E+02  -0.540E+01    -11.77         22        0.9047        0.4879
180.00   0.387E+02  0.444E+02  -0.563E+01    -12.69         23        0.9191        0.5484
190.00   0.368E+02  0.427E+02  -0.586E+01    -13.73         24        0.9335        0.6144
200.00   0.346E+02  0.407E+02  -0.609E+01    -14.95         25        0.9478        0.6862
210.00   0.322E+02  0.384E+02  -0.629E+01    -16.36         26        0.9622        0.7640

AAD=     8.745539
SD1=     4.686991
SD2=    9.3973741E-02
```

R718

```
*******************
PRESSURE COMPARISON
*******************
```

TABLE E8

```
---------------------------------------------------------------------------------------------------------------
TEMP        PRESSURE   PSIA          ABS          PERCENT        N           TR              PR
DEG F       CALCD      PUBLD         ERROR        ERROR
---------------------------------------------------------------------------------------------------------------
  0.00    0.571E+03  0.611E+03  -0.404E+02     -6.61          1        0.4220          0.0000
 10.00    0.116E+04  0.123E+04  -0.631E+02     -5.14          2        0.4374          0.0001
 20.00    0.225E+04  0.234E+04  -0.926E+02     -3.96          3        0.4529          0.0001
 30.00    0.412E+04  0.425E+04  -0.121E+03     -2.86          4        0.4683          0.0002
 40.00    0.725E+04  0.738E+04  -0.136E+03     -1.84          5        0.4838          0.0003
 50.00    0.122E+05  0.123E+05  -0.116E+03     -0.94          6        0.4992          0.0006
 60.00    0.199E+05  0.199E+05  -0.300E+02     -0.15          7        0.5147          0.0009
 70.00    0.314E+05  0.312E+05   0.166E+03      0.53          8        0.5301          0.0014
 80.00    0.479E+05  0.474E+05   0.538E+03      1.14          9        0.5456          0.0022
 90.00    0.713E+05  0.701E+05   0.116E+04      1.65         10        0.5610          0.0032
100.00    0.103E+06  0.101E+06   0.211E+04      2.08         11        0.5765          0.0047
110.00    0.147E+06  0.143E+06   0.350E+04      2.44         12        0.5919          0.0067
120.00    0.204E+06  0.199E+06   0.542E+04      2.73         13        0.6074          0.0093
130.00    0.278E+06  0.270E+06   0.798E+04      2.95         14        0.6228          0.0126
140.00    0.373E+06  0.361E+06   0.113E+05      3.13         15        0.6383          0.0169
150.00    0.491E+06  0.476E+06   0.156E+05      3.27         16        0.6537          0.0223
160.00    0.639E+06  0.618E+06   0.207E+05      3.36         17        0.6692          0.0290
170.00    0.819E+06  0.792E+06   0.269E+05      3.40         18        0.6846          0.0371
180.00    0.104E+07  0.100E+07   0.344E+05      3.43         19        0.7001          0.0470
190.00    0.130E+07  0.125E+07   0.429E+05      3.42         20        0.7155          0.0588
200.00    0.161E+07  0.155E+07   0.529E+05      3.40         21        0.7310          0.0729
210.00    0.197E+07  0.191E+07   0.640E+05      3.36         22        0.7464          0.0894
220.00    0.239E+07  0.232E+07   0.762E+05      3.29         23        0.7619          0.1086
230.00    0.288E+07  0.280E+07   0.899E+05      3.21         24        0.7773          0.1308
240.00    0.345E+07  0.334E+07   0.105E+06      3.14         25        0.7928          0.1564
250.00    0.409E+07  0.397E+07   0.120E+06      3.03         26        0.8082          0.1857
260.00    0.483E+07  0.469E+07   0.137E+06      2.93         27        0.8237          0.2189
270.00    0.565E+07  0.550E+07   0.154E+06      2.80         28        0.8391          0.2564
280.00    0.658E+07  0.641E+07   0.171E+06      2.67         29        0.8546          0.2986
290.00    0.762E+07  0.744E+07   0.188E+06      2.53         30        0.8700          0.3458
300.00    0.879E+07  0.858E+07   0.204E+06      2.38         31        0.8855          0.3965
310.00    0.101E+08  0.986E+07   0.219E+06      2.22         32        0.9009          0.4569
320.00    0.115E+08  0.113E+08   0.228E+06      2.02         33        0.9164          0.5217
330.00    0.131E+08  0.128E+08   0.232E+06      1.80         34        0.9318          0.5931
340.00    0.148E+08  0.146E+08   0.223E+06      1.53         35        0.9473          0.6717
350.00    0.167E+08  0.165E+08   0.197E+06      1.19         36        0.9627          0.7579
360.00    0.188E+08  0.187E+08   0.139E+06      0.74         37        0.9782          0.8522
370.00    0.211E+08  0.210E+08   0.312E+05      0.15         38        0.9936          0.9552

AAD=      2.564522
SD1=      111741.2
SD2=    2.9003220E-02
```

R500

TABLE E9

```
*******************
PRESSURE COMPARISON
*******************

------------------------------------------------------------------------------------------------
 TEMP        PRESSURE   PSIA          ABS          PERCENT       N          TR            PR
 DEG F       CALCD     PUBLD         ERROR         ERROR
------------------------------------------------------------------------------------------------
-40.00    0.107E+02  0.109E+02 -0.242E+00      -2.21         1        0.6158        0.0167
-30.00    0.138E+02  0.141E+02 -0.289E+00      -2.05         2        0.6304        0.0215
-20.00    0.176E+02  0.179E+02 -0.334E+00      -1.87         3        0.6451        0.0274
-10.00    0.221E+02  0.225E+02 -0.395E+00      -1.75         4        0.6598        0.0345
  0.00    0.275E+02  0.280E+02 -0.449E+00      -1.60         5        0.6744        0.0429
 10.00    0.339E+02  0.344E+02 -0.521E+00      -1.51         6        0.6891        0.0528
 20.00    0.414E+02  0.420E+02 -0.589E+00      -1.40         7        0.7038        0.0645
 30.00    0.500E+02  0.507E+02 -0.666E+00      -1.31         8        0.7185        0.0779
 40.00    0.600E+02  0.608E+02 -0.733E+00      -1.21         9        0.7331        0.0935
 50.00    0.714E+02  0.723E+02 -0.812E+00      -1.12        10        0.7478        0.1113
 60.00    0.845E+02  0.853E+02 -0.875E+00      -1.03        11        0.7625        0.1316
 70.00    0.992E+02  0.100E+03 -0.927E+00      -0.93        12        0.7771        0.1545
 80.00    0.116E+03  0.117E+03 -0.960E+00      -0.82        13        0.7918        0.1803
 90.00    0.134E+03  0.135E+03 -0.100E+01      -0.74        14        0.8065        0.2092
100.00    0.155E+03  0.156E+03 -0.902E+00      -0.58        15        0.8212        0.2415
110.00    0.178E+03  0.179E+03 -0.813E+00      -0.45        16        0.8358        0.2773
120.00    0.203E+03  0.204E+03 -0.679E+00      -0.33        17        0.8505        0.3169
130.00    0.231E+03  0.232E+03 -0.438E+00      -0.19        18        0.8652        0.3606
140.00    0.262E+03  0.262E+03 -0.125E+00      -0.05        19        0.8798        0.4086
150.00    0.296E+03  0.296E+03  0.231E+00       0.08        20        0.8945        0.4612
160.00    0.333E+03  0.332E+03  0.806E+00       0.24        21        0.9092        0.5186
170.00    0.373E+03  0.372E+03  0.138E+01       0.37        22        0.9239        0.5812
180.00    0.417E+03  0.415E+03  0.215E+01       0.52        23        0.9385        0.6492
190.00    0.464E+03  0.461E+03  0.311E+01       0.67        24        0.9532        0.7230
200.00    0.515E+03  0.511E+03  0.426E+01       0.83        25        0.9679        0.8029
210.00    0.571E+03  0.567E+03  0.342E+01       0.60        26        0.9825        0.8891
220.00    0.630E+03  0.630E+03  0.710E+00       0.11        27        0.9972        0.9821

AAD=    0.9106809
SD1=     1.465343
SD2=    1.1217823E-02
```

TABLE E9 CONTINUED

```
*************************
LIQUID DENSITY COMPARISON
*************************

------------------------------------------------------------------------------------------------
 TEMP        DENS  IN  LB/FT3         ABS          PERCENT       N          TR            PR
 DEG F       CALCD     PUBLD         ERROR         ERROR
------------------------------------------------------------------------------------------------
-40.00    0.904E+02  0.843E+02  0.609E+01       7.23         1        0.6158        0.0167
-30.00    0.894E+02  0.833E+02  0.606E+01       7.27         2        0.6304        0.0215
-20.00    0.884E+02  0.824E+02  0.601E+01       7.29         3        0.6451        0.0274
-10.00    0.874E+02  0.814E+02  0.593E+01       7.28         4        0.6598        0.0345
  0.00    0.863E+02  0.805E+02  0.583E+01       7.25         5        0.6744        0.0429
 10.00    0.852E+02  0.795E+02  0.571E+01       7.19         6        0.6891        0.0528
 20.00    0.840E+02  0.784E+02  0.556E+01       7.09         7        0.7038        0.0645
 30.00    0.828E+02  0.774E+02  0.537E+01       6.94         8        0.7185        0.0779
 40.00    0.815E+02  0.763E+02  0.517E+01       6.77         9        0.7331        0.0935
 50.00    0.802E+02  0.753E+02  0.493E+01       6.55        10        0.7478        0.1113
 60.00    0.788E+02  0.741E+02  0.465E+01       6.27        11        0.7625        0.1316
 70.00    0.773E+02  0.730E+02  0.435E+01       5.97        12        0.7771        0.1545
 80.00    0.758E+02  0.718E+02  0.401E+01       5.59        13        0.7918        0.1803
 90.00    0.742E+02  0.706E+02  0.364E+01       5.15        14        0.8065        0.2092
100.00    0.725E+02  0.693E+02  0.322E+01       4.65        15        0.8212        0.2415
110.00    0.707E+02  0.679E+02  0.276E+01       4.05        16        0.8358        0.2773
120.00    0.688E+02  0.666E+02  0.225E+01       3.39        17        0.8505        0.3169
130.00    0.668E+02  0.651E+02  0.170E+01       2.61        18        0.8652        0.3606
140.00    0.646E+02  0.635E+02  0.111E+01       1.74        19        0.8798        0.4086
150.00    0.623E+02  0.618E+02  0.454E+00       0.73        20        0.8945        0.4612
160.00    0.598E+02  0.600E+02 -0.252E+00      -0.42        21        0.9092        0.5186
170.00    0.570E+02  0.580E+02 -0.101E+01      -1.74        22        0.9239        0.5812
180.00    0.540E+02  0.558E+02 -0.182E+01      -3.26        23        0.9385        0.6492
190.00    0.506E+02  0.533E+02 -0.270E+01      -5.06        24        0.9532        0.7230
200.00    0.465E+02  0.502E+02 -0.362E+01      -7.21        25        0.9679        0.8029
210.00    0.415E+02  0.460E+02 -0.451E+01      -9.80        26        0.9825        0.8891
220.00    0.336E+02  0.384E+02 -0.476E+01     -12.39        27        0.9972        0.9821

AAD=     5.589523
SD1=     4.330630
SD2=    6.3139342E-02
```

```
 ***************
 LIQUID ENTHALPY                                                                      TABLE E9  CONTINUED
 ***************

-------------------------------------------------------------------------------------------------------------------
 TEMP         H IN BTU/LB           ABS          PERCENT        N            TR                PR
 DEG F      CALCD      PUBLD         ERROR         ERROR
-------------------------------------------------------------------------------------------------------------------
-40.00    0.000E+00  0.000E+00  0.000E+00      0.00          1         0.6158            0.0167
-30.00    0.259E+01  0.238E+01  0.211E+00      8.85          2         0.6304            0.0215
-20.00    0.520E+01  0.479E+01  0.411E+00      8.59          3         0.6451            0.0274
-10.00    0.784E+01  0.722E+01  0.615E+00      8.52          4         0.6598            0.0345
  0.00    0.105E+02  0.971E+01  0.785E+00      8.09          5         0.6744            0.0429
 10.00    0.132E+02  0.122E+02  0.954E+00      7.80          6         0.6891            0.0528
 20.00    0.159E+02  0.148E+02  0.112E+01      7.55          7         0.7038            0.0645
 30.00    0.187E+02  0.174E+02  0.126E+01      7.26          8         0.7185            0.0779
 40.00    0.215E+02  0.200E+02  0.141E+01      7.04          9         0.7331            0.0935
 50.00    0.243E+02  0.228E+02  0.155E+01      6.82         10         0.7478            0.1113
 60.00    0.272E+02  0.255E+02  0.171E+01      6.72         11         0.7625            0.1316
 70.00    0.301E+02  0.283E+02  0.185E+01      6.55         12         0.7771            0.1545
 80.00    0.331E+02  0.311E+02  0.201E+01      6.47         13         0.7918            0.1803
 90.00    0.362E+02  0.340E+02  0.219E+01      6.44         14         0.8065            0.2092
100.00    0.393E+02  0.370E+02  0.237E+01      6.40         15         0.8212            0.2415
110.00    0.426E+02  0.400E+02  0.255E+01      6.38         16         0.8358            0.2773
120.00    0.459E+02  0.431E+02  0.276E+01      6.41         17         0.8505            0.3169
130.00    0.493E+02  0.463E+02  0.298E+01      6.45         18         0.8652            0.3606
140.00    0.528E+02  0.496E+02  0.322E+01      6.50         19         0.8798            0.4086
150.00    0.565E+02  0.530E+02  0.349E+01      6.59         20         0.8945            0.4612
160.00    0.603E+02  0.565E+02  0.380E+01      6.73         21         0.9092            0.5186
170.00    0.644E+02  0.602E+02  0.414E+01      6.88         22         0.9239            0.5812
180.00    0.687E+02  0.641E+02  0.454E+01      7.08         23         0.9385            0.6492
190.00    0.733E+02  0.683E+02  0.503E+01      7.36         24         0.9532            0.7230
200.00    0.785E+02  0.729E+02  0.566E+01      7.77         25         0.9679            0.8029
210.00    0.847E+02  0.768E+02  0.793E+01     10.33         26         0.9825            0.8891
220.00    0.937E+02  0.860E+02  0.767E+01      8.92         27         0.9972            0.9821

AAD=      7.055314
SD1=      3.436757
SD2=    7.3944241E-02

 ***************
 VAPOUR ENTHALPY                                                                      TABLE E9  CONTINUED
 ***************

-------------------------------------------------------------------------------------------------------------------
 TEMP          BTU/LB               ABS          PERCENT        N            TR                PR
 DEG F      CALCD      PUBLD         ERROR         ERROR
-------------------------------------------------------------------------------------------------------------------
-40.00    0.895E+02  0.877E+02  0.178E+01      2.03          1         0.6158            0.0167
-30.00    0.910E+02  0.890E+02  0.199E+01      2.24          2         0.6304            0.0215
-20.00    0.925E+02  0.903E+02  0.222E+01      2.45          3         0.6451            0.0274
-10.00    0.940E+02  0.916E+02  0.243E+01      2.65          4         0.6598            0.0345
  0.00    0.954E+02  0.928E+02  0.264E+01      2.85          5         0.6744            0.0429
 10.00    0.969E+02  0.940E+02  0.283E+01      3.01          6         0.6891            0.0528
 20.00    0.983E+02  0.952E+02  0.303E+01      3.18          7         0.7038            0.0645
 30.00    0.996E+02  0.964E+02  0.322E+01      3.34          8         0.7185            0.0779
 40.00    0.101E+03  0.975E+02  0.340E+01      3.49          9         0.7331            0.0935
 50.00    0.102E+03  0.986E+02  0.357E+01      3.62         10         0.7478            0.1113
 60.00    0.103E+03  0.997E+02  0.374E+01      3.76         11         0.7625            0.1316
 70.00    0.105E+03  0.101E+03  0.390E+01      3.87         12         0.7771            0.1545
 80.00    0.106E+03  0.102E+03  0.404E+01      3.97         13         0.7918            0.1803
 90.00    0.107E+03  0.103E+03  0.417E+01      4.06         14         0.8065            0.2092
100.00    0.108E+03  0.104E+03  0.429E+01      4.14         15         0.8212            0.2415
110.00    0.109E+03  0.104E+03  0.439E+01      4.20         16         0.8358            0.2773
120.00    0.110E+03  0.105E+03  0.446E+01      4.24         17         0.8505            0.3169
130.00    0.110E+03  0.106E+03  0.453E+01      4.28         18         0.8652            0.3606
140.00    0.111E+03  0.107E+03  0.457E+01      4.29         19         0.8798            0.4086
150.00    0.112E+03  0.107E+03  0.459E+01      4.29         20         0.8945            0.4612
160.00    0.112E+03  0.107E+03  0.457E+01      4.26         21         0.9092            0.5186
170.00    0.112E+03  0.108E+03  0.453E+01      4.21         22         0.9239            0.5812
180.00    0.112E+03  0.107E+03  0.445E+01      4.14         23         0.9385            0.6492
190.00    0.111E+03  0.107E+03  0.431E+01      4.02         24         0.9532            0.7230
200.00    0.110E+03  0.106E+03  0.408E+01      3.83         25         0.9679            0.8029
210.00    0.108E+03  0.104E+03  0.400E+01      3.83         26         0.9825            0.8891
220.00    0.103E+03  0.987E+02  0.444E+01      4.50         27         0.9972            0.9821

AAD=      3.657464
SD1=      3.882189
SD2=    3.7921775E-02
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PERCHLOROETHYLENE

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********************
PRESSURE COMPARISON                                                        TABLE E10
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------------------------------------------------------------------------------------------
TEMP      PRESSURE  PSIA           ABS       PERCENT     N         TR            PR
DEG F     CALCD     PUBLD          ERROR     ERROR
------------------------------------------------------------------------------------------
-40.00   0.229E+02  0.211E+02  0.170E+01     8.05        1       0.3761        0.0000
-30.00   0.598E+02  0.543E+02  0.553E+01    10.19        2       0.3922        0.0000
-20.00   0.134E+03  0.127E+03  0.756E+01     5.96        3       0.4083        0.0000
-10.00   0.281E+03  0.274E+03  0.740E+01     2.70        4       0.4245        0.0001
  0.00   0.552E+03  0.550E+03  0.184E+01     0.33        5       0.4406        0.0001
 10.00   0.103E+04  0.104E+04 -0.120E+02    -1.15        6       0.4567        0.0002
 20.00   0.183E+04  0.187E+04 -0.459E+02    -2.45        7       0.4728        0.0004
 30.00   0.310E+04  0.321E+04 -0.106E+03    -3.30        8       0.4890        0.0007
 40.00   0.507E+04  0.527E+04 -0.203E+03    -3.86        9       0.5051        0.0011
 50.00   0.801E+04  0.836E+04 -0.352E+03    -4.21       10       0.5212        0.0017
 60.00   0.123E+05  0.128E+05 -0.567E+03    -4.42       11       0.5374        0.0026
 70.00   0.182E+05  0.191E+05 -0.868E+03    -4.54       12       0.5535        0.0038
 80.00   0.264E+05  0.277E+05 -0.127E+04    -4.60       13       0.5696        0.0056
 90.00   0.375E+05  0.393E+05 -0.180E+04    -4.59       14       0.5857        0.0079
100.00   0.519E+05  0.544E+05 -0.248E+04    -4.55       15       0.6019        0.0109
110.00   0.706E+05  0.740E+05 -0.332E+04    -4.49       16       0.6180        0.0148
120.00   0.944E+05  0.987E+05 -0.435E+04    -4.41       17       0.6341        0.0198
130.00   0.124E+06  0.130E+06 -0.558E+04    -4.31       18       0.6503        0.0260
140.00   0.161E+06  0.168E+06 -0.701E+04    -4.19       19       0.6664        0.0337
150.00   0.205E+06  0.214E+06 -0.865E+04    -4.04       20       0.6825        0.0431
160.00   0.259E+06  0.269E+06 -0.105E+05    -3.88       21       0.6986        0.0543
170.00   0.323E+06  0.335E+06 -0.124E+05    -3.70       22       0.7148        0.0677
180.00   0.398E+06  0.412E+06 -0.144E+05    -3.49       23       0.7309        0.0836
190.00   0.486E+06  0.503E+06 -0.164E+05    -3.25       24       0.7470        0.1021
200.00   0.589E+06  0.607E+06 -0.181E+05    -2.99       25       0.7632        0.1236
210.00   0.707E+06  0.726E+06 -0.195E+05    -2.68       26       0.7793        0.1484
220.00   0.842E+06  0.862E+06 -0.202E+05    -2.35       27       0.7954        0.1767
230.00   0.996E+06  0.102E+07 -0.200E+05    -1.97       28       0.8115        0.2090
240.00   0.117E+07  0.119E+07 -0.184E+05    -1.55       29       0.8277        0.2455
250.00   0.137E+07  0.138E+07 -0.151E+05    -1.09       30       0.8438        0.2866
260.00   0.158E+07  0.159E+07 -0.931E+04    -0.58       31       0.8599        0.3326
270.00   0.183E+07  0.183E+07 -0.525E+03    -0.03       32       0.8761        0.3840
280.00   0.210E+07  0.209E+07  0.121E+05     0.58       33       0.8922        0.4410
290.00   0.240E+07  0.237E+07  0.293E+05     1.24       34       0.9083        0.5042
300.00   0.273E+07  0.268E+07  0.523E+05     1.95       35       0.9245        0.5739
310.00   0.310E+07  0.302E+07  0.821E+05     2.72       36       0.9406        0.6505
320.00   0.350E+07  0.338E+07  0.120E+06     3.55       37       0.9567        0.7346
330.00   0.394E+07  0.377E+07  0.168E+06     4.44       38       0.9728        0.8265
340.00   0.442E+07  0.419E+07  0.226E+06     5.40       39       0.9890        0.9268
350.00   0.493E+07  0.464E+07  0.294E+06     6.33       40       1.0051        1.0352

AAD=     3.503570
SD1=     70456.25
SD2=    4.0931337E-02
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R13B1 — R152a

E11

BROMOTRIFLUOROMETHANE AND DIFLUOROETHANE

TEMP	PRESSURE (PA)		LIQ MASS CONC		LIQ MOL CONC		VAP MASS CONC		VAP MOL CONC	
DEG C	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC
-17.80	0.30310E+06	0.30871E+06			0.2491				0.6296	0.6321
-17.80	0.39543E+06	0.38924E+06			0.4985				0.7593	0.7625
-17.80	0.45125E+06	0.44387E+06			0.7483				0.8570	0.8598
-17.80	0.32655E+06	0.33954E+06			0.3277				0.6817	0.6845
-17.80	0.36172E+06	0.36145E+06			0.3956				0.7162	0.7192
-17.80	0.39410E+06	0.39045E+06			0.5034				0.7612	0.7644
-17.80	0.42714E+06	0.42087E+06			0.6370				0.8119	0.8151
-17.80	0.46032E+06	0.45354E+06			0.7974				0.8792	0.8817
-17.80	0.48443E+06	0.47855E+06			0.9343				0.9541	0.9552
-17.70	0.48989E+06	0.48708E+06			0.9774				0.9833	0.9837
-17.60	0.49055E+06	0.49204E+06			1.0000				1.0000	1.0000
25.00	0.10349E+07	0.10381E+07			0.2475				0.5041	0.4977
25.00	0.13070E+07	0.12968E+07			0.4959				0.6811	0.6771
25.00	0.15055E+07	0.14843E+07			0.7465				0.8229	0.8210
25.00	0.16174E+07	0.16192E+07			1.0000				1.0000	1.0000
54.40	0.20091E+07	0.20099E+07			0.2440				0.4187	0.4121
54.40	0.25061E+07	0.24850E+07			0.4932				0.6185	0.6135
54.40	0.28711E+07	0.28490E+07			0.7448				0.7920	0.7896
54.40	0.30923E+07	0.30969E+07			1.0000				1.0000	1.0000

R11 — R22

E12

CHLORODIFLUOROMETHANE AND TRICHLOROFLUOROMETHANE

TEMP	PRESSURE (PA)		LIQ MASS CONC		LIQ MOL CONC		VAP MASS CONC		VAP MOL CONC	
DEG C	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC
25.00	0.31000E+06	0.29925E+06			0.1568				0.6788	0.6847
25.00	0.40000E+06	0.40975E+06			0.2590				0.7831	0.7869
25.00	0.51000E+06	0.53396E+06			0.3884				0.8521	0.8543
25.00	0.66000E+06	0.66486E+06			0.5426				0.9010	0.9018
25.00	0.78000E+06	0.78392E+06			0.6942				0.9355	0.9356
25.00	0.90000E+06	0.90821E+06			0.8505				0.9672	0.9669
25.00	0.92000E+06	0.92485E+06			0.8704				0.9713	0.9710
50.00	0.57000E+06	0.55598E+06			0.1568				0.6073	0.6130
50.00	0.74000E+06	0.74634E+06			0.2590				0.7254	0.7294
50.00	0.96000E+06	0.96726E+06			0.3884				0.8085	0.8108
50.00	0.12000E+07	0.12089E+07			0.5426				0.8698	0.8708
50.00	0.14300E+07	0.14366E+07			0.6942				0.9145	0.9146
50.00	0.16800E+07	0.16804E+07			0.8505				0.9562	0.9560
50.00	0.17100E+07	0.17134E+07			0.8704				0.9617	0.9614
75.00	0.96000E+06	0.94668E+06			0.1568				0.5353	0.5409
75.00	0.12300E+07	0.12444E+07			0.2590				0.6626	0.6663
75.00	0.15900E+07	0.16001E+07			0.3884				0.7572	0.7594
75.00	0.19800E+07	0.20032E+07			0.5426				0.8303	0.8312
75.00	0.23700E+07	0.23974E+07			0.6942				0.8855	0.8856
89.00	0.12500E+07	0.12364E+07			0.1568				0.4958	0.5004
95.00	0.17700E+07	0.17799E+07			0.2590				0.6080	0.6114
100.00	0.30500E+07	0.30756E+07			0.5426				0.7775	0.7781

R12 — R152a

E13

DICHLORODIFLUOROMETHANE AND DIFLUOROETHANE

TEMP	PRESSURE (PA)		LIQ MASS CONC		LIQ MOL CONC		VAP MASS CONC		VAP MOL CONC	
DEG C	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC
0.00	0.30868E+06	0.30925E+06	1.0000				1.0000	1.0000		
0.00	0.33605E+06	0.33208E+06	0.9499				0.9224	0.9182		
0.00	0.35004E+06	0.34608E+06	0.8998				0.8632	0.8571		
0.00	0.35818E+06	0.35445E+06	0.8499				0.8219	0.8090		
0.00	0.36197E+06	0.35906E+06	0.8018				0.7849	0.7705		
0.00	0.36280E+06	0.36059E+06	0.7747				0.7610	0.7511		
0.00	0.36342E+06	0.36146E+06	0.7496				0.7449	0.7342		
0.00	0.36349E+06	0.36168E+06	0.7395				0.7410	0.7276		
0.00	0.36342E+06	0.36177E+06	0.7348				0.7367	0.7246		
0.00	0.36349E+06	0.36183E+06	0.7302				0.7336	0.7217		
0.00	0.36328E+06	0.36193E+06	0.7200				0.7253	0.7154		
0.00	0.36287E+06	0.36195E+06	0.6984				0.7078	0.7022		
0.00	0.35832E+06	0.35912E+06	0.5972				0.6455	0.6440		
0.00	0.35025E+06	0.35285E+06	0.5001				0.5685	0.5885		
0.00	0.33881E+06	0.34290E+06	0.3974				0.4918	0.5237		
0.00	0.32336E+06	0.32889E+06	0.2912				0.3894	0.4422		
0.00	0.30681E+06	0.31354E+06	0.1997				0.2912	0.3511		
0.00	0.28682E+06	0.29282E+06	0.0993				0.1671	0.2122		

TEMP	PRESSURE (PA)		LIQ MASS CONC		LIQ MOL CONC		VAP MASS CONC		VAP MOL CONC	
DEG C	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC
-18.10	0.21450E+06	0.21244E+06			0.0360				0.2301	0.2447
-18.10	0.27210E+06	0.26850E+06			0.0791				0.3985	0.4178
-18.10	0.35670E+06	0.35988E+06			0.1535				0.5653	0.5864
-18.10	0.44910E+06	0.45757E+06			0.2392				0.6862	0.6945
-18.10	0.56120E+06	0.57001E+06			0.3461				0.7793	0.7759
-18.10	0.67470E+06	0.68136E+06			0.4602				0.8401	0.8331
-18.10	0.78590E+06	0.79626E+06			0.5841				0.8877	0.8789
-18.10	0.97230E+06	0.97887E+06			0.7817				0.9460	0.9375
-18.10	0.11052E+07	0.11089E+07			0.9123				0.9794	0.9741
-18.00	0.12078E+07	0.12086E+07			1.0000				1.0000	1.0000

E15 R12 — R2

CHLORODIFLUOROMETHANE AND DICHLORODIFLUOROMETHANE

TEMP	PRESSURE (PA)		LIQ MASS CONC		LIQ MOL CONC		VAP MASS CONC		VAP MOL CONC	
DEG C	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC
-40.80	0.10133E+06	0.10204E+06	1.0000							
-40.76	0.10133E+06	0.10254E+06	0.9860							
-40.80	0.10133E+06	0.10264E+06	0.9710							
-40.94	0.10133E+06	0.10237E+06	0.9480							
-40.89	0.10133E+06	0.10286E+06	0.9310							
-40.99	0.10133E+06	0.10264E+06	0.9100							
-41.31	0.10133E+06	0.10160E+06	0.8500							
-41.41	0.10133E+06	0.10124E+06	0.7810							
-41.41	0.10133E+06	0.10100E+06	0.7220							
-41.39	0.10133E+06	0.10071E+06	0.6750							
-41.39	0.10133E+06	0.99917E+05	0.6120							
-40.93	0.10133E+06	0.10104E+06	0.5560							
-40.73	0.10133E+06	0.10025E+06	0.4840							
-40.63	0.10133E+06	0.10004E+06	0.4610							
-40.54	0.10133E+06	0.99294E+05	0.4250							
-40.54	0.10133E+06	0.98980E+05	0.4160							
-39.84	0.10133E+06	0.99774E+05	0.3580							
-38.93	0.10133E+06	0.10092E+06	0.3010							
-38.33	0.10133E+06	0.10161E+06	0.2690							
-37.14	0.10133E+06	0.10294E+06	0.2160							
-35.87	0.10133E+06	0.10330E+06	0.1610							
-34.26	0.10133E+06	0.10354E+06	0.1060							

E16

DICHLORODIFLUOROMETHANE AND TRICHLOROTRIFLUOROETHANE

TEMP	PRESSURE (PA)		LIQ MASS CONC		LIQ MOL CONC		VAP MASS CONC		VAP MOL CONC	
DEG C	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC	PUB	CALC
50.00	0.10090E+07	0.10261E+07			0.8300				0.9700	0.9640
60.00	0.10090E+07	0.10535E+07			0.6500				0.9200	0.9180
70.00	0.10090E+07	0.10633E+07			0.5000				0.8600	0.8618
80.00	0.10090E+07	0.10492E+07			0.3750				0.7800	0.7887
90.00	0.10090E+07	0.10010E+07			0.2650				0.6800	0.6871
100.00	0.10090E+07	0.90058E+06			0.1600				0.5600	0.5306
20.00	0.42330E+06	0.44045E+06			0.7350				0.9670	0.9642
30.00	0.42330E+06	0.46482E+06			0.5450				0.9300	0.9270
40.00	0.42330E+06	0.47315E+06			0.3950				0.8700	0.8751
50.00	0.42330E+06	0.46767E+06			0.2800				0.7800	0.8012
60.00	0.42330E+06	0.45845E+06			0.1950				0.6800	0.7020
70.00	0.42330E+06	0.44890E+06			0.1300				0.5700	0.5732
80.00	0.42330E+06	0.41830E+06			0.0680				0.3800	0.3777
90.00	0.42330E+06	0.40616E+06			0.0240				0.1700	0.1576

APPENDIX F

PURE SUBSTANCE PROPERTY TABLES

Table	Fluid
F.1	R11
F.2	R12
F.3	R13
F.4	R13B1
F.5	R22
F.6	R113
F.7	R152a
F.8	R718
F.9	R500
F.10	Perchloroethylene

Nomenclature

B = Availability
D = Density
FC = Fugacity coefficient
H = Enthalpy
P = Pressure
PR = Reduced pressure
S = Entropy
T = Temperature
TR = Reduced temperature
V = Specific volume
Z = Compressibility

(F) = Liquid
(G) = Vapour
(FG) = Latent value

Note: Availability datum is 24 deg C and 101.325 KPa.

SATURATED PROPERTIES OF TRICHLOROFLUOROMETHANE REFRIGERANT 11 (CCL3F)

TABLE F1

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
-40.0	5185.8	1720.1	2.7132	0.00	199.71	199.71	0.0000	0.8565	233.2	-40.0
-30.0	9267.7	1701.2	1.5804	7.79	197.10	204.90	0.0353	0.8459	243.2	-30.0
-20.0	15730.4	1681.3	0.9669	15.68	194.45	210.13	0.0695	0.8376	253.2	-20.0
-10.0	25513.1	1660.6	0.6175	23.67	191.71	215.39	0.1028	0.8313	263.2	-10.0
0.0	39762.8	1638.8	0.4094	31.77	188.88	220.65	0.1352	0.8267	273.2	0.0
10.0	59827.9	1615.8	0.2804	39.98	185.93	225.92	0.1668	0.8235	283.2	10.0
20.0	87255.8	1591.7	0.1975	48.32	182.84	231.16	0.1978	0.8215	293.2	20.0
30.0	123777.9	1566.3	0.1427	56.78	179.58	236.36	0.2281	0.8205	303.2	30.0
40.0	171313.8	1539.4	0.1053	65.38	176.13	241.51	0.2579	0.8203	313.2	40.0
50.0	231937.9	1511.1	0.0792	74.13	172.44	246.58	0.2872	0.8208	323.2	50.0
60.0	307881.2	1481.0	0.0606	83.05	168.50	251.54	0.3161	0.8218	333.2	60.0
70.0	401512.0	1449.1	0.0470	92.14	164.25	256.39	0.3446	0.8232	343.2	70.0
80.0	515329.5	1415.1	0.0369	101.43	159.65	261.09	0.3728	0.8248	353.2	80.0
90.0	651958.3	1378.8	0.0293	110.95	154.66	265.60	0.4007	0.8266	363.2	90.0
100.0	814142.0	1340.0	0.0235	120.70	149.20	269.91	0.4286	0.8284	373.2	100.0
110.0	1004735.6	1298.2	0.0189	130.74	143.22	273.96	0.4563	0.8301	383.2	110.0
120.0	1226719.0	1253.1	0.0153	141.10	136.60	277.70	0.4841	0.8316	393.2	120.0
130.0	1483198.1	1204.0	0.0125	151.84	129.23	281.07	0.5121	0.8327	403.2	130.0
140.0	1777404.3	1150.2	0.0102	163.05	120.95	283.99	0.5404	0.8332	413.2	140.0
150.0	2112714.5	1090.7	0.0083	174.83	111.51	286.34	0.5693	0.8329	423.2	150.0
160.0	2492666.8	1023.8	0.0067	187.36	100.57	287.92	0.5992	0.8314	433.2	160.0
170.0	2920971.5	946.7	0.0054	200.94	87.51	288.44	0.6306	0.8280	443.2	170.0
180.0	3401546.8	854.3	0.0043	216.16	71.12	287.29	0.6647	0.8216	453.2	180.0
190.0	3938531.8	731.9	0.0032	234.69	48.03	282.72	0.7050	0.8087	463.2	190.0
191.0	3995503.0	716.4	0.0031	236.91	44.98	281.89	0.7097	0.8066	464.2	191.0
192.0	4053082.8	700.0	0.0030	239.24	41.68	280.92	0.7147	0.8043	465.2	192.0
193.0	4111280.0	682.2	0.0029	241.72	38.08	279.80	0.7199	0.8016	466.2	193.0
194.0	4170103.5	662.8	0.0027	244.38	34.08	278.46	0.7256	0.7985	467.2	194.0
195.0	4229551.0	641.2	0.0026	247.30	29.51	276.81	0.7318	0.7948	468.2	195.0
196.0	4289630.0	616.2	0.0025	250.60	24.03	274.64	0.7387	0.7900	469.2	196.0
197.0	4350330.0	585.7	0.0023	254.55	16.65	271.20	0.7471	0.7825	470.2	197.0

SATURATED PROPERTIES OF CCL3F F1 CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.4949	5185.8	0.0012	0.0002	0.9970	0.9973	0.9970	0.11E+02	-0.44E+02	-40.0
-30.0	0.5161	9267.7	0.0021	0.0004	0.9952	0.9955	0.9952	0.80E+01	-0.36E+02	-30.0
-20.0	0.5373	15730.4	0.0036	0.0006	0.9926	0.9928	0.9927	0.58E+01	-0.28E+02	-20.0
-10.0	0.5585	25513.1	0.0058	0.0010	0.9891	0.9893	0.9892	0.39E+01	-0.21E+02	-10.0
0.0	0.5798	39762.8	0.0090	0.0015	0.9845	0.9848	0.9848	0.23E+01	-0.14E+02	0.0
10.0	0.6010	59827.9	0.0136	0.0022	0.9787	0.9791	0.9791	0.11E+01	-0.81E+01	10.0
20.0	0.6222	87255.8	0.0198	0.0031	0.9714	0.9722	0.9721	0.26E+00	-0.22E+01	20.0
30.0	0.6434	123777.9	0.0281	0.0043	0.9626	0.9639	0.9638	-0.29E+00	0.33E+01	30.0
40.0	0.6647	171313.8	0.0389	0.0059	0.9520	0.9541	0.9541	-0.54E+00	0.85E+01	40.0
50.0	0.6859	231937.9	0.0526	0.0078	0.9397	0.9429	0.9428	-0.49E+00	0.13E+02	50.0
60.0	0.7071	307881.2	0.0698	0.0103	0.9254	0.9302	0.9301	-0.15E+00	0.18E+02	60.0
70.0	0.7283	401512.0	0.0911	0.0133	0.9090	0.9160	0.9160	0.47E+00	0.22E+02	70.0
80.0	0.7496	515329.5	0.1169	0.0170	0.8904	0.9005	0.9005	0.14E+01	0.27E+02	80.0
90.0	0.7708	651958.3	0.1479	0.0215	0.8695	0.8836	0.8836	0.26E+01	0.31E+02	90.0
100.0	0.7920	814142.0	0.1846	0.0269	0.8461	0.8655	0.8654	0.41E+01	0.34E+02	100.0
110.0	0.8132	1004735.6	0.2279	0.0334	0.8201	0.8462	0.8461	0.59E+01	0.38E+02	110.0
120.0	0.8345	1226719.0	0.2782	0.0411	0.7913	0.8258	0.8258	0.80E+01	0.41E+02	120.0
130.0	0.8557	1483198.1	0.3364	0.0505	0.7593	0.8044	0.8044	0.10E+02	0.44E+02	130.0
140.0	0.8769	1777404.3	0.4031	0.0618	0.7238	0.7823	0.7822	0.13E+02	0.47E+02	140.0
150.0	0.8981	2112714.5	0.4792	0.0756	0.6842	0.7593	0.7593	0.16E+02	0.50E+02	150.0
160.0	0.9193	2492666.8	0.5653	0.0929	0.6397	0.7358	0.7358	0.20E+02	0.52E+02	160.0
170.0	0.9406	2920971.5	0.6625	0.1150	0.5886	0.7117	0.7117	0.24E+02	0.53E+02	170.0
180.0	0.9618	3401546.8	0.7715	0.1452	0.5278	0.6873	0.6873	0.29E+02	0.54E+02	180.0
190.0	0.9830	3938531.8	0.8933	0.1920	0.4484	0.6625	0.6625	0.36E+02	0.53E+02	190.0
191.0	0.9851	3995503.0	0.9062	0.1985	0.4384	0.6600	0.6600	0.37E+02	0.53E+02	191.0
192.0	0.9873	4053082.8	0.9192	0.2057	0.4278	0.6575	0.6575	0.38E+02	0.53E+02	192.0
193.0	0.9894	4111280.0	0.9324	0.2136	0.4162	0.6550	0.6550	0.39E+02	0.52E+02	193.0
194.0	0.9915	4170103.5	0.9458	0.2225	0.4035	0.6525	0.6525	0.39E+02	0.52E+02	194.0
195.0	0.9936	4229551.0	0.9593	0.2328	0.3892	0.6500	0.6500	0.41E+02	0.51E+02	195.0
196.0	0.9958	4289630.0	0.9729	0.2451	0.3720	0.6475	0.6475	0.42E+02	0.51E+02	196.0
197.0	0.9979	4350330.0	0.9866	0.2610	0.3478	0.6450	0.6450	0.43E+02	0.49E+02	197.0

SATD COND (DEG C) (KPA) (TR)	DEGREES OF SUPERHEAT 10K V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)	20K V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)	30K V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)	40K V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)
(-40.0) (5.186) (0.4949)	2.830	204.98	0.8812	-46.1614	0.9973	2.948	210.32	0.9052	-47.9420	0.9976	3.065	215.74	0.9285	-49.4573	0.9978	3.182	221.22	0.9512	-50.7219	0.9980
(-30.0) (9.268) (0.5161)	1.646	210.25	0.8699	-37.5209	0.9957	1.712	215.67	0.8932	-39.0368	0.9961	1.778	221.16	0.9159	-40.3017	0.9964	1.843	226.71	0.9381	-41.3285	0.9968
(-20.0) (15.730) (0.5373)	1.006	215.55	0.8609	-29.5562	0.9934	1.045	221.05	0.8837	-30.8217	0.9940	1.083	226.61	0.9059	-31.8488	0.9945	1.122	232.24	0.9275	-32.6492	0.9950
(-10.0) (25.513) (0.5585)	0.642	220.89	0.8540	-22.1777	0.9902	0.666	226.46	0.8763	-23.2053	0.9911	0.690	232.10	0.8979	-24.0060	0.9918	0.714	237.80	0.9191	-24.5905	0.9925
(0.0) (39.763) (0.5798)	0.425	226.24	0.8489	-15.3037	0.9861	0.440	231.88	0.8706	-16.1048	0.9873	0.456	237.59	0.8918	-16.6892	0.9884	0.472	243.37	0.9125	-17.0671	0.9893
(10.0) (59.828) (0.6010)	0.291	231.58	0.8452	-8.8697	0.9809	0.301	237.31	0.8665	-9.4541	0.9825	0.312	243.09	0.8872	-9.8315	0.9839	0.322	248.94	0.9075	-10.0113	0.9852
(20.0) (87.256) (0.6222)	0.205	236.90	0.8428	-2.8220	0.9745	0.212	242.71	0.8636	-3.1987	0.9766	0.219	248.58	0.8840	-3.3773	0.9784	0.226	254.50	0.9038	-3.3662	0.9801
(30.0) (123.778) (0.6434)	0.148	242.19	0.8414	2.8825	0.9668	0.153	248.08	0.8618	2.7055	0.9694	0.158	254.03	0.8818	2.7187	0.9718	0.163	260.03	0.9013	2.9140	0.9739
(40.0) (171.314) (0.6647)	0.109	247.43	0.8409	8.2802	0.9577	0.113	253.41	0.8609	8.2963	0.9610	0.117	259.44	0.8805	8.4951	0.9640	0.120	265.52	0.8998	8.8689	0.9667
(50.0) (231.938) (0.6859)	0.082	252.60	0.8410	13.3991	0.9473	0.085	258.66	0.8608	13.6026	0.9513	0.088	264.78	0.8801	13.9817	0.9549	0.091	270.95	0.8990	14.5293	0.9582

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
-40.0	65562.8	1613.2	0.2386	0.00	167.91	167.91	0.0000	0.7202	233.2	-40.0
-30.0	101843.4	1582.9	0.1586	8.43	164.46	172.90	0.0382	0.7146	243.2	-30.0
-20.0	152257.6	1550.6	0.1090	17.06	160.76	177.82	0.0756	0.7106	253.2	-20.0
-10.0	220172.2	1516.0	0.0772	25.89	156.76	182.65	0.1123	0.7080	263.2	-10.0
0.0	309250.8	1479.0	0.0559	34.94	152.40	187.35	0.1484	0.7064	273.2	0.0
10.0	423426.9	1439.2	0.0414	44.25	147.63	191.88	0.1841	0.7054	283.2	10.0
20.0	566877.7	1396.2	0.0311	53.85	142.35	196.20	0.2194	0.7050	293.2	20.0
30.0	744013.8	1349.6	0.0238	63.77	136.49	200.25	0.2546	0.7048	303.2	30.0
40.0	959459.0	1298.8	0.0183	74.06	129.92	203.98	0.2897	0.7046	313.2	40.0
50.0	1218071.5	1243.0	0.0142	84.81	122.49	207.31	0.3250	0.7040	323.2	50.0
60.0	1524937.6	1181.2	0.0111	96.11	114.00	210.11	0.3607	0.7029	333.2	60.0
70.0	1885397.3	1111.7	0.0087	108.11	104.14	212.24	0.3973	0.7008	343.2	70.0
80.0	2305077.8	1032.1	0.0068	121.04	92.40	213.44	0.4353	0.6970	353.2	80.0
90.0	2789927.0	938.1	0.0052	135.37	77.89	213.26	0.4759	0.6903	363.2	90.0
100.0	3346270.5	819.3	0.0039	152.13	58.48	210.60	0.5215	0.6782	373.2	100.0
110.0	3980889.0	629.8	0.0025	176.12	24.13	200.25	0.5844	0.6474	383.2	110.0
111.0	4048918.3	595.4	0.0023	180.14	16.85	196.99	0.5948	0.6386	384.2	111.0

SATURATED PROPERTIES OF CCL2F2 CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.6054	65562.8	0.0159	0.0025	0.9757	0.9763	0.9762	0.47E+02	0.77E+00	-40.0
-30.0	0.6313	101843.4	0.0247	0.0038	0.9658	0.9669	0.9669	0.44E+02	0.74E+01	-30.0
-20.0	0.6573	152257.6	0.0370	0.0056	0.9536	0.9555	0.9555	0.41E+02	0.14E+02	-20.0
-10.0	0.6832	220172.2	0.0535	0.0080	0.9386	0.9419	0.9419	0.39E+02	0.19E+02	-10.0
0.0	0.7092	309250.8	0.0751	0.0111	0.9208	0.9262	0.9262	0.38E+02	0.24E+02	0.0
10.0	0.7352	423426.9	0.1029	0.0151	0.8999	0.9084	0.9084	0.36E+02	0.29E+02	10.0
20.0	0.7611	566877.7	0.1377	0.0201	0.8757	0.8886	0.8886	0.36E+02	0.34E+02	20.0
30.0	0.7871	744013.8	0.1808	0.0264	0.8481	0.8669	0.8669	0.35E+02	0.38E+02	30.0
40.0	0.8131	959459.0	0.2331	0.0343	0.8166	0.8436	0.8435	0.35E+02	0.41E+02	40.0
50.0	0.8390	1218071.5	0.2960	0.0441	0.7809	0.8187	0.8187	0.35E+02	0.45E+02	50.0
60.0	0.8650	1524937.6	0.3705	0.0563	0.7405	0.7925	0.7925	0.36E+02	0.48E+02	60.0
70.0	0.8910	1885397.3	0.4581	0.0719	0.6947	0.7652	0.7652	0.37E+02	0.51E+02	70.0
80.0	0.9169	2305077.8	0.5601	0.0919	0.6419	0.7369	0.7369	0.39E+02	0.53E+02	80.0
90.0	0.9429	2789927.0	0.6779	0.1191	0.5799	0.7080	0.7080	0.41E+02	0.55E+02	90.0
100.0	0.9688	3346270.5	0.8131	0.1591	0.5025	0.6784	0.6784	0.44E+02	0.56E+02	100.0
110.0	0.9948	3980889.0	0.9673	0.2399	0.3793	0.6485	0.6485	0.49E+02	0.55E+02	110.0
111.0	0.9974	4048918.3	0.9838	0.2574	0.3538	0.6455	0.6455	0.50E+02	0.54E+02	111.0

SATD COND (DEG C) (KPA) (TR)	DEGREES OF SUPERHEAT																			
	10K					20K					30K					40K				
	V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)	V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)	V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)	V(G) M3/KG	H(G) KJ/KG	S(G) KJ/KG.K	B(G) KJ/KG	FC(G)
(-40.0) (65.563) (0.6054)	0.250	173.43	0.7462	-1.4573	0.9787	0.260	179.04	0.7716	-3.3893	0.9808	0.271	184.74	0.7964	-5.0422	0.9826	0.282	190.52	0.8205	-6.4303	0.9842
(-30.0) (101.843) (0.6313)	0.166	178.54	0.7401	5.4774	0.9702	0.173	184.26	0.7649	3.8201	0.9730	0.180	190.07	0.7892	2.4292	0.9756	0.187	195.96	0.8128	1.2917	0.9778
(-20.0) (152.258) (0.6573)	0.114	183.59	0.7356	11.8450	0.9597	0.119	189.44	0.7600	10.4500	0.9635	0.124	195.36	0.7838	9.3100	0.9668	0.128	201.36	0.8070	8.4129	0.9698
(-10.0) (220.172) (0.6832)	0.081	188.55	0.7326	17.7194	0.9473	0.084	194.53	0.7565	16.5760	0.9521	0.087	200.58	0.7799	15.6774	0.9564	0.091	206.70	0.8027	15.0120	0.9602
(0.0) (309.251) (0.7092)	0.058	193.40	0.7306	23.1585	0.9329	0.061	199.51	0.7542	22.2577	0.9389	0.063	205.69	0.7772	21.5926	0.9442	0.066	211.94	0.7997	21.1519	0.9489
(10.0) (423.427) (0.7352)	0.043	198.09	0.7294	28.2067	0.9165	0.045	204.36	0.7527	27.5418	0.9238	0.047	210.68	0.7755	27.1039	0.9303	0.049	217.07	0.7977	26.8824	0.9361
(20.0) (566.878) (0.7611)	0.033	202.60	0.7288	32.8974	0.8983	0.034	209.04	0.7519	32.4636	0.9070	0.036	215.52	0.7744	32.2486	0.9147	0.037	222.05	0.7964	32.2424	0.9217
(30.0) (744.014) (0.7871)	0.025	206.87	0.7285	37.2537	0.8783	0.026	213.50	0.7515	37.0486	0.8885	0.027	220.16	0.7739	37.0547	0.8976	0.028	226.86	0.7957	37.2618	0.9058
(40.0) (959.459) (0.8131)	0.019	210.85	0.7283	41.2891	0.8567	0.020	217.71	0.7513	41.3139	0.8685	0.021	224.58	0.7737	41.5416	0.8791	0.022	231.46	0.7954	41.9624	0.8886
(50.0) (1218.072) (0.8390)	0.015	214.50	0.7281	45.0087	0.8337	0.016	221.63	0.7512	45.2685	0.8472	0.017	228.74	0.7736	45.7219	0.8593	0.018	235.83	0.7953	46.3597	0.8703

SATURATED PROPERTIES OF [illegible]

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
-40.0	600798.2	1425.7	0.0267	0.00	126.68	126.68	0.0000	0.5433	233.2	-40.0
-30.0	838495.7	1361.1	0.0191	10.19	119.47	129.66	0.0454	0.5367	243.2	-30.0
-20.0	1139827.3	1288.6	0.0138	21.11	111.07	132.18	0.0917	0.5304	253.2	-20.0
-10.0	1514586.9	1205.9	0.0101	32.91	101.10	134.01	0.1393	0.5235	263.2	-10.0
0.0	1973200.3	1109.4	0.0074	45.86	88.95	134.81	0.1891	0.5148	273.2	0.0
10.0	2526816.3	992.4	0.0053	60.55	73.41	133.97	0.2429	0.5021	283.2	10.0
20.0	3187448.8	837.5	0.0036	78.52	51.33	129.85	0.3054	0.4805	293.2	20.0
21.0	3259890.5	818.2	0.0035	80.66	48.44	129.09	0.3127	0.4774	294.2	21.0
22.0	3333546.0	797.7	0.0033	82.90	45.33	128.22	0.3203	0.4738	295.2	22.0
23.0	3408428.8	775.7	0.0032	85.27	41.96	127.22	0.3282	0.4699	296.2	23.0
24.0	3484554.3	752.0	0.0030	87.80	38.26	126.05	0.3367	0.4654	297.2	24.0
25.0	3561933.3	726.0	0.0028	90.54	34.12	124.66	0.3458	0.4603	298.2	25.0
26.0	3640586.8	696.7	0.0027	93.57	29.36	122.93	0.3559	0.4540	299.2	26.0
27.0	3720532.3	662.4	0.0025	97.06	23.61	120.66	0.3674	0.4460	300.2	27.0
28.0	3801752.3	619.0	0.0022	101.39	15.72	117.11	0.3816	0.4338	301.2	28.0
28.1	3809946.3	613.8	0.0022	101.91	14.67	116.57	0.3833	0.4320	301.3	28.1
28.2	3818149.5	608.3	0.0022	102.44	13.50	115.95	0.3851	0.4299	301.4	28.2
28.3	3826360.5	602.6	0.0021	103.01	12.16	115.16	0.3869	0.4273	301.5	28.3

SATURATED PROPERTIES OF CCLF3 CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.7721	600798.2	0.1553	0.0227	0.8642	0.8794	0.8794	0.86E+02	0.52E+02	-40.0
-30.0	0.8052	838495.7	0.2168	0.0318	0.8262	0.8505	0.8505	0.83E+02	0.57E+02	-30.0
-20.0	0.8383	1139827.3	0.2947	0.0439	0.7816	0.8191	0.8191	0.80E+02	0.61E+02	-20.0
-10.0	0.8714	1514586.9	0.3916	0.0600	0.7294	0.7856	0.7856	0.78E+02	0.65E+02	-10.0
0.0	0.9045	1973200.3	0.5101	0.0818	0.6677	0.7503	0.7503	0.76E+02	0.68E+02	0.0
10.0	0.9376	2526816.3	0.6533	0.1130	0.5931	0.7137	0.7137	0.75E+02	0.71E+02	10.0
20.0	0.9708	3187448.8	0.8241	0.1631	0.4956	0.6762	0.6762	0.74E+02	0.73E+02	20.0
21.0	0.9741	3259890.5	0.8428	0.1702	0.4835	0.6724	0.6724	0.74E+02	0.74E+02	21.0
22.0	0.9774	3333546.0	0.8618	0.1779	0.4707	0.6686	0.6686	0.74E+02	0.74E+02	22.0
23.0	0.9807	3408428.8	0.8812	0.1864	0.4571	0.6648	0.6648	0.74E+02	0.74E+02	23.0
24.0	0.9840	3484554.3	0.9009	0.1959	0.4424	0.6610	0.6610	0.74E+02	0.74E+02	24.0
25.0	0.9873	3561933.3	0.9209	0.2068	0.4262	0.6571	0.6571	0.74E+02	0.74E+02	25.0
26.0	0.9906	3640586.8	0.9412	0.2195	0.4078	0.6533	0.6533	0.74E+02	0.74E+02	26.0
27.0	0.9939	3720532.3	0.9619	0.2351	0.3860	0.6495	0.6495	0.74E+02	0.75E+02	27.0
28.0	0.9973	3801752.3	0.9829	0.2562	0.3557	0.6457	0.6457	0.74E+02	0.75E+02	28.0
28.1	0.9976	3809946.3	0.9850	0.2589	0.3514	0.6453	0.6453	0.74E+02	0.75E+02	28.1
28.2	0.9979	3818149.5	0.9871	0.2617	0.3465	0.6449	0.6449	0.74E+02	0.75E+02	28.2
28.3	0.9982	3826360.5	0.9892	0.2647	0.3406	0.6445	0.6445	0.74E+02	0.75E+02	28.3

SUPERHEATED PROPERTIES OF CHLOROTRIFLUOROMETHANE REFRIGERANT R13 (CCLF3)

F3

DEGREES OF SUPERHEAT

SATD COND (DEG C) (KPA) (TR)	10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(-40.0) (600.798) (0.7721)	0.028	132.68	0.5719	49.1300	0.8925	0.030	138.83	0.5998	46.9628	0.9038	0.032	145.11	0.6273	45.0965	0.9137	0.033	151.51	0.6541	43.5218	0.9223
(-30.0) (838.496) (0.8052)	0.020	136.10	0.5659	54.3205	0.8664	0.022	142.62	0.5943	52.4178	0.8802	0.023	149.23	0.6218	50.8214	0.8922	0.024	155.90	0.6487	49.5145	0.9028
(-20.0) (1139.827) (0.8383)	0.015	139.14	0.5605	58.9681	0.8380	0.016	146.08	0.5893	57.3344	0.8544	0.017	153.04	0.6172	56.0084	0.8687	0.018	160.02	0.6442	54.9685	0.8814
(-10.0) (1514.587) (0.8714)	0.011	141.64	0.5549	63.1182	0.8077	0.012	149.10	0.5846	61.7575	0.8268	0.013	156.46	0.6129	60.7052	0.8436	0.013	163.79	0.6402	59.9355	0.8585
(0.0) (1973.200) (0.9045)	0.008	143.43	0.5486	66.7905	0.7759	0.009	151.55	0.5796	65.7136	0.7980	0.010	159.43	0.6087	64.9452	0.8174	0.010	167.17	0.6364	64.4528	0.8344
(10.0) (2526.816) (0.9376)	0.006	144.27	0.5407	69.9809	0.7433	0.007	153.34	0.5738	69.2149	0.7685	0.007	161.88	0.6041	68.7499	0.7904	0.008	170.12	0.6325	68.5495	0.8098
(20.0) (3187.449) (0.9708)	0.005	143.93	0.5305	72.6644	0.7104	0.005	154.39	0.5671	72.2649	0.7388	0.006	163.77	0.5991	72.1383	0.7634	0.006	172.64	0.6285	72.2533	0.7851
(30.0) (3964.322) (1.0039)	0.003	142.45	0.5183	74.8053	0.6787	0.004	154.82	0.5597	74.8693	0.7103	0.005	165.23	0.5939	75.1295	0.7374	0.005	174.81	0.6246	75.5890	0.7611
(40.0) (4855.447) (1.0370)	0.003	141.18	0.5084	76.4961	0.6507	0.003	155.23	0.5536	77.0915	0.6847	0.004	166.65	0.5898	77.7723	0.7138	0.004	176.95	0.6217	78.5998	0.7394

SATURATED PROPERTIES OF BROMOTRIFLUOROMETHANE   REFRIGERANT 1381 (CBRF3)   TABLE F4

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
-40.0	219762.3	2032.0	0.0555	0.00	111.84	111.84	0.0000	0.4797	233.2	-40.0
-30.0	321124.3	1975.1	0.0387	6.85	108.26	115.11	0.0309	0.4761	243.2	-30.0
-20.0	454584.3	1913.2	0.0277	13.95	104.29	118.24	0.0615	0.4734	253.2	-20.0
-10.0	626054.9	1845.6	0.0202	21.33	99.83	121.16	0.0919	0.4712	263.2	-10.0
0.0	841800.0	1771.3	0.0150	29.04	94.78	123.82	0.1223	0.4693	273.2	0.0
10.0	1108436.6	1689.0	0.0113	37.15	89.00	126.15	0.1529	0.4672	283.2	10.0
20.0	1432937.5	1596.8	0.0085	45.74	82.30	128.04	0.1839	0.4647	293.2	20.0
30.0	1822662.9	1491.9	0.0064	54.96	74.38	129.34	0.2159	0.4612	303.2	30.0
40.0	2285418.0	1369.5	0.0048	65.06	64.73	129.79	0.2494	0.4561	313.2	40.0
50.0	2829508.8	1220.2	0.0036	76.54	52.33	128.87	0.2859	0.4479	323.2	50.0
60.0	3463855.3	1017.4	0.0025	90.87	34.20	125.07	0.3295	0.4322	333.2	60.0
61.0	3532615.3	991.1	0.0024	92.63	31.71	124.34	0.3348	0.4297	334.2	61.0
62.0	3602386.8	962.7	0.0023	94.51	28.99	123.50	0.3404	0.4269	335.2	62.0
63.0	3673178.8	931.6	0.0022	96.53	25.97	122.50	0.3463	0.4236	336.2	63.0
64.0	3744999.8	896.9	0.0020	98.76	22.51	121.27	0.3529	0.4196	337.2	64.0
65.0	3817859.5	856.6	0.0019	101.29	18.37	119.66	0.3603	0.4146	338.2	65.0
66.0	3891765.8	806.7	0.0017	104.37	12.87	117.24	0.3693	0.4072	339.2	66.0
66.1	3899207.8	800.8	0.0017	104.72	12.17	116.89	0.3703	0.4062	339.3	66.1
66.2	3906669.0	794.8	0.0017	105.09	11.41	116.50	0.3714	0.4050	339.4	66.2
66.3	3914131.3	788.4	0.0017	105.47	10.58	116.06	0.3725	0.4037	339.5	66.3
66.4	3921600.8	781.8	0.0016	105.87	9.64	115.51	0.3737	0.4021	339.6	66.4
66.5	3929035.0	774.7	0.0016	106.30	8.45	114.75	0.3749	0.3998	339.7	66.5

SATURATED PROPERTIES OF CBRF3 F4 CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.6854	219762.3	0.0554	0.0083	0.9369	0.9404	0.9404	0.51E+02	0.20E+02	-40.0
-30.0	0.7148	321124.3	0.0810	0.0120	0.9162	0.9222	0.9222	0.49E+02	0.24E+02	-30.0
-20.0	0.7442	454584.3	0.1147	0.0168	0.8915	0.9014	0.9014	0.47E+02	0.28E+02	-20.0
-10.0	0.7736	626054.9	0.1579	0.0231	0.8625	0.8781	0.8780	0.45E+02	0.32E+02	-10.0
0.0	0.8030	841800.0	0.2123	0.0312	0.8288	0.8525	0.8525	0.44E+02	0.35E+02	0.0
10.0	0.8324	1108436.6	0.2796	0.0415	0.7900	0.8249	0.8248	0.43E+02	0.38E+02	10.0
20.0	0.8618	1432937.5	0.3614	0.0548	0.7453	0.7955	0.7955	0.42E+02	0.41E+02	20.0
30.0	0.8912	1822662.9	0.4597	0.0722	0.6938	0.7647	0.7647	0.42E+02	0.43E+02	30.0
40.0	0.9206	2285418.0	0.5765	0.0954	0.6334	0.7327	0.7327	0.42E+02	0.45E+02	40.0
50.0	0.9500	2829508.8	0.7137	0.1285	0.5603	0.6998	0.6998	0.42E+02	0.47E+02	50.0
60.0	0.9794	3463855.3	0.8737	0.1830	0.4625	0.6662	0.6662	0.44E+02	0.47E+02	60.0
61.0	0.9824	3532615.3	0.8911	0.1911	0.4498	0.6629	0.6628	0.44E+02	0.47E+02	61.0
62.0	0.9853	3602386.8	0.9087	0.2000	0.4362	0.6595	0.6595	0.44E+02	0.47E+02	62.0
63.0	0.9882	3673178.8	0.9265	0.2101	0.4213	0.6561	0.6561	0.44E+02	0.47E+02	63.0
64.0	0.9912	3744999.8	0.9446	0.2218	0.4045	0.6527	0.6527	0.45E+02	0.47E+02	64.0
65.0	0.9941	3817859.5	0.9630	0.2361	0.3846	0.6493	0.6493	0.45E+02	0.47E+02	65.0
66.0	0.9971	3891765.8	0.9817	0.2548	0.3579	0.6459	0.6459	0.45E+02	0.47E+02	66.0
66.1	0.9974	3899207.8	0.9835	0.2570	0.3544	0.6456	0.6456	0.46E+02	0.47E+02	66.1
66.2	0.9976	3906669.0	0.9854	0.2594	0.3505	0.6452	0.6452	0.46E+02	0.47E+02	66.2
66.3	0.9979	3914131.3	0.9873	0.2619	0.3461	0.6449	0.6449	0.46E+02	0.47E+02	66.3
66.4	0.9982	3921600.8	0.9892	0.2646	0.3408	0.6445	0.6445	0.46E+02	0.47E+02	66.4
66.5	0.9985	3929035.0	0.9911	0.2674	0.3337	0.6442	0.6442	0.46E+02	0.47E+02	66.5

DEGREES OF SUPERHEAT

SATD COND (DEG C) (KPA) (TR)	10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(-40.0) (219.762) (0.6854)	0.058	116.13	0.5000	18.3839	0.9466	0.061	120.49	0.5199	16.8530	0.9521	0.064	124.93	0.5392	15.5395	0.9568	0.067	129.44	0.5581	14.4324	0.9610
(-30.0) (321.124) (0.7148)	0.041	119.55	0.4963	22.9224	0.9301	0.043	124.05	0.5159	21.5994	0.9371	0.045	128.62	0.5350	20.4863	0.9431	0.047	133.25	0.5537	19.5728	0.9485
(-20.0) (454.584) (0.7442)	0.029	122.84	0.4934	27.0577	0.9112	0.031	127.49	0.5128	25.9354	0.9198	0.032	132.20	0.5318	25.0169	0.9273	0.033	136.97	0.5503	24.2918	0.9340
(-10.0) (626.055) (0.7736)	0.021	125.95	0.4912	30.8331	0.8899	0.022	130.77	0.5105	29.9067	0.9003	0.024	135.64	0.5293	29.1785	0.9095	0.025	140.55	0.5477	28.6382	0.9177
(0.0) (841.800) (0.8030)	0.016	128.83	0.4893	34.2800	0.8665	0.017	133.85	0.5086	33.5469	0.8789	0.018	138.90	0.5274	33.0070	0.8898	0.018	143.98	0.5457	32.6495	0.8996
(10.0) (1108.437) (0.8324)	0.012	131.44	0.4875	37.4190	0.8412	0.013	136.70	0.5070	36.8795	0.8557	0.013	141.95	0.5259	36.5282	0.8685	0.014	147.22	0.5442	36.3540	0.8800
(20.0) (1432.938) (0.8618)	0.009	133.70	0.4855	40.2593	0.8144	0.010	139.25	0.5054	39.9185	0.8310	0.010	144.76	0.5244	39.7600	0.8458	0.011	150.24	0.5429	39.7722	0.8591
(30.0) (1822.663) (0.8912)	0.007	135.51	0.4831	42.7999	0.7863	0.008	141.46	0.5035	42.6697	0.8053	0.008	147.27	0.5230	42.7129	0.8221	0.009	153.02	0.5416	42.9186	0.8372
(40.0) (2285.418) (0.9206)	0.005	136.78	0.4798	45.0268	0.7572	0.006	143.25	0.5013	45.1312	0.7787	0.006	149.46	0.5213	45.3926	0.7977	0.007	155.52	0.5403	45.8036	0.8146
(50.0) (2829.509) (0.9500)	0.004	137.33	0.4754	46.9125	0.7277	0.005	144.56	0.4984	47.2959	0.7518	0.005	151.28	0.5193	47.8023	0.7729	0.005	157.73	0.5389	48.4367	0.7917
(60.0) (3463.855) (0.9794)	0.003	137.04	0.4693	48.6200	0.6983	0.004	145.37	0.4949	49.1597	0.7250	0.004	152.74	0.5170	49.9499	0.7483	0.004	159.65	0.5373	50.8311	0.7690

SATURATED PROPERTIES OF CHLORODIFLUOROMETHANE REFRIGERANT 22 (CHCLF2) TABLE F5

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
-40.0	105882.9	1439.6	0.2054	0.00	232.54	232.54	0.0000	0.9973	233.2	-40.0
-30.0	164249.9	1409.4	0.1364	10.45	226.97	237.43	0.0478	0.9812	243.2	-30.0
-20.0	245194.5	1377.0	0.0936	21.20	220.96	242.16	0.0947	0.9675	253.2	-20.0
-10.0	354029.5	1342.0	0.0661	32.28	214.41	246.69	0.1410	0.9558	263.2	-10.0
0.0	496549.7	1304.1	0.0478	43.73	207.22	250.95	0.1870	0.9456	273.2	0.0
10.0	678972.1	1263.0	0.0352	55.62	199.26	254.88	0.2326	0.9363	283.2	10.0
20.0	907921.8	1218.1	0.0263	68.01	190.36	258.37	0.2783	0.9277	293.2	20.0
30.0	1190425.8	1168.8	0.0199	81.00	180.34	261.33	0.3243	0.9192	303.2	30.0
40.0	1533914.5	1114.1	0.0152	94.71	168.92	263.62	0.3710	0.9104	313.2	40.0
50.0	1946243.1	1052.7	0.0117	109.33	155.71	265.04	0.4187	0.9006	323.2	50.0
60.0	2435736.8	982.8	0.0089	125.15	140.14	265.29	0.4684	0.8891	333.2	60.0
70.0	3011242.0	901.0	0.0068	142.66	121.19	263.85	0.5212	0.8744	343.2	70.0
80.0	3682226.8	800.6	0.0050	162.91	96.75	259.66	0.5799	0.8538	353.2	80.0
90.0	4458872.0	661.4	0.0035	189.12	60.25	249.37	0.6527	0.8186	363.2	90.0
91.0	4542765.0	642.7	0.0033	192.49	55.08	247.57	0.6619	0.8131	364.2	91.0
92.0	4627836.5	622.3	0.0032	196.13	49.32	245.45	0.6718	0.8068	365.2	92.0
93.0	4714100.0	599.5	0.0030	200.16	42.74	242.90	0.6827	0.7994	366.2	93.0
94.0	4801561.0	573.1	0.0028	204.77	34.87	239.64	0.6951	0.7901	367.2	94.0
95.0	4890231.0	540.4	0.0026	210.39	24.41	234.80	0.7102	0.7765	368.2	95.0
95.1	4899160.5	536.6	0.0026	211.04	23.07	234.11	0.7120	0.7746	368.3	95.1
95.2	4908110.0	532.6	0.0025	211.72	21.62	233.34	0.7138	0.7725	368.4	95.2

SATURATED PROPERTIES OF CHCLF2 F5 CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.6316	105882.9	0.0213	0.0033	0.9700	0.9708	0.9708	0.77E+02	0.13E+02	-40.0
-30.0	0.6587	164249.9	0.0330	0.0050	0.9579	0.9595	0.9595	0.73E+02	0.23E+02	-30.0
-20.0	0.6858	245194.5	0.0493	0.0073	0.9429	0.9458	0.9458	0.70E+02	0.32E+02	-20.0
-10.0	0.7129	354029.5	0.0711	0.0104	0.9247	0.9296	0.9296	0.67E+02	0.40E+02	-10.0
0.0	0.7400	496549.7	0.0998	0.0145	0.9030	0.9110	0.9110	0.65E+02	0.47E+02	0.0
10.0	0.7670	678972.1	0.1364	0.0197	0.8776	0.8900	0.8900	0.63E+02	0.53E+02	10.0
20.0	0.7941	907921.8	0.1824	0.0264	0.8481	0.8669	0.8669	0.62E+02	0.60E+02	20.0
30.0	0.8212	1190425.8	0.2392	0.0349	0.8141	0.8418	0.8418	0.61E+02	0.65E+02	30.0
40.0	0.8483	1533914.5	0.3082	0.0457	0.7753	0.8149	0.8149	0.61E+02	0.70E+02	40.0
50.0	0.8754	1946243.1	0.3910	0.0595	0.7308	0.7865	0.7865	0.62E+02	0.74E+02	50.0
60.0	0.9025	2435736.8	0.4894	0.0774	0.6795	0.7567	0.7567	0.63E+02	0.78E+02	60.0
70.0	0.9296	3011242.0	0.6050	0.1013	0.6195	0.7259	0.7259	0.65E+02	0.81E+02	70.0
80.0	0.9567	3682226.8	0.7398	0.1354	0.5465	0.6943	0.6943	0.67E+02	0.83E+02	80.0
90.0	0.9837	4458872.0	0.8958	0.1931	0.4467	0.6621	0.6620	0.72E+02	0.83E+02	90.0
91.0	0.9865	4542765.0	0.9127	0.2019	0.4334	0.6588	0.6588	0.73E+02	0.83E+02	91.0
92.0	0.9892	4627836.5	0.9298	0.2118	0.4188	0.6555	0.6555	0.73E+02	0.83E+02	92.0
93.0	0.9919	4714100.0	0.9471	0.2233	0.4024	0.6523	0.6523	0.74E+02	0.82E+02	93.0
94.0	0.9946	4801561.0	0.9647	0.2373	0.3829	0.6490	0.6490	0.75E+02	0.82E+02	94.0
95.0	0.9973	4890231.0	0.9825	0.2556	0.3566	0.6458	0.6458	0.76E+02	0.81E+02	95.0
95.1	0.9976	4899160.5	0.9843	0.2579	0.3531	0.6454	0.6454	0.76E+02	0.81E+02	95.1
95.2	0.9978	4908110.0	0.9861	0.2602	0.3492	0.6451	0.6451	0.76E+02	0.81E+02	95.2

DEGREES OF SUPERHEAT

SATD COND (DEG C) (KPA) (TR)	10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(-40.0) (105.883) (0.6316)	0.215	238.38	1.0259	10.3787	0.9738	0.224	244.33	1.0538	8.0512	0.9765	0.234	250.40	1.0810	6.0273	0.9788	0.243	256.58	1.1076	4.2928	0.9809
(-30.0) (164.250) (0.6587)	0.143	243.44	1.0093	20.3708	0.9636	0.149	249.56	1.0367	18.3389	0.9672	0.155	255.79	1.0636	16.5992	0.9704	0.161	262.13	1.0898	15.1385	0.9731
(-20.0) (245.195) (0.6858)	0.098	248.36	0.9953	29.4619	0.9511	0.102	254.67	1.0224	27.7144	0.9558	0.106	261.07	1.0489	26.2493	0.9600	0.111	267.58	1.0748	25.0541	0.9636
(-10.0) (354.030) (0.7129)	0.069	253.10	0.9833	37.7589	0.9364	0.072	259.60	1.0101	36.2872	0.9423	0.075	266.20	1.0364	35.0892	0.9476	0.078	272.89	1.0620	34.1528	0.9523
(0.0) (496.550) (0.7400)	0.050	257.60	0.9729	45.3461	0.9193	0.052	264.32	0.9996	44.1440	0.9267	0.055	271.13	1.0256	43.2080	0.9333	0.057	278.02	1.0511	42.5264	0.9392
(10.0) (678.972) (0.7670)	0.037	261.80	0.9637	52.2864	0.9001	0.039	268.77	0.9903	51.3509	0.9091	0.040	275.81	1.0163	50.6746	0.9171	0.042	282.93	1.0417	50.2457	0.9243
(20.0) (907.922) (0.7941)	0.028	265.62	0.9552	58.6253	0.8789	0.029	272.89	0.9819	57.9570	0.8896	0.030	280.20	1.0079	57.5412	0.8992	0.032	287.57	1.0333	57.3660	0.9077
(30.0) (1190.426) (0.8212)	0.021	268.98	0.9471	64.3921	0.8558	0.022	276.60	0.9741	63.9965	0.8684	0.023	284.23	1.0003	63.8460	0.8796	0.024	291.89	1.0258	63.9288	0.8896
(40.0) (1533.915) (0.8483)	0.016	271.78	0.9390	69.6000	0.8311	0.017	279.83	0.9665	69.4894	0.8456	0.018	287.84	0.9930	69.6145	0.8586	0.019	295.83	1.0187	69.9638	0.8702
(50.0) (1946.243) (0.8754)	0.013	273.89	0.9305	74.2449	0.8051	0.013	282.49	0.9588	74.4423	0.8216	0.014	290.96	0.9859	74.8610	0.8364	0.015	299.35	1.0120	75.4915	0.8497

SATURATED PROPERTIES OF TRICHLOROTRIFLUOROETHANE REFRIGERANT 113 (CCL2F-CCLF2)

F6 TABLE

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
-40.0	1592.7	1796.9	6.4873	0.00	164.45	164.45	0.0000	0.7053	233.2	-40.0
-30.0	3050.9	1779.3	3.5284	7.51	162.30	169.81	0.0334	0.7009	243.2	-30.0
-20.0	5515.0	1760.8	2.0293	15.17	160.13	175.30	0.0661	0.6986	253.2	-20.0
-10.0	9470.4	1741.4	1.2258	22.99	157.92	180.91	0.0980	0.6982	263.2	-10.0
0.0	15543.2	1721.1	0.7730	30.96	155.66	186.63	0.1294	0.6993	273.2	0.0
10.0	24508.0	1699.7	0.5062	39.09	153.34	192.44	0.1602	0.7018	283.2	10.0
20.0	37299.5	1677.3	0.3426	47.39	150.94	198.32	0.1905	0.7054	293.2	20.0
30.0	55001.6	1653.6	0.2387	55.84	148.44	204.28	0.2203	0.7100	303.2	30.0
40.0	78856.6	1628.7	0.1707	64.46	145.82	210.28	0.2497	0.7154	313.2	40.0
50.0	110250.5	1602.4	0.1248	73.25	143.06	216.32	0.2787	0.7214	323.2	50.0
60.0	150711.3	1574.5	0.0930	82.22	140.14	222.36	0.3073	0.7279	333.2	60.0
70.0	201896.2	1545.1	0.0705	91.37	137.04	228.41	0.3356	0.7349	343.2	70.0
80.0	265586.8	1513.8	0.0543	100.71	133.71	234.43	0.3636	0.7422	353.2	80.0
90.0	343681.2	1480.5	0.0424	110.26	130.14	240.40	0.3913	0.7497	363.2	90.0
100.0	438188.3	1444.9	0.0334	120.02	126.29	246.30	0.4188	0.7573	373.2	100.0
110.0	551223.0	1406.9	0.0266	130.01	122.10	252.11	0.4462	0.7649	383.2	110.0
120.0	685006.8	1366.1	0.0214	140.25	117.53	257.78	0.4735	0.7724	393.2	120.0
130.0	841865.8	1322.0	0.0172	150.77	112.51	263.29	0.5008	0.7798	403.2	130.0
140.0	1024237.0	1274.2	0.0140	161.61	106.97	268.58	0.5281	0.7870	413.2	140.0
150.0	1234667.1	1222.0	0.0114	172.82	100.78	273.60	0.5555	0.7937	423.2	150.0
160.0	1475829.9	1164.5	0.0093	184.46	93.80	278.27	0.5833	0.7998	433.2	160.0
170.0	1750532.8	1100.5	0.0075	196.65	85.82	282.47	0.6115	0.8052	443.2	170.0
180.0	2061728.8	1027.7	0.0061	209.54	76.48	286.02	0.6407	0.8094	453.2	180.0
190.0	2412540.3	942.8	0.0048	223.45	65.17	288.62	0.6712	0.8119	463.2	190.0
200.0	2806277.0	837.9	0.0038	239.04	50.52	289.56	0.7045	0.8113	473.2	200.0
210.0	3246474.8	685.7	0.0027	258.71	27.57	286.28	0.7453	0.8024	483.2	210.0
211.0	3293191.5	663.5	0.0026	261.28	23.98	285.27	0.7506	0.8001	484.2	211.0
212.0	3340414.0	638.1	0.0024	264.15	19.72	283.87	0.7565	0.7971	485.2	212.0
213.0	3388143.3	607.2	0.0022	267.50	14.10	281.60	0.7633	0.7923	486.2	213.0

SATURATED PROPERTIES OF CCL2F-CCLF2 CONTINUED F6

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.4785	1592.7	0.0005	0.0001	0.9987	0.9980	0.9987	0.94E+01	-0.36E+02	-40.0
-30.0	0.4990	3050.9	0.0009	0.0002	0.9977	0.9977	0.9977	0.70E+01	-0.29E+02	-30.0
-20.0	0.5195	5515.0	0.0016	0.0003	0.9963	0.9963	0.9963	0.49E+01	-0.23E+02	-20.0
-10.0	0.5401	9470.4	0.0028	0.0005	0.9942	0.9943	0.9942	0.32E+01	-0.17E+02	-10.0
0.0	0.5606	15543.2	0.0045	0.0007	0.9913	0.9914	0.9913	0.19E+01	-0.12E+02	0.0
10.0	0.5811	24508.0	0.0071	0.0011	0.9874	0.9877	0.9876	0.87E+00	-0.67E+01	10.0
20.0	0.6016	37299.5	0.0108	0.0017	0.9824	0.9828	0.9827	0.16E+00	-0.19E+01	20.0
30.0	0.6222	55001.6	0.0160	0.0025	0.9762	0.9768	0.9767	-0.24E+00	0.27E+01	30.0
40.0	0.6427	78856.6	0.0229	0.0035	0.9685	0.9694	0.9694	-0.35E+00	0.71E+01	40.0
50.0	0.6632	110250.5	0.0321	0.0048	0.9592	0.9607	0.9607	-0.16E+00	0.11E+02	50.0
60.0	0.6837	150711.3	0.0438	0.0065	0.9482	0.9506	0.9505	0.30E+00	0.15E+02	60.0
70.0	0.7043	201896.2	0.0587	0.0086	0.9353	0.9390	0.9389	0.11E+01	0.19E+02	70.0
80.0	0.7248	265586.8	0.0772	0.0112	0.9204	0.9259	0.9259	0.21E+01	0.23E+02	80.0
90.0	0.7453	343681.2	0.0999	0.0144	0.9035	0.9114	0.9113	0.34E+01	0.27E+02	90.0
100.0	0.7658	438188.3	0.1274	0.0183	0.8843	0.8955	0.8954	0.50E+01	0.31E+02	100.0
110.0	0.7863	551223.0	0.1602	0.0230	0.8627	0.8782	0.8782	0.68E+01	0.34E+02	110.0
120.0	0.8069	685006.8	0.1991	0.0287	0.8385	0.8597	0.8597	0.89E+01	0.38E+02	120.0
130.0	0.8274	841865.8	0.2447	0.0356	0.8116	0.8400	0.8400	0.11E+02	0.41E+02	130.0
140.0	0.8479	1024237.0	0.2978	0.0438	0.7818	0.8193	0.8193	0.14E+02	0.44E+02	140.0
150.0	0.8684	1234667.1	0.3589	0.0538	0.7486	0.7976	0.7975	0.17E+02	0.47E+02	150.0
160.0	0.8890	1475829.9	0.4290	0.0659	0.7116	0.7750	0.7749	0.21E+02	0.50E+02	160.0
170.0	0.9095	1750532.8	0.5089	0.0809	0.6701	0.7516	0.7516	0.24E+02	0.53E+02	170.0
180.0	0.9300	2061728.8	0.5994	0.0998	0.6231	0.7277	0.7276	0.29E+02	0.55E+02	180.0
190.0	0.9505	2412540.3	0.7014	0.1245	0.5685	0.7031	0.7031	0.33E+02	0.57E+02	190.0
200.0	0.9710	2806277.0	0.8158	0.1595	0.5018	0.6782	0.6782	0.39E+02	0.58E+02	200.0
210.0	0.9916	3246474.8	0.9438	0.2208	0.4059	0.6530	0.6529	0.47E+02	0.57E+02	210.0
211.0	0.9936	3293191.5	0.9574	0.2310	0.3916	0.6504	0.6504	0.48E+02	0.57E+02	211.0
212.0	0.9957	3340414.0	0.9711	0.2432	0.3747	0.6479	0.6479	0.49E+02	0.56E+02	212.0
213.0	0.9977	3388143.3	0.9850	0.2587	0.3518	0.6453	0.6453	0.50E+02	0.56E+02	213.0

SUPERHEATED PROPERTIES OF TRICHLOROTRIFLUOROETHANE REFRIGERANT R113 (CCL2F-CCLF2) F6

DEGREES OF SUPERHEAT

SATD COND (DEG C) (KPA) (TR)	10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(-40.0) (1.593) (0.4785)	6.766	169.84	0.7298	-37.6238	0.9988	7.046	175.38	0.7539	-39.2489	0.9989	7.325	181.06	0.7776	-40.6179	0.9990	7.604	186.87	0.8009	-41.7389	0.9991
(-30.0) (3.051) (0.4990)	3.674	175.35	0.7250	-30.6858	0.9979	3.820	181.03	0.7487	-32.0549	0.9981	3.966	186.85	0.7720	-33.1761	0.9983	4.112	192.80	0.7950	-34.0569	0.9985
(-20.0) (5.515) (0.5195)	2.110	180.98	0.7223	-24.2628	0.9966	2.191	186.80	0.7457	-25.3842	0.9969	2.272	192.76	0.7687	-26.2652	0.9972	2.353	198.84	0.7913	-26.9130	0.9974
(-10.0) (9.470) (0.5401)	1.273	186.73	0.7215	-18.2776	0.9947	1.320	192.69	0.7445	-19.1588	0.9952	1.368	198.77	0.7672	-19.8067	0.9956	1.415	204.98	0.7895	-20.2284	0.9960
(0.0) (15.543) (0.5606)	0.802	192.59	0.7223	-12.6618	0.9921	0.831	198.68	0.7450	-13.3098	0.9928	0.860	204.89	0.7673	-13.7315	0.9934	0.889	211.22	0.7893	-13.9335	0.9939
(10.0) (24.508) (0.5811)	0.525	198.53	0.7245	-7.3586	0.9886	0.543	204.75	0.7468	-7.7802	0.9896	0.562	211.09	0.7689	-7.9821	0.9905	0.580	217.55	0.7905	-7.9706	0.9912
(20.0) (37.300) (0.6016)	0.355	204.56	0.7278	-2.3188	0.9842	0.367	210.91	0.7498	-2.5203	0.9855	0.379	217.37	0.7716	-2.5082	0.9867	0.391	223.95	0.7930	-2.2889	0.9877
(30.0) (55.002) (0.6222)	0.247	210.64	0.7321	2.4951	0.9786	0.255	217.12	0.7538	2.5080	0.9803	0.264	223.71	0.7753	2.7283	0.9819	0.272	230.41	0.7964	3.1501	0.9833
(40.0) (78.857) (0.6427)	0.177	216.78	0.7372	7.1158	0.9718	0.182	223.38	0.7586	7.3377	0.9740	0.188	230.09	0.7798	7.7613	0.9761	0.194	236.91	0.8007	8.3807	0.9779
(50.0) (110.251) (0.6632)	0.129	222.94	0.7429	11.5692	0.9638	0.133	229.67	0.7642	11.9952	0.9666	0.138	236.51	0.7851	12.6173	0.9691	0.142	243.44	0.8057	13.4296	0.9714

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	DEG K	DEG C
-40.0	48794.7	973.7	0.5910	0.00	341.94	341.94	0.0000	1.4666	233.2	-40.0
-30.0	79293.1	956.2	0.3761	11.42	334.71	346.13	0.0531	1.4296	243.2	-30.0
-20.0	123372.4	937.6	0.2490	23.43	327.03	350.46	0.1064	1.3982	253.2	-20.0
-10.0	184847.7	917.6	0.1704	36.02	318.81	354.83	0.1598	1.3713	263.2	-10.0
0.0	267976.2	896.0	0.1199	49.21	309.93	359.14	0.2133	1.3479	273.2	0.0
10.0	377443.0	872.8	0.0864	63.02	300.27	363.29	0.2671	1.3275	283.2	10.0
20.0	518325.2	847.7	0.0636	77.51	289.66	367.17	0.3212	1.3092	293.2	20.0
30.0	696068.1	820.3	0.0475	92.76	277.93	370.70	0.3758	1.2926	303.2	30.0
40.0	916478.0	790.4	0.0360	108.88	264.85	373.73	0.4313	1.2771	313.2	40.0
50.0	1185717.0	757.4	0.0275	126.03	250.11	376.14	0.4881	1.2620	323.2	50.0
60.0	1510320.6	720.7	0.0211	144.41	233.32	377.73	0.5466	1.2469	333.2	60.0
70.0	1897221.5	679.4	0.0163	164.36	213.87	378.23	0.6077	1.2309	343.2	70.0
80.0	2353793.8	632.1	0.0125	186.38	190.84	377.21	0.6725	1.2129	353.2	80.0
90.0	2887910.5	576.2	0.0095	211.32	162.56	373.88	0.7432	1.1908	363.2	90.0
100.0	3508027.5	506.3	0.0070	241.11	125.31	366.42	0.8244	1.1602	373.2	100.0
110.0	4223284.0	401.9	0.0047	282.77	64.76	347.53	0.9336	1.1027	383.2	110.0
111.0	4300419.5	386.0	0.0044	288.84	54.74	343.58	0.9493	1.0918	384.2	111.0
112.0	4378615.5	367.0	0.0041	295.96	42.28	338.24	0.9676	1.0773	385.2	112.0
113.0	4457739.5	341.9	0.0036	305.21	22.01	327.21	0.9913	1.0483	386.2	113.0

SATURATED PROPERTIES OF CH3CHF2 CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.6030	48794.7	0.0109	0.0017	0.9825	0.9828	0.9827	0.80E+02	-0.13E+02	-40.0
-30.0	0.6289	79293.1	0.0176	0.0027	0.9743	0.9750	0.9749	0.76E+02	0.18E+01	-30.0
-20.0	0.6547	123372.4	0.0274	0.0041	0.9638	0.9651	0.9650	0.72E+02	0.15E+02	-20.0
-10.0	0.6806	184847.7	0.0411	0.0061	0.9507	0.9529	0.9528	0.69E+02	0.28E+02	-10.0
0.0	0.7065	267976.2	0.0596	0.0087	0.9346	0.9384	0.9383	0.66E+02	0.39E+02	0.0
10.0	0.7323	377443.0	0.0840	0.0121	0.9154	0.9215	0.9215	0.64E+02	0.49E+02	10.0
20.0	0.7582	518325.2	0.1153	0.0166	0.8927	0.9024	0.9023	0.63E+02	0.59E+02	20.0
30.0	0.7840	696068.1	0.1548	0.0222	0.8663	0.8810	0.8810	0.62E+02	0.67E+02	30.0
40.0	0.8099	916478.0	0.2039	0.0294	0.8358	0.8577	0.8577	0.61E+02	0.75E+02	40.0
50.0	0.8358	1185717.0	0.2638	0.0385	0.8009	0.8324	0.8324	0.61E+02	0.82E+02	50.0
60.0	0.8616	1510320.6	0.3360	0.0500	0.7610	0.8056	0.8055	0.62E+02	0.88E+02	60.0
70.0	0.8875	1897221.5	0.4220	0.0646	0.7154	0.7772	0.7772	0.64E+02	0.93E+02	70.0
80.0	0.9134	2353793.8	0.5236	0.0838	0.6626	0.7476	0.7476	0.67E+02	0.97E+02	80.0
90.0	0.9392	2887910.5	0.6424	0.1096	0.6005	0.7171	0.7171	0.71E+02	0.10E+03	90.0
100.0	0.9651	3508027.5	0.7804	0.1475	0.5235	0.6857	0.6857	0.77E+02	0.10E+03	100.0
110.0	0.9909	4223284.0	0.9395	0.2178	0.4101	0.6538	0.6538	0.86E+02	0.10E+03	110.0
111.0	0.9935	4300419.5	0.9566	0.2304	0.3925	0.6506	0.6506	0.87E+02	0.10E+03	111.0
112.0	0.9961	4378615.5	0.9740	0.2461	0.3706	0.6473	0.6473	0.89E+02	0.99E+02	112.0
113.0	0.9987	4457739.5	0.9916	0.2682	0.3310	0.6441	0.6441	0.91E+02	0.96E+02	113.0

SATD COND (DEG C) (KPA) (TR)	DEGREES OF SUPERHEAT 10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(-40.0) (48.795) (0.6030)	0.618	346.95	1.4929	-16.1993	0.9846	0.644	352.36	1.5197	-18.7749	0.9861	0.670	358.14	1.5470	-21.0973	0.9875	0.697	364.25	1.5745	-23.1528	0.9887
(-30.0) (79.293) (0.6289)	0.393	351.59	1.4567	-0.8080	0.9775	0.409	357.42	1.4841	-3.1370	0.9797	0.426	363.57	1.5118	-5.1969	0.9817	0.442	370.04	1.5395	-6.9835	0.9834
(-20.0) (123.372) (0.6547)	0.260	356.35	1.4259	13.1054	0.9685	0.271	362.57	1.4538	11.0389	0.9715	0.281	369.09	1.4817	9.2485	0.9742	0.292	375.90	1.5097	7.7376	0.9766
(-10.0) (184.848) (0.6806)	0.178	361.14	1.3995	25.7418	0.9574	0.185	367.74	1.4277	23.9457	0.9614	0.192	374.63	1.4560	22.4324	0.9649	0.200	381.79	1.4843	21.2013	0.9681
(0.0) (267.976) (0.7065)	0.125	365.87	1.3766	37.2532	0.9441	0.130	372.86	1.4053	35.7364	0.9493	0.136	380.13	1.4339	34.5057	0.9538	0.141	387.67	1.4624	33.5614	0.9579
(10.0) (377.443) (0.7323)	0.090	370.45	1.3567	47.7636	0.9287	0.094	377.86	1.3858	46.5333	0.9351	0.098	385.54	1.4148	45.5937	0.9408	0.102	393.49	1.4437	44.9432	0.9459
(20.0) (518.325) (0.7582)	0.067	374.81	1.3391	57.3669	0.9111	0.069	382.68	1.3687	56.4342	0.9190	0.072	390.81	1.3982	55.7950	0.9260	0.075	399.23	1.4277	55.4501	0.9323
(30.0) (696.068) (0.7840)	0.050	378.86	1.3232	66.1354	0.8915	0.052	387.25	1.3535	65.5132	0.9009	0.054	395.90	1.3837	65.1896	0.9093	0.057	404.84	1.4139	65.1678	0.9169
(40.0) (916.478) (0.8099)	0.038	382.53	1.3087	74.1187	0.8700	0.040	391.52	1.3399	73.8276	0.8811	0.041	400.76	1.3710	73.8418	0.8911	0.043	410.32	1.4020	74.1683	0.9000
(50.0) (1185.717) (0.8358)	0.029	385.70	1.2950	81.3487	0.8468	0.031	395.41	1.3274	81.4194	0.8597	0.032	405.37	1.3597	81.8036	0.8713	0.033	415.65	1.3919	82.5098	0.8817

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
0.0	570.6	860.7	220.9413	0.00	2559.09	2559.09	0.0000	9.3686	273.2	0.0
10.0	1163.9	854.5	112.2705	46.44	2531.22	2577.66	0.1838	9.1230	283.2	10.0
20.0	2246.4	849.1	60.2128	90.70	2505.55	2596.25	0.3534	8.9001	293.2	20.0
30.0	4124.6	843.6	33.9049	134.94	2479.90	2614.85	0.5173	8.6977	303.2	30.0
40.0	7247.9	837.8	19.9233	179.20	2454.22	2633.43	0.6759	8.5129	313.2	40.0
50.0	12233.0	831.8	12.1747	223.51	2428.46	2651.97	0.8296	8.3444	323.2	50.0
60.0	19910.0	825.5	7.7059	267.89	2402.57	2670.46	0.9790	8.1904	333.2	60.0
70.0	31355.9	819.1	5.0346	312.39	2376.46	2688.85	1.1242	8.0494	343.2	70.0
80.0	47928.5	812.3	3.3850	357.03	2350.07	2707.10	1.2656	7.9201	353.2	80.0
90.0	71297.4	805.4	2.3357	401.86	2323.32	2725.17	1.4036	7.8011	363.2	90.0
100.0	103459.2	798.1	1.6501	446.90	2296.11	2743.01	1.5384	7.6916	373.2	100.0
110.0	146771.2	790.6	1.1909	492.21	2268.35	2760.56	1.6703	7.5904	383.2	110.0
120.0	203949.2	782.7	0.8763	537.82	2239.93	2777.75	1.7995	7.4968	393.2	120.0
130.0	278078.7	774.6	0.6562	583.77	2210.73	2794.50	1.9263	7.4098	403.2	130.0
140.0	372614.3	766.1	0.4993	630.12	2180.64	2810.76	2.0509	7.3288	413.2	140.0
150.0	491374.4	757.2	0.3854	676.92	2149.51	2826.43	2.1734	7.2531	423.2	150.0
160.0	638539.3	747.9	0.3015	724.22	2117.21	2841.42	2.2943	7.1821	433.2	160.0
170.0	818628.3	738.2	0.2386	772.09	2083.57	2855.66	2.4135	7.1151	443.2	170.0
180.0	1036503.6	728.1	0.1909	820.59	2048.43	2869.02	2.5314	7.0517	453.2	180.0
190.0	1297348.9	717.4	0.1542	869.81	2011.61	2881.42	2.6481	6.9914	463.2	190.0
200.0	1606662.1	706.3	0.1257	919.83	1972.90	2892.73	2.7639	6.9335	473.2	200.0
210.0	1970241.4	694.6	0.1033	970.75	1932.09	2902.84	2.8790	6.8778	483.2	210.0
220.0	2394178.0	682.3	0.0854	1022.67	1888.93	2911.60	2.9935	6.8238	493.2	220.0
230.0	2884859.0	669.3	0.0711	1075.73	1843.13	2918.86	3.1078	6.7710	503.2	230.0
240.0	3448960.0	655.6	0.0595	1130.07	1794.38	2924.45	3.2222	6.7189	513.2	240.0
250.0	4093420.8	641.1	0.0500	1185.86	1742.31	2928.18	3.3369	6.6673	523.2	250.0
260.0	4825493.5	625.7	0.0422	1243.32	1686.49	2929.81	3.4522	6.6154	533.2	260.0
270.0	5652703.0	609.3	0.0358	1302.68	1626.40	2929.08	3.5686	6.5630	543.2	270.0
280.0	6582902.0	591.8	0.0304	1364.26	1561.40	2925.66	3.6866	6.5093	553.2	280.0
290.0	7624248.0	573.0	0.0258	1428.44	1490.70	2919.14	3.8066	6.4537	563.2	290.0
300.0	8785244.0	552.7	0.0220	1495.73	1413.28	2909.01	3.9295	6.3953	573.2	300.0
310.0	10074747.0	530.7	0.0187	1566.77	1327.79	2894.57	4.0563	6.3332	583.2	310.0
320.0	11502014.0	506.7	0.0158	1642.52	1232.35	2874.87	4.1882	6.2659	593.2	320.0
330.0	13076721.0	480.0	0.0134	1724.32	1124.21	2848.53	4.3274	6.1913	603.2	330.0
340.0	14809037.0	449.8	0.0112	1814.35	998.97	2813.32	4.4769	6.1061	613.2	340.0
350.0	16709607.0	414.8	0.0093	1916.50	848.76	2765.27	4.6425	6.0045	623.2	350.0
360.0	18789686.0	371.8	0.0074	2039.32	656.22	2695.55	4.8369	5.8733	633.2	360.0
370.0	21061154.0	309.8	0.0056	2213.22	357.66	2570.88	5.1061	5.6622	643.2	370.0
371.0	21299302.0	300.8	0.0053	2238.18	311.22	2549.40	5.1444	5.6275	644.2	371.0
372.0	21539528.0	290.5	0.0051	2266.66	255.99	2522.66	5.1880	5.5848	645.2	372.0
373.0	21781706.0	278.3	0.0047	2300.79	182.26	2483.06	5.2403	5.5223	646.2	373.0

SATURATED PROPERTIES OF H2O F O CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
0.0	0.4220	570.6	0.0000	0.0000	0.9999	1.0003	0.9999	0.16E+02	-0.21E+03	0.0
10.0	0.4374	1163.9	0.0001	0.0000	0.9998	1.0000	0.9998	0.80E+01	-0.12E+03	10.0
20.0	0.4529	2246.4	0.0001	0.0000	0.9996	0.9998	0.9996	0.19E+01	-0.32E+02	20.0
30.0	0.4683	4124.6	0.0002	0.0000	0.9994	0.9999	0.9994	-0.26E+01	0.46E+02	30.0
40.0	0.4838	7247.9	0.0003	0.0001	0.9990	0.9992	0.9990	-0.55E+01	0.12E+03	40.0
50.0	0.4992	12233.0	0.0006	0.0001	0.9985	0.9986	0.9985	-0.69E+01	0.19E+03	50.0
60.0	0.5147	19910.0	0.0009	0.0002	0.9977	0.9978	0.9977	-0.68E+01	0.25E+03	60.0
70.0	0.5301	31355.9	0.0014	0.0002	0.9967	0.9968	0.9967	-0.55E+01	0.31E+03	70.0
80.0	0.5456	47928.5	0.0022	0.0004	0.9953	0.9954	0.9953	-0.29E+01	0.37E+03	80.0
90.0	0.5610	71297.4	0.0032	0.0005	0.9935	0.9936	0.9935	0.94E+00	0.42E+03	90.0
100.0	0.5765	103459.2	0.0047	0.0008	0.9912	0.9913	0.9913	0.59E+01	0.47E+03	100.0
110.0	0.5919	146771.2	0.0067	0.0010	0.9883	0.9885	0.9885	0.12E+02	0.52E+03	110.0
120.0	0.6074	203949.2	0.0093	0.0014	0.9848	0.9851	0.9850	0.19E+02	0.57E+03	120.0
130.0	0.6228	278078.7	0.0126	0.0019	0.9806	0.9810	0.9809	0.28E+02	0.61E+03	130.0
140.0	0.6383	372614.3	0.0169	0.0026	0.9756	0.9762	0.9761	0.37E+02	0.65E+03	140.0
150.0	0.6537	491374.4	0.0223	0.0033	0.9697	0.9706	0.9705	0.47E+02	0.69E+03	150.0
160.0	0.6692	638539.3	0.0290	0.0043	0.9628	0.9641	0.9641	0.59E+02	0.72E+03	160.0
170.0	0.6846	818628.3	0.0371	0.0054	0.9550	0.9568	0.9568	0.71E+02	0.76E+03	170.0
180.0	0.7001	1036503.6	0.0470	0.0068	0.9461	0.9487	0.9486	0.85E+02	0.79E+03	180.0
190.0	0.7155	1297348.9	0.0588	0.0085	0.9360	0.9396	0.9396	0.99E+02	0.82E+03	190.0
200.0	0.7310	1606662.1	0.0729	0.0104	0.9248	0.9297	0.9296	0.11E+03	0.85E+03	200.0
210.0	0.7464	1970241.4	0.0894	0.0127	0.9122	0.9188	0.9188	0.13E+03	0.88E+03	210.0
220.0	0.7619	2394178.0	0.1086	0.0154	0.8984	0.9071	0.9071	0.15E+03	0.90E+03	220.0
230.0	0.7773	2884859.0	0.1308	0.0186	0.8831	0.8945	0.8945	0.17E+03	0.92E+03	230.0
240.0	0.7928	3448960.0	0.1564	0.0222	0.8664	0.8811	0.8811	0.19E+03	0.94E+03	240.0
250.0	0.8082	4093420.8	0.1857	0.0264	0.8480	0.8669	0.8669	0.21E+03	0.96E+03	250.0
260.0	0.8237	4825493.5	0.2189	0.0313	0.8281	0.8520	0.8519	0.23E+03	0.98E+03	260.0
270.0	0.8391	5652703.0	0.2564	0.0370	0.8064	0.8363	0.8363	0.26E+03	0.10E+04	270.0
280.0	0.8546	6582902.0	0.2986	0.0436	0.7827	0.8199	0.8199	0.28E+03	0.10E+04	280.0
290.0	0.8700	7624248.0	0.3458	0.0512	0.7570	0.8029	0.8029	0.31E+03	0.10E+04	290.0
300.0	0.8855	8785244.0	0.3985	0.0601	0.7290	0.7854	0.7854	0.34E+03	0.10E+04	300.0
310.0	0.9009	10074747.0	0.4569	0.0705	0.6984	0.7673	0.7673	0.38E+03	0.10E+04	310.0
320.0	0.9164	11502014.0	0.5217	0.0829	0.6648	0.7488	0.7488	0.41E+03	0.10E+04	320.0
330.0	0.9318	13076721.0	0.5931	0.0979	0.6276	0.7298	0.7298	0.45E+03	0.10E+04	330.0
340.0	0.9473	14809037.0	0.6717	0.1163	0.5858	0.7105	0.7105	0.50E+03	0.10E+04	340.0
350.0	0.9627	16709607.0	0.7579	0.1400	0.5376	0.6909	0.6909	0.55E+03	0.10E+04	350.0
360.0	0.9782	18789686.0	0.8522	0.1729	0.4789	0.6710	0.6710	0.62E+03	0.97E+03	360.0
370.0	0.9936	21061154.0	0.9552	0.2290	0.3944	0.6509	0.6509	0.71E+03	0.90E+03	370.0
371.0	0.9951	21299302.0	0.9660	0.2382	0.3817	0.6489	0.6489	0.73E+03	0.89E+03	371.0
372.0	0.9967	21539528.0	0.9769	0.2490	0.3665	0.6468	0.6468	0.74E+03	0.88E+03	372.0

SUPERHEATED PROPERTIES OF WATER REFRIGERANT R718 (H20) F 8

DEGREES OF SUPERHEAT

SATD COND (DEG C) (KPA) (TR)	10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(0.0) (0.571) (0.4220)	229.032	2577.70	9.4521	-214.9257	0.9999	237.122	2596.34	9.5329	-220.2704	0.9999	245.212	2615.03	9.6110	-224.8098	0.9999	253.303	2633.75	9.6868	-228.5940	0.9999
(10.0) (1.164) (0.4374)	116.237	2596.31	9.2038	-122.5105	0.9998	120.204	2615.00	9.2819	-127.0499	0.9998	124.171	2633.72	9.3577	-130.8343	0.9998	128.137	2652.49	9.4312	-133.9079	0.9999
(20.0) (2.246) (0.4529)	62.269	2614.94	8.9783	-36.8809	0.9997	64.324	2633.67	9.0541	-40.6651	0.9997	66.380	2652.44	9.1276	-43.7387	0.9997	68.435	2671.25	9.1990	-46.1428	0.9997
(30.0) (4.125) (0.4683)	35.025	2633.58	8.7734	42.6359	0.9995	36.145	2652.35	8.8470	39.5625	0.9995	37.265	2671.17	8.9184	37.1587	0.9995	38.385	2690.03	8.9878	35.3880	0.9996
(40.0) (7.248) (0.4838)	20.561	2652.21	8.5865	116.8211	0.9991	21.199	2671.03	8.6579	114.4183	0.9992	21.836	2689.89	8.7274	112.6481	0.9992	22.474	2708.80	8.7949	111.4768	0.9993
(50.0) (12.233) (0.4992)	12.553	2670.80	8.4159	186.1071	0.9986	12.931	2689.68	8.4854	184.3382	0.9987	13.309	2708.59	8.5530	183.1681	0.9988	13.687	2727.55	8.6188	182.5668	0.9989
(60.0) (19.910) (0.5147)	7.939	2689.34	8.2600	250.9892	0.9979	8.171	2708.27	8.3276	249.8209	0.9981	8.404	2727.25	8.3935	249.2218	0.9982	8.636	2746.26	8.4576	249.1626	0.9983
(70.0) (31.356) (0.5301)	5.183	2707.79	8.1171	311.8857	0.9969	5.330	2726.79	8.1830	311.2894	0.9972	5.478	2745.82	8.2473	311.2339	0.9974	5.626	2764.89	8.3099	311.6914	0.9975
(80.0) (47.928) (0.5456)	3.482	2726.12	7.9860	369.1585	0.9957	3.579	2745.18	8.0504	369.1076	0.9960	3.676	2764.28	8.1131	369.5705	0.9962	3.773	2783.42	8.1743	370.5239	0.9965
(90.0) (71.297) (0.5610)	2.401	2744.27	7.8655	423.1227	0.9940	2.466	2763.40	7.9283	423.5930	0.9944	2.532	2782.58	7.9896	424.5536	0.9948	2.597	2801.79	8.0495	425.9829	0.9951

DEG C	PA	KG/M3	M3/KG	KJ/KG	KJ/KG	KJ/KG	KJ/KG.K	KJ/KG.K	DEG K	DEG C
-40.0	73827.9	1447.6	0.2578	0.00	208.23	208.23	0.0000	0.8931	233.2	-40.0
-30.0	115642.3	1419.4	0.1698	10.88	203.65	214.53	0.0491	0.8866	243.2	-30.0
-20.0	174148.3	1389.3	0.1158	21.93	198.73	220.66	0.0968	0.8818	253.2	-20.0
-10.0	253433.2	1356.9	0.0814	33.19	193.41	226.60	0.1435	0.8784	263.2	-10.0
0.0	357979.2	1322.0	0.0586	44.71	187.61	232.31	0.1892	0.8760	273.2	0.0
10.0	492611.9	1284.4	0.0431	56.53	181.22	237.75	0.2344	0.8744	283.2	10.0
20.0	662486.0	1243.5	0.0322	68.71	174.16	242.87	0.2791	0.8732	293.2	20.0
30.0	873062.2	1199.0	0.0244	81.33	166.26	247.59	0.3237	0.8721	303.2	30.0
40.0	1130115.0	1150.0	0.0187	94.47	157.38	251.84	0.3683	0.8708	313.2	40.0
50.0	1439726.0	1095.8	0.0144	108.24	147.25	255.49	0.4134	0.8690	323.2	50.0
60.0	1808314.6	1035.1	0.0111	122.82	135.56	258.38	0.4593	0.8662	333.2	60.0
70.0	2242666.3	965.9	0.0086	138.46	121.76	260.23	0.5067	0.8616	343.2	70.0
80.0	2749985.8	884.9	0.0066	155.62	104.96	260.58	0.5568	0.8540	353.2	80.0
90.0	3337956.8	785.4	0.0049	175.22	83.24	258.46	0.6119	0.8411	363.2	90.0
100.0	4014831.8	645.9	0.0034	200.32	50.38	250.70	0.6798	0.8148	373.2	100.0
101.0	4087745.8	626.9	0.0033	203.54	45.63	249.17	0.6883	0.8103	374.2	101.0
102.0	4161649.5	605.9	0.0031	207.05	40.28	247.32	0.6976	0.8049	375.2	102.0
103.0	4236546.5	582.1	0.0029	210.95	34.04	245.00	0.7079	0.7984	376.2	103.0
104.0	4312453.5	553.7	0.0027	215.51	26.29	241.80	0.7198	0.7895	377.2	104.0

SATURATED PROPERTIES OF R12 & R152A CONTINUED

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.6158	73827.9	0.0167	0.0026	0.9751	0.9757	0.9756	0.61E+02	0.40E+01	-40.0
-30.0	0.6422	115642.3	0.0261	0.0040	0.9647	0.9659	0.9658	0.57E+02	0.12E+02	-30.0
-20.0	0.6686	174148.3	0.0393	0.0059	0.9518	0.9538	0.9538	0.54E+02	0.20E+02	-20.0
-10.0	0.6950	253433.2	0.0573	0.0085	0.9359	0.9395	0.9395	0.52E+02	0.27E+02	-10.0
0.0	0.7214	357979.2	0.0809	0.0118	0.9169	0.9229	0.9228	0.50E+02	0.33E+02	0.0
10.0	0.7478	492611.9	0.1113	0.0162	0.8946	0.9040	0.9039	0.48E+02	0.39E+02	10.0
20.0	0.7742	662486.0	0.1497	0.0217	0.8686	0.8829	0.8829	0.47E+02	0.45E+02	20.0
30.0	0.8006	873062.2	0.1973	0.0287	0.8388	0.8599	0.8599	0.46E+02	0.50E+02	30.0
40.0	0.8270	1130115.0	0.2554	0.0375	0.8046	0.8350	0.8350	0.46E+02	0.54E+02	40.0
50.0	0.8534	1439726.0	0.3253	0.0486	0.7657	0.8086	0.8086	0.47E+02	0.58E+02	50.0
60.0	0.8798	1808314.6	0.4086	0.0626	0.7213	0.7808	0.7807	0.47E+02	0.62E+02	60.0
70.0	0.9062	2242666.3	0.5067	0.0808	0.6703	0.7517	0.7517	0.49E+02	0.65E+02	70.0
80.0	0.9327	2749985.8	0.6214	0.1051	0.6107	0.7218	0.7218	0.51E+02	0.68E+02	80.0
90.0	0.9591	3337956.8	0.7542	0.1398	0.5381	0.6911	0.6911	0.55E+02	0.70E+02	90.0
100.0	0.9855	4014831.8	0.9072	0.1989	0.4378	0.6598	0.6598	0.59E+02	0.70E+02	100.0
101.0	0.9881	4087745.8	0.9236	0.2081	0.4241	0.6567	0.6567	0.60E+02	0.70E+02	101.0
102.0	0.9908	4161649.5	0.9403	0.2187	0.4090	0.6535	0.6535	0.61E+02	0.69E+02	102.0
103.0	0.9934	4236546.5	0.9573	0.2311	0.3915	0.6504	0.6504	0.62E+02	0.69E+02	103.0
104.0	0.9960	4312453.5	0.9744	0.2466	0.3698	0.6472	0.6472	0.63E+02	0.68E+02	104.0

SUPERHEATED PROPERTIES OF 73.8% CCL2F2 26.2% CH3CHF2 REFRIGERANT R500 (R12 & R152A) F9

DEGREES OF SUPERHEAT

SATD COND (DEG C) (KPA) (TR)	10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(-40.0) (73.828) (0.6158)	0.270	215.22	0.9260	1.2066	0.9782	0.281	222.26	0.9577	-1.1854	0.9804	0.293	229.34	0.9884	-3.2198	0.9823	0.305	236.48	1.0181	-4.9208	0.9840
(-30.0) (115.642) (0.6422)	0.178	221.60	0.9185	9.8110	0.9693	0.185	228.72	0.9493	7.7708	0.9723	0.193	235.90	0.9792	6.0660	0.9749	0.200	243.14	1.0082	4.6760	0.9773
(-20.0) (174.148) (0.6686)	0.121	227.84	0.9129	17.7113	0.9583	0.126	235.06	0.9429	16.0009	0.9623	0.131	242.36	0.9722	14.6077	0.9658	0.136	249.72	1.0006	13.5137	0.9689
(-10.0) (253.433) (0.6950)	0.085	233.90	0.9088	24.9927	0.9452	0.089	241.26	0.9383	23.5947	0.9503	0.092	248.69	0.9669	22.4988	0.9548	0.096	256.19	0.9949	21.6892	0.9588
(0.0) (357.979) (0.7214)	0.061	239.77	0.9059	31.7236	0.9300	0.064	247.29	0.9349	30.6248	0.9364	0.067	254.88	0.9631	29.8154	0.9420	0.069	262.53	0.9907	29.2808	0.9470
(10.0) (492.612) (0.7478)	0.045	245.41	0.9039	37.9558	0.9127	0.047	253.11	0.9325	37.1468	0.9204	0.049	260.88	0.9604	36.6160	0.9273	0.051	268.71	0.9877	36.3504	0.9335
(20.0) (662.486) (0.7742)	0.034	250.75	0.9024	43.7281	0.8933	0.035	258.68	0.9309	43.2029	0.9026	0.037	266.65	0.9586	42.9465	0.9109	0.038	274.68	0.9856	42.9465	0.9184
(30.0) (873.062) (0.8006)	0.026	255.77	0.9013	49.0662	0.8721	0.027	263.95	0.9297	48.8236	0.8831	0.028	272.17	0.9573	48.8409	0.8929	0.029	280.42	0.9842	49.1056	0.9017
(40.0) (1130.115) (0.8270)	0.020	260.37	0.9003	53.9848	0.8492	0.021	268.87	0.9287	54.0288	0.8619	0.022	277.37	0.9564	54.3225	0.8733	0.023	285.88	0.9832	54.8544	0.8836
(50.0) (1439.726) (0.8534)	0.015	264.49	0.8990	58.4859	0.8249	0.016	273.37	0.9277	58.8267	0.8394	0.017	282.21	0.9555	59.4053	0.8525	0.018	291.01	0.9825	60.2103	0.8643

T DEG C	P PA	D(F) KG/M3	V(G) M3/KG	H(F) KJ/KG	H(FG) KJ/KG	H(G) KJ/KG	S(F) KJ/KG.K	S(G) KJ/KG.K	T DEG K	T DEG C
-40.0	22.9	1808.2	511.6261	0.00	252.01	252.01	0.0000	1.0854	233.2	-40.0
-30.0	59.8	1796.9	203.8285	7.79	249.52	257.31	0.0349	1.0614	243.2	-30.0
-20.0	134.4	1785.4	94.4237	15.63	247.05	262.68	0.0685	1.0445	253.2	-20.0
-10.0	281.0	1772.1	46.9550	23.68	244.44	268.12	0.1017	1.0306	263.2	-10.0
0.0	552.1	1760.3	24.7974	31.59	242.04	273.64	0.1331	1.0192	273.2	0.0
10.0	1029.9	1748.0	13.7762	39.58	239.64	279.22	0.1636	1.0098	283.2	10.0
20.0	1825.1	1735.4	8.0450	47.63	237.24	284.87	0.1933	1.0025	293.2	20.0
30.0	3100.7	1722.3	4.8937	55.75	234.82	290.57	0.2222	0.9967	303.2	30.0
40.0	5070.1	1708.6	3.0888	63.95	232.39	296.33	0.2504	0.9925	313.2	40.0
50.0	8008.1	1694.5	2.0155	72.21	229.93	302.14	0.2780	0.9895	323.2	50.0
60.0	12258.2	1679.9	1.3552	80.55	227.43	307.99	0.3049	0.9876	333.2	60.0
70.0	18238.4	1664.6	0.9362	88.97	224.90	313.87	0.3313	0.9866	343.2	70.0
80.0	26443.9	1648.8	0.6627	97.47	222.31	319.78	0.3571	0.9866	353.2	80.0
90.0	37458.6	1632.4	0.4795	106.05	219.66	325.71	0.3824	0.9873	363.2	90.0
100.0	51939.4	1615.3	0.3539	114.71	216.93	331.65	0.4073	0.9887	373.2	100.0
110.0	70630.3	1597.5	0.2659	123.47	214.12	337.58	0.4318	0.9906	383.2	110.0
120.0	94355.9	1578.9	0.2030	132.31	211.21	343.51	0.4558	0.9930	393.2	120.0
130.0	124019.4	1559.6	0.1573	141.24	208.18	349.42	0.4794	0.9958	403.2	130.0
140.0	160599.1	1539.4	0.1235	150.28	205.02	355.29	0.5027	0.9990	413.2	140.0
150.0	205144.9	1518.2	0.0981	159.42	201.71	361.13	0.5257	1.0024	423.2	150.0
160.0	258773.1	1496.1	0.0788	168.67	198.24	366.91	0.5484	1.0061	433.2	160.0
170.0	322672.6	1473.0	0.0639	178.03	194.58	372.62	0.5709	1.0099	443.2	170.0
180.0	398088.0	1448.7	0.0523	187.52	190.72	378.24	0.5930	1.0139	453.2	180.0
190.0	486325.9	1423.2	0.0431	197.15	186.63	383.78	0.6150	1.0180	463.2	190.0
200.0	588753.3	1396.3	0.0357	206.92	182.28	389.20	0.6368	1.0220	473.2	200.0
210.0	706783.9	1368.0	0.0298	216.85	177.64	394.49	0.6584	1.0261	483.2	210.0
220.0	841898.6	1338.1	0.0250	226.94	172.69	399.63	0.6799	1.0301	493.2	220.0
230.0	995626.7	1306.4	0.0211	237.23	167.36	404.60	0.7014	1.0340	503.2	230.0
240.0	1169556.3	1272.7	0.0178	247.73	161.63	409.36	0.7228	1.0377	513.2	240.0
250.0	1365334.9	1236.8	0.0151	258.48	155.42	413.90	0.7441	1.0412	523.2	250.0
260.0	1584665.0	1198.4	0.0129	269.49	148.67	418.16	0.7656	1.0445	533.2	260.0
270.0	1829319.8	1157.1	0.0109	280.82	141.28	422.11	0.7872	1.0473	543.2	270.0
280.0	2101132.0	1112.4	0.0093	292.54	133.13	425.67	0.8091	1.0497	553.2	280.0
290.0	2402014.0	1063.6	0.0079	304.71	124.05	428.76	0.8313	1.0516	563.2	290.0
300.0	2733959.5	1009.8	0.0067	317.46	113.80	431.26	0.8540	1.0526	573.2	300.0
310.0	3099044.5	949.5	0.0056	330.98	101.99	432.97	0.8776	1.0525	583.2	310.0
320.0	3499441.5	880.2	0.0047	345.58	87.98	433.56	0.9026	1.0509	593.2	320.0
330.0	3937433.3	796.8	0.0038	361.93	70.42	432.35	0.9299	1.0466	603.2	330.0
340.0	4415421.0	684.5	0.0029	381.98	45.29	427.27	0.9626	1.0365	613.2	340.0
341.0	4465514.5	669.9	0.0028	384.42	41.87	426.29	0.9665	1.0347	614.2	341.0
342.0	4516040.0	654.2	0.0027	387.01	38.13	425.14	0.9707	1.0327	615.2	342.0

T DEG C	TR	P PA	PR	Z(F)	Z(G)	FC(F)	FC(G)	B(F) KJ/KG	B(G) KJ/KG	T DEG C
-40.0	0.3761	22.9	0.0000	0.0000	1.0000	1.0939	1.0000	0.10E+02	-0.61E+02	-40.0
-30.0	0.3922	59.8	0.0000	0.0000	0.9999	1.0086	0.9999	0.74E+01	-0.48E+02	-30.0
-20.0	0.4083	134.4	0.0000	0.0000	0.9999	1.0024	0.9999	0.52E+01	-0.38E+02	-20.0
-10.0	0.4245	281.0	0.0001	0.0000	0.9998	1.0005	0.9998	0.34E+01	-0.28E+02	-10.0
0.0	0.4406	552.1	0.0001	0.0000	0.9996	0.9999	0.9996	0.20E+01	-0.19E+02	0.0
10.0	0.4567	1029.9	0.0002	0.0000	0.9993	0.9975	0.9993	0.94E+00	-0.11E+02	10.0
20.0	0.4728	1825.1	0.0004	0.0001	0.9989	0.9983	0.9989	0.17E+00	-0.31E+01	20.0
30.0	0.4890	3100.7	0.0007	0.0001	0.9982	0.9981	0.9982	-0.31E+00	0.43E+01	30.0
40.0	0.5051	5070.1	0.0011	0.0002	0.9973	0.9974	0.9973	-0.50E+00	0.11E+02	40.0
50.0	0.5212	8008.1	0.0017	0.0003	0.9961	0.9962	0.9961	-0.42E+00	0.18E+02	50.0
60.0	0.5374	12258.2	0.0026	0.0004	0.9945	0.9946	0.9945	-0.83E-01	0.24E+02	60.0
70.0	0.5535	18238.4	0.0038	0.0006	0.9924	0.9925	0.9924	0.50E+00	0.31E+02	70.0
80.0	0.5696	26443.9	0.0056	0.0009	0.9897	0.9899	0.9898	0.13E+01	0.37E+02	80.0
90.0	0.5857	37458.6	0.0079	0.0013	0.9864	0.9866	0.9866	0.24E+01	0.42E+02	90.0
100.0	0.6019	51939.4	0.0109	0.0017	0.9824	0.9827	0.9827	0.36E+01	0.48E+02	100.0
110.0	0.6180	70630.3	0.0148	0.0023	0.9775	0.9781	0.9780	0.51E+01	0.53E+02	110.0
120.0	0.6341	94355.9	0.0198	0.0030	0.9719	0.9726	0.9726	0.68E+01	0.58E+02	120.0
130.0	0.6503	124019.4	0.0260	0.0039	0.9652	0.9663	0.9663	0.87E+01	0.63E+02	130.0
140.0	0.6664	160599.1	0.0337	0.0050	0.9576	0.9592	0.9592	0.11E+02	0.68E+02	140.0
150.0	0.6825	205144.9	0.0431	0.0064	0.9488	0.9512	0.9511	0.13E+02	0.73E+02	150.0
160.0	0.6986	258773.1	0.0543	0.0080	0.9390	0.9423	0.9422	0.16E+02	0.78E+02	160.0
170.0	0.7148	322672.6	0.0677	0.0099	0.9279	0.9324	0.9324	0.18E+02	0.82E+02	170.0
180.0	0.7309	398088.0	0.0836	0.0121	0.9156	0.9217	0.9216	0.21E+02	0.87E+02	180.0
190.0	0.7470	486325.9	0.1021	0.0147	0.9019	0.9101	0.9100	0.24E+02	0.91E+02	190.0
200.0	0.7632	588753.3	0.1236	0.0178	0.8868	0.8976	0.8975	0.28E+02	0.95E+02	200.0
210.0	0.7793	706783.9	0.1484	0.0213	0.8703	0.8843	0.8842	0.31E+02	0.10E+03	210.0
220.0	0.7954	841898.6	0.1767	0.0254	0.8523	0.8702	0.8701	0.35E+02	0.10E+03	220.0
230.0	0.8115	995626.7	0.2090	0.0302	0.8326	0.8553	0.8553	0.39E+02	0.11E+03	230.0
240.0	0.8277	1169556.3	0.2455	0.0357	0.8112	0.8397	0.8397	0.43E+02	0.11E+03	240.0
250.0	0.8438	1365334.9	0.2866	0.0421	0.7880	0.8235	0.8235	0.47E+02	0.11E+03	250.0
260.0	0.8599	1584665.0	0.3326	0.0495	0.7627	0.8066	0.8066	0.52E+02	0.12E+03	260.0
270.0	0.8761	1829319.8	0.3840	0.0580	0.7352	0.7892	0.7892	0.57E+02	0.12E+03	270.0
280.0	0.8922	2101132.0	0.4410	0.0681	0.7053	0.7713	0.7713	0.62E+02	0.12E+03	280.0
290.0	0.9083	2402014.0	0.5042	0.0800	0.6726	0.7529	0.7529	0.68E+02	0.13E+03	290.0
300.0	0.9245	2733959.5	0.5739	0.0942	0.6364	0.7342	0.7342	0.74E+02	0.13E+03	300.0
310.0	0.9406	3099044.5	0.6505	0.1116	0.5961	0.7151	0.7151	0.80E+02	0.13E+03	310.0
320.0	0.9567	3499441.5	0.7346	0.1337	0.5500	0.6957	0.6956	0.87E+02	0.13E+03	320.0
330.0	0.9728	3937433.3	0.8265	0.1634	0.4951	0.6760	0.6760	0.96E+02	0.13E+03	330.0
340.0	0.9890	4415421.0	0.9268	0.2098	0.4217	0.6562	0.6562	0.11E+03	0.13E+03	340.0
341.0	0.9906	4465514.5	0.9373	0.2165	0.4121	0.6542	0.6542	0.11E+03	0.13E+03	341.0
342.0	0.9922	4516040.0	0.9480	0.2238	0.4017	0.6522	0.6522	0.11E+03	0.13E+03	342.0

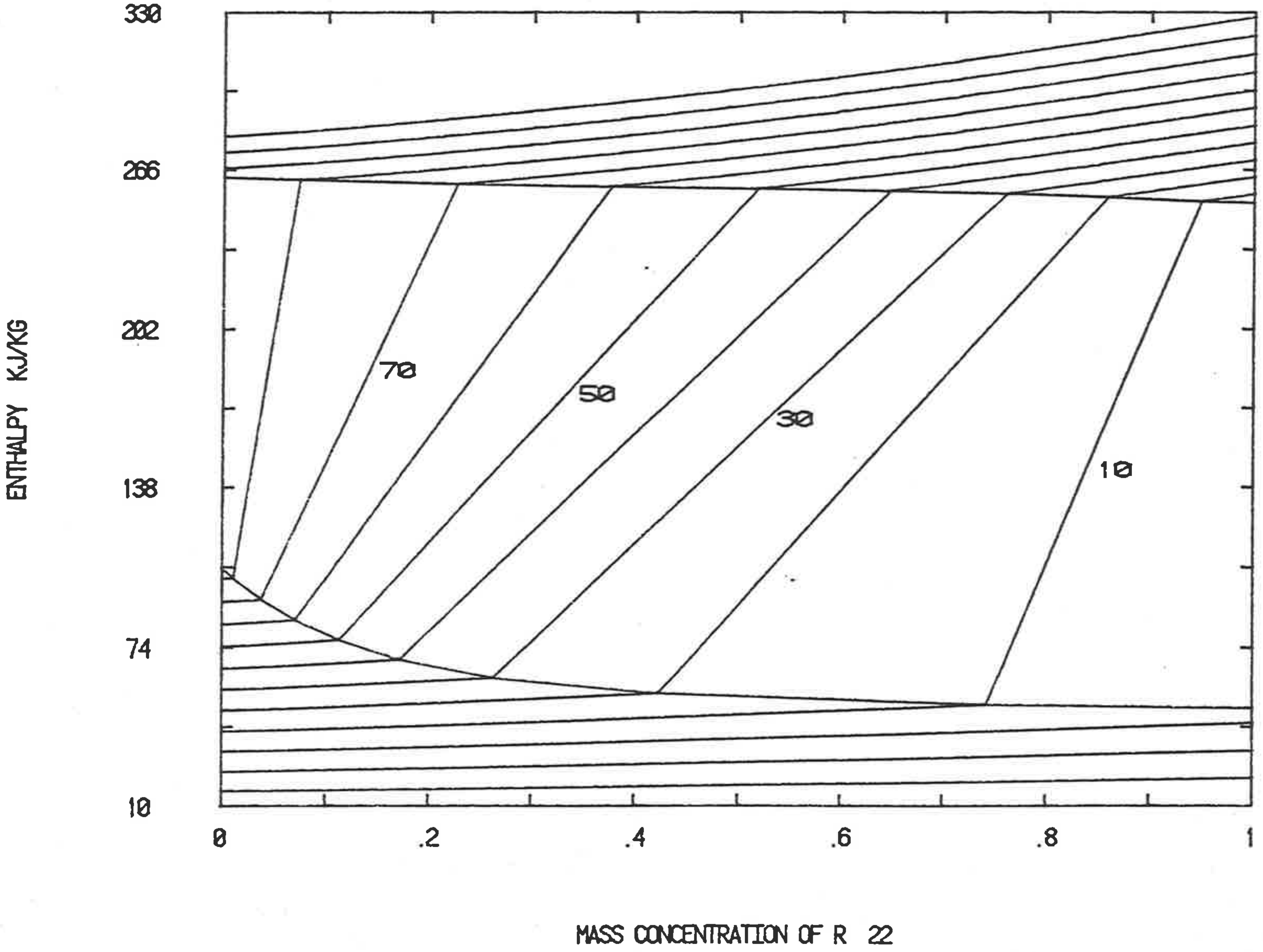
DEGREES OF SUPERHEAT

SATD COND (DEG C) (KPA) (TR)	10K V(G) M3/KG	10K H(G) KJ/KG	10K S(G) KJ/KG.K	10K B(G) KJ/KG	10K FC(G)	20K V(G) M3/KG	20K H(G) KJ/KG	20K S(G) KJ/KG.K	20K B(G) KJ/KG	20K FC(G)	30K V(G) M3/KG	30K H(G) KJ/KG	30K S(G) KJ/KG.K	30K B(G) KJ/KG	30K FC(G)	40K V(G) M3/KG	40K H(G) KJ/KG	40K S(G) KJ/KG.K	40K B(G) KJ/KG	40K FC(G)
(-40.0) (0.023) (0.3761)	533.571	257.31	1.1097	-62.4855	1.0000	555.515	262.68	1.1334	-64.1475	1.0000	577.459	268.13	1.1564	-65.5483	1.0000	599.404	273.65	1.1789	-66.7017	1.0000
(-30.0) (0.060) (0.3922)	212.212	262.68	1.0851	-49.8098	0.9999	220.596	268.13	1.1082	-51.2106	1.0000	228.979	273.65	1.1306	-52.3640	1.0000	237.363	279.24	1.1525	-53.2823	1.0000
(-20.0) (0.134) (0.4083)	98.155	268.12	1.0676	-39.1462	0.9999	101.885	273.65	1.0900	-40.2997	0.9999	105.616	279.24	1.1119	-41.2179	0.9999	109.347	284.90	1.1333	-41.9123	0.9999
(-10.0) (0.281) (0.4245)	48.740	273.64	1.0530	-29.3161	0.9998	50.525	279.24	1.0750	-30.2343	0.9998	52.311	284.90	1.0964	-30.9287	0.9998	54.096	290.63	1.1173	-31.4096	0.9998
(0.0) (0.552) (0.4406)	25.706	279.23	1.0411	-20.1707	0.9996	26.615	284.90	1.0625	-20.8651	0.9997	27.523	290.63	1.0834	-21.3460	0.9997	28.432	296.43	1.1038	-21.6229	0.9997
(10.0) (1.030) (0.4567)	14.263	284.88	1.0312	-11.5797	0.9994	14.751	290.62	1.0521	-12.0606	0.9994	15.238	296.42	1.0725	-12.3375	0.9995	15.725	302.28	1.0926	-12.4191	0.9995
(20.0) (1.825) (0.4728)	8.320	290.60	1.0234	-3.5425	0.9990	8.595	296.40	1.0438	-3.8194	0.9990	8.870	302.26	1.0638	-3.9010	0.9991	9.146	308.19	1.0834	-3.7955	0.9992
(30.0) (3.101) (0.4890)	5.056	296.37	1.0172	4.0663	0.9984	5.218	302.24	1.0372	3.9848	0.9985	5.380	308.16	1.0568	4.0904	0.9986	5.542	314.15	1.0760	4.3754	0.9987
(40.0) (5.070) (0.5051)	3.188	302.20	1.0125	11.2943	0.9975	3.287	308.13	1.0321	11.4000	0.9977	3.387	314.12	1.0513	11.6851	0.9979	3.486	320.16	1.0701	12.1429	0.9980
(50.0) (8.008) (0.5212)	2.079	308.07	1.0091	18.1849	0.9964	2.141	314.06	1.0283	18.4703	0.9967	2.204	320.11	1.0471	18.9283	0.9969	2.267	326.22	1.0655	19.5522	0.9971
(60.0) (12.258) [illegible]	1.396	313.98	1.0068	[illegible]	[illegible]	1.438	320.04	1.0256	25.2353	0.9953	1.479	326.15	1.0441	25.8597	0.9956	1.520	332.31	1.0622	26.6436	0.9959

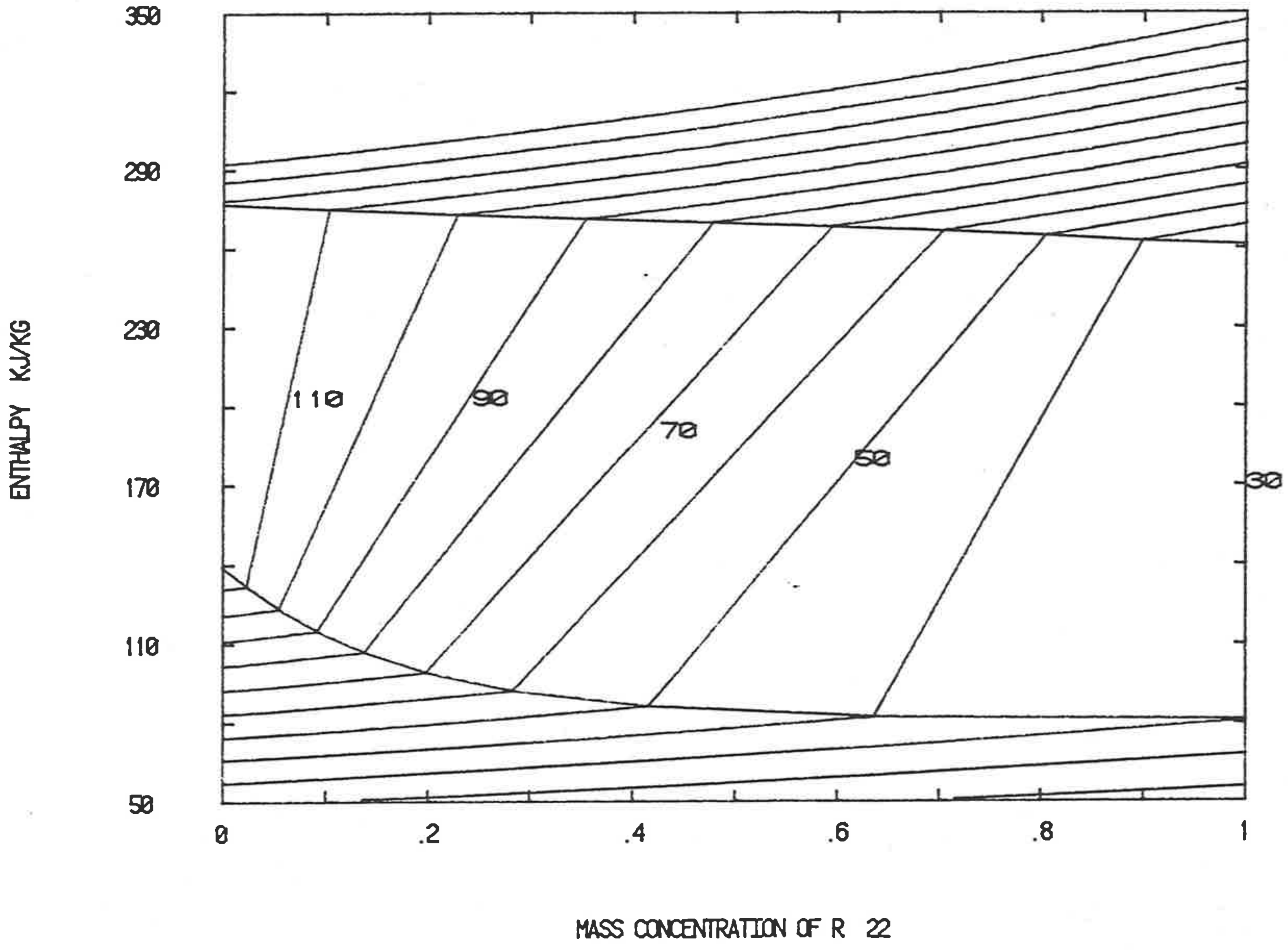
APPENDIX G

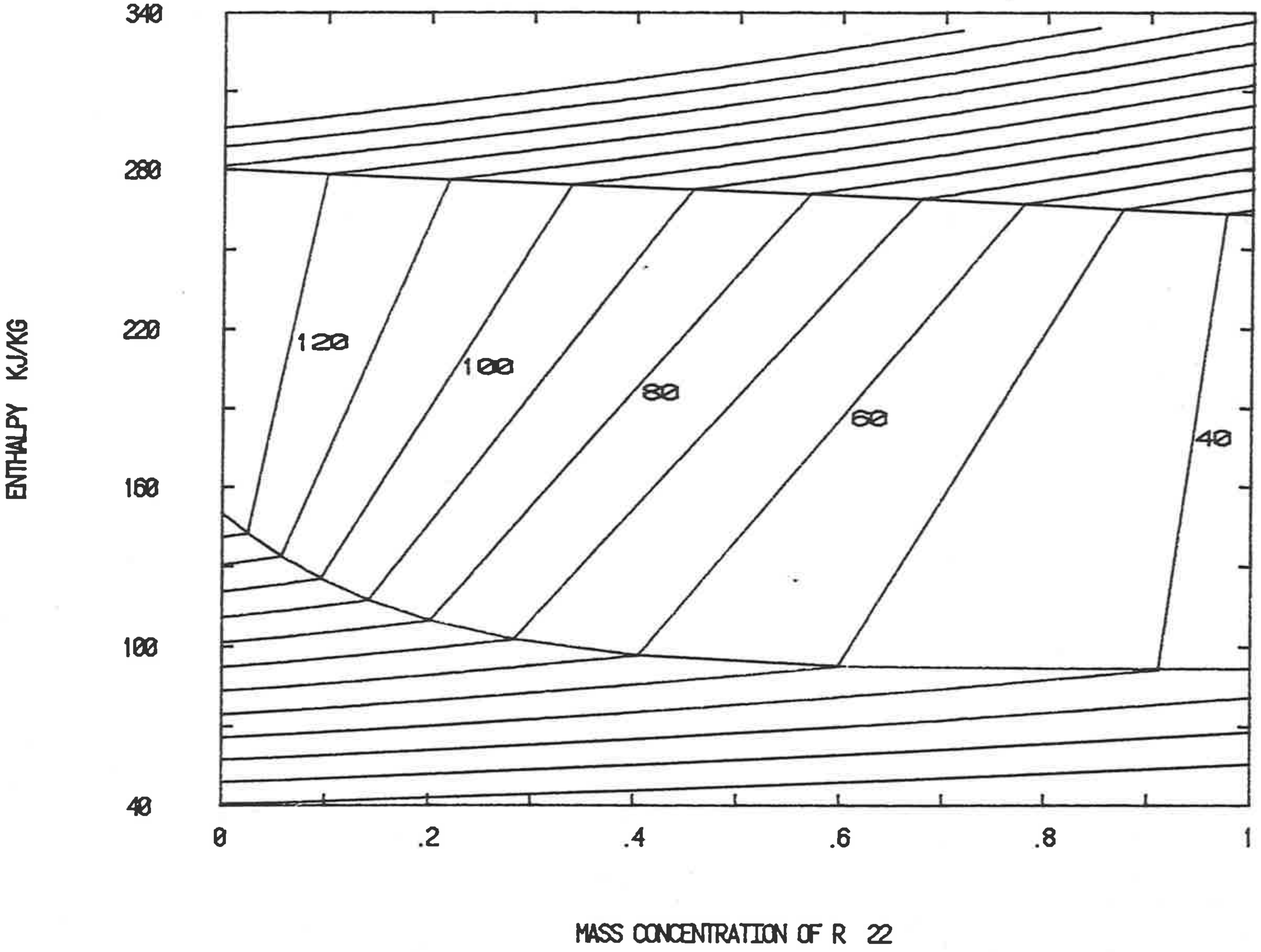
ENTHALPY CONCENTRATION DIAGRAMS

NOTE: All isotherm temperatures are deg C.


ENTHALPY CONC DIAG R 22 -R 11 (PRESSURE= 578878.4 PA)

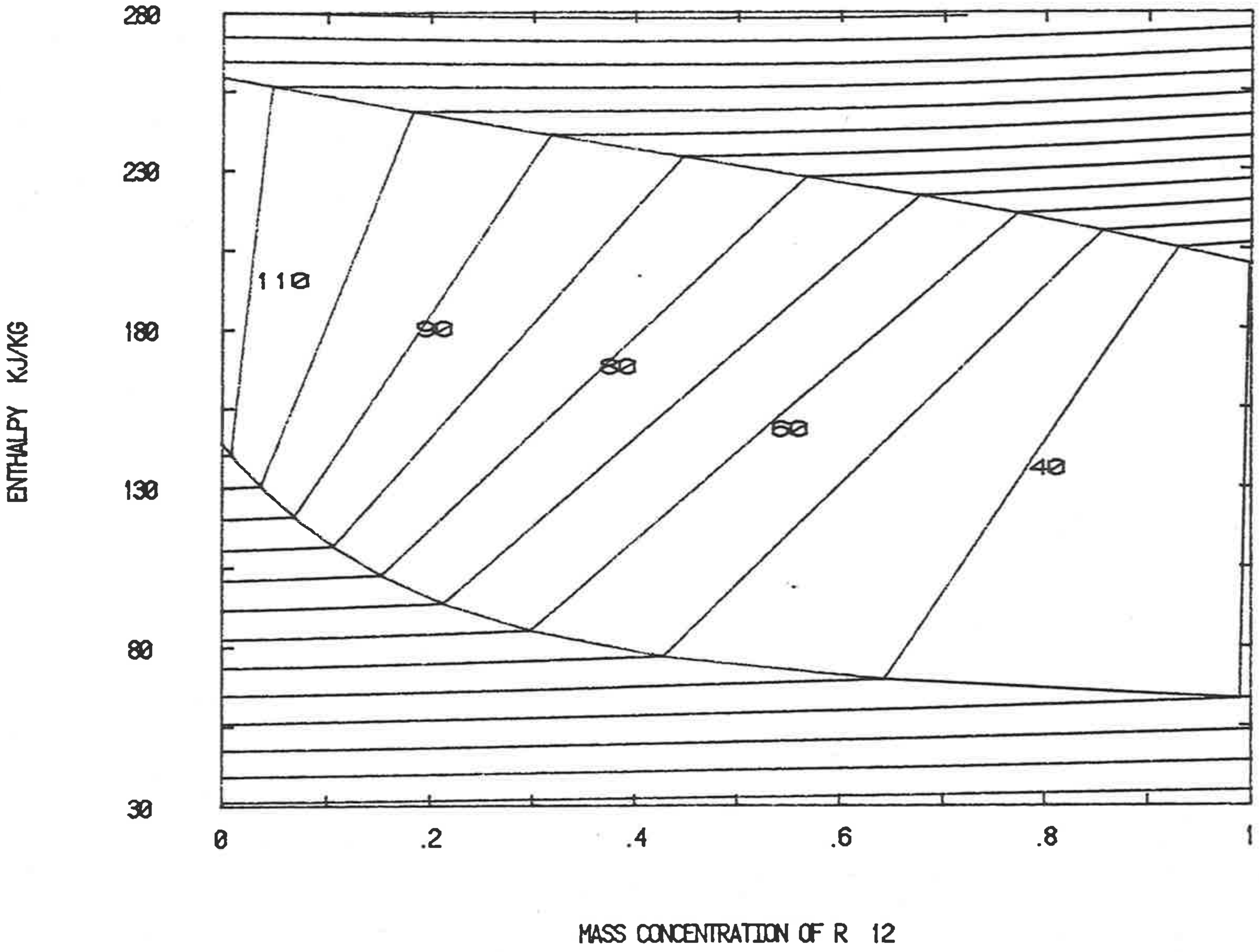
ENTHALPY CONC DIAG R 22 -R 11 (PRESSURE= 1190425.8 PA)

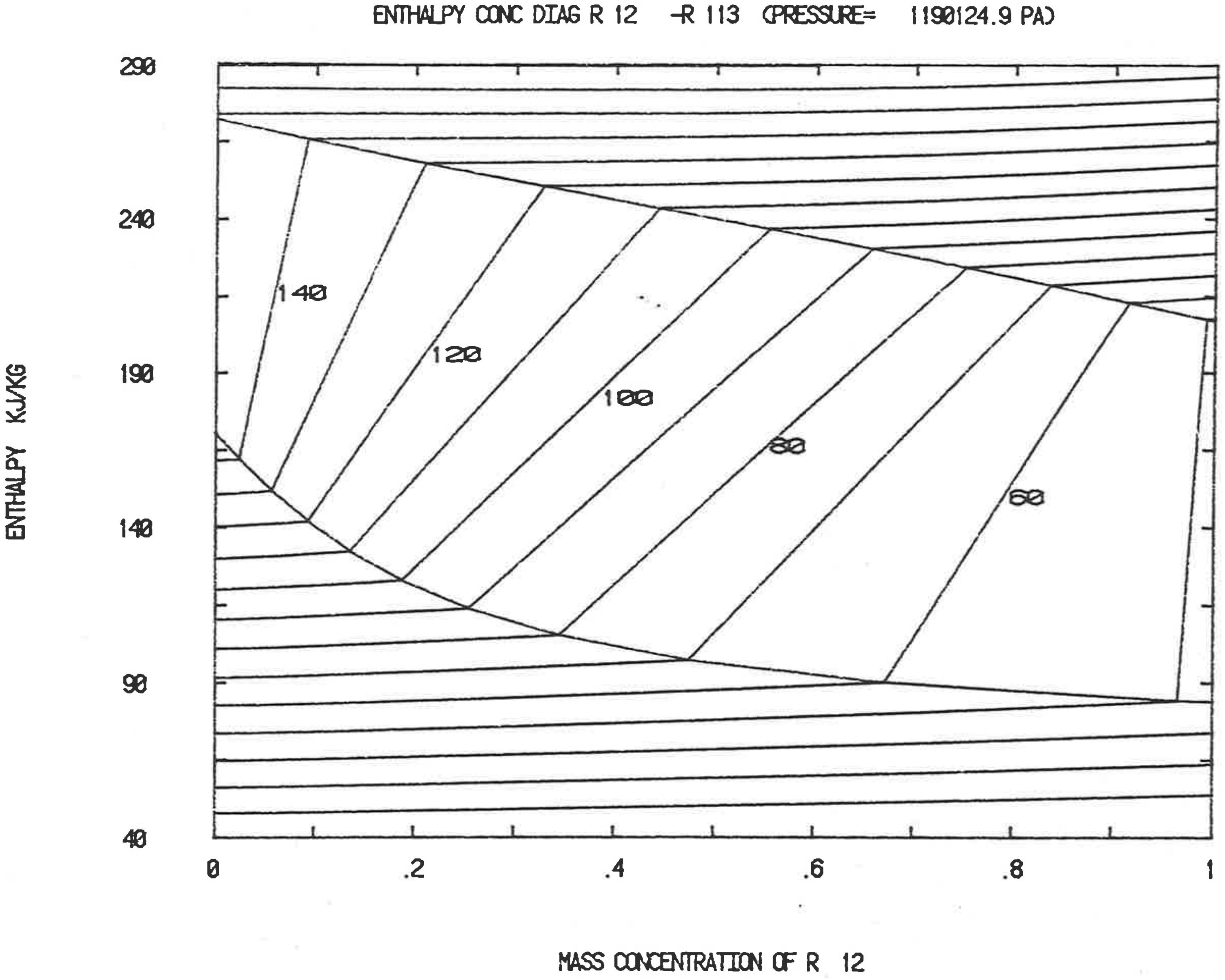




ENTHALPY CONC DIAG R 22 -R 11 (PRESSURE= 1451000.0 PA)

ENTHALPY CONC DIAG R 12 -R 113 (PRESSURE= 739000.0 PA)



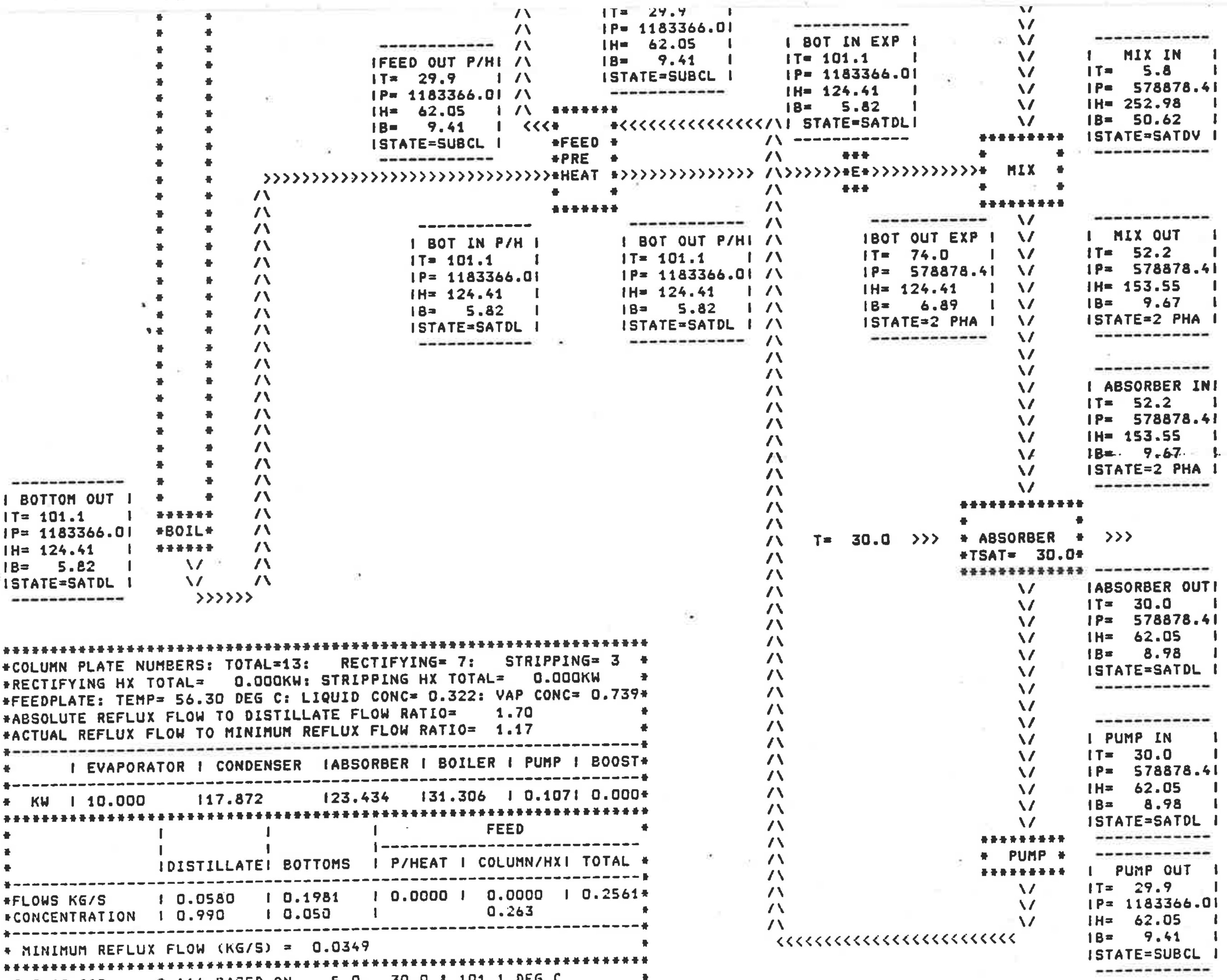

ENTHALPY CONC DIAG R 12 -R 113 (PRESSURE= 1190124.9 PA)
ENTHALPY KJ/KG
290
240
190
140
90
40
140
120
100
80
60
0
.2
.4
.6
.8
1
MASS CONCENTRATION OF R 12

APPENDIX H

COMPUTER MODEL SAMPLE OUTPUTS

Figure	Referenced from section
H1	3.2.1
H2	3.2.2
H3	3.2.3
H4	3.2.4
H5	3.2.5
H6	3.2.6
H7	3.2.7
H8	3.2.8
H9	3.2.9
H10	3.2.10
H11	3.3.1
H12	3.4

```
*******************************************************                                        ****************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      *  ---------------------                 *              *
* R  11     CHLORODIFLUOROMETHANE     ( CHCLF2     )  * |  DATA AND   UNITS  |                 *              *
* R  22     TRICHLOROFLUOROMETHANE    ( CCL3F      )  * |T=TEMPERATURE DEG C |                 *              *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=   5.0   <<<  * EVAPORATOR   * <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  4.41                  * |H=ENTHALPY KJ/KG    |                 * TSAT=  5.8   *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* |B=AVAILABILITY KJ/KG| ------------    *              *    ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG *  ---------------------|  EVAP IN   |   *              *   |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=            0.0 DEG *                       |T=    5.0   |   ****************   |T=    5.8   |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=     0.0 DEG *                       |P=  578878.4|     /\        \/     |P=  578878.4|
* APPROACH FLUID OFF EVAP TO EVAP IN    =  0.0 DEG    *                       |H=  80.71   |     /\        \/     |H= 252.98   |
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------    |B=  63.81   |     /\        \/     |B=  50.62   |
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 11     *      |EXPANSION IN|   |STATE=2 PHA |    ***        \/     |STATE=SATDV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  30.0    |    ------------     *E*        \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=    101.3 KPA*      |P= 1183366.0|                     ***        \/
*******************************************************      |H=  80.71   |                      /\        \/
                                                             |B=  65.56   |                      /\        \/
                                                             |STATE=SATDL |                      /\        \/
                        ------------                          ------------                       /\        \/
                       |  COND OUT  |                                                            /\        \/
                       |T=  30.0    |                                                            /\        \/
                       |P= 1183366.0|                                                            /\        \/
                       |H=  80.71   |                                                            /\        \/
                       |B=  65.56   |                                                            /\        \/
                       |STATE=SATDL |                                                            /\        \/
                        ------------                                                             /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>         \/
                     I       TSAT=  30.0                                                                   \/
                  ******                                                                                   \/
T=  30.0   >>>    *COND*    >>>                                                                            \/
                  ******                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                  ------------                                     \/
   ------------   *    *                                 | FEED       |                                    \/
  | COLUMN FEED|  *    *   *************                 |T=   29.9   |                                    \/
  |T=  29.9    |  ******   *   FEED    *                 |P= 1183366.0|                                    \/
  |P= 1183366.0|  *FEED*<<<*  BOOST    *<<<<<<<<<<<<<<<< |H=   62.05  |                                    \/
  |H=  62.05   |  ******   *  HEATER   *               /\|B=    9.41  |                                    \/
```



```
I T=  29.9          I
I P= 1183366.0 I
I H=   62.05      I
I B=    9.41       I
I STATE=SUBCL I

I FEED OUT P/H I
I T=  29.9          I
I P= 1183366.0 I
I H=  62.05        I
I B=    9.41        I
I STATE=SUBCL I

I BOT IN EXP I
I T= 101.1         I
I P= 1183366.0 I
I H= 124.41       I
I B=    5.82        I
I STATE=SATDL I

I   MIX IN          I
I T=    5.8           I
I P=  578878.4  I
I H= 252.98        I
I B=   50.62        I
I STATE=SATDV I

I BOT IN P/H   I
I T= 101.1         I
I P= 1183366.0 I
I H= 124.41       I
I B=    5.82        I
I STATE=SATDL I

I BOT OUT P/H I
I T= 101.1         I
I P= 1183366.0 I
I H= 124.41       I
I B=    5.82        I
I STATE=SATDL I

I BOT OUT EXP I
I T=   74.0         I
I P=  578878.4  I
I H= 124.41       I
I B=    6.89        I
I STATE=2 PHA I

I  MIX OUT       I
I T=   52.2         I
I P=  578878.4  I
I H= 153.55       I
I B=    9.67        I
I STATE=2 PHA I

I ABSORBER IN I
I T=   52.2         I
I P=  578878.4  I
I H= 153.55       I
I B=    9.67        I
I STATE=2 PHA I

I BOTTOM OUT I
I T= 101.1         I
I P= 1183366.0 I
I H= 124.41       I
I B=    5.82        I
I STATE=SATDL I

I ABSORBER OUT I
I T=   30.0         I
I P=  578878.4  I
I H=   62.05       I
I B=    8.98        I
I STATE=SATDL I

I PUMP IN        I
I T=   30.0         I
I P=  578878.4  I
I H=   62.05       I
I B=    8.98        I
I STATE=SATDL I

I  PUMP OUT     I
I T=   29.9         I
I P= 1183366.0 I
I H=   62.05       I
I B=    9.41        I
I STATE=SUBCL I
```

```
********************************************************************
*COLUMN PLATE NUMBERS: TOTAL=13:   RECTIFYING= 7:   STRIPPING= 3  *
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   0.000KW    *
*FEEDPLATE: TEMP= 56.30 DEG C: LIQUID CONC= 0.322: VAP CONC= 0.739*
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.70           *
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.17           *
*-----------------------------------------------------------------*
*      I EVAPORATOR I CONDENSER  IABSORBER I BOILER I PUMP I BOOST*
*-----------------------------------------------------------------*
*  KW  I 10.000      I17.872      I23.434   I31.306  I 0.107I 0.000*
********************************************************************
*                I          I         I           FEED            *
*                I          I         I----------------------------
*                IDISTILLATEI BOTTOMS  I P/HEAT I COLUMN/HXI TOTAL *
*-----------------------------------------------------------------*
*FLOWS KG/S      I 0.0580   I 0.1981  I 0.0000 I   0.0000  I 0.2561*
*CONCENTRATION   I 0.990    I 0.050   I            0.263          *
*-----------------------------------------------------------------*
* MINIMUM REFLUX FLOW (KG/S) =  0.0349                            *
********************************************************************
*CARNOT COP=    2.114 BASED ON    5.0,   30.0 & 101.1 DEG C       *
*COP=  0.318   COPHEAT= 1.315    PUMP KW AS %=    0.3             *
********************************************************************
```

FIGURE H1

```
-----------------------------------------------------------------------------------------------------------------------
NO I  TEMP  I  K   IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C  I Y/X  I  KW    I  KG/S    I KJ/S   I      I CONC I KJ/KG  IKJ/KG KI KJ/KG  ICOMPT 1 ICOMPT 2 I KG/S
-----------------------------------------------------------------------------------------------------------------------
 1 I  30.0  I 1.01 I 17.872I  0.0000  I -0.006I LIQ  I0.990 I  80.71 I 0.327 I  65.56 I  0.847 I  0.001 I 0.0990
   I        I      I       I          I       I VAP  I0.997 I 261.28 I 0.000 I   0.00 I  0.000 I  0.000 I 0.0000
   I        I      I       I          I       I      I      I        I       I        I        I        I
 2 I  30.7  I 1.03 I  0.000I  0.0000  I -0.013I LIQ  I0.962 I  80.75 I 0.334 I  61.85 I  0.859 I  0.187 I 0.0410
   I        I      I       I          I       I VAP  I0.990 I 261.31 I 0.922 I  65.62 I  0.844 I  0.720 I 0.0990
   I        I      I       I          I       I      I      I        I       I        I        I        I
 3 I  31.7  I 1.07 I  0.000I  0.0000  I -0.012I LIQ  I0.917 I  80.82 I 0.342 I  56.69 I  0.881 I  0.185 I 0.0408
   I        I      I       I          I       I VAP  I0.978 I 261.19 I 0.925 I  64.21 I  0.845 I  0.731 I 0.0990
   I        I      I       I          I       I      I      I        I       I        I        I        I
 4 I  33.5  I 1.13 I  0.000I  0.0000  I -0.014I LIQ  I0.846 I  80.98 I 0.352 I  49.54 I  0.921 I  0.183 I 0.0406
   I        I      I       I          I       I VAP  I0.960 I 261.50 I 0.929 I  62.21 I  0.848 I  0.733 I 0.0989
   I        I      I       I          I       I      I      I        I       I        I        I        I
 5 I  36.4  I 1.26 I  0.000I  0.0000  I -0.019I LIQ  I0.740 I  81.37 I 0.363 I  40.14 I  0.994 I  0.183 I 0.0402
   I        I      I       I          I       I VAP  I0.931 I 262.01 I 0.934 I  59.42 I  0.852 I  0.738 I 0.0986
   I        I      I       I          I       I      I      I        I       I        I        I        I
 6 I  40.9  I 1.47 I  0.000I  0.0000  I -0.024I LIQ  I0.604 I  82.42 I 0.373 I  29.43 I  1.123 I  0.188 I 0.0398
   I        I      I       I          I       I VAP  I0.888 I 262.79 I 0.940 I  55.79 I  0.858 I  0.745 I 0.0983
   I        I      I       I          I       I      I      I        I       I        I        I        I
 7 I  46.7  I 1.77 I  0.000I  0.0000  I -0.024I LIQ  I0.470 I  84.64 I 0.381 I  20.20 I  1.315 I  0.203 I 0.0397
   I        I      I       I          I       I VAP  I0.833 I 264.06 I 0.946 I  51.76 I  0.866 I  0.753 I 0.0978
   I        I      I       I          I       I      I      I        I       I        I        I        I
 8 I  52.3  I 2.08 I  0.000I  0.0000  I -0.014I LIQ  I0.375 I  87.52 I 0.388 I  14.46 I  1.519 I  0.225 I 0.0399
   I        I      I       I          I       I VAP  I0.779 I 265.16 I 0.950 I  48.28 I  0.873 I  0.760 I 0.0977
   I        I      I       I          I       I      I      I        I       I        I        I        I
 9 I  56.3  I 2.30 I  0.000I  0.2561  I -0.734I LIQ  I0.322 I  89.89 I 0.392 I  11.63 I  1.671 I  0.244 I 0.3367
   I        I      I       I          I       I VAP  I0.739 I 265.88 I 0.952 I  46.02 I  0.878 I  0.766 I 0.0980
   I        I      I       I          I       I      I      I        I       I        I        I        I
10 I  59.1  I 2.45 I  0.000I  0.0000  I -0.068I LIQ  I0.291 I  91.67 I 0.396 I  10.09 I  1.781 I  0.259 I 0.3391
   I        I      I       I          I       I VAP  I0.711 I 266.44 I 0.953 I  44.52 I  0.882 I  0.769 I 0.1386
   I        I      I       I          I       I      I      I        I       I        I        I        I
11 I  66.7  I 2.85 I  0.000I  0.0000  I -0.416I LIQ  I0.221 I  96.97 I 0.406 I   7.16 I  2.095 I  0.306 I 0.3475
   I        I      I       I          I       I VAP  I0.629 I 267.70 I 0.952 I  40.74 I  0.891 I  0.778 I 0.1410
   I        I      I       I          I       I      I      I        I       I        I        I        I
12 I  82.3  I 3.58 I  0.000I  0.0000  I -1.106I LIQ  I0.125 I 108.87 I 0.428 I   4.87 I  2.771 I  0.426 I 0.3698
   I        I      I       I          I       I VAP  I0.447 I 270.06 I 0.939 I  34.97 I  0.911 I  0.793 I 0.1495
   I        I      I       I          I       I      I      I        I       I        I        I        I
13 I 101.1  I 4.22 I-31.306I  0.0000  I  4.998I LIQ  I0.050 I 124.41 I 0.457 I   5.82 I  3.630 I  0.617 I 0.1981
   I        I      I       I          I       I VAP  I0.211 I 273.25 I 0.900 I  32.89 I  0.939 I  0.811 I 0.1717
   I        I      I       I          I       I      I      I        I       I        I        I        I
NOTE; A/BY CH   is for streams only.
```

FIGURE H1 CONTD

```
                SECOND LAW ANALYSIS              KJ/S      PERCENT OF AVAILABILITY LOSS
------------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                      0.000     0.000
    PRECOOLER LIQ OUT TO EXPANSION IN                  0.000     0.000
    EVAPORATOR OUT TO PRECOOLER IN                     0.000     0.000
    PRECOOLER VAP OUT TO MIXING IN                     0.000     0.000
    MIXING OUT TO ABSORBER IN                          0.000     0.000
    ABSORBER OUT TO PUMP IN                            0.000     0.000
    PUMP OUT TO FEED SPLIT                             0.000     0.000
    FEED SPLIT TO PREHEATER IN                         0.000     0.000
    PREHEATER OUT TO FEED JOIN                         0.000     0.000
    FEED SPLIT TO RECTIFIER HX IN                      0.000     0.000
    RECTIFIER HX OUT TO FEED JOIN                      0.000     0.000
    BOTTOM OUT OF COLUMN TO HX IN                      0.000     0.000
    BOTTOM HX OUT TO PREHEATER IN                      0.000     0.000
    PREHEATER OUT TO EXPANSION IN                      0.000     0.000
------------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                              -0.101     1.674
    BOTTOMS EXPANSION                                  0.212    -3.499
------------------------------------------------------------
PUMP                                                   0.109
------------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                          0.000     0.000
    PREHEATER                                          0.000     0.000
------------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                             0.102    -1.689
    EVAP REFRIGERANT STREAMS ONLY   -0.766
    EVAP CARNOT   -0.868                                        14.328


ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY      -2.003    33.060
    CARNOT FROM AVERAGE TEMP    0.000

COLUMN
    CARNOT ONLY                                        5.949
    (STREAMS ONLY =     2.555 )
    COLUMN ONLY=CARNOT-STREAMS                        -3.394    56.028
    (MINIMUM SEPERATION WORK=    2.549)

CONDENSER
    COND CARNOT                                        0.000     0.000
    CONDENSER STREAMS ONLY                            -0.006     0.097
------------------------------------------------------------
                                                       0.000
                                                ------------
```

FIGURE H1 CONTD

```
*******************************************************                                        ***************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      *  --------------------                  *             *
* R  11     CHLORODIFLUOROMETHANE      ( CHCLF2    )  * |  DATA AND   UNITS  |                 *             *
* R  22     TRICHLOROFLUOROMETHANE     ( CCL3F     )  * |T=TEMPERATURE DEG C |                 *             *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=   5.0   <<<  * EVAPORATOR  *  <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  4.41                  * |H=ENTHALPY KJ/KG    |                 * TSAT=  5.8  *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* |B=AVAILABILITY KJ/KG| ------------    *             *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG *  -------------------- |  EVAP IN   |   *             *    |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=            0.0 DEG *                       |T=   5.0    |   ***************    |T=   5.8    |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=    0.0 DEG *                       |P=  578878.4|     /\        \/     |P=  578878.4|
* APPROACH FLUID OFF EVAP TO EVAP IN    =  0.0 DEG    *                       |H=  80.71   |     /\        \/     |H= 252.98   |
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------    |B=  63.81   |     /\        \/     |B=  50.62   |
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 11     *      |EXPANSION IN|   |STATE=2 PHA |    ***       \/     |STATE=SATDV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  30.0    |    ------------     *E*       \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=   101.3 KPA*      |P= 1183366.0|                     ***       \/
*******************************************************      |H=  80.71   |                      /\        \/
                                                             |B=  65.56   |                      /\        \/
                                                             |STATE=SATDL |                      /\        \/
                        ------------                          ------------                       /\        \/
                       |  COND OUT  |                                                            /\        \/
                       |T=  30.0    |                                                            /\        \/
                       |P= 1183366.0|                                                            /\        \/
                       |H=  80.71   |                                                            /\        \/
                       |B=  65.56   |                                                            /\        \/
                       |STATE=SATDL |                                                            /\        \/
                        ------------                                                             /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                     |      TSAT=  30.0                                                                    \/
                 ******                                                                                    \/
T=  30.0   >>>   *COND*    >>>                                                                             \/
                 ******                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                  ------------                                      \/
  ------------   *    *                                 | FEED       |                                     \/
 | COLUMN FEED|  *    *   *************                 |T=  66.4    |                                     \/
 |T=  66.4    |  ******   *   FEED    *                 |P= 1183366.0|                                     \/
 |P= 1183366.0|  *FEED*<<<*   BOOST   *<<<<<<<<<<<<<<<  |H= 113.48   |                                     \/
 |H= 113.48   |  ******   *  HEATER   *               /\|B=  11.46   |                                     \/
 |B=  11.46   |  *    *   *************               /\|STATE=2 PHA |                                     \/
 |STATE=2 PHA |  *    *                               /\ ------------                                      \/
```

```
                 *    *                  -------------  /\       |H=  62.05   |      | BOT IN EXP |           \/       ------------
                 *    *                 |FEED OUT P/H|  /\       |B=   9.41   |      |T=  29.9    |           \/      |   MIX IN   |
                 *    *                 |T=  66.4    |  /\       |STATE=SUBCL |      |P= 1183366.0|           \/      |T=    5.8   |
                 *    *                 |P= 1183366.0|  /\        ------------       |H=  57.91   |           \/      |P=  578878.4|
                 *    *                 |H= 113.48   |  /\  *******                  |B=   2.88   |           \/      |H= 252.98   |
                 *    *                 |B=  11.46   |   <<<*     *<<<<<<<<<<<<<<<</\| STATE=SUBCL|           \/      |B=  50.62   |
                 *    *                 |STATE=2 PHA |      *FEED *                /\ -------------       **********  |STATE=SATDV |
                 *    *                  -------------      *PRE  *                /\      ***            *        *   ------------
                 *    *     >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT *>>>>>>>>>>>>>>> /\>>>>>>*E*>>>>>>>>>>>>*  MIX   *
                 *    *    /\                               *     *                /\      ***            *        *
                 *    *    /\                               *******                /\                     **********
                 *    *    /\                -------------           -------------  /\        -------------   \/       ------------
                 *    *    /\               | BOT IN P/H |         | BOT OUT P/H|  /\       |BOT OUT EXP |   \/      |   MIX OUT  |
                 *    *    /\               |T= 101.1    |         |T=   29.9   |  /\       |T=   30.1   |   \/      |T=   39.1   |
                 *    *    /\               |P= 1183366.0|         |P= 1183366.0|  /\       |P=  578878.4|   \/      |P=  578873.4|
                 *    *    /\               |H= 124.41   |         |H=  57.91   |  /\       |H=  57.91   |   \/      |H= 102.12   |
                 *    *    /\               |B=    5.82  |         |B=   2.88   |  /\       |B=    2.48  |   \/      |B=    8.25  |
                 *    *    /\               |STATE=SATDL |         |STATE=SUBCL |  /\       |STATE=SUBCL |   \/      |STATE=2 PHA |
                 *    *    /\                -------------           -------------  /\        -------------   \/       ------------
                 *    *    /\                                                      /\                         \/
                 *    *    /\                                                      /\                         \/       ------------
                 *    *    /\                                                      /\                         \/      | ABSORBER IN|
                 *    *    /\                                                      /\                         \/      |T=   39.1   |
                 *    *    /\                                                      /\                         \/      |P=  578878.4|
                 *    *    /\                                                      /\                         \/      |H= 102.12   |
                 *    *    /\                                                      /\                         \/      |B=    8.25  |
 -------------   *    *    /\                                                      /\                         \/      |STATE=2 PHA |
| BOTTOM OUT |   *    *    /\                                                      /\                         \/       ------------
|T= 101.1    |   ******    /\                                                      /\                   **************
|P= 1183366.0|   *BOIL*    /\                                                      /\                   *            *
|H= 124.41   |   ******    /\                                                      /\   T=  30.0  >>>   * ABSORBER   *  >>>
|B=    5.82  |      \/     /\                                                      /\                   *TSAT=  30.0*
|STATE=SATDL |      \/     /\                                                      /\                   **************  ------------
 -------------       >>>>>>                                                        /\                         \/      |ABSORBER OUT|
                                                                                   /\                         \/      |T=   30.0   |
                                                                                   /\                         \/      |P=  578878.4|
***********************************************************************            /\                         \/      |H=   62.05  |
*COLUMN PLATE NUMBERS: TOTAL=12:   RECTIFYING= 7:   STRIPPING= 2      *            /\                         \/      |B=    8.98  |
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   0.000KW        *            /\                         \/      |STATE=SATDL |
*FEEDPLATE: TEMP= 68.30 DEG C: LIQUID CONC= 0.209: VAP CONC= 0.611    *            /\                         \/       ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.99               *            /\                         \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.15               *            /\                         \/       ------------
*---------------------------------------------------------------------*            /\                         \/      | PUMP IN    |
*       | EVAPORATOR | CONDENSER   |ABSORBER | BOILER | PUMP | BOOST  *            /\                         \/      |T=   30.0   |
*---------------------------------------------------------------------*            /\                         \/      |P=  578878.4|
*  KW  | 10.000      |20.913      |10.263    |21.178   | 0.107| 0.000 *            /\                         \/      |H=   62.05  |
***********************************************************************            /\                         \/      |B=    8.98  |
*                  |          |          |            FEED            *            /\                         \/      |STATE=SATDL |
*                  |          |          |---------------------------              /\                     *********    ------------
*                  |DISTILLATE| BOTTOMS  | P/HEAT | COLUMN/HX| TOTAL  *            /\                     *  PUMP *    ------------
*---------------------------------------------------------------------*            /\                     *********   |  PUMP OUT  |
*FLOWS KG/S        | 0.0580   | 0.1981   | 0.2561 |  0.0000  | 0.2561 *            /\                         \/      |T=   29.9   |
*CONCENTRATION     | 0.990    | 0.050    |           0.263            *            /\                         \/      |P= 1183366.0|
*---------------------------------------------------------------------*            /\                         \/      |H=   62.05  |
* MINIMUM REFLUX FLOW (KG/S) =  0.0501                                *             <<<<<<<<<<<<<<<<<<<<<<<<<<        |B=    9.41  |
***********************************************************************                                               |STATE=SUBCL |
*CARNOT COP=    2.114 BASED ON    5.0,  30.0 & 101.1 DEG C            *                                                ------------
*COP=  0.470   COPHEAT= 1.465    PUMP KW AS %=    0.5                 *
***********************************************************************
```

FIGURE H2

```
--------------------------------------------------------------------------------------------------------------------------------
NO I   TEMP   I  K     IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C    I Y/X    I  KW   I  KG/S   I KJ/S  I      I CONC I KJ/KG  IKJ/KG KI KJ/KG  ICOMPT 1 ICOMPT 2 I KG/S
--------------------------------------------------------------------------------------------------------------------------------
 1 I   30.0   I 1.01   I 20.913I  0.0000 I -0.007I LIQ  I0.990 I  80.71 I 0.327 I  65.56 I  0.847 I  0.001 I 0.1158
   I          I        I       I         I       I VAP  I0.997 I 261.28 I 0.000 I   0.00 I  0.000 I  0.000 I 0.0000
   I          I        I       I         I       I      I      I        I       I        I        I        I
 2 I   30.7   I 1.03   I  0.000I  0.0000 I -0.020I LIQ  I0.962 I  80.75 I 0.334 I  61.85 I  0.859 I  0.187 I 0.0577
   I          I        I       I         I       I VAP  I0.990 I 261.31 I 0.922 I  65.62 I  0.844 I  0.720 I 0.1158
   I          I        I       I         I       I      I      I        I       I        I        I        I
 3 I   32.0   I 1.08   I  0.000I  0.0000 I -0.028I LIQ  I0.908 I  80.84 I 0.344 I  55.72 I  0.886 I  0.185 I 0.0576
   I          I        I       I         I       I VAP  I0.976 I 261.43 I 0.926 I  63.94 I  0.846 I  0.731 I 0.1157
   I          I        I       I         I       I      I      I        I       I        I        I        I
 4 I   34.6   I 1.18   I  0.000I  0.0000 I -0.047I LIQ  I0.806 I  81.10 I 0.357 I  45.83 I  0.946 I  0.183 I 0.0570
   I          I        I       I         I       I VAP  I0.949 I 261.61 I 0.931 I  61.13 I  0.849 I  0.735 I 0.1156
   I          I        I       I         I       I      I      I        I       I        I        I        I
 5 I   39.8   I 1.41   I  0.000I  0.0000 I -0.085I LIQ  I0.636 I  82.10 I 0.371 I  31.83 I  1.088 I  0.186 I 0.0561
   I          I        I       I         I       I VAP  I0.899 I 262.70 I 0.939 I  56.67 I  0.857 I  0.743 I 0.1150
   I          I        I       I         I       I      I      I        I       I        I        I        I
 6 I   48.5   I 1.87   I  0.000I  0.0000 I -0.115I LIQ  I0.437 I  85.48 I 0.383 I  18.12 I  1.377 I  0.209 I 0.0561
   I          I        I       I         I       I VAP  I0.816 I 264.59 I 0.948 I  50.62 I  0.868 I  0.755 I 0.1142
   I          I        I       I         I       I      I      I        I       I        I        I        I
 7 I   58.3   I 2.41   I  0.000I  0.0000 I -0.076I LIQ  I0.298 I  91.20 I 0.395 I  10.46 I  1.752 I  0.255 I 0.0571
   I          I        I       I         I       I VAP  I0.718 I 266.32 I 0.953 I  44.90 I  0.881 I  0.768 I 0.1141
   I          I        I       I         I       I      I      I        I       I        I        I        I
 8 I   65.0   I 2.76   I  0.000I  0.0000 I -0.030I LIQ  I0.234 I  95.76 I 0.403 I   7.66 I  2.024 I  0.295 I 0.0584
   I          I        I       I         I       I VAP  I0.647 I 267.55 I 0.952 I  41.52 I  0.889 I  0.776 I 0.1151
   I          I        I       I         I       I      I      I        I       I        I        I        I
 9 I   68.3   I 2.93   I  0.000I  0.2561 I -0.275I LIQ  I0.209 I  98.11 I 0.408 I   6.74 I  2.161 I  0.316 I 0.2916
   I          I        I       I         I       I VAP  I0.611 I 267.86 I 0.951 I  40.03 I  0.893 I  0.779 I 0.1164
   I          I        I       I         I       I      I      I        I       I        I        I        I
10 I   74.1   I 3.21   I  0.000I  0.0000 I -0.192I LIQ  I0.169 I 102.47 I 0.416 I   5.61 I  2.410 I  0.359 I 0.2982
   I          I        I       I         I       I VAP  I0.544 I 268.90 I 0.948 I  37.65 I  0.900 I  0.785 I 0.0935
   I          I        I       I         I       I      I      I        I       I        I        I        I
11 I   85.6   I 3.71   I  0.000I  0.0000 I -0.539I LIQ  I0.109 I 111.55 I 0.433 I   4.80 I  2.921 I  0.457 I 0.3133
   I          I        I       I         I       I VAP  I0.406 I 270.53 I 0.933 I  34.14 I  0.916 I  0.796 I 0.1001
   I          I        I       I         I       I      I      I        I       I        I        I        I
12 I  101.1   I 4.22   I-21.178I  0.0000 I  3.439I LIQ  I0.050 I 124.42 I 0.457 I   5.82 I  3.630 I  0.617 I 0.1981
   I          I        I       I         I       I VAP  I0.211 I 273.24 I 0.900 I  32.89 I  0.939 I  0.811 I 0.1152
   I          I        I       I         I       I      I      I        I       I        I        I        I
NOTE; A/BY CH   is for streams only.
```

FIGURE H2 CONTD

```
                    SECOND LAW ANALYSIS                  KJ/S      PERCENT OF AVAILABILITY LOSS
-----------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                        0.000     0.000
    PRECOOLER LIQ OUT TO EXPANSION IN                    0.000     0.000
    EVAPORATOR OUT TO PRECOOLER IN                       0.000     0.000
    PRECOOLER VAP OUT TO MIXING IN                       0.000     0.000
    MIXING OUT TO ABSORBER IN                            0.000     0.000
    ABSORBER OUT TO PUMP IN                              0.000     0.000
    PUMP OUT TO FEED SPLIT                               0.000     0.000
    FEED SPLIT TO PREHEATER IN                           0.000     0.000
    PREHEATER OUT TO FEED JOIN                           0.000     0.000
    FEED SPLIT TO RECTIFIER HX IN                        0.000     0.000
    RECTIFIER HX OUT TO FEED JOIN                        0.000     0.000
    BOTTOM OUT OF COLUMN TO HX IN                        0.000     0.000
    BOTTOM HX OUT TO PREHEATER IN                        0.000     0.000
    PREHEATER OUT TO EXPANSION IN                        0.000     0.000
-----------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                                -0.101     2.454
    BOTTOMS EXPANSION                                   -0.080     1.944
-----------------------------------------------------------
                                                         0.109
PUMP
-----------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                            0.000     0.000
    PREHEATER                                           -0.057     1.379
-----------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                               0.102    -2.475
    EVAP REFRIGERANT STREAMS ONLY     -0.766
    EVAP CARNOT   -0.868                                          20.999

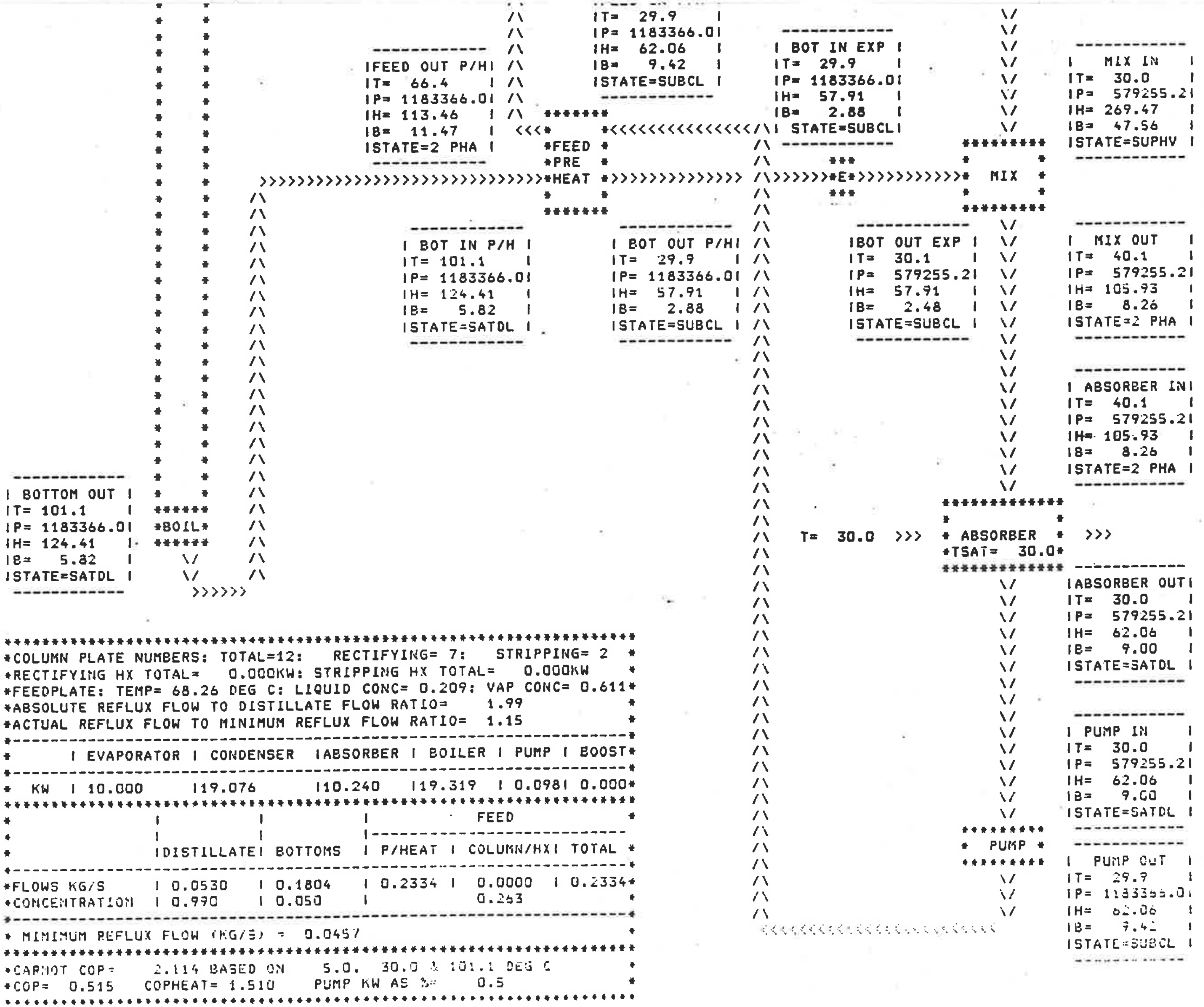

ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY        -1:129    27.308
    CARNOT FROM AVERAGE TEMP     0.000

COLUMN
    CARNOT ONLY                                          4.024
    (STREAMS ONLY =      2.031 )
    COLUMN ONLY=CARNOT-STREAMS                          -1.993    48.224
    (MINIMUM SEPERATION WORK=     2.024)

CONDENSER
    COND CARNOT                                          0.000     0.000
    CONDENSER STREAMS ONLY                              -0.007     0.167
-----------------------------------------------------------
                                                         0.000
                                                    -----------
```

FIGURE H2 CONTD

```
*******************************************************                                        ****************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      * ----------------------                 *              *
* R  11     CHLORODIFLUOROMETHANE     ( CHCLF2     )  * |  DATA AND   UNITS  |                 *              *
* R  22     TRICHLOROFLUOROMETHANE    ( CCL3F      )  * |T=TEMPERATURE DEG C |                 *              *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=   5.0   <<<  * EVAPORATOR   * <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  4.41                  * |H=ENTHALPY KJ/KG    |                 * TSAT=  5.8   *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* |B=AVAILABILITY KJ/KG| ------------    *              *    ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG * ----------------------|  EVAP IN   |   *              *   |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=           0.0 DEG *                       |T=   5.0    |   ****************   |T=   5.8    |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=    0.0 DEG *                       |P=  579255.2|     /\        \/     |P=  579255.2|
* APPROACH FLUID OFF EVAP TO EVAP IN     =  0.0 DEG   *                       |H=  64.22   |     /\        \/     |H= 252.99   |
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------    |B=  66.38   |     /\        \/     |B=  50.64   |
* ALL CONCENTRATIONS ARE MASS CONCS OF        R 11    *      |EXPANSION IN|   |STATE=2 PHA |    ***        \/     |STATE=SATDV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  17.2    |    ------------     *E*        \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=   101.3 KPA*      |P= 1183366.0|                     ***        \/
*******************************************************      |H=  64.22   |                      /\        \/
                                                             |B=  67.17   |    ------------      /\        \/      ------------
                                                             |STATE=SUBCL |   |P/COOL L OUT|     /\        \/     |P/COOL V IN |
                       ------------                           ------------    |T=  17.2    |   ****************   |T=   5.8    |
                      |  COND OUT  |                                          |P= 1183366.0|   *              *   |P=  579255.2|
                      |T=  30.0    |                                          |H=  64.22   |   *              *   |H= 252.99   |
                      |P= 1183366.0|                                          |B=  67.17   |   *  PRECOOLER   *   |B=  50.64   |
                      |H=  80.71   |                                          |STATE=SUBCL |   *              *   |STATE=SATDV |
                      |B=  65.56   |                                           ------------    *              *    ------------
                      |STATE=SATDL |                                                           ****************
                       ------------                                                              /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                     /\      TSAT=   30.0                                                                  \/
                  ******                                                       ------------                \/      ------------
T=  30.0   >>>    *COND*    >>>                                               |P/COOL L IN |               \/     |P/COOL V OUT|
                  ******                                                      |T=  30.0    |               \/     |T=  30.0    |
                  *    *                                                      |P= 1183366.0|               \/     |P=  579255.2|
                  *    *                                                      |H=  80.71   |               \/     |H= 269.47   |
                  *    *                                                      |B=  65.56   |               \/     |B=  47.56   |
                  *    *                                                      |STATE=SATDL |               \/     |STATE=SUPHV |
                  *    *                                                       ------------                \/      ------------
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                  ------------                                     \/
   ------------   *    *                                 | FEED       |                                    \/
  | COLUMN FEED|  *    *   ************                  |T=  66.4    |                                    \/
  |T=  66.4    |  ******   *   FEED   *                  |P= 1183366.0|                                    \/
  |P= 1183366.0|  *FEED*<<<*   BOOST  *<<<<<<<<<<<<<<<<  |H= 113.46   |                                    \/
  |H= 113.46   |  ******   *  HEATER  *                /\|B=  11.47   |                                    \/
```



```
|T=   29.9     |
|P= 1183366.0|
|H=   62.06    |
|B=    9.42    |
|STATE=SUBCL  |

|FEED OUT P/H|
|T=  66.4     |
|P= 1183366.0|
|H= 113.46    |
|B=  11.47    |
|STATE=2 PHA |

| BOT IN EXP |
|T=  29.9     |
|P= 1183366.0|
|H=  57.91    |
|B=   2.88    |
| STATE=SUBCL|

|   MIX IN    |
|T=  30.0     |
|P=  579255.2|
|H= 269.47    |
|B=  47.56    |
|STATE=SUPHV |

| BOT IN P/H |
|T= 101.1     |
|P= 1183366.0|
|H= 124.41    |
|B=   5.82    |
|STATE=SATDL |

| BOT OUT P/H|
|T=  29.9     |
|P= 1183366.0|
|H=  57.91    |
|B=   2.88    |
|STATE=SUBCL |

|BOT OUT EXP |
|T=  30.1     |
|P=  579255.2|
|H=  57.91    |
|B=   2.48    |
|STATE=SUBCL |

|  MIX OUT    |
|T=  40.1     |
|P=  579255.2|
|H= 105.93    |
|B=   8.26    |
|STATE=2 PHA |

| ABSORBER IN|
|T=  40.1     |
|P=  579255.2|
|H= 105.93    |
|B=   8.26    |
|STATE=2 PHA |

| BOTTOM OUT |
|T= 101.1     |
|P= 1183366.0|
|H= 124.41    |
|B=   5.82    |
|STATE=SATDL |

T=  30.0  >>>  * ABSORBER  *  >>>
               *TSAT=  30.0*

|ABSORBER OUT|
|T=  30.0     |
|P=  579255.2|
|H=  62.06    |
|B=   9.00    |
|STATE=SATDL |

| PUMP IN     |
|T=  30.0     |
|P=  579255.2|
|H=  62.06    |
|B=   9.00    |
|STATE=SATDL |

|  PUMP OUT   |
|T=  29.9     |
|P= 1183366.0|
|H=  62.06    |
|B=   9.42    |
|STATE=SUBCL |
```

```
**********************************************************************
*COLUMN PLATE NUMBERS: TOTAL=12:   RECTIFYING= 7:   STRIPPING= 2   *
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   0.000KW      *
*FEEDPLATE: TEMP= 68.26 DEG C: LIQUID CONC= 0.209: VAP CONC= 0.611*
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.99              *
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.15              *
*-------------------------------------------------------------------*
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST*
*-------------------------------------------------------------------*
*  KW  | 10.000      |19.076      |10.240   |19.319  | 0.098| 0.000*
**********************************************************************
*                  |          |          |         FEED              *
*                  |          |          |---------------------------
*                  |DISTILLATE| BOTTOMS  | P/HEAT | COLUMN/HX| TOTAL *
*-------------------------------------------------------------------*
*FLOWS KG/S        | 0.0530   | 0.1804   | 0.2334 |  0.0000  | 0.2334*
*CONCENTRATION     | 0.990    | 0.050    |           0.263           *
*-------------------------------------------------------------------*
* MINIMUM REFLUX FLOW (KG/S) =  0.0457                              *
**********************************************************************
*CARNOT COP=     2.114 BASED ON    5.0.  30.0 & 101.1 DEG C         *
*COP=  0.515   COPHEAT= 1.510    PUMP KW AS %=    0.5               *
**********************************************************************
```

FIGURE H3

```
------------------------------------------------------------------------------------------------------------------------------------------------
NO |  TEMP   |  K    |HEAT TF|FEED FLOW|A/BY CH|PHASE| MASS  |ENTHALPY|ENTROPY |AVAIL/TY|FUG COEF|FUG COEF| FLOW
   | DEG C   | Y/X   |  KW   |  KG/S   | KJ/S  |     | CONC  | KJ/KG  |KJ/KG K | KJ/KG  |COMPT 1 |COMPT 2 | KG/S
------------------------------------------------------------------------------------------------------------------------------------------------
 1 |  30.0   | 1.01  | 19.076|  0.0000 | -0.006| LIQ |0.990  |  80.71 | 0.327  |  65.56 | 0.847  | 0.001  | 0.1056
   |         |       |       |         |       | VAP |0.997  | 261.28 | 0.000  |   0.00 | 0.000  | 0.000  | 0.0000
   |         |       |       |         |       |     |       |        |        |        |        |        |
 2 |  30.7   | 1.03  |  0.000|  0.0000 | -0.018| LIQ |0.962  |  80.75 | 0.334  |  61.85 | 0.859  | 0.187  | 0.0526
   |         |       |       |         |       | VAP |0.990  | 261.31 | 0.922  |  65.62 | 0.844  | 0.720  | 0.1056
   |         |       |       |         |       |     |       |        |        |        |        |        |
 3 |  32.0   | 1.08  |  0.000|  0.0000 | -0.026| LIQ |0.908  |  80.84 | 0.344  |  55.72 | 0.886  | 0.185  | 0.0525
   |         |       |       |         |       | VAP |0.976  | 261.45 | 0.926  |  63.94 | 0.846  | 0.731  | 0.1056
   |         |       |       |         |       |     |       |        |        |        |        |        |
 4 |  34.6   | 1.18  |  0.000|  0.0000 | -0.043| LIQ |0.806  |  81.10 | 0.357  |  45.85 | 0.946  | 0.183  | 0.0520
   |         |       |       |         |       | VAP |0.949  | 261.61 | 0.931  |  61.14 | 0.849  | 0.735  | 0.1055
   |         |       |       |         |       |     |       |        |        |        |        |        |
 5 |  39.7   | 1.41  |  0.000|  0.0000 | -0.078| LIQ |0.637  |  82.09 | 0.371  |  31.86 | 1.087  | 0.186  | 0.0512
   |         |       |       |         |       | VAP |0.899  | 262.69 | 0.939  |  56.68 | 0.857  | 0.743  | 0.1049
   |         |       |       |         |       |     |       |        |        |        |        |        |
 6 |  48.5   | 1.87  |  0.000|  0.0000 | -0.105| LIQ |0.437  |  85.47 | 0.383  |  18.14 | 1.377  | 0.209  | 0.0511
   |         |       |       |         |       | VAP |0.816  | 264.58 | 0.948  |  50.64 | 0.868  | 0.755  | 0.1041
   |         |       |       |         |       |     |       |        |        |        |        |        |
 7 |  58.3   | 2.41  |  0.000|  0.0000 | -0.069| LIQ |0.299  |  91.18 | 0.395  |  10.48 | 1.751  | 0.255  | 0.0520
   |         |       |       |         |       | VAP |0.719  | 266.31 | 0.953  |  44.92 | 0.881  | 0.768  | 0.1041
   |         |       |       |         |       |     |       |        |        |        |        |        |
 8 |  65.0   | 2.76  |  0.000|  0.0000 | -0.027| LIQ |0.235  |  95.74 | 0.403  |   7.67 | 2.023  | 0.294  | 0.0532
   |         |       |       |         |       | VAP |0.647  | 267.55 | 0.953  |  41.54 | 0.889  | 0.776  | 0.1050
   |         |       |       |         |       |     |       |        |        |        |        |        |
 9 |  68.3   | 2.93  |  0.000|  0.2334 | -0.251| LIQ |0.209  |  98.09 | 0.408  |   6.75 | 2.159  | 0.316  | 0.2657
   |         |       |       |         |       | VAP |0.611  | 267.86 | 0.951  |  40.05 | 0.893  | 0.779  | 0.1062
   |         |       |       |         |       |     |       |        |        |        |        |        |
10 |  74.1   | 3.21  |  0.000|  0.0000 | -0.175| LIQ |0.170  | 102.45 | 0.416  |   5.61 | 2.409  | 0.359  | 0.2718
   |         |       |       |         |       | VAP |0.545  | 268.90 | 0.948  |  37.65 | 0.900  | 0.785  | 0.0853
   |         |       |       |         |       |     |       |        |        |        |        |        |
11 |  85.6   | 3.71  |  0.000|  0.0000 | -0.493| LIQ |0.109  | 111.54 | 0.433  |   4.80 | 2.921  | 0.457  | 0.2855
   |         |       |       |         |       | VAP |0.406  | 270.53 | 0.934  |  34.14 | 0.916  | 0.796  | 0.0913
   |         |       |       |         |       |     |       |        |        |        |        |        |
12 | 101.1   | 4.22  |-19.319|  0.0000 |  3.137| LIQ |0.050  | 124.42 | 0.457  |   5.82 | 3.630  | 0.617  | 0.1804
   |         |       |       |         |       | VAP |0.211  | 273.24 | 0.900  |  32.89 | 0.939  | 0.811  | 0.1051
   |         |       |       |         |       |     |       |        |        |        |        |        |
NOTE; A/BY CH   is for streams only.
```

FIGURE H3 CONTD

```
                  SECOND LAW ANALYSIS              KJ/S      PERCENT OF AVAILABILITY LOSS
-----------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                   0.000     0.000
    PRECOOLER LIQ OUT TO EXPANSION IN               0.000     0.000
    EVAPORATOR OUT TO PRECOOLER IN                  0.000     0.000
    PRECOOLER VAP OUT TO MIXING IN                  0.000     0.000
    MIXING OUT TO ABSORBER IN                       0.000     0.000
    ABSORBER OUT TO PUMP IN                         0.000     0.000
    PUMP OUT TO FEED SPLIT                          0.000     0.000
    FEED SPLIT TO PREHEATER IN                      0.000     0.000
    PREHEATER OUT TO FEED JOIN                      0.000     0.000
    FEED SPLIT TO RECTIFIER HX IN                   0.000     0.000
    RECTIFIER HX OUT TO FEED JOIN                   0.000     0.000
    BOTTOM OUT OF COLUMN TO HX IN                   0.000     0.000
    BOTTOM HX OUT TO PREHEATER IN                   0.000     0.000
    PREHEATER OUT TO EXPANSION IN                   0.000     0.000
-----------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                           -0.042     1.114
    BOTTOMS EXPANSION                              -0.073     1.941
-----------------------------------------------------------
PUMP                                                0.099
-----------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                      -0.078     2.059
    PREHEATER                                      -0.052     1.380
-----------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                          0.033    -0.883
    EVAP REFRIGERANT STREAMS ONLY   -0.834
    EVAP CARNOT   -0.867                                     23.000


ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY   -0.867    22.990
    CARNOT FROM AVERAGE TEMP    0.000

COLUMN
    CARNOT ONLY                                     3.671
    (STREAMS ONLY =     1.852 )
    COLUMN ONLY=CARNOT-STREAMS                     -1.818    48.232
    (MINIMUM SEPERATION WORK=    1.846)

CONDENSER
    COND CARNOT                                     0.000     0.000
    CONDENSER STREAMS ONLY                         -0.006     0.167
-----------------------------------------------------------
                                                    0.000
                                               ------------
```

FIGURE H3 CONTD

```
********************************************************                                         ***************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM       *  ---------------------                  *             *
* R  11     CHLORODIFLUOROMETHANE      ( CHCLF2     )  * |  DATA AND   UNITS  |                  *             *
* R  22     TRICHLOROFLUOROMETHANE     ( CCL3F      )  * |T=TEMPERATURE DEG C |                  *             *
* CONCENTRATION OF DISTILLATE=  0.990                  * |P=PRESSURE KPA      | T=   5.0    <<<  * EVAPORATOR  *  <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  4.41                   * |H=ENTHALPY KJ/KG    |                  * TSAT=  5.8  *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00*  |B=AVAILABILITY KJ/KG|  ------------    *             *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=      0.0 DEG *  --------------------- |  EVAP IN   |   *             *    |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=             0.0 DEG *                        |T=   5.0    |   ***************    |T=   5.8    |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=      0.0 DEG *                        |P=  579255.2|     /\        \/     |P=  579255.2|
* APPROACH FLUID OFF EVAP TO EVAP IN     =  0.0 DEG    *                        |H=  64.22   |     /\        \/     |H= 252.99   |
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG       *       -------------    |B=  66.38   |     /\        \/     |B=  50.64   |
* ALL CONCENTRATIONS ARE MASS CONCS OF        R 11     *      |EXPANSION IN|    |STATE=2 PHA |   ***         \/     |STATE=SATDV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =    -40.0DEG C*      |T=  17.2    |     ------------    *E*         \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=    101.3 KPA*      |P= 1183366.0|                     ***         \/
********************************************************      |H=  64.22   |                       /\        \/
                                                              |B=  67.17   |     ------------      /\        \/      ------------
                                                              |STATE=SUBCL |    |P/COOL L OUT|     /\        \/     |P/COOL V IN |
                         ------------                          -------------    |T=  17.2    |   ***************    |T=   5.8    |
                        |  COND OUT  |                                          |P= 1183366.0|   *             *    |P=  579255.2|
                        |T=  30.0    |                                          |H=  64.22   |   *             *    |H= 252.99   |
                        |P= 1183366.0|                                          |B=  67.17   |   *  PRECOOLER  *    |B=  50.64   |
                        |H=  80.71   |                                          |STATE=SUBCL |   *             *    |STATE=SATDV |
                        |B=  65.56   |                                           ------------    *             *     ------------
                        |STATE=SATDL |                                                           ***************
                         ------------                                                              /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                     /\      TSAT=   30.0                                                                    \/
                  ******                                                         ------------                \/      ------------
T=  30.0   >>>    *COND*    >>>                                                 |P/COOL L IN |               \/     |P/COOL V OUT|
                  ******                                                        |T=  30.0    |               \/     |T=  30.0    |
                  *    *                                                        |P= 1183366.0|               \/     |P=  579255.2|
                  *    *                                                        |H=  80.71   |               \/     |H= 269.47   |
                  *    *                                                        |B=  65.56   |               \/     |B=  47.56   |
                  *    *                                                        |STATE=SATDL |               \/     |STATE=SUPHV |
                  *    *                                                         ------------                \/      ------------
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                                                                     \/
                  *    *                                   ------------                                      \/
   ------------   *    *                                  | FEED       |                                     \/
  | COLUMN FEED|  *    *   *************                  |T=  57.9    |                                     \/
  |T=  57.9    |  ******   *   FEED    *                  |P= 1183366.0|                                     \/
  |P= 1183366.0|  *FEED*<<<*   BOOST   *<<<<<<<<<<<<<<<<  |H=  89.52   |                                     \/
  |H=  89.52   |  ******   *  HEATER   *                /\|B=   8.75   |                                     \/
  |B=   8.75   |  *    *   *************                /\|STATE=SUBCL |                                     \/
```

```
                *    *                               /\       |FEED IN P/H |                             \/
                *    *                               /\       |T=  29.9    |                             \/
                *    *                               /\       |P= 1183366.0|      ------------           \/
                *    *                 ------------  /\       |H=  62.06   |     | BOT IN EXP |          \/      ------------
                *    *                |FEED OUT P/H| /\       |B=   9.42   |     |T=  29.9    |          \/     |   MIX IN   |
                *    *                |T=  57.9    | /\       |STATE=SUBCL |     |P= 1183366.0|          \/     |T=  30.0    |
                *    *                |P= 1183366.0| /\        ------------      |H=  57.91   |          \/     |P=  579255.2|
                *    *                |H=  89.52   | /\  *******                 |B=   2.88   |          \/     |H= 269.47   |
                *    *                |B=   8.75   |  <<<*     *<<<<<<<<<<<<<<<</\| STATE=SUBCL|          \/     |B=  47.56   |
 ------------   *    *               |STATE=SUBCL  |     *FEED *               /\ ------------       *********  |STATE=SUPHV |
| BOT HX OUT |  *    *                 ------------      *PRE  *               /\      ***           *       *   ------------
|T=  69.5    |  *    *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT * >>>>>>>>>>>>  /\>>>>>>*E*>>>>>>>>>>>*  MIX  *
|P= 1183366.0|  *    *                                   *     *               /\      ***           *       *
|H=  93.44   |  *    *                                   *******               /\                    *********
|B=   2.71   |  *    *                     ------------          ------------  /\         ------------   \/      ------------
|STATE=SUBCL |  *    *                    | BOT IN P/H |        | BOT OUT P/H| /\        |BOT OUT EXP |  \/     |  MIX OUT   |
 ------------   *    *                    |T=  69.5    |        |T=  29.9    | /\        |T=  30.1    |  \/     |T=  40.1    |
                *    *                    |P= 1183366.0|        |P= 1183366.0| /\        |P=  579255.2|  \/     |P=  579255.2|
                *    *                    |H=  93.44   |        |H=  57.91   | /\        |H=  57.91   |  \/     |H= 105.93   |
                *    *                    |B=   2.71   |        |B=   2.88   | /\        |B=   2.48   |  \/     |B=   8.26   |
 ------------   *    *                    |STATE=SUBCL |        |STATE=SUBCL | /\        |STATE=SUBCL |  \/     |STATE=2 PHA |
| BOT HX IN  |  *    *                     ------------          ------------  /\         ------------   \/      ------------
|T= 101.1    |  *    *                                                         /\                        \/
|P= 1183366.0|  *    *                                                         /\                        \/      ------------
|H= 124.41   |  *    *                                                         /\                        \/     | ABSORBER IN|
|B=   5.82   |  *    *                                                         /\                        \/     |T=  40.1    |
|STATE=SATDL |  *    *                                                         /\                        \/     |P=  579255.2|
 ------------   *    *                                                         /\                        \/     |H= 105.93   |
                *    *<<<<<                                                    /\                        \/     |B=   8.26   |
 ------------   *    *    /\                                                   /\                        \/     |STATE=2 PHA |
| BOTTOM OUT |  *    *    /\                                                   /\                        \/      ------------
|T= 101.1    |  ******    /\                                                   /\                  *************
|P= 1183366.0|  *BOIL*    /\                                                   /\                  *           *
|H= 124.41   |  ******    /\                                                   /\   T=  30.0  >>>  * ABSORBER  *  >>>
|B=   5.82   |     \/     /\                                                   /\                  *TSAT=  30.0*
|STATE=SATDL |     \/     /\                                                   /\                  ************* ------------
 ------------       >>>>>>                                                     /\                        \/     |ABSORBER OUT|
                                                                               /\                        \/     |T=  30.0    |
                                                                               /\                        \/     |P=  579255.2|
*******************************************************************            /\                        \/     |H=  62.06   |
*COLUMN PLATE NUMBERS: TOTAL=12:   RECTIFYING= 7:   STRIPPING= 2  *            /\                        \/     |B=   9.00   |
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   5.587KW    *            /\                        \/     |STATE=SATDL |
*FEEDPLATE: TEMP= 64.51 DEG C: LIQUID CONC= 0.239: VAP CONC= 0.653*            /\                        \/      ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.89           *            /\                        \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.24           *            /\                        \/      ------------
*-----------------------------------------------------------------*            /\                        \/     | PUMP IN    |
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST*            /\                        \/     |T=  30.0    |
*-----------------------------------------------------------------*            /\                        \/     |P=  579255.2|
*  KW  | 10.000     |18.050      |10.240   |18.297  | 0.098| 0.000*            /\                        \/     |H=  62.06   |
*******************************************************************            /\                        \/     |B=   9.00   |
*               |          |          |           FEED            *            /\                        \/     |STATE=SATDL |
*               |          |          |---------------------------             /\                    *********   ------------
*               |DISTILLATE| BOTTOMS  | P/HEAT | COLUMN/HX| TOTAL *            /\                    *  PUMP *   ------------
*-----------------------------------------------------------------*            /\                    *********  |  PUMP OUT  |
*FLOWS KG/S     | 0.0530   | 0.1804   | 0.2334 |  0.0000  | 0.2334*            /\                        \/     |T=  29.9    |
*CONCENTRATION  | 0.990    | 0.050    |           0.263           *            /\                        \/     |P= 1183366.0|
*-----------------------------------------------------------------*            /\                        \/     |H=  62.06   |
* MINIMUM REFLUX FLOW (KG/S) =  0.0380                            *             <<<<<<<<<<<<<<<<<<<<<<<<<       |B=   9.42   |
*******************************************************************                                             |STATE=SUBCL |
*CARNOT COP=    2.114 BASED ON    5.0,  30.0 & 101.1 DEG C        *                                              ------------
*COP=  0.544   COPHEAT= 1.538    PUMP KW AS %=     0.5            *
*******************************************************************
```

FIGURE H4

```
------------------------------------------------------------------------------------------------------------------
NO I  TEMP   I  K    IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C   I Y/X   I  KW   I  KG/S   I KJ/S   I     I CONC I KJ/KG  IKJ/KG KI KJ/KG  ICOMPT 1 ICOMPT 2 I KG/S
------------------------------------------------------------------------------------------------------------------
 1 I  30.0   I 1.01  I 18.050I  0.0000 I -0.006I LIQ I0.990 I  80.71  I 0.327 I  65.56 I  0.847 I  0.001 I 0.0999
   I         I       I       I         I       I VAP I0.997 I 261.28  I 0.000 I   0.00 I  0.000 I  0.000 I 0.0000
   I         I       I       I         I       I     I      I         I       I        I        I        I
 2 I  30.7   I 1.03  I  0.000I  0.0000 I -0.016I LIQ I0.962 I  80.75  I 0.334 I  61.85 I  0.859 I  0.187 I 0.0469
   I         I       I       I         I       I VAP I0.990 I 261.31  I 0.922 I  65.62 I  0.844 I  0.720 I 0.0999
   I         I       I       I         I       I     I      I         I       I        I        I        I
 3 I  31.9   I 1.07  I  0.000I  0.0000 I -0.020I LIQ I0.911 I  80.83  I 0.343 I  56.05 I  0.885 I  0.185 I 0.0469
   I         I       I       I         I       I VAP I0.977 I 261.44  I 0.925 I  64.03 I  0.845 I  0.731 I 0.0999
   I         I       I       I         I       I     I      I         I       I        I        I        I
 4 I  34.2   I 1.16  I  0.000I  0.0000 I -0.029I LIQ I0.820 I  81.05  I 0.355 I  47.11 I  0.937 I  0.183 I 0.0465
   I         I       I       I         I       I VAP I0.953 I 261.52  I 0.930 I  61.51 I  0.849 I  0.734 I 0.0999
   I         I       I       I         I       I     I      I         I       I        I        I        I
 5 I  38.5   I 1.35  I  0.000I  0.0000 I -0.049I LIQ I0.673 I  81.79  I 0.368 I  34.66 I  1.051 I  0.184 I 0.0458
   I         I       I       I         I       I VAP I0.910 I 262.40  I 0.937 I  57.65 I  0.855 I  0.741 I 0.0994
   I         I       I       I         I       I     I      I         I       I        I        I        I
 6 I  45.7   I 1.72  I  0.000I  0.0000 I -0.069I LIQ I0.491 I  84.17  I 0.380 I  21.56 I  1.279 I  0.200 I 0.0455
   I         I       I       I         I       I VAP I0.843 I 263.89  I 0.945 I  52.44 I  0.865 I  0.751 I 0.0988
   I         I       I       I         I       I     I      I         I       I        I        I        I
 7 I  54.3   I 2.19  I  0.000I  0.0000 I -0.054I LIQ I0.347 I  88.67  I 0.390 I  12.95 I  1.594 I  0.234 I 0.0461
   I         I       I       I         I       I VAP I0.759 I 265.55  I 0.951 I  47.14 I  0.876 I  0.763 I 0.0985
   I         I       I       I         I       I     I      I         I       I        I        I        I
 8 I  61.0   I 2.55  I  0.000I  0.0000 I -0.022I LIQ I0.271 I  92.92  I 0.398 I   9.20 I  1.856 I  0.270 I 0.0468
   I         I       I       I         I       I VAP I0.691 I 266.62  I 0.953 I  43.54 I  0.884 I  0.771 I 0.0991
   I         I       I       I         I       I     I      I         I       I        I        I        I
 9 I  64.5   I 2.74  I  0.000I  0.2334 I -0.133I LIQ I0.239 I  95.39  I 0.403 I   7.84 I  2.002 I  0.291 I 0.2879
   I         I       I       I         I       I VAP I0.653 I 267.33  I 0.953 I  41.78 I  0.888 I  0.775 I 0.0998
   I         I       I       I         I       I     I      I         I       I        I        I        I
10 I  73.2   I 3.17  I -2.794I  0.0000 I  0.020I LIQ I0.175 I 101.75  I 0.415 I   5.75 I  2.369 I  0.352 I 0.2811
   I         I       I       I         I       I VAP I0.555 I 268.78  I 0.948 I  38.01 I  0.899 I  0.784 I 0.1075
   I         I       I       I         I       I     I      I         I       I        I        I        I
11 I  86.1   I 3.73  I -2.794I  0.0000 I -0.119I LIQ I0.107 I 111.94  I 0.434 I   4.80 I  2.943 I  0.461 I 0.2799
   I         I       I       I         I       I VAP I0.400 I 270.62  I 0.933 I  34.04 I  0.915 I  0.797 I 0.1006
   I         I       I       I         I       I     I      I         I       I        I        I        I
12 I 101.2   I 4.22  I-18.297I  0.0000 I  2.980I LIQ I0.050 I 124.44  I 0.457 I   5.82 I  3.631 I  0.617 I 0.1804
   I         I       I       I         I       I VAP I0.211 I 273.19  I 0.900 I  32.89 I  0.939 I  0.811 I 0.0995
   I         I       I       I         I       I     I      I         I       I        I        I
NOTE; A/BY CH   is for streams only.
```

FIGURE H4 CONTD

```
                 SECOND LAW ANALYSIS                 KJ/S      PERCENT OF AVAILABILITY LOSS
----------------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                     0.000    0.000
    PRECOOLER LIQ OUT TO EXPANSION IN                 0.000    0.000
    EVAPORATOR OUT TO PRECOOLER IN                    0.000    0.000
    PRECOOLER VAP OUT TO MIXING IN                    0.000    0.000
    MIXING OUT TO ABSORBER IN                         0.000    0.000
    ABSORBER OUT TO PUMP IN                           0.000    0.000
    PUMP OUT TO FEED SPLIT                            0.000    0.000
    FEED SPLIT TO PREHEATER IN                        0.000    0.000
    PREHEATER OUT TO FEED JOIN                        0.000    0.000
    FEED SPLIT TO RECTIFIER HX IN                     0.000    0.000
    RECTIFIER HX OUT TO FEED JOIN                     0.000    0.000
    BOTTOM OUT OF COLUMN TO HX IN                     0.000    0.000
    BOTTOM HX OUT TO PREHEATER IN                     0.000    0.000
    PREHEATER OUT TO EXPANSION IN                     0.000    0.000
----------------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                             -0.042    1.174
    BOTTOMS EXPANSION                                -0.073    2.047
----------------------------------------------------------------
PUMP                                                  0.099
----------------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                        -0.078    2.170
    PREHEATER                                        -0.127    3.556
----------------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                            0.033   -0.931
    EVAP REFRIGERANT STREAMS ONLY   -0.834
    EVAP CARNOT   -0.867                                      24.249


ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY     -0.867   24.238
    CARNOT FROM AVERAGE TEMP    0.000

COLUMN
    CARNOT ONLY                                       3.477
    (STREAMS ONLY =     1.927 )
    COLUMN ONLY=CARNOT-STREAMS                       -1.549   43.331
    (MINIMUM SEPERATION WORK=    2.482)

CONDENSER
    COND CARNOT                                       0.000    0.000
    CONDENSER STREAMS ONLY                           -0.006    0.166
----------------------------------------------------------------
                                                      0.000
                                                  ------------
```

FIGURE H4 CONTD

```
*******************************************************                                         ***************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      *  --------------------                   *             *
* R  11     CHLORODIFLUOROMETHANE     ( CHCLF2    )   * |  DATA AND   UNITS  |                  *             *
* R  22     TRICHLOROFLUOROMETHANE    ( CCL3F     )   * |T=TEMPERATURE DEG C |                  *             *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=   5.0    <<<  * EVAPORATOR  *  <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  4.41                  * |H=ENTHALPY KJ/KG    |                  * TSAT=  5.8  *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 0.99* |B=AVAILABILITY KJ/KG|  ------------    *             *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG *  --------------------  |  EVAP IN   |   *             *    |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=           0.0 DEG *                        |T=  5.0     |   ***************    |T=    5.8   |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=    0.0 DEG *                        |P=  579255.2|     /\        \/     |P=  579255.2|
* APPROACH FLUID OFF EVAP TO EVAP IN    =  0.0 DEG    *                        |H=  64.22   |     /\        \/     |H= 252.99   |
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------     |B=  66.38   |     /\        \/     |B=  50.64   |
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 11     *      |EXPANSION IN|    |STATE=2 PHA |    ***        \/     |STATE=SATDV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  17.2    |     ------------     *E*        \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=   101.3 KPA*      |P= 1183366.0|                      ***        \/
*******************************************************      |H=  64.22   |                       /\        \/
                                                             |B=  67.17   |     ------------      /\        \/      ------------
                                                             |STATE=SUBCL |    |P/COOL L OUT|     /\        \/     |P/COOL V IN |
                        ------------                          ------------     |T=  17.2    |   ***************    |T=    5.8   |
                       |  COND OUT  |                                          |P= 1183366.0|   *             *    |P=  579255.2|
                       |T=  30.0    |                                          |H=  64.22   |   *             *    |H= 252.99   |
                       |P= 1183366.0|                                          |B=  67.17   |   *  PRECOOLER  *    |B=  50.64   |
                       |H=  80.71   |                                          |STATE=SUBCL |   *             *    |STATE=SATDV |
                       |B=  65.56   |                                           ------------    *             *     ------------
                       |STATE=SATDL |                                                           ***************
                        ------------                                                              /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>         \/
                      /\     TSAT=   30.0                                                                   \/
                  ******                                                        ------------                \/      ------------
T=  30.0   >>>    *COND*    >>>                                                |P/COOL L IN |               \/     |P/COOL V OUT|
                  ******                                                       |T=  30.0    |               \/     |T=  30.0    |
                  *    *                                                       |P= 1183366.0|               \/     |P=  579255.2|
                  *    *                                                       |H=  80.71   |               \/     |H= 269.47   |
                  *    *                                                       |B=  65.56   |               \/     |B=  47.56   |
                  *    *                                                       |STATE=SATDL |               \/     |STATE=SUPHV |
                  *    *                                                        ------------                \/      ------------
   ------------   *    *                                                                                    \/
  | RECT HX IN |  *    *                                                                                    \/
  |T=  29.9    |  *    *                                                                                    \/
  |P= 1183366.0|  *    *                                                                                    \/
  |H=  62.06   |  *    *<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<                          \/
  |B=   9.42   |  *    *                                                          /\                        \/
  |STATE=SUBCL |  *    *                                                          /\                        \/
   ------------|  *    *                                                          /\                        \/
                  *    *                                                          /\                        \/
   ------------   *    *                                                          /\                        \/
  | RECT HX OUT|  *    *                                                          /\                        \/
  |T=  60.2    |  *    *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>                          /\                        \/
  |P= 1183366.0|  *    *                                \/                        /\                        \/
  |H=  91.85   |  *    *                                \/                        /\                        \/
  |B=   8.80   |  *    *                                \/                        /\                        \/
  |STATE=SUBCL    *    *                                \/                        /\                        \/
   ------------   *    *                                \/                        /\                        \/
                  *    *                                \/                        /\                        \/
                  *    *                                \/ ------------           /\ ------------           \/
   ------------   *    *                                \/| FEED JOIN  |          /\| FEED SPLIT |          \/
  | COLUMN FEED|  *    *   ************                 \/|T=  53.0    |          /\ |T=  29.9    |         \/
  |T=  53.0    |  ******   *   FEED   *                 \/|P= 1183366.0|          /\ |P= 1183366.|          \/
  |P= 1183366.0|  *FEED*<<<*   BOOST  *<<<<<<<<<<<<<<<<<  |H=  84.60   |         </\ |H=  62.06   |         \/
  |H=  84.60   |  ******   *  HEATER  *                 /\ |B=   8.68   |       V /\ |B=   9.42   |         \/
  |B=   8.68   |  *    *   ************                 /\ |STATE=SUBCL|        V /\ |STATE=SUBCL|          \/
```

```
                *    *                               /\      |T=  29.9    | V /\                        \/
                *    *                               /\      |P= 1183366.0| V /\ -------------          \/
                *    *                 ------------  /\      |H=  62.06   | V /\ |BOT IN  EXP |         \/      ------------
                *    *                |FEED OUT P/H| /\      |B=   9.42   | V /\ |T=  29.9    |         \/     |   MIX IN   |
                *    *                |T=  53.0    | /\      |STATE=SUBCL | V /\ |P= 1183366.|          \/     |T=  30.0    |
                *    *                |P= 1183366.0| /\       ------------  V /\ |H=  57.91   |         \/     |P=  579255.2|
                *    *                |H=  84.53   | /\ *******             V /\ |B=   2.88   |         \/     |H= 269.47   |
                *    *                |B=   8.68   | <<<*     *<<<<<<<<<<<<<  /\ |STATE=SUBCL|          \/     |B=  47.56   |
 ------------   *    *               |STATE=SUBCL  |    *FEED *               /\ -------------      *********  |STATE=SUPHV |
| BOT HX OUT |  *    *                 ------------     *PRE  *               /\      ***           *       *   ------------
|T=  62.2    |  *    *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT * >>>>>>>>>>>>  /\>>>>>>*E*>>>>>>>>>>>*  MIX  *
|P= 1183366.0|  *    *                                  *     *               /\      ***           *       *
|H=  86.69   |  *    *                                  *******               /\                    *********
|B=   2.41   |  *    *                     ------------         ------------  /\         ------------   \/      ------------
|STATE=SUBCL |  *    *                    | BOT IN P/H |       | BOT OUT P/H| /\        |BOT OUT EXP |  \/     |  MIX OUT   |
 ------------   *    *                    |T=  62.2    |       |T=  29.9    | /\        |T=  30.1    |  \/     |T=  40.1    |
                *    *                    |P= 1183366.0|       |P= 1183366.0| /\        |P=  579255.2|  \/     |P=  579255.2|
                *    *                    |H=  86.69   |       |H=  57.91   | /\        |H=  57.91   |  \/     |H= 105.93   |
                *    *                    |B=   2.41   |       |B=   2.88   | /\        |B=   2.48   |  \/     |B=   8.26   |
 ------------   *    *                    |STATE=SUBCL |       |STATE=SUBCL | /\        |STATE=SUBCL |  \/     |STATE=2 PHA |
| BOT HX IN  |  *    *                     ------------         ------------  /\         ------------   \/      ------------
|T= 101.1    |  *    *                                                        /\                        \/
|P= 1183366.0|  *    *                                                        /\                        \/      ------------
|H= 124.41   |  *    *                                                        /\                        \/     | ABSORBER IN|
|B=   5.82   |  *    *                                                        /\                        \/     |T=  40.1    |
|STATE=SATDL |  *    *                                                        /\                        \/     |P=  579255.2|
 ------------   *    *                                                        /\                        \/     |H= 105.93   |
                *    *<<<<<                                                   /\                        \/     |B=   8.26   |
 ------------   *    *    /\                                                  /\                        \/     |STATE=2 PHA |
| BOTTOM OUT |  *    *    /\                                                  /\                        \/      ------------
|T= 101.1    |  ******    /\                                                  /\                  *************
|P= 1183366.0|  *BOIL*    /\                                                  /\                  *           *
|H= 124.41   |  ******    /\                                                  /\   T=  30.0  >>>  * ABSORBER  *  >>>
|B=   5.82   |     \/     /\                                                  /\                  *TSAT=  30.0*
|STATE=SATDL |     \/     /\                                                  /\                  ************* ------------
 ------------         >>>>>>                                                  /\                        \/     |ABSORBER OUT|
                                                                              /\                        \/     |T=  30.0    |
                                                                              /\                        \/     |P=  579255.2|
*******************************************************************           /\                        \/     |H=  62.06   |
*COLUMN PLATE NUMBERS: TOTAL=13:   RECTIFYING= 7:   STRIPPING= 3  *           /\                        \/     |B=   9.00   |
*RECTIFYING HX TOTAL=   0.070KW: STRIPPING HX TOTAL=  6.805KW     *           /\                        \/     |STATE=SATDL |
*FEEDPLATE: TEMP= 61.00 DEG C: LIQUID CONC= 0.271: VAP CONC= 0.690*           /\                        \/      ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=   1.66            *           /\                        \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO= 0.95            *           /\                        \/      ------------
*-----------------------------------------------------------------*           /\                        \/     | PUMP IN    |
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST*           /\                        \/     |T=  30.0    |
*-----------------------------------------------------------------*           /\                        \/     |P=  579255.2|
*  KW  | 10.000     |15.857      |10.240   |16.110   | 0.098| 0.000*           /\                        \/     |H=  62.06   |
*******************************************************************           /\                        \/     |B=   9.00   |
*               |          |          |          FEED             *           /\                        \/     |STATE=SATDL |
*               |          |          |---------------------------            /\                    *********   ------------
*               |DISTILLATE| BOTTOMS  | P/HEAT | COLUMN/HX| TOTAL *           /\                    *  PUMP *  |  PUMP OUT  |
*-----------------------------------------------------------------*           /\                    *********  |T=  29.9    |
*FLOWS KG/S     | 0.0530   | 0.1804   | 0.2311 |  0.0023  | 0.2334*           /\                        \/     |P= 1183366.0|
*CONCENTRATION  | 0.990    | 0.050    |           0.263           *           /\                        \/     |H=  62.06   |
*-----------------------------------------------------------------*           /\                        \/     |B=   9.42   |
* MINIMUM REFLUX FLOW (KG/S) =  0.0367                            *            <<<<<<<<<<<<<<<<<<<<<<<<<       |STATE=SUBCL |
*******************************************************************                                             ------------
*CARNOT COP=    2.114 BASED ON    5.0,  30.0 & 101.1 DEG C        *
*COP=  0.617   COPHEAT= 1.610    PUMP KW AS %=    0.6             *
*******************************************************************
```

FIGURE H5

```
------------------------------------------------------------------------------------------------------------------------------------
NO I  TEMP   I  K     IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS  IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C   I Y/X    I  KW   I  KG/S   I KJ/S   I      I CONC  I KJ/KG   IKJ/KG KI KJ/KG   ICOMPT 1 ICOMPT 2 I KG/S
------------------------------------------------------------------------------------------------------------------------------------
 1 I  30.0   I 1.01   I 15.857I  0.0000 I -0.005I LIQ  I0.990  I  80.71  I 0.327  I  65.56 I  0.847  I  0.001 I 0.0878
   I         I        I       I         I       I VAP  I0.997  I 261.28  I 0.000  I   0.00 I  0.000  I  0.000 I 0.0000
   I         I        I       I         I       I      I       I         I        I        I         I        I
 2 I  30.7   I 1.03   I  0.010I  0.0000 I -0.007I LIQ  I0.962  I  80.75  I 0.334  I  61.85 I  0.859  I  0.187 I 0.0349
   I         I        I       I         I       I VAP  I0.990  I 261.31  I 0.922  I  65.62 I  0.844  I  0.720 I 0.0878
   I         I        I       I         I       I      I       I         I        I        I         I        I
 3 I  31.7   I 1.07   I  0.010I  0.0000 I -0.001I LIQ  I0.917  I  80.82  I 0.342  I  56.69 I  0.881  I  0.185 I 0.0348
   I         I        I       I         I       I VAP  I0.978  I 261.17  I 0.925  I  64.21 I  0.845  I  0.731 I 0.0879
   I         I        I       I         I       I      I       I         I        I        I         I        I
 4 I  33.6   I 1.14   I  0.010I  0.0000 I  0.006I LIQ  I0.843  I  80.98  I 0.352  I  49.34 I  0.922  I  0.183 I 0.0344
   I         I        I       I         I       I VAP  I0.959  I 261.48  I 0.929  I  62.15 I  0.848  I  0.733 I 0.0878
   I         I        I       I         I       I      I       I         I        I        I         I        I
 5 I  36.8   I 1.27   I  0.010I  0.0000 I  0.014I LIQ  I0.729  I  81.43  I 0.364  I  39.22 I  1.002  I  0.183 I 0.0338
   I         I        I       I         I       I VAP  I0.927  I 262.06  I 0.934  I  59.13 I  0.852  I  0.738 I 0.0876
   I         I        I       I         I       I      I       I         I        I        I         I        I
 6 I  42.0   I 1.52   I  0.010I  0.0000 I  0.022I LIQ  I0.575  I  82.77  I 0.375  I  27.34 I  1.157  I  0.190 I 0.0328
   I         I        I       I         I       I VAP  I0.877  I 263.12  I 0.941  I  54.98 I  0.860  I  0.746 I 0.0871
   I         I        I       I         I       I      I       I         I        I        I         I        I
 7 I  49.2   I 1.91   I  0.010I  0.0000 I  0.031I LIQ  I0.424  I  85.86  I 0.384  I  17.31 I  1.405  I  0.212 I 0.0319
   I         I        I       I         I       I VAP  I0.809  I 264.59  I 0.948  I  50.15 I  0.869  I  0.756 I 0.0865
   I         I        I       I         I       I      I       I         I        I        I         I        I
 8 I  56.4   I 2.30   I  0.010I  0.0000 I  0.016I LIQ  I0.321  I  89.94  I 0.392  I  11.58 I  1.674  I  0.244 I 0.0318
   I         I        I       I         I       I VAP  I0.738  I 265.92  I 0.952  I  45.97 I  0.878  I  0.766 I 0.0862
   I         I        I       I         I       I      I       I         I        I        I         I        I
 9 I  61.0   I 2.55   I  0.000I  0.2334 I -0.107I LIQ  I0.271  I  92.96  I 0.398  I   9.18 I  1.859  I  0.270 I 0.2759
   I         I        I       I         I       I VAP  I0.690  I 266.59  I 0.953  I  43.51 I  0.884  I  0.771 I 0.0865
   I         I        I       I         I       I      I       I         I        I        I         I        I
10 I  65.9   I 2.81   I -2.268I  0.0000 I  0.095I LIQ  I0.227  I  96.37  I 0.405  I   7.40 I  2.060  I  0.300 I 0.2679
   I         I        I       I         I       I VAP  I0.638  I 267.68  I 0.952  I  41.13 I  0.890  I  0.777 I 0.0975
   I         I        I       I         I       I      I       I         I        I        I         I        I
11 I  74.0   I 3.21   I -2.268I  0.0000 I -0.011I LIQ  I0.170  I 102.37  I 0.416  I   5.63 I  2.404  I  0.358 I 0.2638
   I         I        I       I         I       I VAP  I0.546  I 268.87  I 0.948  I  37.70 I  0.900  I  0.785 I 0.0893
   I         I        I       I         I       I      I       I         I        I        I         I        I
12 I  86.4   I 3.74   I -2.268I  0.0000 I -0.153I LIQ  I0.106  I 112.14  I 0.435  I   4.80 I  2.954  I  0.463 I 0.2655
   I         I        I       I         I       I VAP  I0.397  I 270.66  I 0.932  I  33.99 I  0.917  I  0.797 I 0.0847
   I         I        I       I         I       I      I       I         I        I        I         I        I
13 I 101.2   I 4.22   I-16.110I  0.0000 I  2.598I LIQ  I0.050  I 124.47  I 0.457  I   5.83 I  3.633  I  0.617 I 0.1805
   I         I        I       I         I       I VAP  I0.210  I 273.20  I 0.900  I  32.89 I  0.939  I  0.811 I 0.0857
   I         I        I       I         I       I      I       I         I        I        I         I        I
NOTE; A/BY CH   is for streams only.
```

FIGURE H5 CONTD

```
                  SECOND LAW ANALYSIS                KJ/S      PERCENT OF AVAILABILITY LOSS
------------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                       0.000     0.000
    PRECOOLER LIQ OUT TO EXPANSION IN                   0.000     0.000
    EVAPORATOR OUT TO PRECOOLER IN                      0.000     0.000
    PRECOOLER VAP OUT TO MIXING IN                      0.000     0.000
    MIXING OUT TO ABSORBER IN                           0.000     0.000
    ABSORBER OUT TO PUMP IN                             0.000     0.000
    PUMP OUT TO FEED SPLIT                              0.000     0.000
    FEED SPLIT TO PREHEATER IN                          0.000     0.000
    PREHEATER OUT TO FEED JOIN                          0.000    -0.003
    FEED SPLIT TO RECTIFIER HX IN                       0.000     0.000
    RECTIFIER HX OUT TO FEED JOIN                       0.000     0.009
    BOTTOM OUT OF COLUMN TO HX IN                       0.000     0.000
    BOTTOM HX OUT TO PREHEATER IN                       0.000     0.000
    PREHEATER OUT TO EXPANSION IN                       0.000     0.000
------------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                               -0.042     1.329
    BOTTOMS EXPANSION                                  -0.073     2.316
------------------------------------------------------------
PUMP                                                    0.099
------------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                          -0.078     2.456
    PREHEATER                                          -0.086     2.710
------------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                              0.033    -1.054
    EVAP REFRIGERANT STREAMS ONLY    -0.834
    EVAP CARNOT   -0.867                                         27.436


ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY       -0.867    27.425
    CARNOT FROM AVERAGE TEMP    0.000

COLUMN
    CARNOT ONLY                                         3.061
    (STREAMS ONLY =    1.885 )
    COLUMN ONLY=CARNOT-STREAMS                         -1.176    37.211
    (MINIMUM SEPERATION WORK=    2.497)

CONDENSER
    COND CARNOT                                         0.000     0.000
    CONDENSER STREAMS ONLY                             -0.005     0.165
------------------------------------------------------------
                                                        0.000
                                                   ------------
```

FIGURE H5 CONTD

```
********************************************************                                        ****************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM       * ----------------------                 *              *
* R  11     CHLORODIFLUOROMETHANE      ( CHCLF2     )  * I  DATA AND   UNITS  I                 *              *
* R  22     TRICHLOROFLUOROMETHANE     ( CCL3F      )  * IT=TEMPERATURE DEG C I                 *              *
* CONCENTRATION OF DISTILLATE=  0.990                  * IP=PRESSURE KPA      I T=  5.0   <<<   * EVAPORATOR   *  <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  6.85                   * IH=ENTHALPY KJ/KG    I                 * TSAT=  5.8   *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER=  1.00* IB=AVAILABILITY KJ/KGI ------------    *              *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG  * ----------------------I  EVAP IN   I   *              *    I  EVAP OUT  I
* FEED SUBCOOLING AT ABSORBER OUT=            0.0 DEG  *                       IT=   5.0    I   ****************    IT=   5.8    I
* DISTILLATE SUBCOOLING AT CONDENSER OUT=     0.0 DEG  *                       IP=  579069.8I      /\      \/       IP=  579069.8I
* APPROACH FLUID OFF EVAP TO EVAP IN    =  0.0 DEG     *                       IH=  69.51   I      /\      \/       IH= 252.98   I
*APPROACH CONDENSER AND ABSORBER=  0.0    0.0 DEG      *       ------------    IB=  73.08   I      /\      \/       IB=  53.43   I
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 11      *      IEXPANSION INI   ISTATE=2 PHA I   ***        \/       ISTATE=SATDV I
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =    -40.0DEG C*      IT=  21.4    I    ------------    *E*        \/        ------------
*AVBTY DATUMS: TEMP=  38.0DEG C :PRESSURE=     101.3 KPA*      IP= 1451145.8I                    ***        \/
********************************************************      IH=  69.51   I                       /\      \/
                                                              IB=  74.84   I    ------------       /\      \/        ------------
                                                              ISTATE=SUBCL I   IP/COOL L OUTI      /\      \/       IP/COOL V IN I
                        ------------                           ------------    IT=  21.4    I   ****************    IT=   5.8    I
                       I  COND OUT  I                                          IP= 1451145.8I   *              *    IP=  579069.8I
                       IT=  38.0    I                                          IH=  69.51   I   *              *    IH= 252.98   I
                       IP= 1451145.8I                                          IB=  74.84   I   *  PRECOOLER   *    IB=  53.43   I
                       IH=  91.56   I                                          ISTATE=SUBCL I   *              *    ISTATE=SATDV I
                       IB=  72.62   I                                           ------------    *              *     ------------
                       ISTATE=SATDL I                                                           ****************
                        ------------                                                               /\      \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>         \/
                     /\      TSAT=   38.0                                                                  \/
                  ******                                                        ------------               \/        ------------
T=  38.0   >>>    *COND*    >>>                                                IP/COOL L IN I              \/       IP/COOL V OUTI
                  ******                                                       IT=  38.0    I              \/       IT=  38.0    I
                  *    *                                                       IP= 1451145.8I              \/       IP=  579069.8I
                  *    *                                                       IH=  91.56   I              \/       IH= 275.03   I
                  *    *                                                       IB=  72.62   I              \/       IB=  48.99   I
                  *    *                                                       ISTATE=SATDL I              \/       ISTATE=SUPHV I
                  *    *                                                        ------------               \/        ------------
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                  ------------                                     \/
   ------------   *    *                                 I FEED       I                                    \/
  I COLUMN FEEDI  *    *   *************                 IT=  79.3    I                                    \/
  IT=  79.3    I  ******   *   FEED    *                 IP= 1451145.8I                                    \/
  IP= 1451145.8I  *FEED*<<<*   BOOST   *<<<<<<<<<<<<<<<< IH= 108.57   I                                    \/
  IH= 108.57   I  ******   *  HEATER   *               /\IB=  11.16   I                                    \/
  IB=  11.16   I  *    *   *************               /\ISTATE=SUBCL I                                    \/
```

```
               *      *                    /\      |FEED IN P/H |              \/
               *      *                    /\      |T=  37.8    |              \/
               *      *                    /\      |P= 1451145.8|              \/
               *      *          ------------/\    |H=  67.88   |  ------------  \/   -------------
               *      *          |FEED OUT P/H| /\ |B=  11.27   |  |BOT IN EXP |  \/   |  MIX IN    |
               *      *          |T=  79.3    | /\ |STATE=SUBCL |  |T=  37.8   |  \/   |T=  38.0    |
               *      *          |P= 1451145.8| /\ ------------   |P= 1451145.8| \/   |P= 579069.8|
               *      *          |H= 108.57   | /\  *******       |H=  64.88   |  \/   |H= 275.03   |
               *      *          |B=  11.16   | <<<*     *<<<<<<<<<<<<<<<</\|B=  7.89 |\/ |B=  48.99   |
 ------------  *      *          |STATE=SUBCL |    *FEED *        /\| STATE=SUBCL|  ********* |STATE=SUPHV |
| BOT HX OUT | *      *          ------------      *PRE  *        /\ ------------  *       *  -------------
|T=  89.3    | *      *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT *  >>>>>>>>>>>>/\>>>>>>>*E*>>>>>>>>>>>>>*  MIX  *
|P= 1451145.8| *      *                            *     *        /\      ***      *       *
|H= 112.53   | *      *                            *******        /\               *********
|B=   8.51   | *      *                                           /\                  \/
|STATE=SUBCL | *      *           ------------      ------------  /\  ------------    \/    -------------
 ------------  *      *           | BOT IN P/H |    | BOT OUT P/H|/\  |BOT OUT EXP |  \/    |  MIX OUT   |
               *      *           |T=  89.3    |    |T=  37.8    |/\  |T=  38.1    |  \/    |T=  45.8    |
               *      *           |P= 1451145.8|    |P= 1451145.8|/\  |P= 579069.8|  \/    |P= 579069.8|
               *      *           |H= 112.53   |    |H=  64.88   |/\  |H=  64.88   |  \/    |H=  95.57   |
               *      *           |B=   8.51   |    |B=   7.89   |/\  |B=   7.30   |  \/    |B=   9.52   |
 ------------  *      *           |STATE=SUBCL |    |STATE=SUBCL |/\  |STATE=SUBCL |  \/    |STATE=2 PHA |
| BOT HX IN  | *      *           ------------      ------------  /\  ------------    \/    -------------
|T= 112.4    | *      *                                           /\                  \/
|P= 1451145.8| *      *                                           /\                  \/    -------------
|H= 136.13   | *      *                                           /\                  \/    | ABSORBER IN|
|B=  11.28   | *      *                                           /\                  \/    |T=  45.8    |
|STATE=SATDL | *      *                                           /\                  \/    |P= 579069.8|
 ------------  *      *<<<<<                                      /\                  \/    |H=  95.57   |
               *      *    /\                                     /\                  \/    |B=   9.52   |
 ------------  *      *    /\                                     /\                  \/    |STATE=2 PHA |
| BOTTOM OUT | *      *    /\                                     /\                        -------------
|T= 112.4    | ******      /\                                     /\            *************
|P= 1451145.8| *BOIL*      /\                                     /\            *           *
|H= 136.13   | ******      /\                                     /\  T= 38.0 >>> * ABSORBER  * >>>
|B=  11.28   |   \/        /\                                     /\            *TSAT=  38.0*
|STATE=SATDL |   \/        /\                                     /\            *************
 ------------     >>>>>>                                          /\                  \/    |ABSORBER OUT|
                                                                  /\                  \/    |T=  38.0    |
                                                                  /\                  \/    |P= 579069.8|
*****************************************************************  /\                 \/    |H=  67.88   |
*COLUMN PLATE NUMBERS: TOTAL=12:   RECTIFYING= 7:   STRIPPING= 2 * /\                 \/    |B=  10.66   |
*RECTIFYING HX TOTAL=    0.000KW: STRIPPING HX TOTAL=    7.520KW * /\                 \/    |STATE=SATDL |
*FEEDPLATE: TEMP= 84.78 DEG C: LIQUID CONC= 0.171: VAP CONC= 0.516* /\                \/     ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=     2.44         * /\                 \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.22          * /\                 \/     ------------
*----------------------------------------------------------------* /\                 \/    | PUMP IN    |
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST* /\               \/    |T=  38.0    |
*----------------------------------------------------------------* /\                 \/    |P= 579069.8|
*  KW  | 10.000      122.809      110.334    123.165  | 0.224| 0.000* /\              \/    |H=  67.88   |
****************************************************************** /\                 \/    |B=  10.66   |
*                |           |          |       FEED             * /\                 \/    |STATE=SATDL |
*                |           |          |------------------------  /\             *********   ------------
*                |DISTILLATE| BOTTOMS   | P/HEAT | COLUMN/HX| TOTAL * /\            * PUMP  *   ------------
*----------------------------------------------------------------* /\             *********  |  PUMP OUT  |
*FLOWS KG/S      | 0.0545    | 0.3187   | 0.3732 |  0.0000  | 0.3732* /\              \/     |T=  37.8    |
*CONCENTRATION   | 0.990     | 0.050    |           0.187          * /\               \/    |P= 1451145.8|
*----------------------------------------------------------------* /\                 \/    |H=  67.88   |
* MINIMUM REFLUX FLOW (KG/S) =   0.0642                          *  <<<<<<<<<<<<<<<<<<<<<<<<  |B=  11.27   |
******************************************************************                           |STATE=SUBCL |
*CARNOT COP=     1.626 BASED ON    5.0,  38.0 & 112.4 DEG C      *                            ------------
*COP=  0.428   COPHEAT= 1.417    PUMP KW AS %=    1.0            *
******************************************************************
```

FIGURE H6

NO	TEMP DEG C	K Y/X	HEAT TF KW	FEED FLOW KG/S	A/BY CH KJ/S	PHASE	MASS CONC	ENTHALPY KJ/KG	ENTROPY KJ/KG K	AVAIL/TY KJ/KG	FUG COEF COMPT 1	FUG COEF COMPT 2	FLOW KG/S
1	38.0	1.01	22.809	0.0000	-0.007	LIQ	0.990	91.56	0.364	72.62	0.825	0.001	0.1329
						VAP	0.997	263.19	0.000	0.00	0.000	0.000	0.0000
2	38.6	1.03	0.000	0.0000	-0.025	LIQ	0.965	91.55	0.370	69.19	0.836	0.194	0.0782
						VAP	0.990	263.22	0.915	72.67	0.823	0.684	0.1329
3	40.0	1.07	0.000	0.0000	-0.043	LIQ	0.913	91.56	0.379	63.07	0.860	0.193	0.0780
						VAP	0.975	263.38	0.919	70.84	0.825	0.694	0.1327
4	42.8	1.17	0.000	0.0000	-0.083	LIQ	0.809	91.68	0.392	52.50	0.919	0.191	0.0771
						VAP	0.945	263.73	0.924	67.57	0.829	0.699	0.1325
5	49.0	1.42	0.000	0.0000	-0.167	LIQ	0.624	92.65	0.406	36.76	1.069	0.197	0.0756
						VAP	0.884	264.89	0.934	62.03	0.839	0.709	0.1316
6	60.1	1.93	0.000	0.0000	-0.234	LIQ	0.403	97.04	0.419	21.53	1.400	0.230	0.0758
						VAP	0.777	267.44	0.944	54.28	0.856	0.726	0.1301
7	72.7	2.51	0.000	0.0000	-0.153	LIQ	0.259	104.78	0.433	13.94	1.827	0.294	0.0783
						VAP	0.649	269.74	0.947	47.19	0.874	0.743	0.1303
8	81.0	2.86	0.000	0.0000	-0.056	LIQ	0.195	110.69	0.444	11.60	2.123	0.346	0.0807
						VAP	0.559	271.13	0.944	43.39	0.885	0.753	0.1328
9	84.8	3.01	0.000	0.3732	-0.161	LIQ	0.171	113.58	0.449	10.95	2.264	0.374	0.4659
						VAP	0.516	271.66	0.941	41.88	0.891	0.757	0.1352
10	91.9	3.27	-3.760	0.0000	0.230	LIQ	0.133	119.11	0.459	10.28	2.527	0.429	0.4568
						VAP	0.434	273.04	0.934	39.55	0.901	0.765	0.1472
11	101.1	3.55	-3.760	0.0000	0.142	LIQ	0.091	126.65	0.473	10.25	2.877	0.510	0.4527
						VAP	0.324	274.68	0.920	37.57	0.916	0.775	0.1381
12	112.4	3.81	-23.165	0.0000	3.948	LIQ	0.050	136.18	0.489	11.29	3.304	0.621	0.3188
						VAP	0.190	276.81	0.894	37.24	0.936	0.787	0.1340

NOTE; A/BY CH is for streams only.

FIGURE H6 CONTD

```
                SECOND LAW ANALYSIS                  KJ/S     PERCENT OF AVAILABILITY LOSS
------------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                    0.000     0.000
    PRECOOLER LIQ OUT TO EXPANSION IN                0.000     0.000
    EVAPORATOR OUT TO PRECOOLER IN                   0.000     0.000
    PRECOOLER VAP OUT TO MIXING IN                   0.000     0.000
    MIXING OUT TO ABSORBER IN                        0.000     0.000
    ABSORBER OUT TO PUMP IN                          0.000     0.000
    PUMP OUT TO FEED SPLIT                           0.000     0.000
    FEED SPLIT TO PREHEATER IN                       0.000     0.000
    PREHEATER OUT TO FEED JOIN                       0.000     0.000
    FEED SPLIT TO RECTIFIER HX IN                    0.000     0.000
    RECTIFIER HX OUT TO FEED JOIN                    0.000     0.000
    BOTTOM OUT OF COLUMN TO HX IN                    0.000     0.000
    BOTTOM HX OUT TO PREHEATER IN                    0.000     0.000
    PREHEATER OUT TO EXPANSION IN                    0.000     0.000
------------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                            -0.096     2.049
    BOTTOMS EXPANSION                               -0.188     4.005
------------------------------------------------------------
PUMP                                                 0.228
------------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                       -0.121     2.567
    PREHEATER                                       -0.238     5.064
------------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                           0.083    -1.772
    EVAP REFRIGERANT STREAMS ONLY   -1.071
    EVAP CARNOT    -1.154                                     24.580

ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY    -1.019    21.690
    CARNOT FROM AVERAGE TEMP      0.000

COLUMN
    CARNOT ONLY                                      4.468
    (STREAMS ONLY =     2.511 )
    COLUMN ONLY=CARNOT-STREAMS                      -1.957    41.666
    (MINIMUM SEPERATION WORK=     3.388)

CONDENSER
    COND CARNOT                                      0.000     0.000
    CONDENSER STREAMS ONLY                          -0.007     0.151
------------------------------------------------------------
                                                     0.000
                                                -----------
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FIGURE H6 CONTD

```
*******************************************************                                        **************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      *  --------------------                  *            *
* R  11     CHLORODIFLUOROMETHANE      ( CHCLF2    )  * I  DATA AND   UNITS  I                 *            *
* R  22     TRICHLOROFLUOROMETHANE     ( CCL3F     )  * IT=TEMPERATURE DEG C I                 *            *
* CONCENTRATION OF DISTILLATE=  0.990                 * IP=PRESSURE KPA      I T=   5.0   <<<  * EVAPORATOR *  <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  4.41                  * IH=ENTHALPY KJ/KG    I                 * TSAT=  5.8 *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* IB=AVAILABILITY KJ/KGI ------------    *            *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG *  -------------------- I  EVAP IN   I   *            *    I  EVAP OUT  I
* FEED SUBCOOLING AT ABSORBER OUT=            0.0 DEG *                       IT=   5.0    I   **************    IT=   5.8    I
* DISTILLATE SUBCOOLING AT CONDENSER OUT=     0.0 DEG *                       IP=  579255.2I    /\        \/     IP=  579255.2I
* APPROACH FLUID OFF EVAP TO EVAP IN    =  0.0 DEG    *                       IH=  64.22   I    /\        \/     IH= 252.99   I
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------    IB=  66.38   I    /\        \/     IB=  50.64   I
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 11     *      IEXPANSION INI   ISTATE=2 PHA I   ***        \/     ISTATE=SATDV I
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      IT=  17.2    I    ------------    *E*        \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=   101.3 KPA*      IP= 1183366.0I                    ***        \/
*******************************************************      IH=  64.22   I                     /\        \/
                                                             IB=  67.17   I    ------------     /\        \/      ------------
                                                             ISTATE=SUBCL I   IP/COOL L OUTI    /\        \/     IP/COOL V IN I
                        ------------                          ------------    IT=  17.2    I   **************    IT=   5.8    I
                       I  COND OUT  I                                         IP= 1183366.0I   *            *    IP=  579255.2I
                       IT=  30.0    I                                         IH=  64.22   I   *            *    IH= 252.99   I
                       IP= 1183366.0I                                         IB=  67.17   I   *  PRECOOLER *    IB=  50.64   I
                       IH=  80.71   I                                         ISTATE=SUBCL I   *            *    ISTATE=SATDV I
                       IB=  65.56   I                                          ------------    *            *     ------------
                       ISTATE=SATDL I                                                          **************
                        ------------                                                            /\        \/
                     >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                    /\      TSAT=   30.0                                                                  \/
                 ******                                                        ------------               \/      ------------
T=  30.0   >>>   *COND*     >>>                                               IP/COOL L IN I              \/     IP/COOL V OUTI
                 ******                                                       IT=  30.0    I              \/     IT=  30.0    I
                 *    *                                                       IP= 1183366.0I              \/     IP=  579255.2I
                 *    *                                                       IH=  80.71   I              \/     IH= 269.47   I
                 *    *                                                       IB=  65.56   I              \/     IB=  47.56   I
                 *    *                                                       ISTATE=SATDL I              \/     ISTATE=SUPHV I
                 *    *                                                        ------------               \/      ------------
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                  ------------                                     \/
  ------------   *    *                                 I FEED       I                                    \/
 I COLUMN FEEDI  *    *   ************                  IT=  58.5    I                                    \/
 IT=  58.5    I  ******   *   FEED   *                  IP= 1183366.0I                                    \/
 IP= 1183366.0I  *FEED*<<<*   BOOST  *<<<<<<<<<<<<<<<<  IH=  90.20   I                                    \/
 IH=  90.20   I  ******   *  HEATER  *                /\IB=   8.76   I                                    \/
 IB=   8.76   I  *    *   ************                /\ISTATE=SUBCL I                                    \/
```

```
                *    *                               /\        |T=  29.9    |                            \/
                *    *                               /\        |P= 1183366.0|     ------------           \/
                *    *                 ------------  /\        |H=  62.06   |    | BOT IN EXP |          \/       ------------
                *    *                |FEED OUT P/H| /\        |B=   9.42   |    |T=  29.9    |          \/      |   MIX IN   |
                *    *                |T=  58.5    | /\        |STATE=SUBCL |    |P= 1183366.0|          \/      |T=  30.0    |
                *    *                |P= 1183366.0| /\         ------------     |H=  57.91   |          \/      |P=  579255.2|
                *    *                |H=  90.20   | /\  *******                 |B=   2.88   |          \/      |H= 269.47   |
                *    *                |B=   8.76   |  <<<*     *<<<<<<<<<<<<<<</\| STATE=SUBCL|          \/      |B=  47.56   |
 ------------   *    *               |STATE=SUBCL  |     *FEED *               /\ ------------       *********   |STATE=SUPHV |
| BOT HX OUT |  *    *                 ------------      *PRE  *               /\      ***           *       *    ------------
|T=  70.4    |  *    *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT * >>>>>>>>>>>>> /\>>>>>>*E*>>>>>>>>>>>*  MIX  *
|P= 1183366.0|  *    *                                   *     *               /\      ***           *       *
|H=  94.31   |  *    *                                   *******               /\                    *********
|B=   2.76   |  *    *                     ------------          ------------  /\          ------------  \/       ------------
|STATE=SUBCL |  *    *                    | BOT IN P/H |        | BOT OUT P/H| /\         |BOT OUT EXP | \/      |  MIX OUT   |
 ------------   *    *                    |T=  70.4    |        |T=  29.9    | /\         |T=  30.1    | \/      |T=  40.1    |
                *    *                    |P= 1183366.0|        |P= 1183366.0| /\         |P=  579255.2| \/      |P=  579255.2|
                *    *                    |H=  94.31   |        |H=  57.91   | /\         |H=  57.91   | \/      |H= 105.93   |
                *    *                    |B=   2.76   |        |B=   2.88   | /\         |B=   2.48   | \/      |B=   8.26   |
 ------------   *    *                    |STATE=SUBCL |        |STATE=SUBCL | /\         |STATE=SUBCL | \/      |STATE=2 PHA |
| BOT HX IN  |  *    *                     ------------          ------------  /\          ------------  \/       ------------
|T= 101.1    |  *    *                                                         /\                        \/
|P= 1183366.0|  *    *                                                         /\                        \/       ------------
|H= 124.41   |  *    *                                                         /\                        \/      | ABSORBER IN|
|B=   5.82   |  *    *                                                         /\                        \/      |T=  40.1    |
|STATE=SATDL |  *    *                                                         /\                        \/      |P=  579255.2|
 ------------   *    *                                                         /\                        \/      |H= 105.93   |
                *    *<<<<<                                                    /\                        \/      |B=   8.26   |
 ------------   *    *    /\                                                   /\                        \/      |STATE=2 PHA |
| BOTTOM OUT |  *    *    /\                                                   /\                        \/       ------------
|T= 101.1    |  ******    /\                                                   /\                  **************
|P= 1183366.0|  *BOIL*    /\                                                   /\                  *            *
|H= 124.41   |  ******    /\                                                   /\   T=  30.0  >>>  * ABSORBER   * >>>
|B=   5.82   |     \/     /\                                                   /\                  *TSAT=   30.0*
|STATE=SATDL |     \/     /\                                                   /\                  ************** ------------
 ------------       >>>>>>                                                     /\                        \/      |ABSORBER OUT|
                                                                               /\                        \/      |T=  30.0    |
                                                                               /\                        \/      |P=  579255.2|
*******************************************************************            /\                        \/      |H=  62.06   |
*COLUMN PLATE NUMBERS: TOTAL= 8:   RECTIFYING= 4:   STRIPPING= 1  *            /\                        \/      |B=   9.00   |
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   5.431KW    *            /\                        \/      |STATE=SATDL |
*FEEDPLATE: TEMP= 65.25 DEG C: LIQUID CONC= 0.232: VAP CONC= 0.645*            /\                        \/       ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    2.81           *            /\                        \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  2.51           *            /\                        \/       ------------
*-----------------------------------------------------------------*            /\                        \/      | PUMP IN    |
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST*            /\                        \/      |T=  30.0    |
*-----------------------------------------------------------------*            /\                        \/      |P=  579255.2|
*  KW  | 10.000     |26.893      |10.240   |27.133  | 0.098| 0.000*            /\                        \/      |H=  62.06   |
*******************************************************************            /\                        \/      |B=   9.00   |
*               |          |          |           FEED            *            /\                        \/      |STATE=SATDL |
*               |          |          |---------------------------             /\                    *********    ------------
*               |DISTILLATE| BOTTOMS  | P/HEAT | COLUMN/HX| TOTAL *            /\                    *  PUMP *    ------------
*-----------------------------------------------------------------*            /\                    *********   |  PUMP OUT  |
*FLOWS KG/S     | 0.0530   | 0.1804   | 0.2334 |  0.0000  | 0.2334*            /\                        \/      |T=  29.9    |
*CONCENTRATION  | 0.990    | 0.050    |           0.263           *            /\                        \/      |P= 1183366.0|
*-----------------------------------------------------------------*            /\                        \/      |H=  62.06   |
* MINIMUM REFLUX FLOW (KG/S) =  0.0381                            *             <<<<<<<<<<<<<<<<<<<<<<<<<        |B=   9.42   |
*******************************************************************                                              |STATE=SUBCL |
*CARNOT COP=    2.114 BASED ON    5.0,  30.0 & 101.1 DEG C        *                                               ------------
*COP=  0.367   COPHEAT= 1.364    PUMP KW AS %=    0.4             *
*******************************************************************
```

FIGURE H7

```
---------------------------------------------------------------------------------------------------------------------------
NO I  TEMP   I  K     IHEAT  TFIFEED FLOWIA/BY CHIPHASEI MASS  IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C   I Y/X    I  KW    I  KG/S    I KJ/S   I     I CONC  I KJ/KG   IKJ/KG KI KJ/KG   ICOMPT 1  ICOMPT 2  I KG/S
---------------------------------------------------------------------------------------------------------------------------
 1 I  30.0   I 1.01   I 26.893I  0.0000  I -0.009I LIQ  I0.990 I   80.71 I 0.327 I  65.56 I  0.847 I  0.001 I 0.1489
   I         I        I       I          I       I VAP  I0.997 I  261.28 I 0.000 I   0.00 I  0.000 I  0.000 I 0.0000
   I         I        I       I          I       I      I      I         I       I        I        I        I
 2 I  30.7   I 1.03   I  0.000I  0.0000  I -0.039I LIQ  I0.962 I   80.75 I 0.334 I  61.85 I  0.859 I  0.187 I 0.0958
   I         I        I       I          I       I VAP  I0.990 I  261.31 I 0.922 I  65.62 I  0.844 I  0.720 I 0.1489
   I         I        I       I          I       I      I      I         I       I        I        I        I
 3 I  32.3   I 1.09   I  0.000I  0.0000  I -0.085I LIQ  I0.892 I   80.87 I 0.346 I  54.10 I  0.894 I  0.184 I 0.0953
   I         I        I       I          I       I VAP  I0.972 I  261.46 I 0.926 I  63.49 I  0.846 I  0.732 I 0.1488
   I         I        I       I          I       I      I      I         I       I        I        I        I
 4 I  36.8   I 1.27   I  0.000I  0.0000  I -0.219I LIQ  I0.728 I   81.44 I 0.364 I  39.07 I  1.004 I  0.183 I 0.0938
   I         I        I       I          I       I VAP  I0.927 I  262.12 I 0.934 I  59.09 I  0.853 I  0.738 I 0.1483
   I         I        I       I          I       I      I      I         I       I        I        I        I
 5 I  47.9   I 1.83   I  0.000I  0.0000  I -0.475I LIQ  I0.449 I   85.17 I 0.382 I  18.83 I  1.355 I  0.207 I 0.0932
   I         I        I       I          I       I VAP  I0.822 I  264.40 I 0.947 I  51.03 I  0.867 I  0.754 I 0.1468
   I         I        I       I          I       I      I      I         I       I        I        I        I
 6 I  65.3   I 2.77   I  0.000I  0.2334  I -0.666I LIQ  I0.232 I   95.91 I 0.404 I   7.59 I  2.033 I  0.296 I 0.3379
   I         I        I       I          I       I VAP  I0.645 I  267.50 I 0.952 I  41.42 I  0.889 I  0.776 I 0.1462
   I         I        I       I          I       I      I      I         I       I        I        I        I
 7 I  82.7   I 3.60   I -5.431I  0.0000  I -0.371I LIQ  I0.123 I  109.20 I 0.429 I   4.86 I  2.790 I  0.430 I 0.3292
   I         I        I       I          I       I VAP  I0.442 I  270.10 I 0.938 I  34.86 I  0.912 I  0.794 I 0.1574
   I         I        I       I          I       I      I      I         I       I        I        I        I
 8 I 101.1   I 4.22   I-27.133I  0.0000  I  4.343I LIQ  I0.050 I  124.41 I 0.457 I   5.82 I  3.630 I  0.617 I 0.1804
   I         I        I       I          I       I VAP  I0.211 I  273.19 I 0.900 I  32.88 I  0.939 I  0.811 I 0.1487
   I         I        I       I          I       I      I      I         I       I        I        I        I
NOTE; A/BY CH   is for streams only.
```

FIGURE H7 CONTD

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                  SECOND LAW ANALYSIS              KJ/S      PERCENT OF AVAILABILITY LOSS
------------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                   0.000     0.000
    PRECOOLER LIQ OUT TO EXPANSION IN               0.000     0.000
    EVAPORATOR OUT TO PRECOOLER IN                  0.000     0.000
    PRECOOLER VAP OUT TO MIXING IN                  0.000     0.000
    MIXING OUT TO ABSORBER IN                       0.000     0.000
    ABSORBER OUT TO PUMP IN                         0.000     0.000
    PUMP OUT TO FEED SPLIT                          0.000     0.000
    FEED SPLIT TO PREHEATER IN                      0.000     0.000
    PREHEATER OUT TO FEED JOIN                      0.000     0.000
    FEED SPLIT TO RECTIFIER HX IN                   0.000     0.000
    RECTIFIER HX OUT TO FEED JOIN                   0.000     0.000
    BOTTOM OUT OF COLUMN TO HX IN                   0.000     0.000
    BOTTOM HX OUT TO PREHEATER IN                   0.000     0.000
    PREHEATER OUT TO EXPANSION IN                   0.000     0.000
------------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                           -0.042     0.799
    BOTTOMS EXPANSION                              -0.073     1.393
------------------------------------------------------------
PUMP                                                0.079
------------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                      -0.078     1.477
    PREHEATER                                      -0.133     2.524
------------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                          0.033    -0.634
    EVAP REFRIGERANT STREAMS ONLY   -0.834
    EVAP CARNOT   -0.867                                      16.501


ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY   -0.867    16.494
    CARNOT FROM AVERAGE TEMP    0.000

COLUMN
    CARNOT ONLY                                     5.156
    (STREAMS ONLY =     1.936 )
    COLUMN ONLY=CARNOT-STREAMS                     -3.220    61.277
    (MINIMUM SEPERATION WORK=    2.478)

CONDENSER
    COND CARNOT                                     0.000     0.000
    CONDENSER STREAMS ONLY                         -0.009     0.169
------------------------------------------------------------
                                                    0.000
                                                ------------
```

FIGURE H7 CONTD

```
*******************************************************                                        ****************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      *  --------------------                  *              *
* R  11     CHLORODIFLUOROMETHANE     ( CHCLF2     )  * |  DATA AND   UNITS  |                 *              *
* R  22     TRICHLOROFLUOROMETHANE    ( CCL3F      )  * |T=TEMPERATURE DEG C |                 *              *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=   5.0   <<<  * EVAPORATOR   * <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE=  6.20                  * |H=ENTHALPY KJ/KG    |                 * TSAT=  5.8    *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* |B=AVAILABILITY KJ/KG| ------------    *              *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG *  -------------------- |  EVAP IN   |   *              *    |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=            0.0 DEG *                       |T=   5.0    |   ****************    |T=   5.8    |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=     0.0 DEG *                       |P=  579255.2|      /\        \/     |P=  579255.2|
* APPROACH FLUID OFF EVAP TO EVAP IN     =  0.0 DEG   *                       |H=  64.22   |      /\        \/     |H= 252.99   |
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------    |B=  66.38   |      /\        \/     |B=  50.64   |
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 11     *      |EXPANSION IN|   |STATE=2 PHA |   ***          \/     |STATE=SATDV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  17.2    |    ------------    *E*          \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=   101.3 KPA*      |P= 1183366.0|                    ***          \/
*******************************************************      |H=  64.22   |                       /\        \/
                                                             |B=  67.17   |    ------------       /\        \/      ------------
                                                             |STATE=SUBCL |   |P/COOL L OUT|      /\        \/     |P/COOL V IN |
                        ------------                          ------------    |T=  17.2    |   ****************    |T=   5.8    |
                       |  COND OUT  |                                         |P= 1183366.0|   *              *    |P=  579255.2|
                       |T=  30.0    |                                         |H=  64.22   |   *              *    |H= 252.99   |
                       |P= 1183366.0|                                         |B=  67.17   |   *  PRECOOLER   *    |B=  50.64   |
                       |H=  80.71   |                                         |STATE=SUBCL |   *              *    |STATE=SATDV |
                       |B=  65.56   |                                          ------------    *              *     ------------
                       |STATE=SATDL |                                                          ****************
                        ------------                                                              /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                     /\      TSAT=   30.0                                                                   \/
                  ******                                                       ------------                 \/      ------------
T=  30.0   >>>    *COND*    >>>                                               |P/COOL L IN |                \/     |P/COOL V OUT|
                  ******                                                      |T=  30.0    |                \/     |T=  30.0    |
                  *    *                                                      |P= 1183366.0|                \/     |P=  579255.2|
                  *    *                                                      |H=  80.71   |                \/     |H= 269.47   |
                  *    *                                                      |B=  65.56   |                \/     |B=  47.56   |
                  *    *                                                      |STATE=SATDL |                \/     |STATE=SUPHV |
                  *    *                                                       ------------                 \/      ------------
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                                                                    \/
                  *    *                                  ------------                                      \/
   ------------   *    *                                 | FEED       |                                     \/
  | COLUMN FEED|  *    *   ************                  |T=  60.2    |                                     \/
  |T=  60.2    |  ******   *   FEED   *                  |P= 1183366.0|                                     \/
  |P= 1183366.0|  *FEED*<<<*   BOOST  *<<<<<<<<<<<<<<<<  |H=  91.87   |                                     \/
  |H=  91.87   |  ******   *  HEATER  *                /\|B=   8.80   |                                     \/
  |B=   8.80   |  *    *   ************                /\|STATE=SUBCL |                                     \/
  |STATE=SUBCL |  *    *                               /\ ------------                                      \/
```

```
                *    *                               /\        ------------                              \/
                *    *                               /\       |FEED IN P/H |                             \/
                *    *                               /\       |T=  29.9    |                             \/
                *    *                               /\       |P= 1183366.0|     ------------            \/
                *    *                 ------------  /\       |H=  62.06   |    | BOT IN EXP |           \/     ------------
                *    *                |FEED OUT P/H| /\       |B=   9.42   |    |T=  29.9    |           \/    |   MIX IN   |
                *    *                |T=  60.2    | /\       |STATE=SUBCL |    |P= 1183366.0|           \/    |T=  30.0    |
                *    *                |P= 1183366.0| /\        ------------     |H=  59.28   |           \/    |P=  579255.2|
                *    *                |H=  91.87   | /\  *******                |B=   4.07   |           \/    |H= 269.47   |
                *    *                |B=   8.80   |  <<<*     *<<<<<<<<<<<<<</\| STATE=SUBCL|           \/    |B=  47.56   |
 ------------   *    *                |STATE=SUBCL |     *FEED *              /\ ------------       *********  |STATE=SUPHV |
| BOT HX OUT |  *    *                 ------------      *PRE  *              /\      ***           *       *   ------------
|T=  68.2    |  *    *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT * >>>>>>>>>>>> /\>>>>>>*E*>>>>>>>>>>>*  MIX  *
|P= 1183366.0|  *    *                                   *     *              /\      ***           *       *
|H=  94.82   |  *    *                                   *******              /\                    *********
|B=    3.82  |  *    *                     ------------         ------------  /\         ------------    \/     ------------
|STATE=SUBCL |  *    *                    | BOT IN P/H |       | BOT OUT P/H| /\        |BOT OUT EXP |   \/    |  MIX OUT   |
 ------------   *    *                    |T=  68.2    |       |T=  29.9    | /\        |T=  30.1    |   \/    |T=  36.9    |
                *    *                    |P= 1183366.0|       |P= 1183366.0| /\        |P=  579255.2|   \/    |P=  579255.2|
                *    *                    |H=  94.82   |       |H=  59.28   | /\        |H=  59.28   |   \/    |H=  93.19   |
                *    *                    |B=    3.82  |       |B=   4.07   | /\        |B=   3.66   |   \/    |B=   8.34   |
 ------------   *    *                    |STATE=SUBCL |       |STATE=SUBCL | /\        |STATE=SUBCL |   \/    |STATE=2 PHA |
| BOT HX IN  |  *    *                     ------------         ------------  /\         ------------    \/     ------------
|T=  82.5    |  *    *                                                        /\                         \/
|P= 1183366.0|  *    *                                                        /\                         \/     ------------
|H= 109.06   |  *    *                                                        /\                         \/    | ABSORBER IN|
|B=    4.86  |  *    *                                                        /\                         \/    |T=  36.9    |
|STATE=SATDL |  *    *                                                        /\                         \/    |P=  579255.2|
 ------------   *    *                                                        /\                         \/    |H=  93.19   |
                *    *<<<<<                                                   /\                         \/    |B=   8.34   |
 ------------   *    *    /\                                                  /\                         \/    |STATE=2 PHA |
| BOTTOM OUT |  *    *    /\                                                  /\                         \/     ------------
|T=  82.5    |  ******    /\                                                  /\                  *************
|P= 1183366.0|  *BOIL*    /\                                                  /\                  *           *
|H= 109.06   |  ******    /\                                                  /\   T=  30.0  >>>  * ABSORBER  *  >>>
|B=    4.86  |     \/     /\                                                  /\                  *TSAT=  30.0*
|STATE=SATDL |     \/     /\                                                  /\                  ************* ------------
 ------------       >>>>>>                                                    /\                         \/    |ABSORBER OUT|
                                                                              /\                         \/    |T=  30.0    |
                                                                              /\                         \/    |P=  579255.2|
*******************************************************************           /\                         \/    |H=  62.06   |
*COLUMN PLATE NUMBERS: TOTAL=11:   RECTIFYING= 7:   STRIPPING= 1  *           /\                         \/    |B=   9.00   |
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   3.923KW    *           /\                         \/    |STATE=SATDL |
*FEEDPLATE: TEMP= 62.96 DEG C: LIQUID CONC= 0.252: VAP CONC= 0.670*           /\                         \/     ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.85           *           /\                         \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.16           *           /\                         \/     ------------
*-----------------------------------------------------------------*           /\                         \/    | PUMP IN    |
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST*           /\                         \/    |T=  30.0    |
*-----------------------------------------------------------------*           /\                         \/    |P=  579255.2|
*  KW  | 10.000     |17.674      |10.224   |17.898  | 0.137| 0.000*           /\                         \/    |H=  62.06   |
*******************************************************************           /\                         \/    |B=   9.00   |
*               |          |          |           FEED            *           /\                         \/    |STATE=SATDL |
*               |          |          |---------------------------            /\                    *********   ------------
*               |DISTILLATE| BOTTOMS  | P/HEAT | COLUMN/HX| TOTAL *           /\                    *  PUMP *   ------------
*-----------------------------------------------------------------*           /\                    *********  |  PUMP OUT  |
*FLOWS KG/S     | 0.0530   | 0.2755   | 0.3285 |  0.0000  | 0.3285*           /\                         \/    |T=  29.9    |
*CONCENTRATION  | 0.990    | 0.124    |           0.263           *           /\                         \/    |P= 1183366.0|
*-----------------------------------------------------------------*           /\                         \/    |H=  62.06   |
* MINIMUM REFLUX FLOW (KG/S) =  0.0386                            *            <<<<<<<<<<<<<<<<<<<<<<<<<       |B=   9.42   |
*******************************************************************                                            |STATE=SUBCL |
*CARNOT COP=    1.643 BASED ON    5.0,  30.0 &  82.5 DEG C        *                                             ------------
*COP=  0.554   COPHEAT= 1.547    PUMP KW AS %=    0.8             *
```

FIGURE H8

```
--------------------------------------------------------------------------------------------------------------------------------------
NO I  TEMP  I  K    IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C  I Y/X   I  KW   I  KG/S   I KJ/S   I     I CONC I KJ/KG  IKJ/KG KI KJ/KG  ICOMPT 1 ICOMPT 2 I KG/S
--------------------------------------------------------------------------------------------------------------------------------------
 1 I  30.0  I 1.01  I 17.674I  0.0000 I -0.006I LIQ I0.990 I  80.71 I 0.327 I  65.56 I  0.847 I  0.001 I 0.0979
   I        I       I       I         I       I VAP I0.997 I 261.28 I 0.000 I   0.00 I  0.000 I  0.000 I 0.0000
   I        I       I       I         I       I     I      I        I       I        I        I        I
 2 I  30.7  I 1.03  I  0.000I  0.0000 I -0.015I LIQ I0.962 I  80.75 I 0.334 I  61.85 I  0.859 I  0.187 I 0.0448
   I        I       I       I         I       I VAP I0.990 I 261.31 I 0.922 I  65.62 I  0.844 I  0.720 I 0.0979
   I        I       I       I         I       I     I      I        I       I        I        I        I
 3 I  31.8  I 1.07  I  0.000I  0.0000 I -0.018I LIQ I0.912 I  80.83 I 0.343 I  56.18 I  0.884 I  0.185 I 0.0448
   I        I       I       I         I       I VAP I0.977 I 261.44 I 0.925 I  64.07 I  0.845 I  0.731 I 0.0978
   I        I       I       I         I       I     I      I        I       I        I        I        I
 4 I  34.1  I 1.16  I  0.000I  0.0000 I -0.025I LIQ I0.825 I  81.04 I 0.355 I  47.61 I  0.934 I  0.183 I 0.0444
   I        I       I       I         I       I VAP I0.954 I 261.52 I 0.930 I  61.65 I  0.849 I  0.734 I 0.0978
   I        I       I       I         I       I     I      I        I       I        I        I        I
 5 I  38.1  I 1.33  I  0.000I  0.0000 I -0.041I LIQ I0.687 I  81.69 I 0.367 I  35.77 I  1.038 I  0.184 I 0.0439
   I        I       I       I         I       I VAP I0.915 I 262.31 I 0.936 I  58.02 I  0.854 I  0.740 I 0.0974
   I        I       I       I         I       I     I      I        I       I        I        I        I
 6 I  44.6  I 1.66  I  0.000I  0.0000 I -0.057I LIQ I0.513 I  83.74 I 0.378 I  23.04 I  1.243 I  0.197 I 0.0435
   I        I       I       I         I       I VAP I0.853 I 263.68 I 0.944 I  53.14 I  0.863 I  0.750 I 0.0968
   I        I       I       I         I       I     I      I        I       I        I        I        I
 7 I  52.7  I 2.10  I  0.000I  0.0000 I -0.046I LIQ I0.369 I  87.74 I 0.388 I  14.14 I  1.533 I  0.227 I 0.0438
   I        I       I       I         I       I VAP I0.775 I 265.26 I 0.951 I  48.06 I  0.874 I  0.761 I 0.0965
   I        I       I       I         I       I     I      I        I       I        I        I        I
 8 I  59.2  I 2.45  I  0.000I  0.0000 I -0.023I LIQ I0.289 I  91.77 I 0.396 I  10.01 I  1.787 I  0.260 I 0.0446
   I        I       I       I         I       I VAP I0.709 I 266.58 I 0.953 I  44.44 I  0.882 I  0.769 I 0.0967
   I        I       I       I         I       I     I      I        I       I        I        I        I
 9 I  63.0  I 2.65  I  0.000I  0.3285 I -0.064I LIQ I0.252 I  94.30 I 0.401 I   8.39 I  1.938 I  0.282 I 0.3776
   I        I       I       I         I       I VAP I0.670 I 266.92 I 0.953 I  42.53 I  0.887 I  0.773 I 0.0976
   I        I       I       I         I       I     I      I        I       I        I        I        I
10 I  69.3  I 2.98  I -3.923I  0.0000 I  0.162I LIQ I0.201 I  98.86 I 0.409 I   6.50 I  2.204 I  0.323 I 0.3636
   I        I       I       I         I       I VAP I0.600 I 268.21 I 0.951 I  39.59 I  0.894 I  0.780 I 0.1021
   I        I       I       I         I       I     I      I        I       I        I        I        I
11 I  82.5  I 3.59  I-17.898I  0.0000 I  2.053I LIQ I0.124 I 109.07 I 0.429 I   4.86 I  2.782 I  0.429 I 0.2755
   I        I       I       I         I       I VAP I0.444 I 270.08 I 0.938 I  34.90 I  0.911 I  0.794 I 0.0881
   I        I       I       I         I       I     I      I        I       I        I        I        I
NOTE; A/BY CH   is for streams only.
```

FIGURE H8 CONTD

```
                SECOND LAW ANALYSIS                    KJ/S      PERCENT OF AVAILABILITY LOSS
------------------------------------------------------------------
PIPEWORK
     CONDENSER OUT TO PRECOOLER IN                     0.000     0.000
     PRECOOLER LIQ OUT TO EXPANSION IN                 0.000     0.000
     EVAPORATOR OUT TO PRECOOLER IN                    0.000     0.000
     PRECOOLER VAP OUT TO MIXING IN                    0.000     0.000
     MIXING OUT TO ABSORBER IN                         0.000     0.000
     ABSORBER OUT TO PUMP IN                           0.000     0.000
     PUMP OUT TO FEED SPLIT                            0.000     0.000
     FEED SPLIT TO PREHEATER IN                        0.000     0.000
     PREHEATER OUT TO FEED JOIN                        0.000     0.000
     FEED SPLIT TO RECTIFIER HX IN                     0.000     0.000
     RECTIFIER HX OUT TO FEED JOIN                     0.000     0.000
     BOTTOM OUT OF COLUMN TO HX IN                     0.000     0.000
     BOTTOM HX OUT TO PREHEATER IN                     0.000     0.000
     PREHEATER OUT TO EXPANSION IN                     0.000     0.000
------------------------------------------------------------------
EXPANSION
     DISTILLATE EXPANSION                             -0.042     1.509
     BOTTOMS EXPANSION                                -0.114     4.080
------------------------------------------------------------------
PUMP                                                   0.140
------------------------------------------------------------------
INTERNAL HEAT EXCHANGERS
     PRECOOLER                                        -0.078     2.788
     PREHEATER                                        -0.132     4.755
------------------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                             0.033    -1.197
     EVAP REFRIGERANT STREAMS ONLY    -0.834
     EVAP CARNOT    -0.867                                      31.156


ABSORBER
     ABSORBER AND MIXING REFRIGERANT STREAMS ONLY     -0.573    20.606
     CARNOT FROM AVERAGE TEMP     0.000

COLUMN
     CARNOT ONLY                                       2.643
     (STREAMS ONLY =     1.639 )
     COLUMN ONLY=CARNOT-STREAMS                       -1.005    36.094
     (MINIMUM SEPERATION WORK=     1.920)

CONDENSER
     COND CARNOT                                       0.000     0.000
     CONDENSER STREAMS ONLY                           -0.006     0.209
------------------------------------------------------------------
                                                       0.000
                                                   ------------
```

FIGURE H8 CONTD

```
1*******************************************************                                        ***************
 * R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      *  --------------------                  *             *
 * R  11     CHLORODIFLUOROMETHANE     ( CHCLF2     )  * I  DATA AND   UNITS  I                 *             *
 * R  22     TRICHLOROFLUOROMETHANE    ( CCL3F      )  * IT=TEMPERATURE DEG C I                 *             *
 * CONCENTRATION OF DISTILLATE=  0.930                 * IP=PRESSURE KPA      I T=   5.0   <<<  * EVAPORATOR  *  <<<   T=  24.0
 * RATIO OF FEED TO DISTILLATE=  4.48                  * IH=ENTHALPY KJ/KG    I                 * TSAT= 10.9  *
 * PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* IB=AVAILABILITY KJ/KGI ------------    *             *     ------------
 * DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG *  -------------------- I  EVAP IN   I   *             *    I  EVAP OUT  I
 * FEED SUBCOOLING AT ABSORBER OUT=            0.0 DEG *                       IT=   5.0    I   ***************    IT=  10.9    I
 * DISTILLATE SUBCOOLING AT CONDENSER OUT=     0.0 DEG *                       IP=  557506.1I     /\        \/     IP=  557506.1I
 * APPROACH FLUID OFF EVAP TO EVAP IN    =  0.0 DEG    *                       IH=  66.01   I     /\        \/     IH= 253.23   I
 *APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------    IB=  58.76   I     /\        \/     IB=  43.58   I
 * ALL CONCENTRATIONS ARE MASS CONCS OF       R 11     *      IEXPANSION INI   ISTATE=2 PHA I    ***        \/     ISTATE=SATDV I
 *ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      IT=  19.7    I    ------------     *E*        \/      ------------
 *AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=   101.3 KPA*      IP= 1140875.0I                     ***        \/
 *******************************************************      IH=  66.01   I                      /\        \/
                                                              IB=  59.44   I    ------------      /\        \/      ------------
                                                              ISTATE=SUBCL I   IP/COOL L OUTI     /\        \/     IP/COOL V IN I
                         ------------                          ------------    IT=  19.7    I   ***************    IT=  10.9    I
                        I  COND OUT  I                                         IP= 1140875.0I   *             *    IP=  557506.1I
                        IT=  30.0    I                                         IH=  66.01   I   *             *    IH= 253.23   I
                        IP= 1140875.0I                                         IB=  59.44   I   *  PRECOOLER  *    IB=  43.58   I
                        IH=  78.98   I                                         ISTATE=SUBCL I   *             *    ISTATE=SATDV I
                        IB=  58.24   I                                          ------------    *             *     ------------
                        ISTATE=SATDL I                                                          ***************
                         ------------                                                             /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                      /\     TSAT=   30.0                                                                   \/
                   ******                                                       ------------                \/      ------------
 T=  30.0   >>>    *COND*    >>>                                               IP/COOL L IN I               \/     IP/COOL V OUTI
                   ******                                                      IT=  30.0    I               \/     IT=  30.0    I
                   *    *                                                      IP= 1140875.0I               \/     IP=  557506.1I
                   *    *                                                      IH=  78.98   I               \/     IH= 266.20   I
                   *    *                                                      IB=  58.24   I               \/     IB=  41.31   I
                   *    *                                                      ISTATE=SATDL I               \/     ISTATE=SUPHV I
                   *    *                                                       ------------                \/      ------------
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                                                                   \/
                   *    *                                 ------------                                      \/
   ------------    *    *                                I FEED       I                                     \/
  I COLUMN FEEDI   *    *   ************                 IT=  52.9    I                                     \/
  IT=  52.9    I   ******   *   FEED   *                 IP= 1140875.0I                                     \/
  IP= 1140875.0I   *FEED*<<<*   BOOST  *<<<<<<<<<<<<<<<  IH=  83.92   I                                     \/
  IH=  83.92   I   ******   *  HEATER  *               /\IB=   7.86   I                                     \/
  IB=   7.86   I   *    *   ************               /\ISTATE=SUBCL I                                     \/
  ISTATE=SUBCL I   *    *                              /\ ------------                                      \/
```

```
                                                                              /\                                                                                  \/
   *     *                                        /\       |FEED IN P/H |                                 \/
   *     *                                        /\       |T=  29.9    |                                 \/
   *     *                                        /\       |P= 1140875.0|      ------------               \/
   *     *                       ------------     /\       |H=  61.69   |     | BOT IN EXP |              \/        ------------
   *     *                      |FEED OUT P/H|    /\       |B=   8.60   |     |T=  29.9    |              \/       |   MIX IN   |
   *     *                      |T=  52.9    |    /\       |STATE=SUBCL |     |P= 1140875.0|              \/       |T=  30.0    |
   *     *                      |P= 1140875.0|    /\        ------------      |H=  57.90   |              \/       |P=  557506.1|
   *     *                      |H=  83.92   |    /\  *******                 |B=   2.86   |              \/       |H= 266.20   |
   *     *                      |B=   7.86   |   <<<*     *<<<<<<<<<<<<<<<<</\| STATE=SUBCL|              \/       |B=  41.31   |
 ------------  *     *          |STATE=SUBCL |       *FEED *                /\  ------------         ********* *       |STATE=SUPHV |
| BOT HX OUT | *     *           ------------        *PRE  *                /\       ***            *         *        ------------
|T=  62.0    | *     *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT * >>>>>>>>>>>> /\>>>>>>*E*>>>>>>>>>>>>* MIX     *
|P= 1140875.0| *     *                               *     *                /\       ***            *         *
|H=  86.51   | *     *                               *******                /\                      *********
|B=   2.37   | *     *                                                      /\                          \/        ------------
|STATE=SUBCL | *     *            ------------         ------------         /\   ------------           \/       | MIX OUT    |
 ------------  *     *           | BOT IN P/H |       | BOT OUT P/H|        /\  |BOT OUT EXP |          \/       |T=  40.3    |
               *     *           |T=  62.0    |       |T=  29.9    |        /\  |T=  30.1    |          \/       |P=  557506.1|
               *     *           |P= 1140875.0|       |P= 1140875.0|        /\  |P=  557506.1|          \/       |H= 104.35   |
               *     *           |H=  86.51   |       |H=  57.90   |        /\  |H=  57.90   |          \/       |B=   7.32   |
               *     *           |B=   2.37   |       |B=   2.86   |        /\  |B=   2.46   |          \/       |STATE=2 PHA |
               *     *           |STATE=SUBCL |-      |STATE=SUBCL |        /\  |STATE=SUBCL |          \/        ------------
 ------------  *     *            ------------         ------------         /\   ------------           \/
| BOT HX IN  | *     *                                                      /\                          \/        ------------
|T=  99.2    | *     *                                                      /\                          \/       | ABSORBER IN|
|P= 1140875.0| *     *                                                      /\                          \/       |~~T=  40.3~~ |
|H= 122.42   | *     *                                                      /\                          \/       |P=  557506.1|
|B=   5.52   | *     *                                                      /\                          \/       |H= 104.35   |
|STATE=SATDL | *     *                                                      /\                          \/       |B=   7.32   |
 ------------  *     *<<<<<                                                 /\                          \/       |STATE=2 PHA |
               *     *    /\                                                /\                          \/        ------------
 ------------  *     *    /\                                                /\                     *************
| BOTTOM OUT | ******     /\                                                /\                     *           *
|T=  99.2    | *BOIL*     /\                                                /\   T=  30.0  >>>       * ABSORBER  *  >>>
|P= 1140875.0| ******     /\                                                /\                     *TSAT=  30.0*
|H= 122.42   |    \/      /\                                                /\                     *************  ------------
|B=   5.52   |    \/      /\                                                /\                          \/       |ABSORBER OUT|
|STATE=SATDL |     >>>>>>                                                   /\                          \/       |T=  30.0    |
 ------------                                                               /\                          \/       |P=  557506.1|
                                                                            /\                          \/       |H=  61.69   |
                                                                            /\                          \/       |B=   8.19   |
                                                                            /\                          \/       |STATE=SATDL |
                                                                            /\                          \/        ------------
                                                                            /\                          \/
                                                                            /\                          \/        ------------
                                                                            /\                          \/       | PUMP IN    |
                                                                            /\                          \/       |T=  30.0    |
                                                                            /\                          \/       |P=  557506.1|
                                                                            /\                          \/       |H=  61.69   |
                                                                            /\                          \/       |B=   8.19   |
                                                                            /\                          \/       |STATE=SATDL |
                                                                            /\                      *********     ------------
                                                                            /\                      * PUMP  *     ------------
                                                                            /\                      *********    | PUMP OUT   |
                                                                            /\                          \/       |T=  29.9    |
                                                                            /\                          \/       |P= 1140875.0|
                                                                            /\                          \/       |H=  61.69   |
                                                                             <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<      |B=   8.60   |
                                                                                                                 |STATE=SUBCL |
                                                                                                                  ------------
```

```
*****************************************************************************
*COLUMN PLATE NUMBERS: TOTAL= 9:   RECTIFYING= 3:   STRIPPING= 3   *
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   6.684KW     *
*FEEDPLATE: TEMP= 60.70 DEG C: LIQUID CONC= 0.256: VAP CONC= 0.679*
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.73            *
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.27            *
*------------------------------------------------------------------*
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST*
*------------------------------------------------------------------*
*  KW  | 10.000     |16.877      |10.217   |17.096  | 0.096| 0.000*
*****************************************************************************
*                |           |          |          FEED               *
*                |           |          |--------------------------   *
*                |DISTILLATE| BOTTOMS   | P/HEAT | COLUMN/HX| TOTAL  *
*------------------------------------------------------------------*
*FLOWS KG/S      | 0.0534   | 0.1861    | 0.2395 |  0.0000  | 0.2395*
*CONCENTRATION   | 0.930    | 0.050     |           0.246            *
*------------------------------------------------------------------*
* MINIMUM REFLUX FLOW (KG/S) =   0.0306                               *
*****************************************************************************
*CARNOT COP=     2.057 BASED ON    5.0,  30.0 &  99.2 DEG C          *
*COP=  0.582   COPHEAT= 1.576    PUMP KW AS %=    0.6                *
*****************************************************************************
```

FIGURE H9

```
-----------------------------------------------------------------------------------------------------------------
NO I  TEMP   I  K     IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS  IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C   I Y/X    I  KW    I  KG/S    I KJ/S   I      I CONC  I KJ/KG   IKJ/KG KI KJ/KG   ICOMPT 1  ICOMPT 2 I KG/S
-----------------------------------------------------------------------------------------------------------------
 1 I  30.0   I 1.06   I 16.877I  0.0000  I -0.036I LIQ  I0.930  I  78.98  I 0.334  I  58.24  I  0.878  I  0.009 I 0.0924
   I         I        I       I          I       I VAP  I0.982  I 261.01  I 0.000  I   0.00  I  0.000  I  0.000 I 0.0000
   I         I        I       I          I       I      I       I         I        I         I         I        I
 2 I  35.1   I 1.27   I  0.000I  0.0000  I -0.109I LIQ  I0.735  I  79.62  I 0.357  I  39.72  I  1.003  I  0.181 I 0.0382
   I         I        I       I          I       I VAP  I0.930  I 261.68  I 0.935  I  58.63  I  0.856  I  0.743 I 0.0924
   I         I        I       I          I       I      I       I         I        I         I         I        I
 3 I  43.8   I 1.70   I  0.000I  0.0000  I -0.101I LIQ  I0.498  I  82.27  I 0.373  I  22.01  I  1.274  I  0.197 I 0.0378
   I         I        I       I          I       I VAP  I0.849  I 263.44  I 0.946  I  52.10  I  0.867  I  0.757 I 0.0916
   I         I        I       I          I       I      I       I         I        I         I         I        I
 4 I  53.8   I 2.27   I  0.000I  0.0000  I -0.062I LIQ  I0.331  I  87.62  I 0.386  I  12.05  I  1.653  I  0.238 I 0.0385
   I         I        I       I          I       I VAP  I0.751  I 265.31  I 0.953  I  45.92  I  0.880  I  0.770 I 0.0912
   I         I        I       I          I       I      I       I         I        I         I         I        I
 5 I  60.7   I 2.65   I  0.000I  0.2395  I -0.150I LIQ  I0.256  I  92.13  I 0.394  I   8.47  I  1.934  I  0.276 I 0.2896
   I         I        I       I          I       I VAP  I0.679  I 266.25  I 0.954  I  42.25  I  0.888  I  0.778 I 0.0919
   I         I        I       I          I       I      I       I         I        I         I         I        I
 6 I  65.4   I 2.90   I -2.228I  0.0000  I  0.107I LIQ  I0.216  I  95.49  I 0.401  I   6.88  I  2.136  I  0.306 I 0.2817
   I         I        I       I          I       I VAP  I0.628  I 267.37  I 0.953  I  39.98  I  0.894  I  0.783 I 0.1035
   I         I        I       I          I       I      I       I         I        I         I         I        I
 7 I  73.1   I 3.29   I -2.228I  0.0000  I  0.021I LIQ  I0.164  I 101.21  I 0.412  I   5.32  I  2.472  I  0.362 I 0.2771
   I         I        I       I          I       I VAP  I0.540  I 268.46  I 0.948  I  36.79  I  0.903  I  0.791 I 0.0956
   I         I        I       I          I       I      I       I         I        I         I         I        I
 8 I  84.8   I 3.81   I -2.228I  0.0000  I -0.128I LIQ  I0.104  I 110.46  I 0.429  I   4.57  I  3.008  I  0.464 I 0.2779
   I         I        I       I          I       I VAP  I0.397  I 270.10  I 0.933  I  33.32  I  0.918  I  0.802 I 0.0910
   I         I        I       I          I       I      I       I         I        I         I         I        I
 9 I  99.2   I 4.30   I-17.096I  0.0000  I  2.713I LIQ  I0.050  I 122.43  I 0.451  I   5.52  I  3.689  I  0.616 I 0.1861
   I         I        I       I          I       I VAP  I0.215  I 272.52  I 0.901  I  32.21  I  0.940  I  0.815 I 0.0917
   I         I        I       I          I       I      I       I         I        I         I         I        I
NOTE; A/BY CH   is for streams only.
```

FIGURE H9 CONTD

```
*******************************************************                                        ***************
* R  12  -R  113 ABSORPTION REFRIGERATION SYSTEM      *  --------------------                  *             *
* R  12     DICHLORODIFLUOROMETHANE   ( CCL2F2     )  * |  DATA AND   UNITS  |                 *             *
* R  113    TRICHLOROTRIFLUOROETHANE  ( CCL2F-CCLF2)  * |T=TEMPERATURE DEG C |                 *             *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=   5.0   <<<  * EVAPORATOR  *  <<<    T=  24.0
* RATIO OF FEED TO DISTILLATE=  4.04                  * |H=ENTHALPY KJ/KG    |                 * TSAT=  6.4  *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* |B=AVAILABILITY KJ/KG| ------------    *             *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     0.0 DEG *  -------------------- |  EVAP IN   |   *             *    |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=            0.0 DEG *                       |T=   5.0    |   ***************    |T=   6.4    |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=     0.0 DEG *                       |P=  360458.5|     /\        \/     |P=  360458.5|
* APPROACH FLUID OFF EVAP TO EVAP IN    =  0.0 DEG    *                       |H=  49.11   |     /\        \/     |H= 190.35   |
*APPROACH CONDENSER AND ABSORBER=  0.0   0.0 DEG      *       ------------    |B=  38.77   |     /\        \/     |B=  26.88   |
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 12     *      |EXPANSION IN|   |STATE=2 PHA |    ***        \/     |STATE=SATDV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  15.2    |    ------------     *E*        \/      ------------
*AVBTY DATUMS: TEMP=  30.0DEG C :PRESSURE=   101.3 KPA*      |P=  739267.7|                     ***        \/
*******************************************************      |H=  49.11   |                      /\        \/
                                                             |B=  39.27   |    ------------      /\        \/      ------------
                                                             |STATE=SUBCL |   |P/COOL L OUT|     /\        \/     |P/COOL V IN |
                        ------------                          ------------    |T=  15.2    |   ***************    |T=   6.4    |
                       |  COND OUT  |                                         |P=  739267.7|   *             *    |P=  360458.5|
                       |T=  30.0    |                                         |H=  49.11   |   *             *    |H= 190.35   |
                       |P=  739267.7|                                         |B=  39.27   |   *  PRECOOLER  *    |B=  26.88   |
                       |H=  63.66   |                                         |STATE=SUBCL |   *             *    |STATE=SATDV |
                       |B=  37.86   |                                          ------------    *             *     ------------
                       |STATE=SATDL |                                                          ***************
                        ------------                                                             /\        \/
                     >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>           \/
                    /\     TSAT=   30.0                                                                    \/
                 ******                                                        ------------                \/      ------------
T=  30.0   >>>   *COND*   >>>                                                 |P/COOL L IN |               \/     |P/COOL V OUT|
                 ******                                                       |T=  30.0    |               \/     |T=  30.0    |
                 *    *                                                       |P=  739267.7|               \/     |P=  360458.5|
                 *    *                                                       |H=  63.66   |               \/     |H= 204.90   |
                 *    *                                                       |B=  37.86   |               \/     |B=  24.62   |
                 *    *                                                       |STATE=SATDL |               \/     |STATE=SUPHV |
                 *    *                                                        ------------                \/      ------------
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                                                                    \/
                 *    *                                   ------------                                     \/
  ------------   *    *                                  | FEED       |                                    \/
 | COLUMN FEED|  *    *   ************                   |T=  53.3    |                                    \/
 |T=  53.3    |  ******   *   FEED   *                   |P=  739267.7|                                    \/
 |P=  739267.7|  *FEED*<<<*   BOOST  *<<<<<<<<<<<<<<<<   |H=  78.73   |                                    \/
 |H=  78.73   |  ******   *  HEATER  *                 /\|B=   2.23   |                                    \/
```

```
                *    *                               /\       |FEED IN P/H |                             \/
                *    *                               /\       |T=  29.9    |                             \/
                *    *                               /\       |P=  739267.7|      ------------           \/
                *    *                 ------------  /\       |H=  57.51   |     | BOT IN EXP |          \/      ------------
                *    *                |FEED OUT P/H| /\       |B=   2.61   |     |T=  29.9    |          \/     |   MIX IN   |
                *    *                |T=  53.3    | /\       |STATE=SUBCL |     |P=  739267.7|          \/     |T=  30.0    |
                *    *                |P=  739267.7| /\        ------------      |H=  56.23   |          \/     |P=  360458.5|
                *    *                |H=  78.73   | /\  *******                 |B=  -0.99   |          \/     |H= 204.90   |
                *    *                |B=   2.23   |  <<<*     *<<<<<<<<<<<<<<</\| STATE=SUBCL|          \/     |B=  24.62   |
 ------------   *    *               |STATE=SUBCL  |     *FEED *               /\ ------------       *********  |STATE=SUPHV |
| BOT HX OUT |  *    *                 ------------      *PRE  *               /\      ***           *       *   ------------
|T=  61.8    |  *    *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT * >>>>>>>>>>>>  /\>>>>>>*E*>>>>>>>>>>>*  MIX  *
|P=  739267.7|  *    *                                   *     *               /\      ***           *       *
|H=  84.43   |  *    *                                   *******               /\                    *********
|B=  -0.98   |  *    *                     ------------          ------------  /\         ------------   \/      ------------
|STATE=SUBCL |  *    *                    | BOT IN P/H |        | BOT OUT P/H| /\        |BOT OUT EXP |  \/     |  MIX OUT   |
 ------------   *    *                    |T=  61.8    |        |T=  29.9    | /\        |T=  30.1    |  \/     |T=  41.4    |
                *    *                    |P=  739267.7|        |P=  739267.7| /\        |P=  360458.5|  \/     |P=  360458.5|
                *    *                    |H=  84.43   |        |H=  56.23   | /\        |H=  56.23   |  \/     |H=  93.05   |
                *    *                    |B=  -0.98   |        |B=  -0.99   | /\        |B=  -1.23   |  \/     |B=   2.08   |
 ------------   *    *                    |STATE=SUBCL |        |STATE=SUBCL | /\        |STATE=SUBCL |  \/     |STATE=2 PHA |
| BOT HX IN  |  *    *                     ------------          ------------  /\         ------------   \/      ------------
|T= 105.9    |  *    *                                                         /\                        \/
|P=  739267.7|  *    *                                                         /\                        \/      ------------
|H= 126.64   |  *    *                                                         /\                        \/     | ABSORBER IN|
|B=   3.67   |  *    *                                                         /\                        \/     |T=  41.4    |
|STATE=SATDL |  *    *                                                         /\                        \/     |P=  360458.5|
 ------------   *    *                                                         /\                        \/     |H=  93.05   |
                *    *<<<<<                                                    /\                        \/     |B=   2.08   |
 ------------   *    *    /\                                                   /\                        \/     |STATE=2 PHA |
| BOTTOM OUT |  *    *    /\                                                   /\                        \/      ------------
|T= 105.9    |  ******    /\                                                   /\                  *************
|P=  739267.7|  *BOIL*    /\                                                   /\                  *           *
|H= 126.64   |  ******    /\                                                   /\   T=  30.0  >>>  * ABSORBER  *  >>>
|B=   3.67   |    \/      /\                                                   /\                  *TSAT=  30.0*
|STATE=SATDL |    \/      /\                                                   /\                  ************* ------------
 ------------       >>>>>>                                                     /\                        \/     |ABSORBER OUT|
                                                                               /\                        \/     |T=  30.0    |
                                                                               /\                        \/     |P=  360458.5|
*******************************************************************            /\                        \/     |H=  57.51   |
*COLUMN PLATE NUMBERS: TOTAL=11;   RECTIFYING= 5;   STRIPPING= 3  *            /\                        \/     |B=   2.36   |
*RECTIFYING HX TOTAL=   0.000KW; STRIPPING HX TOTAL=   9.076KW    *            /\                        \/     |STATE=SATDL |
*FEEDPLATE; TEMP= 60.91 DEG C; LIQUID CONC= 0.289; VAP CONC= 0.765*            /\                        \/      ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.65           *            /\                        \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.19           *            /\                        \/      ------------
*-----------------------------------------------------------------*            /\                        \/     | PUMP IN    |
*      | EVAPORATOR | CONDENSER  |ABSORBER | BOILER | PUMP | BOOST*            /\                        \/     |T=  30.0    |
*-----------------------------------------------------------------*            /\                        \/     |P=  360458.5|
*  KW  | 10.000     |15.980      |10.159   |16.176  | 0.069| 0.000*            /\                        \/     |H=  57.51   |
*******************************************************************            /\                        \/     |B=   2.36   |
*               |          |          |           FEED            *            /\                        \/     |STATE=SATDL |
*               |          |          |---------------------------             /\                    *********   ------------
*               |DISTILLATE| BOTTOMS  | P/HEAT | COLUMN/HX| TOTAL *            /\                    *  PUMP *   ------------
*-----------------------------------------------------------------*            /\                    *********  |  PUMP OUT  |
*FLOWS KG/S     | 0.0708   | 0.2150   | 0.2858 |  0.0000  | 0.2858*            /\                        \/     |T=  29.9    |
*CONCENTRATION  | 0.990    | 0.050    |           0.283           *            /\                        \/     |P=  739267.7|
*-----------------------------------------------------------------*            /\                        \/     |H=  57.51   |
* MINIMUM REFLUX FLOW (KG/S) =  0.0383                            *             <<<<<<<<<<<<<<<<<<<<<<<<<       |B=   2.61   |
*******************************************************************                                             |STATE=SUBCL |
*CARNOT COP=   2.227 BASED ON    5.0,  30.0 & 105.9 DEG C         *                                              ------------
*COP=  0.616   COPHEAT= 1.609    PUMP KW AS %=    0.4             *
                                  *********************************
```

FIGURE H10

```
--------------------------------------------------------------------------------------------------------------------------------------
NO I   TEMP   I  K      IHEAT TFIFEED FLOWIA/BY CHIPHASEI  MASS  IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI  FLOW
   I  DEG C   I Y/X     I  KW    I   KG/S   I KJ/S   I        I  CONC I  KJ/KG  IKJ/KG KI  KJ/KG  ICOMPT 1 ICOMPT 2 I  KG/S
--------------------------------------------------------------------------------------------------------------------------------------
 1 I   30.0   I 1.01    I 15.980I   0.0000 I -0.006I  LIQ   I0.990  I   63.66 I  0.257  I   37.86 I  0.872  I  0.001  I 0.1165
   I          I         I       I          I       I  VAP   I0.998  I  200.28 I  0.000  I    0.00 I  0.000  I  0.000  I 0.0000
   I          I         I       I          I       I        I       I         I         I         I         I         I
 2 I   31.1   I 1.05    I  0.000I   0.0000 I -0.018I  LIQ   I0.945  I   64.31 I  0.266  I   34.05 I  0.896  I  0.135  I 0.0449
   I          I         I       I          I       I  VAP   I0.990  I  200.83 I  0.709  I   37.91 I  0.869  I  0.748  I 0.1165
   I          I         I       I          I       I        I       I         I         I         I         I         I
 3 I   33.6   I 1.14    I  0.000I   0.0000 I -0.024I  LIQ   I0.851  I   65.76 I  0.282  I   27.59 I  0.953  I  0.134  I 0.0430
   I          I         I       I          I       I  VAP   I0.973  I  202.08 I  0.716  I   36.59 I  0.872  I  0.761  I 0.1157
   I          I         I       I          I       I        I       I         I         I         I         I         I
 4 I   38.7   I 1.38    I  0.000I   0.0000 I -0.042I  LIQ   I0.681  I   68.96 I  0.303  I   18.09 I  1.096  I  0.137  I 0.0404
   I          I         I       I          I       I  VAP   I0.937  I  204.86 I  0.728  I   34.40 I  0.878  I  0.769  I 0.1138
   I          I         I       I          I       I        I       I         I         I         I         I         I
 5 I   47.1   I 1.83    I  0.000I   0.0000 I -0.049I  LIQ   I0.479  I   74.88 I  0.326  I    9.04 I  1.385  I  0.156  I 0.0384
   I          I         I       I          I       I  VAP   I0.878  I  209.35 I  0.745  I   31.49 I  0.887  I  0.781  I 0.1112
   I          I         I       I          I       I        I       I         I         I         I         I         I
 6 I   55.7   I 2.33    I  0.000I   0.0000 I -0.028I  LIQ   I0.347  I   81.59 I  0.344  I    4.36 I  1.722  I  0.190  I 0.0382
   I          I         I       I          I       I  VAP   I0.810  I  213.90 I  0.761  I   28.99 I  0.895  I  0.792  I 0.1092
   I          I         I       I          I       I        I       I         I         I         I         I         I
 7 I   60.9   I 2.64    I  0.000I   0.2858 I -0.122I  LIQ   I0.289  I   85.89 I  0.355  I    2.65 I  1.942  I  0.215  I 0.3376
   I          I         I       I          I       I  VAP   I0.765  I  216.58 I  0.769  I   27.65 I  0.900  I  0.798  I 0.1090
   I          I         I       I          I       I        I       I         I         I         I         I         I
 8 I   66.8   I 2.98    I -3.025I   0.0000 I  0.157I  LIQ   I0.238  I   90.86 I  0.368  I    1.51 I  2.198  I  0.249  I 0.3228
   I          I         I       I          I       I  VAP   I0.709  I  220.11 I  0.777  I   26.33 I  0.906  I  0.804  I 0.1226
   I          I         I       I          I       I        I       I         I         I         I         I         I
 9 I   76.0   I 3.50    I -3.025I   0.0000 I  0.108I  LIQ   I0.175  I   98.95 I  0.387  I    0.80 I  2.624  I  0.313  I 0.3129
   I          I         I       I          I       I  VAP   I0.613  I  225.35 I  0.788  I   24.71 I  0.915  I  0.812  I 0.1078
   I          I         I       I          I       I        I       I         I         I         I         I         I
10 I   89.7   I 4.18    I -3.025I   0.0000 I  0.048I  LIQ   I0.108  I  111.41 I  0.416  I    1.34 I  3.292  I  0.431  I 0.3112
   I          I         I       I          I       I  VAP   I0.450  I  233.89 I  0.798  I   23.68 I  0.929  I  0.824  I 0.0979
   I          I         I       I          I       I        I       I         I         I         I         I         I
11 I  106.0   I 4.79    I-16.176I   0.0000 I  2.814I  LIQ   I0.050  I  126.78 I  0.450  I    3.70 I  4.125  I  0.610  I 0.2151
   I          I         I       I          I       I  VAP   I0.237  I  245.25 I  0.799  I   25.35 I  0.948  I  0.836  I 0.0961
   I          I         I       I          I       I        I       I         I         I         I         I         I
NOTE; A/BY CH   is for streams only.
```

FIGURE 10 CONTD

```
                  SECOND LAW ANALYSIS              KJ/S      PERCENT OF AVAILABILITY LOSS
------------------------------------------------------------
PIPEWORK
    CONDENSER OUT TO PRECOOLER IN                  0.000     0.000
    PRECOOLER LIQ OUT TO EXPANSION IN              0.000     0.000
    EVAPORATOR OUT TO PRECOOLER IN                 0.000     0.000
    PRECOOLER VAP OUT TO MIXING IN                 0.000     0.000
    MIXING OUT TO ABSORBER IN                      0.000     0.000
    ABSORBER OUT TO PUMP IN                        0.000     0.000
    PUMP OUT TO FEED SPLIT                         0.000     0.000
    FEED SPLIT TO PREHEATER IN                     0.000     0.000
    PREHEATER OUT TO FEED JOIN                     0.000     0.000
    FEED SPLIT TO RECTIFIER HX IN                  0.000     0.000
    RECTIFIER HX OUT TO FEED JOIN                  0.000     0.000
    BOTTOM OUT OF COLUMN TO HX IN                  0.000     0.000
    BOTTOM HX OUT TO PREHEATER IN                  0.000     0.000
    PREHEATER OUT TO EXPANSION IN                  0.000     0.000
------------------------------------------------------------
EXPANSION
    DISTILLATE EXPANSION                          -0.035     1.061
    BOTTOMS EXPANSION                             -0.052     1.557
------------------------------------------------------------
PUMP                                               0.071
------------------------------------------------------------
INTERNAL HEAT EXCHANGERS
    PRECOOLER                                     -0.060     1.824
    PREHEATER                                     -0.110     3.336
------------------------------------------------------------
EXTERNAL HEAT EXCHANGERS
EVAPORATOR                                         0.001    -0.034
    EVAP REFRIGERANT STREAMS ONLY   -0.842
    EVAP CARNOT    -0.843                                   25.487


ABSORBER
    ABSORBER AND MIXING REFRIGERANT STREAMS ONLY  -0.803    24.267
    CARNOT FROM AVERAGE TEMP    0.000

COLUMN
    CARNOT ONLY                                    3.237
    (STREAMS ONLY =     1.838 )
    COLUMN ONLY=CARNOT-STREAMS                    -1.400    42.316
    (MINIMUM SEPERATION WORK=     2.832)

CONDENSER
    COND CARNOT                                    0.000     0.000
    CONDENSER STREAMS ONLY                        -0.006     0.185
------------------------------------------------------------
                                                   0.000
                                            ------------
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FIGURE H10 CONTD

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*******************************************************                                        ****************
* R  11  -R  22  ABSORPTION REFRIGERATION SYSTEM      *  ---------------------                 *              *
* R  11     CHLORODIFLUOROMETHANE     ( CHCLF2     )  * |  DATA AND   UNITS  |                 *              *
* R  22     TRICHLOROFLUOROMETHANE    ( CCL3F      )  * |T=TEMPERATURE DEG C |                 *              *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=  15.0   <<<  * EVAPORATOR   * <<<   T=  24.0
* RATIO OF FEED TO DISTILLATE= 10.69                  * |H=ENTHALPY KJ/KG    |                 * TSAT=  7.7   *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* |B=AVAILABILITY KJ/KG|  ------------   *              *     ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=     1.0 DEG *  --------------------- |  EVAP IN   |  *              *    |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=            5.0 DEG *                        |T=   7.0    |  ****************    |T=   8.7    |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=     1.0 DEG *                        |P=  614929.6|    /\        \/      |P=  614929.6|
* APPROACH FLUID OFF EVAP TO EVAP IN    =  8.0 DEG    *                        |H=  82.15   |    /\        \/      |H= 254.40   |
*APPROACH CONDENSER AND ABSORBER= 10.0   5.0 DEG      *       ------------     |B=  70.94   |    /\        \/      |B=  54.56   |
* ALL CONCENTRATIONS ARE MASS CONCS OF     R 11       *      |EXPANSION IN|    |STATE=2 PHA |   ***        \/      |STATE=SUPHV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  31.3    |     ------------    *E*        \/       ------------
*AVBTY DATUMS: TEMP=  38.0DEG C :PRESSURE=   101.3 KPA*      |P= 1889815.0|                     ***        \/
*******************************************************      |H=  82.15   |                      /\        \/
                                                             |B=  73.72   |     ------------     /\        \/       ------------
                                                             |STATE=SUBCL |    |P/COOL L OUT|    /\        \/      |P/COOL V IN |
                        ------------                          ------------     |T=  31.3    |  ****************    |T=   8.7    |
                       |  COND OUT  |                                          |P= 1889815.0|  *              *    |P=  614929.6|
                       |T=  48.0    |                                          |H=  82.15   |  *              *    |H= 254.40   |
                       |P= 1889815.0|                                          |B=  73.72   |  *  PRECOOLER   *    |B=  54.56   |
                       |H= 105.85   |                                          |STATE=SUBCL |  *              *    |STATE=SUPHV |
                       |B=  72.26   |                                           ------------   *              *     ------------
                       |STATE=SUBCL |                                                          ****************
                        ------------                                                             /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                     /\      TSAT=   49.0                                                                  \/
                  ******                                                        ------------               \/       ------------
T=  38.0   >>>    *COND*    >>>                                                |P/COOL L IN |              \/      |P/COOL V OUT|
                  ******                                                       |T=  48.0    |              \/      |T=  43.0    |
                  *    *                                                       |P= 1889815.0|              \/      |P=  614929.6|
                  *    *                                                       |H= 105.85   |              \/      |H= 278.10   |
                  *    *                                                       |B=  72.26   |              \/      |B=  50.16   |
                  *    *                                                       |STATE=SUBCL |              \/      |STATE=SUPHV |
                  *    *                                                        ------------               \/       ------------
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                                                                   \/
                  *    *                                  ------------                                     \/
   ------------   *    *                                 | FEED       |                                    \/
  | COLUMN FEED|  *    *   ************                  |T=  96.7    |                                    \/
  |T=  96.7    |  ******   *  FEED    *                  |P= 1889815.0|                                    \/
  |P= 1889815.0|  *FEED*<<<*  BOOST   *<<<<<<<<<<<<<<<<  |H= 124.46   |                                    \/
```

```
                 *    *                                /\       |FEED IN P/H |                             \/
                 *    *                                /\       |T=  42.7    |                             \/
                 *    *                                /\       |P= 1889815.0|      -------------          \/
                 *    *                 ------------   /\       |H=  71.34   |     | BOT IN EXP |          \/      ------------
                 *    *                |FEED OUT P/H|  /\       |B=   9.50   |     |T=  47.7    |          \/     |   MIX IN   |
                 *    *                |T=  96.7    |  /\       |STATE=SUBCL |     |P= 1889815.0|          \/     |T=   43.0   |
                 *    *                |P= 1889815.0|  /\        ------------      |H=  73.75   |          \/     |P=  614929.6|
                 *    *                |H= 124.46   |  /\ *******                  |B=   7.66   |          \/     |H= 278.10   |
                 *    *                |B=  11.20   |  <<<*     *<<<<<<<<<<<<<<<</\| STATE=SUBCL|          \/     |B=  50.16   |
 ------------    *    *               |STATE=SUBCL |      *FEED *                /\ -------------      *********  |STATE=SUPHV |
| BOT HX OUT |   *    *                 ------------      *PRE  *                /\      ***           *       *   ------------
|T= 109.0    |   *    *>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>*HEAT *  >>>>>>>>>>>>  /\>>>>>>*E*>>>>>>>>>>>*  MIX  *
|P= 1889815.0|   *    *                                   *     *                /\      ***           *       *
|H= 132.35   |   *    *                                   *******                /\                    *********
|B=  10.98   |   *    *                     ------------          ------------   /\         ------------   \/      ------------
|STATE=SUBCL |   *    *                    | BOT IN P/H |        | BOT OUT P/H|  /\        |BOT OUT EXP |  \/     |  MIX OUT   |
 ------------    *    *                    |T= 109.0    |        |T=  47.7    |  /\        |T=  48.1    |  \/     |T=  53.3    |
                 *    *                    |P= 1889815.0|        |P= 1889815.0|  /\        |P=  614929.6|  \/     |P=  614929.6|
                 *    *                    |H= 132.35   |        |H=  73.75   |  /\        |H=  73.75   |  \/     |H=  92.86   |
                 *    *                    |B=  10.98   |        |B=   7.66   |  /\        |B=   6.81   |  \/     |B=   8.26   |
 ------------    *    *                    |STATE=SUBCL |        |STATE=SUBCL |  /\        |STATE=SUBCL |  \/     |STATE=2 PHA |
| BOT HX IN  |   *    *                     ------------          ------------   /\         ------------   \/      ------------
|T= 127.9    |   *    *                                                          /\                        \/
|P= 1889815.0|   *    *                                                          /\                        \/      ------------
|H= 153.11   |   *    *                                                          /\                        \/     | ABSORBER IN|
|B=  14.31   |   *    *                                                          /\                        \/     |T=  53.3    |
|STATE=SATDL |   *    *                                                          /\                        \/     |P=  614929.6|
 ------------    *    *                                                          /\                        \/     |H=  92.86   |
                 *    *<<<<<                                                     /\                        \/     |B=   8.26   |
 ------------    *    *    /\                                                    /\                        \/     |STATE=2 PHA |
| BOTTOM OUT |   *    *    /\                                                    /\                        \/      ------------
|T= 127.9    |  ******     /\                                                    /\                  *************
|P= 1889815.0|  *BOIL*     /\                                                    /\                  *           *
|H= 153.11   |  ******     /\                                                    /\  T=  38.0   >>>  * ABSORBER  *  >>>
|B=  14.31   |      \/     /\                                                    /\                  *TSAT=  48.0*
|STATE=SATDL |      \/     /\                                                    /\                  ************* ------------
 ------------       >>>>>>                                                       /\                        \/     |ABSORBER OUT|
                                                                                 /\                        \/     |T=  43.0    |
                                                                                 /\                        \/     |P=  614929.6|
********************************************************************             /\                        \/     |H=  71.34   |
*COLUMN PLATE NUMBERS: TOTAL=13:   RECTIFYING= 7:    STRIPPING= 3  *             /\                        \/     |B=   8.63   |
*RECTIFYING HX TOTAL=   0.000KW: STRIPPING HX TOTAL=   11.678KW    *             /\                        \/     |STATE=SUBCL |
*FEEDPLATE: TEMP=103.95 DEG C: LIQUID CONC= 0.150: VAP CONC= 0.428*              /\                        \/      ------------
*ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    3.19            *             /\                        \/
*ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.48            *             /\                        \/      ------------
*------------------------------------------------------------------*             /\                        \/     | PUMP IN    |
*      | EVAPORATOR | CONDENSER   |ABSORBER | BOILER | PUMP | BOOST*             /\                        \/     |T=  43.0    |
*------------------------------------------------------------------*             /\                        \/     |P=  614929.6|
*  KW  | 10.000     |29.481       |13.360   |32.801  | 0.541| 0.000*             /\                        \/     |H=  71.34   |
********************************************************************             /\                        \/     |B=   8.63   |
*               |          |           |          FEED             *             /\                        \/     |STATE=SUBCL |
*               |          |           |---------------------------              /\                   *********    ------------
*               |DISTILLATE| BOTTOMS   | P/HEAT | COLUMN/HX| TOTAL *             /\                   *  PUMP *    ------------
*------------------------------------------------------------------*             /\                   *********   |  PUMP OUT  |
*FLOWS KG/S     | 0.0581   | 0.5626    | 0.6206 |  0.0000  | 0.6206*             /\                        \/     |T=  42.7    |
*CONCENTRATION  | 0.990    | 0.050     |           0.138           *             /\                        \/     |P= 1889815.0|
*------------------------------------------------------------------*             /\                        \/     |H=  71.34   |
* MINIMUM REFLUX FLOW (KG/S) =  0.0859                             *              <<<<<<<<<<<<<<<<<<<<<<<<<        |B=   9.50   |
********************************************************************                                              |STATE=SUBCL |
*CARNOT COP=    2.807 BASED ON   15.0.  38.0 & 127.9 DEG C         *                                               ------------
*COP=  0.300   COPHEAT= 1.285    PUMP KW AS %=     1.6             *
********************************************************************
```

FIGURE H11

```
--------------------------------------------------------------------------------------------------------------------------------------------------
NO I  TEMP   I  K    IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C   I Y/X   I  KW   I  KG/S   I KJ/S  I      I CONC I KJ/KG  IKJ/KG KI KJ/KG  ICOMPT 1 ICOMPT 2 I KG/S
--------------------------------------------------------------------------------------------------------------------------------------------------
 1 I  49.0   I 1.01  I 29.481I  0.0000 I -0.997I LIQ  I0.990 I 105.85 I 0.411 I  72.26 I  0.780 I  0.200 I 0.1853
   I         I       I       I         I       I VAP  I0.997 I 264.94 I 0.000 I   0.00 I  0.000 I  0.000 I 0.0000
   I         I       I       I         I       I      I      I        I       I        I        I        I
 2 I  49.6   I 1.02  I  0.000I  0.0000 I -0.046I LIQ  I0.969 I 107.33 I 0.421 I  69.37 I  0.802 I  0.205 I 0.1282
   I         I       I       I         I       I VAP  I0.990 I 264.98 I 0.905 I  77.64 I  0.792 I  0.632 I 0.1853
   I         I       I       I         I       I      I      I        I       I        I        I        I
 3 I  50.8   I 1.05  I  0.000I  0.0000 I -0.064I LIQ  I0.925 I 107.23 I 0.429 I  64.10 I  0.822 I  0.204 I 0.1277
   I         I       I       I         I       I VAP  I0.976 I 265.11 I 0.908 I  75.87 I  0.794 I  0.641 I 0.1863
   I         I       I       I         I       I      I      I        I       I        I        I        I
 4 I  53.6   I 1.13  I  0.000I  0.0000 I -0.133I LIQ  I0.834 I 107.11 I 0.440 I  54.72 I  0.868 I  0.203 I 0.1265
   I         I       I       I         I       I VAP  I0.945 I 265.49 I 0.914 I  72.61 I  0.799 I  0.646 I 0.1858
   I         I       I       I         I       I      I      I        I       I        I        I        I
 5 I  59.7   I 1.33  I  0.000I  0.0000 I -0.277I LIQ  I0.663 I 107.53 I 0.452 I  39.91 I  0.988 I  0.208 I 0.1234
   I         I       I       I         I       I VAP  I0.883 I 266.41 I 0.923 I  66.95 I  0.811 I  0.657 I 0.1846
   I         I       I       I         I       I      I      I        I       I        I        I        I
 6 I  71.5   I 1.77  I  0.000I  0.0000 I -0.453I LIQ  I0.433 I 111.36 I 0.464 I  23.97 I  1.272 I  0.240 I 0.1226
   I         I       I       I         I       I VAP  I0.767 I 269.45 I 0.935 I  58.62 I  0.831 I  0.677 I 0.1815
   I         I       I       I         I       I      I      I        I       I        I        I        I
 7 I  86.8   I 2.33  I  0.000I  0.0000 I -0.388I LIQ  I0.263 I 120.38 I 0.480 I  15.37 I  1.694 I  0.313 I 0.1273
   I         I       I       I         I       I VAP  I0.612 I 272.79 I 0.939 I  50.39 I  0.857 I  0.700 I 0.1806
   I         I       I       I         I       I      I      I        I       I        I        I        I
 8 I  98.2   I 2.69  I  0.000I  0.0000 I -0.153I LIQ  I0.182 I 128.65 I 0.494 I  13.00 I  2.024 I  0.383 I 0.1330
   I         I       I       I         I       I VAP  I0.491 I 274.89 I 0.933 I  45.80 I  0.876 I  0.715 I 0.1853
   I         I       I       I         I       I      I      I        I       I        I        I        I
 9 I 103.9   I 2.84  I  0.000I  0.6206 I -0.320I LIQ  I0.150 I 133.11 I 0.502 I  12.55 I  2.192 I  0.423 I 0.7941
   I         I       I       I         I       I VAP  I0.428 I 276.06 I 0.928 I  44.04 I  0.886 I  0.722 I 0.1910
   I         I       I       I         I       I      I      I        I       I        I        I        I
10 I 107.0   I 2.92  I  0.000I  0.0000 I -0.155I LIQ  I0.135 I 135.51 I 0.506 I  12.47 I  2.280 I  0.445 I 0.8057
   I         I       I       I         I       I VAP  I0.395 I 276.81 I 0.925 I  43.28 I  0.892 I  0.726 I 0.2315
   I         I       I       I         I       I      I      I        I       I        I        I        I
11 I 112.6   I 3.04  I -5.839I  0.0000 I  0.768I LIQ  I0.109 I 140.08 I 0.513 I  12.57 I  2.444 I  0.489 I 0.7878
   I         I       I       I         I       I VAP  I0.332 I 277.93 I 0.917 I  42.18 I  0.903 I  0.733 I 0.2431
   I         I       I       I         I       I      I      I        I       I        I        I        I
12 I 119.3   I 3.16  I -5.839I  0.0000 I  0.718I LIQ  I0.081 I 145.75 I 0.523 I  13.08 I  2.639 I  0.545 I 0.7747
   I         I       I       I         I       I VAP  I0.258 I 279.30 I 0.905 I  41.48 I  0.917 I  0.741 I 0.2252
   I         I       I       I         I       I      I      I        I       I        I        I        I
13 I 127.8   I 3.28  I-32.801I  0.0000 I  6.768I LIQ  I0.050 I 153.05 I 0.534 I  14.30 I  2.880 I  0.621 I 0.5625
   I         I       I       I         I       I VAP  I0.165 I 281.07 I 0.887 I  41.76 I  0.936 I  0.752 I 0.2121
   I         I       I       I         I       I      I      I        I       I        I        I
NOTE: A/BY CH   is for streams only.
```

FIGURE H11 CONTD

```
*******************************************************                                        ***************
* R  12  -R  113 ABSORPTION REFRIGERATION SYSTEM      *  --------------------                  *             *
* R  12     DICHLORODIFLUOROMETHANE   ( CCL2F2     )  * |  DATA AND   UNITS  |                 *             *
* R  113    TRICHLOROTRIFLUOROETHANE  ( CCL2F-CCLF2)  * |T=TEMPERATURE DEG C |                 *             *
* CONCENTRATION OF DISTILLATE=  0.990                 * |P=PRESSURE KPA      | T=  23.3   <<<  * EVAPORATOR  *  <<<  T=  27.5
* RATIO OF FEED TO DISTILLATE=  3.96                  * |H=ENTHALPY KJ/KG    |                 * TSAT=  4.2  *
* PROPORTION OF FEED FLOW THROUGH FEED PREHEATER= 1.00* |B=AVAILABILITY KJ/KG| ------------    *             *    ------------
* DISTILLATE SUPERHEAT AT EVAPORATOR OUT=    21.0 DEG *  -------------------- |  EVAP IN   |   *             *   |  EVAP OUT  |
* FEED SUBCOOLING AT ABSORBER OUT=           2.0 DEG *                       |T=   2.8    |   ***************   |T=  25.2    |
* DISTILLATE SUBCOOLING AT CONDENSER OUT=    0.0 DEG *                       |P=  336050.8|    /\        \/     |P=  336050.8|
* APPROACH FLUID OFF EVAP TO EVAP IN    = 20.5 DEG    *                       |H=  62.94   |    /\        \/     |H= 202.22   |
*APPROACH CONDENSER AND ABSORBER=  8.3   1.1 DEG      *       ------------    |B=  31.11   |    /\        \/     |B=  22.18   |
* ALL CONCENTRATIONS ARE MASS CONCS OF       R 12      *      |EXPANSION IN|   |STATE=2 PHA |   ***        \/     |STATE=SUPHV |
*ENTROPY AND ENTHALPY DATUM TEMPERATURE =   -40.0DEG C*      |T=  29.3    |    ------------    *E*        \/      ------------
*AVBTY DATUMS: TEMP=  21.4DEG C :PRESSURE=   101.3 KPA*      |P=  733459.6|                    ***        \/
*******************************************************      |H=  62.94   |                     /\        \/
                                                             |B=  32.12   |    ------------     /\        \/      ------------
                                                             |STATE=SUBCL |   |P/COOL L OUT|    /\        \/     |P/COOL V IN |
                        ------------                          ------------    |T=  29.3    |   ***************   |T=  25.2    |
                       |  COND OUT  |                                         |P=  733459.6|   *             *   |P=  336050.8|
                       |T=  29.7    |                                         |H=  62.94   |   *             *   |H= 202.22   |
                       |P=  733459.6|                                         |B=  32.12   |   *  PRECOOLER  *   |B=  22.18   |
                       |H=  63.36   |                                         |STATE=SUBCL |   *             *   |STATE=SUPHV |
                       |B=  32.10   |                                          ------------    *             *    ------------
                       |STATE=SATDL |                                                          ***************
                        ------------                                                            /\        \/
                      >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>          \/
                    /\      TSAT=   29.7                                                                  \/
                 ******                                                       ------------                \/      ------------
T=  21.4  >>>    *COND*    >>>                                               |P/COOL L IN |               \/     |P/COOL V OUT|
                 ******                                                      |T=  29.7    |               \/     |T=  25.8    |
                 *    *                                                      |P=  733459.6|               \/     |P=  330050.8|
                 *    *                                                      |H=  63.36   |               \/     |H= 202.64   |
                 *    *                                                      |B=  32.10   |               \/     |B=  21.81   |
                 *    *                                                      |STATE=SATDL |               \/     |STATE=SUPHV |
                 *    *                                                       ------------                \/      ------------
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                                                                   \/
                 *    *                                  ------------                                     \/
  ------------   *    *                                 | FEED       |                                    \/
 | COLUMN FEED|  *    *   ************                  |T=  53.5    |                                    \/
 |T=  53.5    |  ******   *   FEED   *                  |P=  733459.6|                                    \/
 |P=  733459.6|  *FEED*<<<*   BOOST  *<<<<<<<<<<<<<<<<  |H=  78.67   |                                    \/
 |H=  78.67   |  ******   *  HEATER  *                /\|B=  -4.72   |                                    \/
```

```
                  +    +                                  /\       IT=  22.4    I                                 \/
                  +    +                                  /\       IP=  733459.6I       ------------              \/
                  +    +                  ------------    /\       IH=  50.84   I      I BOT IN EXP I             \/      ------------
                  +    +                 IFEED OUT P/HI   /\       IB=  -4.69   I      IT=  22.7    I             \/     I   MIX IN   I
                  +    +                 IT=  53.5    I   /\       ISTATE=SUBCL I      IP=  733459.6I             \/     IT=  25.8    I
                  +    +                 IP=  733459.6I   /\        ------------       IH=  49.98   I             \/     IP=  320050.8I
                  +    +                 IH=  78.67   I   /\  +++++++                  IB=  -0.39   I             \/     IH= 202.76   I
                  +    +                 IB=  -4.72   I    <<<+     +<<<<<<<<<<<<<<<</\I STATE=SUBCLI             \/     IB=  21.23   I
                  +    +                ISTATE=SUBCL I        +FEED +                /\  ------------        +++++++++   ISTATE=SUPHV I
 ------------     +    +                  ------------        +PRE  +                /\       +++            +       +    ------------
I BOT HX OUT I    +    +>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>+HEAT + >>>>>>>>>>>>>  /\>>>>>>+E+>>>>>>>>>>>>>+  MIX  +
IT=  65.1    I    +    +                                      +     +                /\       +++            +       +
IP=  733459.6I    +    +                                      +++++++                /\                      +++++++++
IH=  87.19   I    +    +                       ------------           ------------   /\          ------------     \/      ------------
IB=    0.46  I    +    +                      I BOT IN P/H I         I BOT OUT P/HI  /\         IBOT OUT EXP I    \/     I  MIX OUT   I
ISTATE=SUBCL I    +    +                      IT=  65.1    I         IT=  22.7    I  /\         IT=  22.9    I    \/     IT=  38.1    I
 ------------     +    +                      IP=  733459.6I         IP=  733459.6I  /\         IP=  320050.8I    \/     IP=  320050.8I
                  +    +                      IH=  87.19   I         IH=  49.98   I  /\         IH=  49.98   I    \/     IH=  88.53   I
                  +    +                      IB=    0.46  I         IB=  -0.39   I  /\         IB=  -0.64   I    \/     IB=  -3.01   I
                  +    +                      ISTATE=SUBCL I         ISTATE=SUBCL I  /\         ISTATE=SUBCL I    \/     ISTATE=2 PHA I
 ------------     +    +                       ------------           ------------   /\          ------------     \/      ------------
I BOT HX  IN I    +    +                                                             /\                           \/
IT= 115.3    I    +    +                                                             /\                           \/      ------------
IP=  733459.6I    +    +                                                             /\                           \/     I ABSORBER INI
IH= 135.82   I    +    +                                                             /\                           \/     IT=  37.3    I
IB=   7.83   I    +    +                                                             /\                           \/     IP=  310050.8I
ISTATE=SATDL I    +    +                                                             /\                           \/     IH=  88.53   I
 ------------     +    +                                                             /\                           \/     IB=  -3.07   I
                  +    +<<<<<<                                                       /\                           \/     ISTATE=2 PHA I
 ------------     +    +    /\                                                       /\                           \/      ------------
I BOTTOM OUT I    +    +    /\                                                       /\                    ++++++++++++
IT= 115.3    I    ++++++    /\                                                       /\                    +          +
IP=  733459.6I    +BOIL+    /\                                                       /\   T=  21.4  >>>    + ABSORBER +  >>>
IH= 135.82   I    ++++++    /\                                                       /\                    +TSAT= 24.5+
IB=   7.83   I      \/      /\                                                       /\                    ++++++++++++   ------------
ISTATE=SATDL I      \/      /\                                                       /\                           \/     IABSORBER OUTI
 ------------         >>>>>>                                                         /\                           \/     IT=  22.5    I
                                                                                     /\                           \/     IP=  301050.8I
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++            /\                           \/     IH=  50.84   I
+COLUMN PLATE NUMBERS: TOTAL=12:    RECTIFYING= 5:    STRIPPING= 4      +            /\                           \/     IB=  -4.97   I
+RECTIFYING HX TOTAL=    0.000KW: STRIPPING HX TOTAL=    1.517KW        +            /\                           \/     ISTATE=SUBCL I
+FEEDPLATE: TEMP= 62.28 DEG C: LIQUID CONC= 0.273: VAP CONC= 0.750     +            /\                           \/      ------------
+ABSOLUTE REFLUX FLOW TO DISTILLATE FLOW RATIO=    1.68                 +            /\                           \/
+ACTUAL REFLUX FLOW TO MINIMUM REFLUX FLOW RATIO=  1.20                 +            /\                           \/      ------------
+-----------------------------------------------------------------------+            /\                           \/     I  PUMP IN   I
+       I EVAPORATOR I CONDENSER   IABSORBER I BOILER I PUMP  I BOOST   +            /\                           \/     IT=  22.5    I
+-----------------------------------------------------------------------+            /\                           \/     IP=  301050.8I
+  KW   I   1.466      I 2.426       I 1.572    I 2.528   I 0.011I 0.000+            /\                           \/     IH=  50.84   I
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++            /\                           \/     IB=  -4.97   I
+                 I           I           I            FEED             +            /\                           \/     ISTATE=SUBCL I
+                 I           I           I------------------------------            /\                      +++++++++    ------------
+                 IDISTILLATEI BOTTOMS    I P/HEAT  I COLUMN/HXI TOTAL  +            /\                      + PUMP  +    ------------
+-----------------------------------------------------------------------+            /\                      +++++++++   I  PUMP OUT  I
+FLOWS KG/S       I 0.0105    I 0.0312    I 0.0417 I    0.0000    I 0.0417+          /\                           \/     IT=  22.4    I
+CONCENTRATION    I 0.990     I 0.021     I              0.265          +            /\                           \/     IP=  733459.6I
+-----------------------------------------------------------------------+            /\                           \/     IH=  50.84   I
+ MINIMUM REFLUX FLOW (KG/S) =   0.0060                                 +             <<<<<<<<<<<<<<<<<<<<<<<<<<<        IB=  -4.69   I
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++                                               ISTATE=SUBCL I
+CARNOT COP=  -37.728 BASED ON    23.3,  21.4 & 115.3 DEG C            +                                                ------------
+COP=  0.577    COPHEAT= 1.575     PUMP KW AS %=     0.4                +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

FIGURE H12

```
--------------------------------------------------------------------------------------------------------------------------------
NO I  TEMP   I  K     IHEAT TFIFEED FLOWIA/BY CHIPHASEI MASS  IENTHALPYIENTROPYIAVAIL/TYIFUG COEFIFUG COEFI FLOW
   I DEG C   I Y/X    I  KW    I  KG/S   I KJ/S   I       I CONC  I KJ/KG  IKJ/KG KI KJ/KG  ICOMPT 1  ICOMPT 2 I KG/S
--------------------------------------------------------------------------------------------------------------------------------
 1 I  29.7   I 1.01   I  2.426I  0.0000 I -0.067I LIQ  I0.990 I  63.36 I 0.256 I  32.10 I  0.873 I  0.001 I 0.0177
   I         I        I       I         I       I VAP  I0.998 I 200.16 I 0.000 I   0.00 I  0.000 I  0.000 I 0.0000
   I         I        I       I         I       I      I      I        I       I        I        I        I
 2 I  30.8   I 1.05   I  0.000I  0.0000 I -0.003I LIQ  I0.945 I  64.01 I 0.265 I  28.27 I  0.897 I  0.134 I 0.0070
   I         I        I       I         I       I VAP  I0.990 I 200.71 I 0.709 I  35.92 I  0.870 I  0.750 I 0.0177
   I         I        I       I         I       I      I      I        I       I        I        I        I
 3 I  33.4   I 1.15   I  0.000I  0.0000 I -0.004I LIQ  I0.847 I  65.52 I 0.281 I  21.51 I  0.957 I  0.133 I 0.0067
   I         I        I       I         I       I VAP  I0.972 I 202.03 I 0.716 I  34.58 I  0.873 I  0.763 I 0.0175
   I         I        I       I         I       I      I      I        I       I        I        I        I
 4 I  38.9   I 1.40   I  0.000I  0.0000 I -0.008I LIQ  I0.667 I  68.97 I 0.303 I  11.36 I  1.112 I  0.137 I 0.0063
   I         I        I       I         I       I VAP  I0.934 I 205.04 I 0.729 I  32.29 I  0.879 I  0.771 I 0.0172
   I         I        I       I         I       I      I      I        I       I        I        I        I
 5 I  48.0   I 1.90   I  0.000I  0.0000 I -0.009I LIQ  I0.457 I  75.47 I 0.327 I   1.89 I  1.432 I  0.160 I 0.0060
   I         I        I       I         I       I VAP  I0.869 I 209.88 I 0.748 I  29.23 I  0.889 I  0.784 I 0.0168
   I         I        I       I         I       I      I      I        I       I        I        I        I
 6 I  57.0   I 2.44   I  0.000I  0.0000 I -0.005I LIQ  I0.327 I  82.64 I 0.347 I  -2.59 I  1.796 I  0.197 I 0.0060
   I         I        I       I         I       I VAP  I0.797 I 214.67 I 0.764 I  26.64 I  0.898 I  0.795 I 0.0165
   I         I        I       I         I       I      I      I        I       I        I        I        I
 7 I  62.3   I 2.75   I  0.000I  0.0417 I -0.020I LIQ  I0.273 I  87.00 I 0.358 I  -3.99 I  2.020 I  0.224 I 0.0500
   I         I        I       I         I       I VAP  I0.750 I 217.35 I 0.772 I  25.31 I  0.903 I  0.801 I 0.0165
   I         I        I       I         I       I      I      I        I       I        I        I        I
 8 I  68.5   I 3.11   I -0.379I  0.0000 I  0.028I LIQ  I0.222 I  92.29 I 0.371 I  -4.95 I  2.297 I  0.262 I 0.0484
   I         I        I       I         I       I VAP  I0.690 I 221.09 I 0.780 I  23.93 I  0.908 I  0.807 I 0.0188
   I         I        I       I         I       I      I      I        I       I        I        I        I
 9 I  78.1   I 3.64   I -0.379I  0.0000 I  0.125I LIQ  I0.161 I 100.79 I 0.391 I  -3.13 I  2.748 I  0.331 I 0.0476
   I         I        I       I         I       I VAP  I0.586 I 226.62 I 0.790 I  22.26 I  0.918 I  0.816 I 0.0172
   I         I        I       I         I       I      I      I        I       I        I        I        I
10 I  91.2   I 4.27   I -0.379I  0.0000 I  0.127I LIQ  I0.100 I 112.74 I 0.419 I   0.10 I  3.396 I  0.449 I 0.0478
   I         I        I       I         I       I VAP  I0.428 I 234.91 I 0.798 I  21.28 I  0.931 I  0.826 I 0.0164
   I         I        I       I         I       I      I      I        I       I        I        I        I
11 I 104.8   I 4.78   I -0.379I  0.0000 I  0.040I LIQ  I0.052 I 125.61 I 0.447 I   4.13 I  4.098 I  0.600 I 0.0486
   I         I        I       I         I       I VAP  I0.249 I 244.48 I 0.799 I  22.57 I  0.947 I  0.837 I 0.0166
   I         I        I       I         I       I      I      I        I       I        I        I        I
12 I 115.3   I 5.05   I -2.528I  0.0000 I  0.573I LIQ  I0.021 I 135.73 I 0.468 I   7.80 I  4.647 I  0.737 I 0.0312
   I         I        I       I         I       I VAP  I0.107 I 252.56 I 0.791 I  30.47 I  0.963 I  0.846 I 0.0174
   I         I        I       I         I       I      I      I        I       I        I        I
NOTE: A/BY CH   is for streams only.
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FIGURE H12 CONTD

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