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Preliminary Flashing Multiphase
Flow Analysis with Application
to Letdown Valves in Coal
Conversion Processes

L. J. Ott

A. A. Khan

ORNL/TM--8160

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Fossil
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Printed in the United States of America Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A07; Microfiche A01

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ORNL/TM-8160

Contract No. W-7405-eng-26

Engineering Technology Division

**PRELIMINARY FLASHING MULTIPHASE FLOW ANALYSIS WITH
APPLICATION TO LETDOWN VALVES IN COAL-
CONVERSION PROCESSES**

L. J. Ott A. A. Khan

Date Published - September 1982

NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

**Prepared by the
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SUMMARY

All coal conversion processes require valves for controlling the flow of fluids containing solid particles and other harsh contaminants derived from coal at high temperature and/or pressure. Pilot-plant experience with coal liquefaction processes has shown that the high-pressure slurry letdown valves are prone to fail. No scientific procedure exists for accurately sizing letdown valves accepting high-pressure/high-temperature streams comprised of coal particles suspended in a mixture of hydrocarbons that undergo changes of state and composition as the fluid passes through the valve.

As part of the Oak Ridge National Laboratory's technical support to large coal liquefaction projects, attempts have been made to (1) develop the methodology for characterizing and predicting multicomponent, multiphase, non-Newtonian flow behavior within letdown valves and devices and (2) analyze the fluid flow in the entire letdown region of the process.

An engineering model that can be used in the analysis of multicomponent, multiphase, flashing, flowing systems has been developed. A preliminary version of a user-oriented computer code for this model has been developed and is fully described.

Sample problems solved with the computer code ranging from single-phase multicomponent flow to flashing, multicomponent flow with an injected side stream are also presented.

PRELIMINARY FLASHING MULTIPHASE FLOW ANALYSIS WITH
APPLICATION TO LETDOWN VALVES IN
COAL CONVERSION PROCESSES

L. J. Ott A. A. Khan

ABSTRACT

As part of the Oak Ridge National Laboratory's technical support to large coal liquefaction projects, attempts have been made to (1) develop the methodology for characterizing and predicting multicomponent, multiphase, non-Newtonian flow behavior within letdown valves and devices and (2) analyze the fluid flow in the entire letdown region of the process.

An engineering model that can be used in the analysis of multicomponent, multiphase, flashing, flowing systems has been developed. A preliminary version of a user-oriented computer code for this model has been developed and is fully described.

1. INTRODUCTION

1.1 Background

During the decade from 1970 to 1980, coal increased in importance as an energy source that would allow the United States to reduce its dependence on oil imports. Serious attention has been given to commercializing advanced processes for converting coal to clean liquids and gases. Most of these processes are either in the pilot-plant stage or are ready for scale-up to demonstration-size units. All of these coal conversion processes require valves for controlling the flow of fluids containing solid particles and other harsh contaminants derived from coal at high temperature and/or pressure.

An extensive study¹ by J. F. Gardner of the Morgantown Energy Technology Center of the applications of valves for solids throttling in the coal conversion processes indicates two critical needs:

1. a control valve for slurry letdown service and
2. a control valve for hot dirty gas service.

Current experience with letdown valves comes from usage by existing pilot

plants (for instance, the SRC-I facility at Wilsonville, Alabama, and the SRC-II facility at Ft. Lewis, Washington) and demonstration plants (the H-Coal facility at Catlettsburg, Kentucky). Normally, the pilot plant is used to prove or improve a chemical process; from that viewpoint, techniques are devised by the operators to keep the plant functioning long enough to collect process data in spite of equipment limitations. Such has been the case with pilot-plant slurry letdown valves. The short lifetime of the valve bodies and trim has been a major concern of pilot-plant personnel, and the techniques that keep the pilot plant operating are not practical for large-scale demonstration and/or commercial plants.

A summary of the letdown valve requirements, the conditions that must be specified to select (design) letdown valves acceptable for coal conversion, and the industry's current ability to supply these valves has been published by Hatcher et al.² at the Oak Ridge National Laboratory (ORNL). Hatcher states that these letdown valves are exposed to very erosive and corrosive streams containing solids at high temperatures and pressures. Under these conditions, the valve body design, valve trim material characteristics, stream conditions (proneness to flashing and/or cavitation), and piping geometry upstream and downstream of the valve are important.

However, no scientific procedure presently³ exists for accurately calculating the size of letdown valves accepting streams comprised of coal particles suspended in a mixture of hydrocarbons that undergo changes of state (flashing) and composition as the fluid passes through the valve. There is a tendency to oversize these valves, which can result in rapid erosion of the trim among other effects. Some design engineers of the valve manufacturers will admit that for this application their design methods range from "educated guesswork" to "seat of the pants engineering."

Considering the magnitude of the problems encountered with letdown valves in coal conversion pilot plants, several needs must be met before these equipment items can become reliable, integrated units in future coal conversion demonstration and commercial plants. First, as stated by Hatcher² and Bhide,³ the data required for proper valve design must be accumulated. The best place to acquire these data is in existing operating pilot and demonstration plants. Second, efforts should be made to

learn from past pilot-plant operating experience: that is, a survey of pilot-plant engineers and operators should be made to determine (1) what valves were used for this service, (2) whether or not they failed, (3) how long they operated, (4) the failure mode, (5) the condition of the valve after removal, (6) the measures taken to fix the valve and put it back in service, and especially (7) any "break-through" that allowed reasonably reliable valve operation. A common complaint of valve manufacturers is the lack of feedback from past pilot-plant experience. Finally, a "design tool" should be developed that would allow the engineer to analyze the flow of coal liquids mixed with solids and gases undergoing flashing at adiabatic and nonadiabatic conditions. This design tool would provide the nonexistent scientific procedure referred to by Bhide.

1.2 ORNL Involvement

In the area of component development and process evaluation, the ORNL objective is to ensure that coal conversion (liquefaction, gasification, pyrolysis) processes, subsystems, and components have satisfactory functional performance, lifetime, reliability, and safety for their intended applications, and that sufficient component and subsystem performance data are available to permit process design optimizations. Current activities are primarily those carried out as part of the technical support to large liquefaction projects.

The objectives of the ORNL letdown valve reliability subtask are (1) to collect information and data on past slurry letdown valve performance, (2) to develop the methodology for characterizing and predicting multicomponent, multiphase, non-Newtonian flow behavior within letdown valves and devices, and (3) to analyze the fluid flow in the entire letdown region of the process. Ultimately, this subtask goal is to provide recommendations, guidelines, and engineering techniques for the design and modification of slurry letdown valves and systems.

Data and information on pilot-plant letdown valve experience (primarily SRC-I and SRC-II) and related industrial experience have recently been collected and published.⁴ Items 2 and 3 of the letdown valve reliability subtask are addressed by this report.

2. OBJECTIVES

The primary objective of this study is the development of an engineering model that can be used in the analysis of multicomponent, multiphase, flashing, flowing systems. This preliminary engineering tool is presented as a computer program, Version 1.0 of the Flashing Fluid Flow Analysis Program (FFFAP).

This engineering model was developed with intended application to coal liquefaction high-pressure letdown systems. Specific applications (after verification) include the following:

1. evaluation of existing (and past) high-pressure letdown systems (valves and piping),
2. evaluation of proposed letdown systems, and
3. design of new letdown systems.

Final verification and application of the code to existing (and past) pilot-plant and demonstration plant high-pressure letdown systems will be reported in a subsequent publication.

Note that the FFFAP engineering model and code is highly generalized. Although designed for the analysis of the coal liquefaction letdown system, it can be applied to any piping system with any fluid constituents.

3. MODEL DESCRIPTION

3.1 Introduction

The engineering thermal-hydraulic model of the fluid system essentially consists of macroscopic mass, momentum, and energy balances on incremental segments of the system. Thus, by specifying the initial boundary conditions and with a steady-state limitation, the equations of change can be step-wise integrated along the entire length of the flow system. Therefore, the results (temperature, pressure, etc.) from the model are computed as functions of position in the flow system.

Note that these are preliminary versions of the model and the code. Because of time constraints, some features (such as the nonadiabatic and non-Newtonian capabilities) have not been verified and included in the first release of the code. In the remaining sections of Chap. 3, attention is drawn to those features that will be added at a later date; a more in-depth coverage of future model improvements is presented in Chap. 5.

3.2 Control Volume Concept

The fluid system to be analyzed by FFFAP must be fully specified by the user. The user describes the system geometry by specifying fluid volumes and junctions (flow paths) between the volumes. These user-specified volumes (control volumes) are the "incremental segments" around which the equations of change are formulated and are used to represent the fluid in the system piping.

Consider the control volume shown in Fig. 1; because this is a steady-state initial value problem, the inputs to the control volume are known. Then via the mass, momentum, and energy balances, the control volume outputs can be calculated.

Thus, FFFAP considers a thermal-hydraulic system as a series of interconnected user-defined control volumes. The FFFAP code then solves the equations of change for the volumes under the limitations given in Sect. 3.3.

KNOWNs:

P_{IN}	PRESSURE IN
T_{IN}	TEMPERATURE IN
$\{X_{IN}\}_i, \{Y_{IN}\}_i$	CONSTITUENT CONCENTRATION OF THE INLET LIQUID AND GAS STREAMS, RESPECTIVELY
G_{IN}, L_{IN}, W	FLOW RATES OF INLET GAS, LIQUID AND INERT STREAMS
Q_{IN}	HEAT INPUT OVER THE INCREMENTAL LENGTH $\Delta \ell$

UNKNOWNs:

P_{OUT}	PRESSURE OUT
T_{OUT}	TEMPERATURE OUT
$\{X_{OUT}\}_i, \{Y_{OUT}\}_i$	CONSTITUENT CONCENTRATION OF THE OUTLET STREAMS
G_{OUT}, L_{OUT}, W	OUTLET FLOW RATES OF THE GAS, LIQUID AND INERT STREAMS

Fig. 1. FFFAP control volume.

3.3 Model Limitations

The engineering model and FFFAP-Version 1.0 have the following limitations and assumptions:

1. the flow is one-dimensional and steady-state;
2. the gas and liquid streams are in thermodynamic equilibrium;
3. the fluid is homogeneous (i.e., no slip);
4. available fluid-dynamic and thermodynamic correlations are used;
5. the process is adiabatic (Version 1.0 only);
6. the fluid is Newtonian (Version 1.0 only);
7. the user cannot specify experimentally available liquid density, viscosity, and liquid/gas interfacial surface tension (Version 1.0 only); and
8. no chemical reaction occurs.

3.4 Physical Property and Thermodynamic Relationships

Reliable values of the properties of materials are essential in the design, operation, and analysis of industrial equipment and processes. Reliable experimental data are always to be preferred over values obtained by even the best estimation methods; however, if the process involves chemical mixtures or relatively new materials, available experimental data may not exist. For instance, the coal liquids from liquefaction processes are complex mixtures of individual chemical compounds, the formation of which are dependent on the process, the operating conditions, and the coal type used; however to date, the physical and thermodynamic properties of these liquids are still being researched. Nevertheless, the lack of data does not alleviate the engineer's need for the data, and in such cases, the data must be estimated.

The work relies heavily on the critical review of Reid, Prausnitz, and Sherwood⁵ of various estimation procedures for a limited number of properties of gases and liquids and the more timely comments of Henley and Seader.⁶ Also, a literature survey has been made of recent research in physical property and thermodynamic property estimation procedures. An effort has been made to include in the engineering model and FFFAP the

best methods of estimating each property. (In some cases, there are several methods; thus, the code user has a choice of techniques).

Version 1.0 of FFFAP does not have the capability of allowing the user to input experimentally available mixture liquid density, viscosity, liquid/gas interfacial surface tension, or equilibrium vapor/liquid ratios (K values). This improvement will be made in the next version of FFFAP.

A summary⁷⁻¹⁸ of the physical property and thermodynamic relationships employed in Version 1.0 of FFFAP is given in Table 1. Included in parentheses in Table 1 are correlations that are intended to be added in a subsequent version of FFFAP.

3.4.1 Gas equation of state

In high-pressure gas/liquid systems, there is a need to estimate the volumetric behavior of a real gas, because significant departures from the low-pressure ideal gas assumptions can exist. The nonideality of a gas is conveniently expressed by the compressibility factor Z as

$$Z = \frac{PV}{RT} \quad (1)$$

where

V = molar volume,

P = absolute pressure,

T = absolute temperature, and

R = universal gas constant.

For ideal gases $Z = 1.0$; for real gases, Z is normally less than unity, except at very high pressures or temperatures.

The analytical modified Redlich-Kwong-Soave equation of state is used in FFFAP. For hydrocarbon systems, Reid et al. suggested the Redlich-Kwong-Soave and Lee-Erbar-Edmister equations of state and noted that they were generalized equations, accurate to within 1 to 2%, and well tested. However, the one exception to their recommendation was systems containing hydrogen. Recent work by Graboski and Daubert¹⁴⁻¹⁶ has resulted in the modified Redlich-Kwong-Soave equation of state that does not have the previous restriction. The utility of the equation has been

Table 1. Summary of physical and thermodynamic property relationships employed in Version 1.0 of FFFAP

Physical or thermodynamic property	Correlation ^a	References
Enthalpy: including subcooled liquid, saturated liquid, saturated vapor, and superheated vapor	Yen and Alexander (Lee, Erbar, and Edmister) (Edmister, Persyn, and Erbar)	5,7 5,8 6
Liquid density	Chueh/Prausnitz (Yeh and Woods) (User-supplied)	5,9,10 5,11
Liquid activity coefficient	Scatchard/Hildebrand (Scatchard/Hildebrand with Lee, Erbar, and Edmister interaction coefficients)	5,12
Liquid fugacity coefficient	Grayson/Streed (Lee, Erbar, and Edmister)	13 8
Vapor fugacity coefficient	Modified Redlich-Kwong-Soave equation of state (Lee, Erbar and Edmister equation of state)	14,15,16 5, 8
Liquid/vapor interfacial surface tension	Macleod/Sugden (User-supplied)	5
Liquid viscosity ^b	$T_r \leq 0.75$ vanVelzen $T_r > 0.75$ Letsou/Stiel $\mu_m = e(\sum \chi_i \ln \mu_i)$ (User-supplied)	5 5,17 5
Vapor viscosity	Dean and Stiel	5,18

^a Parentheses indicate features to be included in a later version of FFFAP.

^b T_r = reduced temperature, χ = mole fraction, and μ = viscosity.

well demonstrated,¹⁴⁻¹⁶ especially for vapor-liquid equilibria calculations for mixtures of hydrocarbons of importance to the natural gas and petroleum refining industries.

The equation of state can also be used to compute the vapor-mixture enthalpy;^{5,6} combined with the liquid mixture enthalpy computation technique of Edmister et al.,⁶ the enthalpy of any state point can be calculated.

The fugacity coefficient of a component in the vapor phase is needed to predict phase equilibrium. The vapor-phase fugacity coefficient can also be determined via the equation of state (classical derivation).

3.4.2 Vaporization equilibrium ratios

A general correlation of vapor/liquid equilibria for a large class of mixtures is much needed in engineering calculations where generality, reliability, and ease of use are primary considerations. In the FFFAP model, every iteration in the solution of the equations of change for a control volume requires multiple evaluations of vaporization equilibrium ratios (K values) just in the determination of the mixture bubble-point and dew-point temperatures. Also, if the fluid is two-phase (bubble-point temperature < fluid temperature < dew-point temperature), additional K-value computations must be made to determine the vapor/liquid split.

Vaporization equilibrium ratios are calculated in the model according to the thermodynamic identity

$$K_i = \frac{v_i \gamma_i}{\phi_i} , \quad (2)$$

where the subscript refers to component identity. K_i is defined as the ratio of the mole fractions in the equilibrium gas and liquid phases,

$$K_i = Y_i / X_i , \quad (3)$$

where Y_i and X_i are the vapor and liquid mole fractions, respectively, of component i .

The other quantities in Eq. (2) are

v_i = fugacity coefficient of component i as a pure liquid,
 γ_i = activity coefficient of i in the liquid solution, and
 ϕ_i = fugacity coefficient of i in the vapor mixture.

As noted in Sect. 3.4.1, the fugacity coefficient ϕ_i of i in the vapor mixture can be determined via a classical thermodynamic derivation using the equation of state. The derivation starts with the relation of the chemical potential to the Gibbs or Helmholtz energies. The details will not be given here; rather, the reader is referred to thermodynamic texts, Reid et al.⁵ or Henley and Seader.⁶ The point to be made is that, given an equation of state for the gas, an expression for the fugacity coefficient ϕ_i can be defined from thermodynamic relationships.

The fugacity coefficient (v_i) of i as a pure liquid is determined from the Grayson/Streed correlation,¹³ which is an extension of the Chao/Seader¹⁹ empirical expression for v_i in terms of the reduced temperature T_r , reduced pressure P_r , and the acentric factor ω .

The liquid activity coefficient γ_i of i is calculated by the Scatchard/Hildebrand¹² (solubility-parameter) equation, assuming "regular" liquid solutions. A regular solution is one in which nonideality is caused entirely by the heat of mixing. The properties of solutions of nonpolar fluids such as hydrocarbons are approximated by regular solution equations. The Scatchard/Hildebrand relation gives the activity coefficient as a function of temperature and composition, but it is independent of pressure.

As noted earlier, reliable experimental data are preferable, and this would be especially true for the K -value determination. A future version of FFFAP should include the capability (option) of allowing the user to input a K -value subroutine in which experimental values of K are determined as functions of pressure and temperature. However, this option is not available in Version 1.0; thus, the vaporization equilibria ratios are computed via Eq. (2).

3.5 Fluid-Dynamic Correlations

For single-phase (gas or liquid) Newtonian flow our engineering foundation is very firm; little improvement has been made in our knowledge of the effect of Reynolds number Re and relative pipe roughness k/d on the turbulent friction factor f since 1940. The one possible exception is Wood's²⁰ (1966) empirical set of equations that are explicit in f . The turbulent-flow friction factor relations (Wood²⁰ and Colebrook²⁰ correlations for partially rough wall turbulence; Nikuradse²⁰ correlation for fully rough wall turbulence; Drew et al.²⁰ and Nikuradse²⁰ correlations for smooth wall turbulence) combined with the laminar relationship ($f = 16/Re$) and a smooth transition between laminar and turbulent flow are commonly known in a graphical form as a Moody²¹ diagram. These relations are all combined in one routine in FFFAP that, given an Re and k/d set, calculates the friction factor f .

Version 1.0 of FFFAP has been limited to Newtonian fluids. Non-Newtonian flow and the option that would allow the user to include his own liquid viscosity relationship will be included in a later version of FFFAP.

The subject of two-phase flow in pipes is not as straightforward as that of single-phase Newtonian flow. Since Lockhart and Martinelli²² published their two-phase correlation in 1949, dozens of correlations and models have been published for dealing with various aspects of the flow of gas-liquid mixtures in pipes. Thankfully, some researchers, the most prominent being Dukler et al. at the University of Houston and Gregory et al. at the University of Calgary, have undertaken critical reviews of existing correlations, thus easing the task of the engineer who must select one of these methods for use in a particular problem. These reviews²³⁻³¹ have definitely had a bearing on the correlations chosen for inclusion in Version 1.0 of FFFAP. The correlations currently in FFFAP for the two-phase flow friction factor, the liquid holdup, and the flow pattern maps for vertical and horizontal flow are presented in Table 2.

Two-phase flow of solids and gas or solids and liquid is discussed extensively by Govier and Aziz.²⁰ Relying on their critique and including the latter work of Turian and Yuan,³² five correlations are available in

Table 2. Summary of fluid-dynamic correlations
employed in Version 1.0 of FFFAP

Application	Correlation ^a	References
Single-phase friction factor		
Partially rough wall turbulence	Wood	20
	Colebrook	20
Fully rough wall turbulence	Nikuradse	20
Smooth wall turbulence	Drew, Koo, and McAdams	20
	Nikuradse	20
Two-phase (solid and gas or liquid) friction factor		
Vertical flow	Newitt, Richardson, and Gliddon	33
	Turian/Yuan	32
	Rose/Duckworth	34
Horizontal flow	Newitt et al.	35
	Rose/Duckworth	34
	Zandi/Govatos	20
	Turian/Yuan	32
Two-phase (gas and liquid) friction factor		
Vertical flow	Orkiszewski	36
	(Other)	
Horizontal flow	Dukler	24,37
	Lockhart/Martinelli	22,24
	(Other)	
Liquid holdup in two-phase flow		
Vertical flow	Hughmark	24,38
	(Other)	
Horizontal flow	Hughmark	24,38
	Dukler	25
	Lockhart/Martinelli	22,24
Flow pattern maps for two-phase flow		
Vertical flow	Dukler	26
	(Other)	
Horizontal flow	Mandhane, Gregory, and Aziz	27
	(Other)	

^a Parentheses indicate features to be included in a later version of FFFAP (single-phase friction factor - non-Newtonian flow).

FFFAP for the two-phase (solid and gas or liquid) friction factor for vertical and horizontal flow.

A summary of the fluid-dynamic correlations employed in Version 1.0 of FFFAP is presented in Table 2.

4. COMPUTER PROGRAM

4.1 Code Description

Version 1.0 of FFFAP is written in FORTRAN IV and is currently operable on ORNL's IBM 3033 computer. The code consists of 36 modules (subroutines, function subprograms, etc.), each of which is designed primarily for one function. The entire code requires ~410 K bytes of computer core storage. A summary of the FFFAP modules (a total of 36) is presented in Table 3 along with a very brief description of each module function. In any given problem, many of these routines will not be used. The code user has some control (via input control parameters which will be described later) over which modules will be involved in the calculations. For instance, the user has the choice of four friction factor correlations for horizontal pipeline slurry flow; in a specific problem, only one of these correlations (the user's choice) will be used.

In reviewing the FFFAP module descriptions in Table 3, it becomes apparent that the modules are functionally designed for one general purpose only. For example, CUBE determines the roots of a cubic equation, and FICFAC returns the Fanning friction factor for a given Reynolds number and relative roughness value. What cannot be seen from these module descriptions is the logic transfer and the basic building blocks (libraries) that are used for information transfer within the code. Six specific "libraries" must be generated by the code user:

1. control volume geometry,
2. chemical component,
3. wall component,
4. experimental data,
5. feed streams, and
6. logic control.

A detailed description of what is required in these libraries is covered in Sect. 4.2 and Appendix A. The remaining paragraphs in this section contain overview comments on the libraries.

The fluid system to be analyzed by FFFAP must be fully specified by the user. It must be modeled by fluid volumes (control volumes) that the

Table 3. FFFAP modules (Version 1.0)

Module (multiple entries)	Description
MAIN	The main driver or controlling routine that (1) directs the proper sequence calls to the supporting routines and (2) contains the primary pressure convergence sections and the side stream injection flow section
BLOCK	Initializes the common block variables
BUBPRS (DEWPRS)	Solved by FALSE to determine the bubble- and dew-point pressures for a stream of n components at a given composition and temperature
BUBTMP (DEWTMP)	Solved by FALSE to determine the bubble- and dew-point temperatures for a stream of n components at a given composition and pressure
CUBE	Solves for (1) the roots of a cubic equation and (2) the compressibility factor using the modified Redlich-Kwong-Soave equation of state ¹⁴⁻¹⁶
DPCALC	Controls the pressure-drop calculations; that is, depending on the state of the fluid and the user input control parameters, control is switched to the proper section and correlation in the routine
DUKLER	Determines the frictional pressure loss for gas/liquid flow in horizontal piping using Dukler et al. correlations ^{23,27}
DUKRL	Determines the liquid holdup in cocurrent gas/liquid flow in horizontal piping using Dukler's method ²⁵
ENTHYA	Determines the enthalpy of a specified stream (given its state) by the method of Yen and Alexander ^{5,7}
FALSE	Given a function of X, $f(X)$, FALSE determines the value of X for which $f(X) = 0$ via the method of Reguli Falsi (bubble-point and dew-point pressures and temperatures and SUMDXY)
FALSE2	Same as FALSE except it is only used in the solution of HBAL
FICFAC	Given the Reynolds number and the relative roughness factor, FICFAC determines the Fanning friction factor
FINDS	A Lagrangean interpolation routine

Table 3 (continued)

Module (multiple entries)	Description
FPTHOR	Determines the flow pattern region for two-phase gas/liquid cocurrent flow in horizontal pipes, according to the flow pattern map of Mandhane et al. ²⁷
FPTVRT	Determines the flow pattern region for two-phase gas/liquid cocurrent flow in vertical pipes via the flow transition criteria of Dukler et al. ²⁶
GAMMAI	Computes the activity coefficients in the liquid solution by the Scatchard-Hildebrand relationship ^{5,12}
HBAL	Solved by FALSE2 to determine the root (i.e., the temperature) of a control volume heat balance
HUPGAH	Determines the liquid holdup in co-current gas/liquid flow for horizontal, inclined, or vertical flow via Hughmark's correlation ^{24,38}
IFLASH	Given a stream of n components with known composition and stream temperature and pressure, IFLASH determines the condition of the stream and, if two-phase, performs isothermal flash calculations to determine the vapor/liquid split
INPUT	Reads the user-generated input stream (ergo, card image deck)
KVALUE	Calculates the vaporization equilibria ratios
LIQDEN	Determines the liquid density of a mixture via the Chueh/Prausnitz correlation ^{5,9,10}
LOCHRT	Determines the frictional pressure loss for gas/liquid flow in horizontal piping using the method of Lockhart and Martinelli ^{22,24}
NEWHOR	Determines the friction factor for horizontal pipeline flow of slurries via the correlation of Newitt et al. ³⁵
NEWVRT	Determines the friction factor for vertical pipeline flow of slurries via the correlation of Newitt et al. ³³

Table 3 (continued)

Module (multiple entries)	Description
NUGRSD	Computes the fugacity coefficients for the pure components in the liquid phase by the Grayson/Streed correlation ¹³
ORKISZ	Follows the method developed by J. Orkiszewski ³⁶ for calculating the pressure gradient in vertical two-phase flow
OUTPT1 (OUTPT2, OUTPT3, OUTPT4)	Does all of the FFFAP-generated output (except for error messages)
PHIRKS	Determines the fugacity coefficients of the gas mixture and the gas compressibility factor by the modified Redlich-Kwong-Soave equation of state ¹⁴⁻¹⁶
ROSDUC	Determines a slurry friction factor for vertical and horizontal flow of fluid/solid mixtures via the Rose and Duckworth correlation ³⁴
SUMDXY	Solved by FALSE to determine the mole fraction vaporized for a feed stream of n components at a given composition, temperature and pressure
SURTEN	Computes the surface tension of the mixture by the Macleod/Sugden correlation ⁵
TURYUN	Determines the friction factor for flow of slurries in horizontal pipelines based on the work of Turian and Yuan ³²
TURVRT	Determines the friction factor for flow of slurries in vertical pipelines via the Turian/Yuan correlation ³²
VISLIQ	Depending on the reduced temperature, component liquid viscosity is computed by the van van Velzen method ⁵ or Letsou/Stiel correlation; ^{5,17} the mixture viscosity is also calculated
VISVAP	Uses methods developed by Dean and Stiel ^{5,18} to calculate the viscosity of nonpolar gas mixtures at moderate and high pressures
ZANGOV	Determines the friction factor for flow of slurries in horizontal pipelines via the Zandi/Govatos correlation ²⁰

user specifies to represent the piping system. The code currently has an upper limit of 500 such control volumes.

The user must also create a chemical component library (up to 50 compounds) that may contain more, but definitely not fewer, compounds than are specified in the primary feed and secondary injected feed streams. The library on each compound contains all the information that would be needed for any of the code correlations (e.g., molecular weight; critical temperature, pressure, volume, and compressibility; acentric factor; parachor; and more that will be described in a later section). An indexing system is employed to relate the user-specified feed components to the chemical component library.

In Version 1.0 of FFFAP, no heat can be transferred into or out of a control volume (i.e., the process is adiabatic) and the user does not need to create a control volume, wall component library. However, the code input module and storage capacity currently have the capability for the user to create a wall component library (up to ten materials). In a later edition of FFFAP, the user will have the ability to specify that a control volume be nonadiabatic; then it will be necessary to determine the heat transferred through the control volume wall. In the energy equation, this control volume loss or gain term is currently set equal to zero (Version 1.0 of FFFAP only). An indexing system is again employed to relate the user-specified control volume wall composition to the wall component library.

If the user is analyzing an existing piping configuration, the capability exists to directly compare (within the code) experimental and computed values for the fluid pressure, temperature, density, and volumetric flow rate. The user need only include the experimental data in the appropriate section of the input deck and specify to which control volume the data applies. In the code output for that volume, the experimental data will also be output. Multiple data sets for a control volume are allowed and the maximum number of data sets is 100.

One primary feed stream is required. The initial composition (referring to the chemical component library by an index), flow rate, temperature, and pressure of the primary feed stream are required user input. There can be up to ten injected feed streams (i.e., feed streams that are

injected into the primary feed stream). The information required of the primary feed stream is also needed for each injected stream; additionally, the position in the piping configuration (i.e., the control volume number) into which the stream is injected must be stated.

The control parameter library is simply a method by which the user can specify which correlations or techniques are to be used in the problem calculations. As evident in Sect. 4.2, many of the user options that are planned for FFFAP are not available in Version 1.0.

4.2 Code User Input Description

This section (like Appendix A) is not intended to be a user input guide to FFFAP; rather, it is intended to illustrate the structure of the input and to indicate to the user what is required to generate each of the libraries discussed in Sect. 4.1. The primary blocks and the required order in the user-generated input are shown in Fig. 2. The problem heading (Fig. 2) is a user-descriptor for the current problem that will be included in the "starburst" output pages. The remaining six blocks in Fig. 2 refer to the libraries discussed in Sect. 4.1.

QRNL-DWG 02-5236 ETD

Fig. 2. Outline of FFFAP user input requirements.

The control parameter library is specified after the problem heading. Quite simply, this library is one variable array (ICS) that the user initializes in the input. As stated previously, these control parameters (ICS) specify the correlations and calculational techniques to be used in the current problem. An explanation for each of the ICS control variables is given in Table 4. Under the status column of Table 4, if "Not available" is indicated, then that option does not exist in FFFAP-Version 1.0; these options are intended to be added in a later version of FFFAP. The user also has the option of not initializing the ICS array - in which case the code would use the default values given in Table 4.

The fluid system to be analyzed by FFFAP must be fully specified by the user. The system is modeled by user-specified interconnecting fluid volumes (control volumes). The third block in Fig. 2 contains the user-generated control volume geometry library. For each control volume, the information shown in Fig. 3 must be furnished by the user. For instance, given a specific problem, a user decides to model the system with 20 control volumes; then each of the 20 control volumes must be described (the information shown in Fig. 3) by the user. More specific information on the control volume input is given in Appendix A. The FFFAP has a maximum limit of 500 control volumes.

The fourth block in the FFFAP input contains the user-generated chemical component library. This library can contain up to 50 chemical compounds. Each compound must be described by the following information.

Required user input for each chemical compound in
the chemical component library

1. Chemical index (i.e., a number between 1 and 50). Note: duplicate indices are not allowed. Exception: if index = 50 (reserved for solids), then only (1)-(3) and the following are needed:
 - the constants in the solids heat capacity equation where $CP = CAP + CPD \cdot T + CPC \cdot T^2$
 - the solid particle mean diameter
 - the solid particle mean density
2. An abbreviated chemical formula (≤ 8 letters and/or numbers). Note: user shorthand notation for output purposes only
3. Chemical name for compound (≤ 28 letters and/or numbers)
4. An indicator for interaction coefficients (0, if none)

Table 4. User-specified control parameter library (FFFAP-Version 1.0)

Control variable (ICS No.)	Explanation			Status	Default value
	Function	ICS value	Correlation or technique		
1	Flash technique	1	Lee/Erbar/Edmister	Not available	2
		2	High pressure (Prausnitz)		
2	Enthalpy calculations	1	Yen/Alexander		1
		2	Henley/Seader recommendation	Not available	
		3	Lee/Erbar/Edmister	Not available	
3	Bubble- and dew-point calculations	1	High pressure (Prausnitz)		1
		2	Lee/Erbar/Edmister	Not available	
4	Frictional correlations for vertical slurry flow	1	Newitt		2
		2	Turian/Yuan		
		3	Rose/Duckworth		
5	Frictional correlations for horizontal slurry flow	1	Newitt		4
		2	Rose/Duckworth		
		3	Zandi/Govatos		
		4	Turian/Yuan		
6	Frictional correlations for vertical two-phase flow	1	Orkiszewski		1
		2	Other	Not available	
7	Frictional correlations for horizontal two-phase flow	1	Dukler No. 1		2
		2	Dukler No. 2		
		3	Lockhart/Martinelli		
		4	Other	Not available	
8	Frictional correlations for single-phase flow	1	Fanning		1
		2	Metzner/Reed	Not available	
		3	Harris	Not available	
9	Liquid holdup correlations for vertical flow	1	Hughmark		1
		2	Other	Not available	
10	Liquid holdup correlations for horizontal flow	1	Hughmark		1
		2	Dukler		
		3	Lockhart/Martinelli		
11	Computation of liquid viscosity	1	Van Velzen and Letson/Stiel		1
		2	User-supplied subroutine	Not available	
12	Computation of liquid density	1	Chueh/Prausnitz		1
		2	User-supplied subroutine	Not available	
13	Computation of interfacial surface tension	1	Macleod/Sugden		1
		2	User-supplied subroutine	Not available

REQUIRED INPUT AT THE INLET AND OUTLET CONTROL VOLUME FACES:

1. FLOW AREA
2. WETTED PERIMETER
3. FLOW RESISTANCE COEFFICIENT
4. RELATIVE ROUGHNESS
5. PIPE INNER RADIUS
6. ANGLE OF INCLINATION, α (RELATIVE TO THE HORIZONTAL)
7. FLOW LENGTH, ℓ (FACE TO CONTROL VOLUME CENTER)

ADDITIONAL REQUIRED INPUT FOR EACH CONTROL VOLUME:

1. SPECIFICATION OF CONTROL VOLUME CENTER (X, Y, Z)
2. INDICATION OF INJECTED FLOW
3. INDICATION OF AVAILABLE EXPERIMENTAL DATA
4. INDICATION OF NONADIABATIC CONTROL VOLUME

IF THE CONTROL VOLUME IS NONADIABATIC, THE FOLLOWING IS REQUIRED:

1. NUMBER OF PIPE WALL COMPONENTS
2. FOR EACH WALL COMPONENT: INDICATE THE WALL INDEX, THE THICKNESS OF THE WALL, AND THE CONTACT RESISTANCE BETWEEN WALL COMPONENTS
3. TYPE OF EXTERIOR BOUNDARY CONDITION: IF FLUX IS INDICATED, SPECIFY THE FLUX; IF AN EXTERNAL SINK TEMPERATURE AND HEAT TRANSFER COEFFICIENT ARE INDICATED, THEY MUST BE SPECIFIED.

Fig. 3. Required user input for each control volume.

5. An indicator for vapor pressure model (Lee-Kesler correlation^s if = 0; Antoine correlation^s if = 1)
6. Molecular weight
7. Critical temperature
8. Critical pressure
9. Critical specific volume
10. Critical compressibility
11. Pitzer's acentric factor
12. The normal boiling point
13. The heat of vaporization at the normal boiling point
14. The parachor
15. Constants in the ideal gas heat capacity equation where $CP = CPA + CPB \cdot T + CPC \cdot T^2 + CPD \cdot T^3$
16. Constants in the van Velzen liquid viscosity equation where $\log_{10}(\text{viscosity}) = A (1/T - 1/B)$
17. The solubility parameter
18. The liquid molar volume
19. If the indicator in (5) = 1, Antoine vapor pressure equation coefficients where $\ln(\text{vapor pressure}) = A - B/T + C$
20. Interaction coefficients of this compound with other compounds [needed if indicator in (4) > 0]

The one exception is for a chemical index equal to 50, which is reserved for solids. More specific information on the input structure is given in Appendix A.

The wall component library is used if heat can be transferred into or out of a control volume (i.e., a nonadiabatic process that will be indicated by the input for each control volume, Fig. 3). As noted previously, FFFAP-Version 1.0 is limited to the adiabatic process; therefore, generating a wall component library is not necessary. The library can contain up to ten materials, and each material must be described by the following information.

Required user input for each material
in the wall component library

1. Material index (i.e., a number between 1 and 10)
Note: duplicate indices are not allowed
2. User name for the material (<20 letters and/or numbers)
3. Constants in the thermal conductivity equation for the material where

$$K = A_1 + A_2 \cdot T + A_3 \cdot T^2 + A_4 \cdot T^3 + A_5 \cdot T^4$$

By specifying the feed streams (primary and injected), the FFFAP user is also specifying the boundary conditions for the model. The initial boundary conditions are indicated by the user-specified primary feed stream. The required input for the primary feed stream is as follows:

Required user input for
the primary feed stream

1. The number of components
2. The feed temperature
3. The feed pressure
4. For each component
 - (a) the chemical index (referring to a compound in the chemical component library)
 - (b) the mass flow rate

The fluid system may have injected side streams (for example, an injected quench gas or a recycle stream), and the user may include these streams in the problem. The required user input for each injected feed stream is as follows:

Required user input for each
injected feed stream

1. The feed position (i.e., the control volume into which the stream is injected)
2. The number of components
3. The feed temperature
4. The feed pressure
5. For each component
 - (a) the chemical index (referring to a compound in the chemical component library)
 - (b) the mass flow rate

There is a limit of ten injected streams in FFFAP-Version 1.0.

The last block in the outline in Fig. 2 contains user-specified experimental data. If the user is analyzing an existing piping configuration and flow system, experimental data (fluid temperature, pressure, etc.) may be available; if so, this block allows the user to directly compare (in the code output) computed and observed values. The user has a limit of 100 experimental data sets that can be input (multiple sets can

be input for one control volume); the input requirements for each data set are as follows:

Required user input for each
experimental data set

1. The position in the fluid system
(i.e., the control volume in which
the data was taken)
2. Any or all of the following:
 - (a) pressure
 - (b) temperature
 - (c) volumetric flow rate
 - (d) density

4.3 Code Output Description

A brief outline of the FFFAP-Version 1.0 code output is presented in Table 5. For every problem solved by FFFAP, there will be $13+n$ pages of code generated output (where n = number of control volumes specified by the user).

Table 5. Outline of FFFAP-Version 1.0 output

Page	Explanation
1	Echo of the user-defined input stream
2	Starburst with input heading
3	User-specified program controls
4	Chemical library
5	Pipe wall library
6	Experimental data sets
7	Model geometry and nodding
8	Model geometry and nodding (continued)
9	Primary feed stream
10	Injected feed streams
11	Initial condition (state) of the primary feed stream
12	Starburst with heading
13-12+n	Node-by-node thermal-hydraulic analysis of the specified model (n = number of control volumes specified by user)
13+n	Final condition (state) of the primary feed stream

After reading each card image of the user-defined input stream, the INPUT module will output the card image (page 1 of the output). INPUT checks the order of the input stream (i.e., it checks for the required sequence of the card images); if it finds card images out of sequence, the code will terminate the job at that point. Each card image has a six-digit sequential identifier in the first ten columns that INPUT uses to check the order. An example of page 1 output is shown in Fig. 4. All examples of FFFAP output are taken from sample problem 5 (Appendix B).

Starburst output pages [Fig. 5 (FFFAP pages 2 and 12)] are simply eye catchers and separators. These pages begin the two primary parts of the FFFAP output. Pages 3-10 contain the user-generated FFFAP libraries in a more readable form than page 1. These libraries are output for two reasons: (1) problem definition and (2) aiding the user in verifying the code input. Figure 6 illustrates the control parameter library output (FFFAP-page 3). Figure 7 presents the chemical component library output (page 4). Figure 8 shows pages 5 and 6 of sample problem 5 (pipe wall component library and experimental data sets, respectively); for this problem, there were no entries for these two libraries. Pages 7 and 8 of the output (Fig. 9) contain the user-specified control volume library. The feed stream specifications are output on pages 9 and 10 (Fig. 10) for the primary and injected feed streams, respectively.

Pages 11 and 13+n (the last page) contain the initial and final state (condition) of the primary feed stream. The initial state of the fluid (page 11) applies at the front face (junction) of the first control volume; this is the initial fluid boundary condition. The final state of the fluid (page 13+n) applies at the rear face of the nth control volume and, thus, is the final state of the fluid for the user-specified problem. If only the initial and final states of the fluid are desired by the user, then pages 11 and 13+n are sufficient; but the user still receives a bonus of n pages of node-to-node calculations. The output format of pages 11 and 13+n is dependent on the state of the fluid, and the examples (Figs. 11 and 12) from sample problem 5 show both extremes. The output for these

FFFAP-VERSION 1.0

Fig. 4. Example of FFFAP page 1 output.

FFFAP-VERSION 1.0

P- 3

```

*****
**                                     **
**      USER SPECIFIED              **
**      PROGRAM CONTROLS            **
**                                     **
*****
    
```

CONTROL VARIABLES ARE SPECIFIED ON CARDS 50002 AND 50003 OF THE USER GENERATED PROGRAM INPUT.

CONTROL VARIABLE	EXPLANATION	STATUS	INPUT VALUE	DEFAULT VALUE
ICS(1) FLASH TECHNIQUE:	=1 LEE/ERBAR/EDMISTER =2 HIGH PRESSURE (PRAUSNITZ)	NOT AVAILABLE	2	2
ICS(2) ENTHALPY CALCULATIONS:	=1 YEN/ALEXANDER =2 HENLEY/SCADER RECOMMENDATION =3 LEE/ERBAR/EDMISTER	NOT AVAILABLE NOT AVAILABLE	1	1
ICS(3) BUBBLE AND DEW POINT CALC:	=1 HIGH PRESSURE (PRAUSNITZ) =2 LEE/ERBAR/EDMISTER	NOT AVAILABLE	1	1
ICS(4) FRICTIONAL CORREL. FOR VERTICAL SLURRY FLOW:	=1 NEWITT =2 TURIAN/YUAN =3 ROSE/DUCKWORTH		2	2
ICS(5) FRICTIONAL CORREL. FOR HORIZONTAL SLURRY FLOW:	=1 NEWITT =2 ROSE/DUCKWORTH =3 ZANDI/GCVATOS =4 TURIAN/YUAN		4	4
ICS(6) FRICTIONAL CORREL. FOR VERTICAL TWO-PHASE FLOW:	=1 ORKISZEWSKI =2 OTHER	NOT AVAILABLE	1	1
ICS(7) FRICTIONAL CORREL. FOR HORIZONTAL TWO-PHASE FLOW:	=1 DUKLER NO.1 =2 DUKLER NO.2 =3 LOCKHART/MARTINELLI =4 OTHER	NOT AVAILABLE	2	2
ICS(8) FRICTIONAL CORREL. FOR SINGLE PHASE FLOW:	=1 FANNING =2 METZNER/REED =3 HARRIS	NOT AVAILABLE NOT AVAILABLE	1	1
ICS(9) LIQUID HOLDUP CORREL. FOR VERTICAL FLOW:	=1 HUGHMARK =2 OTHER	NOT AVAILABLE	1	1
ICS(10) LIQUID HOLDUP CORREL. FOR HORIZONTAL FLOW:	=1 HUGHMARK =2 DUKLER =3 LOCKHART/MARTINELLI		1	1
ICS(11) COMPUTATION OF LIQUID VISCOSITY:	=1 VAN VELZEN AND LETSOU/STIEL =2 USER SUPPLIED SUBROUTINE	NOT AVAILABLE	1	1
ICS(12) COMPUTATION OF LIQUID DENSITY:	=1 CHUEH/PRAUSNITZ =2 USER SUPPLIED SUBROUTINE	NOT AVAILABLE	1	1
ICS(13) COMPUTATION OF INTERFACIAL SURFACE TENSION:	=1 MACLEOD/SUGDEN =2 USER SUPPLIED SUBROUTINE	NOT AVAILABLE	1	1

Fig. 6. Control parameter library output.

 **
 ** CHEMICAL LIBRARY **
 **

THERE IS A TOTAL OF 5 CHEMICAL COMPOUND(S) IN THE CURRENT LIBRARY.

N	INDEX	FORMULA	NAME	MOL.WT.	TCRIT	PCRIT	VCRT	ZCRIT	OMEGA	TBOIL	HFGB	PARACHOR	SOL	VML
1	1	H2	HYDROGEN	2.02	59.8	1PR.0	65.0	0.305	-0.220	36.7	216.0	33.5	3.25	31.0
IDEAL GAS SPEC. HEAT: $CP = 0.64830 \cdot 01 + 0.12310 \cdot 02 \cdot T + -0.10180 \cdot 05 \cdot T^2 + 0.31310 \cdot 09 \cdot T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.138200 \cdot 02 + (1.6/T) - (1.0 / 0.53900 \cdot 01)$ VAPOR PRESSURE EQN: $LN(VP) = 0.136330 \cdot 02 - 0.164900 \cdot 03 / (T + 0.319000 \cdot 01)$ TMIN= 14.0 TMAX= 25.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.														
2	2	CH4	METHANE	16.04	343.1	667.0	99.0	0.288	0.008	201.1	1955.0	74.7	5.68	52.0
IDEAL GAS SPEC. HEAT: $CP = 0.45980 \cdot 01 + 0.69170 \cdot 02 \cdot T + 0.88270 \cdot 06 \cdot T^2 + -0.46350 \cdot 09 \cdot T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.114140 \cdot 03 + (1.6/T) - (1.0 / 0.576000 \cdot 02)$ VAPOR PRESSURE EQN: $LN(VP) = 0.152240 \cdot 02 - 0.897840 \cdot 03 / (T + -0.716000 \cdot 01)$ TMIN= 93.0 TMAX= 120.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.														
3	3	C2H6	ETHANE	30.07	549.7	708.0	148.0	0.285	0.098	332.1	3515.0	110.0	6.05	68.0
IDEAL GAS SPEC. HEAT: $CP = 0.12920 \cdot 01 + 0.23630 \cdot 01 \cdot T + -0.51140 \cdot 05 \cdot T^2 + 0.75680 \cdot 09 \cdot T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.156600 \cdot 03 + (1.6/T) - (1.0 / 0.955700 \cdot 02)$ VAPOR PRESSURE EQN: $LN(VP) = 0.156640 \cdot 02 - 0.151140 \cdot 04 / (T + -0.171600 \cdot 02)$ TMIN= 130.0 TMAX= 190.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.														
4	4	C3H6	PROPENE (PROPYLENE)	42.08	657.0	670.0	181.0	0.275	0.148	405.7	4400.0	139.7	6.43	70.0
IDEAL GAS SPEC. HEAT: $CP = 0.88600 \cdot 00 + 0.31120 \cdot 01 \cdot T + -0.85520 \cdot 05 \cdot T^2 + 0.99300 \cdot 09 \cdot T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.273840 \cdot 03 + (1.6/T) - (1.0 / 0.131630 \cdot 03)$ VAPOR PRESSURE EQN: $LN(VP) = 0.157030 \cdot 02 - 0.180750 \cdot 04 / (T + -0.261500 \cdot 02)$ TMIN= 160.0 TMAX= 240.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.														
5	5	C3H8	PROPANE	44.10	665.6	615.5	203.0	0.281	0.152	416.0	4487.0	143.5	6.40	84.0
IDEAL GAS SPEC. HEAT: $CP = -0.10090 \cdot 01 + 0.40540 \cdot 01 \cdot T + -0.11600 \cdot 06 \cdot T^2 + 0.11170 \cdot 08 \cdot T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.222670 \cdot 03 + (1.6/T) - (1.0 / 0.133410 \cdot 03)$ VAPOR PRESSURE EQN: $LN(VP) = 0.157260 \cdot 02 - 0.187250 \cdot 04 / (T + -0.251600 \cdot 02)$ TMIN= 164.0 TMAX= 240.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.														

Fig. 7. Chemical component library output.

```

*****
**                                     **
**   PIPE WALL COMPONENT LIBRARY   **
**                                     **
*****
  
```

THERE IS A TOTAL OF 0 PIPE WALL COMPONENTS IN THE CURRENT LIBRARY.

N	INDEX	NAME	THERMAL CONDUCTIVITY	TEMPERATURE	FIT
---	-------	------	----------------------	-------------	-----

```

*****
**                                     **
**   EXPERIMENTAL DATA SETS     **
**                                     **
*****
  
```

THERE IS A TOTAL OF 0 EXPERIMENTAL DATA SET(S) IN THE CURRENT JOB INPUT.

N	NODE	PRESSURE	TEMPERATURE	FLOW	DENSITY
---	------	----------	-------------	------	---------

Fig. 8. Pipe wall component library and experimental data sets output pages.

MODEL GEOMETRY AND NODING

THERE IS A TOTAL OF 20 CONTROL VOLUMES IN THE CURRENT MODEL.

NOCE	X	Y	Z	JI	JO	FAI	FAO	WPI	WPO	ANGI	KI	ANGO	KO	EODI	EODO	DLI	DLO
1	110.0	0.0	0.0	1	2	12.750	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
2	330.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
3	556.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
4	770.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
5	990.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
6	1210.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
7	1325.3	0.0	2.2	1	6	12.730	20.006	12.648	15.856	22.5	0.135	67.5	0.135	0.00036	0.00036	110.0	110.0
8	1327.5	0.0	12.0	5	6	20.006	20.006	15.856	15.856	90.0	0.0	90.0	0.0	0.00036	0.00036	112.5	112.5
9	1327.5	0.0	345.0	5	6	20.006	20.006	15.856	15.856	90.0	0.0	90.0	0.0	0.00036	0.00036	112.5	112.5
10	1327.5	0.0	570.0	5	6	20.006	20.006	15.856	15.856	90.0	0.0	90.0	0.0	0.00036	0.00036	112.5	112.5
11	1327.5	0.0	795.0	5	6	20.006	20.006	15.856	15.856	90.0	0.0	90.0	0.0	0.00036	0.00036	112.5	112.5
12	1329.7	0.0	912.8	5	6	20.006	20.006	15.856	15.856	67.5	0.034	22.5	0.034	0.00036	0.00036	112.5	112.5
13	1447.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5
14	1672.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5
15	1897.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5
16	2122.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5
17	2347.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5
18	2572.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5
19	2797.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5
20	3022.5	0.0	915.0	1	2	20.006	20.006	15.856	15.856	0.0	0.0	0.0	0.0	0.00036	0.00036	112.5	112.5

MODEL GEOMETRY AND NODING (CONTINUED):

NODE	KADBTC	KEXDTS	KIFLWS	MCPNTS	KPCCTP
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

Fig. 9. Control volume library output.

 ** PRIMARY AND INJECTED FEED STREAMS **

PRIMARY FEED STREAM:
 THERE IS A TOTAL OF 3 CHEMICAL COMPOUNDS IN THE CURRENT MODEL.
 FEED STREAM TEMPERATURE = 25.0 DEG F
 FEED STREAM PRESSURE = 100.0 PSIA

N	INDEX	FORMULA	USER CHEMICAL NAME	MASS FLOW RATE
1	3	C2H6	ETHANE	80.00
2	4	C3H6	PROPENE (PROPYLENE)	400.00
3	5	C3H8	PROPANE	320.00

INJECTED FEED STREAMS:

THERE IS A TOTAL OF 1 INJECTED FEED STREAMS IN THE CURRENT MODEL.

STREAM NO. 1 IS INJECTED IN NODE 12 AND HAS A TOTAL OF 2 CHEMICAL COMPOUNDS.
 STREAM TEMPERATURE = 30.0 DEG F
 STREAM PRESSURE = 100.0 PSIA

N	INDEX	FORMULA	USER CHEMICAL NAME	MASS FLOW RATE
1	4	C3H6	PROPENE (PROPYLENE)	100.00
2	5	C3H8	PROPANE	100.00

Fig. 10. User-specified feed streams.

 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 25.0 DEG F
 PRESSURE OF THE FEED STREAM = 100.00 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 28.2 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 43.1 DEG F

STATE OR CONDITION OF THE FEED STREAM : SURCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.66 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 52.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000058 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

Fig. 11. Initial state of the feed stream.

**
** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
**

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LEMOLE/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	83.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	590.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3959

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
TEMPERATURE OF THE FEED STREAM = 22.7 DEG F
PRESSURE OF THE FEED STREAM = 84.14 PSIA
BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 21.3 DEG F
DEW POINT TEMPERATURE OF THE FEED STREAM = 34.8 DEG F

THE FEED STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	-----LIQUID-----				-----VAPOR-----			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LEMOLE/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LEMOLE/MIN)	MOLE FRACTION
ETHANE	69.67	0.0730	2.317	0.1012	10.33	0.2254	0.344	0.2925
PROPENE (PROPYLENE)	479.22	0.5022	11.383	0.4974	20.78	0.4535	0.494	0.4211
PROPANE	405.28	0.4248	9.191	0.4014	14.72	0.3211	0.334	0.2846

TOTAL LIQUID MASS FLOW RATE = 954.17 LBS/MIN
TOTAL VAPOR MASS FLOW RATE = 45.83 LBS/MIN
WEIGHT FRACTION OF THE FEED STREAM THAT IS VAPOR = 0.0458
HEAT CONTENT OF THE LIQUID = -149061.88 BTU/MIN = -156.22 BTU/LB
HEAT CONTENT OF THE VAPOR = -24.00 BTU/MIN = -0.52 BTU/LB
TOTAL HEAT CONTENT OF THE STREAM = -149085.87 BTU/MIN = -149.09 BTU/LB

LIQUID DENSITY = 33.09 LBM/CU.FT.
LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
LIQUID MEAN MOLECULAR WEIGHT = 41.678

VAPOR DENSITY = 0.7083 LBM/CU.FT.
VAPOR VISCOSITY = 0.557180-05 LBM/FT*SEC = 0.829140-02 CP
VAPOR MEAN MOLECULAR WEIGHT = 39.077
VAPOR COMPRESSIBILITY FACTOR = 0.8969

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.559050-03 LBF/FT = 8.741 DYNE/CM

IHC0021 STCP 0

Fig. 12. Final state of the feed stream.

pages generally takes the following form:

Page 12 is a starburst that signals the beginning of the node-by-node thermal-hydraulic analysis of the user-specified model. Each subsequent page contains a complete analysis for the user-specified control volumes. Two examples of the output are given in Figs. 13 and 14 (for the first and last control volumes in sample problem 5). Again the output format is dependent on the state of the fluid (at the specified control volume center), and the output generally takes the following form:

FFFAP-VERSION 1.0

CONTROL VOLUME (NODE) NO. 1

P- 13

INLET FACE = 1
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

OUTLET FACE = 2
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 110.0000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 0.0 IN.
 I FLOW LENGTH I FLOW LENGTH I
 I 110.0000IN I 110.0000IN I

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	430.00	0.5000	42.08	9.505	0.4994
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 99.97 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 28.1 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 43.0 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.66 BTU/MIN = -140.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000066 LBM/FT.SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	100.00	99.97	99.93
TEMPERATURE (F)	25.00	25.00	25.00
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	4.61
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	4.61
PRESSURE DROP (PSIA)	0.03	0.03	0.03
FRICTION	0.03	0.03	0.03
ACCELERATION	0.12550-16	-0.25380-06	0.0
POTENTIAL	0.0	0.0	0.0

Fig. 13. Example of nodal analysis (fluid, single-phase).

FFFAP-VERSION 1.0

CONTROL VOLUME (NODE) NO. 20

INLET FACE = 1
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 3022.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 15.0000 IN.

FLOW LENGTH	FLOW LENGTH
112.5000 IN	112.5000 IN

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	50.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 22.7 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.19 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.3 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 34.8 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.69	0.0730	2.318	0.1012	10.31	0.2254	0.443	0.2829
PROPENE (PROPYLENE)	479.27	0.5022	11.389	0.4974	20.73	0.4535	3.493	0.4211
PROPANE	405.32	0.4247	9.192	0.4014	14.63	0.3211	0.333	0.2845

TOTAL LIQUID MASS FLOW RATE = 954.28 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 45.72 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0457
 HEAT CONTENT OF THE LIQUID = -149062.18 BTU/MIN = -156.20 BTU/LB
 HEAT CONTENT OF THE VAPOR = -23.57 BTU/MIN = -0.52 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149085.74 BTU/MIN = -149.69 BTU/LB

LIQUID DENSITY = 33.08 LBM/CU. FT.
 LIQUID VISCOSITY = 0.006670 LBM/FT. SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.478

VAPOR DENSITY = 0.7687 LBM/CU. FT.
 VAPOR VISCOSITY = 0.557230 LBM/FT. SEC = 0.029210-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.076
 VAPOR COMPRESSIBILITY FACTOR = 0.8444

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.598870-03 LBF/FT = 9.733 DYNE/CM

	CONTROL VOLUME		
	FACE	CENTER	FACE
PRESSURE (PSIA)	84.24	84.19	84.14
TEMPERATURE (F)	22.76	22.73	22.70
S. VAPOR VELOCITY (FT/SEC)	7.72	7.72	7.76
S. LIQUID VELOCITY (FT/SEC)	3.46	3.46	3.46
S. LIQUID/SGLID VELOCITY (FT/SEC)	3.46	3.46	3.46
PRESSURE DROP (PSIA)	0.05	0.05	0.05
FRICTION	0.05	0.05	0.05
ACCELERATION	0.23610-02	0.23680-02	0.23680-02
POTENTIAL	0.0	0.0	0.0

Fig. 14. Example of nodal analysis (fluid, two-phase).

the normal nodal output, the state(s) of the injected feed stream and the combined streams is also output for that control volume (an example of this situation is shown on page 24 of the case 5 output).

4.4 Code Applications

Version 1.0 of FFFAP can be used to analyze multicomponent, multiphase, Newtonian, adiabatic flow behavior in piping systems. The fluid may be single-phase (vapor or liquid), may contain solids, may be flashing (vaporizing), and there may be injected side streams. Although the specific application objective for this code is the high-pressure coal liquefaction letdown process, the code is generalized and can be applied to any piping and fluid system. In the future, the Newtonian and adiabatic restrictions will be removed by proposed model improvements and a subsequent FFFAP version.

However, the universal applicability of FFFAP is questionable because most of the correlations (physical property and thermodynamic) apply to nonpolar compounds. For instance, the results from the code in an application to a water or methanol flow system should be considered suspect until it can be verified experimentally or by some other means.

The code applicability will be demonstrated via five sample problems. The piping system to be studied is relatively simple (a schematic of the system is shown in Fig. 15). Flow in the system is from point 1 to point 2 (Fig. 15), and the fluid is a mixture of ethane, propene, and propane. The five case descriptions are given in Table 6. The initial boundary conditions for the fluid at point 1 in Fig. 15 are known and are given in Table 6. The only difference between cases 1-4 is the initial temperature of the fluid. Case 5 contains an additional twist: the initial conditions at point 1 are the same as for case 4, but a side stream has been introduced into the upper elbow in the piping system. The primary objective in these sample problems will be to determine the overall pressure drop between points 1 and 2 (Fig. 15) and to determine the final state of the fluid at point 2.

In these sample problems, 20 control volumes (nodes) are used to represent the piping system in Fig. 15. The noding representation of the

Table 6. Sample problem descriptions from piping system (Fig. 15)

Case No.	Fluid	Injected fluid	Condition of feed at $\triangle 1$	Condition of injected feed
1	α	None	Subcooled liquid at 258.2 K and 689.5 kPa (5°F and 100 psia)	N/A
2	α	None	Superheated vapor at 283.2 K and 689.5 kPa (50°F and 100 psia)	N/A
3	α	None	Two-phase mixture at 273.7 K and 689.5 kPa (33°F and 100 psia)	N/A
4	α	None	Subcooled liquid at 269.3 K and 689.5 kPa (25°F and 100 psia)	N/A
5	α	b	Subcooled liquid at 269.3 K and 689.5 kPa (25°F and 100 psia)	Subcooled liquid at 272 K and 689.5 kPa (30°F and 100 psia)

α Ethane - 0.605 kg/s (80 lb/min)
 Propene - 3.024 kg/s (400 lb/min)
 Propane - 2.419 kg/s (320 lb/min)

b Propene - 0.756 kg/s (100 lb/min)
 Propane - 0.756 kg/s (100 lb/min)

Note: In case 5, the injected fluid is introduced into the piping system in the 5-in. welding elbow.

Fig. 15. Piping system for sample problems.

piping system is shown in Fig. 16. The code input for cases 1-4 is exactly the same except for the primary feed stream temperature. Because there are 20 control volumes in the model, there would be 33 total pages of FFFAP output for each sample problem. For case 5, the complete FFFAP-Version 1.0 output (all 33 pages) will be given in Appendix B.7; however, for the remaining cases only pages 11 and 33 of the FFFAP output will be presented, because these pages contain the initial and final states of the fluid in the system.

In case 1, the fluid is ~ 12.8 K (23°F) subcooled initially and remains subcooled throughout the piping system. The initial and final states of the fluid (points 1 and 2 in Fig. 15, respectively) from the FFFAP output for this case are presented in Appendix B.3. In summary, a pressure drop of 128 kPa (18.6 psi) and a temperature drop of ~ 0.39 K (0.7°F) occur between points 1 and 2 for case 1.

In case 2, the fluid is ~ 3.6 K (6.5°F) superheated initially and, like the fluid in case 1, remains single-phase through the system. The FFFAP results (pages 11 and 33) are given in Appendix B.4. For this case, there is an overall pressure drop of 242.7 kPa (35.2 psi) and a temperature drop of 2.39 K (4.3°F).

At the initial conditions of 273.7 K (33°F) and 689.5 kPa (100 psia), the fluid in case 3 is two-phase, and the weight fraction of the feed

Fig. 16. Control volume representation of piping system for sample problems.

stream is vapor equal to 0.1628. There is an overall pressure loss of 155.8 kPa (22.6 psi), a temperature drop of 8.1 K (14.6°F), and an increase in the fraction vaporized to 0.2064. The FFFAP results (pages 11 and 33) are given in Appendix B.5.

In case 4, the fluid is ~ 1.8 K (3.2°F) subcooled initially and remains subcooled until control volume 9 (Fig. 16), where the computed bubble-point temperature falls below the primary stream temperature and flashing occurs. Flashing initiates in node 9 and additional vaporization continues through node 20. The initial and final states of the fluid for case 4 are presented in Appendix B.6. Overall, there is a pressure drop of ~ 107.6 kPa (15.6 psi), a temperature drop of 3.1 K (5.6°F), and a weight fraction vaporized of 0.054.

The initial set-up for case 5 is the same as for case 4. In fact, the calculational results are the same through control volume 11; however, an injected side stream is then introduced into control volume 12, thus causing differences in case 4 and 5 calculations downstream of control volume 12. The complete 33-page FFFAP output for this case is given in Appendix B.7.

Hopefully, the versatility, capability, and applicability of FFFAP have been demonstrated via these sample problems.

In anticipation of reader comments about the sample problems, the following observations can be made:

1. the sample problem piping system is relatively simple (i.e., no valves, orifices, etc.);
2. the sample problems are at a relatively low pressure;
3. even though it is a multicomponent system, the fluid is still relatively simple (i.e., compared with a coal liquefaction fluid).

These statements are all true, but what has been attempted in this phase of the work is to demonstrate the capability of FFFAP-Version 1.0. The intent of the next phase of the work is to apply FFFAP (maybe with model improvements) to more complex geometries (i.e., valves and orifices) and to model existing (or past) high-pressure coal liquefaction letdown systems (Chaps. 5 and 6).

4.5 Code Verification

Currently, two approaches have been taken to verify the computations of FFFAP-Version 1.0. The first is the validation of the individual FFFAP modules. The second is the comparison of FFFAP results with alternative program results or hand calculations. However, no alternative computer programs do the same calculations as FFFAP.

As noted in Sect. 4.1 (code description), FFFAP consists of 36 modules, each of which is designed primarily for one function. This approach has allowed the validation of each individual module over the full range of the input parameters to the module. In other words, when a module has been developed, it is rather simple to develop a driving routine to check the module over the full range of the module's required input parameters and then compare the results with known data. For example, the FICFAC module (Table 3) that determines the Fanning friction factor, given a Reynolds number and a relative roughness factor, was verified by developing a routine that used FICFAC to determine the friction factor for eight roughness factors over the Reynolds number range of 100 – 10^9 ; the results from this routine were then compared with existing data (Moody chart). A plot of the results from this routine is shown in Fig. 17.

Fig. 17. Fanning friction factor as a function of Reynolds number and relative roughness.

Similarly, the horizontal slurry pressure-drop correlations were reviewed and a plot of those results is shown in Fig. 18. Each routine (module) in FFFAP-Version 1.0 has been verified in this manner.

Even though each module may be verified as described previously, the integration of these individual routines into a large complex code such as FFFAP can create many additional problems. Once the large code (FFFAP) has been generated, it too must be verified. Ideally, this would be experimental verification (which hopefully will be done in the future). Lacking experimental verification, the next best validation tool would be another code that can solve a similar problem — none exists. Therefore, the verification technique used for FFFAP-Version 1.0 is the classical hand calculation. "Hand calculation" is used rather loosely here because a great deal of hand calculator use is required. Computational techniques as outlined in Crane³⁹ will be used for compressible and noncompressible flow configurations.

Three FFFAP case results (for sample problems 1-3) given in Sect. 4.4 and Appendix B will be compared with the hand calculations. In case 1, the fluid is subcooled 12.8 K (~23°F) throughout the system, the temperature drop is ~0.39 K (0.7°F), and the fluid density is approximately constant; therefore, the incompressible flow equations from Crane³⁹ should

Fig. 18. Pressure-drop correlations for slurry flow in horizontal pipes.

give very similar results to FFFAP. A comparison of the results is shown in Table 7.

The fluid in case 2 is ~ 3.6 K (6.5°F) superheated initially and remains one-phase throughout the system; however, the fluid temperature drops 2.39 K (4.3°F), the density decreases by $\sim 38\%$, and the gas compressibility factor ranges from 0.88 to 0.93. Among other assumptions, the compressible equation developed in Crane assumes (1) isothermal flow, and (2) that the gas obeys the perfect gas laws. Therefore, the comparison should not be as close as for case 1; but the results should be reasonably similar. The results are compared in Table 8.

In sample problem 3, the fluid is two-phase throughout the system with the weight fraction vaporized ranging from 0.1628 to 0.2064. Techniques suggested by Atherton and DeGance²⁴ were used to perform the hand calculations. The results are compared in Table 9.

Table 7. Comparison of pressure-drop calculations for sample problem 1

	Hand calculations [kPa (psi)]	FFFAP [kPa (psi)]
Potential loss	123.4 (17.90)	123.3 (17.88)
Acceleration loss	-0.3 (-0.04)	-0.3 (-0.04)
Frictional loss	4.7 (0.69)	4.6 (0.66)
Overall pressure drop	127.8 (18.55)	127.6 (18.50)

Table 8. Comparison of pressure-drop calculations for sample problem 2

	Hand calculations [kPa (psi)]	FFFAP [kPa (psi)]
Potential loss	2.3 (0.34)	2.2 (0.32)
Acceleration loss	3.2 (0.46)	1.0 (0.14)
Frictional loss	255.7 (37.08)	239.6 (34.75)
Overall pressure drop	261.2 (37.88)	242.8 (35.21)

Table 9. Comparison of pressure-drop calculations for sample problem 3

	Hand calculations [kPa (psi)]	FFFAP [kPa (psi)]
Potential loss	72.4 (10.50)	72.3 (10.49)
Acceleration loss	0.7 (0.10)	0.5 (0.07)
Frictional loss	103.8 (15.06)	82.9 (12.02)
Overall pressure drop	176.9 (25.66)	155.7 (22.58)

In reviewing the comparisons, the following points should be considered:

1. In the hand calculations, the system (Fig. 15) was broken down into two horizontal runs and one vertical run; mean properties and flows were used in the computations. The results from each section were combined into the loss terms shown in the tables.

2. FFFAP used more control volumes (20) to represent the system and an iterative technique that included changes in physical properties and weight fraction vaporized for pressure convergence (from junction face to node center and from node center to junction face).

Thus, the hand calculations must be considered coarser than the FFFAP computations; even so, the comparisons are reasonably close enough to give credence to the results generated by FFFAP. Ultimate verification of FFFAP will have to be done experimentally.

5. FUTURE MODEL IMPROVEMENTS

As noted previously, FFFAP-Version 1.0 is a preliminary version of the engineering model and the code. Primarily because of time constraints, some desired features (such as the nonadiabatic and non-Newtonian capabilities) have not been verified and included in the model and the code. Future efforts will include removing many of the limitations and assumptions (Sect. 3.3) imposed on the engineering model and this release of FFFAP.

FFFAP-Version 1.0 is currently limited to Newtonian fluids. Implications are made in Tables 1 and 4 that efforts are under way to remove this restriction. For instance, the purposes of one of the control parameters (No. 11, Table 4) is to signal the internal code logic that the user has supplied a module that will compute the apparent liquid viscosity. This module (to be coded by the user) could describe a power-law fluid, a Bingham plastic, or a model of the user's choice; it could be a function of shear rate, temperature, and pressure. For the criteria of turbulence for power-law slurries, the approach by Metzner and Reed⁴⁰ will be used; to account for the settling nature of the slurry, a correlation by Harris and Quader⁴¹ may be used.

The next major restriction in FFFAP-Version 1.0 is that the process is adiabatic. The framework exists within the current version of FFFAP to solve the nonadiabatic problem within a control volume. What is lacking is the capability to compute a heat transfer coefficient at the control volume inner wall. Not only are heat transfer correlations required but also correlations for fluid heat capacity and thermal conductivity. Neither the heat transfer nor the physical property correlations exist in FFFAP-Version 1.0; they would need to be added.

Most of the physical property correlations that are in FFFAP are based on corresponding states theory. If experimental data were available, preferably, the user would supply the code with that data. Provisions will be made to allow the user to specify experimentally available liquid density, viscosity, liquid/gas interfacial surface tension, and vaporization equilibrium ratios via user-supplied FFFAP modules.

Currently, the user has a fair degree of flexibility in the hydrodynamic relationships (Table 2) that are employed in a problem to be solved by FFFAP. However, the user is not given much choice in the physical property and thermodynamic relationships (Table 1) that are used. More user flexibility is needed in this area, and proposed correlations for addition to FFFAP are listed in Table 1.

The points made in the preceding four paragraphs will probably be given first priority in future efforts, but the following are additional concerns (assumptions) that should be reviewed when the time and funds become available:

1. the assumption that the fluid is homogeneous (i.e., no slip), and
2. the assumption that the gas and liquid streams are in thermodynamic equilibrium.

The model and code are presently one-dimensional. If the effects of solids erosion in coal liquefaction letdown valves are given due study, then it would be preferable to know (at least) the two-dimensional flow fields (patterns) in the valve. So far, a simplified particle trajectory approach has been taken, but this area (i.e., particle erosion) needs more study and possibly a more rigorous engineering model.

On the subject of future model improvements, current recommendations cannot be made to the user about FFFAP modeling techniques or the use of a specific physical property, thermodynamic, or hydrodynamic relationships. These suggestions can only come from attempts to model an experimental flow system. Given an experimental apparatus, the code could be verified, different modeling techniques could be tried, and the physical property, thermodynamic, and hydrodynamic relationships could be studied. Then, positive recommendations could be made to the user on modeling methods and preferred correlations.

6. CONCLUSIONS AND RECOMMENDATIONS

A preliminary engineering model and computer code (FFFAP-Version 1.0) have been developed for use in the analysis of multicomponent, multiphase, flashing, flowing systems. This model and code were developed with intended application to coal liquefaction high-pressure letdown systems. The code is highly generalized; although it was designed for the analysis of coal liquefaction letdown systems, it can be applied to any piping system with any fluid constituents.

A general description of the model, its limitations, and the physical property, thermodynamic, and fluid-dynamic relationships employed in the model are presented. A fairly detailed description of the preliminary computer code is given, and the applicability of the code is illustrated by five sample problems that range from single-phase flow to flashing multicomponent flow with injected side streams.

These are preliminary versions of the model and the code; because of time constraints, some desired features (such as nonadiabatic, non-Newtonian capabilities) have not been verified and included in this version of the code. Future model improvements (such as the inclusion of the nonadiabatic, non-Newtonian capabilities) are suggested. Also, the point is made that verifying the code and testing various modeling techniques, can best be done with an experimental system.

The next phase of the work should be to apply the code (maybe with model improvements) to more complex geometries (valves and orifices) and to model existing (and past) high-pressure coal liquefaction letdown systems.

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Appendix A

DETAILED CODE INPUT DESCRIPTION

This appendix could be used as an abbreviated user input guide to FFFAP; however, it is intended to illustrate instead the structure of the code input in more detail than was given in Sect. 4.2. The primary information blocks and the required order in the user-generated input are shown in Fig. A.1. As noted in Sect. 4.3, the INPUT module in FFFAP checks the order of the input stream (that is, it checks for the required sequence of the card images); if it finds card images out of sequence, the code will terminate the job at that point. Each card image uses the first ten columns for identification information: the first four columns are alphanumeric and are primarily used to identify libraries (the blocks in Fig. A.1); the next six columns contain a six-digit sequential identifier that INPUT uses to check the order. An example of a code input deck is given in Appendix B.2.

The card image construction for the FFFAP user-defined input stream is illustrated on pages 60 and 61. At the top of each page (below the heading) is a line showing the 80-column field width of a card image. The

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Fig. A.1. Outline of FFFAP user input requirements.

remainder of each page (60 and 61) contains the card images required and the input variables required for each card. The blocks in the outline in Fig. A.1 can be identified on pages 60 and 61 by the three letters beginning each card and by Table A.1.

Table A.1. FFFAP input blocks
and card identifiers

Block ^a	Card identifier ^b
Problem heading	HDR
Program controls	CTI
Control volume specification	NOD
Chemical component specification	CHE
Wall component specification	WAL
Primary feed specification	FED
Injected feed specification	IFD
Experimental data	DAT

^aFig. A.1.

^bPages 60 and 61.

The variable definitions (descriptions) for the control volume specification block (cards 100000-1XXX1J) are given on pages 62 and 63. Line 100000 appears only once and initiates the user-defined control volume information section. Line 100001 appears only once and defines the number of control volume modules (lines 1XXX00-1XXX1J) to be read (i.e., it is the total number of control volumes used by the user to model a flow system). Lines 1XXX00-1XXX03 are required for each control volume and lines 1XXX04 and 1XXX10-1XXX1J are optional for each control volume (included only if KADBTC is nonzero).

The chemical library variable definitions (cards 200000-20XX07) are given on page 64. Line 200000 appears only once and initiates the user chemical library section of the input. Line 200001 appears only once and defines the number of chemical compound modules (lines 20XX00-20XX07) to be read. See page 68 for other pertinent notes on the chemical library input.

The wall component library variable definitions (cards 250000-25YY01) are given on page 65. Lines 250000 and 250001 appear only once. These lines initiate the user wall component library input section and define the number of wall material modules (lines 25YY00 and 25YY01) to be read.

The primary and injected feed stream variable definitions (cards 300000-30000J and 350000-35ZZ0J) are given on page 66. Line 300000 appears once and initiates the user-defined feed stream specification section. Line 300001 appears once and defines the number of chemical compounds in the feed stream and specifies the feed stream temperature and pressure. Lines 300002-3000JJ fully define the feed stream composition by specifying the components in the stream and their mass flow rates. Line 350000 appears only once and initiates the user-defined injected feed stream specification section. Line 350001 appears only once and defines the number of injection feed stream modules (lines 35ZZ00-35ZZJJ) to be read.

The experimental data variable definitions (cards 400000-4001JJ) are given on page 67. Line 400000 appears only once and initiates the user-defined experimental data specification section. Line 400100 appears only once and defines the number of experimental data sets (lines 400101-4001JJ) to be read.

A summary of pertinent notes related to the user-defined input stream is given on page 68.

Line 999999 appears only once and defines the last line of user input.

*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
 *** USER-DEFINED INPUT STREAM ***
 *** THE LINE/FIELD COLUMN CONSTRUCTION ***

1 2 3 4 5 6 7 8
 0 0 0 0 0 0 0 0
 - - - - -

HDR 50000 HEADER AND CONTROL INFORMATION

HDR 50001 HEADER-----

CTL 50002 ICS(1) ICS(2) ICS(3) ICS(4) ICS(5) ICS(6) ICS(7)

CTL 50003 ICS(8) ICS(9) ICS(10) ICS(11) ICS(12) ICS(13) ICS(14)

NOD 100000 CONTROL VOLUME INFORMATION

NOD 100001 NTOTAL

NOD 1XXX00

NOD 1XXX01 XNCNTR YNCNTR ZNCNTR KA0BTC KEXDTS KIFLWS

NOD 1XXX02 IJCTNI FAREAI WPMTRI ANGI RESI RLRGHI DLTALI PIPIRI

NOD 1XXX03 IJCTNO FAREAO WPMTRO ANGO RESO RLRGHO DLTALO PIFIRO

NOD 1XXX04 NCPNTS KBCTYP TEFLUX HTCEXT TSNKEX

NOD 1XXX10

NOD 1XXX11 IDXCP1 THKCP1 CTCRS1

*
*
*

NOD 1XXX1J IDXCPJ THKCPJ CTCRSJ

CHE 200000 CHEMICAL LIBRARY

CHE 200001 NTCHEM

CHE 20XX00 MINDXJ FRMULA--CHMNAM----- INTRAC IVAPCR

CHE 20XX01 AMOLWT TCRIT PCRIT VCRIT ZCRIT

CHE 20XX02 ACENTR TBOIL DHVB PARCLR SOL VML

CHE 20XX03 CPA CPB CPC CPD

CHE 20XX04 ANUB ANUTO

CHE 20XX05 ANTA ANTB ANTC ANTTMN ANTTMX

CHE 20XX06 I1 C(,I1) I2 C(,I2) I3 C(,I3) I4 C(,I4) I5 C(,I5) I6 C(,I6) I7 C(,I7)

*
*
*

CHE 20XX06 I1 C(,I1) I2 C(,I2) I3 C(,I3) I4 C(,I4) I5 C(,I5) I6 C(,I6) I7 C(,I7)

CHE 20XX07 PDIA PDENS PCPA PCPB PCPC

*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
 *** USER-DEFINED INPUT STREAM ***
 *** THE LINE/FIELD COLUMN CONSTRUCTION ***

1	2	3	4	5	6	7	8
0	0	0	0	0	0	0	0

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WAL 250000                                WALL MATERIAL LIBRARY
WAL 250001      NTWALL
WAL 25YY00      NINDXJ  WALNAM-----
WAL 25YY01      AK1      AK2      AK3      AK4      AK5
FED 300000                                FEED STREAM COMPOSITION AND CONDITION
FED 300001      NFEEED      FTEMP      FPRESS
FED 300002      IFEEED1      FLOW1
*
*
FED 30000J      IFEEEDJ      FLOWJ
IFD 350000                                INJECTED STREAM POSITION, COMPOSITION AND CONDITION
IFD 350001      INJECT
IFD 352200      INODEK      IFEEKK      ATEMPK      APRCSK
IFD 352201      JFEED1      AFLOW1
*
*
IFD 35220J      JFEEDJ      AFLOWJ
DAT 400000                                EXPERIMENTAL DATA RESULTS
DAT 400100      NEXDAT
DAT 400101      NODE1      PREAD1      TREAD1      VREAD1      DREAD1
*
*
DAT 40010J      NODEJJ      PREADJ      TREADJ      VREADJ      DREADJ
END 999999
  
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*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
*** THE USER-DEFINED INPUT STREAM ***
*** CONTROL VOLUME INFORMATION SECTION ***
*** THE REQUIRED CONTROL VOLUME VARIABLE DESCRIPTIONS ***

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```

NTOTAL    THE TOTAL NUMBER OF CNTRL-V'S COMPRISING THE CURRENT MODEL /
           1 .LE. NTOTAL .LE. 499 /
           DIMENSIONLESS /

XXX       THE SEQUENTIAL CNTRL-V IDENTIFIER ( INCREMENTED BY 1 ) /
           1 .LE. XXX .LE. NTOTAL /
           DIMENSIONLESS /

XNCNTR    THE CNTRL-V NODAL GEOMETRIC CENTER X-AXIS LOCATION /
           0.0 .LE. XNCNTR /
           IN /

YNCNTR    THE CNTRL-V NODAL GEOMETRIC CENTER Y-AXIS LOCATION /
           0.0 .LE. YNCNTR /
           IN /

ZNCNTR    THE CNTRL-V NODAL GEOMETRIC CENTER Z-AXIS LOCATION /
           0.0 .LE. ZNCNTR /
           IN /

KADBTC    THE CNTRL-V CONDUCTIVE THERMAL ENERGY LOSS OR GAIN PARAMETER /
           0 .EQ. KADBTC -- ADIABATIC CNTRL-V PROCESS /
           1 .EQ. KADBTC -- NON-ADIABATIC CNTRL-V PROCESS /
           DIMENSIONLESS /

KEXDTS    THE CNTRL-V EXPERIMENTAL DATA SET PARAMETER /
           0 .EQ. KEXDTS -- CNTRL-V INSTRUMENT RESPONSES UNAVAILABLE /
           1 .EQ. KEXDTS -- CNTRL-V INSTRUMENT RESPONSES AVAILABLE /
           DIMENSIONLESS /

KIFLWS    THE CNTRL-V INJECTED FLOW SET PARAMETER /
           0 .EQ. KIFLWS -- NO INJECTED FLOWS /
           1 .EQ. KIFLWS -- INJECTED FLOWS /
           DIMENSIONLESS /

IJCINI    THE CNTRL-V INLET JUNCTION SEQUENTIAL IDENTIFIER /
           1 .LE. IJCINI .LE. 5 /
           DIMENSIONLESS /

FAREAI    THE CNTRL-V INLET JUNCTION FLOW AREA /
           0.0 .LE. FAREAI /
           IN .IN /

WPMTRI    THE CNTRL-V INLET JUNCTION WETTED PERIMETER /
           0.0 .LE. WPMTRI /
           IN /

ANGI      THE CNTRL-V INLET ANGLE RELATIVE TO THE HORIZONTAL /
           DEGREES /

RESI      THE CNTRL-V INLET JUNCTION ASSOCIATED FLOW RESISTANCE COEFF. /
           0.0 .LE. RESCFI /
           DIMENSIONLESS /

RLRGHI    THE CNTRL-V INLET JUNCTION ASSOCIATED RELATIVE ROUGHNESS /
           0.0 .LE. RLRGHI /
           DIMENSIONLESS /

DLTALI    THE CNTRL-V INLET JUNCTION ASSOCIATED FLOW LENGTH /
           0.0 .LE. DLTALI /
           IN /

PIPIRI    THE CNTRL-V INLET JUNCTION PIPE INTER RADIUS /
           0.0 .LE. PIPIRI / IN /

IJCINO    THE CNTRL-V OUTLET JUNCTION SEQUENTIAL IDENTIFIER /
           1 .LE. IJCINO .LE. 5 /
           DIMENSIONLESS /

FAREAO    THE CNTRL-V OUTLET JUNCTION FLOW AREA /
           0.0 .LE. FAREAO /
           IN .IN /

WPMTRO    THE CNTRL-V OUTLET JUNCTION WETTED PERIMETER /
           0.0 .LE. WPMTRO /
           IN /

ANGO      THE CNTRL-V OUTLET ANGLE RELATIVE TO THE HORIZONTAL /
           DEGREES /

RESO      THE CNTRL-V OUTLET JUNCTION ASSOCIATED FLOW RESISTANCE COEFF. /
           0.0 .LE. RESCFO /
           DIMENSIONLESS /

RLRGHO    THE CNTRL-V OUTLET JUNCTION ASSOCIATED RELATIVE ROUGHNESS /
           0.0 .LE. RLRGHO /
           DIMENSIONLESS /

DLTALO    THE CNTRL-V OUTLET JUNCTION ASSOCIATED FLOW LENGTH /
           0.0 .LE. DLTALO /
           IN /

PIPIRO    THE CNTRL-V OUTLET JUNCTION PIPE INTER RADIUS /
           0.0 .LE. PIPIRO / IN /

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*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
*** THE USER-DEFINED INPUT STREAM ***
*** CONTROL VOLUME INFORMATION SECTION ***
*** THE OPTIONAL CONTROL VOLUME VARIABLE DESCRIPTIONS ***

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```

NCPNTS  THE NUMBER OF CNTRL-V WALL COMPONENTS ( LAYERS ) /
        1 .LE. NCPNTS .LE. 9 /
        DIMENSIONLESS /
KBCTYP  THE NON-ADIABATIC PROCESS BOUNDARY CONDITION TYPE /
        0 .EQ. KBCTYP -- INCORPORATE TEFLUX /
        1 .EQ. KBCTYP -- INCORPORATE HTCEXT AND TSNKEX /
        DIMENSIONLESS /
TEFLUX  THE THERMAL ENERGY FLUX BOUNDARY CONDITION /
        0.0 .GT. TEFLUX -- THERMAL ENERGY WITHDRAWN FROM CNTRL-V /
        0.0 .LE. TEFLUX -- THERMAL ENERGY SUPPLIED TO CNTRL-V /
        BTU/(MIN.IN.IN) /
HTCEXT  THE EXTERIOR HEAT TRANSFER COEFFICIENT BOUNDARY CONDITION /
        0.0 .LE. HTCEXT /
        BTU/(MIN.F.IN.IN) /
TSNKEX  THE EXTERIOR AMBIENT TEMPERATURE BOUNDARY CONDITION /
        0.0 .LE. TSNKEX /
        F /
IDXCPJ  THE MATERIAL INDEX FOR CNTRL-V WALL COMPONENT J /
        001 .LE. IDXCPJ .LE. 010 / 1 .LE. J .LE. NCPNTS /
        DIMENSIONLESS /
THKCPJ  THE THICKNESS OF CNTRL-V WALL COMPONENT J /
        0.0 .LE. THKCPJ / 1 .LE. J .LE. NCPNTS /
        IN /
CTCRSJ  THE CONTACT RESISTANCE BETWEEN CNTRL-V WALL COMPONENTS J AND J+1 /
        0.0 .LE. CTCRSJ / 1 .LE. J .LE. NCPNTS /
        (MIN.F.IN.IN)/BTU /

```

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*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
*** THE USER-DEFINED INPUT STREAM ***
*** CHEMICAL LIBRARY INFORMATION SECTION ***
*** THE CHEMICAL LIBRARY VARIABLE DESCRIPTIONS ***

```

```

NTCHEM      THE TOTAL NUMBER OF CHEMICAL COMPOUNDS USED (INCLUDING FEED
              AND INJECTED STREAMS) IN THE CURRENT MODEL /
              1 .LE. NTCHEM .LE. 50 / DIMENSIONLESS /

XX           THE CHEMICAL SEQUENTIAL IDENTIFIER (START AT 1 AND INCREMENT
              BY 1) / 1 .LE. XX .LE. NTCHEM /

MINDXJ      THE INDEX FOR COMPOUND J / 1 .LE. MINDXJ .LE. 50 /
              THERE CAN BE NO DUPLICATE INDICES IN THE CURRENT MODEL /

FORMULA      CHEMICAL FORMULA (8 COLS.) FOR COMPOUND J (DOES NOT HAVE TO BE
              EXACT; THIS IS USER SHORTHAND NOTATION FOR OUTPUT PURPOSES) /

CHMNAM      CHEMICAL NAME FOR COMPOUND J (28 COLUMNS) /

INTRAC      THE NUMBER OF INTERACTION COEFFICIENTS TO BE READ FOR
              COMPOUND J / ENTER 0, IF NONE /

IVAPOR      COMPOUND J VAPOR PRESSURE MODELED BY LEE-KESLER CORRELATION
              IF SET EQUAL TO 0 ; BY ANTOINE CORRELATION IF SET EQUAL TO 1 /
              0 .LE. IVAPOR .LE. 1 /

AMOLWT      THE MOLECULAR WEIGHT OF COMPOUND J /

TCRIT       THE CRITICAL TEMPERATURE OF COMPOUND J /
              R /

PCRIT       THE CRITICAL PRESSURE OF COMPOUND J /
              PSIA /

VCRIT       THE CRITICAL SPECIFIC VOLUME OF COMPOUND J /
              CC PER G-MOLE /

ZCRIT       THE CRITICAL COMPRESSIBILITY OF COMPOUND J /

ACENTR      PITZER'S ACENTRIC FACTOR FOR COMPOUND J /

TBOIL       THE NORMAL BOILING POINT FOR COMPOUND J /
              R /

DHVB        THE HEAT OF VAPORIZATION AT THE NORMAL BOILING POINT FOR
              COMPOUND J / CAL PER G-MOLE /

PARCLR      THE PARACHOR (USING MACLEOD-SUGDEN TABLES) FOR COMPOUND J /

SOL         THE SOLUBILITY PARAMETER / (CAL PER ML)**0.5

VML         THE LIQUID MOLAR VOLUME / ML PER GM-MOLE

CP-         CONSTANTS IN THE IDEAL-GAS HEAT CAPACITY EQUATION
              WHERE CP=CPA+CPB*T+CPCT**2+CPD*T**3
              CP IN BTU PER LB-MOLE*R ; T IN R /

ANU--       CONSTANTS IN THE LIQUID VISCOSITY EQUATION (VAN VELZEN, ET.AL.)
              WHERE LOG(VISCOSITY)=ANUD*(1/T-1/ANUTO)
              VISCOSITY IN CENTIPOISES ; T IN K /

ANT---      ANTOINE VAPOR-PRESSURE-EQUATION COEFFICIENTS
              WHERE LN(VP)=ANTA-ANTB/(T+ANTC)
              WITH ANTTMN AND ANTMX THE MINIMUM AND MAXIMUM TEMPERATURES
              OF APPLICABILITY / VP IN MM OF HG ; T IN K /
              NEEDED ONLY IF IVAPOR .EQ. 1 /

C(--,I)     INTERACTION COEFFICIENT OF COMPOUND J WITH COMPOUND I
              WHERE I IS THE INDEX FOR COMPOUND I /
              NEEDED ONLY IF INTPAC .GT. 0 /

PDIA        MEAN PARTICLE DIAMETER (FOR COMPOUND WITH INDEX .EQ. 50) /
              IN/

PDENS       MEAN PARTICLE DENSITY (FOR COMPOUND WITH INDEX .EQ. 50) /
              LB PER CU.FT /

PCP-        CONSTANTS IN THE HEAT CAPACITY EQUATION
              WHERE CP=PCPA+PCPB*T+PCPC*T**2
              CP IN BTU PER LB*R ; T IN R /

```

```

*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
*** THE USER-DEFINED INPUT STREAM ***
*** WALL LIBRARY INFORMATION SECTION ***
*** THE MATERIAL WALL LIBRARY VARIABLE DESCRIPTIONS ***

```

```

NTWALL THE TOTAL NUMBER OF MATERIALS USED IN THE CONTROL VOLUME
        WALL CONSTRUCTION / 1 .LE. NTWALL .LE. 10 /
YY      THE MATERIAL SEQUENTIAL IDENTIFIER (START AT 1 AND INCREMENT
        BY 1) / 1 .LE. YY .LE. NTWALL /
NINDEXJ THE INDEX FOR MATERIAL J / 1 .LE. NINDEXJ .LE. 10 /
        THERE CAN BE NO DUPLICATE INDICES IN THE CURRENT MODEL /
WALNAM  NAME FOR MATERIAL J (20 COLUMNS) /
AK-     CONSTANTS IN THE THERMAL CONDUCTIVITY EQUATION FOR MATERIAL J
        WHERE  $K = AK1 + AK2 * T + AK3 * T^{**2} + AK4 * T^{**3} + AK5 * T^{**4}$ 
        K IN BTU PER IN*MIN*R ; T IN R /

```

```

*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
*** THE USER-DEFINED INPUT STREAM ***
*** FEED STREAM INFORMATION SECTION ***
*** THE FEED AND INJECTED STREAM VARIABLE DESCRIPTIONS ***

```

```

NFEEED      TOTAL NUMBER OF CHEMICAL COMPOUNDS IN THE FEED STREAM /
1 .LE. NFEEED .LE. 50 /
FTEMP      THE TEMPERATURE OF THE FEED STREAM /
F /
FPRESS      THE PRESSURE OF THE FEED STREAM /
PSIA /

IFEEDJ      THE INDEX FOR COMPOUND J (CORRESPONDING TO ONE OF THE MINDXJ) /
FLOWJ      MASS FLOW RATE FOR COMPOUND J /
LBS PER MIN /

INJECT      TOTAL NUMBER OF INJECTED FLOW STREAMS /
0 .LE. INJECT .LE. 10 /

ZZ          THE INJECTION SEQUENTIAL IDENTIFIER (START AT 1 AND INCREMENT
BY 1) / 1 .LE. ZZ .LE. INJECT /

INODEK      CONTROL VOLUME IDENTIFIER (CORRESPONDS TO ONE OF THE XXX)
INTO WHICH THE INJECTED FLOW (K) IS MADE /
IFEEDK      TOTAL NUMBER OF CHEMICAL COMPOUNDS IN THE INJECTED FLOW STREAM K /
1 .LE. IFEEDK .LE. 50 /
ATEMPK      THE TEMPERATURE OF THE INJECTED FLOW STREAM /
F /
APRESK      THE PRESSURE OF THE INJECTED FLOW STREAM /
PSIA /

JFEEDJ      THE INDEX FOR COMPOUND J (CORRESPONDING TO ONE OF THE MINDXJ) /
AFLOWJ      MASS FLOW RATE FOR COMPOUND J /
LBS PER MIN /

```

```

*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
*** THE USER-DEFINED INPUT STREAM ***
*** EXPERIMENTAL DATA INFORMATION SECTION ***
*** THE EXPERIMENTAL DATA VARIABLE DESCRIPTIONS ***

```

```

NEXDAT THE TOTAL NUMBER OF EXPERIMENTAL DATA SETS /
      0 .LE. NEXDAT .LE. 100 /

JJ EXPERIMENTAL DATA SET SEQUENTIAL IDENTIFIER (START AT 1 AND
   INCREMENT BY 1) /
   1 .LE. JJ .LE. NEXDAT /

NODEJJ CONTROL VOLUME IDENTIFIER (CORRESPONDS TO ONE OF THE XXX)
      IN WHICH THE EXPERIMENTAL DATA CAN BE RELATED. /

PREADJ THE MEASURED CONTROL VOLUME (JJ) PRESSURE /
      PSIA /

TREADJ THE MEASURED CONTROL VOLUME (JJ) TEMPERATURE /
      F /

VREADJ THE MEASURED CONTROL VOLUME (JJ) VOLUMETRIC FLOW /
      FT*FT*FT PER SEC /

DREADJ THE MEASURED CONTROL VOLUME (JJ) DENSITY /
      LB PER FT*FT*FT /

```



```

*** THE FLASHING FLUID FLOW ANALYSIS PROGRAM-VERSION 1.0 ***
*** THE USER-DEFINED INPUT STREAM ***
*** PERTINENT NOTES ***

```

- # LINE 100000 APPEARS ONLY ONCE AND INITIATES THE USER-DEFINED INPUT STREAM CNTRL-V INFORMATION SECTION
- # LINE 100001 APPEARS ONLY ONCE AND DEFINES THE NUMBER OF CNTRL-V VARIABLE MODULES (LINES 1XXX00 THROUGH 1XXX1J) TO BE READ
- # LINES 1XXX00 THROUGH 1XXX03 ARE REQUIRED FOR EACH CNTRL-V
- # LINES 1XXX04 AND 1XXX10 THROUGH 1XXX1J ARE OPTIONAL FOR EACH CNTRL-V AND ARE INCLUDED ONLY IF KADBTC IS NONZERO
- # LINE 200000 APPEARS ONLY ONCE AND INITIATES THE USER-DEFINED INPUT STREAM CHEMICAL LIBRARY INFORMATION SECTION
- # LINE 200001 APPEARS ONLY ONCE AND DEFINES THE NUMBER OF CHEMICAL COMPOUND MODULES (LINES 20XX00 THROUGH 20XX06) TO BE READ
- # LINES 20XX00 THROUGH 20XX04 ARE REQUIRED FOR EACH CHEMICAL COMPOUND (EXCEPT FOR XX.EQ.50, THEN ONLY LINES 20XX00 AND 20XX07 ARE NEEDED)
- # LINE 20XX05 IS OPTIONAL FOR EACH CHEMICAL COMPOUND AND IS INCLUDED ONLY IF IVAPOR IS EQUAL TO 1
- # LINE(S) 20XX06 IS OPTIONAL FOR EACH CHEMICAL COMPOUND AND IS (ARE) INCLUDED ONLY IF INTRAC IS NONZERO. LINE 20XX06 CAN BE REPEATED AS MANY TIMES FOR EACH COMPOUND AS NECESSARY TO INPUT INTRAC VALUES OF THE INTERACTION COEFFICIENT (7 PER LINE).
- # LINE 20XX07 IS TO BE USED ONLY WHEN XX.EQ.50 [THAT IS, XX.EQ.50 IS RESERVED FOR SOLIDS (ERGO, INERTS)]
- # LINE 250000 APPEARS ONLY ONCE AND INITIATES THE USER-DEFINED INPUT STREAM WALL MATERIAL LIBRARY SECTION.
- # LINE 250001 APPEARS ONLY ONCE AND DEFINES THE NUMBER OF WALL MATERIAL MODULES (LINES 25YY00 AND 25YY01) TO BE READ.
- # LINES 25YY00 AND 25YY01 ARE REQUIRED FOR EACH WALL MATERIAL.
- # LINE 300000 APPEARS ONLY ONCE AND INITIATES THE USER-DEFINED INPUT STREAM FEED STREAM SPECIFICATION SECTION.
- # LINE 300001 APPEARS ONLY ONCE AND DEFINES THE NUMBER OF CHEMICAL COMPOUNDS IN THE FEED STREAM AND SPECIFIES THE FEED STREAM TEMPERATURE AND PRESSURE.
- # LINES 300002 THROUGH 30000J FULLY DEFINE THE FEED STREAM COMPOSITION BY SPECIFYING THE COMPONENTS IN THE STREAM AND THEIR MASS FLOW RATES.
- # LINE 350000 APPEARS ONLY ONCE AND INITIATES THE USER-DEFINED INPUT STREAM INJECTION FEED STREAM SPECIFICATION SECTION.
- # LINE 350001 APPEARS ONLY ONCE AND DEFINES THE NUMBER OF INJECTION FEED STREAM MODULES (LINES 35ZZ00 THROUGH 35ZZ0J) TO BE READ.
- # LINES 35ZZ00 THROUGH 35ZZ0J ARE REQUIRED FOR EACH INJECTION FEED STREAM.
- # LINE 400000 APPEARS ONLY ONCE AND INITIATES THE USER-DEFINED INPUT STREAM EXPERIMENTAL DATA SPECIFICATION SECTION.
- # LINE 400100 APPEARS ONLY ONCE AND DEFINES THE NUMBER OF EXPERIMENTAL DATA SETS (LINES 400101 THROUGH 4001JJ) TO BE READ.
- # LINE 999999 APPEARS ONLY ONCE AND DEFINES THE LAST LINE OF USER INPUT.

Appendix B

SAMPLE PROBLEMS

B.1 Problem Definition and Description

Five sample problems will be presented to demonstrate the versatility, capability, and applicability of FFFAP-Version 1.0.

The piping system to be studied is relatively simple (a schematic of the system is shown in Fig. B.1). Flow in the system is from point 1 to point 2 in Fig. B.1, and the fluid is a mixture of ethane, propene, and propane. The five case descriptions are given in Table B.1. The initial boundary conditions for the fluid at point 1 (Fig. B.1) are known and are given in Table B.1. The only difference between cases 1-4 is the initial temperature of the fluid. Case 5 contains an additional twist: the initial conditions at point 1 are the same as for case 4, but a side stream has been introduced into the upper elbow in the piping system. The primary objective in these sample problems will be to determine the overall pressure drop between points 1 and 2 (Fig. B.1) and to determine the final state of the fluid at point 2.

In these sample problems, 20 control volumes (nodes) are used to represent the piping system (Fig. B.1). The noding representation of

Fig. B.1. Piping system for sample problems.

Table B.1. Sample problem descriptions from piping system (Fig. B.1)

Case No.	Fluid	Injected fluid	Condition of feed at $\triangle 1$ in Fig. B.1	Condition of injected feed
1	<i>a</i>	None	Subcooled liquid at 258.2 K and 689.5 kPa (5°F and 100 psia)	N/A
2	<i>a</i>	None	Superheated vapor at 283.2 K and 689.5 kPa (50°F and 100 psia)	N/A
3	<i>a</i>	None	Two-phase mixture at 273.7 K and 689.5 kPa (33°F and 100 psia)	N/A
4	<i>a</i>	None	Subcooled liquid at 269.3 K and 689.5 kPa (25°F and 100 psia)	N/A
5	<i>a</i>	<i>b</i>	Subcooled liquid at 269.3 K and 689.5 kPa (25°F and 100 psia)	Subcooled liquid at 272 K and 689.5 kPa (30°F and 100 psia)

^a Ethane - 0.605 kg/s (80 lb/min)
 Propene - 3.024 kg/s (400 lb/min)
 Propane - 2.419 kg/s (320 lb/min)

^b Propene - 0.756 kg/s (100 lb/min)
 Propane - 0.756 kg/s (100 lb/min)

Note: In case 5, the injected fluid is introduced into the piping system in the 5-in. welding elbow.

the piping system is shown in Fig. B.2. The code input for cases 1-4 is exactly the same except for the primary feed stream temperature. Since there are 20 control volumes in the model, there would be 33 total pages of FFFAP output for each sample problem. For case 5, the complete FFFAP-Version 1.0 output (all 33 pages) will be given in Appendix B.7; however, for the remaining cases only pages 11 and 33 of the FFFAP output will be presented because these pages contain the initial and final state of the fluid in the system.

Fig. B.2. Control volume representation of piping system for sample problems.

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B.2 Code Input for Case 5

The required code input for sample problem 5 is shown on the following page. The differences in the inputs for sample problems 4 and 5 are the following:

1. the last entry on card 101201 is 0,
2. the entry on card 350001 is 0, and
3. cards 350100-350102 are not included.

The only difference in the inputs for sample problems 1-4 is the primary feed stream temperature (the second entry on card 300001).

REGURGITATION OF THE USER-DEFINED INPUT STREAM														
SAMPLE PROBLEM NO.5: SIMPLE PIPING SYSTEM WITH INJECTED/FLASH. FLO														
2 1 1 2 4 1 2 0														
NOD	50000													
NOD	50001													
CTL	50002	2	1	1	2	4	1	2	0					
NOD	10000													
NOD	10001	20												
NOD	100100													
NOD	100101	0.1100	03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100102			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100103			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100200													
NOD	100201	0.3300	03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100202			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100203			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100300													
NOD	100301	0.5500	03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100302			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100303			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100400													
NOD	100401	0.7700	03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100402			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100403			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100500													
NOD	100501	0.9900	03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100502			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100503			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100600													
NOD	100601	0.1210	04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100602			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100603			0.1270	02	0.1260	02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100700													
NOD	100701	0.1330	04	0.0	0.0	0.2200	01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100702			0.1270	02	0.1260	02	22.5	0.14	0.4470	-03	0.5800	01	0.2520
NOD	100703			0.2000	02	0.1590	02	67.5	0.04	0.3570	-03	0.5800	01	0.2520
NOD	100800													
NOD	100801	0.1330	04	0.0	0.0	0.1200	03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOD	100802			0.2000	02	0.1590	02	90.0	0.0	0.3570	-03	0.1130	03	0.2520
NOD	100803			0.2000	02	0.1590	02	90.0	0.0	0.3570	-03	0.1130	03	0.252

B.3 Case 1: One-Phase (Liquid) Multicomponent Flow

In case 1, the fluid is ~ 12.8 K (23°F) subcooled initially and remains subcooled throughout the piping system. The initial and final state of the fluid (points 1 and 2 in Fig. B.1, respectively) from the FFFAP output for this case are presented on the next two pages. In summary, a pressure drop of 128 kPa (18.6 psi) and a temperature drop of ~ 0.39 K (0.7°F) occur between points 1 and 2 for case 1.

 **
 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
 **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1030	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5030	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4030	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 5.0 DEG F
 PRESSURE OF THE FEED STREAM = 100.00 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 28.2 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 43.1 DEG F

STATE OR CONDITION OF THE FEED STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -131005.23 BTU/MIN = -163.76 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 33.79 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000075 LBM/FT*SEC = 0.11 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

 **
 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
 **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 4.3 DEG F
 PRESSURE OF THE FEED STREAM = 81.41 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 14.9 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 31.1 DEG F

STATE OR CONDITION OF THE FEED STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -131007.01 BTU/MIN = -163.76 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 33.81 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000075 LBM/FT*SEC = 0.11 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

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B.4 Case 2: One-Phase (Vapor) Multicomponent Flow

In case 2, the fluid is ~ 3.6 K (6.5°F) superheated initially and, like the fluid in case 1, remains one-phase through the system. The FFFAP results (pages 11 and 33) are given on the next two pages. For this case, there is (1) an overall pressure drop of 242.7 kPa (35.2 psi) and (2) a temperature drop of 2.39 K (4.3°F).

 **
 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
 **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 50.0 DEG F
 PRESSURE OF THE FEED STREAM = 100.00 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 28.3 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 43.5 DEG F

STATE OR CONDITION OF THE FEED STREAM : SUPERHEATED VAPOR

HEAT CONTENT OF THE LIQUID = 0.0 BTU/LB
 HEAT CONTENT OF THE VAPOR = 7842.17 BTU/LB = 9.80 BTU/LB

VAPOR DENSITY = 0.8528 LBM/CU.FT.
 VAPOR VISCOSITY = 0.58C53D-05 LBM/FT*SEC = 0.85329D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 41.189
 VAPOR COMPRESSIBILITY FACTOR = 0.8832

 **
 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
 **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOLR/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 45.7 DEG F
 PRESSURE OF THE FEED STREAM = 64.79 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 1.3 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 18.1 DEG F

STATE OR CONDITION OF THE FEED STREAM : SUPERHEATED VAPOR

HEAT CONTENT OF THE LIQUID = 0.0 BTU/MIN = 0.0 BTU/LB
 HEAT CONTENT OF THE VAPOR = 7827.32 BTU/MIN = 9.78 BTU/LB

VAPOR DENSITY = 0.5319 LBM/CU.FT.
 VAPOR VISCOSITY = 0.56771D-05 LBM/FT*SEC = 0.84480D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 41.189
 VAPOR COMPRESSIBILITY FACTOR = 0.9253

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B.5 Case 3: Two-Phase (Vapor/Liquid) Multicomponent Flow

At the initial conditions of 273.7 K (33°F) and 689.5 kPa (100 psia), the fluid in case 3 is two-phase with the weight fraction of the feed stream being vapor equal to 0.1628. There is (1) an overall pressure loss of 155.8 kPa (22.6 psi), (2) a temperature drop of 8.1 K (14.6°F), and (3) an increase in the fraction vaporized to 0.2064. The FFFAP results (pages 11 and 33) are given on the next two pages.

 **
 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
 **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 33.0 DEG F
 PRESSURE OF THE FEED STREAM = 100.00 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 28.1 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 43.6 DEG F

THE FEED STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	50.93	0.0768	1.694	0.1052	29.07	0.2232	0.967	0.2905
PROPENE (PROPYLENE)	340.14	0.5078	8.083	0.5022	59.86	0.4596	1.422	0.4274
PROPANE	278.70	0.4162	6.320	0.3927	41.30	0.3172	0.937	0.2814

TOTAL LIQUID MASS FLOW RATE = 669.78 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 130.22 LBS/MIN
 WEIGHT FRACTION OF THE FEED STREAM THAT IS VAPOR = 0.1628
 HEAT CONTENT OF THE LIQUID = -101098.66 BTU/MIN = -150.94 BTU/LB
 HEAT CONTENT OF THE VAPOR = 246.10 BTU/MIN = 1.89 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -100852.56 BTU/MIN = -126.07 BTU/LB

LIQUID DENSITY = 32.52 LBM/CU.FT.
 LIQUID VISCOSITY = 0.001066 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.614

VAPOR DENSITY = 0.8385 LBM/CU.FT.
 VAPOR VISCOSITY = 0.57103D-05 LBM/FT*SEC = 0.84974D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.133
 VAPOR COMPRESSIBILITY FACTOR = 0.8822

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.55035D-03 LBF/FT = 8.031 DYNE/CM

 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 18.4 DEG F
 PRESSURE OF THE FEED STREAM = 77.42 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 11.9 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 28.3 DEG F

THE FEED STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	-----LIQUID-----				-----VAPOR-----			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	43.84	0.0691	1.458	0.0959	36.16	0.2190	1.202	0.2855
PROPENE (PROPYLENE)	323.69	0.5098	7.692	0.5057	76.31	0.4622	1.814	0.4306
PROPANE	267.35	0.4211	6.063	0.3986	52.65	0.3188	1.194	0.2835

TOTAL LIQUID MASS FLOW RATE = 634.88 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 165.12 LBS/MIN
 WEIGHT FRACTION OF THE FEED STREAM THAT IS VAPOR = 0.2064

HEAT CONTENT OF THE LIQUID = -100616.07 BTU/MIN = -158.48 BTU/LB
 HEAT CONTENT OF THE VAPOR = -243.36 BTU/MIN = -1.47 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -100859.43 BTU/MIN = -126.07 BTU/LB

LIQUID DENSITY = 33.36 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000071 LBM/FT*SEC = 0.11 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.738

VAPOR DENSITY = 0.6556 LBM/CU.FT.
 VAPOR VISCOSITY = 0.55135D-05 LBM/FT*SEC = 0.82047D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.207
 VAPOR COMPRESSIBILITY FACTOR = 0.9026

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.62286D-03 LBF/FT = 9.089 DYNE/CM

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B.6 Case 4: Flashing Multicomponent Flow

In case 4, the fluid is ~ 1.8 K (3.2°F) subcooled initially and remains subcooled until control volume 9 (Fig. B.2), where the computed bubble-point temperature falls below the primary stream temperature and thus flashing occurs. Flashing initiates in node 9, and additional vaporization continues through node 20. The initial and final states of the fluid for case 4 are presented on the next two pages. Overall, there is (1) a pressure drop of ~ 107.6 kPa (15.6 psi), (2) a temperature drop of 3.1 K (5.6°F), and (3) a weight fraction vaporized of 0.054.

 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 25.0 DEG F
 PRESSURE OF THE FEED STREAM = 100.00 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 28.2 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 43.1 DEG F

STATE OR CONDITION OF THE FEED STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -11957.66 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

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**  CONDITION (STATE) OF THE PRIMARY FEED STREAM  **
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CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 19.4 DEG F
 PRESSURE OF THE FEED STREAM = 84.36 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 17.5 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 33.3 DEG F

THE FEED STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	-----LIQUID-----				-----VAPOR-----			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	68.29	0.0902	2.271	0.1241	11.71	0.2705	0.389	0.3455
PROPENE (PROPYLENE)	381.15	0.5037	9.058	0.4951	18.85	0.4356	0.448	0.3974
PROPANE	307.29	0.4061	6.969	0.3809	12.71	0.2937	0.288	0.2557

TOTAL LIQUID MASS FLOW RATE = 756.73 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 43.27 LBS/MIN
 WEIGHT FRACTION OF THE FEED STREAM THAT IS VAPOR = 0.0541
 HEAT CONTENT OF THE LIQUID = -119464.23 BTU/MIN = -157.87 BTU/LB
 HEAT CONTENT OF THE VAPOR = -73.51 BTU/MIN = -1.70 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -119537.74 BTU/MIN = -149.42 BTU/LB

LIQUID DENSITY = 33.31 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.362

VAPOR DENSITY = 0.7015 LBM/CU.FT.
 VAPOR VISCOSITY = 0.55618D-05 LBM/FT*SEC = 0.82765D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 38.387
 VAPOR COMPRESSIBILITY FACTOR = 0.8981

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.60655D-03 LBF/FT = 8.851 DYNE/CM

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**B.7 Case 5: Flashing Multicomponent Flow
with an Injected Side Stream**

The initial set-up for case 5 is the same as for case 4. In fact, the calculational results are the same through control volume 11; however, an injected side stream is then introduced into control volume 12, thus causing differences in case 4 and 5 calculations downstream of control volume 12. The complete 33-page FFFAP output for this case is presented in the following pages.

REGURGITATION OF THE USER-DEFINED INPUT STREAM

FFFAP-VERSION 1.0

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HDR 50000
HDR 50001 SAMPLE PROBLEM NO.5: SIMPLE PIPING SYSTEM WITH INJECTED/FLASH. FLJ
CTL 50002 2 1 1 2 4 1 2
CTL 50003 1 1 1 1 1 1 0
NOD 100000 20
NOD 100100
NOD 100101 0.1100 03 0.0 0.0 0.0 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100102 1 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100103 2 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100200
NOD 100201 0.3300 03 0.0 0.0 0.0 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100202 1 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100203 2 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100300
NOD 100301 0.5500 03 0.0 0.0 0.0 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100302 1 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100303 2 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100400
NOD 100401 0.7700 03 0.0 0.0 0.0 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100402 1 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100403 2 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100500
NOD 100501 0.9900 03 0.0 0.0 0.0 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100502 1 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100503 2 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100600
NOD 100601 0.1210 04 0.0 0.0 0.0 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100602 1 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100603 2 0.1270 02 0.1260 02 0.0 0.0 0.0 0.4470-03 0.1100 03 0.2010 01
NOD 100700
NOD 100701 0.1330 04 0.0 0.0 0.2200 01 0.0 0.0 0.0 0.4470-03 0.5800 01 0.2010 01
NOD 100702 1 0.1270 02 0.1260 02 22.5 0.14 0.4470-03 0.5800 01 0.2010 01
NOD 100703 6 0.2000 02 0.1590 02 67.5 0.14 0.3570-03 0.5800 01 0.2520 01
NOD 100800
NOD 100801 0.1330 04 0.0 0.0 0.1200 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 100802 5 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 100803 6 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 100900
NOD 100901 0.1330 04 0.0 0.0 0.3450 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 100902 5 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 100903 6 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101000
NOD 101001 0.1330 04 0.0 0.0 0.5700 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101002 5 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101003 6 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101100
NOD 101101 0.1330 04 0.0 0.0 0.7950 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101102 5 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101103 6 0.2000 02 0.1590 02 90.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101200
NOD 101201 0.1330 04 0.0 0.0 0.9130 03 0.0 0.0 0.0 0.3570-03 0.5800 01 0.2520 01
NOD 101202 5 0.2000 02 0.1590 02 67.5 0.03 0.3570-03 0.5800 01 0.2520 01
NOD 101203 2 0.2000 02 0.1590 02 22.5 0.03 0.3570-03 0.5800 01 0.2520 01
NOD 101300
NOD 101301 0.1450 04 0.0 0.0 0.9130 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101302 1 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101303 2 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101400
NOD 101401 0.1670 04 0.0 0.0 0.9130 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101402 1 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101403 2 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101500
NOD 101501 0.1900 04 0.0 0.0 0.9130 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101502 1 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101503 2 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101600
NOD 101601 0.2120 04 0.0 0.0 0.9130 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101602 1 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101603 2 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101700
NOD 101701 0.2350 04 0.0 0.0 0.9130 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101702 1 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101703 2 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101800
NOD 101801 0.2570 04 0.0 0.0 0.9130 03 0.0 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101802 1 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01
NOD 101803 2 0.2000 02 0.1590 02 0.0 0.0 0.3570-03 0.1130 03 0.2520 01

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*****
**      USER SPECIFIED      **
**      PROGRAM CONTROLS    **
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CONTROL VARIABLES ARE SPECIFIED ON CARDS 50002 AND 50003 OF THE USER GENERATED PROGRAM INPUT.

CONTROL VARIABLE	EXPLANATION	STATUS	INPUT VALUE	DEFAULT VALUE
ICS(1)	FLASH TECHNIQUE: =1 LEE/ERBAR/EDMISTER =2 HIGH PRESSURE (PRAUSNITZ)	NOT AVAILABLE	2	2
ICS(2)	ENTHALPY CALCULATIONS: =1 YEN/ALEXANDER =2 MENLEY/SEADER RECOMMENDATION =3 LEE/ERBAR/EDMISTER	NOT AVAILABLE NOT AVAILABLE	1	1
ICS(3)	BUBBLE AND DEW POINT CALC: =1 HIGH PRESSURE (PRAUSNITZ) =2 LEE/ERBAR/EDMISTER	NOT AVAILABLE	1	1
ICS(4)	FRICTIONAL CORREL. FOR VERTICAL SLURRY FLOW: =1 NEWITT =2 TURIAN/YUAN =3 ROSE/DUCKWORTH		2	2
ICS(5)	FRICTIONAL CORREL. FOR HORIZONTAL SLURRY FLOW: =1 NEWITT =2 ROSE/DUCKWORTH =3 ZANDI/GOVATOS =4 TURIAN/YUAN		4	4
ICS(6)	FRICTIONAL CORREL. FOR VERTICAL TWO-PHASE FLOW: =1 ORKISZEWSKI =2 OTHER	NOT AVAILABLE	1	1
ICS(7)	FRICTIONAL CORREL. FOR HORIZONTAL TWO-PHASE FLOW: =1 DUKLER NO.1 =2 DUKLER NO.2 =3 LOCKHART/MARTINELLI =4 OTHER	NOT AVAILABLE	2	2
ICS(8)	FRICTIONAL CORREL. FOR SINGLE PHASE FLOW: =1 FANNING =2 METZNER/REED =3 HARRIS	NOT AVAILABLE NOT AVAILABLE	1	1
ICS(9)	LIQUID HOLDUP CORREL. FOR VERTICAL FLOW: =1 HUGHMARK =2 OTHER	NOT AVAILABLE	1	1
ICS(10)	LIQUID HOLDUP CORREL. FOR HORIZONTAL FLOW: =1 HUGHMARK =2 DUKLER =3 LOCKHART/MARTINELLI		1	1
ICS(11)	COMPUTATION OF LIQUID VISCOSITY: =1 VAN VELZEN AND LETSOU/STIEL =2 USER SUPPLIED SUBROUTINE	NOT AVAILABLE	1	1
ICS(12)	COMPUTATION OF LIQUID DENSITY =1 CHUEH/PRAUSNITZ =2 USER SUPPLIED SUBROUTINE	NOT AVAILABLE	1	1
ICS(13)	COMPUTATION OF INTERFACIAL SURFACE TENSION: =1 MACLEOD/SUGDEN =2 USER SUPPLIED SUBROUTINE	NOT AVAILABLE	1	1

 ** CHEMICAL LIBRARY **

THERE IS A TOTAL OF 5 CHEMICAL COMPOUND(S) IN THE CURRENT LIBRARY.

N	INDEX	FORMULA	NAME MOL.WT.	TCRIT	PCRIT	VCRT	ZCRIT	OMEGA	TBOIL	HFGB	PARACHOR	SOL	VML
1	1	H2	HYDROGEN 2.02	59.8	188.0	65.0	0.305	-0.222	36.7	216.0	33.5	3.25	31.0
IDEAL GAS SPEC. HEAT: $CP = 0.6483D 01 + 0.1231D -02 * T + -0.1018D -05 * T^2 + 0.3131D -09 * T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.1382D 02 + ((1.0/T) - (1.0/0.5390D 01))$ VAPOR PRESSURE EQN: $LN(VP) = 0.15633D 02 - 3.1649D 03 / (T + 0.3190D 01)$ TMIN= 14.0 TMAX= 25.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.													
2	2	CH4	METHANE 16.04	343.1	667.C	95.C	0.288	0.008	201.1	1955.0	74.7	5.68	52.0
IDEAL GAS SPEC. HEAT: $CP = 0.4598D 01 + 0.6917D -02 * T + 0.8827D -06 * T^2 + -0.4635D -09 * T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.11414D 03 + ((1.0/T) - (1.0/0.5760D 02))$ VAPOR PRESSURE EQN: $LN(VP) = 0.15224D 02 - 9.89784D 03 / (T + -0.7160D 01)$ TMIN= 93.0 TMAX= 120.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.													
3	3	C2H6	ETHANE 30.07	549.7	708.C	148.0	0.285	0.098	332.1	3515.0	110.0	6.05	68.0
IDEAL GAS SPEC. HEAT: $CP = 0.1292D 01 + 0.2363D -01 * T + -0.5114D -05 * T^2 + 0.3568D -09 * T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.1565D 03 + ((1.0/T) - (1.0/0.9557D 02))$ VAPOR PRESSURE EQN: $LN(VP) = 0.15664D 02 - 0.15114D 04 / (T + -0.1716D 02)$ TMIN= 130.0 TMAX= 199.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.													
4	4	C3H6	PROPENE (PROPYLENE) 42.08	657.0	670.C	181.0	0.275	0.148	405.7	4409.0	139.7	6.43	79.0
IDEAL GAS SPEC. HEAT: $CP = 0.8860D 00 + 0.3112D -01 * T + -0.8552D -05 * T^2 + 0.9030D -09 * T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.27384D 03 + ((1.0/T) - (1.0/0.13163D 03))$ VAPOR PRESSURE EQN: $LN(VP) = 0.15703D 02 - 0.18075D 04 / (T + -0.2615D 02)$ TMIN= 160.0 TMAX= 240.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.													
5	5	C3H8	PROPANE 44.10	665.6	615.E	203.0	0.281	0.152	416.0	4487.0	143.5	6.40	84.0
IDEAL GAS SPEC. HEAT: $CP = 0.1609D 01 + 0.4064D -01 * T + -0.1169D -05 * T^2 + 0.1317D -08 * T^3$ LIQUID VISCOSITY EQN: $LOG(VISCOSITY) = 0.22267D 03 + ((1.0/T) - (1.0/0.13341D 03))$ VAPOR PRESSURE EQN: $LN(VP) = 0.15726D 02 - 0.18725D 04 / (T + -0.2516D 02)$ TMIN= 164.0 TMAX= 249.0 INTERACTION COEFFICIENTS: ALL.EQ.0.0, EXCEPT FOR THOSE NOTED.													

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**      PIPE WALL COMPONENT LIBRARY      **
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THERE IS A TOTAL OF 0 PIPE WALL COMPONENTS IN THE CURRENT LIBRARY.

N INDEX

NAME

THERMAL CONDUCTIVITY TEMPERATURE FIT

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**      EXPERIMENTAL DATA SETS      **  
**  
*****
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THERE IS A TOTAL OF 0 EXPERIMENTAL DATA SET(S) IN THE CURRENT JOB INPUT.

N	NODE	PRESSURE	TEMPERATURE	FLOW	DENSITY
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 **
 ** MODEL GEOMETRY AND NODING **
 **

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THERE IS A TOTAL OF 20 CONTROL VOLUMES IN THE CURRENT MODEL.

NODE	X	Y	Z	JI	JO	FAI	FAO	WPI	WPO	ANGI	KI	ANGO	KO	EODI	EODO	DLI	DLO
1	110.0	0.0	9.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
2	335.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
3	556.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
4	776.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
5	996.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
6	1216.0	0.0	0.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
7	1436.0	0.0	2.2	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
8	1656.0	0.0	4.5	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
9	1876.0	0.0	6.8	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
10	2096.0	0.0	9.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
11	2316.0	0.0	11.3	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
12	2536.0	0.0	13.6	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
13	2756.0	0.0	15.9	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
14	2976.0	0.0	18.2	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
15	3196.0	0.0	20.5	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
16	3416.0	0.0	22.8	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
17	3636.0	0.0	25.1	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
18	3856.0	0.0	27.4	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
19	4076.0	0.0	29.7	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0
20	4296.0	0.0	32.0	1	2	12.730	12.730	12.648	12.648	0.0	0.0	0.0	0.0	0.00045	0.00045	110.0	110.0

MODEL GEOMETRY AND NODING (CONTINUED):

FFFAP-VERSION 1.0

P- 8

NODE	KADBTC	KEXDTS	KIFLWS	NCPNTS	FBCTYP
1	0	0	0		
2	0	0	0		
3	0	0	0		
4	0	0	0		
5	0	0	0		
6	0	0	0		
7	0	0	0		
8	0	0	0		
9	0	0	0		
10	0	0	0		
11	0	0	0		
12	0	0	0		
13	0	0	0		
14	0	0	0		
15	0	0	0		
16	0	0	0		
17	0	0	0		
18	0	0	0		
19	0	0	0		
20	0	0	0		

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** PRIMARY AND INJECTED FEED STREAMS **  
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PRIMARY FEED STREAM:
THERE IS A TOTAL OF 3 CHEMICAL COMPOUND(S) IN THE CURRENT MODEL.
FEED STREAM TEMPERATURE = 25.0 DEG F
FEED STREAM PRESSURE = 100.0 PSIA

N	INDEX	FORMULA	USER CHEMICAL NAME	MASS FLOW RATE
1	3	C2H6	ETHANE	80.00
2	4	C3H6	PROPENE (PROPYLENE)	400.00
3	5	C3H8	PROPANE	320.00

INJECTED FEED STREAMS:

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THERE IS A TOTAL OF 1 INJECTED FEED STREAMS IN THE CURRENT MODEL.

STREAM NO. 1 IS INJECTED IN NODE 12 AND HAS A TOTAL OF 2 CHEMICAL COMPOUNDS.
 STREAM TEMPERATURE = 30.0 DEG F
 STREAM PRESSURE = 100.0 PSIA

N	INDEX	FORMULA	USER CHEMICAL NAME	MASS FLOW RATE
1	4	C3H6	PROPENE (PROPYLENE)	100.00
2	5	C3H8	PROPANE	100.00

 **
 ** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
 **

CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 25.0 DEG F
 PRESSURE OF THE FEED STREAM = 100.00 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 28.2 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 43.1 DEG F

STATE OR CONDITON OF THE FEED STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.66 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

MODEL TITLE:

104

FFFAP-VERSION 1.0

CONTROL VOLUME (NODE) NO. 1

P- 13

INLET FACE = 1
FLOW AREA = 12.7303 SQ.IN.
WETTED PERIMETER = 12.6481 IN..
RESIST.COEFF. = 0.0
RELATIVE ROUGH. = 0.000447
INNER WALL RADIUS = 2.0130 IN.
ANGLE (REL.TO HOR.) = 0.0 DEG

OUTLET FACE = 2
FLOW AREA = 12.7303 SQ.IN.
WETTED PERIMETER = 12.6481 IN..
RESIST.COEFF. = 0.0
RELATIVE ROUGH. = 0.000447
INNER WALL RADIUS = 2.0130 IN.
ANGLE (REL.TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
INJECTED FLOW: NO
ADIABATIC: YES

X(CENTER) = 110.0000 IN.
Y(CENTER) = 0.0 IN.
Z(CENTER) = 0.0 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
PRESSURE OF THE PRIMARY STREAM = 99.97 PSIA
BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 28.1 DEG F
DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 43.0 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.66 BTU/MIN = -149.43 BTU/LB
HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
LIQUID MEAN MOLECULAR WEIGHT = 41.185

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	100.00	99.97	99.93
TEMPERATURE (F)	25.00	25.00	25.00
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	4.61
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	4.61
PRESSURE DROP (PSIA)	0.03	0.03	0.03
FRICTION	0.03	0.03	0.03
ACCELERATION	0.1255D-16	-0.2538D-06	0.0
POTENTIAL	0.0	0.0	0.0

FFFAP-VERSION 1.0

CONTROL VOLUME (NODE) NO. 2

P- 14

INLET FACE = 1
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

OUTLET FACE = 2
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 330.0000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 0.0 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 99.90 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 28.1 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 43.0 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.68 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	99.95	99.90	99.86
TEMPERATURE (F)	25.00	24.99	24.99
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	4.51
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	4.61
PRESSURE DROP (PSIA)	0.03	0.03	0.03
FRICTION	0.03	0.03	0.03
ACCELERATION	-0.2541D-06	-0.2544D-05	0.0
POTENTIAL	0.0	0.0	0.0

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CONTROL VOLUME (NODE) NO. 3

P- 15

INLET FACE = 1
FLOW AREA = 12.7303 SQ.IN.
WETTED PERIMETER = 12.6481 IN.
RESIST.COEFF. = 0.0
RELATIVE ROUGH. = 0.000447
INNER WALL RADIUS = 2.0130 IN.
ANGLE (REL.TO HOR.) = 0.0 DEG

OUTLET FACE = 2
FLOW AREA = 12.7303 SQ.IN.
WETTED PERIMETER = 12.6481 IN.
RESIST.COEFF. = 0.0
RELATIVE ROUGH. = 0.000447
INNER WALL RADIUS = 2.0130 IN.
ANGLE (REL.TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
INJECTED FLOW: NO
ADIABATIC: YES

X(CENTER) = 550.0000 IN.
Y(CENTER) = 0.0 IN.
Z(CENTER) = 0.0 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
PRESSURE OF THE PRIMARY STREAM = 99.83 PSIA
BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 28.1 DEG F
DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 43.0 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.70 BTU/MIN = -149.43 BTU/LB
HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	99.86	99.83	99.79
TEMPERATURE (F)	24.99	24.99	24.99
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	4.61
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	4.61
PRESSURE DROP (PSIA)	0.03	0.03	0.03
FRICTION	0.03	0.03	0.03
ACCELERATION	-0.2546D-06	-0.2546D-06	-0.2546D-06
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

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X(CENTER)= 770.0000 IN.
Y(CENTER)= 0.0 IN.
Z(CENTER)= 0.0 IN.
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OUTLET FACE = 2
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 99.76 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 28.0 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 42.9 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.71 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.11 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	99.79	99.76	99.72
TEMPERATURE (F)	24.99	24.99	24.99
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	4.61
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	4.61
PRESSURE DROP (PSIA)	0.03	0.33	
FRICTION	0.03	0.03	
ACCELERATION	-0.25510-06	-0.25540-06	
POTENTIAL	0.0	0.0	

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CONTROL VOLUME (NODE) NO. 5

P- 17

INLET FACE = 1
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.5481 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

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X(CENTER) = 990.0000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 0.0 IN.

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OUTLET FACE = 2
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBHOLE/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 99.69 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 28.0 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 42.9 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.73 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CENTER	FACE
PRESSURE (PSIA)	99.72	99.69	99.65
TEMPERATURE (F)	24.99	24.98	24.98
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	4.61
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	4.61
PRESSURE DROP (PSIA)	0.03	0.03	0.03
FRICTION	0.03	0.03	0.03
ACCELERATION	-0.25570-06	-0.25590-06	-0.25590-06
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

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X(CENTER) = 1210.0000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 0.0 IN.

I	FLOW LENGTH	I	FLOW LENGTH	I
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OUTLET FACE = 2
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000447
 INNER WALL RADIUS = 2.0130 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	329.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 99.62 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 27.9 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 42.9 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.74 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	99.65	99.62	99.58
TEMPERATURE (F)	24.98	24.98	24.98
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	4.61
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	4.61
PRESSURE DROP (PSIA)	0.03	0.03	
FRICTION	0.03	0.03	
ACCELERATION	-0.2562E-06	-3.2565E-06	
POTENTIAL	0.0	0.0	

FFFAP-VERSION 1.0

CONTROL VOLUME (NODE) NO. 7

P- 19

INLET FACE = 1
 FLOW AREA = 12.7303 SQ.IN.
 WETTED PERIMETER = 12.6481 IN.
 RESIST.COEFF. = 0.1350
 RELATIVE ROUGH. = 0.00047
 INNER WALL RADIUS = 2.0133 IN.
 ANGLE (REL.TO HOR.) = 22.54 DEG

OUTLET FACE = 6
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.1350
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 67.46 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 1325.3000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 2.2000 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 25.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 99.50 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 27.9 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 42.8 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119547.77 BTU/MIN = -149.43 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.00068 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	99.58	99.50	99.42
TEMPERATURE (F)	24.98	24.97	24.97
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	4.61	4.61	2.93
S.LIQUID/SOLID VELOCITY (FT/SEC)	4.61	4.61	2.93
PRESSURE DROP (PSIA)	0.08	0.07	
FRICTION	0.04	0.02	
ACCELERATION	-0.2567D-06	-0.4464D-01	
POTENTIAL	0.04	0.10	

111

INLET FACE = 5
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 90.00 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 1327.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 120.0000 IN.
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CUTLET FACE = 6
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 90.00 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 24.9 DEG F
 PRESSURE OF THE PRIMARY STREAM = 97.28 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 26.5 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 41.6 DEG F

STATE OR CONDITION OF THE PRIMARY STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -119548.26 BTU/MIN = -149.44 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 32.73 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LEM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.189

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	99.42	97.28	95.14
TEMPERATURE (F)	24.57	24.86	24.75
S.VAPOR VELOCITY (FT/SEC)	0.0	0.0	0.0
S.LIQUID VELOCITY (FT/SEC)	2.93	2.93	2.93
S.LIQUID/SOLIC VELOCITY (FT/SEC)	2.93	2.93	2.93
PRESSURE DROP (PSIA)	2.14	2.14	
FRICTION	0.01	0.01	
ACCELERATION	-0.6622D-05	-0.7037D-05	
POTENTIAL	2.13	2.13	

INLET FACE = 5
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 90.00 DEG

OUTLET FACE = 6
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 90.00 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 1327.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 345.0000 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	60.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 25.2 DEG F
 PRESSURE OF THE PRIMARY STREAM = 93.51 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 24.0 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 39.4 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
ETHANE	72.31	0.0937	2.405	0.1267	7.69	0.2725	0.256	0.3477
PROPENE (PROPYLENE)	387.75	0.5024	9.214	0.4931	12.25	0.4344	0.291	0.3960
PROPANE	311.73	0.4039	7.069	0.3783	8.27	0.2931	0.187	0.2550

TOTAL LIQUID MASS FLOW RATE = 771.80 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 28.20 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0353

HEAT CONTENT OF THE LIQUID = -119537.73 BTU/MIN = -154.88 BTU/LB
 HEAT CONTENT OF THE VAPOR = -10.41 BTU/MIN = -0.37 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -119548.14 BTU/MIN = -149.44 BTU/LB

LIQUID DENSITY = 32.77 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000068 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.300

VAPOR DENSITY = 0.7746 LBM/CU.FT.
 VAPOR VISCOSITY = 0.554080-05 LBM/FT*SEC = 0.839400-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 38.365
 VAPOR COMPRESSIBILITY FACTOR = 0.8902

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.576980-03 LBF/FT = 8.420 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	95.14	93.51	91.86
TEMPERATURE (F)	24.75	25.20	24.18
S.VAPOR VELOCITY (FT/SEC)	0.0	4.37	4.86
S.LIQUID VELOCITY (FT/SEC)	2.93	2.83	2.81
S.LIQUID/SOLID VELOCITY (FT/SEC)	2.93	2.83	2.81
PRESSURE DROP (PSIA)	1.63	1.64	
FRICTION	0.05	0.05	
ACCELERATION	0.11760-02	0.12430-02	
PCTENTIAL	1.58	1.59	

INLET FACE = 5
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 90.00 DEG

OUTLET FACE = 6
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 90.00 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 1327.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 570.0000 IN.
 FLOW LENGTH = 112.5000 IN.
 FLOW LENGTH = 112.5000 IN.

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 23.1 DEG F
 PRESSURE OF THE PRIMARY STREAM = 30.21 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.7 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 37.2 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	70.88	0.0325	2.357	0.1271	9.12	0.2719	0.303	0.3469
PROPENE (PROPYLENE)	385.41	0.5029	9.150	0.4938	14.59	0.4348	0.347	0.3965
PROPANE	310.16	0.4047	7.034	0.3792	9.84	0.2933	0.223	0.2552

TOTAL LIQUID MASS FLOW RATE = 766.45 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 33.55 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0419
 HEAT CONTENT OF THE LIQUID = -119521.55 BTU/MIN = -155.94 BTU/LB
 HEAT CONTENT OF THE VAPOR = -28.04 BTU/MIN = -0.84 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -119549.55 BTU/MIN = -149.44 BTU/LB

LIQUID DENSITY = 32.89 LBM/CU-FT.
 LIQUID VISCOSITY = 0.000069 LBM/FT-SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.322

VAPOR DENSITY = 0.7482 LBM/CU-FT.
 VAPOR VISCOSITY = 0.561270-05 LBM/FT-SEC = 0.835223-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 38.170
 VAPOR COMPRESSIBILITY FACTOR = 0.8530

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.58738E-03 LBF/FT = 8.571 DYNE/CM

	FACE 1	CONTROL VOLUME CENTER	FACE 2
PRESSURE (PSIA)	91.86	90.21	88.53
TEMPERATURE (F)	24.18	23.15	22.09
S.VAPOR VELOCITY (FT/SEC)	4.86	5.38	5.92
S.LIQUID VELOCITY (FT/SEC)	2.81	2.80	2.78
S.LIQUID/SOLID VELOCITY (FT/SEC)	2.81	2.80	2.78
PRESSURE DROP (PSIA)	1.66	1.67	
FRICTION	0.06	0.07	
ACCELERATION	0.1312E-02	0.1385E-02	
POTENTIAL	1.59	1.60	

INLET FACE = 5
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 99.00 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 1327.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 795.0000 IN.

I	FLOW LENGTH	I	FLOW LENGTH	I
1	112.5000 IN	1	112.5000 IN	1

OUTLET FACE = 6
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 90.00 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.08	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 21.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 86.85 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 19.3 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 35.0 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
ETHANE	69.41	0.0912	2.308	0.1254	10.59	0.2712	0.352	0.3461
PROPENE (PROPYLENE)	383.00	0.5033	9.101	0.4945	17.00	0.4353	0.404	0.3970
PROPANE	308.54	0.4055	6.997	0.3802	11.46	0.2935	0.260	0.2555

TOTAL LIQUID MASS FLOW RATE = 760.94 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 39.06 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0488

HEAT CONTENT OF THE LIQUID = -119499.50 BTU/MIN = -157.04 BTU/LB
 HEAT CONTENT OF THE VAPOR = -51.61 BTU/MIN = -1.33 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -119551.31 BTU/MIN = -149.44 BTU/LB

LIQUID DENSITY = 33.02 LBM/CU. FT.
 LIQUID VISCOSITY = 0.090069 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.344

VAPOR DENSITY = 0.7213 LBM/CU. FT.
 VAPOR VISCOSITY = 0.558360-05 LBM/FT*SEC = 0.830890-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 38.378
 VAPOR COMPRESSIBILITY FACTOR = 0.8959

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.598280-03 LBF/FT = 8.730 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	88.53	86.85	85.14
TEMPERATURE (F)	22.09	21.00	19.89
S. VAPOR VELOCITY (FT/SEC)	5.92	6.49	7.09
S. LIQUID VELOCITY (FT/SEC)	2.78	2.76	2.75
S. LIQUID/SOLID VELOCITY (FT/SEC)	2.78	2.76	2.75
PRESSURE DROP (PSIA)		1.69	1.70
FRICTION		0.08	0.09
ACCELERATION		0.14610-02	0.15410-02
POTENTIAL		1.60	1.61

INLET FACE = 5
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0340
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 67.46 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: YES
 ADIABATIC: YES

X(CENTER) = 1329.7000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 912.8000 IN.

1	1	1	1
FLOW LENGTH	FLOW LENGTH		
5.8000 IN	5.8000 IN		

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0340
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 22.54 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.1000	30.07	2.660	0.1370
2	4	C3H6	PROPENE (PROPYLENE)	400.00	0.5000	42.03	9.505	0.4894
3	5	C3H8	PROPANE	320.00	0.4000	44.10	7.257	0.3736

TOTAL MASS FLOW RATE = 800.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 19.8 DEG F
 PRESSURE OF THE PRIMARY STREAM = 85.03 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 13.0 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 33.7 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOLE/MIN)	MOLE FRACTION
ETHANE	68.60	0.0905	2.261	0.1245	11.40	0.2708	0.379	0.3457
PROPENE (PROPYLENE)	381.67	0.5036	9.070	0.4949	18.33	0.4355	0.436	0.3973
PROPANE	307.64	0.4059	6.976	0.3807	12.36	0.2937	0.280	0.2556

TOTAL LIQUID MASS FLOW RATE = 757.92 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 42.08 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0526

HEAT CONTENT OF THE LIQUID = -119484.11 BTU/MIN = -157.65 BTU/LB
 HEAT CONTENT OF THE VAPOR = -67.32 BTU/MIN = -1.60 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -119551.44 BTU/MIN = -149.44 BTU/LB

LIQUID DENSITY = 33.09 LBM/CU.FT.
 LIQUID VISCOSITY = 0.00070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.357

VAPOR DENSITY = 0.7068 LBM/CU.FT.
 VAPOR VISCOSITY = 0.55E-05 LBM/FT*SEC = 0.828E-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 38.384
 VAPOR COMPRESSIBILITY FACTOR = 0.8975

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.60433D-03 LBF/FT = 8.819 DYNE/CM

*****CONDITION (STATE) OF THE INJECTED FEED STREAM*****
 CONTENTS OF THE FEED STREAM: (2 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	4	C3H6	PROPENE (PROPYLENE)	100.00	0.5000	42.08	2.376	0.5117
2	5	C3H8	PROPANE	100.00	0.5000	44.10	2.268	0.4883

TOTAL MASS FLOW RATE = 200.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 30.0 DEG F
 PRESSURE OF THE FEED STREAM = 100.00 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 50.3 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 50.9 DEG F

STATE OR CONDITION OF THE FEED STREAM : SUBCOOLED LIQUID

HEAT CONTENT OF THE LIQUID = -29527.20 BTU/MIN = -147.64 BTU/LB
 HEAT CONTENT OF THE VAPOR = 0.0 BTU/MIN = 0.0 BTU/LB

LIQUID DENSITY = 33.38 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000073 LBM/FT*SEC = 0.11 CP
 LIQUID MEAN MOLECULAR WEIGHT = 43.065

*****CONDITION (STATE) OF THE COMBINED FEED STREAMS*****
 CONTENTS OF THE COMBINED STREAMS: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 23.3 DEG F
 PRESSURE OF THE FEED STREAM = 85.03 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 21.9 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 35.4 DEG F

THE FEED STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	70.08	0.0733	2.330	0.1016	9.92	0.2256	0.330	0.2931
PROPENE (PROPYLENE)	480.06	0.5021	11.408	0.4973	19.94	0.4534	0.474	0.4210
PROPANE	405.88	0.4246	9.204	0.4012	14.12	0.3210	0.320	0.2845

TOTAL LIQUID MASS FLOW RATE = 956.01 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 43.99 LBS/MIN
 WEIGHT FRACTION OF THE FEED STREAM THAT IS VAPOR = 0.0440

HEAT CONTENT OF THE LIQUID = -149061.00 BTU/MIN = -155.92 BTU/LB
 HEAT CONTENT OF THE VAPOR = -16.93 BTU/MIN = -0.38 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149077.93 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.05 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.673

VAPOR DENSITY = 0.7154 LBM/CU.FT.
 VAPOR VISCOSITY = 0.55798D-05 LBM/FT*SEC = 0.83032D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.074
 VAPOR COMPRESSIBILITY FACTOR = 0.8961

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.59608D-03 LBF/FT = 8.698 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	85.14	85.03	84.95
TEMPERATURE (F)	19.89	19.81	23.24
S.VAPOR VELOCITY (FT/SEC)	7.09	7.14	7.41
S.LIQUID VELOCITY (FT/SEC)	2.75	2.75	3.47
S.LIQUID/SOLID VELOCITY (FT/SEC)	2.75	2.75	3.47
PRESSURE DROP (PSIA)		0.12	0.07
FRICTION		0.04	0.05
ACCELERATION		0.1562D-02	0.2303D-02
POTENTIAL		0.08	0.03

INLET FACE = 1
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 9.0 DEG

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 1447.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 315.0000 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 23.2 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.90 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.8 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 35.3 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	70.02	0.1733	2.329	0.1015	9.98	0.2256	0.332	0.2931
PROPENE (PROPYLENE)	479.94	0.5022	11.405	0.4973	20.06	0.4534	0.477	0.4210
PROPANE	405.75	0.4245	9.202	0.4012	14.21	0.3211	0.322	0.2845

TOTAL LIQUID MASS FLOW RATE = 955.75 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 44.25 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0443

HEAT CONTENT OF THE LIQUID = -149060.25 BTU/MIN = -155.96 BTU/LB
 HEAT CONTENT OF THE VAPOR = -17.89 BTU/MIN = -0.40 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149078.14 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.06 LBM/CU. FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.673

VAPOR DENSITY = 0.7144 LBM/CU. FT.
 VAPOR VISCOSITY = 0.55787D-05 LBM/FT*SEC = 0.8211D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.075
 VAPOR COMPRESSIBILITY FACTOR = 0.8962

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.5555D-03 LBF/FT = 8.704 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	84.95	84.90	84.85
TEMPERATURE (F)	23.24	23.21	23.17
S. VAPOR VELOCITY (FT/SEC)	7.41	7.41	7.45
S. LIQUID VELOCITY (FT/SEC)	3.47	3.47	3.47
S. LIQUID/SOLID VELOCITY (FT/SEC)	3.47	3.47	3.47
PRESSURE DROP (PSIA)		0.05	0.05
FRICTION		0.05	0.05
ACCELERATION		0.2304D-02	0.2311D-02
POTENTIAL		0.0	0.0

INLET FACE = 1
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

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 X(CENTER)= 1672.5000 IN.
 Y(CENTER)= 0.0 IN.
 Z(CENTER)= 915.0000 IN.
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OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	530.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 23.1 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.80 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.8 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 35.2 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.97	0.0732	2.327	0.1015	10.03	0.2255	0.333	0.2931
PROPENE (PROPYLENE)	479.84	0.5022	11.403	0.4973	20.16	0.4534	0.479	0.4210
PROPANE	405.73	0.4246	9.201	0.4013	14.27	0.3211	0.324	0.2845

TOTAL LIQUID MASS FLOW RATE = 955.54 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 44.46 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0445
 HEAT CONTENT OF THE LIQUID = -149060.55 BTU/MIN = -156.00 BTU/LB
 HEAT CONTENT OF THE VAPOR = -18.67 BTU/MIN = -0.42 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149079.22 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.06 LBM/CU. FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.674

VAPOR DENSITY = 0.7136 LBM/CU. FT.
 VAPOR VISCOSITY = 0.557780-05 LBM/FT*SEC = 0.830020-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.075
 VAPOR COMPRESSIBILITY FACTOR = 0.8963

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.596830-03 LBF/FT = 8.709 DYNE/CM

	CONTROL VOLUME		
	FACE	CENTER	FACE
PRESSURE (PSIA)	84.85	84.83	84.75
TEMPERATURE (F)	23.17	23.14	23.11
S. VAPOR VELOCITY (FT/SEC)	7.45	7.45	7.50
S. LIQUID VELOCITY (FT/SEC)	3.47	3.47	3.47
S. LIQUID/SOLID VELOCITY (FT/SEC)	3.47	3.47	3.47
PRESSURE DROP (PSIA)	0.05	0.05	0.05
FRICTION	0.05	0.05	0.05
ACCELERATION	0.23120-02	0.23120-02	0.23120-02
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 3.0 DEG

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 1897.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 915.0000 IN.

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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H8	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 23.1 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.70 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.7 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 25.1 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.93	0.0732	2.325	0.1014	10.07	0.2255	0.335	0.2931
PROPENE (PROPYLENE)	479.75	0.5022	11.401	0.4973	20.25	0.4534	0.481	0.4210
PROPANE	405.66	0.4246	9.199	0.4013	14.34	0.3211	0.325	0.2845

TOTAL LIQUID MASS FLOW RATE = 955.33 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 44.67 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0447

HEAT CONTENT OF THE LIQUID = -149080.84 BTU/MIN = -156.03 BTU/LB
 HEAT CONTENT OF THE VAPOR = -15.46 BTU/MIN = -0.44 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149080.30 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.06 LBM/CU. FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.675

VAPOR DENSITY = 0.7128 LBM/CU. FT.
 VAPOR VISCOSITY = 0.557690-05 LBM/FT*SEC = 0.829830-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.075
 VAPOR COMPRESSIBILITY FACTOR = 0.8964

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.597170-03 LBF/FT = 8.714 DYNE/CM

	FACE	CENTER	FACE
PRESSURE (PSIA)	84.75	84.70	84.65
TEMPERATURE (F)	23.11	23.07	23.04
S.VAPOR VELOCITY (FT/SEC)	7.50	7.50	7.54
S.LIQUID VELOCITY (FT/SEC)	3.47	3.47	3.47
S.LIQUID/SOLID VELOCITY (FT/SEC)	3.47	3.47	3.47
PRESSURE DROP (PSIA)	0.05	0.05	0.05
FRICTION	0.05	0.05	0.05
ACCELERATION	0.23200-02	0.23270-02	0.23270-02
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST.COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL.TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 2122.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 915.0000 IN.

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112.5000IN	112.5000IN

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	83.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 23.0 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.60 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.6 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 35.1 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.88	0.0732	2.324	0.1314	10.12	0.2255	0.337	0.2930
PROPENE (PROPYLENE)	479.65	0.5022	11.398	0.4973	29.35	0.4534	0.484	0.4210
PROPANE	450.59	0.4246	9.198	0.4013	14.41	0.3211	0.327	0.2845

TOTAL LIQUID MASS FLOW RATE = 955.12 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 44.88 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0449

HEAT CONTENT OF THE LIQUID = -149061.12 BTU/MIN = -156.06 BTU/LB
 HEAT CONTENT OF THE VAPOR = -20.26 BTU/MIN = -0.45 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149081.38 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.07 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.675

VAPOR DENSITY = 0.7120 LBM/CU.FT.
 VAPOR VISCOSITY = 0.55760D-05 LBM/FT*SEC = 0.82976D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.075
 VAPOR COMPRESSIBILITY FACTOR = 0.8965

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.59750D-03 LBF/FT = 8.719 DYNE/CM

	CONTROL VOLUME		
	FACE	CENTER	FACE
PRESSURE (PSIA)	84.65	84.60	84.55
TEMPERATURE (F)	23.04	23.00	22.97
S.VAPOR VELOCITY (FT/SEC)	7.54	7.54	7.58
S.LIQUID VELOCITY (FT/SEC)	3.47	3.47	3.46
S.LIQUID/SOLID VELOCITY (FT/SEC)	3.47	3.47	3.46
PRESSURE DROP (PSIA)	0.05	0.05	0.05
FRICTION	0.05	0.05	0.05
ACCELERATION	0.2328D-02	0.2335D-02	0.2335D-02
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 2347.5000 IN.
 Y(CENTER) = 3.0 IN.
 Z(CENTER) = 915.0000 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 22.9 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.50 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.5 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 35.0 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.83	0.0731	2.322	0.1014	10.17	0.2255	0.338	0.2930
PROPENE (PROPYLENE)	479.56	0.5022	11.396	0.4974	20.44	0.4534	0.486	0.4210
PROPANE	405.52	0.4247	9.196	0.4014	14.48	0.3211	0.328	0.2845

TOTAL LIQUID MASS FLOW RATE = 954.91 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 45.09 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0451
 HEAT CONTENT OF THE LIQUID = -149061.40 BTU/MIN = -156.10 BTU/LB
 HEAT CONTENT OF THE VAPOR = -21.07 BTU/MIN = -0.47 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149682.47 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.07 LBM/CU. FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.576

VAPOR DENSITY = 0.7112 LBM/CU. FT.
 VAPOR VISCOSITY = 0.557500-95 LBM/FT*SEC = 1.625620-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.076
 VAPOR COMPRESSIBILITY FACTOR = 0.8956

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 1.591840-03 LBF/FT = 8.724 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
PFRESSURE (PSIA)	84.55	34.50	84.45
TEMPERATURE (F)	22.97	22.94	22.90
S.VAPOR VELOCITY (FT/SEC)	7.58	7.58	7.63
S.LIQUID VELOCITY (FT/SEC)	3.46	3.46	3.46
S.LIQUID/SOLID VELOCITY (FT/SEC)	3.46	3.46	3.46
PFRESSURE DROP (PSIA)	0.05	0.05	0.05
FRICTION	0.05	0.05	0.05
ACCELERATION	0.23360-02	0.23440-02	0.23440-02
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ. IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

X(CENTER) = 2572.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 915.0000 IN.
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CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.09	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 22.9 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.40 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.5 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 34.9 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.79	0.0731	2.321	0.1013	10.21	0.2255	0.340	0.2930
PROPENE (PROPYLENE)	479.46	0.5022	11.394	0.4974	20.54	0.4534	0.488	0.4211
PROPANE	405.46	0.4247	9.195	0.4014	14.54	0.3211	0.330	0.2845

TOTAL LIQUID MASS FLOW RATE = 954.70 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 45.30 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0453

HEAT CONTENT OF THE LIQUID = -149061.67 BTU/MIN = -156.13 BTU/LB
 HEAT CONTENT OF THE VAPOR = -21.89 BTU/MIN = -0.48 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149083.56 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.08 LBM/CU. FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.676

VAPOR DENSITY = 0.7103 LBM/CU. FT.
 VAPOR VISCOSITY = 3.557410-05 LBM/FT*SEC = 0.829480-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.076
 VAPOR COMPRESSIBILITY FACTOR = 0.8967

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.598190-03 LBF/FT = 8.729 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	84.45	84.40	84.35
TEMPERATURE (F)	22.90	22.87	22.83
S.VAPOR VELOCITY (FT/SEC)	7.63	7.63	7.67
S.LIQUID VELOCITY (FT/SEC)	3.46	3.46	3.46
S.LIQUID/SOLID VELOCITY (FT/SEC)	3.46	3.46	3.46
PRESSURE DROP (PSIA)	0.05	0.05	0.05
FRICTION	0.05	0.05	0.05
ACCELERATION	0.23440-02	0.23520-02	0.23520-02
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

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 X(CENTER) = 2797.5000 IN.
 Y(CENTER) = 0.0 IN.
 Z(CENTER) = 915.0000 IN.
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OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.666	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 22.8 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.29 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.4 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 34.9 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.74	0.0731	2.319	0.1013	10.26	0.2254	0.341	0.2930
PROPENE (PROPYLENE)	479.36	0.5022	11.391	0.4974	20.64	0.4535	0.490	0.4211
PROPANE	405.39	0.4247	9.193	0.4014	14.61	0.3211	0.331	0.2845

TOTAL LIQUID MASS FLOW RATE = 954.49 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 45.51 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0455

HEAT CONTENT OF THE LIQUID = -149061.92 BTU/MIN = -156.17 BTU/LB
 HEAT CONTENT OF THE VAPOR = -22.73 BTU/MIN = -0.50 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149084.55 BTU/MIN = -149.08 BTU/LB

LIQUID DENSITY = 33.08 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.677

VAPOR DENSITY = 0.7095 LBM/CU.FT.
 VAPOR VISCOSITY = 0.5732D-05 LBM/FT*SEC = 0.82935D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.076
 VAPOR COMPRESSIBILITY FACTOR = 0.8968

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.54853D-03 LBF/FT = 8.734 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
PRESSURE (PSIA)	84.35	84.29	84.24
TEMPERATURE (F)	22.83	22.80	22.76
S.VAPOR VELOCITY (FT/SEC)	7.67	7.67	7.72
S.LIQUID VELOCITY (FT/SEC)	3.46	3.46	3.46
S.LIQUID/SOLID VELOCITY (FT/SEC)	3.46	3.46	3.46
PRESSURE DROP (PSIA)	0.05	0.05	0.05
FRICTION	0.05	0.05	0.05
ACCELERATION	0.2353D-02	0.2353D-02	0.2353D-02
POTENTIAL	0.0	0.0	0.0

INLET FACE = 1
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

OUTLET FACE = 2
 FLOW AREA = 20.0058 SQ.IN.
 WETTED PERIMETER = 15.8556 IN.
 RESIST. COEFF. = 0.0
 RELATIVE ROUGH. = 0.000357
 INNER WALL RADIUS = 2.5235 IN.
 ANGLE (REL. TO HOR.) = 0.0 DEG

EXPERIMENTAL DATA: NO
 INJECTED FLOW: NO
 ADIABATIC: YES

CONTENTS OF THE PRIMARY STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE PRIMARY STREAM = 22.7 DEG F
 PRESSURE OF THE PRIMARY STREAM = 84.19 PSIA
 BUBBLE POINT TEMPERATURE OF THE PRIMARY STREAM = 21.3 DEG F
 DEW POINT TEMPERATURE OF THE PRIMARY STREAM = 34.8 DEG F

THE PRIMARY STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.69	0.0730	2.318	0.1012	10.31	0.2254	0.343	0.2929
PROPENE (PROPYLENE)	479.27	0.5022	11.389	0.4974	20.73	0.4535	0.493	0.4211
PROPANE	405.32	0.4247	9.192	0.4014	14.68	0.3211	0.333	0.2845

TOTAL LIQUID MASS FLOW RATE = 954.28 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 45.72 LBS/MIN
 WEIGHT FRACTION OF THE PRIMARY STREAM THAT IS VAPOR = 0.0457

HEAT CONTENT OF THE LIQUID = -149062.18 BTU/MIN = -156.20 BTU/LB
 HEAT CONTENT OF THE VAPOR = -23.57 BTU/MIN = -0.52 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149085.74 BTU/MIN = -149.69 BTU/LB

LIQUID DENSITY = 33.08 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.678

VAPOR DENSITY = 0.7087 LBM/CU.FT.
 VAPOR VISCOSITY = 0.55723D-05 LBM/FT*SEC = 0.82921D-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 39.076
 VAPOR COMPRESSIBILITY FACTOR = 0.8969

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 0.59887D-03 LBF/FT = 8.739 DYNE/CM

	FACE	CONTROL VOLUME CENTER	FACE
	84.24	84.19	84.14
PRESSURE (PSIA)	22.76	22.73	22.70
TEMPERATURE (F)	7.72	7.72	7.76
S.VAPOR VELOCITY (FT/SEC)	3.46	3.46	3.46
S.LIQUID VELOCITY (FT/SEC)	3.46	3.46	3.46
S.LIQUID/SOLID VELOCITY (FT/SEC)			
PRESSURE DROP (PSIA)	0.05		0.05
FRICTION	0.05		0.05
ACCELERATION	0.2361D-02		0.2368D-02
POTENTIAL	0.0		0.0

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** CONDITION (STATE) OF THE PRIMARY FEED STREAM **
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CONTENTS OF THE FEED STREAM: (3 COMPONENTS)

N	INDEX	FORMULA	USER CHEMICAL NAME	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	MOLECULAR WEIGHT	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
1	3	C2H6	ETHANE	80.00	0.0800	30.07	2.660	0.1105
2	4	C3H6	PROPENE (PROPYLENE)	500.00	0.5000	42.08	11.882	0.4937
3	5	C3H8	PROPANE	420.00	0.4200	44.10	9.524	0.3958

TOTAL MASS FLOW RATE = 1000.0 LBS/MIN
 TEMPERATURE OF THE FEED STREAM = 22.7 DEG F
 PRESSURE OF THE FEED STREAM = 84.14 PSIA
 BUBBLE POINT TEMPERATURE OF THE FEED STREAM = 21.3 DEG F
 DEW POINT TEMPERATURE OF THE FEED STREAM = 54.8 DEG F

THE FEED STREAM IS TWO-PHASE AND HAS THE FOLLOWING VAPOR/LIQUID SPLIT:

COMPONENT	LIQUID				VAPOR			
	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION	FLOW RATE (LBS/MIN)	WEIGHT FRACTION	FLOW RATE (LBMOL/MIN)	MOLE FRACTION
ETHANE	69.67	0.0730	2.317	0.1012	10.33	0.2254	0.344	0.2929
PROPENE (PROPYLENE)	479.22	0.5022	11.386	0.4974	20.78	0.4535	0.494	0.4211
PROPANE	405.28	0.4248	9.191	0.4014	14.72	0.3211	0.334	0.2846

TOTAL LIQUID MASS FLOW RATE = 954.17 LBS/MIN
 TOTAL VAPOR MASS FLOW RATE = 45.83 LBS/MIN
 WEIGHT FRACTION OF THE FEED STREAM THAT IS VAPOR = 0.0458
 HEAT CONTENT OF THE LIQUID = -149061.88 BTU/MIN = -155.22 BTU/LB
 HEAT CONTENT OF THE VAPOR = -24.00 BTU/MIN = -0.52 BTU/LB
 TOTAL HEAT CONTENT OF THE STREAM = -149035.88 BTU/MIN = -149.09 BTU/LB

LIQUID DENSITY = 33.09 LBM/CU.FT.
 LIQUID VISCOSITY = 0.000070 LBM/FT*SEC = 0.10 CP
 LIQUID MEAN MOLECULAR WEIGHT = 41.678

VAPOR DENSITY = 0.7083 LBM/CU.FT.
 VAPOR VISCOSITY = 0.557180-05 LBM/FT*SEC = 1.829140-02 CP
 VAPOR MEAN MOLECULAR WEIGHT = 35.077
 VAPOR COMPRESSIBILITY FACTOR = 0.8969

VAPOR/LIQUID INTERFACIAL SURFACE TENSION = 1.539150-03 LBF/FT = 8.741 DYNE/CM

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