5-15-2009

An Evaluation and Redesign of a Thermal Compression Evaporator

Benjamin Marc Day
University of New Orleans

An Evaluation and Redesign of a Thermal Compression Evaporator

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
in
Mechanical Engineering
Thermal Sciences

By

Benjamin Marc Day, P.E.

May, 2009

DEDICATION

This thesis is dedicated to my wife Emily and my children Avalyn and Brennan. Without Emily's constant patience and fortitude to endure my long hours at work and school this degree would not have been possible.

ACKNOWLEDGEMENT

I would like to express my extreme gratitude to Dr. Ting Wang for the time that he dedicated to my growth as an engineer. He never stopped believing in me and never stopped pushing me to strive for greatness. while helping me forge that path through his knowledge and mentoring.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Evaporators separate liquids from solutions. For maximum efficiency, designers reduce the temperature difference between the heating and heated media using multiple-stage evaporators. This efficiency requires increased size and bulk.

A vendor claimed its thermal compression evaporator achieved high efficiency with only two stages. It did not function as claimed.

This project investigated the evaporator’s design to identify its problems and propose an alternative design with a minimized footprint.

The analysis showed theoretical flaws and design weaknesses in the evaporator, including violation of the first law of thermodynamics.

An alternative thermal compressor design was created through computational fluid dynamics using spreadsheet methods developed in house, aided by the software product FLUENT. Detailed component sizing was done using the software product HYSYS. The proposed redesign achieved four to one efficiency with two stage thermal compression, using one half of the space of a traditional system of similar performance.

Keywords: Thermal Compression Evaporation, Evaporator, Thermal Compressor

CHAPTER ONE

INTRODUCTION

Background

Evaporation is a special case of the larger topic of heat transfer to a boiling liquid. This process occurs so often that it has been given its own topic title. Evaporation is the removal of solvent as a vapor from a solution or slurry. Evaporation often encroaches on the unit operation of distillation, but evaporation differs by making no attempt to separate the components in the vapor phase.

The objective of evaporation is to concentrate a solution that consists of two liquids, one of the liquids consisting of a volatile solute and the other being a nonvolatile solute. Usually in evaporation processes the nonvolatile liquid is of value while the volatile vapors are condensed and discarded. However, the converse is true for the demineralization of water; the evaporation process is used for the removal of solids to make solid-free water. The solid-free water is used for boiler feed water, special chemical equipment, and human consumption.

A natural gas processing and gathering facility located in Louisiana. consists of a 300 million standard cubic feet per day (MMSCFD) cryogenic expander plant; a one billion standard cubic feet per day (SCFD) lean oil absorption plant; a 30,000 barrel per day (bbl/day) fractionation train; and a 13 megawatt (MW) power plant with 900,000 pounds mass per hour (lbm/hr) of 600 pounds per square inch gauge (psig) superheated 700 defree Fahrenheit (°F) steam capability.

In 2004 the facility purchased a newly designed thermal compression flash evaporator that had the compressors located inside of the evaporator, and employed impinging jet spray across the heat transfer surface. The evaporator was to be usedto desalinate brackish water from Tauphine Pass. The water produced would be used as boiler feed water in the network of superheated boilers that provide steam. The steam is used for both motive force for turbines and as heating medium source in the process operations. The evaporator was designed to deliver 150gallons per minute (gpm) of fresh water with a total suspended solids of less than one part per million (ppm), producing nine pounds per hour of fresh water using only one pound per hour

of fifty five psig saturated steam. Upon startup of the thermal compression evaporator (TCE), the unit fell well short of its original design criteria producing less than two pounds per hour of fresh water per pound of steam. Since the manufacturer was unable to find the cause of the problem, this study was initiated.

Objectives

The objectives of this study were to investigate the design of this commercial thermal compressor evaporator systemto examine the function of each component, to identify the cause of the failure to perform as specified, and to offer a solution. The following specific tasks were designed to reach the study objectives. The tasks, and the techniques each will use follow.:

1. Examine the overall energy and mass balance of the system. This will determine if the evaporator can achieve a steam economy of producing nine pounds of fresh water for each one pound of steam consumed.
2. Examine the function of each component. The necessary mechanisms will be verified by modeling the fluid mechanics, heat transfer, and mass transfer of the system.. This can help delineate any design errors incorporated into the original product.
3. Propose a solution. FLUENT (a commercial simulation program) simulation models will be run on the original thermal compressor design, and on a series of proposed new geometries for the compressor design , to determine if it is possible to enhance the performance and economy of the original design.

The mass and energy balances of the global model and of each component model will be evaluated by using the commercial process simulator HYSIS, and calculated using Microsoft Excel spreadsheets. Any thermal-fluid behavior, for example flow going through the thermal compressor, will be simulated by employing the commercial CFD package FLUENT.

CHAPTER TWO

LITERATURE SEARCH

Focus of Literature Search

The literature search focuses on:

the characteristics of evaporation and types of evaporators;

the performance, measurment and design considerations of evaporators.

Characteristics of Evaporation and types of evaporators

Evaporation is considered one of the first industrial operations used in manufacturing. During the 14th century the evaporation process was employed in the manufacturing of salt from sea water.

Figure 2.1: Fourteenth Century Salt Plant Courtesy of the British Library

As the development began to emerge of other industrial processes such as sugar production and water desalination for military naval ships[1], evaporation technology began to grow from a simple open pot used to collect the solid slurry to being able to capture the vapor and re-condensing it as a product. Even with these advancements this type of setup provided poor efficiency compared to the amount of heat required to boil the liquid. The reason for this

poor economy,(the pounds of solvent evaporated per pound of “heat” added), is that at atmospheric pressure it requires roughly one pound of steam for each pound of water (solvent) evaporated. This poor economy was improved by the development of multiple-effect evaporators (Figure 2.2).

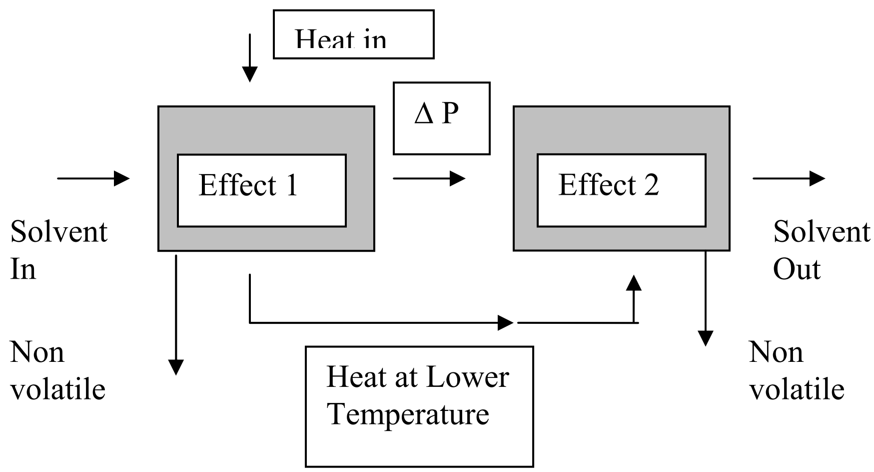


Figure 2.2: Multiple-Effect Evaporator

Performance, Measurment And Design Considerations Of Evaporators

Multiple-effect evaporators work on the concept of cascading energy. The solvent enters the first stage of the evaporator at some pressure P_1, and concentration C_{A1} where these variables determine the boiling point T_1 of the solvent. Heat is introduced into the effect-one to begin boiling the solvent. Since the boiling process is done under constant pressure the solvent leaving effect-one is approximately equal to $P_{1,}$ but the concentration C_{A1} of the solvent, has changed to C_{A2} so a new boiling point temperature exists by the equation of state; $T_n= P_n/C_{An}R$, n=1,2,3 .

To be able to take advantage of the exiting heat from effect-one and use it to induce boiling in effect-two the pressure in the solvent stream entering effect-two is lowered. This process is usually done with baffles or orifices placed in the path of the flow. With the pressure lowered the boiling point will also be lowered and heat from the effect-one can be used to promote boiling of the solvent in effect-two. This cascading of energy reduces the temperature differential between the heat source and the solvent so more energy can be extracted from the heat stream,resulting in improved economy of the unit.

The major advantage of multiple-effect evaporators is their high economy in terms of pounds of product per pound of steam. However the capital costs and footprint size associated

with these types of units can restrict their use. These problems arise because maintaining the heat delivery into the solvent stream with decreased temperature differential requires a greater heat exchange surface area in the evaporator.

Proof:

Eq. 2.1 Qstage = UAΔTlm, stage- Governing equation for staged heat transfer

Eq. 2.2 Qstage1= Qstage2 – For the same amount of heat in each stage

Substitute Eq. 2.1 into Eq. 2.2 to yield Eq. 2.3

Eq.2.3 U1A1ΔTlm 1= U2A2ΔTlm 2

Solving for A2

Eq.2.4 A2= A1*(ΔTlm 1/ΔTlm 2)*(U1/ U2)

Under the assumption of $U_1 = U_2$ this is valid when the two stages being evaluated have similar fluid properties. This usually can be ensured if the stages being evaluated are right next to each other as to not have much variation in the composition of the solvent or heating medium.

Eq. 2.5 $A_2 = A_1 * (\Delta T_{lm\ 1} / \Delta T_{lm\ 2})$

This shows that as $\Delta T_{lm\ 2} < \Delta T_{lm\ 1}$ the required surface area/stage increases.

This problem led designers and engineers to search for a way to decrease the required footprint and capital costs associated with multiple-effect evaporators,whie maintaining their high economy. This led to the introduction of the recompression evaporator.

There are two types of recompression evaporators. One uses mechanical compression and the other uses thermal compression. Both types of evaporator employ the same concept of upgrading the “value” of the heating medium stream as to increase the difference in approach temperatures between the solvent and heating medium/stage. This difference in the approach temperature between stages reduces the surface area required per stage. The reduction of surface area lowers the capital costs and foot print of the evaporator.

Mechanical compression evaporators (Figure 2.3) work by increasing the pressure of the working media, typically steam. This raises the saturation temperature of the media, by the equation of state. The increased temperature working media is then recycled back into the main heating media stream. This will cause a greater ΔT_{lm} and as a result a higher quantity of vapor will be produced per unit surface area. This type of compression is usually achieved by a compressor driven by an electric motor. Not only does the compressor increase the saturation

temperature of the media by raising the pressure, but the non-isentropic compression adds frictional heat which will superheat the media. (Figure 2.4)

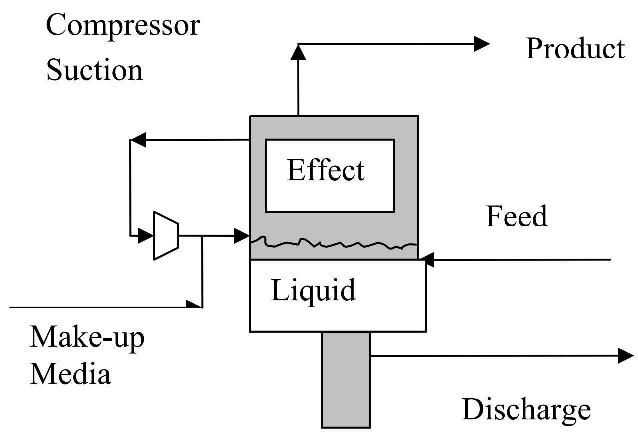


Figure 2.3: Single Stage Mechanical Vapor Compression Evaporator

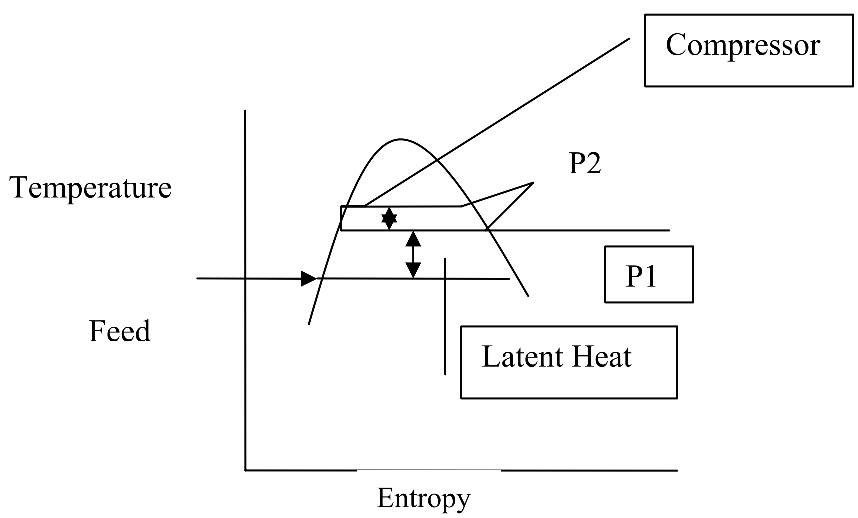


Figure 2.4: T-S Plot of a Single Stage Mechanical Vapor Compression Evaporator

This higher thermodynamic advantage of adding a compressor to reduce evaporator footprint comes at a price. The cost of operating the unit will go up as the horsepower requirement of the compressor increases. This design consideration must be weighed against the lower capital investment of a smaller footprint unit.

The higher cost of operation that exists with mechanical compression units has led to developments of other means of producing a higher grade of media. One of these developments is the thermal compressor. Although not as effective as a mechanical compressor it offers the

advantage of using an existing utility system for power instead having to add electrical load to a manufacturing plant or commercial facility.

The thermal compressor works on the principle of momentum transfer. Two streams enter the compressor, one stream of lower grade and one of high grade, with the hope of making a medium grade stream to be used in the evaporator. (Figure2.5) The high grade stream enters through a nozzle and expands through a converging-diverging nozzle. This high velocity fluid then entrains the low grade stream by a suction effect created by the high velocity passing the suction entrance. The two fluids are then mixed prior to the inlet to the throat where the velocity of the mixed stream is then reconverted to pressure energy by traveling through the throat and diffuser to make a medium grade stream.

The problem with the thermal compressor is that the momentum transfer is very sensitive to geometry since it is designed as a fixed orifice metering device. Any change in process condition that would require a change in pressure of the motive stream, the suction stream, or the discharge stream causes a proportionate change inthe ration of mass flow of motive fluid to suction fluid, resulting in a change of discharge flow. This can cause large inefficiencies in the compressor unit, resulting in underperformance of the evaporator and the waste of the high grade stream.

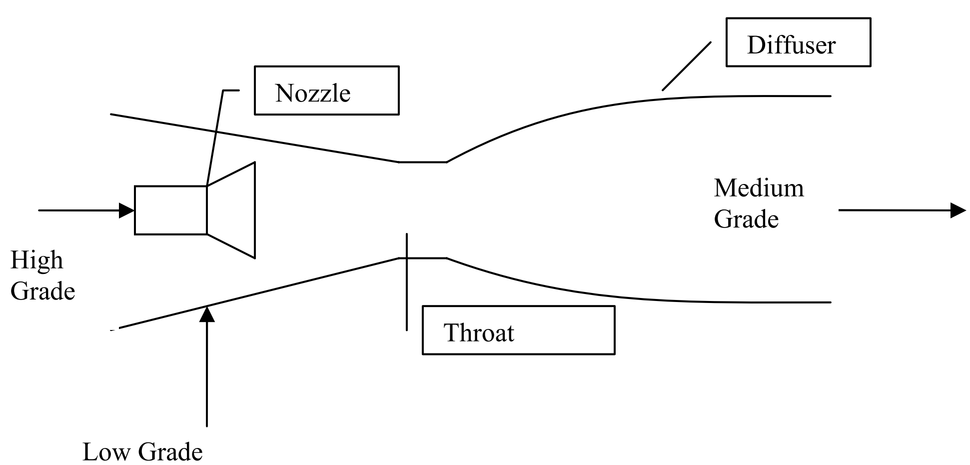


Figure 2.5: Process Flow of a Thermal Compressor

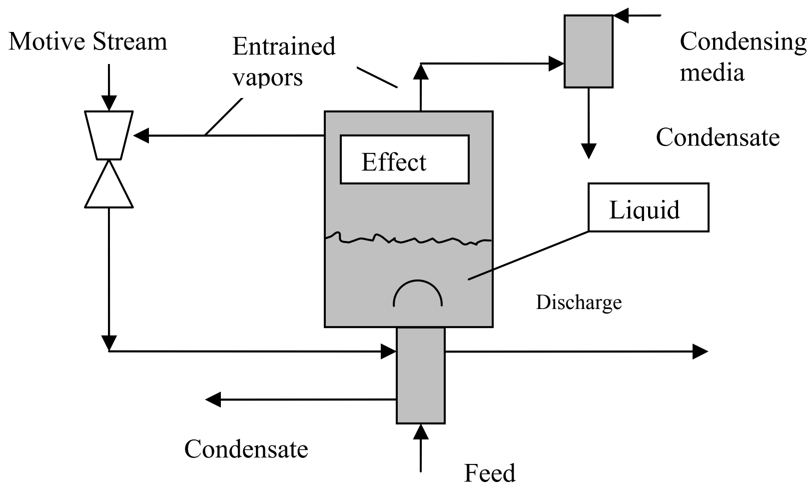


Figure 2.6: Single Stage Thermal Compression Evaporator

A thermal compressor evaporator and a mechanical compression evaporator work on the same design principle, as the with the exception of the source of motive power.. Instead of using an electric motor a high grade motive stream is used.. This is done to add value to the heating stream to provide a higher ΔT_{lm} so a smaller surface area can be used, which results in both a smaller footprint and a smaller capital cost.

There are several other types of evaporators other than the three that are mentioned. These other types were not considered in this thesis since no aspect of their design was used in the original commercial system. However the natural circulating evaporator does warrant a brief description due to its overwhelming use in industrial operations. Natural circulation evaporators or thermosiphons depend upon density differences of the fluid to produce the required flow rates. Vaporization creates an aerated liquid with a density less than that of the liquid system. The resulting differences produce a hydraulic head that will promote circulation of the fluid. The circulating fluid will travel through a heat exchanger where it will boil and where a portion of the vapor will separate from the liquid and be taken out of the evaporator as the volatile component.

Finally no discussion of evaporators would be complete without discussing the liquid characteristics of the streams,, because liquid characteristics are often a critical factor in evaporator design.. Some of the more important properties to consider follow.

Concentration

As the solution begins to thicken from increased boiling, the density and viscosity,increase with the solid concentration until the solution becomes saturated or the

solution becomes too sluggish for proper heat transfer. If saturation occurs, continued boiling of the liquid will cause crystals to form which may plugg the tubes. Another effect to be considered is that the boiling point of the solution may increase without an increase in pressure. This is caused by the higher concentration of solids in the stream produced from increased boiling.

Foaming

Some liquid solutions maybe more prone to foaming, most often from the introduction of organic compounds in the solution. A stable foam exists at the interface between the vapor and liquid phase. This foam causes entrainment of liquid into the vapor. If the quantity of this foam becomes extreme then all of liquid may boil out into the vapor and be lost.

Temperature Sensitivity

Consideration of the product to be evaporated is a concern. Excess heat added to the solution to “boil out” the lighter component may cause the liquid to burn as uneven heating may occur.

Biot Number

The liquid Biot Number should be considered, ensuring even heating of the solution.

CHAPTER THREE

EVALUATION OF COMMERCIAL UNIT

Subject of this Study

A commercial two-stage thermo-compression evaporator was examined. The evaporator consists of two effects or stages where the evaporation of fresh water from salt water solution takes place. The condenser is where all of the evaporated water and uncondensed motive steam will change phases from vapor to liquid and end up as product in the distillate stream. A pre-heater is used to help bring the water supply temperature closer to the evaporation temperature. Finally a vent condenser is used to condense a side stream of supply steam to help remove any incondensables in the condenser. Each effect is fitted with a thermal compressor to increase the "value" of the heating steam supplied to each effect. The manufacturer claims that its new design of adding thermal compressors to each stage will increase the economy of the unit from the three to one ratio that is to be expected from a conventional two-stage evaporator up to a ratio of 9.1 to 1.. This claim means that for every one pound of steam supplied to the unit, s the user may expect eight-and-one-tenth pounds of new distillate and one pound of condensed supply steam for a total of nine-and-one-tenth pounds of produced distillate.

Theory of Operation of the Commercial Unit

The piping and instrumentation diagram (P&ID) of the unit under study (Figure 3-6) shows four streams.

Stream **[A]**, is the superheated steam supply stream, at 60 psig and 350°F, which should provide both heating supply and motive force for the thermal compressors installed in each effect. A portion of the supply steam is also used to draw a vacuum on the unit and remove incondensables through the air inductor.

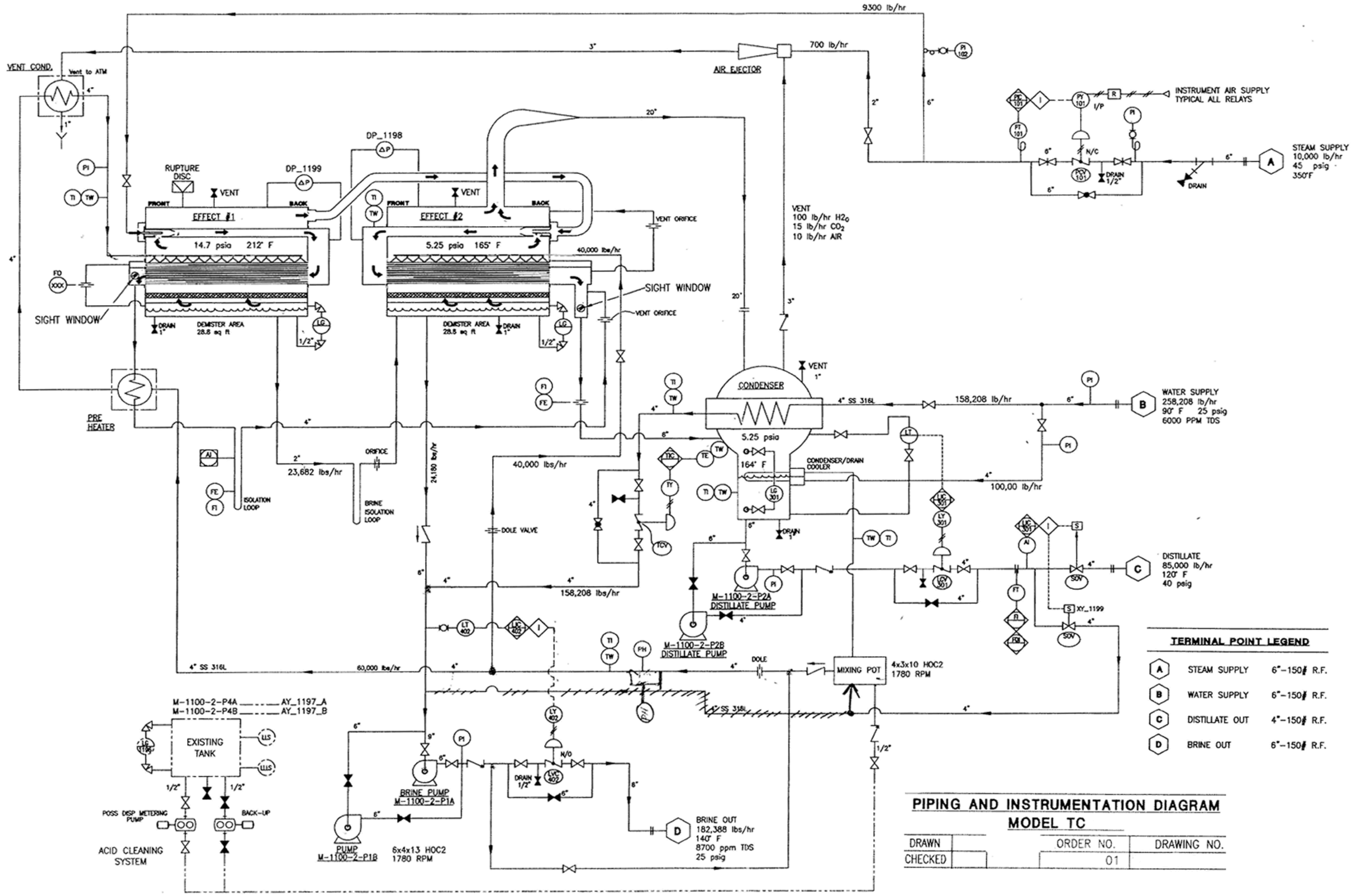


Figure 3.1 P&ID of the commercial thermo-compression Evaporator

Stream **[B]**, the water supply, provides raw feed water to both effects (100,000 pounds per hour) and also provides cooling water to condense the distillate from vapor to liquid (about 154,000 pounds per hour). The 100,000 pound per hour feed water split is heated to 164° F and then is directed into a mixing pot where sulfuric acid is injected to lower the PH of the water from 7.0 to 6.5. This acidification helps remove scaling from the tubes and shell of the effects. The feed water stream is split again with 60,000 pounds per hour being fed to effect one after being pre-heated with the saturated steam leaving effect one to approximately 212°F.. The remaining 40,000 pounds per hour goes to effect #2 with an entrance temperature of 165°F. The water entering into effect one and effect two is distributed via a spray bar to a horizontal bundle where steam from the steam supply combines with the suction of the thermal compressor to make a medium grade steam (approximately 212°F and 14.7 psia) in effect #1. This medium grade steam recirculates through the tube bundle in order to increase the mass flow rate in the tube bundle. The manufacturer claims this increased mass flow rate increases the evaporation rate of water, therefore improving the economy of each stage and providing the claimed overall economy of 9.1 to 1. Any steam that is not drawn up into the suction of the effect one compressor travels through a duct into effect two. This medium-grade steam from effect one is at a higher pressure and is used as the motive steam to drive the thermal compressors in effect two, where the steam is recirculated as described for effect one.

Stream**[C]** is the distillate stream. The vapor produced in effect one is used as heating media in the effect one feed water pre-heater, where it cools and then combines with the vapor produced in effect two. The combined output of the two effects flow into the condenser, condenses to liquid form and exits via Stream [C]as distillate product..

Stream **[D]** is the discharge of the condenser cooling water outflow and the concentrated evaporator bottoms.

The detailed component views and information are shown in Figs. 3.2 to 3.4 and Table 3.1.

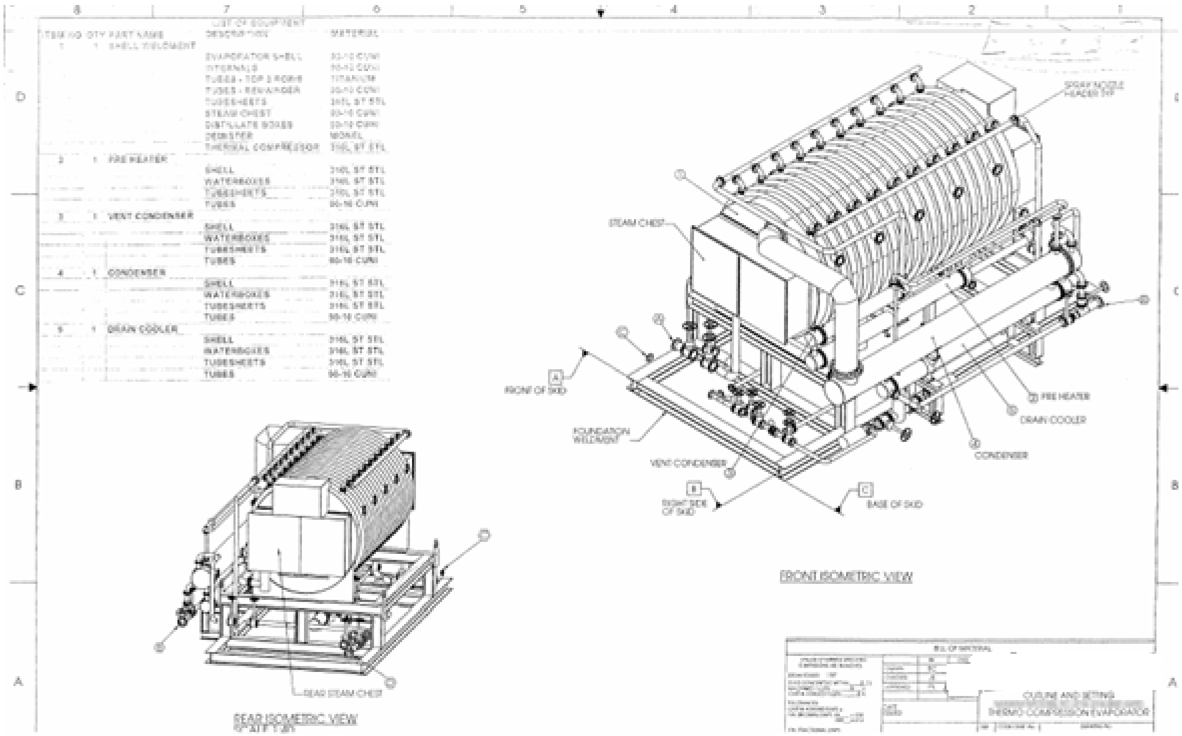


Figure 3.2 Commercial Thermal Compression Evaporator Isometric View

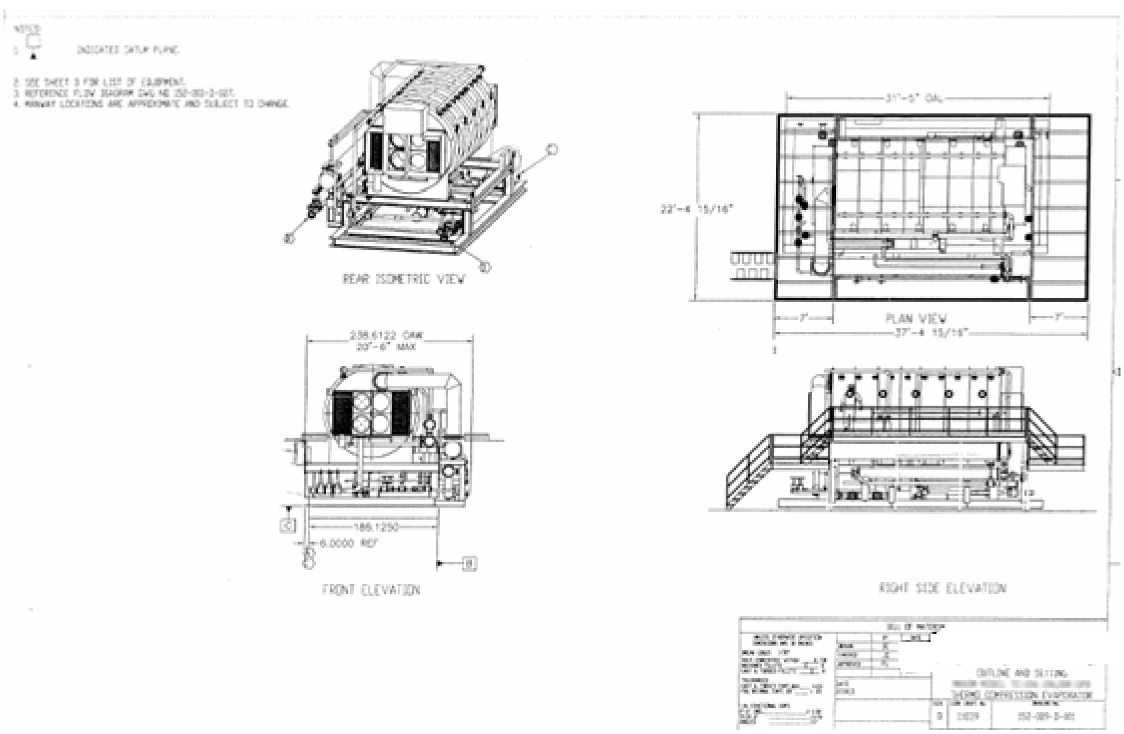


Figure 3.3 Commercial Thermal Compression Evaporator Elevation View

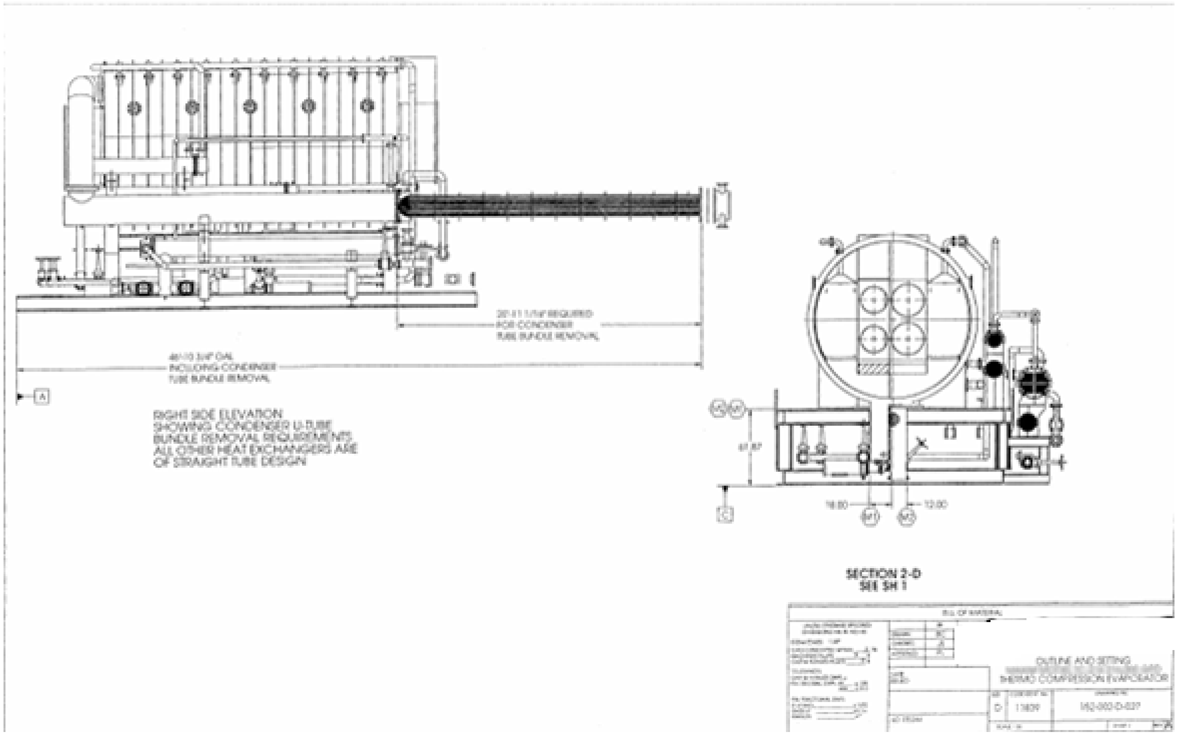


Figure 3.4 Commercial Thermal Compression Evaporator Heat Exchanger View

Description	Number of tubes	Material of Tube	Effective Length in.	Gauge of Tube BWG	Outside Diameter in.
Effect #1	1638	90/10 Cu-Ni	237	20	0.75
Effect #2	1638	90/10 Cu-Ni	237	20	0.75
Drain Cooler	163	90/10 Cu-Ni	198	20	0.75
Condenser	376	90/10 Cu-Ni	241	20	0.75
Vent Condenser	121	90/10 Cu-Ni	92	20	0.75
Pre-Heater	163	90/10 Cu-Ni	167	20	0.75

Table 3.1 Equipment specifications

Field Test and Modifications

The components designed as described above went through one test run before the unit was shutdown during commissioning. The results of that test run follow.

Stream Description	Flowrate lb/hr	Pressure psig	Temperature deg F
Steam Supply	17480	55	365
Water Supply	348600	38	N/A
Effect #1	N/A	35	N/A
Effect #2	N/A	N/A	N/A
Distillate	23406	38	160
Condenser	N/A	5	225

Table 3.2 Field Run Data

Based on the field run data, the evaporator produced an economy of 1.34 to 1 (23,406/17,480) significantly short of the original designed value of 9.1 to 1. The manufacturer believes that the poor result was a thermal compressor design bust where there was not enough increase in mass flow rate circulation through each effect to produce the design economy of 9.1 to 1..

The manufacturer reconfigured the thermal compressors. The original three-nozzle configuration (Figure 3.5) was replaced with a one-nozzle configuration (Figure 3-6). The redesign placed two thermal compressors in series through each effect. This brought the total compressor count up to four per effect.

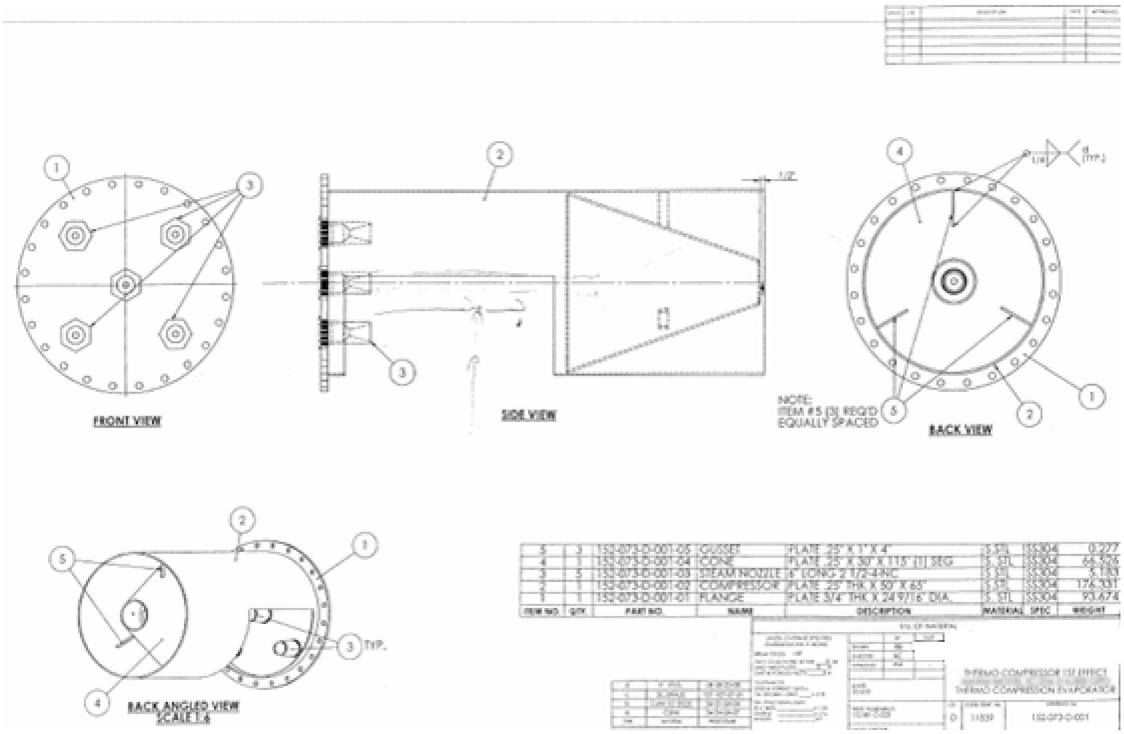


Figure 3.5 Commercial Thermal Compressors for Evaporator

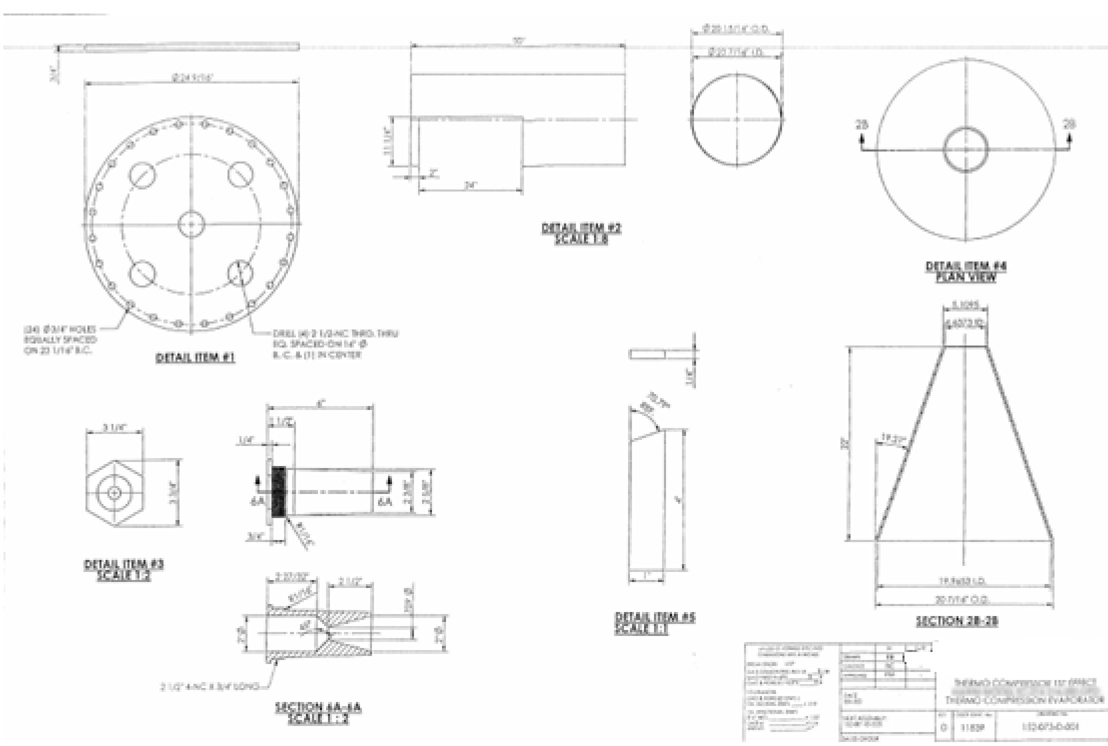


Figure 3.6 Commercial Thermal Compressors Nozzle Design

The retrofit was completed and the unit was started. Upon startup the pressure in the first effect rose to 55 psig which caused the rupture disc to release and vented all of the steam in the shell in the first effect to atmosphere. The follow-up inspection showed that the unit was mechanically damaged. The wall that separated the first effect and the second had been bent due to excessive differential pressure between the first and second effect.

This damage prompted the initiation of this research by examining the fundamental design principles through (a) global material and energy balance evaluation and (b) component to component evaluation. The global material and energy balance is described below. The component evaluation indicated that the probable cause was the thermo-compressor design. Hence, a comprehensive evaluation of thermo-compressor was conducted and is described in Chapter 4.

Material and Energy Balances of the Original Design

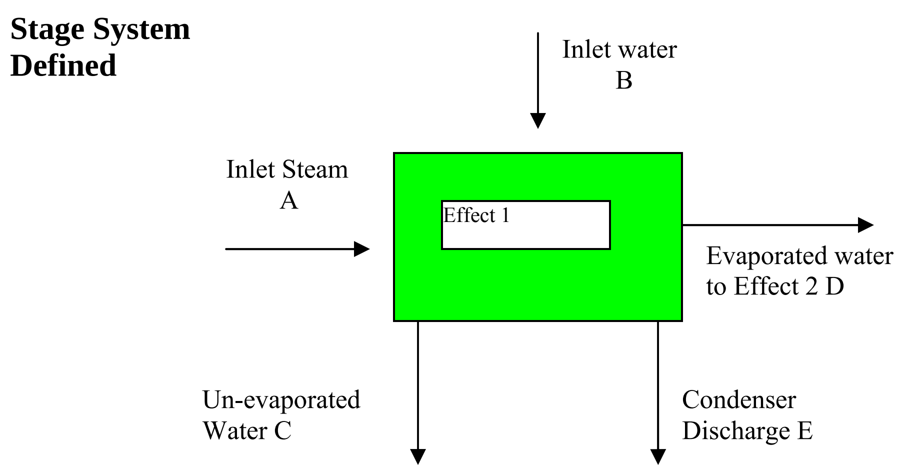


Figure 3-7 Stage Diagram Indicating Process Streams

Method of approach

An overall energy balance for each stage of the evaporator was done based on the process conditions indicated on the piping and instrumentation diagram (Figure 3.1).

Material Balance

First a system was defined indicating all of the material streams entering and exiting the system (see above system diagram in Figure 3.7). Then all of the enthalpy streams were established based on the pressures and temperatures specified on Figure 3.1. Finally to establish the claim that the thermal compressors internal recycle would produce the claimed economy per stage, four different cases were calculated. The suction rate of the compressor is defined as a function of inlet steam such that S= I *A, where S is the suction rate to the compressor, I is any non-negative integer indicating the suction ratio, and A is the inlet mass flow rate of steam. The sign convention used is negative for the energy exiting the compressor and positive for energy entering the compressor.

Energy Balance:

Compressor Balance -The enthalpy of stream E is established by the balance for constant composition of fluids. In this analysis it was assumed that the mixing was isentropic for the initial analysis.

$$H_{Discharge} = \sum_{i=1}^{\infty} \frac{M_i}{M_{Total}} (H_i) \qquad \text{(Eq. 3.1)}$$

M_i: The mass flow rate of an inlet stream to the compressor

H_i: The stream enthalpy of an inlet stream to the compressor

M_{Total}: The total mass flow rate of all inlet streams to the compressor

$H_{Discharge}$: The stream enthalpy of the discharge of the compressor

Expanding Eq.7 for all applicable streams to the compressor, the total energy of the discharge stream is found.

$$Q_{discharge\ E} = M_E\,[M_A/M_{Total}\,(H_A) + M_S/M_{Total}\,(H_S)] \qquad \text{(Eq.3.2)}$$

M_E: The mass flow rate of the discharge of the compressor

M_A: The mass flow rate of the motive stream to the compressor

M_S: The suction rate to the compressor that is defined as an integer multiple of the motive stream

Overall Balance

Qinlet- Qoutlet=0 (Eq.3.3)

Process Stream number	Flowrate (lb/hr)	Pressure psig	Temp- deg F	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guessed Value for S=constant*A
A	4650	60	350	1205.00	5.60	1
D	13950	14.7	212	1150.5	-16.05	
B	30441	14.7	212	180.17	5.485	
S	4650			1150.5		
C	11841	14.7	212	180.17	-2.133	
E	9300			1177.75	-10.953	
					-18.05	

Table 3.3 Energy Balance with Suction Rate Equal to Motive Steam Rate

Process Stream number	Flowrate (lb/hr)	Pressure PSIG	Temp- deg F	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guessed Value for S=constant*A
A	4650	60	350	1205.00	5.60	2
D	9300	14.7	212	1150.5	-10.70	
B	30441	14.7	212	180.17	5.485	
S	9300			1150.5		
C	11841	14.7	212	180.17	-2.133	
E	13950			1168.66667	-16.303	
					-18.05	

Table 3.4 Energy Balance with Suction Rate Equal to Two Times that of Motive Steam Rate

Process Stream number	Flowrate (lb/hr)	Pressure PSIG	Temp- deg F	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guessed Value for S=constant*A
A	4650	60	350	1205.00	5.60	3
D	4650	14.7	212	1150.5	-5.35	
B	30441	14.7	212	180.17	5.485	
S	13950			1150.5		
C	11841	14.7	212	180.17	-2.133	
E	18600			1164.125	-21.653	
					-18.05	

Table 3.5 Energy Balance with Suction Rate Equal to Three Times that of Motive Steam Rate

Process Stream number	Flowrate (lb/hr)	Pressure PSIG	Temp- deg F	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guessed Value for S=constant*A
A	4650	60	350	1205.00	5.60	4
D	0	14.7	212	1150.5	0.00	
B	30441	14.7	212	180.17	5.485	
S	18600			1150.5		
C	11841	14.7	212	180.17	-2.133	
E	23250			1161.4	-27.003	
					-18.05	

Table 3.6 Energy Balance with Suction Rate Equal to Four Times that of Motive Steam Rate

Results

In the four cases that are evaluated by varying the suction rate to the compressor, it shows the energy balance was never satisfied. The energy balance shows that the unit is “creating” energy on the order of 18MMBtu/hr. This creation of energy shows that there is a fundamental mistake conceptual problem with the design of the evaporator.

The conceptual flaw is the assumption that the compressors, with an increase of the mass flow rate to each stage tube bundle, the total energy of the stage will increase with the mass flow rate to each stage tube bundle. In realty, the increase of the mass flow rate to each stage tube bundle is just a redistribution of the mass flow rate from the motive steam to the tube bundle and this redistribution of mass flow rate does not increase the total energy entering the control volume of the entire stage. Since the total energy of the stage is not changed, then the increase in mass flow rate cannot increase additional evaporation because no additional energy is added.

Based on the energy balance calculation results, it is concluded that even with the assumption that the thermo-compressors can deliver the designed suction rate (9.1:1) that it will be never possible to achieve the claimed economy of 9.1/1 that the vendor made based on this design.

CHAPTER FOUR

THERMAL COMPRESSOR DESIGN AND ANALYSIS

Numerical Simulation of Alternative Designs

One of the problems of the original design has been identified as the steam jet suction effect . The designed suction flow rate should be about 3.5 times of the steam jet flow rate, but the energy and mass balances of the evaporator test indicates the suction flow rate was very low, only about 24% of the designed value. To examine the mechanism of the steam jet suction flow rate, numerical simulation was conducted using the commercial software product, FLUENT. FLUENT is a Computational Fluids Dynamics (CFD) software package specifically written to simulate thermal flow, mass and heat transfer, combustion, and similar phenomena. Heat transfer between the steam jet and suction flow was calculated, and the compressibility effect was also considered. To improve the suction flow rate, the existing design and various revalued parameters were considered and incorporated to improve the suction flow rate. These parameters include the location of the jet exit, flow resistance due to the downstream contraction cones, size of the suction openings, contours of the contraction cone, and the addition of a diffuser downstream of the contraction. The simulations were performed by Dr. Xianchang Li, a Project Engineer of the Energy Conversion and Conservation Center of University of New Orleans.

The simplified geometry of the existing design is shown in Figure 3-1. It was assumed the flow was axisymmetric. The total length of the pipe is 248 inches with a diameter of 20 inches. The diameter of the jet is two inches, injecting from the same location as the contraction cone entrance in the mainstream direction. The first contraction cone is close to the steam jet and has a length of 22 inches. The other two downstream contraction cones have a length of 21 inches each. The exit diameters of the three contraction cones are 5.0, 4.4 and 4.0 inches, respectively. The left cone is located 28 inches from the left end of the pipe. The distance between the other two cones is 20 inches. Starting from the left end, the suction opening is 24 inches.

During numerical analysis, the suction opening and the outlet were fixed at a constant pressure (atmosphere). The jet velocity was 100 meters per second (m/s) with a total flow rate of 0.099 kilograms per second (kg/s). The steam jet was assumed to be 450 degrees Kelvin (°K) or 350 degrees Fahrenheit (°F), and the suction flow had a temperature of 373°K (212°F).

Notice that in the real situation, the steam jet mass flow rate was higher due to its higher pressure. It is believed that the mechanism of suction presented in this report is applied to the real system with higher steam pressures present because the critical factor is the pressure difference. The actual pressure plays a secondary role.

Results

The computed pressure and temperature fields of the existing design are shown in figure 4.1 and the velocity field and stream function distribution are shown in figure 4.2. These figures show that the static pressure was high between the first and second contraction cones. The high temperature jet mixed with the cool entrained (suctioned) steam and became a moderate temperature flow. Strong recirculation occured inside the contraction cones and in the suddenly opened section immediately downstream of the contraction cones. The recirculation signifies inefficient aerodynamic performance and increased pressure losses as well as entropy production.

The simulation result indicates that the suction flow rate was only about 24% of the steam jet flow rate, significantly lower than the designed value of 350% of the steam jet flow rate. Thus low suction rate is considered to be the main cause of the low output of distilled water. A comprehensive study has been performed to simulate parameters that can potentially affect the suction flow rate. About twenty cases have been simulated.Only the cases with favorable results are presented here.

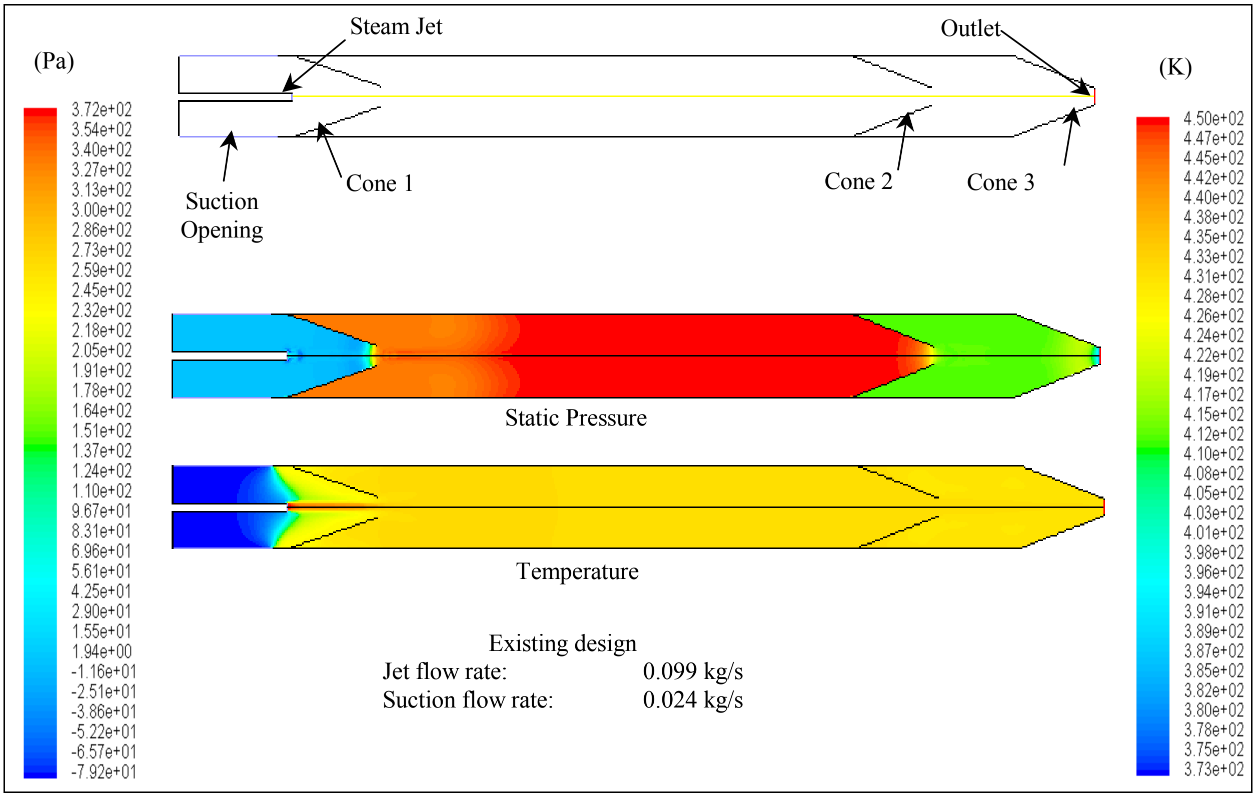


Figure 4.1: Pressure and Temperature Fields of the Existing Design

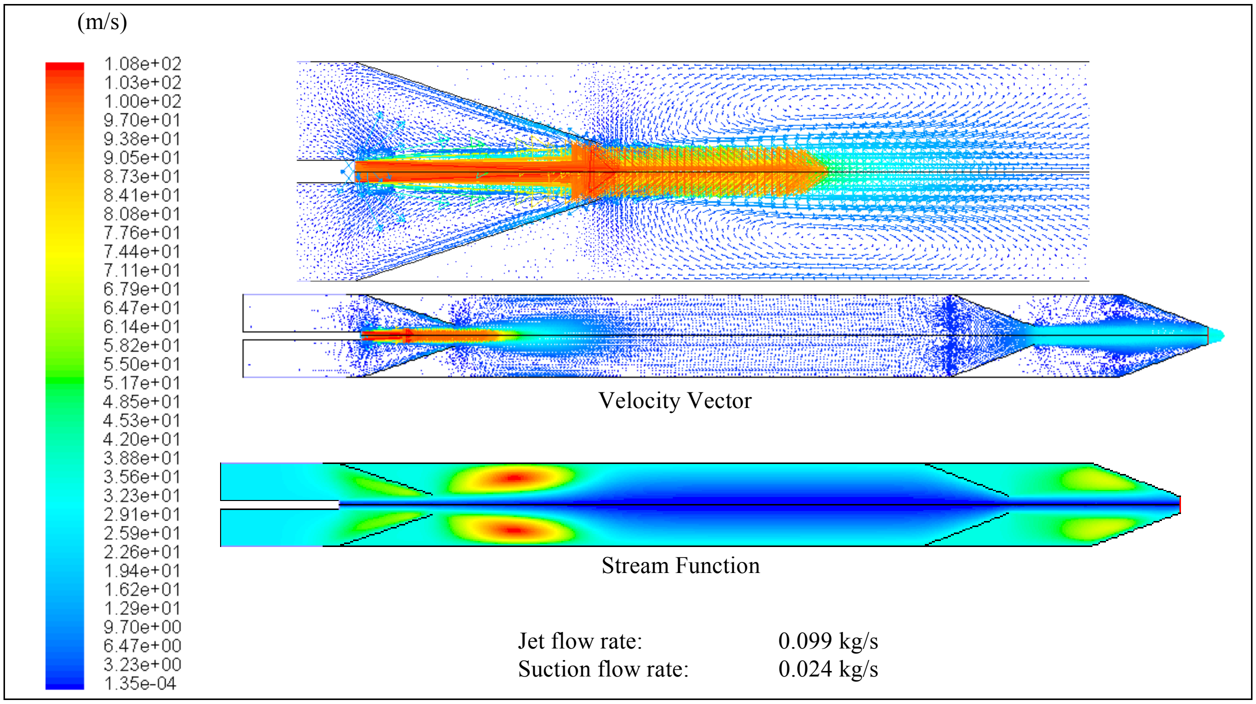


Figure 4.2: Velocity Field and Stream Function of the Existing Design

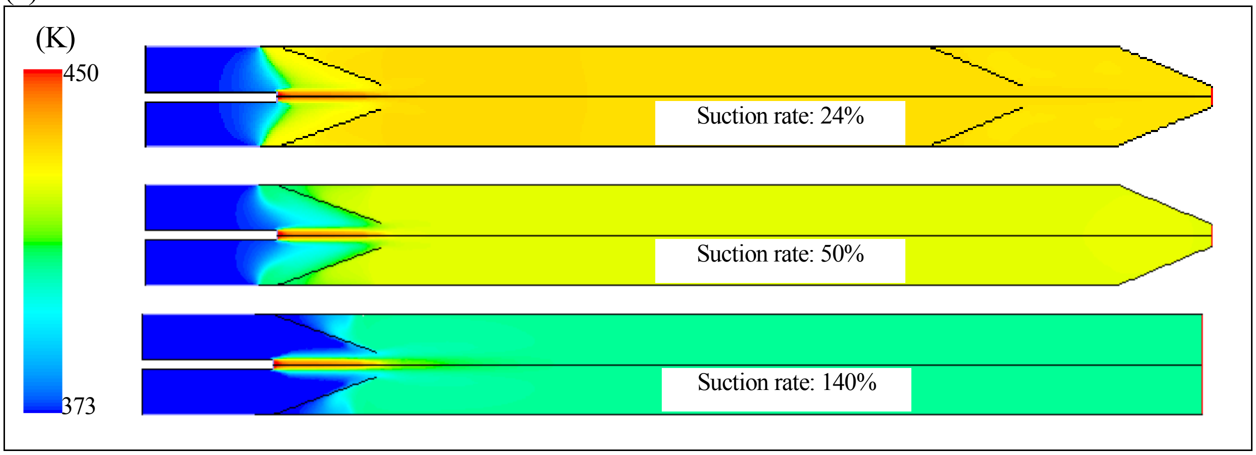
Effect of Adding a Downstream Contraction Cone

The effect of downstream contraction cones was simulated by removing one of the downstream cones in subsequent simulations. Figure 4.3 shows that by removing one cone the suction rate is increased from 24% of the steam jet flow rate to 50%. Removing both the downstream cones increased the suction rate to 140% . . .a six-fold augmentation! The reverse flow inside the contraction cone is weakened; however, the flow recirculation downstream of the contraction cone still occurs. With both downstream contraction cones being removed, the suction flow rate increases, and the temperature of the mixed flow becomes lower, as shown in figure 3(b). These results clearly show that the downstream contraction cones do not provide additional momentum transfer or suction power as originally designed. Instead, they adversely create high flow resistance and significantly impede the suction performance of the first stage steam jet.

Effect of Adding a Downstream Diffuser

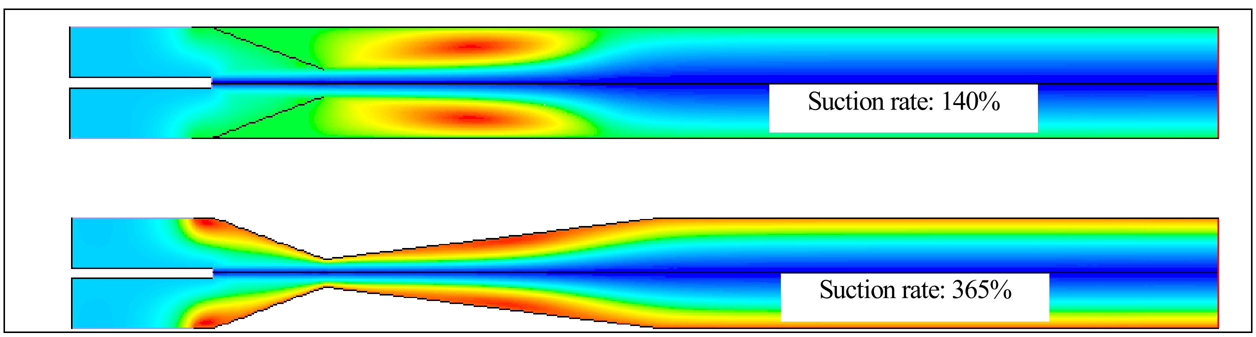
, In the simulation, a diffuser was added into the pipe to reduce the flow recirculation downstream of the contraction cone. The diffuser followed the design of a standard Venturi nozzle. The length of the diffuser was 66 inches, resulting in a diffusing angle of 6.5 degrees(°), to reduce flow separation near the wall. Figure 4.4 shows the comparison between the cases with and without the downstream diffuser. The flow recirculation area is obvious downstream without the diffuser. The flow separation is negligible inside the diffuser. With the diffuser the suction flow rate is increased to 365%, a 2.6-fold increase from the case without the diffuser and 15.2 times more than the real world design. The temperature of the mixed flow becomes even lower due to the high suction flow rate. From these results, it can be concluded that employing a downstream diffuser to reduce aerodynamic losses is extremely important. It is easy to completely remove the flow separation by reducing the diffuser's included angle below 6°..

(a) Stream function

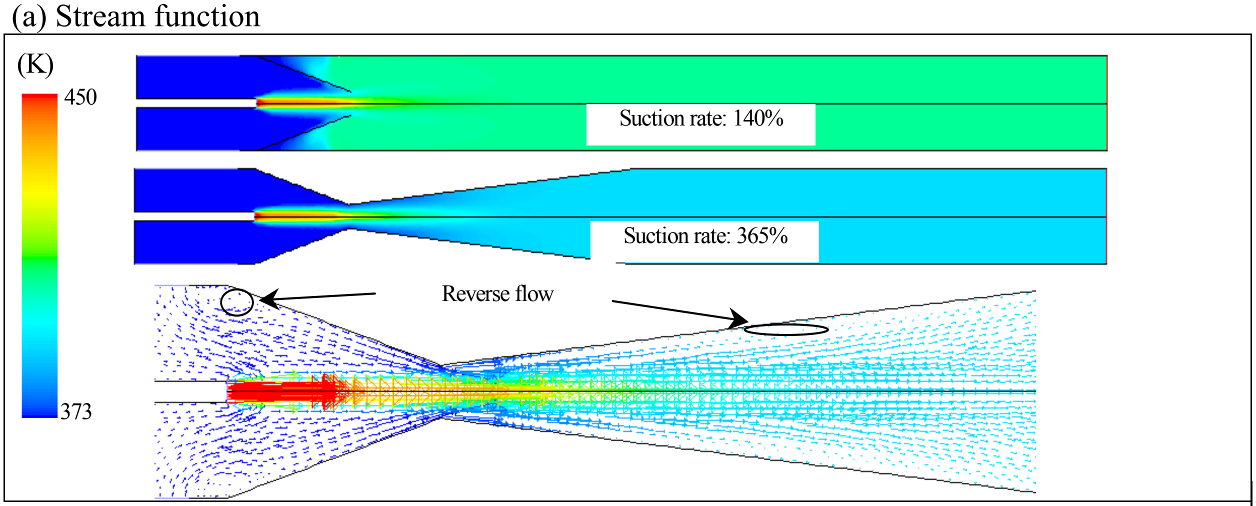


(b) Temperature

Figure 4.3: Effect of Downstream Resistance



(a) Stream function

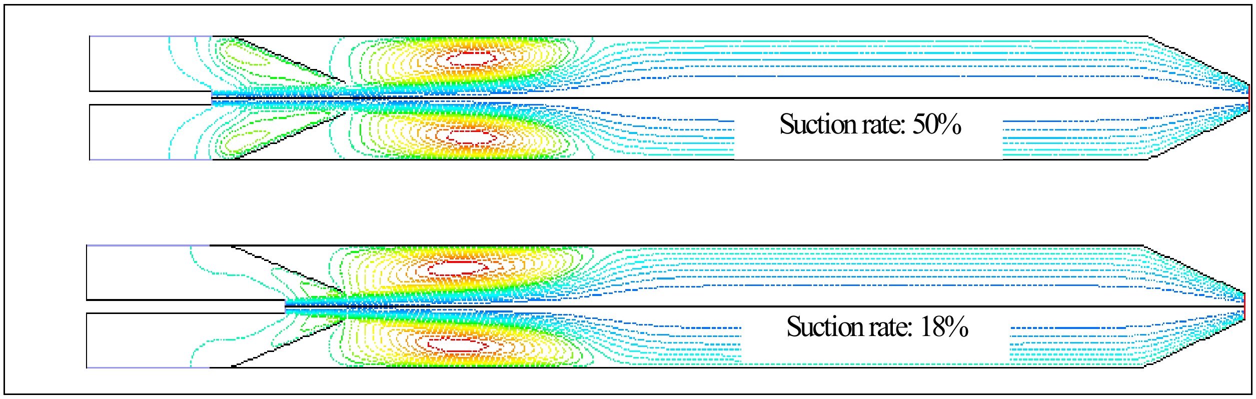


(b) Temperature and Velocity Vector

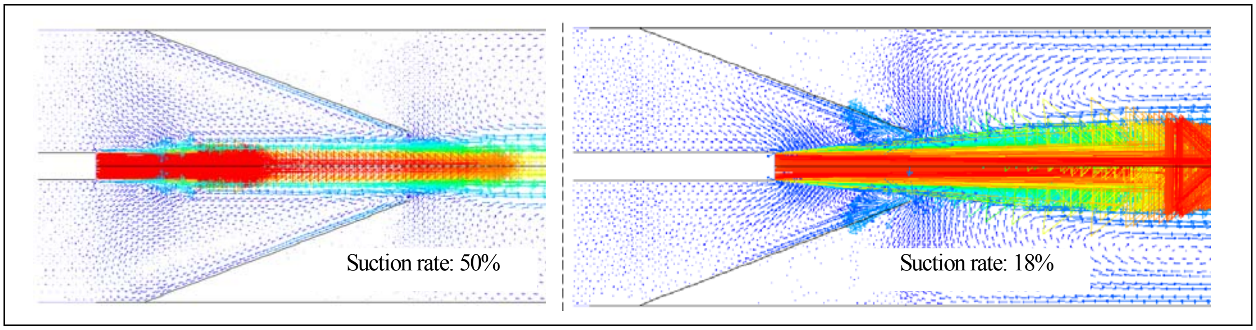
Figure 4.4: Effect of Downstream Diffuser

Effect of the Location of the Steam Jet

To provide for a more effective suction ratio, the effect of the location of the steam jet exit was examined. Several cases were studied by moving the steam injector, originally located at the the contraction cone entrance, both away from and toward the contraction cone entrance. Figure 4.5 shows results of two cases: one where the steam jet was located in the plane of the cone entrance, and another case where the steam jet was moved half way into the contraction cone. Both cases included one downstream contraction cone. The reverse flow became stronger in the second case, resulting in a reduction of suction flow rate from 50% to 18%. After comparing many locations of the steam jet, it was concluded that best result occurs when the steam jet is located right at the centerline at the contraction cone entrance. A slight displacement of the jet did not result in any significant change in the suction flow rate.



(a) Stream function



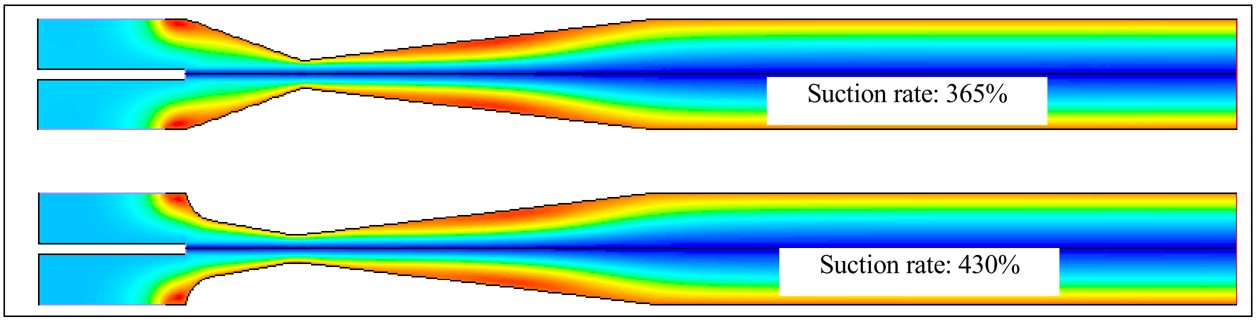
(b) Velocity Vector

Figure 4.5 Effect of Jet Location

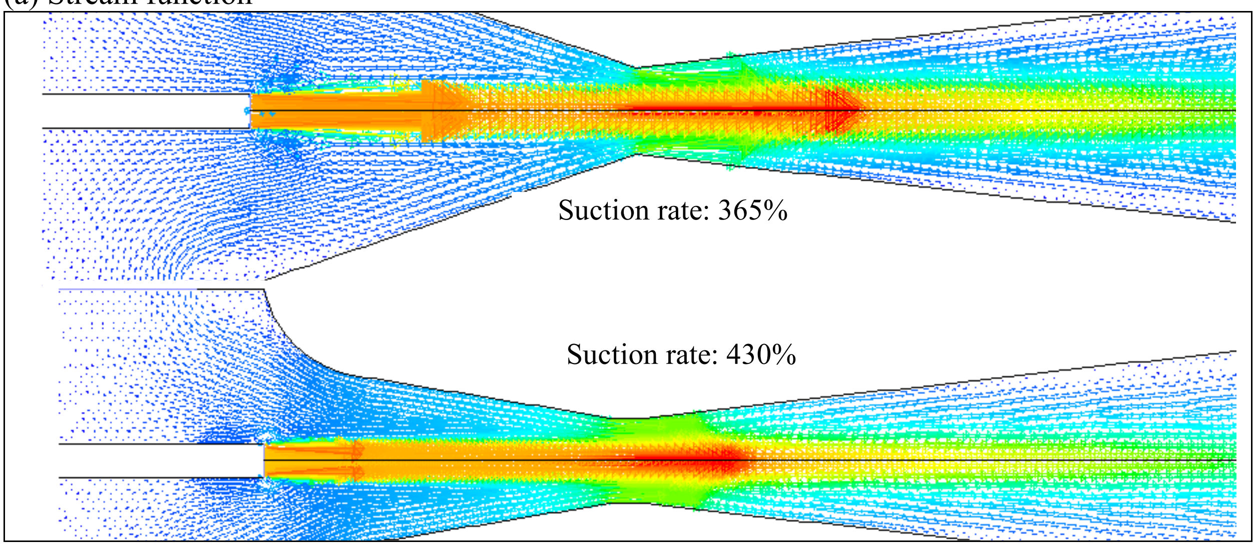
Effect of the Contraction Cone Wall Contour

Simple straight-wall contraction cones and diffusers are easier to manufacture than contoured cones and diffusers, Even so, the possible enhancement of the suction flow rate by adding contoured wall to the contraction cone was investigate.. Figure 4.6 shows the results

using a modified cone and diffuser geometry. The contraction cone has a contoured wall, and a small section of straight transition (4 inches) was added between the cone and diffuser to smooth the transition from the convergent cone to the divergent cone. The result indicates the contoured contraction cone and the added transition piece increase the suction flow rate about 20% from 365% to 430% of the steam jet flow rate.



(a) Stream function



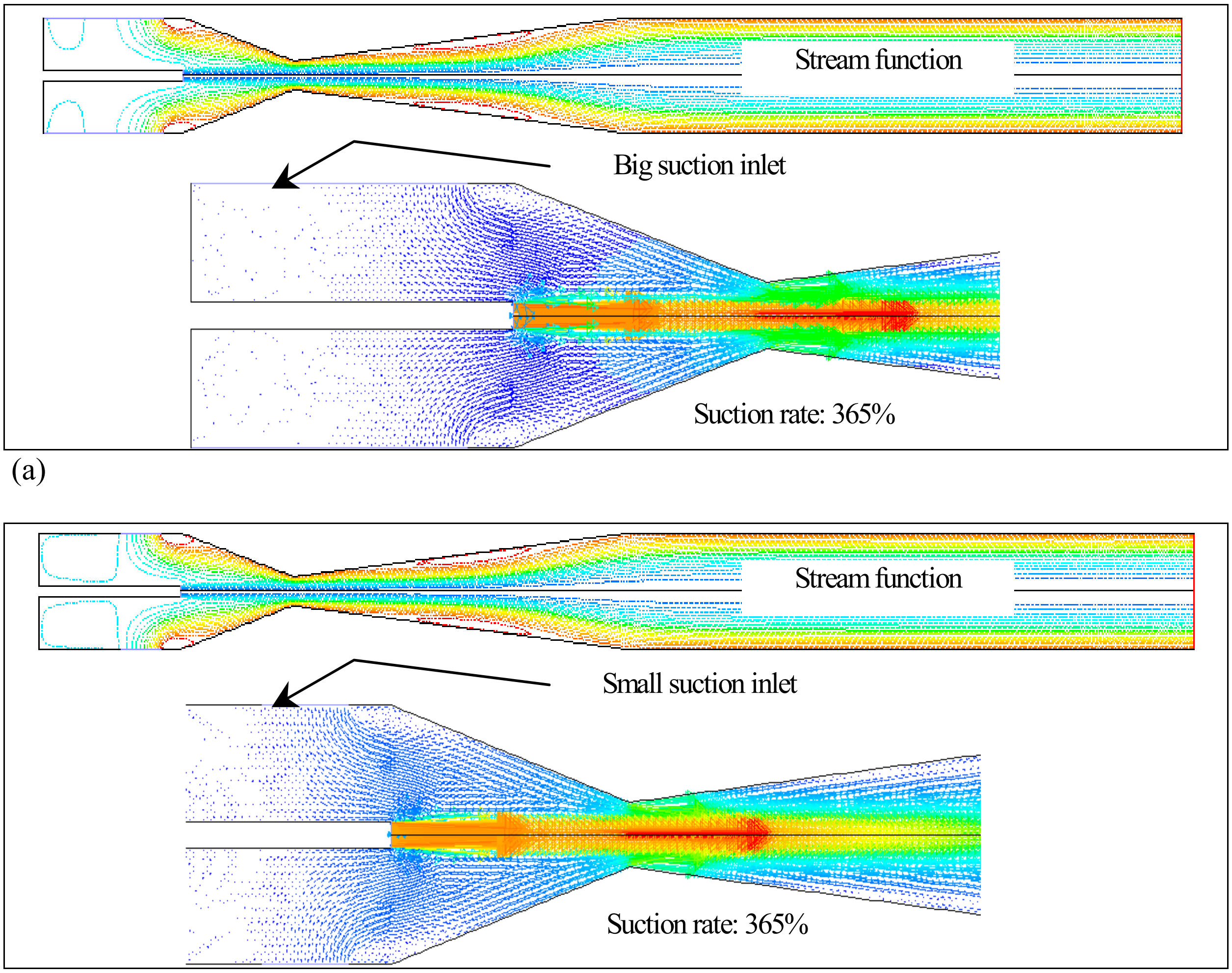
(b) Velocity Vector

Figure 4.6 Effect of Cone Contour

Effect of the Size of the Suction Opening

The suction opening is an opening connecting the evaporating volume to the thermal pump duct. The designed opening is a cut-through section on the chamber wall housing the steam injector and the contraction cone. The opening is 24 inch long and cut-through about one half of the pipe surface. As an approximation, the suction opening is treated as an axisymmetric opening slot during the simulation. Since it is not clear if the opening size would affect the suction flow rate, the effect of suction opening size is then examined. Two cases are studied,

Case (a) has a baseline opening size, and Case (b) has a smaller suction opening (1/3 of the baseline opening). The results in figure 4.7 indicate that the stream function as well as the velocity vector does not change much in these two cases. The corresponding suction flow rates are almost the same at 365%.



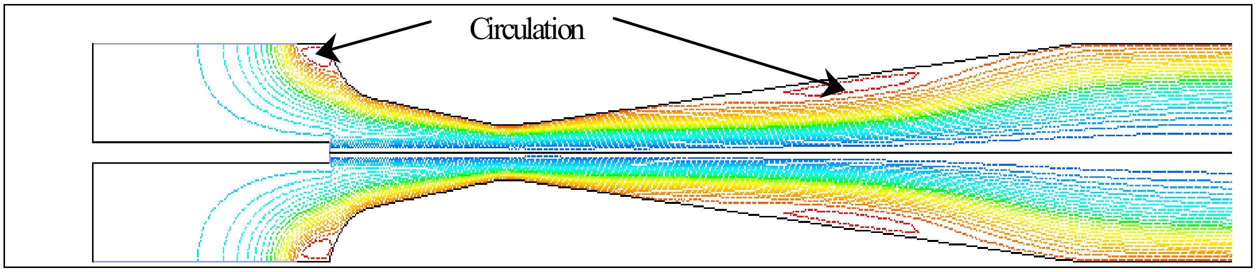
(b)

Figure 4.7 Effect of Suction Opening Size

Effect of Adding a Suction Flow Guide

To reduce the large flow recirculation near the contraction cone entrance, a contoured flow guide was added between the existing contraction wall and the steam jet injection tube. Two cases were compared: one without and the other with the flow guide. Both cases had the downstream diffuser and a downstream contraction cone. The results in Fig. 4.8 show that these two cases showed similar suction flow rates: 104% (0.103 kg/s) in the first case versus 99%

(0.0982 kg/s) in the second. The benefit of adding a flow guide is negligible and probably not worth the expense of adding it.



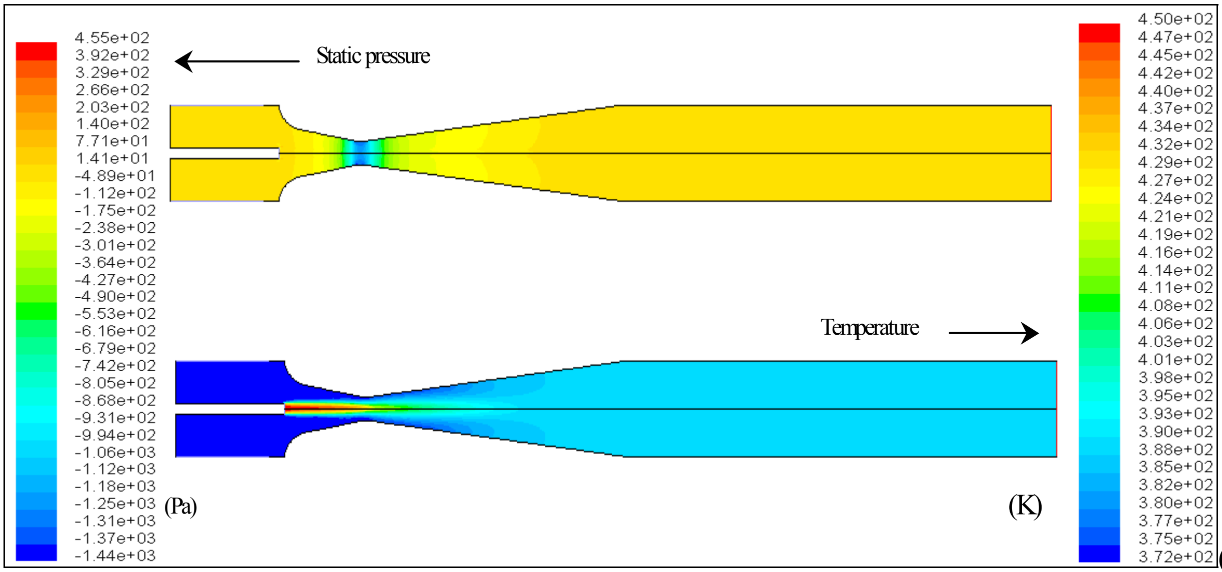
(a) Stream function

Figure 4.8 Effect of Suction Flow Guide

An Optimal Case

The favorable features discovered in the course of the simulations were combined into an optimal case.This optimal simulation used a contoured contraction cone with a long downstream diffuser and a transition piece between the contraction cone and the diffuser. This simulation used no downstream contraction cones. The result in Fig. 4.9 shows smooth flow field with minimized flow recirculation zone. The suction flow rate is 0.4233 kg/s or 430% the steam jet flow rate. Further optimization can be conducted if needed.

This study considers several different ways of enhancing the suction flow rate of the thermal compressor in a certain thermal compression steam evaporator. The actual suction flow rate is subject to the numerical uncertainty when applied to real situations; however, the knowledge obtained from the numerical simulations is extremely useful in providing an approach to solve the problems manifested by the existing system.



(b

(b) Temperature and Velocity Vector

<u>Figure 4.9 Case with Contoured Cone and Downstream Diffuser</u>

Conclusions after numerical simulations

Considering the results of the previously described numerical simulation, the following conclusions are made:

1. Neither of the downstream contraction cones provide additional momentum or additional suction flow rate as claimed in the original design. Instead, they create large downstream flow resistance and impede the overall suction performance. Removing both downstream cones significantly increases the suction capacity. The suction rate doubles by removing the first contraction cone and increases 5.8 times by removing the second contraction cone.
2. Adding a diffuser downstream of the contraction cone provides a significant increase in the suction flow rate. Adding a simple straight diffuser with an included angle of 6.5^{o} increases the suction flow rate by 2.6 times.
3. The location of the steam jet injection point affects the suction flow rate. The best location appears to be at the center of the contraction cone entrance. The suction flow rate reduces when the steam jet injection location is moved into or away from the entrance plane. When the injection location is placed half way between the entrance and the contraction exit, the suction flow rate decreases 67%.

4.   Employing an aerodynamically contoured contraction cone provides a 20% augmentation of suction flow rate. This favorable effect, while significant, would not by itself cure the problems of the original design..

5.   The suction opening connecting to the vapor plenum is not important. Shrinking the suction opening to one-third or two-thirds of the original size does not change the suction flow rate.

6.   Adding a contoured annular passage to guide the entrained flow shows little effect on the suction flow rate.

Recommendations

Based on the above study, an optimal design can be obtained by

(A) installing a contraction cone with an aerodynamically contoured wall profile;

(B) adding a 90-inch long diffuser downstream of the contraction cone;

(C) removing all the downstream contraction cones; and

(D) locating the steam jet injection point at the center of the contraction cone entrance plane.

(E) adding a 4-inch straight transition piece between the contraction cone and the diffuser;

(F) filing smooth all of the welded joints and fillings all gaps along the thermal compression flow path;

(G) continuing optimization studies to determine if additional improvements might be made.

The suction flow rate of this optimal case is 0.4233 kg/s, which is 4.3 times the flow rate of the steam jet and 18 times better than the existing design.

CHAPTER FIVE

ALTERNATIVE DESIGN

Development of Alternative Design

General Methodology

Since the original commercial unit did not work, an alternative design is required. The alternative design will use both spreadsheet calculations and the commercial software program HYSYS to validate the calculations. HYSYS is a thermodynamic simulator that allows modeling of process equipment. This simulator is based on the Peng-Robinson equation of state. It allows the user to define a networked system of process equipment; such as heat exchangers, reactors, pumps, and compressors. The user then defines the inlet and outlet material and energy streams; or just the inlets and configures the individual pieces of process equipment. Based on the users input HYSYS will calculate the output of the system based on the specified equipment, or the equipment specification of each piece of process equipment needed, based on the specified output. The design conditions for the newly designed unit will use the same process feed conditions as the original commercial unit. The alternative design is based on using the same thermal compressor principle to increase the evaporation economy ratio with a minimized footprint.

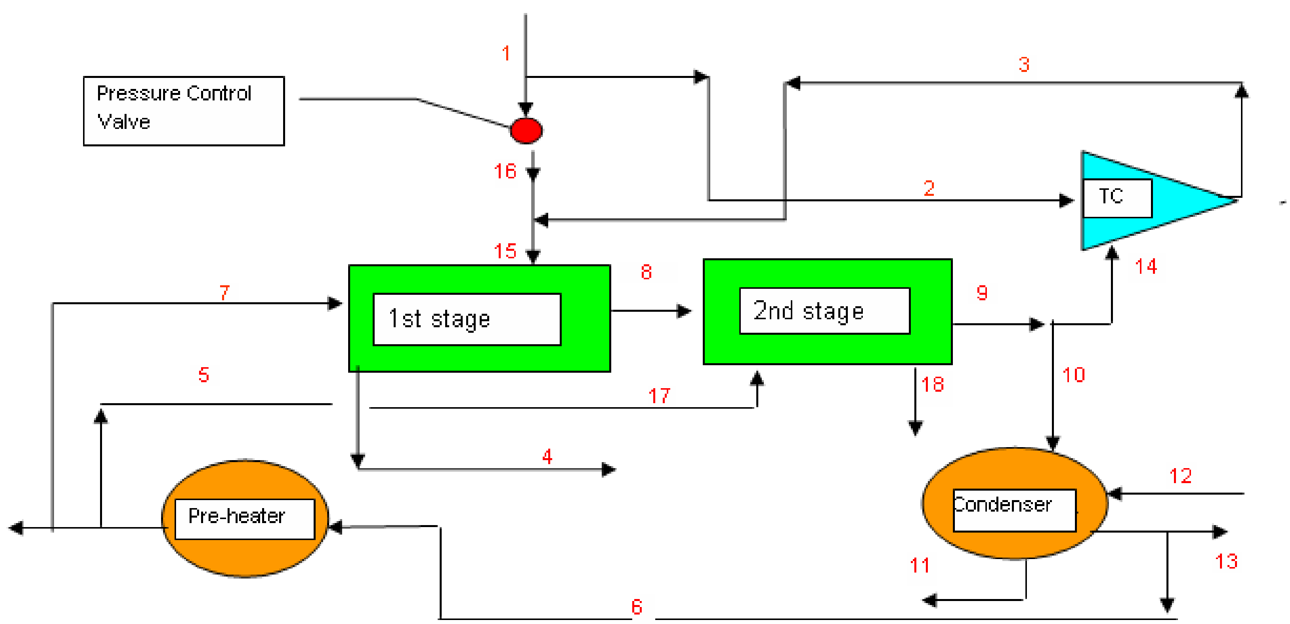


Figure 5.1 Process Flow of the Redesigned Alternative Thermal Compressor Evaporator

Description of Proposed Process Flow

Inlet steam enters along stream 1, where it is split into two streams, 2 and 16. Stream 2 goes to the thermal compressor as the motive steam to generate suction to draw in more lower-grade steam mass from the exit of stage 2 in order to achieve a higher evaporation economy ratio. The remaining portion of stream 1 goes through a pressure control valve as stream 16 to match the discharge pressure of the thermal compressor, stream 3. The discharge of the thermal compressor, stream 3, and stream 16 combine together to make stream 15. Stream 15 then feeds into stage 1 as the heating medium which will then evaporate the feed water, stream 7. The evaporated feed water leaves the first stage as stream 8 and proceeds to stage 2 to provide heating medium to evaporate the feed water, stream 17, which enters into stage 2 and evaporates to form stream 9. Stream 9 is then subject to the suction force generated by the thermal compressor. Depending on the prime motive-steam energy quality (pressure and temperature), a portion of stream 9 is drawn into the thermal compressor as stream 14 and mixes with the prime motive stream 2 to form a medium-grade steam with multiplied mass flow rate as stream 3. The remaining amount of stream 9 turns into stream 10, and is condensed in the condenser as product and is combined with stream 18 and stream 4 as the total product streams.

The evaporation ratio of this design depends on the thermal compressor performance.

Four cases were evaluated based on the thermal compressor suction rate as a function of the motive steam. As in the evaluation with the commercial unit the suction rate is looked at as an integer function of motive steam rate, such that $S = I * A$ where S is the suction rate to the compressor, I is any non-negative integer indicating the suction ratio, and A is the inlet mass flow rate of steam. The results of the four cases with the suction ratio from 1 to 4 are shown in Table 5.1 through Table 5.5. .

Simple Two-Stage Evaporator with No Thermal Compression

The first simulation run is a simple two-stage evaporator with no thermal compression. This is done to establish a base line of how much distillate can be produced without the use of a thermal compressor. The total energy balance sums zero for each stage showing that energy is conserved going in and out of the unit. The total distillate that is formed is 44.36gpm. This is the total product that would be made using the commercial design's specifications with no thermal compressor. This design yields an overall economy of 2.2.

Stream Number	Process fluid	Pressure psia	Temp deg F	Mole Flow lb-mol/hr	Mass Flow lbm/hr	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guess Stream 14= constant * Stream 2	
1	Inlet steam	75	375	555.56	10000	1218	12.18	Constant=	0
2	Motive steam	75	375	0.00	0	1218	0		
3	Steam from TC	#DIV/0!	#DIV/0!	0.00	0	#DIV/0!	#DIV/0!		
4	Saturated water	14.7	212	555.56	10000	180.17	1.80		
5	Subcooled water	14.7		555.56	10000				
6	Subcooled water	20	150	0.00					
7	Saturated water	20	212	586.76	10561.7	180.17	1.90		
8	Saturated steam	14.7	212	586.76	10561.7	1150.5	-12.15		
9	Saturated steam	5	162.24	640.43	11527.8	1131.1			
10	Saturated steam	5	162.24	640.43	11527.8	1131.1			
11	Distillate	5	162.24	640.43	11527.8	130.2			
12	Cooling Water	20	80	0.00					
13	Cooling Water	20	152.24	0.00					
14	Saturated steam	5	162.24	0.00	0	1131.1			
15	Steam to stage 1	75	375	555.56	10000	1205	12.05		
16	Reduced pressure steam	75	375	555.56	10000	1218	12.18		
17	Saturated water	20	212	640.43	11527.8	196.31	2.263		
18	Saturated water	5	162.24	586.76	10561.7	130.2	-1.375		
stage 1 EB	0								
Stage 2 EB	0								
Total Distillate produced lb/hr	22089.5								
Distillate total gpm	44.36								

Table 5.1 Material and Energy Balance with No Thermal Compression

Thermal Compressor Suction to Motive Force Ratio of 1 to 1

Utilizing a thermal compressor in the second stage to recirculate a portion of the outlet, stream 9, the total produced distillate improved from 44.36gpm to 56.76gpm. The addition of the compressor yields an economy of 2.82; the overall economy increased by .62 (or 28%). The addition of a thermal compressor with a suction rate equal to one time the motive steam rate added an improved distillate rate of 12.4gpm over the base case.

Stream Number	Process fluid	Pressure psia	Temp deg F	Mole Flow lb-mol/hr	Mass Flow lbm/hr	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guess Steam 14= constant * Stream 2	
1	inlet steam	75	375	555.56	10000	1218	12.18	Constant=	1
2	motive steam	75	375	166.67	3000	1218	3.65		
3	steam from TC	18.47	265.43	333.33	6000	1174.55	7.05		
4	Saturated water	14.7	212	722.22	13000	180.17	-2.34		
5	Subcooled water	14.7		722.22	13000				
6	Subcooled water	20	150	0.00					
7	Saturated water	20	212	757.54	13635.7	180.17	2.46		
8	Saturated steam	14.7	212	757.54	13635.7	1150.5	-15.69		
9	Saturated steam	5	162.24	812.80	14630.4	1131.1	-16.55		
10	Saturated steam	5	162.24	646.13	11630.4	1131.1			
11	Distillate	5	162.24	646.13	11630.4	130.2			
12	Cooling Water	20	80	0.00					
13	Cooling Water	20	110	0.00					
14	Saturated steam	5	162.24	166.67	3000	1131.1	3.39		
15	Steam to stage 1	18.47	324.429231	722.22	13000	1197.946	15.57		
16	Reduced pressure steam	18.47	375	388.89	7000	1218	8.53		
17	Saturated water	20	212	812.80	14630.4	180.17	2.64		
18	Saturated water	5	162.24	757.54	13635.7	130.2	-1.78		
stage 1 EB	0								
Stage 2 EB	1.8626E-15								
Distillate total produced lb/hr	28266.0								
Distillate total gpm	56.76								

Table 5.2 Material and Energy Balance - Thermal Compressor Suction to Motive Force Ratio of 1 to 1

Thermal Compressor Suction to Motive Force Ratio of 2 to 1

The same design, modifying only the thermal compressor suction rate to 2 times that of the motive force, yields a total distillate rate improvement from 44.36gpm to 69gpm. This results in an economy of 3.43. The overall economy improved by 1.23 (or 56%) when compared to the base case with no thermal compressor.

Stream Number	Process fluid	Pressure psia	Temp deg F	Mole Flow lb-mol/hr	Mass Flow lbm/hr	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guess Steam 14= constant * Stream 2	
1	inlet steam	75	375	555.6	10000	1218	12.18	Constant=	2
2	motive steam	75	375	166.7	3000	1218	3.65		
3	steam from TC	10.21	210	500	9000	1160.067	10.44		
4	Saturated water	14.7	212	888.9	16000	180.17	-2.88		
5	Subcooled water	14.7		888.9	16000				
6	Subcooled water	20	150	0					
7	Saturated water	20	212	920.9	16575.7	180.17	2.99		
8	Saturated steam	14.7	212	920.9	16575.7	1150.5	-19.07		
9	Saturated steam	5	162.24	988.0	17784.9	1131.1	-20.12		
10	Saturated steam	5	162.24	654.7	11784.9	1131.1			
11	Distillate	5	162.24	654.7	11784.9	130.2			
12	Cooling Water	20	80	0					
13	Cooling Water	20	110	0					
14	Saturated steam	5	162.24	333.3	6000	1131.1	6.79		
15	Steam to stage 1	10.21	273.4375	888.9	16000	1185.413	18.97		
16	Reduced pressure steam	10.21	355	388.9	7000	1218	8.53		
17	Saturated water	20	212	988.0	17784.9	180.17	3.20		
18	Saturated water	5	162.24	920.9	16575.7	130.2	-2.16		
stage 1 EB	0								
Stage 2 EB	0								
Distillate total produced lb/hr	34360.6								
Distillate total gpm	69.00								

Table 5.3 Material and Energy Balance - Thermal Compressor Suction to Motive Force Ratio of 2 to 1

Thermal Compressor Suction to Motive Force Ratio of 3 to 1

By increasing the thermal compressor suction flow rate to three times that of the motive force flow rate, the total distillate rate improved from 44.36gpm to 83.3gpm, resulting in an economy of 4.15. The overall economy improved by 1.95 (or 88.6%) when compared to the base case with no thermal compressor.

Stream Number	Process fluid	Pressure psia	Temp deg F	Mole Flow lb-mol/hr	Mass Flow lbm/hr	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guess Steam 14= constant * Stream 2	
1	inlet steam	75	375	555.6	10000	1218	12.18	Constant=	3
2	motive steam	75	375	166.7	3000	1218	3.65		
3	steam from TC	9.9	305	666.7	12000	1193	14.32		
4	Saturated water	14.7	212	1055.6	19000	180.17	-3.42		
5	Subcooled water	14.7		1055.6	19000				
6	Subcooled water	20	150	0					
7	Saturated water	20	212	1111.8	20012.5	180.17	3.61		
8	Saturated steam	14.7	212	1111.8	20012.5	1150.5	-23.02		
9	Saturated steam	5	162.24	1192.9	21472.4	1131.1	-24.29		
10	Saturated steam	5	162.24	692.9	12472.4	1131.1			
11	Distillate	5	162.24	692.9	12472.4	130.2			
12	Cooling Water	20	80	0					
13	Cooling Water	20	110	0					
14	Saturated steam	5	162.24	500	9000	1131.1	10.18		
15	Steam to stage 1	9.9	322.25	1055.6	19000	1202.211	22.84		
16	Reduced pressure steam	9.9	351.81	388.9	7000	1218	8.53		
17	Saturated water	20	212	1192.9	21472.4	180.17	3.87		
18	Saturated water	5	162.24	1111.8	20012.5	130.2	-2.61		
stage 1 EB	0								
Stage 2 EB	0								
Distillate total produced lb/hr	41485.0								
Distillate total gpm	83.30								

Table 5.4 Material and Energy Balance - Thermal Compressor Suction to Motive Force Ratio of 3 to 1

Thermal Compressor Suction to Motive Force Ratio of 4 to 1

Finally, increasing the thermal compressor theoretical suction flow rate maximum to four times that of the motive force flow rate, the product distillate rate is 93.47gpm as compared to the base case of 44.36gpm. This yields an overall unit economy of 4.65 with a 220% improvement as compared to the base case of 2.2 to1.

Stream Number	Process fluid	Pressure psia	Temp deg F	Mole Flow lb-mol/hr	Mass Flow lbm/hr	enthalpy Btu/lbm	Energy Stream MMBTU/hr	Guess Steam 14= constant * Stream 2	
1	inlet steam	75	375	555.6	10000	1218	12.18	Constant=	4
2	motive steam	75	375	166.7	3000	1218	3.65		
3	steam from TC	8.8	253	833.3	15000	1148.48	17.23		
4	Saturated water	14.7	212	1222.2	22000	180.17	-3.96		
5	Subcooled water	14.7		1222.2	22000				
6	Subcooled water	20	150	0					
7	Saturated water	20	212	1247.5	22455.7	180.17	4.05		
8	Saturated steam	14.7	212	1247.5	22455.7	1150.5	-25.84		
9	Saturated steam	5	162.24	1338.5	24093.9	1131.1	-27.25		
10	Saturated steam	5	162.24	671.9	12093.9	1131.1			
11	Distillate	5	162.24	671.9	12093.9	130.2			
12	Cooling Water	20	80	0					
13	Cooling Water	20	110	0					
14	Saturated steam	5	162.24	666.7	12000	1131.1	13.57		
15	Steam to stage 1	8.8	283.83	1222.2	22000	1170.6	25.75		
16	Reduced pressure steam	8.8	349.9	388.9	7000	1218	8.53		
17	Saturated water	20	212	1338.5	24093.9	180.17	4.34		
18	Saturated water	5	162.24	1247.5	22455.7	130.2	-2.92		
stage 1 EB	0								
Stage 2 EB	0								
Distillate total produced lb/hr	46549.6								
Distillate total gpm	93.47								

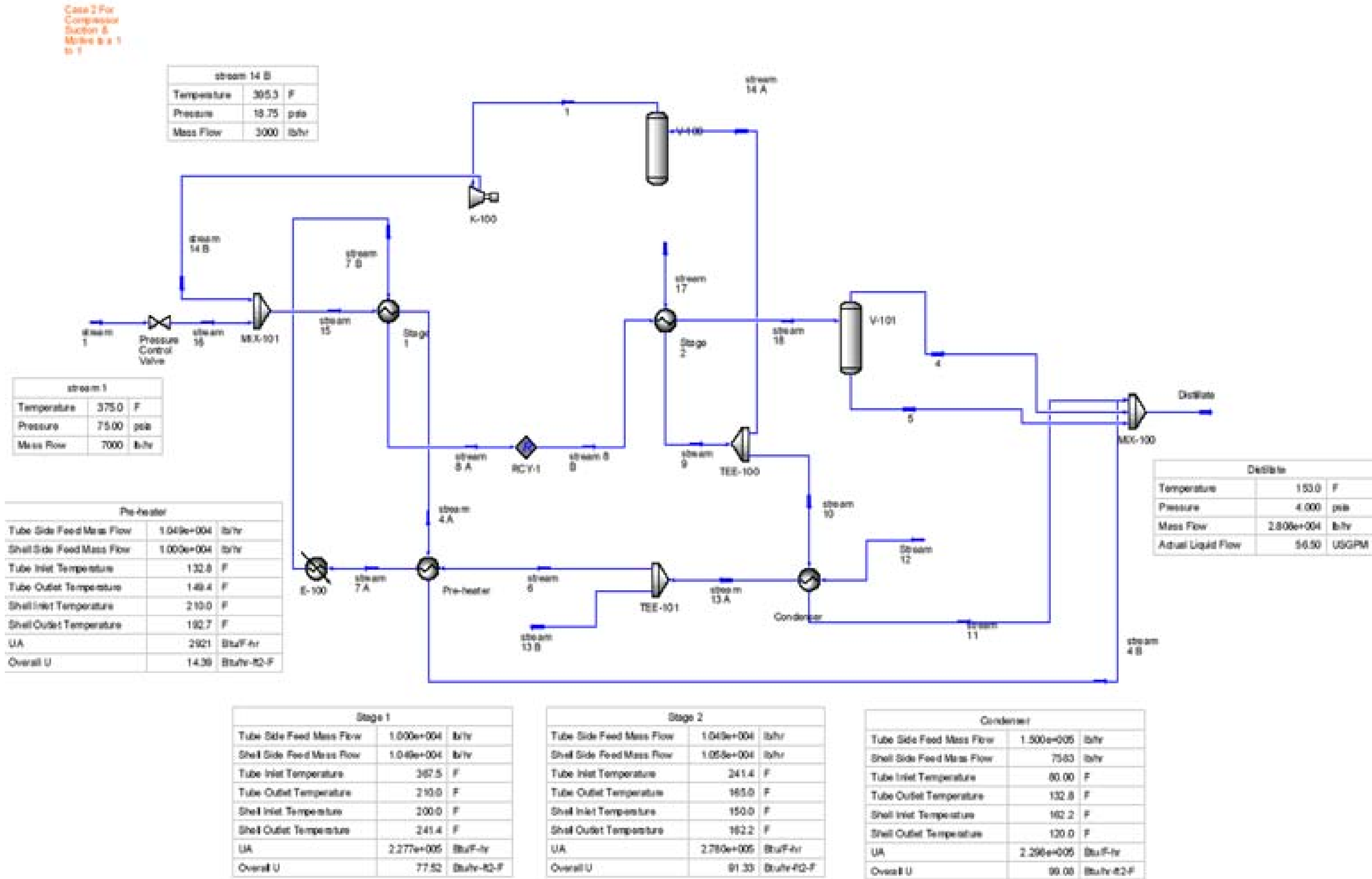
Table 5.5 Material and Energy Balance - Thermal Compressor Suction to Motive Force Ratio of 4 to 1

HYSYS Case Model Simulations

Based on these conditions HYSYS simulations were built to evaluate and validate the individual process components determined by in-house spread sheet calculations. The evaluation includes the heat exchanger network design and verification of compressor output conditions.

HYSYS Case Model Two - Thermal Compressor Suction to Motive Force Ratio of 1 to 1

Case Model Two was evaluated in HYSYS with a compressor suction rate to motive force ratio of one to one. The results from the commercial simulator match well with the initial material balance calculated by the in-house spreadsheet. HYSYS predicts a distillate flow rate of 56.5gpm compared to the in-house result of 56.76gpm, a difference of 0.26gpm (0.46%). (figure 5.2)



stream 14 B		
Temperature	395.3	F
Pressure	18.75	psia
Mass Flow	3000	lb/hr

stream 1		
Temperature	375.0	F
Pressure	75.00	psia
Mass Flow	7000	lb/hr

Distillate		
Temperature	153.0	F
Pressure	4.000	psia
Mass Flow	2.808e+004	lb/hr
Actual Liquid Flow	56.50	USGPM

Pre-heater		
Tube Side Feed Mass Flow	1.049e+004	lb/hr
Shell Side Feed Mass Flow	1.000e+004	lb/hr
Tube Inlet Temperature	132.8	F
Tube Outlet Temperature	149.4	F
Shell Inlet Temperature	210.0	F
Shell Outlet Temperature	182.7	F
UA	2921	Btu/F-hr
Overall U	14.39	Btu/hr-ft2-F

Stage 1		
Tube Side Feed Mass Flow	1.000e+004	lb/hr
Shell Side Feed Mass Flow	1.049e+004	lb/hr
Tube Inlet Temperature	367.5	F
Tube Outlet Temperature	210.0	F
Shell Inlet Temperature	200.0	F
Shell Outlet Temperature	241.4	F
UA	2.277e+005	Btu/F-hr
Overall U	77.52	Btu/hr-ft2-F

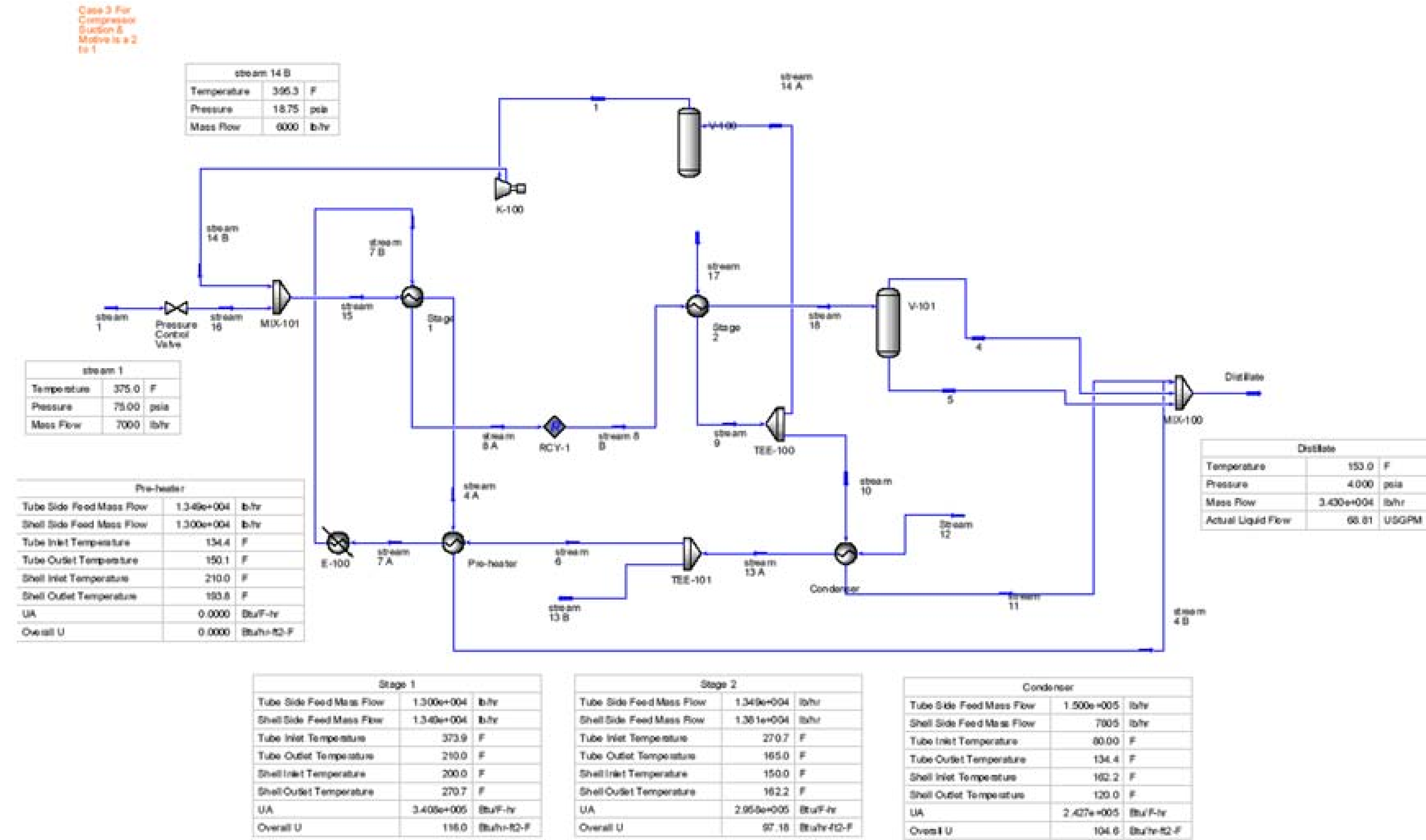
Stage 2		
Tube Side Feed Mass Flow	1.049e+004	lb/hr
Shell Side Feed Mass Flow	1.058e+004	lb/hr
Tube Inlet Temperature	241.4	F
Tube Outlet Temperature	165.0	F
Shell Inlet Temperature	150.0	F
Shell Outlet Temperature	162.2	F
UA	2.780e+005	Btu/F-hr
Overall U	91.33	Btu/hr-ft2-F

Condenser		
Tube Side Feed Mass Flow	1.500e+005	lb/hr
Shell Side Feed Mass Flow	7583	lb/hr
Tube Inlet Temperature	80.00	F
Tube Outlet Temperature	132.8	F
Shell Inlet Temperature	162.2	F
Shell Outlet Temperature	120.0	F
UA	2.298e+005	Btu/F-hr
Overall U	99.08	Btu/hr-ft2-F

Figure 5.2 HYSYS Results for Thermal Compressor Suction to Motive Force of 1 to 1

HYSYS Case Model Three - Thermal Compressor Suction to Motive Force Ratio of 2 to 1

Case Model Three was evaluated in HYSYS with a compressor suction flow rate to motive force flow rate ratio of two to one. The results from the commercial simulator also match well with the initial material balance calculated by in-house program. HYSYS predicts a distillate flow rate of 68.81 gpm while the design sheets predicted a result of 69 gpm; a difference of 0.19 gpm (0.27%). (figure 5.3)



stream 14 B		
Temperature	395.3	F
Pressure	18.75	psia
Mass Flow	6000	lb/hr

stream 1		
Temperature	375.0	F
Pressure	75.00	psia
Mass Flow	7000	lb/hr

Pre-heater		
Tube Side Feed Mass Flow	1.349e+004	lb/hr
Shell Side Feed Mass Flow	1.300e+004	lb/hr
Tube Inlet Temperature	134.4	F
Tube Outlet Temperature	150.1	F
Shell Inlet Temperature	210.0	F
Shell Outlet Temperature	193.8	F
UA	0.0000	Btu/F-hr
Overall U	0.0000	Btu/hr-ft2-F

Distillate		
Temperature	153.0	F
Pressure	4.000	psia
Mass Flow	3.430e+004	lb/hr
Actual Liquid Flow	68.81	USGPM

Stage 1		
Tube Side Feed Mass Flow	1.300e+004	lb/hr
Shell Side Feed Mass Flow	1.349e+004	lb/hr
Tube Inlet Temperature	373.9	F
Tube Outlet Temperature	210.0	F
Shell Inlet Temperature	200.0	F
Shell Outlet Temperature	270.7	F
UA	3.408e+005	Btu/F-hr
Overall U	116.0	Btu/hr-ft2-F

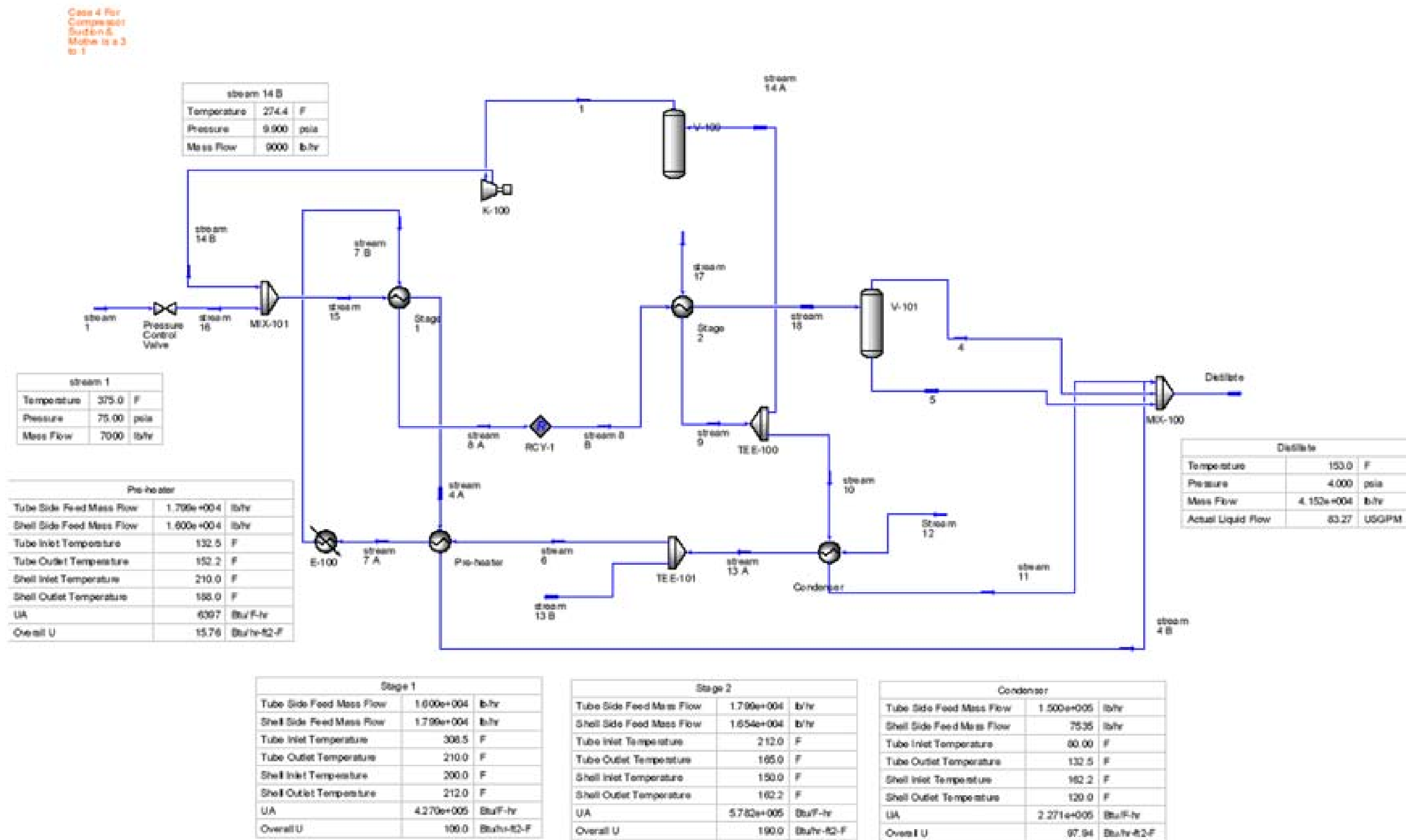
Stage 2		
Tube Side Feed Mass Flow	1.349e+004	lb/hr
Shell Side Feed Mass Flow	1.381e+004	lb/hr
Tube Inlet Temperature	270.7	F
Tube Outlet Temperature	165.0	F
Shell Inlet Temperature	150.0	F
Shell Outlet Temperature	162.2	F
UA	2.958e+005	Btu/F-hr
Overall U	97.18	Btu/hr-ft2-F

Condenser		
Tube Side Feed Mass Flow	1.500e+005	lb/hr
Shell Side Feed Mass Flow	7805	lb/hr
Tube Inlet Temperature	80.00	F
Tube Outlet Temperature	134.4	F
Shell Inlet Temperature	162.2	F
Shell Outlet Temperature	120.0	F
UA	2.427e+005	Btu/F-hr
Overall U	104.6	Btu/hr-ft2-F

Figure 5.3 HYSYS Results for Thermal Compressor Suction to Motive Force of 2 to 1

HYSYS Case Model Four - Thermal Compressor Suction to Motive Force Ratio of 3 to 1

Case Model Four was evaluated in HYSYS with a compressor suction flow rate to motive force flow rate ratio of three to one. The results from HYSYS match the in-house calculation within 0.04% with 83.27gpm versus 83.3gpm. (figure 5.4)



stream 14 B		
Temperature	274.4	F
Pressure	9.900	psia
Mass Flow	9000	lb/hr

stream 1		
Temperature	375.0	F
Pressure	75.00	psia
Mass Flow	7000	lb/hr

Pre-heater		
Tube Side Feed Mass Flow	1.799e+004	lb/hr
Shell Side Feed Mass Flow	1.600e+004	lb/hr
Tube Inlet Temperature	132.5	F
Tube Outlet Temperature	152.2	F
Shell Inlet Temperature	210.0	F
Shell Outlet Temperature	188.0	F
UA	6397	Btu/F-hr
Overall U	15.76	Btu/hr-ft2-F

Distillate		
Temperature	153.0	F
Pressure	4.000	psia
Mass Flow	4.152e+004	lb/hr
Actual Liquid Flow	83.27	USGPM

Stage 1		
Tube Side Feed Mass Flow	1.600e+004	lb/hr
Shell Side Feed Mass Flow	1.799e+004	lb/hr
Tube Inlet Temperature	308.5	F
Tube Outlet Temperature	210.0	F
Shell Inlet Temperature	200.0	F
Shell Outlet Temperature	212.0	F
UA	4.270e+005	Btu/F-hr
Overall U	109.0	Btu/hr-ft2-F

Stage 2		
Tube Side Feed Mass Flow	1.799e+004	lb/hr
Shell Side Feed Mass Flow	1.654e+004	lb/hr
Tube Inlet Temperature	212.0	F
Tube Outlet Temperature	165.0	F
Shell Inlet Temperature	150.0	F
Shell Outlet Temperature	162.2	F
UA	5.782e+005	Btu/F-hr
Overall U	190.0	Btu/hr-ft2-F

Condenser		
Tube Side Feed Mass Flow	1.500e+005	lb/hr
Shell Side Feed Mass Flow	7535	lb/hr
Tube Inlet Temperature	80.00	F
Tube Outlet Temperature	132.5	F
Shell Inlet Temperature	162.2	F
Shell Outlet Temperature	120.0	F
UA	2.271e+005	Btu/F-hr
Overall U	97.94	Btu/hr-ft2-F

Figure 5.4 HYSYS Results for Thermal Compressor Suction to Motive Force of 3 to 1

HYSYS Case Model Five - Thermal Compressor Suction to Motive Force Ratio of 4 to 1

Case Model Five was evaluated in HYSYS with a compressor suction flow rate to motive force flow rate ratio of four to one. The results of, HYSYS matches the in-house calculation within 0.54 with a predicted distillate flow rate of 93.98 gpm versus 93.47 gpm. (Figure 5.5)

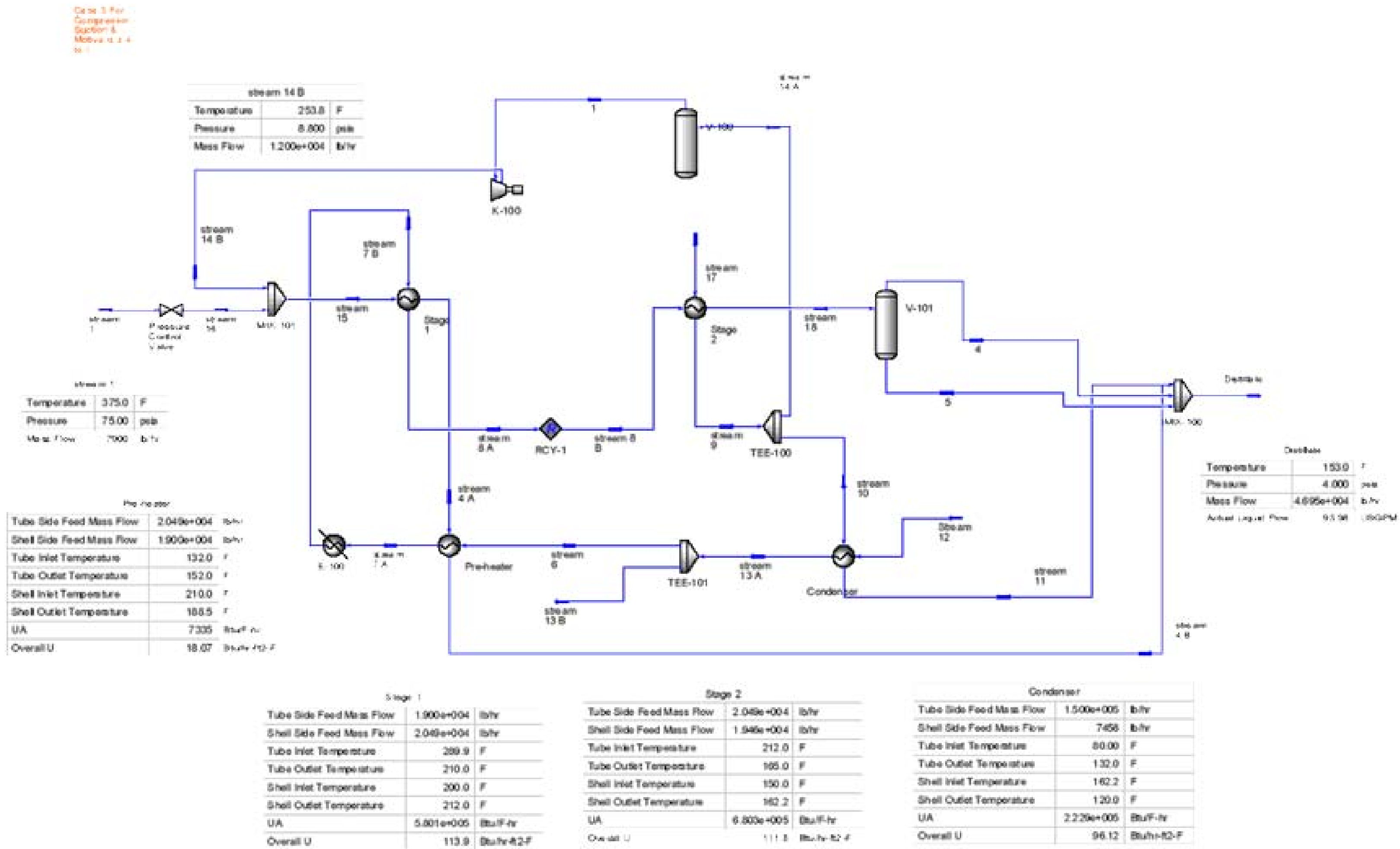


Figure 5.5 HYSYS Results for Thermal Compressor Suction to Motive Force of 4 to 1

Conclusion

Since both the in-house design spreadsheets and the commercial simulator HYSYS are in excellent agreement with the alterative design, this concludes that thermodynamically the alterative design is a viable option that can be used instead of the original commercial design that was built.

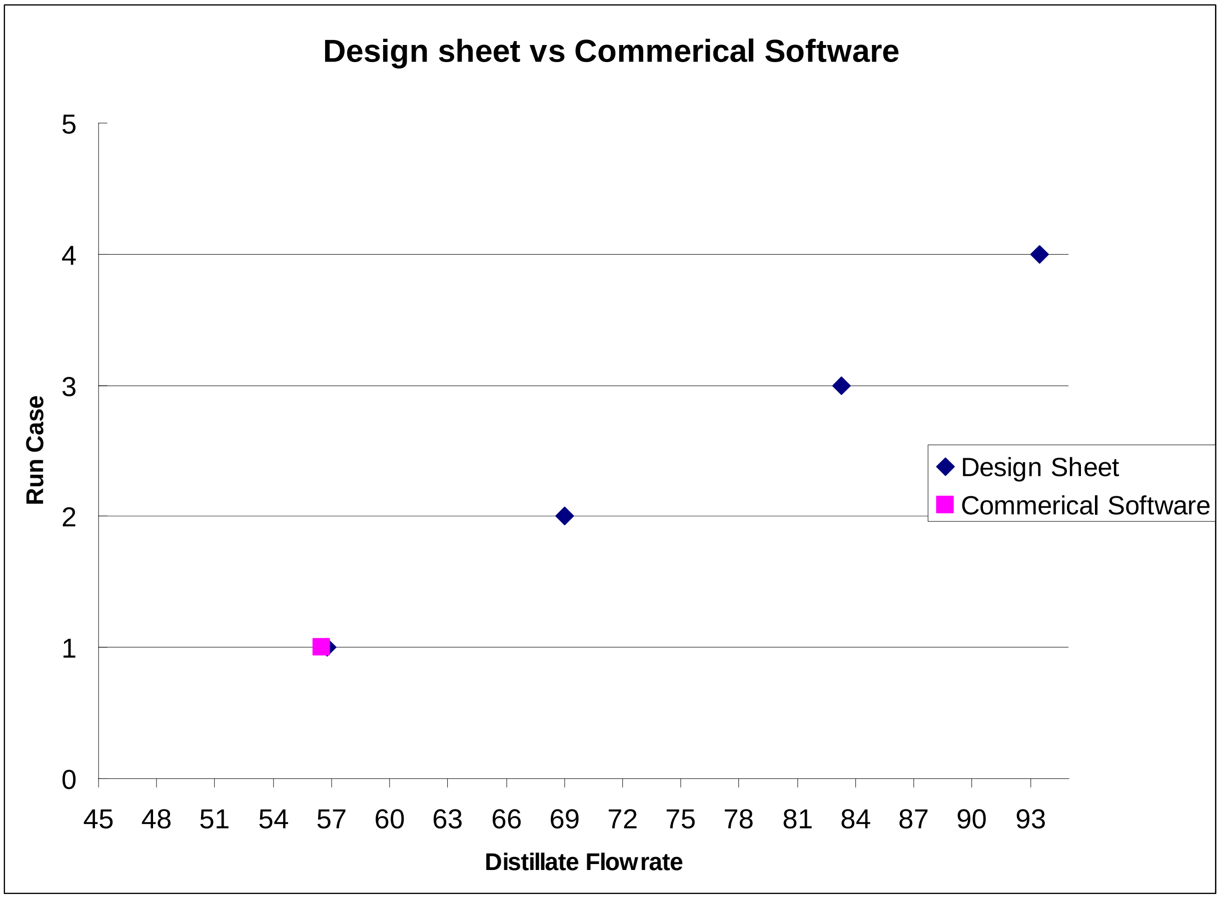


Figure 5.6 Variation between Methods

Chapter 6

Conclusions

A commercial evaporator incorporating the thermal compression principal claimed to achieve an economy of 9 to1 with only two stages, occupying a physical volume of only 25% of that of a conventional 8-stage evaporator. Unfortunately, this commercial unit failed miserably with an economy of only 1.34 to1. A complete thermal balance and fluid flow analysis was conducted and it was found that the design of the commercial unit never satisfied the energy balance. The commercial unit was "creating energy" on the order of 18 million BTU per hour (MMBtu/hr). It was also shown through a computational fluid dynamics (CFD) model that the thermal compressors supplied with the commercial unit were not able to reach the process designers conditions of a (steam suction flow rate to steam motive flow rate) of 4 to 1.

Guided by the CFD iterations, the thermal compressor unit was redesigned to achieve the suction economy of 4 to1. Based on these results, an alternative design of the entire evaporator was proposed that would keep the high efficiency of a multistage evaporator with the advantages gained using a thermal compressor. Two different theoretical approaches were used to reach this alternative design. . The first approach was to write an in-house program that would apply the conservation equations of mass and energy to the proposed design. The proposed design was applied using four suction steam to motive steam ratios of 1to1, 2 to 1, 3 to 1 and 4 to 1.

The second method was to use the commercially available thermodynamic simulator, (HYSYS) to conduct more detailed component designs. The results of the two methods were compared and found to be in good agrproven vieement. The final design using the CFD designed thermal compressor is able to achieve 4:1 evaporation economy with a 50% reduction of footprint of a conventional 8-stage evaporator.

BIBLIOGRAPHY

Perry, Green. *Perry's Chemical Engineers Handbook. 7th Ed.* New York: McGraw-Hill, 1997.

Burmeister, Louis C. *Convective Heat Transfer. 2nd Ed*. New York: John Wiley & Sons, Inc. 1993.

Anderson, John D. *Modern Compressible Flow with Historical Perspective. 3rd Ed.* Boston: McGraw-Hill, 2003.

Smith, Van Ness, Abbott M. M. *Introduction to Chemical Engineering Thermodynamics*. 5th Ed. New York: McGraw-Hill, 1996.

Collier, John G. *Convective Boiling and Condensation*. London: McGraw-Hill, 1981.

Minton, Paul E. *Handbook of Evaporation Technology*. Park Ridge: Noyes Publications, 1986.

Welty, James R., Charles E. Wicks, and Robert E. Wilson. *Fundamentals of Momentum, Heat, and Mass Transfer. 3rd E*d. New York: Jon Wiley & Sons, 1984.

Croll-Reynolds. *Thermocompressors.* Westfield: Croll-Reynolds Company, Inc., 1986.

Chato, John C. "Laminar Condensation" ASHRAE Journal 4 (1962): 52-60.

Sadhukhan, Pasupati. "Process of Desalination by Direct Contact Heat Transfer." US Patent 4238296. December 1980.

Miller, Joel V. "Desalinization Method and Apparatus." US Patent 5729987. March 1998.

Roller, Paul S. "Method and Apparatus for Converting Saline Water to Fresh Water." US Patent 3951752. April 1976.

APPENDIX

HYSYS Case 2 Report

EPCO HOLDINGS, INC. Burlington, MA USA	Case Name: CASE2 C.HSC Unit Set: GasPlant1 Date/Time: Fri Apr 10 14:21:44 2009

Material Stream: 1

Fluid Package: Basis-1

Property Package: ASME Steam

CONDITIONS

		Overall	Vapour Phase	Aqueous Phase
Vapour / Phase Fraction		1.0000	1.0000	0.0000
Temperature:	(F)	162.2 *	162.2	162.2
Pressure:	(psig)	-9.696 *	-9.696	-9.696
Molar Flow	(MMSCFD)	1.517	1.517	0.0000
Mass Flow	(lb/hr)	3000	3000	0.0000
Std Ideal Liq Vol Flow	(USGPM)	6.003	6.003	0.0000
Molar Enthalpy	(Btu/lbmole)	-1.030e+005	-1.030e+005	-1.210e+005
Molar Entropy	(Btu/lbmole-F)	33.23	33.23	4.233
Heat Flow	(MMBtu/hr)	-17.15	-17.15	0.0000
Liq Vol Flow @Std Cond	(USGPM)	5.998 *	5.998	0.0000

PROPERTIES

		Overall	Vapour Phase	Aqueous Phase
Molecular Weight		18.02	18.02	18.02
Molar Density	(lbmole/ft3)	7.547e-004	7.547e-004	3.382
Mass Density	(lb/ft3)	1.360e-002	1.360e-002	60.93
Act. Volume Flow	(barrel/day)	9.432e+005	9.432e+005	0.0000
Mass Enthalpy	(Btu/lb)	-5715	-5715	-6717
Mass Entropy	(Btu/lb-F)	1.845	1.845	0.2350
Heat Capacity	(Btu/lbmole-F)	8.357	8.357	18.04
Mass Heat Capacity	(Btu/lb-F)	0.4639	0.4639	1.001
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000	0.0000
Mass Lower Heating Value	(Btu/lb)	---	---	---
Phase Fraction [Vol. Basis]		---	1.000	---
Phase Fraction [Mass Basis]		4.941e-324	1.000	0.0000
Partial Pressure of CO2	(psig)	-14.70	---	---
Cost Based on Flow	(Cost/s)	0.0000	0.0000	0.0000
Act. Gas Flow	(ACFM)	3678	3678	---
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458	3.458
Specific Heat	(Btu/lbmole-F)	8.357	8.357	18.04
Std. Gas Flow	(MMSCFD)	1.517	1.517	0.0000
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30	62.30
Act. Liq. Flow	(USGPM)	0.0000	---	0.0000
Z Factor		---	0.9927	2.215e-004
Watson K		---	---	---
User Property		---	---	---
Partial Pressure of H2S	(psig)	-14.70	---	---
Cp/(Cp - R)		1.312	1.312	1.124
Cp/Cv		1.336	1.336	1.071
Heat of Vap.	(Btu/lbmole)	1.804e+004	---	---
Kinematic Viscosity	(cSt)	50.44	50.44	0.3973
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36	62.36
Liq. Vol. Flow (Std. Cond)	(USGPM)	5.998	5.998	0.0000
Liquid Fraction		0.0000	0.0000	1.000
Molar Volume	(ft3/lbmole)	1325	1325	0.2957
Mass Heat of Vap.	(Btu/lb)	1001	---	---
Phase Fraction [Molar Basis]		1.0000	1.0000	0.0000
Surface Tension	(lbf/ft)	---	---	4.367e-003
Thermal Conductivity	(Btu/hr-ft-F)	1.293e-002	1.293e-002	0.3838
Viscosity	(cP)	1.098e-002	1.098e-002	0.3877
Cv (Semi-Ideal)	(Btu/lbmole-F)	6.372	6.372	16.05

* Specified by user.

aspentech	EPCO HOLDINGS, INC. Burlington, MA USA	Case Name: CASE2 C.HSC Unit Set: GasPlant1 Date/Time: Fri Apr 10 14:21:44 2009

Material Stream: 1 (continued)

Fluid Package: Basis-1

Property Package: ASME Steam

PROPERTIES

	Overall	Vapour Phase	Aqueous Phase		
Mass Cv (Semi-Ideal) (Btu/lb-F)	0.3537	0.3537	0.8911		
Cv (Btu/lbmole-F)	6.255	6.255	16.84		
Mass Cv (Btu/lb-F)	0.3472	0.3472	0.9347		
Cv (Ent. Method) (Btu/lbmole-F)	---	---	---		
Mass Cv (Ent. Method) (Btu/lb-F)	---	---	---		
Cp/Cv (Ent. Method)	---	---	---		
Reid VP at 37.8 C (psig)	---	---	---		
True VP at 37.8 C (psig)	-13.75	-13.75	-13.75		
Liq. Vol. Flow - Sum(Std. Cond) (barrel/day)	205.7	205.7	0.0000		

COMPOSITION

Overall Phase

Vapour Fraction 1.0000

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	166.5270	1.0000	3000.0000	1.0000	205.8330	1.0000
Total	166.5270	1.0000	3000.0000	1.0000	205.8330	1.0000

Vapour Phase

Phase Fraction 1.000

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	166.5270	1.0000	3000.0000	1.0000	205.8330	1.0000
Total	166.5270	1.0000	3000.0000	1.0000	205.8330	1.0000

Aqueous Phase

Phase Fraction 0.0000

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
Total	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000

K VALUE

COMPONENTS	MIXED	LIGHT	HEAVY
H2O	1.000	---	1.000

UNIT OPERATIONS

FEED TO		PRODUCT FROM		LOGICAL CONNECTION
Compressor:	K-100	Separator:	V-100	

UTILITIES

(No utilities reference this stream)

PROCESS UTILITY

DYNAMICS

Pressure Specification	(Active):	-9.696 psig *			
Flow Specification	(Inactive)	Molar: 1.517 MMSCFD	Mass: 3000 lb/hr	Std Ideal Liq Volume: 6.003 USGPM	

User Variables

NOTES

* Specified by user.

EPCO HOLDINGS, INC. Burlington, MA USA	Case Name: CASE2 C.HSC Unit Set: GasPlant1 Date/Time: Fri Apr 10 14:21:44 2009

Material Stream: 1 (continued)

Fluid Package: Basis-1
Property Package: ASME Steam

Description

Material Stream: Distillate

Fluid Package: Basis-1
Property Package: ASME Steam

CONDITIONS

		Overall	Vapour Phase	Aqueous Phase		
Vapour / Phase Fraction		0.0135	0.0135	0.9865		
Temperature:	(F)	153.0	153.0	153.0		
Pressure:	(psig)	-10.70	-10.70	-10.70		
Molar Flow	(MMSCFD)	14.19	0.1911	14.00		
Mass Flow	(lb/hr)	2.808e+004	378.0	2.770e+004		
Std Ideal Liq Vol Flow	(USGPM)	56.19	0.7563	55.43		
Molar Enthalpy	(Btu/lbmole)	-1.209e+005	-1.030e+005	-1.212e+005		
Molar Entropy	(Btu/lbmole-F)	4.360	33.56	3.962		
Heat Flow	(MMBtu/hr)	-188.5	-2.162	-186.3		
Liq Vol Flow @Std Cond	(USGPM)	56.14 *	0.7557	55.38		

PROPERTIES

		Overall	Vapour Phase	Aqueous Phase		
Molecular Weight		18.02	18.02	18.02		
Molar Density	(lbmole/ft3)	4.489e-002	6.123e-004	3.392		
Mass Density	(lb/ft3)	0.8087	1.103e-002	61.12		
Act. Volume Flow	(barrel/day)	1.484e+005	1.465e+005	1937		
Mass Enthalpy	(Btu/lb)	-6712	-5719	-6726		
Mass Entropy	(Btu/lb-F)	0.2420	1.863	0.2199		
Heat Capacity	(Btu/lbmole-F)	17.90	8.307	18.03		
Mass Heat Capacity	(Btu/lb-F)	0.9934	0.4611	1.001		
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000	0.0000		
Mass Lower Heating Value	(Btu/lb)	---	---	---		
Phase Fraction [Vol. Basis]		1.346e-002	1.346e-002	0.9865		
Phase Fraction [Mass Basis]		1.346e-002	1.346e-002	0.9865		
Partial Pressure of CO2	(psig)	-14.70	---	---		
Cost Based on Flow	(Cost/s)	0.0000	0.0000	0.0000		
Act. Gas Flow	(ACFM)	---	571.1	---		
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458	3.458		
Specific Heat	(Btu/lbmole-F)	17.90	8.307	18.03		
Std. Gas Flow	(MMSCFD)	14.19	0.1911	14.00		
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30	62.30		
Act. Liq. Flow	(USGPM)	56.50	---	56.50		
Z Factor		---	0.9938	1.794e-004		
Watson K		---	---	---		
User Property		---	---	---		
Partial Pressure of H2S	(psig)	-14.70	---	---		
Cp/(Cp - R)		1.125	1.314	1.124		
Cp/Cv		1.002	1.335	1.064		
Heat of Vap.	(Btu/lbmole)	1.814e+004	---	---		
Kinematic Viscosity	(cSt)	---	60.99	0.4254		
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36	62.36		
Liq. Vol. Flow (Std. Cond)	(USGPM)	56.14	0.7557	55.38		
Liquid Fraction		0.9865	0.0000	1.000		

* Specified by user.

Material Stream: Distillate (continued)

Fluid Package: Basis-1
Property Package: ASME Steam

PROPERTIES

	Overall	Vapour Phase	Aqueous Phase		
Molar Volume (ft3/lbmole)	22.28	1633	0.2948		
Mass Heat of Vap. (Btu/lb)	1007	---	---		
Phase Fraction [Molar Basis]	0.0135	0.0135	0.9865		
Surface Tension (lbf/ft)	4.431e-003	---	4.431e-003		
Thermal Conductivity (Btu/hr-ft-F)	---	1.271e-002	0.3813		
Viscosity (cP)	---	1.078e-002	0.4165		
Cv (Semi-Ideal) (Btu/lbmole-F)	15.91	6.321	16.04		
Mass Cv (Semi-Ideal) (Btu/lb-F)	0.8831	0.3509	0.8904		
Cv (Btu/lbmole-F)	17.87	6.221	16.95		
Mass Cv (Btu/lb-F)	0.9918	0.3453	0.9409		
Cv (Ent. Method) (Btu/lbmole-F)	---	---	---		
Mass Cv (Ent. Method) (Btu/lb-F)	---	---	---		
Cp/Cv (Ent. Method)	---	---	---		
Reid VP at 37.8 C (psig)	---	---	---		
True VP at 37.8 C (psig)	-13.75	-13.75	-13.75		
Liq. Vol. Flow - Sum(Std. Cond) (barrel/day)	1925	25.91	1899		

COMPOSITION

Overall Phase

Vapour Fraction 0.0135

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	1558.5010	1.0000	28076.5517	1.0000	1926.3606	1.0000
Total	1558.5010	1.0000	28076.5517	1.0000	1926.3606	1.0000

Vapour Phase

Phase Fraction 1.346e-002

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	20.9799	1.0000	377.9546	1.0000	25.9318	1.0000
Total	20.9799	1.0000	377.9546	1.0000	25.9318	1.0000

Aqueous Phase

Phase Fraction 0.9865

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	1537.5211	1.0000	27698.5972	1.0000	1900.4287	1.0000
Total	1537.5211	1.0000	27698.5972	1.0000	1900.4287	1.0000

K VALUE

COMPONENTS	MIXED	LIGHT	HEAVY
H2O	1.000	---	1.000

UNIT OPERATIONS

FEED TO	PRODUCT FROM		LOGICAL CONNECTION
	Mixer:	MIX-100	

UTILITIES

(No utilities reference this stream)

PROCESS UTILITY

4

* Specified by user.

Material Stream: Distillate (continued)

Fluid Package: Basis-1
Property Package: ASME Steam

DYNAMICS

Pressure Specification (Inactive) -10.70 psig

Flow Specification (Inactive) Molar: 14.19 MMSCFD | Mass: 2.808e+004 lb/hr | Std Ideal Liq Volume: 56.19 USGPM

User Variables

NOTES

Description

Material Stream: stream 16

Fluid Package: Basis-1
Property Package: ASME Steam

CONDITIONS

		Overall	Vapour Phase			
Vapour / Phase Fraction		1.0000	1.0000			
Temperature:	(F)	355.6	355.6			
Pressure:	(psig)	4.054	4.054			
Molar Flow	(MMSCFD)	3.539	3.539			
Mass Flow	(lb/hr)	7000	7000			
Std Ideal Liq Vol Flow	(USGPM)	14.01	14.01			
Molar Enthalpy	(Btu/lbmole)	-1.014e+005	-1.014e+005			
Molar Entropy	(Btu/lbmole-F)	32.83	32.83			
Heat Flow	(MMBtu/hr)	-39.40	-39.40			
Liq Vol Flow @Std Cond	(USGPM)	14.00 *	14.00			

PROPERTIES

		Overall	Vapour Phase			
Molecular Weight		18.02	18.02			
Molar Density	(lbmole/ft3)	2.160e-003	2.160e-003			
Mass Density	(lb/ft3)	3.892e-002	3.892e-002			
Act. Volume Flow	(barrel/day)	7.689e+005	7.689e+005			
Mass Enthalpy	(Btu/lb)	-5628	-5628			
Mass Entropy	(Btu/lb-F)	1.822	1.822			
Heat Capacity	(Btu/lbmole-F)	8.585	8.585			
Mass Heat Capacity	(Btu/lb-F)	0.4766	0.4766			
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000			
Mass Lower Heating Value	(Btu/lb)	---	---			
Phase Fraction [Vol. Basis]		---	1.000			
Phase Fraction [Mass Basis]		4.941e-324	1.000			
Partial Pressure of CO2	(psig)	-14.70	---			
Cost Based on Flow	(Cost/s)	0.0000	0.0000			
Act. Gas Flow	(ACFM)	2998	2998			
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458			
Specific Heat	(Btu/lbmole-F)	8.585	8.585			
Std. Gas Flow	(MMSCFD)	3.539	3.539			
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30			
Act. Liq. Flow	(USGPM)	---	---			
Z Factor		0.9921	5 0.9921			
Watson K		---	---			
User Property		---	---			

* Specified by user.

Material Stream: stream 16 (continued)

Fluid Package: Basis-1

Property Package: ASME Steam

PROPERTIES

		Overall	Vapour Phase			
Partial Pressure of H2S	(psig)	-14.70	---			
Cp/(Cp - R)		1.301	1.301			
Cp/Cv		1.323	1.323			
Heat of Vap.	(Btu/lbmole)	1.734e+004	---			
Kinematic Viscosity	(cSt)	24.55	24.55			
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36			
Liq. Vol. Flow (Std. Cond)	(USGPM)	14.00	14.00			
Liquid Fraction		0.0000	0.0000			
Molar Volume	(ft3/lbmole)	462.9	462.9			
Mass Heat of Vap.	(Btu/lb)	962.5	---			
Phase Fraction [Molar Basis]		1.0000	1.0000			
Surface Tension	(lbf/ft)	---	---			
Thermal Conductivity	(Btu/hr-ft-F)	1.814e-002	1.814e-002			
Viscosity	(cP)	1.531e-002	1.531e-002			
Cv (Semi-Ideal)	(Btu/lbmole-F)	6.599	6.599			
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.3663	0.3663			
Cv	(Btu/lbmole-F)	6.487	6.487			
Mass Cv	(Btu/lb-F)	0.3601	0.3601			
Cv (Ent. Method)	(Btu/lbmole-F)	---	---			
Mass Cv (Ent. Method)	(Btu/lb-F)	---	---			
Cp/Cv (Ent. Method)		---	---			
Reid VP at 37.8 C	(psig)	---	---			
True VP at 37.8 C	(psig)	-13.75	-13.75			
Liq. Vol. Flow - Sum(Std. Cond)	(barrel/day)	479.9	479.9			

COMPOSITION

Overall Phase

Vapour Fraction 1.0000

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	388.5629	1.0000	7000.0000	1.0000	480.2771	1.0000
Total	388.5629	1.0000	7000.0000	1.0000	480.2771	1.0000

Vapour Phase

Phase Fraction 1.000

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	388.5629	1.0000	7000.0000	1.0000	480.2771	1.0000
Total	388.5629	1.0000	7000.0000	1.0000	480.2771	1.0000

K VALUE

COMPONENTS	MIXED	LIGHT	HEAVY
H2O	---	---	---

UNIT OPERATIONS

FEED TO		PRODUCT FROM		LOGICAL CONNECTION	
Mixer:	MIX-101	Valve:	Pressure Control Valve	Set:	SET-1

UTILITIES

(No utilities reference this stream)

* Specified by user.

Material Stream: stream 16 (continued)

Fluid Package: Basis-1

Property Package: ASME Steam

PROCESS UTILITY

DYNAMICS

Pressure Specification (Inactive)	4.054 psig			
Flow Specification (Inactive)	Molar:	3.539 MMSCFD	Mass: 7000 lb/hr	Std Ideal Liq Volume: 14.01 USGPM

User Variables

NOTES

Description

Material Stream: stream 15

Fluid Package: Basis-1

Property Package: ASME Steam

CONDITIONS

		Overall	Vapour Phase			
Vapour / Phase Fraction		1.0000	1.0000			
Temperature:	(F)	367.5	367.5			
Pressure:	(psig)	4.054 *	4.054			
Molar Flow	(MMSCFD)	5.055	5.055			
Mass Flow	(lb/hr)	1.000e+004	1.000e+004			
Std Ideal Liq Vol Flow	(USGPM)	20.01	20.01			
Molar Enthalpy	(Btu/lbmole)	-1.013e+005	-1.013e+005			
Molar Entropy	(Btu/lbmole-F)	32.95	32.95			
Heat Flow	(MMBtu/hr)	-56.23	-56.23			
Liq Vol Flow @Std Cond	(USGPM)	19.99 *	19.99			

PROPERTIES

		Overall	Vapour Phase			
Molecular Weight		18.02	18.02			
Molar Density	(lbmole/ft3)	2.128e-003	2.128e-003			
Mass Density	(lb/ft3)	3.834e-002	3.834e-002			
Act. Volume Flow	(barrel/day)	1.115e+006	1.115e+006			
Mass Enthalpy	(Btu/lb)	-5623	-5623			
Mass Entropy	(Btu/lb-F)	1.829	1.829			
Heat Capacity	(Btu/lbmole-F)	8.578	8.578			
Mass Heat Capacity	(Btu/lb-F)	0.4762	0.4762			
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000			
Mass Lower Heating Value	(Btu/lb)	---	---			
Phase Fraction [Vol. Basis]		---	1.000			
Phase Fraction [Mass Basis]		4.941e-324	1.000			
Partial Pressure of CO2	(psig)	-14.70	---			
Cost Based on Flow	(Cost/s)	0.0000	0.0000			
Act. Gas Flow	(ACFM)	4348	4348			
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458			
Specific Heat	(Btu/lbmole-F)	8.578	8.578			
Std. Gas Flow	(MMSCFD)	5.056	5.056			
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30			
Act. Liq. Flow	(USGPM)	---	---			

* Specified by user.

Material Stream: stream 15 (continued)

Fluid Package: Basis-1
Property Package: ASME Steam

PROPERTIES

		Overall	Vapour Phase			
Z Factor		0.9926	0.9926			
Watson K		---	---			
User Property		---	---			
Partial Pressure of H2S	(psig)	-14.70	---			
Cp/(Cp - R)		1.301	1.301			
Cp/Cv		1.322	1.322			
Heat of Vap.	(Btu/lbmole)	1.734e+004	---			
Kinematic Viscosity	(cSt)	25.37	25.37			
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36			
Liq. Vol. Flow (Std. Cond)	(USGPM)	19.99	19.99			
Liquid Fraction		0.0000	0.0000			
Molar Volume	(ft3/lbmole)	469.9	469.9			
Mass Heat of Vap.	(Btu/lb)	962.5	---			
Phase Fraction [Molar Basis]		1.0000	1.0000			
Surface Tension	(lbf/ft)	---	---			
Thermal Conductivity	(Btu/hr-ft-F)	1.849e-002	1.849e-002			
Viscosity	(cP)	1.558e-002	1.558e-002			
Cv (Semi-Ideal)	(Btu/lbmole-F)	6.592	6.592			
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.3659	0.3659			
Cv	(Btu/lbmole-F)	6.489	6.489			
Mass Cv	(Btu/lb-F)	0.3602	0.3602			
Cv (Ent. Method)	(Btu/lbmole-F)	---	---			
Mass Cv (Ent. Method)	(Btu/lb-F)	---	---			
Cp/Cv (Ent. Method)		---	---			
Reid VP at 37.8 C	(psig)	---	---			
True VP at 37.8 C	(psig)	-13.75	-13.75			
Liq. Vol. Flow - Sum(Std. Cond)	(barrel/day)	685.5	685.5			

COMPOSITION

Overall Phase

Vapour Fraction 1.0000

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	555.0899 *	1.0000 *	10000.0000 *	1.0000 *	686.1101 *	1.0000 *
Total	555.0899	1.0000	10000.0000	1.0000	686.1101	1.0000

Vapour Phase

Phase Fraction 1.000

COMPONENTS	MOLAR FLOW (lbmole/hr)	MOLE FRACTION	MASS FLOW (lb/hr)	MASS FRACTION	LIQUID VOLUME FLOW (barrel/day)	LIQUID VOLUME FRACTION
H2O	555.0899	1.0000	10000.0000	1.0000	686.1101	1.0000
Total	555.0899	1.0000	10000.0000	1.0000	686.1101	1.0000

K VALUE

COMPONENTS	MIXED	LIGHT	HEAVY
H2O	---	---	---

UNIT OPERATIONS

FEED TO		PRODUCT FROM		LOGICAL CONNECTION	
Heat Exchanger:	Stage 1	Mixer: 8	MIX-101	Set:	SET-1
				Set:	SET-2

* Specified by user.

Material Stream: stream 15 (continued)

Fluid Package: Basis-1
Property Package: ASME Steam

UTILITIES

(No utilities reference this stream)

PROCESS UTILITY

DYNAMICS

Pressure Specification	(Active):	4.054 psig *				
Flow Specification	(Active)	Molar:	5.055 MMSCFD	Mass:	1.000e+004 lb/hr	Std Ideal Liq Volume: 20.01 USGPM

User Variables

NOTES

Description

Heater: E-100

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
stream 7 A	Heat Exchanger	Pre-heater

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
stream 7 B	Heat Exchanger	Stage 1

Energy Stream

STREAM NAME	FROM UNIT OPERATION
Q-102	

PARAMETERS

Pressure Drop:	1.337 psi	Duty:	0.5325 MMBtu/hr	Volume:	3.531 ft3
Function:	Not Selected	Zones:	1		

User Variables

RATING

NOZZLE PARAMETERS

Base Elevation Relative to Ground Level 0.0000 ft *

		stream 7 A	stream 7 B	
Diameter	(ft)	0.1640	0.1640	
Elevation (Base)	(ft)	0.0000	0.0000	
Elevation (Ground)	(ft)	0.0000	0.0000	

CONDITIONS

Name	stream 7 A	stream 7 B	Q-102	
Vapour	0.0000	0.0000	---	

Heater: E-100 (continued)

CONDITIONS

Temperature	(F)	149.3850	200.0000 *	---	
Pressure	(psig)	6.1079	4.7708 *	---	
Molar Flow	(MMSCFD)	5.3049	5.3049	---	
Mass Flow	(lb/hr)	10493.9425	10493.9425	---	
Std Ideal Liq Vol Flow	(USGPM)	21.0000	21.0000 *	---	
Molar Enthalpy	(Btu/lbmole)	-1.212e+005	-1.203e+005	---	
Molar Entropy	(Btu/lbmole-F)	3.856	5.298	---	
Heat Flow	(MMBtu/hr)	-7.0618e+01	-7.0086e+01	5.3248e-01	

PROPERTIES

Name		stream 7 A	stream 7 B			
Molecular Weight		18.02	18.02			
Molar Density	(lbmole/ft3)	3.397	3.336			
Mass Density	(lb/ft3)	61.19	60.09			
Act. Volume Flow	(barrel/day)	733.1	746.5			
Mass Enthalpy	(Btu/lb)	-6729	-6679			
Mass Entropy	(Btu/lb-F)	0.2140	0.2941			
Heat Capacity	(Btu/lbmole-F)	18.02	18.11			
Mass Heat Capacity	(Btu/lb-F)	1.000	1.005			
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000			
Mass Lower Heating Value	(Btu/lb)	---	---			
Phase Fraction [Vol. Basis]		---	---			
Phase Fraction [Mass Basis]		0.0000	0.0000			
Partial Pressure of CO2	(psig)	-14.70	-14.70			
Cost Based on Flow	(Cost/s)	0.0000	0.0000			
Act. Gas Flow	(ACFM)	---	---			
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458			
Specific Heat	(Btu/lbmole-F)	18.02	18.11			
Std. Gas Flow	(MMSCFD)	5.305	5.305			
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30			
Act. Liq. Flow	(USGPM)	21.38	21.77			
Z Factor		9.371e-004	8.244e-004			
Watson K		---	---			
User Property		---	---			
Partial Pressure of H2S	(psig)	-14.70	-14.70			
Cp/(Cp - R)		1.124	1.123			
Cp/Cv		1.061	1.105			
Heat of Vap.	(Btu/lbmole)	1.728e+004	1.732e+004			
Kinematic Viscosity	(cSt)	0.4372	0.3115			
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36			
Liq. Vol. Flow (Std. Cond)	(USGPM)	20.98	20.98			
Liquid Fraction		1.000	1.000			
Molar Volume	(ft3/lbmole)	0.2944	0.2998			
Mass Heat of Vap.	(Btu/lb)	958.9	961.2			
Phase Fraction [Molar Basis]		0.0000	0.0000			
Surface Tension	(lbf/ft)	4.456e-003	4.102e-003			
Thermal Conductivity	(Btu/hr-ft-F)	0.3803	0.3915			
Viscosity	(cP)	0.4285	0.2998			
Cv (Semi-Ideal)	(Btu/lbmole-F)	16.04	16.13			
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.8901	0.8951			
Cv	(Btu/lbmole-F)	16.99	16.39			
Mass Cv	(Btu/lb-F)	0.9432	0.9097			

10

* Specified by user.

Heater: E-100 (continued)

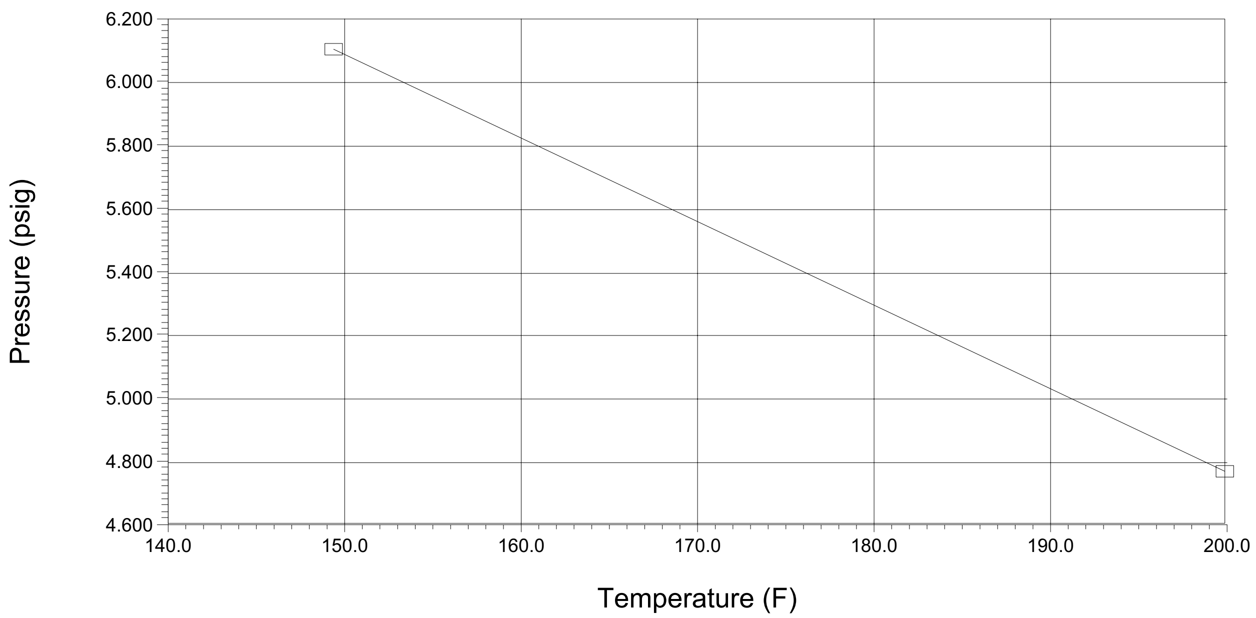
PROPERTIES

Name	stream 7 A	stream 7 B			
Cv (Ent. Method) (Btu/lbmole-F)	---	---			
Mass Cv (Ent. Method) (Btu/lb-F)	---	---			
Cp/Cv (Ent. Method)	---	---			
Reid VP at 37.8 C (psig)	---	---			
True VP at 37.8 C (psig)	-13.75	-13.75			
Liq. Vol. Flow - Sum(Std. Cond) (barrel/day)	719.4	719.4			

PERFORMANCE PROFILES

Zone	Pressure (psig)	Temperature (F)	Vapour Fraction	Enthalpy (Btu/lbmole)
Inlet	6.11	149.38	0.0000	-121230.55
0	4.77	200.00	0.0000	-120316.44

PERFORMANCE PLOT



PERFORMANCE TABLE

Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Vapour Fraction
149.38	6.11	0.00	-121230.55	0.0000
200.00	4.77	0.53	-120316.44	0.0000

Vapour Phase

Mass Flow (lb/hr)	Molecular Weight	Density (lb/ft3)	Mass Specific Heat (Btu/lb-F)	Viscosity (cP)	Thermal Conductivity (Btu/hr-ft-F)
---	---	---	---	---	---
---	---	---	---	---	---

* Specified by user.

Heater: E-100 (continued)

PERFORMANCE TABLE

Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	Mass Specific Heat (Btu/lb-F)	Viscosity (cP)	Thermal Conductivity (Btu/hr-ft-F)	Surface Tension (lbf/ft)
---	---	---	---	---	---
---	---	---	---	---	---

Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	Mass Specific Heat (Btu/lb-F)	Viscosity (cP)	Thermal Conductivity (Btu/hr-ft-F)	Surface Tension (lbf/ft)
10493.94	61.19	1.00	---	---	0.00
10493.94	60.09	1.01	0.30	0.39	0.00

DYNAMICS

Model Details: Supplied Duty

Zone		1 *	Delta P	(psi)	1.337
Volume	(ft3)	3.531 *	Overall K	(lb/hr/sqrt(psia-lb/ft3))	1169 *
Duty	(MMBtu/hr)	0.5325			

Holdup Details

Phase	Accumulation (MMSCFD)	Moles (lbmole)	Volume (ft3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Individual Zone Holdups: Zone 0

Delta P Specs and Duties

Zone	dP Value (psi)	dP Option	Duty (MMBtu/hr)
0 *	1.337 *	not specified	0.0000 *

Zone Conductance Specifications

Zone	k (lb/hr/sqrt(psia-lb/ft3))	Specification
0 *	1169	Disabled

NOTES

Heat Exchanger: Pre-heater

CONNECTIONS

Tube Side				Shell Side			
Inlet		Outlet		Inlet		Outlet	
Name	stream 6	Name	stream 7 A	Name	stream 4 A	Name	stream 4 B
From Op.	TEE-101 Tee	To Op.	Heater E-100	From Op.	Heat Excha Stage 1	To Op.	Mixer MIX-100

* Specified by user.

Heat Exchanger: Pre-heater (continued)

Temp	132.83 F	Temp	149.38 F	Temp	210.00 F *	Temp	192.73 F

PARAMETERS

Steady State Rating

Tube Side Data		Shell Side Data	
Heat Transfer Coefficient	378.07 Btu/hr-ft2-F	Heat Transfer Coefficient	15.18 Btu/hr-ft2-F
Tube Pressure Drop	0.20 psi	Shell Pressure Drop	0.00 psi
Fouling	0.00000 F-hr-ft2/Btu	Fouling	0.00000 F-hr-ft2/Btu
Tube Length	19.69 ft	Shell Passes	1
Tube O.D.	0.79 in *	Shell Series	1 *
Tube Thickness	0.0787 in	Shell Parallel	1 *
Tube Pitch	1.9685 in *	Baffle Type	Single
Orientation	Horizontal	Baffle Cut(%Area)	20.00
Passes Per Shell	2 *	Baffle Orientation	Horizontal
Tubes Per Shell	50 *	Spacing	31.4961 in *
Layout Angle	Triangular (30 degrees)	Diameter	16.7064 in *
TEMA Type	A E L	Area	202.89 ft2

SPECS

	Specified Value	Current Value	Relative Error	Active	Estimate
E-100 Heat Balance	0.0000 MMBtu/hr	9.446e-014 MMBtu/hr	5.440e-013	On	Off
E-100 UA	0.0000 Btu/F-hr	2921 Btu/F-hr	1541	On	Off

Detailed Specifications

E-100 Heat Balance

Type: Duty	Pass: Error	Spec Value: 0.0000 MMBtu/hr

E-100 UA

Type: UA	Pass: Overall	Spec Value: 0.0000 Btu/F-hr

User Variables

RATING

Sizing

Overall Data

Configuration

# of Shells in Series	1 *	Tube Passes per Shell	2 *	Elevation (Base)	0.0000 ft
# of Shells in Parallel	1 *	Exchange Orientation	Horizontal	First Tube Pass Flow Direction	Counter

TEMA Type:	A	E	L

Calculated Information

Shell HT Coeff	15.18 Btu/hr-ft2-F	Overall U	0 Btu/hr-ft2-F	Shell DP	40e-004 psi	Shell Vol per Shell	26.64 ft3	HT Area per Shell	202.9 ft2
Tube HT Coeff	378.1 Btu/hr-ft2-F	Overall UA	)000 Btu/F-hr	Tube DP	0.1961 psi	Tube Vol per Shell	2.130 ft3		

Shell Data

Shell and Tube Bundle

Shell Diameter	16.71 in *	Tube Pitch	1.969 in *	Shell Fouling	0.0000 F-hr-ft2/Btu
# of Tubes per Shell	50 *	Tube Layout Angle		Triangular (30 degrees)	

Shell Baffles

Shell Baffle Type	Single	Shell Baffle Orientation	Horizontal	Baffle Cut (%Area)	20.00	Baffle Spacing	31.50 in *

Tube Data

Dimensions

OD	0.7874 in *	ID	0.6299 in *	Tube Thickness	7.874e-002 in	Tube Length	19.69 ft

Tube Properties

Tube Fouling	0.0000 F-hr-ft2/Btu	Thermal Cond.	26.00 Btu/hr-ft-F *	Wall Cp	---	Wall Density	---

* Specified by user.

Heat Exchanger: Pre-heater (continued)

Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 ft

		stream 6	stream 4 A	stream 7 A
Diameter	(ft)	0.1640	0.1640	0.1640
Elevation (Base)	(ft)	0.0000	0.0000	0.0000
Elevation (Ground)	(ft)	0.0000	0.0000	0.0000
Elevation (% of Height)	(%)	0.00	0.00	0.00
		stream 4 B		
Diameter	(ft)	0.1640		
Elevation (Base)	(ft)	0.0000		
Elevation (Ground)	(ft)	0.0000		
Elevation (% of Height)	(%)	0.00		

CONDITIONS

Name		stream 6	stream 4 A	stream 7 A	stream 4 B
Vapour		0.0000	0.0000	0.0000	0.0000
Temperature	(F)	132.8341	210.0000 *	149.3850	192.7320
Pressure	(psig)	6.3040	0.0040 *	6.1079	0.0039
Molar Flow	(MMSCFD)	5.3049	5.0552	5.3049	5.0552
Mass Flow	(lb/hr)	10493.9425	10000.0000	10493.9425	10000.0000
Std Ideal Liq Vol Flow	(USGPM)	21.0000	20.0115	21.0000	20.0115
Molar Enthalpy	(Btu/lbmole)	-1.215e+005	-1.201e+005	-1.212e+005	-1.204e+005
Molar Entropy	(Btu/lbmole-F)	3.360	5.571	3.856	5.097
Heat Flow	(MMBtu/hr)	-7.0792e+01	-6.6687e+01	-7.0618e+01	-6.6860e+01

PROPERTIES

Name		stream 6	stream 4 A	stream 7 A	stream 4 B	
Molecular Weight		18.02	18.02	18.02	18.02	
Molar Density	(lbmole/ft3)	3.413	3.322	3.397	3.345	
Mass Density	(lb/ft3)	61.49	59.85	61.19	60.26	
Act. Volume Flow	(barrel/day)	729.5	714.3	733.1	709.3	
Mass Enthalpy	(Btu/lb)	-6746	-6669	-6729	-6686	
Mass Entropy	(Btu/lb-F)	0.1865	0.3092	0.2140	0.2830	
Heat Capacity	(Btu/lbmole-F)	18.00	18.14	18.02	18.10	
Mass Heat Capacity	(Btu/lb-F)	0.9993	1.007	1.000	1.004	
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000	0.0000	0.0000	
Mass Lower Heating Value	(Btu/lb)	---	---	---	---	
Phase Fraction [Vol. Basis]		---	---	---	---	
Phase Fraction [Mass Basis]		0.0000	0.0000	0.0000	0.0000	
Partial Pressure of CO2	(psig)	-14.70	-14.70	-14.70	-14.70	
Cost Based on Flow	(Cost/s)	0.0000	0.0000	0.0000	0.0000	
Act. Gas Flow	(ACFM)	---	---	---	---	
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458	3.458	3.458	
Specific Heat	(Btu/lbmole-F)	18.00	18.14	18.02	18.10	
Std. Gas Flow	(MMSCFD)	5.305	5.056	5.305	5.056	
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30	62.30	62.30	
Act. Liq. Flow	(USGPM)	21.28	20.83	21.38	20.69	
Z Factor		9.676e-004	6.157e-004	9.371e-004	6.277e-004	
Watson K		---	---	---	---	
User Property		---	---	---	---	
Partial Pressure of H2S	(psig)	-14.70	-14.70	-14.70	-14.70	
Cp/(Cp - R)		1.124	1.123	1.124	1.123	
Cp/Cv		1.047	1.115	1.061	1.098	

* Specified by user.

EPCO HOLDINGS, INC.
Burlington, MA
USA

Case Name:	CASE2 C.HSC
Unit Set:	GasPlant1
Date/Time:	Fri Apr 10 14:21:44 2009

Heat Exchanger: Pre-heater (continued)

PROPERTIES

Name		stream 6	stream 4 A	stream 7 A	stream 4 B	
Heat of Vap.	(Btu/lbmole)	1.727e+004	1.748e+004	1.728e+004	1.748e+004	
Kinematic Viscosity	(cSt)	0.5003	0.2944	0.4372	0.3251	
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36	62.36	62.36	
Liq. Vol. Flow (Std. Cond)	(USGPM)	20.98	19.99	20.98	19.99	
Liquid Fraction		1.000	1.000	1.000	1.000	
Molar Volume	(ft3/lbmole)	0.2930	0.3010	0.2944	0.2989	
Mass Heat of Vap.	(Btu/lb)	958.6	970.6	958.9	970.6	
Phase Fraction [Molar Basis]		0.0000	0.0000	0.0000	0.0000	
Surface Tension	(lbf/ft)	4.568e-003	4.030e-003	4.456e-003	4.154e-003	
Thermal Conductivity	(Btu/hr-ft-F)	0.3753	0.3930	0.3803	0.3903	
Viscosity	(cP)	0.4928	0.2823	0.4285	0.3138	
Cv (Semi-Ideal)	(Btu/lbmole-F)	16.02	16.15	16.04	16.11	
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.8891	0.8966	0.8901	0.8942	
Cv	(Btu/lbmole-F)	17.19	16.27	16.99	16.47	
Mass Cv	(Btu/lb-F)	0.9542	0.9034	0.9432	0.9145	
Cv (Ent. Method)	(Btu/lbmole-F)	---	---	---	---	
Mass Cv (Ent. Method)	(Btu/lb-F)	---	---	---	---	
Cp/Cv (Ent. Method)		---	---	---	---	
Reid VP at 37.8 C	(psig)	---	---	---	---	
True VP at 37.8 C	(psig)	-13.75	-13.75	-13.75	-13.75	
Liq. Vol. Flow - Sum(Std. Cond)	(barrel/day)	719.4	685.5	719.4	685.5	

DETAILS

Overall/Detailed Performance

Duty:	1.736e-01 MMBtu/hr	UA:	2.921e+03 Btu/F-hr	UA Curv. Error:	0.00e-01 Btu/F-hr	Ft Factor:	---
Heat Leak:	000e-01 MMBtu/hr	Min. Approach:	59.90 F	Hot Pinch Temp:	192.7 F	Uncorrected Lmtd:	60.26 F
Heat Loss:	000e-01 MMBtu/hr	Lmtd:	59.46 F	Cold Pinch Temp:	132.8 F		

TABLES

Shell Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
192.73	0.00	0.00	-120448.21	0.0000	0.0000	---
196.19	0.00	0.03	-120385.59	0.0000	0.0000	---
199.65	0.00	0.07	-120323.03	0.0000	0.0000	---
203.10	0.00	0.10	-120260.49	0.0000	0.0000	---
206.55	0.00	0.14	-120197.95	0.0000	0.0000	---
210.00	0.00	0.17	-120135.39	0.0000	0.0000	---

Shell Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

* Specified by user.

Heat Exchanger: Pre-heater (continued)

Shell Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravity	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---

Shell Side - Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravity	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
10000.00	60.26	1.00	0.31	0.00	0.00	18.02	0.68	3193.54	705.47	0.34	0.97
10000.00	60.18	1.00	0.31	0.00	0.00	18.02	0.68	3193.54	705.47	0.34	0.96
10000.00	60.10	1.01	0.30	0.00	0.00	18.02	0.68	3193.54	705.47	0.34	0.96
10000.00	60.02	1.01	0.29	0.00	0.00	18.02	0.68	3193.54	705.47	0.34	0.96
10000.00	59.93	1.01	0.29	0.00	0.00	18.02	0.68	3193.54	705.47	0.34	0.96
10000.00	59.85	1.01	0.28	0.00	0.00	18.02	0.68	3193.54	705.47	0.34	0.96

Shell Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravity	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Tube Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
132.83	6.30	0.00	-121528.66	0.0000	0.0000	---
136.15	6.30	0.03	-121469.04	0.0000	0.0000	---
139.46	6.30	0.07	-121409.40	0.0000	0.0000	---
142.77	6.30	0.10	-121349.78	0.0000	0.0000	---
146.08	6.30	0.14	-121290.15	0.0000	0.0000	---
149.38	6.30	0.17	-121230.55	0.0000	0.0000	---

Tube Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Heat Exchanger: Pre-heater (continued)

Tube Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ass Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---

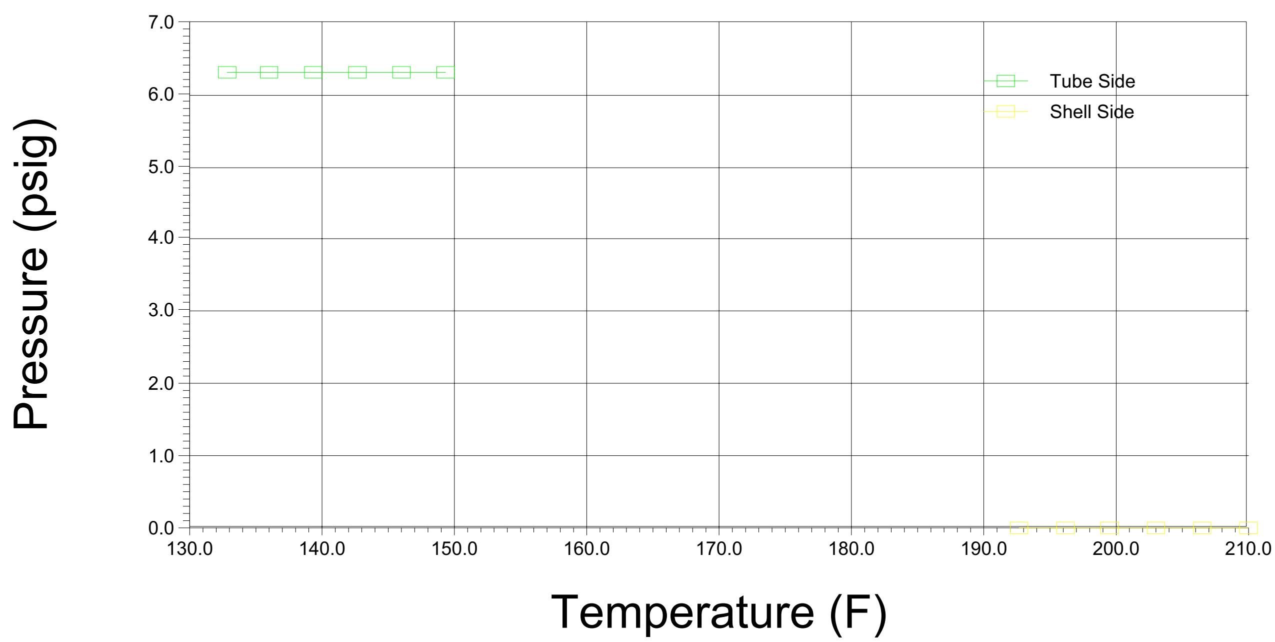
Tube Side - Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ass Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
10493.94	61.49	1.00	0.49	0.00	0.00	18.02	0.65	3193.54	705.47	0.34	0.98
10493.94	61.43	1.00	0.48	0.00	0.00	18.02	0.65	3193.54	705.47	0.34	0.98
10493.94	61.37	1.00	0.47	0.00	0.00	18.02	0.65	3193.54	705.47	0.34	0.98
10493.94	61.31	1.00	0.45	0.00	0.00	18.02	0.65	3193.54	705.47	0.34	0.98
10493.94	61.25	1.00	0.44	0.00	0.00	18.02	0.66	3193.54	705.47	0.34	0.98
10493.94	61.19	1.00	0.43	0.00	0.00	18.02	0.66	3193.54	705.47	0.34	0.98

Tube Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ass Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Heat Exchanger: Pre-heater (continued)



DYNAMICS

Basic Model

Model Parameters

Tube Volume	(ft3)	3.531	Shell UA	(lb/hr)	---
Shell Volume	(ft3)	3.531	Tube UA	(lb/hr)	---
Elevation	(ft)	0.0000	Minimum Flow Scale Factor		0.0000 *
Overall UA	(Btu/F-hr)	0.0000			

Summary

Shell Duty: ---	Tube Duty: ---

Pressure Flow Specifications

Shell Side Specification

Delta P	(psi)	---	Active	k	lb/hr/sqrt(psia-lb/ft3)	---	Not Active

Tube Side Specifications

Delta P	(psi)	---	Active	k	lb/hr/sqrt(psia-lb/ft3)	---	Not Active

Holdup

Shell Holdup

Phase	Accumulation (MMSCFD)	Moles (lbmole)	Volume (ft3)
Vapour	0.0000	0.0000 *	0.0000
Liquid	0.0000	0.0000 *	0.0000
Aqueous	0.0000	0.0000 *	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

* Specified by user.

Heat Exchanger: Pre-heater (continued)

Tube Holdup

Phase	Accumulation (MMSCFD)	Moles (lbmole)		Volume (ft3)
Vapour	0.0000	0.0000	*	0.0000
Liquid	0.0000	0.0000	*	0.0000
Aqueous	0.0000	0.0000	*	0.0000
Total	**0.0000**	**0.0000**		**0.0000**

NOTES

HTFS

HTFS+

Heat Exchanger: Condenser

CONNECTIONS

Tube Side											
Inlet			Outlet			Shell Side Inlet			Outlet		
Name		Stream 12	Name		stream 13 A	Name		stream 10	Name		stream 11
From Op.			To Op.	Tee	TEE-101	From Op.	Tee	TEE-100	To Op.	Mixer	MIX-100
Temp		80.00 F *	Temp		132.83 F	Temp		162.24 F	Temp		120.00 F *

PARAMETERS

Exchanger Design (End Point)

Tube Side DeltaP:	4.000 psi	Shell Side DeltaP:	0.9999 psi	Passes:	---
UA:	2.298e+005 Btu/F-hr	Tolerance:	1.0000e-04		

Tube Side Data		Shell Side Data	
Heat Transfer Coefficient	---	Heat Transfer Coefficient	---
Tube Pressure Drop	4.00 psi	Shell Pressure Drop	1.00 psi
Fouling	0.00000 F-hr-ft2/Btu	Fouling	0.00000 F-hr-ft2/Btu
Tube Length	15.00 ft *	Shell Passes	1
Tube O.D.	0.79 in *	Shell Series	1 *
Tube Thickness	0.0787 in	Shell Parallel	1 *
Tube Pitch	1.9685 in *	Baffle Type	Single
Orientation	Horizontal	Baffle Cut(%Area)	20.00
Passes Per Shell	1 *	Baffle Orientation	Horizontal
Tubes Per Shell	750 *	Spacing	31.4961 in *
Layout Angle	Triangular (30 degrees)	Diameter	48.0000 in *
TEMA Type	A E L	Area	2319.09 ft2

SPECS

	Specified Value	Current Value	Relative Error	Active	Estimate
E-102 Heat Balance	0.0000 MMBtu/hr	2.405e-013 MMBtu/hr	3.040e-014	On	Off
E-102 UA	---	2.298e+005 Btu/F-hr	---	Off	On

* Specified by user.

Heat Exchanger: Condenser (continued)

Detailed Specifications

E-102 Heat Balance

Type: Duty	Pass: Error	Spec Value: 0.0000 MMBtu/hr

E-102 UA

Type: UA	Pass: Overall	Spec Value: ---

User Variables

RATING

Sizing

Overall Data

Configuration

# of Shells in Series	1 *	Tube Passes per Shell	1 *	Elevation (Base)	0.0000 ft
# of Shells in Parallel	1 *	Exchange Orientation	Horizontal	First Tube Pass Flow Direction	Counter

TEMA Type:	A	E	L

Calculated Information

Shell HT Coeff	---	Overall U	8 Btu/hr-ft2-F	Shell DP	0.9999 psi	Shell Vol per Shell	150.5 ft3	HT Area per Shell	2319 ft2
Tube HT Coeff	---	Overall UA	-005 Btu/F-hr	Tube DP	4.000 psi	Tube Vol per Shell	24.35 ft3		

Shell Data

Shell and Tube Bundle

Shell Diameter	48.00 in *	Tube Pitch	1.969 in *	Shell Fouling	0.0000 F-hr-ft2/Btu
# of Tubes per Shell	750 *	Tube Layout Angle		Triangular (30 degrees)	

Shell Baffles

Shell Baffle Type	Single	Shell Baffle Orientation	Horizontal	Baffle Cut (%Area)	20.00	Baffle Spacing	31.50 in *

Tube Data

Dimensions

OD	0.7874 in *	ID	0.6299 in *	Tube Thickness	7.874e-002 in	Tube Length	15.00 ft *

Tube Properties

Tube Fouling	0.0000 F-hr-ft2/Btu	Thermal Cond.	26.00 Btu/hr-ft-F *	Wall Cp	0.1130 Btu/lb-F *	Wall Density	487.0 lb/ft3 *

Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 ft

		Stream 12	stream 10	stream 13 A
Diameter	(ft)	0.1640	0.1640	0.1640
Elevation (Base)	(ft)	0.0000	0.0000	0.0000
Elevation (Ground)	(ft)	0.0000 *	0.0000 *	0.0000 *
Elevation (% of Height)	(%)	0.00 *	0.00 *	0.00 *

		stream 11		
Diameter	(ft)	0.1640		
Elevation (Base)	(ft)	0.0000		
Elevation (Ground)	(ft)	0.0000 *		
Elevation (% of Height)	(%)	0.00 *		

CONDITIONS

Name		Stream 12	stream 10	stream 13 A	stream 11
Vapour		0.0000 *	1.0000	0.0000	0.0000
Temperature	(F)	80.0000 *	162.2400	132.8341	120.0000 *
Pressure	(psig)	10.3040 *	-9.6960	6.3040 *	-10.6959 *
Molar Flow	(MMSCFD)	75.8287	3.8332	75.8287	3.8332
Mass Flow	(lb/hr)	150000.0000 *	7582.6092	150000.0000	7582.6092
Std Ideal Liq Vol Flow	(USGPM)	300.1732	15.1740	300.1732	15.1740
Molar Enthalpy	(Btu/lbmole)	-1.225e+005	-1.030e+005	-1.215e+005	-1.218e+005

EPCO HOLDINGS, INC.
Burlington, MA
USA

Case Name:	CASE2 C.HSC
Unit Set:	GasPlant1
Date/Time:	Fri Apr 10 14:21:44 2009

Heat Exchanger: Condenser (continued)

CONDITIONS

Molar Entropy	(Btu/lbmole-F)	1.680	33.23	3.360	2.966
Heat Flow	(MMBtu/hr)	-1.0198e+03	-4.3338e+01	-1.0119e+03	-5.1250e+01

PROPERTIES

Name		Stream 12	stream 10	stream 13 A	stream 11	
Molecular Weight		18.02	18.02	18.02	18.02	
Molar Density	(lbmole/ft3)	3.453	7.547e-004	3.413	3.425	
Mass Density	(lb/ft3)	62.21	1.360e-002	61.49	61.70	
Act. Volume Flow	(barrel/day)	1.031e+004	2.384e+006	1.043e+004	525.4	
Mass Enthalpy	(Btu/lb)	-6799	-5715	-6746	-6759	
Mass Entropy	(Btu/lb-F)	9.324e-002	1.845	0.1865	0.1646	
Heat Capacity	(Btu/lbmole-F)	17.99	8.357	18.00	17.99	
Mass Heat Capacity	(Btu/lb-F)	0.9984	0.4639	0.9993	0.9988	
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000	0.0000	0.0000	
Mass Lower Heating Value	(Btu/lb)	---	---	---	---	
Phase Fraction [Vol. Basis]		---	---	---	---	
Phase Fraction [Mass Basis]		0.0000	4.941e-324	0.0000	0.0000	
Partial Pressure of CO2	(psig)	-14.70	-14.70	-14.70	-14.70	
Cost Based on Flow	(Cost/s)	0.0000	0.0000	0.0000	0.0000	
Act. Gas Flow	(ACFM)	---	9295	---	---	
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458	3.458	3.458	
Specific Heat	(Btu/lbmole-F)	17.99	8.357	18.00	17.99	
Std. Gas Flow	(MMSCFD)	75.83	3.833	75.83	3.833	
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30	62.30	62.30	
Act. Liq. Flow	(USGPM)	300.6	---	304.1	15.32	
Z Factor		1.250e-003	0.9927	9.676e-004	1.878e-004	
Watson K		---	---	---	---	
User Property		---	---	---	---	
Partial Pressure of H2S	(psig)	-14.70	-14.70	-14.70	-14.70	
Cp/(Cp - R)		1.124	1.312	1.124	1.124	
Cp/Cv		1.012	1.336	1.047	1.038	
Heat of Vap.	(Btu/lbmole)	1.716e+004	1.804e+004	1.727e+004	1.814e+004	
Kinematic Viscosity	(cSt)	0.8606	50.44	0.5003	0.5612	
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36	62.36	62.36	
Liq. Vol. Flow (Std. Cond)	(USGPM)	299.9	15.16	299.9	15.16	
Liquid Fraction		1.000	0.0000	1.000	1.000	
Molar Volume	(ft3/lbmole)	0.2896	1325	0.2930	0.2920	
Mass Heat of Vap.	(Btu/lb)	952.4	1001	958.6	1007	
Phase Fraction [Molar Basis]		0.0000	1.0000	0.0000	0.0000	
Surface Tension	(lbf/ft)	4.921e-003	---	4.568e-003	4.655e-003	
Thermal Conductivity	(Btu/hr-ft-F)	0.3545	1.293e-002	0.3753	0.3709	
Viscosity	(cP)	0.8576	1.098e-002	0.4928	0.5546	
Cv (Semi-Ideal)	(Btu/lbmole-F)	16.00	6.372	16.02	16.01	
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.8881	0.3537	0.8891	0.8886	
Cv	(Btu/lbmole-F)	17.77	6.255	17.19	17.34	
Mass Cv	(Btu/lb-F)	0.9863	0.3472	0.9542	0.9626	
Cv (Ent. Method)	(Btu/lbmole-F)	---	---	---	---	
Mass Cv (Ent. Method)	(Btu/lb-F)	---	---	---	---	
Cp/Cv (Ent. Method)		---	---	---	---	
Reid VP at 37.8 C	(psig)	---	---	---	---	
True VP at 37.8 C	(psig)	-13.75	-13.75	-13.75	-13.75	
Liq. Vol. Flow - Sum(Std. Cond)	(barrel/day)	1.028e+004	519.8	1.028e+004	519.8	

Heat Exchanger: Condenser (continued)

DETAILS

Overall/Detailed Performance

Duty:	7.912e+00 MMBtu/hr	UA:	2.298e+05 Btu/F-hr	UA Curv. Error:	0.00e-01 Btu/F-hr	Ft Factor:	---
Heat Leak:	000e-01 MMBtu/hr	Min. Approach:	29.41 F	Hot Pinch Temp:	162.2 F	Uncorrected Lmtd:	34.43 F
Heat Loss:	000e-01 MMBtu/hr	Lmtd:	34.43 F	Cold Pinch Temp:	132.8 F		

TABLES

Shell Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
120.00	-10.70	-0.00	-121760.43	0.0000	0.0000	18135.4313
153.29	-10.66	0.25	-121160.90	0.0000	0.0000	18131.9347
162.24	-9.70	7.91	-102963.36	1.0000	1.0000	18036.1734

Shell Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---	---	---	3193.54	705.47	---	---
0.00	18.02	0.01	0.46	0.01	0.20	0.07	---	3193.54	705.47	0.99	0.00
7582.61	18.02	0.01	0.46	0.01	0.20	0.07	---	3193.54	705.47	0.99	1.93

Shell Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravity	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Shell Side - Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravity	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
7582.61	61.70	1.00	0.55	0.20	0.00	18.02	0.26	---	---	0.00	1.93
7582.61	61.11	1.00	0.42	0.20	0.00	18.02	0.26	---	---	0.00	1.93
---	---	---	---	---	---	---	---	---	---	---	---

Shell Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravity	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
11630.00	61.70	1.00	0.55	0.37	0.00	18.02	0.99	---	---	0.26	0.34
11630.00	61.11	1.00	0.42	0.38	0.00	18.02	0.98	---	---	0.26	0.34
---	---	---	---	---	---	---	---	---	---	---	---

Tube Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
80.00	10.30	0.00	-122478.86	0.0000	0.0000	---
132.83	6.30	7.91	-121528.66	0.0000	0.0000	---

* Specified by user.

Heat Exchanger: Condenser (continued)

Tube Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Tube Side - Light Liquid Phase

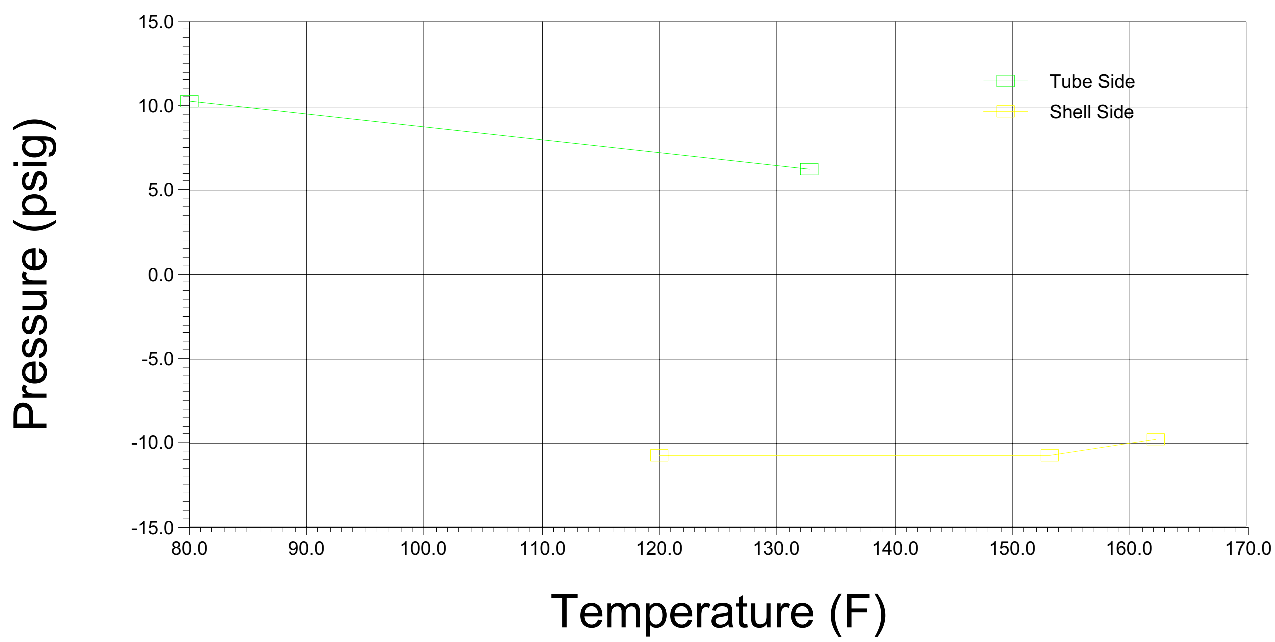
Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---

Tube Side - Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
150000.00	62.21	1.00	0.86	0.00	0.00	18.02	0.61	---	---	0.34	1.00
150000.00	61.49	1.00	0.49	0.00	0.00	18.02	0.65	---	---	0.34	0.98

Tube Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---



DYNAMICS

Detailed Model

Model Data

* Specified by user.

Heat Exchanger: Condenser (continued)

Model Data

Tube Volume	(ft3)	24.35	Shell Passes	1
Shell Volume	(ft3)	150.5	Tube Passes	1 *
Heat Trans. Area	(ft2)	2319	Orientation	Horizontal
Elevation	(ft)	0.0000 *	Zones Per Shell Pass	3 *

Model Parameters

Overall U	(Btu/hr-ft2-F)	99.08	Shell HT Coefficient	(Btu/hr-ft2-F)	---
Overall UA	(Btu/F-hr)	2.298e+005	Tube HT Coefficient	(Btu/hr-ft2-F)	---

Pressure Flow Specifications

Shell Side Specifications

Pressure Flow K	(lb/hr/sqrt(psia-lb/ft3))	---	Delta P	(psi)	0.9999
User Pressure Flow K		Not Active	Delta P Calculator		Hysim Correlation

Tube Side Specifications

Pressure Flow K	(lb/hr/sqrt(psia-lb/ft3))	---	Delta P	(psi)	4.000
User Pressure Flow K		Not Active	Delta P Calculator		Hysim Correlation

Overall Holdup Details

Stream Side: Stream 12

Phase	Accumulation (MMSCFD)	Moles (lbmole)	Volume (ft3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Individual Zone Holdup

Shell Pass: Pass 0	Zone: Zone 0	Holdup: Shell

NOTES

HTFS

HTFS+

Heat Exchanger: Stage 1

CONNECTIONS

Tube Side								Shell Side							
Inlet				Outlet				Inlet				Outlet			
Name		stream 15		Name		stream 4 A		Name		stream 7 B		Name		stream 8 A	
From Op.	MIX-101	Mixer		To Op.	Heat Excha	Pre-heater		From Op.	Heater	E-100		To Op.	Recycle	RCY-1	
Temp		367.47 F		Temp		210.00 F	*	Temp		200.00 F	*	Temp		241.37 F	

PARAMETERS

* Specified by user.

Heat Exchanger: Stage 1 (continued)

Exchanger Design (End Point)

Tube Side DeltaP:	4.050 psi	Shell Side DeltaP:	4.771 psi	Passes:	---
UA:	2.277e+005 Btu/F-hr	Tolerance:	1.0000e-04		

Tube Side Data		Shell Side Data	
Heat Transfer Coefficient	---	Heat Transfer Coefficient	---
Tube Pressure Drop	4.05 psi	Shell Pressure Drop	4.77 psi
Fouling	0.00000 F-hr-ft2/Btu	Fouling	0.00000 F-hr-ft2/Btu
Tube Length	19.00 ft *	Shell Passes	1
Tube O.D.	0.79 in *	Shell Series	1 *
Tube Thickness	0.0787 in	Shell Parallel	1 *
Tube Pitch	1.9685 in *	Baffle Type	Single
Orientation	Horizontal	Baffle Cut(%Area)	20.00
Passes Per Shell	2 *	Baffle Orientation	Horizontal
Tubes Per Shell	750 *	Spacing	31.4961 in *
Layout Angle	Triangular (30 degrees)	Diameter	48.0000 in *
TEMA Type	A E L	Area	2937.51 ft2

SPECS

	Specified Value	Current Value	Relative Error	Active	Estimate
E-100 Heat Balance	0.0000 MMBtu/hr	4.655e-015 MMBtu/hr	4.450e-016	On	Off
E-100 UA	---	2.277e+005 Btu/F-hr	---	Off	On

Detailed Specifications

E-100 Heat Balance

Type: Duty	Pass: Error	Spec Value: 0.0000 MMBtu/hr

E-100 UA

Type: UA	Pass: Overall	Spec Value: ---

User Variables

RATING

Sizing

Overall Data

Configuration

# of Shells in Series	1 *	Tube Passes per Shell	2 *	Elevation (Base)	0.0000 ft
# of Shells in Parallel	1 *	Exchange Orientation	Horizontal	First Tube Pass Flow Direction	Counter

TEMA Type:	A	E	L

Calculated Information

Shell HT Coeff	---	Overall U	2 Btu/hr-ft2-F	Shell DP	4.771 psi	Shell Vol per Shell	190.6 ft3	HT Area per Shell	2938 ft2
Tube HT Coeff	---	Overall UA	-005 Btu/F-hr	Tube DP	4.050 psi	Tube Vol per Shell	30.84 ft3		

Shell Data

Shell and Tube Bundle

Shell Diameter	48.00 in *	Tube Pitch	1.969 in *	Shell Fouling	0.0000 F-hr-ft2/Btu
# of Tubes per Shell	750 *	Tube Layout Angle		Triangular (30 degrees)	

Shell Baffles

Shell Baffle Type	Single	Shell Baffle Orientation	Horizontal	Baffle Cut (%Area)	20.00	Baffle Spacing	31.50 in *

Tube Data

Dimensions

OD	0.7874 in *	ID	0.6299 in *	Tube Thickness	7.874e-002 in	Tube Length	19.00 ft *

Tube Properties

Tube Fouling	0.0000 F-hr-ft2/Btu	Thermal Cond.	26.00 Btu/hr-ft-F *	Wall Cp	0.1130 Btu/lb-F *	Wall Density	487.0 lb/ft3 *

Nozzle Parameters

Heat Exchanger: Stage 1 (continued)

Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 ft

		stream 15	stream 7 B	stream 4 A
Diameter	(ft)	0.1640	0.1640	0.1640
Elevation (Base)	(ft)	0.0000	0.0000	0.0000
Elevation (Ground)	(ft)	0.0000 *	0.0000 *	0.0000 *
Elevation (% of Height)	(%)	0.00 *	0.00 *	0.00 *

		stream 8 A		
Diameter	(ft)	0.1640		
Elevation (Base)	(ft)	0.0000		
Elevation (Ground)	(ft)	0.0000 *		
Elevation (% of Height)	(%)	0.00 *		

CONDITIONS

Name		stream 15	stream 7 B	stream 4 A	stream 8 A
Vapour		1.0000	0.0000	0.0000	1.0000
Temperature	(F)	367.4743	200.0000 *	210.0000 *	241.3661
Pressure	(psig)	4.0540 *	4.7708 *	0.0040 *	0.0000 *
Molar Flow	(MMSCFD)	5.0552	5.3049	5.0552	5.3049
Mass Flow	(lb/hr)	10000.0000	10493.9425	10000.0000	10493.9425
Std Ideal Liq Vol Flow	(USGPM)	20.0115	21.0000 *	20.0115	21.0000
Molar Enthalpy	(Btu/lbmole)	-1.013e+005	-1.203e+005	-1.201e+005	-1.024e+005
Molar Entropy	(Btu/lbmole-F)	32.95	5.298	5.571	32.03
Heat Flow	(MMBtu/hr)	-5.6226e+01	-7.0086e+01	-6.6687e+01	-5.9626e+01

PROPERTIES

Name		stream 15	stream 7 B	stream 4 A	stream 8 A	
Molecular Weight		18.02	18.02	18.02	18.02	
Molar Density	(lbmole/ft3)	2.128e-003	3.336	3.322	1.978e-003	
Mass Density	(lb/ft3)	3.834e-002	60.09	59.85	3.564e-002	
Act. Volume Flow	(barrel/day)	1.115e+006	746.5	714.3	1.259e+006	
Mass Enthalpy	(Btu/lb)	-5623	-6679	-6669	-5682	
Mass Entropy	(Btu/lb-F)	1.829	0.2941	0.3092	1.778	
Heat Capacity	(Btu/lbmole-F)	8.578	18.11	18.14	8.651	
Mass Heat Capacity	(Btu/lb-F)	0.4762	1.005	1.007	0.4802	
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000	0.0000	0.0000	
Mass Lower Heating Value	(Btu/lb)	---	---	---	---	
Phase Fraction [Vol. Basis]		---	---	---	---	
Phase Fraction [Mass Basis]		4.941e-324	0.0000	0.0000	4.941e-324	
Partial Pressure of CO2	(psig)	-14.70	-14.70	-14.70	-14.70	
Cost Based on Flow	(Cost/s)	0.0000	0.0000	0.0000	0.0000	
Act. Gas Flow	(ACFM)	4348	---	---	4908	
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458	3.458	3.458	
Specific Heat	(Btu/lbmole-F)	8.578	18.11	18.14	8.651	
Std. Gas Flow	(MMSCFD)	5.056	5.305	5.056	5.305	
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30	62.30	62.30	
Act. Liq. Flow	(USGPM)	---	21.77	20.83	---	
Z Factor		0.9926	8.244e-004	6.157e-004	0.9875	
Watson K		---	---	---	---	
User Property		---	---	---	---	
Partial Pressure of H2S	(psig)	-14.70	-14.70	-14.70	-14.70	
Cp/(Cp - R)		1.301	1.123	1.123	1.298	
Cp/Cv		1.322	1.105	1.115	1.337	
Heat of Vap.	(Btu/lbmole)	1.734e+004	1.732e+004	1.748e+004	1.749e+004	

* Specified by user.

Heat Exchanger: Stage 1 (continued)

PROPERTIES

Name		stream 15	stream 7 B	stream 4 A	stream 8 A	
Kinematic Viscosity	(cSt)	25.37	0.3115	0.2944	22.26	
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36	62.36	62.36	
Liq. Vol. Flow (Std. Cond)	(USGPM)	19.99	20.98	19.99	20.98	
Liquid Fraction		0.0000	1.000	1.000	0.0000	
Molar Volume	(ft3/lbmole)	469.9	0.2998	0.3010	505.5	
Mass Heat of Vap.	(Btu/lb)	962.5	961.2	970.6	970.6	
Phase Fraction [Molar Basis]		1.0000	0.0000	0.0000	1.0000	
Surface Tension	(lbf/ft)	---	4.102e-003	4.030e-003	---	
Thermal Conductivity	(Btu/hr-ft-F)	1.849e-002	0.3915	0.3930	1.502e-002	
Viscosity	(cP)	1.558e-002	0.2998	0.2823	1.271e-002	
Cv (Semi-Ideal)	(Btu/lbmole-F)	6.592	16.13	16.15	6.665	
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.3659	0.8951	0.8966	0.3700	
Cv	(Btu/lbmole-F)	6.489	16.39	16.27	6.469	
Mass Cv	(Btu/lb-F)	0.3602	0.9097	0.9034	0.3591	
Cv (Ent. Method)	(Btu/lbmole-F)	---	---	---	---	
Mass Cv (Ent. Method)	(Btu/lb-F)	---	---	---	---	
Cp/Cv (Ent. Method)		---	---	---	---	
Reid VP at 37.8 C	(psig)	---	---	---	---	
True VP at 37.8 C	(psig)	-13.75	-13.75	-13.75	-13.75	
Liq. Vol. Flow - Sum(Std. Cond)	(barrel/day)	685.5	719.4	685.5	719.4	

DETAILS

Overall/Detailed Performance

Duty:	1.046e+01 MMBtu/hr	UA:	2.277e+05 Btu/F-hr	UA Curv. Error:	0.00e-01 Btu/F-hr	Ft Factor:	---
Heat Leak:	000e-01 MMBtu/hr	Min. Approach:	10.00 F	Hot Pinch Temp:	210.0 F	Uncorrected Lmtd:	---
Heat Loss:	000e-01 MMBtu/hr	Lmtd:	45.93 F	Cold Pinch Temp:	200.0 F		

TABLES

Shell Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
200.00	4.77	0.00	-120316.44	0.0000	0.0000	---
226.18	4.64	0.28	-119841.31	0.0000	0.0000	---
212.23	0.07	10.31	-102612.53	1.0000	1.0000	---
241.37	0.00	10.46	-102358.96	1.0000	1.0000	---

Shell Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	'seudo Omega
---	---	---	---	---	---	---	---	3193.54	705.47	---	---
0.00	18.02	0.05	0.49	0.01	0.57	0.80	0.00	3193.54	705.47	0.34	---
10493.94	18.02	0.04	0.48	0.01	0.57	0.80	1.74	3193.54	705.47	0.34	---
10493.94	18.02	0.04	0.48	0.01	0.57	0.80	1.74	3193.54	705.47	0.34	---

Shell Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	'seudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---

* Specified by user.

EPCO HOLDINGS, INC. Burlington, MA USA	Case Name: CASE2 C.HSC Unit Set: GasPlant1 Date/Time: Fri Apr 10 14:21:44 2009

Heat Exchanger: Stage 1 (continued)

Shell Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Shell Side - Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
10493.94	60.09	1.01	0.30	0.00	0.00	18.02	0.68	---	---	0.34	0.96
10493.94	59.43	1.01	0.26	0.00	0.00	18.02	0.68	---	---	0.34	0.95
0.00	59.79	1.01	0.28	0.00	---	18.02	0.68	---	---	0.34	0.96
---	---	---	---	---	---	---	---	---	---	---	---

Shell Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Tube Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
210.00	0.00	0.00	-120135.39	0.0000	0.0000	---
212.04	0.01	0.02	-120098.37	0.0000	0.0000	---
223.79	3.79	9.77	-102535.93	1.0000	1.0000	---
367.47	4.05	10.46	-101290.91	1.0000	1.0000	---

Tube Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	---	---	---	3193.54	705.47	---	---
0.00	18.02	0.04	0.48	0.01	0.57	0.80	0.00	3193.54	705.47	0.34	---
10000.00	18.02	0.05	0.49	0.01	0.57	0.80	1.66	3193.54	705.47	0.34	---
10000.00	18.02	0.04	0.48	0.02	0.57	0.80	1.66	3193.54	705.47	0.34	---

Tube Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Tube Side - Heavy Liquid Phase

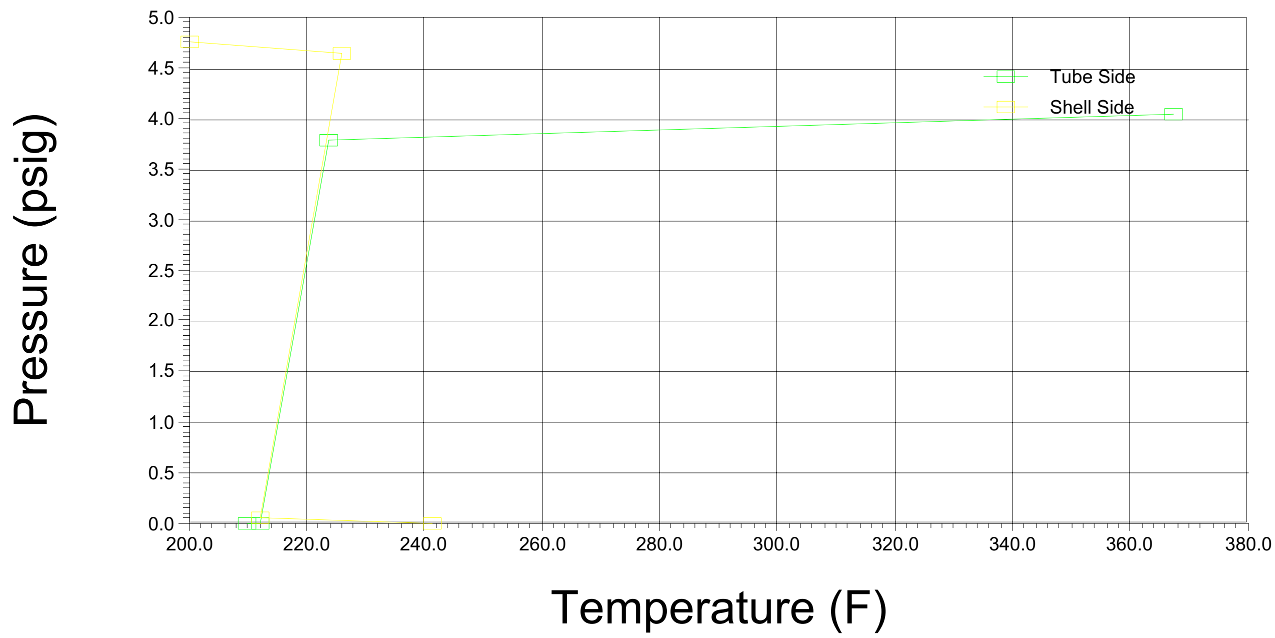
Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
10000.00	59.85	1.01	0.28	0.00	0.00	18.02	0.68	---	---	0.34	0.96
10000.00	59.80	1.01	0.28	0.00	0.00	18.02	0.68	---	---	0.34	0.96
0.00	59.50	1.01	0.26	0.00	---	18.02	0.68	---	---	0.34	0.95
---	---	---	---	---	---	---	---	---	---	---	---

* Specified by user.

Heat Exchanger: Stage 1 (continued)

Tube Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ass Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---



DYNAMICS

Detailed Model

Model Data

Tube Volume	(ft3)	30.84	Shell Passes	1
Shell Volume	(ft3)	190.6	Tube Passes	2 *
Heat Trans. Area	(ft2)	2938	Orientation	Horizontal
Elevation	(ft)	0.0000 *	Zones Per Shell Pass	3 *

Model Parameters

Overall U	(Btu/hr-ft2-F)	77.52	Shell HT Coefficient	(Btu/hr-ft2-F)	---
Overall UA	(Btu/F-hr)	2.277e+005	Tube HT Coefficient	(Btu/hr-ft2-F)	---

Pressure Flow Specifications

Shell Side Specifications

Pressure Flow K	(lb/hr/sqrt(psia-lb/ft3))	---	Delta P	(psi)	4.771
User Pressure Flow K		Not Active	Delta P Calculator		Hysim Correlation

Tube Side Specifications

* Specified by user.

EPCO HOLDINGS, INC. Burlington, MA USA	Case Name: CASE2 C.HSC Unit Set: GasPlant1 Date/Time: Fri Apr 10 14:21:44 2009

Heat Exchanger: Stage 1 (continued)

Tube Side Specifications

Pressure Flow K	(lb/hr/sqrt(psia-lb/ft3))	---	Delta P	(psi)	4.050
User Pressure Flow K		Not Active	Delta P Calculator		Hysim Correlation

Overall Holdup Details

Stream Side: stream 15

Phase	Accumulation (MMSCFD)	Moles (lbmole)	Volume (ft3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Individual Zone Holdup

Shell Pass: Pass 0	Zone: Zone 0	Holdup: Shell

NOTES

HTFS

HTFS+

Heat Exchanger: Stage 2

CONNECTIONS

Tube Side						Shell Side					
Inlet			Outlet			Inlet			Outlet		
Name		stream 8 B	Name		stream 18	Name		stream 17	Name		stream 9
From Op.	RCY-1	Recycle	To Op.	Separator	V-101	From Op.			To Op.	Tee	TEE-100
Temp		241.37 F *	Temp		165.00 F *	Temp		150.00 F *	Temp		162.24 F

PARAMETERS

Exchanger Design (End Point)

Tube Side DeltaP:	9.360 psi	Shell Side DeltaP:	9.696 psi	Passes:	---
UA:	2.780e+005 Btu/F-hr	Tolerance:	1.0000e-03 *		

Tube Side Data		Shell Side Data	
Heat Transfer Coefficient	---	Heat Transfer Coefficient	---
Tube Pressure Drop	9.36 psi	Shell Pressure Drop	9.70 psi
Fouling	0.00000 F-hr-ft2/Btu	Fouling	0.00000 F-hr-ft2/Btu
Tube Length	19.69 ft	Shell Passes	1
Tube O.D.	0.79 in *	Shell Series	1 *
Tube Thickness	0.0787 in	Shell Parallel	1 *
Tube Pitch	1.9685 in *	Baffle Type	Single
Orientation	Horizontal	Baffle Cut(%Area)	20.00
Passes Per Shell	2 *	Baffle Orientation	Horizontal
Tubes Per Shell	750 *	Spacing	31.4961 in *
Layout Angle	Triangular (30 degrees)	Diameter	48.0000 in *
TEMA Type	A E L	Area	3043.42 ft2

* Specified by user.

Heat Exchanger: Stage 2 (continued)

SPECS

	Specified Value	Current Value	Relative Error	Active	Estimate
E-101 Heat Balance	0.0000 MMBtu/hr	-6.455e-013 MMBtu/hr	-6.019e-014	On	Off
E-101 UA	---	2.780e+005 Btu/F-hr	---	Off	On

Detailed Specifications

E-101 Heat Balance

Type: Duty	Pass: Error	Spec Value: 0.0000 MMBtu/hr

E-101 UA

Type: UA	Pass: Overall	Spec Value: ---

User Variables

RATING

Sizing

Overall Data

Configuration

# of Shells in Series	1 *	Tube Passes per Shell	2 *	Elevation (Base)	0.0000 ft
# of Shells in Parallel	1 *	Exchange Orientation	Horizontal	First Tube Pass Flow Direction	Counter

TEMA Type:	A	E	L

Calculated Information

Shell HT Coeff	---	Overall U	3 Btu/hr-ft2-F	Shell DP	9.696 psi	Shell Vol per Shell	197.4 ft3	HT Area per Shell	3043 ft2
Tube HT Coeff	---	Overall UA	-005 Btu/F-hr	Tube DP	9.360 psi	Tube Vol per Shell	31.95 ft3		

Shell Data

Shell and Tube Bundle

Shell Diameter	48.00 in *	Tube Pitch	1.969 in *	Shell Fouling	0.0000 F-hr-ft2/Btu
# of Tubes per Shell	750 *	Tube Layout Angle		Triangular (30 degrees)	

Shell Baffles

Shell Baffle Type	Single	Shell Baffle Orientation	Horizontal	Baffle Cut (%Area)	20.00	Baffle Spacing	31.50 in *

Tube Data

Dimensions

OD	0.7874 in *	ID	0.6299 in *	Tube Thickness	7.874e-002 in	Tube Length	19.69 ft

Tube Properties

Tube Fouling	0.0000 F-hr-ft2/Btu	Thermal Cond.	26.00 Btu/hr-ft-F *	Wall Cp	---	Wall Density	---

Nozzle Parameters

Base Elevation Relative to Ground Level 0.0000 ft

		stream 8 B	stream 17	stream 18
Diameter	(ft)	0.1640	0.1640	0.1640
Elevation (Base)	(ft)	0.0000	0.0000	0.0000
Elevation (Ground)	(ft)	0.0000	0.0000	0.0000
Elevation (% of Height)	(%)	0.00	0.00	0.00

		stream 9		
Diameter	(ft)	0.1640		
Elevation (Base)	(ft)	0.0000		
Elevation (Ground)	(ft)	0.0000		
Elevation (% of Height)	(%)	0.00		

CONDITIONS

Name		stream 8 B	stream 17	stream 18	stream 9
Vapour		1.0000	0.0000	0.0100 *	1.0000
Temperature	(F)	241.3661 *	150.0000 *	165.0000 *	162.2400

* Specified by user.

Heat Exchanger: Stage 2 (continued)

CONDITIONS

Pressure	(psig)	0.0000 *	0.0000 *	-9.3599	-9.6960
Molar Flow	(MMSCFD)	5.3049 *	5.3498	5.3049	5.3498
Mass Flow	(lb/hr)	10493.9425	10582.6092	10493.9425	10582.6092
Std Ideal Liq Vol Flow	(USGPM)	21.0000	21.1774	21.0000	21.1774
Molar Enthalpy	(Btu/lbmole)	-1.024e+005	-1.212e+005	-1.208e+005	-1.030e+005
Molar Entropy	(Btu/lbmole-F)	32.03	3.874	4.601	33.23
Heat Flow	(MMBtu/hr)	-5.9626e+01	-7.1209e+01	-7.0350e+01	-6.0484e+01

PROPERTIES

Name		stream 8 B	stream 17	stream 18	stream 9	
Molecular Weight		18.02	18.02	18.02	18.02	
Molar Density	(lbmole/ft3)	1.978e-003	3.396	7.837e-002	7.547e-004	
Mass Density	(lb/ft3)	3.564e-002	61.18	1.412	1.360e-002	
Act. Volume Flow	(barrel/day)	1.259e+006	739.5	3.177e+004	3.327e+006	
Mass Enthalpy	(Btu/lb)	-5682	-6729	-6704	-5715	
Mass Entropy	(Btu/lb-F)	1.778	0.2151	0.2554	1.845	
Heat Capacity	(Btu/lbmole-F)	8.651	18.02	17.95	8.357	
Mass Heat Capacity	(Btu/lb-F)	0.4802	1.000	0.9962	0.4639	
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000	0.0000	0.0000	
Mass Lower Heating Value	(Btu/lb)	---	---	---	---	
Phase Fraction [Vol. Basis]		---	---	1.000e-002	---	
Phase Fraction [Mass Basis]		4.941e-324	0.0000	1.000e-002	4.941e-324	
Partial Pressure of CO2	(psig)	-14.70	-14.70	-14.70	-14.70	
Cost Based on Flow	(Cost/s)	0.0000	0.0000	0.0000	0.0000	
Act. Gas Flow	(ACFM)	4908	---	---	1.297e+004	
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458	3.458	3.458	
Specific Heat	(Btu/lbmole-F)	8.651	18.02	17.95	8.357	
Std. Gas Flow	(MMSCFD)	5.305	5.350	5.305	5.350	
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30	62.30	62.30	
Act. Liq. Flow	(USGPM)	---	21.57	21.28	---	
Z Factor		0.9875	6.615e-004	---	0.9927	
Watson K		---	---	---	---	
User Property		---	---	---	---	
Partial Pressure of H2S	(psig)	-14.70	-14.70	-14.70	-14.70	
Cp/(Cp - R)		1.298	1.124	1.124	1.312	
Cp/Cv		1.337	1.061	1.001	1.336	
Heat of Vap.	(Btu/lbmole)	1.749e+004	1.749e+004	1.801e+004	1.804e+004	
Kinematic Viscosity	(cSt)	22.26	0.4351	---	50.44	
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36	62.36	62.36	
Liq. Vol. Flow (Std. Cond)	(USGPM)	20.98	21.16	20.98	21.16	
Liquid Fraction		0.0000	1.000	0.9900	0.0000	
Molar Volume	(ft3/lbmole)	505.5	0.2945	12.76	1325	
Mass Heat of Vap.	(Btu/lb)	970.6	970.6	999.5	1001	
Phase Fraction [Molar Basis]		1.0000	0.0000	0.0100	1.0000	
Surface Tension	(lbf/ft)	---	4.451e-003	4.348e-003	---	
Thermal Conductivity	(Btu/hr-ft-F)	1.502e-002	0.3805	---	1.293e-002	
Viscosity	(cP)	1.271e-002	0.4264	---	1.098e-002	
Cv (Semi-Ideal)	(Btu/lbmole-F)	6.665	16.04	15.96	6.372	
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.3700	0.8902	0.8860	0.3537	
Cv	(Btu/lbmole-F)	6.469	16.99	17.93	6.255	
Mass Cv	(Btu/lb-F)	0.3591	0.9428	0.9950	0.3472	
Cv (Ent. Method)	(Btu/lbmole-F)	---	---	---	---	

* Specified by user.

Heat Exchanger: Stage 2 (continued)

PROPERTIES

Name		stream 8 B	stream 17	stream 18	stream 9	
Mass Cv (Ent. Method)	(Btu/lb-F)	---	---	---	---	
Cp/Cv (Ent. Method)		---	---	---	---	
Reid VP at 37.8 C	(psig)	---	---	---	---	
True VP at 37.8 C	(psig)	-13.75	-13.75	-13.75	-13.75	
Liq. Vol. Flow - Sum(Std. Cond)	(barrel/day)	719.4	725.5	719.4	725.5	

DETAILS

Overall/Detailed Performance

Duty:	1.072e+01 MMBtu/hr	UA:	2.780e+05 Btu/F-hr	UA Curv. Error:	0.00e-01 Btu/F-hr	Ft Factor:	---
Heat Leak:	000e-01 MMBtu/hr	Min. Approach:	15.00 F	Hot Pinch Temp:	165.0 F	Uncorrected Lmtd:	---
Heat Loss:	000e-01 MMBtu/hr	Lmtd:	38.58 F	Cold Pinch Temp:	150.0 F		

TABLES

Shell Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
150.00	0.00	0.00	-121219.74	0.0000	0.0000	17485.0258
209.99	-0.58	0.64	-120135.56	0.0000	0.0000	17507.9807
162.24	-9.70	10.72	-102963.36	1.0000	1.0000	18036.1734

Shell Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	---	---	---	3193.54	705.47	---	---
0.00	18.02	0.04	0.48	0.01	0.15	---	0.34	3193.54	705.47	0.02	0.99
10582.61	18.02	0.01	0.46	0.01	0.15	---	0.34	3193.54	705.47	0.02	0.99

Shell Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Shell Side - Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
10582.61	61.18	1.00	0.43	0.15	0.00	18.02	---	---	---	0.66	0.00
10582.61	59.85	1.01	0.28	0.15	0.00	18.02	---	---	---	0.68	0.00
---	---	---	---	---	---	---	---	---	---	---	---

Shell Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ss Specific He (Btu/lb-F)	Viscosity (cP)	rmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	seudo Omega
---	61.18	1.00	0.43	0.38	0.00	18.02	0.98	---	---	0.26	0.34
---	59.85	1.01	0.28	0.39	0.00	18.02	0.96	---	---	0.26	0.34
---	---	---	---	---	---	---	---	---	---	---	---

* Specified by user.

Heat Exchanger: Stage 2 (continued)

Tube Side - Overall Phase

Temperature (F)	Pressure (psig)	Heat Flow (MMBtu/hr)	Enthalpy (Btu/lbmole)	Molar Vap Frac	Mass Vap Frac	Heat of Vap. (Btu/lbmole)
165.00	-9.36	0.00	-120769.60	0.0100	0.0100	---
211.54	-0.13	10.57	-102617.16	1.0000	1.0000	---
241.37	0.00	10.72	-102358.96	1.0000	1.0000	---

Tube Side - Vapour Phase

Mass Flow (lb/hr)	olecular Weig	Density (lb/ft3)	ıss Specific He (Btu/lb-F)	Viscosity (cP)	ırmal Conducti (Btu/hr-ft-F)	Std Gas Flow (MMSCFD)	Z Factor	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
104.94	18.02	0.01	0.46	0.01	0.57	0.80	0.02	3193.54	705.47	0.34	---
10493.94	18.02	0.04	0.48	0.01	0.57	0.80	1.74	3193.54	705.47	0.34	---
10493.94	18.02	0.04	0.48	0.01	0.57	0.80	1.74	3193.54	705.47	0.34	---

Tube Side - Light Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ıss Specific He (Btu/lb-F)	Viscosity (cP)	ırmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	0.00	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

Tube Side - Heavy Liquid Phase

Mass Flow (lb/hr)	Density (lb/ft3)	ıss Specific He (Btu/lb-F)	Viscosity (cP)	ırmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
10389.00	60.87	1.00	0.38	0.00	0.00	18.02	0.67	---	---	0.34	0.98
0.00	59.81	1.01	0.28	0.00	---	18.02	0.68	---	---	0.34	0.96
---	---	---	---	---	---	---	---	---	---	---	---

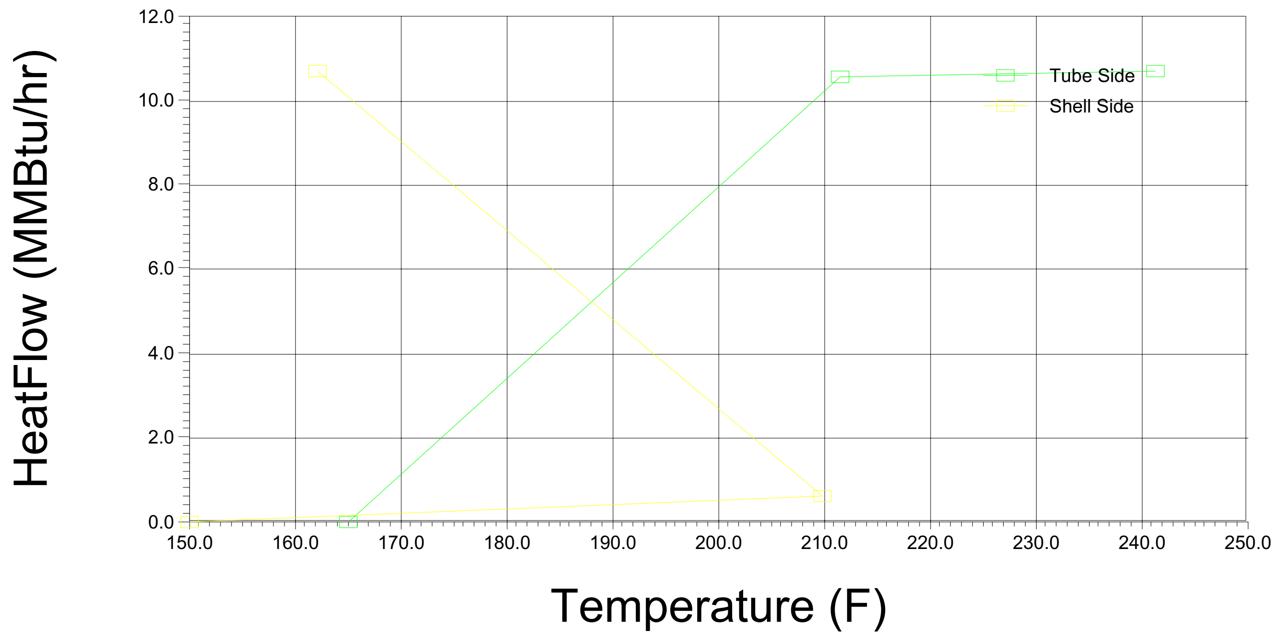
Tube Side - Mixed Liquid

Mass Flow (lb/hr)	Density (lb/ft3)	ıss Specific He (Btu/lb-F)	Viscosity (cP)	ırmal Conducti (Btu/hr-ft-F)	urface Tensio (lbf/ft)	olecular Weig	pecific Gravit	Pseudo Pc (psig)	Pseudo Tc (F)	Pseudo Zc	Pseudo Omega
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---

---

* Specified by user.

Heat Exchanger: Stage 2 (continued)



DYNAMICS

Basic Model

Model Parameters

Tube Volume	(ft3)	3.531	Shell UA	(lb/hr)	---
Shell Volume	(ft3)	3.531	Tube UA	(lb/hr)	---
Elevation	(ft)	0.0000	Minimum Flow Scale Factor		0.0000 *
Overall UA	(Btu/F-hr)	2.780e+005			

Summary

Shell Duty: ---	Tube Duty: ---

Pressure Flow Specifications

Shell Side Specification

Delta P	(psi)	---	Active	k	lb/hr/sqrt(psia-lb/ft3)	---	Not Active

Tube Side Specifications

Delta P	(psi)	---	Active	k	lb/hr/sqrt(psia-lb/ft3)	---	Not Active

Holdup

Shell Holdup

Phase	Accumulation (MMSCFD)	Moles (lbmole)	Volume (ft3)
Vapour	0.0000	0.0000 *	0.0000
Liquid	0.0000	0.0000 *	0.0000
Aqueous	0.0000	0.0000 *	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

* Specified by user.

Heat Exchanger: Stage 2 (continued)

Tube Holdup

Phase	Accumulation (MMSCFD)	Moles (lbmole)	Volume (ft3)
Vapour	0.0000	0.0000 *	0.0000
Liquid	0.0000	0.0000 *	0.0000
Aqueous	0.0000	0.0000 *	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

NOTES

HTFS

HTFS+

Valve: Pressure Control Valve

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION
stream 1	

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
stream 16	Mixer	MIX-101

PARAMETERS

Physical Properties

Pressure Drop:	56.25 psi

User Variables

RATING

Sizing

Sizing Conditions

Inlet Pressure	60.30 psig *	Molecular Weight	18.02	Current	
Valve Opening	100.00 % *	Delta P	56.25 psi	Flow Rate	7000 lb/hr *

Valve Manufacturer and Valve Type

Manufacturer: Universal Gas Sizing	Type: ---

Valve Operating Characteristic and Sizing Method

Linear				Sizing Method: Cg			
C1	25.00	Km	0.9000	Cv	77.34 USGPM	Cg	1934 *

Nozzle Parameters

Base Elevation Relative to Ground Level		0.0000 ft *

	stream 1	stream 16
Diameter (ft)	0.1640	0.1640

* Specified by user.

Valve: Pressure Control Valve (continued)

Elevation (Base)	(ft)	0.0000	0.0000	
Elevation (Ground)	(ft)	0.0000	0.0000	
Elevation (% of Height)	(%)			

CONDITIONS

Name		stream 1	stream 16		
Vapour		1.0000	1.0000		
Temperature	(F)	375.0000 *	355.5668		
Pressure	(psig)	60.3040 *	4.0540		
Molar Flow	(MMSCFD)	3.5387	3.5387		
Mass Flow	(lb/hr)	7000.0000 *	7000.0000		
Std Ideal Liq Vol Flow	(USGPM)	14.0081	14.0081		
Molar Enthalpy	(Btu/lbmole)	-1.014e+005	-1.014e+005		
Molar Entropy	(Btu/lbmole-F)	30.12	32.83		
Heat Flow	(MMBtu/hr)	-3.9398e+01	-3.9398e+01		

PROPERTIES

Name		stream 1	stream 16			
Molecular Weight		18.02	18.02			
Molar Density	(lbmole/ft3)	8.635e-003	2.160e-003			
Mass Density	(lb/ft3)	0.1556	3.892e-002			
Act. Volume Flow	(barrel/day)	1.923e+005	7.689e+005			
Mass Enthalpy	(Btu/lb)	-5628	-5628			
Mass Entropy	(Btu/lb-F)	1.672	1.822			
Heat Capacity	(Btu/lbmole-F)	9.445	8.585			
Mass Heat Capacity	(Btu/lb-F)	0.5243	0.4766			
Lower Heating Value	(Btu/lbmole)	0.0000	0.0000			
Mass Lower Heating Value	(Btu/lb)	---	---			
Phase Fraction [Vol. Basis]		---	---			
Phase Fraction [Mass Basis]		4.941e-324	4.941e-324			
Partial Pressure of CO2	(psig)	-14.70	-14.70			
Cost Based on Flow	(Cost/s)	0.0000	0.0000			
Act. Gas Flow	(ACFM)	749.9	2998			
Avg. Liq. Density	(lbmole/ft3)	3.458	3.458			
Specific Heat	(Btu/lbmole-F)	9.445	8.585			
Std. Gas Flow	(MMSCFD)	3.539	3.539			
Std. Ideal Liq. Mass Density	(lb/ft3)	62.30	62.30			
Act. Liq. Flow	(USGPM)	---	---			
Z Factor		0.9696	0.9921			
Watson K		---	---			
User Property		---	---			
Partial Pressure of H2S	(psig)	-14.70	-14.70			
Cp/(Cp - R)		1.266	1.301			
Cp/Cv		1.349	1.323			
Heat of Vap.	(Btu/lbmole)	1.630e+004	1.734e+004			
Kinematic Viscosity	(cSt)	6.265	24.55			
Liq. Mass Density (Std. Cond)	(lb/ft3)	62.36	62.36			
Liq. Vol. Flow (Std. Cond)	(USGPM)	14.00	14.00			
Liquid Fraction		0.0000	0.0000			
Molar Volume	(ft3/lbmole)	115.8	462.9			
Mass Heat of Vap.	(Btu/lb)	904.5	962.5			
Phase Fraction [Molar Basis]		1.0000	1.0000			
Surface Tension	(lbf/ft)	---	---			
Thermal Conductivity	(Btu/hr-ft-F)	1.910e-002	1.814e-002			

* Specified by user.

Valve: Pressure Control Valve (continued)

PROPERTIES

Name		stream 1	stream 16			
Viscosity	(cP)	1.561e-002	1.531e-002			
Cv (Semi-Ideal)	(Btu/lbmole-F)	7.459	6.599			
Mass Cv (Semi-Ideal)	(Btu/lb-F)	0.4141	0.3663			
Cv	(Btu/lbmole-F)	6.999	6.487			
Mass Cv	(Btu/lb-F)	0.3885	0.3601			
Cv (Ent. Method)	(Btu/lbmole-F)	---	---			
Mass Cv (Ent. Method)	(Btu/lb-F)	---	---			
Cp/Cv (Ent. Method)		---	---			
Reid VP at 37.8 C	(psig)	---	---			
True VP at 37.8 C	(psig)	-13.75	-13.75			
Liq. Vol. Flow - Sum(Std. Cond)	(barrel/day)	479.9	479.9			

DYNAMICS

Dynamic Specifications

Total Delta P	(psi)	56.25	Not Active
Pressure Flow Relation			Active

Dynamic Parameters

Valve Opening	(%)	100.00 *	Mass Flow	(lb/hr)	7000 *
Conductance	(USGPM)	77.34	Friction Delta P	(psi)	56.25

Pipe Model Parameters

Material		Cast Iron	Darcy Friction Factor		---
Roughness	(ft)	8.497e-004	Pipe k	(lb/hr/sqrt(psia-lb/ft3))	0.0000 *
Pipe Length	(ft)	0.0000 *	Velocity	(ft/s)	591.4 *
Feed Diameter	(ft)	0.1640	Reynolds Number		1.439e+006 *

Hold-Up Volume: 0.0000 ft3 *

Phase	Accumulation (MMSCFD)	Moles (lbmole)	Volume (ft3)
Vapour	0.0000	0.0000 *	0.0000
Liquid	0.0000	0.0000 *	0.0000
Aqueous	0.0000	0.0000 *	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Actuator Parameters

Parameters Mode: Instantaneous

Actuator Time Constant	(seconds)	1.000 *	Actuator Linear Rate	1.000e-002 *
Valve Stickiness Time Constant	(seconds)	---		

Activator Position

Fail Position: None

	Min (%)	Max (%)	Current (%)	Desired (%)	Offset (%)
Valve	0.00 *	100.00 *	100.00 *	---	0.00 *
Actuator	0.00 *	100.00 *	100.00 *	100.00 *	---

* Specified by user.

VITA

Benjamin Day was born in Cambridge, Ontario, Canada. He moved to Baton Rouge, Louisiana when he was three years of age. He attended high school at Catholic High in Baton Rouge, and received his B.S. from Louisiana State University in Chemical Engineering.

Benjamin has been a practicing engineer in Industry for 10years and a Professional Engineer for the last 5 years. Most of Benjamin's experience has been in the Natural Gas processing and Liquids business where he has served as lead process design engineer and technical support roles for processing facilities.