DRAFT FINAL REPORT

DESCRIPTION OF COMPUTER PROGRAM FOR CALCULATION OF TEMPERATURES, PRESSURES AND LIQUID LEVELS OF TANK CARS ENGULFED IN FIRES

Contract No. DTFR53-81-C-00016: Task VC-4

IITRI Project K06049

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1. INTRODUCTION

This report describes work that has been carried out under Federal Railroad Administration Contract No. DTFR53-81-C-00016, Task Order VC-4, entitled "Temperatures, Pressures and Liquid Levels of Tank Cars Engulfed in Fires".

The objective of this task order was the further development and utilization of a procedure for calculating the fire effects on a tank car containing certain hazardous materials. This report describes the analytical procedure and the computer program which was used to analyze the effects of safety relief valve flow capacities and thermal shield conductances on the vulnerability of cars containing liquids and liquified gases in the pool fire environment (complete fire engulfment). Results from the use of the program to calculate the effects on cars containing ethylene oxide and propane are described in Ref. 1. Results from the use of the program to calculate the effects on cars containing propylene, 1,3-butadiene, vinyl chloride, monomethylamine or propylene oxide are described in Ref. 2.

The program has been written in FORTRAN and has been run on a Data General ECLIPSE computer. The program is designed for interactive use with a terminal. The initial conditions are entered at the terminal. The results can be displayed at the terminal or printed at a line printer. Another option is to provide plots of pressure, tank wall temperature over the vapor space and liquid fraction as a function of time.

Section 2 of this report gives an overview of the modeling procedure. Section 3 presents a flow chart of the program and discusses the technical background for specific steps in the calculation. Program listings are presented in Section 4. A sample problem with results is presented in Section 5.

2. ANALYTICAL PROCEDURE

The calculational procedure, which has been developed under this program to model fire effects on tank cars, allows the conditions within the tank to be determined as a function of time for arbitrary characteristics of the thermal insulation system and the flow capacity of the safety relief valve. The assumption is made that the car is fully engulfed by the fire so that the fire is of uniform intensity all over the tank. The calculational procedure begins by assuming that the car has been loaded in accordance with allowable filling density tables so that there is an outage volume which is occupied by the product in the vapor state. Figure 1 illustrates the basic phenomena which must be taken into consideration. Four different sets of conditions are recognized. The first deals with the situation where the car is in the upright position venting vapor. Most of the heat is conducted into the car through the wetted area of the tank. The properties of the thermal shield determines the rate of heat transfer into the liquid product. Some heat is also conducted through the thermal shield over the vapor space which increases the temperature of the tank wall. As the temperature rises, some heat is radiated from the wall to the liquid below. The amount of heat radiated depends on both the radiation surface configuration factor of the surface of the liquid and the temperatures of the wall and liquid. This factor decreases as the liquid level drops.

The burst strength of the tank is estimated as a function of the wall temperature over the vapor space. When the tank is no longer capable of containing the vapor pressure, failure is assumed causing the sudden release of the remaining product within the car.

The vapor pressure within the tank is a function of the temperature of the liquid product, increasing as its temperature increases. The presence of nitrogen, which is used as a pad of inert gas, must be considered for cars containing certain commodities. When the vapor pressure within the tank exceeds the start-to-discharge pressure of the valve, the valve opens allowing the vapor to exhaust from the car. A slight rise in the pressure above this value causes the valve to move to the fully open position. If the valve flow capacity is adequate, the liquid will tend to remain at a nearly constant temperature as it is vaporized and is exhausted from the tank. If

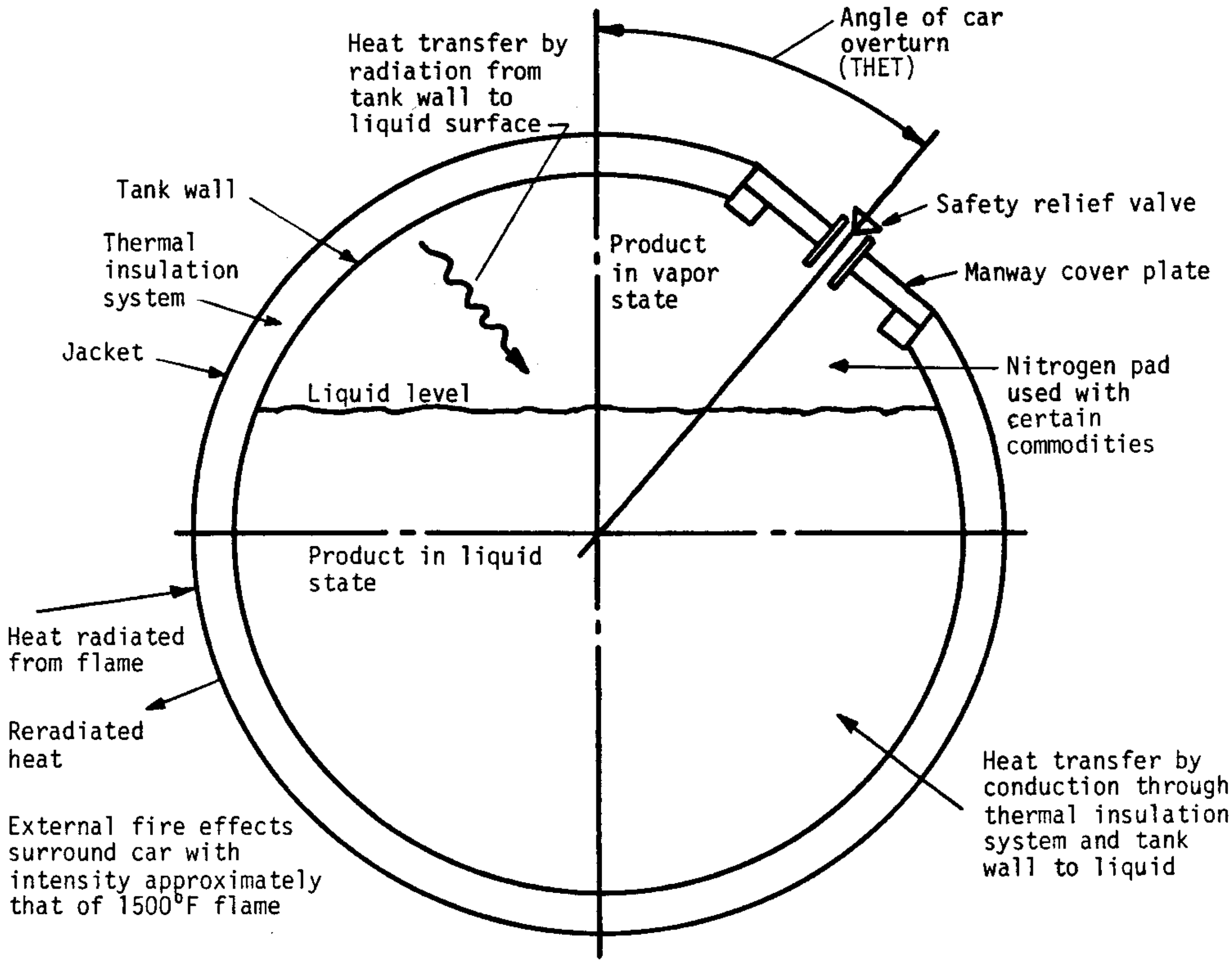


FIGURE 1. CONDITIONS CONSIDERED IN THE ANALYSIS OF TANK CARS SUBJECTED TO FIRE

the valve flow capacity is not large enough, the pressure in the tank will rise allowing the temperature of the liquid to increase and also resulting in a somewhat larger mass flow rate through the valve.

The second set of conditions which must be considered is the overturned car case. The conditions are similar to those of the upright car case except that the car is assumed to be partially rolled over so that when the safety relief valve opens it will vent liquid instead of vapor. The volumetric flow rate for liquid discharge is less than for the vapor case at any given pressure, but the mass flow rate may be larger because of the greater density of the fluid. Liquid flow through the valve is calculated assuming homogeneous isentropic two phase flow (liquid and vapor) and a liquid discharge coefficient of 0.7.

The third set of conditions is the case where the tank car is "shell full" (of liquid) and for all practical purposes there is no vapor space left within the tank. This condition occurs when the car is initially filled with only a small empty volume above the liquid surface. When the car is exposed to the fire, the temperature of the product rises and its specific volume increases so that eventually all of the tank is filled with liquid. DOT requirements, for example, allow some products within Class 105 tank cars to be filled so that the car becomes shell full when the product temperature rises to 105°F. When the car becomes shell full, any further increase in temperature of the product will cause liquid flow through the safety relief valve. An increase of the pressure within the tank above the saturated vapor pressure may be necessary to cause a sufficient flow rate. If the capacity of the valve is small and the rate of increase in the specific volume of the liquid is large, very high pressures can be developed. The calculation of the fire effects under these conditions assumes the heat is transferred to the liquid over the entire area of the tank shell.

The fourth set of conditions is the case where all the liquid has been vaporized. This condition is also associated with the case where the critical temperature of the product is exceeded before all the liquid is vaporized so that the vapor state is the only phase in which the product can exist. The temperature of the vapor will increase at a fairly rapid rate because heat is both convected and radiated to the product and because the mass of the product within the tank is relatively small. Under almost all conditions, the safety relief valve is fully capable of relieving any increases in pressure as the vapor becomes hotter. The pressure would be maintained near the valve closing pressure. The tank wall temperature also increases fairly rapidly during this phase because there is no cooling effect from liquid product within the tank.

The calculational procedure assumes that each of the parameters remain constant over a given time step. The parameters are then updated at the end of the time step. An integration time step of 0.1 minutes has been used for the parametric analyses conducted under this study. This time step has been found to be fully adequate for describing the various phenomena. The computer program contains an optional time period for printing out intermediate results.

3. DESCRIPTION OF COMPUTER PROGRAM

The computer program is described in this section. Five subroutines are used with the basic program:

SURFACET to calculate the surface temperature of the outside of the tank insulation system,

PROPERTIES to establish the thermal properties of the product as a function of temperature,

VCAP to calculate the liquid flow capacity of the safety relief valve as a function of the fluid properties,

TSHIELD to calculate the effective conductance of a thermal shield system where temperature dependent conductivity is assumed as a function of the temperature on the inside and outside faces of the system, and

PLT3 to construct plots of tank wall temperature over the vapor space, liquid fraction remaining, and pressure versus time.

Figure 2 shows a flow chart for the steps which are carried out during each calculational cycle.

3.1 ESTABLISHMENT OF INITIAL VALUES

The first step is to enter initial values for the analysis into the computer terminal. The following information must be provided:

Display Type: Whether the results are to be displayed at a terminal or line printer

Plot or Print Data: Whether a plot of temperature, pressure and liquid fraction versus time is desired or tabulated results

Product Within Tank

Angle of Rollover for Safety Valve Orientation

Tank Diameter

Tank Wall Thickness

Volumetric Capacity of Tank

Volumetric Fraction of Tank Initially Filled with Liquid

Safety Relief Valve Flow Rating Pressure

Safety Relief Valve Start-to-Discharge Pressure

Net Absorptivity of Tank Wall Surface

Net Emissivity of Tank Wall Surface

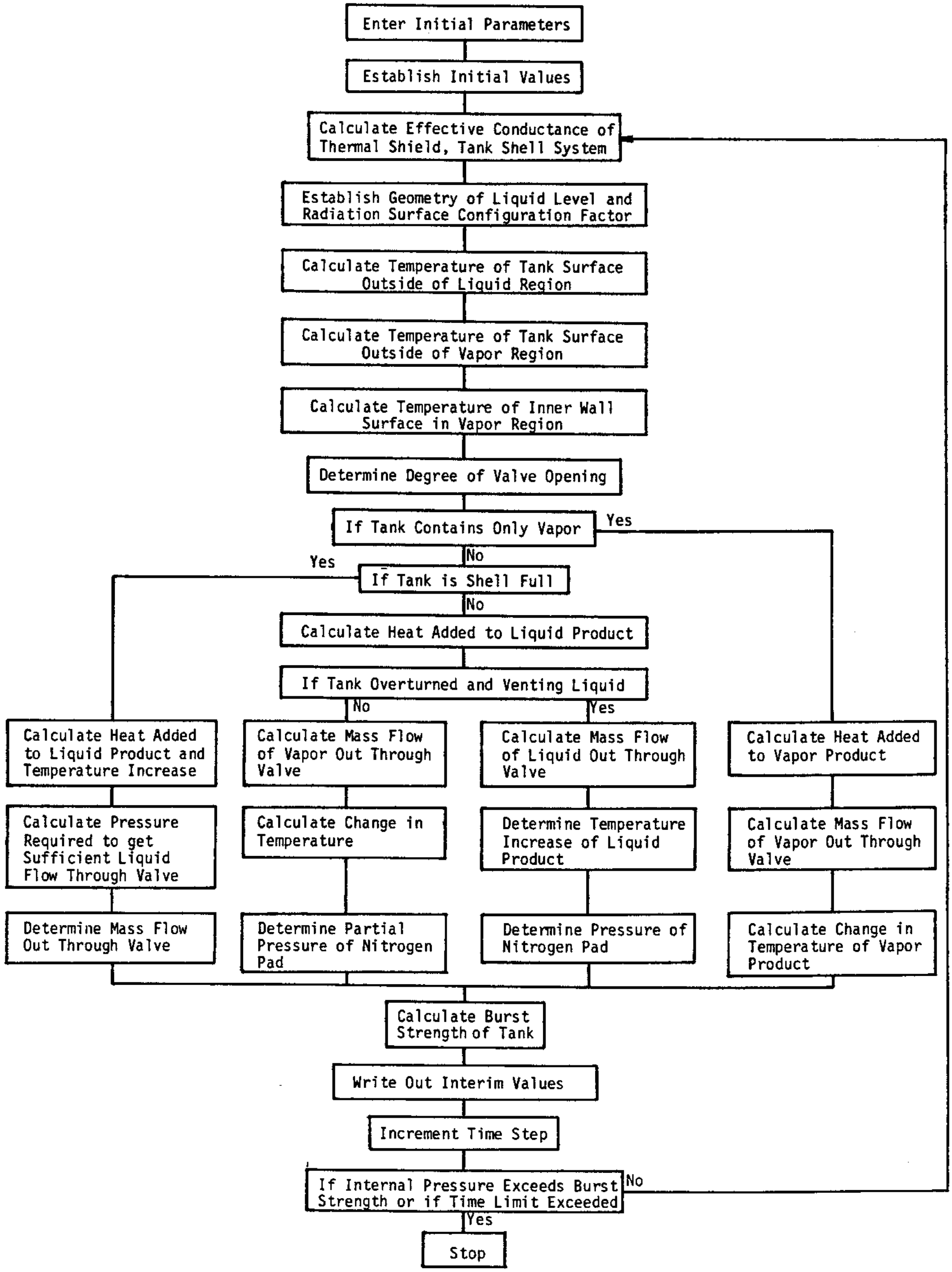


FIGURE 2. FLOW CHART OF COMPUTATIONAL PROCEDURE

Bursting Strength of Tank

Thermal Shield Conductance

Safety Relief Valve Rated Flow Capacity

Constant Conductivity or Temperature Dependent Conductivity of Tank Insulation Material: If temperature dependent conductivity is selected, the thickness of the insulation material is also entered.

Consideration of Initial Conductance: This option permits entry of an initial value for conductance of the thermal insulation system which is different than the value of conductance previously entered. If this option is selected the desired initial value is also entered.

Flame Temperature

Nitrogen Padding Pressure

Area Exponent: This is an exponent which is applied to the surface area of the tank to determine the effective area subjected to the fire. Normally it would be 1.0. It is included in the calculation so that comparisons can be made to AAR valve design criteria where an exponent of 0.82 is used (Ref. 3).

Initial Temperature of Tank and Contents

Time Increment

Number of Time Steps Between Display of Data

Gas Compressibility Factor (Z)

Safety Relief Valve Gas Flow Constant: This constant (VLCON) is explained in Section 3.11.3.

Typical values which have been used for the tank car design parameters are listed below:

Parameter	105A100W Car Containing Ethylene Oxide	105A300W Car Containing Propane	112A340W Car Containing Propane
Tank diameter (ft)	9.5	9.9	10.0
Tank wall thickness (in.)	0.562	0.562	0.625
Nominal capacity (gals)	25,000	33,600	33,600
Safety valve flow rating pressure (psia)	99.7	284.7	320.7
Safety valve start-to discharge pressure (psia)	89.7	262.2	295.2
Burst Strength of Tank (psi)	500	750	850

3.2 ESTABLISH INITIAL VALUES

The program proceeds with the calculation of other parameters such as the volume of the tank, tank length, tank surface area, weight of tank shell, weight of liquid product, weight of nitrogen gas pad, weight of product in the vapor space, etc. Subroutine PROPERTIES is called to get the product data for these calculations.

An estimate is made of the cross sectional area of the safety valve. It is based on an assumed discharge coefficient of 0.9 for the passage of air. The equation is given as follows:

$$A_v = (SCFM)/(C_d P_s 2638) \qquad (1)$$

where A_v is the cross sectional area of the valve (ft^2)
C_d is the discharge coefficient, and
P_s is the valve flow rating pressure (psia)

3.3 DETERMINE CONDUCTANCE OF THERMAL SHIELD

The calculational cycle which is carried out each time step begins with the establishment of the conductance of the thermal shield. Two options are provided: one where constant conductivity is assumed (except for the first thirty minutes as indicated below) and the other where temperature dependent conductivity of the thermal insulation material is assumed. This has the effect of allowing the conductance to change as a function of time because the average temperature through the insulation changes with time. If temperature dependent conductivity is assumed the calculation of the effective conductance of the shield is carried out in subroutine TSHIELD. This subroutine utilizes an algebraic relationship for defining the conductivity as a function of temperature. An iterative solution is used to determine the effective conductance of the system when operating between the temperature limits on the inside and outside of the faces of the material at this point in the calculational cycle.

A second option is provided, which allows one to consider that there is an initial value of conductance and that there is a linear relationship between this value and the value which normally would be reached after a 30 minute period. This option is included to represent conditions that have been observed for some types of 105 car insulation materials when they are exposed to a fire environment. The initial value of these conductances is quite low and is based on the allowable conductance in the AAR tank car specifications. It has been found that these materials lose their effectiveness as they become heated and that the period of the breakdown of the insulation typically can be assumed to take place over an approximate 30 minute period. Therefore, when calculating the effects on a 105 tank car it is reasonable to give the final value of the conductance as the high temperature value of the thermal insulation and the initial value as called for in the AAR specification. This value is 0.30 (BTU/hr-ft^2-°F) and is based on the assumptions described in the AAR Tank Car Specifications (Ref. 3).

3.4 CALCULATE TEMPERATURE OF TANK SURFACE OUTSIDE OF LIQUID REGION

The next step is the calculation of the temperature of the outer surface of the tank in the liquid region. This calculation is carried out in subroutine SURFACET. It is assumed that a quasi-steady temperature distribution exists through the tank wall thermal insulation system and that the inside wall temperature maintains the value which has been established in the last calculational cycle. The heat input to the outside surface is assumed to be the radiant energy from the flame at the flame temperature. The radiation surface configuration factor is assumed to be unity and the surface emissivity factor is assumed to be 0.8. A heat balance then exists between the heat radiated to the outside surface of the shell, the heat that is being conducted through the insulation, and the heat being radiated away back to the fire from the outside surface of the tank. The solution for the temperature of the outside wall is carried out in an iterative manner to find the solution for the heat balance under these conditions.

3.5 ESTABLISH GEOMETRY OF LIQUID LEVELS

The calculation requires the establishment of the angle (THET), as defined in Figure 1 associated with the liquid level in the tank. The angle THET is a function of the fraction of tank volume occupied by the liquid, which is defined as FRAC. The determination of THET requires an iterative solution of the equation:

$$FRAC = \frac{1}{\pi} \left[\frac{\pi}{2} + THET + \sin(THET)\cos(THET) \right] \quad (2)$$

The area of the surface of the liquid (AREALQ) is also calculated at this point.

3.6 RADIATION SURFACE CONFIGURATION FACTOR

Next the radiation surface configuration factor for the transfer of radiant energy from the tank wall over the vapor space to the surface of the liquid is established. The view factor is estimated from the relationship:

$$A_1F_{12} = A_2F_{21} \quad (3)$$

where F_{ij} is the radiation surface configuration factor for a gray body. F_{12} can be calculated taking into account the emissivities of the two surfaces by using the following equation:

$$F_{12} = \frac{1}{\frac{1}{f_{12}} + \left(\frac{1}{\varepsilon_1} - 1\right) + \frac{A_1}{A_2}\left(\frac{1}{\varepsilon_2} - 1\right)} \quad (4)$$

where f_{12} is the radiation surface configuration for a black body, and ε_1 and ε_2 are the emissivities of surfaces 1 and 2.

In using this equation it is assumed that $f_{liq,tk} = 1$ since the area of the liquid surface sees only the tank wall.

The radiation surface configuration for the liquid to the tank is designated FLQT, and the coefficient for the tank to the liquid is designated FTLQ. FTLQ is calculated from FLQT using the recirocal relationship.

These equations are used with the assumption that the conditions are uniform on the inside surface of the tank. This is not strictly correct because the temperature of the inner wall surface would be cooler for regions closer to the surface of the liquid. The temperature would depend on the length of time the wall has been exposed to the vapor and also the amount of radiant energy that has been received from the hotter part of the wall. Uniform conditions will be closely approached when the liquid level is near the top of the tank, because a slight drop in the liquid level will expose a large area of the inner surface of the tank. Uniform conditions will also be approached when the level of the liquid is low. To make an adjustment for the condition when the angle THET of the liquid is between approximately 60° and 120°, where the temperature of the tank wall immediately above the liquid surface would not be as high as at the top of the tank, the black body radiation surface configuration factor is assumed to be only 0.75.

3.7 CALCULATION OF TEMPERATURE OF OUTER WALL SURFACE IN VAPOR REGION

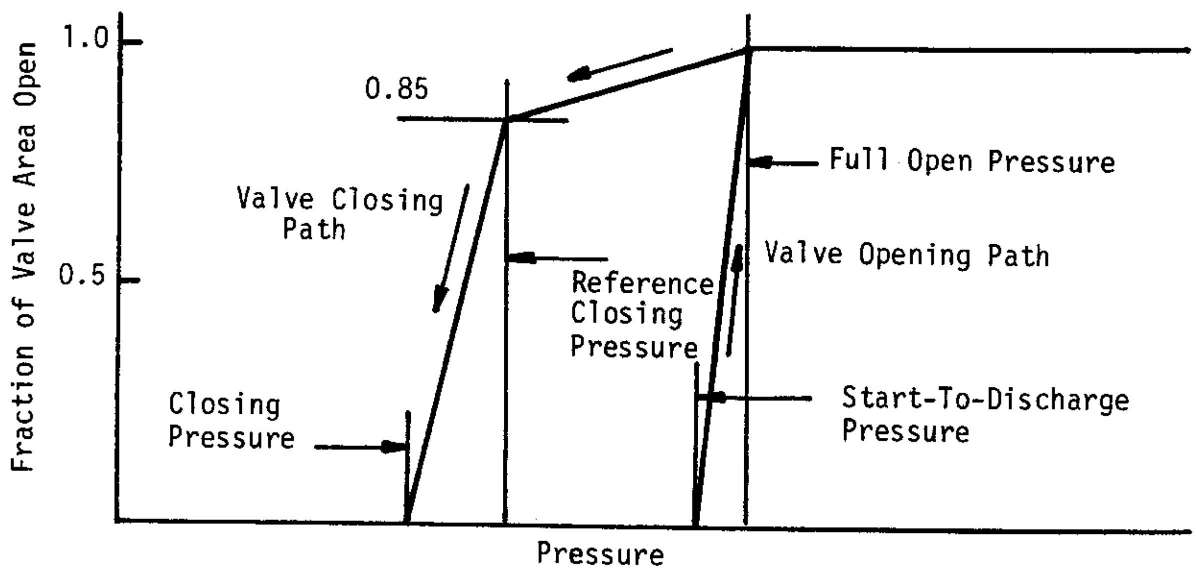
The calculation of the temperature of the outer wall surface in the vapor region is also made using subroutine SURFACET. The assumption is made that even when the tank is shell full, there is a small volume of vapor between the top of the shell and the surface of the liquid so that the tank wall is not cooled by conduction with the liquid product. This allows for the fact that the tank might not be completely level allowing a small region of vapor at the high end of the tank.

3.8 CALCULATE TEMPERATURE OF INNER WALL SURFACE IN VAPOR REGION

The next step in the procedure is to calculate the temperature of the tank wall in the vapor region. This is done taking the value for the outer tank wall surface previously computed and establishing a heat balance on the inside surface between the heat that is being conducted through the tank wall and insulation system and the heat that is being lost by convection and radiation to the inside of the tank. For radiant heat transfer, a surface emissivity of 0.8 is assumed. The calculation considers that there is a small amount of convected heat loss (0.18 BTU/hr-ft^2-°F) when the car is more than 0.4 filled, the car is in the upright position and venting vapor through the safety relief valve. A larger convection coefficient is assumed if the flow rate through the valve is greater than 1,500 lbs/min. This characteristic has been deduced from the full scale fire tests.

3.9 DETERMINE THE DEGREE OF VALVE OPENING

The next step in the calculation is to determine the amount to which the safety relief valve has opened. Three pressure levels are defined with reference to the start-to-discharge pressure. These are the fully opened pressure, which is assumed to be 103% of the start-to-discharge pressure, the valve closing pressure, which is assumed to be 82% of the start-to-discharge pressure, and a reference pressure on the closing stroke of the valve which is 85% of the start-to-discharge pressure. The degree to which the valve is opened depends on whether the pressure is increasing or decreasing. The functional relationship between the degree of valve openings and the pressure is shown in the following figure:



3.10 DETERMINE CONDITIONS IN THE TANK

The next step in the calculation is to determine which of the four conditions exist within the tank. These have previously been defined as:

- Liquid and vapor within the tank venting vapor,
- Liquid and vapor within the tank venting liquid,
- Shell full of liquid product,
- Containing only product in the vapor phase

The calculational procedure is divided at this point so that each of these cases are considered separately. The general procedure is the same in each case, the major difference being associated with the determination of the mass flow rate of the product through the valve.

3.11 LIQUID AND VAPOR WITHIN TANK VENTING VAPOR

3.11.1 Calculate Heat Transfer to Liquid Product

The heat transfer to the liquid product is determined by calculating the heat conducted through the portion of the tank shell which is in contact with the liquid and by estimating the radiant heat transfer to the surface of the liquid from the tank wall above the liquid. In the calculation of the heat conducted through the wetted area of the shell, it is assumed that the heat transfer in the circumferential direction is negligible, a quasi-steady situation exists (transient effects are neglected), and that the heat capacity of the jacket and insulation materials can be neglected.

The radiant exchange of energy between the tank shell above the liquid and the liquid surface has been discussed in Section 3.6.

3.11.2 Calculate Mass Flow Rate Through Safety Relief Valve

The mass flow rate through the safety relief valve is computed for vapor flow by using the standard valve flow equation:

$$\dot{W} = C_d A p \sqrt{\frac{g}{ZRT} \gamma \left(\frac{2}{\gamma+1}\right)^{\left(\frac{\gamma+1}{\gamma-1}\right)}} \qquad (5)$$

where $\dot{W}$ is flow rate (lbs/sec)

- A is minimum cross sectional area of valve (ft^2)
- C_d is the valve discharge coefficient
- p is upstream gas pressure (lbs/ft^2)
- T is upstream gas temperature (°R)
- g is the gravitational constant (ft/sec^2)
- Z is the gas compressibility factor
- R is the gas constant (ft/°R)
- γ is the ratio of specific heats

For air, the above equation reduces to:

$$\dot{W}_{air} = C_d A p \sqrt{\frac{g}{ZRT} (.4689)} \qquad (6)$$

For both ethylene oxide and propane the same equation is obtained for $\dot{W}$:

$$\dot{W} = C_d A p \sqrt{\frac{g}{ZRT} (.4027)} \qquad (7)$$

Noting that the rated capacity of the valve, SCFM, can be related to $\dot{W}_{air}$ as follows:

$$SCFM = 60 \, (\dot{W}_{air})/\rho_{sc} \qquad (8)$$

where ρ_{sc} is the density of air at standard conditions

Dividing Equation 7 by Equation 6 and substituting Equation 8 results in the following equation:

$$\dot{W} = 0.063 \, (p/p_r) \, (SCFM)/\sqrt{TZ} \qquad (9)$$

where $\dot{W}$ is mass flow rate (lbs/min),

p_r is the valve flow rating pressure (psia), and

p is the flowing pressure of the gas (psia)

A value of 0.7 is assumed for Z in this equation for the propane, propylene and ethylene oxide cases. The following values of Z are assumed for the other commodities: butadiene, 0.77; vinyl chloride, 0.72; monomethylamine, 0.93; and propylene oxide, 0.99.

The constant 0.063 in Equation 9 is entered separately at the beginning of the analysis. The value 0.063 is satisfactory for propane, ethylene oxide and propylene. For other commodities the following values are used: butadiene, 0.0692; vinyl chloride, 0.0761; monomethylamine, 0.0535; and propylene oxide, 0.0692.

Where a nitrogen pad pressure is present it is assumed that the mass flow of each component (product and nitrogen) is proportional to the partial pressure of each gas. Because the total mass of nitrogen in the car is small in relationship to the product, the effect of the nitrogen on the mass flow rate becomes negligible after a short period of time.

3.11.3 Calculate Temperature Rise of Liquid

The temperature rise of the liquid product is calculated by determining the net heat flow into the liquid product which is the difference of the total heat flow to the product and the heat lost by the vaporization of the product.

3.11.4 Calculate Change in Mass of Product

The next step in the calculation is to determine the change in the mass of the product within the tank and its apportionment between the liquid and vapor state. The change in mass of the nitrogen pad is also determined.

3.12 LIQUID AND VAPOR WITHIN TANK VENTING LIQUID

3.12.1 Calculate Heat Input to Liquid Product

The heat transferred to the liquid product within the time increment is determined by calculating the heat conducted through the wetted area of the tank and the heat radiated to the surface of the liquid from the inner tank shell surface over the vapor space as described in Section 3.6.

3.12.2 Calculate Liquid Flow Rate through Safety Relief Valve

The liquid flow rate through the safety relief valve is calculated in subroutine VCAP. Homogeneous, isentropic, two-phase flow (liquid and vapor) and a liquid discharge coefficient of 0.7 are assumed.

3.12.3 Calculate Change in Temperature

The change in temperature of the liquid product over the time increment is calculated by considering the heat added to the liquid product, the amount of liquid that is vaporized within the time increment and the work done in expelling the fluid from the tank.

3.12.4 Determine New Properties

The properties of the product at the new temperature are determined by calling subroutine PROPERTIES.

3.12.5 Recalculate Remaining Mass of Product Nitrogen Pad Pressure

The remaining mass of the product within the tank, both liquid and vapor components, are recalculated under the new temperature and pressure conditions.

For the cases where nitrogen gas padding is used the following assumptions are made: First, it is assumed that the nitrogen in the vapor phase is in equilibrium with the nitrogen dissolved in the liquid product. Because of the small outage volume in which the nitrogen gas is contained, there may be more nitrogen dissolved in the product than present in the vapor phase. It is also assumed that there is no exchange between the nitrogen dissolved in the fluid and the nitrogen in the vapor phase during the course of the exposure to the fire environment. If equilibrium were to be maintained between the nitrogen in the vapor phase and the nitrogen dissolved in the product there would first be an increase in the amount of the dissolved nitrogen and a corresponding decrease in the amount of nitrogen vapor. This would be caused by the increase in pressure when the outage volume is diminished by the expansion of the product as it is heated. This would mean the pressure of the nitrogen padding gas would be less than that predicted by the assumption of no exchange between the vapor in the dissolved state. After the safety valve opens and the product starts to flow from the car the outage volume would increase and the corresponding decrease in the vapor pressure of the nitrogen would cause more nitrogen to be liberated from the fluid thus tending to maintain the partial pressure of the nitrogen above that predicted by the assumption of no exchange between the vapor and the liquid dissolved states. Thus, the effects of assuming that equilibrium were maintained would be to delay the time at which the safety valve is first opened, but increase the pressure after the product starts to flow through the valve. These effects would counteract one another. In any event, when the liquid level gets to approximately 10-20% outage the effect of the nitrogen padding gas becomes insignificant on the prediction of flow through the valve.

The major reason that the exchange of nitrogen between the vapor state and the dissolved state is not included in the analysis is that one would expect that equilibrium conditions would not be attained during the course of the phenomena predicted by the fire environment. There would not be sufficient time for the effect of the partial pressure of the nitrogen gas in the vapor state to be communicated to all portions of the liquid within the tank and for the gas to be absorbed in the early phases of the predicted effects. Similarly, the effect of the decrease in the partial pressure of the nitrogen gas once the valve is opened, would not be immediately communicated to all portions of the liquid in the tank so a non-equilibrium situation would exist. Consequently the assumption has been made that there is no exchange of the nitrogen padding gas from the vapor phase to the dissolved state and this assumption is believed to have minimal significance in the predicted events associated with the flow of the product from the tank car.

3.13 SHELL FULL CONDITIONS

3.13.1 Calculate Heat Transferred to Liquid Product

The total heat transmitted to the liquid product of the tank in the time increment is calculated with the assumption that heat is transferred through the entire surface area of the surface of the tank.

3.13.2 Calculate Change in Temperature

The change in temperature of the liquid product is established from the heat transferred into the tank.

3.13.3 Determine New Properties

The new properties of the product at the higher temperature are determined by calling subroutine PROPERTIES.

3.13.4 Calculate Required Volume of Flow

The volume that must be discharged through the safety relief valve in the time increment is determined by calculating the change in the specific volume of the product over the time increment.

3.13.5 Calculate Pressure Required to Generate Sufficient Flow

The pressure that must be developed within the tank so that the required volume will be discharged through the valve is calculated next. This pressure is calculated in two different ways. First, it is assumed that the critical pressure for the flow through the valve will be the saturated pressure and the excess fluid pressure which will be required to generate sufficient flow is determined. The following formula is utilized:

$$\dot{W} = C_d A \rho \sqrt{\frac{2g}{\rho} \, (p_c - p_s)} \qquad (10)$$

where C_d is the liquid discharge coefficient of the valve

A is the cross sectional area of the valve (ft^2)

ρ is the density of the liquid (lbs/ft^3)

p_c is the fluid pressure (lbs/ft^2)

p_s is the saturated vapor pressure at the temperature of the fluid (lbs/ft^2)

The second estimate of the pressure is made by assuming that saturated conditions exist at the entry to the valve and the saturated vapor pressure that would give rise to sufficient flow is determined. Subroutine VCAP could be used for this calculation, but in order to reduce calculational time a linear expression for this pressure as a function of the required flow rate is used. Use of subroutine VCAP as a separate program has shown that the saturated vapor liquid flow rate through the valve can be closely represented by a linear function of the saturated vapor pressure over a wide range of pressures. The minimum of these two pressures is then used as the best estimate of the pressure required to develop sufficient flow through the valve.

If sufficient flow can be generated with a pressure at saturated conditions (the second pressure calculated) sufficient flow may be passed through the valve so that the tank will not be shell full the next time through the calculational cycle. If this condition is not realized, the mass of the fluid remaining in the tank is set so that a shell full condition will be recognized the next time through the calculational cycle.

Two adjustments are made in the calculated pressures to provide a better representation of the behavior of the valve when the vapor is less than the valve start-to-discharge pressure. First, if the calculated pressure is less than the start-to-discharge pressure of the valve and the valve is closed, the pressure is reset to the start-to-discharge pressure and the valve is reset to the open position. Second, if the pressure is less than the closing pressure of the valve and the valve is open, the valve is reset to be closed. This gives a more accurate representation of the valve cycling open and closed.

3.13.6 Calculate Mass of Product Remaining in Tank

The remaining mass in the tank is calculated. The mass flow from the tank will be the larger of the mass flow required to accommodate the increase in specific volume of the product and the mass flow calculated from isentropic flow through the valve starting from the saturated vapor pressure of the fluid at its current temperature.

3.14 VAPOR PHASE ONLY WITHIN TANK

This condition occurs after the critical temperature is reached (a condition obtained only for a few cases with propane and propylene while there is still liquid product within the tank) or after the vaporization of all of the liquid within the tank. The temperature of the remaining product within the tank will increase at a fairly rapid rate during this phase because of the relatively low mass of product and the fact that there is no heat absorbed by the vaporization of the liquid. During this phase the pressure within the tank will begin to increase due to the increased pressure of the product, but the increased pressure will be relieved by flow through the safety valve. The pressure within the tank will be maintained near the valve closing pressure.

3.14.1 Calculate Heat Transfer to Vapor Product

The first step in the calculation of this case is to calculate the heat transfer to the vapor product. This is estimated by assuming that there is a convection coefficient of 1.0 BTU/hr-ft^2-°F between the vapor and the inner wall of the tank.

3.14.2 Calculate Change in Pressure

The change in pressure of the vapor within the tank can be calculated using the ideal gas law and considering the change in temperature from the beginning of the time increment.

3.14.3 Calculate Mass Flow Out

The mass out through the safety valve is calculated using the equation previously presented for vapor flow (Equation 5). The compressibility factor, Z, of 0.7 is assumed for all commodities except for propane where Z is represented as a function of the total pressure within the tank, the temperature and specific volume.

3.14.4 Calculate Change in Tank Temperature

The change in the temperature of the product within the tank over the time increment is calculated on the basis of the heat transferred to the product and the work done in expelling the gas from the tank.

3.15 CALCULATE BURST STRENGTH OF TANK

The brust strength of the tank is assumed to be a function of temperature. The temperature used in this calculation is that of the tank shell over the vapor regions.

3.16 DISPLAY DATA

The program provides two different types of format for displaying the results of the calculation. The first format prints out data at selected time intervals during the course of the analysis. The interval is selectable as a multiple of the time increments used during the analysis.

The second format gives a plot of the temperature of the tank wall above the vapor space, the pressure within the tank, and the liquid fraction remaining in the tank as a function of time.

3.17 COMPARE BURST STRENGTH AND INTERNAL PRESSURE

The final step in the calculation is to compare the internal pressure in the tank with the burst strength. If the internal pressure exceeds the burst strength it is assumed that the tank will fail and the calculation is stopped. A comparison is also made to determine if the time limit has been exceeded and if this has occurred the calculation is also halted. Otherwise the time is incremented and the calculation returns to the point where the effective conductance of the thermal shield is determined (Section 3.3).

4. COMPUTER PROGRAM LISTINGS

Listings of the basic computer program and the subroutines are presented in this section. The basic program is designated FEAVIT for Fire Effects Analysis of Vented Insulated Tanks. The principal parameters used in the basic program are indicated as follows:

KPRD	Product type
TILT	Angle of valve overturn from vertical (deg)
PREF	Vapor pressure of product (psia)
PTOT	Total pressure within tank (psia)
PPAD	Partial pressure of nitrogen pad (psi)
PATD	Start-to-discharge pressure of safety relief valve (psia)
HTIN	Heat transmitted to product in time increment (BTU)
FRAC	Fraction of tank volume filled with liquid
FMSS	Mass of product in tank (lbs)
FMAT	Fraction of original mass remaining in tank
WOUT	Mass of product vented through safety relief valve in time increment (lbs)
WLIQ	Weight of liquid product in tank (lbs)
WVAP	Weight of product in vapor plane (lbs)
TFLA	Temperature of flame (°R/1000)
TTNK	Temperature of tank wall adjacent to liquid (°R/1000)
TTNV	Temperature of tank wall adjacent to vapor space (°R/1000)
CNDD	Conductance of thermal insulation system (BTU/hr-ft^2-°F)
DELT	Time increment (min)

Other parameters are defined in the initial section of the program listing and the descriptions of the subroutines.

```
C       PROGRAM FEAVIT (FIRE EFFECTS ANALYSIS OF VENTED INSULATED
C       TANKS) FOR ANALYSIS OF CARS CONTAINING PROPANE, ETHYLENE OXIDE,
C       PROPYLENE, 1,3-BUTADIENE, VINYL CHLORIDE,
C       MONOMETHYLAMINE, OR PROPYLENE OXIDE IN THE POOL
C       FIRE ENVIRONMENT VENTING LIQUID OR VAPOR.....TILT ANGLE
C       OF THE SAFETY RELIEF VALVE IS SPECIFIED (Ø-18Ø DEGREES).
C       THE PROGRAM USES SUBROUTINES SURFACET, PROPERTIES,
C       VCAP, TSHIELD, AND PLT3.
C
        ACCEPT "DISPLAY TYPE, LPT-12.....CONSOLE-1Ø" ,KW
        IF (KW.EQ.1Ø)GO TO 15
        OPEN 12, "@LPT", ATT="OP"
15      ACCEPT "PLOT-2  PRINT TERM OR LPT-1" ,KPLT
        ACCEPT "PROP-1 EO-2 PROPYL-3 BUTA-4 VC-5 MONO-6 POX-7" ,KPRD
        ACCEPT "ANGLE OF TILT (DEG)" ,TILT
        TRLT=1.57Ø8-TILT/18Ø.Ø*3.1416
        ACCEPT "TANK DIAMETER (FT)" ,DHTK
        ACCEPT "TANK WALL THICKNESS(IN.)" ,DHTW
        ACCEPT "NOMINAL CAPACITY (GALLS)" ,SIZE
        ACCEPT "INITIAL FRACTION FILLED" ,FRAT
        ACCEPT "SAFETY VALVE FLOW RATING PRESSURE (PSIA)" ,PASD
        ACCEPT "SAFETY VALVE START TO DISCHARGE PRESS (PSIA)" ,PATD
        ACCEPT "NET ABSORPTIVITY" ,EABS
        ACCEPT "NET EMISSIVITY" ,ERAD
        ACCEPT "TANK BURSTING STRENGTH (PSI)" ,PBRT
        ACCEPT "CAR CONDUCTANCE (BTU/HR SQFT DEG F)" ,CNDD
        ACCEPT "SAFETY VALVE RATED FLOW CAPACITY (SCFM,AIR)" ,SCFM
        ACCEPT "TYPE 1 FOR CONSTANT CONDUCT. OR 2 FOR VAR. CND.", KCND
        IF(KCND.EQ.2)GO TO 14
        ACCEPT "INITIAL CAR CONDUCTANCE (BTU/HR SQFT DEG F)" ,CNDI
        GO TO 17
14      ACCEPT "THICKNESS OF INSULATION(INS.)", THIC
        ACCEPT "WISH TO CONSID. INIT. CNDT. YES-1 NO-2" ,KINDX
        IF(KINDX.EQ.2)GO TO 17
        ACCEPT "INITIAL CAR CONDUCTANCE (BTU/HR SQFT DEG F)" ,CNDI
17      ACCEPT "FLAME TEMPERATURE (DEG F)" ,TEMF
        ACCEPT "PRESSURE(PSI) OF NITROGEN PAD" ,PPAD
        ACCEPT "AREA EXPONENT" ,EXPP
        ACCEPT "INITIAL TEMPERATURE (DEG F)" ,TEMC
        ACCEPT "TIME INCREMENT (MIN),(MUST BE EVEN TENTH)" ,DELT
        ACCEPT "NUMBER OF TIME STEPS BETWEEN DISPLAY" ,INTV
        ACCEPT "GAS COMPRESSIBILITY FACTOR,Z" ,ZPRO
        ACCEPT "VALVE GAS FLOW CONSTANT" ,VLCON
C
C       INITIALIZATION OF PARAMETERS AT BEGINNING OF EACH ANALYSIS
C
        TEMP=TEMC
        PREF=1ØØ.
        SPEC=Ø.6
        SPLQ=Ø.Ø3
        HFLV=1ØØ.Ø
        VVAP=1.Ø
        DVDT=1.Ø
        DLDT=1.Ø
        TWAL=Ø.5
        TWAV=Ø.5
C
        CALL PROPERTIES(KPRD,TEMP,PREF,SPEC,SPLQ,HFLV,VVAP,DVDT,DLDT)
C
        SZGL=SIZE/7.48
```

```
      WGHT=SZGL*(FRAT/SPLQ)+(1.Ø-FRAT)*SZGL/VVAP
      LENG=SIZE/(5.875*DHTK*DHTK)
      AREA=Ø.535*SIZE/DHTK+1.57Ø8*DHTK*DHTK
      WTWL=DHTW*Ø.283*144.Ø
      WGNT=(1.Ø-FRAT)*SZGL*2.61*PPAD/(46Ø.+TEMC)
      WNIT=WGNT
C
      FRAC=FRAT
      TIME=Ø.Ø
      WOUT=Ø.Ø
      WLET=1.Ø
      WPRT=Ø.Ø
      ATEM=Ø.Ø
      FMSS=WGHT
      PTOT=PREF
      PNIT=PPAD
      KTCT=1
      KCNT=Ø
      KIDN=Ø
      WLIQ=SZGL*FRAT/SPLQ
      WVAP=(1.Ø-FRAT)*SZGL/VVAP
      WOLST=Ø.Ø
      PICR=Ø.Ø
      TCLST=Ø.Ø
      TFLA=(TEMF+46Ø.Ø)/1ØØØ.Ø
      TTNK=(TEMC+46Ø.Ø)/1ØØØ.Ø
      TTMC=TTNK
      TTNV=(TEMC+46Ø.Ø)/1ØØØ.Ø
      TTMV=TTNV
      TWAL=TFLA-Ø.Ø5Ø
      TWAV=TWAL
      PLST=Ø.Ø
      POPN=1.Ø3*(PATD-14.7)+14.7
      PRTN=Ø.88*(PATD-14.7)+14.7
      PCLS=Ø.82*(PATD-14.7)+14.7
C
C     COMPUTE NOMINAL VALVE AREA; ASSUME DISCHARGE COEF: CVAD
C
      CVAD=Ø.9
      AVLV=SCFM/(CVAD*PASD*2638.)
C
C     BEGINNING OF CALCULATION: DETERMINE COND. OF THERMAL SHIELD
C
21    IF(KCND.EQ.2)GO TO 22
      CVP=CNDD
      CLQ=CNDD
      GO TO 23
22    CALL TSHIELD(TWAL,TTNK,CLQ,THIC)
      CALL TSHIELD(TWAV,TTNV,CVP,THIC)
23    IF(KINDX.EQ.2.OR.TIME.GT.3Ø.Ø)GO TO 26
      CNDLQ=CNDI+(CLQ-CNDI)*(TIME/3Ø.)
      CNDVP=CNDI+(CVP-CNDI)*(TIME/3Ø.)
      GO TO 28
26    CNDVP=CVP
      CNDLQ=CLQ
28    CONTINUE
C
C     DETERMINE OUTER WALL TEMPERATURE ADJACENT TO THE LIQUID.
C
      CALL SURFACET(TWAL,TTNK,EABS,ERAD,CNDLQ,TFLA)
```

```
C
C       DETERMINE GEOMETRY OF LIQUID LEVEL.
C
        IF(FRAC.GT.Ø.ØØØ1)GO TO 521
        THET=-1.57Ø8
        GO TO 55Ø
521     THOU=Ø.1Ø
        THEM=1.57Ø8
522     FTST=(1.57Ø8+THEM+COS(THEM)*SIN(THEM))/3.1416
        IF(ABS(FTST-FRAC).LT.Ø.ØØØ1)GO TO 545
        IF(FTST.LT.FRAC)GO TO 531
        THEM=THEM-THOU
        IF(THEM.LE.(-1.57Ø8))GO TO 531
        GO TO 522
531     THEM=THEM+THOU
        THOU=THOU/5.Ø
        THEM=THEM-THOU
        GO TO 522
545     THET=THEM
55Ø     CONTINUE
        AREALQ=DHTK*COS(THET)*LENG+1.Ø
        ATANK=AREA*(1.57Ø8-THET)/3.1416+1.Ø
C
C       DETERMINE RADIATION SURFACE CONFIGURATION FACTOR.
C
        FLQT=1.Ø/(1.25+Ø.25*(AREALQ/ATANK))
        FAFTLQ=FLQT*AREALQ/ATANK
        FLQT=1.Ø/(1.58+Ø.33*(AREALQ/ATANK))
        FBFTLQ=1.33*FLQT*AREALQ/ATANK
        FCFTLQ=(-THET-Ø.53)*FBFTLQ/Ø.Ø4+(Ø.57+THET)*FAFTLQ/Ø.Ø4
        FTLQ=FAFTLQ
        IF(THET.LT.Ø.55.AND.THET.GE.(-Ø.53))FTLQ=FBFTLQ
        IF(THET.LT.(-Ø.53).AND.THET.GT.(-Ø.57))FTLQ=FCFTLQ
C
C       DETERMINE OUTER SURFACE TEMPERATURE ADJACENT TO VAPOR SPACE.
C
        CALL SURFACET(TWAV,TTNV,EABS,ERAD,CNDVP,TFLA)
C
C       DETERMINE INNER WALL TEMPERATURE NEXT TO VAPOR SPACE.
C
151     HCNV=Ø.Ø
        IF(KIDN.NE.1)GO TO 152
        IF(WPRT.GT.15ØØ.Ø)GO TO 154
        IF(FRAC.GT.Ø.9)HCNV=Ø.Ø5
        IF(FRAC.GT.Ø.4.AND.FRAC.LE.Ø.9)HCNV=Ø.Ø5
        GO TO 152
154     IF(FRAC.GT.Ø.9)HCNV=6.Ø
        IF(FRAC.GT.Ø.4.AND.FRAC.LE.Ø.9)HCNV=1.5
152     DELV=Ø.48*FTLQ*(TTNV**4-TTNK**4)
        DELV=DELV+HCNV*(TTNV-TTNK)
        DELV=(TWAV-TTNV)*(CNDVP/3.6)-DELV
        DELV=(DELV/WTWL)*(6Ø.Ø/125.Ø)*DELT
        TTNV=TTNV+DELV
        TTMV=TTNV
C
C       DETERMINE THE DEGREE OF VALVE OPENING.
C
12Ø     CONTINUE
        IF(PTOT.LT.POPN)GO TO 3Ø2
        TCFM=SCFM
```

```
      GO TO 35Ø
 3Ø2  IF(PTOT.GT.PLST.AND.TCLST.EQ.Ø.Ø)GO TO 32Ø
      IF(PTOT.LE.PRTN)GO TO 3Ø4
      TCFM=SCFM*(Ø.85+.15*(PTOT-PRTN)/(POPN-PRTN))
      GO TO 35Ø
 3Ø4  IF(PTOT.LE.PCLS)GO TO 3Ø6
      TCFM=SCFM*Ø.85*(PTOT-PCLS)/(PRTN-PCLS)
      GO TO 35Ø
 3Ø6  TCFM=Ø.Ø
      GO TO 35Ø
 32Ø  IF(PTOT.LE.PATD)GO TO 322
      TCFM=SCFM*(PTOT-PATD)/(POPN-PATD)
      GO TO 35Ø
 322  TCFM=Ø.Ø
 35Ø  CONTINUE
      TCLST=TCFM
      CDLQ=Ø.7Ø
      ATEM=AVLV*CDLQ*TCFM/SCFM
C
C     SORT OUT CONDITIONS IN THE TANK.
C
      IF(TTNK.GT.Ø.6659.AND.KPRD.EQ.1)GO TO 43Ø
      IF(TTNK.GT.Ø.83Ø.AND.KPRD.EQ.2)GO TO 43Ø
      IF(TTNK.GT.Ø.6567.AND.KPRD.EQ.3)GO TO 43Ø
      IF(FRAC.LT.Ø.ØØØ5)GO TO 43Ø
C
      IF((FMSS*SPLQ).GT.SZGL)GO TO 41Ø
C
C     BOTH LIQUID AND VAPOR WITHIN TANK. . . . . . . . . . . . . . . .
C
C     DETERMINE HEAT IN THROUGH WETTED AREA AND RADIATED TO SURFACE.
C
      THEA=Ø.Ø
      IF(THET.LT.(-1.Ø))THEA=Ø.1Ø
      HTINR=Ø.48*FLOT*((TTMV)**4-(TTNK)**4)*(AREALQ**EXPP)*DELT*6Ø.Ø
      STDA=AREA*(1.57Ø8+THEA+THET)/3.1416
      HTIN=(TWAL-TTNK)*CNDLQ*(STDA**EXPP)*DELT*6Ø.Ø/3.6+HTINR
      THRML=SPEC*WLIQ+Ø.125*WTWL*STDA
      TLST=TTNK
      SLST=VVAP
      PLST=PTOT
      IF(THET.LE.TRLT)GO TO 42Ø
C
C     LIQUID AND VAPOR IN TANK, VENTING LIQUID. . . . . . . . . . . . .
C
C     CALCULATE MASS FLOW OUT THROUGH VALVE.
C
      CALL VCAP(TTNK,PNIT,WOUT,ATEM,KPRD,PREF,SPEC,SPLQ,
     1 HFLV,VVAP,DVDT,DSDT,DELT)
      QWRK=WOUT*SPLQ*PTOT*144./778.
C
C     DETERMINE TEMPERATURE INCREASE.
C
      AA=THRML*(DVDT-DLDT)
      BB=THRML*(VVAP-SPLQ)-(DVDT-DLDT)*(HTIN-QWRK)
     :-(WLIQ*DLDT+WVAP*DVDT)*HFLV
      CC=-(HTIN-QWRK)*(VVAP-SPLQ)+WOUT*SPLQ*HFLV
      TELT=(-BB+SQRT(BB*BB-4.Ø*AA*CC))/(2.Ø*AA)
      TTNK=TTNK+TELT/1ØØØ.Ø
C
```

```
C       CALCULATE MASS REMAINING IN TANK.
C
        FMSS=FMSS-WOUT
        FMAT=FMSS/WGHT
        IF(KIDN.EQ.2)PICR=14.7
C
        TEMP=(TTNK-Ø.46)*1ØØØ.Ø
        CALL PROPERTIES(KPRD,TEMP,PREF,SPEC,SPLQ,HFLV,VVAP,DVDT,DLDT)
C
        PTOT=PREF
        WLIQ=(FMSS*VVAP-SZGL)/(VVAP-SPLQ)
        WVAP=FMSS-WLIQ
        VLIQ=WLIQ*SPLQ
        FRAC=VLIQ/SZGL
        IF(VLIQ.GE.SZGL)FRAC=1.Ø
        IF(VLIQ.LE.Ø.Ø)FRAC=Ø.Ø
C
C       DETERMINE PRESSURE OF NITROGEN PAD (IF PRESENT).
C
        IF(KPRD.EQ.1)GO TO 391
        IF(KPRD.GE.3.AND.KPRD.LE.6)GO TO 391
        STEST=SZGL-WLIQ*SPLQ
        IF(STEST.LE.Ø.Ø)STEST=Ø.ØØØ5
        PNIT=PPAD*TTNK/TTMC*(1.Ø-FRAT)*SZGL/STEST
        PTOT=PREF+PNIT
391     KIDN=2
        CONTINUE
C
        GO TO 153
C
C       SHELL FULL CASE. . . . . . . . . . . . . . . . . . . . . . . . . .
C
C       CALCULATE CHANGE IN TEMPERATURE.
C
41Ø     HTIN=(TWAL-TTNK)*CNDLQ*(AREA**EXPP)*DELT*6Ø.Ø/3.6
        TELT=HTIN/(SPEC*WLIQ*1ØØØ.Ø+125.Ø*WTWL*AREA)
        TLST=TTNK
        SLST=VVAP
        PLST=PTOT
        TTNK=TTNK+TELT
C
        TEMP=(TTNK-Ø.46)*1ØØØ.Ø
        CALL PROPERTIES(KPRD,TEMP,PREF,SPEC,SPLQ,HFLV,VVAP,DVDT,DLDT)
C
        VLIQ=FMSS*SPLQ
        WVAP=Ø.Ø
        REQL=1ØØØ.Ø*FMSS*DLDT*TELT/DELT
C
        CDLQ=Ø.7
        PTOT=PREF
        IF(KPRD.EQ.1)PISN=REQL/(CDLQ*AVLV*SPLQ*241.Ø)-25Ø.Ø
        IF(KPRD.EQ.2)PISN=REQL/(CDLQ*AVLV*SPLQ*49Ø.Ø)-18.6
        IF(KPRD.EQ.3)PISN=REQL/(CDLQ*AVLV*SPLQ*242.4)-28Ø.Ø
        IF(KPRD.EQ.4)PISN=REQL/(CDLQ*AVLV*SPLQ*31Ø.5)-13Ø.Ø
        IF(KPRD.EQ.5)PISN=REQL/(CDLQ*AVLV*SPLQ*5Ø7.1)-67.6
        IF(KPRD.EQ.6)PISN=REQL/(CDLQ*AVLV*SPLQ*3Ø9.4)-12Ø.2
        IF(KPRD.EQ.7)PISN=REQL/(CDLQ*AVLV*SPLQ*3Ø2.9)-111.Ø
        PCOM=PREF+((REQL/(72Ø.Ø*CDLQ*AVLV))**2)/(64.4*SPLQ)
        PICR=AMIN1(PISN,PCOM)
        IF(PISN.LT.PREF.AND.PTOT.GT.PCLS)GO TO 87
```

```
      IF(PICR.GT.PREF)PTOT=PICR
      IF(PTOT.LT.PATD.AND.TCLST.LT.Ø.ØØ1)GO TO 85
      IF(PICR.LT.PCLS.AND.TCLST.GT.Ø.Ø)PTOT=PREF
      GO TO 84
85    PTOT=PATD
      GO TO 84
C
87    PICR=14.7
      IF(KPRD.EQ.1)WOUT=ATEM*6Ø.*DELT*(1ØØ4.+4.Ø23*PTOT)
      IF(KPRD.EQ.2)WOUT=ATEM*6Ø.Ø*DELT*(152.Ø+8.16*PTOT)
      IF(KPRD.EQ.3)WOUT=ATEM*6Ø.*DELT*(1131.+4.Ø398*PTOT)
      IF(KPRD.EQ.4)WOUT=ATEM*6Ø.*DELT*(673.Ø+5.1753*PTOT)
      IF(KPRD.EQ.5)WOUT=ATEM*6Ø.Ø*DELT*(571.1+8.4515*PTOT)
      IF(KPRD.EQ.6)WOUT=ATEM*6Ø.*DELT*(619.6+5.1563*PTOT)
      IF(KPRD.EQ.7)WOUT=ATEM*6Ø.*DELT*(56Ø.4+5.Ø475*PTOT)
      WROUT=DELT*REQL/SPLQ
      IF(WROUT.GT.WOUT)GO TO 86
C
      FMSS=FMSS-WOUT
      FMAT=FMSS/WGHT
      FRAC=VLIQ/SZGL
      KIDN=32
      IF(VLIQ.GE.SZGL)FRAC=1.Ø
      GO TO 88
C
86    PTOT=PREF
      WOUT=WROUT
84    FMSS=SZGL/SPLQ+1.Ø
      FRAC=1.Ø
      WOUT=DELT*REQL/SPLQ
      KIDN=31
      IF(PCOM.GT.PISN)KIDN=33
      TCLST=1.Ø
      FMAT=FMSS/WGHT
C
88    PNIT=Ø.Ø
      WLIQ=FMSS
      PLST=PTOT
      SLST=SZGL/FMSS
      GO TO 153
C
C     LIQUID AND VAPOR IN CAR, BUT VENTING VAPOR. . . . . . . . . . . .
C
C     CALCULATE MASS FLOW RATE THROUGH VALVE.
C
42Ø   WCHK=WOUT
      WOUT=((PTOT-PNIT)/PASD)*TCFM*VLCON/SQRT(TTNK*ZPRO)*DELT
      IF(FRAC.GT.Ø.Ø25)GO TO 424
      ALFA=Ø.1Ø
      WOUT=WOUT*ALFA+WCHK*(1.Ø-ALFA)
C
C     CALCULATE CHANGE IN TEMPERATURE.
C
424   QVAL=WOUT*HFLV
      TELT=(HTIN-QVAL)/(THRML*1ØØØ.Ø)
      TLST=TTNK
      TTNK=TTNK+TELT
      IF(FRAC.LT.Ø.Ø25)TTNK=Ø.2*TTNK+Ø.8*TLST
      FMSS=FMSS-WOUT
      FMAT=FMSS/WGHT
```

```
      VOLL=FMSS*SPLQ
C
C     CALCULATE CHANGE IN MASS OF NITROGEN PAD (IF PRESENT).
C
      WNOUT=WOUT*PNIT/(PTOT-PNIT)
      WNTST=Ø.4*WNIT
      IF(WNOUT.GT.WNTST)WNOUT=WNTST
      WNIT=WNIT-WNOUT
      IF(WNIT.LT.Ø.Ø)WNIT=Ø.Ø
      IF(WGNT.LE.Ø.Ø.OR.FRAC.GE.1.Ø)GO TO 421
      PNIT=((1.-FRAT)/(1.-FRAC))*PPAD*(TTNK/TTMC)*WNIT/WGNT
      GO TO 422
421   PNIT=Ø.Ø
      WNIT=Ø.Ø
C
422   TEMP=(TTNK-Ø.46)*1ØØØ.Ø
      CALL PROPERTIES(KPRD,TEMP,PREF,SPEC,SPLQ,HFLV,VVAP,DVDT,DLDT)
C
      PTOT=PREF+PNIT
      IF(PREF.GT.PCLS.OR.PTOT.LT.(PATD+1.Ø))GO TO 423
      PNTEMP=PATD-PREF+Ø.5
      WNIT=WNIT*PNTEMP/PNIT
      PNIT=PNTEMP
      PTOT=PNIT+PREF
C
423   IF(KIDN.EQ.1)PICR=Ø.Ø
      WLIQ=(FMSS*VVAP-SZGL)/(VVAP-SPLQ)
      WVAP=FMSS-WLIQ
      VLIQ=WLIQ*SPLQ
      FRAC=VLIQ/SZGL
      SLST=SZGL/FMSS
      IF(VLIQ.GE.SZGL)FRAC=1.Ø
      IF(VLIQ.LE.Ø.Ø)FRAC=Ø.Ø
      PICR=14.7
      KIDN=1
      GO TO 153
C
C     CASE OF TANK FILLED ONLY WITH VAPOR (NITROGEN PAD NEGLECTED):
C
43Ø   HTIN=(TTNV-TTNK)*AREA*1ØØØ.Ø*1.Ø*DELT/6Ø.Ø
      PLST=PTOT
      ZPRO=Ø.7
      PNIT=Ø.Ø
      SVLV=SZGL/FMSS
      IF(KPRD.EQ.1)GO TO 5Ø1
      PTOT=(PLST*SLST/SVLV*TTNK/TLST)*Ø.3+Ø.7*PLST
      SLST=SVLV
      GO TO 5Ø2
5Ø1   CONTINUE
      PTOT=243.4*TTNK/(SVLV-Ø.Ø3226)-17.98/(SVLV**2)
      ZPRO=Ø.ØØ411*PTOT*SVLV/TTNK
5Ø2   CONTINUE
      IF(PTOT.LE.PCLS)PTOT=PCLS+Ø.ØØ1
      WLET=WOUT
      WOUT=(PTOT/PASD)*TCFM*VLCON/SQRT(TTNK*ZPRO)*DELT
      IF(FMAT.GT.Ø.Ø1ØØ)GO TO 5Ø3
      ALFA=Ø.2
      IF(SCFM.GT.15ØØØ.Ø)ALFA=Ø.Ø5
      WOUT=WOUT*ALFA+WLET*(1.Ø-ALFA)
5Ø3   QWRK=WOUT*SVLV*PTOT*144.Ø/778.Ø
```

```
C
C       CALCULATE CHANGE IN TEMPERATURE.
C
        TELT=(HTIN-QWRK)/(FMSS*Ø.4Ø*1ØØØ.Ø)
        TLST=TTNK
        TTNK=TTNK+TELT
        FMSS=FMSS-WOUT
        WLIQ=Ø.Ø
        WVAP=FMSS
        FRAC=Ø.ØØØ
        PICR=14.7
        FMAT=FMSS/WGHT
        TEMP=(TTNK-Ø.46)*1ØØØ.Ø
        CALL PROPERTIES(KPRD,TEMP,PREF,SPEC,SPLQ,HFLV,VVAP,DVDT,DLDT)
        KIDN=4
        GO TO 153
C
C       BURST STRENGTH OF TANK
C
153     IF(TTNV.LT.1.26Ø)FCTR=1.Ø-(Ø.54)*(TTNV-Ø.46)**4
        IF(TTNV.GE.1.26Ø)FCTR=1.74-1.17*(TTNV-Ø.46)
        PBRS=PBRT*FCTR
C
C       SET OUTPUT PARAMETERS.
C
        PSIG=PTOT-14.7
        PACR=PICR-14.7
        WPRT=WOUT/DELT
        TEMP=1ØØØ.Ø*TTNK-46Ø.Ø
        TEMW=1ØØØ.Ø*TWAL-46Ø.Ø
        TEMH=1ØØØ.Ø*TTNV-46Ø.Ø
        TEMQ=1ØØØ.Ø*TTMV-46Ø.Ø
        FRCLQ=WLIQ/WGHT
C
C       HEADINGS FOR OUTPUTS
C
        IF(PBRS.LT.PSIG)GO TO 98
        IF(TIME.GT.Ø.Ø)GO TO 65
        IF(KPRD.EQ.1)WRITE(KW,57)
        IF(KPRD.EQ.2)WRITE(KW,58)
        IF(KPRD.EQ.3)WRITE(KW,55)
        IF(KPRD.EQ.4)WRITE(KW,54)
        IF(KPRD.EQ.5)WRITE(KW,53)
        IF(KPRD.EQ.6)WRITE(KW,52)
        IF(KPRD.EQ.7)WRITE(KW,51)
57      FORMAT(5X,7HPROPANE,1X,3HCAR)
58      FORMAT(5X,8HETHLYENE,1X,5HOXIDE,1X,3HCAR)
55      FORMAT(5X,9HPROPYLENE,1X,3HCAR)
54      FORMAT(5X,13H1,3-BUTADIENE,1X,3HCAR)
53      FORMAT(5X,5HVINYL,1X,8HCHLORIDE,1X,3HCAR)
52      FORMAT(5X,15HMONOMETHYLAMINE,1X,3HCAR)
51      FORMAT(5X,9HPROPYLENE,1X,5HOXIDE,1X,3HCAR)
        WRITE(KW,59)
59      FORMAT(2X,4HSVPR,5X,4HINTT,5X,4HCOND,3X,4HSCFM,3X,4HTEMF,
     1  5X,4HSIZE,2X,4HTILT,2X,6HWEIGHT,2X,5HTHICK)
        WRITE (KW,6Ø)PASD,TEMC,CNDD,SCFM,TEMF,SIZE,TILT,WGHT,THIC
6Ø      FORMAT(F8.2,F8.2,F8.2,F8.Ø,F8.2,F8.Ø,F6.Ø,F8.Ø,F7.3)
        IF(KW.EQ.1Ø)WRITE(KW,63)
        IF(KW.EQ.12)WRITE(KW,64)
63      FORMAT(4X,4HTIME,3X,4HPSIG,4X,4HTTNK,3X,4HTWAL,3X,4HFRAC,
```

```
      1  2X,4HFMAT,2X,4HTVAP,2X,4HWOUT,2X,4HPBRS,4X,4HPNIT,1X,4HKIDN)
 64      FORMAT(4X,4HTIME,3X,4HPSIG,4X,4HTTNK,3X,4HTWAL,3X,4HFRAC,
      1  2X,4HFMAT,2X,4HTVAP,2X,4HWOUT,2X,4HPBRS,4X,4HPNIT,1X,4HKIDN,
      1  3X,5HTHETA,5X,4HPICR,2X,5HCNDLQ,2X,5HCNDVP,2X,6HFRACLQ)
C
65       IF(KCNT.LT.INTV)GO TO 99
C
98       IF(KPLT.EQ.2)CALL PLT3 ("DATA",FRAC,PSIG,TEMQ,TIME)
         IF(KW.EQ.12)GO TO 66
         WRITE(KW,67)TIME,PSIG,TEMP,TEMW,FRAC,FMAT,TEMH,WPRT,PBRS,
      1  PNIT,KIDN
         GO TO 69
66       WRITE(KW,68)TIME,PSIG,TEMP,TEMW,FRAC,FMAT,TEMH,WPRT,PBRS,
      1  PNIT,KIDN,THET,PACR,CNDLQ,CNDVP,FRCLQ
69       CONTINUE
67       FORMAT(F8.2,F8.2,F7.Ø,F8.Ø,F6.3,F6.3,F7.1,F6.Ø,F7.1,F7.1,I3)
68       FORMAT(F8.2,F8.2,F8.Ø,F8.Ø,F6.3,F6.3,F6.Ø,F6.Ø,F6.Ø,F9.1,I3,
      1  F8.3,F9.1,F7.2,F7.2,F7.3)
         KCNT=Ø
         KTCT=KTCT+1
C
         IF(PBRS.LT.PSIG)GO TO 78
C
99       KCNT=KCNT+1
         IF(KTCT.EQ.18.AND.KW.EQ.1Ø)PAUSE
         IF(KTCT.EQ.18)KTCT=1
C
92       DTIME=TIME*2Ø.Ø+Ø.1
         KTIME=IFIX(DTIME)
         DTIME=FLOAT(KTIME)
         TIME=DTIME/2Ø.Ø
         TIME=TIME+DELT
         IF(TIME.GT.6ØØ.Ø)GO TO 78
77       GO TO 21
78       CONTINUE
C
93       IF(KPLT.EQ.2)CALL PLT3 ("PLOT")
C
         IF(KPLT.EQ.2)CALL PLT3 ("STOP")
         STOP
         END
```

4.1 SUBROUTINE PROPERTIES

Subroutine PROPERTIES contains the thermal property data for the commodities considered under this program. The following properties of a product are given at saturated vapor conditions as a function of temperature:

PREF	Vapor pressure (psia)
SPEC	Specific heat of the liquid (BTU/lb °F)
SPLQ	Specific volume of liquid (ft^3/lb)
HFLV	Heat of vaporization (BTU/lb)
VVAP	Specific volume of vapor (ft^3/lb)
DVDT	Rate of change of the function VVAP with temperature (ft^3/lb°F)
DLDT	Rate of change of the function SPLQ with temperature (ft^3/lb°F)

The thermal property data is represented as quadratic functions of temperature within given temperature ranges. A sufficient number of temperature ranges are used with each commodity to give a sufficiently accurate representation of the property data. The subroutine is called with a given value of temperature (TEMP) in °F. The thermal property data is based on the following sources: propane (Ref. 4), ethylene oxide (Ref. 4), propylene (Ref. 4), 1-3 butadiene (Refs. 4 and 5), vinyl chloride (Refs. 4 and 5), monomethylamine (Refs. 4 and 6), and propylene oxide (Ref 7). A listing of the subroutine is presented on the following pages.

```
      SUBROUTINE PROPERTIES(KPRD,TEMP,PREF,SPEC,SPLQ,HFLV,VVAP,
     1 DVDT,DLDT)
C
C     THIS SUBROUTINE CONTAINS REPRESENTATIONS OF THE THERMAL
C        PROPERTIES OF PROPANE(1), ETHYLENE OXIDE(2), PROPYLENE(3),
C        1,3-BUTADIENE(4), VINYL CHLORIDE(5), MONOMETHYLAMINE(6),
C        AND PROPYLENE OXIDE(7) UNDER SATURATED VAPOR CONDITIONS
C        AS A FUNCTION OF TEMPERATURE. PROPERTIES ARE: PREF(VAPOR
C           PREF-VAPOR PRESSURE (PSIA)
C           SPEC-SPECIFIC HEAT OF LIQUID (BTU/LB-DEG F)
C           SPLQ-SPECIFIC VOLUME LIQUID (CU FT/LB)
C           HFLV-HEAT OF VAPORIZATION (BTU/LB)
C           VVAP-SPECIFIC VOLUME VAPOR (CU FT/LB)
C           DVDT-RATE OF CHANGE OF VVAP WITH TEMP (CU FT/LB-DEG F)
C           DLDT-RATE OF CHANGE OF SPLQ WITH TEMP (CU FT/LB-DEF F)
C
      IF(KPRD.EQ.2)GO TO 391
      IF(KPRD.EQ.3)GO TO 811
      IF(KPRD.EQ.4)GO TO 831
      IF(KPRD.EQ.5)GO TO 841
      IF(KPRD.EQ.6)GO TO 851
      IF(KPRD.EQ.7)GO TO 821
C
C     PROPERTIES OF PROPANE
C
      IF(TEMP.GT.81.12)GO TO 313
      PREF=44.809+0.47317*TEMP+0.0096905*TEMP*TEMP
      SPLQ=(31.312+.05029*(TEMP-56.75)+.0002*((TEMP-56.75)**2))/1000.
      VVAP=2.29511-0.02836*TEMP+0.000111*TEMP*TEMP
      DVDT=-0.02836+0.000222*TEMP
      GO TO 319
  313 IF(TEMP.GT.135.59)GO TO 314
      PREF=63.705+0.026189*TEMP+0.012329*TEMP*TEMP
      SPLQ=(32.656+.05999*(TEMP-81.12)+.0003307*((TEMP-81.12)**2)
     * )/1000.
      VVAP=1.86981-0.018250*TEMP+0.000051*TEMP*TEMP
      DVDT=-0.018250+0.000102*TEMP
      GO TO 319
  314 IF(TEMP.GT.172.54)GO TO 315
      PREF=123.25-0.8776297*TEMP+0.015756*TEMP*TEMP
      SPLQ=(36.905+.085936*(TEMP-135.59)+0.001399*((TEMP-135.59)**2)
     * )/1000.
      VVAP=1.34795-0.010280*TEMP+0.000021*TEMP*TEMP
      DVDT=-0.010280+0.000042*TEMP
      GO TO 319
  315 IF(TEMP.GT.201.25)GO TO 316
      PREF=193.32-1.723723*TEMP+0.0183058*TEMP*TEMP
      SPLQ=(41.991+.13595*(TEMP-172.54)+.00901*((TEMP-172.54)**2))
     * /1000.
      VVAP=0.345139+0.0011835*TEMP-0.0000118*TEMP*TEMP
      DVDT=+0.0011835-0.0000236*TEMP
      GO TO 319
  316 PREF=587.84+6.0748*(TEMP-201.25)
      SPLQ=0.053324+(TEMP-201.25)*0.003496
      VVAP=0.107048-(TEMP-201.25)*0.007079
      DVDT=-0.007079
  319 CONTINUE
C
      IF(TEMP.GT.77.395)GO TO 321
      SPEC=0.5890+0.002858*(TEMP-61.185)-0.0000165*((TEMP-61.185)**2)
```

```
      GO TO 329
321   IF(TEMP.GT.123.64)GO TO 322
      SPEC=.631-.ØØØØ6635*(TEMP-77.395)+.ØØØØ5Ø53*((TEMP-77.395)**2)
      GO TO 329
322   IF(TEMP.GT.163.975)GO TO 323
      SPEC=.736+.ØØ19923*(TEMP-123.64)+.ØØØØ5325*((TEMP-123.64)**2)
      GO TO 329
323   IF(TEMP.GT.2Ø1.25)GO TO 324
      SPEC=.9Ø3+.ØØØ33931*(TEMP-163.975)+.ØØØ6224*((TEMP-163.975)**2)
      GO TO 329
324   SPEC=3.976
329   CONTINUE
C
      IF(TEMP.GT.81.12)GO TO 341
      HFLV=166.67-Ø.12991*TEMP-Ø.ØØ2Ø31Ø3*TEMP*TEMP
      GO TO 349
341   IF(TEMP.GT.135.59)GO TO 342
      HFLV=164.54-Ø.1Ø958*TEMP-Ø.ØØ195787*TEMP*TEMP
      GO TO 349
342   IF(TEMP.GT.172.54)GO TO 343
      HFLV=1Ø5.ØØ+Ø.73766Ø7*TEMP-Ø.ØØ496746*TEMP*TEMP
      GO TO 349
343   IF(TEMP.GT.187.63)GO TO 344
      HFLV=84.39-(TEMP-172.54)*1.226
      GO TO 349
344   IF(TEMP.GT.2Ø1.25)GO TO 345
      HFLV=65.88-(TEMP-187.63)*2.472
      GO TO 349
345   HFLV=32.21-(TEMP-2Ø1.25)*6.341
349   CONTINUE
C
      IF(TEMP.GT.77.395)GO TO 381
      DLDT=(.Ø53+.ØØØØ9Ø42*(TEMP-61.185)+.ØØØØ1726*((TEMP-61.185)**2))
     * /1ØØØ.Ø
      GO TO 389
381   IF(TEMP.GT.123.64)GO TO 383
      DLDT=(.Ø59+.ØØØ54482*(TEMP-77.395)+.ØØØØØ178*((TEMP-77.395)**2))
     * /1ØØØ.
      GO TO 389
383   IF(TEMP.GT.163.975)GO TO 385
      DLDT=(.Ø88+.ØØØ33791*(TEMP-123.64)
     * +.ØØØØ3895*((TEMP-123.64)**2))/1ØØØ.Ø
      GO TO 389
385   IF(TEMP.GT.2Ø1.25)GO TO 386
      DLDT=(.165+.ØØØ61313*(TEMP-163.975)+.ØØØ37422*((TEMP-163.975)**
     * 2))/1ØØØ.Ø
      GO TO 389
386   DLDT=Ø.ØØ3496
389   GO TO 899
C
C     PROPERTIES OF ELHYLENE OXIDE
C
391   IF(TEMP.GE.16Ø.Ø)GO TO 713
      PREF=12.784-Ø.2172*TEMP+Ø.ØØ475*TEMP*TEMP
      VVAP=585.Ø7/TEMP+Ø.ØØ48*TEMP-3.1188
      DVDT=-585.Ø7/(TEMP*TEMP)+Ø.ØØ48
      GO TO 72Ø
713   IF(TEMP.GE.28Ø.Ø)GO TO 715
      PREF=191.52-2.423*TEMP+Ø.Ø1156*TEMP*TEMP
      VVAP=541.67/TEMP+Ø.ØØ373*TEMP-2.6762
```

```
      DVDT=-541.7/(TEMP*TEMP)+Ø.ØØ37
      GO TO 72Ø
715   PREF=658.24-5.8526*TEMP+Ø.Ø1785*TEMP*TEMP
      VVAP=382.63/TEMP+Ø.ØØ1477*TEMP-1.478Ø
      DVDT=-382.6/(TEMP*TEMP)+Ø.ØØ15
72Ø   CONTINUE
C
      IF(TEMP.GE.265.Ø)GO TO 723
      SPEC=Ø.46754-.ØØØ386*TEMP+Ø.ØØØØØ53*TEMP*TEMP
      GO TO 73Ø
723   SPEC=Ø.565Ø79-Ø.ØØØ9733*TEMP+Ø.ØØØØØ62*TEMP*TEMP
73Ø   CONTINUE
C
      IF(TEMP.GE.13Ø.Ø)GO TO 733
      SPLQ=(18.2ØØ+Ø.Ø1195*(TEMP-7Ø.)+Ø.ØØØØ672*(TEMP-7Ø.)**2)/1ØØØ.Ø
      GO TO 74Ø
733   IF(TEMP.GE.19Ø.Ø)GO TO 734
      SPLQ=(19.159+Ø.Ø21Ø8*(TEMP-13Ø.)+Ø.ØØØØ65*(TEMP-13Ø.)**2)/1ØØØ.
      GO TO 74Ø
734   IF(TEMP.GT.25Ø.Ø)GO TO 735
      SPLQ=(2Ø.658+Ø.Ø2888*(TEMP-19Ø.)+Ø.ØØØØ828*(TEMP-19Ø.)**2)/1ØØØ.
      GO TO 74Ø
735   IF(TEMP.GT.31Ø.Ø)GO TO 736
      SPLQ=(22.689+Ø.Ø3543*(TEMP-25Ø.)+Ø.ØØØ273*(TEMP-25Ø.)**2)/1ØØØ.
      GO TO 74Ø
736   IF(TEMP.GT.37Ø.Ø)GO TO 737
      SPLQ=(25.799+Ø.Ø6Ø*(TEMP-31Ø.Ø)+Ø.ØØ1*(TEMP-31Ø.Ø)**2)/1ØØØ.Ø
      GO TO 74Ø
737   SPLQ=Ø.Ø32999+Ø.ØØ12499*(TEMP-37Ø.Ø)
74Ø   CONTINUE
C
      IF(TEMP.GE.25Ø.Ø)GO TO 743
      HFLV=261.Ø4-Ø.2219*TEMP-Ø.ØØØ451*TEMP*TEMP
      GO TO 75Ø
743   HFLV=11Ø.94+Ø.995*TEMP-Ø.ØØ2917*TEMP*TEMP
75Ø   CONTINUE
C
      IF(TEMP.GE.115.Ø)GO TO 773
      DLDT=(7.95+.1997*(TEMP-51.)-Ø.ØØØ668*((TEMP-51.)**2))/(1Ø.**6)
      GO TO 78Ø
773   IF(TEMP.GE.175.Ø)GO TO 774
      DLDT=(18.+.1865*(TEMP-115.)-.ØØØ628*((TEMP-115.)**2))/(1Ø.**6)
      GO TO 78Ø
774   IF(TEMP.GT.235.Ø)GO TO 775
      DLDT=(26.93+.1393*(TEMP-175.)+.ØØØ289*((TEMP-175.)**2))/
     *(1Ø.**6)
      GO TO 78Ø
775   IF(TEMP.GT.295.)GO TO 776
      DLDT=(36.33+.Ø91667*(TEMP-235.)+.ØØ5Ø56*((TEMP-235.)**2))/
     *(1Ø.**6)
      GO TO 78Ø
776   IF(TEMP.GT.37Ø.Ø)GO TO 777
      DLDT=(6Ø.Ø3+.4985*(TEMP-295.)+.Ø16683*((TEMP-295.)**2))/
     *(1Ø.**6)
      GO TO 78Ø
777   DLDT=Ø.ØØ125
78Ø   GO TO 899
C
C     PROPERTIES OF PROPYLENE
C
```

```
811     IF(TEMP.GT.80.0)GO TO 813
        F=TEMP-40.0
        PREF=96.52+1.5303*F+0.0106*F*F
        SPEC=0.5817-0.0007975*F+0.0000334*F*F
        SPLQ=(29633.0+60.13*F-0.2*F*F)/10.0**6
        HFLV=160.1-0.458250*F+0.000088*F*F
        VVAP=1.141923-0.017456*F+0.000113*F*F
        DVDT=-(18349.0-329.625*F+2.36375*F*F)/10.0**6
        DLDT=(48.05+0.4005*F)/10.0**6
        GO TO 899
C
813     IF(TEMP.GT.120.0)GO TO 814
        F=TEMP-80.0
        PREF=174.71+2.3750*F+0.01343*F*F
        SPEC=0.6032+0.0010350*F-0.0000160*F*F
        SPLQ=(31716.0+56.03*F+0.4*F*F)/10.0**6
        HFLV=141.91-0.475250*F-0.001263*F*F
        VVAP=0.624061-0.008598*F+0.000050*F*F
        DVDT=-(8496.0-138.400*F+0.933*F*F)/10.0**6
        DLDT=(64.07+0.2003*F+0.010013*F*F)/10.0**6
        GO TO 899
C
314     IF(TEMP.GT.160.0)GO TO 815
        F=TEMP-120.0
        PREF=291.19+3.4445*F+0.01750*F*F
        SPEC=0.6190-0.000385*F+0.000206*F*F
        SPLQ=(34599.0+100.15*F+1.0*F*F)/10.0**6
        HFLV=120.88-0.479250*F-0.006388*F*F
        VVAP=0.359924-0.004661*F+0.000018*F*F
        DVDT=-(4902.0-60.750*F+0.553*F*F)/10.0**6
        DLDT=(88.10+2.6025*F-0.010000*F*F)/10.0**6
        GO TO 899
C
815     IF(TEMP.GT.180.0)GO TO 816
        F=TEMP-160.0
        PREF=456.97+4.8570*F+0.02160*F*F
        SPEC=0.9328+0.010760*F+0.000432*F*F
        SPLQ=(40205.0+128.15*F+4.81*F*F)/10.0**6
        HFLV=91.49-1.038500*F-0.013550*F*F
        VVAP=0.202948-0.003356*F+0.0000056*F*F
        DVDT=-(3356.0-14.400*F+0.320*F*F)/10.0**6
        DLDT=(176.20-1.2020*F+0.600700*F*F)/10.0**6
        GO TO 899
C
816     F=TEMP-180.0
        PREF=562.75+5.6680*F+0.03460*F*F
        SPEC=1.3208+0.020692*F+0.011466*F*F
        SPLQ=(44690.0-1048.19*F+156.08*F*F)/10.0**6
        HFLV=65.30+0.986603*F-0.278960*F*F
        VVAP=0.138075-0.0023618*F-0.0000842*F*F
        DVDT=-(3196.0-3.832*F+6.003*F*F)/10.0**6
        DLDT=(392.44-92.23676*F+20.519276*F*F)/10.0**6
        IF(TEMP.GE.190.0)GO TO 899
        G=TEMP-170.0
        SPLQ=(41967.0+152.15*G+12.02*G*G)/10.0**6
        HFLV=79.75-1.266*G-0.0179*G*G
        DLDT=(224.25-31.2495*G+4.80685*G*G)/10.0**6
        GO TO 899
C
C       PROPERTIES OF PROPYLENE OXIDE
```

```
C
821     IF(TEMP.GT.16Ø.Ø)GO TO 822
        F=TEMP-4Ø.Ø
        PREF=4.4+Ø.Ø5667*F+Ø.ØØ2417*F*F
        SPEC=Ø.482+Ø.ØØ1167*F+Ø.ØØØØØ17*F*F
        SPLQ=(1885Ø.Ø+14.667*F+Ø.Ø14*F*F)/1Ø.Ø**6
        HFLV=216.Ø-Ø.24*F
        VVAP=19.31187-23.264172*F/(42.585136+F)
        DVDT=-(Ø.364ØØ-Ø.523542*F/(69.8Ø3922+F))
        DLDT=(14.Ø+Ø.Ø3333*F)/1Ø.Ø**6
        GO TO 899
C
822     IF(TEMP.GT.28Ø.Ø)GO TO 823
        F=TEMP-16Ø.Ø
        PREF=46.Ø+Ø.55ØØØ*F+Ø.ØØ75ØØ*F*F
        SPEC=Ø.646+Ø.ØØ12583*F+Ø.ØØØØ135*F*F
        SPLQ=(2Ø81Ø.Ø+16.5ØØ*F+Ø.Ø83*F*F)/1Ø.Ø**6
        HFLV=187.2-Ø.24*F-Ø.ØØØ5ØØ*F*F
        VVAP=2.14117-2.993435*F/(9Ø.529783+F)
        DVDT=-(Ø.Ø33ØØ-Ø.Ø478Ø1*F/(87.Ø79646+F))
        DLDT=(18.Ø+Ø.Ø9167*F+Ø.ØØØ69*F*F)/1Ø.Ø**6
        GO TO 899
C
823     F=TEMP-28Ø.Ø
        PREF=22Ø.Ø+1.55556*F+Ø.Ø18519*F*F
        SPEC=Ø.991+Ø.ØØ21944*F+Ø.ØØØØØ76*F*F
        SPLQ=(2399Ø.Ø+11.556*F+Ø.752*F*F)/1Ø.Ø**6
        HFLV=151.2-Ø.19*F-Ø.ØØ6333*F*F
        VVAP=Ø.43494-Ø.899Ø8Ø*F/(188.41Ø256+F)
        DVDT=-(Ø.ØØ53Ø-Ø.Ø1472Ø*F/(324.Ø+F))
        DLDT=(39.Ø+Ø.443567*F+141.867*F**4/1Ø.Ø**8)/1Ø.Ø**6
825     GO TO 899
C
C       PROPERTIES OF 1,3-BUTADIENE
C
831     IF(TEMP.GT.8Ø.Ø)GO TO 832
        F=TEMP-4Ø.Ø
        PREF=2Ø.49+Ø.4Ø325Ø*F+Ø.ØØ3888*F*F
        SPEC=Ø.522+Ø.ØØØ7ØØ*F
        SPLQ=(25Ø3Ø.Ø+26.25*F+Ø.Ø375*F*F)/1Ø.Ø**6
        HFLV=174.89-Ø.229ØØ*F-Ø.ØØØ525*F*F
        VVAP=4.61652-6.65973*F/(75.24724+F)
        DVDT=-(Ø.Ø9Ø5-Ø.13Ø55ØØ*F/(59.847328+F))
        DLDT=(26.Ø+Ø.Ø65Ø*F+Ø.ØØ1ØØ*F*F)/1Ø.Ø**6
        GO TO 899
C
832     IF(TEMP.GT.12Ø.Ø)GO TO 833
        F=TEMP-8Ø.Ø
        PREF=42.84+Ø.71425*F+Ø.ØØ5438*F*F
        SPEC=Ø.55Ø+Ø.ØØØ775*F+Ø.ØØØØØ13*F*F
        SPLQ=(2614Ø.Ø+3Ø.75*F+Ø.Ø625*F*F)/1Ø.Ø**6
        HFLV=164.89-Ø.25775*F-Ø.ØØØ613*F*F
        VVAP=2.3Ø5Ø6-3.38Ø68*F/(89.63582+F)
        DVDT=-(Ø.Ø382-Ø.Ø55455Ø*F/(7Ø.9Ø9Ø91+F))
        DLDT=(3Ø.2+Ø.15ØØ*F+Ø.ØØØØØ*F*F)/1Ø.Ø**6
        GO TO 899
C
833     IF(TEMP.GT.16Ø.Ø)GO TO 834
        F=TEMP-12Ø.Ø
        PREF=8Ø.11+1.14975*F+Ø.ØØ7Ø63*F*F
```

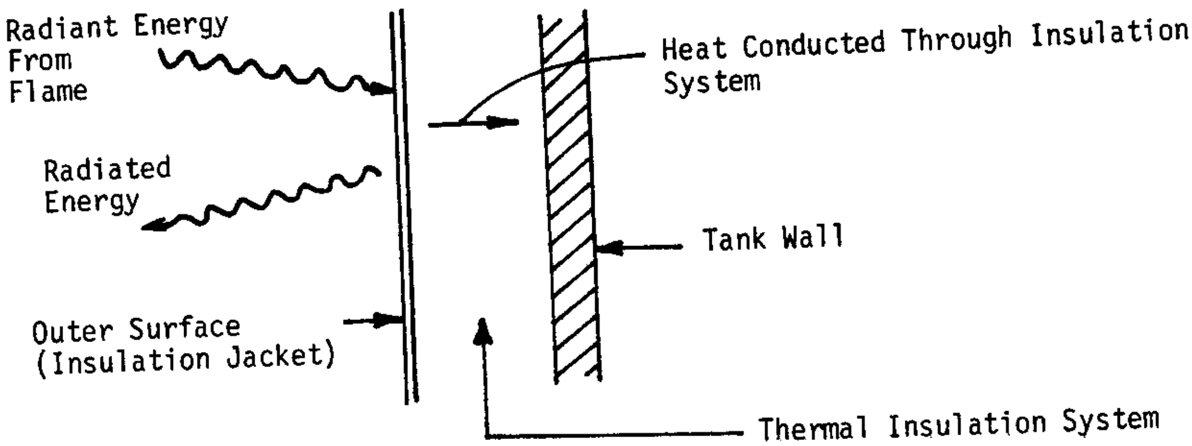
```
      SPEC=Ø.583+Ø.ØØØ875*F+Ø.ØØØØØ13*F*F
      SPLQ=(2747Ø.Ø+35.5Ø*F+Ø.125Ø*F*F)/1Ø.Ø**6
      HFLV=153.6Ø-Ø.3Ø825*F-Ø.ØØØ613*F*F
      VVAP=1.26193-1.92821*F/(1Ø6.71ØØ5+F)
      DVDT=-(Ø.Ø182-Ø.Ø26237Ø*F/(82.891566+F))
      DLDT=(36.2+Ø.1975*F+Ø.ØØØ88*F*F)/1Ø.Ø**6
      GO TO 899
C
834   IF(TEMP.GT.2ØØ.Ø)GO TO 835
      F=TEMP-16Ø.Ø
      PREF=137.4Ø+1.7215Ø*F+Ø.ØØ89ØØ*F*F
      SPEC=Ø.62Ø+Ø.ØØ15ØØ*F
      SPLQ=(29Ø9Ø.Ø+45.ØØ*F+Ø.2ØØØ*F*F)/1Ø.Ø**6
      HFLV=14Ø.29-Ø.36275*F-Ø.ØØ1113*F*F
      VVAP=Ø.73621-1.2Ø622*F/(126.5Ø152+F)
      DVDT=-(Ø.ØØ966-Ø.Ø1Ø3113*F/(65.217391+F))
      DLDT=(45.5+Ø.2825*F+Ø.ØØØ88*F*F)/1Ø.Ø**6
      GO TO 899
C
835   IF(TEMP.GT.24Ø.Ø)GO TO 836
      F=TEMP-2ØØ.Ø
      PREF=22Ø.5Ø+2.5125Ø*F+Ø.Ø13125*F*F
      SPEC=Ø.68Ø+Ø.ØØ1325*F+Ø.ØØØØØ88*F*F
      SPLQ=(3121Ø.Ø+52.25*F+Ø.3625*F*F)/1Ø.Ø**6
      HFLV=124.ØØ-Ø.255ØØ*F-Ø.ØØ385Ø*F*F
      VVAP=Ø.44643-Ø.723699*F/(118.45396+F)
      DVDT=-(Ø.ØØ574-Ø.ØØ827Ø7*F/(121.37931+F))
      DLDT=(58.2+Ø.185*F+Ø.Ø1525*F*F)/1Ø.Ø**6
      GO TO 899
C
836   F=TEMP-24Ø.Ø
      PREF=342.ØØ+3.7ØØØØ*F+Ø.ØØ75ØØ*F*F
      SPEC=Ø.747+Ø.ØØ255Ø*F+Ø.ØØØØ175*F*F
      SPLQ=(3388Ø.Ø+87.5Ø*F+1.5ØØØ*F*F)/1Ø.Ø**6
      HFLV=1Ø7.64-Ø.58Ø5Ø*F-Ø.ØØ8325*F*F
      VVAP=Ø.26374-1.331294*F/(362.72Ø7Ø+F)
      DVDT=-(Ø.ØØ369-Ø.ØØ299ØØ*F/(133.33333+F))
      DLDT=(9Ø.Ø+1.525*F+Ø.Ø4875*F*F)/1Ø.Ø**6
      GO TO 899
C
C
C     PROPERTIES OF VINYL CHLORIDE
C
841   IF(TEMP.GT.1ØØ.Ø)GO TO 842
      F=TEMP-4Ø.Ø
      PREF=29.4Ø+Ø.71ØØ*F+Ø.ØØ2778*F*F
      SPEC=Ø.3Ø34+Ø.ØØØ688*F
      SPLQ=(171ØØ.Ø+14.33*F+Ø.Ø33Ø*F*F)/1Ø.Ø**6
      HFLV=135.9Ø-Ø.2117Ø*F+Ø.ØØØ167*F*F
      VVAP=2.482-2.8944Ø*F/(49.1542Ø+F)
      DVDT=-(Ø.Ø46Ø-Ø.Ø532*F/(27.Ø466+F))
      DLDT=(13.Ø+Ø.Ø93Ø*F+Ø.ØØØ6Ø*F*F)/1Ø.Ø**6
      GO TO 899
C
842   IF(TEMP.GT.14Ø.Ø)GO TO 843
      F=TEMP-1ØØ.Ø
      PREF=82.ØØ+Ø.925ØØ*F+Ø.ØØ875Ø*F*F
      SPEC=Ø.3445+Ø.ØØØ678*F
      SPLQ=(18Ø8Ø.Ø+22.5Ø*F+Ø.Ø25Ø*F*F)/1Ø.Ø**6
      HFLV=123.8Ø-Ø.175ØØ*F-Ø.ØØ1ØØØ*F*F
```

```
      VVAP=0.89100-1.91450*F/(179.42860+F)
      DVDT=-(0.0093-0.0156*F/(220.000+F))
      DLDT=(20.6+0.1425*F+0.00010*F*F)/10.0**6
      GO TO 899
C
843   IF(TEMP.GT.180.0)GO TO 844
      F=TEMP-140.0
      PREF=133.00+1.57500*F+0.008750*F*F
      SPEC=0.3718+0.000688*F
      SPLQ=(19020.0+23.25*F+0.1880*F*F)/10.0**6
      HFLV=115.20-0.25000*F-0.000500*F*F
      VVAP=0.542-0.84230*F/(122.75860+F)
      DVDT=-(0.0069-0.0099000*F/(96.00+F))
      DLDT=(26.5+0.1925*F+0.0011*F*F)/10.0**6
      GO TO 899
C
844   IF(TEMP.GT.220.0)GO TO 845
      F=TEMP-180.0
      PREF=210.00+2.32500*F+0.016250*F*F
      SPEC=0.3991+0.000685*F
      SPLQ=(20250.0+34.00*F+0.2250*F*F)/10.0**6
      HFLV=104.40-0.2950*F-0.001500*F*F
      VVAP=0.33500-0.61920*F/(152.00+F)
      DVDT=-(0.00400-0.0120*F/(280.00+F))
      DLDT=(36.0+0.2500*F+0.00500*F*F)/10.0**6
      GO TO 899
C
845   F=TEMP-220.0
      PREF=329.00+3.52500*F+0.023750*F*F
      SPEC=0.4265+0.000678*F
      SPLQ=(21970.0+52.25*F+0.4130*F*F)/10.0**6
      HFLV=90.20-0.27500*F-0.004250*F*F
      VVAP=0.20600-0.386200*F/(155.556+F)
      DVDT=-(0.00250-0.0020*F/(60.00+F))
      DLDT=(54.0+3.200*F-0.080*F*F)/10.0**6
      GO TO 899
C
C
C     PROPERTIES OF MONOMETHYLAMINE
C
851   IF(TEMP.GT.86.0)GO TO 852
      F=TEMP-50.0
      PREF=29.87+0.6372*F+0.006728*F*F
      SPEC=0.772+0.000806*F+0.0000077*F*F
      SPLQ=(23740.0+23.89*F+0.0310*F*F)/10.0**6
      HFLV=347.00-0.45830*F-0.000463*F*F
      VVAP=5.653-6.95910*F/(57.0977+F)
      DVDT=-(0.1020-0.0820*F/(21.913+F))
      DLDT=(23.33+0.093*F)/10.0**6
      GO TO 899
C
852   IF(TEMP.GT.122.0)GO TO 853
      F=TEMP-86.0
      PREF=61.53+0.9669*F+0.013627*F*F
      SPEC=0.811+0.001167*F+0.0000031*F*F
      SPLQ=(24640.0+26.11*F+0.0620*F*F)/10.0**6
      HFLV=329.9-0.5083*F-0.000463*F*F
      VVAP=2.962-3.5983*F/(61.7659+F)
      DVDT=-(0.0510-0.1167*F/(132.0+F))
      DLDT=(26.66+0.0930*F)/10.0**6
```

```
      GO TO 899
C
853   IF(TEMP.GT.15Ø.Ø)GO TO 854
      F=TEMP-122.Ø
      PREF=114.ØØ+1.8925Ø*F+Ø.ØØ9451*F*F
      SPEC=Ø.857+Ø.ØØ1132*F+Ø.ØØØØØ16*F*F
      SPLQ=(2566Ø.Ø+3Ø.2Ø*F+Ø.Ø44Ø*F*F)/1Ø.Ø**6
      HFLV=311.ØØ-Ø.5516*F-Ø.ØØ3132*F*F
      VVAP=1.637-2.33Ø9*F/(95.6Ø76+F)
      DVDT=-(Ø.Ø26Ø-Ø.Ø25Ø*F/(33.5Ø63+F))
      DLDT=(3Ø.ØØ+Ø.Ø92Ø*F)/1Ø.Ø**6
      GO TO 899
C
854   IF(TEMP.GT.18Ø.Ø)GO TO 855
      F=TEMP-15Ø.Ø
      PREF=174.4Ø+2.4267*F+Ø.Ø15111*F*F
      SPEC=Ø.89Ø+Ø.ØØ1467*F
      SPLQ=(2654Ø.Ø+32.67*F+Ø.Ø44Ø*F*F)/1Ø.Ø**6
      HFLV=293.1-Ø.6933*F-Ø.ØØ3111*F*F
      VVAP=1.1Ø9-1.6613*F/(116.1538+F)
      DVDT=-(Ø.Ø146-Ø.Ø224*F/(9Ø.Ø+F))
      DLDT=(32.59+Ø.Ø93*F)/1Ø.Ø**6
      GO TO 899
C
855   IF(TEMP.GT.21Ø.Ø)GO TO 856
      F=TEMP-18Ø.Ø
      PREF=26Ø.8Ø+3.2867*F+Ø.Ø16444*F*F
      SPEC=Ø.934+Ø.ØØ1367*F+Ø.ØØØØØ22*F*F
      SPLQ=(2756Ø.Ø+35.33*F+Ø.Ø44Ø*F*F)/1Ø.Ø**6
      HFLV=269.5Ø-Ø.87Ø*F-Ø.ØØ2ØØØ*F*F
      VVAP=Ø.768-1.1124*F/(125.2174+F)
      DVDT=-(Ø.ØØ9ØØ-Ø.Ø144*F/(1Ø5.Ø+F))
      DLDT=(35.37+Ø.Ø93*F)/1Ø.Ø**6
      GO TO 899
C
856   F=TEMP-21Ø.Ø
      PREF=374.2Ø+4.568*F+Ø.Ø2496Ø*F*F
      SPEC=Ø.977+Ø.ØØ13ØØ*F+Ø.ØØØØØ67*F*F
      SPLQ=(2866Ø.Ø+32.67*F+Ø.4*F*F)/1Ø.Ø**6
      HFLV=241.6Ø-Ø.9667*F-Ø.ØØ1778*F*F
      VVAP=Ø.553-3.978Ø*F/(75Ø.Ø+F)
      DVDT=-(Ø.ØØ58Ø-Ø.ØØ91*F/(18Ø.Ø+F))
      DLDT=(38.14+Ø.Ø93*F)/1Ø.Ø**6
      GO TO 899
C
899   RETURN
      END
```

4.2 SUBROUTINE SURFACET

Subroutine SURFACET is used to calculate the surface temperature of the outside of the insulated tank which is engulfed in the fire. It is assumed that the dominant mechanism for the transfer of heat to the outer surface is by radiation from the flame. It is also assumed that a quasi-steady state condition exists for the transfer of heat from the outer surface of the insulation system to the steel wall of the tank. The subroutine uses an iterative solution of the equation defining a heat balance at the outer surface to determine the temperature of the surface. The heat balance is illustrated as follows:



The following equation represents a heat balance at the outer surface of the insulation system:

$$0.48\ [T_f^4\ \varepsilon_a - T_s^4\ \varepsilon_r] = [T_s - T_t]\ \ C_d/3.6 \qquad (11)$$

where T_f is flame temperature (°R/1000)

T_s is surface temperature (°R/1000)

T_t is tank wall temperature (°R/1000)

C is conductance of thermal shield (BTU/hr-ft²-°F)

ε_a is the absorptivity of outer surface

ε_r is the emissivity of outer surface

The principal parameters used in the subroutine are defined as follows:

TFLA	Flame temperature (°R/1000)
TCAL	Surface temperature (°R/1000)
TINS	Tank wall temperature (°R/1000)
COND	Conductance of thermal shield (BTU/hr-ft^2-°F)
EABS	Absorptivity of outer surface
ERAD	Emissivity of outer surface

```
      SUBROUTINE SURFACET(TCAL,TINS,EABS,ERAD,COND,TFLA)
C
C
C     DETERMINE THE TEMPERATURE OF THE OUTER SURFACE OF THE
C        WALL OF THE TANK, TCAL, BY AN ITERATIVE
C        SOLUTION OF THE EQUATION FORMED BY TAKING A HEAT BALANCE
C        AT THIS POINT. NOTE, TINS IS INSIDE WALL TEMPERATURE
C        AT THIS LOCATION.
C
      TCAL=Ø.5ØØ
      TCAL=TCAL-Ø.1
      REFT=(TFLA**4)*Ø.48*EABS+TINS*COND/3.6
      FNCT=(TCAL**4)*Ø.48*ERAD+TCAL*COND/3.6-REFT
      AFWD=Ø.1ØØ
 35   TCAL=TCAL+AFWD
      GNCT=(TCAL**4)*Ø.48*ERAD+TCAL*COND/3.6-REFT
      IF(ABS(FNCT-GNCT).LT.Ø.ØØ1)GO TO 39
      IF(GNCT.LT.Ø.Ø)GO TO 31
      GO TO 37
 31   FNCT=GNCT
      GO TO 35
 37   TCAL=TCAL-AFWD
      AFWD=AFWD/1Ø.Ø
      GO TO 35
 39   RETURN
      END
```

4.3 SUBROUTINE VCAP

Subroutine VCAP is used to calculate liquid flow through the safety relief valve. The liquid flow through the valve is calculated assuming homogeneous isentropic two-phase flow (liquid and vapor). The calculation starts with the fluid conditions at the entry to the valve and integrates the conditions as the pressure and temperature drop when the fluid moves through the valve. The following equation is used:

$$V_1^2 - V_o^2 = 2g \int_o^1 \frac{dp}{\rho} \qquad (12)$$

where V_1 is the flow velocity (ft/sec)

V_o is the entry flow velocity at the valve (ft/sec)

p is pressure (lbs/ft^2)

ρ is the fluid density (lbs/ft^3)

g is the gravitational constant (ft/sec^2)

The integration is carried out along an isentropic path where an integration step equivalent to a 1/2°F drop in temperature of the fluid is used. After each integration step the cross sectional area required to pass a unit mass flow rate is determined. When this area reaches a minimum value in the integration process it is assumed that the critical valve cross section has been reached. This area is related to the cross sectional area of the valve to determine the mass flow rate.

Subroutine VCAP contains algebraic representations of entropy for the liquid and vapor states at saturated conditions for propane, ethylene oxide and propylene. Entropy data was not available for butadiene, vinyl chloride, monomethylamine or propylene oxide. The entropies of these products in the liquid and vapor states were calculated by assuming that the entropy of the liquid under the initial saturated condition had a value of 1.0 and that the entropies at other conditions could be estimated from the following relationships:

$$SL_{t2} = SL_{t1} - 2CP(T_2-T_1)/(T_2+T_1) \quad (13)$$

$$SV_{t2} = SL_{t2} + 2(HFLV_{t2})/(T_2+T_1) \quad (14)$$

where SL_{t2} is the entropy of the liquid at temperature 2 (BTU/lb°R)

SL_{t1} is the entropy of the liquid at temperature 1 (BTU/lb°F)

CP is the average specific heat between temperatures T_1 and T_2 (BTU/lb°R)

SV_{t2} is the entropy of the vapor at temperature 2

HFLV is the heat of vaporization at temperature 2

T_1 and T_2 are temperatures (°R)

Where there is no nitrogen pad present, the velocity, V_o, at the entry to the valve would be assumed to be 0. However, when there is a nitrogen pressure component the saturated condition of the liquid flow through the valve will be reached after the fluid has been given some velocity. Under these conditions V_o in Equation 12 will have a finite value which is estimated from the following formula:

$$V_o = \sqrt{\frac{p}{\rho}\,2g} \quad (15)$$

where ρ is the density of the liquid product (lbs/ft^3)

p is the initial pad pressure (lb/ft^2)

g is the gravitational constant (ft/sec^2)

A listing of the subroutine is presented on the following pages.

```
      SUBROUTINE VCAP(TTNK,PNIT,WOUT,ATEM,KPRD,PREF,SPEC,SPLQ,
     1 HFLV,VVAP,DVDT,DSDT,DELT)
C
C     THIS SUBROUTINE IS USED TO CALCULATE THE LIQUID MASS FLOW
C        RATE THROUGH A SAFETY RELIEF VALVE. HOMOGENEOUS ISENTROPIC
C        FLOW IS ASSUMED. THE PRESENSE OF A NITROGEN PAD PRESSURE
C        IS ALSO TAKEN INTO ACCOUNT.
C
      DEGF=1ØØØ.Ø*TTNK-46Ø.Ø
      TBEG=DEGF
      KCNT=Ø
      GO TO 896
C
C     START WITH INITIAL CONDITIONS; DROP TEMPERATURE BY 1/2 DEGREE
C        AND CALCULATE THE CROSS SECTIONAL VALVE AREA FOR A ONE
C        LB PER SEC MASS FLOW RATE.
C
898   KCNT=1
      ARONE=1ØØØ.Ø
      HTEST=Ø.Ø
      PTEST=PREF
      SSTND=SLIQ
      VLONE=Ø.Ø
      IF(PNIT.LT.Ø.ØØ1)GO TO 897
      VLONE=96.24*SQRT(SPLQ*PNIT)
      ARONE=SPLQ/VLONE
897   ATEST=ARONE
895   DEGF=DEGF-Ø.5
C
896   CALL PROPERTIES(KPRD,DEGF,PREF,SPEC,SPLQ,HFLV,VVAP,DVDT,DSDT)
C
      IF(KPRD.EQ.1)GO TO 824
      IF(KPRD.EQ.3)GO TO 841
      IF(KPRD.GE.4)GO TO 851
C
      IF(DEGF.GE.13Ø.Ø)GO TO 8Ø3
      SLIQ=-Ø.Ø594222+Ø.ØØØ841111*DEGF+Ø.ØØØØØØ1111*DEGF*DEGF
      GO TO 81Ø
8Ø3   IF(DEGF.GE.19Ø.Ø)GO TO 8Ø5
      SLIQ=-Ø.Ø5623+Ø.ØØØ794167*DEGF+Ø.ØØØØØØ2833*DEGF*DEGF
      GO TO 81Ø
8Ø5   IF(DEGF.GE.25Ø.Ø)GO TO 8Ø7
      SLIQ=-Ø.Ø4626556+Ø.ØØØ711111*DEGF+Ø.ØØØØØØ4444*DEGF*DEGF
      GO TO 81Ø
8Ø7   SLIQ=Ø.ØØ984556+Ø.ØØØ25Ø556*DEGF+Ø.ØØØØØ13889*DEGF*DEGF
81Ø   CONTINUE
C
      IF(DEGF.GE.13Ø.Ø)GO TO 813
      SVAP=Ø.5Ø97Ø333-Ø.ØØØ865*DEGF+Ø.ØØØØØ2Ø667*DEGF*DEGF
      GO TO 82Ø
813   IF(DEGF.GE.19Ø.Ø)GO TO 815
      SVAP=Ø.5Ø255333-Ø.ØØØ742833*DEGF+Ø.ØØØØØ155*DEGF*DEGF
      GO TO 82Ø
815   IF(DEGF.GE.25Ø.Ø)GO TO 817
      SVAP=Ø.46Ø964-Ø.ØØØ3Ø1222*DEGF+Ø.ØØØØØØ3778*DEGF*DEGF
      GO TO 82Ø
817   SVAP=Ø.48352Ø-Ø.ØØØ4345*DEGF+Ø.ØØØØØØ55*DEGF*DEGF
82Ø   GO TO 823
C
C     PROPERTIES OF PROPANE
```

```
C
824     IF(DEGF.GT.81.12)GO TO  825
        SLIQ=Ø.99838+Ø.ØØØ6Ø4*DEGF+Ø.ØØØØØ376*DEGF*DEGF
        GO TO 829
825     IF(DEGF.GT.135.59)GO TO 826
        SLIQ=Ø.98298+Ø.ØØ1Ø52*DEGF+Ø.ØØØØØØ58*DEGF*DEGF
        GO TO 829
826     IF(DEGF.GT.172.54)GO TO 827
        SLIQ=1.Ø2457+Ø.ØØØ435*DEGF+Ø.ØØØØØ287*DEGF*DEGF
        GO TO 829
827     IF(DEGF.GT.2Ø1.25)GO TO 828
        SLIQ=1.629Ø2-Ø.ØØ641777*DEGF+Ø.ØØØØ2228*DEGF*DEGF
        GO TO 829
828     SLIQ=1.23985+(DEGF-2Ø1.25)*Ø.ØØ6378
829     CONTINUE
C
        IF(DEGF.GT.81.12)GO TO 832
        SVAP=1.35Ø69-Ø.ØØØ2Ø934*DEGF+Ø.ØØØØØØ37*DEGF*DEGF
        GO TO 839
832     IF(DEGF.GT.135.59)GO TO 833
        SVAP=1.34298-Ø.ØØØØ3735*DEGF-Ø.ØØØØØØ58*DEGF*DEGF
        GO TO 839
833     IF(DEGF.GT.172.54)GO TO 834
        SVAP=1.29831+Ø.ØØØ57Ø1*DEGF-Ø.ØØØØØ263*DEGF*DEGF
        GO TO 839
834     IF(DEGF.GT.2Ø1.25)GO TO 835
        SVAP=Ø.725233+Ø.ØØ7Ø5593*DEGF-Ø.ØØØØ2Ø97*DEGF*DEGF
        GO TO 839
835     SVAP=1.296Ø5-(DEGF-2Ø1.25)*Ø.ØØ4685
839     GO TO 823
C
841     IF(DEGF.GT.8Ø.Ø)GO TO 842
        F=DEGF-4Ø.Ø
        SLIQ=1.Ø6766+Ø.ØØ1Ø783*F+Ø.ØØØØØØ9*F*F
        SVAP=1.386Ø8-Ø.ØØØ325Ø*F+Ø.ØØØØØ13*F*F
        GO TO 849
842     IF(DEGF.GT.12Ø.Ø)GO TO 843
        F=DEGF-8Ø.Ø
        SLIQ=1.11217+Ø.ØØ1Ø975*F-Ø.ØØØØØØ6*F*F
        SVAP=1.375Ø8-Ø.ØØØ171Ø*F-Ø.ØØØØØ26*F*F
        GO TO 849
843     IF(DEGF.GT.16Ø.Ø)GO TO 844
        F=DEGF-12Ø.Ø
        SLIQ=1.155Ø7+Ø.ØØØ925Ø*F+Ø.ØØØØØ55*F*F
        SVAP=1.364Ø8-Ø.ØØØ3ØØØ*F-Ø.ØØØØØ25*F*F
        GO TO 849
844     IF(DEGF.GT.18Ø.Ø)GO TO 845
        F=DEGF-16Ø.Ø
        SLIQ=1.2ØØ87+Ø.ØØ1377Ø*F+Ø.ØØØØ114*F*F
        SVAP=1.348Ø8-Ø.ØØØ55ØØ*F-Ø.ØØØØØ5Ø*F*F
        GO TO 849
845     F=DEGF-18Ø.Ø
        SLIQ=1.23297+Ø.ØØ12273*F+Ø.ØØØ1433*F*F
        SVAP=1.335Ø8+Ø.ØØ12359*F-Ø.ØØØ2Ø36*F*F
        IF(DEGF.GT.19Ø.Ø)GO TO 849
        G=DEGF-17Ø.Ø
        SVAP=1.342Ø8-Ø.ØØØ65ØØ*G-Ø.ØØØØØ5Ø*G*G
849     GO TO 823
C
823     GO TO 86Ø
```

```
C
851       IF(KCNT.EQ.1)GO TO 853
          SLIQ=1.ØØØ
          DGLST=TBEG
          GO TO 86Ø
853       SLIQ=SLIQ+SPEC*(DEGF-DGLST)/((DGLST+DEGF)*Ø.5+459.6)
          SVAP=SLIQ+HFLV/(DEGF+459.6)
          DGLST=DEGF
C
86Ø       IF(KCNT.EQ.Ø)GO TO 898
C
          X=(SSTND-SVAP)/(SLIQ-SVAP)
          VLTST=X*SPLQ+(1.Ø-X)*VVAP
          HTEST=HTEST+(PTEST-PREF)*144.Ø*VLTST*64.4
          VELOCB=SQRT(VLONE**2+HTEST)
          ARTWO=VLTST/VELOCB
          PTEST=PREF
          IF(ARTWO.GT.ATEST.OR.PTEST.LT.14.7)GO TO 821
          ATEST=ARTWO
          GO TO 895
C
C         REPEAT CALCULATIONS UNTIL AREA BECOMES MINIMUM; THEN CALCULA"
C            MASS FLOW RATE.
C
821       WOUT=6Ø.Ø*DELT*ATEM/ATEST
          CALL PROPERTIES(KPRD,TBEG,PREF,SPEC,SPLQ,HFLV,VVAP,DVDT,DSDT
C
          RETURN
          END
```

4.4 SUBROUTINE TSHIELD

Subroutine TSHIELD is used to determine the effective conductance of the thermal shield system which is constructed of a material with a conductivity which is a function of temperature. The subroutine assumes the following functional dependence of conductivity with temperature:

$$K = 0.2 + 0.1938T + 0.6769T^2$$

where T is the temperature in 1000 °F units (°F/1000)
K is the conductivity (BTU-in./hr-ft²-°F)

This relationship gives an approximate tenfold increase in conductivity from 60°F to 1600°F and is representative of the maximum change one would see in a high temperature insulation material used on railroad tank cars. The subroutine requires as input the thickness of the insulation under consideration (THICK) the outer and inner temperature of the insulation system (TOUTR and TINSD, respectively) and the value of the effective conductance that was calculated at the last time step (CNDCT). The output from the subroutine is a calculated value of effective conductance of the thermal shield system which reflects the current temperature distribution through the insulation material.

The subroutine divides the insulation into 50 layers. It then starts at the inside of the shell and using the last value of CNDCT and the heat flux that this implies, it goes through the insulation layer by layer to calculate the outside temperature of the insulation system. If the calculated temperature is not sufficiently a close to TOUTR a new value for the heat flux is assumed and the calculation is repeated. When a sufficiently close value to TOUTR is achieved, it is assumed that the proper heat flux has been established through the insulation material and a new value of the effective conductance (CNDCT) is calculated using the temperature difference across the insulation system.

The principal parameters used in the subroutine are lised as follows:

TOUTR	Temperature of outside of insulation system (°F/1000)
TINSD	Temperature of inside of insulation system (°F/1000)
CNDCT	Effective conductance of insulation system (BTU/hr-ft^2-°F)
THICK	Thickness of insulation system (in.)
CKND	Conductivity of thermal insulation material (BTU-in./hr-ft^2-°F)
QFLX	Heat flux through insulation system (BTU/hr-ft^2)

A listing of the subroutine is presented on the following page.

```
      SUBROUTINE TSHIELD(TOUTR,TINSD,CNDCT,THICK)
C
      QFLX=CNDCT*(TOUTR-TINSD)*1000.0
      KNT=0
      KQT=0
      START=TINSD*1000.0-460.0
      TWALL=START
      TPAST=TOUTR*1000.0-460.0
      TARGET=TOUTR*1000.0-460.0
C
      DELX=THICK/50.
C
100   TL=TWALL/1000.0
      CKND=0.2+0.1938*TL+0.6769*TL*TL
      TWALL=TWALL+QFLX*DELX/CKND
      IF(KNT.EQ.50)GO TO 101
      KNT=KNT+1
      GO TO 100
101   CONTINUE
      KNT=0
C
      IF(ABS(TWALL-TARGET).LT.0.1)GO TO 103
C
      IF(KQT.EQ.1)GO TO 112
      QDELT=ABS(QFLX*(TWALL-TARGET)/TWALL)
      KQT=1
112   CONTINUE
C
      IF(TPAST.LT.TARGET.AND.TWALL.GT.TARGET)QDELT=QDELT/3.0
      IF(TPAST.GT.TARGET.AND.TWALL.LT.TARGET)QDELT=QDELT/3.0
      IF(TWALL.GT.TARGET)QFLX=QFLX-QDELT
      IF(TWALL.LT.TARGET)QFLX=QFLX+QDELT
      TPAST=TWALL
      TWALL=START
      GO TO 100
C
103   CNDCT=QFLX/((TOUTR-TINSD)*1000.0)
      RETURN
      END
```

4.5 SUBROUTINE PLT3

Subroutine PLT3 is a specialized subroutine for constructing plots. It is written solely for use on a Data General Eclipse computer which uses a VERSATEC plotter. A listing of the subroutine is given on the following pages.

[redacted]

```
C---------------------------------------------------------------------------
C PRODUCE ONE PLOT WITH 3 VERTICAL SCALES FOR 3 DATA SETS
C
       SUBROUTINE PLT3 (ICOMMAND, Y1, Y2, Y3, X)
       DIMENSION        ICOMMAND (1)
C
C IF COMMAND EQ 'DATA' THEN PLOT A NEW DATA SET.
C            EQ 'PLOT' THEN START A NEW PLOT PAGE.
C            EQ 'STOP' THEN CLOSE ALL PLOT FILES.
C
C Y1 IS A DATA SET OF THE FIRST  PLOT LINE.
C Y2 IS A DATA SET OF THE SECOND PLOT LINE.
C Y3 IS A DATA SET OF THE THIRD  PLOT LINE.
C X  IS THE COMMON DATA SET FOR ALL Y COORDINATES.
C
C NOTE : THE PLOT COMMANDS ARE CALCOMP CALLS WHICH ARE COMPATABLE
C        WITH ROUTINES FOR THE VERSATEC AND TEKTRONIX LIBRARIES.
C
C---------------------------------------------------------------------------
C
       DIMENSION STORE (4), PLT LAST (4), PLT NEXT (4)
C
C DEFINE THE RANGES FOR ALL SCALES
C
       DIMENSION SCALE 1 (6,3), SCALE 2 (6,3), SCALE 3 (6,3),
     *           SCALE X (6,6)
C
C EACH VERTICAL SCALE HAS 5 UNITS (PLUS THE START EQUALS 6) AND
C      MAY HAVE ONE OF THREE POSSIBLE RANGES.
C
       DATA SCALE 1 /   Ø.Ø,    .2,    .4,    .6,    .8,    1,
     *                  Ø.Ø,    2.,    4.,    6.,    8.,   1Ø,
     *                  Ø.Ø,    2Ø,    4Ø,    6Ø,    8Ø,  1ØØ /
       DATA SCALE 2 /   Ø.Ø,   1ØØ,   2ØØ,   3ØØ,   4ØØ,   5ØØ,
     *                  Ø.Ø,   2ØØ,   4ØØ,   6ØØ,   8ØØ,  1ØØØ,
     *                  Ø.Ø,   3ØØ,   6ØØ,   9ØØ,  12ØØ,  15ØØ /
       DATA SCALE 3 /   Ø.Ø,   2ØØ,   4ØØ,   6ØØ,   8ØØ,  1ØØØ,
     *                  Ø.Ø,   3ØØ,   6ØØ,   9ØØ,  12ØØ,  15ØØ,
     *                  Ø.Ø,   4ØØ,   8ØØ,  12ØØ,  16ØØ,  2ØØØ /
C
C THE HORIZONTAL SCALE ALSO HAS 5 UNITS (PLUS THE START EQUAL 6) AND
C     MAY HAVE ONE OF SIX POSSIBLE RANGES.
C
       DATA SCALE X /     Ø,     5,    1Ø,    15,    2Ø,    25,
     *                    Ø,    1Ø,    2Ø,    3Ø,    4Ø,    5Ø,
     *                    Ø,    2Ø,    4Ø,    6Ø,    8Ø,   1ØØ,
     *                    Ø,    5Ø,   1ØØ,   15Ø,   2ØØ,   25Ø,
     *                    Ø,   1ØØ,   2ØØ,   3ØØ,   4ØØ,   5ØØ,
     *                    Ø,   2ØØ,   4ØØ,   6ØØ,   8ØØ,  1ØØØ /
C
C DEFINE PLOT'S MIN AND MAX STARTING POINTS
C
       DATA XMIN, XMAX, YMIN, YMAX
     *   /  1.5,  6.5,  3.Ø,  8.Ø /
C
C DEFINE PROGRAM INITIAL VARIABLES
C
       DATA ICURRENT, IUSE 1, IUSE 2, IUSE 3, IUSE X
     *   /       Ø,       1,      1,      1,     1/
C
```

```
[redacted]TA IOPEN / Ø /, IUNIT / 7 /
C
C-----------------------------------------------------------------
C SEE IF THE PLOT OR STOP COMMAND IS GIVEN
C
        IF (ICOMMAND (1) .EQ. "PL" .OR. ICOMMAND (1) .EQ. "PL")
     *  GO TO 1ØØ
C
        IF (ICOMMAND (1) .EQ. "ST" .OR. ICOMMAND (1) .EQ. "ST")
     *  GO TO 3ØØ
C
C ON THE FIRST CALL, OPEN UP A SAVE FILE FOR THE DATA SETS.
C
        IF (IOPEN .NE. Ø) GO TO 1Ø
C
        OPEN   IUNIT, "PLT_SAVE.BN"
        REWIND IUNIT
        IOPEN = 1
C
C STORE THE DATA SETS ON THE SAVE FILE
C
1Ø      STORE (1) = Y1
        STORE (2) = Y2
        STORE (3) = Y3
        STORE (4) = X
C
        WRITE BINARY (IUNIT) STORE
C
        ICURRENT  = ICURRENT + 1
C
C SEE WHICH RANGE EACH SCALE WILL BE SET TO
C
        J = IUSE 1
        DO 2Ø I = 3, J, -1
2Ø      IF (Y1 .LE. SCALE 1 (6,I)) IUSE 1 = I
C
        J = IUSE 2
        DO 3Ø I = 3, J, -1
3Ø      IF (Y2 .LE. SCALE 2 (6,I)) IUSE 2 = I
C
        J = IUSE 3
        DO 4Ø I = 3, J, -1
4Ø      IF (Y3 .LE. SCALE 3 (6,I)) IUSE 3 = I
C
        J = IUSE X
        DO 5Ø I = 6, J, -1
5Ø      IF (X  .LE. SCALE X (6,I)) IUSE X = I
C
C       TYPE "SCALES SELECTED ARE", IUSE 1, IUSE 2, IUSE 3, IUSE X
C       TYPE "SCALE 1 MAX =", SCALE 1 (6,IUSE 1)
C       TYPE "SCALE 2 MAX =", SCALE 2 (6,IUSE 2)
C       TYPE "SCALE 3 MAX =", SCALE 3 (6,IUSE 3)
C       TYPE "SCALE X MAX =", SCALE X (6,IUSE X)
C
        RETURN
C
C-----------------------------------------------------------------
C PLOT THE SAVED DATA SET ONTO THE SELECTED SCALES RANGES.
C
1ØØ     TYPE "MAKING PLOT FOR", ICURRENT," DATA POINTS"
```

```
[redacted]WIND IUNIT
C
X       DO 1Ø1 I=1,ICURRENT
X       READ BINARY (IUNIT) STORE
X       TYPE I," DATA =", STORE
X1Ø1    CONTINUE
X       REWIND IUNIT
C
C FIRST PLOT THE BOX WITH THE THREE VERTICAL AND ONE HORIZONTAL SCALES
C
        CALL PLOTS (Ø, Ø, Ø)
C
C DRAW THE BOX WITH THICK SIDES, PLUS AN EXTRA LINE ON THE SIDE
C
        CALL NEWPEN (-3)
C
        CALL PLOT (XMIN, YMIN, 3)
        CALL PLOT (XMIN, YMAX, 2)
        CALL PLOT (XMAX, YMAX, 2)
        CALL PLOT (XMAX, YMIN, 2)
        CALL PLOT (XMIN, YMIN, 2)
C
        CALL PLOT (XMIN - Ø.5, YMIN, 3)
        CALL PLOT (XMIN - Ø.5, YMAX, 2)
C
C DRAW TIC MARKS AROUND THE BOX POINTING INWARDS AND ON THE THIRD SCALE
C
        CALL NEWPEN (1)
C
        IYTIC = 5
        YDIFF = (YMAX - YMIN) / IYTIC
C
        DO 12Ø I = Ø, IYTIC
        TIC = YMIN + (I * YDIFF)
        CALL PLOT (XMIN,        TIC, 3)
        CALL PLOT (XMIN + Ø.1,  TIC, 2)
        CALL PLOT (XMAX,        TIC, 3)
        CALL PLOT (XMAX - Ø.1,  TIC, 2)
        CALL PLOT (XMIN - Ø.5,  TIC, 3)
12Ø     CALL PLOT (XMIN - Ø.57, TIC, 2)
C
        IXTIC = 5
        XDIFF = (XMAX - XMIN) / IXTIC
C
        DO 13Ø I = Ø, IXTIC
        TIC = XMIN + (I * XDIFF)
        CALL PLOT (TIC, YMIN,       3)
        CALL PLOT (TIC, YMIN + Ø.1, 2)
        CALL PLOT (TIC, YMAX,       3)
13Ø     CALL PLOT (TIC, YMAX - Ø.1, 2)
C
C DRAW THE X AXIS 'TIME' WITH INTEGER NUMBERS BELOW THE LINE.
C
        DO 15Ø I = 1, 6
15Ø     CALL NUMBER (XMIN + ((I-1) * XDIFF), YMIN - Ø.2, Ø.1,
     *               SCALE X (I, IUSE X), Ø.Ø, -1)
C
        CALL SYMBOL (XMIN + 1.8, YMIN - Ø.4, Ø.15,
     *               "TIME (MIN)", Ø.Ø, 1Ø)
C
```

```
[illegible] Y1 AXIS 'LIQUID LEVEL' WITH DECIMAL NUMBERS OUTSIDE THE LINE.
C
        DO 16Ø I = 1, 6
16Ø     CALL NUMBER (XMAX + Ø.2, YMIN + ((I-1) * YDIFF)) Ø.1,
     *              SCALE 1 (I, IUSE 1), 9Ø.Ø, +1)
C
        CALL SYMBOL (XMAX + Ø.5, YMIN + 1.7, Ø.15,
     *              "LIQUID LEVEL", 9Ø.Ø, 12)
C
C DRAW THE Y2 AXIS 'PRESURE' WITH INTEGER NUMBERS OUTSIDE THE LINE.
C
        DO 17Ø I = 1, 6
17Ø     CALL NUMBER (XMIN - Ø.1, YMIN + ((I-1) * YDIFF)) Ø.1,
     *              SCALE 2 (I, IUSE 2), 9Ø.Ø, -1)
C
        CALL SYMBOL (XMIN - Ø.25, YMIN + 1.5, Ø.15,
     *              "PRESURE (PSIG)", 9Ø.Ø, 14)
C
C DRAW THE Y3 AXIS 'TANK WALL TEMP' WITH INTEGER NUMBERS OUTSIDE.
C
        DO 18Ø I = 1, 6
18Ø     CALL NUMBER (XMIN - Ø.6, YMIN + ((I-1) * YDIFF)) Ø.1,
     *              SCALE 3 (I, IUSE 3), 9Ø.Ø, -1)
C
        CALL SYMBOL (XMIN - Ø.75, YMIN + 1.Ø, Ø.15,
     *              "TANK WALL TEMP (F )", 9Ø.Ø, 19)
C
        CALL SYMBOL (XMIN - Ø.85, YMIN + 3.55, Ø.Ø5, "O", 9Ø.Ø, 1)
C
C NOW PLOT THE DATA AS THREE SEPARATE LINES.
C
        DO 25Ø NEXT = 1, ICURRENT
        READ BINARY (IUNIT) STORE
C
        PLT NEXT (1) = STORE (1) / SCALE 1 (6, IUSE 1)
        PLT NEXT (2) = STORE (2) / SCALE 2 (6, IUSE 2)
        PLT NEXT (3) = STORE (3) / SCALE 3 (6, IUSE 3)
        PLT NEXT (4) = STORE (4) / SCALE X (6, IUSE X)
C
        DO 22Ø J=1,3
22Ø     PLT NEXT (J) = YMIN + PLT NEXT (J) * (YMAX - YMIN)
        PLT NEXT (4) = XMIN + PLT NEXT (4) * (XMAX - XMIN)
C
        IF (NEXT .EQ. 1) GO TO 24Ø
C
C       CALL NEWPEN (1)
        CALL MODE (1Ø, FLOAT (177777K), 9999., 9999.)
        CALL PLOT (PLT LAST (4), PLT LAST (1), 3)
        CALL PLOT (PLT NEXT (4), PLT NEXT (1), 2)
C
C       CALL NEWPEN (2)
        CALL MODE (1Ø, FLOAT (Ø7Ø7Ø7K), 9999., 9999.)
        CALL PLOT (PLT LAST (4), PLT LAST (2), 3)
        CALL PLOT (PLT NEXT (4), PLT NEXT (2), 2)
C
C       CALL NEWPEN (3)
        CALL MODE (1Ø, FLOAT (1Ø11Ø1K), 9999., 9999.)
        CALL PLOT (PLT LAST (4), PLT LAST (3), 3)
        CALL PLOT (PLT NEXT (4), PLT NEXT (3), 2)
C
```

```
[redacted] 25Ø J=1,4
       PLT LAST (J) = PLT NEXT (J)
25Ø    CONTINUE
C
C FINISH OFF THE CURRENT PLOT AND SET UP FOR A NEW ONE.A
C
       CALL PLOT (Ø.Ø, Ø.Ø, 999)
C
       REWIND IUNIT
C
       ICURRENT = Ø
       IUSE 1   = 1
       IUSE 2   = 1
       IUSE 3   = 1
       IUSE X   = 1
C
       RETURN
C
C-------------------------------------------------------------------------
C STOP ALL PLOTTING PROCESSING.
C
3ØØ    CALL PLOT (Ø.Ø, Ø.Ø, 9999)       ; STOP PLOT PROCESSING
C
       TYPE "TYPE IN 'VCOPY' TO GENERATE A RASTER PLOT."
       RETURN
       END
```

5. SAMPLE PROBLEM

A sample problem is described in this section to illustrate the use of the program. The problem considers the case of a 33,600 gal. Class 105A100W tank car containing 1,3-butadiene, which is in the pool fire environment. It is assumed that the car is overturned 120° so that initially the safety relief valve would vent liquid product. It is also assumed that the thermal insulation system has an effective conductance of 4.0 BTU/hr-ft²-°F and that the safety relief valve has a flow capacity of 20,000 SCFM.

The following table lists the parameters that are entered into the computer to begin the analysis:

TERMINAL PROMPT	ENTERED VALUE
DISPLAY TYPE, LPT-12; CONSOLE-10	12 (10 for second run)
PLOT-2 PRINT TERM OR LPT-1	1 (2 for second run)
PROP-1 EO-2 PROPYL-3 BUTA-4 VC-5 MONO-6 POX-7	4
ANGLE OF TILT (DEG)	120.0
TANK DIAMETER (FT)	9.9
TANK WALL THICKNESS (IN.)	0.5
NOMINAL CAPACITY (GALLS)	33,600.0
INITIAL FRACTION FILLED	0.949
SAFETY VALVE FLOW RATING PRESSURE (PSIA)	99.7
SAFETY VALVE START-TO-DISCHARGE PRESS (PSIA)	89.7
NET ABSORPTIVITY	0.8
NET EMISSIVITY	0.8
TANK BURSTING STRENGTH (PSI)	500.0
CAR CONDUCTANCE (BTU/HR SQFT DEG F)	4.0
SAFETY VALVE RATED FLOW CAPACITY (SCFM,AIR)	20,000.0
TYPE 1 FOR CONSTANT CONDUCT. OR 2 FOR VAR. CND.	1
INITIAL CAR CONDUCTANCE (BTU/HR SQFT DEG F)	0.3
FLAME TEMPERATURE (DEG F)	1,500.0
PRESSURE (PSI) OF NITROGEN PAD	0.0
AREA EXPONENT	1.0
INITIAL TEMPERATURE (DEG F)	60.0
TIME INCREMENT (MIN)	0.1
NUMBER OF TIME STEPS BETWEEN DISPLAY	5 (7 for second run)
GAS COMPRESSIBILITY FACTOR, Z	0.77
VALVE GAS FLOW CONSTANT	0.0692

The problem has been run twice. The first time the output parameters were tabulated every 0.5 minutes. The second time a plot was made of tank wall temperature over vapor space, pressure and liquid fraction remaining as a function of time.

The tabulated output data includes the following information:

<u>Input Conditions</u>

SVPR	Safety valve flow rating pressure (psia)
INIT	Initial temperature (°F)
COND	Input Conductance (BTU/hr-ft²-°F)
SCFM	Valve flow capacity (SCFM)
TEMP	Flame temperature (°F)
SIZE	Car capacity (gallons)
TILT	Angle of safety relief valve from vertical (degrees)
WEIGHT	Initial weight of product (lbs)
THICK	(This parameter applicable only to case of temperature dependent conductivity. Default value of 0.0 is shown.)

<u>Parameters Given as Function of Time</u>

TIME	Time (minutes)
PSIG	Pressure within tank (psig)
TTNK	Temperature of product (°F)
TWAL	Temperature of outside surface of tank in wetted region (°F)
FRAC	Fraction of tank volume occupied by liquid
FMAT	Fraction of original product weight remaining
TVAP	Temperature of tank over vapor space (°F)
WOUT	Mass flow rate through safety valve (lbs/min)
PBRS	Burst strength of tank (psig)
PNIT	Partial pressure of nitrogen padding gas (psi)
KIDN	Identification no. used in program
THETA	Angle of liquid surface from horizontal (radians)
PICR	Parameter associated with liquid flow thorugh valve
CNDLQ	Effective conductance of thermal shield in wetted region (BTU/hr-ft²-°F)
CNDVP	Effective conductance of thermal shield in vapor region (BTU/hr-ft²-°F)
FRACLQ	Fraction of original product weight in liquid state

1,3-BUTADIENE CAR

SVPR	INTT	COND	SCFM	TEMP	SIZE	TILT	WEIGHT	THICK
99.7Ø	6Ø.ØØ	4.ØØ	2ØØØØ.	15ØØ.ØØ	336ØØ.	12Ø.	166786.	.ØØØ

TIME	PSIG	TTNK	TWAL	FRAC	FMAT	TVAP	WOUT	PBRS	PNIT	KIDN	THETA	PICR	CNDLQ	CNDVP	FRACLQ
.5Ø	15.45	6Ø.	1487.	.949	1.ØØØ	62.	Ø.	5ØØ.	.Ø	2	.932	.Ø	.36	.36	1.ØØØ
1.ØØ	15.5Ø	6Ø.	1485.	.949	1.ØØØ	64.	Ø.	5ØØ.	.Ø	2	.932	.Ø	.42	.42	1.ØØØ
1.5Ø	15.55	6Ø.	1483.	.949	1.ØØØ	66.	Ø.	5ØØ.	.Ø	2	.933	.Ø	.48	.48	1.ØØØ
2.ØØ	15.61	6Ø.	1481.	.949	1.ØØØ	68.	Ø.	5ØØ.	.Ø	2	.933	.Ø	.55	.55	1.ØØØ
2.5Ø	15.67	6Ø.	1479.	.949	1.ØØØ	71.	Ø.	5ØØ.	.Ø	2	.934	.Ø	.61	.61	1.ØØØ
3.ØØ	15.75	61.	1477.	.95Ø	1.ØØØ	74.	Ø.	5ØØ.	.Ø	2	.935	.Ø	.67	.67	1.ØØØ
3.5Ø	15.83	61.	1475.	.95Ø	1.ØØØ	77.	Ø.	5ØØ.	.Ø	2	.935	.Ø	.73	.73	1.ØØØ
4.ØØ	15.91	61.	1472.	.95Ø	1.ØØØ	81.	Ø.	5ØØ.	.Ø	2	.936	.Ø	.79	.79	1.ØØØ
4.5Ø	16.ØØ	61.	147Ø.	.95Ø	1.ØØØ	84.	Ø.	5ØØ.	.Ø	2	.936	.Ø	.85	.85	1.ØØØ
5.ØØ	16.11	61.	1468.	.95Ø	1.ØØØ	88.	Ø.	5ØØ.	.Ø	2	.937	.Ø	.92	.92	1.ØØØ
5.5Ø	16.21	61.	1466.	.95Ø	1.ØØØ	93.	Ø.	5ØØ.	.Ø	2	.938	.Ø	.98	.98	1.ØØØ
6.ØØ	16.33	62.	1464.	.951	1.ØØØ	97.	Ø.	5ØØ.	.Ø	2	.939	.Ø	1.Ø4	1.Ø4	1.ØØØ
6.5Ø	16.45	62.	1462.	.951	1.ØØØ	1Ø2.	Ø.	5ØØ.	.Ø	2	.94Ø	.Ø	1.1Ø	1.1Ø	1.ØØØ
7.ØØ	16.58	62.	146Ø.	.951	1.ØØØ	1Ø7.	Ø.	5ØØ.	.Ø	2	.941	.Ø	1.16	1.16	1.ØØØ
7.5Ø	16.71	62.	1458.	.951	1.ØØØ	112.	Ø.	5ØØ.	.Ø	2	.942	.Ø	1.22	1.22	1.ØØØ
8.ØØ	16.86	63.	1455.	.952	1.ØØØ	117.	Ø.	5ØØ.	.Ø	2	.944	.Ø	1.29	1.29	1.ØØØ
8.5Ø	17.Ø1	63.	1453.	.952	1.ØØØ	123.	Ø.	5ØØ.	.Ø	2	.944	.Ø	1.35	1.35	1.ØØØ
9.ØØ	17.16	63.	1451.	.952	1.ØØØ	129.	Ø.	5ØØ.	.Ø	2	.946	.Ø	1.41	1.41	1.ØØØ
9.5Ø	17.33	63.	1449.	.952	1.ØØØ	135.	Ø.	5ØØ.	.Ø	2	.948	.Ø	1.47	1.47	1.ØØØ
1Ø.ØØ	17.5Ø	64.	1447.	.953	1.ØØØ	141.	Ø.	5ØØ.	.Ø	2	.948	.Ø	1.53	1.53	1.ØØØ
1Ø.5Ø	17.68	64.	1445.	.953	1.ØØØ	148.	Ø.	5ØØ.	.Ø	2	.95Ø	.Ø	1.59	1.59	1.ØØØ
11.ØØ	17.87	64.	1443.	.953	1.ØØØ	155.	Ø.	5ØØ.	.Ø	2	.952	.Ø	1.66	1.66	1.ØØØ
11.5Ø	18.Ø6	65.	144Ø.	.954	1.ØØØ	161.	Ø.	5ØØ.	.Ø	2	.953	.Ø	1.72	1.72	1.ØØØ
12.ØØ	18.27	65.	1438.	.954	1.ØØØ	169.	Ø.	5ØØ.	.Ø	2	.955	.Ø	1.78	1.78	1.ØØØ
12.5Ø	18.48	65.	1436.	.955	1.ØØØ	176.	Ø.	5ØØ.	.Ø	2	.956	.Ø	1.84	1.84	1.ØØØ
13.ØØ	18.7Ø	66.	1434.	.955	1.ØØØ	183.	Ø.	5ØØ.	.Ø	2	.959	.Ø	1.9Ø	1.9Ø	1.ØØØ
13.5Ø	18.93	66.	1432.	.955	1.ØØØ	191.	Ø.	5ØØ.	.Ø	2	.96Ø	.Ø	1.96	1.96	1.ØØØ
14.ØØ	19.16	66.	143Ø.	.956	1.ØØØ	199.	Ø.	5ØØ.	.Ø	2	.962	.Ø	2.Ø3	2.Ø3	1.ØØØ
14.5Ø	19.4Ø	67.	1428.	.956	1.ØØØ	2Ø7.	Ø.	5ØØ.	.Ø	2	.964	.Ø	2.Ø9	2.Ø9	1.ØØØ
15.ØØ	19.66	67.	1426.	.957	1.ØØØ	215.	Ø.	499.	.Ø	2	.967	.Ø	2.15	2.15	1.ØØØ
15.5Ø	19.91	68.	1424.	.957	1.ØØØ	223.	Ø.	499.	.Ø	2	.968	.Ø	2.21	2.21	1.ØØØ
16.ØØ	2Ø.18	68.	1421.	.957	1.ØØØ	231.	Ø.	499.	.Ø	2	.971	.Ø	2.27	2.27	1.ØØØ
16.5Ø	2Ø.46	69.	1419.	.958	1.ØØØ	24Ø.	Ø.	499.	.Ø	2	.973	.Ø	2.33	2.33	1.ØØØ
17.ØØ	2Ø.75	69.	1417.	.958	1.ØØØ	249.	Ø.	499.	.Ø	2	.976	.Ø	2.4Ø	2.4Ø	1.ØØØ
17.5Ø	21.Ø4	69.	1415.	.959	1.ØØØ	257.	Ø.	499.	.Ø	2	.978	.Ø	2.46	2.46	1.ØØØ
18.ØØ	21.34	7Ø.	1413.	.959	1.ØØØ	266.	Ø.	499.	.Ø	2	.98Ø	.Ø	2.52	2.52	1.ØØØ
18.5Ø	21.66	7Ø.	1411.	.96Ø	1.ØØØ	275.	Ø.	498.	.Ø	2	.983	.Ø	2.58	2.58	1.ØØØ
19.ØØ	21.98	71.	14Ø9.	.96Ø	1.ØØØ	284.	Ø.	498.	.Ø	2	.986	.Ø	2.64	2.64	1.ØØØ
19.5Ø	22.31	71.	14Ø7.	.961	1.ØØØ	293.	Ø.	498.	.Ø	2	.988	.Ø	2.7Ø	2.7Ø	1.ØØØ
2Ø.ØØ	22.65	72.	14Ø5.	.962	1.ØØØ	3Ø3.	Ø.	498.	.Ø	2	.992	.Ø	2.77	2.77	1.ØØØ
2Ø.5Ø	23.ØØ	72.	14Ø3.	.962	1.ØØØ	312.	Ø.	497.	.Ø	2	.995	.Ø	2.83	2.83	1.ØØØ
21.ØØ	23.36	73.	14ØØ.	.963	1.ØØØ	321.	Ø.	497.	.Ø	2	.998	.Ø	2.89	2.89	1.ØØØ
21.5Ø	23.73	74.	1398.	.963	1.ØØØ	331.	Ø.	497.	.Ø	2	1.ØØ1	.Ø	2.95	2.95	1.ØØØ
22.ØØ	24.1Ø	74.	1396.	.964	1.ØØØ	34Ø.	Ø.	496.	.Ø	2	1.ØØ4	.Ø	3.Ø1	3.Ø1	1.ØØØ
22.5Ø	24.49	75.	1394.	.965	1.ØØØ	35Ø.	Ø.	496.	.Ø	2	1.ØØ8	.Ø	3.Ø7	3.Ø7	1.ØØØ
23.ØØ	24.89	75.	1392.	.965	1.ØØØ	36Ø.	Ø.	495.	.Ø	2	1.Ø11	.Ø	3.14	3.14	1.ØØØ
23.5Ø	25.3Ø	76.	139Ø.	.966	1.ØØØ	369.	Ø.	495.	.Ø	2	1.Ø15	.Ø	3.2Ø	3.2Ø	1.ØØØ
24.ØØ	25.72	77.	1388.	.966	1.ØØØ	379.	Ø.	494.	.Ø	2	1.Ø19	.Ø	3.26	3.26	1.ØØØ
24.5Ø	26.15	77.	1386.	.967	1.ØØØ	389.	Ø.	494.	.Ø	2	1.Ø23	.Ø	3.32	3.32	1.ØØØ
25.ØØ	26.59	78.	1384.	.968	1.ØØØ	398.	Ø.	493.	.Ø	2	1.Ø27	.Ø	3.38	3.38	1.ØØØ
25.5Ø	27.Ø4	78.	1382.	.969	1.ØØØ	4Ø8.	Ø.	493.	.Ø	2	1.Ø31	.Ø	3.44	3.44	1.ØØØ
26.ØØ	27.51	79.	138Ø.	.969	1.ØØØ	418.	Ø.	492.	.Ø	2	1.Ø35	.Ø	3.51	3.51	1.ØØØ
26.5Ø	27.98	8Ø.	1378.	.97Ø	1.ØØØ	427.	Ø.	491.	.Ø	2	1.Ø39	.Ø	3.57	3.57	1.ØØØ
27.ØØ	28.47	8Ø.	1376.	.971	1.ØØØ	437.	Ø.	49Ø.	.Ø	2	1.Ø44	.Ø	3.63	3.63	1.ØØØ
27.5Ø	28.97	81.	1374.	.972	1.ØØØ	447.	Ø.	489.	.Ø	2	1.Ø49	.Ø	3.69	3.69	1.ØØØ

28.ØØ	29.48	82.	1372.	.972	1.ØØØ	456.	Ø.	488.	.Ø	2	1.Ø54	.Ø	3.75	3.75	1.ØØØ
28.5Ø	3Ø.Ø1	83.	137Ø.	.973	1.ØØØ	466.	Ø.	487.	.Ø	2	1.Ø59	.Ø	3.81	3.81	1.ØØØ
29.ØØ	3Ø.55	83.	1367.	.974	1.ØØØ	476.	Ø.	486.	.Ø	2	1.Ø65	.Ø	3.88	3.88	1.ØØØ
29.5Ø	31.1Ø	84.	1365.	.975	1.ØØØ	485.	Ø.	485.	.Ø	2	1.Ø71	.Ø	3.94	3.94	1.ØØØ
3Ø.ØØ	31.67	85.	1363.	.976	1.ØØØ	495.	Ø.	484.	.Ø	2	1.Ø77	.Ø	4.ØØ	4.ØØ	1.ØØØ
3Ø.5Ø	32.25	86.	1364.	.977	1.ØØØ	5Ø4.	Ø.	483.	.Ø	2	1.Ø83	.Ø	4.ØØ	4.ØØ	1.ØØØ
31.ØØ	32.84	86.	1364.	.978	1.ØØØ	513.	Ø.	481.	.Ø	2	1.Ø89	.Ø	4.ØØ	4.ØØ	1.ØØØ
31.5Ø	33.43	87.	1364.	.978	1.ØØØ	522.	Ø.	48Ø.	.Ø	2	1.Ø96	.Ø	4.ØØ	4.ØØ	1.ØØØ
32.ØØ	34.Ø3	88.	1364.	.979	1.ØØØ	531.	Ø.	479.	.Ø	2	1.1Ø3	.Ø	4.ØØ	4.ØØ	1.ØØØ
32.5Ø	34.64	89.	1364.	.98Ø	1.ØØØ	539.	Ø.	477.	.Ø	2	1.11Ø	.Ø	4.ØØ	4.ØØ	1.ØØØ
33.ØØ	35.25	89.	1364.	.981	1.ØØØ	547.	Ø.	476.	.Ø	2	1.117	.Ø	4.ØØ	4.ØØ	1.ØØØ
33.5Ø	35.87	9Ø.	1364.	.982	1.ØØØ	555.	Ø.	474.	.Ø	2	1.125	.Ø	4.ØØ	4.ØØ	1.ØØØ
34.ØØ	36.5Ø	91.	1364.	.983	1.ØØØ	563.	Ø.	473.	.Ø	2	1.132	.Ø	4.ØØ	4.ØØ	1.ØØØ
34.5Ø	37.14	92.	1364.	.984	1.ØØØ	571.	Ø.	471.	.Ø	2	1.141	.Ø	4.ØØ	4.ØØ	1.ØØØ
35.ØØ	37.78	92.	1364.	.985	1.ØØØ	578.	Ø.	47Ø.	.Ø	2	1.149	.Ø	4.ØØ	4.ØØ	1.ØØØ
35.5Ø	38.43	93.	1364.	.986	1.ØØØ	585.	Ø.	468.	.Ø	2	1.158	.Ø	4.ØØ	4.ØØ	1.ØØØ
36.ØØ	39.Ø9	94.	1364.	.987	1.ØØØ	592.	Ø.	467.	.Ø	2	1.167	.Ø	4.ØØ	4.ØØ	1.ØØØ
36.5Ø	39.76	95.	1364.	.988	1.ØØØ	599.	Ø.	465.	.Ø	2	1.177	.Ø	4.ØØ	4.ØØ	1.ØØØ
37.ØØ	4Ø.43	95.	1365.	.989	1.ØØØ	6Ø6.	Ø.	464.	.Ø	2	1.187	.Ø	4.ØØ	4.ØØ	1.ØØØ
37.5Ø	41.12	96.	1365.	.989	1.ØØØ	612.	Ø.	462.	.Ø	2	1.199	.Ø	4.ØØ	4.ØØ	1.ØØØ
38.ØØ	41.81	97.	1365.	.99Ø	1.ØØØ	619.	Ø.	46Ø.	.Ø	2	1.21Ø	.Ø	4.ØØ	4.ØØ	1.ØØØ
38.5Ø	42.5Ø	98.	1365.	.991	1.ØØØ	625.	Ø.	459.	.Ø	2	1.223	.Ø	4.ØØ	4.ØØ	1.ØØØ
39.ØØ	43.21	98.	1365.	.992	1.ØØØ	63Ø.	Ø.	457.	.Ø	2	1.235	.Ø	4.ØØ	4.ØØ	1.ØØØ
39.5Ø	43.93	99.	1365.	.993	1.ØØØ	636.	Ø.	456.	.Ø	2	1.251	.Ø	4.ØØ	4.ØØ	1.ØØØ
4Ø.ØØ	44.65	1ØØ.	1365.	.994	1.ØØØ	642.	Ø.	454.	.Ø	2	1.267	.Ø	4.ØØ	4.ØØ	1.ØØØ
4Ø.5Ø	45.38	1Ø1.	1365.	.995	1.ØØØ	647.	Ø.	453.	.Ø	2	1.283	.Ø	4.ØØ	4.ØØ	1.ØØØ
41.ØØ	46.12	1Ø2.	1365.	.996	1.ØØØ	652.	Ø.	451.	.Ø	2	1.3Ø7	.Ø	4.ØØ	4.ØØ	1.ØØØ
41.5Ø	46.88	1Ø2.	1365.	.997	1.ØØØ	657.	Ø.	45Ø.	.Ø	2	1.331	.Ø	4.ØØ	4.ØØ	1.ØØØ
42.ØØ	47.64	1Ø3.	1365.	.998	1.ØØØ	662.	Ø.	448.	.Ø	2	1.363	.Ø	4.ØØ	4.ØØ	1.ØØØ
42.5Ø	48.42	1Ø4.	1365.	.999	1.ØØØ	667.	Ø.	447.	.Ø	2	1.411	.Ø	4.ØØ	4.ØØ	1.ØØØ
43.ØØ	75.ØØ	1Ø5.	1366.	1.ØØØ	1.ØØØ	671.	347.	445.	.Ø	33	1.571	-125.8	4.ØØ	4.ØØ	1.ØØØ
43.5Ø	5Ø.Ø4	1Ø6.	1366.	1.ØØØ	.999	675.	348.	444.	.Ø	33	1.571	-125.8	4.ØØ	4.ØØ	.999
44.ØØ	75.ØØ	1Ø6.	1366.	1.ØØØ	.998	679.	348.	443.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.998
44.5Ø	51.69	1Ø7.	1366.	1.ØØØ	.997	683.	348.	441.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.997
45.ØØ	75.ØØ	1Ø8.	1366.	1.ØØØ	.996	687.	349.	44Ø.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.996
45.5Ø	53.37	1Ø9.	1366.	1.ØØØ	.994	69Ø.	349.	439.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.994
46.ØØ	75.ØØ	11Ø.	1366.	1.ØØØ	.993	693.	349.	438.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.993
46.5Ø	55.Ø8	111.	1366.	1.ØØØ	.992	697.	349.	436.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.992
47.ØØ	75.ØØ	111.	1366.	1.ØØØ	.991	7ØØ.	35Ø.	435.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.991
47.5Ø	56.82	112.	1366.	1.ØØØ	.99Ø	7Ø3.	35Ø.	434.	.Ø	33	1.571	-125.7	4.ØØ	4.ØØ	.99Ø
48.ØØ	75.ØØ	113.	1366.	1.ØØØ	.989	7Ø6.	35Ø.	433.	.Ø	33	1.571	-125.6	4.ØØ	4.ØØ	.989
48.5Ø	58.58	114.	1367.	1.ØØØ	.988	7Ø9.	35Ø.	432.	.Ø	33	1.571	-125.6	4.ØØ	4.ØØ	.988
49.ØØ	75.ØØ	115.	1367.	1.ØØØ	.987	711.	351.	431.	.Ø	33	1.571	-125.6	4.ØØ	4.ØØ	.987
49.5Ø	6Ø.37	116.	1367.	1.ØØØ	.986	714.	351.	43Ø.	.Ø	33	1.571	-125.6	4.ØØ	4.ØØ	.986
5Ø.ØØ	75.ØØ	116.	1367.	1.ØØØ	.985	717.	351.	429.	.Ø	33	1.571	-125.6	4.ØØ	4.ØØ	.985
5Ø.5Ø	62.19	117.	1367.	1.ØØØ	.984	719.	364.	428.	.Ø	32	1.571	.Ø	4.ØØ	4.ØØ	.984
51.ØØ	63.Ø9	118.	1367.	.999	.982	722.	858.	427.	.Ø	2	1.431	.Ø	4.ØØ	4.ØØ	.982
51.5Ø	63.96	119.	1367.	.996	.979	725.	14ØØ.	426.	.Ø	2	1.331	.Ø	4.ØØ	4.ØØ	.979
52.ØØ	64.81	119.	1367.	.992	.973	727.	1936.	424.	.Ø	2	1.247	.Ø	4.ØØ	4.ØØ	.973
52.5Ø	65.63	12Ø.	1367.	.986	.967	73Ø.	2467.	423.	.Ø	2	1.175	.Ø	4.ØØ	4.ØØ	.966
53.ØØ	66.45	121.	1367.	.978	.958	733.	2828.	422.	.Ø	2	1.1Ø8	.Ø	4.ØØ	4.ØØ	.958
53.5Ø	67.27	122.	1367.	.97Ø	.95Ø	735.	2883.	421.	.Ø	2	1.Ø51	.Ø	4.ØØ	4.ØØ	.949
54.ØØ	68.Ø8	122.	1367.	.962	.941	738.	2939.	42Ø.	.Ø	2	1.ØØ3	.Ø	4.ØØ	4.ØØ	.94Ø
54.5Ø	68.89	123.	1368.	.953	.932	74Ø.	2995.	419.	.Ø	2	.96Ø	.Ø	4.ØØ	4.ØØ	.931
55.ØØ	69.71	124.	1368.	.945	.923	743.	3Ø52.	418.	.Ø	2	.921	.Ø	4.ØØ	4.ØØ	.922
55.5Ø	7Ø.53	124.	1368.	.936	.914	745.	31Ø9.	417.	.Ø	2	.885	.Ø	4.ØØ	4.ØØ	.912
56.ØØ	71.35	125.	1368.	.927	.9Ø4	748.	3168.	416.	.Ø	2	.851	.Ø	4.ØØ	4.ØØ	.9Ø3
56.5Ø	72.17	126.	1368.	.918	.895	75Ø.	3227.	414.	.Ø	2	.819	.Ø	4.ØØ	4.ØØ	.893
57.ØØ	73.ØØ	126.	1368.	.9Ø8	.885	753.	3287.	413.	.Ø	2	.788	.Ø	4.ØØ	4.ØØ	.883
57.5Ø	73.84	127.	1368.	.898	.875	755.	3348.	412.	.Ø	2	.759	.Ø	4.ØØ	4.ØØ	.873

58.00	74.67	128.	1368.	.889	.865	757.	3410.	411.	.0	2	.730	.0	4.00	4.00	.862
58.50	75.52	128.	1368.	.878	.855	759.	3473.	410.	.0	2	.702	.0	4.00	4.00	.852
59.00	76.36	129.	1368.	.868	.844	762.	3537.	409.	.0	2	.675	.0	4.00	4.00	.841
59.50	77.21	130.	1368.	.857	.833	764.	3602.	408.	.0	2	.648	.0	4.00	4.00	.830
60.00	78.07	130.	1368.	.847	.823	766.	3636.	407.	.0	2	.622	.0	4.00	4.00	.819
60.50	78.94	131.	1368.	.836	.812	768.	3661.	406.	.0	2	.597	.0	4.00	4.00	.807
61.00	79.81	132.	1368.	.825	.801	770.	3686.	405.	.0	2	.572	.0	4.00	4.00	.796
61.50	80.68	132.	1369.	.814	.789	772.	3711.	404.	.0	2	.548	.0	4.00	4.00	.785
62.00	81.57	133.	1369.	.803	.778	774.	3736.	403.	.0	2	.524	.0	4.00	4.00	.773
62.50	82.46	134.	1369.	.791	.767	776.	3761.	402.	.0	2	.501	.0	4.00	4.00	.762
63.00	83.36	134.	1369.	.780	.756	778.	3786.	401.	.0	2	.478	.0	4.00	4.00	.750
63.50	84.27	135.	1369.	.768	.744	780.	3811.	400.	.0	2	.455	.0	4.00	4.00	.738
64.00	85.18	136.	1369.	.757	.733	781.	3836.	399.	.0	2	.433	.0	4.00	4.00	.726
64.50	86.11	136.	1369.	.745	.721	783.	3861.	398.	.0	2	.411	.0	4.00	4.00	.714
65.00	87.04	137.	1369.	.733	.710	785.	3887.	398.	.0	2	.389	.0	4.00	4.00	.702
65.50	87.98	138.	1369.	.721	.698	787.	3912.	397.	.0	2	.368	.0	4.00	4.00	.690
66.00	88.93	138.	1369.	.709	.686	788.	3938.	396.	.0	2	.346	.0	4.00	4.00	.678
66.50	89.89	139.	1369.	.697	.674	790.	3963.	395.	.0	2	.325	.0	4.00	4.00	.666
67.00	90.86	140.	1369.	.685	.662	792.	3989.	394.	.0	2	.303	.0	4.00	4.00	.654
67.50	91.84	140.	1369.	.672	.650	794.	4014.	393.	.0	2	.282	.0	4.00	4.00	.641
68.00	92.82	141.	1369.	.660	.638	795.	4040.	392.	.0	2	.261	.0	4.00	4.00	.629
68.50	93.82	142.	1369.	.647	.626	797.	4066.	391.	.0	2	.240	.0	4.00	4.00	.616
69.00	94.82	142.	1370.	.635	.614	799.	4092.	390.	.0	2	.219	.0	4.00	4.00	.603
69.50	95.84	143.	1370.	.622	.602	801.	4119.	402.	.0	2	.198	.0	4.00	4.00	.591
70.00	96.87	144.	1370.	.609	.589	802.	4145.	401.	.0	2	.177	.0	4.00	4.00	.578
70.50	97.90	145.	1370.	.596	.577	804.	4171.	400.	.0	2	.156	.0	4.00	4.00	.565
71.00	98.95	145.	1370.	.583	.564	806.	4198.	399.	.0	2	.135	.0	4.00	4.00	.552
71.50	100.01	146.	1370.	.569	.552	808.	4224.	397.	.0	2	.114	.0	4.00	4.00	.538
72.00	101.08	147.	1370.	.556	.539	810.	4251.	396.	.0	2	.092	.0	4.00	4.00	.525
72.50	102.16	147.	1370.	.542	.526	811.	4278.	395.	.0	2	.071	.0	4.00	4.00	.512
73.00	103.25	148.	1370.	.529	.513	813.	4305.	394.	.0	2	.049	.0	4.00	4.00	.498
73.50	104.35	149.	1370.	.515	.500	815.	4332.	393.	.0	2	.028	.0	4.00	4.00	.485
74.00	105.47	149.	1370.	.501	.487	817.	4360.	392.	.0	2	.006	.0	4.00	4.00	.471
74.50	106.59	150.	1370.	.487	.474	819.	4387.	391.	.0	2	-.016	.0	4.00	4.00	.458
75.00	107.73	151.	1370.	.473	.461	821.	4415.	390.	.0	2	-.038	.0	4.00	4.00	.444
75.50	108.88	152.	1371.	.458	.448	823.	4443.	389.	.0	2	-.061	.0	4.00	4.00	.430
76.00	110.04	152.	1371.	.444	.434	825.	4471.	388.	.0	2	-.084	.0	4.00	4.00	.416
76.50	111.21	153.	1371.	.429	.421	827.	4499.	386.	.0	2	-.107	.0	4.00	4.00	.402
77.00	112.40	154.	1371.	.415	.407	829.	4527.	385.	.0	2	-.130	.0	4.00	4.00	.387
77.50	113.60	155.	1371.	.400	.394	831.	4555.	384.	.0	2	-.154	.0	4.00	4.00	.373
78.00	114.81	155.	1371.	.385	.380	833.	4584.	383.	.0	2	-.178	.0	4.00	4.00	.359
78.50	116.03	156.	1371.	.369	.366	835.	4612.	382.	.0	2	-.203	.0	4.00	4.00	.344
79.00	117.26	157.	1371.	.354	.352	837.	4641.	380.	.0	2	-.228	.0	4.00	4.00	.330
79.50	118.50	158.	1371.	.339	.338	839.	4670.	379.	.0	2	-.254	.0	4.00	4.00	.315
80.00	119.75	158.	1371.	.323	.324	841.	4699.	378.	.0	2	-.280	.0	4.00	4.00	.300
80.50	121.02	159.	1371.	.307	.310	844.	4728.	377.	.0	2	-.307	.0	4.00	4.00	.285
81.00	122.29	160.	1371.	.292	.296	846.	4757.	375.	.0	2	-.335	.0	4.00	4.00	.270
81.50	123.57	161.	1371.	.275	.282	848.	4786.	374.	.0	2	-.363	.0	4.00	4.00	.255
82.00	124.87	161.	1372.	.259	.267	851.	4816.	372.	.0	2	-.392	.0	4.00	4.00	.240
82.50	126.17	162.	1372.	.243	.253	853.	4846.	371.	.0	2	-.423	.0	4.00	4.00	.224
83.00	127.47	163.	1372.	.226	.238	856.	4876.	369.	.0	2	-.454	.0	4.00	4.00	.209
83.50	128.78	163.	1372.	.210	.223	858.	4905.	368.	.0	2	-.488	.0	4.00	4.00	.193
84.00	130.08	164.	1372.	.193	.209	861.	4935.	366.	.0	2	-.522	.0	4.00	4.00	.177
84.50	116.41	156.	1371.	.185	.200	864.	2691.	365.	.0	1	-.544	.0	4.00	4.00	.172
85.00	104.24	149.	1370.	.177	.193	867.	2456.	363.	.0	1	-.560	.0	4.00	4.00	.167
85.50	93.43	142.	1370.	.170	.186	870.	2245.	361.	.0	1	-.576	.0	4.00	4.00	.162
86.00	83.88	135.	1369.	.164	.179	873.	2057.	359.	.0	1	-.590	.0	4.00	4.00	.157
86.50	75.45	128.	1368.	.158	.173	876.	1885.	358.	.0	1	-.604	.0	4.00	4.00	.153
87.00	68.64	123.	1368.	.153	.168	879.	1579.	356.	.0	1	-.616	.0	4.00	4.00	.150
87.50	64.01	119.	1367.	.149	.164	881.	938.	354.	.0	1	-.625	.0	4.00	4.00	.147

88.00	63.18	118.	1367.	.147	.162	884.	533.	353.	.0	1	-.631	.0	4.00	4.00	.145
88.50	63.08	118.	1367.	.146	.161	887.	486.	351.	.0	1	-.634	.0	4.00	4.00	.143
89.00	63.07	118.	1367.	.144	.160	890.	480.	349.	.0	1	-.638	.0	4.00	4.00	.142
89.50	63.07	118.	1367.	.143	.158	893.	479.	348.	.0	1	-.642	.0	4.00	4.00	.140
90.00	63.07	118.	1367.	.141	.157	895.	479.	346.	.0	1	-.645	.0	4.00	4.00	.139
90.50	63.07	118.	1367.	.140	.155	898.	479.	345.	.0	1	-.649	.0	4.00	4.00	.137
91.00	63.07	118.	1367.	.138	.154	900.	478.	343.	.0	1	-.653	.0	4.00	4.00	.136
91.50	63.06	118.	1367.	.137	.152	903.	478.	342.	.0	1	-.656	.0	4.00	4.00	.134
92.00	63.06	118.	1367.	.135	.151	905.	478.	340.	.0	1	-.660	.0	4.00	4.00	.133
92.50	63.06	118.	1367.	.134	.150	908.	477.	339.	.0	1	-.664	.0	4.00	4.00	.132
93.00	63.06	118.	1367.	.132	.148	910.	477.	338.	.0	1	-.668	.0	4.00	4.00	.130
93.50	63.06	118.	1367.	.131	.147	912.	476.	336.	.0	1	-.672	.0	4.00	4.00	.129
94.00	63.06	118.	1367.	.129	.145	915.	476.	335.	.0	1	-.676	.0	4.00	4.00	.127
94.50	63.05	118.	1367.	.128	.144	917.	475.	334.	.0	1	-.679	.0	4.00	4.00	.126
95.00	63.05	118.	1367.	.126	.142	919.	474.	332.	.0	1	-.683	.0	4.00	4.00	.124
95.50	63.05	118.	1367.	.125	.141	921.	474.	331.	.0	1	-.687	.0	4.00	4.00	.123
96.00	63.05	118.	1367.	.123	.140	924.	473.	330.	.0	1	-.691	.0	4.00	4.00	.121
96.50	63.05	118.	1367.	.122	.138	926.	472.	328.	.0	1	-.695	.0	4.00	4.00	.120
97.00	63.04	118.	1367.	.121	.137	928.	472.	327.	.0	1	-.699	.0	4.00	4.00	.118
97.50	63.04	118.	1367.	.119	.135	930.	471.	326.	.0	1	-.703	.0	4.00	4.00	.117
98.00	63.04	118.	1367.	.118	.134	932.	470.	325.	.0	1	-.707	.0	4.00	4.00	.116
98.50	63.03	118.	1367.	.116	.132	934.	469.	324.	.0	1	-.711	.0	4.00	4.00	.114
99.00	63.03	118.	1367.	.115	.131	936.	468.	323.	.0	1	-.715	.0	4.00	4.00	.113
99.50	63.03	118.	1367.	.113	.130	938.	467.	321.	.0	1	-.719	.0	4.00	4.00	.111
100.00	63.03	118.	1367.	.112	.128	940.	466.	320.	.0	1	-.723	.0	4.00	4.00	.110
100.50	63.02	118.	1367.	.110	.127	942.	465.	319.	.0	1	-.727	.0	4.00	4.00	.108
101.00	63.02	118.	1367.	.109	.125	943.	464.	318.	.0	1	-.731	.0	4.00	4.00	.107
101.50	63.02	118.	1367.	.107	.124	945.	463.	317.	.0	1	-.735	.0	4.00	4.00	.106
102.00	63.01	118.	1367.	.106	.123	947.	462.	316.	.0	1	-.739	.0	4.00	4.00	.104
102.50	63.01	118.	1367.	.105	.121	949.	461.	315.	.0	1	-.743	.0	4.00	4.00	.103
103.00	63.01	118.	1367.	.103	.120	951.	460.	314.	.0	1	-.748	.0	4.00	4.00	.101
103.50	63.00	118.	1367.	.102	.119	952.	459.	313.	.0	1	-.752	.0	4.00	4.00	.100
104.00	63.00	118.	1367.	.100	.117	954.	458.	312.	.0	1	-.756	.0	4.00	4.00	.099
104.50	62.99	118.	1367.	.099	.116	956.	457.	311.	.0	1	-.760	.0	4.00	4.00	.097
105.00	62.99	118.	1367.	.097	.114	958.	455.	310.	.0	1	-.764	.0	4.00	4.00	.096
105.50	62.99	118.	1367.	.096	.113	959.	454.	309.	.0	1	-.768	.0	4.00	4.00	.094
106.00	62.98	118.	1367.	.095	.112	961.	453.	308.	.0	1	-.773	.0	4.00	4.00	.093
106.50	62.98	118.	1367.	.093	.110	963.	452.	307.	.0	1	-.777	.0	4.00	4.00	.092
107.00	62.97	118.	1367.	.092	.109	964.	450.	306.	.0	1	-.781	.0	4.00	4.00	.090
107.50	62.97	118.	1367.	.090	.108	966.	449.	305.	.0	1	-.786	.0	4.00	4.00	.089
108.00	62.97	118.	1367.	.089	.106	967.	448.	304.	.0	1	-.790	.0	4.00	4.00	.087
108.50	62.96	118.	1367.	.088	.105	969.	446.	303.	.0	1	-.795	.0	4.00	4.00	.086
109.00	62.96	118.	1367.	.086	.104	971.	445.	302.	.0	1	-.800	.0	4.00	4.00	.085
109.50	62.95	118.	1367.	.085	.102	972.	443.	301.	.0	1	-.804	.0	4.00	4.00	.083
110.00	62.95	118.	1367.	.083	.101	974.	442.	300.	.0	1	-.808	.0	4.00	4.00	.082
110.50	62.94	118.	1367.	.082	.100	975.	440.	299.	.0	1	-.813	.0	4.00	4.00	.081
111.00	62.94	118.	1367.	.081	.098	977.	439.	299.	.0	1	-.817	.0	4.00	4.00	.079
111.50	62.93	118.	1367.	.079	.097	978.	437.	298.	.0	1	-.822	.0	4.00	4.00	.078
112.00	62.93	118.	1367.	.078	.096	980.	435.	297.	.0	1	-.827	.0	4.00	4.00	.077
112.50	62.92	118.	1367.	.077	.094	981.	434.	296.	.0	1	-.832	.0	4.00	4.00	.075
113.00	62.92	118.	1367.	.075	.093	983.	432.	295.	.0	1	-.836	.0	4.00	4.00	.074
113.50	62.91	118.	1367.	.074	.092	985.	430.	294.	.0	1	-.841	.0	4.00	4.00	.073
114.00	62.90	118.	1367.	.073	.091	986.	429.	293.	.0	1	-.845	.0	4.00	4.00	.071
114.50	62.90	118.	1367.	.071	.089	988.	427.	292.	.0	1	-.850	.0	4.00	4.00	.070
115.00	62.89	118.	1367.	.070	.088	989.	425.	291.	.0	1	-.855	.0	4.00	4.00	.069
115.50	62.89	118.	1367.	.069	.087	990.	423.	291.	.0	1	-.860	.0	4.00	4.00	.067
116.00	62.88	118.	1367.	.067	.085	992.	421.	290.	.0	1	-.865	.0	4.00	4.00	.066
116.50	62.87	118.	1367.	.066	.084	993.	420.	289.	.0	1	-.870	.0	4.00	4.00	.065
117.00	62.87	118.	1367.	.065	.083	995.	417.	288.	.0	1	-.875	.0	4.00	4.00	.064
117.50	62.86	118.	1367.	.063	.082	996.	416.	287.	.0	1	-.880	.0	4.00	4.00	.062

118.00	62.86	118.	1367.	.062	.080	998.	414.	286.	.0	1	-.884	.0	4.00	4.00	.061
118.50	62.85	118.	1367.	.061	.079	999.	412.	285.	.0	1	-.890	.0	4.00	4.00	.060
119.00	62.84	118.	1367.	.060	.078	1001.	409.	285.	.0	1	-.895	.0	4.00	4.00	.059
119.50	62.84	118.	1367.	.058	.077	1002.	408.	284.	.0	1	-.900	.0	4.00	4.00	.057
120.00	62.83	118.	1367.	.057	.076	1004.	405.	283.	.0	1	-.905	.0	4.00	4.00	.056
120.50	62.82	118.	1367.	.056	.074	1005.	403.	282.	.0	1	-.910	.0	4.00	4.00	.055
121.00	62.81	118.	1367.	.055	.073	1007.	401.	281.	.0	1	-.916	.0	4.00	4.00	.054
121.50	62.81	118.	1367.	.053	.072	1008.	399.	280.	.0	1	-.921	.0	4.00	4.00	.052
122.00	62.80	118.	1367.	.052	.071	1010.	397.	279.	.0	1	-.926	.0	4.00	4.00	.051
122.50	62.79	118.	1367.	.051	.070	1011.	394.	278.	.0	1	-.932	.0	4.00	4.00	.050
123.00	62.78	118.	1367.	.050	.068	1013.	392.	278.	.0	1	-.937	.0	4.00	4.00	.049
123.50	62.78	118.	1367.	.048	.067	1014.	390.	277.	.0	1	-.943	.0	4.00	4.00	.048
124.00	62.77	118.	1367.	.047	.066	1016.	387.	276.	.0	1	-.948	.0	4.00	4.00	.046
124.50	62.76	118.	1367.	.046	.065	1017.	385.	275.	.0	1	-.954	.0	4.00	4.00	.045
125.00	62.75	118.	1367.	.045	.064	1019.	382.	274.	.0	1	-.960	.0	4.00	4.00	.044
125.50	62.74	118.	1367.	.044	.063	1020.	380.	273.	.0	1	-.965	.0	4.00	4.00	.043
126.00	62.74	118.	1367.	.042	.061	1022.	377.	272.	.0	1	-.971	.0	4.00	4.00	.042
126.50	62.73	118.	1367.	.041	.060	1023.	374.	271.	.0	1	-.976	.0	4.00	4.00	.041
127.00	62.72	118.	1367.	.040	.059	1025.	372.	270.	.0	1	-.983	.0	4.00	4.00	.039
127.50	62.71	118.	1367.	.039	.058	1026.	369.	270.	.0	1	-.988	.0	4.00	4.00	.038
128.00	62.70	118.	1367.	.038	.057	1028.	366.	269.	.0	1	-.994	.0	4.00	4.00	.037
128.50	62.82	118.	1367.	.037	.056	1029.	364.	268.	.0	1	-1.000	.0	4.00	4.00	.036
129.00	62.79	118.	1367.	.035	.055	1031.	394.	267.	.0	1	-1.007	.0	4.00	4.00	.035
129.50	62.78	118.	1367.	.034	.054	1033.	390.	266.	.0	1	-1.014	.0	4.00	4.00	.034
130.00	62.77	118.	1367.	.033	.052	1034.	387.	265.	.0	1	-1.021	.0	4.00	4.00	.032
130.50	62.76	118.	1367.	.032	.051	1036.	384.	264.	.0	1	-1.028	.0	4.00	4.00	.031
131.00	62.75	118.	1367.	.031	.050	1037.	380.	263.	.0	1	-1.035	.0	4.00	4.00	.030
131.50	62.74	118.	1367.	.029	.049	1039.	376.	262.	.0	1	-1.042	.0	4.00	4.00	.029
132.00	62.72	118.	1367.	.028	.048	1041.	373.	261.	.0	1	-1.049	.0	4.00	4.00	.028
132.50	62.71	118.	1367.	.027	.047	1043.	370.	260.	.0	1	-1.057	.0	4.00	4.00	.027
133.00	62.70	118.	1367.	.026	.046	1044.	365.	259.	.0	1	-1.064	.0	4.00	4.00	.026
133.50	62.69	118.	1367.	.025	.045	1046.	362.	258.	.0	1	-1.072	.0	4.00	4.00	.024
134.00	62.67	118.	1367.	.024	.043	1048.	361.	257.	.0	1	-1.080	.0	4.00	4.00	.023
134.50	62.64	118.	1367.	.023	.042	1050.	357.	256.	.0	1	-1.088	.0	4.00	4.00	.022
135.00	62.62	118.	1367.	.021	.041	1051.	352.	255.	.0	1	-1.096	.0	4.00	4.00	.021
135.50	62.60	118.	1367.	.020	.040	1053.	346.	254.	.0	1	-1.104	.0	4.00	4.00	.020
136.00	62.59	118.	1367.	.019	.039	1055.	341.	253.	.0	1	-1.113	.0	4.00	4.00	.019
136.50	62.58	118.	1367.	.018	.038	1057.	337.	252.	.0	1	-1.121	.0	4.00	4.00	.018
137.00	62.56	117.	1367.	.017	.037	1059.	332.	251.	.0	1	-1.130	.0	4.00	4.00	.017
137.50	62.55	117.	1367.	.016	.036	1061.	328.	249.	.0	1	-1.139	.0	4.00	4.00	.016
138.00	62.52	117.	1367.	.015	.035	1063.	322.	248.	.0	1	-1.149	.0	4.00	4.00	.015
138.50	62.51	117.	1367.	.014	.034	1065.	317.	247.	.0	1	-1.157	.0	4.00	4.00	.014
139.00	62.49	117.	1367.	.013	.033	1067.	311.	246.	.0	1	-1.167	.0	4.00	4.00	.013
139.50	62.47	117.	1367.	.012	.032	1069.	306.	245.	.0	1	-1.177	.0	4.00	4.00	.012
140.00	62.45	117.	1367.	.011	.032	1071.	300.	243.	.0	1	-1.187	.0	4.00	4.00	.011
140.50	62.42	117.	1367.	.010	.031	1073.	293.	242.	.0	1	-1.198	.0	4.00	4.00	.010
141.00	62.40	117.	1367.	.010	.030	1075.	286.	241.	.0	1	-1.209	.0	4.00	4.00	.009
141.50	62.38	117.	1367.	.009	.029	1078.	280.	240.	.0	1	-1.221	.0	4.00	4.00	.009
142.00	62.35	117.	1367.	.008	.028	1080.	273.	238.	.0	1	-1.233	.0	4.00	4.00	.008
142.50	62.32	117.	1367.	.007	.027	1082.	265.	237.	.0	1	-1.245	.0	4.00	4.00	.007
143.00	62.29	117.	1367.	.006	.027	1085.	257.	235.	.0	1	-1.257	.0	4.00	4.00	.006
143.50	62.26	117.	1367.	.005	.026	1087.	248.	234.	.0	1	-1.270	.0	4.00	4.00	.005
144.00	62.23	117.	1367.	.005	.025	1090.	239.	232.	.0	1	-1.285	.0	4.00	4.00	.005
144.50	62.19	117.	1367.	.004	.024	1093.	229.	231.	.0	1	-1.301	.0	4.00	4.00	.004
145.00	62.15	117.	1367.	.003	.024	1095.	219.	229.	.0	1	-1.317	.0	4.00	4.00	.003
145.50	62.11	117.	1367.	.003	.023	1098.	207.	228.	.0	1	-1.333	.0	4.00	4.00	.003
146.00	62.05	117.	1367.	.002	.022	1101.	195.	226.	.0	1	-1.353	.0	4.00	4.00	.002
146.50	61.99	117.	1367.	.001	.022	1104.	179.	224.	.0	1	-1.373	.0	4.00	4.00	.001
147.00	61.95	117.	1367.	.001	.021	1107.	165.	222.	.0	1	-1.397	.0	4.00	4.00	.001
147.50	61.82	117.	1367.	.001	.021	1111.	144.	220.	.0	1	-1.429	.0	4.00	4.00	.001

148.00	61.88	126.	1368.	.000	.021	1115.	113.	218.	.0	4	-1.571	.0	4.00	4.00	.000
148.50	61.90	137.	1369.	.000	.020	1119.	125.	215.	.0	4	-1.571	.0	4.00	4.00	.000
149.00	61.90	148.	1370.	.000	.020	1124.	124.	212.	.0	4	-1.571	.0	4.00	4.00	.000
149.50	61.89	159.	1371.	.000	.019	1128.	121.	210.	.0	4	-1.571	.0	4.00	4.00	.000
150.00	61.89	171.	1372.	.000	.019	1133.	118.	207.	.0	4	-1.571	.0	4.00	4.00	.000
150.50	61.88	182.	1374.	.000	.019	1137.	115.	205.	.0	4	-1.571	.0	4.00	4.00	.000
151.00	61.88	194.	1375.	.000	.018	1141.	112.	202.	.0	4	-1.571	.0	4.00	4.00	.000
151.50	61.87	206.	1376.	.000	.018	1146.	109.	200.	.0	4	-1.571	.0	4.00	4.00	.000
152.00	61.86	217.	1377.	.000	.018	1150.	106.	197.	.0	4	-1.571	.0	4.00	4.00	.000
152.50	61.86	229.	1378.	.000	.017	1154.	104.	195.	.0	4	-1.571	.0	4.00	4.00	.000
153.00	61.85	242.	1380.	.000	.017	1158.	101.	193.	.0	4	-1.571	.0	4.00	4.00	.000
153.50	61.84	254.	1381.	.000	.017	1162.	98.	190.	.0	4	-1.571	.0	4.00	4.00	.000
154.00	61.84	266.	1382.	.000	.017	1166.	96.	188.	.0	4	-1.571	.0	4.00	4.00	.000
154.50	61.83	279.	1384.	.000	.016	1170.	93.	186.	.0	4	-1.571	.0	4.00	4.00	.000
155.00	61.83	291.	1385.	.000	.016	1174.	91.	183.	.0	4	-1.571	.0	4.00	4.00	.000
155.50	61.82	304.	1386.	.000	.016	1178.	89.	181.	.0	4	-1.571	.0	4.00	4.00	.000
156.00	61.81	316.	1387.	.000	.015	1182.	86.	179.	.0	4	-1.571	.0	4.00	4.00	.000
156.50	61.81	329.	1389.	.000	.015	1185.	84.	177.	.0	4	-1.571	.0	4.00	4.00	.000
157.00	61.80	342.	1390.	.000	.015	1189.	82.	174.	.0	4	-1.571	.0	4.00	4.00	.000
157.50	61.80	355.	1391.	.000	.015	1193.	80.	172.	.0	4	-1.571	.0	4.00	4.00	.000
158.00	61.79	368.	1393.	.000	.014	1196.	77.	170.	.0	4	-1.571	.0	4.00	4.00	.000
158.50	61.79	381.	1394.	.000	.014	1200.	75.	168.	.0	4	-1.571	.0	4.00	4.00	.000
159.00	61.78	394.	1395.	.000	.014	1203.	73.	166.	.0	4	-1.571	.0	4.00	4.00	.000
159.50	61.78	407.	1397.	.000	.014	1207.	71.	164.	.0	4	-1.571	.0	4.00	4.00	.000
160.00	61.77	420.	1398.	.000	.014	1210.	69.	162.	.0	4	-1.571	.0	4.00	4.00	.000
160.50	61.76	434.	1399.	.000	.013	1214.	68.	160.	.0	4	-1.571	.0	4.00	4.00	.000
161.00	61.76	447.	1401.	.000	.013	1217.	66.	158.	.0	4	-1.571	.0	4.00	4.00	.000
161.50	61.75	460.	1402.	.000	.013	1221.	64.	156.	.0	4	-1.571	.0	4.00	4.00	.000
162.00	61.75	474.	1403.	.000	.013	1224.	62.	154.	.0	4	-1.571	.0	4.00	4.00	.000
162.50	61.74	487.	1405.	.000	.013	1227.	60.	152.	.0	4	-1.571	.0	4.00	4.00	.000
163.00	61.74	500.	1406.	.000	.012	1230.	59.	150.	.0	4	-1.571	.0	4.00	4.00	.000
163.50	61.73	514.	1407.	.000	.012	1234.	57.	148.	.0	4	-1.571	.0	4.00	4.00	.000
164.00	61.73	527.	1409.	.000	.012	1237.	56.	147.	.0	4	-1.571	.0	4.00	4.00	.000
164.50	61.72	540.	1410.	.000	.012	1240.	54.	145.	.0	4	-1.571	.0	4.00	4.00	.000
165.00	61.72	554.	1411.	.000	.012	1243.	53.	143.	.0	4	-1.571	.0	4.00	4.00	.000
165.50	61.72	567.	1413.	.000	.012	1246.	51.	141.	.0	4	-1.571	.0	4.00	4.00	.000
166.00	61.71	580.	1414.	.000	.011	1249.	50.	139.	.0	4	-1.571	.0	4.00	4.00	.000
166.50	61.71	593.	1415.	.000	.011	1252.	48.	138.	.0	4	-1.571	.0	4.00	4.00	.000
167.00	61.70	607.	1417.	.000	.011	1255.	47.	136.	.0	4	-1.571	.0	4.00	4.00	.000
167.50	61.70	620.	1418.	.000	.011	1258.	46.	134.	.0	4	-1.571	.0	4.00	4.00	.000
168.00	61.69	633.	1419.	.000	.011	1260.	44.	133.	.0	4	-1.571	.0	4.00	4.00	.000
168.50	61.69	646.	1421.	.000	.011	1263.	43.	131.	.0	4	-1.571	.0	4.00	4.00	.000
169.00	61.68	659.	1422.	.000	.011	1266.	42.	129.	.0	4	-1.571	.0	4.00	4.00	.000
169.50	61.68	672.	1423.	.000	.011	1269.	41.	128.	.0	4	-1.571	.0	4.00	4.00	.000
170.00	61.68	685.	1424.	.000	.010	1272.	40.	126.	.0	4	-1.571	.0	4.00	4.00	.000
170.50	61.67	697.	1426.	.000	.010	1274.	39.	125.	.0	4	-1.571	.0	4.00	4.00	.000
171.00	61.67	710.	1427.	.000	.010	1277.	37.	123.	.0	4	-1.571	.0	4.00	4.00	.000
171.50	61.66	723.	1428.	.000	.010	1280.	36.	121.	.0	4	-1.571	.0	4.00	4.00	.000
172.00	61.66	735.	1429.	.000	.010	1282.	35.	120.	.0	4	-1.571	.0	4.00	4.00	.000
172.50	61.65	748.	1430.	.000	.010	1285.	35.	118.	.0	4	-1.571	.0	4.00	4.00	.000
173.00	61.64	760.	1432.	.000	.010	1287.	35.	117.	.0	4	-1.571	.0	4.00	4.00	.000
173.50	61.63	772.	1433.	.000	.010	1290.	34.	115.	.0	4	-1.571	.0	4.00	4.00	.000
174.00	61.62	784.	1434.	.000	.010	1292.	32.	114.	.0	4	-1.571	.0	4.00	4.00	.000
174.50	61.62	796.	1435.	.000	.009	1295.	31.	113.	.0	4	-1.571	.0	4.00	4.00	.000
175.00	61.61	808.	1436.	.000	.009	1297.	29.	111.	.0	4	-1.571	.0	4.00	4.00	.000
175.50	61.62	820.	1437.	.000	.009	1299.	28.	110.	.0	4	-1.571	.0	4.00	4.00	.000
176.00	61.62	832.	1439.	.000	.009	1302.	27.	108.	.0	4	-1.571	.0	4.00	4.00	.000
176.50	61.62	844.	1440.	.000	.009	1304.	27.	107.	.0	4	-1.571	.0	4.00	4.00	.000
177.00	61.62	855.	1441.	.000	.009	1306.	27.	106.	.0	4	-1.571	.0	4.00	4.00	.000
177.50	61.62	866.	1442.	.000	.009	1309.	26.	104.	.0	4	-1.571	.0	4.00	4.00	.000

178.ØØ	61.61	877.	1443.	.ØØØ	.ØØ9	1311.	26.	1Ø3.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
178.5Ø	61.6Ø	888.	1444.	.ØØØ	.ØØ9	1313.	25.	1Ø2.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
179.ØØ	61.6Ø	899.	1445.	.ØØØ	.ØØ9	1315.	24.	1ØØ.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
179.5Ø	61.59	91Ø.	1446.	.ØØØ	.ØØ9	1318.	23.	99.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
18Ø.ØØ	61.59	921.	1447.	.ØØØ	.ØØ9	132Ø.	22.	98.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
18Ø.5Ø	61.59	931.	1448.	.ØØØ	.ØØ9	1322.	21.	97.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
181.ØØ	61.59	942.	1449.	.ØØØ	.ØØ8	1324.	21.	95.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
181.5Ø	61.59	952.	145Ø.	.ØØØ	.ØØ8	1326.	2Ø.	94.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
182.ØØ	61.59	962.	1451.	.ØØØ	.ØØ8	1328.	2Ø.	93.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
182.5Ø	61.59	972.	1452.	.ØØØ	.ØØ8	133Ø.	2Ø.	92.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
183.ØØ	61.58	982.	1453.	.ØØØ	.ØØ8	1332.	19.	91.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
183.5Ø	61.58	991.	1454.	.ØØØ	.ØØ8	1334.	18.	9Ø.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
184.ØØ	61.58	1ØØ1.	1455.	.ØØØ	.ØØ8	1336.	18.	88.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
184.5Ø	61.58	1Ø1Ø.	1455.	.ØØØ	.ØØ8	1338.	17.	87.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
185.ØØ	61.57	1Ø19.	1456.	.ØØØ	.ØØ8	134Ø.	17.	86.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
185.5Ø	61.57	1Ø28.	1457.	.ØØØ	.ØØ8	1342.	16.	85.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
186.ØØ	61.57	1Ø37.	1458.	.ØØØ	.ØØ8	1344.	16.	84.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
186.5Ø	61.57	1Ø46.	1459.	.ØØØ	.ØØ8	1345.	15.	83.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
187.ØØ	61.57	1Ø54.	146Ø.	.ØØØ	.ØØ8	1347.	15.	82.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
187.5Ø	61.57	1Ø63.	146Ø.	.ØØØ	.ØØ8	1349.	15.	81.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
188.ØØ	61.56	1Ø71.	1461.	.ØØØ	.ØØ8	1351.	14.	8Ø.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
188.5Ø	61.56	1Ø79.	1462.	.ØØØ	.ØØ8	1353.	14.	79.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
189.ØØ	61.56	1Ø87.	1463.	.ØØØ	.ØØ8	1354.	13.	78.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
189.5Ø	61.56	1Ø95.	1463.	.ØØØ	.ØØ8	1356.	13.	77.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
19Ø.ØØ	61.56	11Ø3.	1464.	.ØØØ	.ØØ8	1358.	13.	76.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
19Ø.5Ø	61.56	111Ø.	1465.	.ØØØ	.ØØ8	1359.	12.	75.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
191.ØØ	61.56	1118.	1465.	.ØØØ	.ØØ8	1361.	12.	74.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
191.5Ø	61.55	1125.	1466.	.ØØØ	.ØØ7	1363.	12.	73.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
192.ØØ	61.55	1132.	1467.	.ØØØ	.ØØ7	1364.	11.	72.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
192.5Ø	61.55	1139.	1467.	.ØØØ	.ØØ7	1366.	11.	71.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
193.ØØ	61.55	1146.	1468.	.ØØØ	.ØØ7	1368.	11.	7Ø.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
193.5Ø	61.55	1153.	1469.	.ØØØ	.ØØ7	1369.	1Ø.	69.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
194.ØØ	61.55	116Ø.	1469.	.ØØØ	.ØØ7	1371.	1Ø.	68.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
194.5Ø	61.55	1166.	147Ø.	.ØØØ	.ØØ7	1372.	1Ø.	67.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
195.ØØ	61.55	1173.	1471.	.ØØØ	.ØØ7	1374.	9.	66.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
195.5Ø	61.54	1179.	1471.	.ØØØ	.ØØ7	1375.	9.	66.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
196.ØØ	61.54	1185.	1472.	.ØØØ	.ØØ7	1377.	9.	65.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
196.5Ø	61.54	1191.	1472.	.ØØØ	.ØØ7	1378.	9.	64.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
197.ØØ	61.54	1197.	1473.	.ØØØ	.ØØ7	138Ø.	9.	63.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
197.5Ø	61.54	12Ø3.	1473.	.ØØØ	.ØØ7	1381.	8.	62.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ
197.9Ø	61.54	12Ø7.	1474.	.ØØØ	.ØØ7	1382.	8.	62.	.Ø	4	-1.571	.Ø	4.ØØ	4.ØØ	.ØØØ

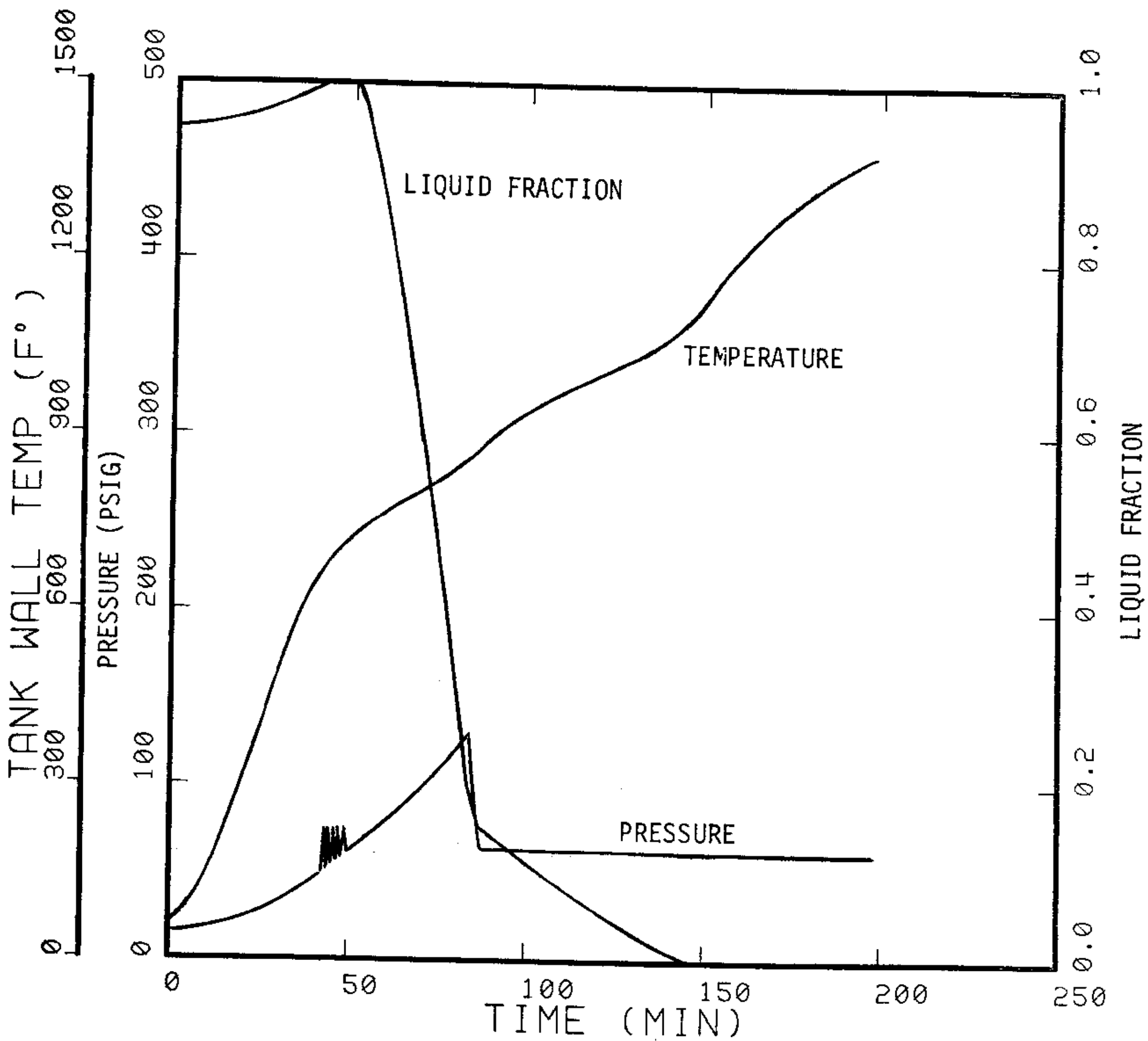


FIGURE 3. PRESSURE, TANK WALL TEMPERATURE OVER VAPOR SPACE AND FRACTION OF TANK VOLUME FILLED WITH LIQUID AS FUNCTION OF TIME; 33,600 GAL. 105A100W TANK CAR CONTAINING 1,3-BUTADIENE, OVERTURNED (120°) CAR CASE, SAFETY RELIEF VALVE FLOW CAPACITY 20,000 SCFM, THERMAL SHIELD CONDUCTANCE 4.0 BTU/HR-FT²-°F

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