(T(X,1)
Halon Vapor Pressure

```
DATA 72.46  73.78  75.12  76.48  77.85  79.25  80.66  82.09  83.54  85.00  86.49  88.00  89.52  91.07  92.63  94.21  95.82
  97.44  99.09  100.8  102.4  104.1  105.9  107.6
DATA 109.4  111.2  113!  114.8  116.7  118.6  120.5  122.4  124.3  126.3  128.3  130.3  132.3  134.4  136.5  138.6  140.7
  142.9  145.1  147.3  149.5  151.7  154!  156.3
DATA 158.7  161.0  163.4  165.8  168.2  170.7  173.2  175.7  178.2  180.8  183.4  186.0  188.6  191.3  194.0  196.7  199.5
  202.3  205.1  207.9  210.8  213.7
```

T(X,2)
LIQUID VOL

```
DATA .00890 .00892 .00893 .00895 .00896 .00898 .00899 .00901 .00902 .00904 .00905 .00907 .00909 .00910 .00912 .00913 .00915
  .00917 .00918 .00920 .00921
DATA .00923 .00925 .00927 .00928 .00930 .00932 .00933 .00935 .00937 .00939 .00941 .00942 .00944 .00946 .00948 .00950 .00952
  .00954 .00956 .00957 .00959
DATA .00961 .00963 .00965 .00967 .00969 .00972 .00974 .00976 .00978 .00980 .00982 .00984 .00987 .00989 .00991 .00993 .00996
  .00998 .01000 .01003 .01005 .01007 .01010 .01012 .01015 .01017 .0102  .01023
```

T(X,3)
Vapor Vol

```
DATA .4070  .3999  .393   .3862  .3795  .373   .3666  .3604  .3542  .3482  .3424  .3366  .3309  .3254  .32    .3146  .3094
  .3043  .2993  .2944  .2895  .2848  .2801  .2756
DATA .2711  .2667  .2624  .25582 .2541  .2500  .2460  .2421  .2382  .2345  .2308  .2271  .2235  .2200  .2166  .2132  .2099
  .2066  .2034  .2002  .1971  .1941  .1911  .1881
DATA .1853  .1824  .1796  .1769  .1742  .1715  .1689  .1663  .1638  .1613  .1589  .1565  .1541  .1518  .1495  .1472  .1450
  .1428  .1407  .1386  .1365  .1344
```

$H_L$
T(X,4)

```
DATA 7.05   7.23   7.40   7.58   7.76   7.94   8.12   8.30   8.48   8.66   8.84   9.02   9.20   9.38   9.56   9.74   9.92
  10.11  10.29  10.47  10.65  10.84  11.02  11.20  11.39  11.57  11.76
DATA 11.94  12.13  12.32  12.50  12.69  12.88  13.06  13.25  13.44  13.63  13.82  14.01  14.19  14.38  14.57  14.77  14.96
  15.15  15.34  15.53  15.72  15.92  16.11  16.31
DATA 16.50  16.69  16.89  17.08  17.29  17.48  17.68  17.87  18.08  18.27  18.47  18.67  18.87  19.07  19.27  19.47  19.67
  19.88  20.08
```

$H_V$
T(X,5)

```
DATA 51.58  51.65  51.72  51.79  51.86  51.93  52.00  52.07  52.14  52.21  52.28  52.35  52.41  52.48  52.55  52.65  52.68
  52.75  52.81  52.88  52.94  53.01  53.08  53.14
DATA 53.2   53.27  53.33  53.39  53.45  53.51  53.58  53.64  53.70  53.76  53.82  53.88  53.93  53.99  54.05  54.11  54.16
  54.22  54.28  54.33  54.39  54.44  54.50  54.55
DATA 54.60  54.65  54.71  54.76  54.81  54.86  54.91  54.96  55.00  55.05  55.10  55.15  55.19  55.24  55.28  55.32  55.37
  55.41  55.45  55.49  55.53  55.57
```

T(X,6)
$S_L$

```
DATA .0159  .0163  .0166  .0170  .0174  .0178  .0181  .0185  .0189  .0193  .0197  .0200  .0204  .0208  .0212  .02158  .0219
 .0223  .0227  .0230  .0234  .0238  .0242  .0245
DATA .0249  .0253  .0257  .0260  .0264  .0268  .0272  .0275  .0279  .0283  .0287  .0290  .0294  .0298  .0301  .0305  .0309
 .0313  .0316  .0320  .0324  .0327  .0332  .0335
DATA .0339  .0342  .0346  .0350  .0354  .0357  .0361  .0365  .0368  .0372  .0376  .0380  .0383  .0387  .0391  .0394  .0398
 .0402  .0406  .0409  .0413  .0417
```

T(X,7)
$S_V$

```
DATA .1125  .1125  .1124  .1124  .1123  .1122  .1122  .1121  .1121  .1120  .1119  .1119  .1118  .1118  .1117  .1117  .1116
 .1116  .1115  .1115  .1114  .1113  .1113  .1112
DATA .1112  .1111  .1111  .1110  .1110  .1109  .1109  .1108  .1108  .1107  .1107  .1106  .1106  .1105  .1104  .1104  .1103
 .1103  .1102  .1102  .1101  .1101  .1100  .1100
DATA .1099  .1099  .1098  .1097  .1097  .1096  .1096  .1095  .1095  .1094  .1094  .1093  .1092  .1092  .1091  .1091  .1090
 .1089  .1089  .1088  .1088  .1087
```

T(X,8)

```
DATA 236.2  236.4  236.6  236.8  237.0  237.3  237.6  237.9  238.0  238.1  238.3  238.5  238.7  239.0  239.1  239.3  239.6
 239.8  239.9  240.0  240.1  240.2  240.4  240.6
DATA 240.8  241.0  241.1  241.2  241.3  241.3  241.5  241.6  241.7  241.7  241.7  241.8  241.8  241.7  241.7  241.7  241.7
 241.7  241.7  241.6  241.6  241.6  241.6  241.5
DATA 241.5  241.4  241.3  241.2  241.1  241.0  240.9  240.8  240.6  240.5  240.3  240.1  240.0  239.8  239.6  239.3  239.1
 238.9  238.7  238.5  238.2  238.0
```

NOMENCLATURE

Let X = Temperature in deg. F.
T(X,1) = H-1301 vapor pressure in PSIA
T(X,2) = Specific volume of liquid in cu.ft./lb.
T(X,3) = Specific volume of vapor in cu.ft./lb.
T(X,4) = Liquid enthalpy in btu/lb.
T(X,5) = Vapor enthalpy in btu/lb.
T(X,6) = Liquid entropy in btu/(lb)(oR)
T(X,7) = Vapor entropy in btu/(lb)(oR)
T(X,8) = Henry's law constants in psi/weight percent

P = Partial pressure of nitrogen in PSI
P2 = New nitrogen PSI after discharge or new temp.
D = Filling density of storage container in lbs/cu.ft.
T = Storage temperature in deg.F.
L = Weight of liquid portion in lbs.
L1 = Incremental weight of liquid in lbs.
L2 = New liquid weight in lbs.
V = Weight of vapor portion in lbs.
V2 = New vapor weight in lbs.
N = Weight of nitrogen in lbs.

Atomic wt N = 14.08

Molecular Wt $N_2$ = 28.16

Molecular Wt H-1301 148.93

32°F 272.5 PSIA - 360 @ 70°F
150.5 PSI $N_2$ Partial Pressure

24°F 206.6 - 99
59° 10.5

12A SUBCOMMITTEE ON HYDRAULIC CALCULATION METHODS

DATE: NOV. 20, 1985

TO: BILL CAREY
SAL CHINES
KEN EASEY
BILL ECKHOLM
CASEY GRANT
DAVE PARRISH

FROM: H. V. Williamson

SUBJECT: CALCULATING H-1301 DISCHARGE PRESSURES AND DENSITIES

The discharge characteristics of H-1301 pressurized with nitrogen can be derived entirely from known thermodynamic data and the solubility effects of nitrogen in liquid H-1301. Thermodynamic data has been published by du Pont in their phamplet T-1301 "THERMODYNAMIC PROPERTIES "FREON" FE1301 FIRE EXTINGUISHING AGENT". They have also provided information on the solubility characteristics of nitrogen in liquid H-1301 and the effect on the specific volume of the liquid phase.

My purpose in writing this letter is to review the unpublished equations used in calculating discharge characteristics and to provide you with a copy of a computer program based on these equations. With the program you can calculate (1) pressure recession in the storage container during discharge, and (2) pressure and density in the piping for specific increments of liquid leaving the storage container.

Anything you can do to check the validity of the assumptions made and the mathemaatics involved would be helpful. Nomenclature for the equations used is provided on a separate page for convenient use. Various items are identified using programming techniques such as arrays to avoid confusion when using the equations in the program. The nomenclature page also provides information on some empirical expressions used to calculate the effect of nitrogen on storage characteristics such as liquid volume

The thermodynamic data used from du Pont T-1301 includes the temperature, PSIA, liquid volume, vapor volume, liquid enthalpy, vapor enthalpy, liquid entropy, and vapor entropy. In addition Henry's Law Constants are included in terms of psi per weight percent units. The data covers the temperature range from 1°F to 70°F. More data could be added to cover a higher or lower range of temperatures. For program use this information is loaded into an eight column array DIM T(70,8) with each column having specific data as listed on the nomenclature page.

## STORAGE CONDITIONS

The first step before any calculations can be made is to set up the storage parameters and determine the existing liquid and vapor portions at the design temperature. Values must be set for P, D, and T. P (the required partial pressure of nitrogen) will be the desired storage pressure in psia minus the vapor pressure of H-1301 at temperature T. The liquid portion can be calculated by setting up two equations to eliminate one unknown. Assuming a container volume of one cu.ft., the weight of the liquid plus the weight of the vapor will be equal to the filling density.

$$L + V = D \qquad (1)$$

A second equation can be set up on the basis of the volume of each phase.

$$L*T(T,2)*(1+.053*P/T(T,8))+V*T(T,3) = 1 \qquad (2)$$

In equation (2) the expression (1+.053*P/T(T,8)) is an empirical relationship to account for the effect of nitrogen on the liquid volume. The background of this will be discussed at another point. To solve the equations for L, substitute V = D-L from (1) for V in (2). After rearranging terms the final solution will become:

$$L = (1-D*T(T,3))/(T(T,2)*(1+.053*P/T(T,8))-T(T,3)) \qquad (3)$$

And $V = D - L$

The weight of nitrogen in the container to start with will be the sum of the weight dissolved in the liquid phase plus the weight in the vapor phase.

$$N = L*.01*P/T(T,8)+V*.188*P/T(T,1) \qquad (4)$$

In equation (4) the term .01 converts the ratio P/T(T,8) to a fraction of liquid and the term .188 is the molecular weight of nitrogen divided by the molecular weight of H-1301.

## PRESSURE RECESSON IN CONTAINER

In this calculation it is assumed that the container volume is one cu. ft. and the filling density is D lbs./cu.ft. Starting at 70°F an increment of L1 lbs. of liquid is removed from the container which had an initial charge of L lbs. of liquid plus V lbs. of vapor. It is assumed that the remaining liquid and vapor expands at constant entropy because it does work on the portion that is removed or discharged. The following steps will explain the procedure used to calculate changing conditions during discharge.

Remove L1 lbs of liquid and set up an equation to determine total entropy based on starting temperature and H-1301 left in container. Including the liquid volume correction factor is a way of including the liquid nitrogen entropy on a volume basis. This also applies to the vapor entropy.

```
E = (L-L1)*(1+.053*P/T(X,8))*T(X,6)+V*(1+P/T(X,8))*T(X,7)

Let  E1 = (1+.053*P/T(X,8))*T(X,6)
     E2 = (1+P/T(X,1))*T(X,7)

     E = (L-L1)*E1+V*E2                                        (5)
```

After expanding to the next lower temperature step in the thermodynamic table, the new liquid portion will be L2 lbs. and the new vapor portion will be V2 lbs. The new total entropy based on a temperature one degree lower will be:

```
     E = L2*(1+.053*P2/T(X-1,8))*T(X-1,6)+V2*(1+P2/T(X-1,1))*
         T(X-1,7)

Let  E3 = (1+.053*P2/T(X-1,8))*T(X-1,6)
     E4 = (1+P2/T(X-1,1))*T(X-1,7)

     E = L2*E3+V2*E4                                           (6)
```

Since the total entropy does not change equations (5) and(6) can be equated to each other to eliminate E.

```
     (L-L1)*E1+V*E2 = L2*E3+V2*E4                              (7)
```

Based on the fact that the cylinder volume does not change, another equation involving L2 and V2 can be set up.

```
     L2*(1+.053*P2/T(X-1,8))*T(X-1,2)+V2*T(X-1,3) = 1 CU. FT.

Let  E5 = (1+.053*P2/T(X-1,8))*T(X-1,2)

Then V2 = (1-L2*E5)/T(X-1,3)                                   (8)
```

Still another equation is based on weight.

```
     (L-L1)*(1+.01*P/T(X,8))+V*(1+.188*P/T(X,1)) =
     L2*(1+.01*P2/T(X-1,8))+V2*(1+.188*P2/T(X-1,1)

Let  E6 = 1+.01*P/T(X-1,8)
     R1 = (1+.188*P/T(X,1)0/E6
     R2 = (1+.01*P2/T(X-1,8))/E6
     R3 = (1+.188*P2/T(X-1.1))/E6

Then (L-L1) = L2*R2+V2*R3-V*R1                                 (9)
```

Substitute the value for (L-L1) from equation (9) into (7)

$$(L2*R2+V2*R3-V*R1)*E1+V*E2 = L2*E3+V2*E4$$

Rearranging terms:

$$L2*(R2*E1-E3)+V2*(R3*E1-E4) = V*(R1*E1-E2) \qquad (10)$$

Finally substituting the value for V2 from equation (8) into equation (10) gives:

$$L2*(R2*E1-E3)+((1-L2*E5)/T(X-1,3))*(R3*E1-E4) = V*(R1*E1-E2)$$

Rearranging terms to solve for L2:

$$L2 = ((V*(R1*E1-E2)*T(X-1,3)-(R3*E1-E4))/((R2*E1-E3)*T(X-1,3)-E5*(R3*E1-E4))$$

Let A1 = (R1*E1-E2)
A2 = (R2*E1-E3)
A3 = (R3*E1-E4)

Then $$L2 = (V*A1*T(X-1,3)-A3)/(A2*T(X-1,3)-E5*A3) \qquad (11)$$

Equation (11) can be solved for L2 by estimating a value for P2 and then calculating V2 using equation (8). The incremental weight discharged (L1) is then the starting weight minus the final weight.

$$L1 = L+V-L2-V2 \qquad (12)$$

If equation (4) is solved for P the result is:

$$P = N/(L*.01/T(T,8)+V*.188/T(T,1))$$

Substituting P3 for P, a new nitrogen weight (N-L1*.01*P/T(X,8)) for N, L2 for L, and using X in place of T the result is:

$$P3 = (N-L1*.01*P/T(X,8))/(L2*.01/T(X-1,8)+V2*.188/T(X-1,1)) \qquad (13)$$

If the calculated value for P3 is not the same as the estimated value for P2, the estimate is corrected and the process repeated until P3 and P2 agree to within 0.1 PSI. This process corrects the incremental quantity L1 until it is just right to lower the temperature in the storage container by just one degree F. The process is impractical by manual means but is no problem for a computer.

PSI 161
401
1195 " 133.8
1205 Temp 63

NOMENCLATURE

Let X = Temperature in deg. F.
T(X,1) = H-1301 vapor pressure in PSIA
T(X,2) = Specific volume of liquid in cu.ft./lb.
T(X,3) = Specific volume of vapor in cu.ft./lb.
T(X,4) = Liquid enthalpy in btu/lb.
T(X,5) = Vapor enthalpy in btu/lb.
T(X,6) = Liquid entropy in btu/(lb)(oR)
T(X,7) = Vapor entropy in btu/(lb)(oR)
T(X,8) = Henry's law constants in psi/weight percent

P = Partial pressure of nitrogen in PSI
P2 = New nitrogen PSI after discharge or new temp.
D = Filling density of storage container in lbs/cu.ft.
T = Storage temperature in deg.F.
L = Weight of liquid portion in lbs.
L1 = Incremental weight of liquid in lbs.
L2 = New liquid weight in lbs.
V = Weight of vapor portion in lbs.
V2 = New vapor weight in lbs.
N = Weight of nitrogen in lbs.

Atomic wt N = 14.08

Molecular Wt $N_2$ = 28.16

Molecular Wt H-1301 148.93

32°F 272.5 PSIA - 360 @ 70°F
150.5 PSI $N_2$ Partial Pressure

24°F 206.6 - 99

59° 104.5

```
    5  REM  PROGRAM FOR CALCULATION PRESSURE RECESSION AND PIPELINE EXPANSION
   10  DATA 72.46,73.78,75.12,76.48,77.85,79.25,80.66,82.09,83.54,85.00,86.49,8
8.00,89.52,91.07,92.63,94.21,95.82,97.44,99.09,100.8,102.4,104.1,105.9,107.6
   20  DATA 109.4,111.2,113.0,114.8,116.7,118.6,120.5,122.4,124.3,126.3,128.3,1
30.3,132.3,134.4,136.5,138.6,140.7,142.9,145.1,147.3,149.5,151.7,154.0,156.3
   30  DATA 158.7,161.0,163.4,165.8,168.2,170.7,173.2,175.7,178.2,180.8,183.4,1
86.0,188.6,191.3,194,0,196.7,199.5,202.3,205.1,207.9,210.8,213.7
   40  DATA .00890,.00892,.00893,.00895,.00896,.00898,.00899,.00901,.00902,.009
04,.00905,.00907,.00909,.00910,.00912,.00913,.00915,.00917,.00918,.00920,.00921
   50  DATA .00923,.00925,.00927,.00928,.00930,.00932,.00933,.00935,.00937,.009
39,.00941,.00942,.00944,.00946,.00948,.00950,.00952,.00954,.00956,.00957,.00959
   60  DATA .00961,.00963,.00965,.00967,.00969,.00972,.00974,.00976,.00978,.009
80,.00982,.00984,.00987,.00989,.00991,.00993,.00996,.00998,.01000,.01003,.01005,
.01007,.01010,.01012,.01015,.01017,.0102,.01023
   70  DATA .4070,.3999,.3930,.3862,.3795,.3730,.3666,.3604,.3542,.3482,.3424,.
3366,.3309,.3254,.3200,.3146,.3094,.3043,.2993,.2944,.2895,.2848,.2801,.2756
   80  DATA .2711,.2667,.2624,.2582,.2541,.2500,.2460,.2421,.2382,.2345,.2308,.
2271,.2235,.2200,.2166,.2132,.2099,.2066,.2034,.2002,.1971,.1941,.1911,.1881
   90  DATA .1853,.1824,.1796,.1769,.1742,.1715,.1689,.1663,.1638,.1613,.1589,.
1565,.1541,.1518,.1495,.1472,.1450,.1428,.1407,.1386,.1365,.1344
  100  DATA 7.05,7.23,7.40,7.58,7.76,7.94,8.12,8.30,8.48,8.66,8.84,9.02,9.20,9.
38,9.56,9.74,9.92,10.11,10.29,10.47,10.65,10.84,11.02,11.20,11.39,11.57,11.76
  110  DATA 11.94,12.13,12.32,12.50,12.69,12.88,13.06,13.25,13.44,13.63,13.82,1
4.01,14.19,14.38,14.57,14.77,14.96,15.15,15.34,15.53,15.72,15.92,16.11,16.31
  120  DATA 16.50,16.69,16.89,17.08,17.29,17.48,17.68,17.87,18.08,18.27,18.47,1
8.67,18.87,19.07,19.27,19.47,19.67,19.88,20.08
  130  DATA 51.58,51.65,51.72,51.79,51.86,51.93,52.00,52.07,52.14,52.21,52.28,5
2.35,52.41,52.48,52.55,52.62,52.68,52.75,52.81,52.88,52.94,53.01,53.07,53.14
  140  DATA 53.2,53.27,53.33,53.39,53.45,53.51,53.58,53.64,53.70,53.76,53.82,53
.88,53.93,53.99,54.05,54.11,54.16,54.22,54.28,54.33,54.39,54.44,54.50,54.55
  150  DATA 54.60,54.65,54.71,54.76,54.81,54.86,54.91,54.96,55.00,55.05,55.10,5
5.15,55.19,55.24,55.28,55.32,55.37,55.41,55.45,55.49,55.53,55.57
  160  DATA .0159,.0163,.0166,.0170,.0174,.0178,.0181,.0185,.0189,.0193,.0197,.
0200,.0204,.0208,.0212,.0215,.0219,.0223,.0227,.0230,.0234,.0238,.0242,.0245
  170  DATA .0249,.0253,.0257,.0260,.0264,.0268,.0272,.0275,.0279,.0283,.0287,.
0290,.0294,.0298,.0301,.0305,.0309,.0313,.0316,.0320,.0324,.0327,.0331,.0335
  180  DATA .0339,.0342,.0346,.0350,.0354,.0357,.0361,.0365,.0368,.0372,.0376,.
0380,.0383,.0387,.0391,.0394,.0398,.0402,.0406,.0409,.0413,.0417
  190  DATA .1125,.1125,.1124,.1124,.1123,.1122,.1122,.1121,.1121,.1120,.1119,.
1119,.1118,.1118,.1117,.1117,.1116,.1116,.1115,.1115,.1114,.1113,.1113,.1112
  200  DATA .1112,.1111,.1111,.1110,.1110,.1109,.1109,.1108,.1108,.1107,.1107,.
1106,.1106,.1105,.1104,.1104,.1103,.1103,.1102,.1102,.1101,.1101,.1100,.1100
  210  DATA .1099,.1099,.1098,.1097,.1097,.1096,.1096,.1095,.1095,.1094,.1094,.
1093,.1092,.1092,.1091,.1091,.1090,.1089,.1089,.1088,.1088,.1087
  220  DATA 236.2,236.4,236.6,236.8,237.0,237.3,237.6,237.9,238.0,238.1,238.3,2
38.5,238.7,239.0,239.1,239.3,239.6,239.8,239.9,240.0,240.1,240.2,240.4,240.6
  230  DATA 240.8,241.0,241.1,241.2,241.2,241.3,241.3,241.5,241.6,241.7,241.7,2
41.7,241.8,241.8,241.7,241.7,241.7,241.7,241.7,241.7,241.6,241.6,241.6,241.5
  240  DATA 241.5,241.4,241.3,241.2,241.1,241.0,240.9,240.8,240.6,240.5,240.3,2
40.1,240.0,239.8,239.6,239.3,239.1,238.9,238.7,238.5,238.2,238.0
 1000 DIM T(70,8)
 1010 FOR Y = 1 TO 8
 1020 FOR X = 1 TO 70
 1030 READ T(X,Y)
 1035 REM LPRINT USING "###.#####";T(X,Y)
 1040 NEXT X
 1050 NEXT Y
```

```
1060 REM FOR X = 1 TO 69
1070 REM A = T(X+1,1)-T(X,1)  REM LINES 1035 AND 1060-1160 USED TO CHECK DATA
1080 REM B = T(X+1,2)-T(X,2)
1090 REM C = T(X,3)-T(X+1,3)
1100 REM D = T(X+1,4)-T(X,4)
1110 REM E = T(X+1,5)-T(X,5)
1120 REM F = T(X+1,6)-T(X,6)
1130 REM G = T(X+1,7)-T(X,7)
1140 REM H = T(X+1,8)-T(X,8)
1150 REM LPRINT USING"##.#####";A,B,C,D,E,F,G,H
1160 REM NEXT X
1170 DIM D(70,5)
1190 P = 161   :REM INSERT 161 FOR 360 SYSTEM OR 401 FOR 600 SYSTEM
1200 D = 70    :REM INSERT DESIRED FILLING DENSITY
1210 T = 70    :REM NORMAL STORAGE DESIGN TEMPERATURE
1215 REM GOTO 2000 :REM OUT TO CALCULATE PRESSURE RECESSION IN STORAGE TANK
1220 L = (1-D*T(T,3))/(T(T,2)*(1+.053*P/T(T,8))-T(T,3))
1230 V = D-L
1240 FOR X = T TO 2 STEP -1
1250 D(X,5) = P+T(X,1)
1260 D(X,2) = L
1270 D(X,3) = V
1280 D(X,4) = P
1290 N = L*.01*P/T(X,8)+V*.188*P/T(X,1)
1300 P2 = P-1
1310 P2 = P2-1
1320 E1 = (1+.053*P/T(X,8))*(.015526+.000374*X)
1330 E5 = (1+.053*P2/T(X-1,8))*T(X-1,2)
1340 E6 = 1+.01*P/T(X,8)
1350 R1 = (1+.188*P/T(X,1))/E6
1360 R2 = (1+.01*P2/T(X-1,8))/E6
1370 R3 = (1+.188*P2/T(X-1,1))/E6
1380 A1 = R1*E1-(1+P/T(X,1))*T(X,7)
1390 A2 = R2*E1-(1+.053*P2/T(X-1,8))*(.015526+.000374*(X-1))
1400 A3 = R3*E1-(1+P2/T(X-1,1))*T(X-1,7)
1410 L2 = (V*A1*T(X-1,3)-A3)/(A2*T(X-1,3)-E5*A3)
1420 V2 = (1-L2*E5)/T(X-1,3)
1430 L1 = L+V-L2-V2
1440 P3 = (N-L1*.01*P/T(X,8))/(L2*.01/T(X-1,8)+V2*.188/T(X-1,1))
1450 IF P3 < P2-.5 GO TO 1490
1460 IF P3 > P2+.1 GO TO 1510
1470 IF P3 < P2-.1 GO TO 1530
1480 GO TO 1550
1490 P2 = P2-1
1500 GO TO 1330
1510 P2 = P2+.1
1520 GO TO 1330
1530 P2 = P2-.1
1540 GO TO 1330
1550 IF L2 < 0 GO TO 1620
1560 D(X-1,1) = D(X,1)+L1
1570 L = L2
1580 V = V2
1590 P = P2
1600 S = S+1
1610 NEXT X
```

144
12
288 1728

```
1620 LPRINT "PRESSURE RECESSION FOR H-1301 PLUS NITROGEN"
1630 LPRINT "FILLING DENSITY ="D"LBS./CU.FT."
1640 LPRINT "STORAGE PRESSURE ="D(T,5)"PSIA AT "T"DEG.F."
1650 LPRINT
1660 LPRINT " TEMP   PSIA    DISC     LIQ      VAP     N-PSI    LDENS"
1670 FOR X = T TO (T-S) STEP -1
1680 LPRINT USING " ###   ###.#   ##.###   ##.###   ##.###   ###.#   ###.##";X
,D(X,5),D(X,1),D(X,2),D(X,3),D(X,4),(1+.01*D(X,4)/T(X,8))/(T(X,2)*(1+.053*D(X,4)
/T(X,8)))
1690 NEXT X
1700 END
2000 DATA 101.5,59, 72.8,45 :REM INSERT DATA FROM PRESSURE RECESSION TABLE
2010 READ P,T
2015 S = S+1
2020 N = .01*P/T(T,8)
2030 D(T,1) = P+T(T,1)
2040 D(T,2) = 1
2050 D(T,3) = 0
2060 D(T,4) = P
2070 D(T,5) = (1+N)/((1+.053*P/T(T,8))*T(T,2))
2080 P2 = P-1
2090 L = 1
2100 V = 0
2110 FOR X = T TO 2 STEP -1
2120 E1 = (1+.053*P/T(X,8))*T(X,4)
2130 E2 = (1+P/T(X,1))*T(X,5)
2140 E6 = (1+.01*P/T(X,8))
2150 E7 = (1+.188*P/T(X,1))
2160 E3 = (1+.053*P2/T(X-1,8))*T(X-1,4)
2170 E4 = (1+P2/T(X-1,1))*T(X-1,5)
2180 E8 = (1+.01*P2/T(X-1,8))
2190 E9 = (1+.188*P2/T(X-1,1))
2200 L2 = (L*(E1*E9-E6*E4)+V*(E2*E9-E7*E4))/(E3*E9-E8*E4)
2210 V2 = 1-L2
2220 P3 = N/(L2*.01/T(X-1,8)+V2*.188/T(X-1,1))
2230 IF P3 < P2-.5 GO TO 2270
2240 IF P3 > P2+.1 GO TO 2290
2250 IF P3 < P2-.1 GO TO 2310
2260 GO TO 2330
2270 P2 = P2-1
2280 GO TO 2160
2290 P2 = P2+.1
2300 GO TO 2160
2310 P2 = P2-.1
2320 GO TO 2160
2330 P = P2
2340 L = L2
2350 V = V2
2360 D(X-1,1) = P+T(X-1,1)
2370 D(X-1,2) = L
2380 D(X-1,3) = V
2390 D(X-1,4) = P
2400 D(X-1,5) = (1+N)/(L*(1+.053*P/T(X-1,8))*T(X-1,2)+V*T(X-1,3))
2410 NEXT X
2420 LPRINT "CONSTANT ENTHALPY EXPANSION FOR H-1301 PLUS N2"
2430 LPRINT
2440 LPRINT "  TEMP   PSIA     LIQ    VAP   N-PSI   DENSITY"
2450 FOR X = T TO 2 STEP -1
2460 LPRINT USING "  ###   ###.#   #.###   .###   ###.##  ###.##";X,D(X,1),D(X
,2),D(X,3),D(X,4),D(X,5)
2470 NEXT X
2480 END
```

$< P_2 - .5$