

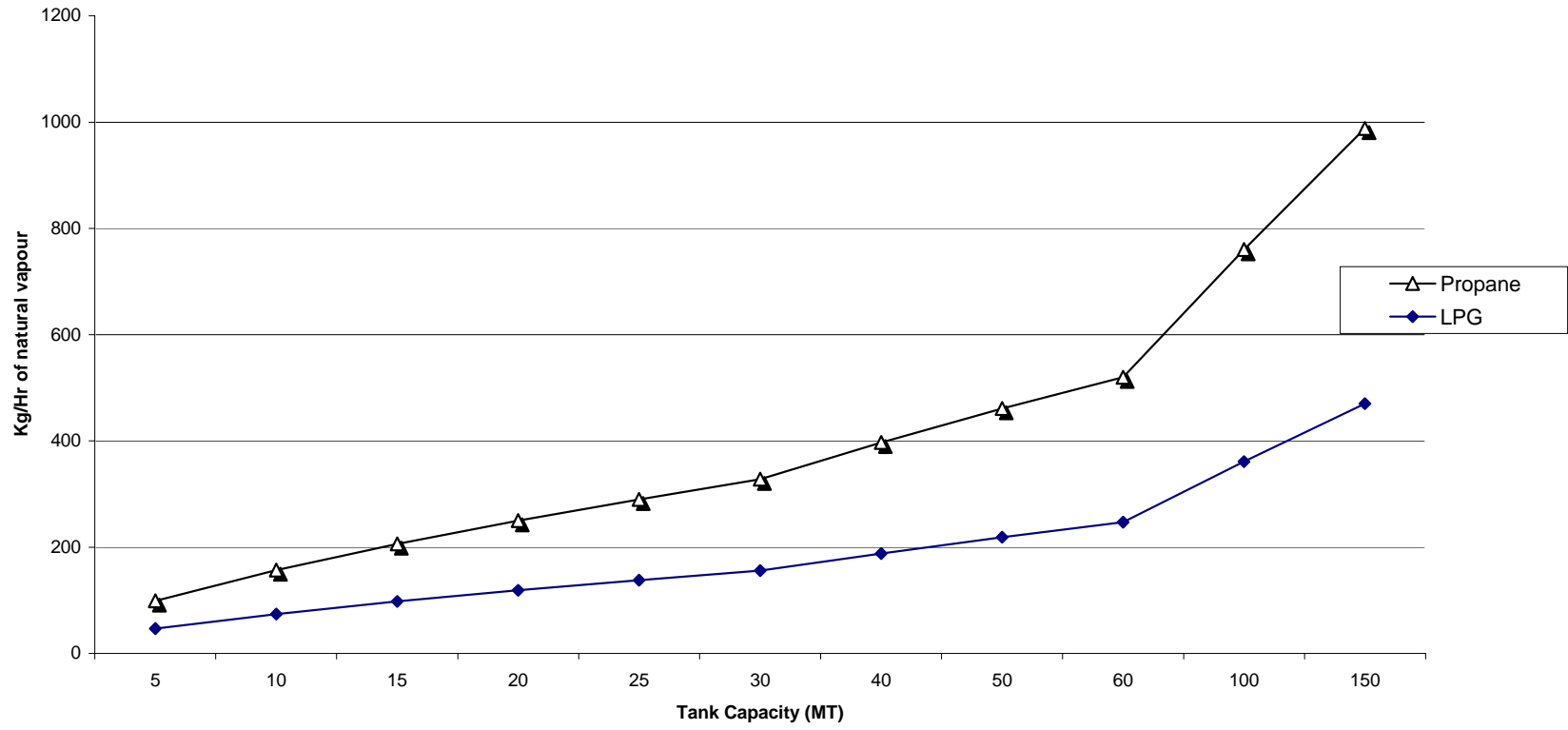
PROPANE VAPOR DENSITY AT TEMP-PRESSURE RELATION

| | | | | | | | | | | | |
|----------|-----|-----------|-----|-----|------|------|------|------|------|------|------|
| Density | 2.0 | Gms/Litre | | | | | | | | | |
| Temp | 0.0 | °C | | | | | | | | | |
| Pressure | 1.0 | Atm | | | | | | | | | |
| | | | | | | | | | | | |
| Temp | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | 11.0 |
| 0.0 | 4.0 | 6.0 | 7.9 | 9.9 | 11.9 | 13.8 | 15.8 | 17.7 | 19.7 | 21.7 | 23.6 |
| 5.0 | 3.9 | 5.9 | 7.8 | 9.7 | 11.6 | 13.6 | 15.5 | 17.4 | 19.4 | 21.3 | 23.2 |
| 10.0 | 3.9 | 5.7 | 7.6 | 9.5 | 11.4 | 13.3 | 15.2 | 17.1 | 19.0 | 20.9 | 22.8 |
| 15.0 | 3.8 | 5.6 | 7.5 | 9.4 | 11.2 | 13.1 | 15.0 | 16.8 | 18.7 | 20.5 | 22.4 |
| 20.0 | 3.7 | 5.6 | 7.4 | 9.2 | 11.0 | 12.9 | 14.7 | 16.5 | 18.4 | 20.2 | 22.0 |
| 25.0 | 3.7 | 5.5 | 7.3 | 9.1 | 10.9 | 12.7 | 14.5 | 16.3 | 18.1 | 19.9 | 21.7 |
| 30.0 | 3.6 | 5.4 | 7.1 | 8.9 | 10.7 | 12.5 | 14.2 | 16.0 | 17.8 | 19.5 | 21.3 |
| 35.0 | 3.5 | 5.3 | 7.0 | 8.8 | 10.5 | 12.2 | 14.0 | 15.7 | 17.5 | 19.2 | 21.0 |
| 40.0 | 3.5 | 5.2 | 6.9 | 8.6 | 10.3 | 12.1 | 13.8 | 15.5 | 17.2 | 18.9 | 20.6 |
| 45.0 | 3.4 | 5.1 | 6.8 | 8.5 | 10.2 | 11.9 | 13.6 | 15.2 | 16.9 | 18.6 | 20.3 |
| 50.0 | 3.4 | 5.0 | 6.7 | 8.4 | 10.0 | 11.7 | 13.3 | 15.0 | 16.7 | 18.3 | 20.0 |
| 55.0 | 3.3 | 5.0 | 6.6 | 8.2 | 9.9 | 11.5 | 13.1 | 14.8 | 16.4 | 18.0 | 19.7 |
| 60.0 | 3.3 | 4.9 | 6.5 | 8.1 | 9.7 | 11.3 | 12.9 | 14.6 | 16.2 | 17.8 | 19.4 |
| 65.0 | 3.2 | 4.8 | 6.4 | 8.0 | 9.6 | 11.2 | 12.7 | 14.3 | 15.9 | 17.5 | 19.1 |
| 70.0 | 3.2 | 4.7 | 6.3 | 7.9 | 9.4 | 11.0 | 12.6 | 14.1 | 15.7 | 17.3 | 18.8 |
| 75.0 | 3.1 | 4.7 | 6.2 | 7.8 | 9.3 | 10.8 | 12.4 | 13.9 | 15.5 | 17.0 | 18.5 |
| 80.0 | 3.1 | 4.6 | 6.1 | 7.6 | 9.2 | 10.7 | 12.2 | 13.7 | 15.2 | 16.8 | 18.3 |
| 85.0 | 3.0 | 4.5 | 6.0 | 7.5 | 9.0 | 10.5 | 12.0 | 13.5 | 15.0 | 16.5 | 18.0 |
| 90.0 | 3.0 | 4.5 | 6.0 | 7.4 | 8.9 | 10.4 | 11.9 | 13.3 | 14.8 | 16.3 | 17.8 |
| 95.0 | 3.0 | 4.4 | 5.9 | 7.3 | 8.8 | 10.3 | 11.7 | 13.2 | 14.6 | 16.1 | 17.5 |
| 100.0 | 2.9 | 4.4 | 5.8 | 7.2 | 8.7 | 10.1 | 11.6 | 13.0 | 14.4 | 15.9 | 17.3 |

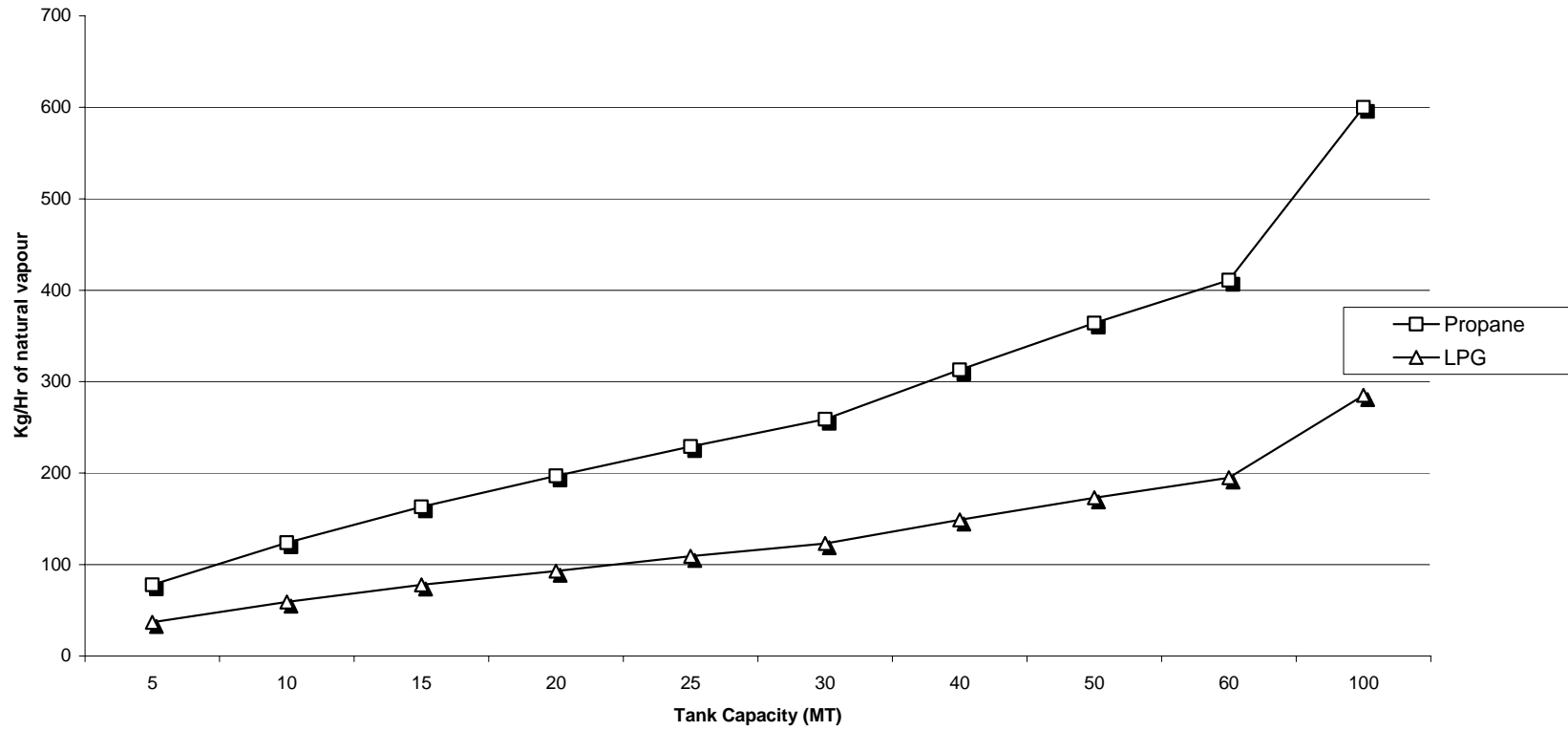
BUTANE VAPOR DENSITY AT TEMP-PRESSURE RELATION

| | | | | | | | | | | |
|----------|-----|-----------|-----|-----|-----|-----|-----|-----|-----|-----|
| Density | 2.6 | Gms/Litre | | | | | | | | |
| Temp | 0.0 | °C | | | | | | | | |
| Pressure | 1.0 | Atm | | | | | | | | |
| Temp | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
| 0.0 | 2.9 | 3.1 | 3.4 | 3.6 | 3.9 | 4.1 | 4.4 | 4.6 | 4.9 | 5.1 |
| 5.0 | 2.8 | 3.0 | 3.3 | 3.5 | 3.8 | 4.0 | 4.3 | 4.5 | 4.8 | 5.0 |
| 10.0 | 2.7 | 3.0 | 3.2 | 3.5 | 3.7 | 4.0 | 4.2 | 4.4 | 4.7 | 4.9 |
| 15.0 | 2.7 | 2.9 | 3.2 | 3.4 | 3.7 | 3.9 | 4.1 | 4.4 | 4.6 | 4.8 |
| 20.0 | 2.7 | 2.9 | 3.1 | 3.4 | 3.6 | 3.8 | 4.1 | 4.3 | 4.5 | 4.8 |
| 25.0 | 2.6 | 2.8 | 3.1 | 3.3 | 3.5 | 3.8 | 4.0 | 4.2 | 4.5 | 4.7 |
| 30.0 | 2.6 | 2.8 | 3.0 | 3.2 | 3.5 | 3.7 | 3.9 | 4.2 | 4.4 | 4.6 |
| 35.0 | 2.5 | 2.7 | 3.0 | 3.2 | 3.4 | 3.6 | 3.9 | 4.1 | 4.3 | 4.5 |
| 40.0 | 2.5 | 2.7 | 2.9 | 3.1 | 3.4 | 3.6 | 3.8 | 4.0 | 4.2 | 4.5 |
| 45.0 | 2.4 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 | 4.0 | 4.2 | 4.4 |
| 50.0 | 2.4 | 2.6 | 2.8 | 3.0 | 3.3 | 3.5 | 3.7 | 3.9 | 4.1 | 4.3 |
| 55.0 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 | 4.3 |
| 60.0 | 2.3 | 2.5 | 2.7 | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 | 4.2 |
| 65.0 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 | 3.9 | 4.1 |
| 70.0 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 | 3.9 | 4.1 |
| 75.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 |
| 80.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 |
| 85.0 | 2.2 | 2.4 | 2.6 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 | 3.9 |
| 90.0 | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 | 3.8 |
| 95.0 | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 |
| 100.0 | 2.1 | 2.3 | 2.5 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.7 |

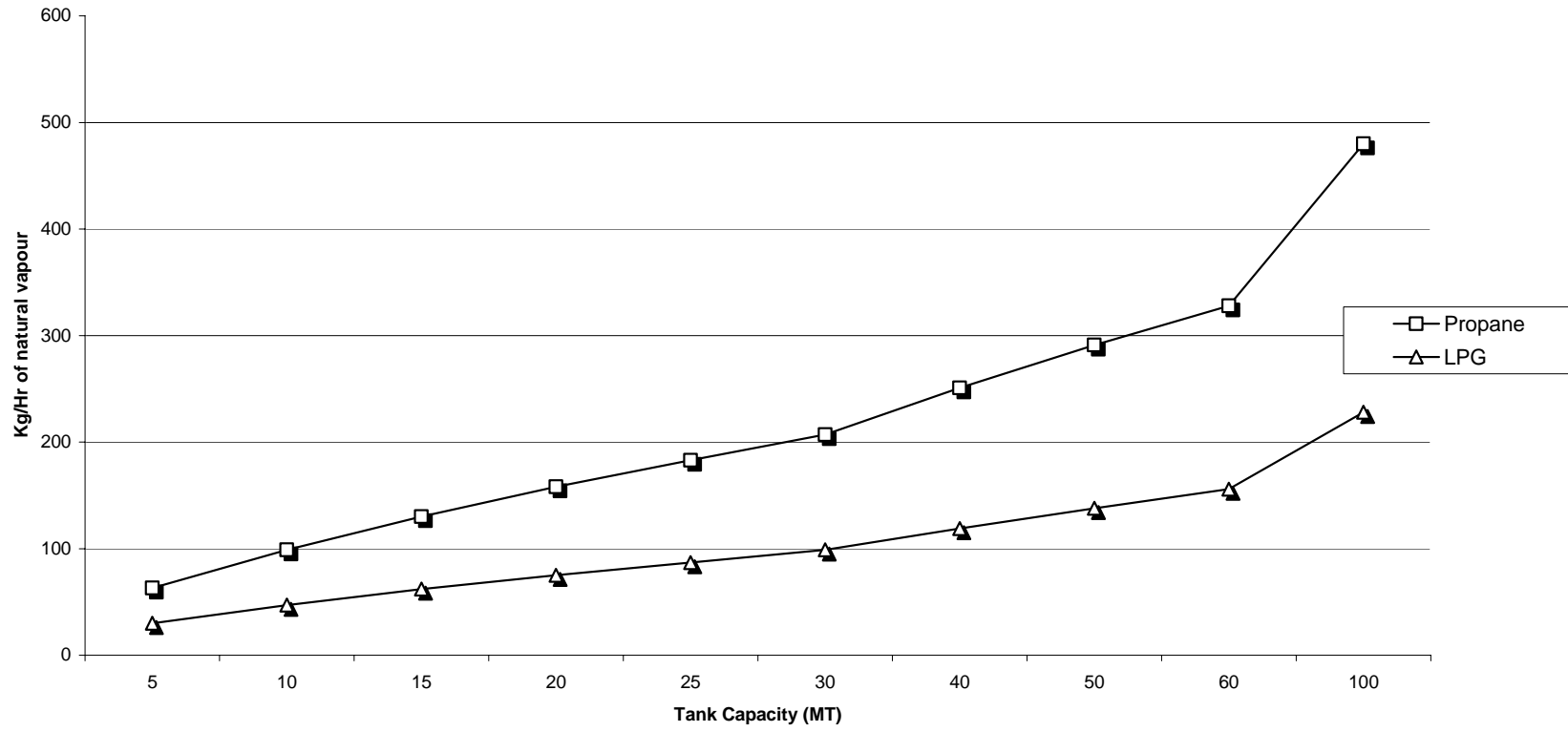
Natural Vaporisation at 80% level



Natural Vaporisation at 50% level



Natural Vaporisation at 30% level



DEW POINT FOR n-BUTANE

| PSIA | PSIG | Kg/Cm2 | Bubble.°C | Dew.°C |
|-------------|-------------|---------------|------------------|---------------|
| 20 | 5.3 | 0.37 | 5.87 | 8.43 |
| 25 | 10.3 | 0.72 | 11.73 | 14.69 |
| 30 | 15.3 | 1.08 | 18.13 | 20.33 |
| 35 | 20.3 | 1.43 | 22.6 | 24.62 |
| 40 | 25.3 | 1.78 | 26.79 | 28.68 |
| 45 | 30.3 | 2.13 | 31.45 | 33.44 |
| 50 | 35.3 | 2.48 | 35.11 | 37.34 |
| 55 | 40.3 | 2.83 | 38.18 | 40.12 |
| 60 | 45.3 | 3.18 | 40.96 | 43.22 |
| 65 | 50.3 | 3.54 | 43.11 | 45.18 |

DEW POINT CALCULATIONS BY De Priester RELATIONS

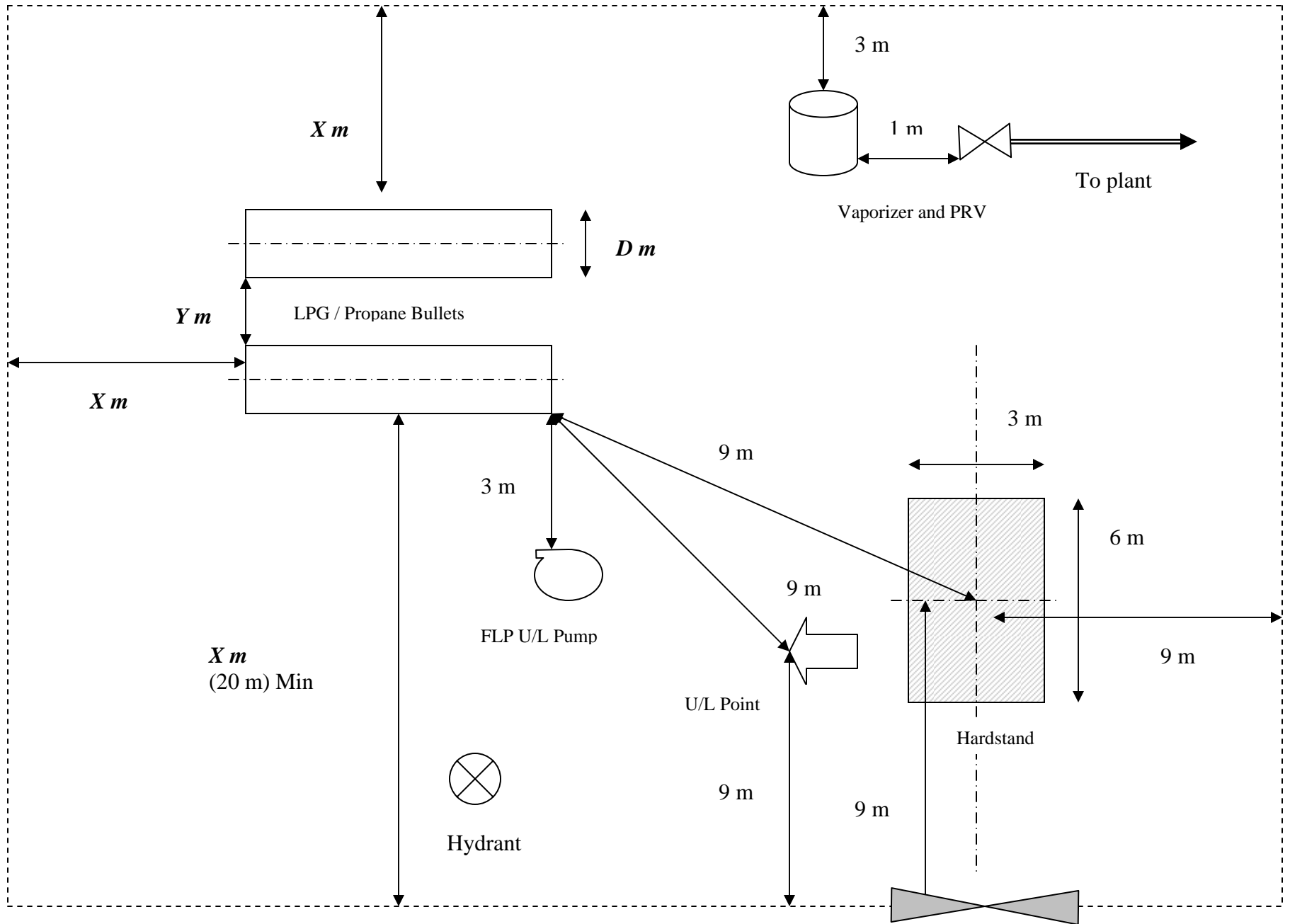
| At a Pressure of 4.5 Kg/cm ² g | | | 80.8 PSia | | | | | |
|---|-------|--------|------------|--------------|---------------------|------------|----------|-------|
| | | | Yi | at 80 deg F | Ri | | | |
| | Wt/Wt | Mol Wt | Mole/ Mole | K factor | Relative Volatility | Yi/Ri | m | |
| n-C3 | 0.35 | 44 | 0.29001883 | 1.75 | 3.5 | 0.082863 | | |
| n-C4 | 0.65 | 58 | 0.70998117 | 0.5 | 1 | 0.709981 | 0.782844 | |
| | | | | | | 0.792844 | | |
| | | | | | | | | |
| | | | | | | from table | 110 | Deg F |
| | | | | | | | 43.3 | Deg C |
| | | | | | | | | |
| | | | | | | | | |
| At a Pressure of 3.5 Kg/cm ² g | | | 66.1 PSia | | | | | |
| | | | Yi | at 100 deg F | Ri | | | |
| | Wt/Wt | Mol Wt | Mole/ Mole | K factor | Relative Volatility | Yi/Ri | m | |
| n-C3 | 0.35 | 44 | 0.29001883 | 2.7 | 3.292683 | 0.08808 | | |
| n-C4 | 0.65 | 58 | 0.70998117 | 0.82 | 1 | 0.709981 | 0.788061 | |
| | | | | | | 0.798061 | | |
| | | | | | | | | |
| | | | | | | from table | 96 | Deg F |
| | | | | | | | 35.6 | Deg C |
| | | | | | | | | |
| | | | | | | | | |
| At a Pressure of 2.5 Kg/cm ² g | | | 51.4 PSia | | | | | |
| | | | Yi | at 100 deg F | Ri | | | |
| | Wt/Wt | Mol Wt | Mole/ Mole | K factor | Relative Volatility | Yi/Ri | m | |
| n-C3 | 0.35 | 44 | 0.29001883 | 3 | 3.333333 | 0.087006 | | |
| n-C4 | 0.65 | 58 | 0.70998117 | 0.9 | 1 | 0.709981 | 0.786987 | |
| | | | | | | 0.796987 | | |
| | | | | | | | | |
| | | | | | | from table | 83 | Deg F |
| | | | | | | | 28.3 | Deg C |

Safety Distances for LPG bulk installations as per SMPV Rules

| Sr No | LPG Storage Capacity in MT | | X m | | Y m | |
|-------|----------------------------|---------------|--------------|-------------------------|--|-------------------------|
| | Above | But not above | Above Ground | Mounded/ Underground | Above Ground | Mounded/ Underground |
| 1. | 0.00 | 0.85 | 5 | 3 | 1 | 1 |
| 2. | 0.85 | 3.18 | 10 | 3 | 1 | 1 |
| 3. | 3.18 | 4.25 | 10 | 5 | 1.5 | 1 |
| 4. | 4.25 | 8.50 | 15 | 7.5 | 2 | 1 |
| 5. | 8.50 | 17.00 | 20 | 10 | 2 | 1 |
| 6. | 17.00 | 148.75 | 30 | 15 | = Max (2 m, 1/4 th of the sum of dia. of adjacent vessels, ½ the dia. of two adjacent vessel) | 1 |
| 7. | 148.75 | 191.25 | 40 | 15 | | 1 |
| 8. | 191.25 | 318.50 | 60 | 15 | | 1 |
| 9. | 318.50 | 1615.00 | 90 | 15 | | 1 |
| 10. | 1615.00 | | 120 | 15 | | 1 |

Capacity calculated considering LPG sp gravity 0.5 and filling density 85%.

At the Unloading side the minimum distance from the bullet to the fence has to be 20m.



Compiled by OPTECH ENGINEERING PRIVATE LIMITED

LIQUID DENSITIES
wrt
TEMPERATURE
FOR
BUTANE AND
PROPANE
RESPECTIVELY

| | 44.1 | 58.1 |
|-------------|-------------|-------------|
| 1.0 | 527.2 | 694.9 |
| 2.0 | 525.8 | 693.1 |
| 3.0 | 524.4 | 691.2 |
| 4.0 | 523.0 | 689.3 |
| 5.0 | 521.5 | 687.4 |
| 6.0 | 520.1 | 685.5 |
| 7.0 | 518.7 | 683.6 |
| 8.0 | 517.2 | 681.7 |
| 9.0 | 515.8 | 679.8 |
| 10.0 | 514.3 | 677.9 |
| 11.0 | 512.8 | 675.9 |
| 12.0 | 511.3 | 674.0 |
| 13.0 | 509.9 | 672.0 |
| 14.0 | 508.4 | 670.1 |
| 15.0 | 506.9 | 668.1 |
| 16.0 | 505.3 | 666.1 |
| 17.0 | 503.8 | 664.1 |
| 18.0 | 502.3 | 662.0 |
| 19.0 | 500.7 | 660.0 |
| 20.0 | 499.2 | 658.0 |
| 21.0 | 497.6 | 655.9 |
| 22.0 | 496.1 | 653.9 |
| 23.0 | 494.5 | 651.8 |
| 24.0 | 492.9 | 649.7 |
| 25.0 | 491.3 | 647.6 |
| 26.0 | 489.7 | 645.4 |
| 27.0 | 488.1 | 643.3 |
| 28.0 | 486.4 | 641.2 |
| 29.0 | 484.8 | 639.0 |
| 30.0 | 483.1 | 636.8 |
| 31.0 | 481.5 | 634.6 |
| 32.0 | 479.8 | 632.4 |
| 33.0 | 478.1 | 630.2 |
| 34.0 | 476.4 | 627.9 |
| 35.0 | 474.7 | 625.7 |
| 36.0 | 473.0 | 623.4 |
| 37.0 | 471.2 | 621.1 |
| 38.0 | 469.5 | 618.8 |
| 39.0 | 467.7 | 616.4 |
| 40.0 | 465.9 | 614.1 |
| 41.0 | 464.1 | 611.7 |
| 42.0 | 462.3 | 609.3 |
| 43.0 | 460.4 | 606.9 |
| 44.0 | 458.6 | 604.4 |
| 45.0 | 456.7 | 602.0 |
| 46.0 | 454.8 | 599.5 |
| 47.0 | 452.9 | 597.0 |
| 48.0 | 451.0 | 594.4 |
| 49.0 | 449.1 | 591.9 |
| 50.0 | 447.1 | 589.3 |
| 51.0 | 445.1 | 586.7 |
| 52.0 | 443.1 | 584.0 |
| 53.0 | 441.1 | 581.4 |
| 54.0 | 439.0 | 578.6 |
| 55.0 | 436.9 | 575.9 |

Compiled by OPTECH ENGINEERING PRIVATE LIMITED

| Hydrocarbon | Supply Pressures for equal mm of water gauge | |
|---|---|-------------------------|
| | Thermal input | Primary Aeration |
| Ethane | 405 | 250 |
| Propane | 350 | 455 |
| Butane | 270 | 555 |
| Above supply pressures are based on 350mm water gauge for propane | | |
| Primary aeration = (Square root of Supply Pressure)/ Extended Wobbe index | | |
| Extended Wobbe Index = Cal. Value*square root of (Supply pressure/ Density) | | |

LPG Properties and some typical specifications

Important Properties:

1. Specific Gravity:

Definition: It is the ratio of density of a substance to that of *water* in case of liquid specific gravity and *air* in case of gaseous specific gravity at same temperature and pressure conditions.

Values:

| At 15 deg C and 1 atm. | Propane | n-Butane | iso-Butane | Commercial Butane |
|------------------------|---------|----------|------------|-------------------|
| Liquid | 0.5077 | 0.5844 | 0.5631 | 0.575 |
| Gaseous | 1.550 | 2.077 | 2.068 | 2.0 |

Importance: It can be seen that LPG is heavy twice than air and hence in case of any leakage it settles down at floor level, and can be hazardous if it accumulates in pits, drains, depressions. **Hence ground level ventilation is very necessary.**

2. Liquid to gas Ratio:

Definition: It is the ratio of volume of gas of certain mass to that of Volume of liquid of same mass at the same temperature.

Value:

| At 15 deg C and 1 atm. | Propane | n-Butane | iso-Butane | Commercial Butane |
|------------------------|---------|----------|------------|-------------------|
| Vol / Vol | 267.4 | 229.8 | 222.3 | 233.0 |

Importance: Any leakage of LPG liquid can cause expansion in vapour, which occupies 246 times, volume to that of liquid and can be very hazardous.

3. Specific Volume:

Definition: It is the reciprocal of Liquid density.

Value:

| At 15 deg C and 1 atm. In M3/Tonne. | Propane | n-Butane | iso-Butane | Commercial Butane |
|-------------------------------------|---------|----------|------------|-------------------|
| Liquid | 1.970 | 1.710 | 1.750 | 1.730 |
| Gaseous | 63.0 | 208.3 | 142.9 | 178.0 |

4. Vapour Pressure:

Definition: Vapour pressure is the pressure exerted on the walls of the container when the gas is enclosed in it. When liquid exists with the gas the pressure is called as Saturated Vapour pressure at that temperature.

Vapour pressure depends of temperature and is independent on the quantity of liquid present in the container.

5. Boiling Point:

Definition: It is the temperature at which the first bubble will form and has the same Vapour pressure as that at the surface of liquid.

Value:

| | Propane | n-Butane | iso-Butane | Commercial Butane |
|-----------------------|---------|----------|------------|-------------------|
| At 1 atm. In Degree C | -42.045 | -0.50 | -11.72 | -7.0 |

6. Flammability Limit:

Explanation: Fuel gases will burn only when mixed with air in the in the certain proportion. The minimum and maximum concentrations of a fuel gas in a fuel/air mixture between which the mixture between can be ignited are termed as the lower and upper limit of inflammability. These limits are narrower in LPG than other fuel gases, making LPG relatively safer in use.

Value:

| Flammability gas/air Vol% | Propane | n-Butane | iso-Butane | Commercial Butane |
|---------------------------|---------|----------|------------|-------------------|
| Lower Limit | 2.10 | 1.86 | 1.80 | 1.80 |
| Upper Limit | 10.1 | 8.41 | 8.44 | 8.50 |

Calorific Value:

Definition: Calorific value is defined as the amount of heat released when a unit quantity of gas is burned at atmospheric pressure and ambient temperature.

Gross calorific value (GCV) is obtained when the contribution from the latent heat of condensation of water vapour formed is recovered The net calorific value is obtained from GCV by subtracting the heat of condensation of water vapour.

Value:

Compiled by OPTech ENGINEERING PRIVATE LIMITED

| | | | | |
|----------------|---------|----------|------------|-------------------|
| At 25 Deg C | Propane | n-Butane | iso-Butane | Commercial Butane |
| Gross Kcal/Kg | 11945 | 11740 | 11715 | 11700 |
| Gross Kcal/SM3 | 23700 | 30600 | 30500 | 30200 |
| Net Kcal/Kg | 10985 | 10830 | 10805 | 10800 |
| Net Kcal/m3 | 22250 | 29400 | 29200 | 29000 |

Importance: Depending on the composition of the LPG the calorific value of fuel will change and in turn it will change the net heating value also.

7. Dew Point:

Explanation: It is the maximum temperature at which the first drop of liquid is formed when a saturated gas is cooled or is brought on contact with a cool surface. As the pressure increases the dew point of LP Gases decreases.

Value: in deg C

| Pressure in ATM. | Propane | n-Butane | iso-Butane |
|------------------|---------|----------|------------|
| 1.0 | -42 | -1 | -11.7 |
| 2.0 | -25 | 21 | 6.1 |
| 3.0 | -14 | 32 | 20 |
| 4.0 | -6 | 42 | 29.5 |
| 5.0 | 2 | | 36 |

Importance: In cold climatic condition when outside temperature is low the LPG tends to condense down which can be very hazardous. Hence by reducing the pressure of gas the dew point can be depressed and the condensation phenomenon can be avoided. When a customer uses a vaporizer the vapour coming out of the vaporizer is in saturated vapour at high temperature and it can reach dew point if cooled to atmospheric temperature at high pressure .

8. Toxicity: LPG contains no toxic material, In case of heavy leakage asphyxiation due to lack of oxygen can be caused. LPG is slightly anesthetic when high concentrations are breathed in for sufficiently long time.
9. Odour: LPG is purposefully odorized by adding Ethyl/Methyl Mercaptan. Its smell is detectable in air at concentrations down to 1/5 of the lower explosive limit. In other words it can be smelt long before it becomes dangerous enough to catch fire.

10. Air to fuel Ratio:

Compiled by OPTech ENGINEERING PRIVATE LIMITED

Air required for complete combustion of a particular amount of fuel.

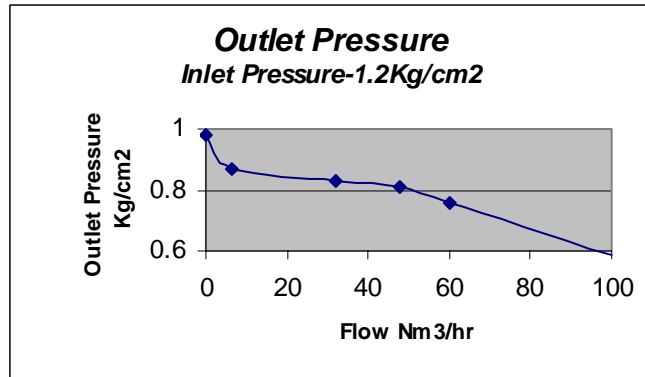
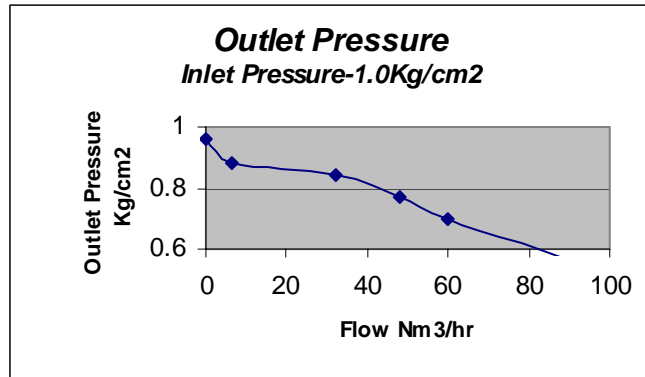
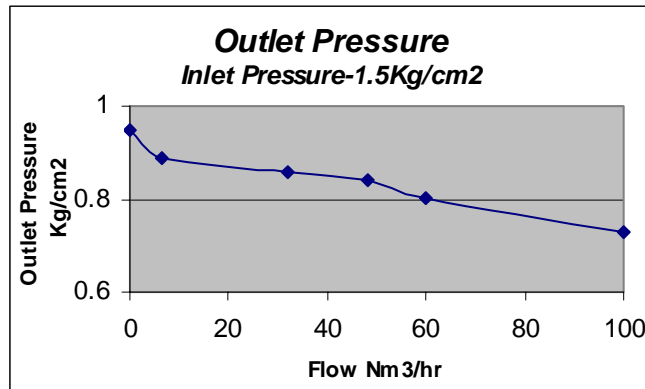
Value:

| | Propane | n-Butane | iso-Butane | Commercial Butane |
|-------------|---------|----------|------------|-------------------|
| Air to Fuel | 23.8 | 31.0 | 31.0 | 30.0 |

Other Properties:

| | Propane | n-Butane | iso-Butane | Commercial Butane |
|---|---------|----------|------------|-------------------|
| Theoretical Flame temperature in air Deg C | 1970 | 1975 | 1975 | 1975 |
| Theoretical Flame temperature in oxygen Deg C | 2740 | 2740 | 2740 | 2740 |
| Ignition Temperature Deg C | 95 | 405 | 462 | 420 |

PERFORMANCE OF R 2304 (VANAZ MAKE) REGULATOR



It can be seen that as the Flow Increases beyond the set point the Pressure Drops drastically and as the flow decreases the pressure increases. This gives us an importance of sizing the regulator and set point

