In Conclusion

High coefficients of friction are required for brakes but at the same time they should have a reasonable life. If brakes get wet or contaminated with oil then the coefficient drops and the brakes can become next to useless. Wet brakes will dry out, oil contaminated discs, drums and pads must be changed.

Tyres also need a high coefficient of friction consistent with good tyre life. Wet runways reduce tyre braking efficiency and at high speed aquaplaning can occur where an actual layer of water becomes interspaced between the tyre and the runway reducing tyre grip to almost zero. A good depth of tread helps reduce the problem of aquaplaning.

Where friction is a problem (bearings, sliding members etc) the surfaces are machined as smooth as possible (consistent with cost) and a lubricant used to help separate the "hills and troughs". Oils, greases and air (under pressure) are used to help keep sliding surfaces separate and reduce the coefficient. Air bearings have extremely low friction coefficients and must never be started until the air pressure has built up to separate the bearing surfaces. When torque loading nuts and bolts, if the threads are lubricated, then the effective torque on the thread is increased for any given torque wrench setting. It is important to check the aircraft manual if the threads are lubricated or kept dry.

FLUID DYNAMICS

The term 'fluid' refers to both the liquid and gaseous state of any substance. From previous work we are aware that in both of these states the molecules are able to move past one another with relative ease, ie they can flow. In any fluid there is an internal friction force present between each layer of molecules as they slide over one another. This internal resistance is called VISCOSITY, and for many fluids it is dependent on temperature, decreasing in value as the temperature rises. This is due to the molecules being further apart following expansion, which in turn, allows them to move past each other with greater ease.

Viscosity is defined as resistance to flow. The higher the viscosity the more the fluid will act in a sluggish and slow manner.

Viscosity is a particularly important property of engine and hydraulic system oils. Too high a value of viscosity will produce a high resistance to flow. Too low a value will produce an easy flowing fluid but it may be prone to leaks and may not give good friction protection to moving surfaces.

Viscosity usually changes with temperature; the higher the temperature the lower the viscosity and the oil flows easier. This change in viscosity with temperature is called VISCOSITY INDEX and most oils are designed so as to minimise the change with temperature.

Hence $Q = a_1 v_1 = a_2 v_2$

where a_1 = inlet cross-sectional area (m2)

a_2 = outlet cross-sectional area (m2)

v_1 = inlet velocity (m/s)

and v_2 = outlet velocity (m/s)

The equation $a_1 v_1 = a_2 v_2$ is often referred to as the continuity of flow equation.

Compressibility

Compressibility occurs in all fluids at all pressures, but only under very high pressures are liquids noticeably compressed. For most hydraulic systems, liquids are usually considered incompressible with their density only being affected by changes in temperature. However, gases are easily compressed as well as being affected by temperature changes.

Air is a gas, and will compress as in a bicycle pump or when a body (such as an aeroplane) moves through it. However when a body moves through air at low speeds, including low speed flight, the amount of compression is so small that for most calculations the air is considered to act as if i is incompressible. But as the speed of sound (762 mph or 1226 km/hr at sea level) is approached, the effect of compressibility (and expansion) in calculations gains more importance and must be considered.

BERNOILLI'S EQUATION

It can be said that, unless work is done on a fluid when it moves from one point to another the total energy level at any point on its journey remains constant. This statement was first proposed by a Swiss mathematician, Daniel Bernoulli (1700-1782) who, in 1738 published one of the first books on fluid flow. With fluid flow, three types of energy are usually considered. These are:

- Pressure energy
- Kinetic energy
- Potential energy

Considering each in turn.

(a) Pressure energy. In aircraft hydraulic systems this is so large a value compared to the other energies, that the other energies are often ignored. But in physics it has to be considered.

$$\text{Pressure energy} = \frac{mp}{\rho} \text{ (Joules)}$$

Temperature

In an earlier section we considered that all matter was made up of molecules which were in constant motion and thus possessed kinetic energy. It has been observed that the greater the kinetic energy, the higher the temperature. If it were possible to measure this kinetic energy then a direct measurement of temperature could be made. However, this is not possible, but the effect of increased molecular kinetic energy or vibration is expansion and this can be measured. The thermometer is an instrument that measures the increase of molecular kinetic energy in terms of the expansion of either mercury or alcohol.

The thermometer itself consists of a bulb, blown at the end of a small-bore glass tube. This bulb is filled with either mercury or coloured alcohol before the small end of the tube is sealed. Since liquids expand more than solids, heating the bulb causes the liquid inside to increase its molecular activity, this causes expansion and it will rise up the bore of the tube.

The height of the liquid column is an indication of the temperature.

The ca1ibration of the thermometer involves the choice of two 'fixed points' (ie, two readily reproducible temperatures). The distance between them is then divided into a number of divisions called 'degrees'. Although several scales of temperature have been used in the past, most countries have standardized on the 'Ce1sius' scale of temperature named after Anders Celsius. A Swedish astronomer who, in 1742 used melting ice and boiling water s the two 'fixed points with 100 divisions between them, each division being one degree Celsius (I° Under normal conditions ice melts at 0^0C and under standard atmosphere pressure of 76Ommof mercury, pure water boils at 100°C.

Although not used so much now, the Fahrenheit scale of temperature may still be encountered. This scale was named after Gabriel Daniel Fahrenheit (1686- 1736) a German physicist and instrument maker, who invented the alcohol thermometer and the mercury thermometer. The 'fixed points' of the Fahrenheit scale were also based on the freezing point and boiling point of water but these were made 32°F and 2 12°F respectively with 180 divisions or degrees between them.

QUESTION : Why did both physicists use the boiling point and freezing point of water as their fixed points? (2 mins)

ANSWER: These points are readily reproducible in a simple laboratory. Ice will give the freezing point of water and boiling some water will give the other fixed point.

The second relationship for a gas was made by Jacques Charles (French physicist), who in 1787 studied the relationship between the volume and temperature of a gas, whilst keeping the pressure of the gas constant. His law, known as 'Charles Law', states that:

"The volume of a given mass of gas at constant pressure varies directly as its absolute temperature" (absolute temperature = the Kelvin scale).

$$\text{ie} \qquad V \propto T$$

$$\text{or} \qquad \frac{V}{T} = \text{constant}$$

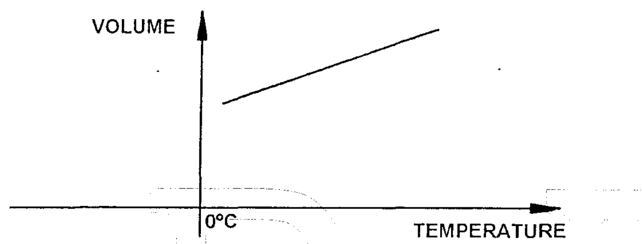

Fig. 20 VOLUME TEMPERATURE GRAPH (2

The graphical representation of this relationship is shown in figure 20.

Charles found that, for a perfect gas, its volume increased by 1/273rd of its original volume, for every 1°C rise in temperature. It followed that the reverse was possible, a reduction of 1/273rd of the original volume for every 1°C fall in temperature. By interpolating this back, it was found that the graph cut the temperature axis at -273°C or more accurately -273.15°C. This formed the origin of a new scale of temperature, the Kelvin or absolute scale (figure 22).

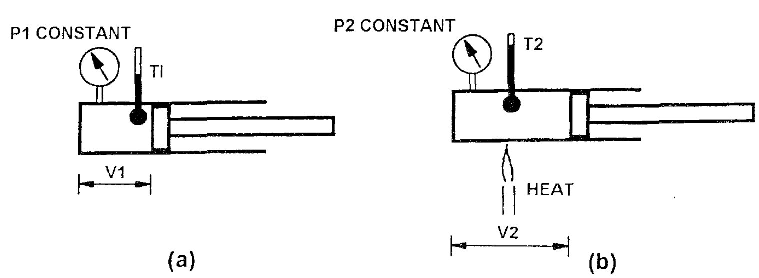

Fig. 21 CHARLES LAW

It is only from this new origin that volume is directly proportional to the temperature, in other words, values of temperature must be in absolute units (K).

THE HEAT ENGINE

The heat engine is a system which operates on a complete cycle and develops a net work output from a supply of heat.

From the Second Law of Thermodynamics it is necessary that a source of heat must be present as well as a sink for the rejection of heat since some heat must always be rejected by the system.

The term 'sink', receiver or cold body refers to a reservoir to which heat may be rejected by the working substance. The radiator in a vehicle is a good example.

Figure 30 shows a heat engine in diagrammatic form.

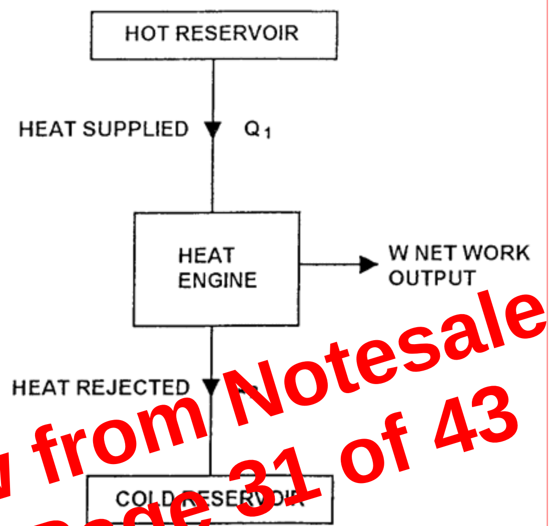

Fig. 30 THE HEAT ENGINE

From the First Law of Thermodynamics

Net Heat Supplied = Net Work Done

Q1 - Q2 = W

and from the Second Law of Thermodynamics

W Q_1 must be greater in magnitude than W

Ie $Q_1 > W$

The thermal efficiency of the heat engine

$$\eta = \frac{W}{Q_1}$$

LATENT HEAT

At the start of this unit when molecular structure was considered, two forms of heat were briefly mentioned, sensible and latent heat. When heat is supplied to a body then the temperature of that body is expected to rise, if it does, then it is acting sensibly, and thus we have the term 'sensible heat'.

When the addition of heat to a body does not cause a rise in temperature then this is called Latent Heat, (hidden heat). In this situation the heat energy is used to produce a change of state and is required to break down or reduce the molecular bonds as the substance changes from a solid to a liquid, or from a liquid to a gas or vapour.

When a substance changes from a solid to a liquid then the latent heat required is known as 'the latent heat of fusion', and is given the symbol L_f.

When the latent heat required is for a change from liquid to vapour or gas, the latent heat is known as 'the latent heat of vaporisation', and given the symbol L_v. For ice at 0°C to be completely melted into water at 0°C, 335kJ of heat energy for each kilogram is required so, L_f for ice = 335kJ/kg.

For water at 100°C to be completely changed into steam at 100°C, 2,257kJ of heat energy is required for each kilogram; hence L for water is 2,257kJ/kg. Both these values apply for water at standard atmospheric pressure (ISA - International Standard Atmosphere at sea level).

To calculate the amount of sensible heat energy to produce a rise in temperature:

Sensible Heat,	Q	=	c x m x Δt (joules)
is used where	c	=	specific heat capacity of the substance
	m	=	the mass of the substance
and Δt (delta t)		=	the temperature change.

To determine the amount of latent heat required to produce a change of state, the mass of the substance involved is multiplied either by L_f, the latent heat of fusion, or the latent heat of vaporisation L_v ie:

For a change of state from solid to liquid, the amount of heat required:

= Latent heat of fusion x mass of substance

= $L_f m$ (joules)

For a change of state from liquid to vapour or gas, the amount of heat required:

= Latent heat of vaporisation x mass of substance

= $L_v m$ (joules)

Because of these variations and to allow standardisation and calibration of instruments and engine performance figures etc, a Standard Atmosphere has been devised.

This allows engines to be test run in almost any ambient conditions and the performance figures adjusted to standard atmospheric conditions — allowing the performance of one engine to be directly compared to that of another.

Pitot static operated instruments can be calibrated using the standard atmosphere and they can be set for flight using the same parameters.

THE ICAO STANDARD ATMOSPHERE

It has been shown that the primary variables (pressure, temperature and density) of the standard atmosphere based on certain assumptions are in good agreement with actual average values observed at about latitude 40° N. Such a standard atmosphere is therefore taken as the reference for these parameters in free air (excluding those dependent on water vapour).

The ICAO standard atmosphere, sometimes called the International Standard Atmosphere (ISA) states that: The air is assumed to be dry. The pressure at sea level is 1013.25mb (millibar) (or 101.325kPa). The temperature is 15°C and the temperature lapse rate is 1.98°C per 1000ft up to a height of 36,000ft where the temperature will remain constant at -56.5°C to 65,800ft. T-he value of g' (gravity) is given a uniform value of 9.81m/sec 2 at sea level. Effectively that means that the temperature falls with altitude at a rate of about 2°C per 1000ft from 15°C at sea level to 36,000ft where it holds almost steady at -56°C until about 36,000ft where the temperature starts to rise.

The graph below shows this graphically and also shows how the atmosphere has been divided into layers. For those working on large aircraft the atmosphere is of interest up to say 60,000ft or so. For those working on small aircraft and helicopters the atmosphere is not of much interest after say, 20,000 ft.

The pressure starts at 10 13mb (14.7psi) at sea level and falls at a non-linear rate with altitude (the line on the graph is a curve). Losing most of its value at the lower altitudes so that at 18,000ft, for example, the pressure is halved to 506mb.

These pressure readings are absolute pressure readings. If an ordinary pressure gauge is open to atmosphere it will read zero. If it is used to check a tyre pressure of, say 3opsi, it will read 3Opsi, but the pressure in the tyre is in fact 3opsi above atmospheric so the absolute pressure in the tyre is 30 + 14.7 = 44.7psi. The tyre pressure as measured by the gauge is called gauge pressure. Its absolute pressure would be gauge pressure plus atmospheric pressure = 44.7psi absolute.