THUNDER & COLT

This Flight Manual is issued for the following balloon:-

SERIAL NUMBER ....

BALLOON REGISTRATION ....

BALLOON SIZE ....

BALLOON TYPE ....

BUILD STANDARD ....

I hereby certify that this Flight Manual, as prepared, for the above balloon and incorporating the Supplements listed below, conforms to the build standard of the above aircraft.

Signed .... Date ....
CAA Approval Reference Number DA1/8293 /72
For Thunder and Colt

The following Flight Manual Supplements are applicable for the operation of this balloon:-

FM Supplement Number	Description	Tick if Applicable
1*	C3 Burner	
2*	Compact Basket	
3*	Magnum Superseal Burner	
4*	Kevlar Flying Wires	
5*	C3 with Vapour Pilot Light	
6*	Magnum with Vapour Pilot Light	
7	Transport Category (Passengers)	
8	Double Wheelchair Basket	
9	Master List Guide	

Supplements marked with a * do not need CAA approval.

FM SUPPLEMENT NUMBER	DESCRIPTION	TICK IF APPLICABLE
10	Not used	
11*	Magnum Superseal Multi-Burner	
12	Tethering	
13	Sky Chariot Mk II	
14	Special Shape	
15	Worthington Mini Cylinder	
16	Wheelchair Basket Mod. No. T135	
17	H-Partition Basket (not yet issued)	
18	Cameron Combinations	
19	Paraplus Deflation System	
20	Rip Panel Safety Locks	
21	Two-Seat Skychariot	
22	Stratus Burner (Double & Quad)	
23	Incorporated into iss. 5	
24	Stratus Burner (Triple & Quad)	
25	Stratus Burner (Single)	
26	Tie Off Points (Velcro Rip)	
27	Smart Vent	
28	Rigging of 8 Pole Baskets	
29	Duo Skychariot, Additional Fuel Tanks	
30	Stratus Burner (Vapour Pilot)	
31	Tri-vent	
32	Single Seat Skychariot, Additional Fuel Tanks	

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40	7/87		85	7/87	
41	7/87		86	7/87	
42	7/87		87	7/87	
43	7/87		88	7/92	
44	7/87		89	4/92	
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	7/87		92	7/87	
			93	7/87	

*Denotes pages changed at revision 5
**Denotes pages changed at revision 7
^Denotes pages changed at revision 6

THUNDER & COLT

BALLOON FLIGHT MANUAL

FOR

THUNDER & COLT
HOT AIR BALLOONS

For all balloons manufactured under:

FAA Type Certificates B2EU and B3EU
French Type Certificate IM94
Canadian Type Certificates B3 and B5
German Type Certificates 8007, 8014, 8015, 8016, 8017 and 8019
And All British Certified Natural Shape T. and C. Balloons

Thunder & Colt
St Johns Street
Bedminster
BRISTOL
BS3 4NH

Tel: 0117-9532772
Fax: 0117-9663638

THUNDER & COLT LTD

CAA/FAA APPROVAL

This flight manual covers the entire range of Thunder & Colt hot air balloons from 31,000 cu. ft. to 315,000 cu. ft.

APPROVAL STATEMENT

The Civil Aviation Authority of the United Kingdom hereby signifies approval of the data contained in this document as listed under EMERGENCY INSTRUCTIONS Section 3 and OPERATIONAL LIMITATIONS Section 4.

Signed and sealed

CIVIL AVIATION AUTHORITY

This Balloon Flight Manual is approved by the Federal Aviation Administration for the United States registered balloons in accordance with provisions of 14 CFR Section 21.29 and is required by FAA Type Certificates B2EU and B3EU.

RECORD OF REVISIONS

NUMBER	DATE	PAGES AFFECTED	APPROVAL
OO1	NOV. 87	3, 31, 45, 61, 63, 94, 95, 96	CIVIL AVIATION AUTHORITY
OO2	JUL. 91	5, 45, 52, 53, 54, 54a, 54b, 55, 55a, 55b, 55c	CIVIL AVIATION AUTHORITY
OO3	APR. 92	i, ia, 1, 3, 5, 6, 28, 45, 65, 72, 89 New pages ii, iii, iv, v	CIVIL AVIATION AUTHORITY
OO4	JUL. 92	ia, ii, iii, v, 13, 17, 23, 33, 34, 36, 88	CIVIL AVIATION AUTHORITY
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1. TECHNICAL DESCRIPTION

1.1 ENVELOPE (See figs 1.1 through 1.5)

The balloon envelope is manufactured from high tenacity nylon or polyester fabric coated with polyurethane. The fabric weave is the load carrying element, while the coating produces an airtight membrane. A network of nylon/polyester webbing, called load tapes, encapsulates the envelope and constitutes a further structural element, and also provides suitable anchor points for the payload. Hot air in-flight venting and final deflation is achieved with a parachute-type valve situated in the envelope crown. It is operated by a red rip line that runs via a block system down into the basket (see figs. 1.2 and 1.3).

An optional velcro-type vent is sometimes fitted, primarily on larger balloons (see fig. 1.4). This vent is for final deflation only and will not reseal after operation. For in-flight venting a smaller parachute is fitted concentric with the velcro panel, and this functions like the above parachute. In this system the velcro panel operating line is coded red and the parachute line is white with a blue end (early balloons white).

Another optional envelope feature is rotation vents, which permit intentional rotation around the vertical axis (see fig. 1.5). These pairs of vents are located diametrically opposed on the envelope equator, and by pulling manoeuvering lines, slits open sending out air tangentially. They reseal after use by internal air pressure in the same way as the parachute valve. The two steering lines are coded black for left, and white for right hand rotation.

The envelope mouth is made from nomex fabric which has a very high resistance to heat, saving the balloon from unnecessary burn damage during inflation and tethering.

As an option, balloons can be fitted with either a skirt or a tapered scoop, also made of nomex, to aid inflation and protect the burner flame from wind gusts.

The flying wires link the envelope to the burner frame. The latter always has four hook-up points; the former normally the same number of wires as gores. Flying wires are connected to the burner and basket wires by means of locking carabiners.

A gore is the fabric section between two adjacent vertical load tapes. The gores are assembled from the individual panels. The panel construction can either be vertical or horizontal. Balloons can be of 8, 12, 16, 20, 24, 28, 30 or 32 gores (see fig. 1.1).

ENVELOPE MODELS

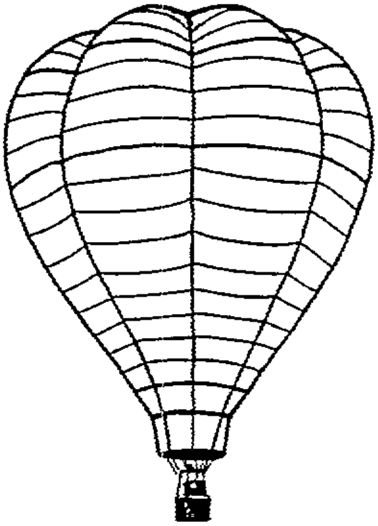
THUNDER		No. Gores
Bolt	42	8
Bolt	56	8
Bolt	65	8
Bolt	77	8
Series I	42	12
Series I	56	12
Series I	65	12
Series I	77	12
Series I	84	12
Series I	90	12
Series I	105	12
Series I	120	12
Series I	160	12
Series I	180	12
Series II	105	20
Series II	120	20
Series II	140	20
Series II	160	20
Series II	180	20
Series II	210	20
Series II	225	20
Series II	250	20
A-Type	56	28
A-Type	69	30
A-Type	77	32
Z-Type	31	16
Z-Type	56	20
Z-Type	65	24
Z-Type	77	24
Z-Type	105	24

COLT		No. Gores
A-Type	31	16
A-Type	42	16
A-Type	56 (H)	20
A-Type	56 (V)	28
Bullet	56	16
A-Type	69 (H)	24
A-Type	69 (V)	30
A-Type	77 (H)	24
A-Type	77 (V)	32
Bullet	77	16
A-Type	90	24
A-Type	105	24
A-Type	120	24
A-Type	140	24
A-Type	160	28
A-Type	180	28
A-Type	210	28
A-Type	240	28
A-Type	260	28
A-Type	300	28
A-Type	315	28

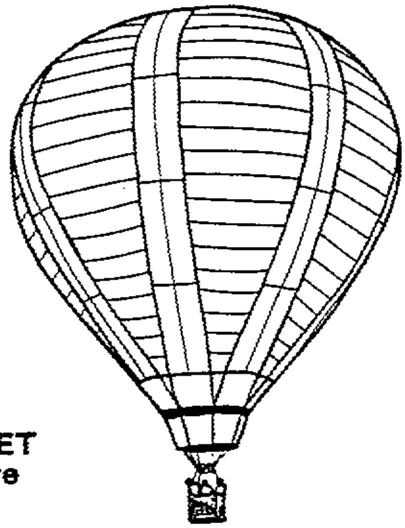
(H) - Horizontal Cut

(V) - Vertical Cut

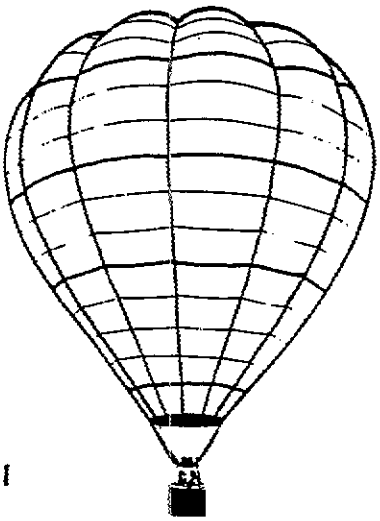
ENVELOPE TYPES



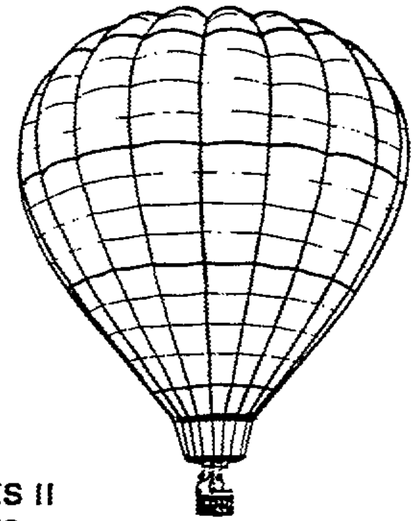
BOLT
8-gore



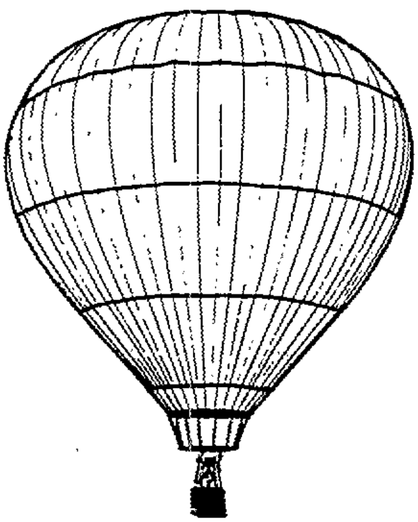
BULLET
16-gore



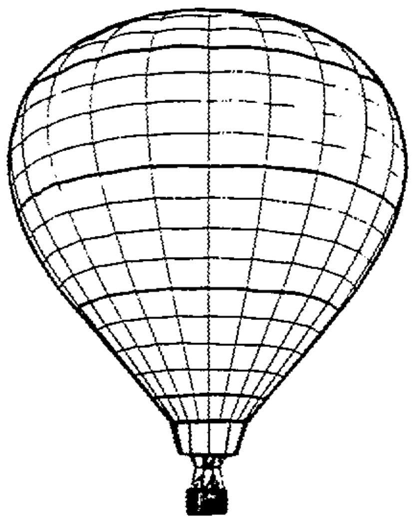
SERIES I
12-gore



SERIES II
20-gore



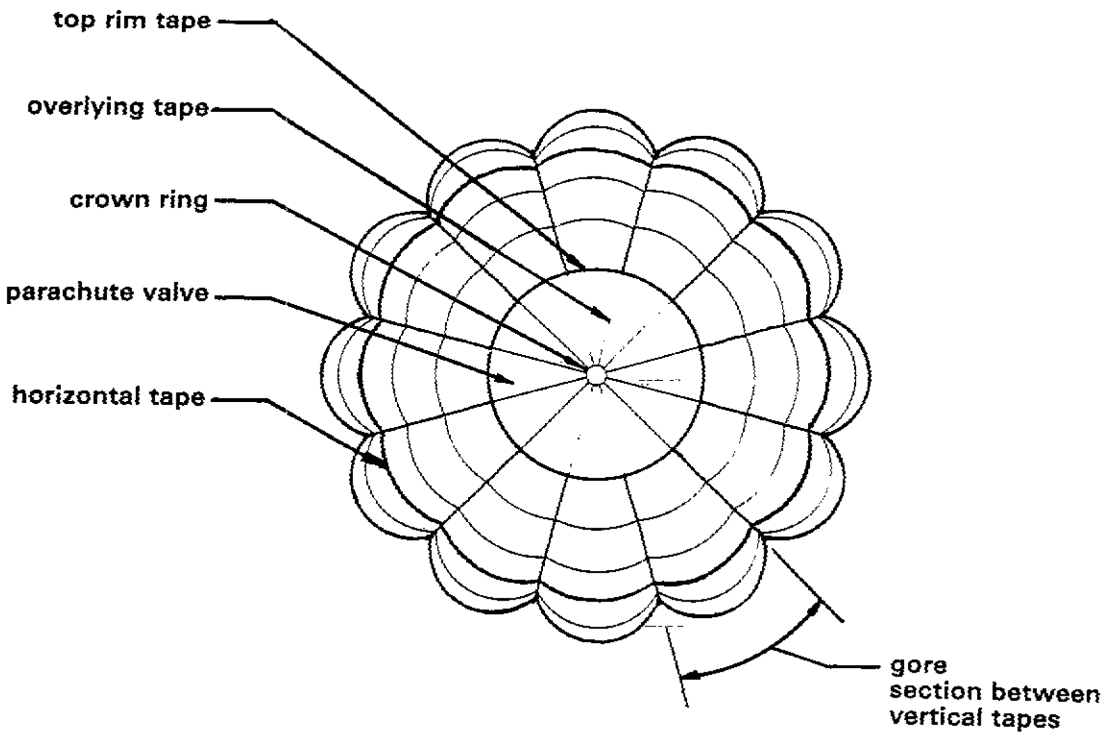
A TYPE
28/30/32-gore
vertical cut



Z TYPE
16/20/24/28-gore
or horizontal cut A type

figure 1.1

ENVELOPE NOMENCLATURE



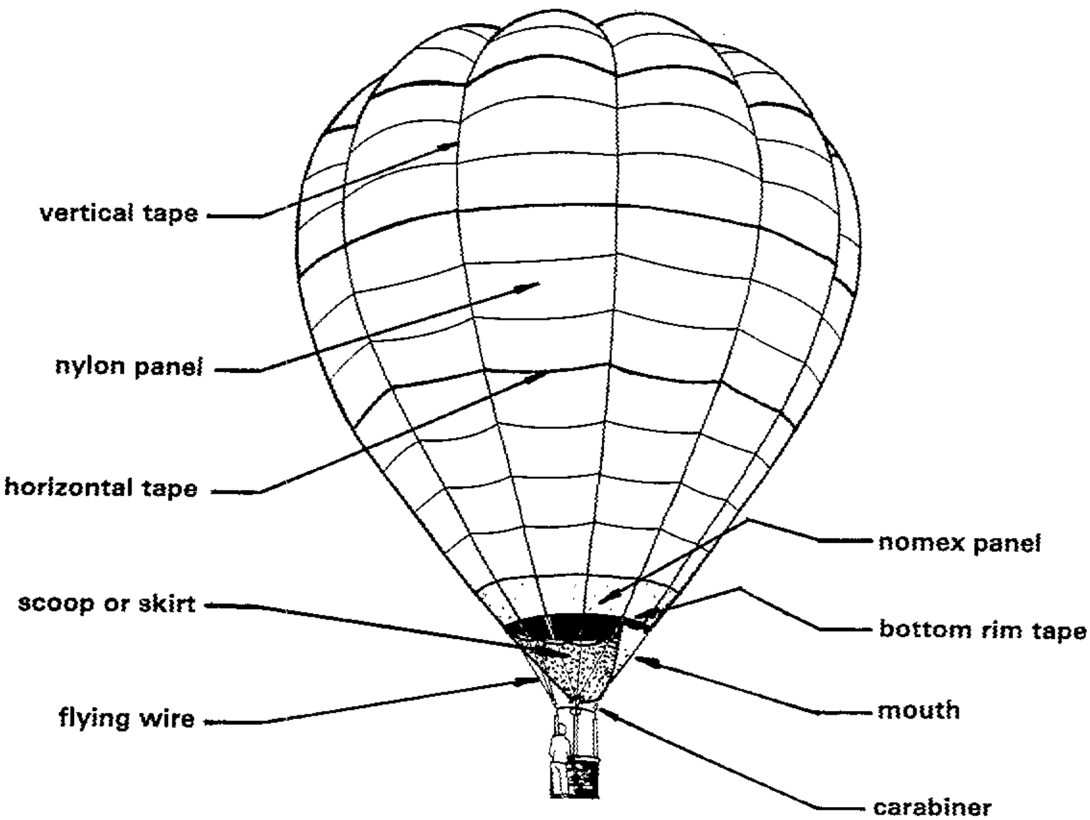
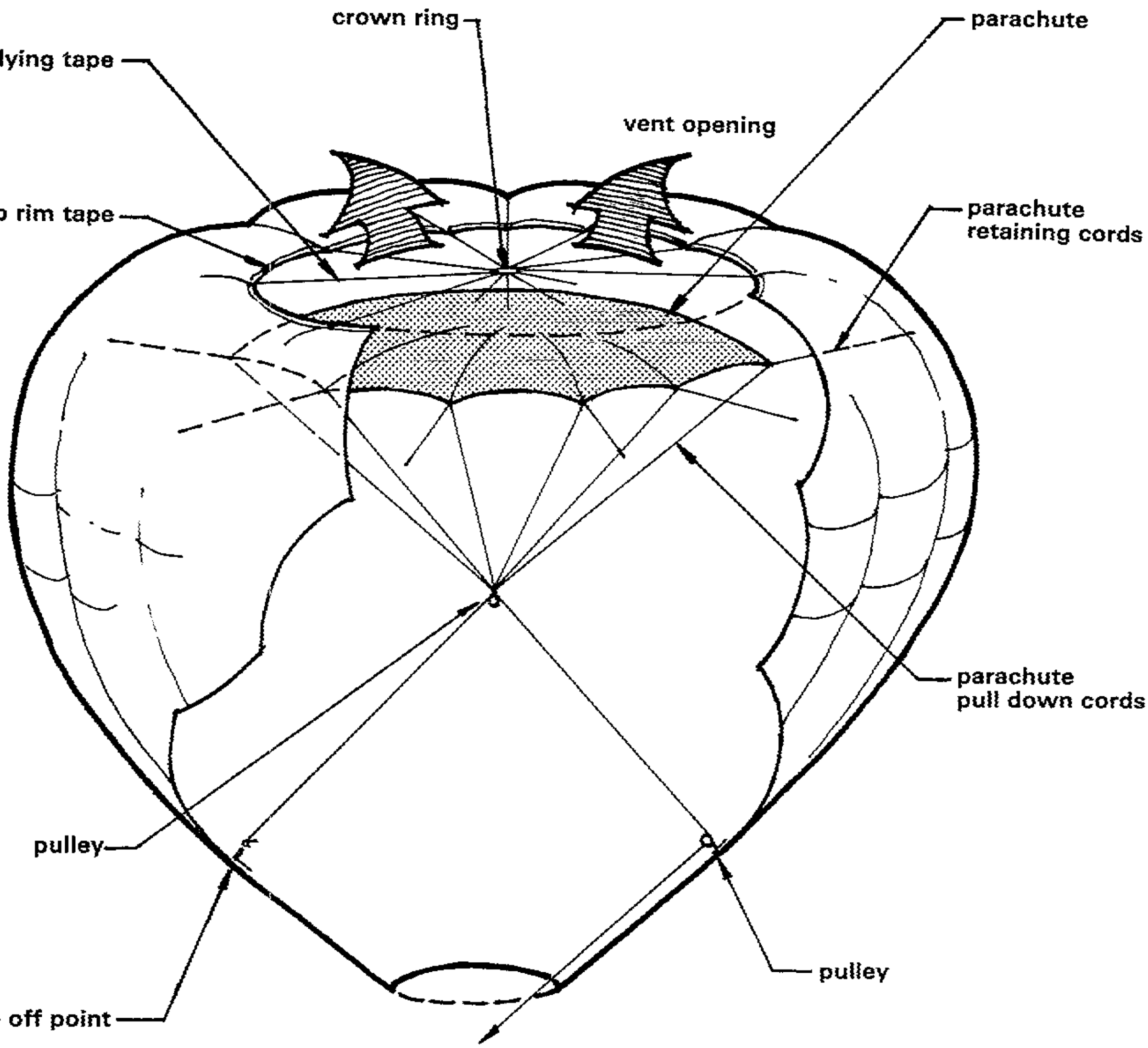


figure 1.2

PARACHUTE

shown in open position

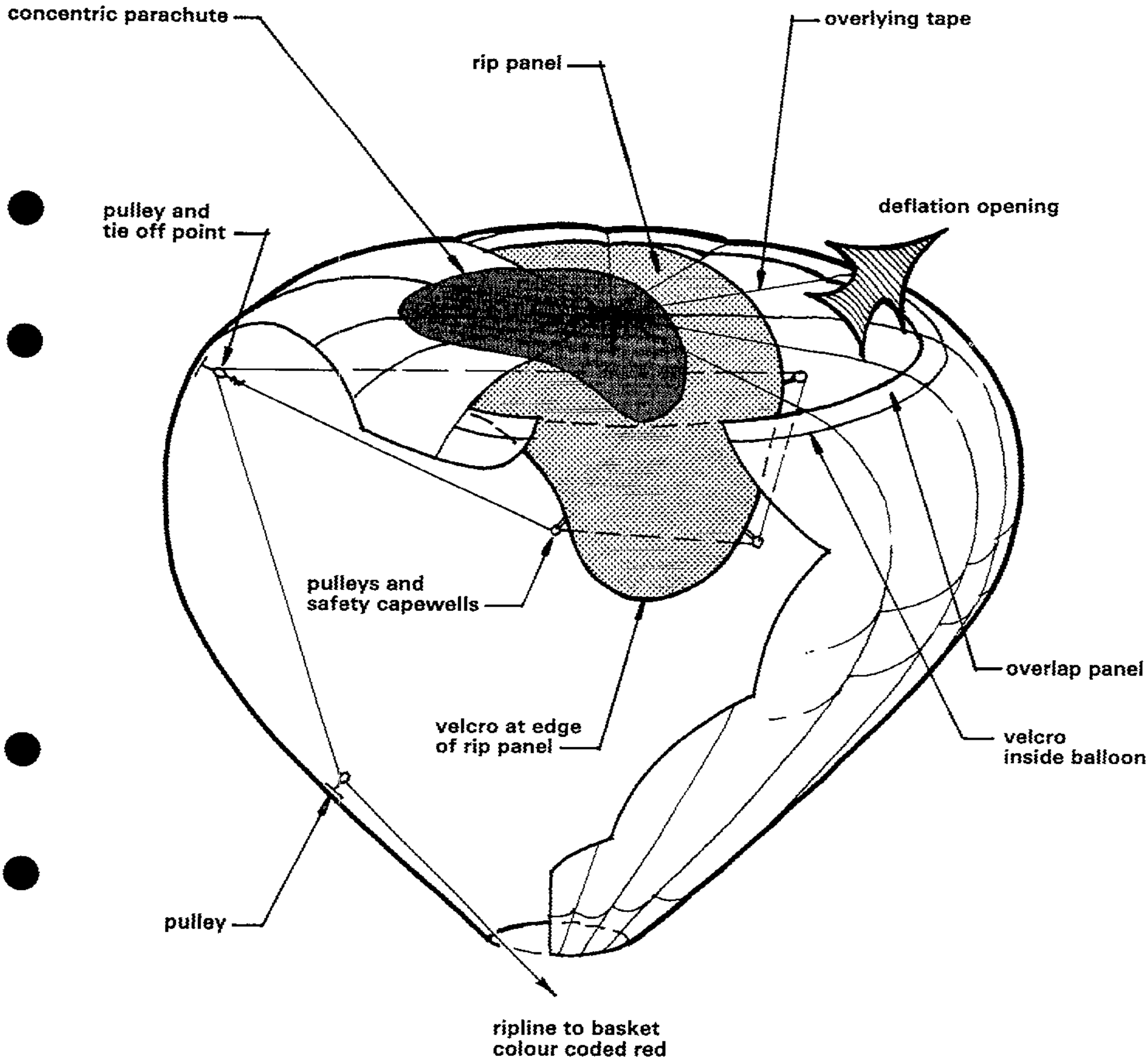


note: parachute reseals automatically when ripline is released due to internal envelope air pressure

figure 1.3

VELCRO RIP PANEL

shown in open position

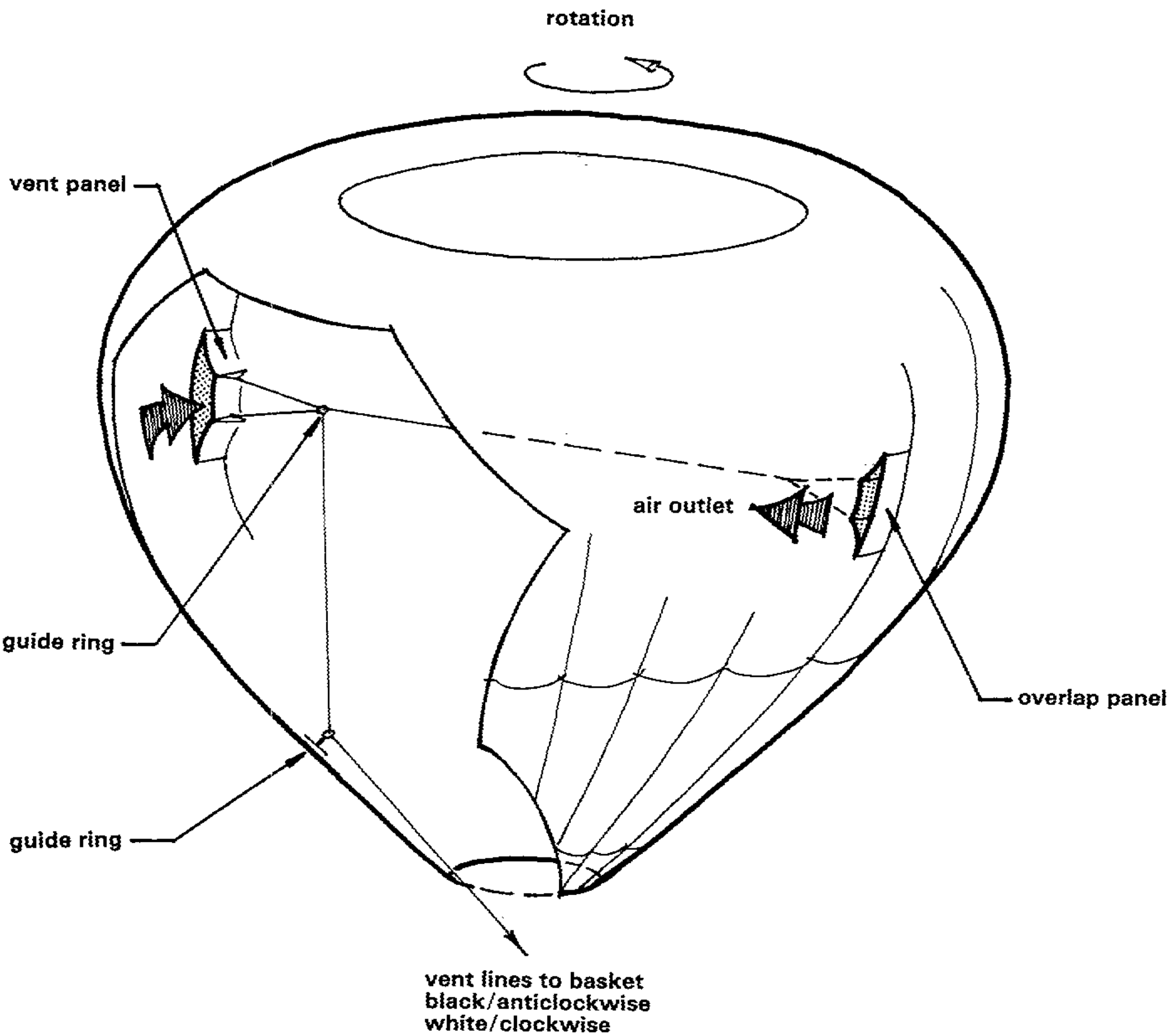


note: velcro rip panel deflation is irreversible and panel will not reseal once rip line has been activated

figure 1.4

TURN VENTS

shown in open position



note: turn vents normally occur in two pairs, one for each rotation direction, located one gore apart; only one pair is illustrated here for the sake of graphic clarity

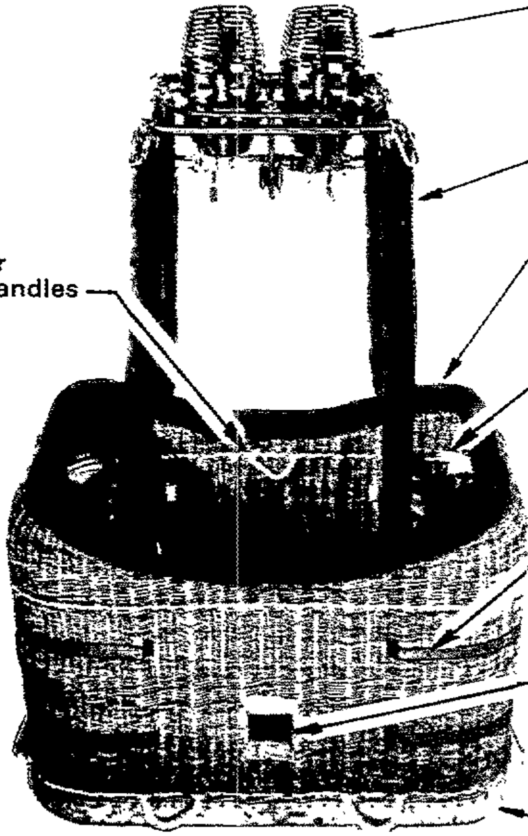
figure 1.5

1.2 BASKET (See fig. 1.6)

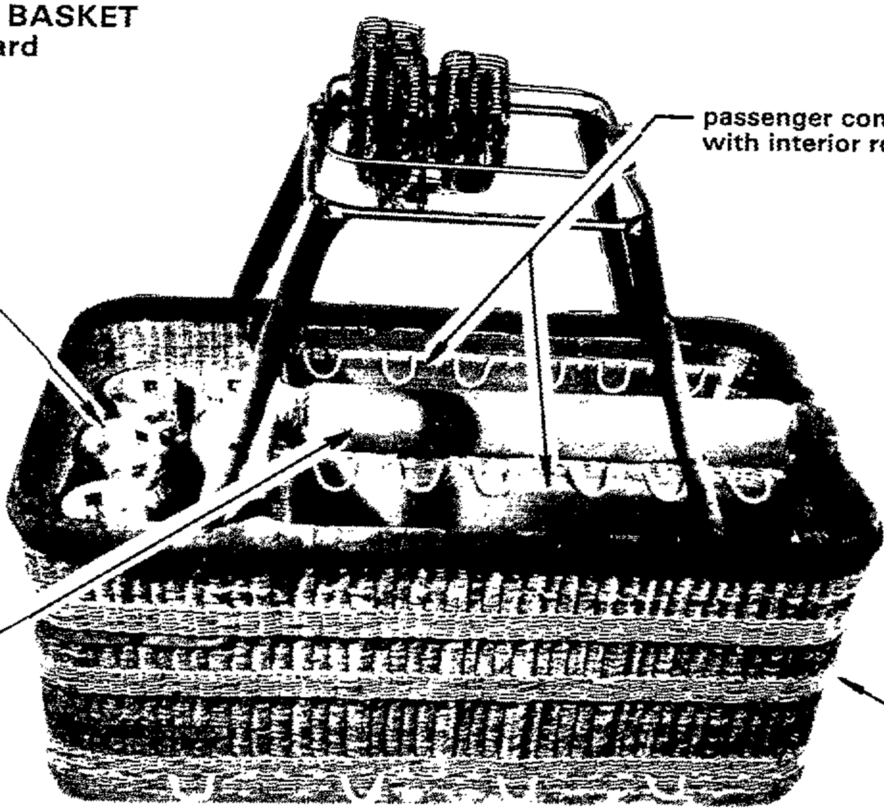
The basket is traditional wickerwork, built on a marine plywood floor, reinforced underneath with ash runners. The structural load is carried by 6mm stainless steel wires forming a continuous sling around the basket. On the top edge of the basket the cane-work is terminated around a tubular stainless steel frame onto which the overhead frame sockets are welded. On smaller baskets a bamboo, rather than a steel frame is fitted. Dense foam covers the top frame which is then trimmed with leather. The bottom edge is protected with rawhide which is nailed underneath the basket and lashed onto the sides. The rawhide serves to protect the bottom edge from damage on landings and in transit. A series of openings in the basket provide passages for strapping in cylinders, instruments etc., and footsteps are provided for easy entry into the basket.

Nylon rods fit into sockets at the basket rim and outer burner frame to support the overhead frame system. The basket wires attach to lugs at the burner frame corners with carabiners, and the upright rods and wires are fitted with leather covers matching the basket trim. Pilot light hoses from the burner are enclosed inside the leather covers, while the main liquid hoses are strapped to the outside of the covers to permit easy cylinder changes in flight. Fuel cylinders are strapped into the basket - not necessarily in the corners - in their proper orientation, as described in Section 2.1. Instruments, map cases, fire extinguisher and other accessories are strapped to the basket as required.

A variety of basket sizes and styles are available. The top rim or handrail of the basket can be either straight or swept top, trimmed with choices of smooth leather or suede in a variety of colours. The smallest standard size is 1.0 m x 1.0 m with heights ranging from 1.05m to 1.15m. Larger baskets range in size up to 1.50m x 3.50m and incorporate internal partitions to segregate passengers from pilot and fuel cylinders. The partitions are covered with padded upholstery and all baskets include internal rope handles for use by passengers during the landing for their comfort and safety, as well as exterior carrying handles.



SWEPT TOP BASKET
standard



160/180/240 BASKET
partitioned

figure 1.6

1.3 BURNER (See fig. 1.7 through 1.9)

The burner is fed with liquid propane which is vapourised in a coil prior to combustion. It is controlled by a lever-operated ball valve (sometimes a toggle valve) commonly referred to as the blast valve. A minimum of two blast valves are always fitted. In a single burner configuration, these feed from two fuel cylinders into the same coil; in a double burner configuration they feed one burner each. On a double burner there is also a transfer valve providing a cross-feed capability between the two burners.

Ignition is achieved with a pilot light of the bunsen type, one for each burner coil. Operation on earlier types was from the tank valve, while on later burners an additional on/off ball valve for the pilot light is fitted adjacent to the blast valve.

Late model burners utilize a Piezo electric ignition system with the pilot light for ease of operation. This system employs the principal of an electrical charge being generated by the bending of a quartz crystal, and provides an instant means of igniting the pilot light.

The burner is swivel-mounted in the inner burner frame, which in its turn is swivel-mounted in the outer frame. This provides a 2-axis gimballed system. The square burner frame has sockets at each corner to accept the nylon rods from the overhead frame system and there are lugs where the envelope carabiners hook up to the basket wires. Larger burner frames incorporate tether lugs adjacent to the rod sockets at each corner.

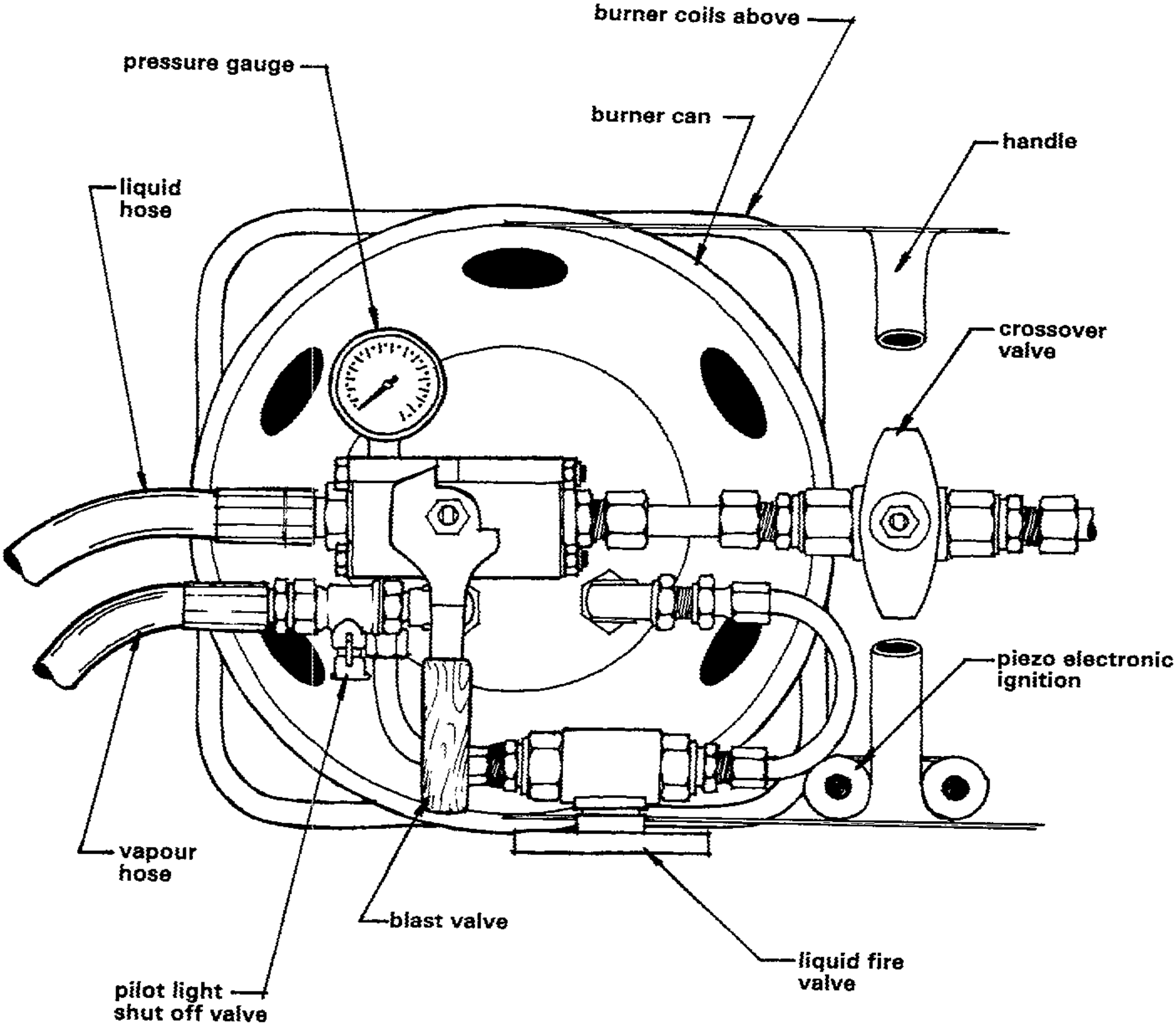
Each burner assembly features a single jet liquid fire where liquid propane is fed directly into one of the burner cans, bypassing the coil. It is operated by a ball valve and is for use in stable flight only. It has a low noise level, and is intended for flying over animals or other noise-sensitive areas.

For larger balloons, triple or quadruple burners can be supplied. As an option these burners can have a larger liquid fire system which consists of six jets in a separate burner can. Operation of this burner system is as above.

Also available, as an option, some burners can be equipped with an electronic blast valve incorporating a remote control unit. This system consists of a solenoid valve at the burner which by-passes one of the blast valves. A small 12-volt rechargeable battery, mounted in the basket, powers the valve which is controlled by a remote, hand-held push-button switch unit on a flexible cord. Electrical connections are made by quick-fitting cannon plugs for easy removal of the battery for recharging. This option allows the pilot the luxury of controlling the blast valve without having to manually reach overhead to operate the burner.

TYPICAL BURNER CONTROLS

burner frame not shown for clarity



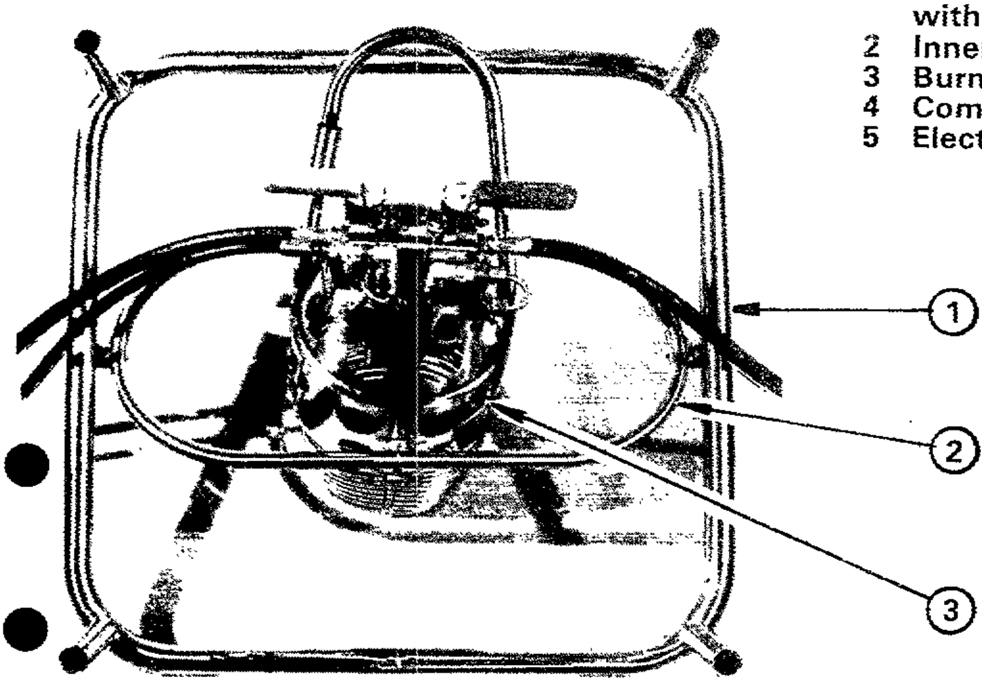
BOTTOM VIEW

note: one can of a Colt double burner system is illustrated; multiple can combinations and single burners utilize the same components in similar configurations

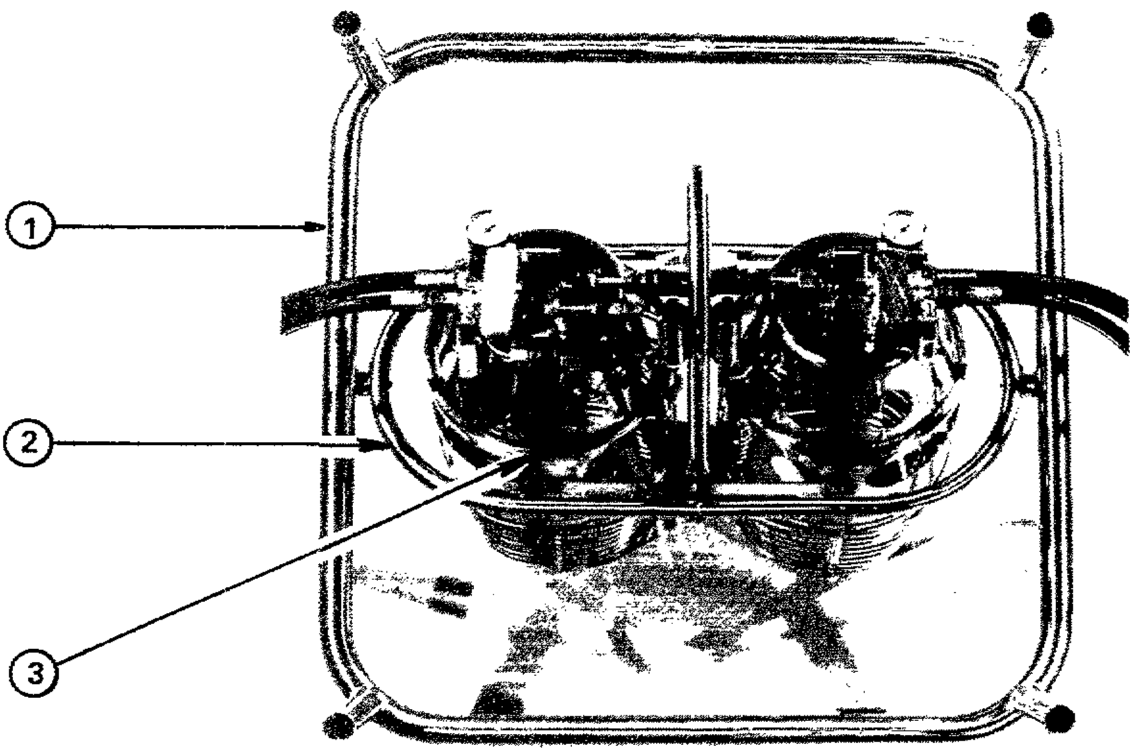
figure 1.7

BURNERS

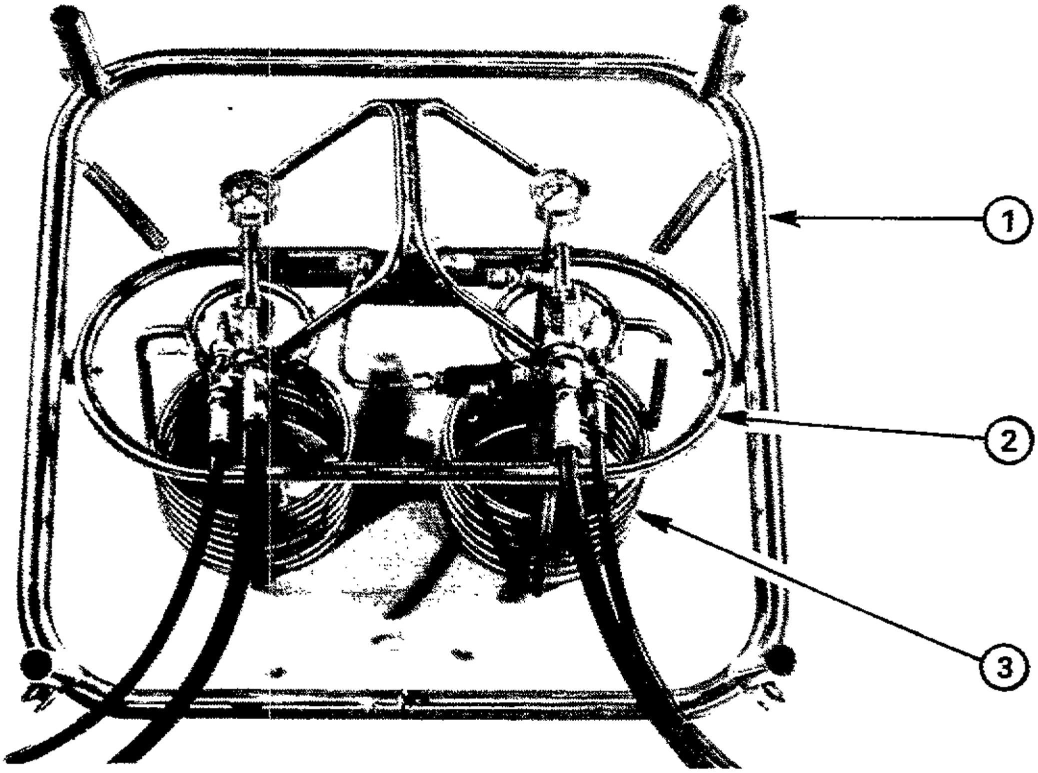
1. Outer Burner Frame with rod sockets
2. Inner Burner Frame
3. Burner Can Assembly
4. Commercial Liquid Fire Burner
5. Electronic Blast Valve



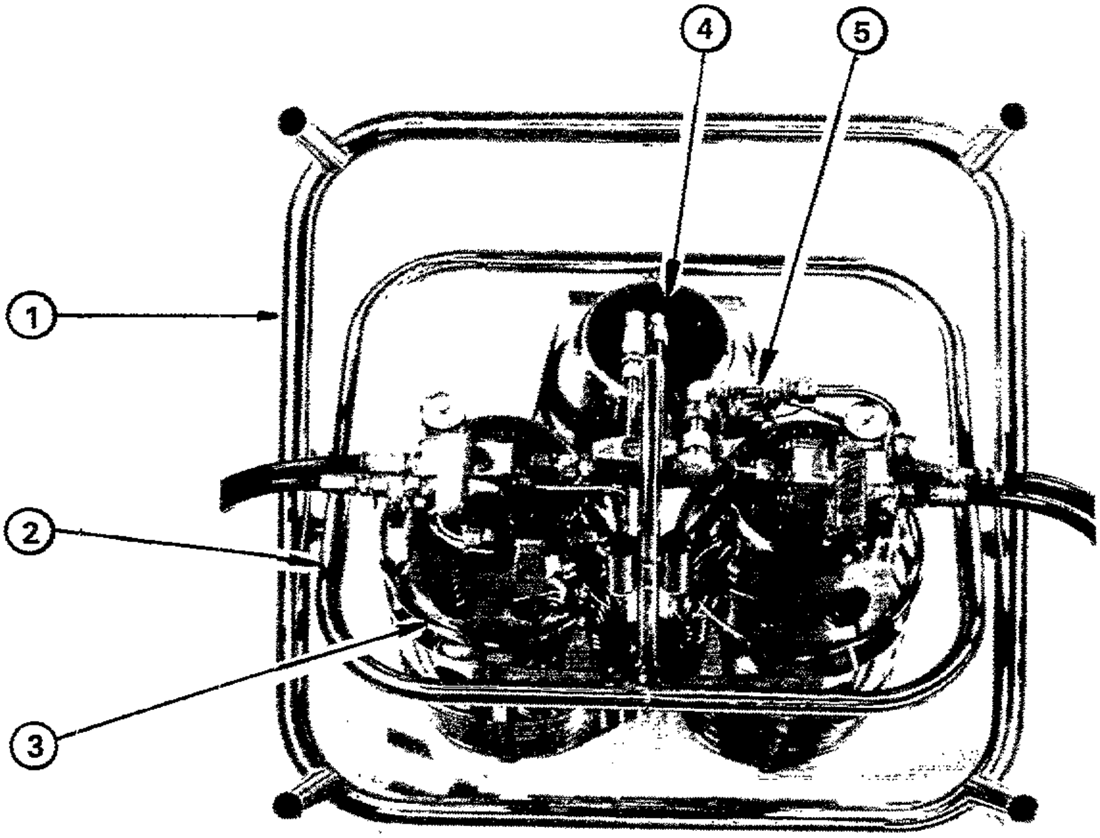
COLT SINGLE



COLT DOUBLE



THUNDER DOUBLE



COLT DOUBLE
with commercial liquid fire
and electronic blast valve

figure 1.9

1.4 FUEL SYSTEMS (See figs. 1.10 and 1.11)

The onboard propane fuel is stored in pressurised cylinders which all have a liquid supply (slave type) and some also a vapour supply (master type). All cylinders also have a pressure relief valve set to discharge at 375 psi (26 bar), a maxfill valve, and a quantity gauge. Fuel cylinders can be fitted with padded fabric covers, and are sometimes equipped with approved electric heating elements contained in the jackets. Four sizes of cylinders are available:

Worthington: 20 kg (10 US gallon) propane capacity, aluminium, master or slave, vertical configuration.

Colt V30: 30 kg (15 US gallon) propane capacity, stainless steel, master or slave, vertical configuration.

Colt H40: 40 kg (20 US gallon) propane capacity, stainless steel, master only, horizontal configuration.

Colt H55: 60 kg (30 US gallon) propane capacity, stainless steel, master only, horizontal configuration.

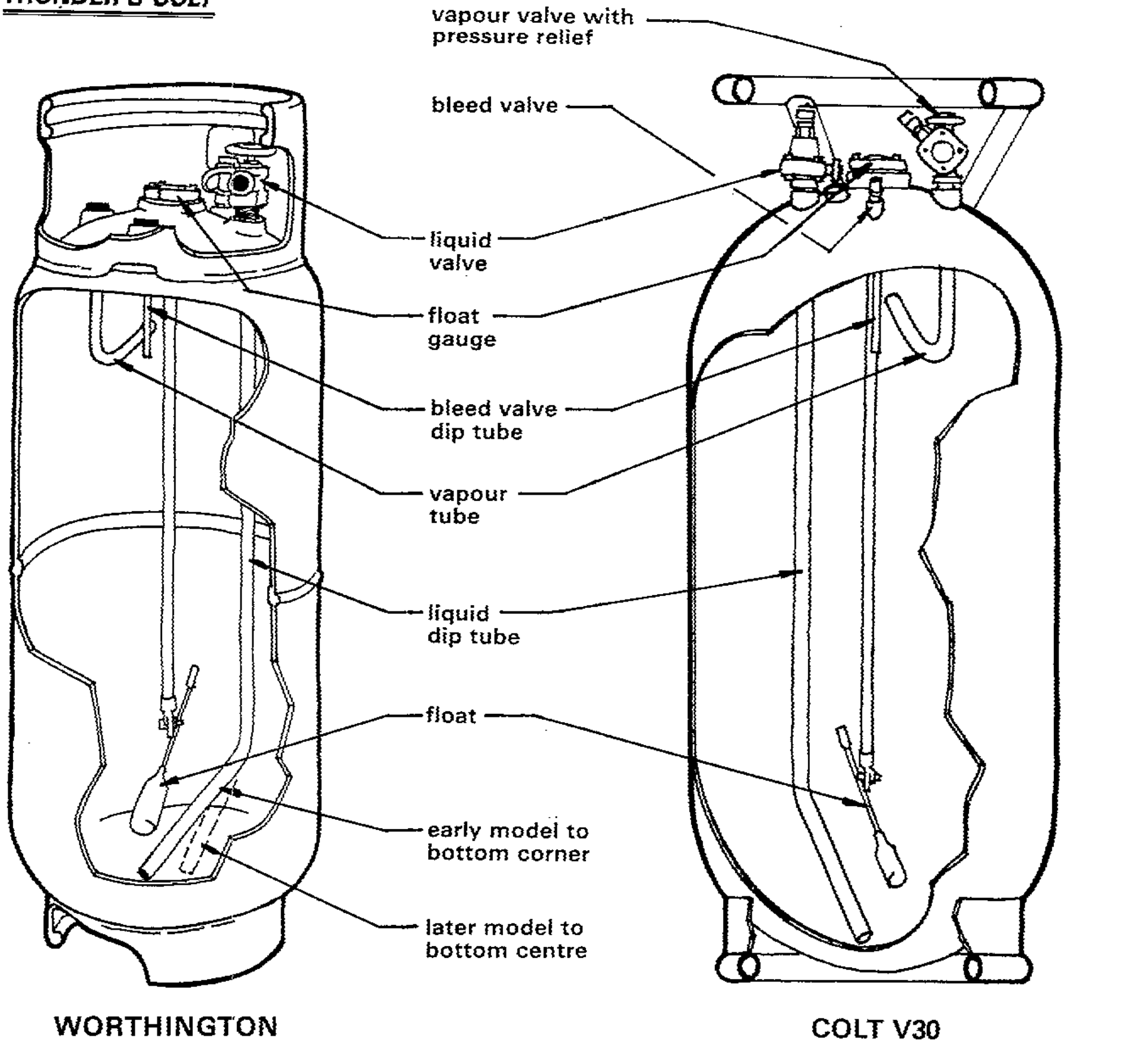
Liquid propane is drawn via a tube going to the bottom of the cylinder. The liquid fuel hose coupling is either the push-on Tema type or the screw-type ACME 1-1/4" (often called the Rego system, after the manufacturer). The Tema coupling is always connected to a Worcester ball valve, while the ACME system can either be integral with a screw valve (i.e. Rego 8180), or connected to a Worcester valve.

Propane vapour is drawn off the top of the cylinder through a screw-type vapour valve connected to a pressure regulator. The vapour hose utilizes a push-on Tema coupling. Both vapour and liquid propane is supplied to the burner through wire-reinforced rubber hoses, terminating at the burner in threaded fittings.

Optional Manifold

If more than two cylinders are carried, a fuel manifold can be used to eliminate the necessity of switching fuel hoses from tank to tank in flight. A fuel manifold is made up from the same type hoses and couplings as in the primary fuel system, with the addition of coupling elements such as elbows, T-fittings etc. The manifold system will operate with any or all of the fuel cylinders connected, as unused hoses have self-sealing connectors fitted. The tank valves can be opened together or in turn, as desired. With the use of the manifold system, the main liquid fuel hoses from the burner can be enclosed inside the leather rod covers, along with the pilot light hoses. Note, however, that use of the manifold system does not obviate the need for careful fuel management, as described in Section 2.7.

FUEL CYLINDERS



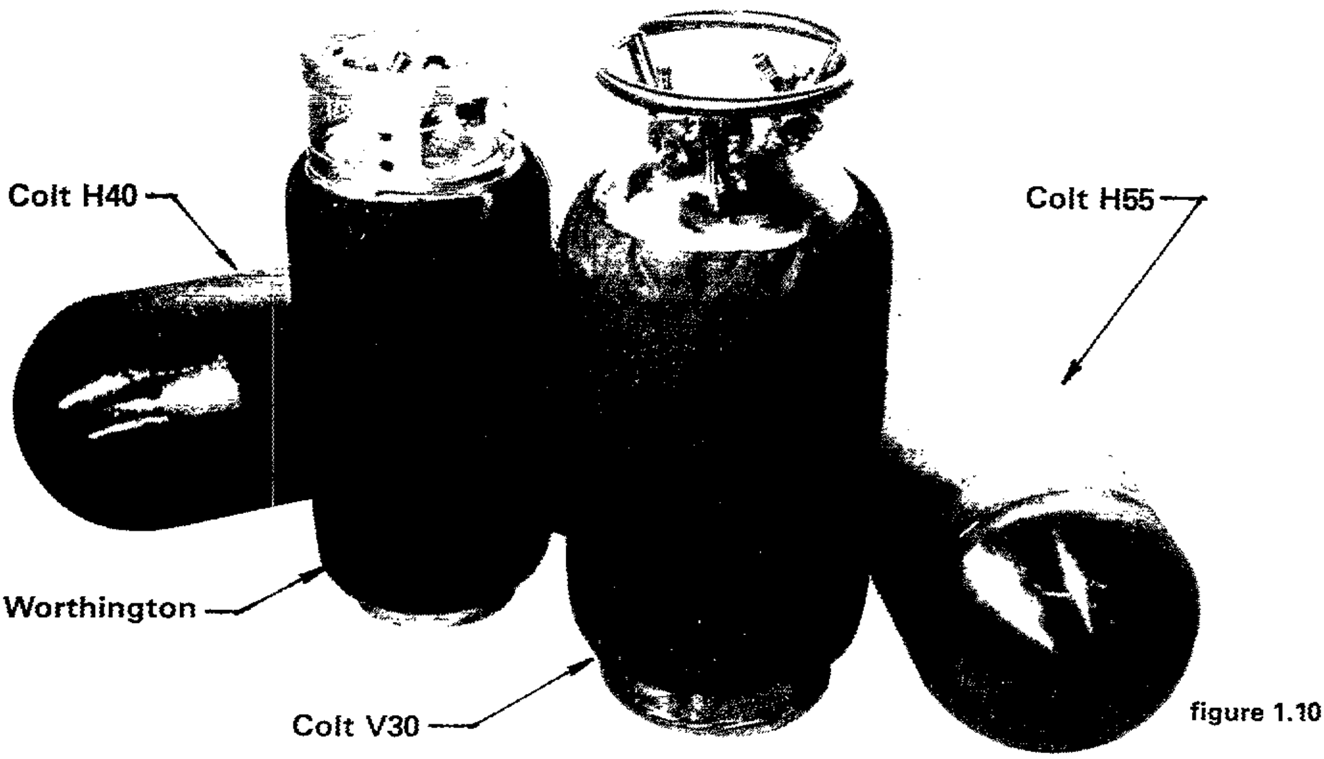
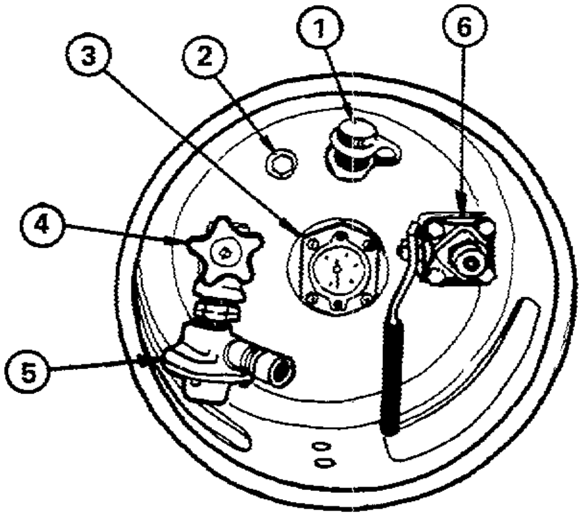


figure 1.10

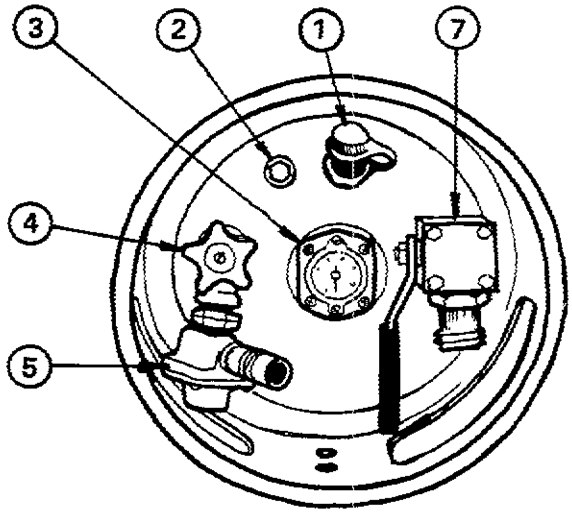
TYPICAL CYLINDER FITTINGS

1 Pressure Relief Valve
2 Maxfill Bleed Valve
3 Fuel Quantity Gauge
4 Vapour Valve
5 Pressure Regulator
6 Ball Valve with Tema Coupling
7 Ball Valve with Acme Fitting
8 Screw Valve with Acme Fitting

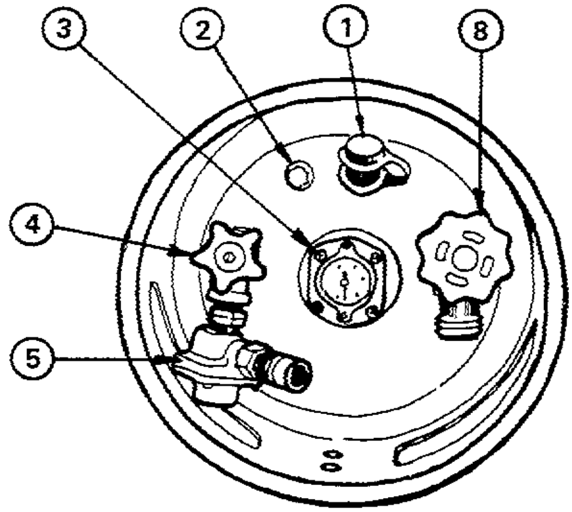
note: all cylinders are shown with DOWN side toward bottom of page



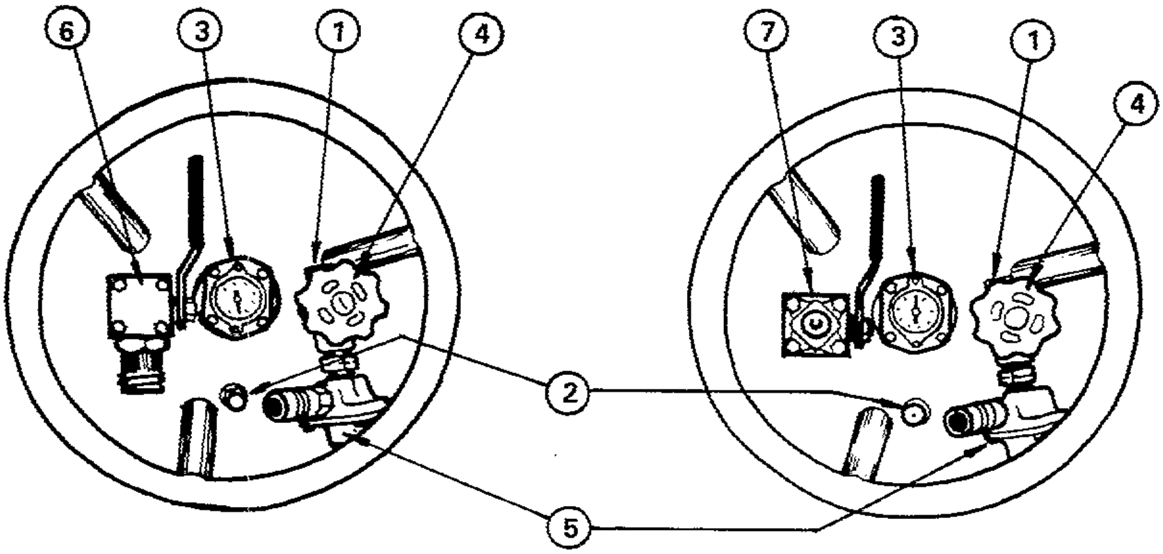
WORTHINGTON



WORTHINGTON



WORTHINGTON



COLT V30

COLT V30

figure 1.11

1.5 INSTRUMENTS (See fig. 1.12)

A range of instruments can be supplied as required. Their type and function is:

Altimeter - measures altitude barometrically in feet or meters.

Vertical Speed Indicators - measures climb or descent in feet/ minute or meters/second.

Thermistor - measures envelope internal temperature in degrees Celsius or Farenheit.

Altimeters

The pressure-sensing element of an altimeter is an evacuated metal capsule. The resulting expansion and contraction of the capsule (or, normally, capsule stack), which is extremely small, is transformed into rotary motion of the pointer by means of gears and levers. A barometric compensating mechanism is operated by a setting knob driving a millibar or inch Hg subscale. This allows the instrument to be adjusted for the daily atmospheric pressure.

The presentation of altitude information is either through the traditional triple-pointer face, or the single-pointer and digital counter.

Vertical Speed Indicators (VSI)

A VSI measures ascents and descents and there are three different variants: Rate of Climb, Variometer and Electric Variometer.

The Rate of Climb indicator measures altitude change from the change in static pressure using an aneroid capsule for pressure reference. One may call it a sensitive differential pressure gauge. The change in aneroid height is transferred via a mechanical linkage to the single pointer. This instrument is normally found in powered aircraft. It is very reliable, but somewhat inert, particularly around the zero position, due to mechanical hysteresis.

The Variometer senses altitude change from the flow of air as it passes in and out of an air box. This can be located inside the instrument, but normally this is a separate flask of about 0.5 litre volume. The measuring element is air vanes arranged into a baffle plate which will swing with the flow of air. This way the instrument will have less mechanical inertia than a Rate of Climb instrument, and will thus be more sensitive. A Variometer is the common VSI in a glider for this reason.

An Electric Variometer measures air flow, but instead of a mechanical linkage to bring the information to a pointer it uses electronic sensing, such as a pressure transducer. Thus all mechanical inertia is eliminated, resulting in a very responsive instrument. Given that the information is processed electronically, these instruments can normally be dual scale for a choice in presentation.

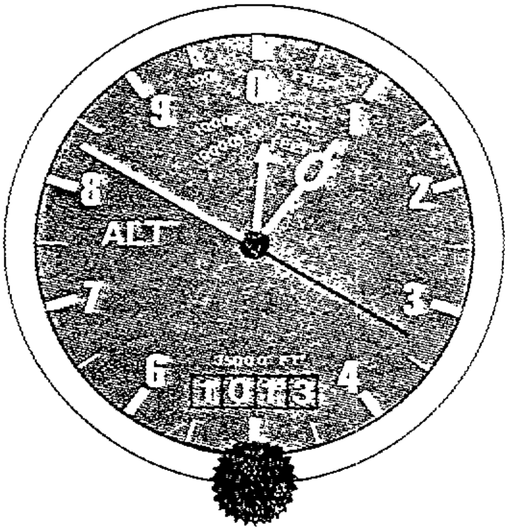
Thermistor

The Thermistor measures ambient and internal envelope temperatures. The ambient sensor is normally located inside the instrument, while the envelope sensor is at the end of a heat-resistant lead ending at the top of the envelope. The presentation is in degrees Celsius or Fahrenheit, and the unit is powered by two 9-volt batteries selected independently. The accuracy of this instrument is approximately $\pm 3^{\circ}C$.

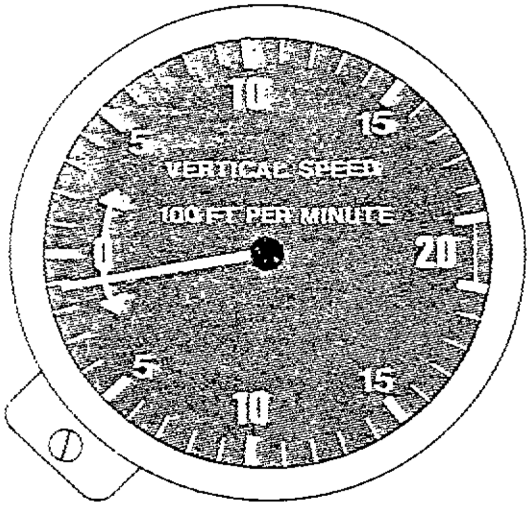
Combination Instruments

The advent of microprocessors has enhanced the possibility of producing the three basic instrument functions above in one electronic unit. The BALL 655 instrument has no aneroids, but uses a pressure transducer to give rate of climb and altitude data. The instrument must therefore be set prior to take-off with either the barometric pressure or the elevation. This instrument uses two independently selected 9-volt batteries, but it must be remembered that battery failure will mean total loss of instrument function. The variometer and thermistor work as described above.

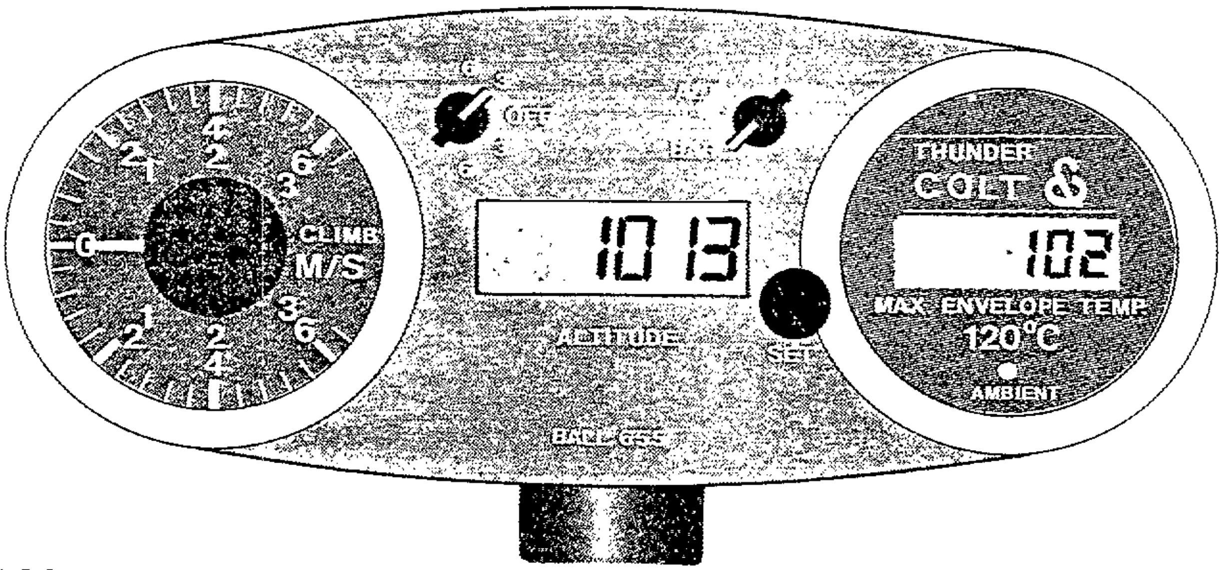
INSTRUMENTS



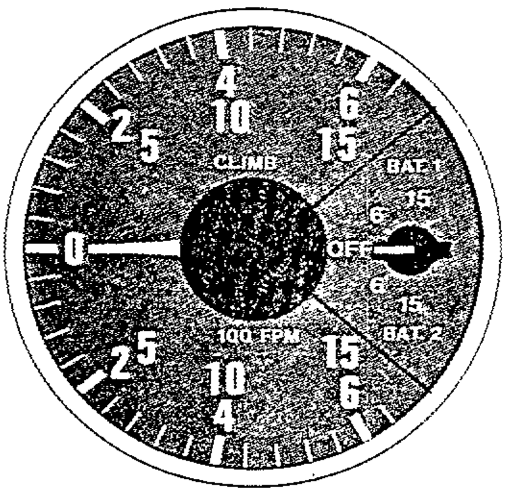
ALTIMETER



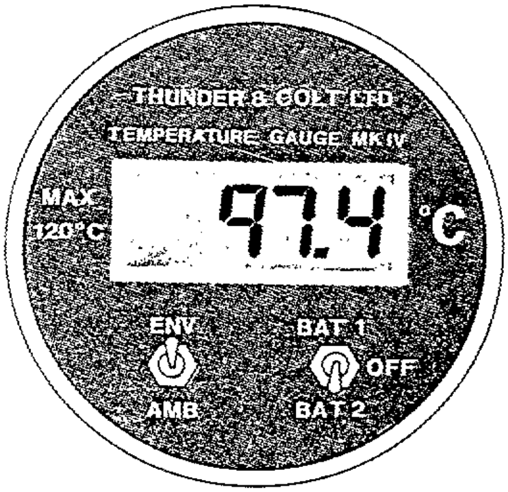
MECHANICAL VARIOMETER



BALL 655 COMBINATION INSTRUMENT



BALL ELECTRONIC VARIOMETER



T & C ELECTRONIC TEMP GAUGE

figure 1.12

2. FLIGHT INSTRUCTIONS

2.1 ASSEMBLY OF BALLOON

The various sub-components of the balloon must be assembled in the correct orientation to each other. To achieve this, some parts are colour-coded, and others have distinguishing features, as below.

Step 1: Slide the four nylon rods into the burner frame socket (fig. 2.1) and stand the burner on the rods. Locate the corner of the basket with the wire end coloured red. This will be at the bottom right hand corner when the basket is tipped over for inflation (viewed from the basket, looking toward the envelope). Bearing this in mind, two people can lift the burner and rod assembly, by the rods, into the sockets on top of the basket. The orientation is correct if the pressure gauges on the burner are the right way up when the basket is tipped over for inflation. The assembly should now look like figure 1.6. In a T-partition basket (160, 180 or 240), the burner is usually offset towards the pilot compartment at the right hand side.

Step 2: Now fit the cylinders. The orientation of master cylinders is important to prevent the pilot light freezing on inflation. (See fig. 1.11).

On Worthington cylinders there are two round holes on the top collar. These should face the ground while the basket is on its side for inflation.

On Colt V30 cylinders, the maxfill valves should face downwards for inflation. There is also a green sticker indicating the down position.

Note that all cylinders should be fixed with two straps. On all Thunder & Colt balloons, the minimum requirement for flight is two full cylinders which are capable of supplying fuel to the pilot light of the burner used. On horizontal type tanks (H40, H55), a green sticker indicates the down position for inflation. These tanks are also strapped in.

Step 3: Connect the fuel tanks as follows: First ensure that the blast valves and tank valves are closed. In this condition the valve handles will be at right angles to the fuel hoses. On screw-type tank valves (e.g. pilot lights) clockwise rotation closes the valve. Now fasten the quick connectors. Always fit both liquid hoses and all pilot hoses.

Check each cylinder in turn for leaks by opening the liquid valve at cylinder (with blast valves closed). If no leaks can be heard or observed, turn on pilot valves at cylinder and burner and light pilot light. Check that it is operating correctly. Now check the blast valve. After a successful burn test, close the tank valves for the liquid supply and vent the fuel system by operating the blast valves. Finally, turn off the pilot light at the burner. Repeat for other side of double burner system.

Step 4 If covers are used over the nylon rods they can be fitted now. Pilot hoses can be covered, but the liquid hoses are best strapped to the outside of the covers to permit easy cylinder changes in flight (unless a fuel manifold is utilized). At this stage remember that the basket wires should be inside the rod covers. See figs. 1.6 and 2.1 for the finished assembly.

Step 5

Passenger briefing (whilst basket is upright):
Show passenger various controls etc. Give the safety briefing - how to climb in, what to hold onto, etc (done at this stage because no noise, no rush, etc).

Step 6

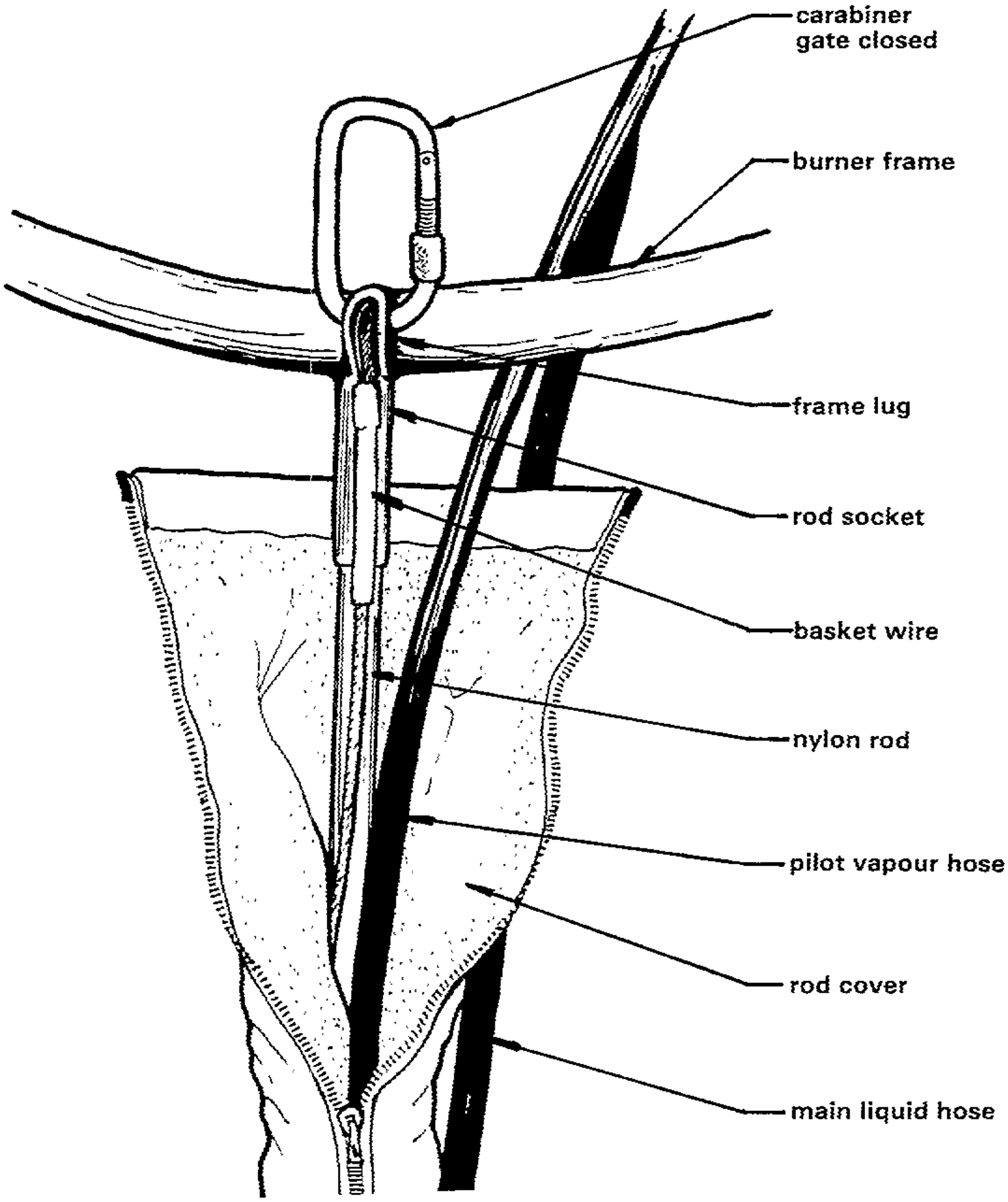
Connection of envelope to assembled basket:
Lay the basket on its side with the burner pointing downwind. In the correct position the basket wire coloured red will be in the bottom right hand corner, looking out of the basket. Stretch out the mouth of the envelope with the red marker in line with the centre of the burner frame. The groups of flying wires should now be as shown in figure 2.2.

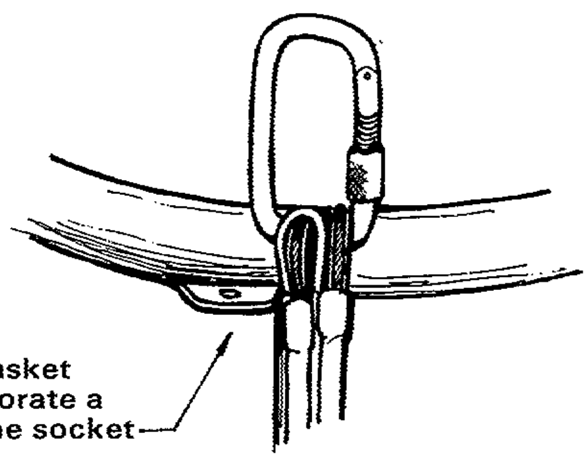
Connect the flying wire carabiners to both the burner frame and basket wire, as shown in figs. 2.1 and 2.2. Care should be taken to see that the flying wires are not crossed or twisted at this point. Screw the carabiner gates closed tight, then back off 1/4 turn.

Note that throughout this stage the wind direction should be towards the mouth of the balloon. Except for that portion of the envelope which has been pulled out to make the burner connection, the remainder of the envelope should stay packed in the bag until the inflation is ready to proceed.

DO NOT LAY OUT COMPLETE BALLOON BEFORE CONNECTION OF FLYING WIRES TO BASKET!

Ensure that restraint system is fitted before envelope pulled out.

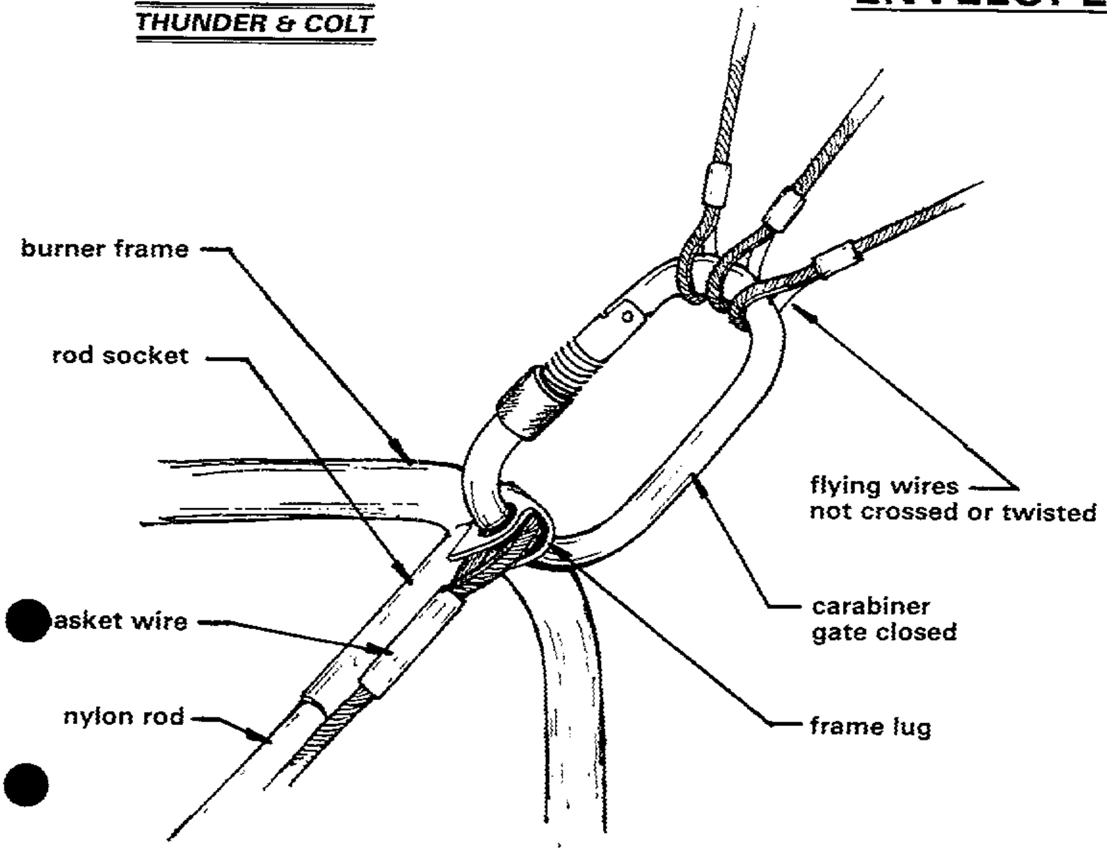




note: larger balloons use two basket wires at each corner and incorporate a tethering lug alongside the frame socket

figure 2.1

ENVELOPE CONNECTION



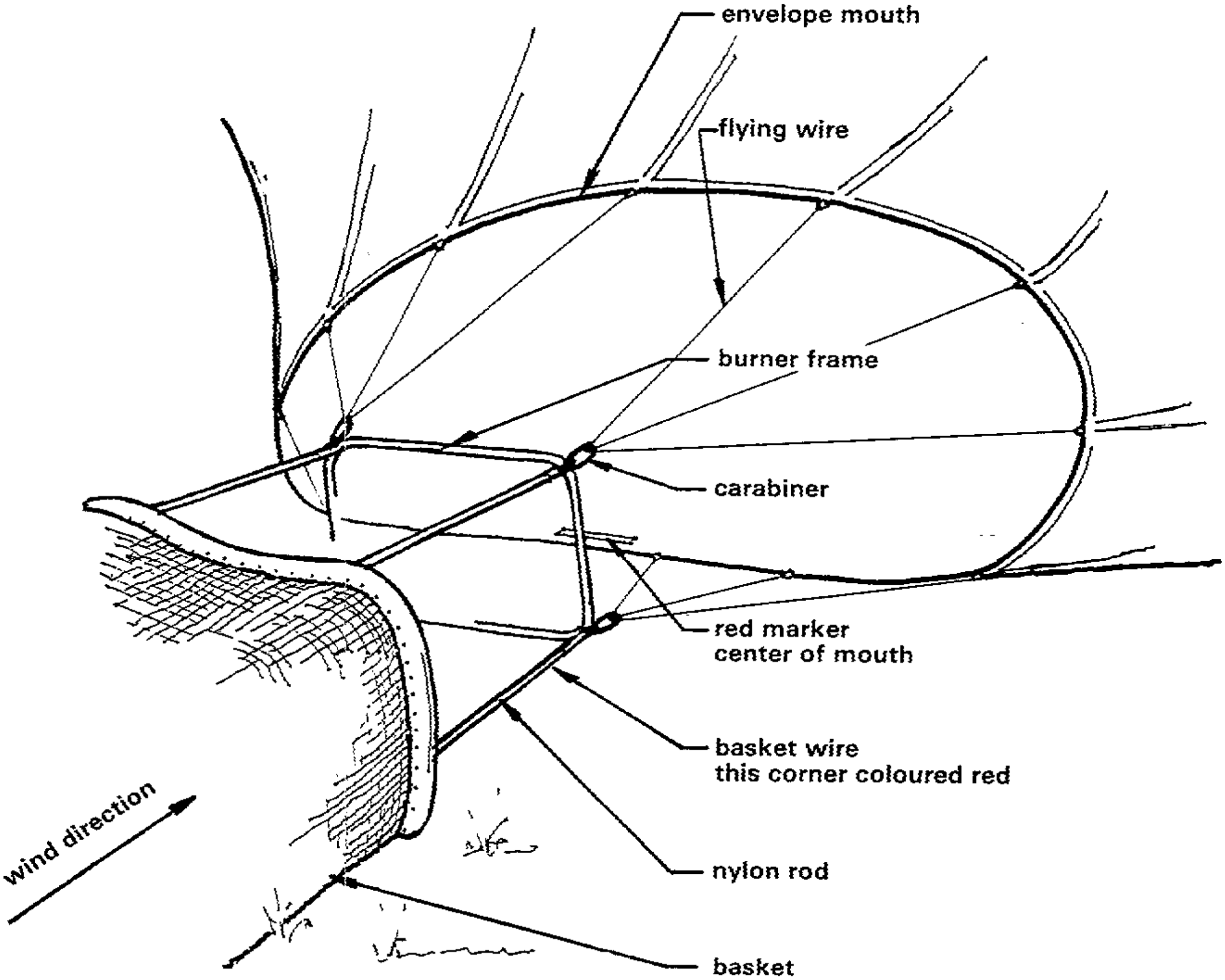


figure 2.2

2.2 WEATHER

Meteorological Criteria for Operation of Hot Air Balloons

(a) Wind Speed and Direction
The wind speed at the launch site, and also in the expected landing area, ought not exceed 10 kts. The wind direction should not carry the balloon into inaccessible areas (mountains, lakes etc.) or over large built-up areas, unless sufficient fuel is carried to safely overfly such areas (See 4.1 for limitations).

(b) Thermal Activity
Do not fly in thermals or in conditions when the wind is gusting at more than 10 kts above the mean wind speed.

(c) Temperature
Temperature should be noted, as this affects lift calculations. The presence of atmospheric inversions will reduce the useful lift of the balloon up to the top level of the inversion layer. If a flight at high altitude is planned, temperatures at altitude should be considered in load calculations and fuel consumption estimates.

(d) Weather Forecasting
If the weather forecast is received some time before the flight, beware of approaching fronts or increase in thermal activity, and update the forecast whenever possible. Never attempt a balloon flight around thunderstorm activity, ahead of approaching frontal systems, or near severe weather of any kind. A balloon pilot should be skilled in recognizing changes in weather during flight and modify flight plans accordingly.

2.3 SITE SELECTION

If the ground wind speed is above 5 kts it is important to inflate the balloon in a sheltered site. The criteria for a good launch site are:

(a) No downwind obstructions or powerlines for 200m in an arc 30 degrees from the take-off point. This is necessary in case of emergency landing or aborted launch.

(b) Area clear of obstructions for 25m either side of balloon to allow for surface wind shifts.

(c) Well sheltered from the wind to ease inflation and take-off.

(d) Area free of rocks, sticks etc. to prevent fabric damage.

At the site, lay out the balloon with the basket 15m downwind of the shelter. Assemble the balloon as described in 2.1 The wind direction should be toward the mouth of the balloon.

2.4 INFLATION PROCEDURE

After attaching the envelope to the basket as in Section 2.1, step 6, spread out the balloon envelope by pulling the load tapes (not the balloon fabric). Check that the crown line is not tangled with the tapes overlying the parachute aperture, and pull it out to the fullest extent away from the basket.

The inflation fan should be positioned on the left side of the basket. With a crew member holding each side of the mouth open, the fan can be started and directed toward the mouth, running at half power. The fan should be manned by a crew member at all times while running. The exhaust manifold and muffler can become quite hot, and on soft ground the vibration of the engine can cause the legs to sink in, and the fan to possible tip. In addition, extreme caution should be exercised to see that no loose cords, lines, or articles of clothing can become entangled in the propeller while the fan is running.

Parachute-Type Deflation System

Now mate the velcro patches which hold the parachute in place during inflation. Check that the patches are aligned correctly by following the parachute retaining cord down to its fixing point on the balloon load tape, and follow the tape back up to the aperture of the balloon. This can best be done as the balloon is starting to cold inflate. Ensure that none of the cords are tangled and the pulley runs freely.

Velcro-Type Deflation System

It is important to check the velcro joint and capewells lock whilst the balloon is cold inflated. The velcro joint should appear neat and even, with no wrinkles or puckers. Check each capewell individually and pull through plenty of ripline to ensure no straining of the locks during inflation. When the balloon is full cold inflated, visually inspect the rigging at the top of the balloon and the control line runs. If a capewell has opened, or a portion of velcro parted, the balloon must be partially deflated and properly reassembled before the hot inflation can proceed. You are now ready for inflation, but first ensure the ground crew and passengers are fully briefed.

Crown Line Crew

One or two persons (more on the larger balloons) should be detailed to hold the end of the crown line of the balloon throughout inflation. They should walk slowly towards the basket as the balloon is hot inflated, maintaining a constant tension until the envelope has come to the full, vertical position, and the pilot has signalled the crew to bring the lines. The crown line crew should be briefed not to wrap the rope around themselves, but merely to hold it so that it can be easily released. This prevents injury in the event of a sudden gust.

Mouth Crew

There should be one person on each side of the balloon mouth. Their job is to hold the mouth to create the largest possible opening for the burner. They should also keep the flying wires taut to prevent them dangling in the flame. The mouth crew must wear heat protective gloves, and long sleeves of a non-synthetic material are recommended. Care should be taken to see that feet and legs cannot become entangled in the flying wires should conditions become gusty or the envelope start to rise quickly. They should hold the base of the nomex panel which will also protect them from the heat of the burner.

Passengers, and any extra crew who are available, should be instructed to hold the basket down as the balloon is hot inflated. This is particularly important on large balloons. Also, the envelope crew should help here as they become available. It is often helpful, especially on larger balloons, to anchor a rope to an upwind vehicle to prevent the partially-inflated balloon from being dragged about by wind gusts.

Now complete the filling of the balloon with cold air. To avoid burn damage around the mouth use the fan to fill the envelope completely, and pull out the fabric until the balloon is entirely taut and wrinkle-free. This is particularly important in windy conditions for a trouble-free inflation.

Inflation

Ensure that the main burner valves are closed. Open the one tank valve and check that fuel pressure is correct and that there are no leaks. Turn on the one pilot valve at the cylinder (and burner, if fitted) and light the pilot light. The balloon can now be hot inflated, using short bursts on the burner. Use only one burner for inflation. The ground crew at the mouth should keep the balloon fabric away from the flame. In breezy conditions, continuing to run the inflation fan, with a crew member directing the airflow at the centre of the mouth while the pilot is heating, can be helpful. The fan pressure will help keep the mouth open wide and overcome back-drafting. This practice also helps "dilute" localized heat build-up at the mouth by mixing fresh air with heated air and thereby reduce the possibility of burn damage to the top of the mouth, as well as speeding up the overall progress of the inflation.

Safety Note

It is recommended that only one cylinder and one pilot light are used for inflation. Do not disconnect the quick release couplings or the pilot hoses when the tanks are horizontal.
A fire extinguisher should be available outside the basket.

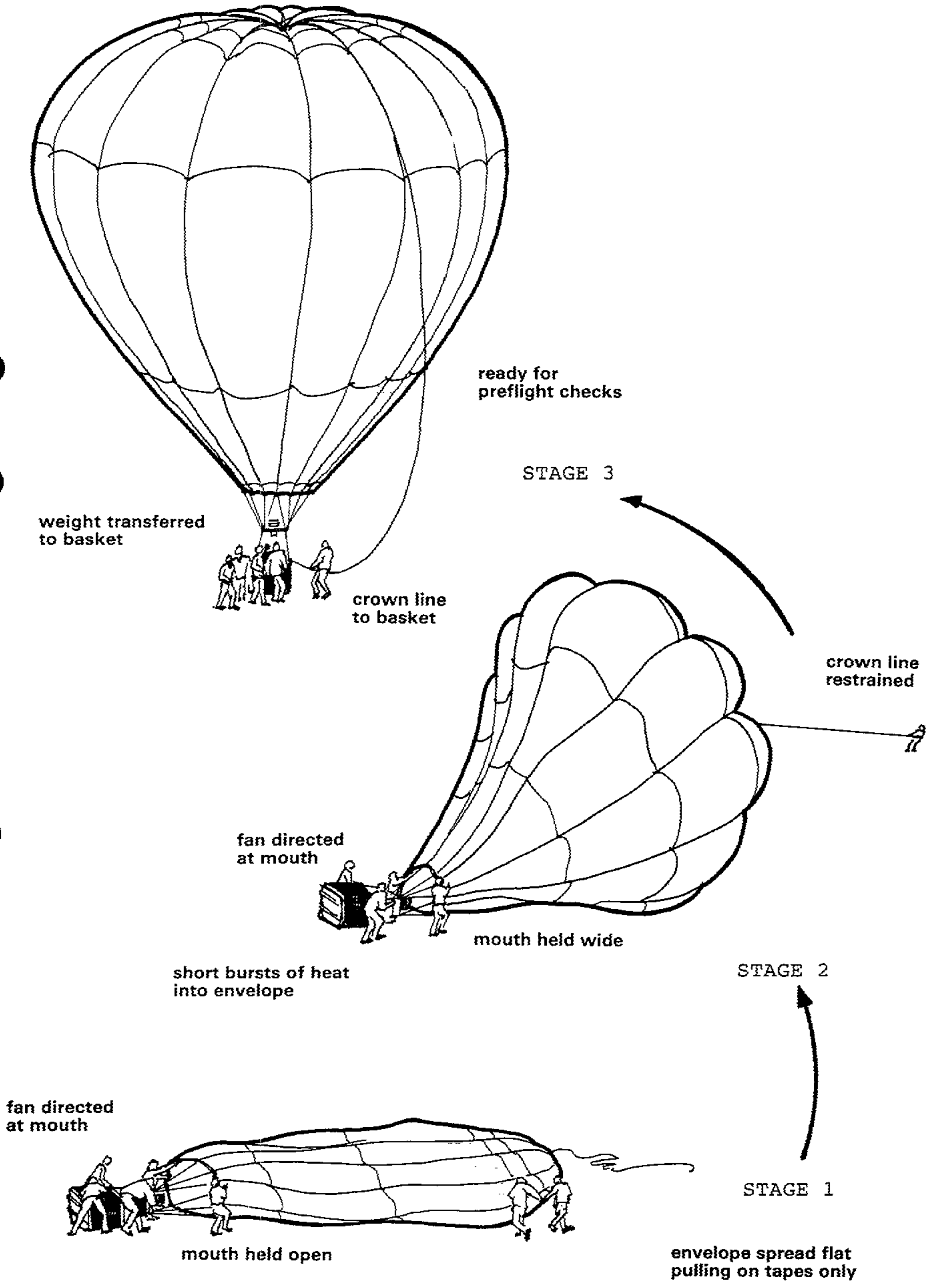

ready for
preflight checks
STAGE 3
weight transferred
to basket
crown line
to basket
crown line
restrained
fan directed
at mouth
mouth held wide
short bursts of heat
into envelope
STAGE 2
fan directed
at mouth
STAGE 1
mouth held open
envelope spread flat
pulling on tapes only

figure 2.3

As the balloon fills, the crown crew should allow the balloon crown to rise slowly by walking towards the basket, as instructed by the pilot. The crew from the balloon mouth should transfer their weight to the basket before the crown line is released. Any passengers should now get into the basket and the balloon should be heated to keep it stable. Operate the parachute in the normal way and visually inspect the rigging at the top of the balloon.

2.5 PRE-TAKE OF CHECKS

(a) Two sources of ignition carried;
(b) Relevant maps carried, anticipated flight path researched;
(c) Fire extinguisher carried;
(d) Base telephone number to contact lost retrieve crew;
(e) Set altimeter;
(f) Set and check radio (if fitted);
(g) Sufficient fuel for flight (min. 2 full tanks);
(h) Fuel cylinders securely strapped in;
(i) Fuel lines properly attached and with no visible damage;
(j) Both fuel systems functioning satisfactorily, and all tanks test fired in turn;
(k) Pilot light flames stable and strong;
(l) Flying wires not twisted;
(m) Carabiners closed and gates screwed shut;
(n) Ripline end secured to basket or burner frame and free from tangles; crown line attached to basket;
(o) (Parachute-type deflation) Test parachute operation, ensuring all velcro patches disengaged;
(p) (Velcro-type deflation) Check velcro panel in place and all capewell locks secured. Visually follow the ripline from top to bottom; test parachute operation;
(q) Envelope free from damage above first 4m of nylon fabric;
(r) Passengers briefed for emergency landing in case of aborted take-off;
(s) Weight limit for planned flight not exceeded;
(t) Required log books or paperwork on board.

2.6 TAKE-OFF

This is most easily controlled by the "hands on", "hands off" routine. The crew should be instructed to hold the edge of the basket down as the balloon is heated. It is important that they should be briefed to keep their feet on the ground and ensure they are not caught in any of the balloon rigging or control ropes. At regular intervals they should be instructed "hands off", when they raise their hands a few inches above the basket, and return them to hold the basket down at the command of "hands on". When the balloon is buoyant the basket will rise when the ground crew are "hands off".

When the pilot has enough buoyancy to take off safely, and is satisfied that the ground crew are not entangled with the balloon rigging, the balloon can be released completely, on command from the pilot, "hands off and stand clear". If a safety tie-off has been utilized, it can be released at this time, taking care to ensure that the rope is not tangled in any of the balloon rigging.

FALSE LIFT

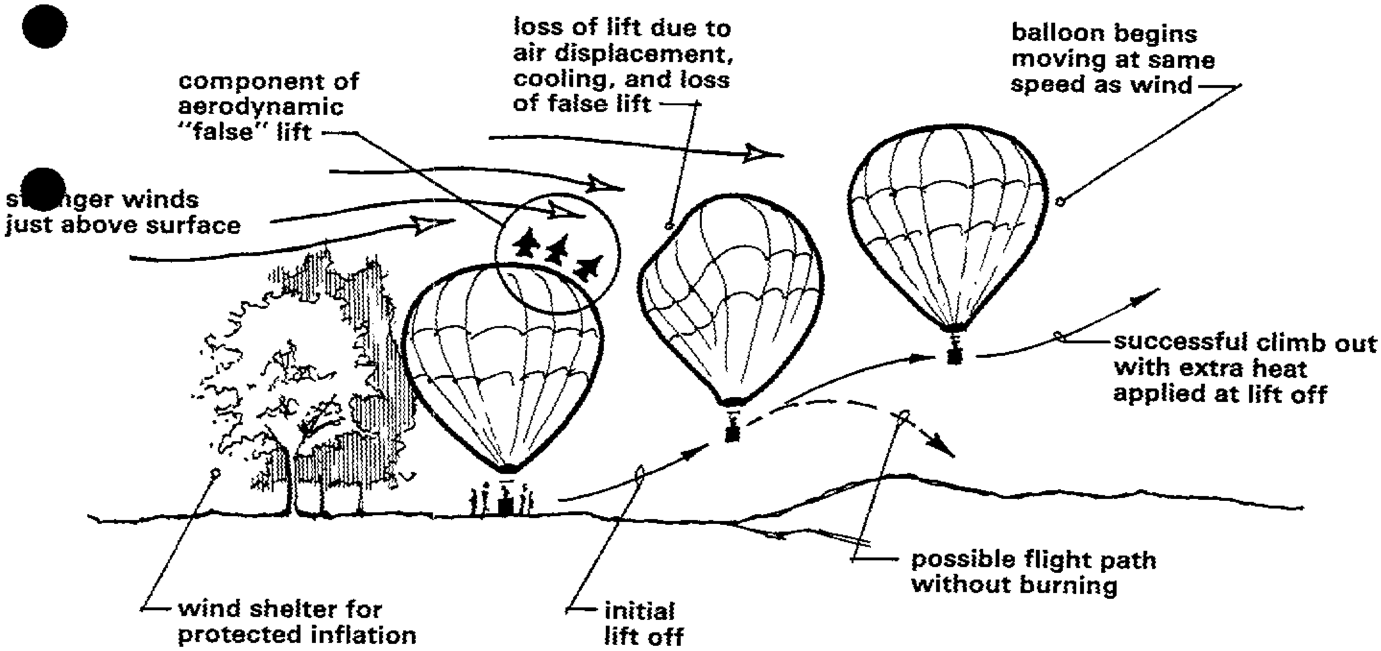


figure 2.4

An apparent loss of lift can occur as the balloon first encounters faster moving air just above the surface under windy conditions. This condition, known as "false lift", is usually more pronounced with a particularly well-sheltered site. Under suspected false-lift conditions, it is best to develop a little extra buoyancy under the controlled "hands off", "hands on" routine, and to add additional heat during the initial climb out to ensure that positive buoyancy is maintained as the balloon enters the faster moving air currents above the surface shelter.

Note: As the balloon rises into faster moving air, there will be an apparent crosswind, and it may be necessary to point the burner upwind to ensure that the heat goes into the balloon and does not endanger the fabric near the mouth.

2.7 FUEL MANAGEMENT

On early Worthington cylinders, and all V30 cylinders, the liquid dip tube was angled towards the downside during inflation, which meant after the liquid level went below the dip tube, sufficient liquid remained to allow vapour pilot light operation for several hours. However, in 1982 Worthington introduced a central dip tube which meant the cylinder could be completely drained by liquid withdrawal only. Therefore it is necessary on these cylinders to leave approximately 3% liquid per hour for pilot light operation. (This precaution is not necessary for burners equipped with a liquid pilot light system). Furthermore, the cylinder must be at least half full for inflation. All Worthington cylinders with a central dip tube carry a sticker describing it as such. All H40 and H55 cylinders have central dip tube. (See fig. 1.10).

Minimum Fuel Requirement: Two Full Cylinders

Run the first cylinder down to 25% and change to the second cylinder. The 25% is a reserve in case of a malfunction in the new cylinder/burner combination. The minimum fuel level for a landing approach is 25% in both tanks. This leaves enough fuel to enable the landing to be aborted and a second approach to be made with appropriate safety margins.

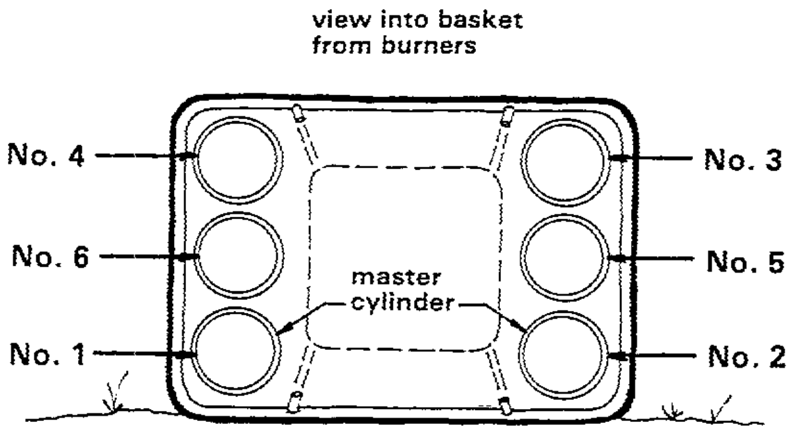


figure 2.5

Flight With More Than Two Cylinders

The two master cylinders (if fitted) should be used for the start of flight.

If all the cylinders are of the slave type, nominate two of the cylinders to act as the landing reserve cylinders.

(1) Fly on 1 until down to 25%, the switch supply to 4;
(2) Fly on 2 until down to 25%, then switch supply to 3;
(3) Empty cylinders in turn (3, 4, 5, 6), but keep the 25% fuel remaining in 1 and 2 for vapour pilot light operation and final landing reserve.

Transer of Fuel Supply Hose from Cylinder to Cylinder

(1) Close liquid valve on spent cylinder;
(2) Operate blast valve to vent fuel line, then close valve;
(3) Transfer the hose from spent cylinder to new cylinder;
(4) Open liquid valve on new cylinder and read fuel pressure;
(5) Relight pilot light on liquid pilot light type burners. Test fire new cylinder;
(6) If burn required during transfer, use other burner or other side of single burner.

2.8 ENVELOPE OVERHEAT

(a) If the balloon is properly loaded it is extremely unlikely that it will be overheated in flight. However, if the envelope temperature flag descends in flight, it signals that a temperature of 127°C or more has been reached.
(b) Descend to lowest practical altitude until landing.
(c) While continuing to fly, minimise vertical manoeuvreing.
(d) Land as soon as practical, lighten load, investigate problem.
(e) Prior to next flight, follow maintenance procedures for maximum allowable operating temperature being exceeded.
(f) Fit new temp flag.

2.9 LANDING PROCEDURE

Pre-Landing Checks

(a) Burners not connected to empty cylinders (25% minimum);
(b) Parachute ripline free and accessible;
(c) Loose items secured;
(d) Passengers briefed for type of landing appropriate.

Passenger Briefing

(a) Face direction in which balloon is travelling (except in partitioned baskets where the passengers should face backwards), at the front edge of the basket;
(b) Hold internal rope handles;
(c) Stand with knees together and slightly bent, muscles tensed;
(d) Stay in the basket until instructed by the pilot to leave.

Criteria for Landing Site

Allowing for possible variations in the wind at ground level, choose a field as follows:

(a) Free of obstructions, especially power lines;
(b) Overshoot area should also be clear;
(c) Field free of crops and animals;
(d) If possible, look for upwind shelter to reduce speed;
(e) If possible, choose a field with good accessibility for retrieve crew, and minimum inconvenience for the owner.

Approach and Landing

Once a suitable landing field has been selected, initiate a descent towards it. Leave plenty of clearance when flying over obstacles. The speed of descent is related to the wind speed. On calm days low rates of descent can be used, but with higher winds it is necessary to deliberately execute a steeper angle of approach. The passengers should be warned that the basket may tip over and then be dragged some distance. This is not unusual or unsafe if the initial briefing is properly issued and understood.

In a partitioned basket (usually 160, 180 or 240´s) use the rotation vents to align the basket for landing, i.e. the long side facing the direction of travel, with the pilot compartment to the right (as for inflation). In partitioned baskets, passengers always face backwards, and hold rope handles provided. In fast conditions backs should be pressed firmly against the cushions provided, knees together and slightly bent, muscles slightly tensed.

The descent speed is controlled by use of the burner and parachute. Immediately prior to touchdown turn off the pilot lights and tank valves, and vent fuel lines by operating burner valves (if time allows). Pull and hold the parachute line. The parachute can be opened fully at up to 20 ft for a fast landing, or after touchdown on a calm day.

Continue holding the parachute line to achieve deflation. When the balloon is stationary, and sufficient air has been vented, instruct a passenger or crew member to take the crown line and pull it away from the basket down wind. This procedure gives the fastest deflation time, which is particularly important on windy days. Caution: always ensure that no-one is allowed to leave the basket until it is safe to do so without the balloon becoming buoyant again.

For fast deflation with a parachute/velcro combination balloon, use the parachute as above,but do not open the velcro rip until ground contact has been made as once the panel starts opening the operation is irreversible and an abort cannot be executed. To achieve full efficiency of the velcro rip, pull in the line fast and continuously. Do not release the ripline until complete deflation of the envelope is well underway.

Check again that the fuel cylinder valves are closed. Vent the fuel lines by operating the burner valves. Disconnect the hoses from the cylinders.

2.10 POST-LANDING

Refitting of Velcro

The velcro joint should be remade immediately after landing. The method of closing the velcro is as follows:

(a) The velcro should be cleaned of any grass, sticks, or other contamination, and dry when assembling.
(b) Starting from one end of the velcro split, align the balloon seam with the rip panel seam. Pull the two pieces tight and compress the mating velcro surfaces firmly together. Continue in this fashion to the end of the split, checking alignment at each gore or panel seam.
(c) Inside the balloon, reassemble the safety capewells, checking to ensure the ripline and parachute cords are not entangled at the capewells.

Pack the envelope. Contact the landowner prior to allowing the retrieve crew to collect the balloon. Balloonist/landowner codes are very important. Follow the procedures recommended by your local or national ballooning organisation.

2.11 FUEL PRESSURISATION

The burner system has a total operating pressure range of 3-16 bar (45-225 psi). However, flying with a fuel pressure below 5 bar (70 psi) requires caution, and it is advisable to keep pressure to at least 7 bar (100 psi) for normal operation. This can be achieved by leaving cylinders at room temperature overnight, or by using an approved electrical heating jacket. It must always be remembered that liquid propane expands rapidly with heat, and the typical temperature tolerance of a full Worthington cylinder is 60°C. Thus, if the cylinder is filled full at -20°C and subsequently heated to +40°C, it will be solid with liquid fuel and will start relieving through the relief valve. Because propane vapour is heavier than air and will simply collect at floor level, cylinders must never be heated or stored in a space with ignition sources available, in case the relief valve should open.

Fuel pressure can also be increased by adding nitrogen to the cylinder through its liquid valve. A cylinder can thus be charged to the pressure level desired. The nitrogen will stay on top of the liquid propane and will do no harm to the system Once a cylinder is charged with nitrogen it cannot be used to draw vapour for pilot light operation. Additional caution as to propane expansion with temperature applies to nitrogen pressurisation. It must be ensured that if cylinders are heated subsequent to nitrogen pressurisation, the maximum operational pressure of 16 bar (225 psi) is never exceeded.

Note: Always leave two master cylinders nitrogen free for vapour pilot lights, and ensure they can be easily identified.

2.12 DROPPING OF LOAD

Parachuting

Any Thunder or Colt balloon can be used for dropping parachutists, providing this is within the normal loading requirements and meets applicable national aviation regulations.

Prior to exit secure all fuel, rip and vent lines out of the way. Instruct the parachutist(s) to either sit on the basket edge and roll out backwards, or to stand on the edge, holding the burner frame, and exit backwards. At the exit point the balloon should be in a descent ranging from 800 fpm (ideal), to not less than 400 fpm (minimum).

The number of parachutists that can be released simultaneously depends on the balloon size, in that no more than 30% of the balloon's maximum allowable weight should be released at any one time. For example, a 77,000 cu ft balloon has a 770 kg m.a.u.w., resulting in a maximum released weight of 231 kg.

Dropping of Hang-Gliders

Regulations vary from one country to another, and air agency approvals and/or waivers are usually required for such operations. The following is the factory-recommended method.

The hang-glider should be suspended from the burner frame carabiners, using two opposite carabiners to give a symmetric loading. This is easiest achieved by splitting the suspension line underneath the basket and running one line either side of the basket and up through opposite carabiners, then routing through either of the two remaining carabiners. Make sure there are no knots above the basket bottom level.

Take-off must be under calm conditions, using three tether lines to stabilise the balloon over the glider. After take-off heave the three lines in, making sure they do not snag the glider.

Climb rate depends on glider stability, but is normally limited to 500 fpm. When release height is achieved, make sure the glider pilot acknowledges your signal, and establish a descent rate of approximately 800 fpm at release point.

The release is effected by cutting the line at the burner frame, letting the two free ends run through. Use a 4-6mm Kevlar cord, and cut with a sharp knife. Avoid the use of unproven mechanical releases. Use this one central suspension line, never use a second line.

<u>DROPPING OF HANG-GLIDERS</u>

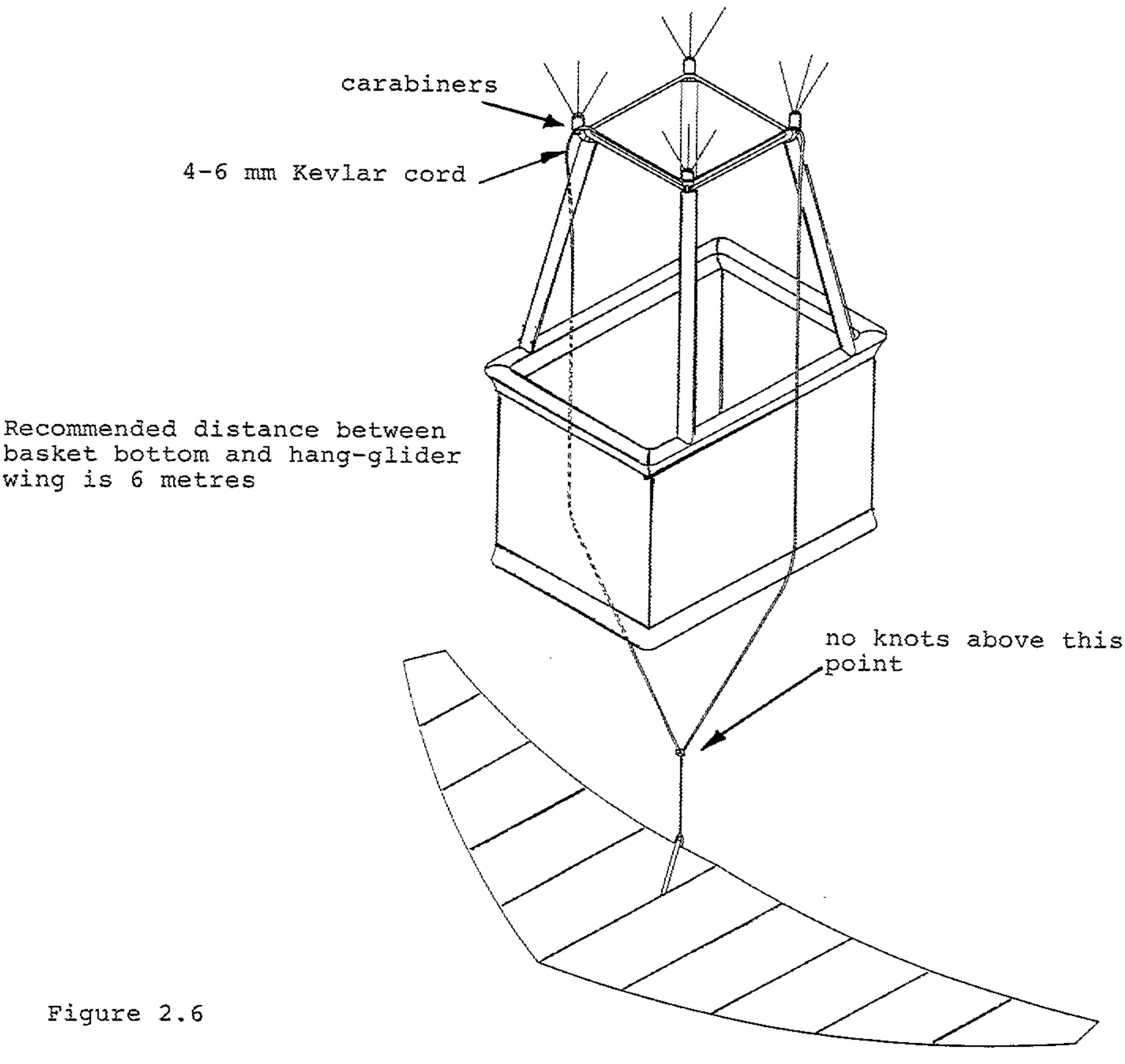


Figure 2.6

3. EMERGENCY INSTRUCTIONS

3.1 GENERAL

Inflight emergencies caused by equipment failure are extremely rare with properly inspected and maintained balloons. Weather related emergencies and ground handling incidents can be prevented by proper pre-flight planning, and the exercise of sound pilot judgment. Should an emergency arise, the following guidelines are presented to be applied, together with pilot judgment and experience, in order to minimize damage or injury.

When exiting the balloon at ground level (as in the case of an onboard fire), the pilot must ensure that all passengers are out, and that the balloon does not remain airborne (exit with the rip line in hand). Jumping from a balloon inflight can present grave physical injuries, even at quite low altitudes, and should be avoided.

3.2 AVOIDANCE OF LOW LEVEL OBSTACLES

The important factor here is to make a decision to climb or descend and then stick to this decision. For fast climbs all burners should be used. At low altitudes (less than 30ft) any ballast (e.g. trail rope) can be dropped if this does not endanger persons or property on the ground. To descend, use the parachute valve, but be ready to slow the sink rate with the burner when it is safe to do so.

When a decision has to be made quickly to climb or descend there are two simple guidelines:

(a) It is easier to maintain or increase the vertical motion of a balloon, either up or down, than to reverse it.

(b) From level flight the balloon responds faster when put into a descent than when put into a climb.

When in doubt, descend.

Do not fly into power lines at any cost. If contact is inevitable descend as fast as possible so that the contact of the wires is with the envelope and not with the basket assembly. Shut down the fuel system and vent lines before contact. If the balloon is caught in the wires DO NOT TOUCH ANY METAL PARTS. If possible, remain in the basket until the power is shut off. Never attempt to remove the balloon until the power authority has arrived. Do not allow crew members to make contact between the ground and the basket until the power is shut off.

3.3 LOSS OF MAIN BURNER

Change to the alternative burner. If one burner fails, fly on the alternative unit and land as soon as possible.

If both burners malfunction, check that the cylinder(s) connected to the burner are not empty, are properly connected and are turned on. If there is still no fuel flow try another cylinder. If the fault cannot be rectified, prepare for a heavy landing. Follow the emergency landing procedure.

The balloon can be flown entirely on the liquid fire burner if the other burner fails. This unit is less powerful, but is sufficient for emergency operation until a landing can be completed.

3.4 LOSS OF PILOT LIGHT

(a) Check that the valves on the cylinder and burner (if fitted) are open.

(b) Check that the pilot light hoses are properly connected to the cylinder.

(c) Relight the pilot light.

(d) If both pilot lights fail and cannot be re-lit, proceed as follows:

If the burner has a liquid fire, open a crack and use this as the pilot light for the main burner until an emergency landing can be safely completed. If not:

Alternative 1 - Burners with Worcester-type Blast Valves
Crack one blast valve partially open and ignite the propane directly on the jets. Adjust the valve to give a flame approximately 1ft (30cm) high. Leave this flame to act as a pilot light. Fly on the other burner and land as soon as possible.

Alternative 2 - Burners with Rego Valves
Crack the blast valve open and light directly on the main jet. Open blast valve fully while slowly closing cylinder valve until only approximately 1ft (30cm) flame remains. Leave flame at this stage to act as a pilot light and fly on the alternative burner until an emergency landing can be safely completed.

Note: continuous operation of a propane valve open at very low settings will result in some freezing and is only satisfactory for short periods of time - LAND AS SOON AS POSSIBLE.

3.5 EMERGENCY LANDING PROCEDURE

Note: Two "hard" landing situations are possible here: a burner failure results in a "heavy" landing impact of primarily vertical forces; a weather emergency can result in an extreme high ground speed or "fast" landing impact of primarily horizontal forces. In a heavy landing the brace should be against vertical compression, with knees only slightly bent, arms braced downward, weight on the balls of the feet, muscles tensed (like a cat landing from a high jump). In the fast landing, the basket may tip forward violently on impact, and the principal forces tend to pitch occupants forward out of the basket in a whiplash action. In this instance, the brace should be quite low (knees well bent) and with the back or shoulder pressed firmly against the front edge of the basket, head level with the leather trim, rope handles firmly held.

(a) Instruct passengers to be prepared for a hard landing (heavy or fast).

(b) Passengers should hold the internal rope handles and stand with their knees together and bent, muscles slightly tensed.

(c) Instruct passengers not to leave the basket until told to do so.

(d) Immediately prior to touchdown it may be possible to remove any emergency ballast, if this can be done without injuring persons on the ground.

(e) Turn off pilot lights.

(f) Turn off cylinder fuel valves.

(g) Vent fuel lines, if time permits.

ARREST OF ANY UNPREMEDITATED DESCENTS

Descents resulting from burner failure or fuel shortage cannot be arrested. Trail ropes etc can be ditched (as 3.2) to give some deceleration.

Descents resulting from thermal activity or other gust conditions can be arrested with the burner. Use all the power available (e.g. double burner and liquid fire) till the descent is arrested or reduced enough for a safe emergency landing to be made. Be ready to use the parachute valve in case of over correction of the descent.

3.6 PARACHUTE MALFUNCTION

(a) Use the burner to control descent.

(b) Check visually to see if the problem can be solved.

(c) If the line is not visibly fouled, try to open the valve briefly and release it abruptly. Follow this with use of the burner. If the problem persists do not use the parachute except for emergency and final deflation. Land as soon as possible.

(d) If the parachute fails closed, follow the procedures for emergency landing (see 3.5) and warn passengers of long drag.

3.7 PROPANE FIRE ON THE GROUND

(a) Turn off the source of propane with the cylinder valve.

(b) Operate the fire extinguisher.

(c) If the fire is not extinguished within 30 seconds abandon the balloon as there is a high risk of explosion. When exiting passengers, make sure to reduce buoyancy to prevent the balloon from becoming airborne. The pilot should exit the balloon last, with the rip line in hand.

3.8 PROPANE FIRE IN FLIGHT

(a) Turn off source of propane at the cylinder.

(b) Operate the fire extinguisher.

(c) After the fire is extinguished, and if the cause of the fire can be determined and corrected, relight the pilot light and proceed.

(d) Land as soon as possible.

4. OPERATIONAL LIMITATIONS

4.1 LIMITATIONS

(a) The balloon may not be flown in conditions exceeding those stated below.

(b) The balloon may not be flown if it has been modified without the manufacturer's or the national airworthiness authorities' approval.

(c) The balloon may not be flown if it has not been maintained in accordance with the approved Maintenance Manual. Permitted fabric damage is no unrepaired holes above first 4m larger than 1" in any direction, or closer than 3/4" to any load tape. No flight is permitted with unrepaired damage to load tapes, suspension system, primary structure, burners, or fuel system components.

(d) Minimum crew required shall be one pilot. Maximum number of occupants should not exceed that number shown on the weight charts (see 4.2(d)). The pilot shall meet the licensing and insurance requirements specified by the aviation authority of his country. Crew must wear gloves when handling the balloon, and pilot must wear gloves at all times.

(e) Burner fuel is LPG, caustic and water-free. Propane is the preferred fuel, but some butane and propylene content is acceptable, provided minimum recommended fuel pressures are maintained throughout the flight.

(f) The balloon should not be flown in thermic conditions or in erratic, gusty winds. Maximum demonstrated surface wind for take-off and landing is 15 knots.

(g) The balloon must not be flown into contact with power lines.

(h) The maximum recommended rate of climb and descent should not exceed 1000 fpm (5m/sec.). The parachute valve should not be held open in flight for more than three seconds without allowing it to reseal before opening again.

(i) The maximum allowable envelope temperature is 120°C (250°F).

(j) The maximum balloon loading shall not exceed that specified in the approved loading charts (see following pages).

4.2 LOAD CALCULATIONS

(a) Maximum All Up Weight (M.A.U.W.)

The maximum all up weight is established for each envelope type. The M.A.U.W. is tabulated below and this weight must never be exceeded.

(b) Empty Weight

The empty weight is particular to each individual balloon and must be computed by adding the weight of all the separate components of that system. These weights should be noted in each balloon logbook, so that individual load calculations can be completed. The chart below lists actual M.A.U.W. values, but gives typical empty weights, to be used for guidelines and general loading estimates only.

(c) Average Cylinder Weights

Use the following table to estimate fuel weight for maximum allowable payload calculations.

CYLINDER	TANK WEIGHT	FUEL CAPACITY	FULL WEIGHT
Worthington	14 kg	20 kg	34 kg
Colt V30	16 kg	30 kg	46 kg
Colt H40	18 kg	40 kg	58 kg
Colt H55	25 kg	60 kg	85 kg

(d) M.A.U.W. Table

Empty weight is approximate and includes envelope, basket, burner, overhead frame, instruments and accessories (but not fuel cylinders or occupants). All figures given are in kilograms. The lift of a balloon is solely a function of envelope volume irrespective of type.

(Note: MAUW = maximum all up weight. This is the figure used in the design and certification of the balloon and must not be exceeded.)

M.A.U.W. TABLE

Balloon Type		Volume (cu. ft)	M.A.U.W. (kg)	Empty Weight (kg)
THUNDER				
Bolt	42	42,000	420	106
Bolt	56	56,000	560	121
Bolt	65	65,000	650	129
Bolt	77	77,000	770	138
Series I	42	42,000	420	110
Series I	56	56,000	560	125
Series I	65	65,000	650	134
Series I	77	77,000	770	143
Series I	84	84,000	840	158
Series I	90	90,000	900	170
Series I	105	105,000	1050	189
Series I	120	120,000	1200	211
Series I	160	160,000	1450	335
Series I	180	180,000	1450	345
Series II	90	90,000	900	174
Series II	105	105,000	1050	193
Series II	120	120,000	1200	216
Series II	140	140,000	1400	245
Series II	160	160,000	1450	255
Series II	180	180,000	1630	276
Series II	210	210,000	1900	353
Series II	225	225,000	2041	490
Series II	250	250,000	2268	510
Z-Type	31	31,000	310	100
Z-Type	56	56,000	560	130
Z-Type	65	65,000	650	138
Z-Type	77	77,000	770	156
Z-Type	105	105,000	1050	195
COLT				
A-Type	31	31,000	310	103
A-Type	42	42,000	420	117
A-Type	56	56,000	560	131
Bullet	56	56,000	560	131
A-Type	69	69,000	650	145
A-Type	77	77,000	770	158
Bullet	77	77,000	770	158
A-Type	90	90,000	900	176
A-Type	105	105,000	1050	198
A-Type	120	120,000	1200	225
A-Type	140	140,000	1400	280
A-Type	160	160,000	1450	335
A-Type	180	180,000	1630	345
A-Type	210	210,000	1900	450
A-Type	240	240,000	1940	480
A-Type	260	260,000	2360	520
A-Type	300	300,000	2700	550
A-Type	315	315,000	2835	700

4.3 LOAD CHARTS

(a) General

There are many variables affecting the lift of a hot air balloon. Calculating the exact lift available for a given specific set of conditions is a mathematical exercise not normally necessary. Detailed lift calculations are included in the Appendix. For most flying conditions a load chart produces sufficient accuracy, and a complete series of load charts is reproduced below. Lift in kilograms is plotted, based on 100°C envelope temperature and ISA (International Standard Atmosphere) conditions, with temperature correction curves for up to plus or minus 20°C on either side of standard (ISA = +15°C, 1013.2 millibar, 1.225 kg/m^3, at sea level).

(b) Use of Charts

First find the table for your balloon size. The horizontal scale is ambient air temperature in °C. The vertical scale is available load (gross lift) in kilograms at an envelope temperature of 100°C. The dark horizontal line indicates Maximum All Up Weight (M.A.U.W.) which must not be exceeded.

To calculate lift available, start with the correct ambient temperature on the horizontal scale. Follow vertically up this temperature line until it intersects the sea level curve, then to the left horizontally to intersect the load scale. This value gives available gross lift at sea level (provided you have not gone above the M.A.U.W. cut-off line).

To correct for altitude, from the first point of intersection on the sea level curve, follow the ISA curves sloping down and to the left until the appropriate altitude curve is intersected, then proceed to the left horizontally until the load scale is reached. You now have available gross lift at altitude. Note that only five ISA curves are shown, so some interpolation is usually required.

(c) Sample Calculation

Balloon:	Colt 56A
Flight Plan:	Sea level to 6000′
Ambient Temperature:	+20°C
Empty Weight:	131 kg
Fuel Carried:	2 Worthington′s, 68 kg

To find the total payload available at 100°C envelope temperature, use appropriate table for Colt 56A. Begin at 20°C on bottom scale and follow up vertically to intersect the sea level curve.

This point corresponds to approximately 410 kg on the vertical load scale. Since this value is well below the M.A.U.W. value of 560 kg, 410 kg will be our gross lift available at sea level.

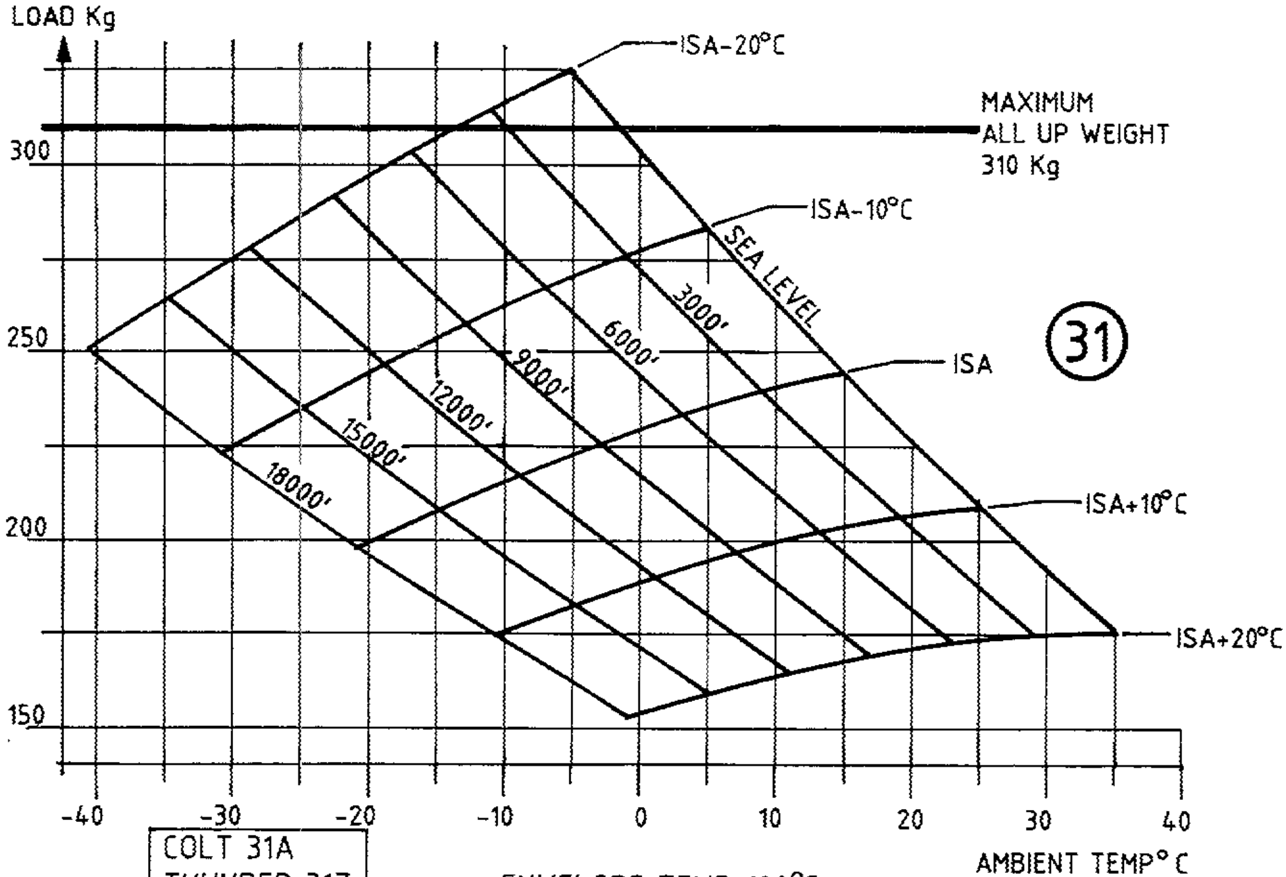
To find lift at 6000´, interpolate a curve midway between ISA and ISA + 10°C. Follow the interpolated curve to its intersection with the 6000´ curve. This point corresponds to approximately 390 kg on the load scale. As a further check on our interpolation, the ISA curve intersects 6000´ at approximately 420 kg, while the ISA + 10°C curve intersects 6000´ at approximately 360 kg. We are at 20°C, or ISA + 5°C, so halfway between 420 kg and 360 kg is 390 kg. Thus we will use 390 kg as gross lift available at 6000´ altitude.

Note that our loss of lift is 20 kg between sea level (410kg) and the 6000 ft altitude (390 kg). Since this amount is not an unreasonable estimate of the weight of fuel that might be used during the climb to altitude, in this instance we can use the sea level lift to compute maximum available payload. However, with a larger balloon or higher altitudes, the gross lift available at altitude, rather than at take-off, can easily become the limiting factor. Both should always be calculated and compared.

Max. gross lift available		=	410 kg
Empty weight	131 kg		
Fuel carried	+68 kg		
subtotal	199 kg		-199 kg
Maximum available payload		=	211 kg

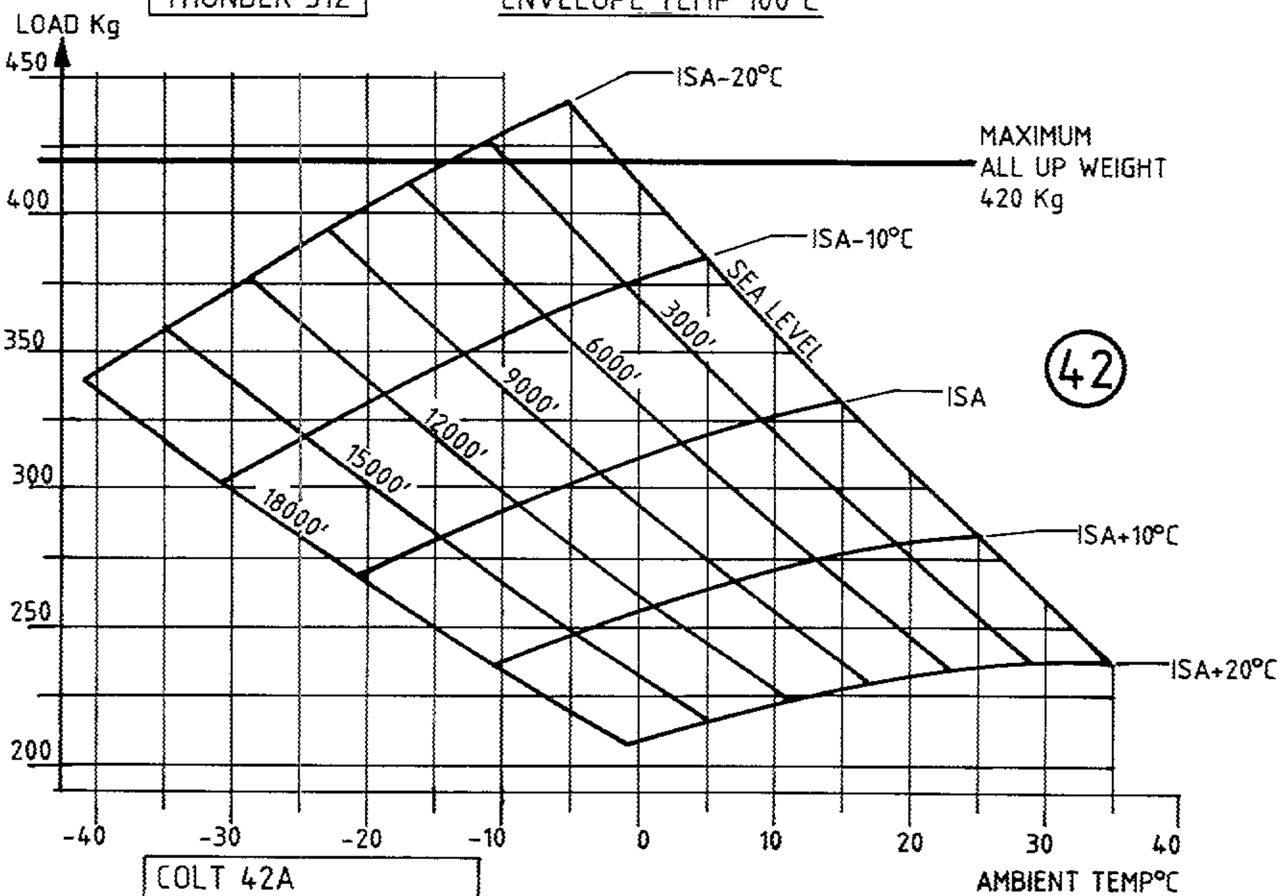
(d) <u>Load Charts</u>

Refer to the following pages for load charts for all balloon sizes.



COLT 31A
THUNDER 31Z

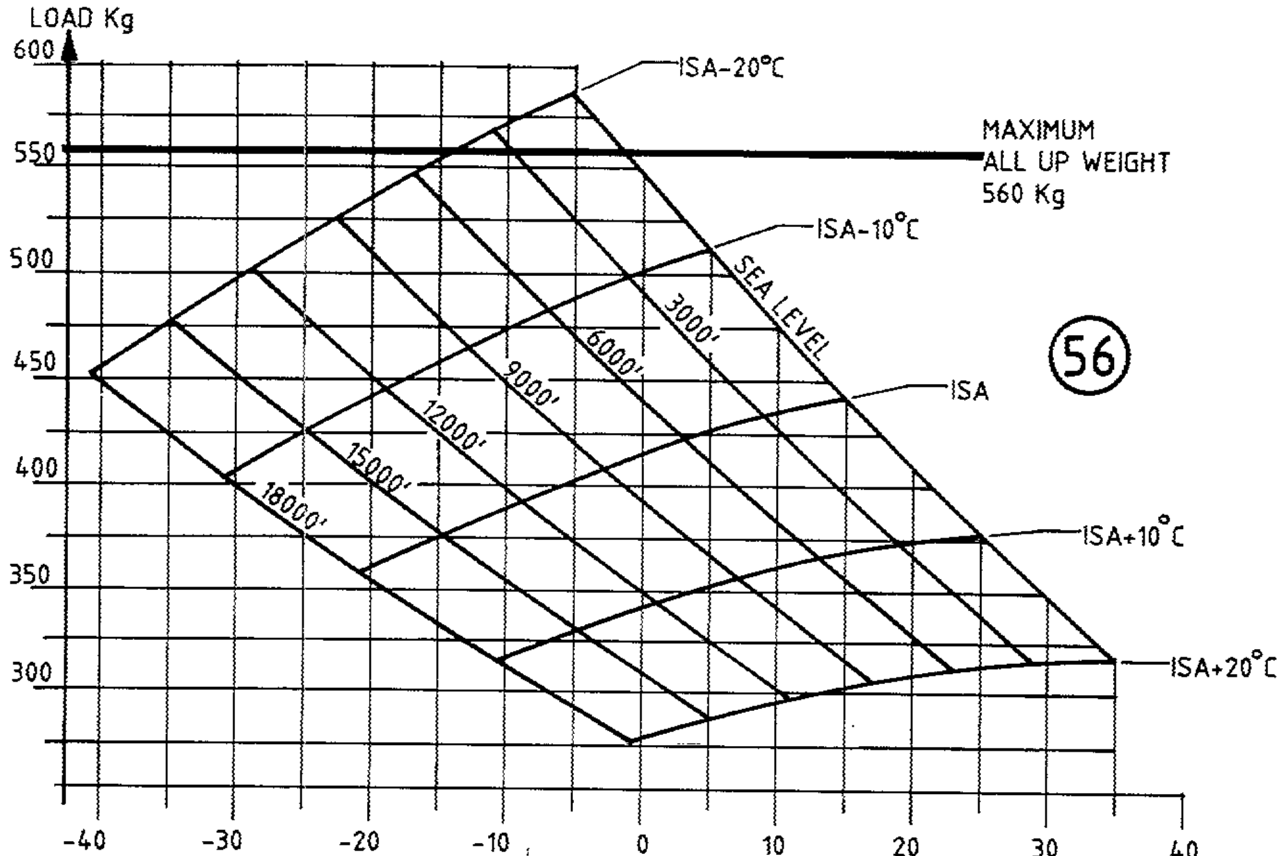
ENVELOPE TEMP 100°C



COLT 42A
THUNDER 42 SERIES 1

ENVELOPE TEMP 100°C

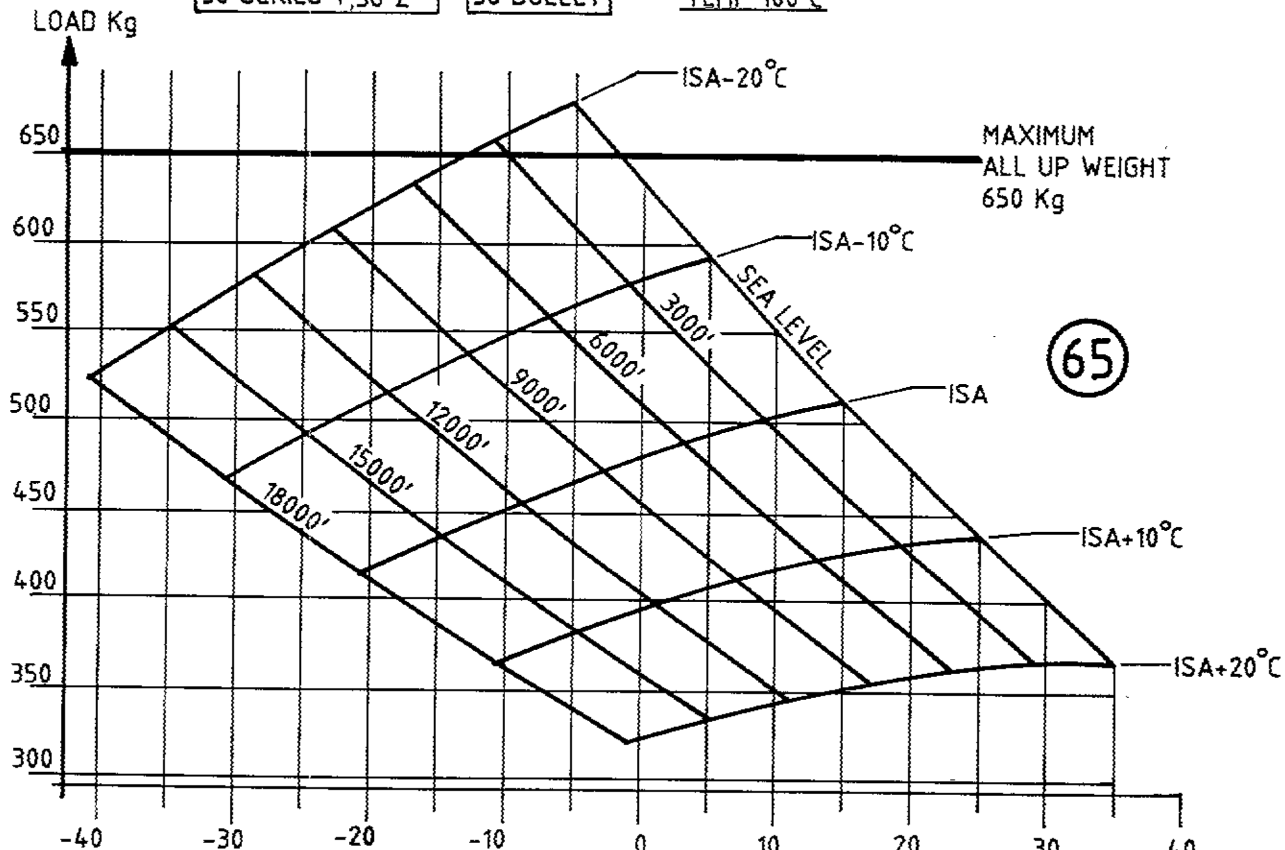
THUNDER & COLT



THUNDER 56 BOLT
56 SERIES 1,56 Z

COLT 56A
56 BULLET

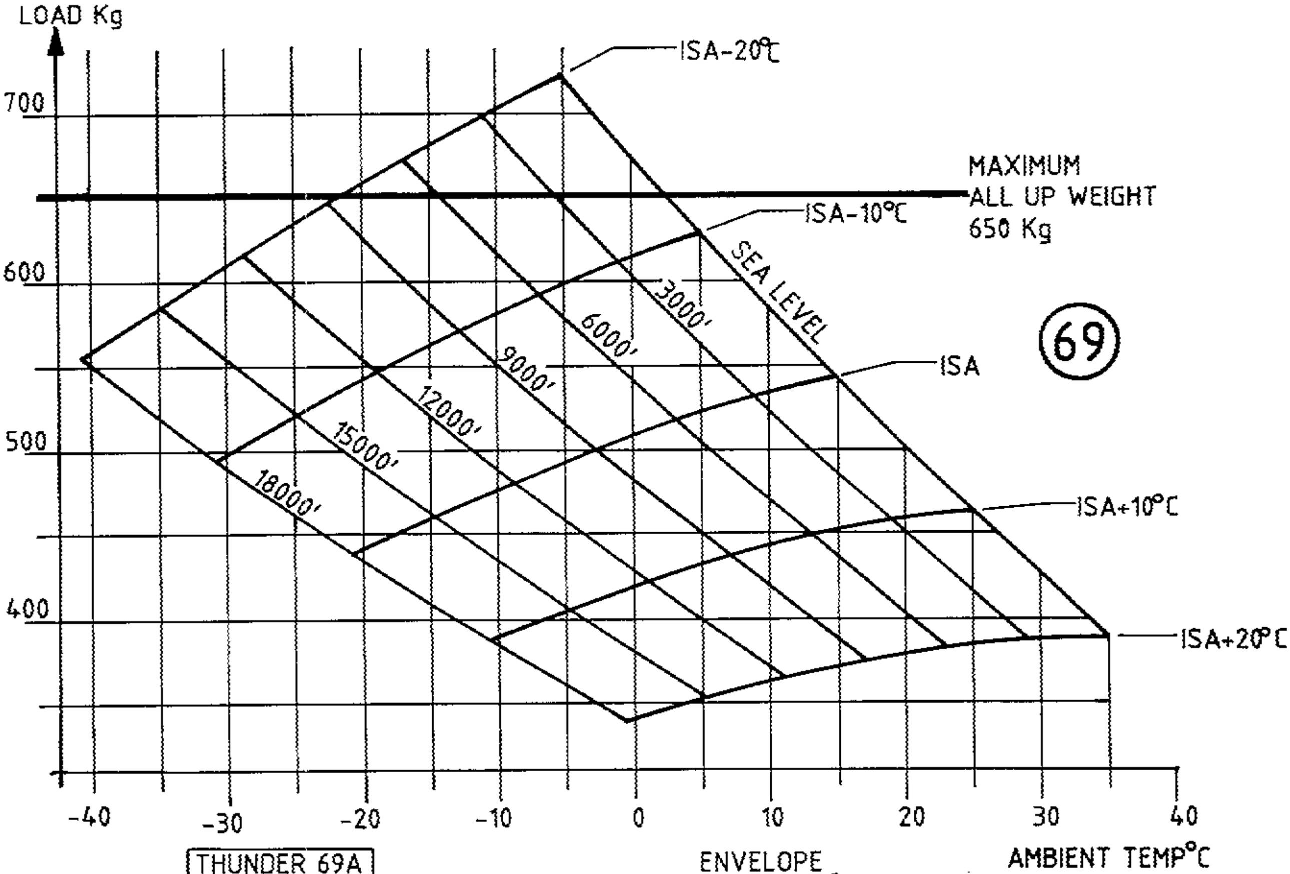
ENVELOPE TEMP 100°C



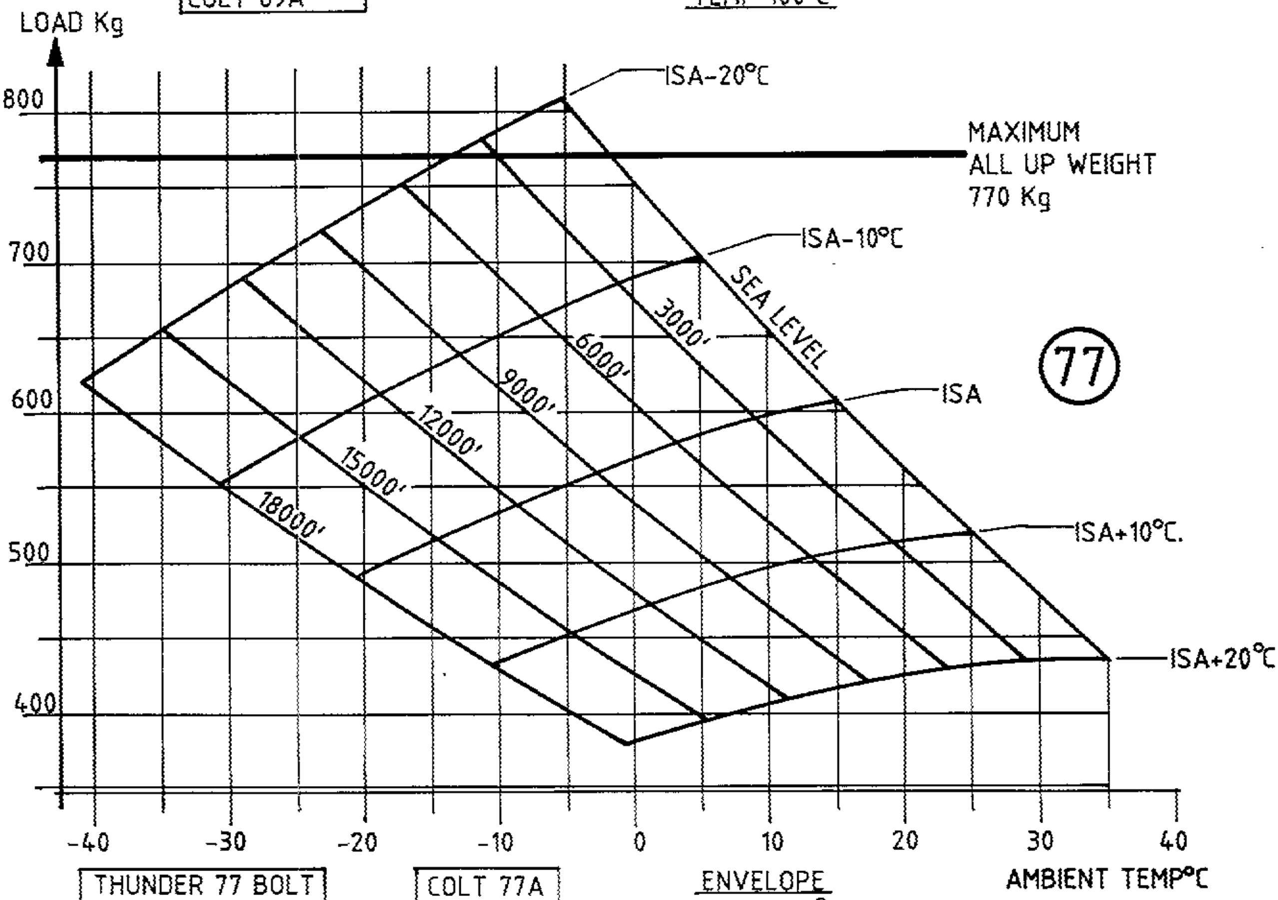
THUNDER 65 BOLT
65 SERIES 1,65Z

ENVELOPE TEMP 100°C

THUNDER & COLT

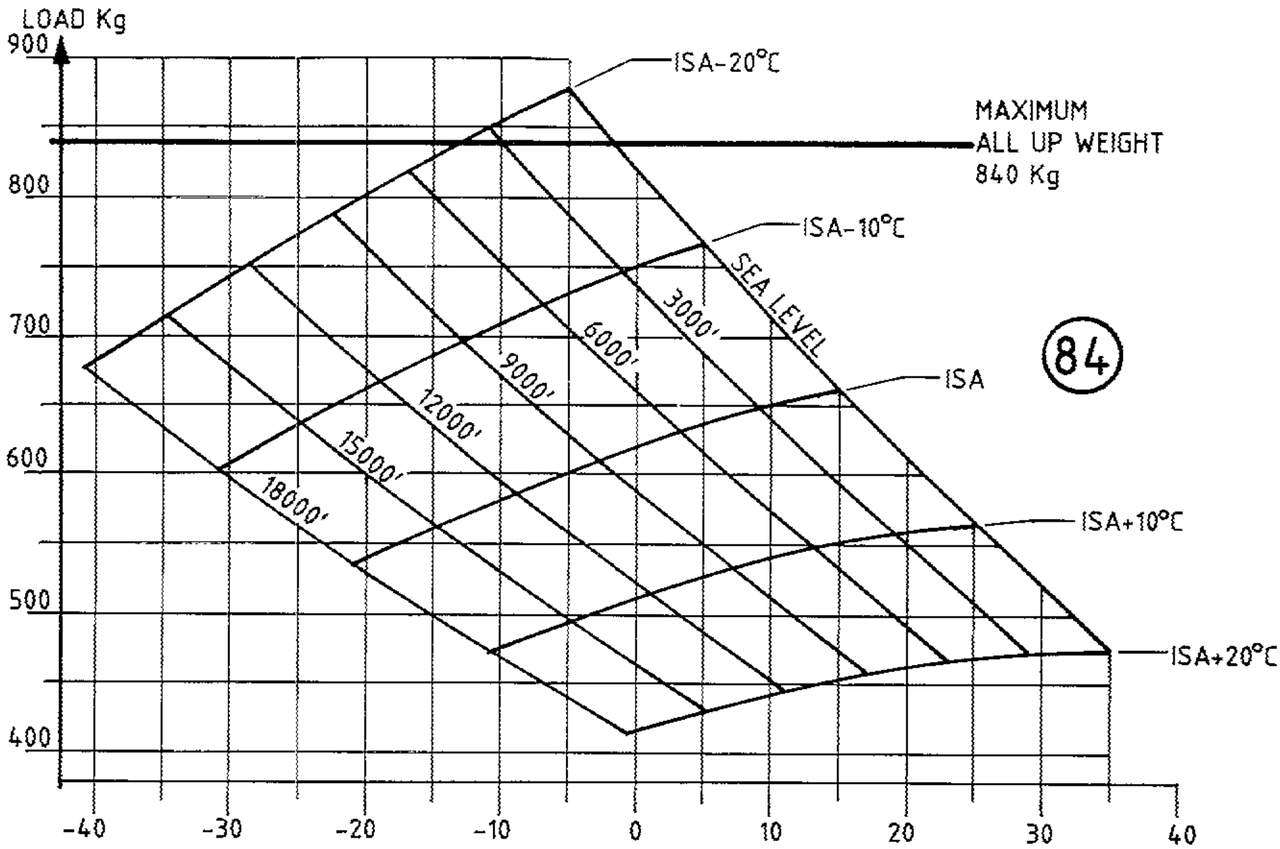


THUNDER 69A
COLT 69A



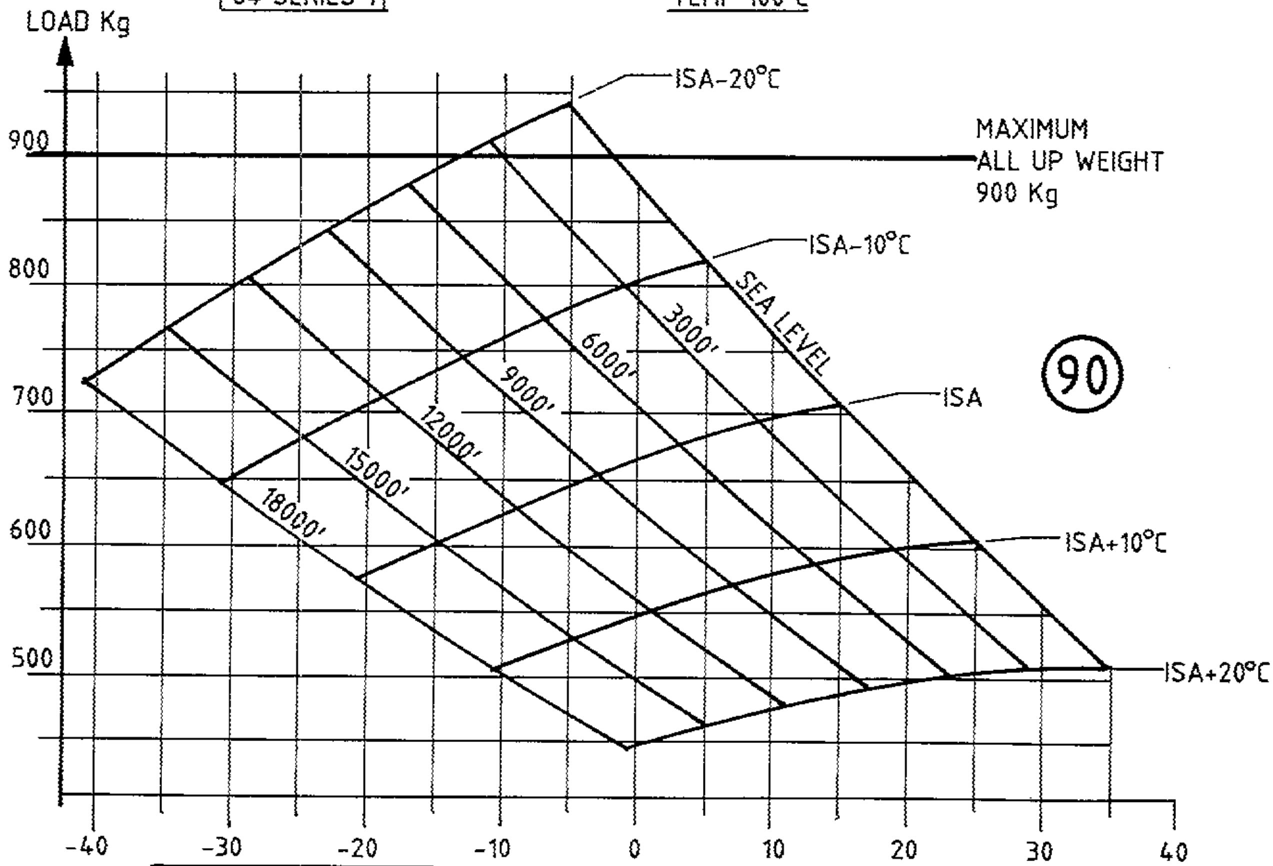
THUNDER 77 BOLT
77 SERIES 1,77Z

COLT 77A
77 BULLET



THUNDER
84 SERIES 1

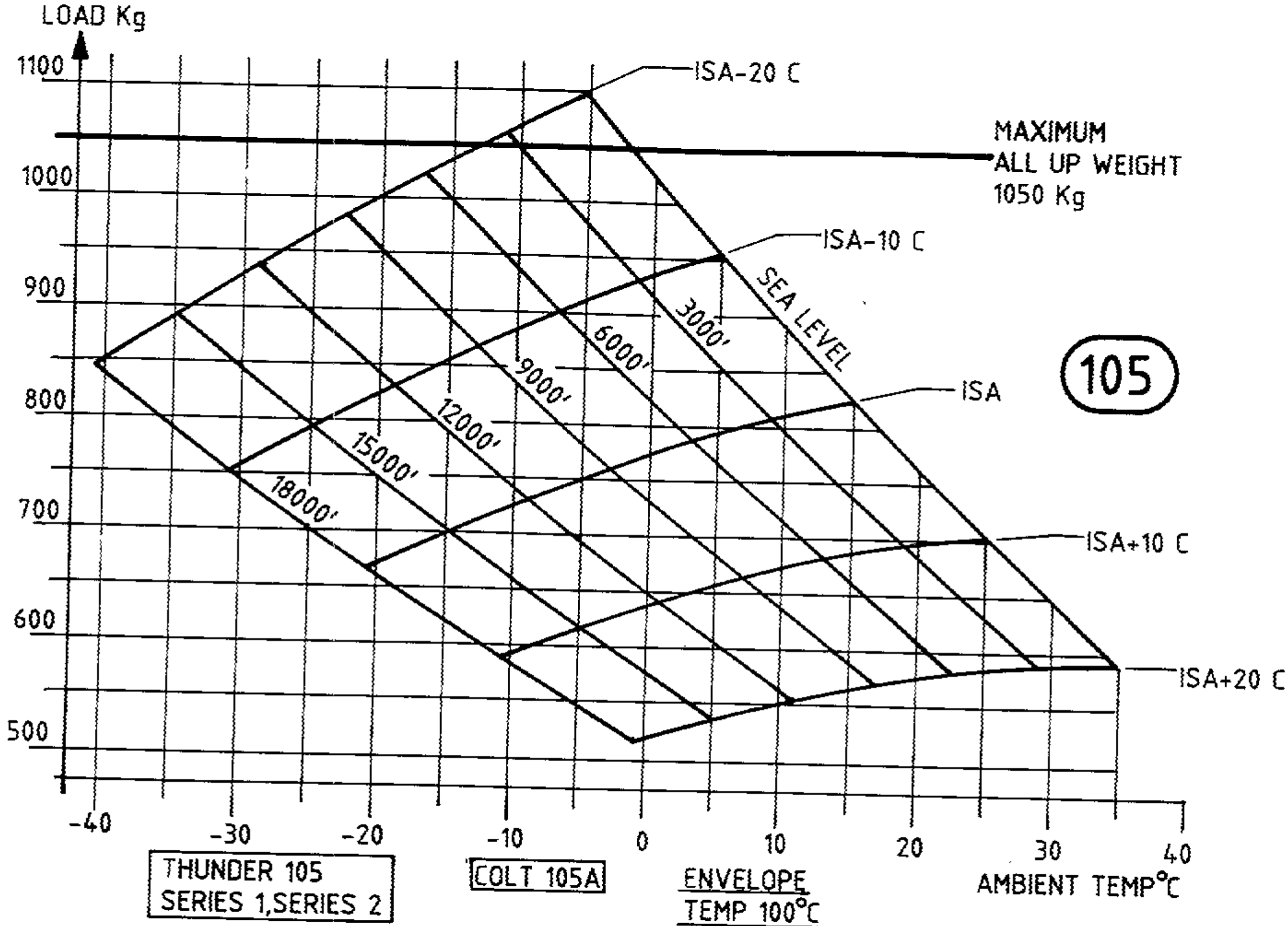
ENVELOPE
TEMP 100°C

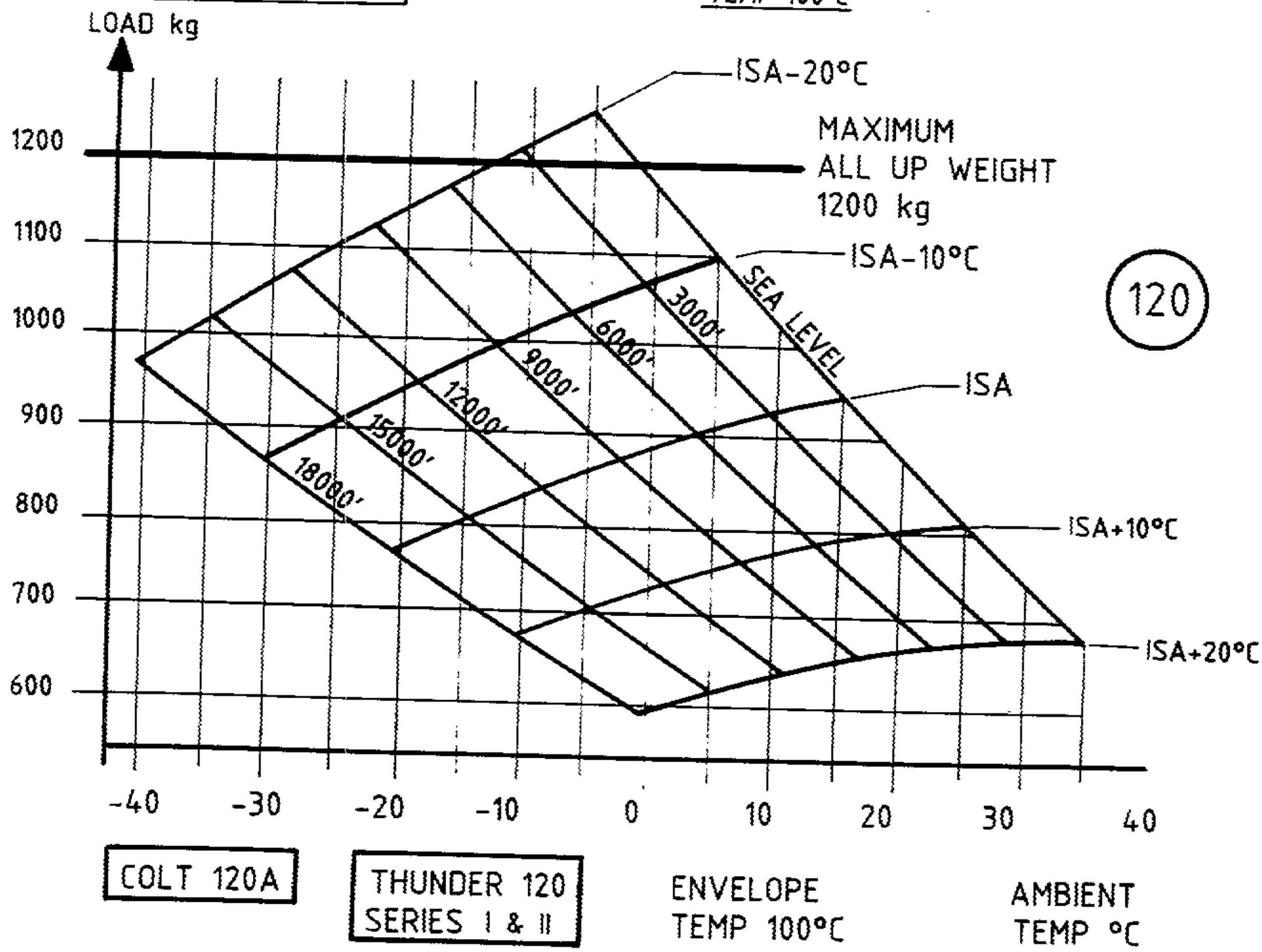


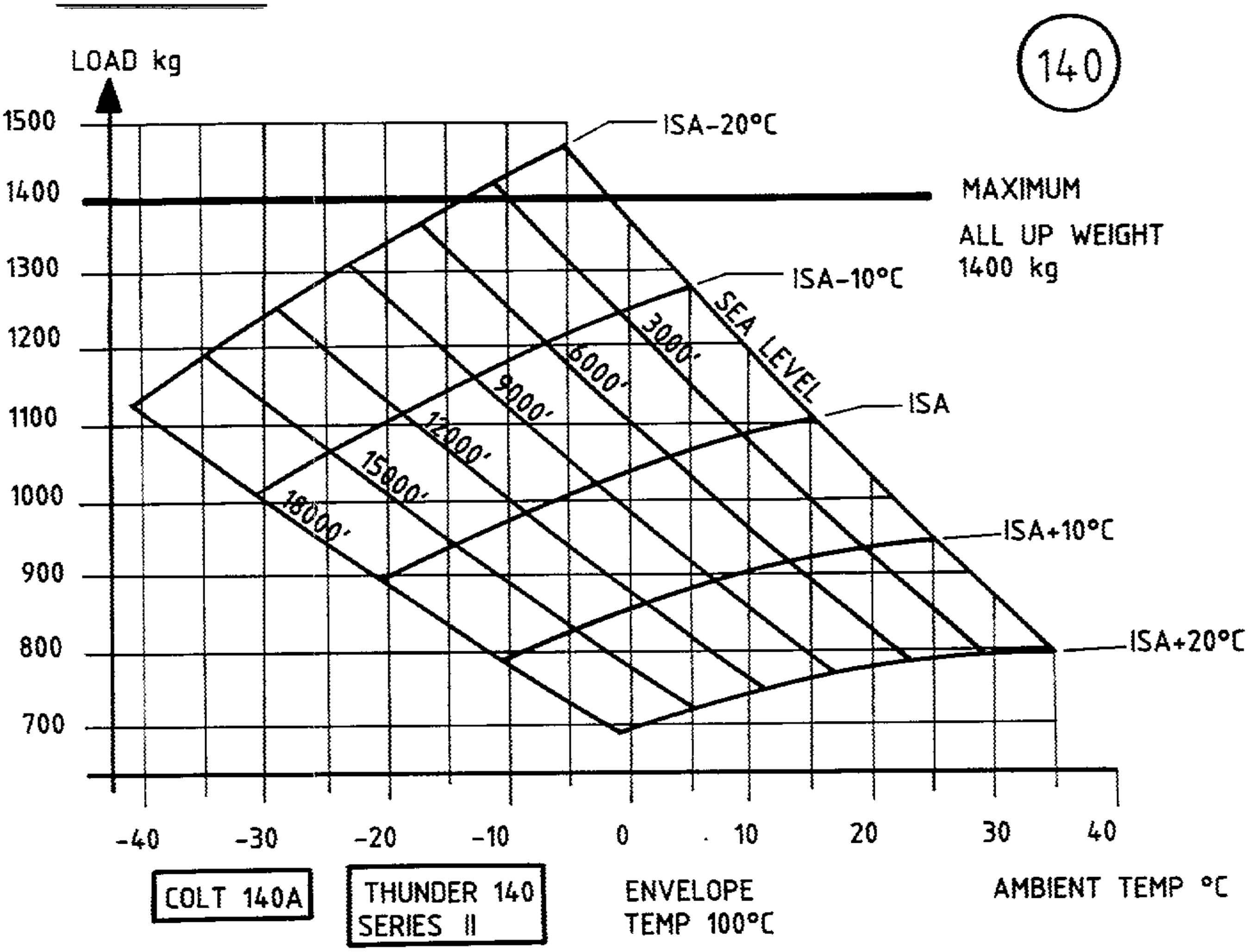
THUNDER 90 SERIES 1
SERIES 2

COLT 90A

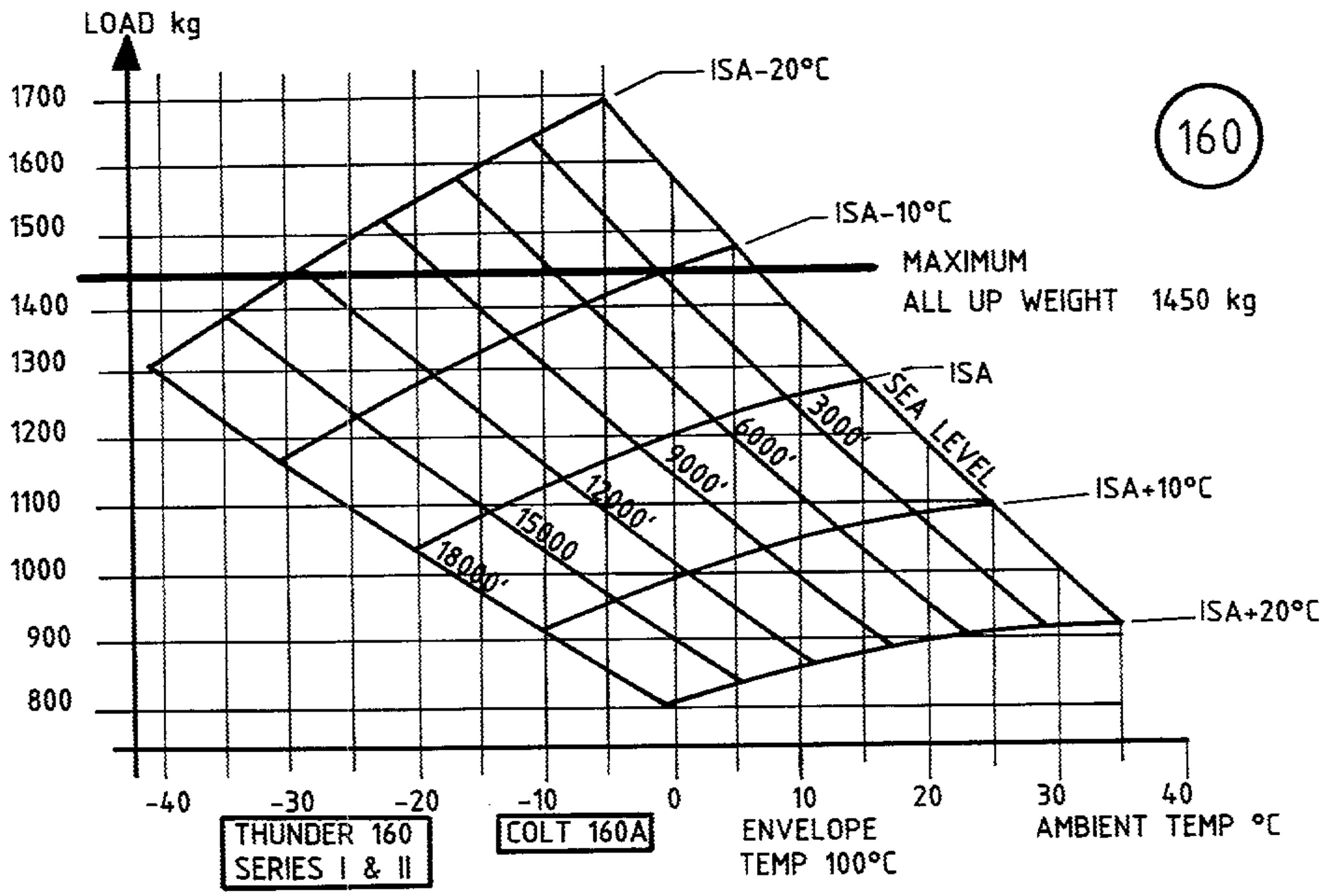
ENVELOPE
TEMP 100°C


LOAD Kg
1100
1000
900
800
700
600
500
ISA-20 C
MAXIMUM
ALL UP WEIGHT
1050 Kg
ISA-10 C
SEA LEVEL
3000'
6000'
9000'
12000'
15000'
18000'
ISA
ISA+10 C
ISA+20 C
105
-40
-30
-20
-10
0
10
20
30
40
THUNDER 105
SERIES 1,SERIES 2
COLT 105A
ENVELOPE
TEMP 100°C
AMBIENT TEMP°C


LOAD kg
1200
1100
1000
900
800
700
600
ISA-20°C
MAXIMUM
ALL UP WEIGHT
1200 kg
ISA-10°C
SEA LEVEL
3000'
6000'
9000'
12000'
15000'
18000'
ISA
ISA+10°C
ISA+20°C
120
-40
-30
-20
-10
0
10
20
30
40
COLT 120A
THUNDER 120
SERIES I & II
ENVELOPE
TEMP 100°C
AMBIENT
TEMP °C

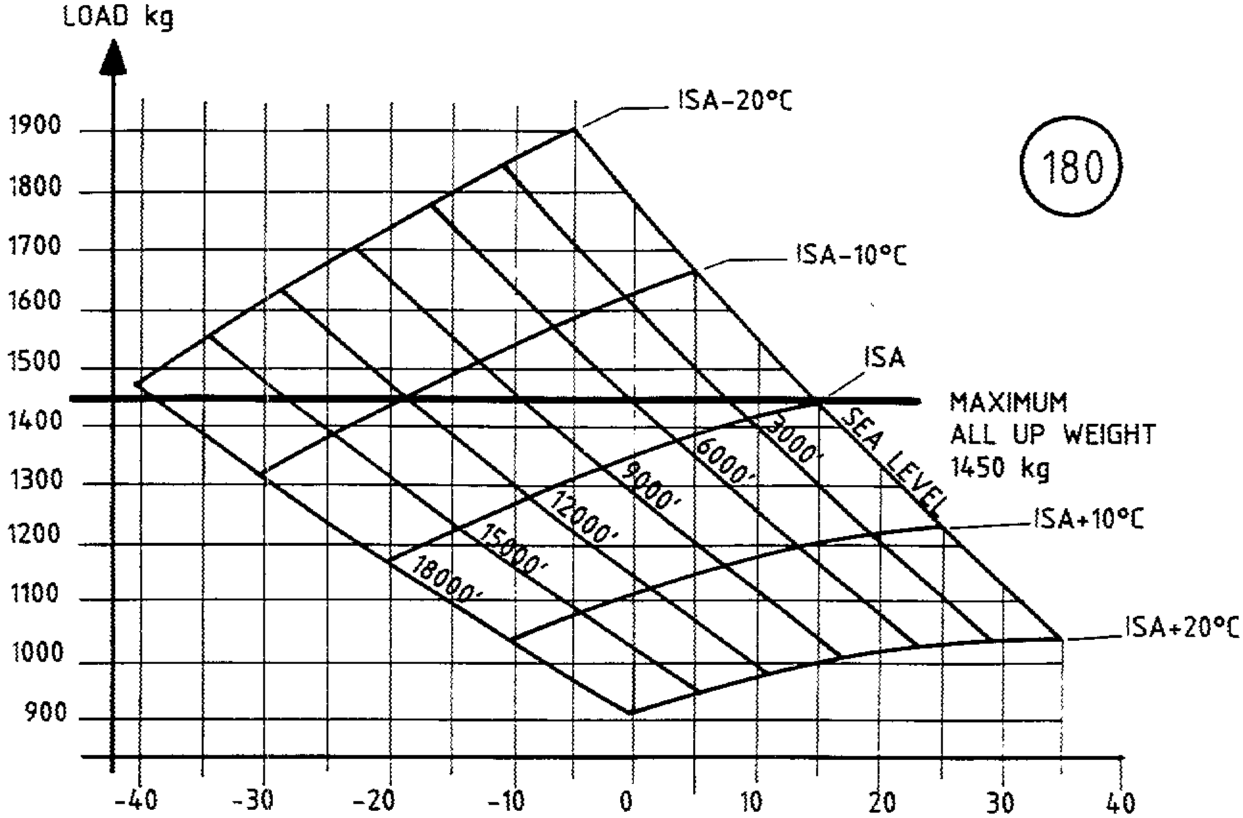


140
LOAD kg
1500
1400
1300
1200
1100
1000
900
800
700
ISA-20°C
MAXIMUM
ALL UP WEIGHT
1400 kg
ISA-10°C
SEA LEVEL
3000'
6000'
9000'
12000'
15000'
18000'
ISA
ISA+10°C
ISA+20°C
-40
-30
-20
-10
0
10
20
30
40
COLT 140A
THUNDER 140
SERIES II
ENVELOPE
TEMP 100°C
AMBIENT TEMP °C

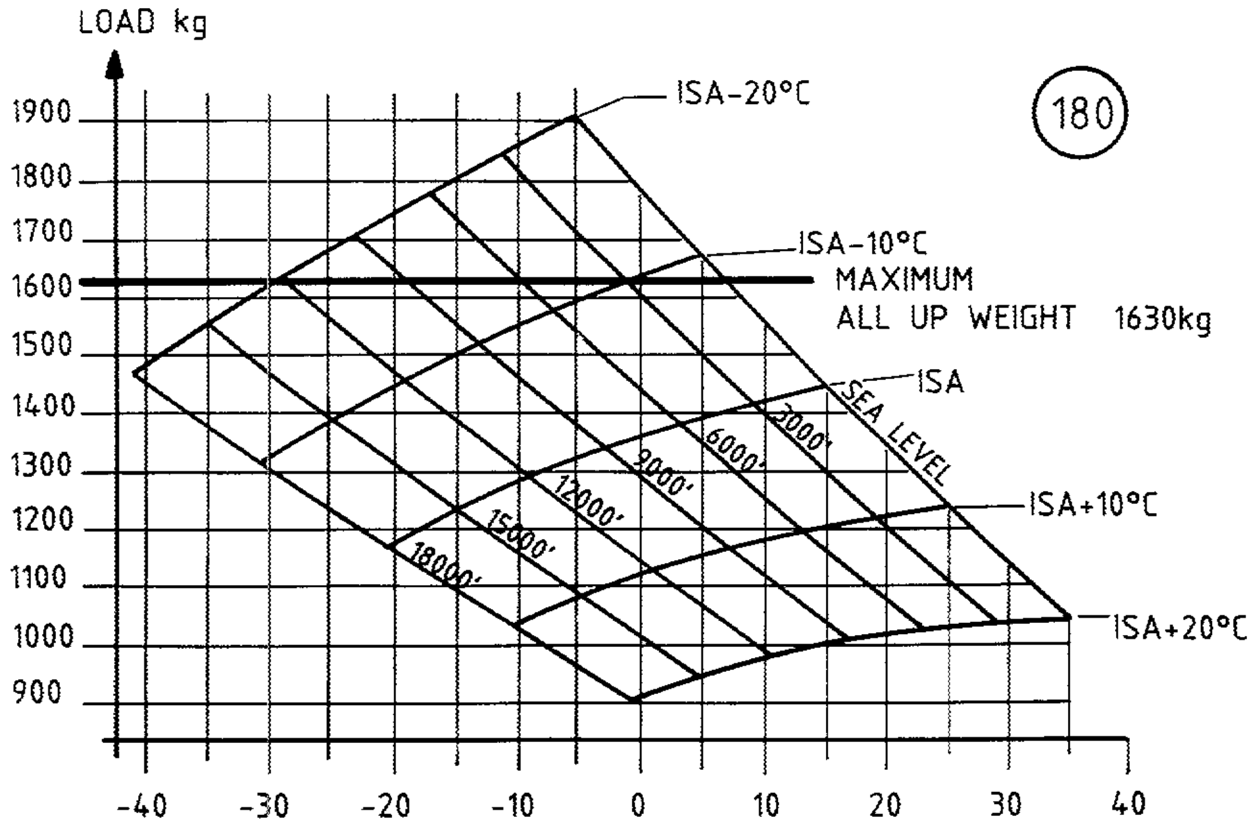


LOAD kg
160
1700
1600
1500
1400
1300
1200
1100
1000
900
800
ISA-20°C
ISA-10°C
MAXIMUM
ALL UP WEIGHT 1450 kg
ISA
SEA LEVEL
3000'
6000'
9000'
12000'
15000
18000'
ISA+10°C
ISA+20°C
-40
-30
-20
-10
0
10
20
30
40
THUNDER 160
SERIES I & II
COLT 160A
ENVELOPE
TEMP 100°C
AMBIENT TEMP °C

THUNDER & COLT



THUNDER 180
SERIES I

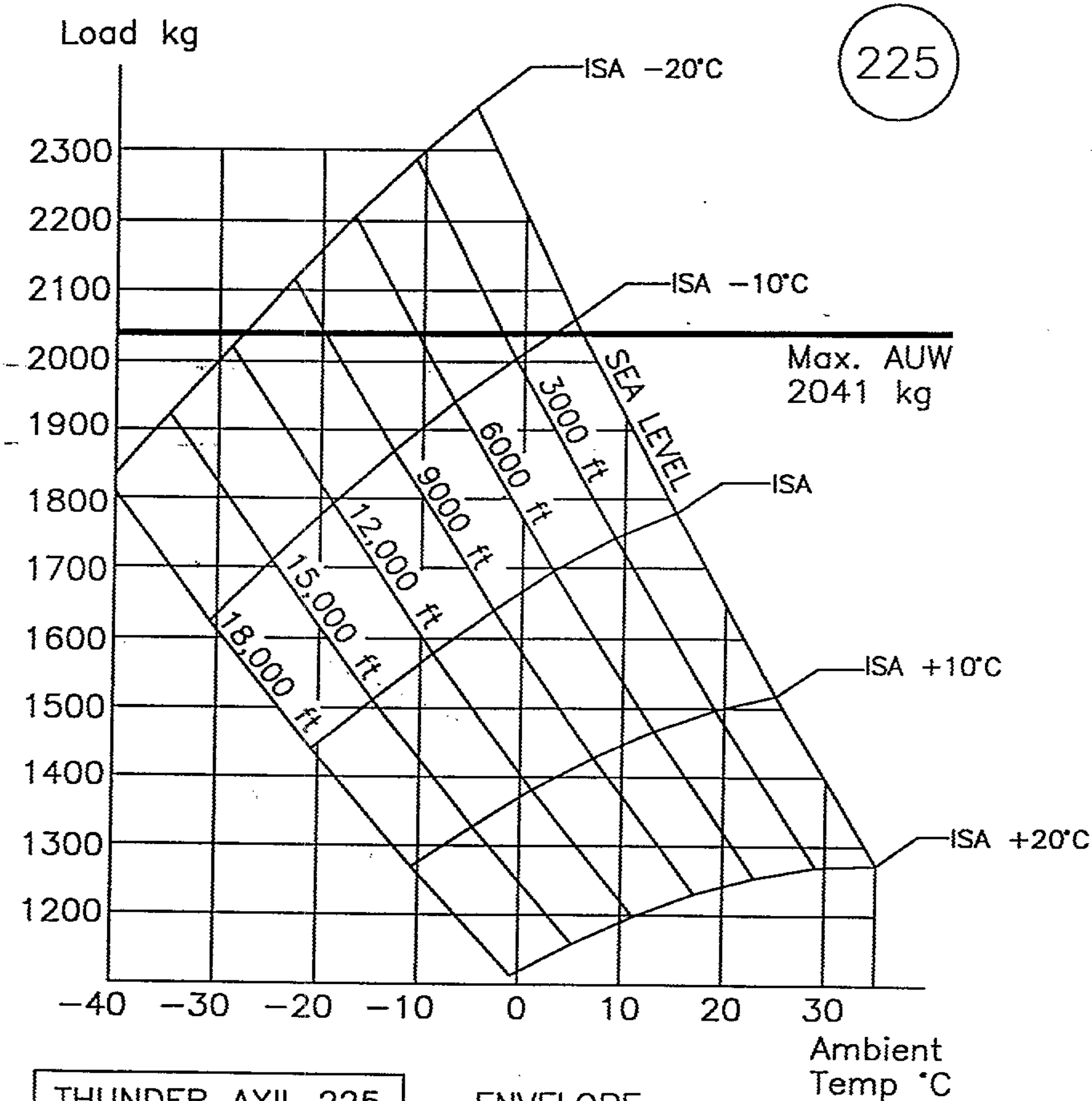


THUNDER 180
SERIES II

COLT 180A

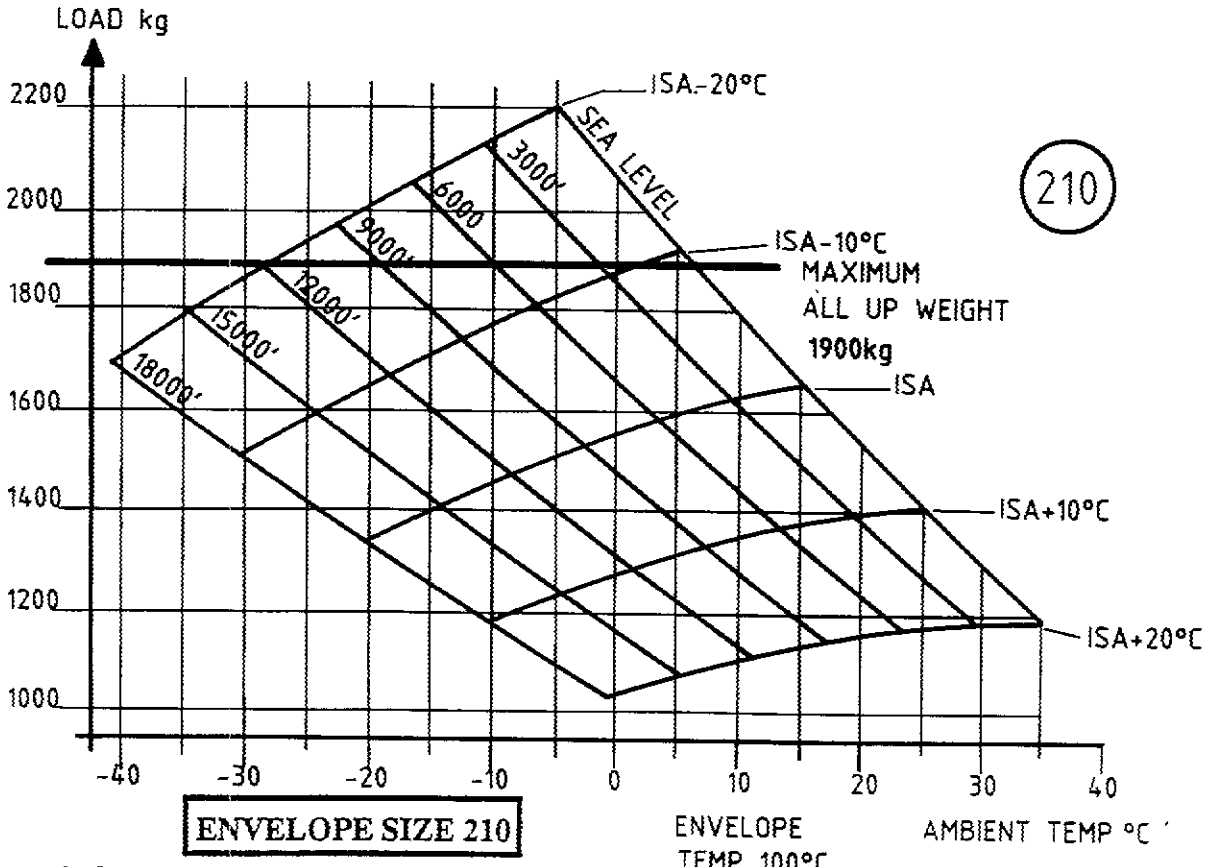
ENVELOPE
TEMP 100°C

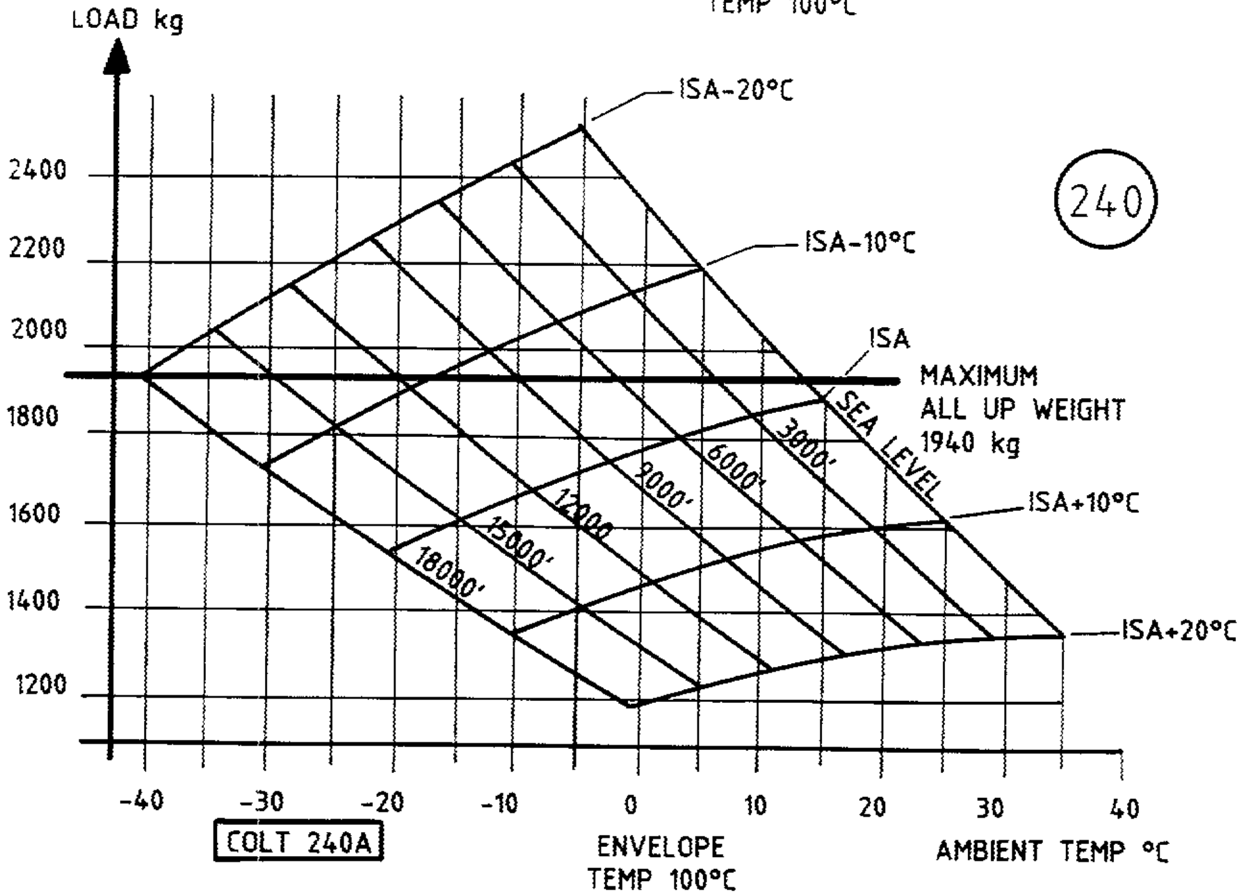
AMBIENT TEMP °C

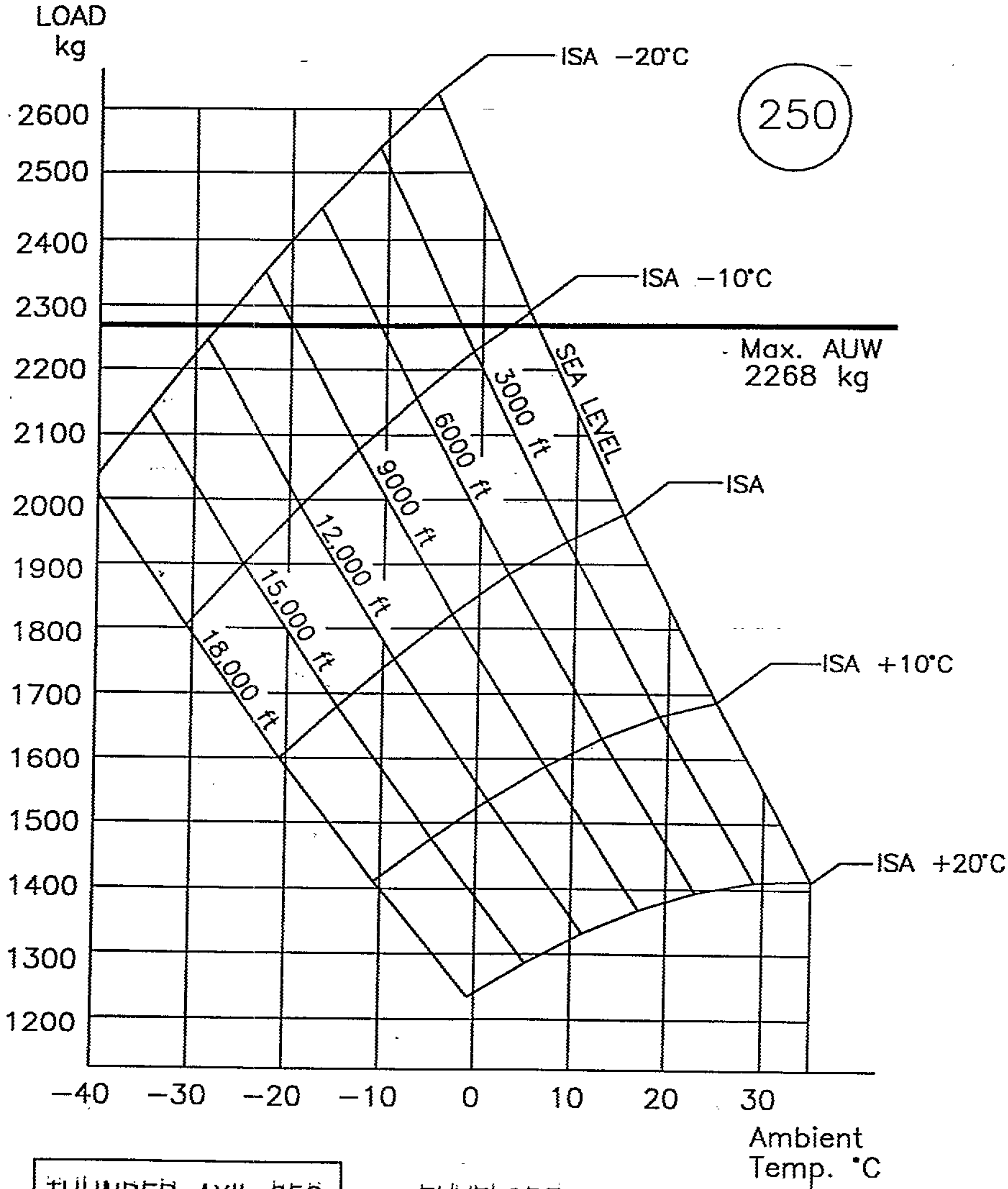


THUNDER AXII−225
SERIES 2

ENVELOPE
TEMP. 100°C

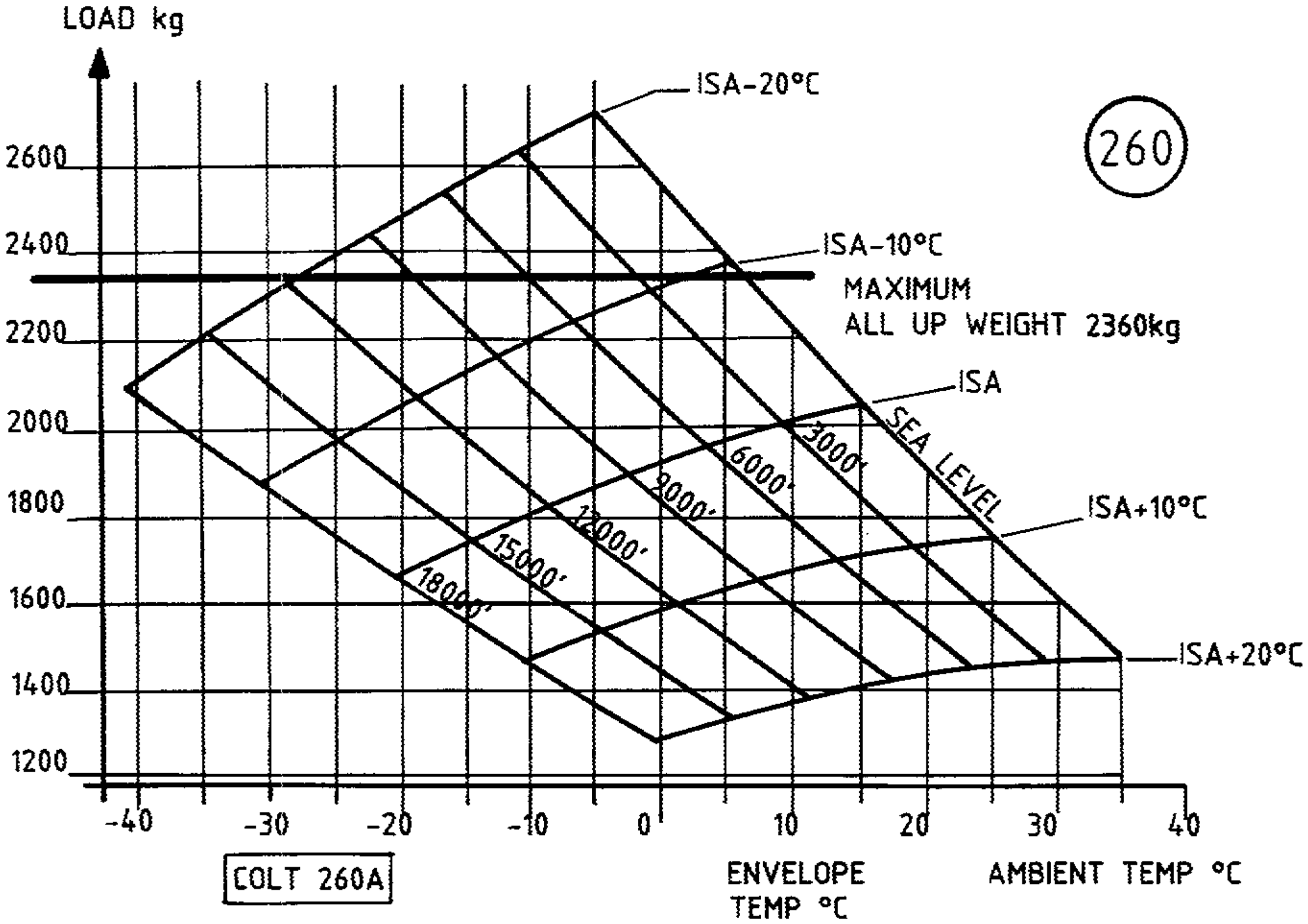

LOAD kg
2200
2000
1800
1600
1400
1200
1000
ISA-20°C
SEA LEVEL
3000'
6000'
9000'
12000'
15000'
18000'
ISA-10°C
MAXIMUM
ALL UP WEIGHT
1900kg
ISA
ISA+10°C
ISA+20°C
210
-40
-30
-20
-10
0
10
20
30
40
ENVELOPE SIZE 210
ENVELOPE
TEMP 100°C
AMBIENT TEMP °C

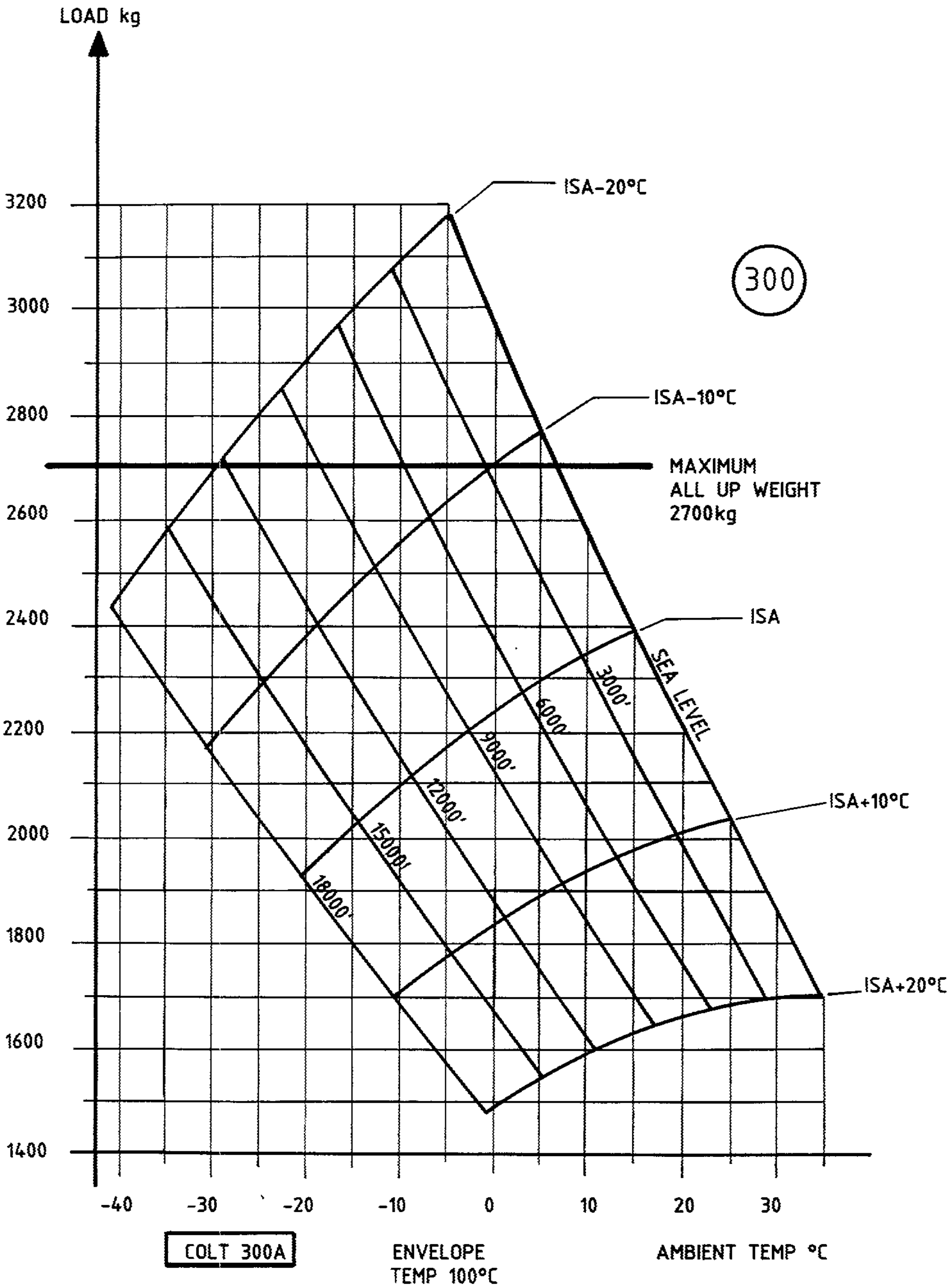

LOAD kg
2400
2200
2000
1800
1600
1400
1200
ISA-20°C
ISA-10°C
ISA
MAXIMUM
ALL UP WEIGHT
1940 kg
SEA LEVEL
3000'
6000'
9000'
12000'
15000'
18000'
ISA+10°C
ISA+20°C
240
-40
-30
-20
-10
0
10
20
30
40
COLT 240A
ENVELOPE
TEMP 100°C
AMBIENT TEMP °C



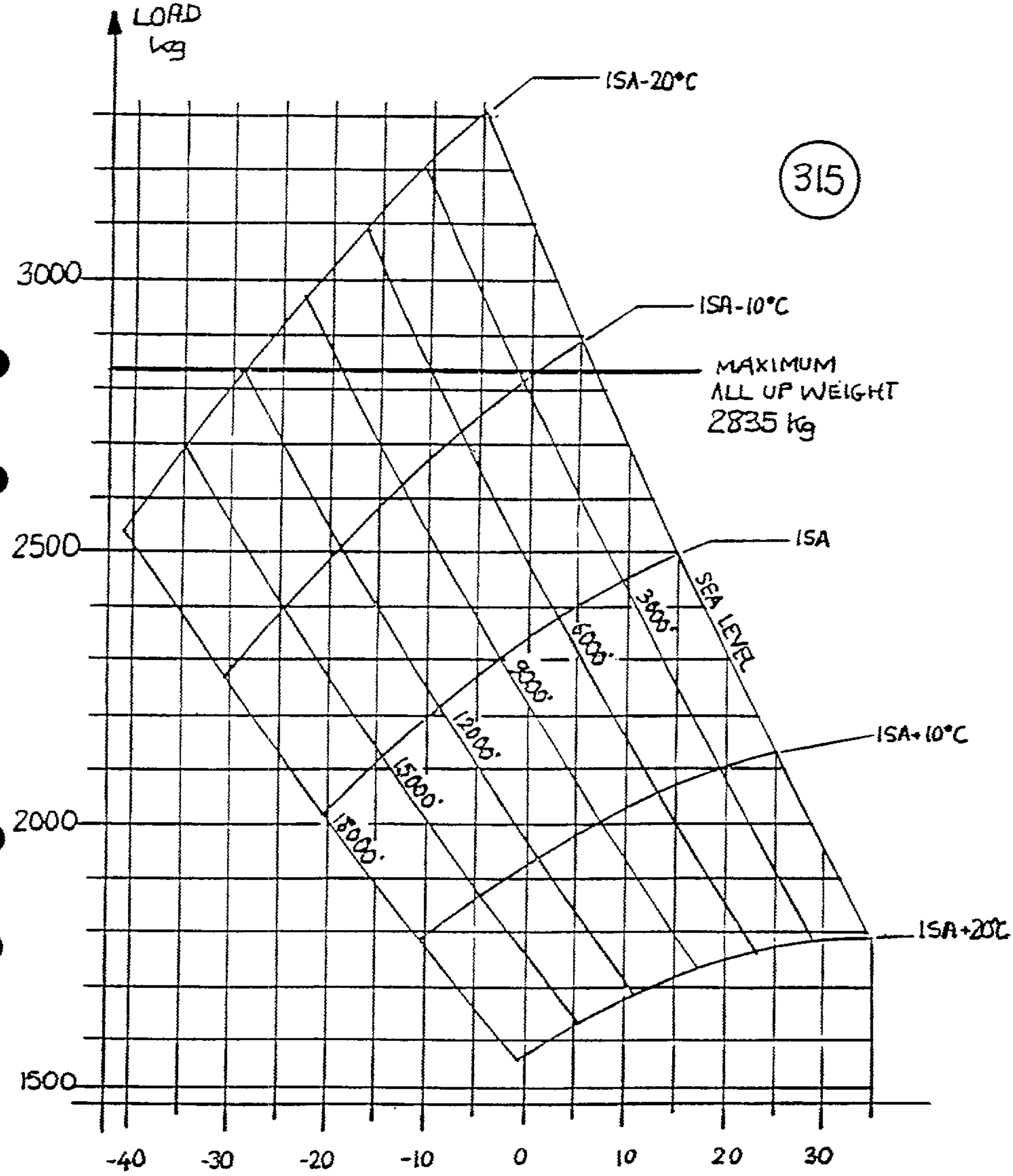
THUNDER AXII-250
SERIES 2

ENVELOPE
TEMP. 100°C


LOAD kg
ISA-20°C
260
2600
2400
ISA-10°C
MAXIMUM
ALL UP WEIGHT 2360kg
2200
ISA
2000
SEA LEVEL
3000'
6000'
9000'
12000'
15000'
18000'
1800
ISA+10°C
1600
ISA+20°C
1400
1200
-40
-30
-20
-10
0
10
20
30
40
COLT 260A
ENVELOPE
TEMP °C
AMBIENT TEMP °C



LOAD kg
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
ISA-20°C
300
ISA-10°C
MAXIMUM
ALL UP WEIGHT
2700kg
ISA
SEA LEVEL
3000'
6000'
9000'
12000'
15000'
18000'
ISA+10°C
ISA+20°C
-40
-30
-20
-10
0
10
20
30
COLT 300A
ENVELOPE
TEMP 100°C
AMBIENT TEMP °C



COLT 315A

ENVELOPE TEMP 100°C

UNIVERSAL LOAD CHART

This chart is used in the same manner as for the individual balloon charts, with the exception that the vertical axis shows the amount of lift available per 1000 cubic feet of envelope. It is then a simple matter to refer to the Balloon Size Chart and read down the column appropriate to your particular balloon to find total available lift in kgs or lbs.

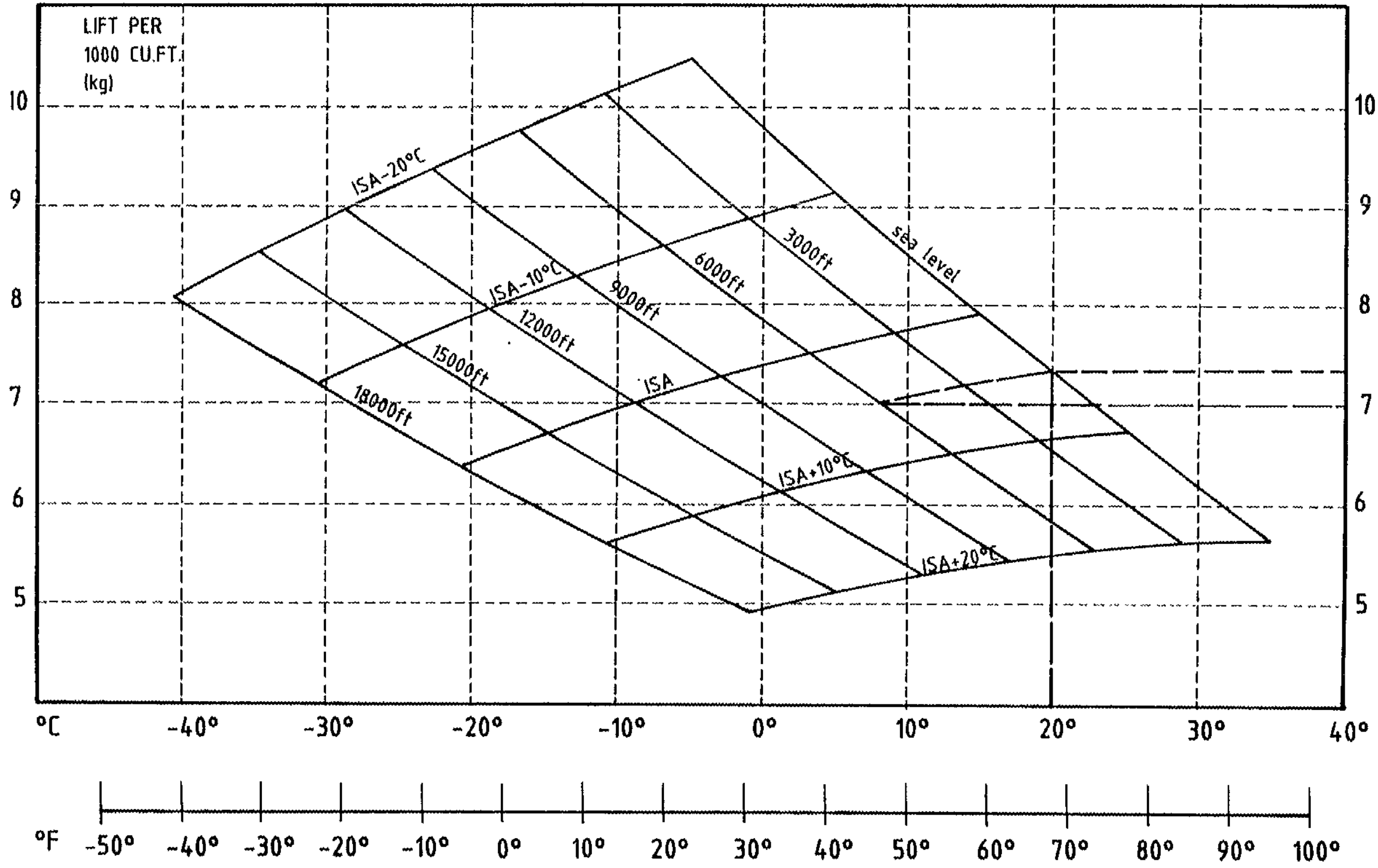
Sample Calculation

This example can be equally applied to the Universal Load Chart.

Follow the 20°C line vertically until it intersects the sea level curve. Read across to the vertical scale to find the lift per 1000 cubic feet, which in this example is about 7.3 kg. Refer to the Balloon Size Chart for your particular balloon and read off the Total Available Lift, which is given in kg or lb. In this case, interpolation is required, and we find that the 56A at sea level will have about 410 kg of available lift.

To find lift at 6000 ft again follow the 20°C line up to the sea level curve. Interpolate a curve midway between ISA and ISA + 10°C, as shown, until it intersects the 6000 ft curve. This point corresponds to 7 kg of lift per 1000 cubic feet, which in turn gives a Total Available Lift of 392 kg for a 56A.

UNIVERSAL LOAD CHART



AMBIENT TEMPERATURE

THUNDER & COLT

LIFT per 1000 cu.ft (kg)	BALLOON SIZE																				
	31	42	56	65	69	77	84	90	105	120	140	160	180 A/S2	180 S1	210	225 S2	240 A	250 S2	260 A	300 A	315 A
3	93 205	126 278	168 370	195 430	207 456	231 509	252 556	270 595	315 694	360 794	420 926	480 1058	540 1190	540 1190	630 1389	675 1488	720 1587	750 1653	780 1720	900 1984	945 2082
4	124 273	168 370	224 494	260 573	276 608	308 679	336 741	360 794	420 926	480 1058	560 1235	640 1411	720 1587	720 1587	840 1852	900 1985	960 2116	1000 2205	1040 2293	1200 2646	1260 2778
5	155 342	210 463	280 617	325 716	345 761	385 849	420 926	450 992	525 1157	600 1323	700 1543	800 1764	900 1984	900 1984	1050 2315	1125 2481	1200 2646	1250 2756	1300 2866	1500 3307	1575 3473
6	186 410	252 556	336 741	390 860	414 913	462 1019	504 1111	540 1190	630 1389	720 1587	840 1852	960 2116	1080 2381	1080 2381	1260 2778	1350 2977	1440 3175	1500 3307	1560 3439	1800 3968	1890 4169
7	217 478	294 648	392 864	455 1003	483 1065	539 1188	588 1296	630 1389	735 1620	840 1852	980 2161	1120 2469	1260 2778	1260 2778	1470 3241	1575 3473	1680 3704	1750 3858	1820 4012	2100 4630	2205 4860
8	248 547	336 741	448 988	520 1146	552 1217	616 1358	672 1481	720 1587	840 1852	960 2116	1120 2469	1280 2822	1440 3175	1440 3175	1680 3704	1800 3969	1920 4233	2000 4409	2080 4586	2400 5291	2520 5555
9	279 615	378 833	504 1111	585 1290	621 1369	693 1528	756 1667	810 1786	945 2083	1080 2381	1260 2778	1440 3175	1620 3571	1450 3197	1890 4167	2025 4465	1940 4277	2250 4960	2340 5159	2700 5952	2835 6250
10	310 683	420 926	560 1235	650 1433	650 1521	770 1698	840 1852	900 1984	1050 2315	1200 2646	1400 3086	1450 3197	1630 3593	1450 3197	1890 4167	2250 4962	1940 4277	2268 5000	2340 5159	2700 5952	2835 6250

TOTAL AVAILABLE LIFT (kg and lb)

5. MAINTENANCE

5.1 QUALIFICATION

The simple maintenance procedures described below are the minimum required to keep a Thunder or Colt hot air balloon airworthy. For any work of greater complexity refer to the Maintenance Manual "Instructions for the Continued Airworthiness of Thunder and Colt Hot Air Balloons".

The degree to which the owner/operator can maintain his/her own balloon, as opposed to work which must be carried out, or signed off, by an approved repair authority, varies from country to country. Thus, no differentiation is made here between owner/operator maintenance and maintenance subject to approval. For further information on these requirements consult your local airworthiness authority.

5.2 COLT Mk2 BURNERS

Liquid Coupling

Type: Tema 3800 Female

This unit should be lubricated internally with graphite dust. If connection is difficult, or leaks occur whilst connected, the two O rings can be replaced. Always use genuine Tema parts in Viton. If the connector leaks when disconnected (through the self-sealing nipple), the whole unit must be replaced.

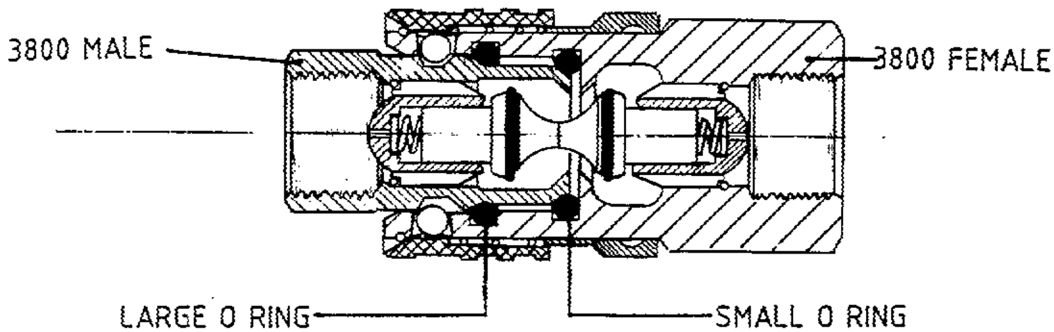


Figure 5.1

Vapour Coupling

Type: Tema 1300 Male
Replace if damaged.

Hoses

Liquid type: SAE 100 R1T06, pin-pricked
3/8 BSPP male ends

Vapour type: SAE 100 R1T04
1/4 BSPP male ends

Hoses must be kept in good condition. If they are kinked or abraded they must be replaced.

Blast Valves

Type: Worcester W44 Ball Valve

Leaks can usually be cured by replacing the seals (see the diagram below). When reassembling, grease the valve stem with silicone grease.

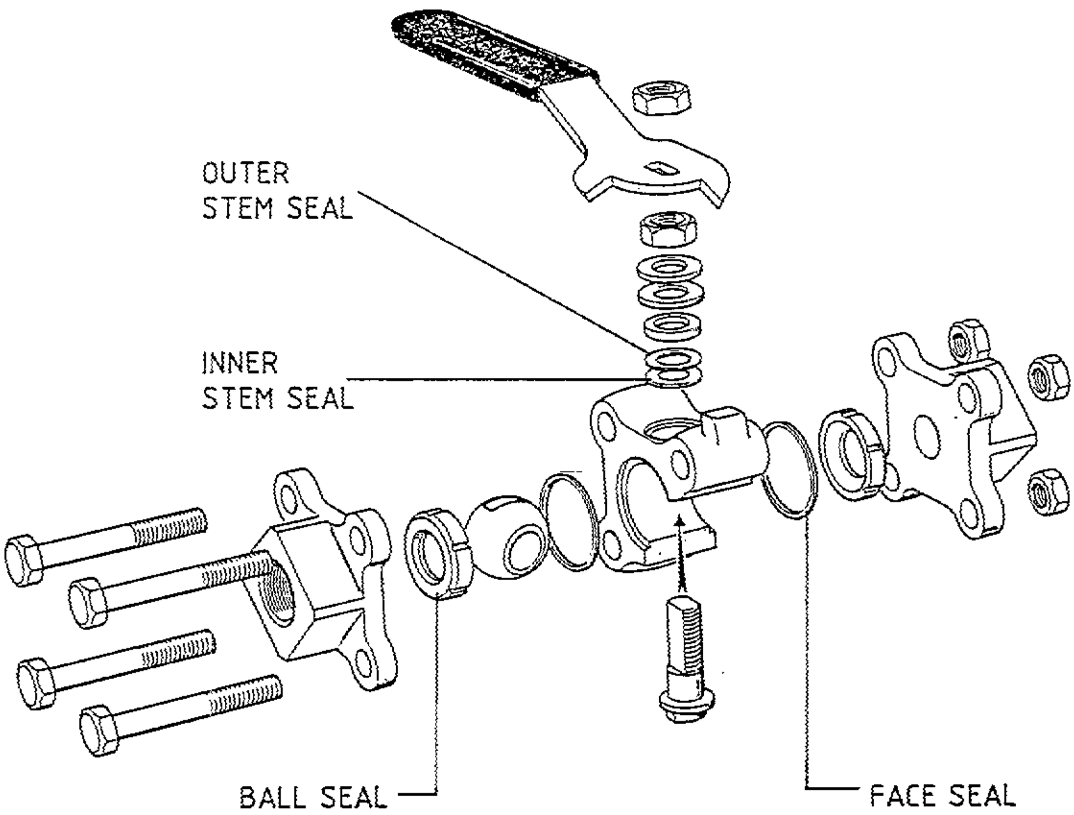


Figure 5.2

Crossover Valve and Liquid Fire Valve

Type: Dynaquip Ball Valve

Crossover - 3/8 BSPP
Liquid fire - 1/4 BSPP

These valves are not repairable. Replace if defective.

Pilot Valve

Type: Klinger 1/4 BSPP Ball Valve

Not repairable. Replace if defective.

Main Jets

Type: Amal 1/8 BSPP

Check that the jets are screwed home tightly. Remove and clean with kerosene if necessary.

Pilot Jet

Type: Amal IBA

To remove the pilot jet, remove the pilot light from the burner. Remove the bolts securing the retaining bracket. The whole pilot light assembly can now be removed from the can and the jet removed for cleaning. Use a fine wire to clean the orifice. Seal the jet into its holder with PTFE tape. Reassemble, taking care to refit all gaskets etc.

5.3 THUNDER MK2 BURNERS

Liquid Coupling

Type: 1-1/4 Acme Female Screw Connector

This item is not repairable. Replace if defective.

Vapour Coupling

As Colt Mk2 (see above).

Hoses

Liquid Type: SAE 100 R1T06, pin-pricked, 1/4 NPT ends

Vapour Type: As Colt Mk2 (see above)
Hoses must be in good condition. If they are kinked or abraded they must be replaced.

Blast Valves

Type: Rego 7553 S or T

Stem leaks can be cured by replacing the stem seals (see below). Alternatively, the whole bonnet assembly can be replaced. Always grease the valve stem with silicone grease on reassembly. Always replace the split pin in the pivot pin of the handle.

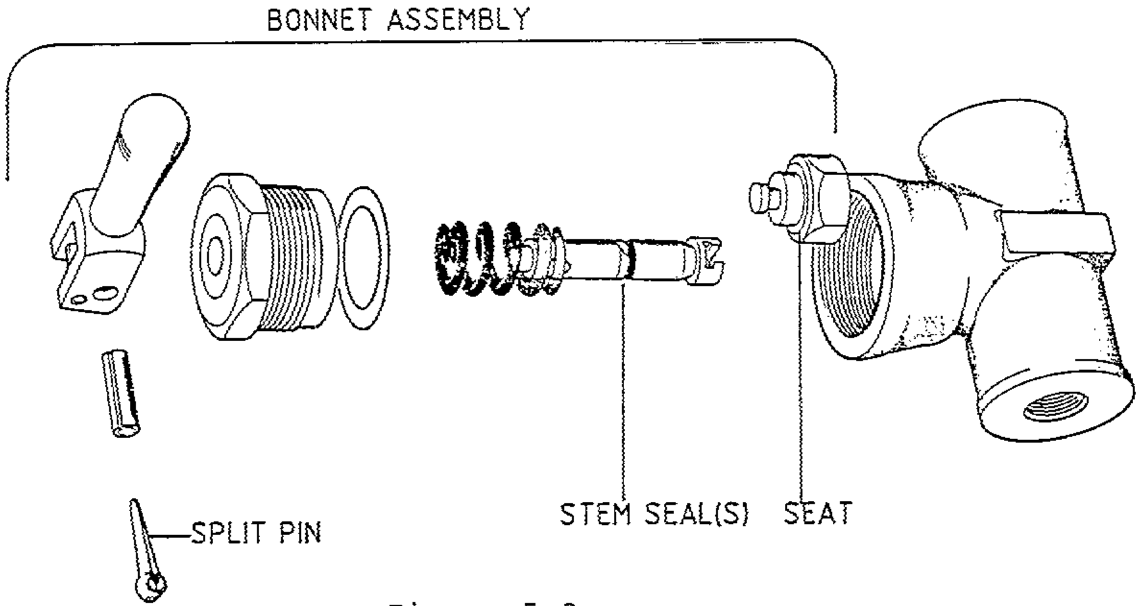


Figure 5.3

Crossover Valve and Liquid Fire Valve

As Colt Mk2 (see above).

Pilot Valve

As Colt Mk2 (see above).

Main Jets

Type: Amal 1BA, orifice 2.5mm

Check that the jets are screwed home tightly. Remove and clean with kerosene when necessary.

Pilot Jet

Type: Amal 1BA

To remove the pilot jet remove the pilot hose and the pilot light bolt. Unscrew the pilot body from the valve to reveal the jet. Clean with a fine wire. Reassemble, taking care to refit all gaskets. Seal the jet in its holder with PTFE tape.

5.4 FUEL CYLINDERS

Inspection and Cleaning

Ensure the cylinders are empty. Remove the bleed screw and no gas leakage will occur if this has been done. Remove the gauge. Purge the cylinder with nitrogen to remove all traces of propane. A small light bulb on wires can be lowered through the gauge hole for visual inspection. Clean by adding a small quantity of kerosene and swilling it around the cylinder. Repeat the process as necessary. Finally, clean the cylinder with alcohol to remove any traces of water.

Screw Type Liquid Valves

If the Acme coupling on the valve leaks on connection, the two O rings can be replaced. If the self-sealing nipple is leaking (with the coupling disconnected), the nipple seal can be replaced by removing the threaded retainer. This can be done with the cylinder under pressure, provided the valve is screwed shut. Any other faults must be rectified by changing the valve. Ensure the cylinder is empty before removing the valve. Ensure the new valve does not have an excess flow device fitted.

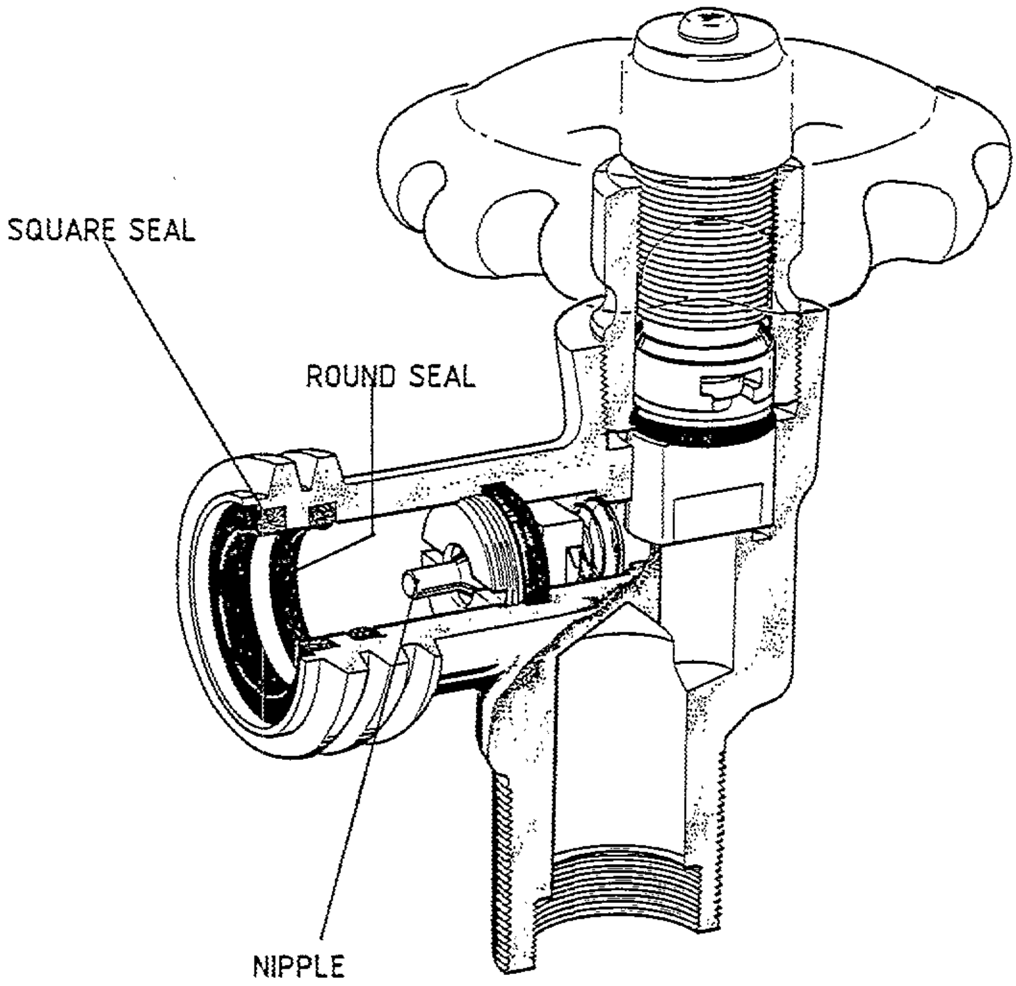


Figure 5.4

Quick Shut-off Ball Valve

As Colt Mk2 burner (see above)

Liquid Couplings

Acme screw-type: Seals are replaceable as on the screw valve.

Tema type: Replace if defective.

Vapour System

Valve - 3/4 NPT inlet, POL outlet screw valve. Note that vapour valves on Colt stainless steel cylinders must be fitted with an integral safety relief valve.

If it is necessary to remove the regulator assembly, note that the POL thread is left-hand. Valves are not repairable. Replace if defective, ensuring the cylinder is empty.

Regulator

Type: BMV 252

To adjust the regulator outlet pressure, remove the blue plastic end cap. Use an Allen key to adjust the pressure. The outlet pressure should be in the range 5-10 psi with the pilot light working.

Connector

Type: Tema 1300 Female

Replace if defective.

Gauge

Type: Float gauge

If the float can be heard moving, but the dial does not register, change the dial only. This can be done with the cylinder under pressure. Other faults require the removal of the gauge (with the cylinder empty), which can then be repaired or replaced.

Bleed Screws

If the bleed screw malfunctions, it is necessary to replace the whole assembly. The dip tube length must be 175mm to give the correct vapour space in the cylinder.

Cylinder Body

This is not repairable. If the body is damaged it must be submitted to an approved authority for inspection. Never attempt to weld on cylinders.

5.5 ENVELOPES

Routine Maintenance

Balloons should never be stored wet. If the balloon has been packed wet if must be dried by hot inflation as soon as possible, and certainly within a week. Minimise the exposure to sunlight. If the balloon is dirty it can be sponged clean, using a weak detergent solution. Ensure the balloon is dry before packing.

Repairs - General Notes

(1) Stitch type: lock stitch. Stitch length: 3-4mm (6-8 stitches/inch).

(2) Thread: metric 40 3-strand continuous filament; strength 4.5kg (10 lb)

(3) Always "lock" the end of stitch lines by overlapping or backtacking. This will prevent the new seam from pulling apart.

(4) Repairs should not cause visible puckering or distortion in the balloon, as this will cause stress concentrations.

(5) Load tape ends must be heat-sealed to prevent fraying. Tape overlaps are always 250mm (10 in.).

(6) When replacing loops, pulleys etc., copy the attachment method from an original feature, noting particularly the positions of heavy back tacks on the tape.

(7) Double stitch lines are 8mm (5/16 in.) apart. The original seams are double-felled, using an 11mm (7/16 in.) folder.

(8) Flying wires are either 3 or 4mm diameter AISI 316 stainless steel, 7 x 19 construction. They are swaged by the Talurit process. The Nico press system, as described in the FAA document "EA-AC 43.13-1A & 2A", is the only suitable alternative.

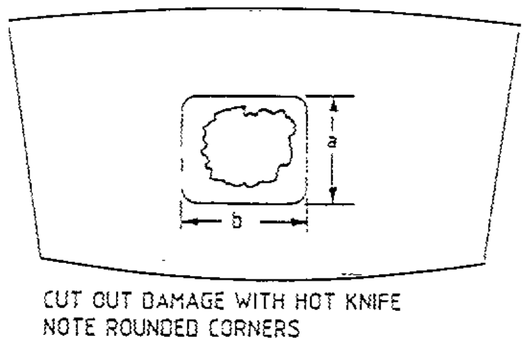
(9) Envelope fabric is rip-stop nylon, coated with polyurethane, finished weight $65g/m^2$.

Minor Repairs to Envelope Fabric

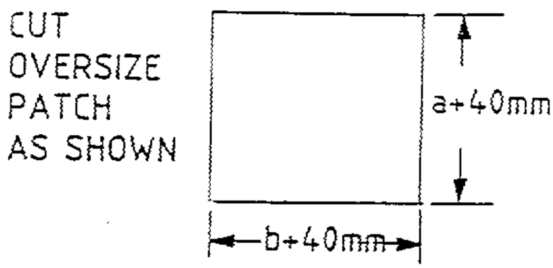
Small holes and tears can most easily be repaired by applying a patch of self-adhesive fabric or rip-stop tape, applied both inside and outside the envelope. Alternatively, a patch of normal balloon fabric can be applied using a good quality contact adhesive. The patch should overlap the damage by 25mm (1 in.) everywhere. If the patch is larger than 75mm (3 in.) in any direction it should be stitched around the edge, using two rows of stitching.

Patching Procedure

If the damaged area is too large to be repaired as above, the simplest technique to use is the "hot cut and overlay" method.



Place a piece of wood inside the balloon, under the damaged panel. Remove the damaged area with a hot knife to fuse the raw edge. Leave the corners rounded.



Cut an oversize patch (as above). Fit it with a fold hem to give the result shown below.

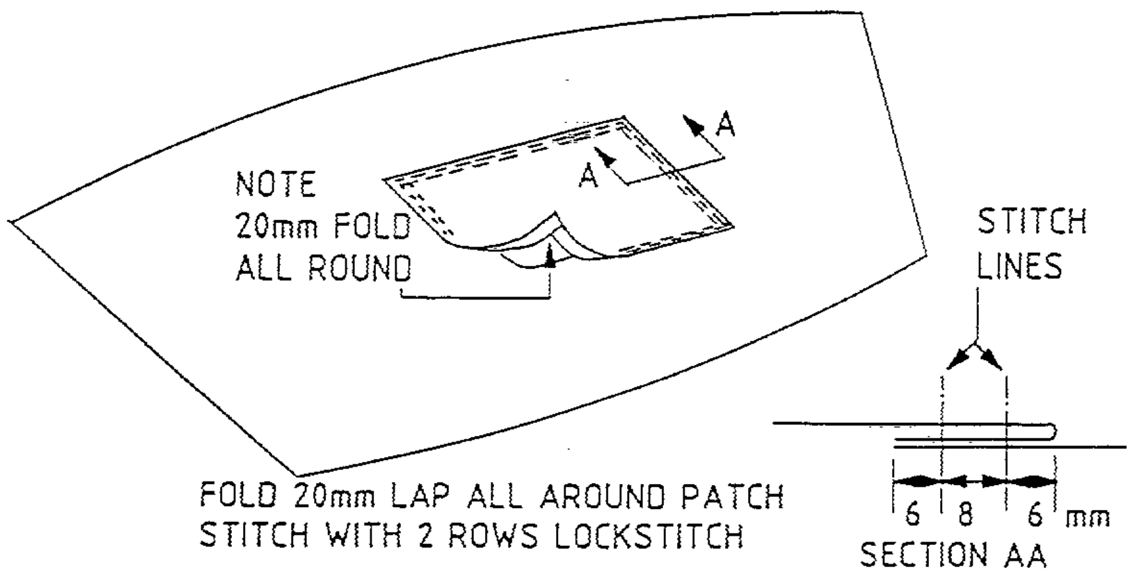


Figure 5.5 HOT CUT OVERLAY PATCHES

Tape Repairs

If a tape is damaged through more than one-third of its cross section it must be replaced. Remove the damaged section, and cut a piece of tape which is 500mm (20 in.) longer than the piece removed. Stitch the new tape, with 250mm (10 in.) overlap at each end. Splice the tape overlaps using one of the patterns shown below.

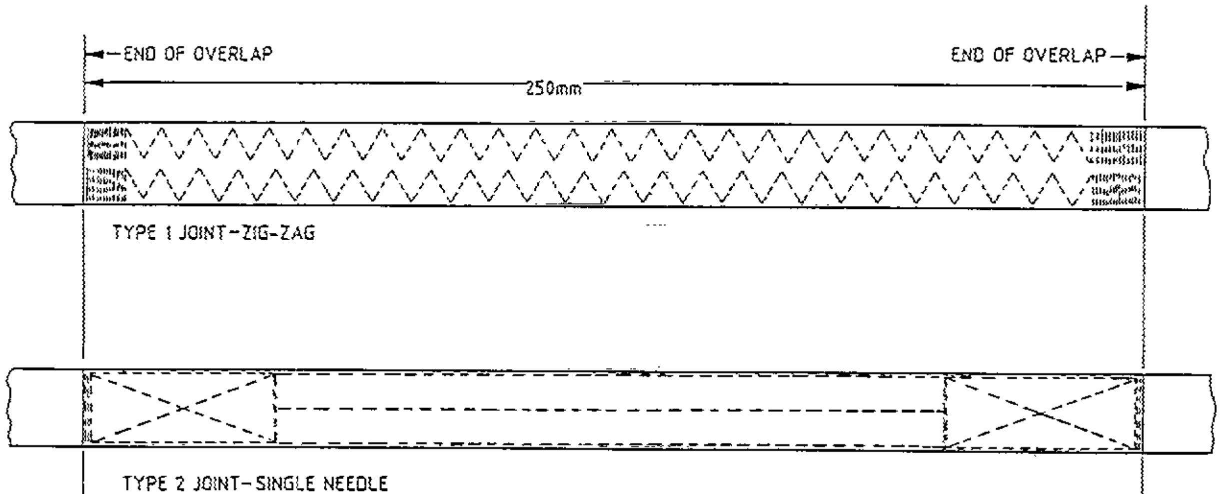


Figure 5.6

Internal Rigging

Parachute Retaining Lines

These are 2mm diameter Kevlar cord. Tie off with a bowline knot and tape the free end to prevent fraying. Kevlar cannot be heat-sealed.

Parachute Pull-down Lines

These are 3mm diameter polyester cord. Cut with a hot knife and tie off with a bowline knot.

Rip Line and/or Parachute Line

These are both heat-set 6mm diameter polyester ropes. Riplines are always red. Parachute lines are red (in parachute-only balloons), or white (in balloons with rip panels as well). Before removing these lines, note the position of the safety knot, just above the tie-off point. This knot must be large enough to jam in a pulley should the tie-off fail. The tie-off knot is a bowline.

5.6 BASKETS

Routine Maintenance

Clean and inspect the basket regularly. If it becomes dull it can be re-varnished with any good quality varnish. In dry climates the cane should be moistened prior to re-varnishing. The suede finish can be cleaned with a suede brush. It is permissible to wash the basket, but it must not be stored wet.

Basket Wires

These must be in good condition. If more than 10% of the cross section is rendered ineffective by fraying or kinking, the damaged section must be replaced. The wire is 6 x 19 construction AISI 316 stainless steel. The splicing can be by either the Talurit or Nico-press process.

Basket Floor and Runners

Basket floors are replaceable, but minor damage can be rectified by glueing and screwing a marine plywood patch over the damage. Any split which exceeds 75 mm (3 in.) in length, and is visible on both sides of the wood, must be repaired as above. Badly worn or split runners should be replaced with a good quality hardwood, glued and bolted in place.

Wickerwork

Holes large enough to allow a hand or foot to pass through must be repaired by local re-weaving. Ensure no sharp ends are left inside the basket.

Rawhide on Bottom Edge

This should be maintained in good condition as it protects the floor-to-cane joint on landing. Damaged sections should be removed and replaced, using nails and lacing, as on the original. Soak the hide before use (to soften it) and varnish when dry.

Suede Top Edge

Remove the lacing or rivets holding the suede in place. Glue a patch on the inside and stitch around the edge. Refit, using new rivets or lacecord as necessary.

5.7 INSPECTION SCHEDULES

(a) PRE-FLIGHT INSPECTION

Envelope

(1) No fabric damage above bottom 4m of nylon panels.
(2) No damage to load tapes. Particularly check flying wire to load tape junction, and crown ring assembly.
(3) Check rip line for damage, and that pulleys are running freely. Pulleys and the rip line tie off should be firmly attached to the envelope. Knots should be tight and safe.
(4) Check envelope rigging wires. Badly kinked or fraying wires should be replaced.
(5) Carabiners should show no signs of deformation and the screw gates should work freely.

Burner

Check the operation of all systems, and look for leaks at all joints and valves etc. The pressure gauges should register on connection to the fuel cylinder. Carry out a burn test.

Basket

No damage to basket wires or swaged ends. No abnormal distortion in the wickerwork.

Fuel Systems

No leak at any joint. The hose connectors should be clean and operate freely. The contents gauge should operate normally.

(b) 250 HOURS AND EVERY SUBSEQUENT 100 HOURS

Carry out the routine pre-flight inspection
plus the 100 hour/annual inspection
plus the following additional requirement:

Fabric Test

The fabric test required is a one-inch grab test. Thunder & Colt Ltd can carry out this test directly on the balloon, but if this is not convenient, it will be necessary to remove a piece of fabric from the top of the balloon to submit to a textile testing laboratory. The test standard required is ASTM-D-1682, and the one-inch grab strength should exceed 14 kg. (30 lbs).

(c) PROCEDURE AFTER SUSPECTED OVERHEATING OF ENVELOPE

If the temperature flag descends (i.e. the fusible link melts) the maximum allowable temperature has been exceeded. The flag separates at 127 °C and the maximum allowable is 120°C.

Inspect the two temperature indicating tags stitched onto the inside surface of the parachute. These tags have ten silver coloured "windows" marked from 88 °C to 138 °C. When the respective temperature has been reached the window will turn black. Note that these tags register the inside surface temperature of the fabric which will always be somewhat less than the inside air temperature.

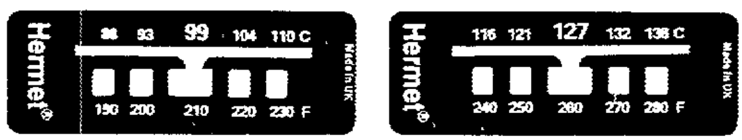
After flag separation when the temperature tags show:

(1) up to 120 °C - No further action required; replace fusible link with new one.

(2) 120 to 127 °C - Carefully inspect the top of the envelope for signs of overheating, particularly the parachute and its retaining lines. Look for undue stiffness and discolouration in materials. If any is visible perform the fabric test specified for the 250 hour inspection. If no signs of overheating are apparent, replace the temperature tags and flag with new fusible link. Always enter into the logbook or maintenance manual that an overheating has occurred and record the maximum temperature reached.

(3) 127 °C or higher - Perform fabric test and enter in logbook or maintenance manual temperature reading and fabric test results.

Note: never attempt to resolder temperature flag fusible link; always replace with a new unit.



Temperature Tags

Figure 5.7

(d) ANNUAL/100 HOUR INSPECTION

To be carried out once annually, or every 100 hours of flight time, which ever comes first. The following is the U.K. Schedule of Inspection, Issue 2.

Qualification

This inspection standard is the minimum required for annual inspections. Inspections should be carried out by suitably qualified inspectors, i.e. B.B.A.C., Category 1, 2 or 3.

Log Book

Must be present at time of inspection. The requirement is CAP398, CAP408 or CAP27. Check the log book with particular reference to repairs, modifications and flights/hours since the previous inspection. Check that entries are up to date.

Envelope Fabric and Load Tapes

Check temperature link still in place. Check temperature label. If overheating is indicated (above 120°C), install a new label alongside and note temperature reached in log book.

Inspect for holes, tears and abrasions. Small holes or low quality repairs in the bottom 4m of nylon panels (i.e. 4m above Nomex) are acceptable, but all other damage must have been repaired using approved methods.

Check fabric porosity by attempting to blow through it. If substantial porosity is suspected, perform a flight test (see below).

Check fabric strength with a 1-in., 14 kg grab test if the balloon has flown more than 250 hours, if it has been overheated, or if fabric weakness is suspected. Always test special shapes as these are subject to higher stresses. The area chosen for the test should be high in the balloon, but not on replacement fabric. The test should be performed three or four times with at least one test across a seam. Parachute edges and the fabric by the top rim tape are subject to the greatest temperatures and wear. Check these areas carefully.

Check both vertical and horizontal tapes for security of stitching. Check especially the stitching of the crown ring and the joints between overlying tapes and top rim tape.

Check the flying wire loops for friction and burn damage. Check Nomex pockets in place.

Parachute Deflation System

Check control line for wear and burn damage. Check knots are secure.

Check pulleys are in good condition and not jammed with loose thread or other foreign material.

Check stitching of control line tie off loops and pulley fixings.

Check retaining cords and release cords are in good condition. Stiffness indicates overheating.

Check knots and stitching of loops to both parachute and balloon.

If there are doubts about the sealing of the parachute the balloon should be inflated. The parachute overlap should be equal all the way round, with no daylight showing and no excessive stress in the retaining lines. Excessive stress is indicated by stress wrinkles in the edge of the parachute.

Concentric Parachute/Velcro Systems

Check parachute as above.

Check velcro rip control line as above.

Check capewells operate correctly.

Check fixing of capewells. The fixing of the female half to the velcro panel is particularly important.

Check condition of velcro.

Check fit of velcro. The velcro panel edge must not be shorter at all,nor significantly longer than, the velcro on the balloon.

On velcro balloons the overlying tapes are gated to a top rim tape. The length of free tape below this rim tape should be 2.5%-5.0% shorter than the corresponding seam length on the velcro panel. Any errors here should be reported to the manufacturer so that the correct repair can be specified.

Triangular Velcro Rip

These are only used on certain special shapes. With one person stretching each corner of the triangular aperture, the fitted velcro panel should be loose below the mesh of overlying tapes. Check rigging and capewell etc. as for parachute/velcro balloons.

Check the condition of the side dump. Check the attachment of release and closing lines as for parachutes (above). Check the elastic closing lines are in good condition.

Load Bearing Attachments

Flying wires must be stainless steel. There should be no loose strands in the wire, and no severe kinks. Slight discolouration is permissible.

Check thimbles and copper ferrules. Damage to the colour-coded plastic sleeving is not critical.

Carabiners should be free of distortion or serious corrosion with fully operational screw gates. Carabiner strengths are 2000 kg (up to 77´s) and 2500 kg (larger balloons).

Basket wires Check for abrasion damage. Check thimbles and copper ferrules.

Burner frame Check for condition of welds, particularly if the frame shows signs of distortion.

Nylon rods are not critical for flight safety. Replace if cracked.

Burner

Check for external signs of damage.

Check tightness of main jets.

Check blast valves for signs of wear or leakage.

Check all joints and connections are leak-proof. Carry out a burner test using each cylinder; observe function of pressure gauge, blast valves, and cylinder valves. Cylinders should be vertical for this test.

Pilot Light

Check by sound and appearance of flame. If blockage is suspected, check hose and jet by removing them and cleaning as necessary. Reassemble with PTFE tape.

Check operation of pilot valves on burner (if fitted).

Hoses

Should be wire braided type. Check for wear, cuts or excessive bends. Liquid hoses should be pinpricked on the outer cover. Hose inspection should include fuel manifolds, if these are fitted.

Fuel Cylinders

Check for external damage.

Check self-seal on couplings by opening the valves with no hoses connected. No leakage should occur. After closing the liquid valve, release the pressure in the coupling by depressing the central pin.

Check operation of contents gauge.

Check cylinder numbers are entered in log book. Internal inspection of cylinders is required after ten years, and thereafter every five years, or if damage is suspected. For convenience, cylinder inspections can be carried out in advance for individual cylinders and the test reported in the log book.

Basket

Check for wear or excessive distortion in weave.

Check the floor where the cane passes through.

Check integrity of wooden floor and runners.

Check rod socket condition.

Check condition of cylinder straps.

Instruments

Instruments are not mandatory in the U.K. and thus do not form a part of these requirements.

Fire Extinguisher

Check by weighing once a year.

Inflation and Flight Test

A test inflation is recommended as this makes detailed fabric inspection much simpler and allows control lines to be checked. If fabric porosity or leaking parachute is suspected, a carefully monitored test flight should be made to assess fuel consumption. High fuel consumption itself is not dangerous, but if the leakage is such that exceptional skill is required to fly the balloon, then the balloon is not airworthy. Balloons over 300 hours must be test flown.

Log Book Entry

Use the B.B.A.C. adhesive certificate; one copy fixed in log book, the other sent to the B.B.A.C. Technical Committee.

5.8 PARTS LIST

ENVELOPE MODELS

COLT A TYPE	THUNDER SERIES 1	THUNDER SERIES 2
31	42	90
42	56	105
56 (H), 56 (V)	65	120
69 (H), 69 (V)	77	140
77 (H), 77 (V)	84	160
90 (H), 90 (V)	90	180
105 (H), 105 (V)	105	210
120	120	225
140	160	250
160	180	
180		
210		
240		
260		
300		
315		

COLT BULLET
56 (H/V)
77 (H/V)

All the above are current types.

This manual also covers the obsolete types:

THUNDER BOLT	THUNDER A-TYPE	THUNDER Z-TYPE
42	56 (V)	31
56	69 (V)	56
65	77 (V)	65
77		77
		105

Unless otherwise specified (above) all balloons are horizontal cut.
(H) - Horizontal cut
(V) - Vertical cut
(H/V) - Mixture

THUNDER & COLT

ENVELOPE MATERIALS

Material	Designation
Lightweight tape, 19mm flat	GW 58402
Medium tape, 19mm flat	GW 59055
Heavy tape, 19mm flat	GW 59056
Top rim tape, 25mm flat	GW 59036
Bottom rim tape, 50mm flat	Various
Narrow fabric (92cm),59g/m^2	N 1026
Narrow fabric (92cm),90g/m^2	HTN 90K
Wide fabric (1.38m)	N 1039
Fire resistant base fabric	Nomex
Rip line/parachute line	6mm,red,8 plait polyester
Parachute line (velcro top)	as above but white
Crown line	8 or 10mm,16 plait polyester
Parachute retaining lines	2mm Kevlar
Parachute opening lines	3mm polyester
Pulleys	1SH or 1BSH
Sewing thread	Metric 40 polyester
Flying wires	3 or 4mm 7x19 construction AISI 316
Ferrules	Talurit code 3.5 (3mm wire) Talurit code 4.5 (4mm wire)
Thimbles	5mm stainless steel
Carabiners	2000Kg, 2500Kg
Safety Capewell	Paragear 365 (female) Paragear 369 (male)
Velcro	50mm (for balloons) 20mm (for banners)
Melt Link	127 C type
Temperature tags	Hermet 88-110 C, 116-138 C
Crown ring	200mm, Colt Mk2 100mm, GQ 30814

THUNDER & COLT

BURNERS.

The following burners have been or are used on Thunder and Colt balloons :-
Thunder MK1, single or double
Thunder MK11, single or double
Colt MK1, double only
Colt MK11, single, double, triple and quad. Commercial liquid fire system available on double and triple.
Colt MK111, single, double, triple and quad. Commercial liquid fire available on double and triple
Colt Magnum, double, triple and quad. Commercial liquid fire available on double and triple.
Stratus (BS Series) single, double triple and quad.

FUEL CYLINDERS.

Worthington 20kg capacity (aluminium)
Colt V20 (stainless steel)
Colt V30 (stainless steel)
Colt V40 (stainless steel)
Colt H40 (stainless steel)
Colt H55 (stainless steel)

Note - V = vertical orientation, H = horizontal orientation.

Fuel cylinder minor parts: Bleed screw ass'y (175mm dip tube), Relief valve (373psi), float gauge and dial (Rochester).

FUEL CYLINDER LIQUID TAKE OFFS.

For full information see "Thunder and Colt Parts Manual"

Tema 3800 vertical orientation
Tema 3800 horizontal take off

1 1/4 Acme male vertical take off
1 1/4 Acme male horizontal take off

(All the above to be used in conjunction with the Worcester ball valve).

1 1/4 Acme male integral with screw valve.

BASKETS.

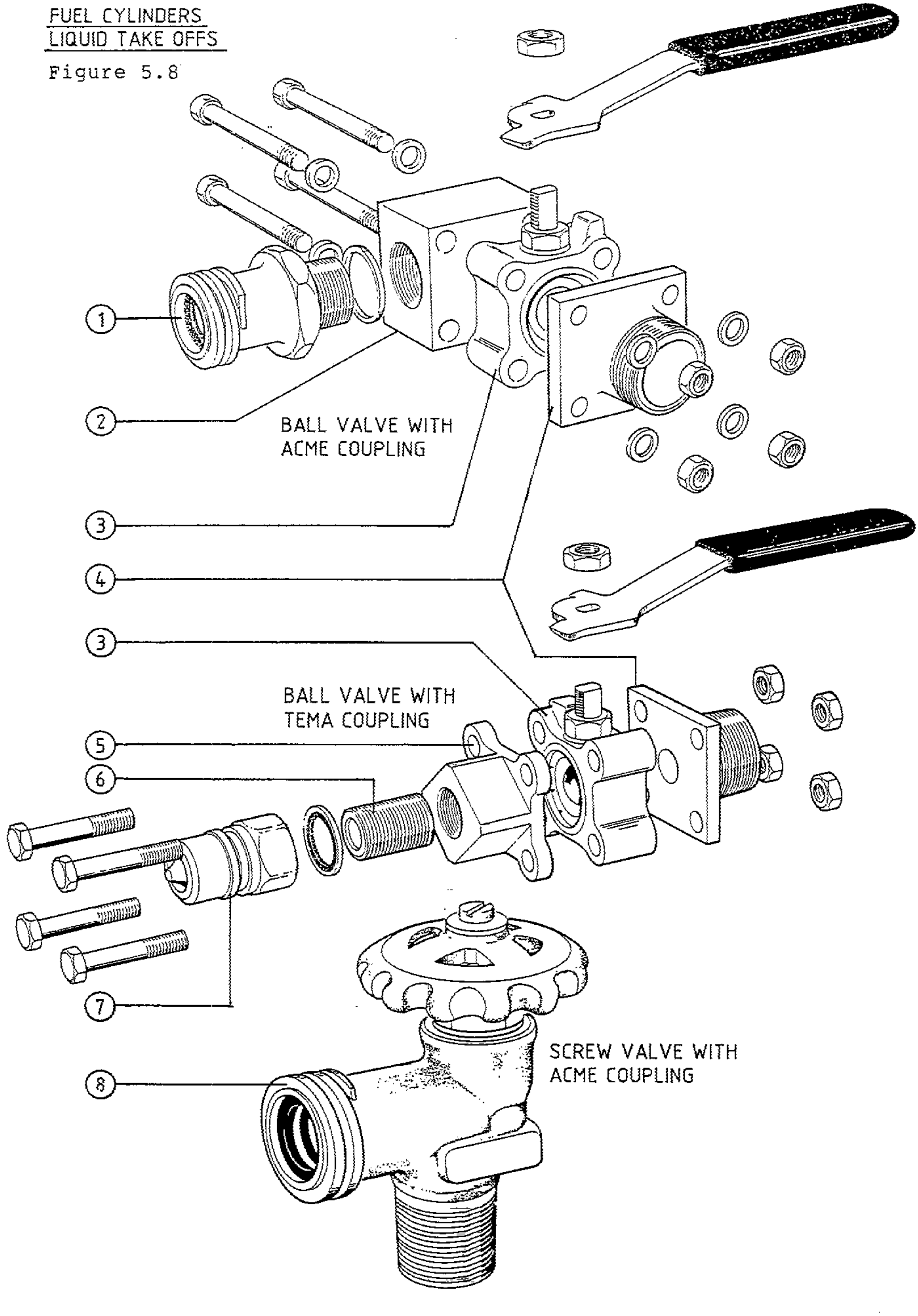
Single compartment baskets are available in the size range 40" x 40" (1m x 1m) to 48" x 68" (1.22m x 1.72m).

T compartment baskets are available in the size range 48" x 68" (1.22m x1.72m) to 60" x 102" (1.50m x 2.60m).

Double T compartmented baskets are available in the range 60" x 98" (1.52m x 2.50m) to 60" x 138" (1.50m x 3.50m).

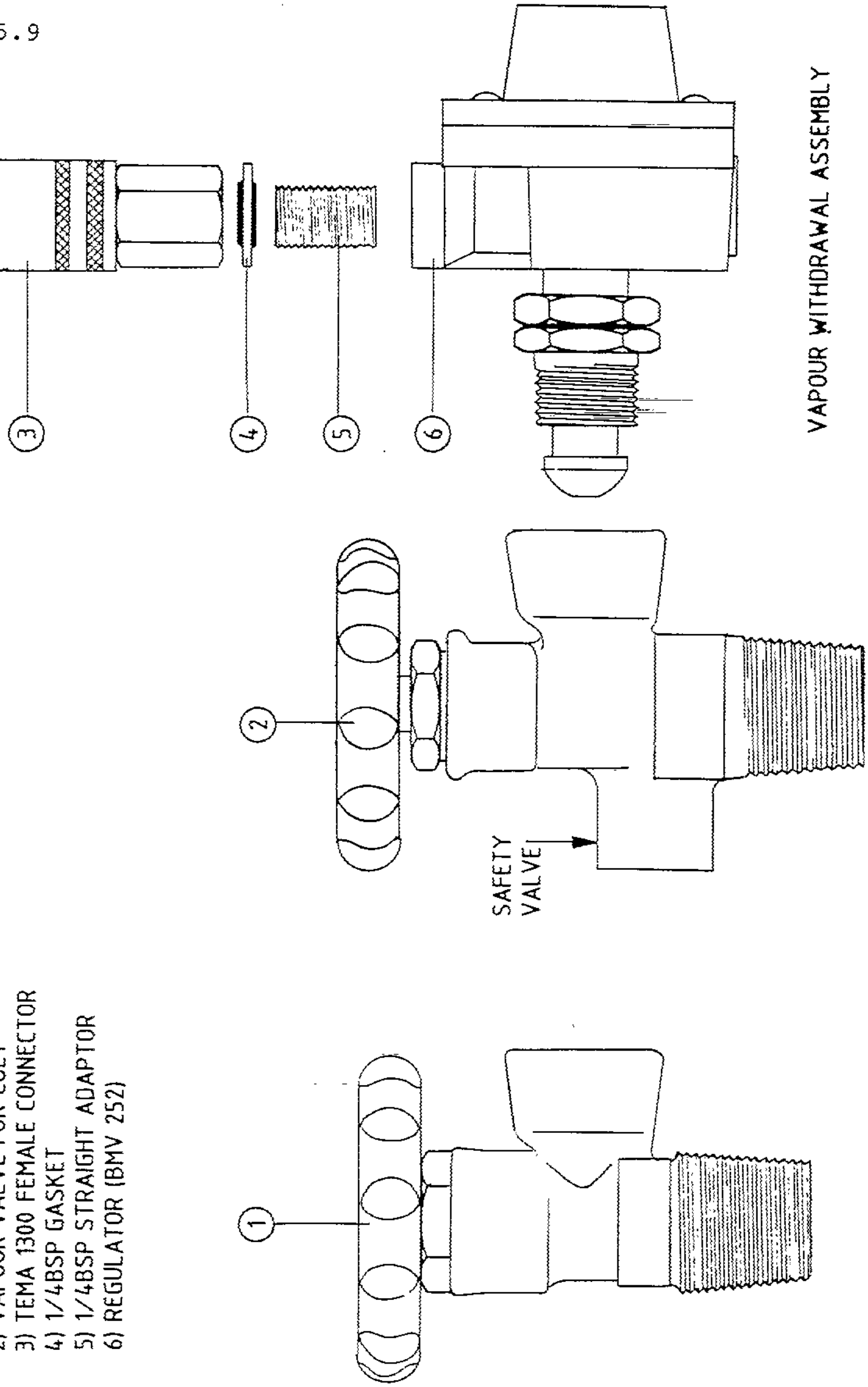
FUEL CYLINDERS
LIQUID TAKE OFFS

Figure 5.8



FUEL CYLINDERS
VAPOUR TAKE OFF

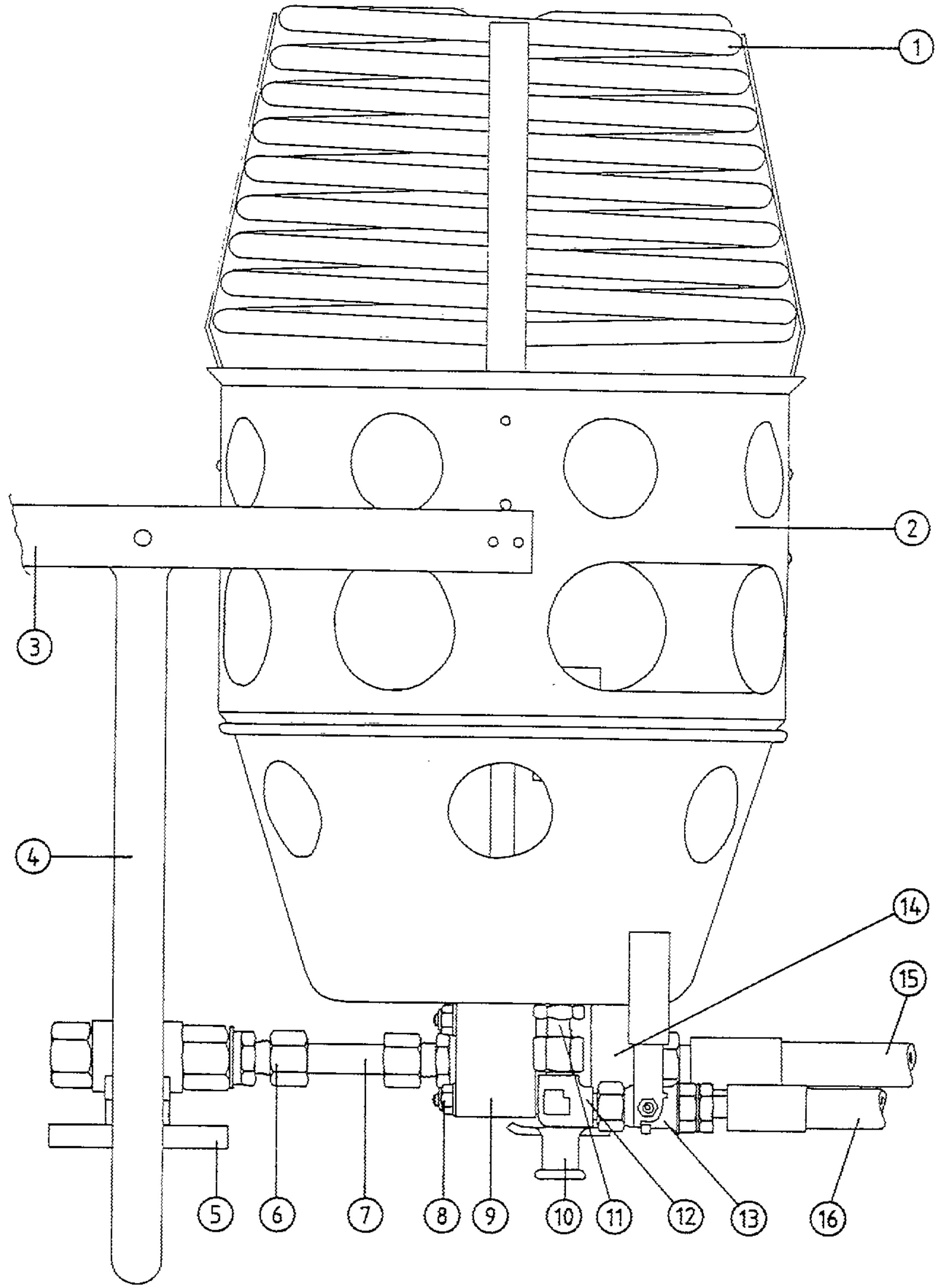
Figure 5.9



1) VAPOUR VALVE FOR WORTHINGTON
2) VAPOUR VALVE FOR COLT
3) TEMA 1300 FEMALE CONNECTOR
4) 1/4BSP GASKET
5) 1/4BSP STRAIGHT ADAPTOR
6) REGULATOR (BMV 252)

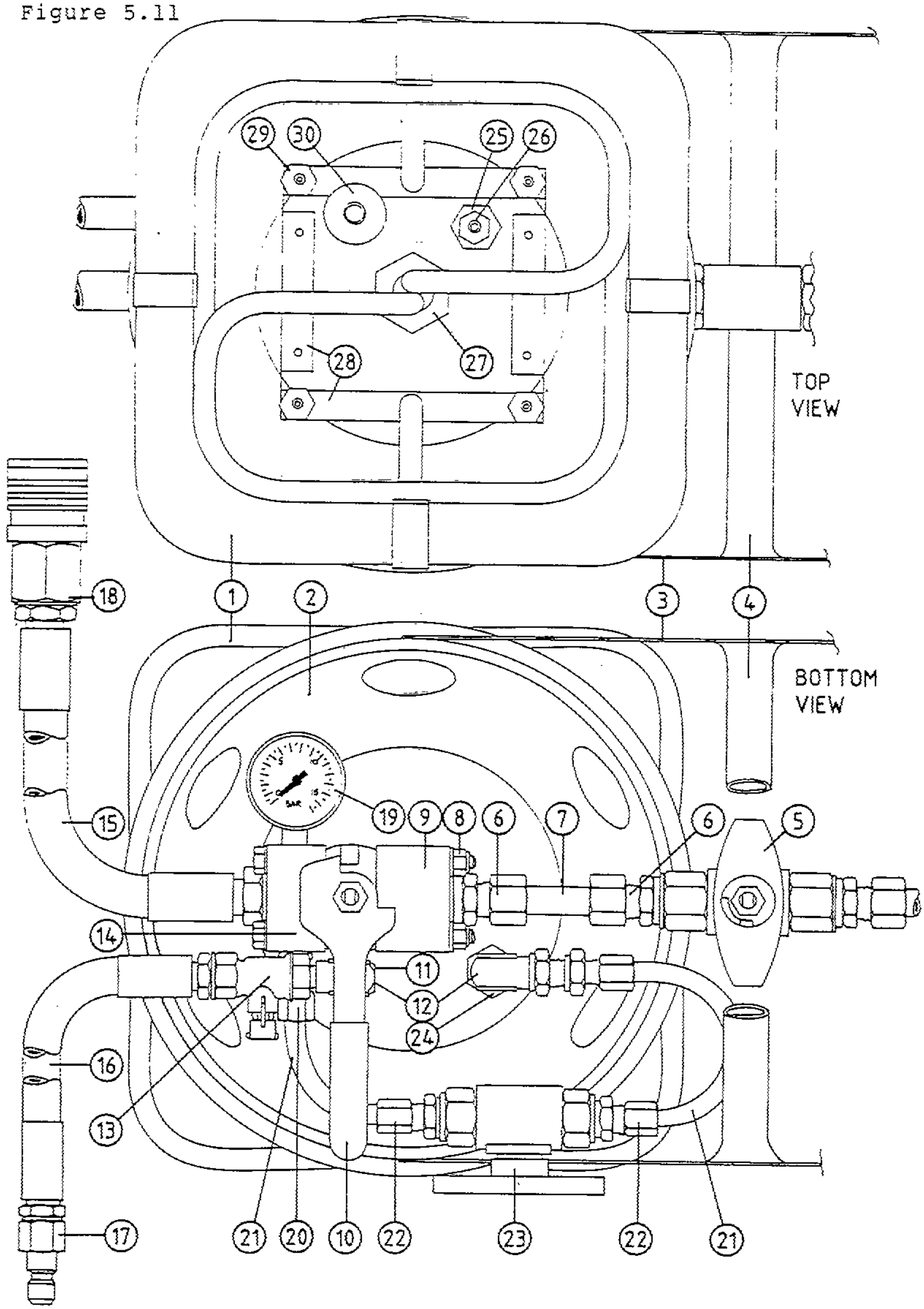
COLT MK2 DOUBLE BURNERS

Figure 5.10



COLT MK2 DOUBLE BURNERS (CONT)

Figure 5.11



COLT MK2 DOUBLE BURNERS (CONT)

The part and material specification is as follows:

Number	Part Name	Specification
1	Coil	3/8" x 20swg seamless AISI 321
2	Can	AISI 304
3	Connecting strip	1" x 14swg AISI 316
4	Handle	3/4" x 18swg AISI 316
5	Transfer valve	3/8" BSP Dyna-quip ball valve
6	Compression coupling	3/8" BSP x 12 mm
7	Tube	12 x 1 mm AISI 316
8	Bolt assy	M6 or 1/4" UNC
9	Outlet metering block	L65 aluminium alloy
10	Blast valve	Worcester W44 ball valve Aluminium body, stainless steel ball and stem, PTFE seals
11	Pilot adaptor	1/4" BSP x 1/8" BSP tapped 1 BA
12	Elbow	1/4" BSP male x 1/4" BSP female
13	Pilot valve	1/4" BSP Klinger
14	Inlet metering block	L65 Aluminium alloy
15	Liquid hose	Stainless braided rubber hose to SAE 100 RIT06 pin pricked 3/8" BSPP male ends

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COLT MK2 DOUBLE BURNERS (CONT)

Number	Part Name	Specification
16	Pilot hose	Stainless steel braided rubber hose to SAE 100 R1T04, 1/4" BSPP male ends
17	Pilot hose connector	Tema 13410 male
18	Liquid hose connector	Tema 3800 female
19	Pressure gauge	0 -200 psi (0 -16 bar), 1/8" BSP
20	Compression fitting	1/8" BSPT - 8 mm
21	Tube	8 x 1 mm AISI 316
22	Compression fitting	1/4" BSP - 8 mm
23	Liquid fire valve	1/4" BSP Dynaquip
24	Nut	1/4" BSP AISI 304
25	Adaptor	1/4" BSP male - 1/8" BSP male AISI 304
26	Liquid fire jet	Amal brass jet. Type 357, size 3060, 1/8" BSP
27	Nut	3/8" BSP, AISI 304
28	Jet bracket	AISI 316
29	Main jet	Amal brass jet. Type 357 size 3060, 1/8" BSP
30	Pilot light	AISI 316

THUNDER MK2 DOUBLE BURNERS

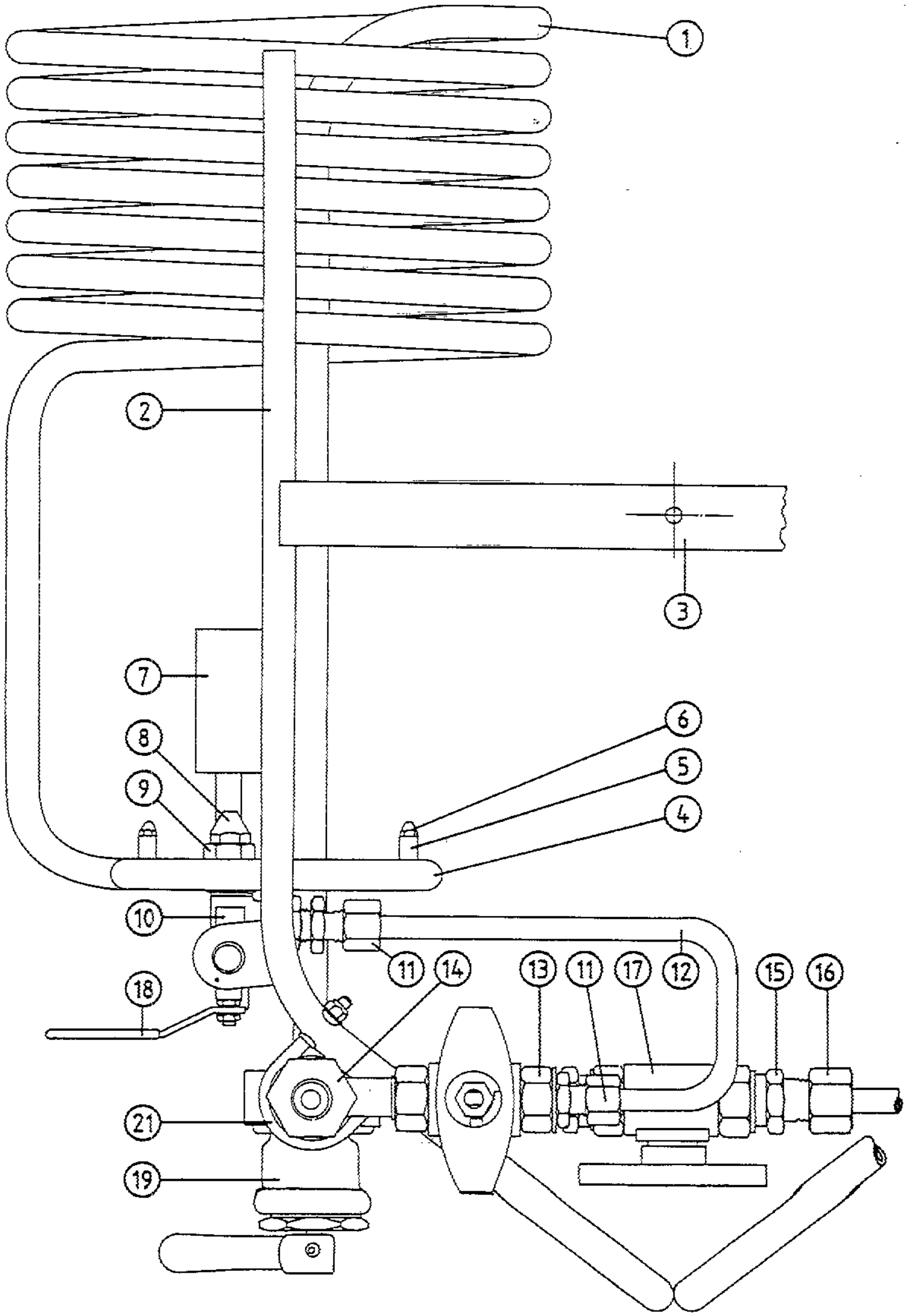


Figure 5.12

THUNDER MK2 DOUBLE BURNERS (CONT)

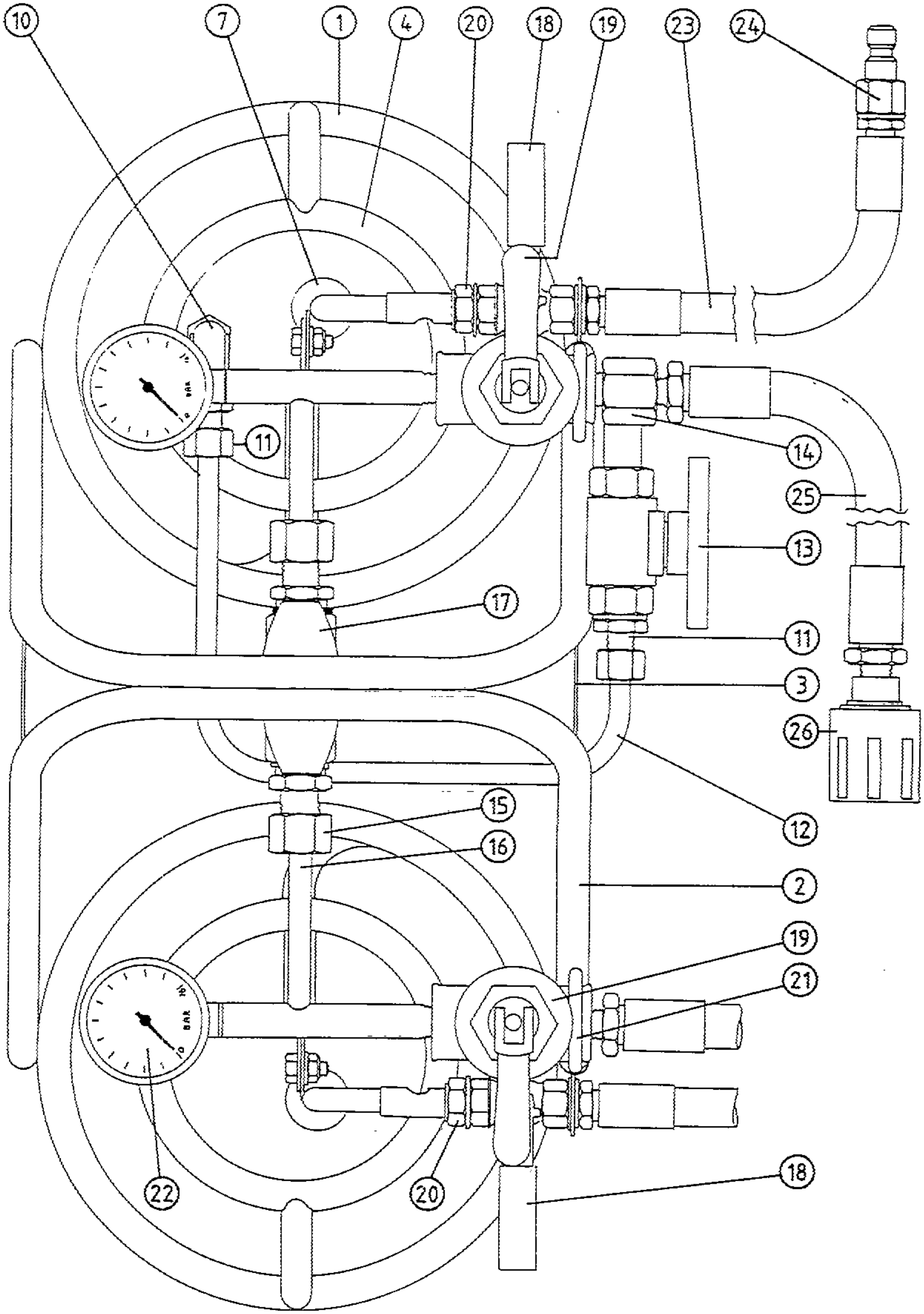


Figure 5.13

THUNDER MK2 DOUBLE BURNERS (CONT)

The part and material specification is as follows:

Number	Part Name	Specification
1	Coil	1/2" x 20 swg) AISI 321 1/2" x 18 swg) seamless tube
2	Handle	1/2" x 18 swg AISI 316
3	Connector Strip	1" x 14 swg AISI 316
4	Jet ring	1/2" x 18 swg AISI 316
5	Jet holder	1/4" OD tapped 1 BA
6	Jet	Amal type 187 drilled 2.5 mm Brass, 1 BA thread
7	Pilot light assy	AISI 316
8	Liquid fire jet	Amal type 357, size 3060 Brass, 1/8 BSP thread
9	Liquid fire jet holder	1/4" BSP - 1/8" BSP AISI 304
10	Elbow	1/4" BSP male - 1/4" BSP female
11	Compression fitting	1/4" BSP/ 8 mm
12	Liquid fire tube	8 x 1.5 mm AISI 316
13	Liquid fire valve	1/4" BSP Dynaquip ball valve
14	Liquid fire adaptor	1/4" NPT male/ 1/4" NPT female with 1/4" BSP female spur AISI 316
15	Compression fitting	1/4" BSP/ 10 mm
16	Connector tube	10 x 1 mm AISI 316
17	Transfer valve	1/4" BSP Dynaquip ball valve
18	Pilot valve	1/4" BSP Klinger ball valve

THUNDER MK2 DOUBLE BURNERS (CONT)

Number	Part name	Specification
19	Blast valve	Rego 7553 S or 7553 T
20	Pilot adaptor	1/4" BSP male/ 1/8 BSP male tapped 1 BA
21	U Bolt	M5 stainless steel
22	Pressure gauge	0-16 bar, 1/4" NPT
23	Pilot hose	Stainless braided rubber hose to SAE 100 R1T-04. Ends 1/4" BSP male
24	Pilot connector	Tema 1300 male
25	Liquid hose	Stainless braided rubber to SAE 100 R1T-06 with pinpricked outer skin. 1/4" NPT male ends
26	Liquid connector	1 1/4" Acme female (Rego 7141F or equivalent)

APPENDIX

APPENDIX 1

Technical Information on Propane Fuel

Propane is the fuel used for hot air ballooning and it is also referred to as LPG or LP-gas, that is, Liquified Petroleum Gas. The principal advantage of Propane is the fact that it can be stored as a liquid and used as a gas. But it is also a characteristic that can cause the most trouble if the material is not properly handled. The basic point to remember is that Propane is inherently safe, it is only misuse or careless handling that can cause safety problems. What distinguishes Propane from other members of the family of petroleum hydrocarbons is simply its boiling (or vaporization) point. It boils or liquifies without pressure at temperatures fairly easily attainable. This is not true of any of the other hydrocarbons. Petrol, kerosene, diesel oil and other similar hydrocarbons are normally liquids at atmospheric pressure and temperature. To make them boil and vaporize requires the application of considerable heat. On the other hand, natural gas, which is primarily methane, remains a gas under these same conditions. To liquify it, without pressure, requires an extreme reduction of temperature.

Propane is normally produced in two ways: the hydrocarbons which are present in natural gas when it is brought up from the earth may be Propane and by stripping it from the natural gas in an absorption plant, marketable Propane may be obtained. The most common method is, however, to obtain it during petroleum refining.

The chemical formula for Propane is C_3H_8; it is in pure state colourless and odourless. It is heavier than air, having specific gravity relative to air of 1.5. Since Propane is colourless and odourless, escaping vapour could be very dangerous and remain undetected, hence commercial Propane (to which all figures hereafter refer) carries some sulphur additives to give a noticeable smell at 1/5 of the lower flammable limit of Propane in air. The amount of sulphur, however, is normally not more than 0.0002% of weight.

The quality requirement for commercial Propane varies from country to country. This can pose a problem as most users of Propane draw only vapour from storage cylinders while we use liquid. What is labelled Commercial Propane can contain up to 5% so-called heavy ends which are long chain hydrocarbons which will not always combust but accumulate in the bottom of the cylinder. This black and oily substance can clog up the fuel system, particularly the vapour side which will necessitate stripping and cleaning the system. Inspection of heavy ends in the cylinder is a primary reason for inspecting these annually.

Another contaminant is water, which can be present in all LPG. Water is heavier than liquid Propane and will always accumulate in the bottom of the cylinder. Thus it will normally only affect the liquid withdrawal and, should internal freezing of the system occur during winter, methanol should be added to the fuel. This will keep the water suspended in the fuel and it will be drawn out and burned in the usual manner.

A further problem is Butane which is blended into what is sold as Propane, particularly in hot climates, to lower the vapour pressure. Butane has very similar physical and chemical properties to Propane and only really differs in vapour pressure which is substantially lower. A small proportion of Butane is quite acceptable, the only limiting factor being the vapour pressure, and as long as this is kept up at normal levels it is quite harmless to operate on a mixture. A balloon burner can operate on pure Butane but only if the fuel is preheated or pressurised with nitrogen. However, minor modifications are necessary for the burner, such as different jets.

Summing up the properties of Propane we have:

Energy content, 1Kg Propane represents		4.6×10^7J
Density as liquid at 15°C	=	0.52g/cm^3
Boiling point at 760mm Hg	=	-44°C

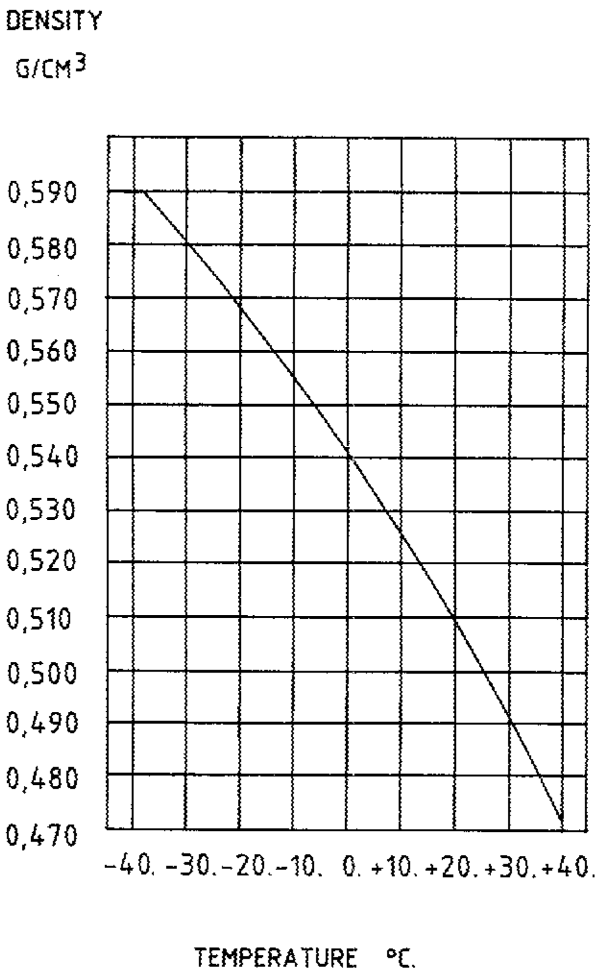
Vapour pressure is dependent on temperature and is detailed overleaf. For our application this is the single most important feature of Propane, since it enables us to work a very high output burner without a fuel pump. But, bear in mind that since we do not have a pump the burner performance is directly linked to the available vapour pressure only, and, consequently, the output follows the fuel temperature closely. In other words, on a hot, summer day we might have a pressure of 10 kg/cm^2 to work from, while on a cold, winter day we might only have 2 kg/cm^2.

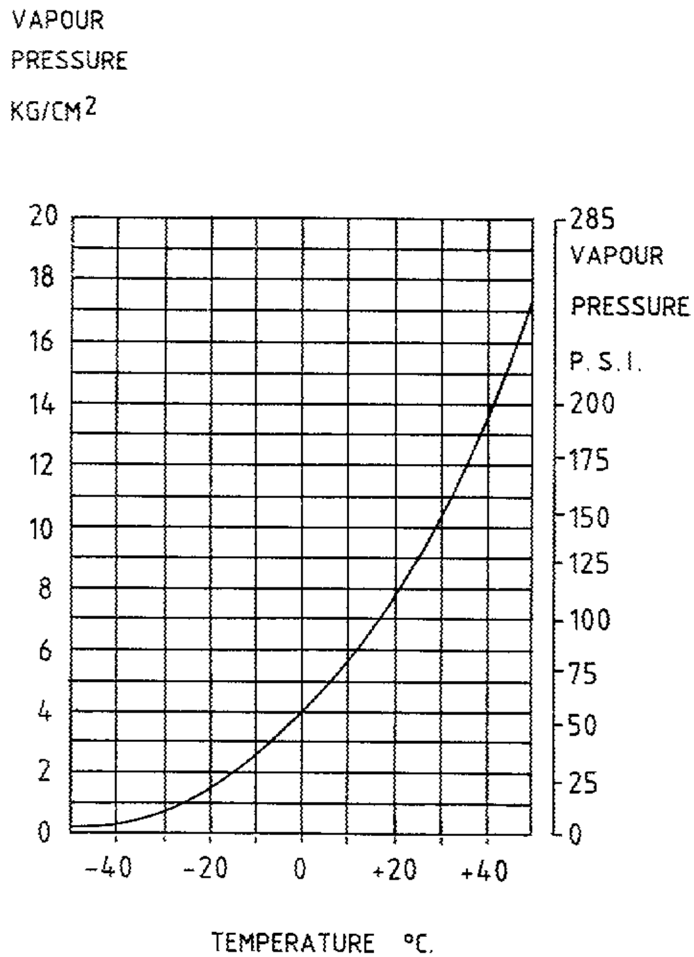
To increase the pressure during the winter the fuel can be warmed by leaving the cylinders at room temperature away from any sources of ignition etc (see LPG code) or preheating with an electric jacket. At no time should the fuel be heated above 25°C. If this facility is not available, the fuel can be pressurised by nitrogen which is brought into the cylinders through the liquid valve. It is important not to over-pressurise the system as the Propane will expand with increased temperature just the same, whether there is nitrogen or not in the bottles. Pressurisation with nitrogen will also render the cylinders useless for vapour withdrawal, as all the nitrogen will collect at the vapour space at the top of the cylinder.

To safeguard the pressure vessels used for storing Propane, in our application the flight cylinders, against accidental high temperatures (and, consequently, pressures) we use a safety relief valve in the cylinder set to discharge at 375 psi (26 kg/cm^2).

Propane liquid expands rapidly with temperature, making it imperative never to completely fill a storage cylinder. A vapour space must be left above the liquid sufficient to allow for temperature variations. This is normally 10-15% of total cylinder volume.

Detailed below is the density against temperature for commercial Propane.





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APPENDIX 2

Refuelling Fuel Cylinders

General Notes

Propane vapour is heavier than air. Do not refill fuel cylinders in the basket (unless they have external bleed) or enclosed spaces or hollows, drains, etc as the vapour can accumulate and cause a fire hazard. Ensure there are no naked lights or cigarettes in the immediate vicinity. The fuel cylinders should be electrically earthed during the filling process. Always wear protective gloves. Always have a fire extinguisher available. Only refuel one cylinder at a time.

Filling from a Bulk Tank with Pump

1. Connect the fill hose to the liquid outlet of the flight cylinder;

2. Open the bleed valve on the flight cylinder just enough to hear gas escaping;

3. Open the valve on the cylinder;

4. Open the supply valve on the bulk tank;

5. Start the pump;

6. When the flow from the bleed valve changes from vapour to liquid, stop the pump immediately and close all the valves. Vent the fill hose;

7. Disconnect the supply hose;

8. Vent the quick connector on the flight cylinder by depressing the centre spigot. This prevents accumulation of liquid Propane in the connector, which can cause damage.

Filling Flight Cylinders from Transportable Bulk Cylinders

Commercial cylinders normally have only one outlet. This is intended to deliver vapour. To obtain liquid the cylinder must be inverted. Proceed as follows:

1. Connect the outlet of the commercial cylinder to the liquid outlet of the flight cylinder;

2. Invert the commercial cylinder (at 45° angle and chocked to stop dirt entering supply.

3. Open the bleed valve on the flight cylinder;

4. Open the valves on the flight cylinder and commercial cylinder;

5. When the flow from the bleed valve changes from vapour to liquid, close all valves;

6. Disconnect the supply hose;

7. Vent the quick connector on the flight cylinder.

APPENDIX 3

LIFT CALCULATIONS FOR BALLOONS

Most of us only refer to the load chart in the Flight Manual for lift calculations. Whilst this is adequate for most ballooning needs, sometimes it is useful to be able to calculate the exact lift for a given situation.

A balloon flies on the Archimedes principle, which states that the lift of the balloon is the product of the balloon volume and the density differential between the air inside and outside the balloon.

Thus, if lift	=	L (Kg)
Air density	=	ρ (Kg/m^3)
Balloon volume	=	V (m^3)

$$\underline{L = \Delta\rho . V}$$

To find the density of air under varying conditions, we use the universal gas law, which states:

If p	=	pressure (Kg/m^2)
T	=	Temperature (Abs., = C + 273)
ρ	=	Density (Kg/m^3)

Then, $$\frac{p}{\rho T} = \text{constant}$$

Thus, if we define the density of air outside the balloon as ρ_o, the temperature as T_o, and the pressure as p_o, the pressure in the balloon will be p_o also (this is only true at the open mouth of the balloon, but the pressure variation in the balloon is negligible).

Defining the temperature inside the balloon as T_i, and the density as ρ_i, the density is calculated as below:

$$\rho_i = \rho_o \frac{(T_o + 273)}{(T_i + 273)}$$

And the density differential:

$$\Delta\rho = \rho_o \left(1 - \frac{(T_o + 273)}{(T_i + 273)}\right)$$

$$\text{and} \quad L = V.\rho_o \frac{(T_i - T_o)}{(T_i + 273)} \qquad \text{(A)}$$

Data on the variation of atmospheric conditions with altitude is given in standard tables called ISA (International Standard

Atmosphere) tables. The Flight Manual charts are derived from these tables. Here is a typical extract:

Altitude m	Temperature °C	Pressure Mb	Density Kg/m³
0	15	1013	1.225
500	11.8	955	1.168
1000	8.5	899	1.112
2000	2.0	795	1.007

If the atmospheric conditions are as shown in the table, the outside air density can be read directly from the table, but for all other occasions we need to make corrections for the temperature and pressure of the day.

For the standard atmosphere:

$$\rho_s = 1.225 \text{ Kg/m}^3$$
$$T_s = 15^oC$$
$$p_s = 1013 \text{ Mb}$$

And, using the gas law again:

$$\frac{p_o}{T_o \rho_o} = \frac{p_s}{T_s \rho_s}$$

Thus, $$\rho_o = \frac{p_o\ (273 + 15)\ 1.225}{1013\ (273 + T_o)} \quad \text{or} \quad \rho_o = \frac{0.3483\ p_o}{(273 + T_o)} \qquad \text{(B)}$$

(T_o in °C, p_o in Mb)

For example, consider the difference in air density at sea level for a cold winters day and a hot summers day:

Case 1

Summer day, p_o = 1010 Mb, T_o = 30°C

$$\rho_o = \frac{0.3483 \times 1010}{273 + 30} = \underline{1.161 \text{ Kg/m}^3}$$

Case 2

Winter day, p_o = 1030 Mb, T_o = -8°C

$$\rho_o = \frac{0.3483 \times 1030}{273 - 8} = \underline{1.354 \text{ Kg/m}^3}$$

For a 56,000 cu ft (1,600 m^3) balloon with a take-off weight of 400 Kg under these conditions, the balloon temperature required will be:

<u>Case 1</u>

$L = 400$ Kg, $\rho_o = 1.161$ Kg/m^3, $T_o = 30^oC$, $V = 1600m^3$

Using formula (A):

$$400 = 1600 \times 1.161 \frac{(T_i - 30)}{(273 + T_i)}$$

$$\text{Giving } T_i = 112^oC$$

<u>Case 2</u>

$L = 400$ Kg, $\rho_o = 1.354$ Kg/m^3, $T_o = -8^oC$, $V = 1600m^3$

Using formula (A):

$$400 = 1600 \times 1.354 \frac{(T_i + 8)}{(273 + T_i)}$$

$$T_i = 52^oC$$

This difference can be further accentuated when flying in hot and high conditions, such as Kenya or Arizona, where great care is required to avoid overheating the envelope. To find the barometric pressure, p_o, for the formula (B), either set the altimeter to read 0m and read the pressure subscale, or contact the local met. office for the QFE. At higher locations there will be insufficient subscale adjustment, and so a proper barometer or atmospheric charts will be required. These charts are issued by the ICAO.

For an example of taking off at high altitude, consider flying a 160 balloon in Kenya:

Ground altitude	=	5,000 ft
Ambient temperature	=	28^oC
Barometric pressure	=	840 Mb
Balloon volume	=	160,000 cu ft = 4500m^3
Balloon temperature	=	100^oC (maximum desired)

To calculate gross lift:

Using formula (B):

$$\rho_o = \frac{0.3483 \times 840}{(273 + 28)} = \underline{0.972 \text{ Kg/m}^3}$$

Using formula (A):

$$L = \frac{4500 \times 0.972 \times (100 - 28)}{(273 + 100)} = \underline{843\ Kg}$$

For the same balloon 5,000 ft above England on an ISA day the temperature would be 5.1°C:

$$\rho_o = \frac{0.3483 \times 840}{(273 + 5.1)} = \underline{1.052\ Kg/m^3}$$

$$L = \frac{4500 \times 1.052 \times (100 - 5.1)}{(273 + 100)} = \underline{1202\ Kg}$$

And, as a final comparison, the lift at sea level under ISA conditions (15°C, 1013 Mb) will be:

$$\rho_o = \frac{0.3483 \times 1013}{(273 + 15)} = \underline{1.1225\ Kg/m^3}$$

$$L = \frac{4500 \times 1.225 \times (100 - 15)}{(273 + 100)} \quad L = \underline{1256\ Kg}$$

Thus it is obvious that air temperature is <u>the</u> important factor, since high air temperatures not only reduce the temperature differential ($T_i - T_o$), but the air density (ρ_o) as well. The pressure stays reasonably constant, for a given altitude, anwhere in the world, but density follows temperature and can therefore vary dramatically. Variations in humidity have only a small effect. High humidity will reduce lift, but this reduction is usually less than 1% and can be safely ignored.

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APPENDIX 4

I.S.A. TABLES

Press. (mb)	Geopot. (m)	Altitude (ft)	Temperature (deg. C)	Density (kg/cu.m)
1013	0	0	15.00	1.2250
1000	111	364	14.28	1.2120
950	540	1773	11.49	1.1627
900	989	3243	8.57	1.1129
850	1457	4781	5.53	1.0626
800	1949	6394	2.33	1.0117
750	2466	8091	-1.03	0.9601
700	3012	9882	-4.58	0.9079
650	3591	11780	-8.34	0.8551
600	4206	13801	-12.34	0.8014
550	4865	15962	-16.62	0.7469
500	5574	18289	-21.23	0.6914
450	6344	20812	-26.23	0.6348
400	7185	23574	-31.71	0.5771
350	8117	26631	-37.76	0.5179
300	9164	30065	-44.57	0.4572
250	10363	33999	-52.36	0.3944
200	11784	38662	-56.50	0.3215
150	13608	44647	-56.50	0.2412
100	16180	53083	-56.50	0.1608