

Introduction

The purpose of this Data Sheet is to provide general operational information for the Skyship 500 and 600 airships. An outline description is given of the following operating considerations:-

- Inflation & Assembly
- General Flight Procedures – Take-Off and Landing
- Mooring
- Hangarage
- Weather
- Helium Supply, Top-Up & Purification

Inflation & Assembly

Inflation and assembly should be carried out inside a suitably sized hangar (where unavoidable and in a stable low wind environment, inflation can be carried out in the open air. There is a precedent for this procedure but it is certainly not general practice). The hangar floor and roof must be in a reasonable condition to ensure that no debris can damage the fabric of the Envelope. When all components for the airship are at the hangar, a protective plastic Ground Sheet is rolled out over the inflation area. The Hull Envelope which is delivered in a fabric valise (only 10' x 4' x 4' for a Skyship 500, for example) is lifted onto one end of the Ground Sheet and unrolled – this operation only takes an hour or so. The Envelope can then be partially inflated with air whilst it is checked over for any pinholes or signs of transit damage, and the internal catenary gondola suspension system coupled up to four load curtains. Once the six Valves and other minor items have been fitted, the ballonet trunks coupled up to the T-Chest and the Inspection Dome fitted, the Envelope can then be covered carefully by an Inflation Net to hold down the Envelope when filled with helium. Sandbags are arranged around the periphery of the Net and emergency restraint lines are attached onto strong points of the Hull. The Envelope is then ready for inflation.

In order to ensure no air is trapped inside the Envelope, a vacuum pump is connected to a fitting on the rear of the Envelope and run for several hours. The helium supply (usually road hauled packs or cylinders) is then coupled up to a non-return valve on the underside of the Envelope and inflation commenced. Moving the sandbags on the Inflation Net around the periphery of the Envelope into the required position as the Envelope fills, the Envelope will gradually rise from the floor.

When the Envelope is filled, the Gondola and Tail Fins can be fitted. The ship is then ballasted, and the net removed. The Nose Cone and Nose Battens are then attached. After final fitting of the Gondola and a full check, the ship is ready for roll-out. The operation can be

carried out within twenty days with an entirely experienced assembly crew.

General Flight Procedures

Take-Off

In addition to normal pre-flight checks, once an airship has been loaded up at the mast with payload and crew it must be "weighed off" (a process which determines whether and to what extent the ship is "light" or "heavy"). On a Skyship this is carried out simply by reading off an instrument in the cockpit which indicates the heaviness of the ship by means of a load cell in the single under-carriage leg. (At take-off, with a full fuel load and payload the ship will normally be substantially heavy – e.g. for a 500 say 1,000 lbs). Any water ballast carried can be dumped by the pilot to achieve the required take-off heaviness.

The engines can then be started up from the ship's own batteries (engines fitted to all Skyships are specifically developed for ease of starting in all conditions). The ship can then be released from the mast and backed away downwind or, where operating from a mobile mast, the mast can be driven away from the ship.

By convention the flight is timed to start at release from the mast. The airship is trimmed to level condition by adjusting the air in the ballonets, the ground crew instructed to let go and stand clear and the ship takes off. In a restricted area take-off can be vertical (VTOL) by using Vectored Thrust at 90°, but where space permits a 'ZTOL' technique involving the use of a lesser vector angle, say 45°, still produces a zero length take off run, but forward speed is built up during the climb out, providing early directional control and the capability of supporting static heaviness by dynamic lift if an engine failure occurs shortly after take-off.

The minimum cleared space for take off and landing has been specified by the CAA as a rectangle of 200m plus ship length by 200m plus ship width although the use of Vectored Thrust might result in a reduced requirement being considered. If an angled climb-out is used the length must be increased by the take off distance to reach 15m (50 ft) which is likely to be of the order of a further 100m.

Landing

Prior to landing the ship should again be trimmed to level condition by adjustment of the air in the forward and aft ballonets, either by slowing down and performing the operation directly, or by maintaining cruising speed and adjusting the ballonets until the ship flies in level attitude with the elevator control in mid position. A normal aircraft

type approach may then be made using Vectored Thrust if necessary to check the descent and finally reverse thrust to check forward speed. As the ship comes to rest it is caught by the ground crew, ballast put aboard if the ship is light and it is then guided to the mast. Engines are not stopped and the flight does not end until the ship is safely secured to the mast. In strong winds a 'high landing' is usually made, the ship being brought to a stop relative to the ground about 20ft up and Vectored Thrust used to bring the ship down vertically.

Once a non-rigid airship has been inflated it is necessary to maintain a positive pressure inside the envelope at all times, both to maintain the shape and to prevent the lifting gas from being contaminated with air. In flight the necessary pressure is obtained by air scoops aft of the propellers, with appropriate ducts and control valves leading to the ballonets. When the main engines are not running the pressure must be maintained by an auxiliary blower, driven either by a separate prime mover or more conveniently by electric motor controlled by a pressure switch from ship or ground power supply. Thus when the ship is moored a ground power supply must be available and a pressure watch maintained to ensure that it remains in safe and shipshape condition.

Mooring

The normal method of mooring an airship in the open is to attach it by the nose to an appropriate mast, thus

permitting the airship to swing such that it is always headed into the direction of the prevailing wind. It should be realised that airships are only required to be hanged for major checks and major maintenance: for all operating conditions, including daily checks and normal maintenance, the airship will remain tethered to its mast "in the field", and both ship and mooring systems have been designed to allow the ship to remain on the mast for wind speeds up to 90 knots.

The standard mooring process is to approach the mast into the wind with neutral buoyancy; a line from the mast-head is attached to the nose cone, and the airship winched in the short remaining distance. The ship is then ballasted to a slightly heavy condition so that the castoring main wheel of the landing gear remains in contact with the ground as the airship weathercocks into wind.

A probe on the nose of the airship engages a socket on the mast-head where it is retained by spring loaded catches, operated by a lever so that they can be set in the 'locked', 'free' or 'release' condition. Once the probe has engaged the catches the lever is moved to the locked position and secured by a pin to prevent inadvertent movement. (To this pin is attached the airship rip cord. If the airship breaks away the rip will be operated and the airship deflated.) On the Skyship the nose probe and mast socket are compatible with the current Goodyear mooring system.



The prototype 500 on a mobile mast at Cardington, Bedfordshire

A variety of mast systems can be used to suit all requirements. For a permanent base a fixed mast is preferred, secured to suitable foundations and with ground power supplies led to the base of the structure. For operations away from base a portable pole mast may be preferred; this is anchored by screw pickets driven into the ground, and cable-braced. For manoeuvring into and out of a hangar the most convenient method is to use a mobile mast, either mounted on a heavy prime mover or as a wide base, ballasted, towed structure. Such a mast can also be used operationally, tied down to strong points if high winds are expected.

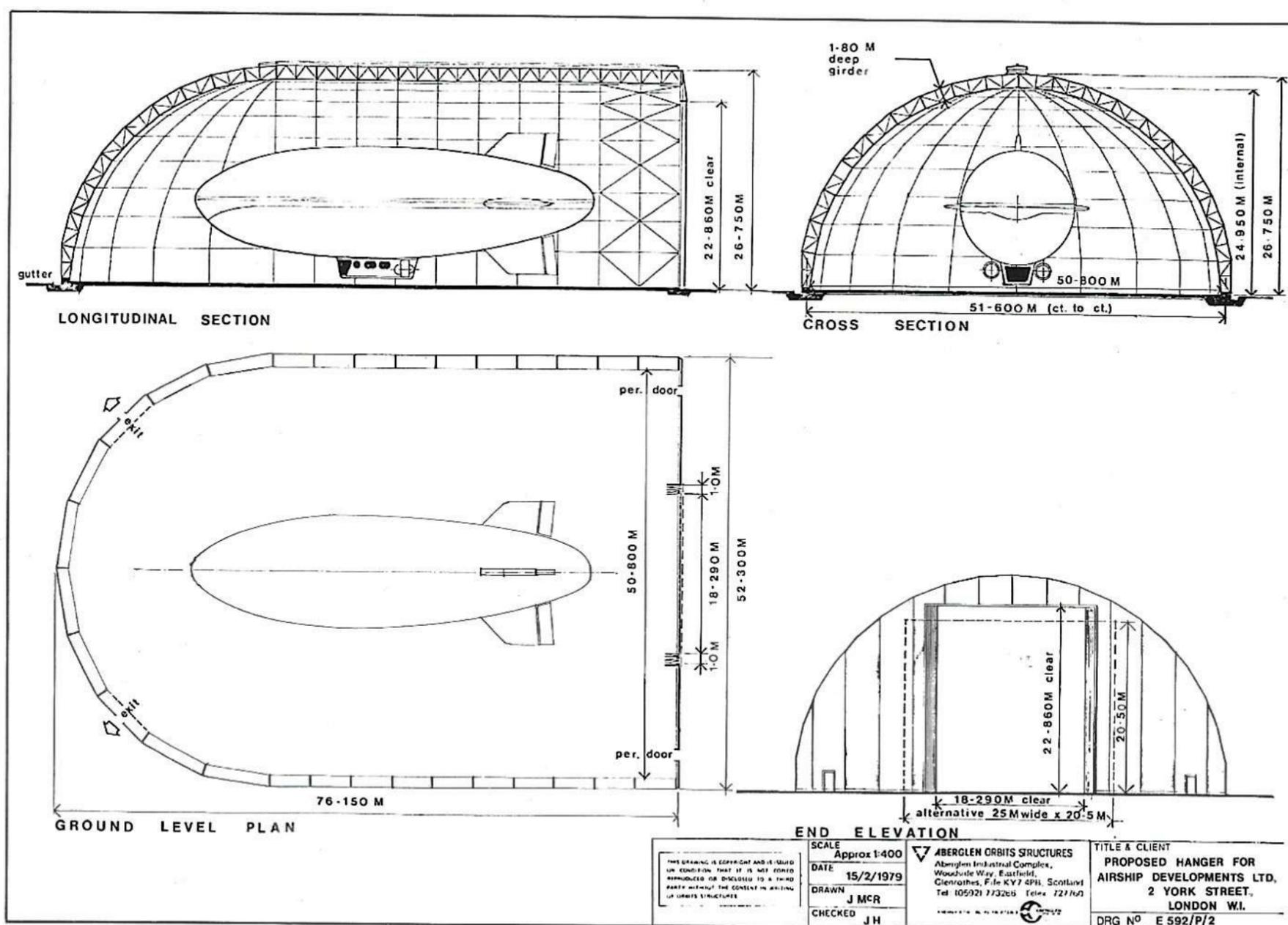
It is possible to secure an airship without the use of a mast. One method is the three wire system where wires from the nose of the ship are attached to anchor points on the ground. The ship is then made 'light' to tauten the wires and it then flies attached to the apex of a triangular pyramid. Simplest of all is to attach lines to all the handling points which are located along the side of the ship, and literally tie the airship down. This scheme was used prior to the development of the mast system, and can be used where short-term landings are required on unprepared sites.

Hangarage

In any operational scenario it is intended that the airship, when not flying, will effectively spend its entire working life moored in the open: the airship has a long history of riding satisfactorily at the mast in all weather conditions. However, there are occasions when the use of a hangar is essential, and others when it is highly desirable.

Hangarage is required when the ship is assembled or disassembled (but it should be noted that in order to minimise the assembly and dis-assembly times the Skyships have been designed to rationalise these procedures). Other occasions for which still air is imperative (and therefore by definition hangarage) are for the alignment of avionic equipment, and for work on the nose cone and associated areas when the ship is of necessity off the mast.

Hangarage is also strongly advisable during periods of major overhaul, or when fitting specialist equipment such as an electronic night-sign to the envelope. It can be convenient, but not essential, for other maintenance operations in inclement weather.



A hangar design proposal.

The Skyship 100 can be accommodated in any 'standard' hangar: however the larger ships require non-conventional hangarage, the size being dictated by the height of the upper tailfin. In England the preferred location for the assembly of ships is Cardington in Bedfordshire, where the two sheds which housed the R.100 and R.101 are maintained in good order: and there are approximately twelve sheds in the United States which are suitable. The European operation of the Goodyear Corporation utilises a purpose-built hangar at Copena, outside Rome. Other airship operators of recent years have preferred the inflatable or semi-inflatable shed, with a light-weight internal structure to support the skin when one end is opened for access. This type of hangar has the distinct advantages of ease of assembly/disassembly and transportation, and minimum requirement for prepared site.

Airship Industries has established a close liaison with the supplier of a quick-assembly fabric hangar, and will be pleased to advise and assist any possible end-user.

In addition the company has had discussions with a leading supplier of conventional hangars who have undertaken preliminary drawings and design specifications. The advantages of the conventional structure are those of proven design and longer life.

Weather

Note: This section is taken from excerpts from NASA 2-8643 AMES Research Centre NACA.

General: No vehicle is truly an all-weather vehicle in that it can effectively perform its assigned mission in any weather conditions except possibly a submarine, which can operate below weather effects. However, many vehicles can survive severe weather conditions and resume operations after the weather has passed. In terms of the severity of weather in which the airship can actually operate, the mid-1950 demonstrations by the Navy and their conclusions are certainly of interest.

In 1954, the Office of Naval Research assigned to the Naval Air Development Unit at South Weymouth, Mass., a **project to demonstrate the all-weather capability of the non-rigid airship**. Technical guidance and instrumentation were furnished by the National Advisory Committee for Aeronautics. During the first two years, nine flights were made in weather conducive to icing, snow, and other winter weather conditions.

On the last two flights, **ice accumulation** was recorded. One flight ascended and descended through a freezing rain and accumulated an estimated 1361 kg (3000 lb) of clear ice. **At no time was the control or flight characteristics of the airship changed**, other than the static heaviness, and the crew became psychologically adapted to flying in icing conditions. The airship was a Model ZPG-2, with an envelope volume of 27,612 cu m (975,000 cu ft) a length

of 104.55 m (343 ft) and a maximum diameter of 22.68 m (75.4 ft).

As a result of this project, several minor modifications were made in the airship used for the experiment, such as adding heating tapes to various valves and drains, heat for the pitot head, protective coating for the upper surfaces of the lower fins (an X arrangement), flush antennas, electrically heated propellers, and rudder and elevator horn pulley covers.

The third year's operations consisted of three phases, as follows:—

Phase I — a weekly flight of approximately 30 hours when the worst weather was predicted.

Phase II — a joint operation with a squadron from Lakehurst N.J., to man a specific station for 10 days during January when the worst winter weather might be expected.

Phase III — a long simulated barrier flight from South Weymouth over the North Atlantic to another base along the eastern seaboard.

During Phase I, seven flights were made, during which icing conditions were encountered on two occasions.

Phase II was scheduled from January 14 to 25, and the worst East Coast weather in many years was experienced; icing, fog, sleet, snow, rain and gale winds were encountered. The station was **manned continuously for 240 hours** using five airships. Eleven flights were made. The 'icing' ship accounted for five of the flights and on one flight spent 30 hours in icing conditions. Even though field conditions at South Weymouth were rigorous, the operations were conducted off a mobile mast; the airship was hangared only once for a regular maintenance check.

Phase III began on schedule on March 15. After successfully completing the assigned mission of a 60-hour patrol across the North Atlantic, the airship continued to circumnavigate the Atlantic without refuelling. It landed at Key West, Fla., after **11 days in the air and covered almost 1.34×10^7 m (8300 mi)**.

The conclusions of the official report on Phase II were:

- "Airship ground handling operations can be accomplished in virtually all weather conditions."
- "Routine ground maintenance can be accomplished under extremely adverse weather conditions."
- "Rime ice accretion at normal airship operating altitudes is not considered a deterrent to proper stationkeeping for protracted periods of time."
- "Maintaining a continuous barrier station over the Atlantic Ocean appears to be feasible under all weather conditions."

Wind: Wind is the most important weather element in airship operations. However, while high winds in themselves are no threat to the structural safety of an airship in flight, historically its limited speed necessitated that high head

winds be avoided by flying the pressure patterns. This technique has been demonstrated in countless instances dating back to the World War I German operations. Ground operations can be delayed, particularly when the winds are turbulent. The airship's ability to remain aloft with minimal fuel consumption and thereby delay a landing until the unfavourable period passes, was a demonstrated operational technique. When the fuel supply was low, the Navy relied on in-flight pickup of fuel in containers while the airship was hovering or flying at low ground speed.

Airships can be masted out in winds up to 46.25 m/s, or 90 knots, (Reference 28) and can be docked and undocked in down hangar winds up to 21.03 m/s (41 knots). As the wind direction approaches 90 deg to the axis of the hangar, the maximum velocity for docking operations approaches 10.28 m/s (20 knots).

Thunderstorms are typically avoided; however, experienced pilots have shown during hundreds of flights in thunderstorms that properly designed airships can safely fly in this environment. Modern weather forecasting, communications, and constant weather updates along with onboard radar would ensure an airship being able to avoid a thunderstorm. Goodyear advertising airships use onboard radar for such purposes.

Snow: Perhaps the most troublesome situation for a moored airship is when a heavy, wet snow of several inches accumulates on the hull and fin topsides. In several instances, the Navy has flushed the snow off with a fire hose. Some promising experiments have been conducted in which the envelope helium was heated to melt the topside snow, but the Navy did not think it necessary to make this operational. Wet snow usually occurs near the ground and can be avoided in flight by a modest increase in altitude.

Lightning: Lightning has never caused concern with a helium-inflated airship. Although all aircraft attempt to avoid lightning areas because of the turbulence that usually exists, there has been evidence of strikes on airship cars, fins and topside radomes but none that caused detectable damage to an envelope of a non-rigid. There have been reports of small holes in the outer coverings of rigid airships where charges hit the metal structure beneath, but the structure was not damaged.

Helium Supply

Helium is one of the rare gases being a naturally-occurring inert element. It occurs in minute quantities in the atmosphere and also dissolved in sea water, but in neither of these cases is recovery an economic proposition. The main natural source is from gas wells where it appears as an associated gas but in only some of these wells is it found in sufficiently large quantities to be economically viable. Most commercial supplies of helium come from the United States

whilst a lesser supply comes from fields in Poland (there is no recovery from the North Sea wells). There is no difficulty in obtaining helium in most parts of the world.

The largest user is the diving industry, where helium is mixed with oxygen to provide a breathable atmosphere for long periods in deep conditions. Other industrial usages are as an inert working fluid in a variety of engineering applications, and in liquid form for the production of very low temperatures. And of course, as a lifting agent for balloons and airships, where it has largely replaced Hydrogen as the lift medium, the former gas being inflammable.

Helium is imported into the United Kingdom and other non-source countries in large liquid Nitrogen shielded, liquid Helium containers. It is delivered to end-users in banks of cylinders under high pressure (200 bars) either as a 'Kelly' — a bank of large cylinders twelve metres long (containing a total of a 5,000 m³ charge), or in racks of cylinders of 9m³ each (the racks containing multiples of sixteen cylinders). One 'Kelly' provides a complete charge for an AD 500 airship. The cost, at 1979 prices, varied from £40.00 to £50.00 per 1,000 ft³ for large quantities, with a cost of about £70.00 per 1,000 ft³ if bought in small quantities by the bottle for 'topping-up' purposes.

Helium is the ideal airship lift gas being an entirely non-flammable, non-poisonous gas, with a lift of approximately 65 lbs per 1,000 cubic foot. In its pure form as used in airships it will not support life and therefore an air supply is required for any personnel who have cause to enter the envelope whilst inflated. Filling the airship is a straightforward operation, requiring however a special hose and end-fittings. Inflation can be completed in under twelve hours on a Skyship 500.

Purification and Top-Up

Helium in an airship loses purity by becoming contaminated with air in spite of the fact that the lift gas is always maintained at a slight positive pressure. The air permeates into the envelope through the skin at a rate of approximately one quarter of that at which Helium permeates out. If the Helium loss is 20% per annum, replaced by a periodic 'topping-up' process, then there will be a 5% air contamination resulting in a 5% loss in lift. In normal terms purification is required when purity levels in the envelope drop below 94-95% and would be required on a once per annum basis.

The purification process itself is straightforward; the gas is taken from the lowest part of the envelope, passed through the purifier and fed back in at the front of the envelope. In due course most of the impurities are removed.

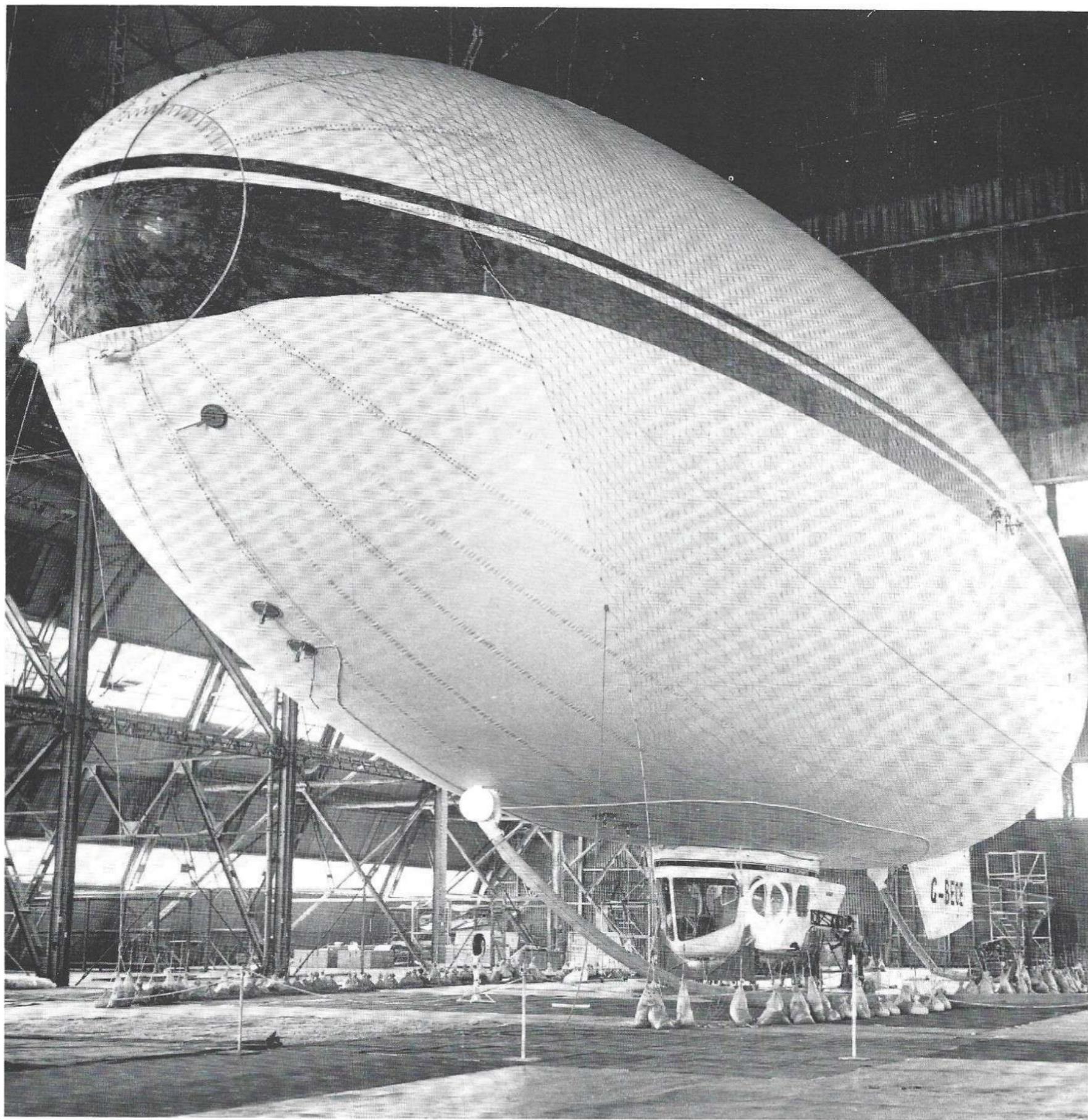
There are two main types of purifiers commercially available, both requiring compression of the gas to 200 bar.

The first employs cryopurification. This relies on the effect that a gas cooled below its critical temperature will liquify when the pressure is above a minimum value. Helium has an extremely low critical temperature and will therefore remain a gas, while oxygen, nitrogen, CO, methane etc. are liquified and can be decanted from a suitable separator. Liquid nitrogen is used as a refrigerant. Water and CO₂ are extracted before the low temperature purification stage. The second type relies on a series of absorption, filter columns removing respectively water, CO₂ and air. An oxidiser bed converts CO to CO₂ prior to the gas being passed through the CO₂ column. In the United Kingdom the Heliux 120 cryopurification system can be supplied by the British Oxygen Company and the absorption system

by the High Pressure Air and Gas Equipment Division of Williams and Jones (Engineers) Limited.

Both types of machines are primarily designed for the recovery of diving gases and are readily available for hire as required. But for air-ship operations it should be possible to obtain a simplified system as for airship operations it is necessary to remove only water and air.

There is an unavoidable loss of Helium during the purification cycle. In the cryogenic system the discharged liquid impurities contain a certain amount of dissolved Helium and the filter columns of the alternative system require periodic purging, thus losing the Helium they contain at the time. The airship will require to be topped up at the end of the purification process.



The Skyship 500 in final stages of assembly