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THE AEROSPACE DEVELOPMENTS CONCEPT

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ABSTRACT: For the last three years, Aerospace Developments have been under contract to Shell International Gas. Their brief has been to assess the viability of using airships for the transport of natural gas, and to complete the initial design of such a system, the airship and its associated subsystems together with a continuing economic analysis of the project. Investigations, on a funded basis, have also been carried out into the application of the airship for A.S.W. and A.E.W. uses, and a further investigation into the transport of mineral concentrates for an Australasian mining concern has recently been completed.

INTRODUCTION

The present day method of transportation for Natural Gas has several major disadvantages. It is a high cost operation, which demands considerable investment both in surface vessels and in fixed ground plant. Briefly, the system in use at present is as follows:

1. The gas is piped from the well (or wells) to a central liquefaction plant. This is usually located at, or near, the coast.

2. From the liquefaction plant the gas is piped aboard liquid Natural Gas (L.N.G.) carriers. It is stored at - 161 °C throughout the voyage.

3. On arrival at the home port the gas is stored in a liquefied state, and is then

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re-gasified and passed into gaseous pipe storage for subsequent distribution to consumers.

Both the tankers and the liquefaction plant are enormously expensive. A large L.N.G. carrier costs, at present day prices, in excess of $100 million, and a large liquefaction plant with its associated tankers, demands an investment approaching $2 billion. Much of this investment has to be concentrated in ground plant located in areas of high political instability (Algeria, Libya, etc.). These assets may be sequestered by the parent countries at any time, and without any notice. The liquefaction plant consumes approximately 20% of the energy it produces in the liquefaction process and the scale of investment required means that a very large market must be assured before any deliveries can be contemplated. Small wonder then that the need for a cheaper, less politically susceptible, more flexible system has been recognised for a long time.

THE AIRSHIP AS A GAS CARRIER

Because the gas methane (the prime constituent of Natural Gas) is lighter than air, with a lifting force of approximately 45 lbs/1000 cubic feet, there is an obvious attraction in using a Lighter Than Air craft for transporting the material, since the payload will also provide the ascensional force (at least on the outward voyage). Even if the gas is assumed to contain its maximum possible concentration of contaminants (sulphur, CO_2 etc.) it is still no heavier than air. The main problem centred around the fact that, because the volume of the gas is increased in the ratio of 645:1 over its liquefied state when it is expanded to atmospheric pressure and ambient temperature, and because hoop stress considerations demand that the gas be carried under these conditions in order to carry a sensible amount of gas, the craft has to be a very large one indeed.

CHOICE OF TYPE OF CRAFT

An initial examination of the economic considerations, together with the knowledge that, within the bounds of technical competence (and certain construction costs) "The Bigger the Better" at least from the point of view of ultimate costs/cubic feet, led to the requirement for a craft approaching 100,000,000 cubic feet, which, in dimensional terms, is very large indeed!

For craft even approaching this size there appears to be only one answer, the Supported Monocoque type of construction. Supported because at some point in the journey the gas will have to be removed from the craft, and therefore gas pressure will not be available to stabilize the outer skin, and Monocoque because this is the only type of construction that is sufficiently amenable to the present day demands of quality control and rapid assembly whilst retaining adequate margins of strength. The "Zeppelin" type of construction is often still held to be the best type of construction, and the reasons for this advocacy are very difficult to ascertain. A fairly rudimentary analysis of craft of this type will show that this system of construction was inadequate to meet the demands on strength grounds alone for the sort of annual utilisations that must be achieved in order to make the system profitable. Even when used for the sort of craft that were constructed forty years ago, the rigid girder construction was not safe enough, by modern standards, and was demanding in terms of in-flight maintenance, and yet many people are still advocating the use of such construction methods for craft far larger than those of old, and they are intending to use these craft in applications far more demanding than any that have been required in the past. There is a great deal of evidence to suggest that even such staunch advocates of conventional airship practise as Charles Burgess were convinced of the need for a "stressed skin" type structure. Had the initial design for such an airship resulted in a much smaller size of craft, then it is possible that a different approach might have been adopted (probably an internally supported "BLIMP") but for a craft of the size required, we are confident that the type of construction system adopted represents an optimum.

THE CRAFT ITSELF (Figure 1)

As may be seen from the illustration, the craft represents a fairly conventional approach to airship aerodynamics. It has a length/diameter ratio of 6:1 which represents a reasonable compromise between controllability and cost of materials (it is interesting to note that recent economic analyses show that, as far as material costs are concerned, there are advantages in reducing the length/diameter ratio to as little as 2:1. These analyses do not take account however of the control and mooring difficulties associated with craft of this type.).

The craft itself is approximately 1,800 feet in length with a maximum diameter of 300 feet. This entails considerable difficulties as records a construction facility, and the methods used to overcome this problem are described later in this report.

The use of a considerable degree of cylindric midship section is a sensible one, there is little, if any, advantage in resistance terms in adopting a fully streamlined form, and the advantages in terms of jigging and construction costs militate heavily in favour of the type of design which has been adopted.

THE BASIC SYSTEM OF CONSTRUCTION (Figure 2)

The primary unit of construction is the "unitary panel" which is 20 feet in length by 10 feet in height. Since there is a very definite need to conserve weight, and because the primary mode of failure is in compressive buckling of the top skin, it was decided to develop a material which combined the best of both worlds. It was decided to utilise a "sandwich" form of construction, using stainless steel outer and inner skins, which are adequate for the tensile loads that will be imposed, together with a Keflar fibre inner core, the purpose of which is to increase the "I" value of the matrix. The result is a material which combines light weight with exceptional strength albeit at a fairly high unit cost. The decision to use a polyamide fibre rather than a metal such as aluminium as the infill for the matrix was based on two major considerations.

1. The need to obviate, as much as possible, the risk of corrosion due to the ingress of water under the outer skin.

2. The necessity to avoid the possibility of electroxytic action between the infill and the outer skins.

In order to minimize the weight of the infill, a honeycomb type of structure has been used for stabilizing the outer and inner skins.

The basic method of the assembly is outlined in Figure 2. Storage is provided for the steel, the honeycomb and the epoxy type adhesive (refrigerated). The honeycomb panels are pre-profiled to an accurate curvature, and the panels are then bonded to the outer and inner skin by an autocalve process, the completed panel then moves to a final finishing bay (edge profiling etc.) before being passed to a completed materials stockyard. This system enables the latest methods of quality control (ultrasonics, radiation, backscatter etc.) to be employed to ensure continuously high standards of material integrity. When one considers that one airship alone of this size will require approximately $1\frac{1}{2}$ million square feet of honeycomb and 3 million square feet of skin material, the necessity for proper quality control will be apparent.

A comprehensive stress analysis, based on "finite element techniques" developed by Professor Argyris, has been carried out on the craft, together with an analysis of likely gust loads that will be imposed on the craft during in service operations, and the results indicate than an overall safety factor approaching 3 is likely to be achieved. (This analysis takes account of the maximum aerodynamic loads likely to be encountered.) These safety factors are considerably in excess of those required for current civil aircraft applications, and at r well for future development.

POWERING REQUIREMENTS FOR AIRSHIPS

As part of the current programme, a comprehensive examination of the powering requirement has been carried out. This programme, carried out under the supervision of Professor Young of Queen Mary College, has entailed a detailed evaluation of the boundary layer conditions obtaining around an airship of the size contemplated. There is an obvious advantage in using a power plant that has already been developed, even though the lower speed of advance of the airship when compared to conventional aircraft may reduce the efficiency of the unit. It is desirable to keep the number of power units to a minimum, in order to reduce the rumber and complexity of associated sub systems, and to ease problems concerned with cockpit control.

A summary of the powering requirements is given below.

Hull Volume 50 million cubic feet

Speed (m.p.h.)	S.H.P.
40.	951.
70.	4, 558.
100.	12, 246.
140.	33, 305.

Hull Volume 100 million cubic feet

Speed (m.p.h.)	S.H.P.
40.	1, 433.
70.	6, 906.
100.	19, 265.
140.	50, 230.

It can be readily appreciated that the powering disbenefit from increased speed is far larger than that imposed by increasing size. Since the economic cruise speed for the craft lies in the range 90 - 100 kts. it is possible to use existing power plants for the smaller craft. In the prototype programme two proteous engines, driving Hovercraft type (i.e. large blade area) prop sets will be adequate. The proteous, which will be of the marine type, has accumulated over 500, 000 operative hours, has a high mean time between overhauls, and is already available shafted to a B.H.Y. type Hovercraft propeilor. For the larger ships it is possible to utilize a multiple (4 or 6) proteous arrangement, but it is rather more likely that an exhaust turbine, connected to a high by-pass fan unit such as the RB-211 would represent a more sensible approach. In the gas carrying application the craft would use a certain amount of gas to fuel the engines, and this further reduces the maintenance requirements.

It is not intended to install these engines in any type of vectoring mounting, this is usually a much more expensive exercise than most people imagine, and often entails major redesign of the power plant itself. As may be seen from the first illustration, the engine units are "podded", this is not an attempt to improve propellor efficiency, but rather an effort to reduce blade tip noise. In the prototype craft it will be possible to mount the engines above the wing section, and to use the wing to further improve the noise attenuation characteristics of the craft.

Because of the thickness of the fin root, it is possible to provide access to the engine pods in flight. It is unlikely, however, that licensing authorities would look kindly on anything other than emergency repairs being carried out whilst the craft is in flight. All electronic and mechanical interfaces have been designed to be as modular as possible, and any major servicing would be carried out on a replacement basis.

Attention has also been focussed on the decision to place the engines on the tail surfaces. It is pointed out (correctly) that this entails an increase in the loading on the tail surfaces. The weight penalty, at least for a gas-turbine engine is, however, small and the control surfaces have to be designed to absorb high aerodynamic forces anyway. In addition, placing the engines at the tail has the following major advantages:

1. The engines are installed well clear of the boundary layer, thus there is little boundary layer interraction, with consequent power savings.

2. When fully pitchable propellers are fitted, the transverse separation of the engines enables a high turning moment to be applied, even at very slow airspeeds, this is particularly useful when approaching or leaving the mast.

3. Because the power units are situated at the mid height of the elevators, rather than on the underside of the hull (common practice on many early airships) there is far less chance of the engine being driven through the hull and into the methane gas in the event of a grounding.

THE BUILDING FACILITY FOR THE CRAFT

One of the major cost areas in the development of this craft, will undoubtedly be the provision of a suitable facility within which the airship may be built. There are those who advocate building the airship in the open, using everything from a roofed over clay pit to a lake, or who suggest that by using turntables etc. a large airship may be constructed without any protection from the elements. This we have always regarded as fanciful. Although the prototype craft are sized to fit inside the facilities still in existence in the U.K., the full scale ships will require a shed some 2,000 feet in length by 400 feet high. Comparative studies of conventional and inflatable structures, which have been commissioned both in the U.S.A. and the U.K. have resulted in the decision to use an air stabilized structure, in which the prime loads are taken by a supporting steelwork and cable system, with inflation being used to stabilize the building against gust loads. A ground plan, showing the existing sheds at Cardington, England, together with the new "super shed" superimposed upon them, is shown in Figure 3. The total cost of such a facility is estimated to be approximately $40 million at present day prices.

GASSING AND DE-GASSING THE SHIP

The ship will almost certainly be gassed through a fairly conventional "Stub" type tubular mast. The gas, fed in through a central connection, is led to individual compartments by four "Box Keels" at 90° to each other within the ship. A "Top Hat" membrane system is used to keep air and gas separate within the craft. At the discharge terminal the gas is forced back through the box keels by purging the ship with a carrier gas.On the other side of the membrane, the gas is passed to ground storage for future distribution. Various systems for returning the craft to the gas field have been under consideration, and the version shown uses an internal helium annulus to provide sufficient buoyancy to lift the craft in the "light ship" condition, the excess buoyancy being counteracted by ballast being taken aboard.

THE PROTOTYPE PROGRAMME

It is regarded as being impossible to construct a full size craft without a comprehensive prototype programme. In addition to a large number of static rigs, a series of craft ranging from 2 million - 30 million cubic feet are intended to be built before work on the 100 million cubic feet ship can commence. These craft will be built using the same techniques and panel sizes intended for the fleet size ships, in order to optimize the assembly techniques and to provide feedback operational information. Because of this, these craft will not be as efficient in terms of their payload/total lift ratio as vessels built by alternative means, nevertheless, these craft still have enough lift to provide a useful payload and illustration 4 shows the 8 million cubic feet ship in an anti submarine role.

CONCLUSION

The work being carried out for Shell is part of an on going process. All being well it is hoped to complete the construction of a prototype craft by the beginning of 1979, and for a full size craft to be operational by 1984. This exercise is by no means a low key area of financial activity, precise costs are classified by Shell, and indeed are as yet not finalized in many areas. But a unit cost of $60 million/ship may confidently be expected. It has been the purpose of this necessarily brief paper to emphasize the fact that at least one major industrial company has seen fit to initiate, and to continue to support, on a significant financial scale, a thorough investigation into the possibility of utilising Lighter Than Air craft on a major scale. It would perhaps be pertinent to add that due to obvious considerations of commercial confidentiality much of the information given has necessarily been of a superficial nature. Should more detailed information on the project be required, it is respectfully suggested that initial approaches should be made to Shell International Gas themselves.

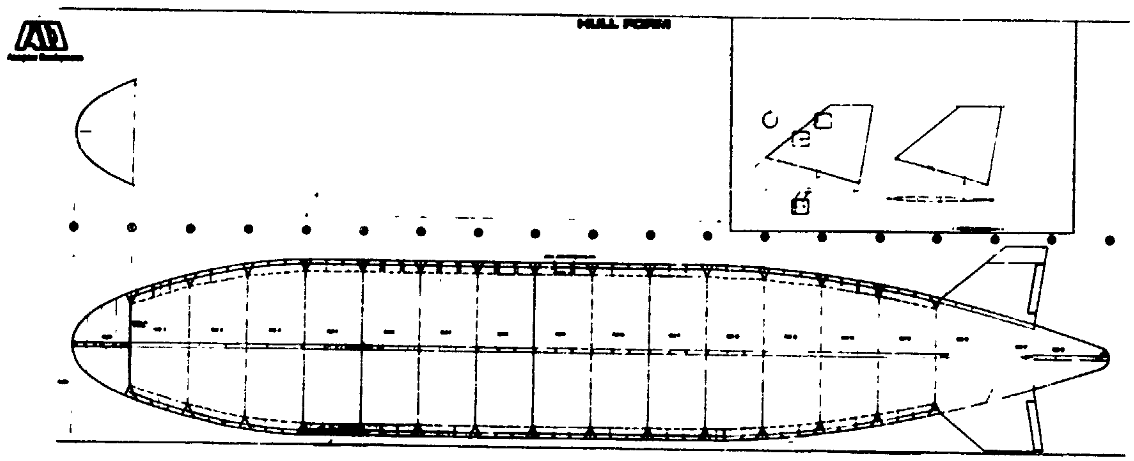

Figure 1

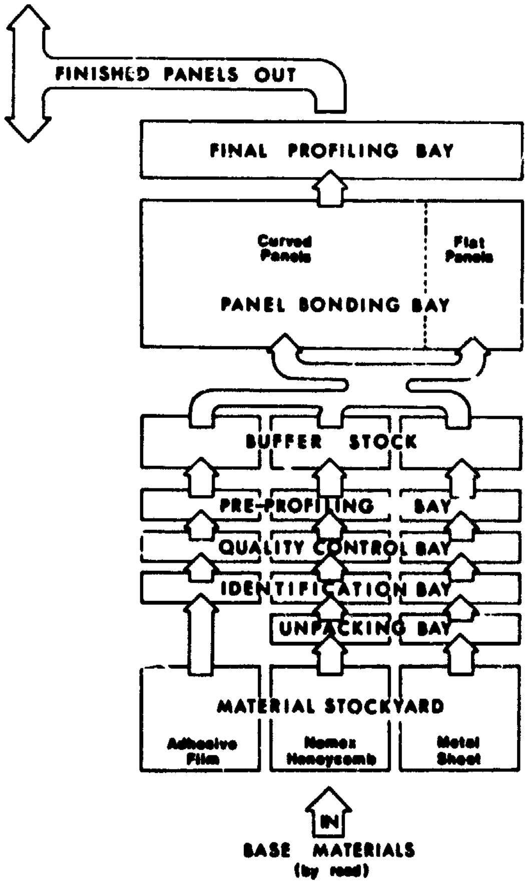

Figure 2

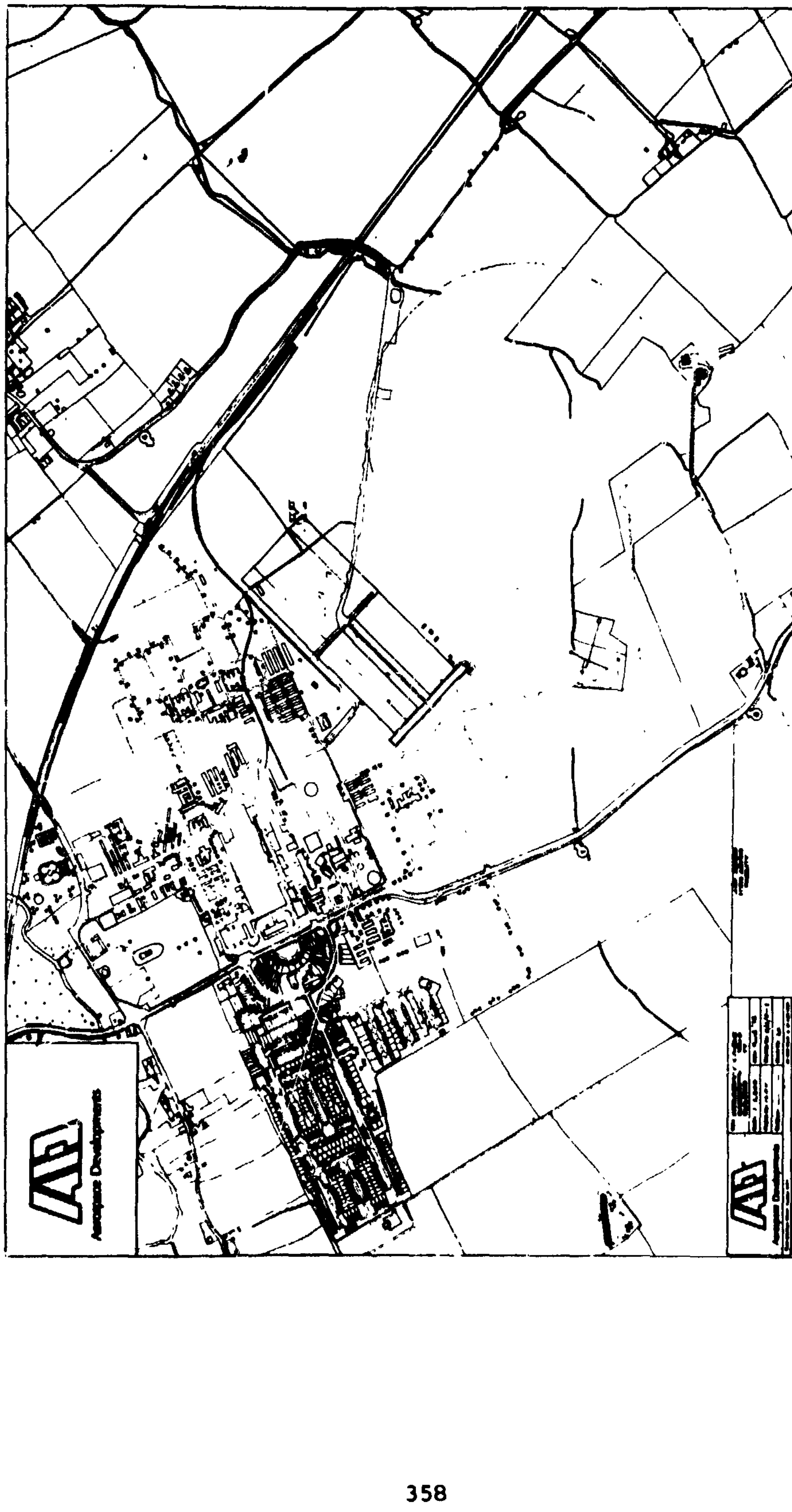

Figure 3