METHOD FOR TRANSPORTING
IMPELLENT GASES

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ABSTRACT: The described system DAL comprises a method and a device for transportation of buoyant impellent gases, without the need for expensive pipes and liquid tankers. The gas is self air-lifted from its source to a consignment point by means of voluminous, light, hollow bodies. Upon release of the gas at the consignment point, the bodies are filled with another cheap buoyant gas (steam or heated air) for the return trip to the source. In both directions substantial quantities of supplementary freight goods can be transported. Requirements and advantages are presented.

THE PROBLEM AND ITS SOLUTION CONCEPT

The Situation

More than 90 % of the presently known finds of natural gas can not yet be used economically as supplies of energy. Annually, billions of cubic meters of natural gas are being burned off at the heads of oil wells. Systematic exploitation and utilization of natural gas fields is by no means fully developed.

Conventional Transport Systems

Contrary to the situation that prevails in the case of transporting oil, pipelines and tankers are not economical for transporting natural gas and must therefore be seen as intermediate solutions. Investments

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for both these modes are extraordinarily high. Even an interconnected system of tankers and pipelines is not flexible enough. Moreover the tanker mode requires refrigeration (-258°F) and loading and unloading while the gas is liquid. Liquefaction cost approximately $ 8 per 1000 norm cubic meters (Nm^3). Thus pipeline and tanker are not economically optimal solutions for the transportation of natural gas.

The Solution Principle

Reflections on a better solution of this problem center on a specific property of natural gas: it is lighter than air. Compared to the earth atmosphere, natural gas has a much lower specific weight which thus makes it possible to transport it through the air in large containers which are able to fly. At the place of delivery of the natural gas, these containers can be filled with another light gas that is cheaply and abundantly available there, in order to make the flight return to the natural gas source. Both steam and hot air are possibilities here.

Special Requirements and Possibilities for Realization

The weight of the containers plus power plant and thrusters, with the necessary accessories, must be less than the lift that is generated by a load of steam or hot air. A lightweight and heat insulated sandwich skin for the containers will be required to guarantee the necessary temperature stability for the steam or other gases. To supply the necessary heat to keep the temperature at prescribed levels, the heat of the engine exhausts is used. The steam or hot air is forced out by natural gas in the loading process. Mixing of the gases is prevented by moveable separating walls in the individual cells.

Comments

The most significant advantages of gas transport by "lighter than air ships" compared to pipelines have been indicated in an expert opinion from Professor Alfred Walz (Technical University of Berlin, Institute for Supersonic Flow). Also Mr. Miles Sonstegaard of the University of Arkansas has determined, for his system, that the transportation of liquid natural gas (LNG) in "lighter than air ships" is decisively more advantageous than fixed pipeline systems.

Patents and Acronym

Detailed construction considerations and calculations form the basis for patent applications in over 40 countries, some of which have already been granted. These patent applications cover construction and mode of operation of the DAL transport system, which requires no hanger or special landing facility. The acronym DAL represents the german conceptual description
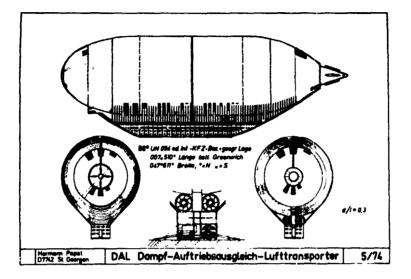
        "Dampf/Erdgas Austausch Lufttransporter"
        (Steam/Natural Gas Exchange Cargo Airship)

In the following section, the concept described above is explained in greater detail via an example of typical airship of the kind mentioned before. The explanation indicates further advantageous construction features.
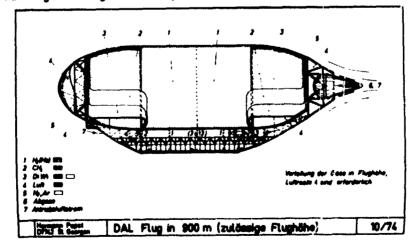
Structure Characteristics

The natural gas air transport system DAL is designed around large, dynamically stable self propelled flying bodies. It is technically

feasible, for example, to consider a ship of 364 m (1100 ft) length and 104 m (317 ft) diameter with a volume of 2,300,000 cubic meters (63,000,000 cubic feet) and which consists of a pressurized skin made of fiber-reinforced plastics. A rigid integrated cabin structure and keel, 130 meters long, 26 meters wide, and 18 meters high, is attached to the pressurized balloon via circumferential bands. The cabin houses the crew, passengers, freight containers, all equipment necessary for driving the vessel, and approximately 150 flexible tanks for ballast water or liquid freight (e. g. oil). In the interior of the airship, flexible bulkheads (dividing walls) are installed to allow separation of the total space into gas compartments of variable size. Figure 10/74 shows the distribution of different gases within the interior of the ship during a single transport journey.

Technical Data

The average speed is planned to be 150 km/hour at 1000 m (3000 ft)
altitude. The required power of the engine is assumed to be 8000 hp.
The volume of natural gas that can be transported over the distance
North-Slope New York (that is 5250 kilometers) for instance is about
2,1 million cubic meters of methane, assuming 90 % of full load and
4 % fuel consumption. The extra available cargo space when heating
the methane to 100°C is about 1200 tons. The action radius with full
load is only limited by economics. This means that circumnavigation of
the earth without intermediate stops is feasible (possible). On the
flight back to the source of the natural gas the payload with steam as
buoyant gas is about 800 tons, with hot air of 100°C, 200 tons, and
with preponderantly hydrogen buoyant gas at 100°C, 2000 tons.
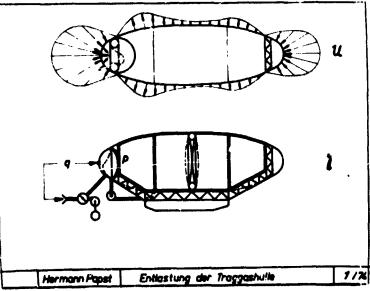
Propulsion and Steering Mechanism

Motive power is produced by a thruster with a ring slot at the stern
of the airship. Steering of the jet stream is performed by excentrical
regulation of the inner cone of the thruster. Thus an effective manue-
vering capability at low air speeds and low noise levels is provided.

Double-Walled Skin

For this concept, the skin of the airship body is the decisive compo-
nent. It must be light and strong, gas tight and heat insulating,
aging resistant and weather resistant.

Weight and Strength - The skin must carry the aerodynamic loads during
flight. The external pressure distribution on the flying body (fig.1/74u
shows, that significantly less strength is sufficient over the large
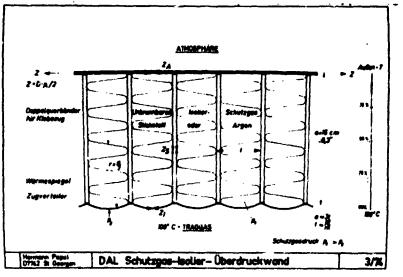surface area of the middle part.

The gas pressure P can be reduced to a quarter of the 7 stream
pressure Q.

| Hermann Papst | Entlastung der Traggashülle | 1/74 |

Use of small spherical cells of higher strength in the bow and stern,
f.i. realized by means of the highly pressurized tube ring element

shown on the left in fig.$\mathcal{U}$, drastically reduces the skin weight via
such divisions of the total skin surface. Fig.$\mathcal{l}$ indicates alternative
solution. Foil and polyester   fabric are intended as skin mate-
rials for a maximum strength to weight ratio.

Temperature Insulation - This tensile fiber polyester fabric hull
consists of two separate walls with a heat insulating protective
gas maintained under pressure in between, thus making it temperature
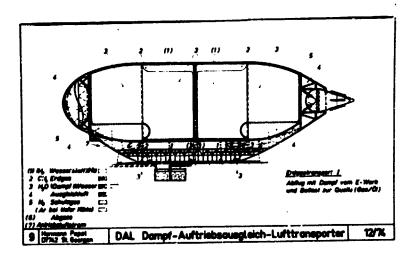resistant to 100° C.

The double-walled skin is pumped full with nitrogen or argon and is
maintained unter a permanent pressure of approximately 20 Torr. For
the wall, about 16 centimeters (6 inches) thick, there exists a heat-
loss value of approximately 20 Kcal/m^2h, i. e., approximately 240 Norm-
m^3/h of natural gas is required to cover the heat loss for the above-
mentioned large flying body with 96,000 m^2 surface area. This is about
8,000 m^3 or .4 % of the natural gas volume for a flight distance of
5,000 km and a cruising speed of 150 km/h. The neat of the exhaust
gases of the motors can cover this heat loss with considerable reserve.
The structure of the double walled skin is characterized by the arrange-
ment of tensile loaded bands between the high strength exterior wall
and the interior wall of the skin. Between these tensile banos, folded
zig zag form aluminium vapor plated foil serves to substantially pre-
vent heat radiation. The skin walls are completely covered inside as
well as outside with aluminium foil, so that diffusion is prevented.
The aluminium is, in turn, covered with a fluoride resin or similar
water repellant material. The protective gas is completely dry. Also
light has no effect on the skin material. Thus the greatest possible
resistance to aging is provided. The skin covering is also immune to
radiation, lightning, rain, and ice formation.

NATURAL GAS SHIPMENT

The medium that provides the lift for the vessel on the way to the na-
tural gas source is either hot air or steam. Figure 12/7 shows the DAL
filled with steam shortly before departure to the natural gas source.
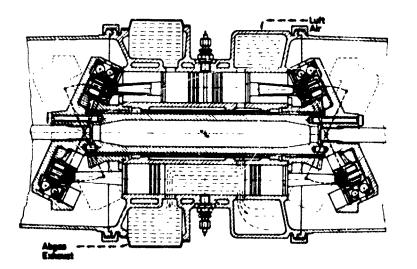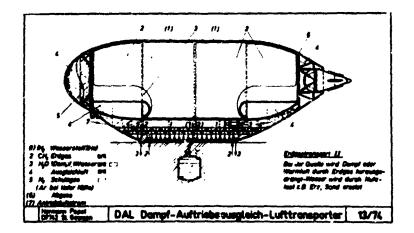
The problem of heat loss is solved technically via regulated additions of heat from the exhaust heat of the motors. The exhaust heat from the axial piston, natural-gas-driven motors keeps the lifting gas at 100°C via a closed steam circulation. Axial piston motors with novel swash-plate power plant are being developed by Papst-Motoren KG.

Because 400 tons of payload are attainable with warm air filling, it is possible to carry even the heaviest drilling rigs, together with the necessary equipment and personnel, directly into regions where oil and natural gas are found, even if they are difficult to reach by way of surface transportation (arctic lands, deserts, continental shelves, tundra, dunes).

Figure 13/74 indicates how steam or warm air is forced out by pumped-in natural gas at the gas source.

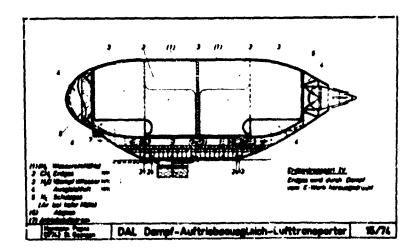DAL Dampf-Auftriebsausgleich-Lufttransporter | 13/74

At this point nearly the entire body has been filled with natural gas.
Only small leftover spaces are available for vapor and warm air to
balance lift. This is the departure condition at the gas source. The
total lift is 1683 tons, if a bouyant volume of 2,3 million cubic me-
ters is assumed, divided as follows:

$$2\ 100\ 000\ m^3\ \text{natural gas}$$
$$200\ 000\ m^3\ \text{balancing air}$$

All gases are heated to $100^\circ C$. For an assumed unloaded weight of the
airship of 570 tons including keel frame, skin, crew, passengers,
supplies, and auxilliary ballast water, a lift of 1,100 tons is avai-
lable for payload, e. g., LNG or oil. At departure from the natural gas
source, the total lift is composed of:

$$1\ 613\ \text{tons natural gas}$$
$$70\ \text{tons warm balancing air}$$

After traveling the example distance of 5 250 km the natural gas compo-
nent is reduced to 1565 tons. This equalized by a steam lifting compo-
nent of 53 tons and a reduction of the air lifting component to 65 tons.
The total departure lift of 1,683 tons is thus maintained.

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After arrival at the delivery destination, steam is pumped into the cells intended for it and the natural gas is thereby forced out. Steam is abundantly available as a byproduct at electric power plants. Thus the cycle is completed! Landing is achieved by setting the DAL against the wind, driving to maintain position, and descending. After landing, the ship is held on the ground via suction. The keel frame is kept airtight against the ground by an inflated tube skirt which encircles the bottom perimeter. Unevenness up to one meter can be equalized by this means. The landing surface can thus lie near the gas source. Small auxilliary suction pumps reduce the pressure under the tube-skirt structure to approximately 300 mm water-column, so that the DAL can also be held fixed in storms with winds up to 150 km/h.

SAFETY CONSIDERATIONS

The life expectancies of the double sheath covering made of highly impact-resistant fiber-reinforced polyester and other plastics as well as the foil gaskets and the aluminium-foil protective covering are very large indeed. The protective gas between the double sheath in the absence of oxygen, moisture or light guarantees maximum lifetime. The danger of ignition of the natural gas is largely controlled by the pressurization of the heat insulated double-sheath with a non flammable gas (e.g. nitrogen). After a puncturing of the exterior wall the protective gas escapes and the neighboring bands and the inner wall attach themselves automatically to the outer wall, thereby sealing the leak. The strength of the outer skin (about 40 000 kp/m) and the seams is eight times the normal load during flight at full speed. The entire double sheath covering remains filled with gas during operation. Arrangement, control and checking of the power plant are based on the fail-safe principle. Even loss of 50 % of the power allows full maneuverability of the ship. The DAL may remain afloat for months without the engines running. Liquid fuel is not needed/used, i.e. higher safety.

COST AND ECONOMIC FEASIBILITY

One natural gas transport vessel with a capacity of 2,3 million cubic meters (63 million cubic feet) of natural gas and 1,200 tons of oil can be built today for about $ 20,000,000 if 50 units are to be manufactured. Cost of operation per year is estimated at $ 1,300,000. On 100 round trips, covering a distance of 5 250 km (3,260 miles) each, a heat equivalent of about 280,000 tons of oil can be transported. Comparing the cost of transportation by air shipment and by pipeline, you find at presumed 68 billions of cubic meter per year and a distance of 5,250 km a demand of 237 DALs. An investment of $ 20,000,000 per DAL means 7 cent per cubic meter transport capacity; out of which result about 0,7 cent per cubic meter gas as transport costs. These conditions will oy far not be reached with the pipeline mode. The costs of transporting for one barrel of gasoline would amount to $ 1,6 These cost figures could be reduced by hauling additional freight or passengers. About 1 % of the transported volume are used up for propulsion and buoyancy per 1 000 kms.

For loading and unloading freight, the bottom of the cabin of the DAL contains special containers for water, capable of holding up to 2,420 tons. Water is pumped out while freight is taken on and the reverse takes place when freight is unloaded. For an exchange of 110 tons of

load the pumping costs amount to approximately 50 cents.
Loading and unloading would usually be done by this gradual process

The annual revenue from goods transported by one DAL of 364 m length
and 104 m diameter, assuming a 70% utilization of freight capacity
and 70% utilization in time, is illustrated in the following table:

Lift generated by	Net cargo capacity	$ Million
Steam	880 t	9.6
Natural Gas	1100 t	11.55
Hydrogen	2200 t	23.10

For 50 round trips over a Distance of 6,215 miles each, this cor-
responds to an annual mileage of 621,500 miles. (Base 3 cts/ton.mile)

SUMMARY

Compared to pipeline or pipeline sh p - pipeline systems of trans-
porting natural gas, the proposed natural gas air transport system
DAL shows the following advantages:

Independence from geographic and climatic hazards. One means of
transportation only for both land and sea routes, door-to-door
transportation even over great distances.

Independence from locally changing political situations. Quick
shifting to alternative soures maximum of flexibility.

Lover investments of reduced risk.

The possibility of large-scale coordination of supplying even re-
mote natural gas sources. Thus additional optimization and ratio-
nalization is feasible.

Lower cost for transporting natural gas via freight and passenger
revunue.

Even small finds will be economically attractive.

CONCLUSION

The DAL-Airship-System in principle can be used:

> for transportation of high volume and heavy goods

> in aero-crane applications

> for passenger transportation purposes with
> maximum comfort.

> for transporting impellent gases and thus puts
> a big question mark over natural-gas-pipeline
> systems.