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# A STUDY OF DIRIGIBLES FOR USE IN THE PERUVIAN SELVA CENTRAL REGION

NORMAN J. MAYER

MARCH, 1982

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# A STUDY OF DIRIGIBLES FOR USE IN THE PERUVIAN SELVA CENTRAL REGION

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SPECIALIST

LIGHTER-THAN-AIR RESEARCH

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HEADQUARTERS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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MARCH, 1982

## PREFACE

This report was prepared at the request of the Peruvian Ministry of Transportation by Mr. Norman Mayer, specialist for lighter-than-air research, National Aeronautics and Space Administration. Mr. Mayer's participation in this effort was based upon his international reputation as an acknowledged authority in the field of lighter-than-air vehicles. Mr. Mayer's association with the National Aeronautics and Space Administration does not necessarily imply endorsement of the conclusions and recommendations contained herein by the United States Government.

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## SUMMARY

The potential for dirigibles as transports in the Selva Central region of Peru was evaluated by means of a mission and economic analysis. Requirements for the mission and data on the Selva Central region were provided by the Office of Economic Studies of the Ministry of Transport and Communications in Peru.

A total requirement to transport over 19 million tons(t) of agricultural produce, lumber, and meat was projected by the year 2004. A primary route involving zones for loading and delivering this cargo was identified. The combination of tonnage and route distances requires the transport system to operate a total of over 400 million ton kilometers.

Although dirigibles are capable of short field operation, all existing airfields must be enlarged in width to allow for all conditions of wind and weather and to provide space for overnight mooring. A maintenance base and operations headquarters, complete with hangar and other service facilities would be required.

The quantities of cargo to be carried establish requirements for fleets of dirigibles of various sizes and capacities. Cargo capacities of 5-100 tons were identified. Fleet sizes up to 106 dirigibles (in 20 t capacities) would be required.

Dirigibles were assumed to be of the nonrigid type except in the 100 t category for which rigid characteristics were assumed.

A method of determining dirigible costs was developed. The values derived were then applied to an economic analysis to determine initial investment and operating costs. Those values were compared against airplane costs operating on the same routes. It was found that larger dirigibles of approximately 20 t capacities or higher could offer significant cost benefits over airplanes, provided cruise speeds were higher than 100km/hr. Dirigible costs, revenues, and economic benefits for a transport requirement of 100M ton km are summarized in Table A.

It is recommended that the information developed in this study be applied to other system studies. Various optimal options for dirigibles should be further explored and initial system and vehicle requirements should be developed.

## CHARACTERISTICS & COSTS OF DIRIGIBLES

| CARGO CAPACITY t | CHARACTERISTICS | | | | | UNIT COST OF DIRIGIBLE $M | TOTAL COST $M * | COST $/tkm | REVENUE COSTS $/tkm ** |
|---|---|---|---|---|---|---|---|---|---|
| | VOL. $m^3$ | LGTH m | DIAM. m | H.P. | VELOC. km/hr. | | | | |
| 10 | 27111 | 98.8 | 23.2 | 1436 | 136 | 4.920 | 62.578 | .63 | 1.04 |
| 20 | 47040 | 118.6 | 27.7 | 2072 | 136 | 7.714 | 49.160 | .49 | .82 |
| 40 | 84509 | 144.2 | 33.8 | 3094 | 118 | 13.027 | 43.999 | .40 | .73 |

* TO TRANSPORT 100M tkm

** WITH 0.75 LOAD FACTOR

TABLE A

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CONTENTS


SUMMARY . . . . . . . . . . . . . . . . . . . . . . . . . . . i

TABLE OF CONTENTS . . . . . . . . . . . . . . . . . . . . . iii

LIST OF FIGURES & TABLES . . . . . . . . . . . . . . . . . . v

INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . . 1

FUNDAMENTAL CONSIDERATIONS . . . . . . . . . . . . . . . . . 3

REQUIREMENTS . . . . . . . . . . . . . . . . . . . . . . . . 5

- CARGOES AND ROUTES . . . . . . . . . . . . . . . . . . . . 5
- AIRPORTS . . . . . . . . . . . . . . . . . . . . . . . . . 6
- WEATHER CONDITIONS . . . . . . . . . . . . . . . . . . . . 17
- GROUND FACILITIES . . . . . . . . . . . . . . . . . . . . 20
- HANDLING & MOORING . . . . . . . . . . . . . . . . . . . . 20
- OPERATIONS & MAINTENANCE BASE . . . . . . . . . . . . . . 21
- HANGARS . . . . . . . . . . . . . . . . . . . . . . . . . 28
- FUEL, OIL, LUBRICANTS . . . . . . . . . . . . . . . . . . 28
- BALLAST . . . . . . . . . . . . . . . . . . . . . . . . . 31
- HELIUM SUPPLY . . . . . . . . . . . . . . . . . . . . . . 31

DIRIGIBLE REQUIREMENTS . . . . . . . . . . . . . . . . . . . 32

DIRIGIBLE CHARACTERISTICS . . . . . . . . . . . . . . . . . 42

ECONOMICS . . . . . . . . . . . . . . . . . . . . . . . . . 48

- THE COST OF DIRIGIBLES . . . . . . . . . . . . . . . . . . 48
- TOTAL SYSTEM COSTS . . . . . . . . . . . . . . . . . . . . 57
- INITIAL INVESTMENT . . . . . . . . . . . . . . . . . . . . 57
- GROUND HANDLING . . . . . . . . . . . . . . . . . . . . . 58
- AIRPORT MODIFICATION . . . . . . . . . . . . . . . . . . . 58
- MOORING SITES . . . . . . . . . . . . . . . . . . . . . . 59
- HANGARS . . . . . . . . . . . . . . . . . . . . . . . . . 59
- MAINTENANCE & OPERATION BASE . . . . . . . . . . . . . . . 59
- OPERATING COSTS . . . . . . . . . . . . . . . . . . . . . 61
- INDIRECT OPERATING COSTS . . . . . . . . . . . . . . . . . 61
- DIRECT OPERATING COSTS . . . . . . . . . . . . . . . . . . 63
- COMPARISONS WITH OTHER AIRCRAFT . . . . . . . . . . . . . 72
- HIGHER SPEED AIRSHIPS . . . . . . . . . . . . . . . . . . 72

- LOWER FUEL CONSUMPTION . . . . . . . . . . . . . . . . . . . 73
- REVENUE COSTS . . . . . . . . . . . . . . . . . . . . . . . . 73
DISCUSSION . . . . . . . . . . . . . . . . . . . . . . . . . . 78
- REQUIREMENTS . . . . . . . . . . . . . . . . . . . . . . . . 78
- DIRIGIBLES . . . . . . . . . . . . . . . . . . . . . . . . . 80
- ECONOMICS . . . . . . . . . . . . . . . . . . . . . . . . . . 80
- INTANGIBLE BENEFITS . . . . . . . . . . . . . . . . . . . . . 81
- THE FUTURE . . . . . . . . . . . . . . . . . . . . . . . . . 82
CONCLUSIONS AND RECOMMENDATIONS . . . . . . . . . . . . . . . . 84
REFERENCES . . . . . . . . . . . . . . . . . . . . . . . . . . 86
APPENDIX A - PRINCIPLES OF AEROSTATICS . . . . . . . . . . . . A1
B - PROJECTED CARGOES . . . . . . . . . . . . . . . . B1
C - AIRFIELDS IN THE SELVA CENTRAL . . . . . . . C1

ORIGINAL PAGE IS
OF POOR QUALITY

## FIGURES & TABLES

FIGURES — PAGE


1- THE SELVA CENTRAL. . . . . . . . . . . . . . . . . . . . . . 2a,b
2- PRIMARY ROUTES FOR CARGO. . . . . . . . . . . . . . . . . . . 7
3- ANNUAL CARGOES ON PRIMARY ROUTES. . . . . . . . . . . . . .12
4- PUERTO BREU. . . . . . . . . . . . . . . . . . . . . . . . 13
5- MAZAMARI. . . . . . . . . . . . . . . . . . . . . . . . . .14
6- LANDING PROCEDURES. . . . . . . . . . . . . . . . . . . . .18
7- FIXED (STICK) MOORING MAST. . . . . . . . . . . . . . . . .22
8- CHARACTERISTICS OF FIXED (STICK) MAST. . . . . . . . . 23
9- MOBILE MOORING MAST. . . . . . . . . . . . . . . . . . . . 24
10- CHARACTERISTICS OF MOBILE MAST. . . . . . . . . . . . . .25
11- MECHANICAL MULE FOR GROUND HANDLING. . . . . . . . . . 26
12- SPECIFICATIONS FOR MECHANICAL MULES. . . . . . . . . . 27
13- VOLUME & H.P. REQUIRED FOR VARIOUS VELOCITIES. . . . 33
14- PRODUCTIVITY vs. VELOCITY. . . . . . . . . . . . . . . . 34
15- DIRIGIBLES REQUIRED FOR TRANSPORT DEMAND. . . . . . .40
16- COMPARISONS OF DIRIGIBLES FOR SELVA MISSION. . . . . 46
17- LOADING PROCEDURE FOR DIRIGIBLES. . . . . . . . . . . .47
18- COSTS OF AIRCRAFT (ALL TYPES). . . . . . . . . . . . . 50
19- COSTS OF AIRCRAFT (BY TYPES). . . . . . . . . . . . . .51
20- ENVELOPE COSTS. . . . . . . . . . . . . . . . . . . . . .54
21- COSTS OF AIRCRAFT STRUCTURES & SYSTEMS. . . . . . . . .55
22- PROPULSION SYSTEM COSTS. . . . . . . . . . . . . . . . . 56
23- INITIAL INVESTMENT COSTS. . . . . . . . . . . . . . . .62
24- INDIRECT OPERATING COSTS. . . . . . . . . . . . . . . .64
25- DIRECT OPERATING COSTS. . . . . . . . . . . . . . . . .66
26- TOTAL COSTS. . . . . . . . . . . . . . . . . . . . . . . 67
27- TOTAL COSTS FOR DIFFERENT RATES OF TRANSPORT DEMAND . . . . 68
28- HYBRID DIRIGIBLE COSTS. . . . . . . . . . . . . . . . .70
29- ANNUAL TOTAL COST- UNIT VS FLEET . . . . . . . . . . . .71
30- COST VS VELOCITY . . . . . . . . . . . . . . . . . . . 74

ORIGINAL PAGE IS
OF POOR QUALITY

TABLES


| TABLES | PAGE |
|---|---|
| 1- ANNUAL REQUIREMENTS FOR AGRICULTURAL CARGOES | 8 |
| 2- ANNUAL REQUIREMENTS FOR CARGOES OF LUMBER | 9 |
| 3- ANNUAL REQUIREMENTS FOR CARGOES OF MEAT | 10 |
| 4- ANNUAL REQUIREMENTS FOR ALL CARGOES | 11 |
| 5- AIRFIELD MODIFICATIONS REQUIRED FOR DIRIGIBLE OPERATION | 16 |
| 6- RATES OF RAINFALL IN SELVA CENTRAL | 19 |
| 7- MAINTENANCE BASE REQUIREMENTS | 29 |
| 8- REQUIREMENTS FOR MOORING AND HANGARS | 30 |
| 9- DATA ON AIRPLANES | 35 |
| 10- BLOCK TIME AND EQUIVALENT PRODUCTIVITY | 37 |
| 11- DIRIGIBLES REQUIRED FOR TRANSPORT DEMAND | 39 |
| 12- COMMON CHARACTERISTICS OF DIRIGIBLES FOR MISSION | 43 |
| 13- SPECIFIC CHARACTERISTICS OF DIRIGIBLES FOR MISSION | 44 |
| 14- DATA ON DIRIGIBLES - PRESENT & CONCEPTUAL | 49 |
| 15- COSTS OF FACILITIES FOR MAINTENANCE & OPERATIONS | 60 |
| 16- CHARACTERISTICS OF ALTERNATE DIRIGIBLES | 75 |
| 17- REVENUE COSTS | 77 |

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# INTRODUCTION

A study to evaluate dirigibles as transport vehicles in the Selva Central region of Peru was authorized by the Office of Economic Studies (O.E.E.) of the Ministry of Transportation and Communications, a department of the Government of Peru. The Selva Central reaches from the eastern side of the Sierra (Andes Mountains) to the border of Brazil and lies approximately between the latitudes of 8-12° S. Its general location and specific details are shown in Figures 1a & 1b. It is, for the most part, an undeveloped area of tropical jungle, densely forested. A major navigable river system flowing mainly north into the Amazon Basin provides surface transport in the western portion of the Selva. The government has broad plans to develop the Selva and exploit its natural resources, including timber from the forests and by extensive agricultural development. A major obstacle is the lack of a suitable system of transport.

A number of small settlements exist mostly along river banks. Many of these are equipped with landing fields suitable for light aircraft operation. This form of transport is the prime means for personal and light cargo movement. Air service to these sites is non-scheduled and is usually obtained by charter. A major improvement in transport capability would be possible if the airfields could be enlarged and hardened to accommodate heavier aircraft. However, this represents a major undertaking involving high costs and the difficulty of transporting construction materials, and not justified by present traffic levels or population densities.

The use of lighter-than-air vehicles (dirigibles) has been suggested as a means of obtaining a large increase in air transport capability without the attendant complication and expense of major airport improvement, and with possible lower operational costs over airplanes of similar capacity. This study was undertaken to evaluate this potential, identify suitable dirigible sizes and types and determine economic benefits.

The study was conducted in three phases:

I Acquisition of basic data and requirements

II Analysis of dirigible types, sizes, and economics

III Preparation and Presentation of Report

The first phase was performed by making a personal visit to Peru to meet with members of the O.E.E. and discuss requirements. This was followed by an aerial inspection of the Selva Central and an examination of various potential operation sites.

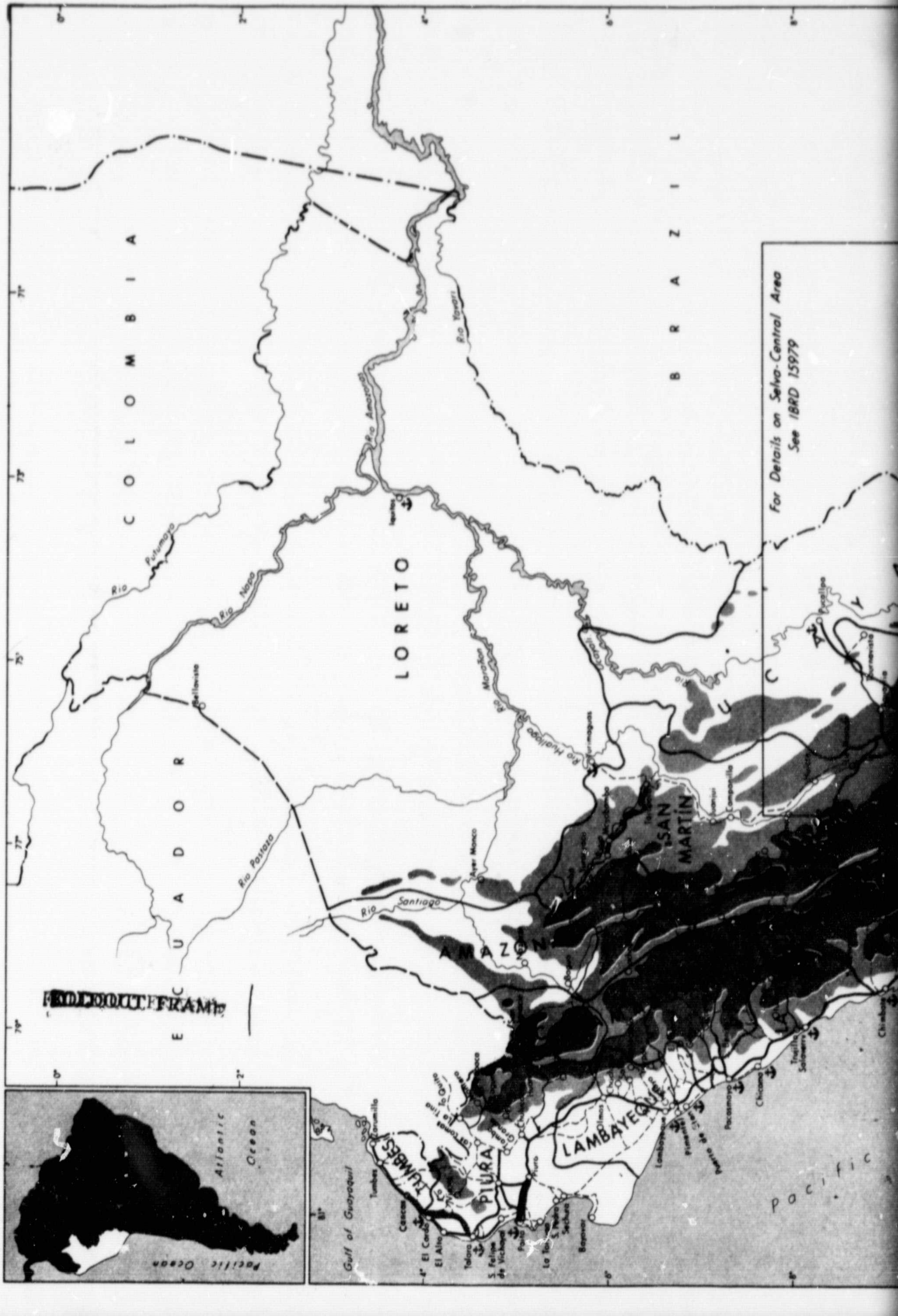
Phase II was conducted using data from the author's files, data from dirigible vendors and manufacturers, computer analysis of dirigible sizes and performance characteristics from the U.S. Navy NAPSAP*program and the NASA-Goodyear developed HLA WER*program, and an integrated analysis of all of this information.

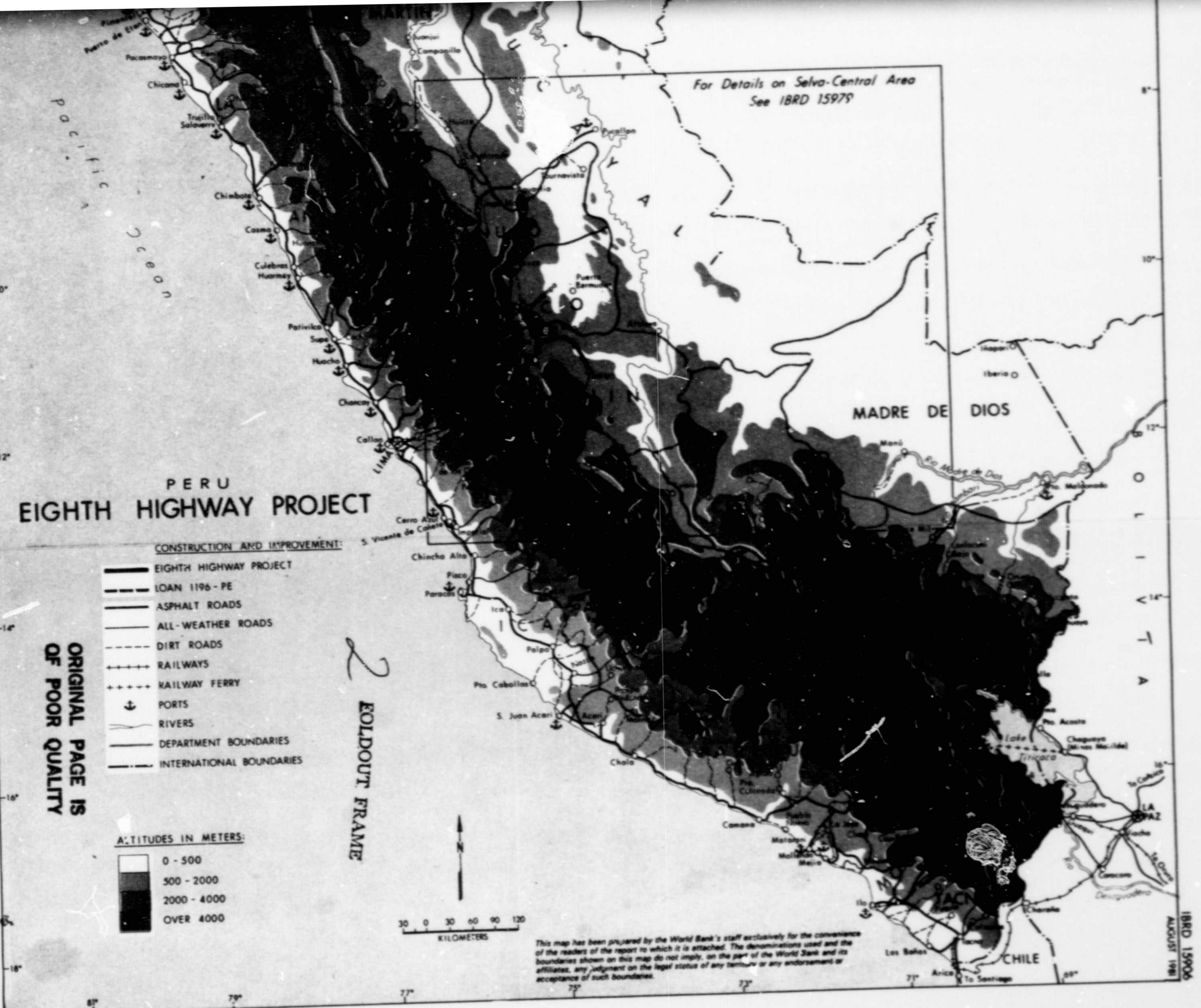
The final phase, the report, was prepared in both Spanish and English versions.

Phase I was conducted between 22 September, and 2 October, 1981. Phase II was initiated 4 November, 1981, and completed 15 March, 1982.

* NAPSAP- Naval Airship Program for Sizing and Performance

HLA-WER- Heavy Lift Airship- Weight Estimating Relationships


COLOMBIA
BRAZIL
ECUADOR
LORETO
SAN MARTIN
AMAZON
PIURA
TUMBES
LAMBAYEQUE
Rio Amazonas
Rio Putumayo
Rio Napo
Rio Pastaza
Rio Santiago
Rio Marañon
Rio Huallaga
Rio Yavari
Gulf of Guayaquil
Pacific
Atlantic Ocean
Pacific Ocean
For Details on Selva-Central Area
See IBRD 15979
FOLDOUT FRAME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EIGHTH HIGHWAY PROJECT
CONSTRUCTION AND IMPROVEMENT:
EIGHTH HIGHWAY PROJECT
LOAN 1196 - PE
ASPHALT ROADS
ALL-WEATHER ROADS
DIRT ROADS
RAILWAYS
RAILWAY FERRY
PORTS
RIVERS
DEPARTMENT BOUNDARIES
INTERNATIONAL BOUNDARIES
ALTITUDES IN METERS:
0 - 500
500 - 2000
2000 - 4000
OVER 4000
30 0 30 60 90 120
KILOMETERS
For Details on Selva-Central Area
See IBRD 15979
MADRE DE DIOS
BOLIVIA
CHILE
Pacific Ocean
IBRD 15906
AUGUST 1981
This map has been prepared by the World Bank's staff exclusively for the convenience of the readers of the report to which it is attached. The denominations used and the boundaries shown on this map do not imply, on the part of the World Bank and its affiliates, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

FIG. 1A

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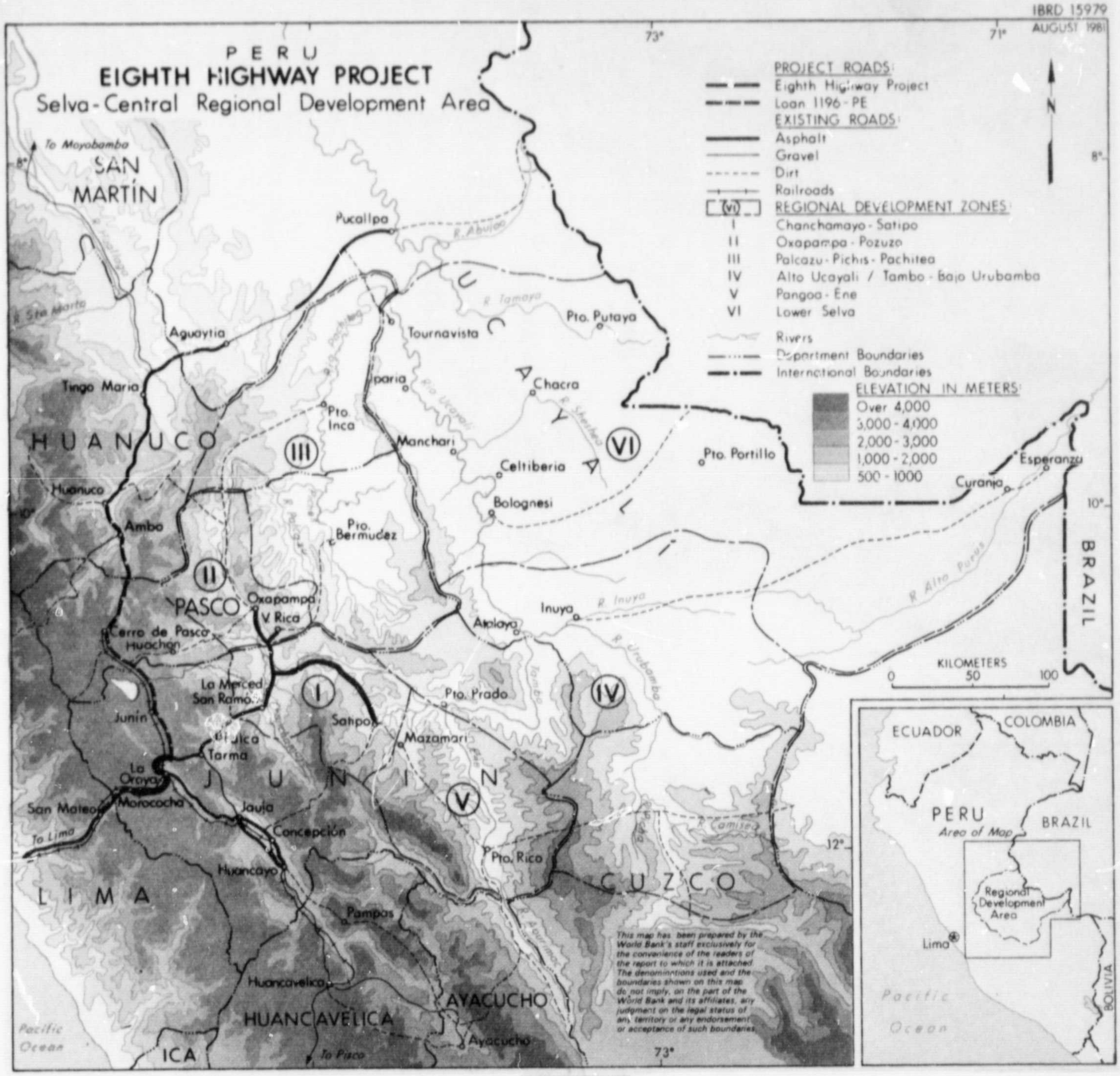



FIG. 1B

## FUNDAMENTAL CONSIDERATIONS

The basic principles of aerostatics are explained in Appendix A. The term dirigible is used as described in Appendix A, and is meant to include all types of powered aerostats.

Two major types have been considered: the conventional dirigible which derives most or all of its lift from buoyancy, and a hybrid which combines static and rotary aerodynamic lift and control. Dirigibles which use vectored thrust to assist in take-off or landing are regarded as conventional unless otherwise noted. These types were chosen as most suitable for the mission requirements. They have also been the subject of some technology development and studies from which much useful data were obtained.

When conventional dirigibles are in equilibrium, they literally float in the atmosphere. However, conditions are seldom constant for more than a few minutes and most often less so that the aircraft will become heavy or light and begin to settle to the ground or rise to higher altitude. Station keeping over a fixed point is also theoretically possible but can be a difficult operation in winds which vary in velocity and direction.

Vectored thrust coupled with forward and reverse propulsion can be used for making small corrections in buoyancy and position, but major alterations of the dirigible's attitude require use of very large forces and consequently much power such as is used in hybrid types. On this basis, hovering flight for cargo loading or unloading is not considered practical for conventional dirigibles. In these cases, landing is regarded as the normal procedure.

When on the ground, it is presumed that conventional dirigibles are restrained by a ground crew for short periods and by a mooring mast for long periods. Cargo loading would be considered a long period operation particularly with large or complex loads requiring special handling and equipment. Some passenger and light cargo loading could be accomplished with the aid of a ground crew only.

The second type of dirigible considered in this study, the hybrid, can be designed in many combinations to provide various ratios of buoyancy and aerodynamic lift. In this study, those which operate at $\beta$ (buoyancy values)* of

$$* \beta = \frac{\text{Gross Lift}}{\text{Gross Weight}}$$

approximately 0.5 are the main types considered. These types are capable of hovering flight and landing or taking off unassisted up to certain maximum wind conditions. During flight, the consumption of fuel reduces the weight of dirigibles. A static condition close to equilibrium is the most desirable at all times for conventional dirigibles, since this allows near vertical take-offs, minimum landing space, and minimum drag during flight. Therefore, the pilot must plan the flight such that the desired conditions are maintained or at least approached. This can be done in two ways: (1) the static heaviness at take-off can be equal to the weight of fuel consumed during flight so that landing can occur at or near equilibrium. This requires a running take-off or the use of vectored thrust. (2) An engine exhaust gas water recovery system can be used to accumulate ballast and prevent weight loss. The hybrid dirigibles discussed in this report do not require these adjustments since they operate statically heavy at all times.

Conventional dirigibles must also carry sufficient removable weight (ballast) so that their total mass remains close to the limits discussed above. Thus during loading of cargo, ballast must be removed to correspond to cargo weight, and in turn, re-installed as cargo is removed. If cargo is being transported in both directions, this can be the equivalent of ballast provided the quantity removed corresponds to the new cargo loaded. Otherwise, non-revenue weight must be removed or carried. A convenient form of ballast is water.

Both conventional and hybrid dirigibles are presumed to be equipped with landing gears such that rolling take-offs are possible, and where mooring for long periods when the aircraft is in contact with the ground is also feasible.

The trade-off between conventional and hybrid types is dependent on mission requirements. Generally, conventional types are less expensive to build, require much less power, and are more fuel efficient. They are also capable of fully buoyant (equilibrium) operation which provides greater safety and reliability. Hybrids provide positive control at all speeds, are capable of hovering and making some cargo pick-ups in the air, and can land and take-off unassisted from unprepared surfaces.

. . . .

## REQUIREMENTS



### Cargoes and Routes

Rates of production of various crops, timber, and meat over a 20 year period beginning in 1985, were provided by the O.E.E. (see Appendix B). These show that a total of 19 million tons of agricultural products, 97,000 tons of forest products, and 17,000 tons of beef would be exported from the region. Present cargoes in or out of the region are insignificant compared to these predictions. Certain zones for collecting and transporting these cargoes were also suggested by the O.E.E., these include: Pto. Ocopa (or Prado), Puyeni, Atalaya, Obenteni, Pto. Rico, Pto. Breu, and Esperanza, with a terminus for all routes at Mazamari. Since it is desirable to keep the flight altitude of dirigibles as low as possible for greatest efficiency, the elevation of Mazamari was used as a maximum airport altitude. Assuming a ground clearance of 1000 ft., a cruise altitude of 3150 ft. (960m) a.s.l. is required. All zones are accessible with this limitation except that routes must be chosen which avoid flight over terrain of higher altitude. One of these is the route from Pto. Rico to Mazamari. Direct flight would involve crossing mountains from 2000-3000m high. Therefore, a course along the Rio Ene to Mazamari via Pto. Ocopa is preferred. This involves a distance of 130km instead of 95 for the direct route.

Another problem exists in the route from Obenteni to Pto. Ocopa. No low altitude course seems available here. A flight altitude, assuming 1000ft. land clearance, or 4281 ft. (1305m) would have to be maintained. Two alternatives are possible: one is raising the maximum flight altitude for the Atalaya-Obenteni-Pto. Ocopa-Mazamari route. The second is reversing the route, starting at Obenteni, flying to Atalaya and thence to Pto. Ocopa and Mazamari. The first alternative allows using the same size dirigible as on the other routes but filled with less helium and therefore carrying lower payload or using a slightly larger dirigible for the same payload. The second choice requires a longer flight distance - 238 vs. 77km.

With the above limitations in mind, the following primary routes were used in the study:

1. Atalaya-Puyeni-Pto. Ocopa-Mazamari
2. Atalaya-Obenteni-Pto. Ocopa-Mazamari
3. Pto. Rico-Pto. Ocopa-Mazamari
4. Esperanza-Atalaya-Pto. Ocopa-Mazamari

5. Pto. Breu-Atalaya-Pto. Ocopa-Mazamari

Figure 2 shows these routes, dirigible flight distance, and relative locations of airports.

Region export rates and route distances are related to vehicle requirements by the term: transport production rate. The transport production rates (ton-km) were calculated for the 20 year period of interest and are shown in tables 1,2,3, and 4. The total rates are plotted in Figure 3. For each location, the dirigible flight route distance was used, with the exception of Obenteni, where the higher altitude route direct to Pto. Ocopa was assumed.

It is obvious, from these requirements that a fleet of dirigibles would be needed to provide transport service to the region. The successive parts of this study are based on this assumption. The sizes of the dirigibles and numbers used in the fleet are primarily dependent on transport demand.

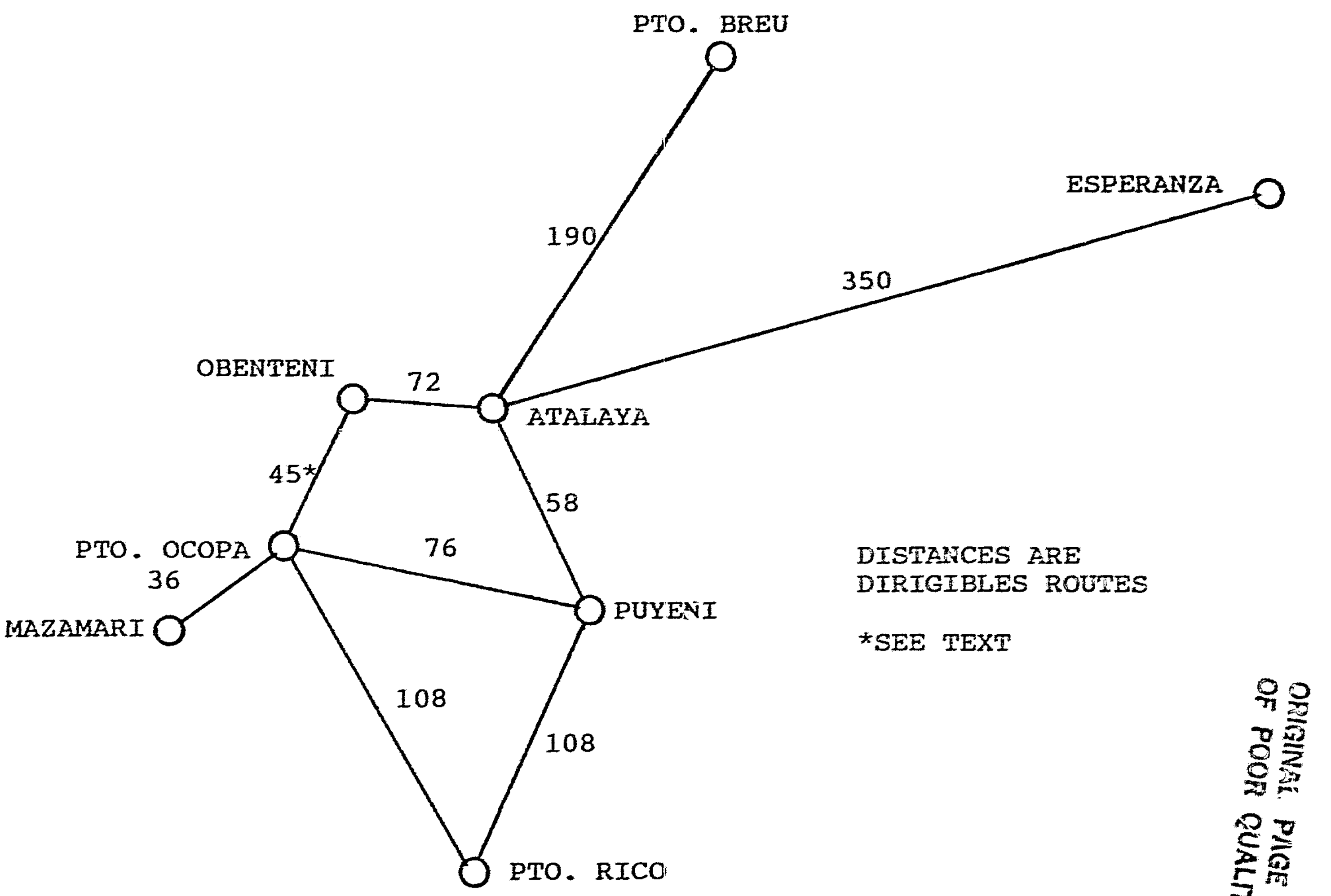
Airports

Dirigible operations require the use of a cleared and leveled landing site. It is conceivable that such sites could be located in the centers of agricultural areas so that direct loading and unloading is possible without need of surface transport. Existing airfields, with proper modifications, can also be used. Figure 4 shows the airstrip at Pto. Breu. This is typical of present facilities in areas where little development has occurred. A more developed site is the airport at Mazamari, the intended terminal point for all cargoes. This is shown in Figure 5. In this study, it was presumed that some development will be required either by enlarging present airfields or by clearing new sites. The former method was chosen as the least expensive procedure although the differences between both methods are relatively insignificant.

Appendix C lists data furnished by the O.E.E. on 71 airports in the Selva Central including those identified along the primary routes. With a few exceptions, most airports are at elevations below the altitude limit noted above. Airports which exceed the elevation limit are:

SELVA CENTRAL

PRIMARY ROUTES
FOR CARGOES




DISTANCES ARE
DIRIGIBLES ROUTES

*SEE TEXT

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FIG. 2

## ANNUAL CARGOES

AGRICULTURE

t km/ $10^3$

| YEAR | PTO OCOPA | PUYENI (1) | ATALAYA (2) | OBENTENI (3) | PTO RICO (1) | PTO BREU (4) | ESPERANZA (4) | TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1985 | 1117 | 13123 | 11078 | 1747 | 3320 | 9223 | 49865 | 89473 |
| 1990 | 1699 | 19735 | 16309 | 2602 | 5065 | 13866 | 74053 | 133329 |
| 1995 | 2592 | 29738 | 24017 | 3881 | 7744 | 20876 | 110085 | 198933 |
| 2000 | 3961 | 44916 | 35491 | 5957 | 11876 | 31523 | 163863 | 297587 |
| 2004 | 5571 | 62568 | 48239 | 7997 | 16755 | 43909 | 225429 | 410468 |

(1) VIA PTO. OCOPA
(2) VIA PUYENI, OCOPA
(3) SEE TEXT
(4) VIA ATALAYA, OCOPA

TABLE 1

# ANNUAL CARGOES

## TIMBER

t km/$10^3$

| YEAR | ATALAYA | PUYENI | PTO RICO | PTO OCOPA | OBENTENI | TOTAL |
|---|---|---|---|---|---|---|
| 1985 | 3821 | 1987 | 4150 | 484 | 888 | 12625 |
| 1990 | | | | | | |
| 1995 | | | | | | |
| 2000 | | | | | | |
| 2004 | 3821 | 1987 | 4150 | 484 | 888 | 12625 |

TABLE 2

# ANNUAL CARGOES

MEAT

t-km/$10^3$

| YEAR | ATALAYA | PUYENI | OBENTENI | ESPERANZA | PTO BREU | TOTAL |
|---|---|---|---|---|---|---|
| 1985 | 25 | 6 | 2 | 48 | 31 | 112 |
| 1990 | 33 | 8 | 3 | 64 | 41 | 149 |
| 1995 | 44 | 10 | 4 | 85 | 55 | 194 |
| 2000 | 59 | 14 | 5 | 113 | 73 | 258 |
| 2004 | 73 | 17 | 6 | 141 | 91 | 321 |

TABLE 3

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# ANNUAL CARGOES
## TOTAL

AGRICULTURE, TIMBER MEAT

$t$-km/$10^3$

| YEAR | PTO OCOPA | PUYENI | ATALAYA | OBENTENI | PTO RICO | PTO BREU | ESPERANZA | TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1985 | 1601 | 15116 | 14924 | 2637 | 7470 | 9254 | 49913 | 102210 |
| 1990 | 2183 | 21731 | 20163 | 3493 | 9215 | 13907 | 74117 | 146103 |
| 1995 | 3076 | 31735 | 27882 | 4773 | 11894 | 20931 | 110166 | 211752 |
| 2000 | 4445 | 46917 | 39371 | 6850 | 16026 | 31596 | 163970 | 310470 |
| 2004 | 6055 | 64573 | 52133 | 8891 | 20905 | 44000 | 225563 | 423414 |

TABLE 4

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# SELVA CENTRAL

## ANNUAL RATES

CARGOES

AGRICULTURE, TIMBER, MEAT
PRIMARY ROUTES

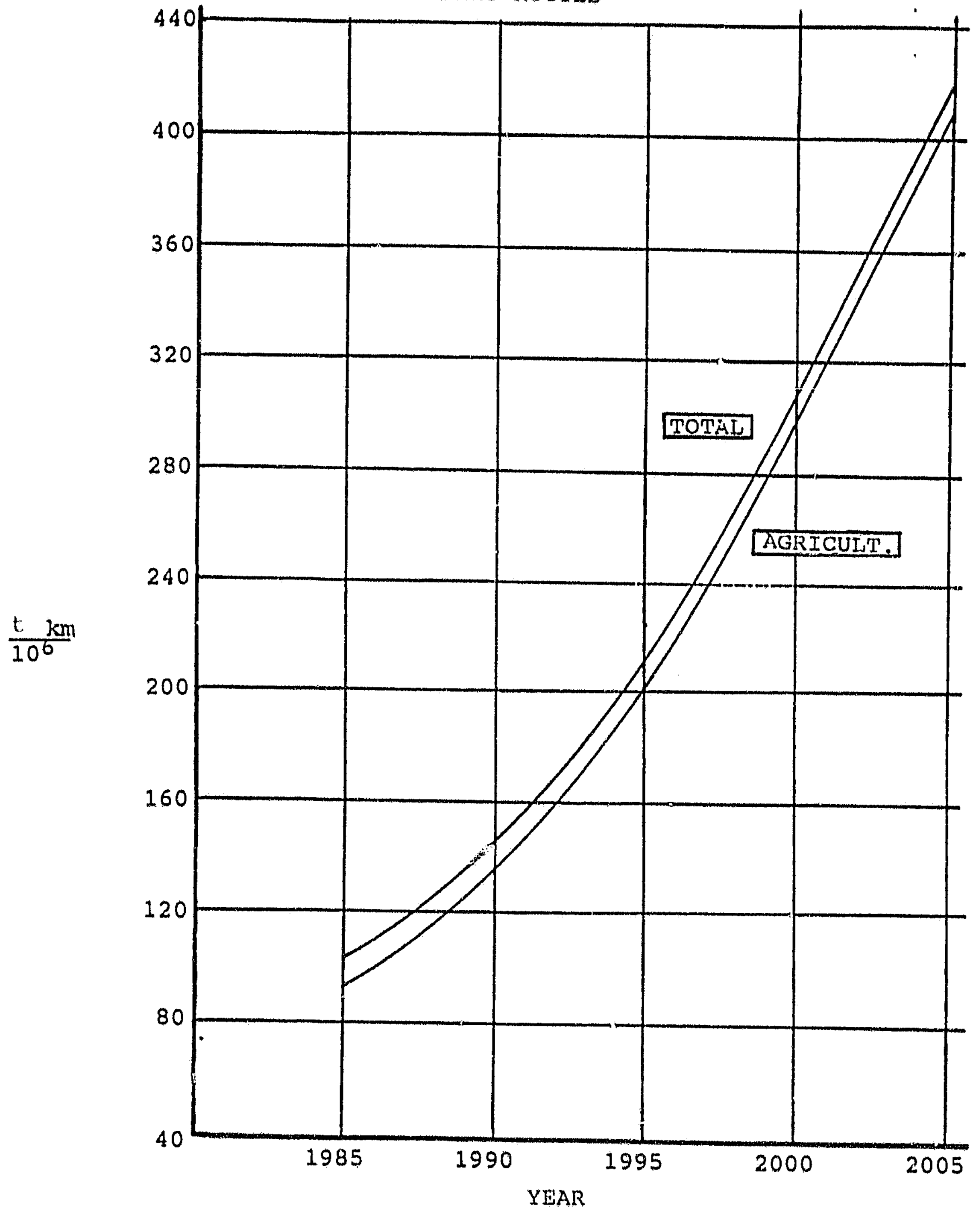


FIG. 3

FIG. 4

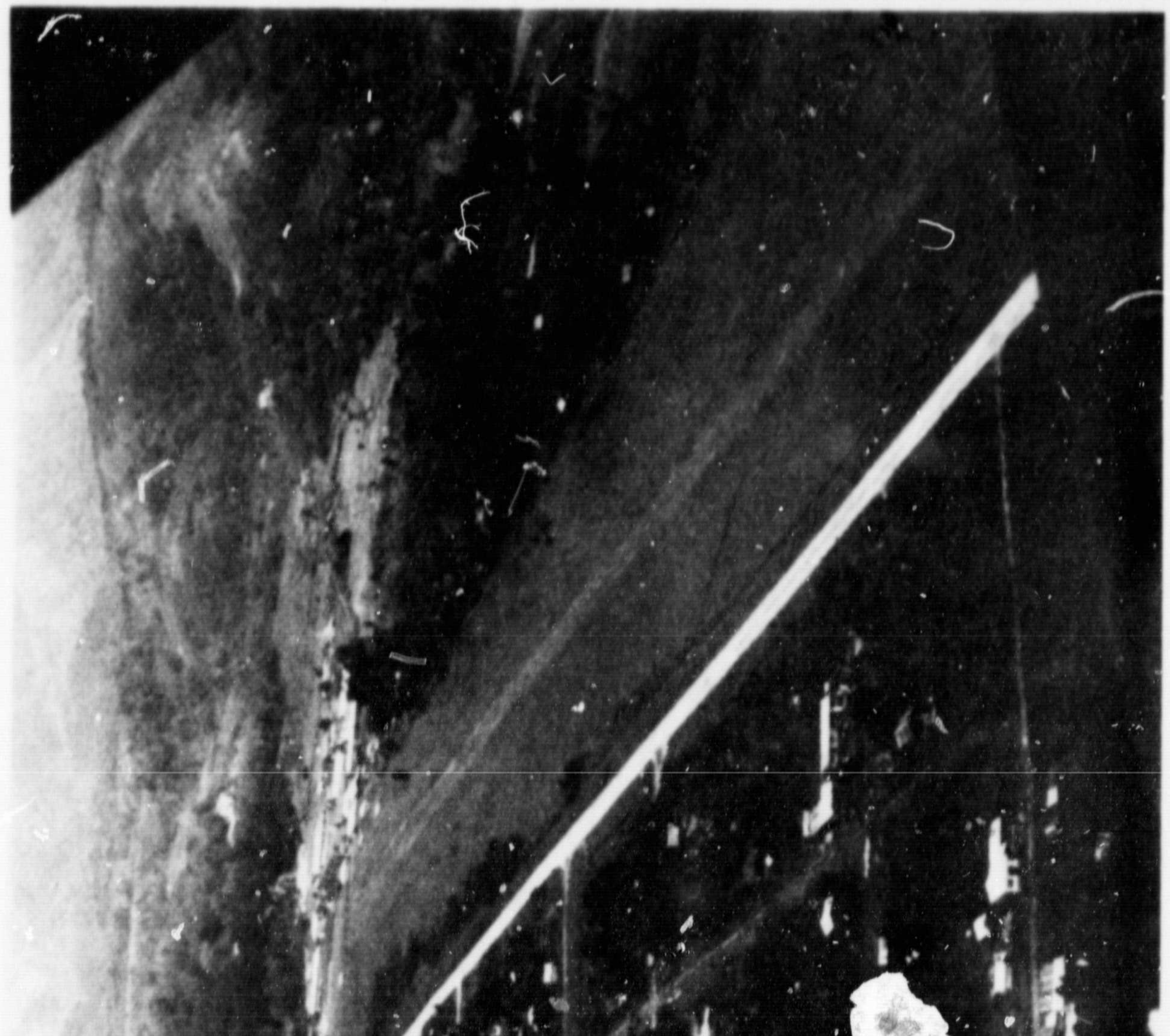

FIG. 5

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Alto Pichanaqui, Kolpiroshiato, Mantaro Chico, Oxapampa, San Ramon, and Zotzique. However, several of the others, although at low enough altitude, are not directly accessible without greatly exceeding the flight altitude limits established for the primary routes, and therefore may not be of interest for dirigible use.

The airport runways along the primary routes vary from 300-1500m in length. Conventional dirigibles operating at maximum design take-off heaviness require about 3 dirigible lengths for a running take-off in order to clear high end of the runway obatacles such as trees. If an airport runway is oriented in the direction of the prevailing wind, it is possible for dirigibles of any type to land with very limited runway widths -- assuming the dimensions of the field at least exceed those of the dirigible, provided there is no shift in the wind direction, and assuming that the aircraft is close to equilibrium. While this can be done under these selected circumstances, daily operation under varying weather conditions dictates having more maneuvering room. Also, unless it can be guaranteed that no wind direction change will occur, field widths equaling at least 2 dirigible lengths are required for mooring. These limitations can be approximately equated to cargo capacity and used to identify dirigible and airport size requirements. All fields along the primary route are of sufficient length to accommodate dirigibles up to 10 tons payload capacity. Beyond this capacity, some airfields must be lengthened. These include: Pto. Breu, Puyeni, and probably Obenteni and Pto. Rico. (No data were furnished on these two). Conventional dirigibles which are equipped with vectoring propellers may be able to operate within all present field lengths, provided that the take-off heavinesses do not exceed the available vertical thrust. Hybrid dirigibles would also be capable of landing and taking-off within present field lengths.

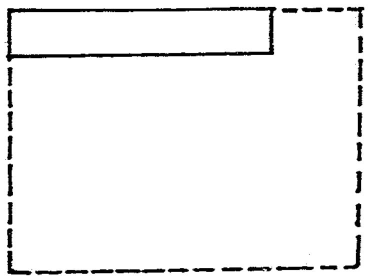
Present airport widths are insufficient for all sizes. None of the fields on the primary routes meet minimum requirements. Two fields, on the list of 71, are known to have sufficient width beyond listed runway dimensions (Pucallpa, Shepahua).

The modifications of airports on the primary routes required for dirigible operations are indicated on Table 5. As shown, all airports required only a type B modification (increase in width) to accommodate dirigibles up to 10T payloads. Airports of higher capacity will require both type A and B modifications. It should be emphasized that these are the very minimum dimensions for airport sizes

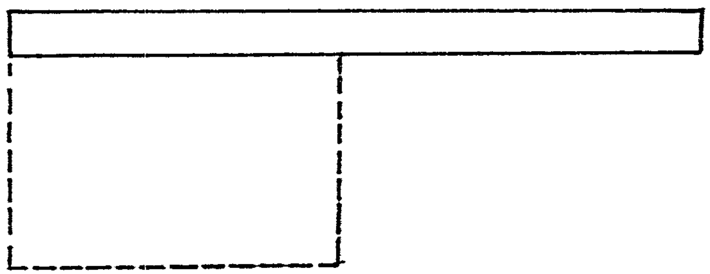
## MINIMUM MODIFICATIONS OF AIRPORTS FOR DIRIGIBLE OPERATIONS

| AIRPORT | DIMENSIONS M | REQUIRED DIMENSIONS: FOR 10 t DIRIGIBLE — LENGTH & WIDTH MINIMUM (m) | FOR 10 t DIRIGIBLE — ADDITIONAL AREA (ha) | FOR 40 t DIRIGIBLE — LENGTH & WIDTH MINIMUM (m) | FOR 40 t DIRIGIBLE — ADDITIONAL AREA (ha) | FOR 100 t DIRIGIBLE — LENGTH & WIDTH MINIMUM (m) | FOR 100 t DIRIGIBLE — ADDITIONAL AREA (ha) |
|---|---|---|---|---|---|---|---|
| ATALAYA | 1500x45 | 360x200 | 4.75 | 370x250 (TIPO B) | 7.59 | 680x460 | 28.22 |
| ESPERANZA | 800x14 | ALL TYPE B | 5.58 | " TYPE B | 8.73 | TYPE B | 30.33 |
| MAZAMARI | 1467x44 | | 4.68 | | 7.62 | TYPE A | 28.29 |
| PTO. BREU | 350x35 | | 4.95 | TYPE A | 8.03 | | 30.05 |
| PTO OCOPA | 1220x45 | | 4.75 | " TYPE B | 7.59 | TYPE B | 28.22 |
| PTO RICO * | 300x20 | | 5.40 | TYPE A | 8.65 | TYPE A | 30.68 |
| OBENTENI * | 300x20 | | 5.40 | | 8.65 | | 30.68 |
| PUYENI | 300x20 | | 5.40 | | 8.65 | | 30.68 |

* ASSUMED DIMENSIONS



MODIFICATION TYPE A



MODIFICATION TYPE B

TABLE 5

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for conventional dirigibles. Current U.S. operations by Goodyear involve airports (for dirigibles only) of approximately 3x the area listed. British airworthiness requirements specify lengths as: take-off distance + 200m and widths as: dirigible width + 200m. (This latter dimension is not adequate for large dirigibles and does not agree with Table 5.

Since hybrids are capable of unassisted landing and take-off, and of maintaining a cross wind hover, they would not require the same modifications to airfields. It might be assumed that cargo would be picked up while hovering and no landing is required. However, this procedure is not practical for passenger operations or for periods involving lengthy loading procedures. It is more convenient to land. If a hybrid is on the ground without power, it must be masted to minimize effects of cross winds. It was assumed, therefore, that as a minimum, all airports on the primary routes would be equipped with masts. Space for a fixed mooring circle may add to the field area required. Figure 6 illustrates the procedures used by the 2 types of dirigibles for landing under cross wind conditions. In the case of conventional dirigibles, the ship must eventually face into the wind when all forward speed ceases. The hybrid can hold a cross wind position up to some maximum wind velocity, but when on the ground without power, this can only be done with high static heaviness and under low wind conditions. Otherwise, the aircraft must be moored as shown.

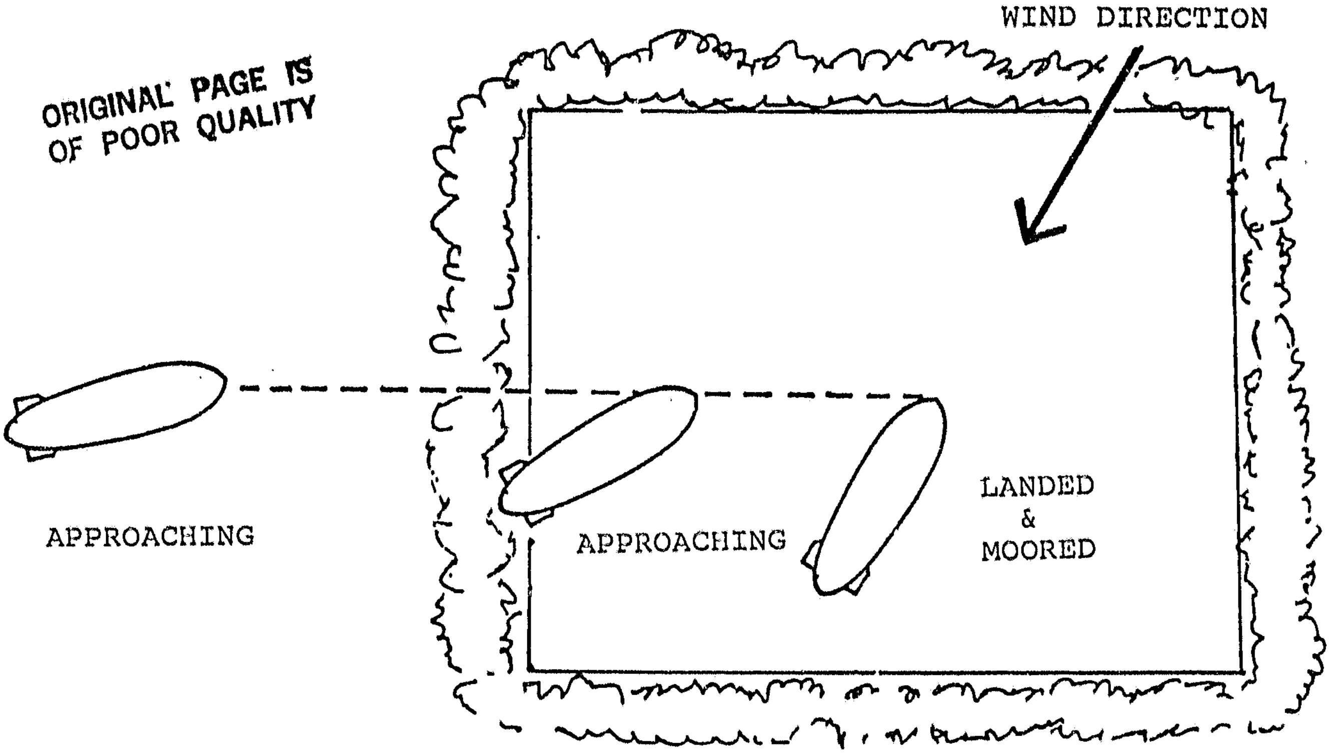
Weather Conditions

Data indicate that mean temperatures range from 30.2$^{o}$ C max. to 18.6$^{o}$ C min. Heavy precipitation during summer months is experienced. The various rates are shown in Table 6. Neither temperatures nor rainfall present any serious problem for dirigible operations.

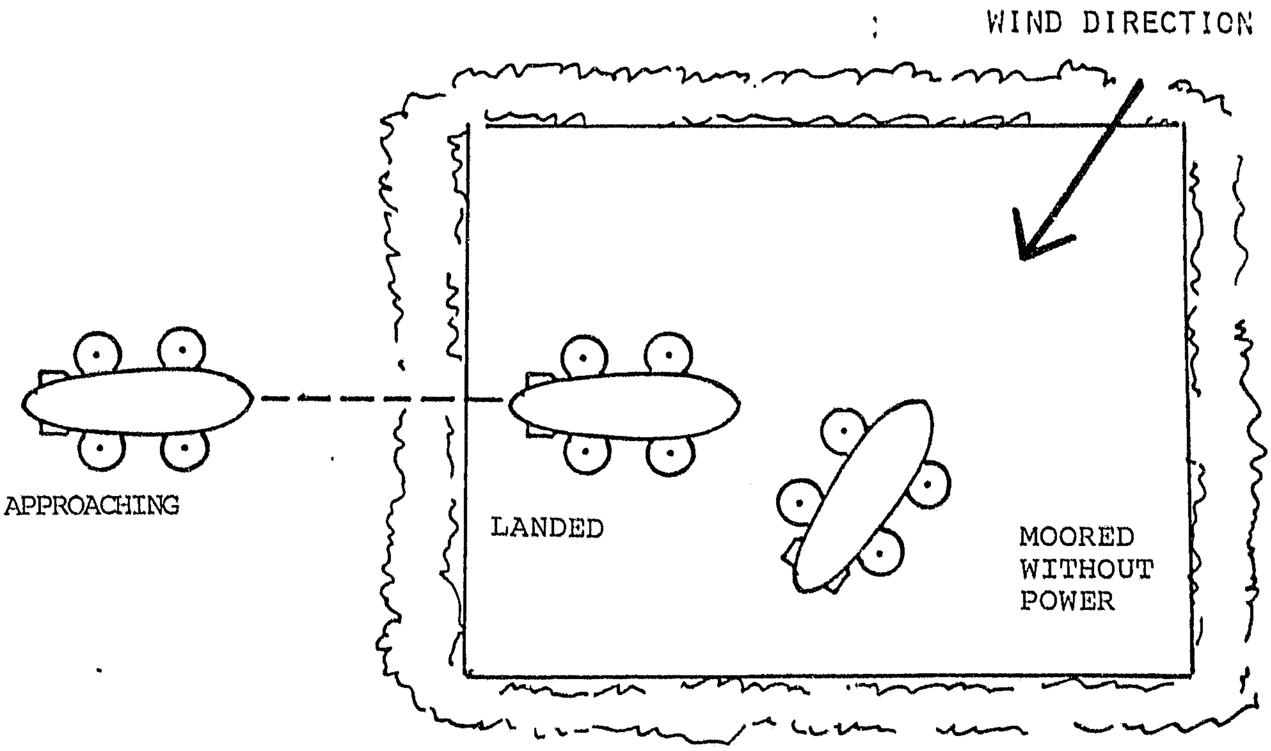
Winds can inhibit landing, take-off, and ground operations for conventional dirigibles, since control at low flight speeds is difficult. Data on velocity and direction of wind were generally not available in any usable form for the region, but it is understood that strong winds are unusual. Winds during flight only decrease or increase ground speeds and require the expenditure of more or less power accordingly.

# PROCEDURES FOR LANDING






CONVENTIONAL DIRIGIBLE




HYBRID DIRIGIBLE

FIG. 6

## PRECIPITATION (mm)

| PLACE | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PTO OCOPA | 200 | 200 | 150 | 80 | 60 | 30 | 35 | 60 | 60 | 120 | 120 | 200 |
| PUYENI | 300 | 300 | 300 | 140 | 110 | 60 | 60 | 90 | 130 | 200 | 200 | 300 |
| ATALAYA | 325 | 375 | 350 | 300 | 140 | 145 | 100 | 120 | 140 | 225 | 300 | 300 |
| OBENTENI | 350 | 300 | 250 | 275 | 160 | 140 | 190 | 120 | 140 | 250 | 250 | 425 |
| PTO RICO | 300 | 300 | 275 | 130 | 100 | 40 | 50 | 90 | 120 | 225 | 180 | 275 |
| PTO BREU | 250 | 300 | 250 | – | 110 | 60 | 90 | 90 | 90 | 160 | 200 | 250 |
| ESPERANZA | 200 | 250 | 200 | 180 | 80 | 60 | 30 | 30 | 100 | 120 | 100 | 300 |
| MAZAMARI | 200 | 200 | 160 | 80 | 60 | 30 | 30 | 80 | 90 | 160 | 140 | 225 |

TABLE 6

## Ground Facilities

Dirigible operations require certain minimum facilities on the ground. These include:

1. Ground handling and mooring equipment.
2. Ballast supply.

In addition, a complete system operation involves certain other facilities:

3. Base of operations.
4. Maintenance base.
5. Fuel supply.
6. Helium supply

It is assumed that all airports will incorporate items 1 and 2. Items 3 and 4 can be at the same airport, and could be a combined facility. It is also presumed that all fueling will occur at the base of operations and none will be required at other route airports. This is likewise true for helium. Actual differences from these assumptions will not be important to this analysis.

## Handling and Mooring

In steady winds of low velocity, it is feasible to load and unload conventional dirigibles without use of auxiliary ground equipment. As a minimum however, a ground crew is required to hold the dirigible at one point on the field. Loading and unloading large and heavy cargoes over long periods of time particularly in unsteady winds is generally beyond the capability of ground crews alone and auxiliary equipment such as a mooring mast must be used.

A mooring mast is needed at each airport since it is presumed that cargo loading will require tethering conventional dirigibles. Although hybrids may not require masts, as the fleet grows, facilities for overnight mooring must be provided at most airports since it would not be practical to base the entire fleet at one airport regardless of the type of dirigible. This means that mooring circles in addition to the one assumed to exist at each airport must be provided -- one for each dirigible.

A mooring site is constructed by clearing and leveling a circular area with a diameter equal to two dirigible lengths. A mast is erected in the center. No special ground preparation for the mast assembly is required.

Mooring masts for normal operations can be fixed and located to one side of the operations area (runway). Fixed masts are normally steel towers anchored to the ground by guy wires and a base fitting. Figure 7 shows a typical mast. Figure 8 lists the characteristics. They are usually designed to be disassembled in sections and can be transported by ground or air vehicles. When a dirigible has landed, it is moved to the mast, which is located in the center of a cleared space or "mooring circle".

Mobile masts are used where more flexibility in ground handling is required such as docking and undocking from a hangar. Mobile masts also provide the advantage of being parked at the side of the airport when not in use. These are tetrahedronal shaped towers mounted on a wheeled base and towed by tractors. (See Figures 9 and 10). It is assumed that dirigibles up to and including those of 10 ton capacity can be ground handled with only the assistance of a ground crew, and beyond this with the aid of mechanical "mules". Mules, as developed for naval dirigibles, are four wheel steerable vehicles equipped with constant tension winches for holding the handling lines of the dirigibles. They are manned by two operators. (See Figures 11 and 12).

Operations and Maintenance Base

This base would be the center for all the fleet pre-flight preparation and major maintenance. It would be the point for all flight scheduling, fueling, and helium replenishment. Each dirigible is scheduled for a once per year, 3 week period, for major maintenance. A complete base would include the following facilities:

Hangar
Mobile Mooring Mast
Fixed Mooring Masts
Mules
Service and Maintenance Equipment
Helium Storage and Supply
Fuel Storage and Supply

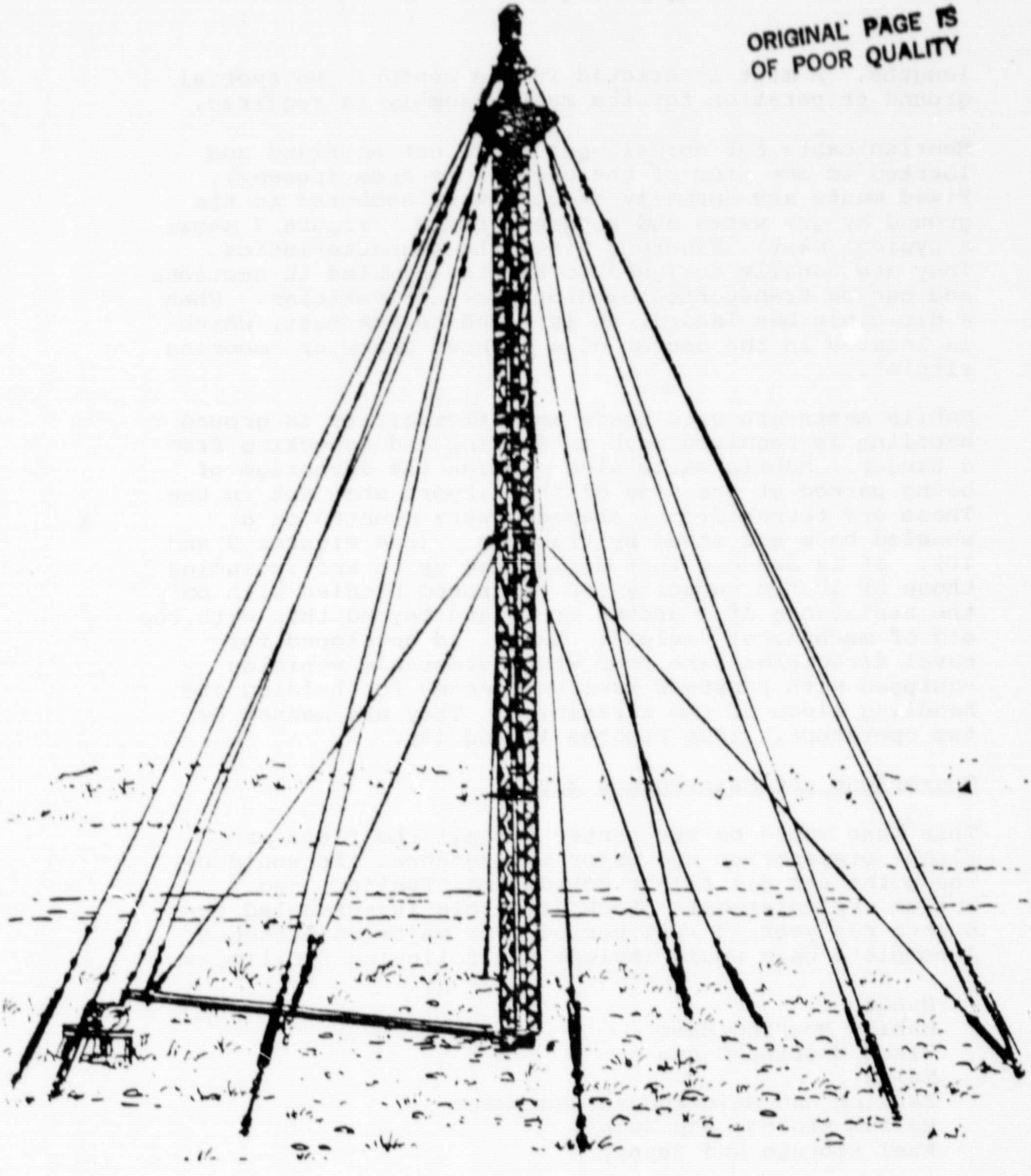
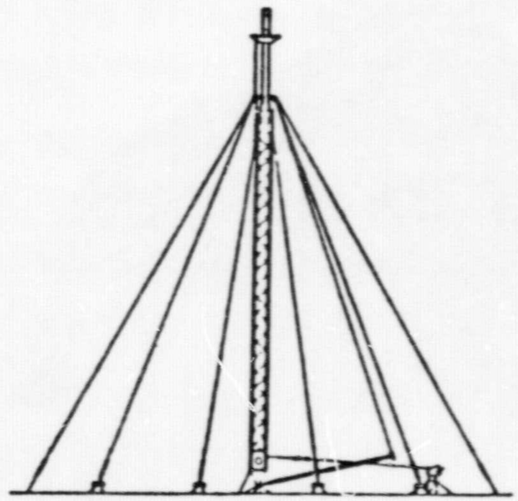


FIG. 7

# TYPE $V_S$ STICK MAST SPECIFICATIONS





STICK MAST - TYPE Vs

| | |
|---|---|
| Application | ZPG-2/-2W/-3W Airships |
| Air transportable | By cargo aircraft |
| Winch load | Up to 78 knots |
| Total weight | 12,548 pounds |
| Height | |
| (Total) | 71 feet, 5.56 inches |
| (Telescoped and less removable section) | 57 feet, 5.12 inches |
| (Telescoping head) | 7 feet, 3 inches |
| Head elevation | By manual winch |
| Mast elevation | By gin pole from horizontal position |
| Mast cup control | Manual |
| Gear Box | |
| Capacity | Rated 26,000 pounds |
| Reduction ratio | 1000 to 1 |
| Ground anchor diameter | 70 feet, 2 inches |
| Construction | |
| (Type) | 30-inch square frame |
| (Material) | Aluminum and steel |

FIG. 8

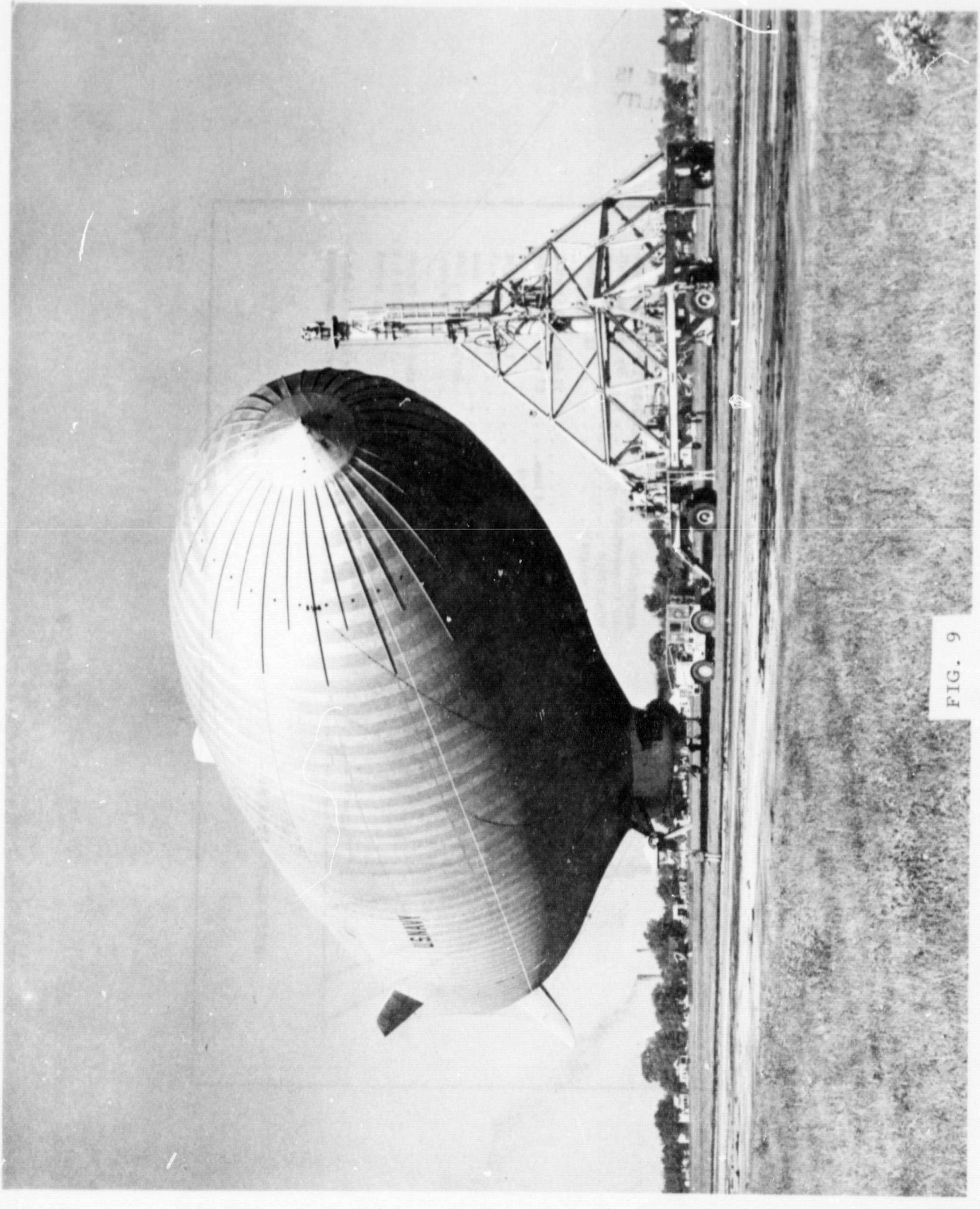


FIG. 9

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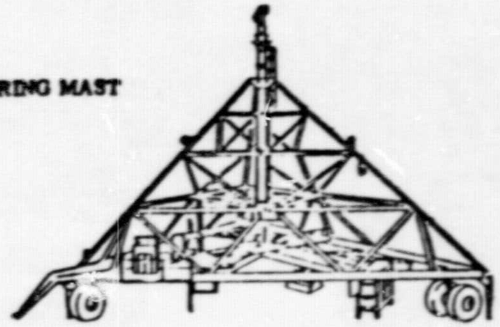
**TYPE V MOBILE MOORING MAST**



| | |
|---|---|
| Construction | Steel pyramid |
| Temperature operating range | -25°F to +125°F |
| Mast cup control | Electrical |
| Mast height control | Hydraulic |
| General dimensions | |
| Length | 60 feet |
| (with gooseneck in tow position) | 72 feet |
| Width | 60 feet |
| Height (Minimum) | 56 feet |
| (Maximum) | 71 feet |
| (to operating platform) | 8 feet |
| Weight (Total) | 128, 670 pounds |
| (Less airship electrical power unit) | 118, 000 pounds |
| Mast Electrical Power System | |
| Type | Gasoline |
| Manufacturer and Model No. | Hercules - Series JXD |
| D-c power | 24-volt |
| A-c power | 60-cycle, 120/208-volt, 3 phase |
| Lights | Running lights and five 12-in, 250W floodlights |
| Airship hauling-in winch | Constant tension |
| Control Console | Operates all components |

| | |
|---|---|
| Airship Electrical Power Unit | |
| Type | Diesel |
| Manufacturer and Model No. | Consolidated Diesel Model 4026 |
| Engine | |
| Type | Diesel |
| Manufacturer and Model No. | Hercules Series DFXE |
| Rating | 169 hp |
| Transformer (step-up) | 75 kva, 200/1000-volt |
| Transformer-Rectifier Pack (17Z815-193-100) | |
| Application | Furnish airship power |
| Type | Removable and mobile |
| Transformer (step-down) | 1000/200-volt |
| Power output | 115/200-volt a-c 28-volt d-c |

FIG. 10

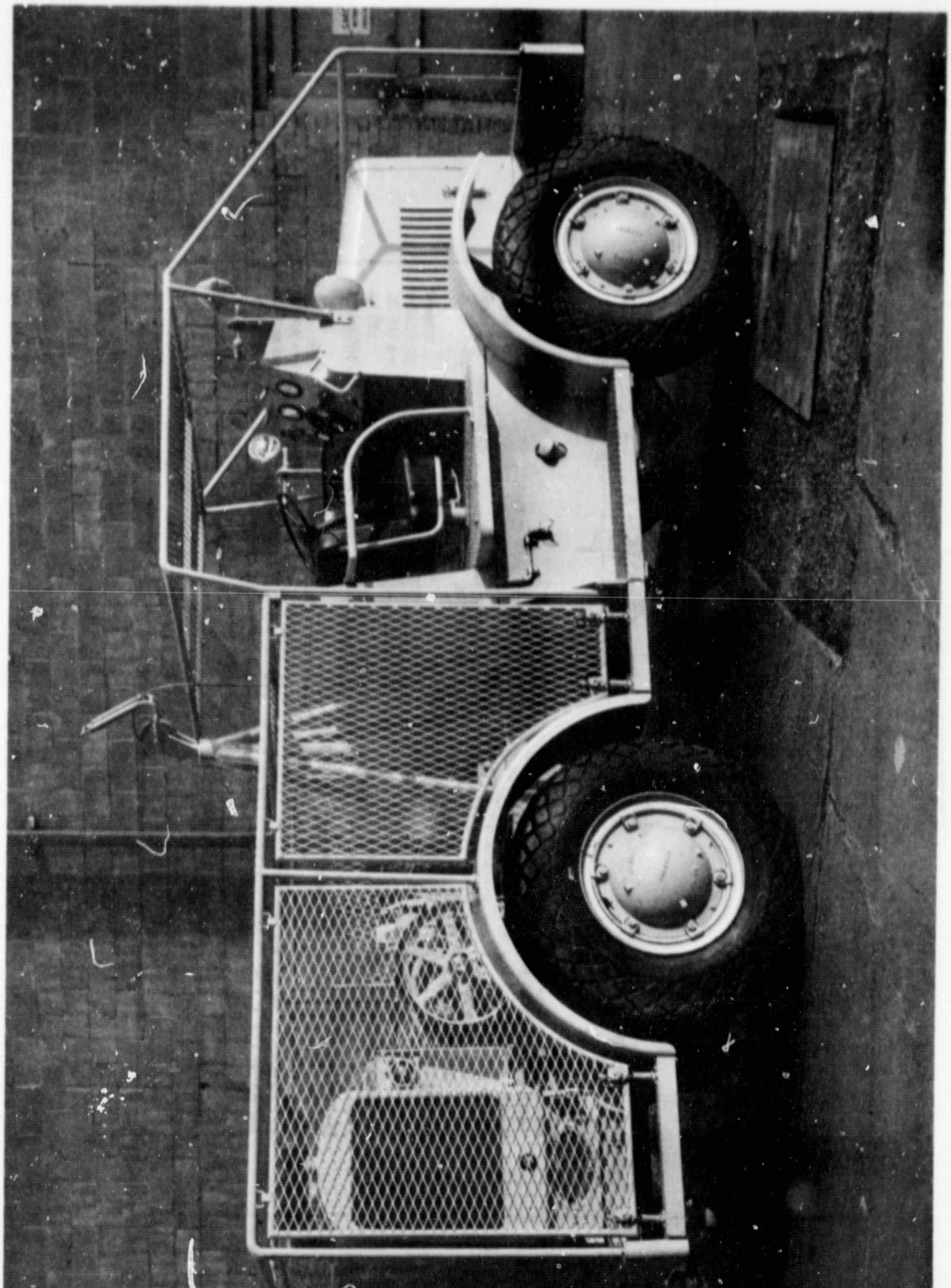
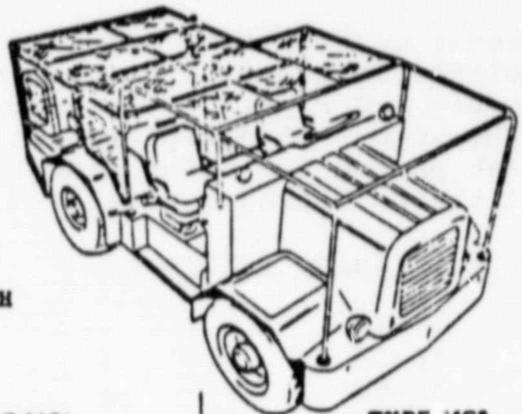


FIG. 11



MOBILE WINCH

| LEADING PARTICULARS | TYPE MC4 | TYPE MC3 |
|---|---|---|
| Application | Airship Ground Handling | Airship Ground Handling |
| Model No. | 260N-001 | 256N-001 |
| Specification | AER-SE-7-31 | AER-SE-7-28 |
| Drive | Independent or 4-wheel | Independent or 4-wheel |
| Steering | Independent or 4-wheel | Independent or 4-wheel |
| Dual operation | Tractor and winch operators | Tractor and winch operators |
| Length (over-all) | 17 feet | 17 feet, 10.75 inches |
| Width (over-all) | 8 feet | 8 feet, 0 inches |
| Height (over-all) | 8 feet, 6 inches | 9 feet, 2.75 inches |
| Weight | 17,590 pounds | 31,000 pounds |
| Tractor | | |
| Manufacturer | Frank Hough Co | American Coleman, Model G-78 |
| Speed (maximum) | 40 mph | 30 mph |
| Turning diameter | 30 feet, 6 inches | 36 feet |
| Drawbar pull | 8,000 pounds | 24,000 pounds |
| Motor | 4-cylinder, gasoline (IH - Series JX-4) | 4-cylinder, diesel (GM - Series 71) |
| Electrical system | 12-volt d-c | 24-volt d-c |
| Transmission | MT-40 | Allison Torqmatic Converters Model TC-500 |
| Winch (power-operated) | | |
| Cable tension (developed) | 3,800 pounds | Hi Speed - 1,600 pounds<br>Low Speed - 8,000 pounds |
| Reel-in speed (maximum) | 300 feet per minute | Hi Speed - 600 feet per minute<br>Low Speed - 100 feet per minute |
| Cable length | 400 feet | 500 feet |
| Engine and controls electrical systems | 12-volt d-c | 12-volt d-c |
| Drive system, electrical (eddy-current coupling generator) | 110-volt d-c | 110-volt d-c |
| Cable cutter | Electrical | Electrical |
| Control console | Controls all components | Controls all components |

FIG. 12

The actual size and complexity of the maintenance base will vary according to the size of the dirigible and the number of ships in the fleet. These requirements are listed in Table 7.

Hangars

A hangar is needed to provide access to the upper parts of dirigibles, and to provide protected facilities for assembly and repair. The size of the building depends on the number of dirigibles in the fleet. Using the 3 week period for maintenance, hangars are required with the following capacities:

| No. of Ships in Fleet | Required Hangar Capacity |
|---|---|
| 1-17 | 1 |
| 18-34 | 2 |
| 35-68 | 3-4 |
| 69-102 | 5-6 |

The hangar must be large enough to allow safe docking and undocking. Required land areas or hangar dimensions are calculated by:

$$A = (1.1L \times 2D)\ N$$

Where: A = Total Land Area
L = Length of Dirigible
D = Max. Dia. of Dirigible
N = No. of Dirigibles to be accommodated

The required land area and hangar dimensions are shown in Table 8. Mooring circle areas are also shown in Table 8.

Fuel, Oil, Lubricants

The operation is analyzed as one requiring fueling at only one point. The round trip from Mazamari is presumed to be made on a single fueling. Therefore, for this analysis, the operations base is assumed to be the only airport with fuel supply and storage. Operational experience may dictate multiple facilities.

# FACILITIES FOR OPERATION & MAINTENANCE

| CARGO t | NUMBER OF DIRIGIBLES | HANGAR TYPE | MOORING MAST MOBIL | MOORING MAST FIXED | HELIUM FACILITY | MECHAN MULES | FIRE EQUIP | FUEL | BALLAST EQUIP | ADMIN BUILD |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 1 | 1 | - | MODULES | | MANUAL | PERMANENT & TRUCK | PERMANENT & TRUCK | IN HANGAR |
| | 43 | 4 | 1 | 2 | PERMANENT | | TRUCK | | | |
| | 85 | 6 | 2 | 3 | | | | | | SEPARATE |
| 10 | 21 | 2 | 1 | 1 | MODULES | | | | | IN HANGAR |
| | 43 | 4 | | 2 | PERMANENT | | | | | SEPAR |
| | 85 | 6 | 2 | 3 | | | | | | |
| 20 | 11 | 1 | 1 | 1 | | 2 | | | | |
| | 21 | 2 | | 1 | | | | | | |
| | 43 | 4 | | 2 | | | | | | |
| | 64 | 4 | | 3 | | | | | | |
| | 85-106 | 6 | 2 | 3 | | | | | | |
| 40 | 5-11 | 1 | 1 | 1 | | | | | | |
| | 21-32 | 2 | | 1 | | | | | | |
| | 43 | 4 | | 2 | | | | | | |
| | 53 | 4 | | 3 | | | | | | |
| 100 | 2-17 | 1 | | 1 | | 4 | | | | |
| | 21 | 2 | | | | | | | | |

TABLE 7

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## REQUIREMENTS FOR MOORING & HANGARS

| DIRIGIBLE CARGO t | AREA OF MOORING CIRCLE $m^2$ | DIMENSIONS /AREA ($m^2$) | | | |
|---|---|---|---|---|---|
| | | CAPACITY | | | |
| | | 1 | 2 | 4 | 6 |
| 5 | 20300 | 88x38 / 3344 | 176x38 / 6688 | 176x67 / 11792 | 264x67 / 17688 |
| 10 | 31000 | 109x46 / 5014 | 218x46 / 10028 | 218x81 / 17658 | 327x81 / 26487 |
| 20 | 47400 | 135x59 / 7965 | 270x59 / 15930 | 270x103 / 27810 | 405x103 / 41715 |
| 40 | 73800 | 169x72 / 12168 | 338x72 / 24336 | 338x126 / 42588 | 507x126 / 63882 |
| 100 | 162900 | 250x93 / 23250 | 500x93 / 46500 | | |

TABLE 8

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## Ballast

Each landing site should be equipped to ballast the dirigibles as may be required. It is possible that most of the time, the desired static condition can be achieved by loading cargo, but temporary additional weight may be required. Since ballast can be in the form of water which is readily pumped into storage facilities on board, this facility is easily provided.

## Helium Supply

It is assumed that all helium is imported. Two procedures may be used based on information in Ref. 1. The choice depends on the size of the dirigibles and the number of ships in the fleet. The first method involves importing modules of helium containing 3257 $m^3$ per module. At the delivery point, such as the maintenance and operations base, the gas is used to inflate the dirigible and the modules can be kept on hand to be used for replenishment. A second method involves building a storage facility. This can be a low pressure, large expandable tank -- or a flexible envelope -- or in the form of high pressure storage cylinders, which can be supplied by the helium distributor. High pressure storage requires manifolds for connecting numbers of cylinders and a compressor. A fully developed facility would have both high and low pressure storage.

## DIRIGIBLE REQUIREMENTS

A measure of transport capability is the term: productivity (P). This is defined as:

$$P = v_a \quad W_p$$

Where: $v_a$ = average route speed

$W_p$ = cargo weight

In the past, dirigibles achieved productivity values which exceeded these of airplanes primarily due to large cargo capacity and relatively small route speed differential. Later developments in airplanes increased the speed differential as well as payloads and reversed this relationship. Dirigibles are limited by their large hull volumes to low speed flight, so that significant increases in transport efficiency cannot be gained by raising the speed. If attempts are made to fly dirigibles in the speed regimes of airplanes, the power required very quickly exceeds that of airplanes of comparable capacity. In addition, the hull volume for equal payload capacity also grow at a rapid rate. An example is illustrated in Figure 13, which plots horsepower and volume required against maximum speed for 10 ton payloads.

Productivity values for different combinations of speed and payload are shown in Figure 14. This provides a useful index for comparing capabilities of various types of aircraft. It is a dependent figure of merit since it is based on $v_a$, which is dependent on route distance. The term $v_a$ can be determined from a calculation of block time ($t_b$). Block time is the total period of movement from and to the airport loading ramps, including the flight time.

Airline operations use precise values of block time based on traffic statistics for particular routes and airports. This is not possible for non-existant routes. Therefore, an equation was developed to account for anticipated effects on the operation of various types of aircraft on the primary routes. The aircraft and their characteristics are listed in Table 9.

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RELATION OF VOLUME & POWER OF DIRIGIBLES VS VELOCITY FOR 10 TON CARGOES

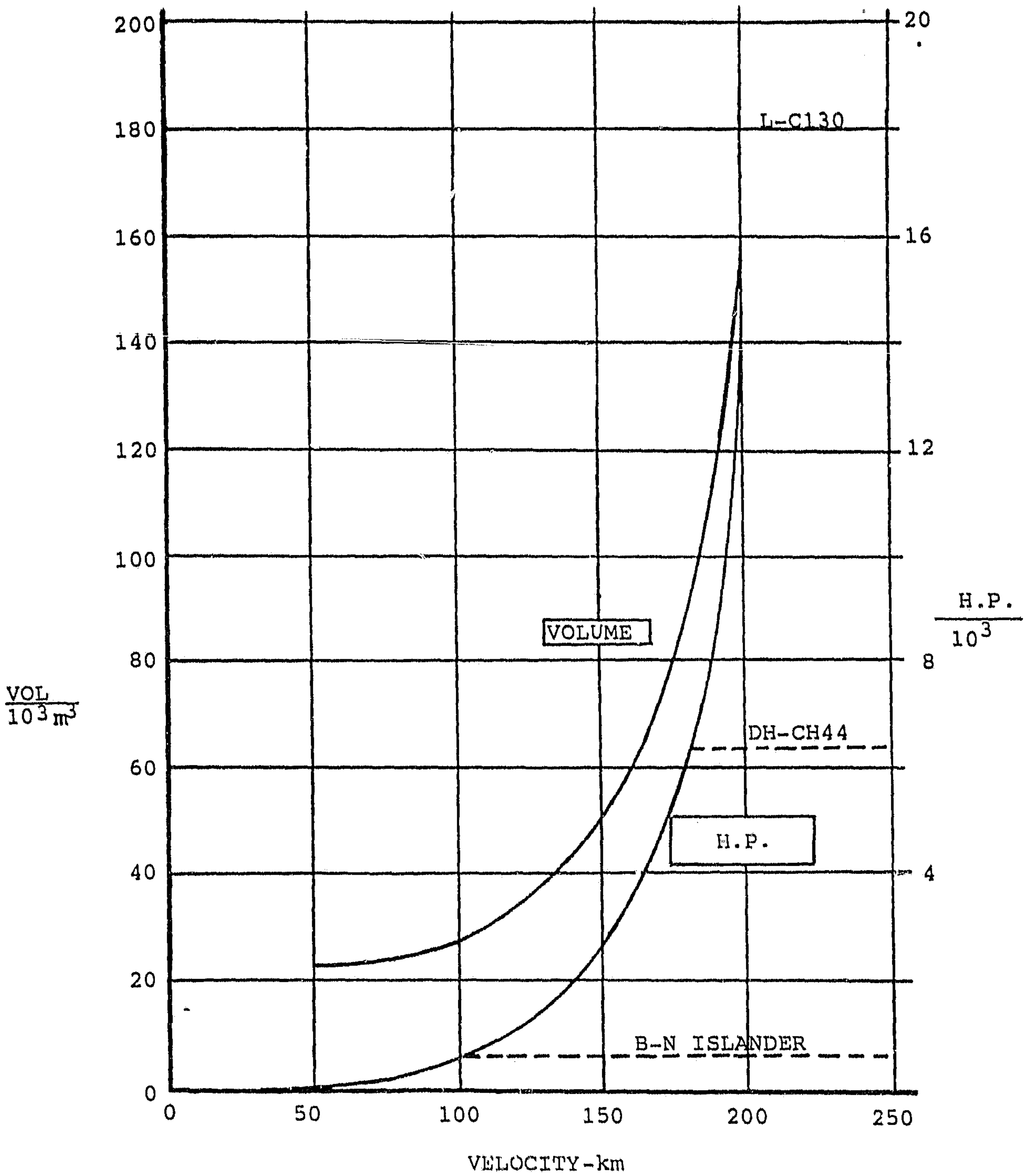


FIG. 13

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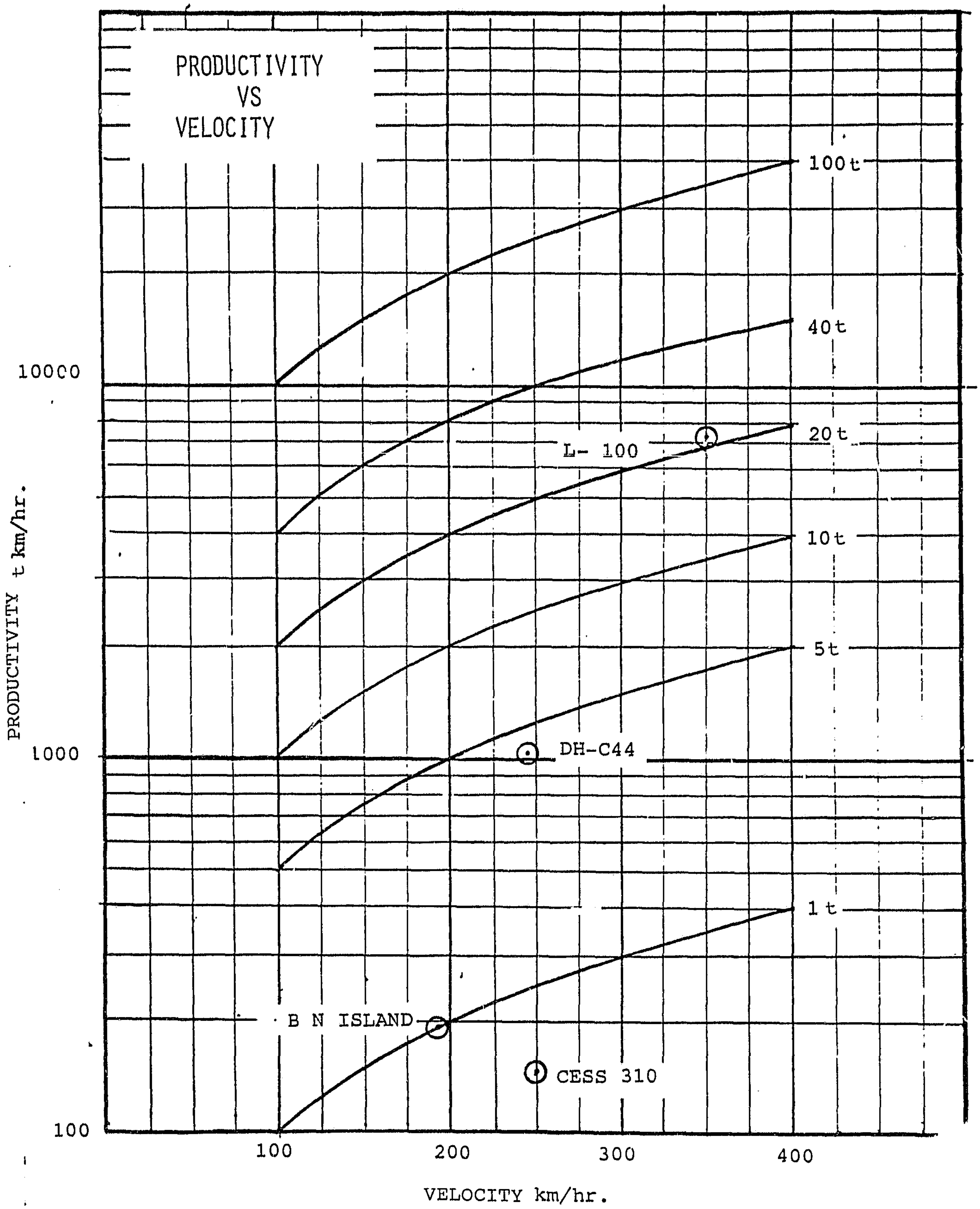


FIG. 14

# AIRPLANES

| AIRPLANE | CARGO kg | VELOCITY km/hr. |
|---|---|---|
| CESSNA 180 | 214 | 288 |
| CESSNA 310 | 606 | 360 |
| B-N ISLANDER | 1001 | 240 |
| DeHAVILLAND DHC-5 | 8163 | 336 |
| LOCKHEED L-100 | 23505 | 554 |

DATA: JANE'S ALL THE WORLD'S AIRCRAFT
AVIATION WEEK

TABLE 9

Block time equals:

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$$t_b = \frac{D + C_h}{v_c \left(1 - \frac{v_w^2}{v_c^2}\right)} + t_g$$

Where: $D$ = route distance
$C_h$ = correction for climb and descent time
$v_c$ = cruise speed at cruise altitude
$v_w$ = wind speed
$t_g$ = time on the ground

$t_g$ was assumed to be 0.25 hours for all aircraft. This time includes taxiing to the end of the runway from the loading point, taking-off, landing, and return to the loading ramp. In the case of dirigibles, it includes connecting to a mast, unmasting, positioning the dirigible for take-off, take-off, and the reverse operation at destination. As route distances become shorter, block time differences between slow and fast aircraft diminish. Table 10 compares block times for various aircraft now in operation in the Selva Central against a dirigible with a design cruise velocity of 100 km/hr. Dirigible payloads are also shown in the Table.

The distance involved represent three legs of the primary route from Esperanza to Mazamari with the Esperanza-Atalaya leg being the longest and Pto. Ocopa-Mazamari as the shortest. The fourth column is for the case where a dirigible is completely loaded at Esperanza and flies directly to Mazamari for a total distance of 516 km. As shown, relative productivity for dirigibles increases as the distance decreases due to the effects of $v_a$.

It should be noted that no time is allowed for refueling, loading, or unloading. If these times were included, the average speeds would decrease for all aircraft, and the ratios between the airplanes and dirigibles would decrease slightly, assuming that equal time would be needed in these operations for all types. The average total route distance for all primary routes is 271 km. The average leg distance is 117 km. A mean of these two values, gives a route distance of 194 km and a route speed ($v_a$) of 84 km/hr. for the dirigible. This case is also listed in Table 10 along with ratios for payloads with equivalent productivity.

Using this average route speed value, the payload capacities

## BLOCK TIME & EQUIVALENT PRODUCTIVITY

| ROUTES | ESPERANZA ATALAYA | | ATALAYA-PTO OCOPA | | PTO OCOPA-MAZAMARI | | ESPERANZA-MAZAMARI | | AVERAGE DISTANCE | |
|---|---|---|---|---|---|---|---|---|---|---|
| AVION | BLOCK TIME | $C_e$ | BLOCK TIME | $C_e$ | BLOCK TIME | $C_e$ | BLOCK TIME | $C_e$ | BLOCK TIME | $C_e$ |
| B-N ISLANDER | 1.75 | 2.3 | 0.64 | 2.0 | 0.41 | 1.6 | 2.29 | 2.6 | 1.08 | 2.1 |
| CESS 180 | 1.49 | 1.3 | 0.53 | 0.5 | 0.38 | 0.3 | 1.89 | 0.7 | 1.94 | 0.5 |
| CESS 310 | 1.40 | 1.7 | 0.49 | 1.5 | 0.37 | 1.0 | 1.75 | 2.1 | 0.89 | 1.6 |
| DHC-5 BUFALO | 1.31 | 24.7 | 0.45 | 21.0 | 0.36 | 14.3 | 1.60 | 30.2 | 0.83 | 22.7 |
| LOCK. L-100 | 0.89 | 105.0 | 0.28 | 81.0 | 0.32 | 46.0 | 0.97 | 143.0 | 0.60 | 90.2 |
| DIRIGIBLE | 3.96 | - | 1.57 | - | 0.63 | - | 5.92 | - | 2.31 | - |

Block Time = HOURS
$C_e$ = DIRIGIBLE CARGO REQUIRED FOR EQUIVALENT PRODUCTIVITY (tons)

TABLE 10

and numbers of dirigibles required to achieve various delivery rates can be calculated as:

$$N = \frac{Q}{qt_t}$$

Where: N = number of dirigibles required
Q = quantity of cargo to be delivered per year ( Tkm)
q = delivery capability of dirigible (tkm./hr.)
$t_t$ = total flight hours per year (2800)

Total flight hours (2800) are chosen on the basis of an 8 hour/day operation with approximately a 3 week period required for major maintenance. This, by the way, is a high utilization rate for short haul services. The various numbers of dirigibles required are shown in Table 11. Dirigible transport capabilities are also plotted in Figure 15.

These numbers signify, for example, that projected 100 M t km cargoes could be transported by a fleet of 22 20t payload dirigibles. Each dirigible would be capable of delivering at any one time loads nearly equal to those carried in L-100 airplanes. Equal productivity, however, would require a dirigible of 90.2 tons payload. The cargo requirement for 1985 (100 million tkm) could also be transported by a fleet of 43 10t or 85 5t dirigibles.

These requirements for various fleet sizes presume that the dirigible starts its flight at the point of first cargo pick-up. Round trips along each route are not included in the route distances or for calculating flight time due to the nature of the route. As an example, it is not presumed that the dirigible flies from Mazamari to Esperanza without cargo and returns with cargo. As a refinement, this kind of route analysis can be made using different combinations of routes and cargoes. In the present analysis, it is presumed that equal loads are flowing in both directions -- although not necessarily the same type of cargo -- so that the fleet sizes listed are really an indication of the transport capacity for a total flight time of 2800 hours per year.

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NUMBER OF DIRIGIBLES REQUIRED
TO SATISFY TRANSPORT DEMAND

| TRANSPORT DEMAND t km'/$10^6$ | CARGO – TONS | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 20 | 40 | 100 |
| 1 | 2 | 1 | | | | |
| 50 | 106 | 43 | 22 | 11 | 6 | 2 |
| 100 | | 85 | 43 | 22 | 11 | 4 |
| 200 | | | 85 | 43 | 22 | 8 |
| 300 | | | | 64 | 32 | 13 |
| 400 | | | | 85 | 43 | 17 |
| 500 | | | | 106 | 53 | 21 |

TABLE 11

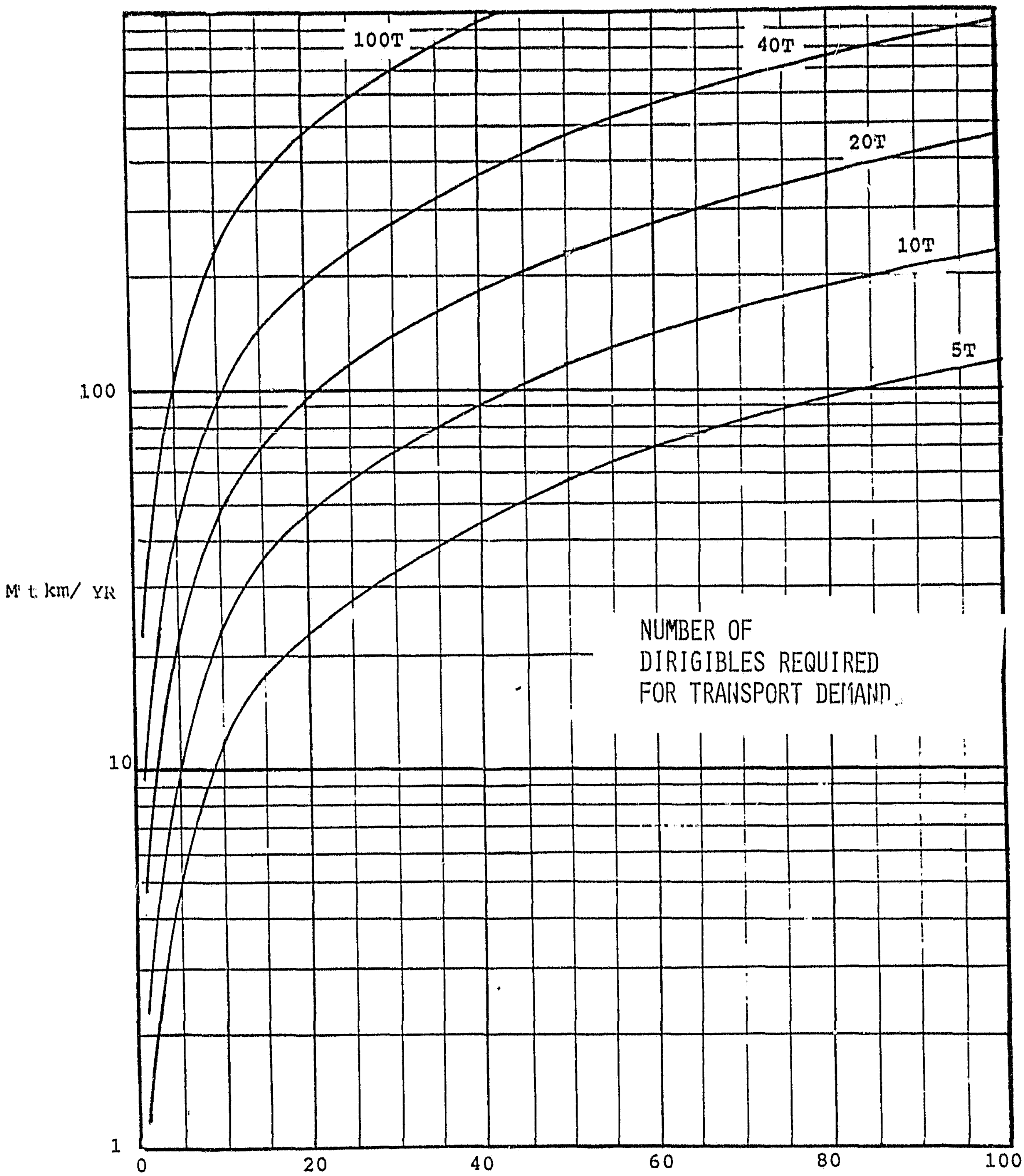
100T
40T
20T
10T
5T
100
10
1
M t km/ YR
NUMBER OF
DIRIGIBLES REQUIRED
FOR TRANSPORT DEMAND.
0
20
40
60
80
100
NUMBER OF DIRIGIBLES

FIG. 15

In listing these numbers, it seems reasonable that the maximum number of dirigibles operating on the primary routes should not exceed approximately 100 due to practical considerations of terminal congestion and ground facilities.

It is also of interest to note that if the needs for cargo transport are not achieved immediately, lower quantities, for example 50-million ton-km, could be transported by a fleet of 11 20 ton payload dirigibles, with a productivity rate approximately equal to De-Havilland Buffalo (DHC-5) airplane. Smaller dirigibles of 2 and 5t capacities are competitive with the light aircraft now in use but are capable of delivering significantly larger cargoes at one time.

No single size of dirigible is necessarily a solution. On long flights such as from Esperanza to Mazamari, larger dirigibles may be desirable to accommodate the heavy cargo requirements from the Esperanza zone. Landing only at Mazamari would favor the overall efficiency of the operation and simplify requirements for ground handling, etc. at intermediate points. Smaller dirigibles might prove to be more effective and easier to handle on shorter routes. Some of the decisions required can be made on the basis of the economic analysis which follows. Others may be based on less tangible factors.

## DIRIGIBLE CHARACTERISTICS

The general characteristics of the dirigibles required for operation in the Selva Central can be identified, based on the mission analysis. As stated, two major types are considered, conventional and hybrid. All dirigibles are proposed as nonrigids with the exception of the 100 ton payload vehicle. This was assumed to be a rigid type because of its size.

All conventional dirigibles were assumed to have identical performance except for their payload capacity. The hybrids were chosen from previous studies with performance as close to the ranges of the conventional types. Table 12 shows the common characteristics for the various sizes used in the study. Specific characteristics for each type are listed in Table 13. The costs were derived from the economic analysis made in the next section. Component weights for 5-40 t ships were derived through the use of the U.S. Navy NAPSAP computer program. It can be noted that a cruise speed of 100 km/hr. is listed for all ships. This was chosen to provide a low fuel consumption rate combined with a useful cruise speed. The maximum speed of 138 km/hr. provides sufficient margin for ample take-off power and for operation in high head winds. Later in this study, the effects of higher speeds are explored.

Ballonet size on each dirigible allows for the normal cruise altitude of 960m with sufficient capacity to compensate for high ambient temperatures and superheat without exceeding pressure height. The ballonet ceiling of 2895 m is more or less standard in nonrigid design and allows for special missions where higher altitude flight is required. As noted, however, the normal pressure height is 1524 m.

The values for finess ratio and prismatic coefficient are based on conventional dirigible shapes.

Fuel capacity for 12 hours of cruise at 100 km/hr. is sufficient to allow flying the entire longest route and returning without refueling. However, sizing and performance calculations were based on the median range round trip with a reserve of about 22%. This is also sufficient for a one-way non-refueled flight over the longest route distance. If longer endurance is required, then payload would have to be adjusted to allow for increased fuel load. All fuel consumption is based on use of turbine engines

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## COMMON CHARACTERISTICS OF CARGO DIRIGIBLES

| | CONVENTIONAL | HYBRID |
|---|---|---|
| VELOCITY | | |
| CRUISE | 100 km/hr. | 110 km/hr. |
| MAXIMUM | 138 km/hr. | - |
| ALTITUDE | | |
| CRUISE | 960 m | SAME |
| PRESS. ALT. | 1524 m | SAME |
| BALLONET ALT. | 2895 m | SAME |
| PRISMATIC COEFF. | 0.65 (5-40 t<br>0.75 (100 t) | SAME |
| FUEL CAPACITY | | |
| NORMAL | 6.55 hrs. @ 100 km/hr. | SAME |
| MAXIMUM | 12.00 hrs. @ 100 km/hr. | SAME |
| MISSION EQUIPMENT | | |
| 5-10 t | 450 kg | SAME |
| 20-100 t | 900 kg | SAME |
| STATIC WEIGHT | 1.1 GROSS LIFT | 2.0 G.L. |

TABLE 12

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SPECIFICATIONS FOR
CARGO DIRIGIBLES

| CARGO t | VOL $m^3$ | L m | D m | RF L/D | Lg kg | WE kg | H.P. | WEIGHT ENV kg | WEIGHT AF kg | WT PROPUL. kg | COST M$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 16360 | 83.3 | 19.6 | 4.25 | 15000 | 8830 | 1033 | 3268 | 4972 | 585 | 3.689 |
| 10 | 26660 | 98.1 | 23.1 | 4.25 | 24448 | 13597 | 1420 | 4934 | 7913 | 750 | 6.419 |
| 20 | 46620 | 118.3 | 27.7 | 4.25 | 42732 | 22125 | 2059 | 8390 | 12656 | 1079 | 11.311 |
| 40 | 84509 | 144.2 | 33.8 | 4.25 | 77473 | 38638 | 3093 | 15213 | 21800 | 1625 | 22.009 |
| 100 | 234494 | 238.0 | 43.3 | 5.50 | 202693 | 89185 | 4618 | – | – | – | 70.573 |
| HYBRID DIRIGIBLES | | | | | | | | | | | |
| 16 | 27698 | 101.7 | 24.4 | 4.17 | 45597* | 22935 | 9600 | 6374 | 10204 | 6357** | 16.000 |
| 50 | 69725 | 131.7 | 32.0 | 4.12 | 125629* | 57733 | 26000 | 14734 | 24825 | 18174** | 48.651 |

*INCLUDES ROTOR LIFT
**INCLUDES ENGINES, ROTORS, CONTROLS

TABLE 13

Electronics and other equipment for navigation and communication are allowed for in the mission equipment weight specified.

The loading of cargo could be accomplished through the use of modularized containers to minimize the time and complexity of this operation. The containers would be wheeled or trailered to the dirigible and connected to the car structure through the use of quick-connect hardware.

Figure 16 shows profile views of the various sizes of dirigibles studied. Figure 17 illustrates a loading procedure.

The characteristics and weights for the 100 ton vehicle were estimated by the author. This was presumed to have four engines.

# DIRIGIBLES

## PROPORTIONS



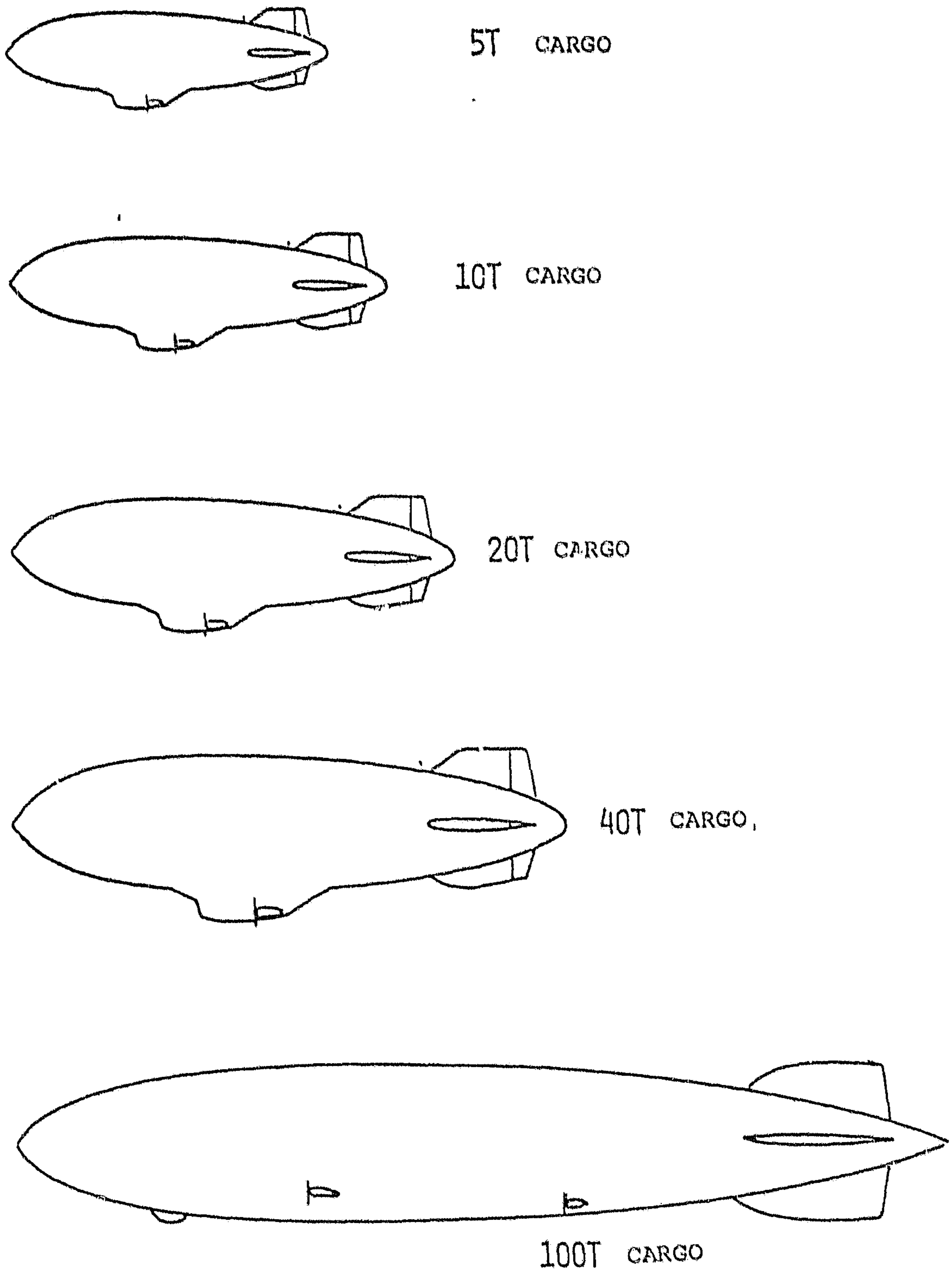


FIG. 16

PROCEDURES FOR CARGO LOADING

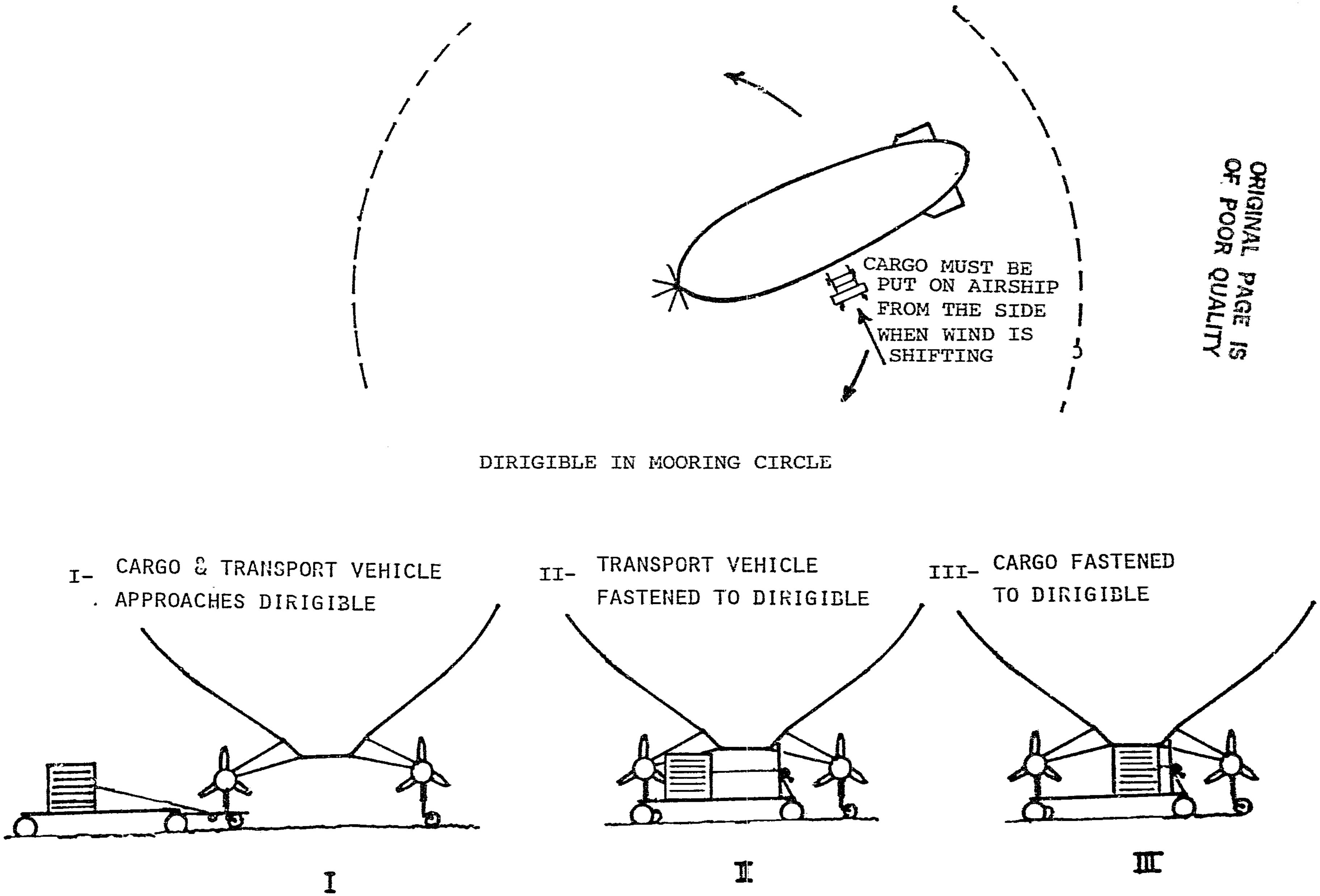


FIG. 17

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# ECONOMICS

Accurate analysis of costs for the acquisition and operation of dirigibles involves three elements: (1) applicable data base, (2) current industrial experience, (3) mission related calculations. The first two provide source material for the third. Unfortunately, neither of these sources exist. Dirigible manufacture and operations of any significant magnitude in the United States were terminated in 1961. Data from these activities are not particularly useful since the dirigibles were designed to carry complex and expensive electronic weapon systems for military use which greatly increased the cost of design, construction, and operation. There were and are no comparable activities anywhere in the world for either civil or military applications. Current enterprises are experimental and of limited scope. On these bases, economic analyses can be subject to some if not considerable inaccuracy. Those performed in the study were made with this fact in mind and many personal judgements combined with data from current activities and estimates from vendors in supply industries were applied in an attempt to reach reasonable conclusions regarding economic potential. All costs are expressed in U.S. 1981 dollars, and all data used were modified in terms of this common base.

## The Cost of Dirigibles

Data from several existing or contemplated dirigibles were studied to establish a cost trend for different sizes. It was found that this could not be done without compensating for large differences in performance and system complexity. The trends established, using data from Table 14, compared with airplanes and helicopters, plotted on the same basis, are shown in Figure 18.

In order to establish a more valid approach, data from several groups of airplanes were plotted as shown in Figure 19. These show a trend opposite to that in Figure 18, and indicate that aircraft of similar types do not cost more per pound of weight with increasing size. The large negative slope for jet transports also shows the effects of high production rates. The exception seems to be for light airplanes but here again, the heavier types in this category generally have higher performance.

# DIRIGIBLE DATA

| DIRIGIBLE | VOL $m^3$ | GROSS WEIGHT @ 760m kg | WEIGHT EMPTY kg | CARGO & FUEL kg | WE/WG | L m | D m | RF | H.P. TOTAL | V Max. | COST $M | COST * $/kg $W_e$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U.K. SS-500 | 5131 | 5068 | 3283 | 1785 | .63 | 50 | 14 | 3.6 | 380 | 115 | 2.05 | 642 |
| U.K. SS-600 | 6055 | 5766 | 3331 | 2435 | .58 | 56 | 14 | 4.0 | 500 | 120 | 2.70 | 811 |
| U.S. GZ-20A | 5741 | 5428 | 4081 | 1347 | .75 | 58.5 | 14 | 4.2 | 420 | 80 | 1.73* | 424 |
| G.F.R. WDL-1 | 6000 | 5846 | 4789 | 1057 | .82 | 60 | 14.5 | 4.1 | 420 | 100 | 1.80 | 376 |
| | | | FUTURE DIRIGIBLES | | | | | | | | | |
| U.S. ZP3G | 24781 | 23434 | 15302 | 8132 | .65 | 99 | 22.4 | 4.4 | 2400 | 155 | 18.[illegible] | 1229 |
| U.S. M.P.A.S. | 22195 | 20989 | 12551 | 8438 | .59 | 93 | 21.1 | 4.4 | 1927 | 144 | 18.6 | 1481 |
| GFR WDL-II | 60000 | 57139 | 15891 | 41248 | .28 | 122 | 30 | 4.1 | 2600 | 140 | – | – |

* SEE TEXT

TABLE 14

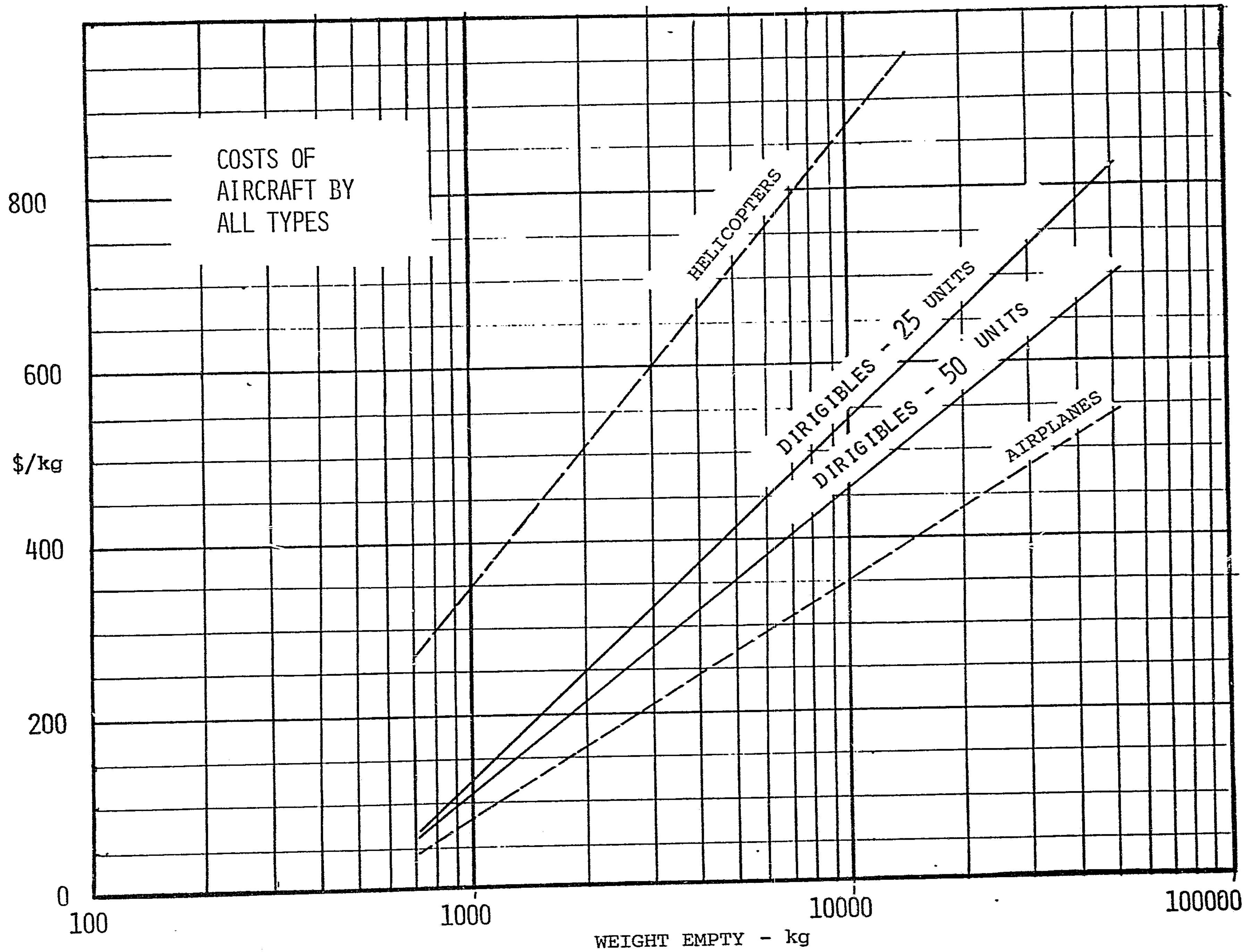


FIG. 18

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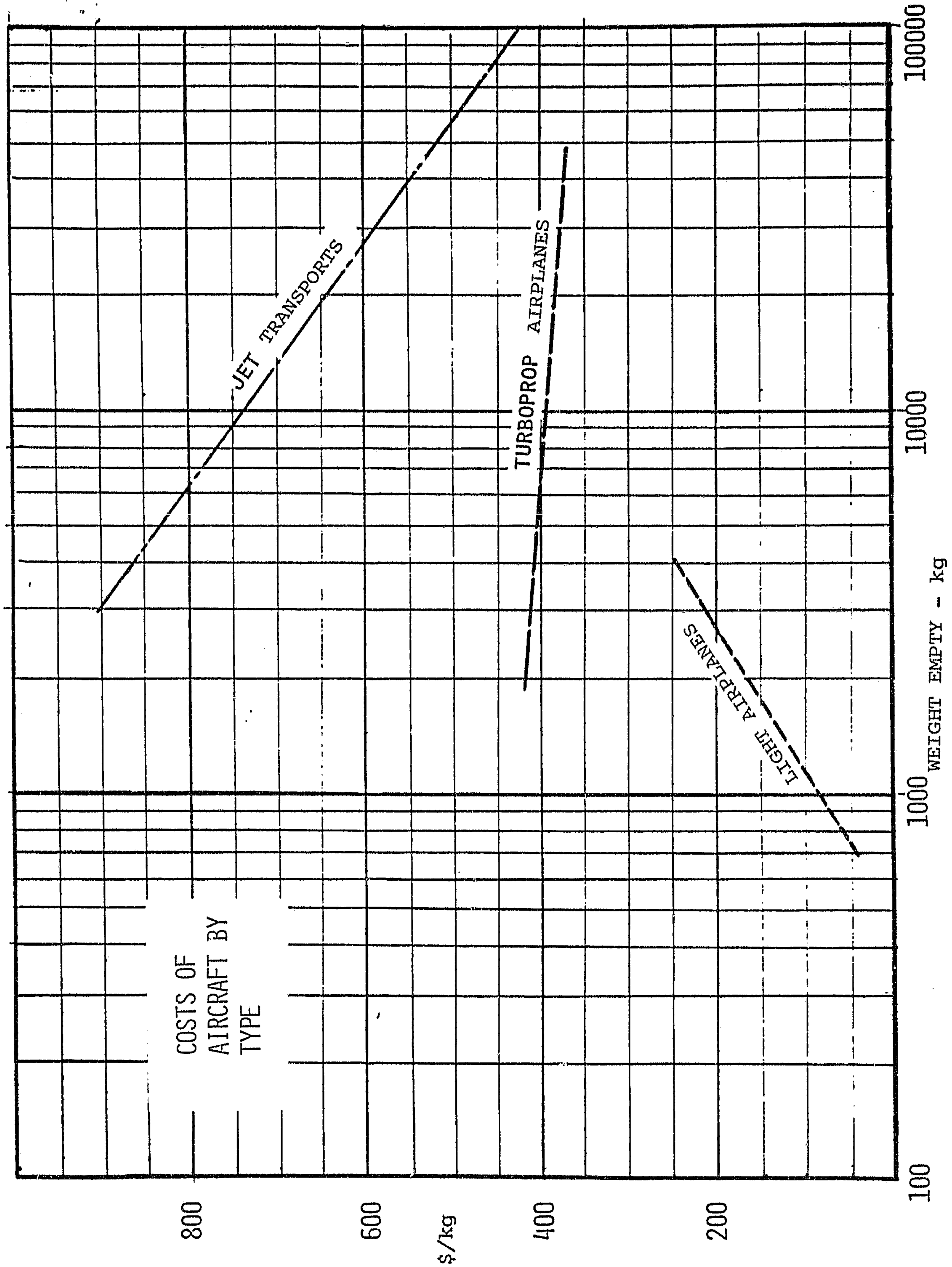


FIG. 19

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The dirigibles being considered for this study are all in the same category of performance except for cargo capacity. Therefore, it is reasonable to expect that cost per pound should be equal through the entire range of sizes, assuming equal production quantities. With these trends as an indication, a cost approach was used which considers a dirigible to consist of three major components: envelope, airframe and systems, and propulsion. This was done on the basis that component costs could be more accurately established and components may be obtained through separate manufacturers. Thus each would already include some profit (to the vendor). Costs for final assembly of the vehicle and some additional amounts for administration and profit must be added.

The component costing method is expressed as follows:

$$C_u = C_{\Delta_1} \left[ \frac{(a f_1 + b f_2 + d f_3) \, WE + cP}{C_{\Delta_2}} \right]$$

Where: $C_u$ = production costs assuming a rate is achieved where appreciable reductions due to learning are not significant.

$C_{\Delta_1}$ = Administrative costs and profits on final production operations (assembly, testing, etc.). Evidence from recent projects suggests a value of 1.5.

$C_{\Delta_2}$ = Assembly cost factor = .85

a,b = Cost per kg of envelope and airframe.

d = Cost per kg of rotor systems (for hybrids)

$f_1$, $f_2$ = Weight fraction of envelope and airframe. The airframe includes all components and systems except envelope and propulsion.

P= H.P.



$f_3$ = Weight fraction of rotor systems (for hybrids).

WE = Weight empty

c = Cost per horsepower of engines, transmissions, and propulsive units (propellers).

The envelope is a component unique to nonrigid dirigibles. Cost data for envelopes were used from actual and estimated construction costs from recent U.S. and British dirigibles and balloons. It was found that a substantial difference existed between these two sources. Some of this can be explained by variations in design and construction methods and the rest by differences in profit and overhead expense. The curves shown in Figure 20, were adjusted for these differences and represents average international competitive price levels. The lower limit was used.

The airframe component is assumed to include all major systems except the propulsion system. The structures involved are similar to airplanes with two differences: they are larger and they are of lighter construction. It was assumed that costs for these components would be similar to airplane components in the same weight category, i.e. -- that portion represented by the dirigible weight fraction.

Airframe costs, including systems, were separated from propulsion costs for the airplanes studied to prepare the curves on Figure 21. Using these trends as a basis and considering the points discussed above, a probable dirigible airframe and systems cost curve was established. A band of values is shown in Figure 21, representing upper and lower bound estimates. A mean value was used to calculate dirigible airframe and system costs. Data from Ref. 2 were used to plot cost trends for propulsion systems as shown in Figure 22.

Component costs were calculated based on the components weights derived in the NAPSAP program. An exception was the 100 ton payload dirigible. Since this was presumed to be a rigid, costs were based on information in Ref. 3.

Hybrid dirigible costs were derived from a combination of the component cost method and data in Ref. 4.

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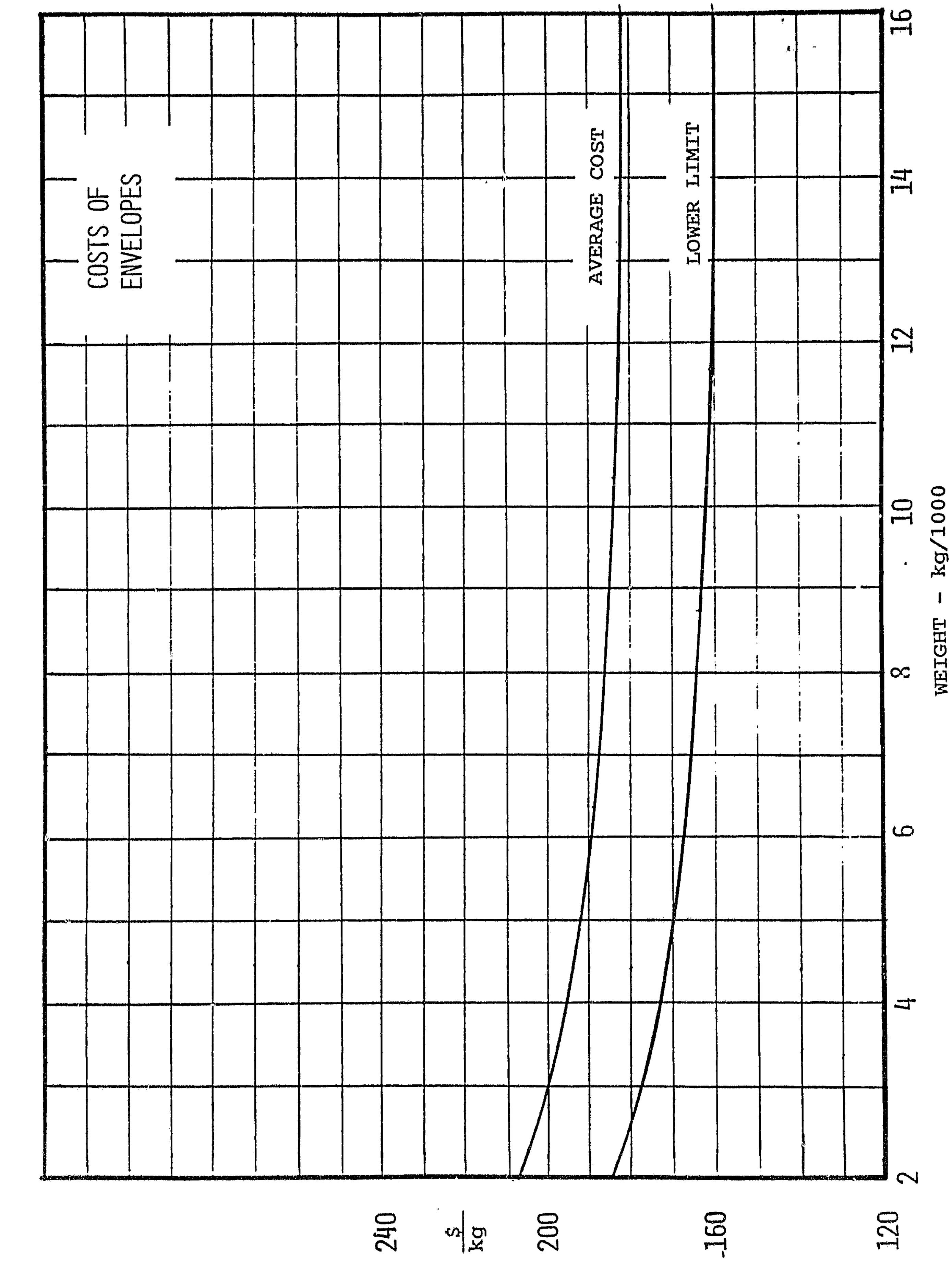


FIG. 20

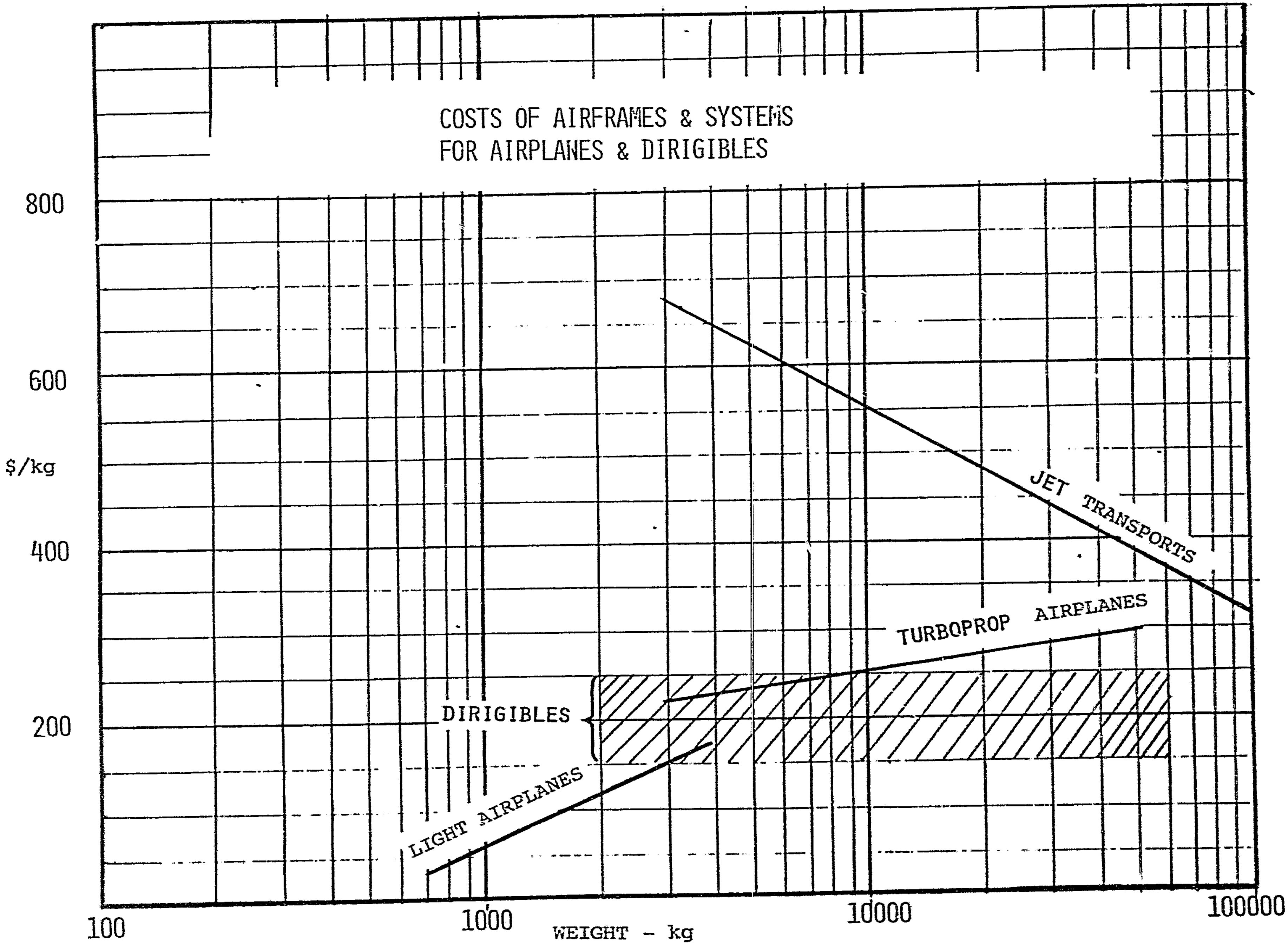
COSTS OF AIRFRAMES & SYSTEMS
FOR AIRPLANES & DIRIGIBLES
800
600
$/kg
400
200
JET TRANSPORTS
TURBOPROP AIRPLANES
DIRIGIBLES
LIGHT AIRPLANES
100
1000
10000
100000
WEIGHT - kg

FIG. 21

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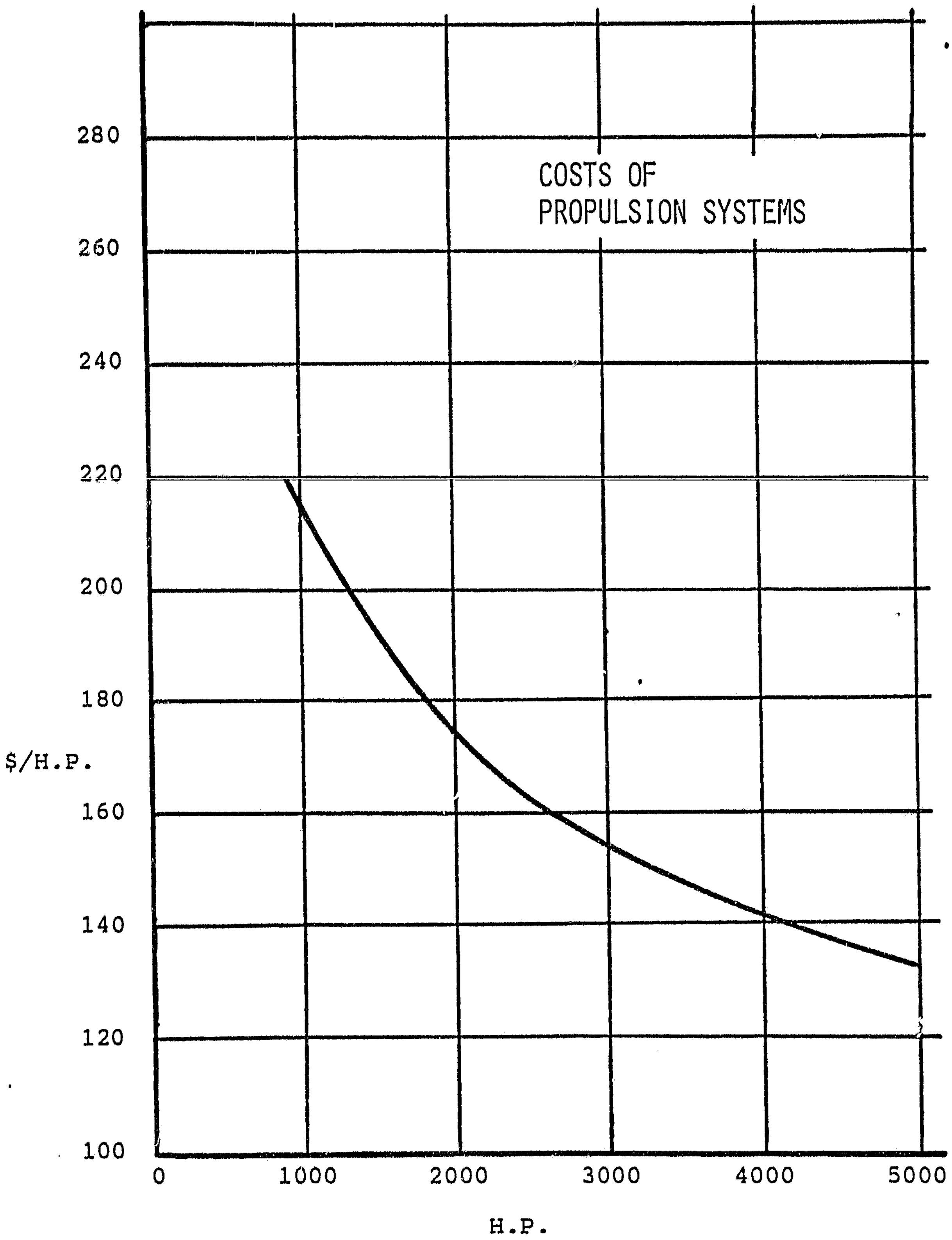


FIG. 22

## Total System Costs

Total System Costs ($C_T$) can be expressed as follows:

$$C_T = C_{II} + C_O$$

Where: $C_{II}$ = Initial investment

$C_O$ = Operating Costs

## Initial Investment

It is obvious from the market analysis that a fleet of dirigibles would be required to meet the cargo requirements as projected for the next 20 years. An operation of this magnitude is akin to airline service and would require a complete transport system including a base of operations, a maintenance base, proper equipment at all airports on the primary route for handling dirigibles, and sufficiently trained and skilled personnel. It is likely, however, that such facilities could be acquired gradually and expanded as the traffic demands. Operations could begin, for example, with a single 5 ton dirigible which would be capable of 1 million ton km of transport, a level likely to represent initial operations or a trial program to evaluate the system.

It was assumed that the minimum required facilities for the primary route are established to begin with, and each airport is modified as previously discussed even for single vehicle operation.

This analyses treats the initial investment as distinct from operating costs since a number of options for financing are possible such as:

1. Considered as basic to the development of the region and not charged against the dirigible operation.
2. Partially charged.
3. Charged completely.

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Whatever method is chosen, its impact can be assessed. It can also be compared to other system investment costs such as: road building, airport enlargement, and runway hardening, etc.

Costs can be expressed as follows:

$$C_{II} = C_v + C_{ab} + C_A$$

Where: $C_{II}$ = Initial investment costs

$C_v$ = Ground handling vehicle costs

$C_{ab}$ = Airport, maintenance and operations base cost

$C_A$ = Dirigible costs

Cost for all items are based on the references noted. Where it was deemed attainable, prices were adjusted to reflect benefits of lower labor costs for items which could be constructed in Peru, such as mooring masts and hangars.

Ground Handling

It is possible under favorable conditions to ground handle dirigibles of any size with manpower alone, and the relatively low cost of manpower in Peru makes this the least expensive method in any case. However, mechanical equipment, as described in the previous section, provides more reliable and safer operations. It is assumed, therefore that ground crews only will be used to handle conventional dirigibles up to 10 t payload capacity, but that mechanical mules will assist this operation for larger sizes. Mules are listed at $380,000 each. Two are required for 20-40 t dirigibles and four for 100 t sizes.

Hybrid dirigibles normally would not require ground crews for landing and taking-off, subject to the limitations previously discussed.

Airport Modification

The costs of airports consist of clearing and grubbing expense. A cost of $1000/ha was used, based on Ref. 5.

Mooring Sites

The cost of mooring sites are a combination of land preparation expense and mast costs. The same rate as for airport modification was used for mooring circles. It was presumed that mooring sites would be constructed for three sizes: 5-10 t payload dirigibles, 20-40 t, and 100 t. A stick mast was assumed in all cases. No cost distinction was made for these, although a slight difference in cost depending on dirigible size would actually be the case. An average cost of $187,500 per mast was used.

Hangars

The cost of a hangar or hangars is assessed on the basis of maintenance requirements. It is assumed that each dirigible will require a 3 week period per year for major maintenance in a hangar. It is assumed that new dirigibles are delivered assembled or that sufficient space exists in the hangar to allow for their assembly either between maintenance schedules for other dirigibles or during them, and no additional hangar facilities are needed for this function. In all cases a single building was assumed, although it may be more practical to consider building more than one unit of smaller size. Unit costs for construction were assumed as $300/m$^2$ based on Ref. 5.

Maintenance and Operations Base

Costs chargeable against the base include land clearing and grubbing for the hangar and mast sites, mooring masts, helium storage, ground handling equipment, fire fighting equipment, fueling facilities, ballast facilities, and space and equipment for management and administration. The degree to which any or all of these facilities is included in the cost calculation is dependent on dirigible and fleet sizes. Costs associated with the required equipment and facilities are listed in Table 15.

All equipment is considered to have an amortization life of 30 years with a loan rate of 15%, with the exception of automotive equipment which is assumed at 10 years.

Initial investment costs for conventional dirigibles

# COSTS OF FACILITIES FOR OPERATION & MAINTENANCE



| | | COST ($) |
|---|---|---|
| LAND CLEARING | | 1000/ha |
| HANGAR CONSTRUCTION | | $300/m^2$ |
| MOORING MASTS | | |
| - MOBILE | | 482500-724000 |
| - FIXED | | 187500 |
| HELIUM FACILITIES | | |
| - GAS | | $2.65/m^3$ |
| - STORAGE CYLINDERS | | 175/cyl. |
| - COMPRESSOR | | 20000 |
| - MODULES | (RENTAL) | 85/day/MOD. |
| MECHANICAL MULES | | 380000 |
| FIRE FIGHTING EQPT. | | 84000 |
| HANGAR EQUIPMENT | (TOTAL) | 719000 |
| HIGH RANGER | 136000 | |
| AUXILIARY GENERATOR | 21000 | |
| GROUND CLOTHS | 5000 | |
| INFLATION NETS | 10000 | |
| INFLATION TUNNELS | 5000 | |
| BOSUNS CHAIRS | 2000 | |
| BLOWERS | 20000 | |
| TOOLS & EQUIPMENT | 500000 | |
| FUEL FACILITY | | 92000 |
| FUEL TRUCK | | 63000 |
| BALLAST FACILITIES | | 7000 |
| ADMINISTRATION BLDG. | | 50-100000 |

TABLE 15

calculated on an annual basis are shown in Figure 23.

Operating Costs

Operating costs can be expressed as:

$$C_o = C_{IOC} + C_{DOC}$$

Where: $C_{IOC}$ = Indirect operating costs

$C_{DOC}$ = Direct operating costs

Indirect Costs:

$$C_{IOC} = C_{vm} + C_{vs} + C_{ch} + C_{gc} + C_{mo} + C_a$$

Where: $C_{vm}$ = Ground equipment maintenance

$C_{vs}$ = Vehicle Servicing

$C_{ch}$ = Cargo Handling

$C_{gc}$ = Ground crew

$C_{mo}$ = Maintenance and Operations Personnel

$C_a$ = Administrative

Maintenance of ground equipment is equivalent to 10% of the initial investment expense (less interest) per year.

Servicing, ground handling, and cargo handling is assumed to be performed by the same personnel at each airport, at a salary cost of $150/man/month or $1800 per year (Ref. 6). Costs for a total of 8 crews are as follows:

| Airship PL(t) | No. In Crew | Cost/Yr. | |
|---|---|---|---|
| 5 | 20 | $ 288,000 | |
| 10 | 30 | 432,000 | |
| 20 | 12 | 173,000 | mechanical mules used with crew. |
| 40 | 12 | 173,000 | |
| 100 | 24 | 346,000 | |

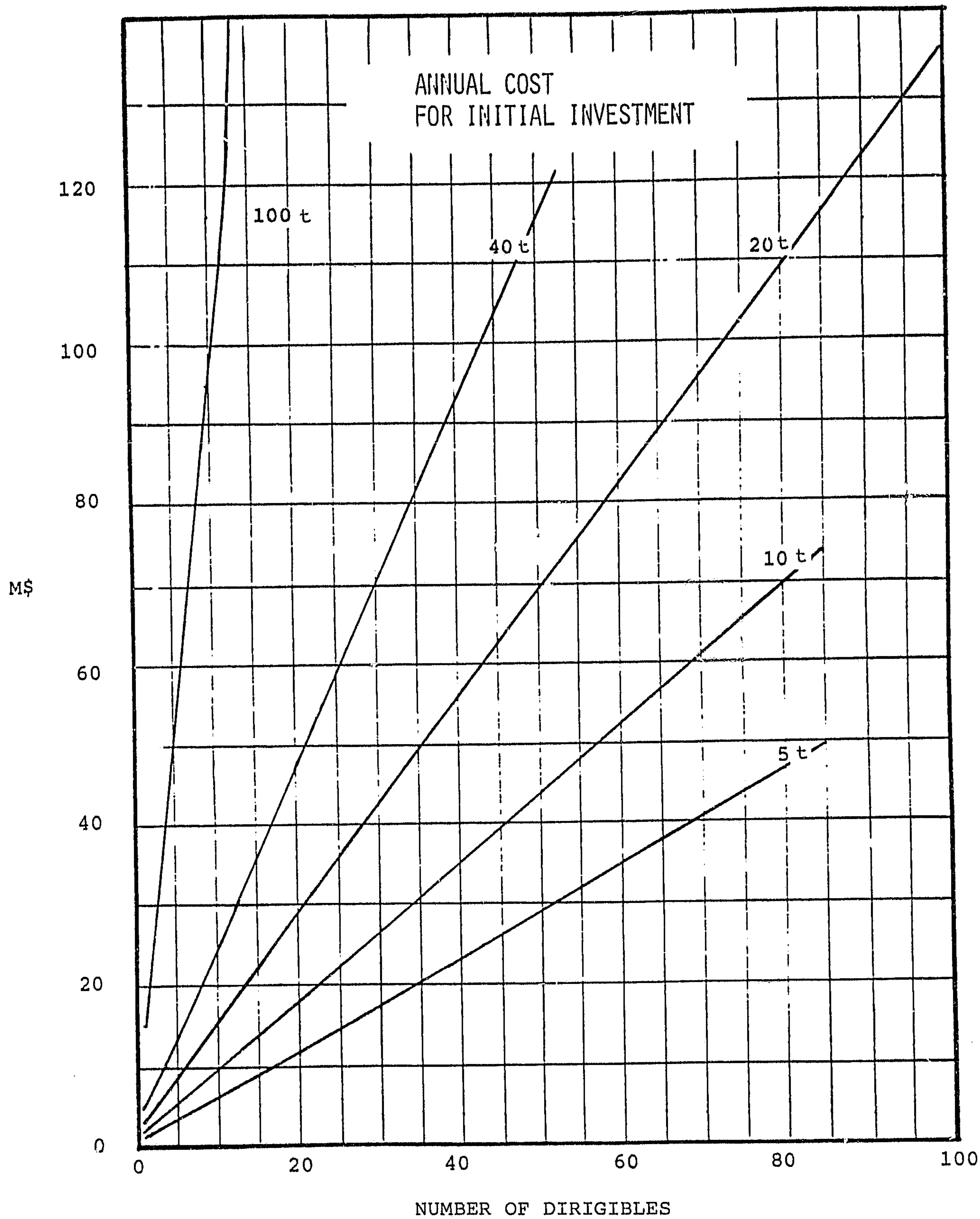
ANNUAL COST
FOR INITIAL INVESTMENT
120
100
80
60
40
20
0
M$
100 t
40 t
20 t
10 t
5 t
0
20
40
60
80
100
NUMBER OF DIRIGIBLES

FIG. 23

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Maintenance base personnel are assumed to include the following:

| | | |
|---|---|---|
| Base Manager | - | \$12,000/yr. |
| Assistant | - | 10,000 |
| Mechanics | - | 5,000 |

The number of mechanics required is adjusted according to the size of the dirigibles and the number in the fleet.

Operations base personnel include:

| | | |
|---|---|---|
| Base Manager | - | \$12,000/yr. |
| Assistant | - | 10,000 |
| Secretary | - | 5,000 |
| Staff | - | 3,000 each |

The number of staff personnel was adjusted in the analysis according to fleet requirements.

Administrative costs are assumed to be equal to management and maintenance personnel costs.

Annual indirect operating costs for conventional dirigibles are plotted in Figure 24.

Direct Operating Costs

Direct operating costs are a function of the number of dirigibles in the fleet expressed in the following terms:

$$C_{DOC} = N \left[ C_c + C_f + C_{de} + C_{od} + C_i + C_{ma} + C_{he} \right]$$

Where: N = Number of dirigibles

$C_c$ = Flight crew costs (at \$12,000/annum/person

$C_f$ = Fuel cost (at \$1.25/gal.

$C_{de}$ = Depreciation (at 8.5% cost of dirigible - This assumes a residual value of 15% and a 10 year life).

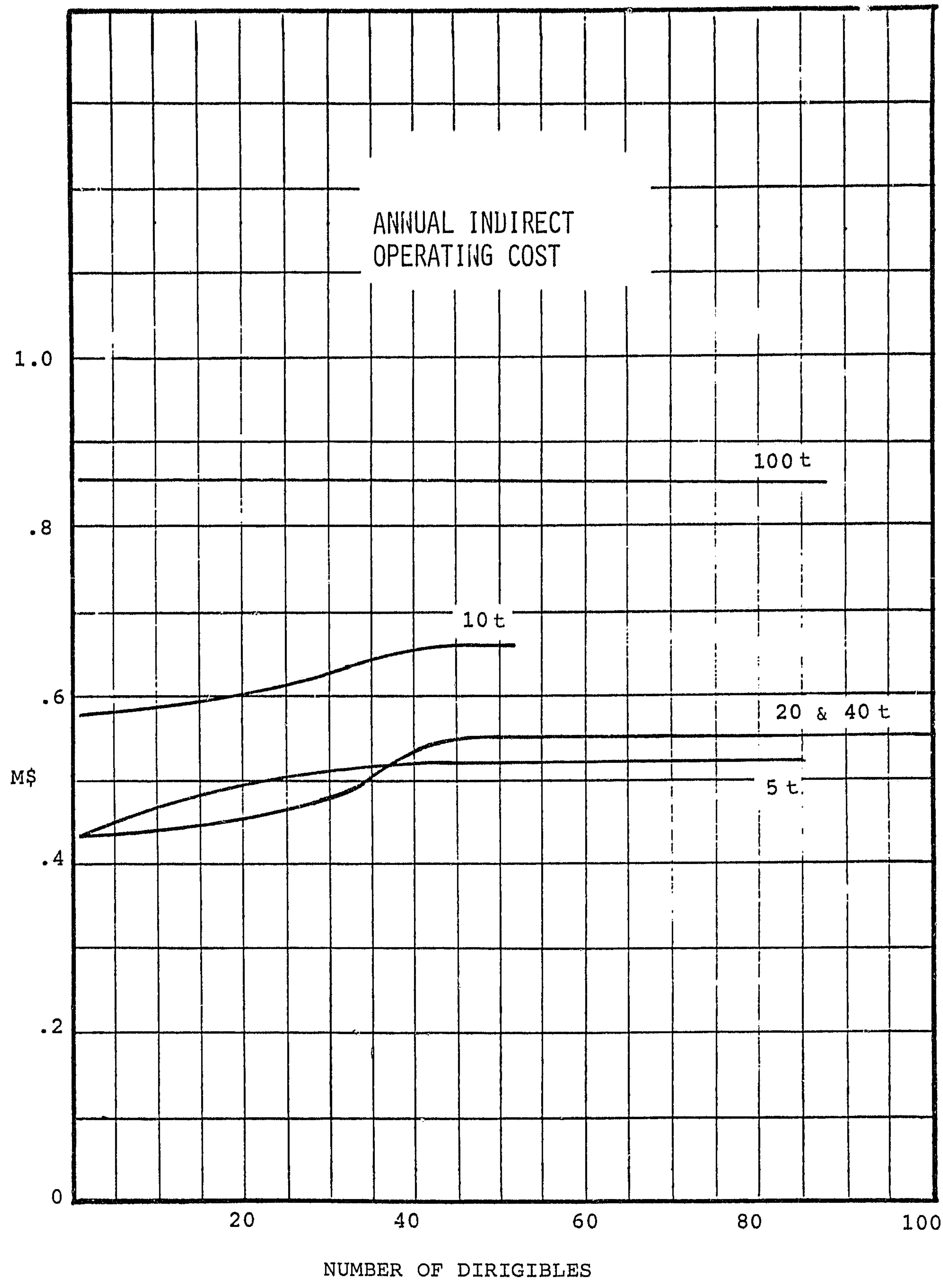
ANNUAL INDIRECT
OPERATING COST
1.0
.8
.6
.4
.2
0
M$
100 t
10 t
20 & 40 t
5 t.
20
40
60
80
100
NUMBER OF DIRIGIBLES

FIG. 24

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$C_{od}$ = Obsolescence & Deterioration (at 0.1% of annual cost of dirigible)

$C_i$ = Insurance (at 1% annual cost of dirigible)

$C_{ma}$ = Dirigible maintenance (based on airplane data and adjusted for local conditions)

$C_{he}$ = Helium replenishment (based on loss of 1/3 dirigible volume per annum)

The particular values used in this study can be combined to give the following expression for DOC:

$$DOC = N \left[ ns + 522q + .0859\ C_a + 12.04\ WE + .883\ \forall \right]$$

Where: n = No. in flight crew

s = Annual Salary

q = Fuel factor

$C_a$ = Cost of dirigible

WE = Weight Empty

$\forall$ = Volume of Envelope

Direct operating costs for conventional dirigibles are plotted in Figure 25 for various quantities of dirigibles. Total costs are plotted in Figure 26.

Figure 27 is a plot of costs for equal delivery capability. The advantages of large dirigibles are readily apparent. The productivity increase provided by the larger size illustrates the benefits of the volumetric efficiency. The 40T dirigibles can operate at lower total costs while delivering equal quantities of cargo.

This conclusion is violated in the case of the 100T dirigible. This is caused by the change in type. Rigid dirigibles are more expensive to manufacture and the cost increase is sufficient to outweigh the advantages of the increased lifting efficiency. On this basis, the 100T

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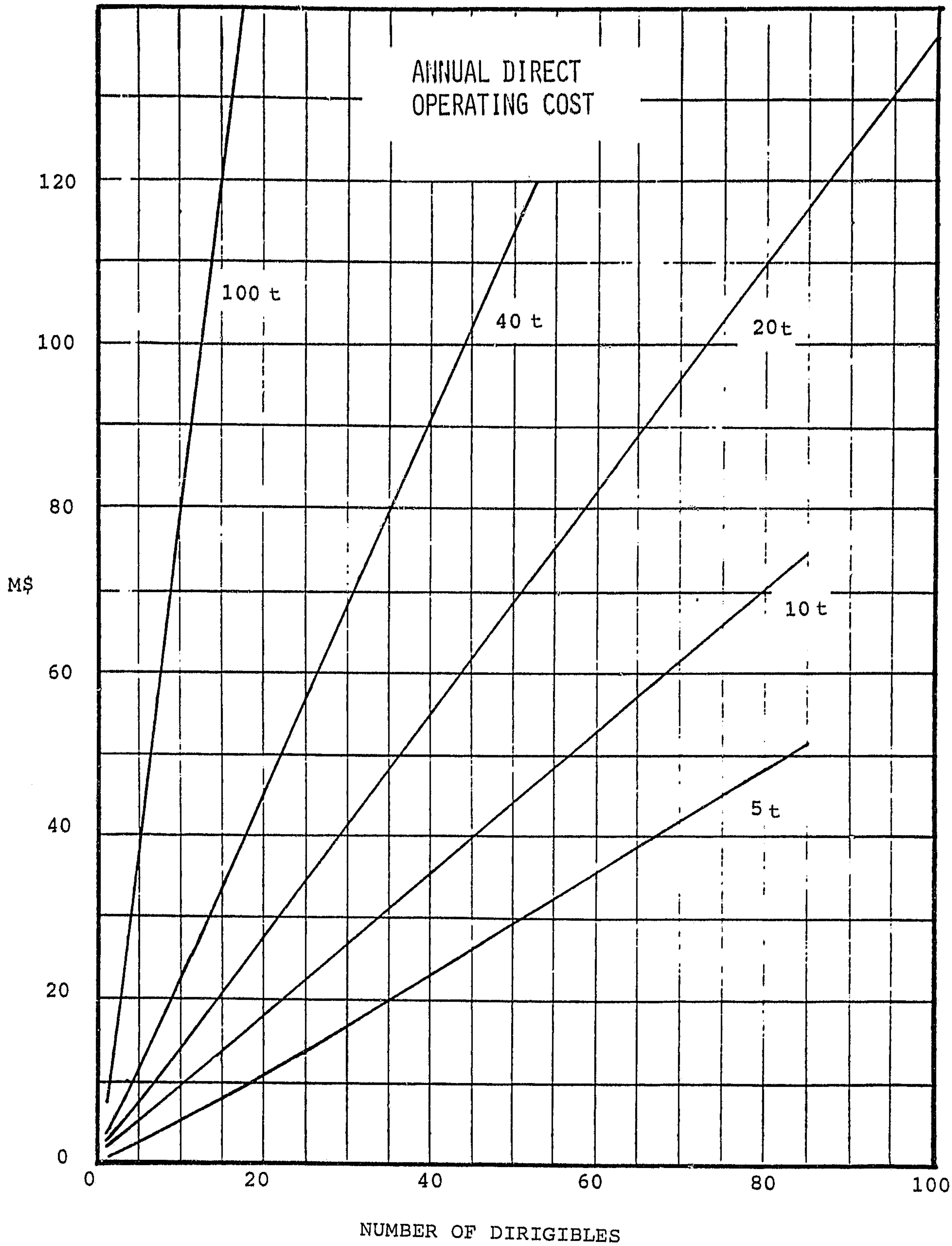


FIG. 25

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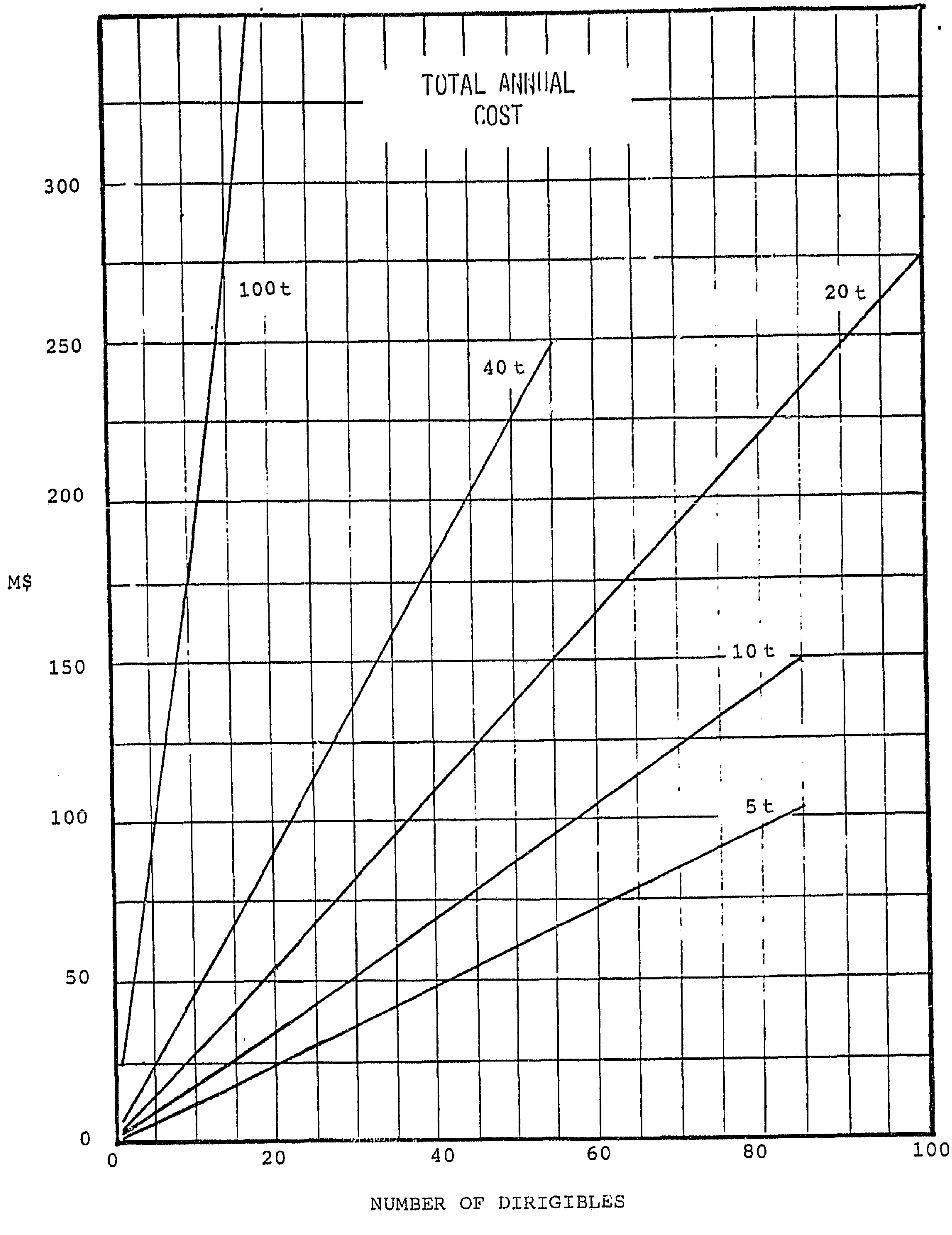


FIG. 26

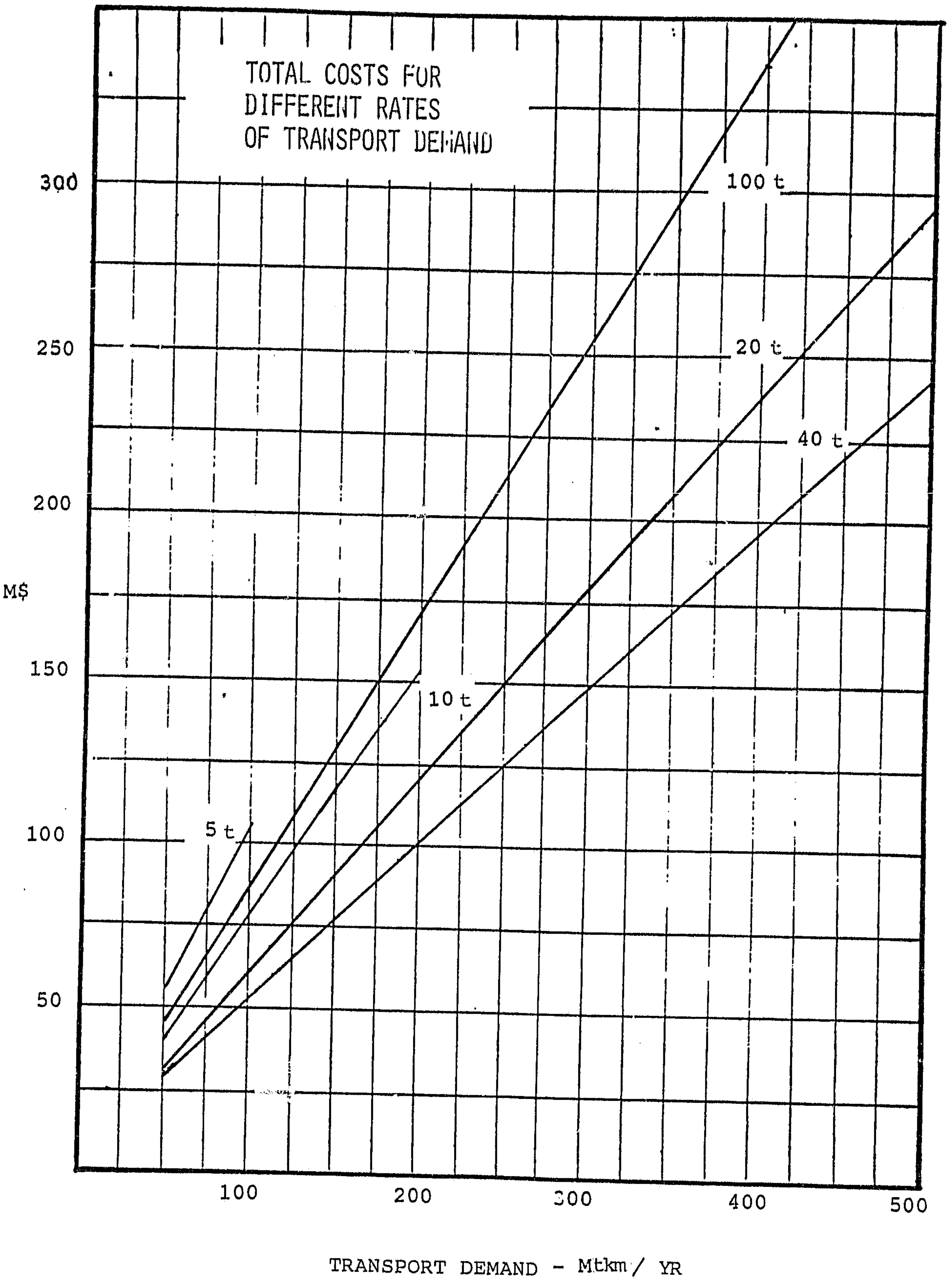
TOTAL COSTS FOR
DIFFERENT RATES
OF TRANSPORT DEMAND
M$
300
250
200
150
100
50
100 t
20 t
40 t
10 t
5 t
100
200
300
400
500
TRANSPORT DEMAND - Mtkm / YR

FIG. 27

dirigible was eliminated from further consideration. As was stated earlier, nonrigids were not regarded as a suitable type in 100 t sizes and therefore rigid construction was assumed.

The comparisons in Figure 27 also tend to eliminate the 5t size dirigible as a serious choice since its delivery capability and costs make it less efficient than the larger dirigibles. However, less tangible factors may dictate different conclusions. One of these would be an initial low transport demand such as 1M t.km which could be accommodated by a single 5 t vehicle. Other factors might include available investment funding and the existance of one size vs. one not built.

In the comparisons and alternatives which follow, the 5 t and 100t dirigibles were eliminated from the analysis but the above points should be remembered in drawing conclusions from this study.

The assumptions regarding the 100t dirigible are subject to further consideration as well. The initial assumptions are based on the fact that the largest nonrigid ever constructed, the U.S. Navy ZPG-3W, had a volume of 42,480 $m^3$, and the largest nonrigid designed for Navy service was the ZWG at 79,298 $m^3$. Material improvements becoming available today would certainly allow larger nonrigids or less costly rigids to be built, but it is beyond the scope of this study to determine present limits.

The costs associated with hybrid dirigibles are plotted in Figure 28. Indirect operating costs were assumed to be the same or less than those for conventional types and are not plotted.

Costs for acquisition and operation of single conventional 20 t dirigibles are compared with those for a fleet (43) in Figure 29. It is obvious that while the base and facilities costs remain practically constant, the costs of dirigibles predominates for fleet quantities. This illustrates the high sensitivity of economic analyses to

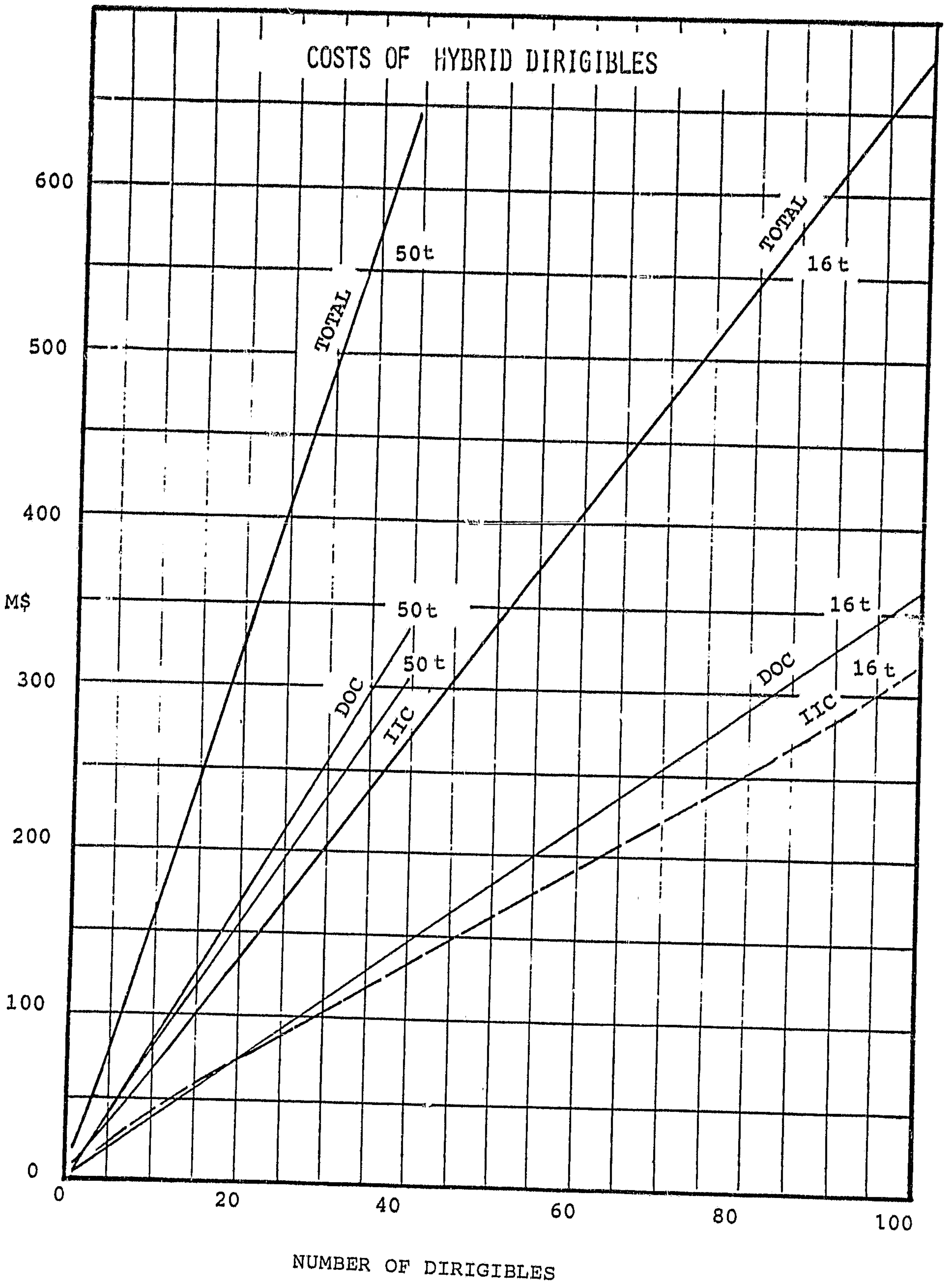
COSTS OF HYBRID DIRIGIBLES
M$
0
100
200
300
400
500
600
TOTAL
50t
16t
DOC
IIC
0
20
40
60
80
100
NUMBER OF DIRIGIBLES

FIG. 28

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ANNUAL TOTAL COST

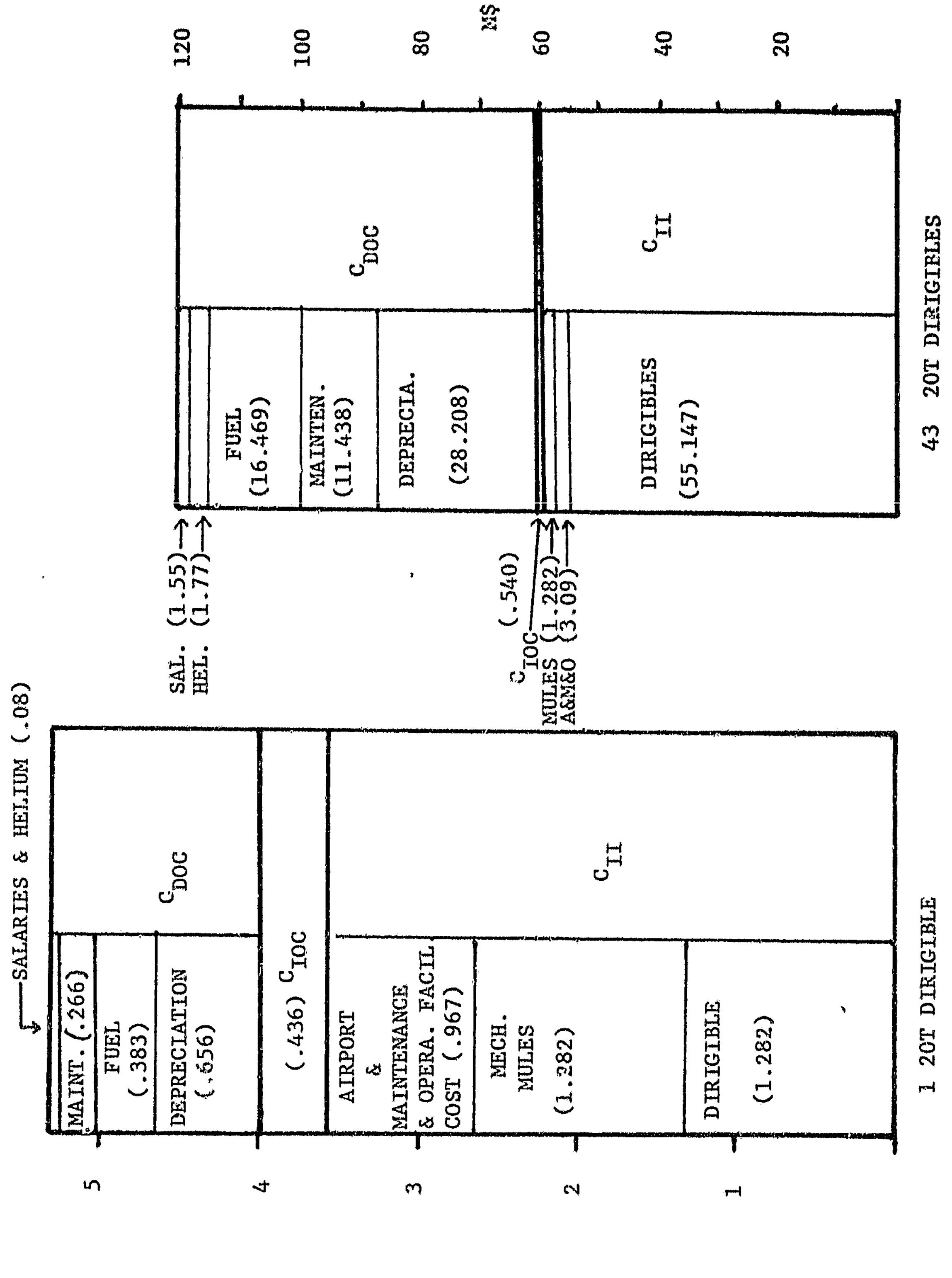


FIG. 29

dirigible costs and emphasizes the care that must be taken in determining such values. Possible variations and their effects are discussed later.

It can also be seen (from Figure 28) that hybrid costs are approximately double those of conventional types.

In both cases, the indirect operating costs are very small compared with investment and direct operating costs.

## COST COMPARISONS WITH OTHER AIRCRAFT

Two airplanes, the DeHavilland DHC-5 and the Lockheed L-100, were used to compare cost and transport capability with the various sizes of conventional dirigibles in this study. The same methodology was applied to divide costs among initial investments and indirect and direct operating costs. The two airplanes chosen are both capable of short field take-off and landing and operation from relatively unprepared fields when lightly loaded, but since their performance was analyzed for maximum payloads, it was assumed that a hardened runway would be required. The cost of this additional facility was charged against the initial investment cost. Data for airport improvement costs were taken from Ref. 5. No allowance was made for possible additional expense of transporting the materials required for the airport modifications.

Two cases were studies initially: single aircraft operation expense and costs for an equal quantity of cargo (100M tkm). All cases were based on block speeds for the median transport distance (194 km) as previously determined.

It was determined that while total costs for a single 20t payload dirigible are less than those for the airplane, the transport of 100M tkm will involve greater total costs because of differences in productivity. Operating costs will be less for the 40t dirigible than for either airplane and less for the 20t than the L-100.

## Higher Speed Airships

It was recognized that although a design cruise speed of 100 km/hr. gave the dirigibles good fuel economy, it also handicaps them in productivity, when compared with airplanes like the DHC-5 and L-100. Raising the cruising speed increases fuel consumption but, does not appreciably change size or maximum power requirements for the relatively short range operations involved in these missions, as long as the maximum speed is not changed. Therefore, the effects of higher cruise speed were investigated. New $V_a$ values were calculated for cruise speeds of 118 and 136 km/hr. These results, shown in Figure 30, clearly demonstrate the benefits of the increase. Total costs for the 40t sizes are significantly less than the airplanes. At 136 km/hr. both 20 and 40t dirigibles have lower total costs than the airplanes as well as lower operating costs.

Lower Fuel Consumption

Since all of the dirigibles in the preceding analysis were assumed to have turbine engines (turboprop propulsion), a case was studied to determine the effects of using reciprocating engines. An improvement in total costs was shown for the 40t dirigibles and in operating costs for both the 20 and 40t sizes compared with the airplanes. However, these improvements are not as great as those derived from higher cruising speeds and turboprop engines. It is obvious that the optimum combination is with reciprocating engines and higher cruise speeds. It should be pointed out that most of these cost differences stem from the decreased numbers of dirigibles required primarily. Therefore the plots of costs for the slower dirigibles shown in Figures 23, 24, 25, and 26 are generally valid.

Characteristics of these alternate dirigibles are compared with the original selections and are listed in Table 16.

REVENUE COSTS

Revenue costs are the expenses to the customers using the transport service. Certain assumptions were made as follows:

1. Flights out to the supply zone are 50% loaded, while return flights are 100%. This gives an average load factor of 75%.

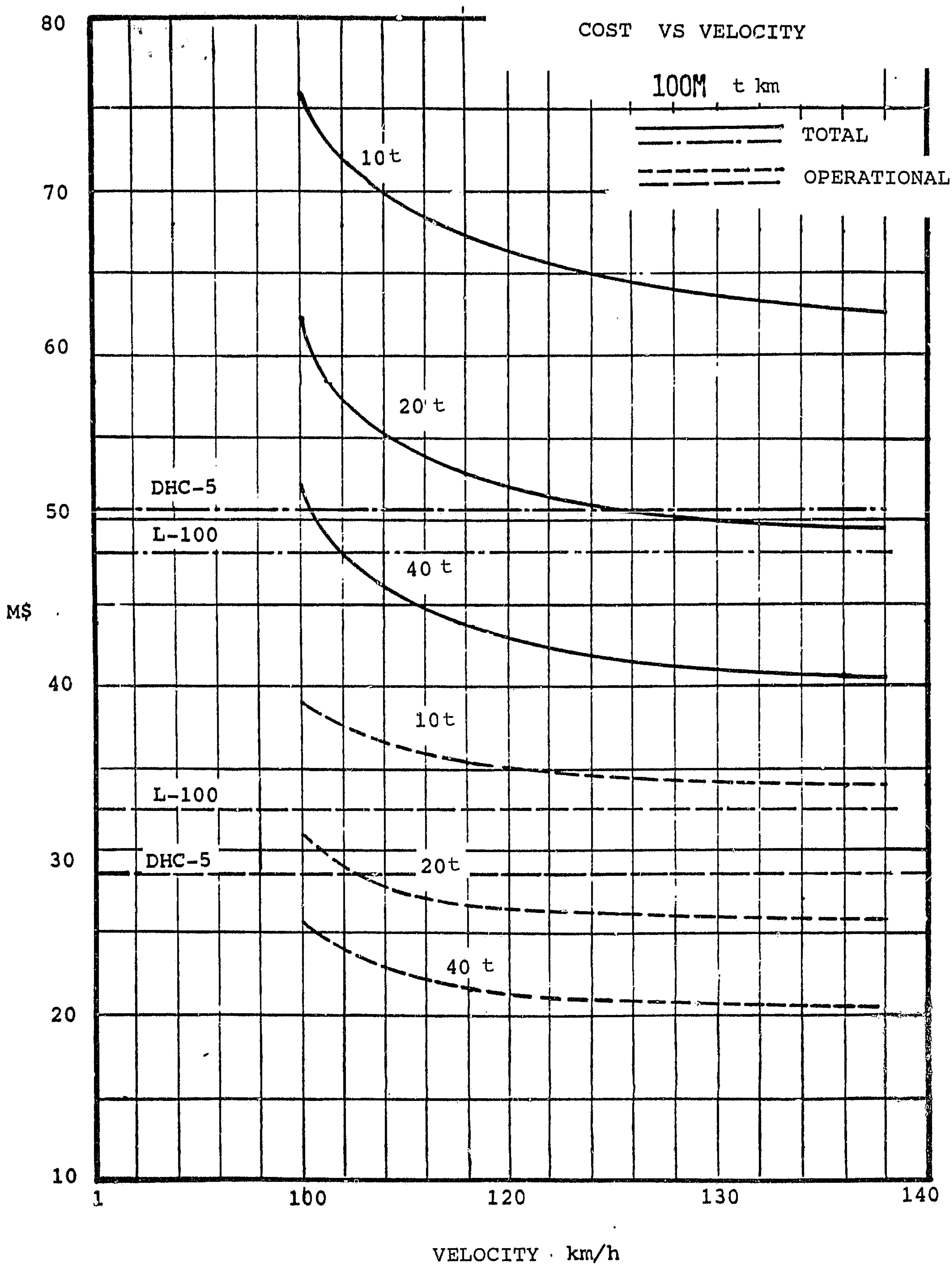
COST VS VELOCITY
100M t km
TOTAL
OPERATIONAL
10t
20 t
40 t
DHC-5
L-100
10t
L-100
DHC-5
20t
40 t
80
70
60
50
40
30
20
10
M$
1
100
120
130
140
VELOCITY · km/h

FIG. 30

CHARACTERISTICS AND COSTS
OF ALTERNATE DIRIGIBLES

| CARGO | VOLUME $m^3$ | | | | WEIGHT EMPTY kg | | | | COST $M | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t | V 100 | V 118 | V 136 | V 100* | V 100 | V 118 | V 136 | V 100* | V 100 | V 118 | V 136 | V 100* |
| 10 | 26666 | 26856 | 27111 | 26026 | 13597 | 13682 | 13795 | 13895 | 4.849 | 4.879 | 4.920 | 4.504 |
| 20 | 46616 | 46786 | 47040 | 46021 | 22125 | 22200 | 22319 | 22665 | 7.647 | 7.673 | 7.714 | 7.205 |
| 40 | 84509 | 84509 | 84764 | 84367 | 38638 | 38639 | 38751 | 39800 | 13.027 | 13.027 | 13.065 | 12.571 |

* WITH RECIPROCATING ENGINES

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TABLE 16

2. Total costs are charged to the operation, or only DOC and IOC costs.

3. The higher cruise speed dirigibles were used (118 & 136 km/hr.).

4. A profit of 25% (before taxes) is assumed.



Thus revenue costs are:

$$C_r = \frac{C_t}{.75} (1 + .25)$$

Revenue costs in \$/t km are listed in Table 17.

COSTS $/t km

100 M t km/ YR.

| CARGO t | TOTAL COSTS M$ | OPERAT COST | COST. TOT. $ / t km | OPERAT. COST $/t km | TOTAL COST WITH PROFIT $/ t km | OPERAT. COST WITH PROFIT $/ tkm* |
|---|---|---|---|---|---|---|
| 10 | 62.578 | 33.79 | .63 | .34 | 1.04 | .45 |
| 20 | 49.160 | 25.37 | .49 | .25 | .82 | .34 |
| 40 | 40.526 | 20.32 | .40 | .20 | .68 | .27 |
| 16-HIB | 171.347 | 91.027 | 1.71 | .91 | 2.86 | 1.52 |
| 50-HIB | 133.068 | 69.676 | 1.33 | .69 | 2.22 | 1.16 |

* WITH 0.75 LOAD FACTOR



TABLE 17

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## DISCUSSION

There are many variables in this type of mission analysis which, if explored, would probably indicate a greater number of optimum combinations than the few identified. However, time and the general paucity of useful reference material did not permit this to occur. Likewise, certain economic comparisons such as a road construction program in place of the dirigible system was not explored. It was expected, however, that some of this comparative data may already be established so that dirigible operations may be compared against any other system.

This entire study was based on essentially state-of-the-art dirigible technology. This does not mean that conventional or hybrid dirigibles exist in the sizes identified for the mission needs, but for the most part, conventional dirigibles were built in these sizes and were of greater complexity than those required here. The particular combinations using turboprop propulsion would not require any new technology development but merely the engineering design required. Turboprops were considered since they now represent currently available propulsion in the necessary horsepower ranges. There are some limited developments occuring in gasoline and diesel reciprocating engines, which could be adapted for dirigible use, if continued. (Ref. 2, & 7,).

The weight analysis assumed use of design methods and materials previously used and did not allow for some of the more advanced materials and structural developments which are likely to offer reduced weight and hence smaller dirigibles using less power. This offers potential for shifting the cost comparisons more in favor of dirigibles.

The mission analysis identifies transportation systems with little distinction among various types of aircraft except the need for airport development. Thus a unique and non-competitive requirement for dirigibles did not emerge. Dispite this, advantages were apparent. The following discussion keeps all of the above points in mind.

### Requirements

This entire study was based on the mission requirements provided by the O.E.E.: in essence, the need for a transportation system in the Selva Central of sufficient capacity to move agricultural products and lumber to a zone or location from which other transport, such as road vehicles can move it to the markets. The projected quantity of cargo was of sufficient magnitude such that vehicles capable of moving loads in multiples of tons are required and fleets of vehicles are needed to meet the demand. The various zones of development at present are isolated except for small airfields of inadequate size and capacity to accommodate large aircraft.

The evaluation of dirigibles as potential cargo vehicles reveals that the Selva region is well suited to their operation. Neither altitude or climate would present any problem for these aircraft. Present airfields, while long enough for operation with 5-10-T dirigibles, would have to be widened so as to provide a nearly square area, and allow room for mooring during loading or overnight storage.

Airport modification could require use of bulldozers for removing tree stumps and leveling the land. This equipment could be flown in by airship under the right conditions, so that construction of a road or use of river transport would not be required. Hardening the airport surface is not required as it would be for heavy airplanes since little of the total weight of the dirigible is born on its landing gear, so that construction beyond the clearing and leveling operation is unnecessary. A dirigible using vectored thrust may allow somewhat more flexibility for the initial preparatory phase by not requiring much additional airport space provided that wind and weather conditions were not severe. Like, wise, the mooring mast equipment for each location could be flown in and set-up while the dirigible waited for completion of that operation.

A more detailed study of each zone should be made to determine whether a new landing site should not be located right at the farm or at least be dedicated to dirigible operations only.

The most complex aspect is the construction of a maintenance base. The fleets of dirigibles identified must have adequate provisions for inspection and maintenance. However, it is possible for an operation to start with one or two dirigibles where servicing at the mast is only required -- provided that the maintenance facility becomes available within a reasonable time (6-12 mos.)

The loading and unloading of cargo in an efficient manner is essential to the success of the system. It has already been suggested that a modular system be used so that containers only are loaded on the dirigible by means of some quick connect arrangement. There is no doubt that there will also be a number of passengers to be transported throughout the area as well as the equipment required to develop and implement the agricultural operation. The design of a dirigible must consider these needs and allow sufficient cargo space for them.

Dirigibles

The dirigibles identified by cargo capacity do not necessarily need to fall into these groups. A detailed design study is required to arrive at optimum sizes to satisfy requirements. The characteristics identified in this study should serve as a guide for the development of specifications. If many of the new technology developments now becoming available are applied, the dirigibles could be smaller and perhaps less expensive than those listed.

Hybrid dirigibles do not seem to be required since conventional, hence more economical types, appear to meet the requireemtns, Hybrids would offer some advantages initially, however. They could be flown into existing locations without any prepared landing sites, even airfields, being required. They could transport heavy construction equipment and place it where it is needed without any intermediate mode being employed. It would appear then, that at least a single heavy-lift type hybrid might be extremely useful during the early stages of the Selva development. Their use would be justified on the basis of a new capability and not in competition with other types.

Economics

The various costs and the comparisons established with airplanes indicate that the larger dirigibles -- 20T and above would produce substantial cost savings over airplanes while meeting the demands for transport. The analysis showed that a dirigible capable of cruising at some speed above the 100 km/hr. originally assumed is required to achieve the productivity levels that result in real cost benefits over airplanes. For the fleets involved, these savings are substantial in terms of millions of dollars per year.

Further economic benefits could result if any of the following could occur:

1. Less expensive dirigibles.

2. Higher fuel costs.

3. More efficient dirigibles.

Less expensive dirigibles are not likely to occur if they are purchased from other countries. If some of the components can be built and the final assembly can be accomplished in Peru, lower costs might be achieved.

Fuel costs seem to be stable at present. However, if further shortages occur and prices rise, the economic differences will favor the dirigible.

More efficient dirigibles can be achieved through technology advancement. The stimulus for industry that would be provided by a fleet order could in turn produce the necessary research and engineering required to improve preformance.

Intangible Benefits

Direct comparisons among different aircraft are not possible without omitting certain characteristics which are not comparable. One of these isthe fact that the larger dirigible can deliver in one load cargoes that may take several trips by airplane. Cargo that cannot be divided such as construction equipment (bulldozers) could not be carried at all in some airplanes. Likewise, externally suspended loads can be flown by dirigible but not by airplane. Thus, even dirigibles of smaller sizes than the types identified as most economically attractive may be useful in handling certain cargoes.

Dirigibles offer more safety for crew and cargo in case of a forced landing since ground contact can be made at zero forward speed. Thus the chances of fatalities are reduced drastically.

The development of hardened runways for airplane operation may have been minimized in the analysis since in most places, roads for transport of construction materials do not exist.

The Future

Since a dirigible industry does not exist, the situation is more complex than one where a new airplane requirement would be generated and implemented. Several problems are involved. One is the general low level of current engineering experience. In the case of present activities, the experience with small dirigibles and little if any effort in design of larger types does not even approach an industrial base. A requirement for development of larger vehicles would no doubt stimulate companies to re-acquire knowledge which none existed in this filed but this learning experience will be reflected in time and cost.

A second problem exists in training of pilots and other personnel. For the purchase of one or a few dirigibles, it can be assumed that pilot and crew training might be provided by the producer. Later however, facilities must be established for the continuous operation of a flight school. If this is considered part of the transport system, its cost must be added to the other expenses previously listed.

A mechanism for initiating a dirigible transport service must be identified. The most difficult part is the acquisition of the first dirigible. It must be of sufficient size and have provisons for carrying the kinds of cargoes projected. Since the analysis indicates the desirability of using vehicles in the 20 t or greater category, for economic effectiveness, it is difficult to justify use of a smaller vehicle. Yet, since the high cargo rates will not be achieved immediately, a smaller dirigible would probably be more than adequate (as previously noted, a single 5 t dirigible could transport 1M t km per year). This size could be used as a combination trial transport and as a training vehicle. Later, it would serve as a training vehicle only. Experience and data developed from this would be useful in the design of a larger ship.

None of these additional expenses were included in the economic analysis. It doesn't seem reasonable for a single system to absorb all of these costs, and if it had to, this could be the persuasion against doing it at all. A more realistic view might include consideration of the needs in other countries where similar requirements from several systems could easily increase the numbers of aircraft needed and help to diminish developmental costs.

## CONCLUSIONS AND RECOMMENDATIONS

The study establishes the general conclusion that dirigibles can be operated in the Selva Central. Optimized combinations of fleet size and dirigible types would require more detailed study. These conclusions should not be construed as necessarily applicable to other types of missions. Specific conclusions are:

1. Neither weather or terrain in the Selva Central would prevent use of dirigibles as transports.

2. Existing airfields would require expansion to accommodate conventional dirigibles in normal operations.

3. Hybrid dirigibles could operate without airfields, but long period operation on the ground or mooring would require facilities similar to those for conventional types.

4. Conventional nonrigid dirigibles are more economical as their size increases.

5. Conventional dirigibles can perform the required transport mission and are cost effective (in large sizes) compared to airplanes.

6. Advanced technology would produce positive benefits for dirigibles and make them more cost effective.

7. The development and acquisition of the first dirigible, and training numbers of pilots and other personnel is a problem that must be solved before a commitment for full system development is made. One possibility exists in multi-national requirements for similar systems.

The following actions are recommended:

1. A dirigible transport system requirement should be developed. This would include a schedule for development of facilities and airfields in the Selva Central and specification for suitable dirigibles.

2. More detailed data should be obtained on weather at the various zones along the intended primary route.

3. Further study comparing the proposed air transport system costs with analyses of road construction and other transport systems should be undertaken.

# REFERENCES


1. Air Products and Chemicals, Inc. Helium Data

2. NASA Report CR 165499 "Propulsion Study for Small Transport Aircraft Technology (STAT) Dec. 1980

3. Goodyear Aerospace Corp. Data (Not for Release)

4. NASA Report CR 152259 " Modification of Weight and Cost Formulas and Parametric Studies of Heavy Lift Air-ships" March, 1979

5 World Bank Data on Airport Construction in Peru

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7. Aviation Mechanics Journal, Nov. 1981


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# APPENDIX

# A

# AEROSTATS
## (LIGHTER-THAN-AIR AIRCRAFT)
## PRINCIPLES AND APPLICATIONS

Introduction  Aircraft are generally classified into two major divisions (1) heavier-than-air, and (2) lighter-than-air. The second refers to those types which employ buoyancy for lift whether partially or totally. The first includes all which fly solely by aerodynamic means.

Lighter-than-air aircraft are also called aerostats. The design and operation of these vehicles is largely influenced by the behavior of the lifting gas and secondarily, in the case of the airships by the dynamic forces of flight.

It is the purpose of this brochure to provide an explanation of the principles governing design and operation of aerostats

## PRINCIPLES OF BUOYANCY AND GAS BEHAVIOR

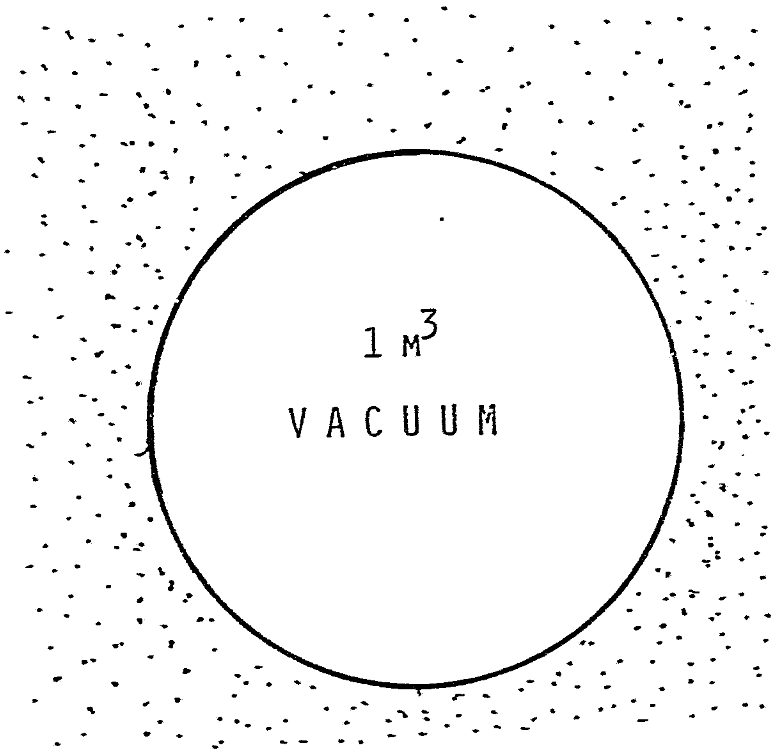
Buoyancy - In the third century, B.C., the Greek physicist, Archimedes, enunciated the principle of buoyancy: that the buoyant force is equal to the weight of the fluid displaced. This explained why ship's could float but it was many centuries later before man was convinced that gases as well as fluids had different densities and therefore could be displaced to obtain buoyancy.

Air is a mixture of gases. A cubic meter has a density of 1.225 kilograms under standard conditions.* Therefore, a container, such as a sphere, with all of the internal air removed would experience a buoyant or lifting force equivalent to the density of the air removed. If a lighter gas, such as hydrogen is substituted for the air in the sphere, the lifting force is reduced by the weight of the hydrogen (about 7%), but the hydrogen provides the necessary function of pressuring the sphere and thus maintaining its shape and volume. Helium lift is 7% less than hydrogen.

* $288^{\circ}$ K, 760mm Hg

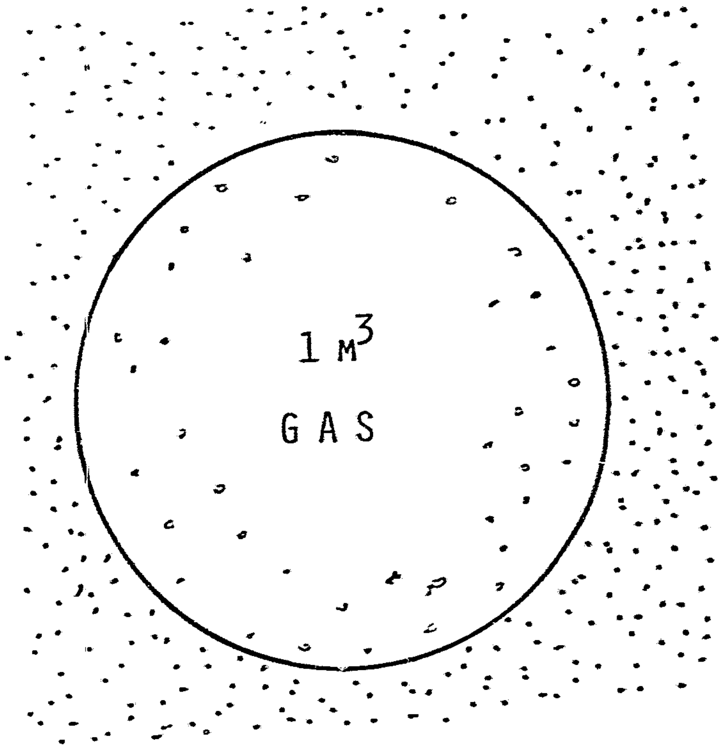
# BUOYANCY

ARCHIMEDES: BUOYANT FORCE IS EQUAL TO WEIGHT OF FLUID (GAS) DISPLACED




LIFT = WEIGHT OF AIR DISPLACED

1.225 KG




LIFT = WEIGHT OF AIR DISPLACED MINUS WEIGHT OF GAS

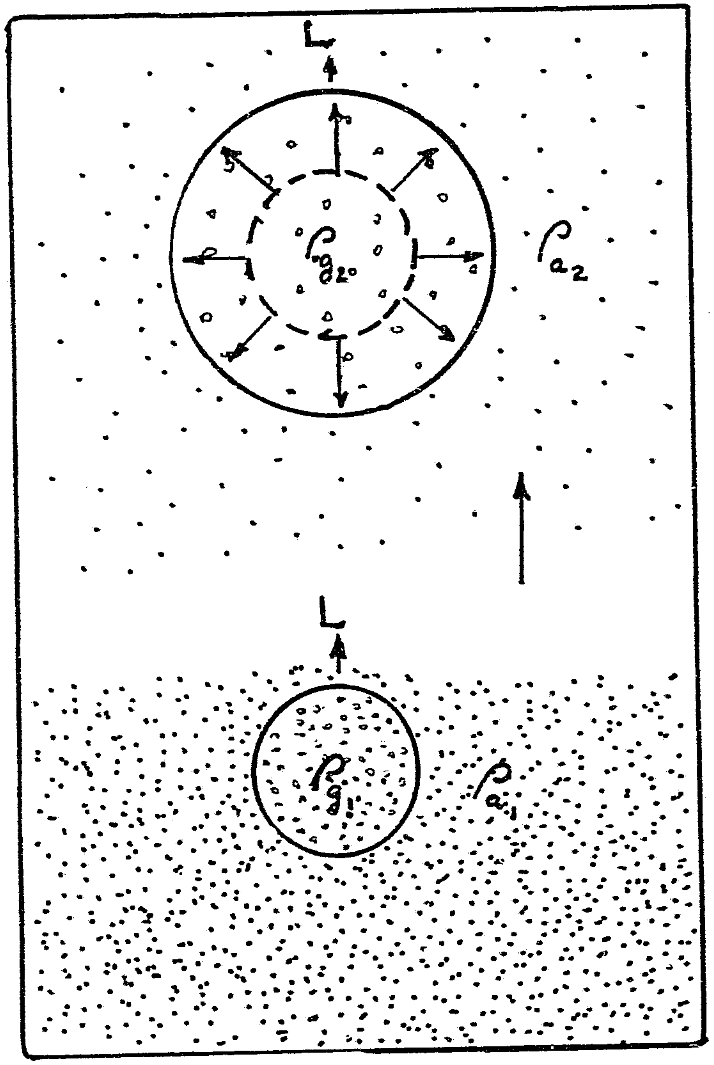
1.14 KG WITH $H_2$

1.06 KG WITH HE

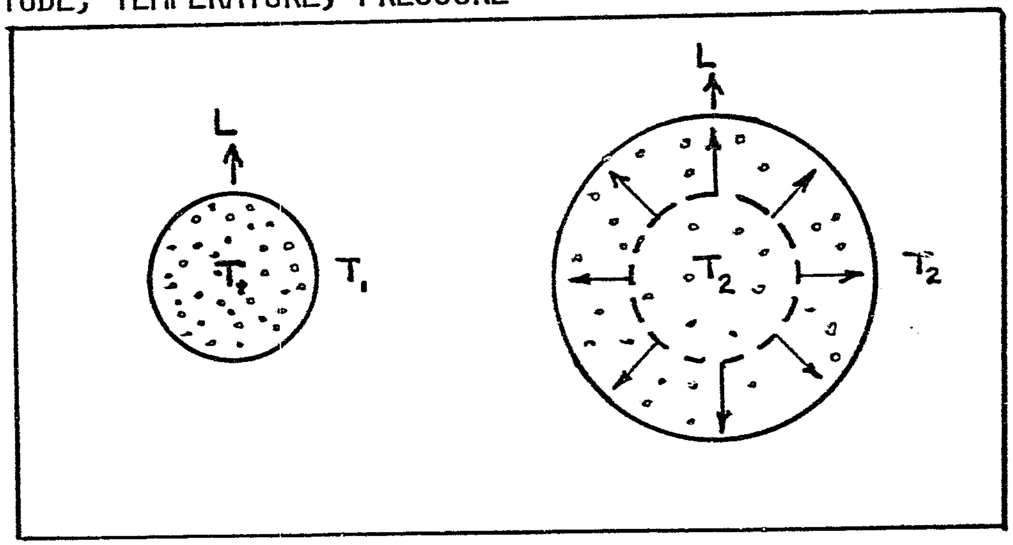
Gas Behavior - All gases react to temperature and pressure changes in the same way. A sphere made of perfectly elastic material and filled with a gas will expand when heated in direct proportion to the absolute temperature, and shrink in the same way when cooled (Charles' Law). The gas will respond in the same manner to pressure changes - expanding as pressure outside the sphere is reduced until the two pressures - inside and outside - are equalized, or contracting as pressure is increased (Boyles' Law). Since all of these changes are in proportion, a constant ratio of densities is maintained. There is no gain or loss in lift when the inside and outside temperatures and pressures are the same. Under normal circumstances, there are differential temperatures and pressures. These effects combined with other conditions, such as humidity, loss of gas, etc. do produce changes in lift.

# BUOYANCY

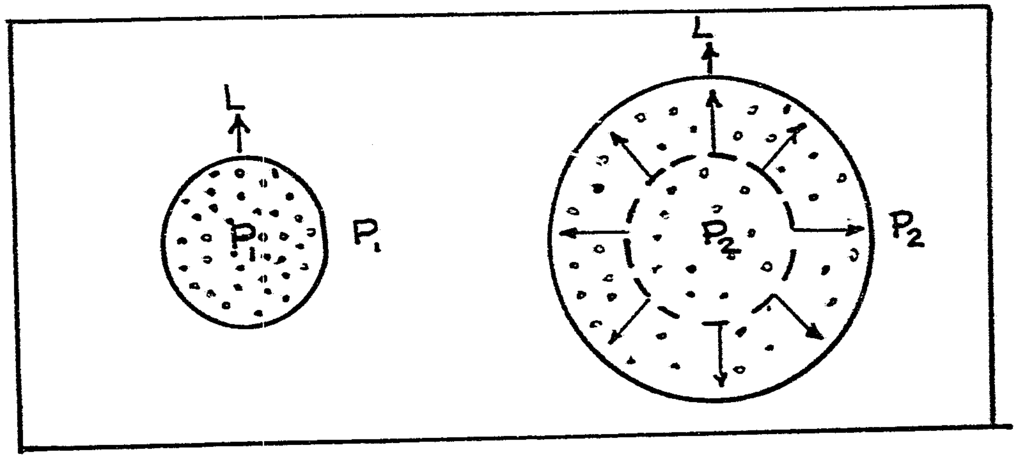
## EFFECTS OF ALTITUDE, TEMPERATURE, PRESSURE




ALTITUDE



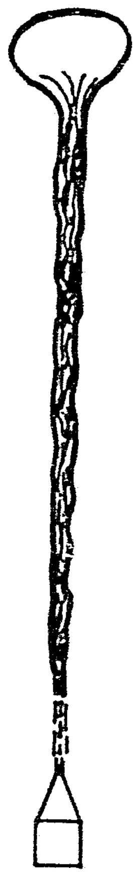

TEMPERATURE



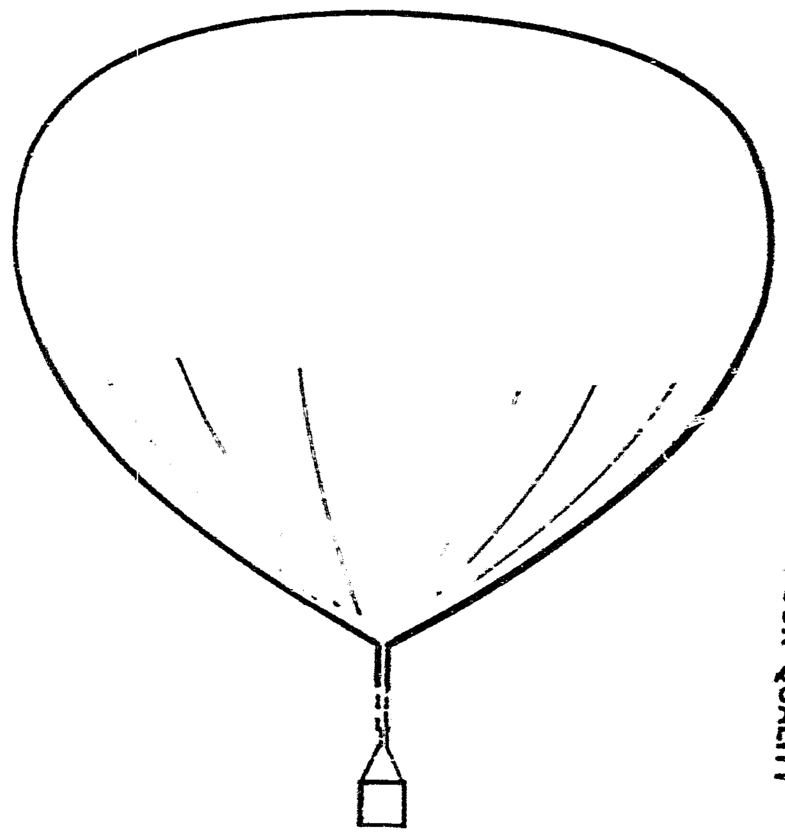

PRESSURE

All buoyant systems must accommodate changes in gas volume by some means. Since there are no perfectly elastic materials, other solutions are employed, the most common being the use of flexible containers. The gas container or envelope can be built so that its full volume is not utilized until the point of maximum gas expansion, thus a surplus of envelope material is carried during most of the flight

ACCOMMODATING GAS EXPANSION
IN SCIENTIFIC BALLOONS



AT LAUNCH

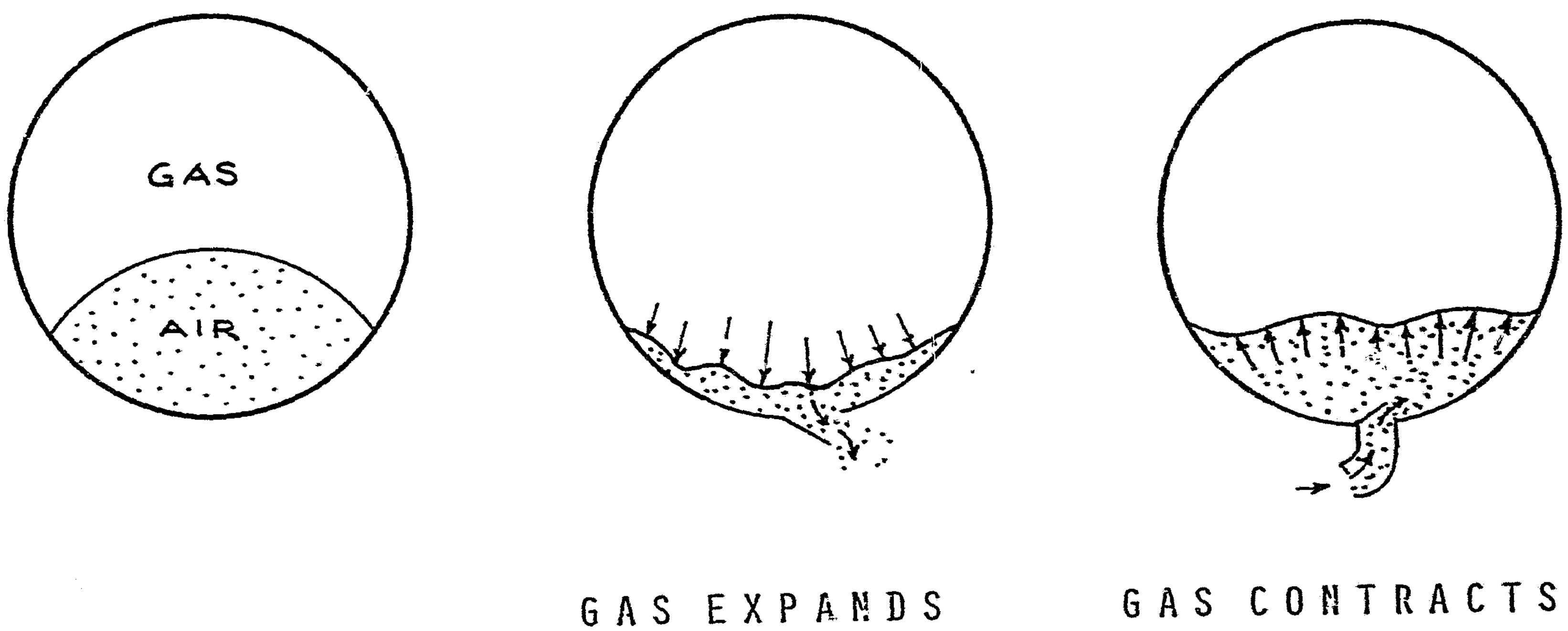


AT MISSION ALTITUDE

When a constant external shape is required, as in airships, the principle of the ballonet is employed. The ballonet is an expandable air compartment separated from the lifting gas by a flexible diaphragm. As the gas expands, air is expelled through a valve. It is forced back by blowers or scoops as the gas contracts. Thus no gas is lost and a constant total volume (air + gas) is maintained.

# PRESSURE & SHAPE CONTROL

## PRINCIPLE OF THE BALLONET

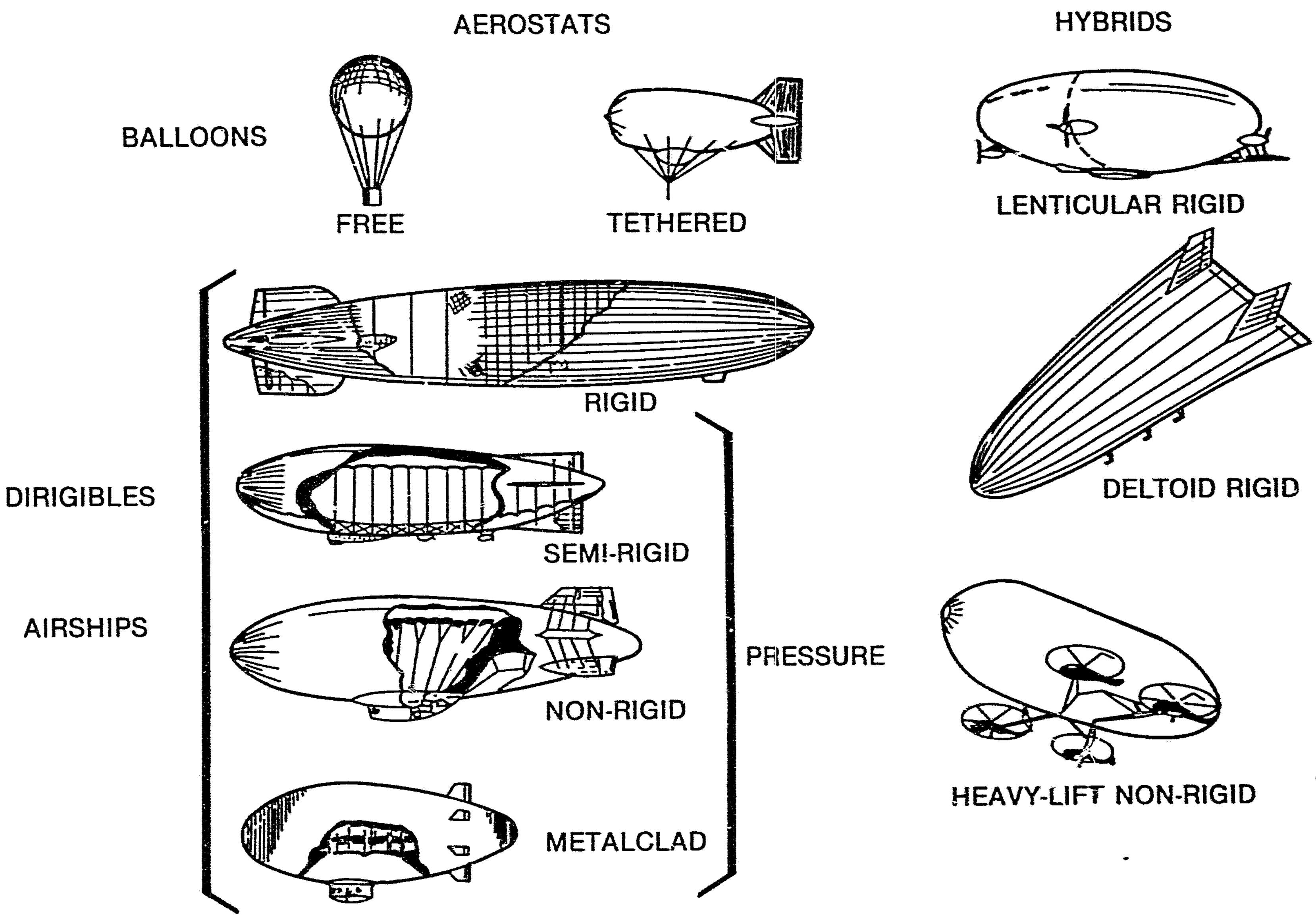


## TYPES OF AEROSTATS

The first historically documented use of buoyancy for a flying vehicle is credited to the Montgolfier brothers in France in 1783. They employed heated air as a lifting gas and used spherically shaped envelopes as containers. Hydrogen filled balloons were also developed in the same year. This latter type has persisted through the centuries. Modern forms use helium since it is an inert gas, hence safer. One variation, used for scientific experiments at very high altitudes, consists of a thin film envelope with most of the volume used to accommodate the very large expansion of the lifting gas. With the development of high efficiency propane burners, the hot air balloon has returned as a popular sport vehicle.

Tethered balloons have been utilized as platforms for supporting observers or equipment of various kinds. Special shapes have been developed to maintain stable flight in winds. These types have used both elastic cord (dilatable gore) and the ballonet principle for accommodating gas volume changes.

# TYPES OF LIGHTER-THAN-AIR AIRCRAFT

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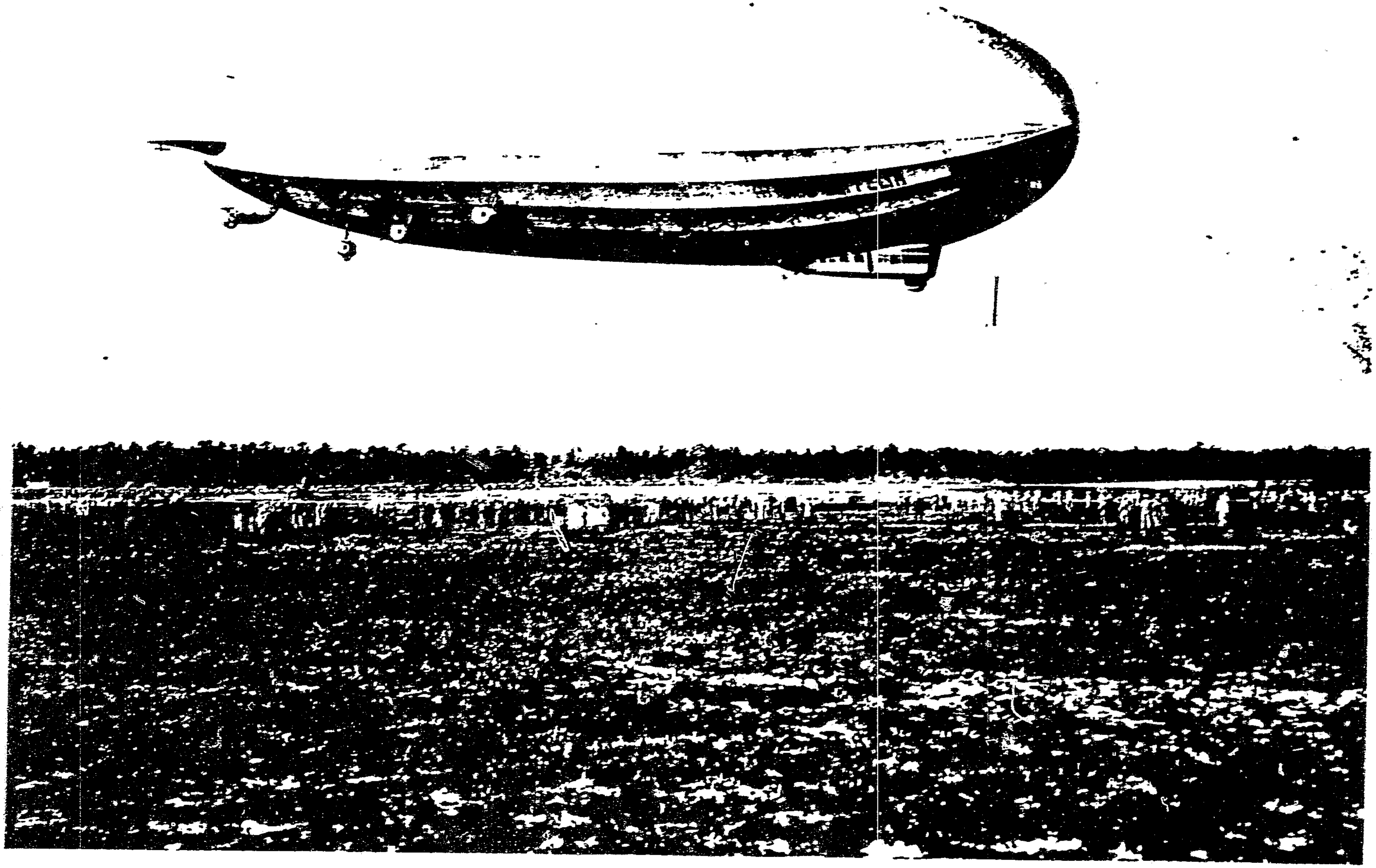


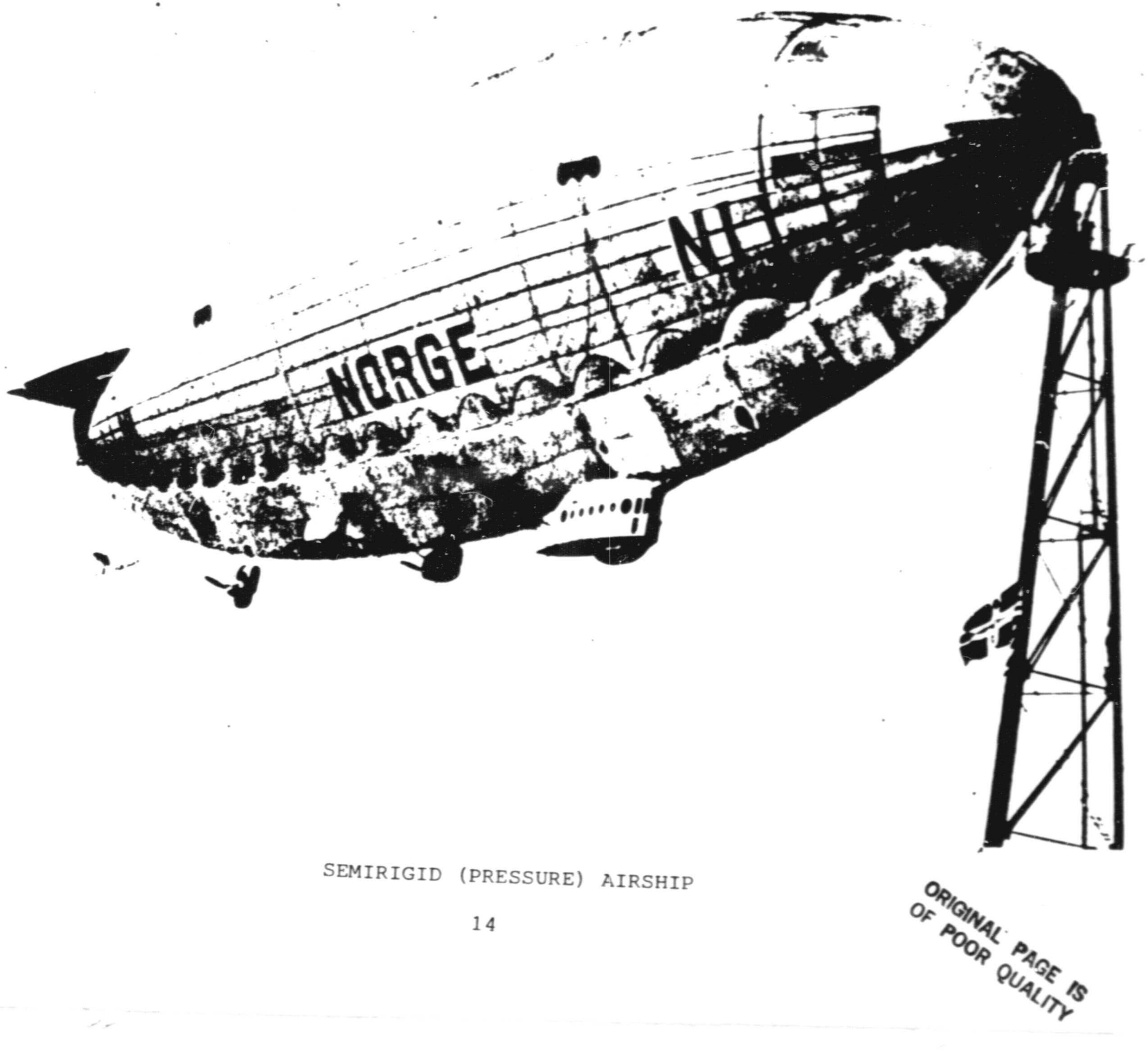
RIGID AIRSHIP

Dirigibles or airships have the common characteristic of being equipped with some means of propulsion and being steerable in all directions. The term "dirigible" is a short form of the french designation "dirigible balloon" meaning steerable. It is used interchangeably with the term "airship". Since these are aircraft, their operation involves the application of dynamic forces for lift and control as well as the static forces of buoyancy.

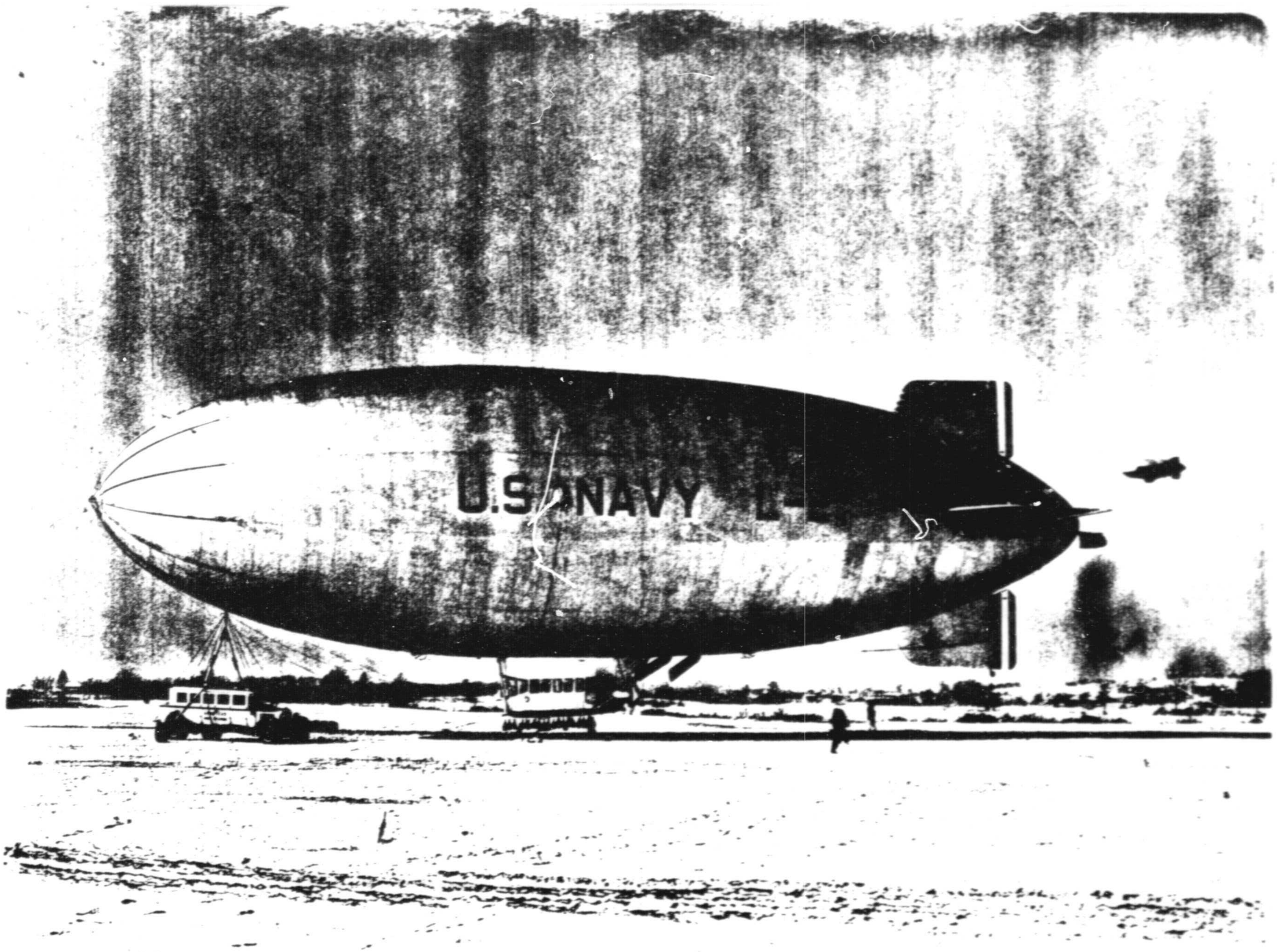
Airships are generally classified according to the structural principle involved in the hull form. With the development of the rigid type by Zeppelin, a system was provided in which the lifting gas could be contained in separate cells under little or no pressure and the hull shape was obtained by a rigid framework covered by a light-weight fabric.

Pressure airships depend on keeping the lifting gas at a value slightly above atmospheric in order to maintain hull shape. Hulls in these types are usually referred to as envelopes. Pressure airships are called semirigids when a keel-like structure is used to assist the envelope in carrying loads.

Nonrigids maintain shape entirely by internal pressure. This type is also called a blimp. Both semirigids and nonrigids use ballonets for shape and pressure control.




SEMIRIGID (PRESSURE) AIRSHIP

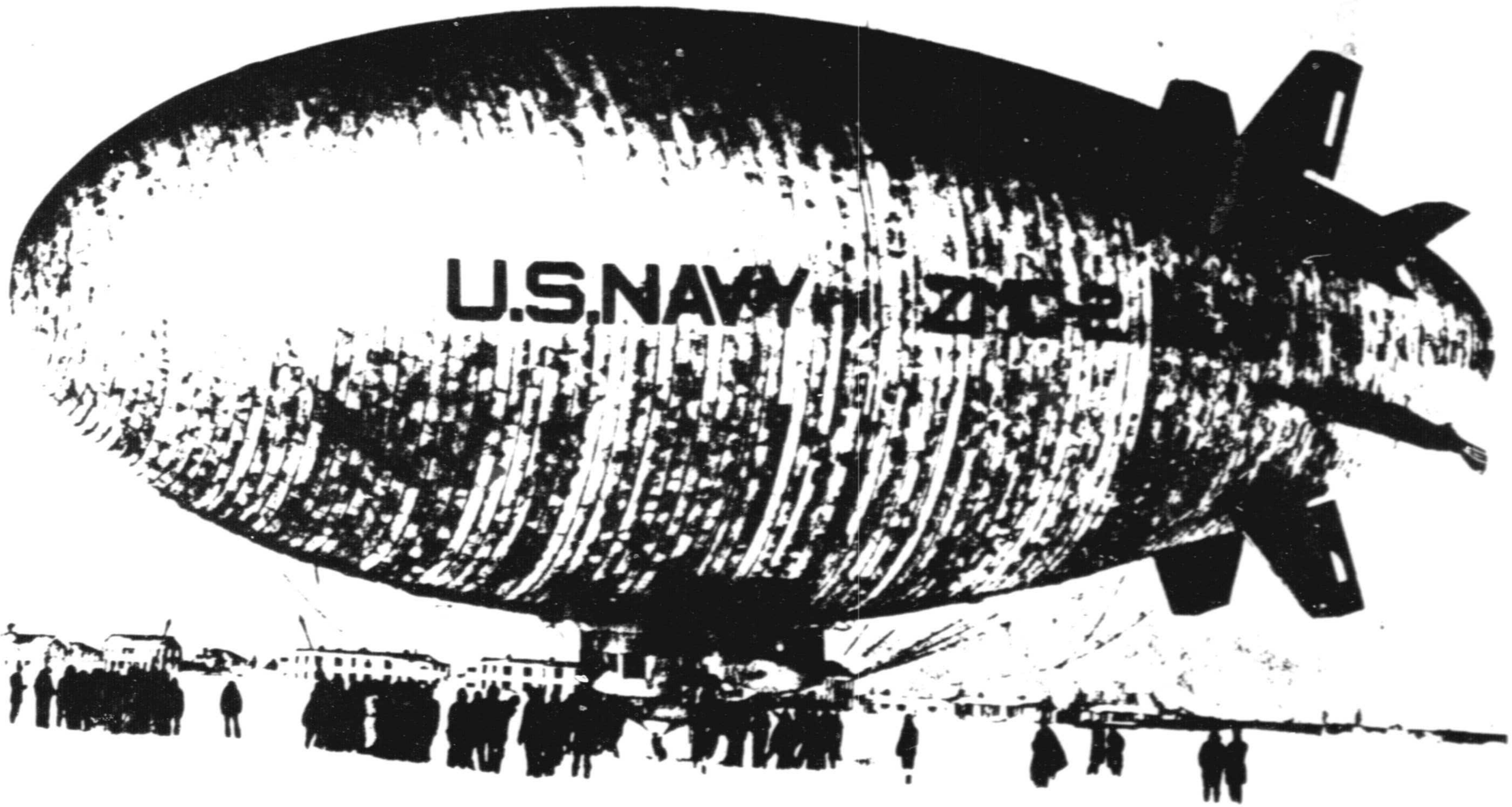




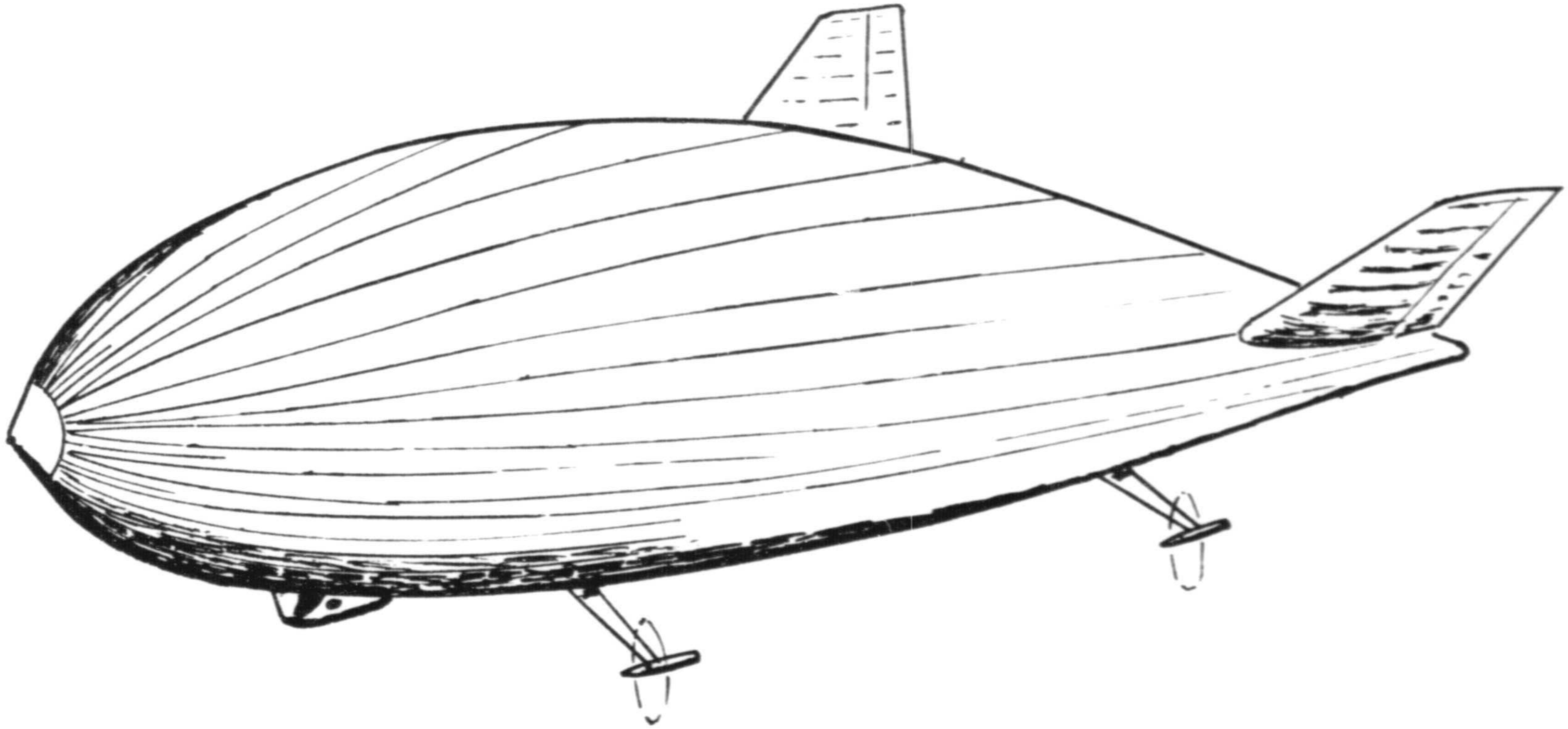

NONRIGID (PRESSURE) AIRSHIP

Some concepts combine the use of pressure for structural integrity with a rigid hull. This principle has been used in some all-metal airships where the skins could not substain a change of hull shape.

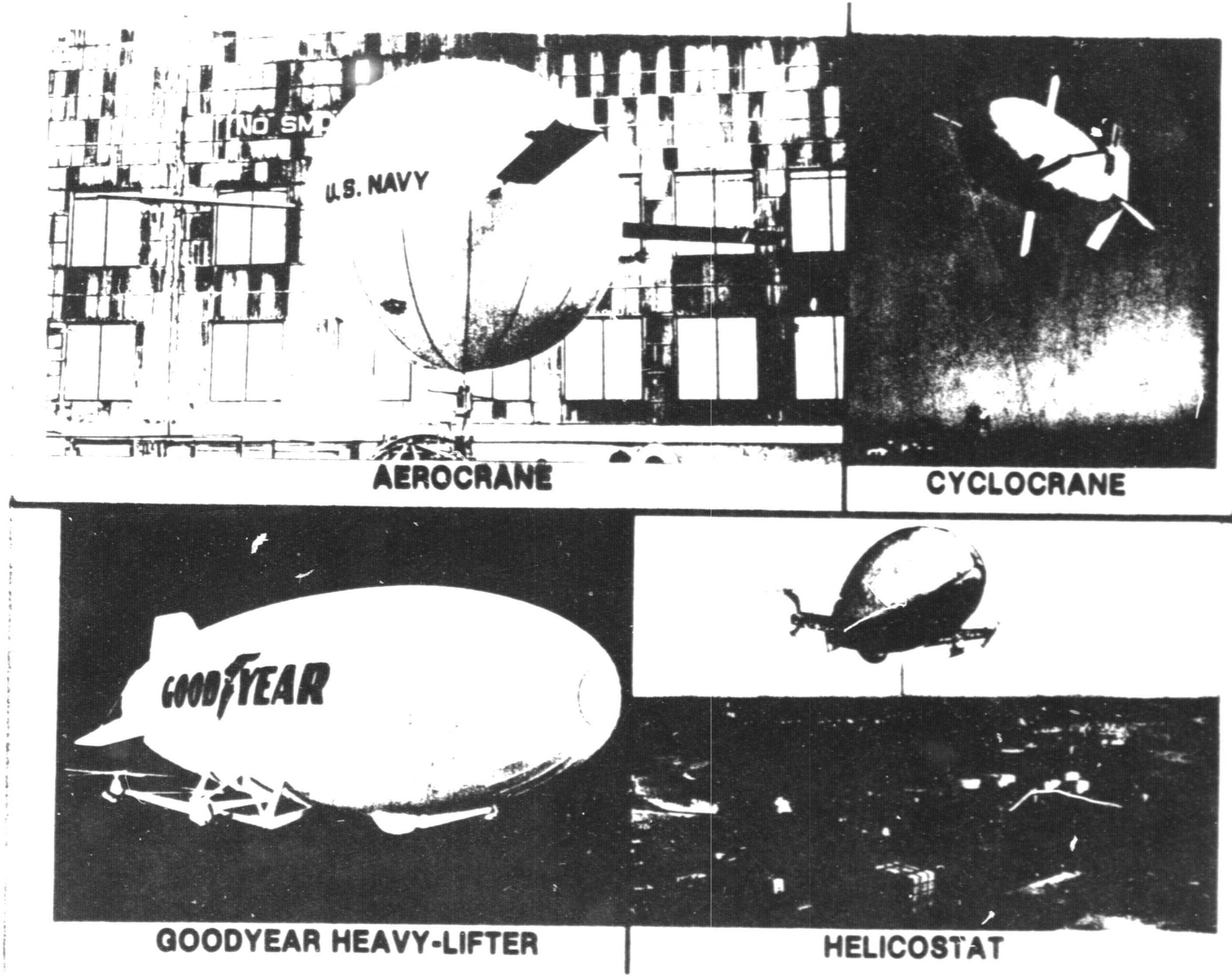
Recent studies have identified aerostats which combine lighter-than-air and heavier-than-air principles to provide lift. These may use large rotors for auxiliary lift or aerodynamically shaped lifting bodies for hulls. Such aircraft can also use rigid or pressure type hulls and are generally classed as "hybrids".




PRESSURE RIGID METALCLAD AIRSHIP



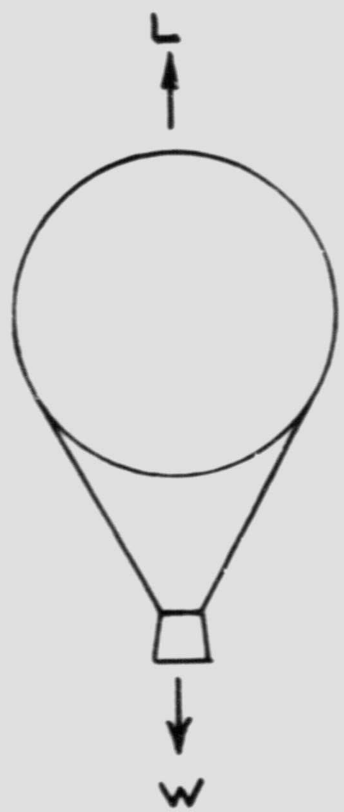
AERODYNAMIC LIFTING BODY HYBRID AIRSHIP




ROTARY WING HYBRID AIRSHIPS

## BUOYANT FLIGHT OPERATIONS

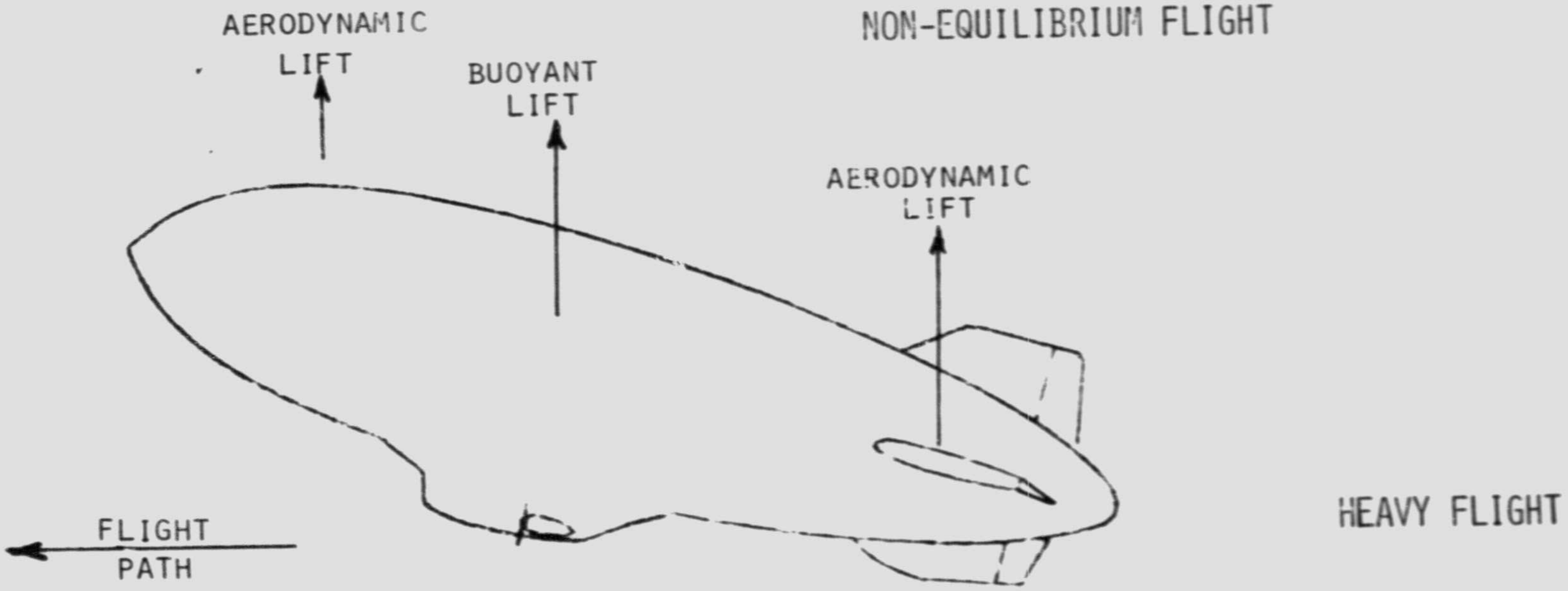
Balloons control their altitude by dropping some kind of disposable weight (ballast) ordinarily sand or water, and by valving some of the lifting gas. Airships behave exactly like balloons when no power is applied. Normally however, lifting gas is not sacrificed in airship flying. The flight condition is either an equilibrium one in which lift and weight are closely balanced or heavy where the airship weight exceeds its buoyancy. When weight is consumed, such as when fuel is burned, ballast must be added to the ship to restore the desired static condition.

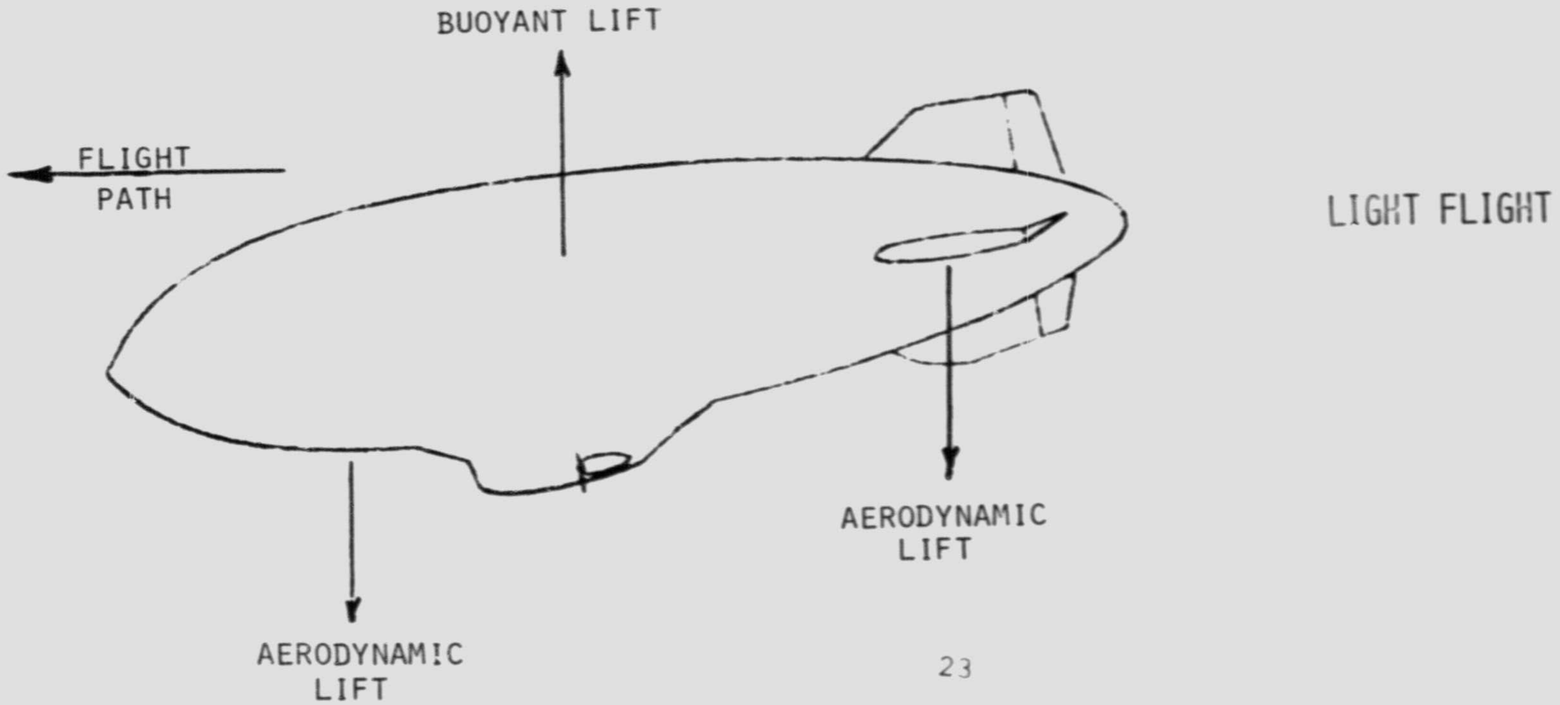



| | |
|---|---|
| L = W | EQUILIBRIUM (BALLOON FLOATS) |
| L < W | HEAVY (BALLOON DESCENDS) |
| L > W | LIGHT (BALLOON RISES) |

Airships under power can operate either heavy or light and still maintain constant altitude by using aerodynamic lift which is created by pitching the hull at an angle either positive or negative to the direction of flight. The hull and its tail surfaces then function as airfoils and balance the forces of excess lift or weight up to some maximum value depending on particular design characteristics and air speed. However, when forward motion ceases, a desired static condition must be restored by proper ballasting or the airship will rise or descend.

NON-EQUILIBRIUM FLIGHT

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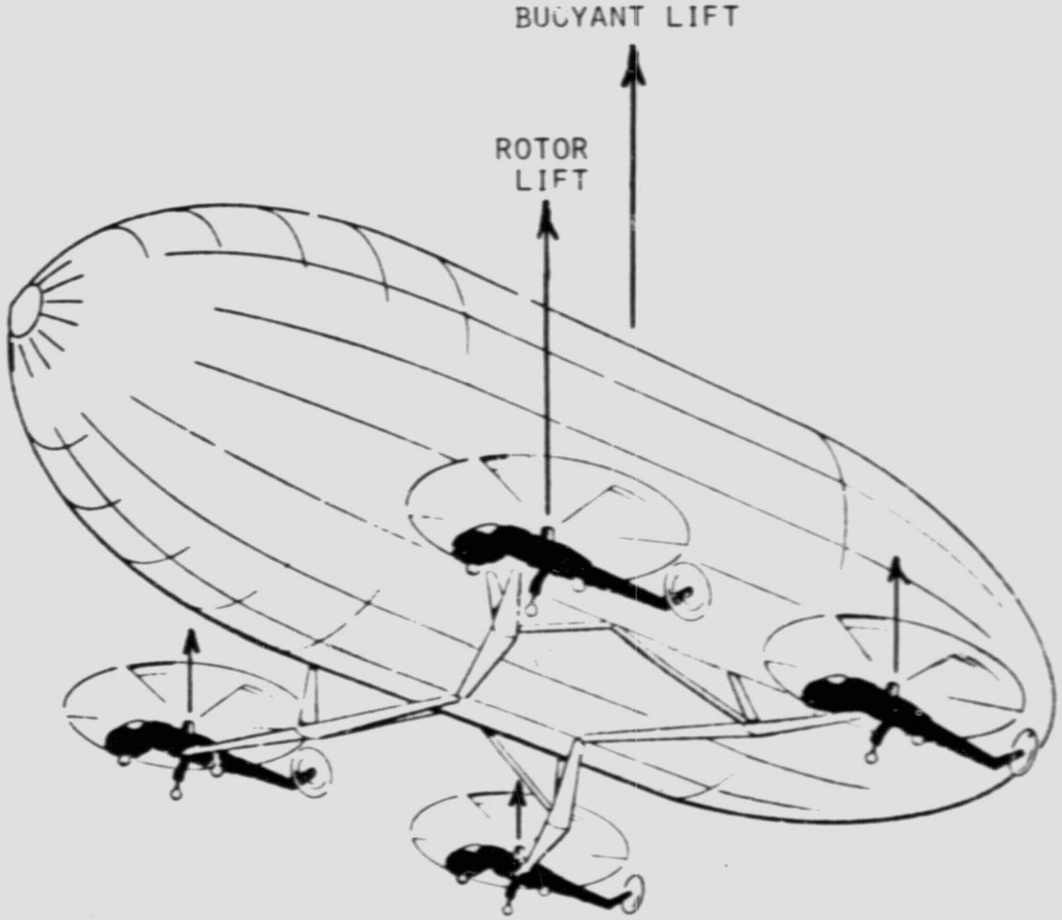
OF POOR QUALITY

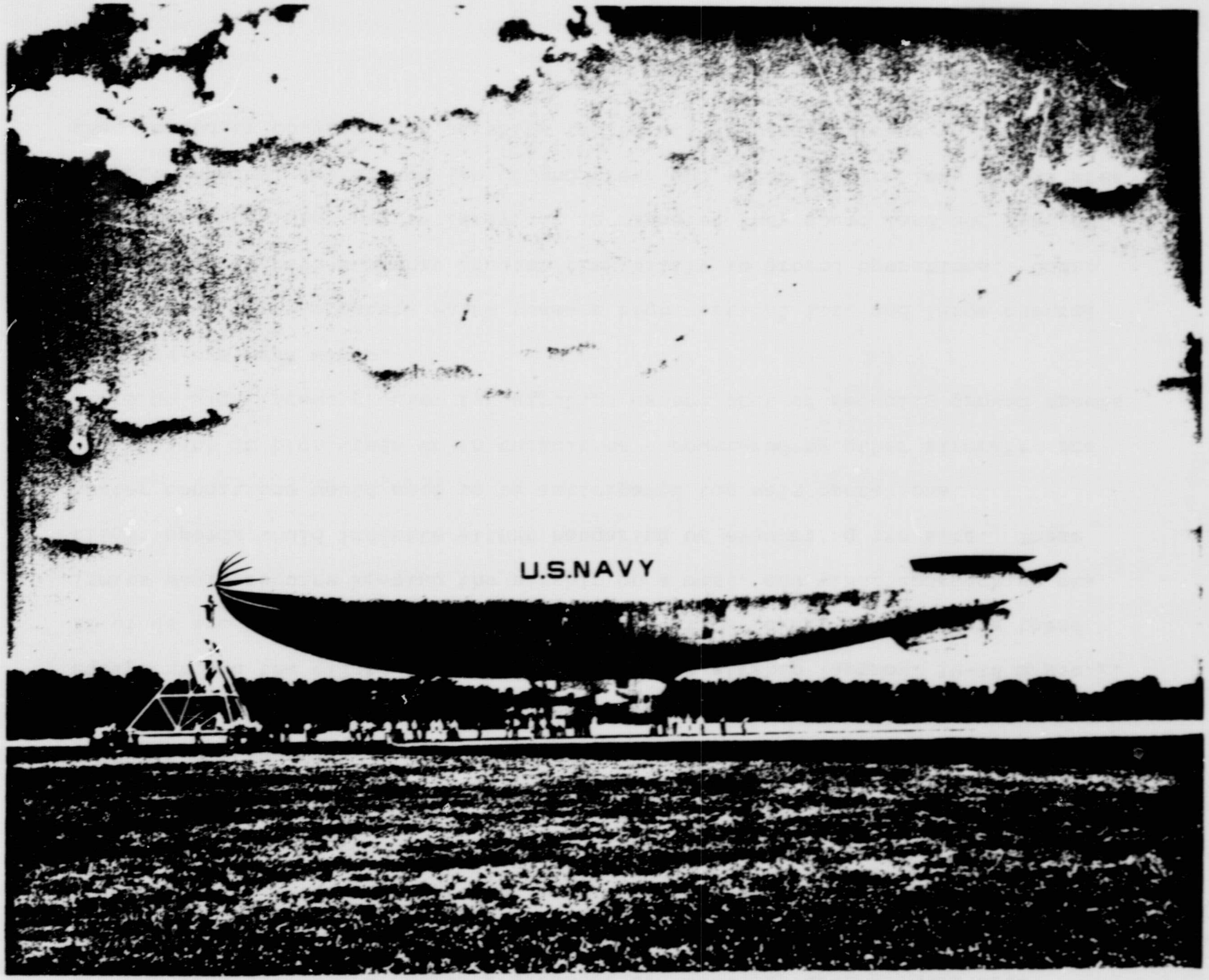
The hybrid types are generally designed for heavy operation where the excess weight is carried by vertical thrusting propellers or rotors or by an airfoil shaped hull. The first type is still capable of vertical take-off or landing using thrust, whereas the second type must operate like an airplane. Combinations of these are also possible .

# HYBRID FLIGHT - HEAVY



Conventional airships can be made capable of heavy take-off and landing by using landing gears equipped with wheels. Thus far this has been accomplished in airships of over 120 m in length. This feature provides considerable flexibility in operation and it is probable that the capability will be continued even in larger sizes.

When airships are on the ground, they must be tethered in some manner to resist wind forces. Although it is conceivable that an airship could be completely restrained, the forces developed are many times greater than than when the airship is allowed to weathervane about a nose mooring point. Normally, then, ground handling which requires complete restraint against cross winds is limited to low wind velocities. At other times airships use mooring masts which are either fixed or mobile which allow them to be tethered in winds equivalent to flight speeds. This technique allows many operations to be carried out for extended periods without the need of hangars. Airships can be made generally accessible such that all but major maintenance can be performed in the open. Naturally for some of this, certain accessories may be required such as portable or mobile work stands, if these features are not integral to the airship.



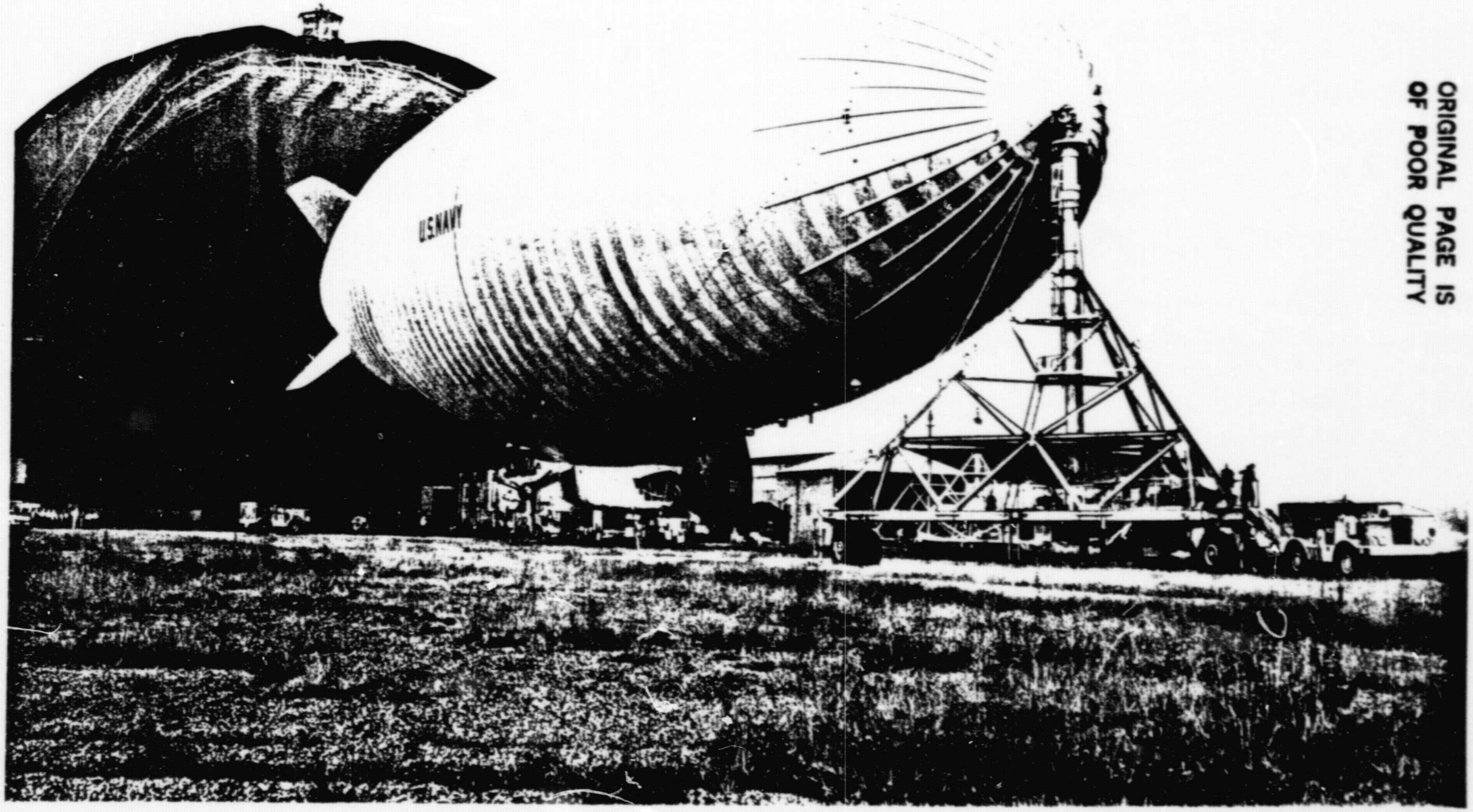

NONRIGID AIRSHIP AT MOORING MAST

There are conditions under which ground operations are limited. Take-off and landings in conventional airships are normally accomplished with the aid of a ground crew and auxiliary equipment such as highly mobile tractors. The development of the latter during past U.S. Navy airship operations severely reduced the number of men required to assist. Masting, unmasting, and hangaring also require the same equipment including, usually, a mobile mooring mast.

Operations are restricted when winds exceed speeds at which ground equipment and the pilots can safely control the airship (approx. 10-18 m/sec.). If winds are rapidly shifting these limits must be lower. Winds above these limits would require keeping the airship on a mast, and winds approaching max. flight speeds would indicate either hangaring or evacuating the site. These latter conditions would need to be anticipated for safe operations.

Flight in high winds or in turbulence encountered by other aircraft, presents no significant problem for airships except that of reducing ground speeds if these are head winds.

Hybrid type aerostats which possess high vertical lift and large control capacity would have somewhat greater flexibility in ground operations. Under low wind conditions, particularly, it is expected they could land and take-off without external assistance (no ground crew) and would require less ground area than needed by conventional airships taking off statically heavy.




GROUND HANDLING WITH MOBILE MAST & TRACTORS (MULES)

# APPENDIX
# B

AREA DE ESTUDIO

- Zonas :

  . Pto. Ocopa (Pto. Prado)
  . Puyeni
  . Obenteni
  . Atalaya
  . Pto. Rico (Río Ene)
  . Pto. Breu
  - Pto. Esperanza

- Rutas Probables :

R-1

Atalaya - Puyeni - Pto. Ocopa - Mazamari

R-2

Atalaya - Obenteni - Pto. Ocopa - Mazamari

R-3

Pto. Rico - Mazamari

R-4

Pto. Breu - Atalaya - Ocopa - Mazamari

R-5

Pto. Esperanza - Atalaya - Pto. Ocopa - Mazamari

AREAS POTENCIALES DE SIEMBRA Y PROGRAMA PROPUESTO

( Has.)

| ZONA / CULTIVO | P.Ocopa P.Prado | Puyeni | Atalaya | Obenteni | Pto. Rico | Pto. Breu | Pto. Esperanza |
|---|---|---|---|---|---|---|---|
| Arroz | | 12,318 | 8,850 | 1,600 | 3,300 | 2,744 | 8,138 |
| Maíz | 200 | 12,318 | 8,100 | 1,600 | 2,340 | 2,950 | 7,161 |
| Tabaco | 400 | 1,648 | 300 | | 300 | | 981 |
| Yuca | 300 | 4,254 | 4,000 | | 900 | 1,100 | 5,273 |
| Plátano | 1,000 | 7,460 | 5,150 | 2,300 | 1,200 | 1,826 | 6,185 |
| Piña | 3,800 | 5,378 | 5,250 | 1,500 | 480 | 1,200 | 7,031 |
| Cítricos | 5,000 | 15,007 | | 1,000 | 4,020 | 3,700 | 5,338 |
| Café | 10,500 | 17,697 | | 8,500 | 11,940 | | |
| Cacao | 3,000 | | 4,500 | | 1,980 | | |
| Achiote | | | 4,500 | | 720 | 2,300 | 5,533 |
| Palma Aceitera | | | 4,000 | | | | |
| Pastos | | 10,670 | 34,000 | 5,000 | | 18,480 | 19,460 |
| TOTAL | 24,200 | 86,750 | 78,650 | 21,500 | 27,180 | 34,300 | 65,100 |

FUENTE : "Informe Sobre Evaluación de Suelos y Potencial Agrícola de Selva Central"
Dr. Hugo Villachica.
Inventario, Evaluación e Integración de los Recursos Naturales de las Zonas: Esperanza - Chandles - Yaco y Alto Yurua - Breu.

EXCEDENTES EXPORTABLES AGRICOLAS

(TN)

Centroide : PTO. OCOPA-PTO.PRADO

| AÑOS \ CULTIVOS | MAIZ | TABACO | YUCA | PLATANO | PIÑA | CITRICOS | CAFE | CACAO | T O T A L |
|---|---|---|---|---|---|---|---|---|---|
| 1985 | 141 | 880 | 1258 | 4,708 | 6,878 | 6,878 | 1,559 | 141 | 31,019 |
| 1986 | 153 | 957 | 1366 | 5,087 | 16,713 | 7,588 | 1,720 | 156 | 32,020 |
| 1987 | 165 | 1045 | 1474 | 5,486 | 18,080 | 8,379 | 1,898 | 172 | 36,699 |
| 1988 | 177 | 1133 | 1582 | 5,905 | 19,538 | 9,251 | 2,095 | 189 | 39,870 |
| 1989 | 192 | 1232 | 1707 | 6,384 | 21,139 | 10,213 | 2,313 | 209 | 43,389 |
| 1990 | 207 | 1342 | 1851 | 6,882 | 22,848 | 11,274 | 2,554 | 230 | 47,188 |
| 1991 | 222 | 1463 | 1995 | 7,421 | 24,719 | 12,443 | 2,819 | 254 | 51,336 |
| 1992 | 240 | 1595 | 2157 | 8,019 | 26,734 | 13,737 | 3,112 | 280 | 55,874 |
| 1993 | 258 | 1738 | 2318 | 8,638 | 28,911 | 15,158 | 3,435 | 308 | 60,764 |
| 1994 | 279 | 1881 | 2498 | 9,336 | 31,249 | 16,731 | 3,292 | 340 | 65,606 |
| 1995 | 303 | 2057 | 2714 | 10,074 | 33,804 | 18,475 | 4,186 | 374 | 71,987 |
| 1996 | 327 | 2233 | 2929 | 10,852 | 36,556 | 20,390 | 4,620 | 413 | 78,320 |
| 1997 | 351 | 2431 | 2145 | 11,710 | 39,525 | 22,512 | 5,099 | 455 | 85,228 |
| 1998 | 381 | 2651 | 3397 | 12,648 | 42,745 | 24,849 | 5,629 | 502 | 92,802 |
| 1999 | 411 | 2882 | 3684 | 13,645 | 46,217 | 27,430 | 6,213 | 553 | 101,035 |
| 2000 | 441 | 3135 | 3972 | 14,722 | 49,995 | 30,280 | 6,859 | 610 | 110,014 |
| 2001 | 477 | 3410 | 4277 | 15,876 | 54,061 | 33,417 | 7,571 | 672 | 119,761 |
| 2002 | 516 | 3718 | 4619 | 17,136 | 58,451 | 36,888 | 8,357 | 741 | 130,426 |
| 2003 | 555 | 4048 | 4996 | 18,493 | 63,218 | 40,724 | 9,224 | 816 | 142,077 |
| 2004 | 600 | 4400 | 5392 | 19,949 | 68,364 | 44,752 | 10,182 | 900 | 154,739 |

## EXCEDENTES EXPORTABLES AGRICOLAS

(TN)

Centroide : PTO. OCOPA-PTO.PRADO

| AÑOS / CULTIVOS | MAIZ | TABACO | YUCA | PLATANO | PIÑA | CITRICOS | CAFE | CACAO | T O T A L |
|---|---|---|---|---|---|---|---|---|---|
| 1985 | 141 | 880 | 1258 | 4,708 | 6,878 | 6,878 | 1,559 | 141 | 31,019 |
| 1986 | 153 | 957 | 1366 | 5,087 | 16,713 | 7,588 | 1,720 | 156 | 32,020 |
| 1987 | 165 | 1045 | 1474 | 5,486 | 18,080 | 8,379 | 1,898 | 172 | 36,699 |
| 1988 | 177 | 1133 | 1582 | 5,905 | 19,538 | 9,251 | 2,095 | 189 | 39,870 |
| 1989 | 192 | 1232 | 1707 | 6,384 | 21,139 | 10,213 | 2,313 | 209 | 43,389 |
| 1990 | 207 | 1342 | 1851 | 6,882 | 22,848 | 11,274 | 2,554 | 230 | 47,188 |
| 1991 | 222 | 1463 | 1995 | 7,421 | 24,719 | 12,443 | 2,819 | 254 | 51,336 |
| 1992 | 240 | 1595 | 2157 | 8,019 | 26,734 | 13,737 | 3,112 | 280 | 55,874 |
| 1993 | 258 | 1738 | 2318 | 8,638 | 28,911 | 15,158 | 3,435 | 308 | 60,764 |
| 1994 | 279 | 1881 | 2498 | 9,336 | 31,249 | 16,731 | 3,292 | 340 | 65,606 |
| 1995 | 303 | 2057 | 2714 | 10,074 | 33,804 | 18,475 | 4,186 | 374 | 71,987 |
| 1996 | 327 | 2233 | 2929 | 10,852 | 36,556 | 20,390 | 4,620 | 413 | 78,320 |
| 1997 | 351 | 2431 | 2145 | 11,710 | 39,525 | 22,512 | 5,099 | 455 | 85,228 |
| 1998 | 381 | 2651 | 3397 | 12,648 | 42,745 | 24,849 | 5,629 | 502 | 92,802 |
| 1999 | 411 | 2882 | 3684 | 13,645 | 46,217 | 27,430 | 6,213 | 553 | 101,035 |
| 2000 | 441 | 3135 | 3972 | 14,722 | 49,995 | 30,280 | 6,859 | 610 | 110,014 |
| 2001 | 477 | 3410 | 4277 | 15,876 | 54,061 | 33,417 | 7,571 | 672 | 119,761 |
| 2002 | 516 | 3718 | 4619 | 17,136 | 58,451 | 36,888 | 8,357 | 741 | 130,426 |
| 2003 | 555 | 4048 | 4996 | 18,493 | 63,218 | 40,724 | 9,224 | 816 | 142,077 |
| 2004 | 600 | 4400 | 5392 | 19,949 | 68,364 | 44,752 | 10,182 | 900 | 154,739 |

EXCEDENTES EXPORTABLES AGRICOLAS

(TM)

Zona : PUYENI

| AÑOS / CULTIVOS | ARROZ | MAIZ | TABACO | YUCA | PLATANO | PIÑA | CITRICOS | CAFE | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| 1985 | 6,870 | 8,603 | 3,630 | 17,810 | 35,130 | 21,858 | 20,642 | 2,626 | 117,169 |
| 1986 | 7,418 | 9,289 | 3,949 | 19,230 | 37,903 | 23,639 | 22,782 | 2,898 | 127,108 |
| 1987 | 8,009 | 10,030 | 4,301 | 20,758 | 40,896 | 25,564 | 25,155 | 3,200 | 137,913 |
| 1988 | 8,646 | 10,827 | 4,675 | 22,411 | 44,127 | 27,651 | 27,762 | 3,532 | 149,631 |
| 1989 | 9,335 | 16,691 | 5,093 | 24,208 | 47,598 | 29,900 | 30,648 | 3,899 | 162,372 |
| 1990 | 10,079 | 12,623 | 5,544 | 26,131 | 51,369 | 32,329 | 33,831 | 4,304 | 176,210 |
| 1991 | 10,881 | 13,627 | 6,028 | 28,216 | 55,418 | 34,973 | 37,346 | 4,751 | 191,240 |
| 1992 | 11,751 | 14,715 | 6,567 | 30,463 | 59,787 | 37,816 | 41,221 | 5,244 | 207,564 |
| 1993 | 12,686 | 15,887 | 7,150 | 32,889 | 64,515 | 40,892 | 45,500 | 5,788 | 225,307 |
| 1994 | 13,696 | 17,152 | 7,777 | 35,513 | 69,602 | 44,220 | 50,229 | 6,389 | 244,578 |
| 1995 | 14,787 | 18,519 | 8,459 | 38,334 | 75,108 | 47,818 | 55,444 | 7,053 | 265,522 |
| 1996 | 15,965 | 19,994 | 9,207 | 41,390 | 81,033 | 51,722 | 61,207 | 7,786 | 288,304 |
| 1997 | 17,239 | 21,589 | 10,021 | 44,696 | 87,437 | 55,932 | 67,563 | 8,593 | 313,070 |
| 1998 | 18,612 | 23,309 | 10,912 | 48,255 | 94,339 | 60,484 | 74,575 | 9,487 | 339,973 |
| 1999 | 20,096 | 25,168 | 11,869 | 52,101 | 101,780 | 65,413 | 82,325 | 10,471 | 369,223 |
| 2000 | 21,698 | 27,173 | 12,925 | 56,252 | 109,819 | 70,738 | 90,875 | 11,559 | 401,039 |
| 2001 | 23,426 | 29,337 | 14,058 | 60,745 | 118,477 | 76,495 | 100,306 | 12,759 | 435,603 |
| 2002 | 25,293 | 31,675 | 15,301 | 65,508 | 127,833 | 82,720 | 110,726 | 14,084 | 473,212 |
| 2003 | 27,309 | 34,199 | 16,654 | 70,810 | 137,928 | 89,466 | 122,224 | 15,546 | 514,136 |
| 2004 | 29,484 | 36,924 | 18,128 | 76,453 | 148,820 | 96,752 | 134,919 | 17,161 | 558,641 |

EXCEDENTES EXPORTABLES AGRICOLAS

(TM)

Zona : ATALAYA

| AÑOS CULTIVOS | ARROZ | MAIZ | PLATANO | PIÑA | TABACO | YUCA | CACAO | ACHIOTE | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| 1985 | 4,936 | 5,656 | 24,238 | 21,355 | 660 | 16,750 | 212 | 1,047 | 74,854 |
| 1986 | 5,328 | 6,106 | 26,153 | 23,100 | 715 | 18,080 | 234 | 1,155 | 80,871 |
| 1987 | 5,755 | 6,595 | 28,208 | 24,971 | 781 | 19,518 | 258 | 1,274 | 87,360 |
| 1988 | 6,211 | 7,119 | 30,442 | 27,004 | 847 | 21,081 | 284 | 1,406 | 94,394 |
| 1989 | 6,707 | 7,686 | 32,856 | 29,198 | 924 | 22,753 | 313 | 1,550 | 101,987 |
| 1990 | 7,241 | 8,300 | 35,449 | 31,573 | 1,012 | 24,568 | 345 | 1,710 | 110,198 |
| 1991 | 7,817 | 8,960 | 38,242 | 34,146 | 1,100 | 26,527 | 380 | 1,886 | 119,058 |
| 1992 | 8,442 | 9,676 | 41,275 | 36,934 | 1,199 | 28,647 | 419 | 2,081 | 128,673 |
| 1993 | 9,115 | 10,447 | 44,526 | 39,939 | 1,298 | 30,930 | 462 | 2,295 | 139,012 |
| 1994 | 9,840 | 11,280 | 48,037 | 43,195 | 1,419 | 33,392 | 510 | 2,531 | 150,204 |
| 1995 | 10,626 | 12,176 | 51,828 | 46,703 | 1,540 | 36,052 | 562 | 2,792 | 162,279 |
| 1996 | 11,472 | 13,147 | 55,937 | 50,499 | 1,672 | 38,927 | 619 | 3,080 | 175,353 |
| 1997 | 12,385 | 14,197 | 60,346 | 54,619 | 1,826 | 42,036 | 683 | 3,398 | 189,490 |
| 1998 | 13,373 | 15,327 | 65,114 | 59,062 | 1,980 | 45,379 | 752 | 3,747 | 204,734 |
| 1999 | 14,438 | 16,550 | 70,260 | 63,866 | 2,156 | 48,992 | 830 | 4,134 | 221,226 |
| 2000 | 15,589 | 17,866 | 75,806 | 69,065 | 2,357 | 52,910 | 914 | 4,560 | 239,805 |
| 2001 | 16,832 | 19,292 | 81,791 | 74,696 | 2,563 | 57,115 | 1,008 | 5,030 | 258,327 |
| 2002 | 18,172 | 20,827 | 88,255 | 80,759 | 2,783 | 61,662 | 1,111 | 5,547 | 279,116 |
| 2003 | 19,621 | 22,488 | 95,217 | 87,343 | 3,036 | 66,586 | 1,225 | 6,120 | 301,636 |
| 2004 | 21,183 | 24,280 | 102,738 | 94,450 | 3,300 | 71,888 | 1,350 | 6,750 | 325,939 |

EXCEDENTES EXPORTABLES AGRICOLA

(TM)

Zona : OBENTENI

| CULTIVOS / AÑOS | ARROZ | MAIZ | PLATANO | PIÑA | CITRICOS | CAFE | TOTAL |
|---|---|---|---|---|---|---|---|
| 1985 | 892 | 1,117 | 10,828 | 6,099 | 1,376 | 1,262 | 21,574 |
| 1986 | 963 | 1,206 | 11,683 | 6,602 | 1,519 | 1,393 | 23,366 |
| 1987 | 1,040 | 1,302 | 12,605 | 7,124 | 1,672 | 1,937 | 25,280 |
| 1988 | 1,123 | 1,406 | 13,601 | 7,718 | 1,852 | 1,697 | 27,397 |
| 1989 | 1,212 | 1,518 | 14,675 | 8,348 | 2,041 | 1,872 | 29,666 |
| 1990 | 1,309 | 1,639 | 15,833 | 9,013 | 2,257 | 2,067 | 32,118 |
| 1991 | 1,413 | 1,770 | 17,083 | 9,751 | 2,490 | 2,281 | 34,788 |
| 1992 | 1,526 | 1,911 | 18,432 | 10,542 | 2,751 | 2,519 | 37,681 |
| 1993 | 1,647 | 2,063 | 19,888 | 11,406 | 3,030 | 2,780 | 40,814 |
| 1994 | 1,779 | 2,228 | 21,458 | 12,341 | 3,344 | 3,069 | 44,219 |
| 1995 | 1,920 | 2,405 | 23,153 | 13,349 | 3,695 | 3,388 | 47,910 |
| 1996 | 2,073 | 2,597 | 24,981 | 14,428 | 4,082 | 3,740 | 51,901 |
| 1997 | 2,239 | 2,804 | 26,953 | 15,598 | 4,504 | 4,128 | 56,226 |
| 1998 | 2,418 | 3,027 | 29,081 | 16,875 | 4,972 | 4,557 | 60,930 |
| 1999 | 2,610 | 3,268 | 31,378 | 18,242 | 5,484 | 5,030 | 66,012 |
| 2000 | 2,818 | 3,529 | 35,855 | 19,735 | 6,060 | 5,551 | 73,548 |
| 2001 | 3,042 | 3,810 | 36,528 | 21,337 | 6,680 | 6,128 | 77,525 |
| 2002 | 2,385 | 4,114 | 39,413 | 23,082 | 7,381 | 6,765 | 84,040 |
| 2003 | 3,547 | 4,442 | 42,525 | 24,953 | 8,145 | 7,467 | 91,079 |
| 2004 | 3,829 | 4,796 | 45,882 | 26,986 | 8,990 | 8,243 | 98,726 |

EXCEDENTES EXPORTABLES AGRICOLAS

(TM)

Zona : PTO. RICO

| AÑOS / CULTIVOS | ARROZ | MAIZ | TABACO | YUCA | PLATANO | PIÑA | CITRICOS | CAFE | CACAO | ACHIOTE | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 1,841 | 1,634 | 660 | 3,774 | 5,646 | 1,943 | 5,529 | 1,771 | 93 | 168 | 23,059 |
| 1986 | 1,987 | 1,763 | 715 | 4,080 | 6,084 | 2,105 | 6,104 | 1,955 | 103 | 186 | 25,082 |
| 1987 | 2,144 | 1,903 | 781 | 4,403 | 6,563 | 2,267 | 6,734 | 2,158 | 113 | 204 | 27,270 |
| 1988 | 2,317 | 2,056 | 847 | 4,745 | 7,102 | 2,465 | 7,435 | 2,382 | 125 | 225 | 29,699 |
| 1989 | 2,501 | 2,221 | 924 | 5,122 | 7,660 | 2,663 | 8,208 | 2,631 | 138 | 249 | 32,317 |
| 1990 | 2,700 | 2,398 | 1,012 | 5,535 | 8,259 | 2,878 | 9,062 | 2,903 | 152 | 275 | 35,174 |
| 1991 | 2,915 | 2,587 | 1,100 | 5,985 | 8,917 | 3,112 | 10,006 | 3,205 | 167 | 303 | 38,297 |
| 1992 | 3,148 | 2,794 | 1,199 | 6,452 | 9,615 | 3,364 | 11,040 | 3,538 | 185 | 333 | 41,668 |
| 1993 | 3,399 | 3,019 | 1,298 | 6,973 | 10,374 | 3,634 | 12,191 | 3,905 | 203 | 368 | 45,364 |
| 1994 | 3,669 | 3,258 | 1,419 | 7,512 | 11,191 | 3,940 | 13,459 | 4,311 | 224 | 405 | 49,388 |
| 1995 | 3,961 | 3,516 | 1,540 | 8,123 | 12,069 | 4,264 | 14,852 | 4,759 | 247 | 447 | 53,778 |
| 1996 | 4,278 | 3,798 | 1,672 | 8,770 | 13,027 | 4,606 | 16,398 | 5,252 | 272 | 494 | 58,567 |
| 1997 | 4,620 | 4,101 | 1,826 | 9,453 | 14,064 | 4,983 | 18,098 | 5,798 | 300 | 545 | 63,788 |
| 1998 | 4,986 | 4,427 | 1,980 | 10,208 | 15,161 | 5,394 | 18,977 | 6,400 | 331 | 600 | 69,467 |
| 1999 | 5,384 | 4,781 | 2,156 | 11,035 | 16,358 | 5,829 | 22,053 | 7,065 | 365 | 662 | 75,688 |
| 2000 | 5,811 | 5,162 | 2,354 | 11,897 | 17,655 | 6,315 | 24,346 | 7,799 | 402 | 731 | 82,472 |
| 2001 | 6,276 | 5,572 | 2,563 | 12,850 | 19,051 | 6,818 | 26,872 | 8,608 | 443 | 806 | 89,859 |
| 2000 | 6,776 | 6,016 | 2,783 | 13,874 | 20,568 | 7,376 | 29,659 | 9,502 | 489 | 888 | 97,931 |
| 2003 | 7,314 | 6,496 | 3,036 | 14,989 | 22,183 | 7,988 | 32,743 | 10,489 | 539 | 980 | 106,757 |
| 2004 | 7,899 | 7,014 | 3,300 | 16,175 | 23,939 | 8,635 | 36,141 | 11,579 | 594 | 1,080 | 116,356 |

EXCEDENTES EXPORTABLES AGRICOLAS

(TM)

Zona : B R E U

| AÑOS / CULTIVOS | ARROZ | MAIZ | PLATANO | PIÑA | CAFE | YUCA | ACHIOTE | TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1985 | 1,530 | 2,059 | 8,478 | 4,875 | 5,084 | 4,601 | 536 | 27,288 |
| 1986 | 1,652 | 2,224 | 9,276 | 5,271 | 5,519 | 4,960 | 591 | 29,593 |
| 1987 | 1,783 | 2,401 | 10,014 | 5,703 | 6,203 | 5,356 | 651 | 32,111 |
| 1988 | 1,925 | 2,593 | 10,792 | 6,171 | 6,842 | 5,787 | 719 | 34,829 |
| 1989 | 2,977 | 2,800 | 11,650 | 6,674 | 7,552 | 6,254 | 792 | 37,799 |
| 1990 | 2,245 | 3,022 | 12,568 | 7,214 | 8,343 | 6,757 | 875 | 41,024 |
| 1991 | 2,423 | 3,261 | 13,565 | 7,808 | 9,206 | 7,297 | 965 | 44,525 |
| 1992 | 2,616 | 3,522 | 14,643 | 8,437 | 10,159 | 7,872 | 1,064 | 48,313 |
| 1993 | 2,824 | 3,804 | 15,800 | 9,121 | 11,220 | 8,501 | 1,173 | 52,443 |
| 1994 | 3,050 | 4,107 | 17,036 | 9,857 | 12,380 | 9,184 | 1,295 | 56,911 |
| 1995 | 3,293 | 4,433 | 18,373 | 10,668 | 13,665 | 9,903 | 1,428 | 61,763 |
| 1996 | 3,556 | 4,787 | 19,829 | 11,532 | 15,086 | 10,693 | 1,575 | 67,058 |
| 1997 | 3,840 | 5,168 | 21,405 | 12,485 | 16,659 | 11,556 | 1,737 | 72,850 |
| 1998 | 4,146 | 5,581 | 23,081 | 13,439 | 18,385 | 12,473 | 1,916 | 79,075 |
| 1999 | 4,476 | 6,025 | 24,916 | 14,590 | 20,291 | 13,479 | 21,114 | 85,891 |
| 2000 | 4,833 | 6,508 | 26,871 | 15,778 | 22,404 | 14,539 | 2,331 | 93,264 |
| 2001 | 5,218 | 7,026 | 29,006 | 17.073 | 24,733 | 15,707 | 2,571 | 101,334 |
| 2002 | 5,635 | 7,584 | 31,300 | 18,458 | 27,295 | 16,965 | 2,835 | 110,072 |
| 2003 | 6,082 | 8,189 | 33,754 | 19,969 | 30,136 | 18,313 | 3,128 | 119,571 |
| 2004 | 6,568 | 8,843 | 36,427 | 21,588 | 33,264 | 19,769 | 3,450 | 129,909 |

## EXCEDENTES EXPORTABLES AGRICOLAS

(TM)

Zona : PTO.ESPERANZA

| CULTIVOS / AÑOS | ARROZ | MAIZ | PLATANO | PIÑA | CITRICOS | TABACO | YUCA | ACHIOTE | T O T A L |
|---|---|---|---|---|---|---|---|---|---|
| 1985 | 4,538 | 5,003 | 29,126 | 28,587 | 7,345 | 2,156 | 22,088 | 1,287 | 100,130 |
| 1986 | 4,900 | 5,402 | 31,420 | 30,908 | 8,109 | 2,343 | 23,849 | 1,419 | 108,350 |
| 1987 | 5,290 | 5,833 | 33,913 | 33,426 | 8,945 | 2,552 | 25,754 | 1,566 | 117,279 |
| 1988 | 5,711 | 6,298 | 36,585 | 36,161 | 9,880 | 2,783 | 27,803 | 1,728 | 126,950 |
| 1989 | 6,169 | 6,799 | 39,479 | 39,093 | 10,905 | 3,025 | 30,013 | 1,905 | 137,388 |
| 1990 | 6,659 | 7,341 | 42,591 | 42,277 | 12,038 | 3,289 | 32,404 | 2,102 | 148,701 |
| 1991 | 7,191 | 7,926 | 45,843 | 45,732 | 13,288 | 3,586 | 34,991 | 2,319 | 160,976 |
| 1992 | 7,762 | 8,555 | 49,573 | 49,438 | 14,663 | 3,905 | 37,777 | 2,558 | 174,231 |
| 1993 | 8,380 | 9,239 | 53,484 | 53,467 | 16,192 | 4,246 | 40,778 | 2,822 | 188,607 |
| 1994 | 9,048 | 9,973 | 57,713 | 57,821 | 17,873 | 4,620 | 44,031 | 3,113 | 204,192 |
| 1995 | 9,771 | 10,767 | 62,261 | 62,535 | 19,725 | 5,027 | 47,536 | 3,432 | 221,054 |
| 1996 | 10,549 | 11,625 | 67,188 | 67,262 | 21,775 | 5,478 | 51,328 | 3,786 | 239,355 |
| 1997 | 11,389 | 12,551 | 72,495 | 73,131 | 24,031 | 5,962 | 55,408 | 4,176 | 259,143 |
| 1998 | 12,296 | 13,652 | 78,220 | 79,086 | 26,531 | 6,490 | 59,829 | 4,607 | 280,611 |
| 1999 | 13,277 | 14,631 | 88,384 | 85,526 | 29,282 | 7,062 | 64,591 | 5,082 | 307,835 |
| 2000 | 14,336 | 15,797 | 91,407 | 92,489 | 32,329 | 7,689 | 69,749 | 5,606 | 329,042 |
| 2001 | 15,477 | 17,056 | 98,229 | 100,009 | 35,683 | 8,371 | 75,303 | 6,183 | 356,891 |
| 2002 | 16,709 | 18,414 | 105,989 | 108,158 | 39,387 | 9,108 | 81,305 | 6,821 | 385,891 |
| 2003 | 18,041 | 19,883 | 114,348 | 116,974 | 43,478 | 9,911 | 87,775 | 7,524 | 417,934 |
| 2004 | 19,479 | 21,466 | 123,385 | 126,491 | 47,991 | 10,791 | 94,766 | 8,300 | 452,669 |

CUADRO N!

FLUJOS DE CARNE POR CENTROIDE

(T.M.)

| AÑOS | ATALAYA | PUYENI | OBENTENI | PTO.ESPERANZA | PTO.BREU |
|---|---|---|---|---|---|
| 1985 | 169.9 | 53.3 | 24.9 | 97.2 | 92.3 |
| 1986 | 179.8 | 56.4 | 26.4 | 102.9 | 97.7 |
| 1987 | 190.2 | 59.7 | 27.9 | 108.8 | 103.4 |
| 1988 | 201.2 | 63.1 | 29.5 | 115.2 | 109.4 |
| 1999 | 212.9 | 66.8 | 31.3 | 121.8 | 115.7 |
| 1990 | 225.3 | 70.7 | 33.1 | 128.9 | 122.4 |
| 1991 | 238.3 | 74.8 | 35.0 | 136.4 | 129.5 |
| 1992 | 252.2 | 79.1 | 37.0 | 144.3 | 137.0 |
| 1993 | 266.8 | 83.7 | 39.2 | 152.7 | 145.0 |
| 1994 | 282.3 | 88.5 | 41.5 | 161.5 | 153.4 |
| 1995 | 298.7 | 93.7 | 43.9 | 170.9 | 162.3 |
| 1996 | 316.0 | 99.1 | 46.4 | 180.8 | 171.7 |
| 1997 | 334.3 | 104.9 | 49.1 | 191.3 | 181.7 |
| 1998 | 353.7 | 111.0 | 52.0 | 202.4 | 192.2 |
| 1999 | 374.2 | 117.4 | 55.0 | 214.2 | 203.4 |
| 2000 | 395.9 | 124.2 | 58.2 | 226.6 | 215.2 |
| 2001 | 418.9 | 131.4 | 61.6 | 239.7 | 227.7 |
| 2002 | 443.2 | 139.0 | 65.1 | 253.6 | 240.9 |
| 2003 | 468.95 | 147.1 | 68.9 | 268.4 | 254.8 |
| 2004 | 496.0 | 155.6 | 72.9 | 283.9 | 269.6 |
| 2005 | 524.8 | 164.7 | 77.1 | 300.4 | 285.3 |

CUADRO N°

## FLUJOS FORESTALES *

Madera Aserrada

(m3.)

| AÑOS | ATALAYA | PUYENI | PTO.RICO | PTO.OCOPA | OBENTENI |
|---|---|---|---|---|---|
| 1985-2004 | 32,270 | 22,176 | 36,022 | 16,807 | 13,700 |



* FLUJOS ANUALES, CONSTANTES DURANTE 20 AÑOS

APPENDIX

C

C 1

CUADRO Nº 1



## INFRAESTRUCTURA AEREA

| AERODROMO | DISTRITO | PROPIEDAD | DIMENSION PISTA | ELEVAC. (PIES) | AVION AUTORIZ. | SUPERF. |
|---|---|---|---|---|---|---|
| **PROVINCIA** | **CHANCHAMAYO** | | | | | |
| San Ramón | San Ramón | Estado | 800 x 40 | 2600 | DC-3 | Arcilla |
| Alto Pichanaqui | Chanchamayo | Estado | 1200 x 45 | 2900 | Avioneta | Arcilla |
| Zotzique | La Merced | Particular | 450 x 30 | 2475 | Avioneta | Arcilla |
| Ipoki | La Merced | Particular | 900 x 80 | 1800 | Avioneta | Tierra |
| Yarinaqui | Chanchamayo | Particular | 400 x 20 | 1200 | Avioneta | Arcilla |
| **PROVINCIA** | **SATIPO** | | | | | |
| Satipo | Satipo | CORPAC | 1180 x 30 | 2100 | DC-3 | Arcilla |
| Pto. Ocopa | Río Tambo | Particular | 1220 x 45 | 1220 | DC-3 | Arcilla |
| Mazamari | Mazamari | Estado | 1467 x 44 | 2150 | DC-3 | Arcilla |
| Aoti | Río Tambo | Particular | 250 x 20 | 1650 | Avioneta | Tierra |
| Ashaninga | Río Tambo | Particular | 380 x 20 | 1080 | Avioneta | Tierra |
| Coriri | Pangoa | Particular | 300 x 15 | 1300 | Avioneta | Tierra |
| Chichireni | Pangoa | Particular | 250 x 20 | 1400 | Avioneta | Tierra |
| Miaria | Pangoa | Particular | 280 x 20 | 950 | Avioneta | Tierra |
| Santaro | Río Tambo | Particular | 200 x 25 | 1000 | Avioneta | Tierra |
| Quempiri | Pangoa | Particular | 300 x 20 | 1300 | Avioneta | Tierra |
| Tsomaveni | Mazamari | Particular | 250 x 15 | 1500 | Avioneta | Tierra |
| Anapati | Río Tambo | Particular | 260 x 20 | 1000 | Avioneta | Tierra |
| Cotivereni | Río Tambo | Particular | 930 x 40 | 1025 | DC-3 | Tierra |
| Pitza | Río Tambo | Particular | 225 x 30 | 2000 | Avioneta | Tierra |
| Rateri | Río Tambo | Particular | 850 x 40 | 900 | DC-3 | Arcilla |
| Puyeni | Río Tambo | Particular | 300 x 20 | 1000 | Avioneta | Arcilla |
| Potsateni | Río Tambo | Particular | 365 x 35 | 1174 | Avioneta | Arenoso |
| Camajini | Río Tambo | Particular | 300 x 30 | 1630 | Avioneta | |
| Saniveni | Río Tambo | Particular | 300 x 30 | 1150 | Avioneta | Arcilla |
| Shevoja | Río Tambo | Particular | 300 x 30 | 915 | Avioneta | Arcilla |
| Tsitsireni | Río Tambo | Particular | 300 x 30 | 1125 | Avioneta | Arcilla |
| Chamiriari | Río Tambo | Particular | 300 x 30 | 1000 | Avioneta | Arcilla |
| Mayapo | Río Tambo | Particular | 300 x 30 | 950 | Avioneta | Arcilla |

C 2

| AERODROMO | DISTRITO | PROPIEDAD | DIMENSION PISTA | ELEVAC. (PIES) | AVION AUTORIZ. | SUPERF. |
|---|---|---|---|---|---|---|
| PROVINCIA | OXAPAMPA | | | | | |
| Pto.Bermúdez | Pto.Bermúdez | CORPAC | 850 x 10 | 820 | DC-3 | Arcilla |
| Iscozacin | Huancabamba | Particular | 1200 x 40 | 900 | DC-3 | Ripio |
| P.Victoria | Pto.Bermúdez | CORPAC | 850 x 30 | 760 | DC-3 | Arcilla |
| Comparachimas | Huancabamba | | | | | |
| Oxapampa | Oxapampa | Estado | 850 x 114 | 5560 | Avioneta | Tierra |
| La Llobera | Pto.Bermúdez | Particular | 500 x 10 | 954 | Avioneta | Arcilla |
| Anacayali | Pto.Bermúdez | Particular | 450 x 15 | 891 | Avioneta | Arcilla |
| Cahuapanas | Pto.Bermúdez | Particular | 380 x 20 | 775 | Avioneta | Arcilla |
| Shirincamasu | Oxapampa | Particular | 550 x 20 | 1100 | Avioneta | Arcilla |
| San Pablo | Huancabamba | Particular | 790 x 15 | 510 | Avioneta | Arcilla |
| Pto.Chuchurras | Huancabamba | Particular | 850 x 13 | 1089 | Avioneta | Ripio |
| Santoche | Pto.Bermúdez | Particular | 350 x 15 | 1148 | Avioneta | Arcilla |
| Villa Rica | Huancabamba | Particular | 400 x 35 | 1175 | Avioneta | Arcilla |
| Rami | Pto.Bermúdez | Particular | 600 x 27 | 900 | Avioneta | Arcilla |
| Esperanza (Amuesha) | Huancabamba | Estado | 400 x 25 | 1100 | Avioneta | Arcilla |
| San José | Pto.Bermúdez | Particular | 500 x 10 | 860 | Avioneta | Arcilla |
| San Cristobal | Oxapampa | Particular | 700 x 10 | 900 | Avioneta | Arcilla |
| San Pedro | Huancabamba | Particular | 600 x 10 | 940 | Avioneta | Arcilla |
| San Juan | Oxapampa | | | | Avioneta | Arcilla |
| Pozuzo | Pozuzo | | | | Avioneta | Arcilla |
| Codo del Pozuzo | Pozuzo | | | | Avioneta | Arcilla |
| PROVINCIA | PACHITEA | | | | | |
| Aguas Calientes | Pachitea | Particular | 1025 x 100 | 528 | DC-3 | Arcilla |
| Pto. Inca | Pto. Inca | CORPAC | 1000 x 80 | 585 | DC-3 | Arcilla |
| Tournavista | Honoria | Particular | 1500 x 62 | 650 | DC-6 | Ripio |
| Fundo Flor | Pto. Inca | Particular | 550 x 10 | 850 | Avioneta | Arcilla |
| Sta. María | Pto. Inca | Particular | 300 x 20 | 900 | Avioneta | Arcilla |
| Llulla Pichis | Pto. Inca | Estado | 520 x 15 | 650 | Avioneta | Arcilla |
| PROVINCIA | CRNEL.PORTILLO | | | | | |
| Atalaya | Raymondi | Estado | 1500 x 45 | 1300 | DC-3 | Tierra |
| Aguaytía | Aguaytía | Particular | 1200 x 45 | 715 | C-46 | Arcilla |
| Los Zorrillos | Aguaytía | Particular | 1352 x 48 | 700 | C-130 | Compactada |

| AERODROMO | DISTRITO | PROPIEDAD | DIMENSION PISTA | ELEVAC. (PIES) | AVION AUTORIZ. | SUPERF. |
|---|---|---|---|---|---|---|
| El Sepa (Colonia Penal) | Raymondi | Estado | 1350 x 40 | 900 | DC-3 | Arcilla |
| Pucallpa Nuevo | Callería | CORPAC | 2500 x 30 | 800 | Boeing 727 | Asfalt. |
| Pto.Esperanza | Purús | Estado | 800 x 14 | 394 | DC-3 | Arcilla |
| Unine | Raymondi | CORPAC | 650 x 10 | 587 | Avioneta | Arcilla |
| Sepahua (antiguo) | Raymondi | CORPAC | 1200 x 30 | 886 | C-47 | Tierra |
| Sepahua (Total) | Raymondi | Estado | 1825 x 30 | 900 | C-130 | Grava |
| Bufeo Pozo | Raymondi | Particular | 340 x 30 | 900 | Avioneta | Tierra |
| Balta | Purús | Particular | 400 x 20 | 600 | Avioneta | Tierra |
| Chicosa | Raymondi | Particular | 300 x 20 | 650 | Avioneta | Tierra |
| Intuto | Tigre | CORPAC | 2000x 45 | 650 | C-130 | Compact. |
| Encuentro | Raymondi | Particular | 300 x 20 | 650 | Avioneta | Tierra |
| Cantagallo | Callería | Estado | 350 x 35 | 200m. | Avioneta | Arcilla |
| Pto. Breu | Callería | Estado | 350 x 35 | 800m. | C-44 | Arc-Aren. |
| Yarinacocha | Yarinacocha | Particular | 550 x 20 | 450 | Avioneta | Tierra |
| San Marcos | Pto. Balsa | Particular | 325 x 30 | 585 | Avioneta | Arena |
| Jatitza | Raymondi | Particular | 300 x 30 | 550 | Avioneta | Tierra |
| Ahuypa | Raymondi | Particular | 500 x 30 | 530 | Avioneta | Tierra |
| Bolognesi | Tahuania | Particular | | | | |
| Culina | Purús | Particular | 430 x 40 | 525 | Avioneta | Arena |
| PROVINCIA | LA CONVENCION | | | | | |
| Teresita | Echarate | Particular | 1300 x 40 | 1968 | Avioneta | Ripio |
| Camisea | Echarate | Particular | 400 x 20 | 1200 | Avioneta | Arcilla |
| Kolpiroshiato | Echarate | Particular | 300 x 30 | 2200 | Avioneta | Arcilla |
| Mipaya | Echarate | Particular | 400 x 20 | 1000 | Avioneta | Arcilla |
| Monte Carmelo | Echarate | Particular | 300 x 30 | 1800 | Avioneta | Arcilla |
| Pacria | Echarate | Particular | 300 x 20 | 980 | Avioneta | Arcilla |
| Picha | Echarate | Particular | 300 x 20 | 300 | Avioneta | Arcilla |
| Mantaro | Echarate | Particular | 375 x 20 | 3300 | Avioneta | Arcilla |
| Mantaro Chico | Echarate | Particular | 500 x 30 | 4000 | Avioneta | Arcilla |
| Miaria | Echarate | Particular | 200 x 20 | 950 | Avioneta | Arcilla |

FUENTE : Dirección General de Transporte Aéreo y Oficina dé Estadística.
30.06.81.

C 4

CUADRO Nº



PARQUE AEREO DEL SERVICIO NO REGULAR DE TAXI AEREO EN SELVA CENTRAL AL 30.12.80

| COMPAÑIAS | AERONAVES | CAPACIDAD PASAJEROS | CAPACIDAD CARGA Kg | OPERACIONES |
|---|---|---|---|---|
| SERVICIOS AEREOS, S.A. | | | | |
| | Cessna 206 | 5 | 54 | Operativo |
| | Cessna 206 | 5 | 54 | Operativo |
| | Cessna U-206 | 5 | 54 | Operativo |
| | Cessna U-206 F | 5 | 54 | Operativo |
| | Cessna 402-B | 9 | 162 | Reparación |
| | Cessna 402-B | 9 | 162 | Operativo |
| | Cessna U-206 F | 5 | 54 | Operativo |
| | Cessna U-206 | 5 | 54 | Operativo |
| | Cessna U-206 | 5 | 54 | Accidentado recuperable |
| | Cessna 206 | 5 | 54 | Operativo |
| | Norman Islandez | 9 | 120 | Operativo |
| AEROFLOTA, S.A. | | | | |
| | Cessna 185 | 5 | 59 | Operativo |
| | Cessna 180 | 3 | 54 | Accidnetado |
| | Cessna U-206 | 5 | 54 | Operativo |
| | Cessna 310 | 5 | 440 | Operativo |
| | Beefchcraf C-33 | 3 | 54 | Operativo |
| TRANSPORTES AEREOS "EL AGUILA", S.A. | Cessna 402 C | 9 | 162 | Operativo |
| | Cessna U-206 | 5 | 54 | Operativo |
| | Cessna U-206 | 5 | 54 | Operativo |
| TRANSPORTES AEREOS "UCHIZA", S.A. | | | | |
| | Cessna TN 206 G | 5 | 87 | Operativo |
| | Cessna TU 206 G | 5 | 87 | Operativo |

Fuente : Dirección General de Transporte Aéreo, Oficina de

(TRANSLATION)

APPENDIX B

PROJECTED LOADS



Page B1: 1. area of study 2. zones 3. probable routes

p B2 :1. potential areas of sowing and programs proposed 2. zone 3. cultivation 4. rice 5. maize 6. tobacco 7. yucca 8 banana-tree 9. pine 10 citrus fruit 11 coffee 12 cocoa 13 arnotto tree 14 oil producing palm-tree 15 pastures 16 Source: "Report on the Evaluation of the Soils and Agricultural Potential of the Central Forest" Dr Hugo Villachia
Inventory, Evaluation and Integration of the N tural Resources of the Zones: Esperanza, Chandles-Yaco and Alto Yurua-Breu

pB3 :1 excess exportable agricultural products 2. Center: Pto Ocopa-Pto Prado 3. years 4. cultivation 5. maize 6. tobacco 7. yucca 8. banana tree 9 pine 10 citrus fruit 11 coffee 12 cocoa

pB4: 1. excess exportable agricultural products 2. center: Pto Ocopa-Pto Prado 3. years 4. cultivation 5. maize 6. tobacco 7. yucca 8 banana tree 9. pine 10. citrus fruit 11. coffee 12 cocoa

pB5: 1. excess agricultural products to be exported 2. zone 3. years 4. cultivation 5. rice 6. maize 7. tobacco 8. yucca 9. banana tree 10 pine 11. citrus fruit 12 coffee

pB6: 1. excess exportable agricultural products 2. zone 3. years 4. cultivation 5. rice 6. maize 7. banana tree 8. pine 9. tobacco 10 yucca 11. cocoa 12 arnotto tree

pB7: 1. excess exportable agricultural products 2. zone Obenteni 3. years 4. cultivation 5. rice 6. maize 7. banana tree 8. pine 9. citrus fruit 10 coffee

pB8: 1. excess agricultural products 2. Zone: Pto Rico 3. years 4. cultivation 5. rice 6 maize 7. tobacco 8. yucca 9. banana tree 10. pine 11. citrus fruit 12 coffee 13 cocoa 14 arnotto tree

pB9: 1. excess agricultural products 2. zone: Breu 3. years 4. cultivation 5. rice 6 maize 7. banana tree 8. pine 9 coffee 10 yucca 11 arnotto tree

pB10: 1. excess agricultural products 2. zone: Pto Esperanza 3. years 4. cultivation 5. rice 6 maize 7. banana tree 8. pine 9. citrus fruit 10 tobacco 11 yucca 12 arnotto tree

pB11: 1. Figure No1; 2. flow of meat through the center (T.M.) 3. years

pB12 :1. Figure No 2; 2. forest flows*; sawn wood ($m^3$) 3. years 1985-2004 4. * annual flows constant over 20 years

(TRANSLATION)

Appendix C: Landing runways in the Central Forest

Table 1: Air infrastructure

Page C1/ 1. airport 2. district 3. property 4. dimensions of the runway 5. altitude (feet) 6. aircraft permitted 7. area 8. province 9. Chanchamayo 10. Satipo

p C2 1. airport 2. district 3. property 4. dimensions of runway 5. altitude (feet) 6. aircraft permitted 7. area 8. province 9. Oxapampa 10 Pachitea 11 Crnel Portillo

C3: 1. airport 2. district 3. property 4. dimensions of runway 5. altitude (feet) 6. aircraft permitted 7. area 8. province 9. La Convencion 10 Source: General Directorate of Air Transport and Statistics Office

C4: Table 3: Air fleet of the non regular air taxi service in the Central Forest on 30 December 1980

1. companies 2. aircraft 3. capacity 4. passengers 5 load 6 operations 7. operational 8. recoverable after accident 9. involved in an accident 10. Source: General Directorate of Air Transport, Statistics Office.