NASA TECHNICAL MEMORANDUM NASA TM-76814

JBFA-BUOYANT FLIGHT, SPECIAL EDITION

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(NASA-TM-76814) JBFA-BUOYANT FLIGHT, SPECIAL EDITION (National Aeronautics and Space Administration) 134 p HC A07/MF A01 N83-10002
CSCL 01B Unclas
G3/01 35482

Translation of "JBFA-buiyanto koku," Special Edition,
Vol. 7, No. 1, 1981, pp. 1-96

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 FEBRUARY 1982

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STANDARD TITLE PAGE

1. Report No. NASA TM-76814	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle JBFA-BOUYANT FLIGHT. SPECIAL EDITION		5. Report Date FEBRUARY 1982
		6. Performing Organization Code
7. Author(s) Chuta Wada, Kazuhiko Terada, Chizuru Ishii, Kazuo Nagamatsu, Mitsuo Makino Saburo Ichiyoshi		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates, Redwood City, California 94063		11. Contract or Grant No. NASw-3541
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "JBFA-buiyanto koku," Special Edition, Vol. 7, No. 1, 1981, pp 1-96

16. Abstract

This edition discusses two projects; the first one is to traverse the Pacific Ocean by manned balloon and the second is the buoyant helicopter system (BHS); The results of research by specialists have been gathered in this report.

17. Key Words (Selected by Author(s))	18. Distribution Statement "Unclassified-Unlimited"

19. Security Classif. (of this report) UNCLASSIFIED	20. Security Classif. (of this page) UNCLASSIFIED	21. No. of Pages	22.

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Project to Traverse Pacific Ocean by Manned Balloon. Buoyant Helicopter System Project

These two projects have been proposed and studied by the members of this organization. The project to traverse the Pacific Ocean by manned balloon has been examined for more than two years by the research group headed by Mr. Chuta Wada. The trans-Pacific project has attracted the interest of balloonists around the world since the success by the American Double Eagle in traversing the Atlantic Ocean in 1978. Projects under research in various countries are still in the paperwork stage, but there are some which have advanced to the implementation stage. Japan as well, which has the tradition of a balloon bomb, truly a unique concept, has not been silent.

Research has begun this year into the buoyant helicopter system (BHS) project proposed by Kazumasa Iinuma. A test scale model of a new type of hybrid lighter-than-air craft combining the buoyancy of bags filled with buoyant gas with the vertical lift-off and landing performance of the helicopter is to be produced.

Since this association fortunately has specialists in various disciplines, the results of research by those specialists in their respective fields have been gathered in this report.

Outdoor flight tests are planned this year since funds for the BHS project are assured, but this cannot be implemented immediately since considerable expenses are required in execution of a trans-Pacific flight. However, research has been conducted by various members of the organization with the intention of actual execution.

With our days being filled with plans for trial production of the BHS and preparations for the trans-Pacific flight, we invite criticisms and suggestions from everyone.

Hidemasa Kimura
Chairman of the Buoyant Flight Association

Trans-Pacific
Summary of project to traverse the Pacific Ocean by manned balloon

° Period and flight plan

The Pacific Ocean is to be crossed utilizing the jet stream in the winter months of November through January. The departure point would be in the northeast (e.g. Furukawa). The target would be a city on the Pacific coast of North America at north latitude of 40 to 50° (e.g. Portland, Oregon). The distance would be 10,000 km and the required time would be 60 hours. The departure time would be a calm period after sunset. Ascent to a cruising altitude of 12,000 to 13,000 meters would be rapid. (Figure 1). /1*

°Balloon system

The balloon would be a zero pressure type with a capacity of 15,000 m^2 of He, and a two man crew would ride in a sealed cabin fitted with an expandable float. The facilities would be sufficient for seven days. The ballast would be adequate for seven sunsets. (Figure 2).

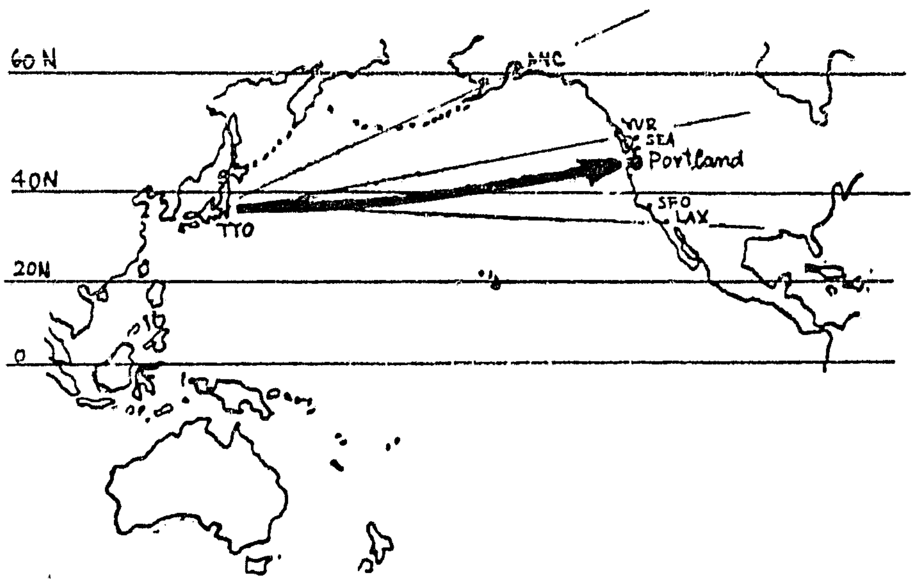


Figure 1. Estimated arrival site

* Numbers in the margin indicate pagination in the Japanese text.

°Communications/navigation

The position would be determined by Omega/VLF navigational equipment, and the air control system over the Pacific would be avoided through ATC communications based on HF. (A sextant and observational chart would be provided for back-up). A transponder, beacon would be installed to prevent mid-air collisions. The flight altitude selected would be the eastern-most possible VFR altitudes of FL 380 (11,590 m) or FL 420 (12,810 m). A rapid rescue system using satellites would be on board, and every effort would be made to ensure safety.

°Weight, expense, schedule

The weight of the balloon system would be 3,000 kg, half of which would be ballast. The direct expense, include production and purchase, would be 96.9 million yen. Additional expenses would be 104.5 million yen for support expenses, 100 million yen for related expenses and 20 million yen for preparatory expenses, for a total of 321.4 million yen.

/2

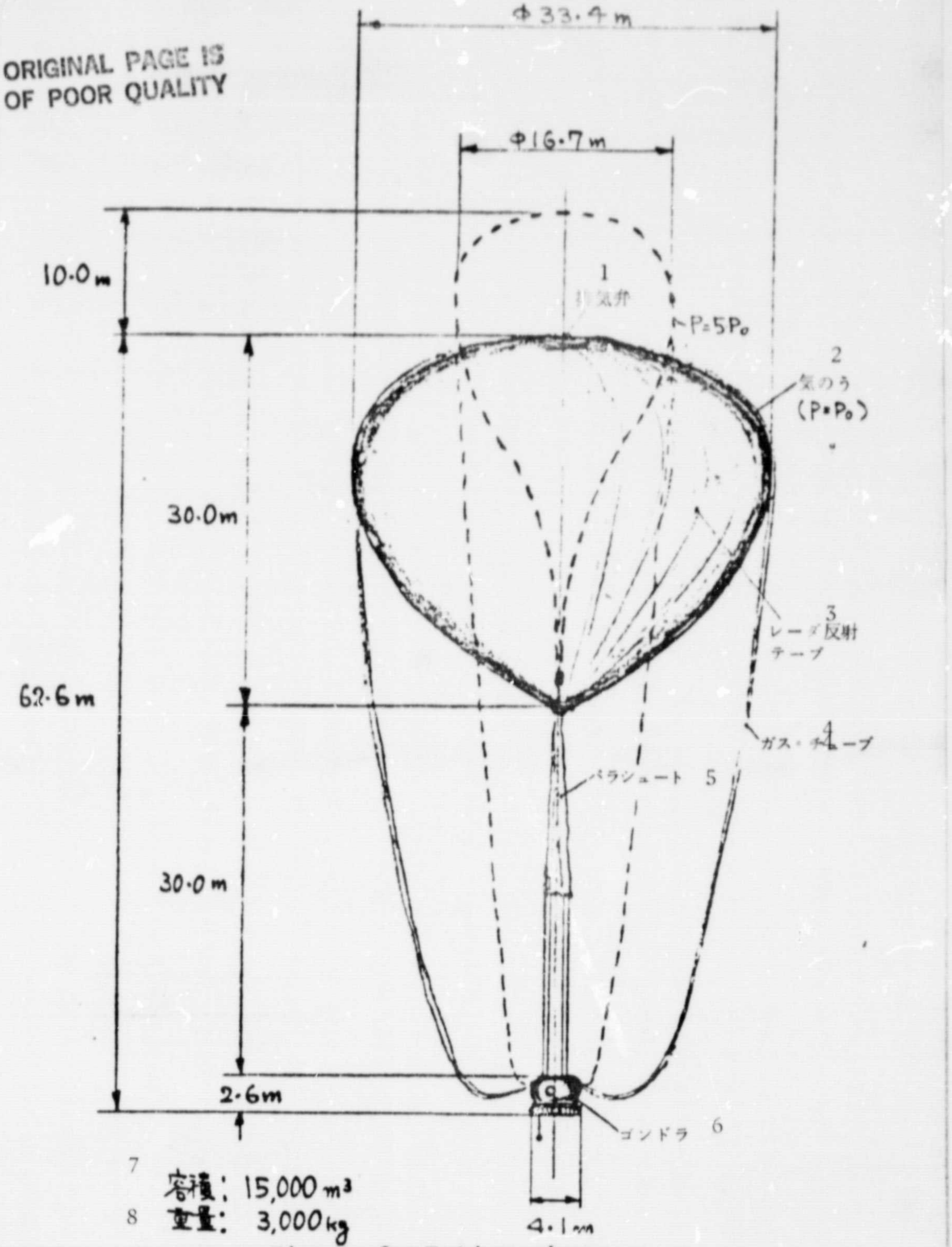


Figure 2. Entire shape

1 exhaust valve
2 air sac
3 radar reflecting tape
4 gas tube
5 ballast
6 gondola
7 capacity: 15,000 m^3
8 weight: 3,000 kg

/3

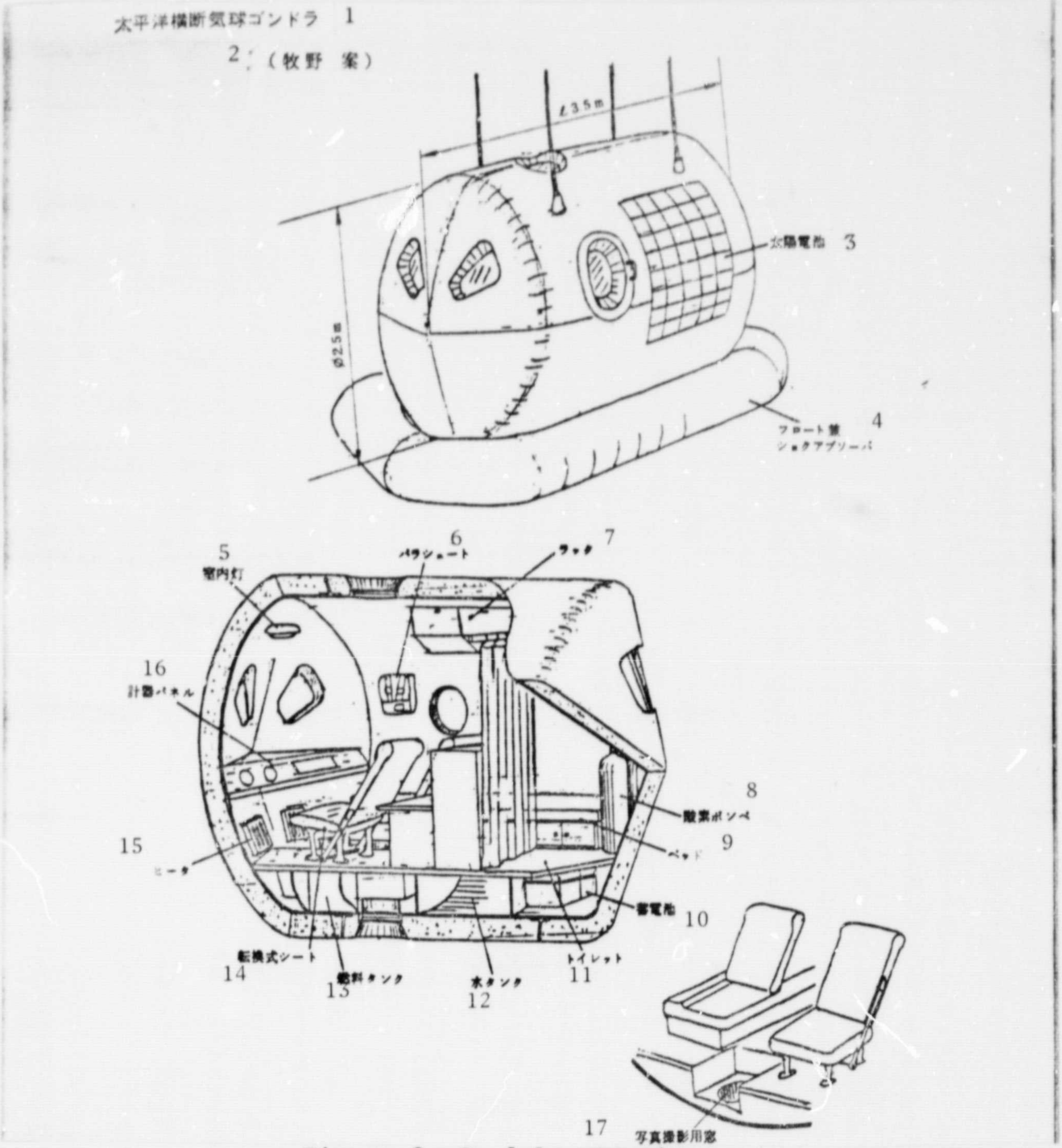


Figure 3. Gondola structure

1 Gondola for trans-Pacific balloon 2 (Makino proposal)
3 solar cells
4 floatation and shock absorber
5 interior light 6 parachute
7 rack 8 oxygen cylinder
9 bed 10 battery
11 toilet 12 water tank
13 fuel tank 14 convertible seat
15 heater 16 instrument panel
17 aperture for photography

Total weight/expense in trans-Pacific balloon /4

[details]	[weight]	[expense]
air sac	500 kg	5,500,000 ¥ (15,000 m^3)
gondola	370 kg	20,300,000 ¥ (sealed cabin)
rigging*	450 kg	33,700,000 ¥ (7 days max)
crew	180 kg	(two man)
ballast	1,500 kg	500,000 ¥ (for 7 times)
* equipment	196 kg	9,940,000 ¥
instruments	12 kg	2,200,000 ¥
recording	7 kg	300,000 ¥
radio	116 kg	18,100,000 ¥
clothing	14 kg	210,000 ¥
food	41 kg	240,000 ¥
miscellaneous	13 kg	360,000 ¥
rescue	51 kg	2,350,000¥
total	3,000 kg	50,000,000 ¥ production-purchase
		4,000,000 ¥ construction-prep.
		4,000,000 ¥ inspection testing
		18,900,000 ¥ He gas charging
		8,000,000 ¥ design
		2,000,000 ¥ project
[direct expenses]	total	96,900,000 ¥

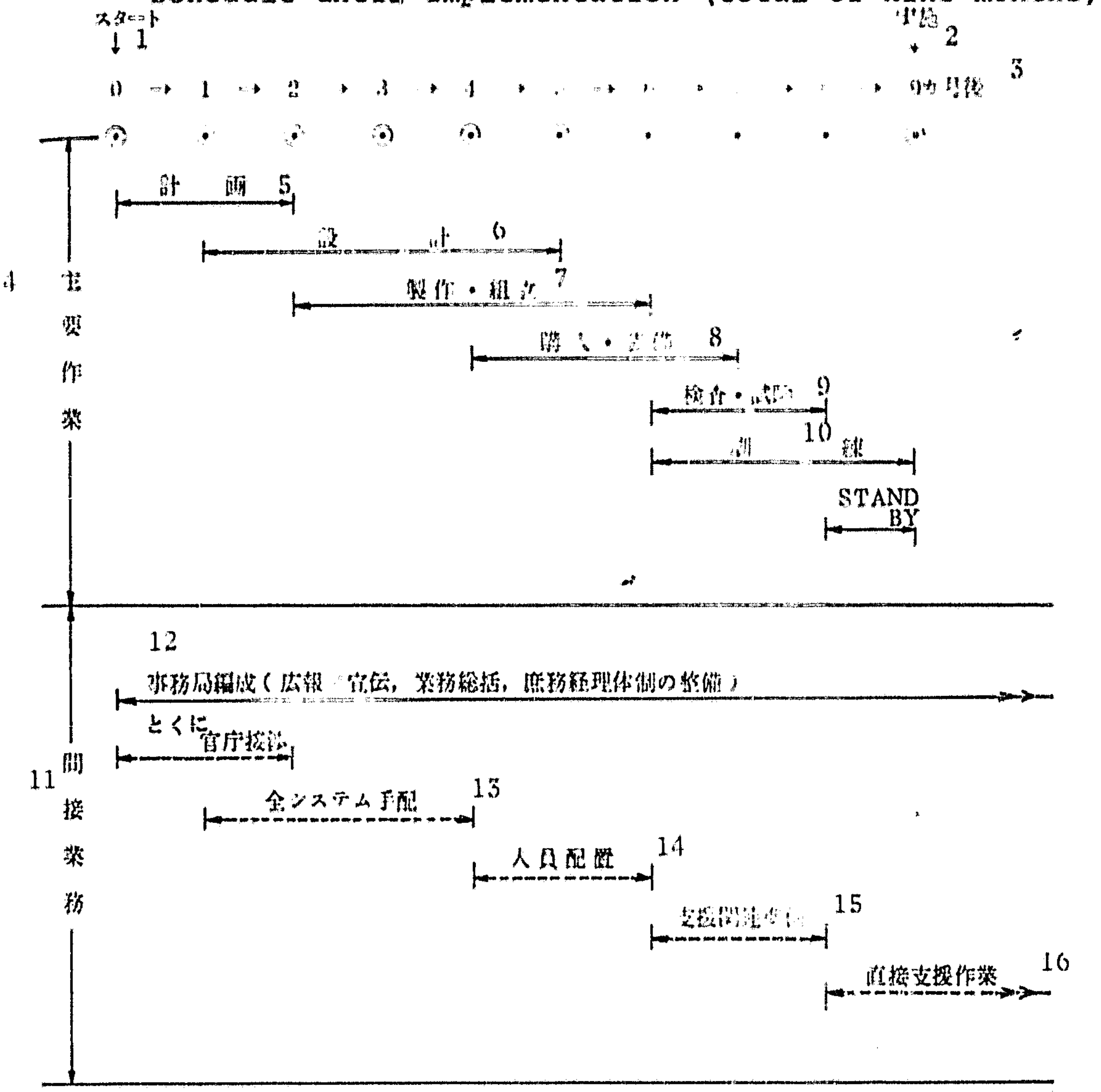
[support expenses] office operations, lift-off site preparation, operations responsibilities (training, simulation, ground) service, insurance, miscellaneous total 104,500,000 ¥

[related expenses] (negotiations with U.S., ground operations, international communications etc.)
total 100,000,000 ¥

Preparatory expenses (approximately 10% of the total of direct expenses and support expenses, rescue etc.)
20,000,000 ¥

Grand total 321,400,000 ¥ /5

Schedule until implementation (total of nine months)



1 start
2 implementation
3 after September
4 principal operations
5 planning
6 design
7 production-assembly
8 purchase, rigging
9 examination-testing
10 training
11 indirect operations
12 assembly of office personnel (announcements/advertisements, operational summaries, preparation of general affairs system), negotiations with government ministries
13 disposition of total system
14 arrangement of personnel
15 preparation of support facilities
16 direct support operations

1. (General Remarks) LTA Utilizing Natural Energy of High Altitudes Chuta Wada /6

1.1 When speaking of "high altitude"

We have experienced the sight of a brilliant midday sun even when lifting off from an airfield in a driving rain after rising above thick storm clouds and a tranquility of a separate world unfolds when rising still higher. This is the "stratosphere", in which there are no severe air currents. The height of the standard atmosphere exceeds 11,000 m, where the air temperature is -56.5°C This is a region of slight vapor and clearness with low temperature and pressure.

The high speed "jet stream" exceeding speeds of 60 m per second, occasionally exceeding 100 m per second, runs through the lower part of the stratosphere or the upper part of the troposphere directly below. It may be termed the ingenious belt conveyor of the natural world. At the end of World War II, the Japanese army used this belt to send several thousand balloon-borne bombs to the United States mainland. The U.S. Army conducted "tests" of this after the war, and the flight paths of the balloons dispatched from western Japan are detailed in the "Angel Report". These tests confirmed the existence of strong wind bands linking Japan and the United States.

Due to large atmospheric circulation, for example, since winds of the northern hemisphere circulate endlessly focusing on the north pole while meandering, it should be possible to travel around the world, returning to the departure point, if the jet stream is 'boarded' somewhere. This was proven in the southern hemisphere in 1966 by the "ghost project", in which an observation balloon flew a circuit around the south pole over a prolonged period of time. The British "Project to go around the world" (sponsored by ICI) which is being prepared is an attempt to prove this in the northern hemisphere by manned free balloon.

There is a tranquil zone in which the wind direction undergoes virtually no movement on balance at altitudes of 20,000 m. The U.S. HAPP and HASPA projects are attempts to float an LTA in this zone to use in monitoring of the earth's surface or as a relay for radio waves. This is an "atmospheric satellite", and it has been called the "Poor man's satellite" since the cost of launching it at far lower altitudes than those of stationary satellites in space is much cheaper. The areas above and below approximately 20,000 m can be considered as individual regions. For example, a balloon at an altitude of 10,000 to 15,000 m would ride on westerly winds while one at an altitude of 30,000 m would ride on easterly winds, eventually returning to the starting point. This is the concept of the Japanese cycling balloon and boomerang balloon. Attention has been directed toward this natural mechanism.

Conversely, there are no methods of utilizing at present the properties of "low temperature, low pressure, low humidity" at high altitudes. It is a dry environment in which raw material does not decay, a natural cold chain. There are also intellige methods of utilization in which overflowing mercury and contaminated water within the cabin can be drawn out, as proposed by Professor Piccard, since it is also a massive vacuum tank, but there do not seem to be other effective uses here. /7

High altitudes are completely abnormal regions for man, even regions which are comfortable for machinery. At least air supply and heating are required for life support, and the exterior world must be blocked off from people. Conversely, this could be a convenient site for work if these conditions are provided. High altitudes are far closer than space, and great technical results can be achieved with greater ease. This seems to be a broad undeveloped region.

1.2 Characteristics and safety of LTA

LTA is for long term endurance flight at low speeds, in contrast to HTA, and it has various properties, including large capacity, but the most striking characteristic is that it is "for high altitudes". In short, it naturally ascends to the equilibrium altitude at which it stably remains as a result of the natural physical fact of "falling upward" due to buoyancy. (This is in precisely opposite relation to HTA which initially is stable on the ground). Furthermore, there are numerous obstacles at low altitudes. An LTA, which is burdened with a large air sac and which is attracted to uneven terrain or structures through turbulent air streams, is instantly damaged without being able to escape. In the history of LTA accidents, most are cases of difficulty in navigation, damage or collisions with the ground due to bad weather. In short, mechanical destruction occurs in the "low altitude" environment, which is most unstable. The defect of the LTA is the low altitude region rather than problems with hydrogen gas.

Higher altitudes are the stable, active regions for the LTA. This is considered to be an essentially stable region. For example, it could be used as a long-term floating platform. Since there are levels of no winds at high altitudes, as well as high speed conveyors such as the jet stream, these could be boarded as required. There are methods of preparation of separate ferries for connection with the ground. In the past, moorings have been provided for rapid descent to the ground identical with HTA for cases of approaching typhoons, but perhaps opposite measures should be employed. It seems that rising to higher altitudes would be a better escape.

The development of high altitude airships required for the military was attempted at the end of the first world war, but the immaturity of peripheral technology precluded success. A high altitude vehicle was omitted in subsequent LTA technology. Even in the current LTA redevelopment, the focus is on utilization at low altitudes for transport of heavy weights and cargos. There is still no conception of vehicles for high altitudes. However, there have been great advances in the technology which could support activity at high altitudes, including materials, controls and systems.

The LTA means of ascent to high altitudes is very pure, simple and even primitive. This can be seen from the long history of balloon flight, with the Swiss scientist Piccard ascending to the stratosphere in a very theoretical balloon more than 50 years ago. A new network of energy saving air transport could be developed if this could be coupled with the jet stream. /8
This would make a great contribution to present needs. The current project is the selection of an actual route for crossing the Pacific in the implementation of long distance flight by manned balloon.

1.3 Advances by "Trans-Pacific research group"

This project was conceived by Chuta Wada, Buoyant Flight Committee Director, at the end of 1978. A total of 13 research meeetings were held from March 29, 1979 (Friday) until November 14, 1980 (Saturday). Examinations were frequently carried out by eight regular participants, and rides on hot air balloons were conducted after October, 1979, with many members experiencing flight.

Various unique proposals were put forth in the course of the examinations, and some are as follows.

(A) Altitude control
- affixing baronettes to the balloon
- capacity control mechanism including direction mechanism
- rapid expansion method using explosive cartridge
- buoyancy adjustment by booster balloon
- examination of gas ballast method
- control by NH_3 liquid/air
- super pressure method combining sub-sphere, main sphere and linkage valve mechanism

(B) Lift off/landing methods
- mechanism for large inflation in air after lift-off of small form
- launching at great speed from restricted municipal region
- main landing on water, with alternate landing on land

system unifying air sac and gondola in a soft mechanism like a stuffed toy

(C) Exploitation of high altitudes
systemization of technology for high altitude airshhip
steam and sail ship type LTA
floating platform and shuttle
implementation of large capacity super pressure type
exploitation of boomerang routes by LTA

(D) Problems in development
utilization and loading of meteorological facsimilies
technological expansion of infrared heat balloon (MIR)
method of measuring wind speed and direction at distant points in the air by ultra-sonic wave/doppler radar

1.4 Important points in project

The current trans-Pacific flight project has focused on the fact that LTA actually exhibits proven safety, and examinations have been conducted based on techniques which are not dangerous. Consequently, the method has built on techniques of meteorological observation balloons with long years of performance. For example, the super pressure method was not adopted since the zero pressure structure, with which we are familiar, was used. The decision was made to employ simple methods involving proven technologies with high reliability, combined with technologies such as materials, control, communication/navigation, which have advanced recently. The crew would be two in a He balloon with a 15,000 m^3 capacity. The weight would be two to three tons, and the flight would be approximately 10,000 km lasting 60 hours at an altitude of 12,000 m to 13,000 m. One may think of this as a reinforced observation balloon with people on board.

There is a strong jet stream above the Japanese archipelago in the winter, but even if the project is based on such physical characteristics, the attempt to cross the Pacific is of great significance.

In this current age, where jet passenger airplanes cross the Pacific regularly, a long distance trans-Pacific flight seems to be of little consequence, in contrast to the past. The basic target is to exploit a new energy saving transportation route at high altitudes skillfully using nature combined with the characteristics of LTA. This combines the past technology of the balloon bomb with peaceful shipping means. /9

Similarly, projects to cross the Pacific Ocean by balloon in 1981 include the British "Project to go around the world" (sponsored by ICI) and the American project "1981 trans-Pacific flight" (Rocky Aoki et al.). There are other American projects

with different members. The ICI project is an attempt to circle the northern hemisphere riding the high altitude jet stream, and its course includes the Pacific Ocean. It is a large capacity balloon exceeding 20,000 m^3 with a four man crew, a gas hybrid of He and hot air, and it is full of various new devices, including power and heat supplied by a gas turbine generator, buoy type pressurized capsule and large amounts of fuel. The objectives resemble those of our project, but the facilities are far more elaborate, and it is much more expensive.

The attempt to reinforce an observatory balloon is believed to be far cheaper. Furthermore, the American proposal involves a He balloon with a capacity of 11,320 m^3 and a four man crew to go from Japan to the United States at an altitude of 9,000 to 10,000 m for 3 to 4 days. The differences include an open type of gondola with passengers wearing air type clothing. This is a prolongation of the technology of the Double Eagle II which successfully crossed the Atlantic Ocean, and two of the original crew would participate here. Another project is believed to be similar to this one.

1.5 Future limitless dreams

Proposals for new energy development include mooring LTA or gliders in the jet stream and mounting wind driven generators on these platforms.

Flights around the world as well as long distance boomerang flights would be possible if the wind direction at high altitudes could be skillfully utilized. A trans-Pacific flight would involve departure from Japan and "disembarkation" in the skies over the United States. The development of a super pressure type to maintain constant altitudes for prolonged periods is very important for that purpose. Furthermore, the development of remote sensing technology of the wind direction and speed would greatly increase the possibility of LTA utilization.

LTA and high altitude would be a very compatibile combination, but the problem is human safety. If very simple, reliable life support equipment for air and heat could be provided, this could be linked subsequently with the air sac. The development of technology for the individual would facilitate future development.

Originally, LTA is very familiar technology. In the beginning of this century, Santos Dumont would "walk" in the skies over Paris in his beloved small airship No. 9, and occasionally would alight in front of his shop for coffee. This technology is lighthearted enough to virtually permit one to go in sandals from his garden for a ride to the stratosphere. Consequently, this is a technology for amateurs.

The current popularity of the sport of high air ballooning is based on this concept. In 1979, the altitude record for hot air balloons of 16,215 m was set, and this is a height entering the stratosphere. In addition, attempts with infrared heated balloons (MIR) have reached the 25 km level, and such new developments simply incite our ever limitless dreams.

2. Jet Stream as Medium Kazuhiro Terada /10

2.1 Major atmospheric circulation

The earth is a sphere with a diameter of 6,370 km. It spins once daily on its axis which passes through the north and south poles. It also circles around the sun tilted at an angle of 23.5° to the plane of the sun. Consequently, the energy from the sun which is received at a point on the earch varies in the winter and summer. Due to this difference, there are four seasons on the earth. To maintain the heat balance, the atmosphere on the outer side of the earth usually moves around the earth. This is termed major atmospheric circulation, and research into this has been carried out for many years.

The primary force behind this motion is the temperature difference between the equator and the poles. Specifically, air heated at the equator rises and flows to higher latitudes in the upper layers, and this air forms westerly winds in northern latitudes through the influence of the earth's rotation. Westerly winds develop near the middle latitudes, and part of the air descends, flowing in lower layers at the equator, where easterly winds form through the influence of the earth's rotation. Thus, the trade winds are formed. This air collides with air coming from lower latitudes near 60°N, forming polar fronts.

These air masses rise along the polar front, and part returns to the poles at higher levels while part flows to lower latitudes. The air which returned to the poles descends at the poles, and part then flows to lower latitudes. The air which has returned to lower latitudes then descends in subtropic high atmospheric pressure. Thus, three cells are formed. The part heated at the equator then transfers to the poles, and the low temperature part at the poles shifts to the middle latitudes where thermal disequilibria on the earth are eliminated. At this time, the ocean surface makes a great contribution to heat delivery. The steam formed through evaporation from the ocean returns to the atmosphere with steam in the form of latent heat, and is involved in conversion to heat. Figure 2.1 illustrates a schematic diagram of major atmospheric circulation.

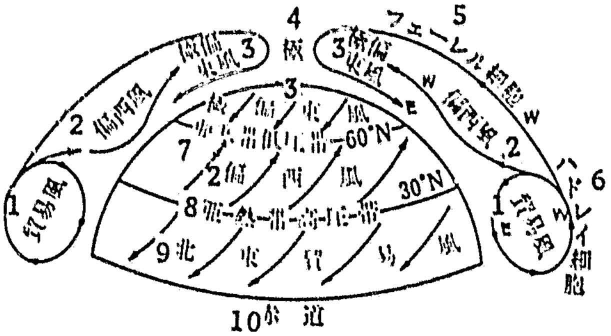


Figure 2.1 Average model of the atmospheric flow on a plane perpendicular to longitudinal line (when the earth rotates).

1 trade winds	2 westerly winds
3 polar easterly winds	4 pole
5 Ferrel cell	6 Hadley cell
7 subpolar high	8 subtropical high
9 north-east trade winds	10 equator

If the earth were likened to the size of an apple, the atmosphere would be as thick as the skin. However, the environment supporting our lives has a high sky in which various winds flow. The temperature falls at higher altitudes, and the pressure falls. /11

It has been quite difficult to understand atmospheric circulation, and it has first become possible to view the earth from far away with the recent development of artificial satellites.

Recently, the movements of clouds have been shown on television during the daily weather forecast. These are explained clearly by the television networks, and the pictures from stationary satellites illustrate the chronological movements of clouds simply enough for novices to comprehend.

Clouds are only seen below 10 km altitudes. Specifically, they are seen only in the troposphere. We do not know why clouds are not seen at higher altitudes. Clouds are basically steam congelation or sublimation, and water droplets or bits of snow flakes are visible. There is no formation of snow in the stratosphere, above the troposphere, since there is little humidity there. A so-called cheerful blue sky is seen there.

There is movement of air at such high altitudes. High altitude conditions and air conditions in the troposphere etc. are measured by monitoring stations scattered in various regions by the meteorological agencies of various countries, which are organizations of the governments. Usually, small balloons fitted with radio probes are launched, and data on the temperature, pressure, humidity etc. from the balloon are radioed back to earth. The upper air finds can also be measured since the balloons are blown about by the wind.

There are currently several hundred weather observation points around the world. Some are located on the ground and on islands, but since the oceans are far broader than the land, there are no measurements at oceanic sites. Observations on the sea are stressed, and high altitude monitoring is carried out by stationary observation ships. These results are transmitted to various countries through the cooperation of the World Meteorological Organization (WMO). At present, data on the upper air from various countries around the world can be easily and immediately studied.

Recently, data on the upper air above 100 km altitude has come from rockets and artificial satellites, but we will present a table on the average conditions up to 50 km altitude. Fairly fine detail is presented to the vicinity of 10 km (table 2.1). Furthermore, a figure of the temperature distribution of the standard atmosphere of the United States by altitude up to 125 km has been prepared (figure 2.2).

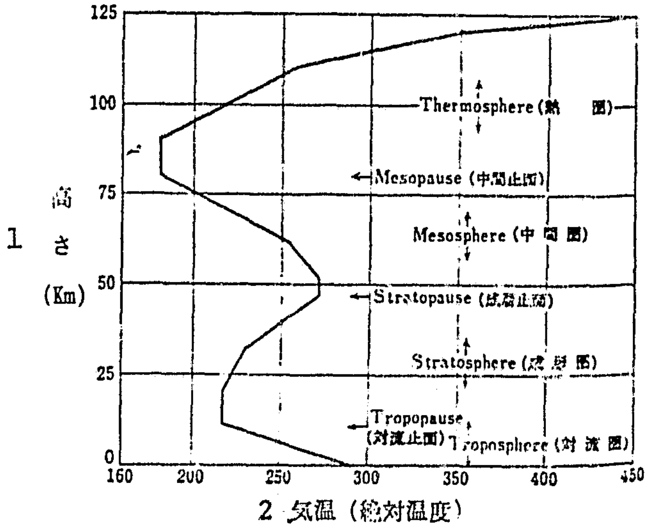


Figure 2.2 Temperature distribution by altitude
1 height (km)
2 temperature (absolute temperature

2.2 Jet Stream

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The air temperature uniformly falls at higher altitudes, as seen in Table 2.1, but the temperature is a constant of 57 degrees below freezing from an altitude of 11 km to 20 km. The atmospheric pressure is 300 mb at 9 km altitude, and is approximately 200 mb at 12 km altitude. The values of the upper winds measured by the Japan Meteorological Station at 300 mb and 100 mb are illustrated (Table 2.2). The range of wind speeds is 20 m/second to 60 m/second, but the value is far lower in the summer in lower latitudes. When considering crossing the Pacific Ocean, the period when the mean wind speed is highest should be considered.

In any event, the summer winds are more intense at higher altitudes. In contrast, the winter winds are intense everywhere. These strong winds are termed the jet stream, and their position differs somewhat between summer and winter. In the upper altitudes of Japan, the jet stream is 30° N, 38° N and 45° N in the winter, while it is seen only at 38° N in the summer.

Since measurements at upper altitudes were not made in the past, atmospheric mass circulation seemed to occur in the troposphere.

However, the existence of the jet stream in the upper atmosphere has become clear. In Japan, Europe and America, where there are many observation sites, the mean conditions became clear, but since the conditions over the ocean are unknown, they can only be surmised.

The mean positions in summer and winter are as illustrated below.

Table 2.1

表2.1

1 高度(km)	2 温 度 (TA ℃)		3 気 圧(mb)	4 密度ρ(kg/m)
0	288.15 k	15.15℃	1013.25	1.2250
5	255.676	−27.324	540.48	0.7361
8	236.215	−36.785	356.516	0.52579
9	229.736	−43.264	308.007	0.46706
10	233.252	−39.748	264.999	0.41351
11	216.774	−54.226	226.999	0.36480
12	216.650	−[illegible]350	193.991	0.31191
1[illegible]	216.650	−57.350	165.796	0.26660
15	216.650	−57.350	122.118	0.19175
20	216.650	−57.350	55.293	0.08891
25	211.552	−61.448	25.492	0.04008
30	226.509	−46.491	11.970	0.01841
40	250.350	−22.650	2.871	0.0040
50	270.650	− 2.350	0.798	0.0010

1 altitude; 2 temperature (TA°C); 3 air pressure
4 density

Table 2.2

表2.2

	1 2 月	2 4 月	3 6 月	4 8 月	5 10月	6 12月	
7 札幌	29.1	33.9	12.0	23.1	34.8	37.3	(m/s)
	21.9	23.1	10.3	11.7	26.9	32.2	•
8 仙台	43.1	37.4	28.8	12.8	43.8	52.1	上：300mb 14
	34.8	29.6	15.0	4.6	29.0	41.8	
9 館野	49.9	35.2	31.5	6.2	41.0	59.4	
	38.2	29.3	15.7	2.5	28.5	42.6	下：100mb 15
10 潮岬	57.4	35.0	29.5	1.2	35.7	63.9	
	45.1	30.1	16.4	5.0	25.2	46.9	
11 福岡	56.1	34.5	29.2	3.3	38.1	60.6	
	49.6	30.7	16.2	4.3	25.8	42.9	
12 鹿児島	59.6	32.0	25.4	1.3	31.0	58.2	
	42.4	28.4	13.9	6.4	20.9	41.0	
13 石垣島	42.6	25.3	4.3	2.7	7.8	33.9	
	26.4	16.5	7.7	12.9	2.9	23.0	

1 February
2 April
3 June
4 August
5 October
6 December
7 Sapporo
8 Sendai
9 Tateno
10 Shionomisaki
11 Fukuoka
12 Kagoshima
13 Ishitatejima

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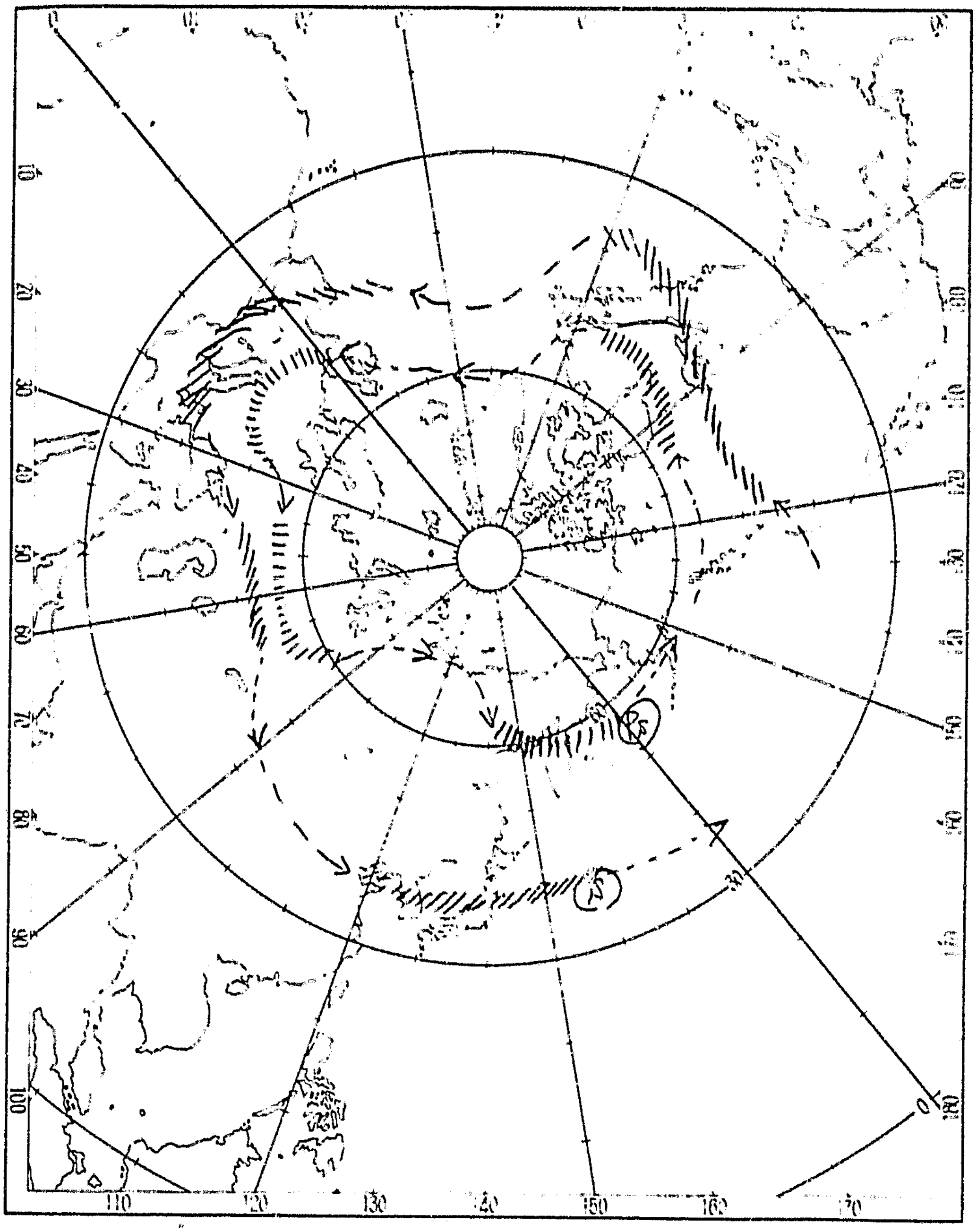

Jet Stream July 1980

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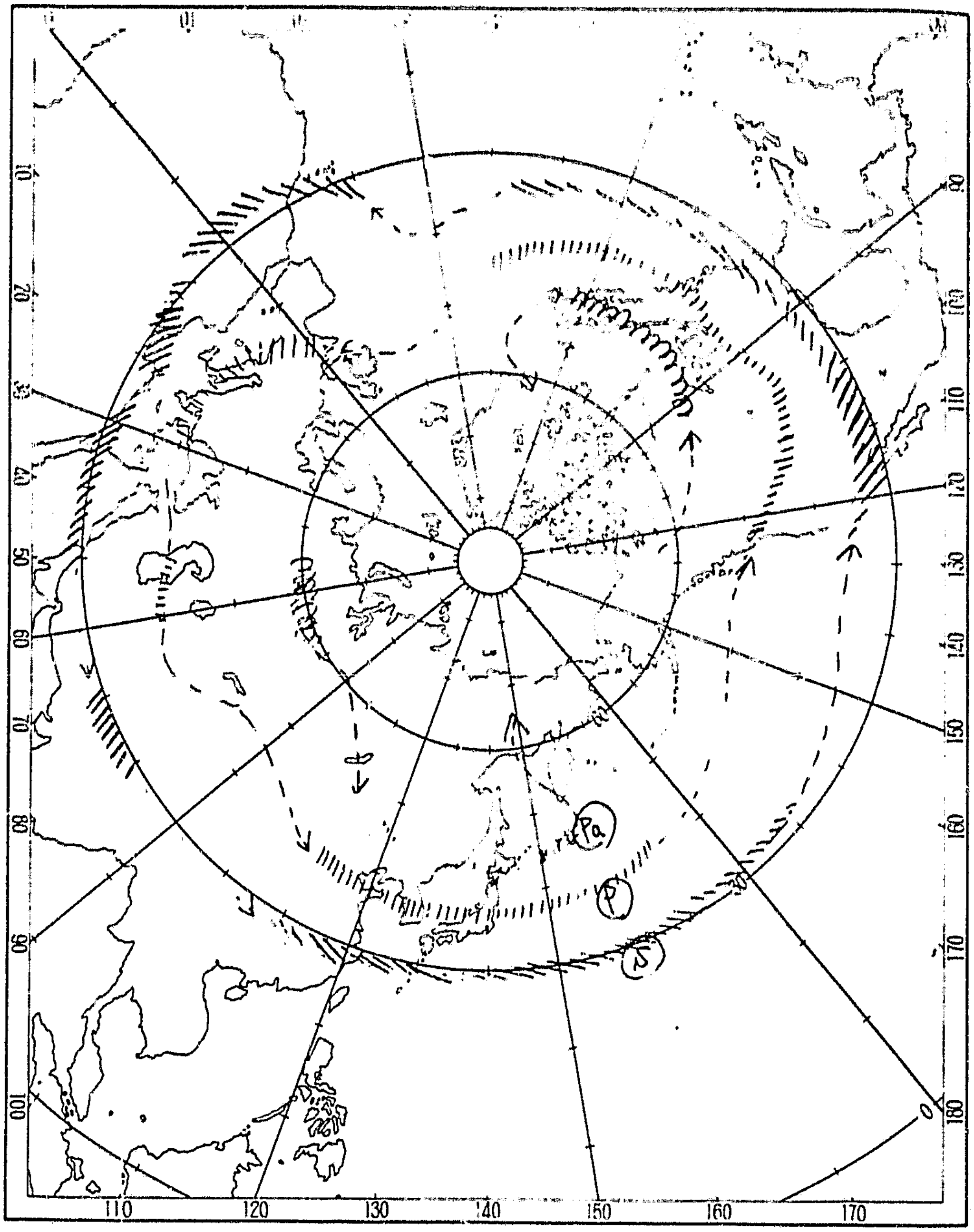


Jet Stream January, 1980

The jet stream is at an altitude of 11 km to 14 km. It has the following characteristics. /15

1. It flows around the poles in both summer and winter.

2. It is farther north in the summer than in the winter. In the winter, it is located in lower latitudes, from 20°N to 35°N, while in the summer, it is located from 35°N to 45°N. The wind speed in the winter is double that in the summer.

3. The location of the jet stream corresponds to the point of maximum temperature slope in the meridian plane at high altitudes in the center of the troposphere

4. The jet stream appears at places where the altitude of the tropopause changes markedly.

5. The difference in wind velocity to the north and south of the jet stream is marked.

Data based on many grid points and on meteorological measurements at various sites throughout the world have been analyzed in studying the jet stream. However, since comprehension of the jet stream is difficult, analysis is usually carried out from isobaric altitude data ranging from 200 mb to 300 mb.

The analysis of high level data in Japan is the work of the Meteorological Agency.

First, the Japanese Meteorological Agency has 20 sites from northern Japan through southern Japan from which high level data are transmitted daily. Much foreign data is also transmitted to the Meteorological Agency.

The data are divided by altitude and inscribed on maps which are the basis of the high level weather maps.

A view of data from the Tateno high level meteorological observatory which has long conducted high level measurements in Japan reveals data at all levels upward from 800 mb, 750 mb, 700 mb, 500 mb, 300 mb, 250 mb and 200 mb. There is greater detail at 175 mb, are 150 mb, 100 mb, 70 mb, 50 mb, 40 mb, 30 mb and 20 mb.

The following example is an inscription of wind data at various levels during December 1 through 5, 1974, from Tateno.

The direction is in a circle from north to east, so that the wind direction is seen to be 270°. Since the 20 mb data on

December 2 at Tateno is 17, we know that the wind is north northeast and the speed is only 6 m/s. However, the data below 50 mb is generally near 270° so that the wind is generally westerly at 10 m/s.

Such data appear daily and are printed as Aerological Data by the Meteorological High Level Section. There are currently data from more than five years ago to 1975. (Subsequent data have been printed in 1981). The five year averages have also been printed and published.

1 高度	2 1日		3 2日		4 3日		5 4日		6 5日	
20mb	7 欠測		17°	6m/s	182°	4m/s	122°	16	109°	8m/s
30	295°	8m/s	246	9	198	3	151	4 m/s	176	12
40	294	12	299	15	301	4	218	10	239	25
50	281	16	311	11	279	8	219	13	249	23
70	286	26	270	20	266	22	256	24	249	38
100	286	38	279	44	267	38	258	46	254	48
150	293	61	289	51	265	61	247	71	260	81
175	291	63	285	68	269	67	250	67	214	80
200	291	61	289	72	268	69	255	64	257	80

Table 2.3 Tateno (Wind direction, speed (m/s) December 1-5, 1974)

1 altitude
2 first
3 second
4 third
5 fourth
6 fifth
7 observations omitted

For example, a view of the averages from 1971 to 1975 reveals 267°, 48.6 m/s at 200 mb in January in Sendai. Consequently, the calculations reveal westerly winds at 48.6 m/s. /16
However, there are fluctuations in these values. Specifically, the maximums at that time were 264°, 103 m/s, and the minimums were 296°, 15 m/s.

2.3 Precautions in using the jet stream

The jet stream may be generally viewed at 200 mb as having a course of 270° ± 15°, and the wind speed may be viewed as 70 m/s ± 10. However, while this range is valid to 150 mb, the fluctuations are greater.

(1) Prior survey

The statistical figures for high level data at some principal points in Japan have been issued by month and altitude from the table of Aerological Data, and the averages as well as fluctuations have been published.

Next, the manner of a Pacific crossing, including the movement and speed along a global route, has been studied. The time of arrival in America by season has been estimated.

The problem is that there are no high level data away from Japan. Data above the Pacific Ocean must be analyzed.

Data on high level weather have been issued by the United States Weather Service, but old data are on microfilm in libraries. That data must be studied.

The difficulty in detailed studies involves the absence of observation points above the Pacific Ocean.

We can do nothing other than shift to treatment during actual flight.

Once a balloon has been launched, it cannot return. It is at the mercy of the winds.

The decision of the crew to ascend or descend based on their position must be based on guidance from the ground.

(2) Ground support

Facsimile data on the ground are used. Such data are transmitted from Japan, America or Canada. Since the time, call signal, frequency, details etc. are determined by WMO, it can be easily received. There are numerous broadcasts daily, as well as broadcasts at various altitudes other than 200 mb. (A Japanese explanation is found in "Interpretation of Meteorological Descriptive Broadcast Schedule" Published by Japan Meteorological Association, 1980).

However, all of these are based on Japanese and American data, and since data describing weather maps are broadcast, values for the center of the Pacific Ocean are insufficient.

The ground support personnel must indicate movement to the balloon with some ambiguity when the balloon is flying in areas of scant data.

The crew of the balloon must plot the "personal position" clearly on a map. The meteorological support unit on the ground would then inscribe the location of the balloon on a facsimile original drawing.

At this time, the original facsimile drawings should be centered on 200 mb, with many at 150 mb and 250 mb. Thus, contact could be made with the balloon and the changes in latitude and course in the next 24 hours could be indicated.

The data from Canada and the United States could then be used. At this time, the balloon would proceed in contact with ground support on the American side.

2.4 Descent after reaching America

Descent would occur after reaching America. There would be considerable movement even then if the balloon were riding the jet stream. Thus, the helium would be released at an appropriate site and the balloon would descend. Meteorological data would certainly have to be used. Thus, the balloon should be in contact with meteorological stations on the American side.

3. Pursuit of minimum system based on results of observation balloons Kazuhiko Terada /17

3.1 Type of balloon

It would take two and a half days to travel by balloon riding the jet stream from Japan to North America. There are two types of balloons, the super pressure type and the zero pressure type, but there are problems with adhesion of cloth as the size of the super pressure type balloon increases. The size limit for such a balloon is 5000 m^3.

Observatory balloons currently used are the zero pressure type, and the balloon skin is polyethylene. At the Space Flight Laboratory of Tokyo University, research into this has already been underway for more than ten years, and they have acquired experience into balloons ranging from 100 m^3 to 200,000 m^3. Based on this experience, we would like to examine the minimum point of just how light the gondola would be in a manned balloon crossing of the Pacific Ocean.

The problem here is that the total buoyancy of a zero pressure balloon decreases with fall of air temperature after sunset. It falls by 7% in relation to the total weight. Since we want to continue flight at a constant altitude, an amount equal to this reduction fraction (specifically the descent fraction) must be removed from the total load to maintain a constant altitude. However, if the flight lasts two and a half days, the load would fall only twice. A ballast load for that purpose must therefore be installed.

Lead powder (0.5 mm ø) is used for the ballast load, based on experiments by Tokyo University. It is restrained by a permanent magnet. When the ballast is to be released, a current

is passed through the magnet to compensate for the magnetism. This method is usually used in experiments. The balloon descent fraction for two sunsets would be sufficient.

We will next discuss the life of the balloon. In experiments by Tokyo University, balloons last for 3 to 5 days. Actually, there are cases of flights to North America, and balloon life poses no problems.

Furthermore, the type of the balloon may be the same as that used in Tokyo University experiments. Since people are riding on the balloon, a heavier type than that used in experiments may be employed, or a double lined balloon as required may be employed.

Tensile force of the balloon is a problem at the lower end since heavy weights are fastened, but load tape at the base of each sheet would be adequate.

A parachute would be effective for landing at a fixed site when the balloon is to descend for landing, but a vent valve may be attached at the head of the balloon to vent air while monitoring a manometer since the initial velocity is great. This is also frequently used in Tokyo University experiments. Moreover, a parachute may be mounted at the top of the gondola, and elimination of the netting of the balloon simultaneously with opening of the parachute may be employed.

3.2 Size of balloon

The capacity of the balloon, the load (including balloon /18
weight) and the air pressure at that site to maintain the balloon at a constant altitude in the upper air would be given using the following formula.

$$P = 1013 \frac{Tb \cdot}{273} \frac{L}{V(\rho_0 - \rho_h)}$$

P atmospheric pressure (mb)
Tb atmospheric temperature at site of balloon floatation (k)
L load (kg)
V volume of balloon (m^3)
ρ_0 density of air
ρ_h density of gas

When helium is introduced, figure 3.1 illustrates the relation of $\rho_0 - \rho_h = 1.226 - 0.179$.

According to this formula, the weights of the gondola and of the balloon pose problems.

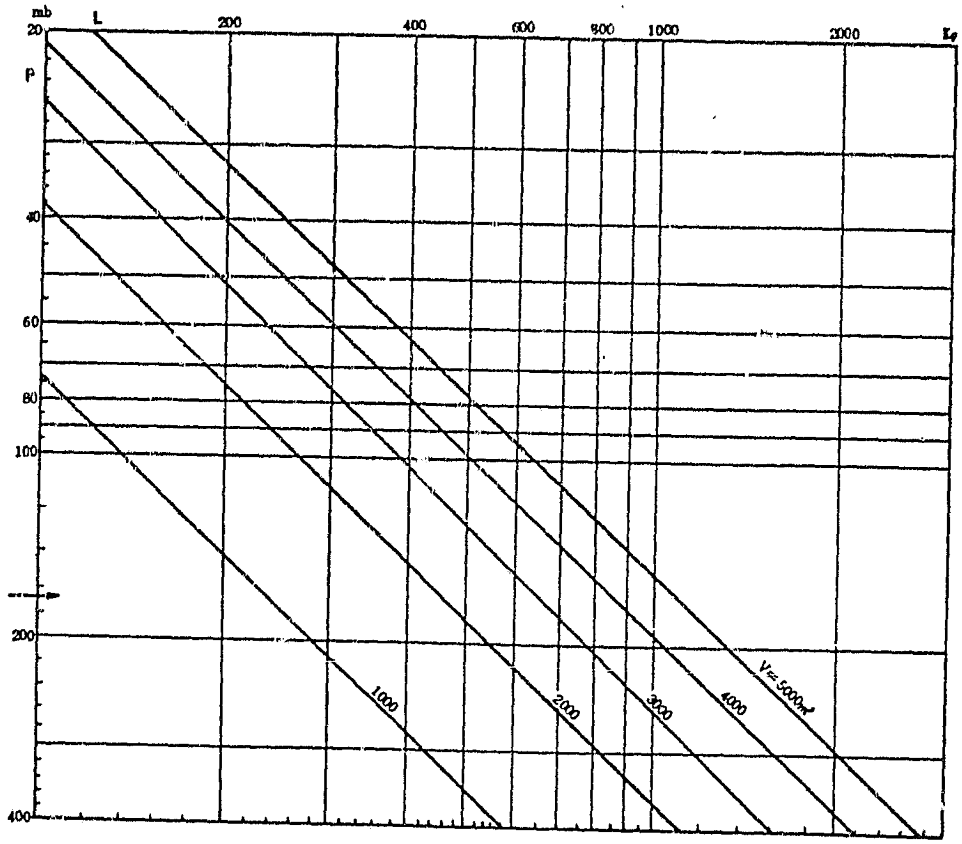


Figure 3.1

3.2.1 Minimum weight

balloon (5000 m^3, conservative)	100 kg
gondola (with partial contents)	180
parachute	30
net weight of people (two)	140 kg
temperature maintenance equipment	40
measurement instruments (radio, direction search equipment etc.)	40
food and water	50
battery etc.	20
total	600
iron powder for ballast	200

Thus, the result would be L=800 kg based on the aforementioned formula.

3.2.2 Capacity

Figure 3.1 indicates that a balloon of 5000 m^3 would be adequate when the altitude reaches 13,000 m.

Moreover, a balloon of 5000 m^3 would be composed of 18 sheets, and tension of 900 kg in the load tapes would provide a sufficient load (50 kg per load tape). /19

3.3 Gondola

Since the dimensions and weight pose problems in determination of the aforementioned balloon, we will consider it here.

The structure would be spherical with a diameter of 1.2 m. It would be enclosed in plastic (4 cm) and steel reinforcement would be attached on the outside. The exterior would be enclosed in 10 cm of plastic foam. The exterior foam is used in experiments at Tokyo University, and the purpose is to cushion the shock of landing. Moreover, the exterior would be painted yellow-brown.

The interior temperature in this structure would not fall below -20°C (according to experiments at Tokyo University).

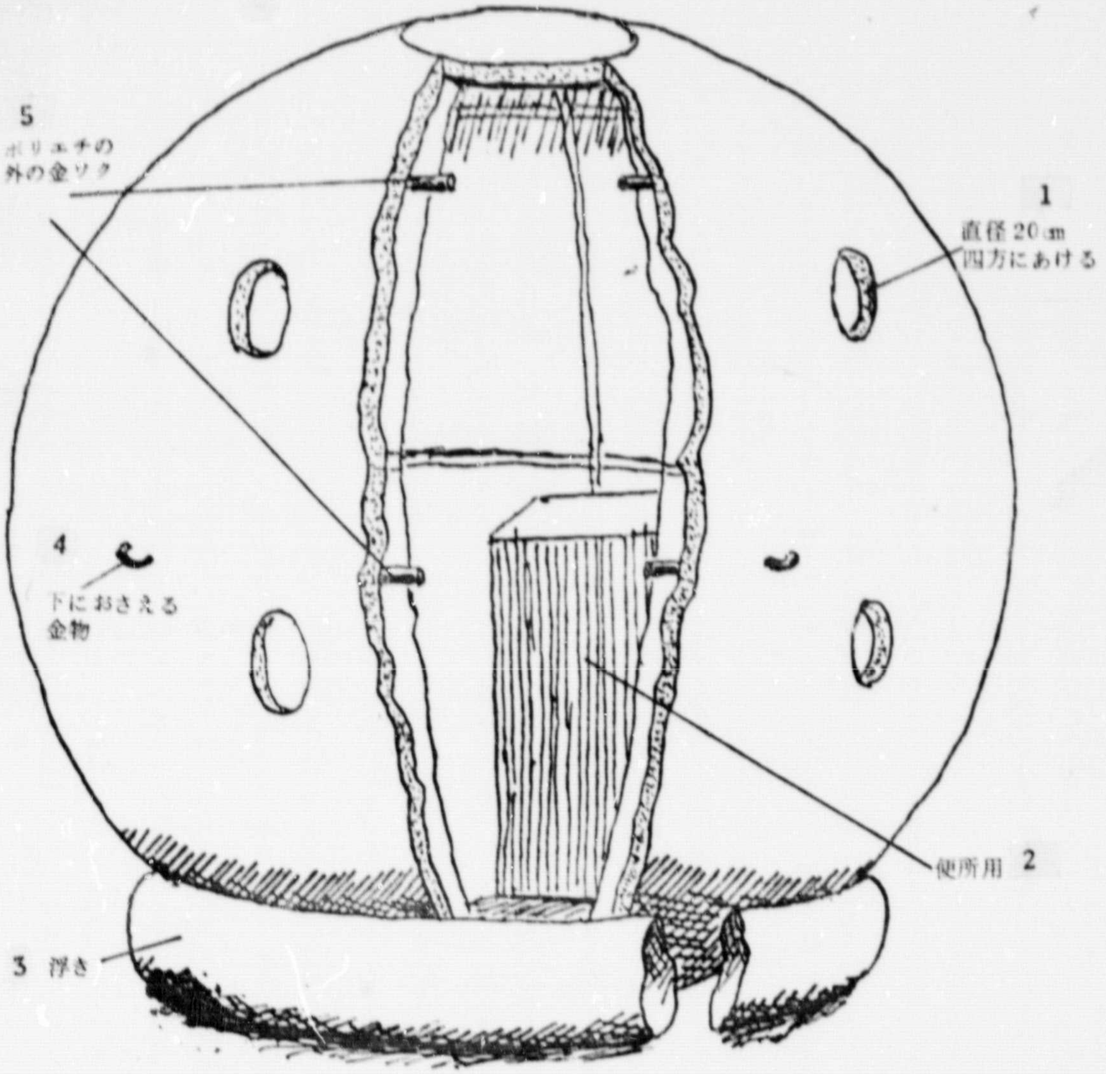


Figure 3.2 Spherical gondola
1 20 cm diameter in each direction
2 for seats
3 floatation
4 lower metal support
5 external metal frame with polyethylene

Furthermore, the bottom of the exterior would be an air bag lined with plastic considering landing in water. Figure 3.2 illustrates the gondola. /20

3.4 Overall mode, lift-off/landing

3.4.1 Gas charging

The balloon must have self buoyancy to rise. Buoyancy exceeding 9% for a load of 800 kg is required to rise at the rate of 300 m per second. Specifically, the following formula would be used:

$$500\ m^3 \times 1.1 \times \frac{165.8}{1013.1} \div 900\ kg$$

(165.8 in the case of 13 km)

$$800\ kg \times \frac{9}{100} = 72\ kg$$

The aforementioned total would be 972 kg (88.2 m^3)

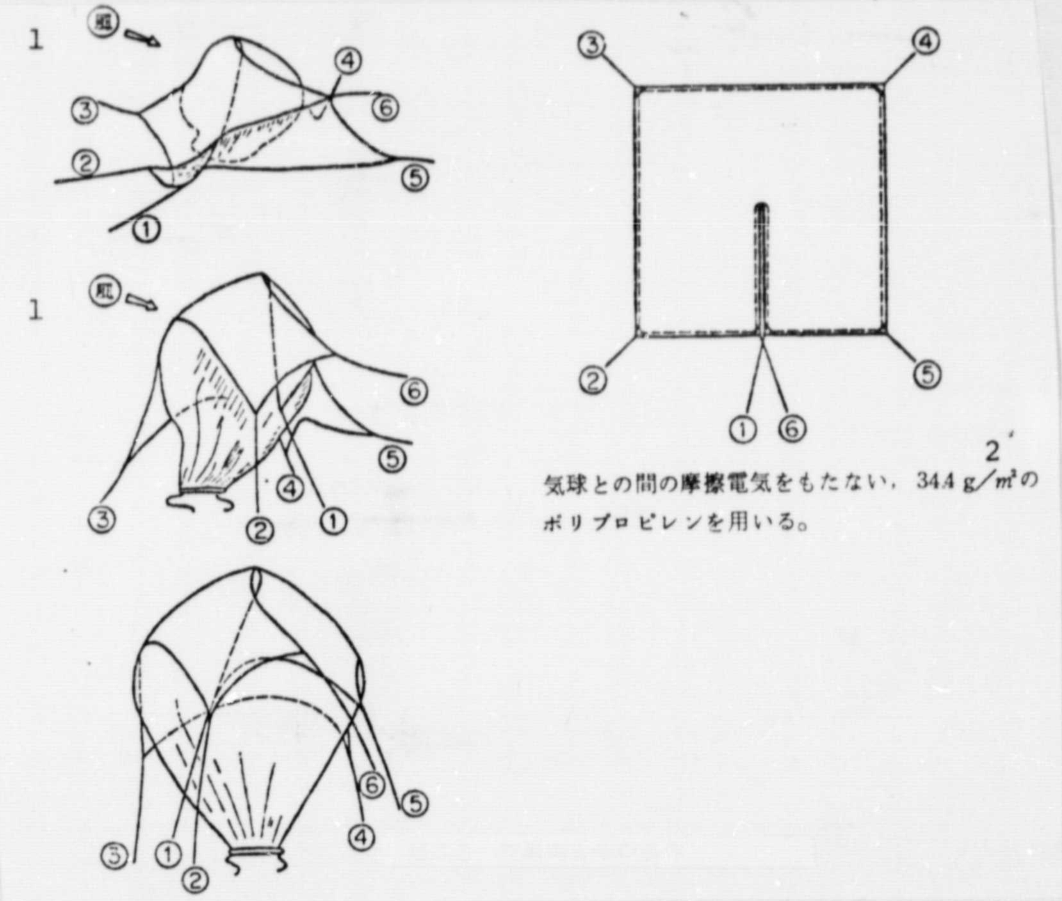


Fig. 3.3 Wind protective cloth and its use

1 wind

2 34.4 g/m^2 polypropylene, which has no friction electricity with the balloon, would be used

130 helium gas cylinders of 7 liter capacity would be required. Loading of these would not be easy. First, gas would have to be introduced at the head of the balloon.

Fastening of the balloon to the mooring (launcher) is not desired with 972 kg of gas (poor to date). Thus, the balloon should first be wrapped in a cloth on the ground, followed by gradual inflation of the balloon. The cloth would be a thin weave of polypropylene fibers (34.4 g/m^2) with a vent valve in the center. This would cover the balloon and expand to a certain degree. The cloth would be removed when a certain amount of gas had entered, and the balloon would be attached to the gondola. Finally, gas charging over the gondola would be completed (Figure 3.3).

The first gas inlet port of the balloon for the introduction of gas in this method would be identical with that in the experiments of Tokyo University, and the second inlet port would be lower than usual. (Probably 22 m below the top, and the /21
length would be approximately 100 m.)

Furthermore, the gas cylinders for gas introduction would have to be at one atmosphere pressure. This is illustrated in figure 3.4. Introduction of gas would take approximately 1.5 hours in this method. If large cylinders such as those in the experiments of Tokyo University were used (enough for three trucks), a charging device would be required (charging in this case would take one hour).

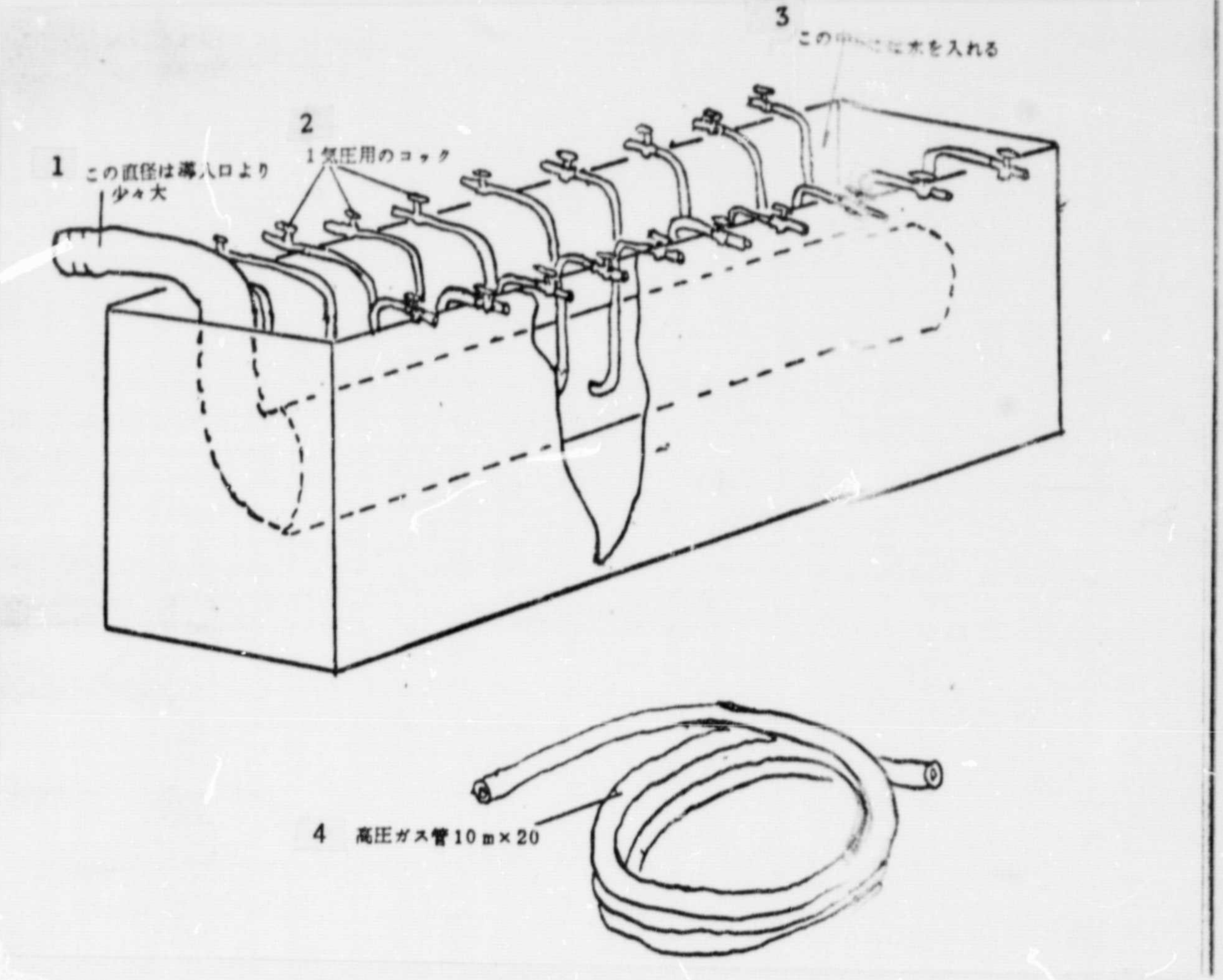


Figure 3.4
1 the diameter is slightly larger than that of the inlet orifice
2 cocks for one atmosphere pressure
3 water is placed in the center
4 high pressure gas hose 10 m x 20

3.4.2 Mooring on the ground /22

The entire balloon must be fastened to the ground in order to affix it to the launcher. Specifically, the central hardware of the gondola would be the restraint in order to affix the entire balloon to the ground. This is illustrated in figure 3.5. The weight of this material and the weight of the entire balloon would be set at 972 kg, which would be the final weight.

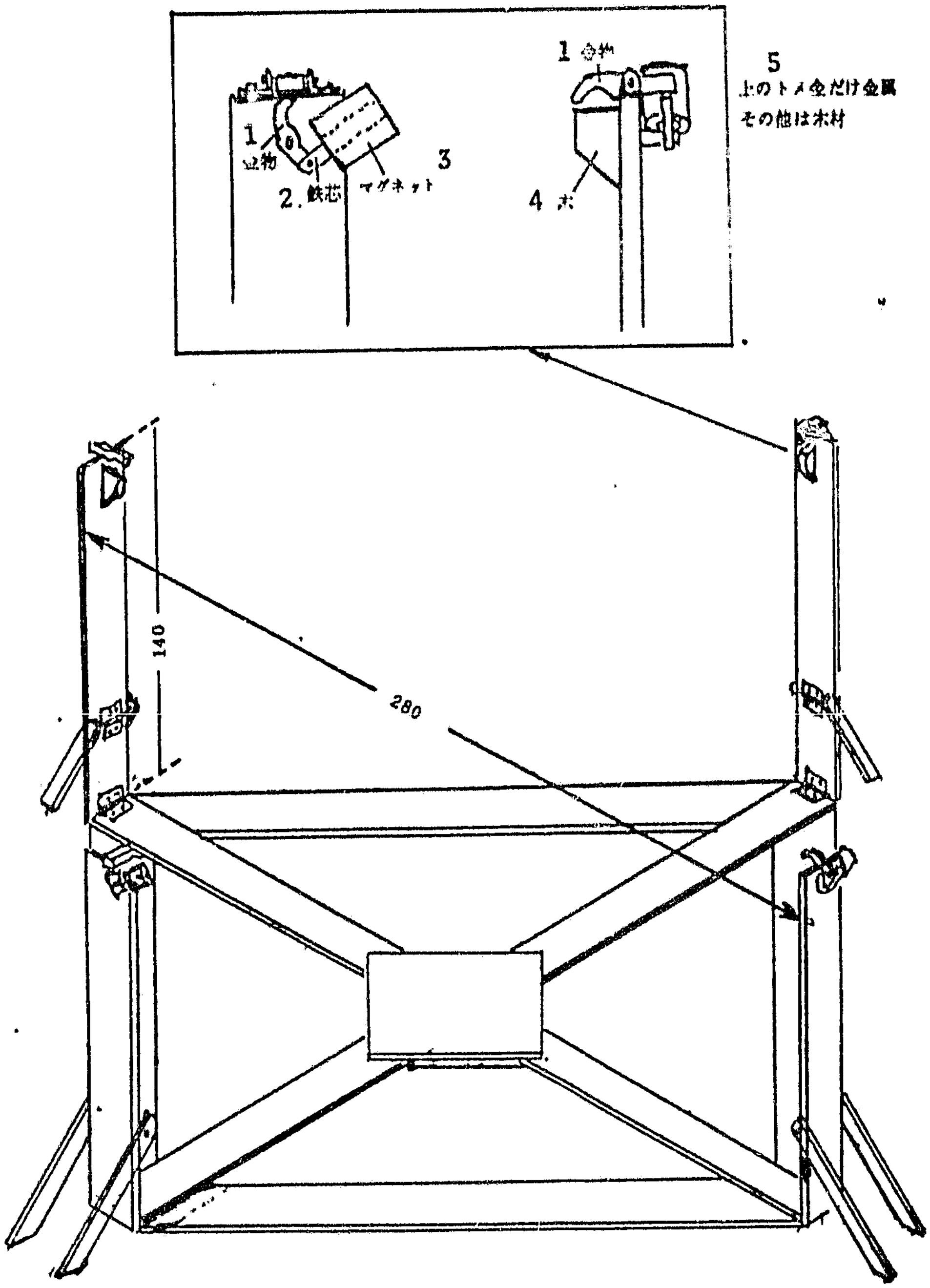


Figure 3.5

1 hardware
2 iron core
3 magnet
4 wood
5 Only the upper clasp is metal. The rest is wood.

3.4.3 In the event of forced landing

/23

In the event of a forced landing in the water, relay of the position by radio should be possible since the position of the gondola in the air was known. The same would be true in the case of landing on land.

3.5 Preliminary flight

In preparation, the degree of descent at sunset and the corresponding amount of ballast needed as well as the temperature inside the gondola must be known. For this reason, tests should be conducted at Niigata. Night-time launching in this region should result in landing at the coast of Miyazaki Prefecture the following morning. In these tests, the gas from the balloon could be vented, and the mode of landing could also be checked. (We decided not to use the base of Tokyo University in Iwate Prefecture).

The national weather maps (especially those issued daily by radio) produced by the Meteorological Agency as well as the maps of various meteorological agencies, especially the high level department of the Sendai and Akita Meteorological Agencies must be consulted for the preliminary flight and the actual flight.

A radio probe from the Meteorological Agency may be affixed during the preliminary flight. This would enable the position of the balloon, the altitude and the air temperature to be monitored during the preliminary flight. The receiver could be borrowed from the Myojo Electric Co.

1 (最小限気球システム)

2 物件	3 仕様	4 価格	5 会社	6 電話	7 場所
気球 8	5,000 m³ 15,000 m³	9 78万円 150万円	藤倉航装 10	385-2111	142 品川区 荏原2-4-46 11
気球布地 12	1 ton	13 1,000万円			
ヘリウムガス 14	15 1 m³ 1回分 140本	16 0.15万円 147万円	丸由工業 17	895-1181	18 116 荒川区 東尾久 7-4-8
排気弁 バラスト弁 バラスト材料 19		3個必要 2個必要 20			
ゾンデ受信機 21			明星電機 22	814-5111	112 文京区小 石川 2-5-7 (佐々木ビル) 23

Reference Table 1. Required material and cost

1 (minimum balloon system)
2 article
3 specifications
4 cost
5 company
6 telephone number
7 site
8 balloon
9 780,000 ¥, 1.5 million ¥
10 142 Shinagawa ku, Ebara 2-4-46
11 balloon cloth
13 10 million ¥
14 helium gas
15 140 cylinders each time
16 1,500 ¥, 1.47 million ¥
17 Maruyu Kogyo
18 116 Aragawaku, Higashioku 7-4-8
19 exhaust gas, ballast valve, ballast material
20 three are required; two are required
21 probe receiver
22 Myojo Electric Co.
23 12 Fumikyoku, Kosekigawa 20507 (Sasaki Bldg.)

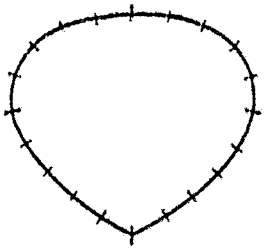
Table of required personnel

preliminary flight	Japan Sea	13 people
	Pacific Ocean	4 people + a
actual flight	Pacific Ocean	17 people + a

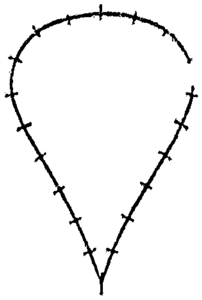
(1) Three balloons were made, one for preliminary, one for actual flight, one spare

(2) Two sets of ballast were prepared (preliminary and actual flights)

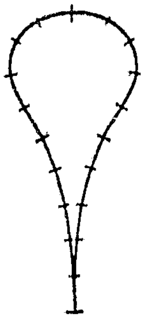
Reference Table 2 /24
Changes in balloon shape



P = Po (μ = 100)



P=2Po (μ=175)



P=5Po (μ=179.2)

1 in the air
2 total length 71.0 m of a 5000 m^3 balloon
in the air total diameter 22.6 m
length 33.4 m
3 when rising from the ground
4 length 66 m width 24 m when inflated, 35 m

4. Various Conditions and Materials Concerning Balloons

Kazuo Nagamatsu /25

4.1 Characteristics required of materials

4.1.1 Ascent limits

Safety must be ensured in all regions through which passes a balloon ascending to high altitudes from the atmospheric pressure and temperature conditions on the ground to low pressure and low temperature at high altitudes.

Figure 4.1 illustrates the volumetric increase of the gas charged in the balloon [He (helium)] when the free expansion is permitted during this period since the atmospheric pressure falls in response to the altitude. This figure is a calculation using the average values over ten years [1] of the actual measurements of the altitude and atmospheric pressure as well as of the altitude and atmospheric temperature in November at Sendai, assuming the meteorological conditions under which this project is most likely to be implemented.

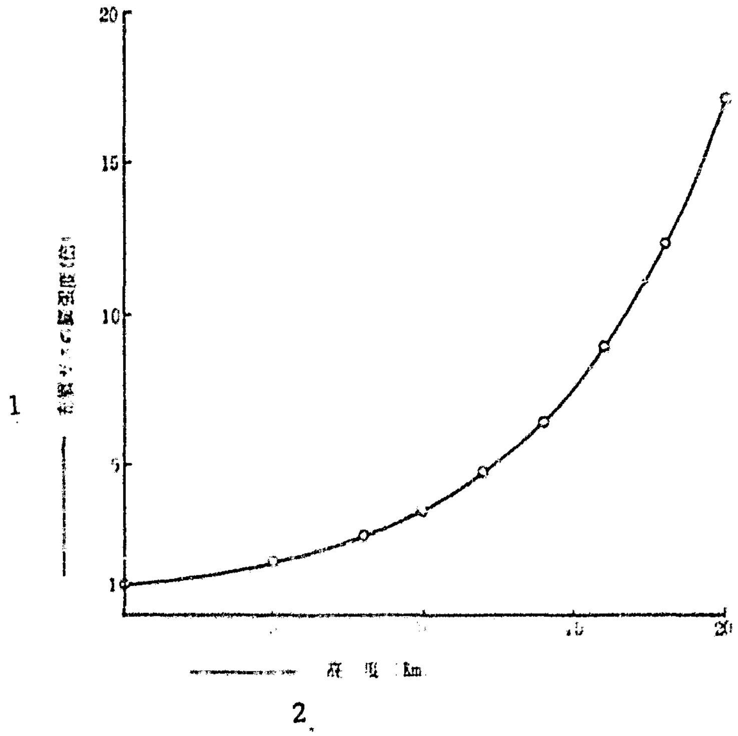


Figure 4.1
1 degree of expansion of charged gas (times)
2 altitude (Km)

In addition, the maximum ascent limits as well as the total load of the balloon under those conditions (Sendai, November) are illustrated in figure 4.2. The total load was held under two

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tons for balloons at 15,000 to 30,000 m^3, or was held under four tons. The "latitude" in relation to the ascent limit differed considerably. /26

4.1.2 Ambient atmospheric pressure of the balloon

The ambient atmospheric pressure of the balloon must be examined first as the basis for calculating the pressure imposed on the balloon.

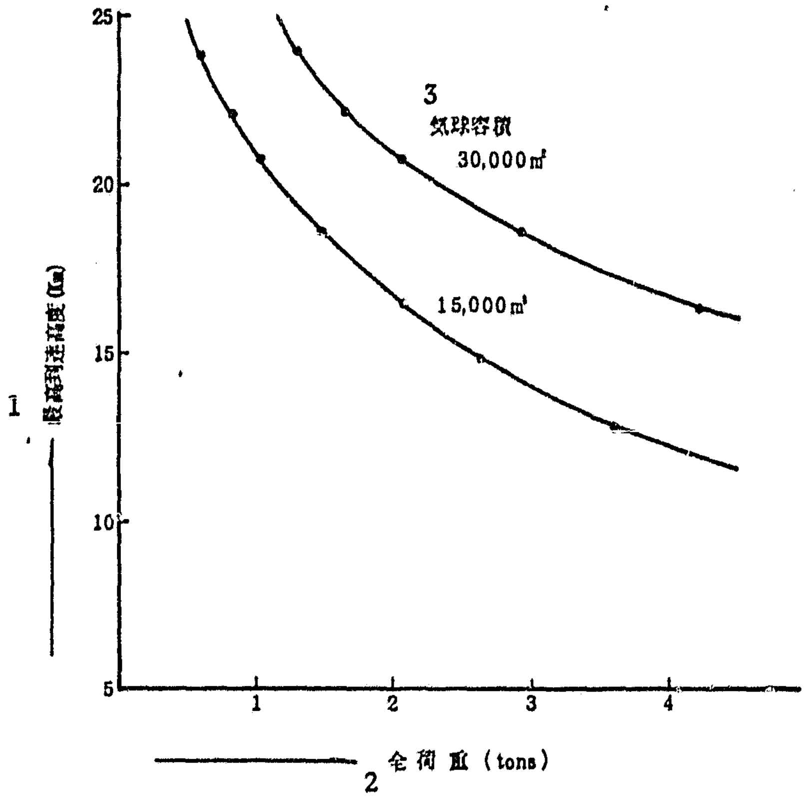

Figure 4.2

1 maximum ascent limit   2 total load
3 balloon volume

(At least) two types of gases must be considered in relation to the balloon, the H within the balloon and the air outside. However, in most considerations, the pressure (atmospheric pressure) P and the height h at each section are linked as in relative formula [4.1]. Specifically,

$$(P-P_0) = e^{-\frac{Mg}{RT}(h-h_0)} \quad [4.1]$$

Wherein,

P: local pressure at height h

Po: local pressure at height ho as the standard
R: gas constant (of ideal gas)
T: absolute temperature
M: molecular weight of gas
g: gravitational acceleration

This formula must use the number (28.98) suitable for the blending ratio in blended gases such as air since the molecular weight M of gas is included. However, the result is formula [4.2] when this number is introduced based on air followed by correlation. Specifically,

$$18400(\log Po - \log P)(1 + \alpha t) = (h - ho) \quad [4.2]$$

Wherein, /27
a: thermal expansion rate of air
t: centigrade temperature

This formula is known as the "Laplace formula" [2] for determining the altitude of a point from the value of the atmospheric pressure.

The decline in pressure in accordance with height is less in He than in air since there are differences in molecular weights M as revealed in a comparison of air and He from formula [4.1].

4.1.3 Pressure imposed on balloon

Before applying formula [4.1] to general conditions of the balloon, we will examine the characteristics using one example. Specifically, a column of air and a column of He of 33.4 m height (diameter of B_{15} type balloon of the Space Flight Laboratory of Tokyo University) which are erected on the ground (1010 mb) are compared. In this case, the pressure at the head declines to 1005.8 mb in the column of air, as illustrated in figure 4.3 (a)(b), while the pressure in He declines only to 1009.4 mb. A pressure difference of 3.6 mb develops between the two. When this is transferred to the balloon, as illustrated in figure 4.3 (c), a pressure Δp of 3.6 mb (specifically water column of approximately 3.6 cm) directed outside from within would develop at the head if the weight of the balloon skin were ignored even in the case of an open zero pressure type when a balloon of 33.4 m diameter is filled with He on the ground.

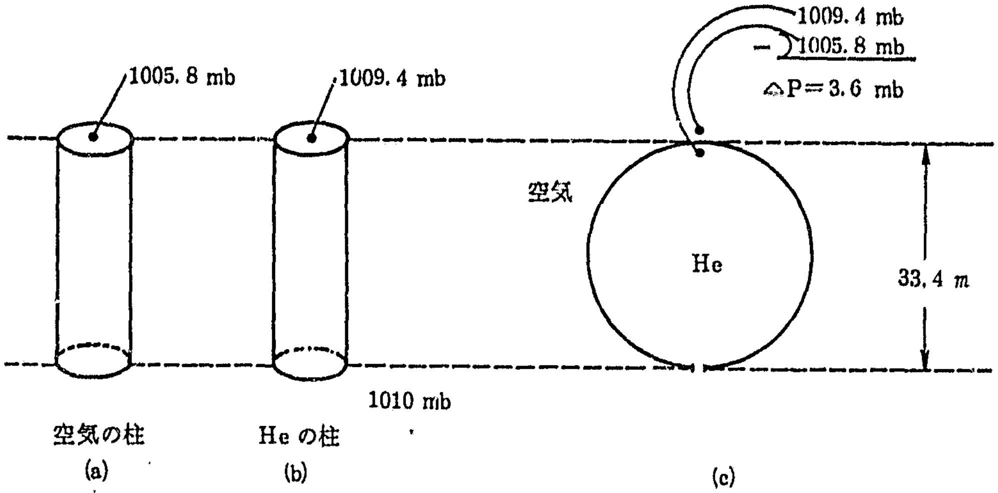

Figure 4.3 Relation between height of gas and pressure
(a) column of air (b) column of He

More generally, the pressure differential ΔP inside and outside the balloon skin increases with height in light of formula [4.1].

Δp can be determined from formula [4.3] which is a modification of formula [4.1] when a zero pressure type of balloon is at high altitudes. Specifically,

$$\log P_{He} - \log P_{air} = \frac{\Delta h}{1.954 \times 10^5} \left(\frac{\Delta M}{T}\right) \qquad [4.3]$$

Wherein
Δh: difference in height between top of balloon and bottom (units: m)
ΔM: difference in molecular weights of air and He.

Actual values must be inserted and calculated to concretely examine ΔP since this formula contains atmospheric pressure Pair and temperature T. Thus, figure 4.4 illustrates the results of calculation of the pressure differential ΔP inside and outside the head along with the height in relation to balloons of various sizes (diameters of 30, 40 and 50 m) using the monitored values in November at Sendai, similarly to the previous case. /28

In addition, the same relation holds even in a sealed balloon since the pressure differential above and below is based on gravity, as illustrated in formula [4.1], and the pressure differential reaches a peak at the head.

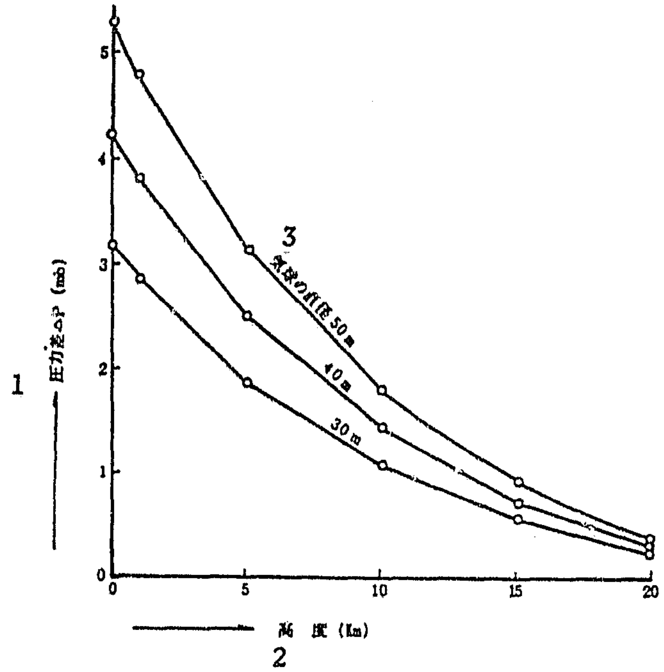

Figure 4.4 Pressure differential P and altitude imposed at head

1 pressure differential P (mb)
2 altitude
3 diameter of balloon, 50 m

4.2 Strength required of film material

The balloon is generally soft, whether it is the zero pressure type or the super pressure type. Since it is produced from flexible material (other than the connecting sections), the sheer stress [note] poses no problems, and the principle problem involves the tensile stress [note], and thus the tensile strength [note].

Conversely, the tensile stress St imposed on the balloon skin when internal pressure p is imposed on the balloon is given by the following formula [4.4] [3]. Specifically,

$$St = \frac{pr}{2} \qquad [4.4]$$

Wherein r: radius of balloon

This formula can be derived most simply using the symmetry

[Note]: The English terms shear stress, tensile stress and tensile strength are used in the Japanese test due to marked differences in their translations depending on the field of specialization.

of the balloon and the pressure p imposed on a non-compressible fluid which realizes Pascal's law, but it can also be derived from a more general standpoint. The following formula materializes in relation to the pressure differential ΔP inside and outside at an arbitrary point and the curvature radius at that point.

$$St = \frac{\Delta pr}{2} \qquad [4:4']$$ /29

Since the right side of this formula is [pressure x length], the dimension of strength is [force/length], but it is usually treated as the force required to rupture the skin of unit width among properties of skin considering a two dimensional body. Consequently, the units of strength are kg/cm.

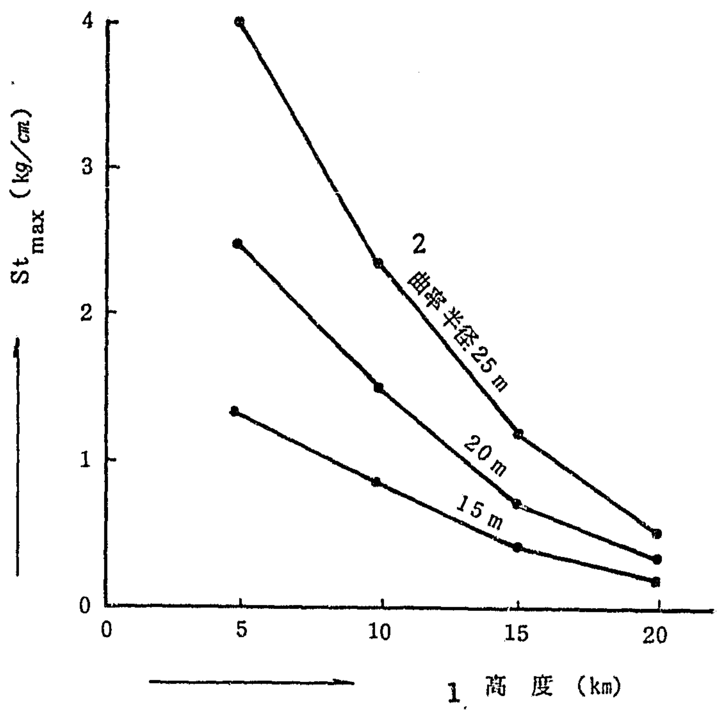

Figure 4.5 Tensile stress St max imposed on head and altitude of balloon
1 altitude (km) 2 curvature radius

The value at the top of the balloon at which the maximum tensile stress develops (assuming a perfect sphere) as well as

the stress could be computed under each set of conditions if conversion of units were carried out at 1 mb = 1.0197 g/cm^2 and using formula [4.4'] from the values of Δp since the relation between Δp and altitude was calculated for numerous balloons in the previous section with the results illustrated in figure 4.4. This is represented as Stmax and the calculation results are summarized in figure 4.5. The section of comparatively low altitude below 1 km is omitted, but this is because that is a region requiring separate examination as stated in section 4.4.

In this range, the tensile stress imposed on the head is a maximum of approximately 4 kg/cm, and balloon skin which can withstand this should have tensile strength above 4 kg/cm. Even material of 0.5 kg/cm could be used under suitable conditions. The quantitative criterion of tensile strength of the material used would be an order of magnitude of several kg/cm based on this figure.

Table 4.1

	重さ (g/m²) 10	Tensile Strength (kg/cm)	用途 11	気密材 17	補強材 25	備考 31	文献 33
① 米 CBV−250 (旧タイプ)	440	35	ケイ留気球 12	合成ゴム 18	26 ナイロン/ポリエステルフイルム	T−COM	(4)
② 米 CBV−250 (新タイプ)	265	40	〃	テドラーフイルム 19	ポリエステルフイルム 27	〃	(4)
③ 日 試作品	308	37〜41	13 木材搬出	テドラーフイルム +ポリエステルフイルム 20	〃		[illegible]
④ 英 AD−500	250	40	14 飛行船	ポリウレタンゴム 21	ポリエステル布 28		[illegible]
⑤ 米 開発中	210	48	15 データのみ	22 テドラー/ポリエステルフイルム	アラミド布 29		[illegible]
⑥ 日 宇航研	19	0.4	16 観測用	23 ポリエチレン		32 実績多数	[illegible]
⑦ 米 RV−CX −27 B	54	8〜4	12 ケイ留気球	ポリエステルフイルム 24	ポリエステル布 30	Arvey Corp	(7)
⑧ 米 GT −1012−2	60	18〜4	〃	〃	〃	〃	(7)
⑨ 米 GT−112	27	7〜3	〃	〃	〃	Schjeldahl	(7)

1. U.S. CBV-250 (obsolete type; 2. U.S. CBV-250 (modern type; 3. Japan test piece; 4. U.K. AD-500; 5. U.S. under development; 6. Japan Natl. Aerospace Lab.; 7. U.S. RV-CX-27B; 8. U.S. GT-1012-2; 9. U.S. GT-112; 10. weight (g/m^2); 11. use; 12. mooring balloon; 13. wood transport; 14. flight: 15. data only; 16. observation; 17. air-sealing material; 18. synthetic rubber; 19. tedra film; 20. tedra film + polyester film; 21. polyurethane rubber; 22. tedra/polyester film; 23. polyethylene; 24. polyester film; 25. reinforcing agent; 26. nylon/polyester film; 27. polyester film; 28. polyester cloth; 29. aramide cloth; 30. polyester cloth; 31. remarks; 32. many actual results; 33. literature.

4.3 Selection of film material

There is little data on the dynamic characteristics of the balloon since it is not mass produced. However, studies have been conducted and data [4-7] have been accumulated, but there is not enough for statistical comparisons. Table 4.1 summarizes typical cases and those approaching the conditions illustrated in /31
the previous section based on this sort of limited study.

Among these, the polyethylene used in (6) from the Japan National Aerospace Laboratory is the one with which we Japanese have had the most experience and results, and the material is unique in that its resistance to cold temperatures at high altitudes has been confirmed, but unfortunately, it has tensile strength of only 0.4 kg/cm^2 [1], which is lower than that required. While it may be used in the design, there is concern that the safety factor would be inadequate. Moreover, the instability increases under excessive conditions during lift off and landing.

Moreover, (3) is material used in a balloon which actually raised approximately 400 kg of logs in July, 1979, in the study "Method of collecting material by mooring balloon" [5,8] conducted in a four year plan from 1976 by the Forestry Agency, Forestry Experiment Station. It was developed by Toyo Spinning Co., and the balloon was molded by the Kawasaki Heavy Industries Corporation. However, there tended to be problems at low temperatures with the properties of the adhesive used in molding the balloon, and the strength for this project was excessive, with weight as an additional problem. However, the development of material matching the objectives seems within the technical capability of Japan since the material used in these experiments by the Forestry Experiment Station was developed in a short period of time and since approximately 22% of the weight (60 g/m^2 out of 308 g/m^2) is alloted to durability to raise the years of service.

However, if known material is to be used, for example, the material of G.T. Schjeldahl Co. noted in (9), it should have a balance of characteristics to match the objectives. Moreover, aramide fibers publicized as ultra-strong fibers (brand name Kevlar by DuPont Co.) have not been demonstrated in examples of use. Thus, it is excessively heavy in regard to the standards of (5) in relation to the aforementioned required properties.

In this range of observation, at present, no applicable domestic material comes to mind. Thus, material from various foreign countries, especially the United States, should be selected as the most appropriate material to be used. However, if the decision is made to import material for the balloon, extensive investigations would have to be made under various sets of conditions. Furthermore, the balloon should be produced abroad to ensure safety and reliability in that case.

4.4 Behavior of balloon during ascent/descent

The balloon should be completely spherical to lighten the weight. Since buoyancy adjustment in the zero pressure type is controlled by the weight ratio (weight %) in relation to total weight so long as buoyancy adjustment is based on discarding of ballast and on discharge of gas, large amounts of ballast proportionally would have to be loaded in heavy balloons, and the vicious circle of increased total load would then result.

However, as illustrated in figure 4.1, since the charged gas expands with rising altitude, there is no sense in filling the balloon on the ground before lift off. Rather, the amount of gas injected should be regulated so as to form a perfect sphere at the peak altitude.

For example, approximately 1/7 of the balloon's capacity (when full) should be injected when a filled sphere is to form at an altitude of 15 km. This is of course true for a super pressure type as well, and the amount of gas injected on the ground would be regulated so that the super pressure type is implemented at the anticipated altitude range.

Consequently, both the zero pressure type and the super pressure type would be "deflated" on the ground and at low /32 altitudes, and they would gradually "fill" at higher altitudes. The head of the balloon is assumed to be a hemisphere and the section below it is assumed to be in conical shape, as illustrated in figure 4.6, as the simplest approximation to estimate changes in the stress imposed on the balloon during this process. In this solid, the length (L) of the circumference from the apex to the tip of the bottom is assumed to be a constant, and the volume V becomes a function only of the radius r of the hemispherical section. In this case, the stress could be calculated at the apex at which the tensile stress reaches a maximum.

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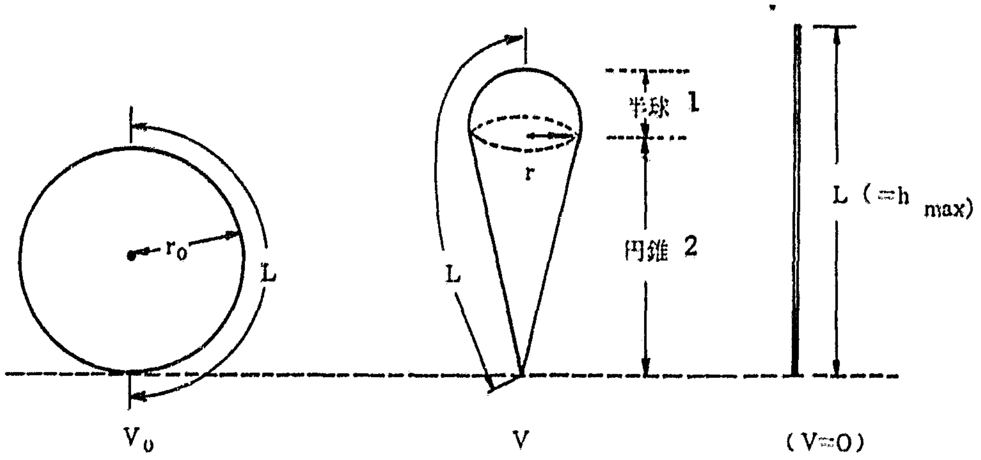

Figure 4.6 Model of changes in shape of balloon during ascent and descent
1 hemisphere 2 cone

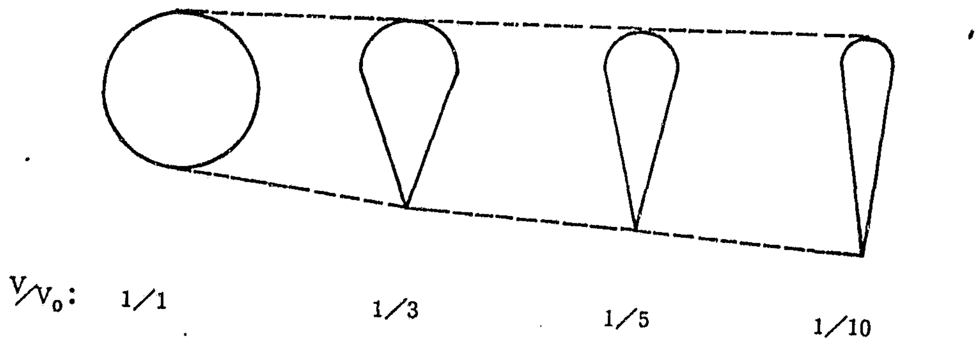

Figure 4.7 Changes in shape of balloon
Ratio of volume (V) in deflated state to volume (V_0) during full period

If this model were used, the balloon would rise in rod shape when the amount of gas injected were at a minimum (V=0), and the height hmax at which the slenderest shape would be exhibited would be as follows in comparison to the diameter $2r_o$ when full.

$h_{max}:2r_o = L : 2r_o = 1/2 \times \text{(circumference)} : 2r_o = \pi r_o : 2r_o$

Specifically, the result would be $\pi/2 \div 1.57$.

Figure 4.7 illustrates the balloon shape when the amount of gas is calculated to be slight in comparison to the full balloon (specifically during "deflated" period).

As this figure indicates, a gentle curve is exhibited in regions in which the amount of gas is 1/3 or less than the full /34
amount, but at 1/3 capacity, a "crease" becomes conspicuous at the seam of the hemispherical section and the conical section, suggesting that the approximation has worsened.

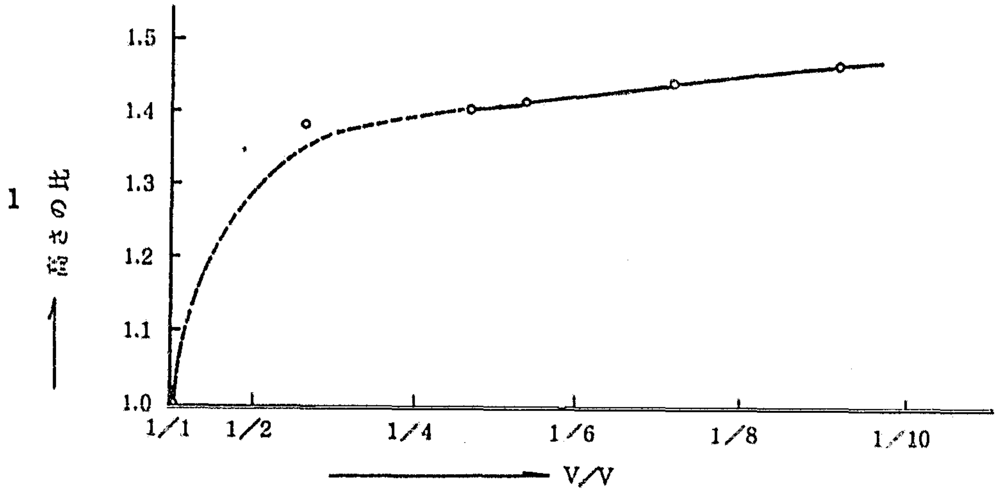

Figure 4.8 (a) Relation between change in volume and height taken as 1 at full period
1 height ratio

Figure 4.8 (a)(b) illustrates the results of calculation of the relation between height and the curvature radius of the top versus the change in volume of the balloon using a model. Here, settings for regions of poor approximation are noted by a broken line. By means of this, the height does not exhibit very great changes in the "deflated" state, but the curvature radius of the top changes comparatively sensitively. This signifies that the pressure ΔP acting on the top increases because of the increased height of the balloon in the "deflated" state, but the stress at the top is slight since the curvature radius becomes smaller. The volume of gas introduced on the ground does not reach 1/100 of the true volume Vo of the balloon even when a balloon with skin of slight tensile strength like polyethylene ascends to high altitudes with a small payload [9]. Consequently, great stress does not develop and the balloon can safely ascend even if the atmospheric pressure of the perimeter is sufficiently low, ΔP is small and the curvature radius is large, even at altitudes at which the curvature radius of the top increases. Consequently, the amount of gas injected on the

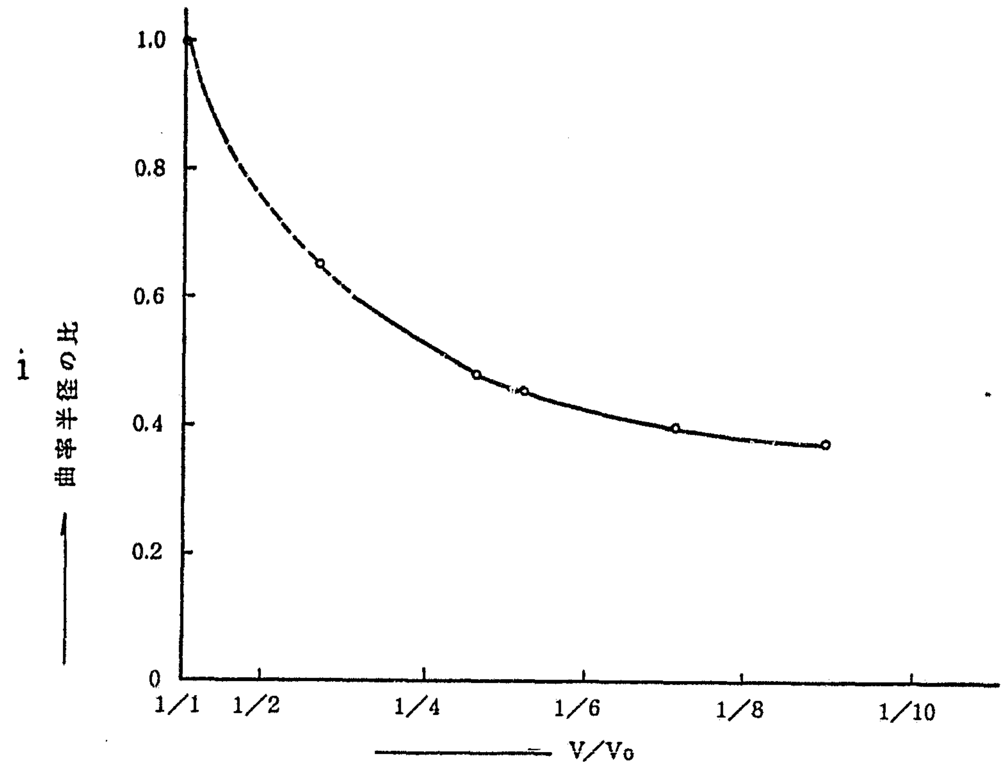

Figure 4.8 (b) Relation between change in volume and curvature radius of the apex taking 1 at the full period
1 ratio of curvature radius

ground must increase when the total load increases even using the same skin material, and the stress increases, rupturing the balloon before reaching the altitude at which the atmospheric pressure is sufficiently low since the balloon swells with increase in the curvature radius of the top. This is the reason that the strength was inadequate in flight to an altitude of more than 10 km with a payload of several tons even though polyethylene has produced good results as the material for observation balloons.

One of the results leading from the aforementioned examination is that the size of the original sphere should be great enough so that the curvature radius does not increase until a sufficiently high altitude is reached and also so that a complete sphere does not form until the target altitude is reached. This is the method of flight assuming the shape of an ice cream cone. This is the shape actually used by Double Eagle II and in other examples, but the weight of the balloon itself is greater than that in the case of a complete sphere.

Polyethylene identical to that used in the balloon of the

Space Flight Laboratory could be used if an ice cream cone shape could be used and if the total load could be held to approximately two tons. However, such factors as the safety coefficient would have to be thoroughly examined in research into the feasibility of this.

Another method of restraining the curvature radius in this region would be to have a squash shaped balloon through design and use of suitable load tape. This is the shape of many balloons, but advanced techniques to prevent distortions during molding are required.

Another conclusion derived from examination of the changes in shape during ascent is that the horizontal cross sectional area of the balloon during ascent and the corresponding circumferential length have important significance in terms of the sites at which vertical stress is imposed for supporting the load, but they must decrease in comparison to the case of a complete sphere (and the "deflated" shape must decrease markedly at very low altitudes). Consequently, a design which supports the load solely by the skin is unreasonable. The design must have the total load supported by load tape as a strength member.

4.5 Handling during lift-off/landing /35

The balloon to travel at high altitudes must have a volume in the "deflated" state approximately ten times greater than the amount of gas on the ground, as mentioned previously. Consequently, the effects of wind on the ground must be anticipated to be much greater than in the case of a balloon which is virtually filled on the ground and which is used at conventional altitudes. Lift-off would be possible during periods of good conditions since this measure is the result of many years of experience with observation balloons at lift-off. However, we have little experience with landing and recovery of observation balloons, and must rely on the feeling of the operator. Consequently, in considering problems arising during landing, a landing site with desirable meteorological conditions must be selected and that site as well as the time of landing must be incorporated into the plans.

4.6 Possibility of super pressure type

Polyethylene was excluded due to its inadequate strength at the target loads and altitudes, as indicated in selection of the skin material, and other materials must have sufficient strength. Since this indicates that the super pressure type could be used, it was reexamined and evaluated. While a slight amount of ballast would be adequate for safety in the super pressure type, one must be prepared for the greater amount of super heating (high transparency) than in the case of an observation balloon with materials other than polyethylene. Consequently, the

ballast would have to be increased, and a considerable difference in total weight would thus be anticipated between the zero pressure type and the super pressure type.

Furthermore, the super pressure type has superior handling and room for improvement. Consequently, it has a promising future.

Whether zero pressure or super pressure type, we know that the dynamic behavior in the course of swelling and deflation of the balloon during lift-off and landing would be complex. We suspect that many of the accidents occurring directly after lift-off or landing involved inadequate caution regarding these transient phenomena. Detailed reexamination using accurate models is essential in the stage of determination of the balloon material and pay-load. At the present stage, only static dynamic characteristics have been considered, but the dynamic (impact) characteristics such as force imposed on the load tape during lift-off/landing must be considered.

Reference Literature /36

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(2) e.g. Rika Nenpyo (1978), p. 193 (Maruzen)

(3) e.g. Ishii, Ataka "Design of film structure", p. 190 (Kogyo Chosakai) (1969)

(4) Proceedings of the Interagency Workshop on LTA Vehicles, pp. 243 and 623 (M.I.T.) (1974)

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(6) Sakai (Kawasaki Heavy Industries), On Design of LTA Craft, ibid pp. 103-106 (1979)

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5. Gondola Structure and Equipment Mitsuo Makino /37

5.1 Type of gondola

There are open and sealed types of gondolas. In the open type, there is no pressure differential between the interior and outside, and even if it appears to be insulated from the outside air, it actually is not. In contrast, the interior of the sealed type is completely blocked off from the outside, and the pressure is maintained at virtually the ground atmospheric pressure.

Flight at low altitudes poses no problems for the open type, but the sealed type of gondola is essential at high altitude (e.g. above 8,000 m) flight to protect the occupants from low pressure and low temperature. Of course, an open gondola may be used even at high altitude flight for short periods of time if warm clothing is worn, but such clothing restricts movements during long term flight, and a sealed gondola is required for comfort. The 1931 flight by Piccard was the first case of use of a sealed gondola in a high altitude balloon, and the U.S. Navy had the Stratolab project in 1961 as an example of use of an open gondola in high altitude flight. An altitude record of 34,668 m (nine hours) was recorded at that time.

5.2 Shape of gondola

When using a sealed gondola, the internal pressure is designed to be one atmosphere while the external pressure is designed to be zero atmosphere. The logical shape would be spherical or cylindrical for pressure resistance at light weight, but a unique design is always desirable for esthetic purposes.

Figure 5.1 illustrates some of the various shapes which have been considered, and the long hexagonal shape of (5) is the best shape in terms of comfort. However, the force imposed on the structure due to the internal pressure was unexpectedly large, although the calculations are somewhat simple, and this shape proved to be disadvantageous in terms of structural strength and light weight. Thus, the spherical shape (1) or the cylindrical shape (2) had to be adopted. Based on considerations in the case of the long hexagon, a cylinder laid sideways was judged to be best for comfort, but there have been no cases of use of such a gondola to date.

5.3 Size of gondola and interior arrangement

The size of the gondola is determined by the crew number. In this trans-Pacific flight, the crew number was initially set at one or two, and either would be permissible. The type of balloon is the determining factor. Specifically, the minimum would be a two man crew, the pilot and navigator, in the case of a zero pressure balloon. In contrast, only a pilot is required since there is no high degree of maneuvering in the case of a /38
super pressure balloon. However, a minimum of two people is essential to deal with unexpected events.

Since the trans-Pacific flight would last three to four days, the interior of the gondola should provide those facilities required for comfort during that period. Specifically, a bed should be provided. However, only one bed should be provided since both crew members should not sleep at the same time. A toilet is not provided, but there should be space for a portable facility and measures should be provided to vent odors outside.

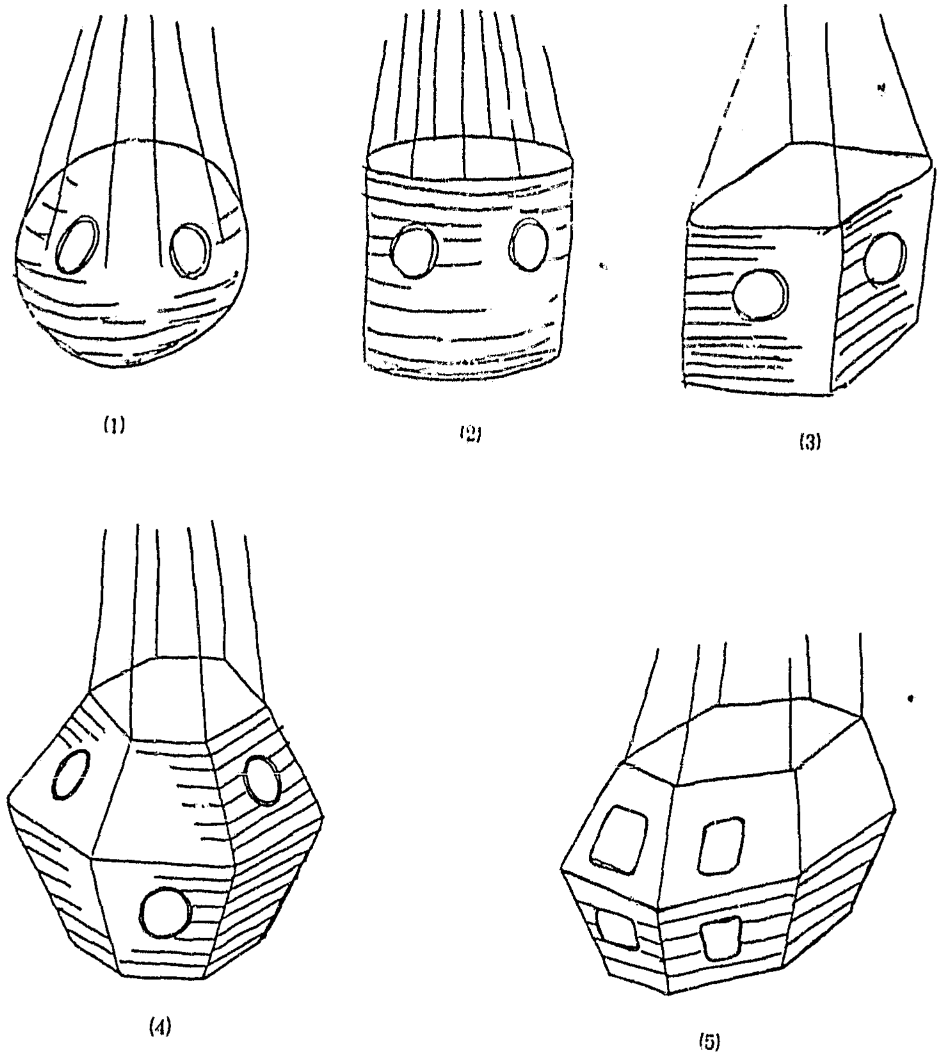


Fig. 5.1 Shape of sealed gondola

In addition, a work table and rack should be provided. Consequently, the interior dimensions of the gondola should be 3.2 m in length by 2.2 m in diameter. /39

5.4 Structure of gondola

The shape should be cylindrical to lighten the weight, as indicated in section 5.2. A monocoque structure was adopted since the original significance was lost due to the use of a skeletal structure even with a cylinder. There is no skeleton in a monocoque structure, and the load is borne by the outer plates. A pure monocoque structure without using longitudinal members can be employed in the case of the gondola of this design in which the length is shorter than the diameter and in which the outer plates are not too thin for ease of handling. However, a semi-monocoque structure incorporating longitudinal members was

employed since four windows were opened on the sides of the cylinder. The frame has one plate near the edges, and two plates incorporated in some places, and this part of the frame is suspended under the balloon.

The heads (end plates) which form both edges are the parts posing problems of strength in the gondola with a cylindrical monocoque structure. There are conical and revolving curved types of head shapes, as illustrated in figure 5.2, and the former is preferable in terms of production. However, very large local torsional stress develops in the part connected to the cylinder, as illustrated in the figure, if roundness of quite large radius ($r \geq 0.06$ D) is not provided. Adoption initially of a rotating curved surface which would be useful for strength would be best since the advantages in production would be reduced by half if roundness is provided.

Finally, aluminum alloy was selected as the material to be used in the outer plates, frame and penetrating members, and honeycombed sandwich material would be used for the floor inside, thereby minimizing weight. Furthermore, the entire exterior surface of the monocoque structure would be enveloped by adiabatic material (foaming plastic), with polyester fiber on top of that.

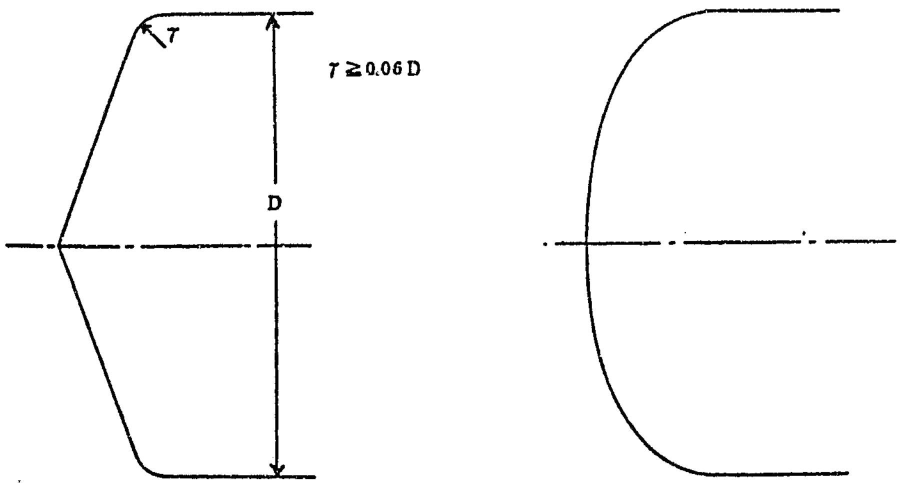
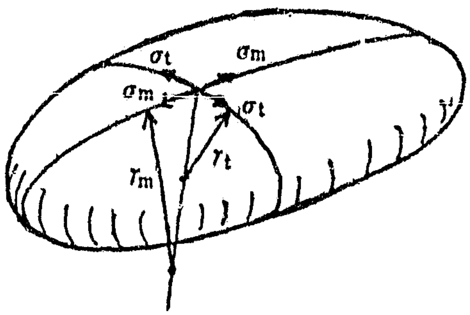


Fig. 5.2 Shape of head

5.5 Strength calculations of gondola

The strength of the monocoque structure could be calculated applying the shell theory. A shell is a thin curved plate which is generally capable of withstanding tensile and compressive stress, torsion stress and perpendicular shearing stress. The tensile stress and compressive stress are paramount in a shell using internal pressure such as a gondola, and the torsion and shear stress are generally low. These are termed secondary stresses, and may be considered only as required. Specifically, the strength can be calculated in this case considering a /40
membrane which cannot withstand torsional or shearing stress.

The following relation develops according to the theory of membrane stress taking p as the pressure difference between internal and external pressure, the plate thickness as t, the curvature radius in the circumferential direction as r_t, the tensile stress as σ_t, the curvature radius in the meridian direction as r_m and the tensile stress as σ_m (refer to figure).



$$\frac{\sigma_m}{r_m} + \frac{\sigma_t}{r_t} = \frac{p}{t} \qquad (1)$$

Determination of a shell structure of uniform strength is a significant problem. Here, we will consider production of a gondola of uniform strength. The maximum shearing stress throughout the shell should be uniform since the maximum shear stress is a standard based on undulation of stretched material according to the theory of maximum shear stress. Here, we will attempt to determine the shape of the head of the gondola following this method so that it will have the same strength as that of the cylindrical section. This method was first employed in 1922 by Biezeno in design of a cylindrical boiler. However, while Biezeno determined the shape by the diagram method, we decided here to advance further and to analytically determine the shape.

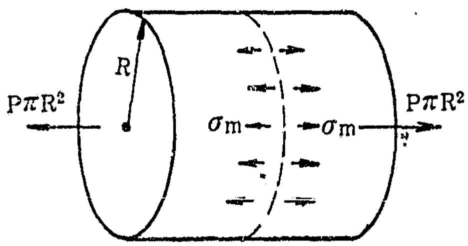
5.5.1 Determination of external plate thickness from cylindrical part

The tensile stress σ_t operating in the circumferential direction on the outer plate of the cylindrical section is obtained in equation (1) by assuming $r_m \to \infty$, and $r_t \to R$ (R is the radius of the cylinder. Specifically.

$$\sigma_t = \frac{pR}{t} \qquad (2)$$

Conversely, the tensile stress σ_m acting in the meridian direction, specifically the longitudinal direction of the cylinder, is determined from balancing the pressure $p\pi R^2$ acting on the head of the gondola with the pressure $\sigma_m \cdot 2\pi R$ acting in the meridian direction of the cylinder (refer to figure). The result would be as follows.

$$\sigma_m = \frac{pR}{2t}$$



Comparison of equations (2) and (3) reveals that σ_m is 1/2 σ_t. Consequently, equation (2) may be used in calculation of the strength. The thickness of the outer plate from equation (2) would be as follows taking σ_t as 40 kg/mm^2 since the diameter of the cylinder is 2.2 m, the differential pressure between interior and exterior is one atmosphere and the tensile strength of the 2024 aluminum alloy is 40 kg/mm^2.

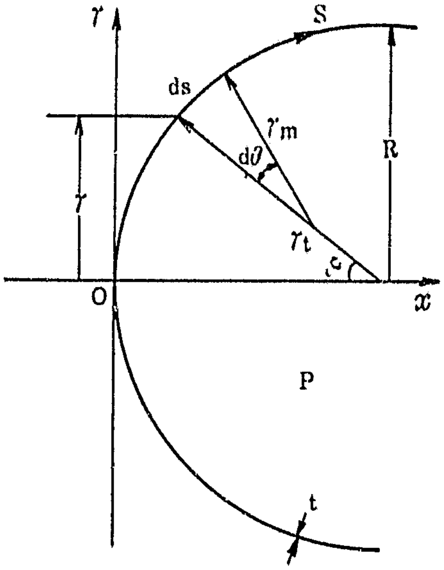
$$t = \frac{1.033 \times 10^{-2} \times 1.1 \times 10^3}{40} = 0.284(mm).$$

Specifically, it would be 0.3 mm. However, the stress collects in this region since windows are opened. Since the local stress approximately triples in the case of round windows, the plate thickness would be triple, 0.9 mm, when the plate thickness is determined based on this local stress. Consequently, the external plate may be 1 mm thick. Conversely, the stress σ_t determined for t = 1 mm would be 11.4 kg/mm^2. This value falls in the middle of the circumferential stress of 7 to 13 kg/mm^2 used in current aircraft.

5.5.2 Determination of the shape of the head

The plate thickness of the head is constant, and the maximum shear stress due to membrane stress obtained from the membrane

stress theory is assumed to be equal to that at the cylinder. The equation of the membrane stress theory could be depicted as follows when intersecting coordinates are adopted as in the figure. /41



$$\frac{\sigma_m}{r_m} + \frac{\sigma_t}{r_t} = \frac{p}{t} \qquad (4)$$

$$2\pi r t \sigma_m \sin\theta = \pi r^2 p \qquad (5)$$

Here, equation (4) is identical with equation (1).

$$r_m d\theta = ds = \frac{dr}{\cos\theta}, \quad r_t = \frac{r}{\sin\theta}$$

Consequently, the following can be written.

$$\frac{1}{r_m} = \frac{\cos\theta d\theta}{dr} = \frac{d\sin\theta}{dr}, \quad \frac{1}{r_t} = \frac{\sin\theta}{r}.$$

When these are introduced into equation (4), the result is

$$\frac{\sigma_m d\sin\theta}{dr} + \frac{\sigma_t \sin\theta}{r} = \frac{p}{t} \qquad (6)$$

Furthermore, the following results from equation (5).

$$\sigma_m = \frac{pr}{2t\sin\theta} \qquad (7)$$

In addition, assuming u = sin θ, equations (6) and (7) would become

$$\sigma_t = \frac{pr}{2tu}\left(2 - \frac{r}{u}\cdot\frac{du}{dr}\right) \qquad (8)$$

$$\sigma_m = \frac{pr}{2tu} \qquad (9)$$

From these two equations, the meridian stress is usually tensile, but the circumferential stress 2-r/y•du/dr = 2 - rt/rm is negative. Specifically, compression develops when $rt > 2r_m$. The maximum shear stress τmax would be 1/3 the difference between the two principal stresses according to the stress circle of Mohr. The result would thus be

$$\tau max = \frac{\sigma_m - \sigma_t}{2} = \frac{1}{2} \cdot \frac{pr}{2tu}\left(\frac{r}{u}\frac{du}{dr} - 1\right)^{*} \quad (10)$$

The result would be as follows in relation to the cylindrical section.

$$\sigma_t = pR/t \quad (11)$$

$$\sigma_m = pR/(2t) \quad (12)$$

This is tensile stress in both cases. Consequently, the maximum shear stress here is 1/2 the difference between the maximum principal stress σ_m and zero. Specifically,

$$\tau max = \frac{1}{2} \cdot \frac{pR}{t} \quad (13)$$

Assuming that the shear stress on the cylindrical section and the shear stress on the head are equal everywhere, the result is

$$\frac{du}{dr} = \frac{u}{r} + 2R\frac{u^2}{r^2} \quad (14)$$

This equation can be solved with the following results.

$$u = \sin\theta = \frac{-r}{2R\ell n\, r + C} \quad (15)$$

The integration constant using r=R at $\theta = \pi/2$ as the boundary condition would be

$$C = -R(1 + 2\ell n R) \quad (16)$$

Consequently, /42

$$\sin\theta = \frac{\frac{r}{R}}{1 - 2\ell n\frac{r}{R}} \quad (17)$$

---

* (Note) Maximum stress theory
Also termed the theory of Guest. This theory asserts, "Rupture occurs when the maximum shear stress within the material is equal to the maximum shear stress at the yielding point during simple tension". Since the maximum shear stress is half of the difference between the maximum and minimum principal stresses, the conditions for rupture would be $|\sigma_1 - \sigma_3|$ 1/2 = $_{\sigma}$Y.P/2

Based on these results. the ultimate equation is

$$\frac{dx}{dr} = \tan\theta = \frac{\frac{r}{R}}{\sqrt{(1-2\ell n\frac{r}{R})^2-(\frac{r}{R})^2}} \quad (18)$$

The point at which σ_t changes from compression to tension is found to be

$$\frac{r}{R} = \frac{1}{\sqrt{e}} = 0.6065$$

When r/R is smaller than this value, σ_t is tension. Moreover, the value of r_m at $r/R = 1/\sqrt{e}$ is equal to R. In regions in which σ_t is tension, the maximum shear stress would be 1/2 σ_m. Specifically,

$$\tau_{max} = \frac{p r_t}{4t} \quad (19)$$

Since this should be equal to the maximum shear stress pR/(2t) at the cylindrical section, this would be equalized as follows.

$$r_t = 2R$$

When this result is used, the following would result in this region.

$$r_m = 2F$$

Specifically, this section would be a spherical surface of radius 2R.

Figure 5.3 illustrates a graph of the meridian cross sectional shape of the head summarizing these results.

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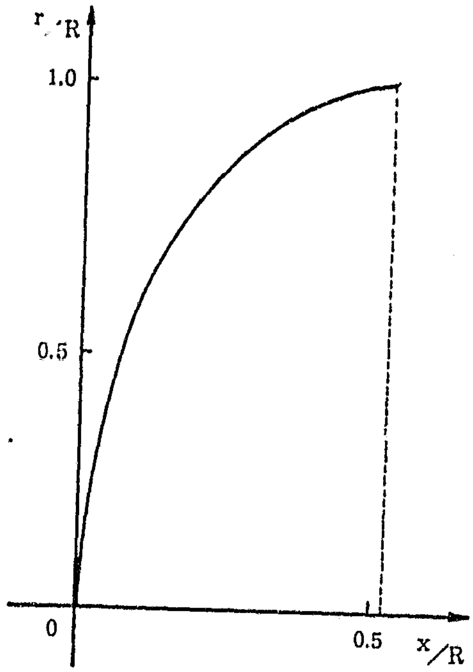
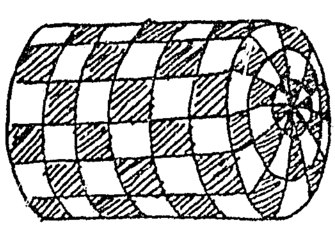


Figure 5.3 Meridian cross sectional shape of head

5.6 External equipment of gondola

A zero pressure balloon must load quite heavy ballast. Sand ballast may be used as well as water ballast in water tanks below the floor. Sand ballast would be packed in bags which are suspended from hand rails surrounding the bottom of the gondola. In addition, a combination air expandable float and shock absorber would be installed below the hand rails, and this would usually be folded, but it would be inflated by compressed air when required.

The gondola would be suspended by four cables, but a parachute would be fitted between it and the balloon, a so-called "cargo parachute". In the event of an emergency, an electric charge could be sent to the explosive separation device, and the gondola could be separated from the balloon. The gondola could have an exterior painted with a red and yellow checkered pattern for easy visibility from the air when the gondola has landed or been forced down in the water.



The entrance-exit would open outside from the windows on the left or right of the seats, but during an emergency, the round windows above and below the seats could be opened outward and the crew could escape from there. There are two windows at the front and one window at the rear, and the shape would be fan-shaped /43 with rounded corners. In addition, there would be a total of seven windows since there would be four round windows incorporating exits as mentioned previously (Figure 5.4).

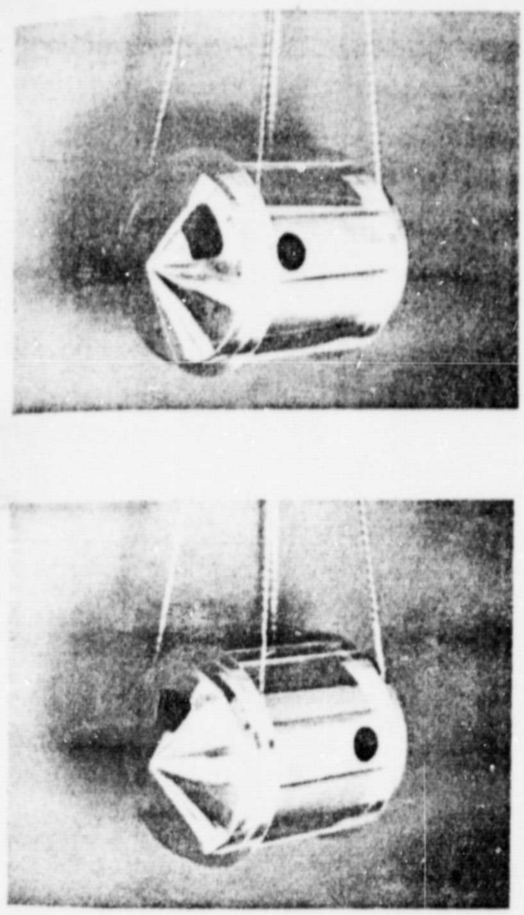


Figure 5.4 Exterior view of cylindrical gondola

5.7 Internal equipment of gondola

Cylinders of liquid air or liquid oxygen would be on board in order to compensate for oxygen deficiencies in the gondola. Furthermore, an air purification device would be provided to

reduce consumption. Liquid fuel in a fuel tank below the floors would be burned for heat, and the interior would be heated via a heat exchanger.

The seats would be reclining seats, and one would be a joint seat and bed. The other seat would switch forward and backward, and would face the work table and rack. Figures 5.5 and 5.6 illustrate the arrangement of the internal and external equipment. The equipment is as follows.

(1) Work table
(2) Rack (primarily containing communication and navigation equipment).
(3) Housing rack (primarily containing sleep gear, clothing and food).
(4) Portable toilet
(5) Fire extinguisher (two)
(6) Drinking water-thermos bottle
(7) First aid kit
(8) Illumination gear
(9) Personal parachute /44

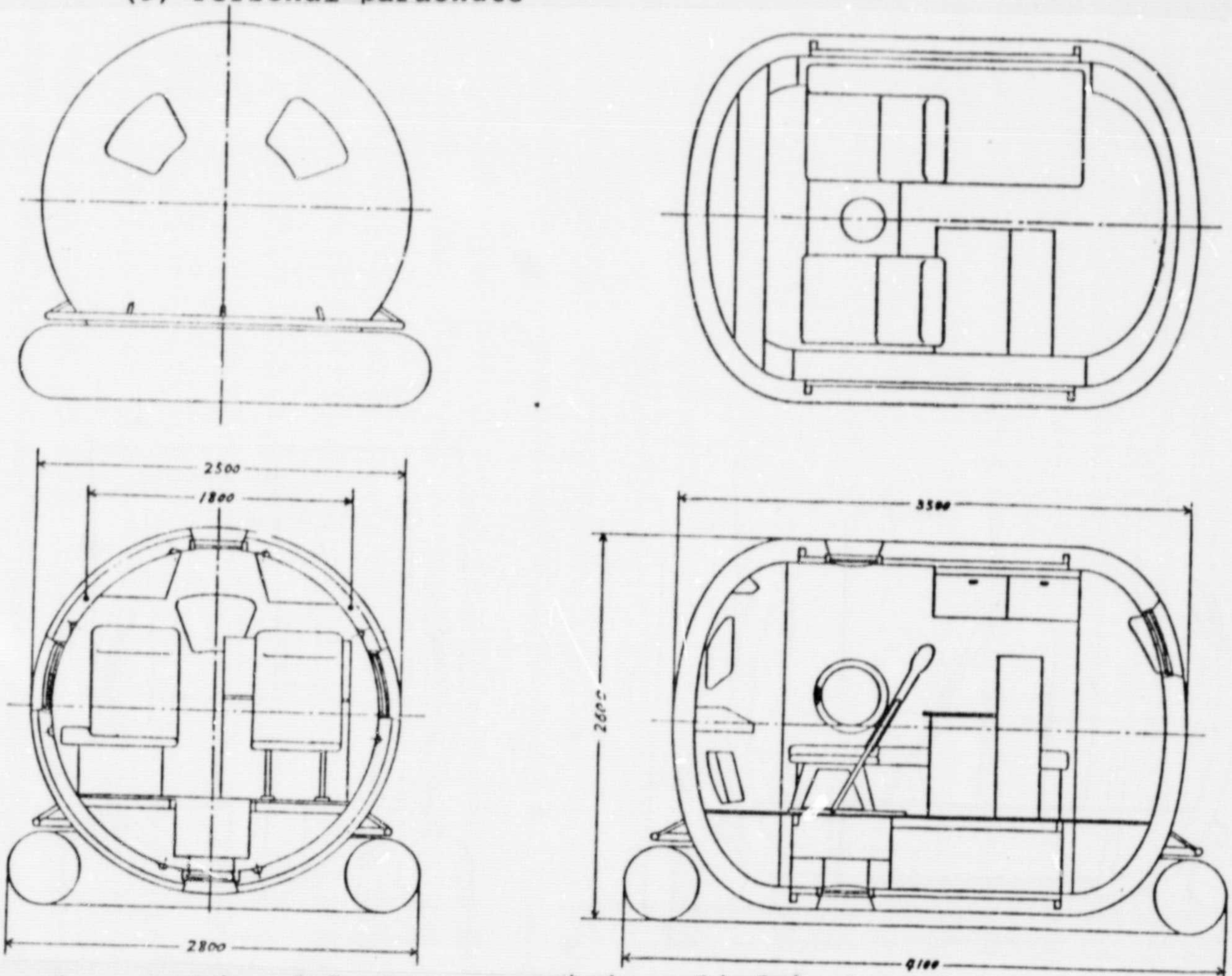


Fig. 5.5 Arrangement in cylindrical gondola

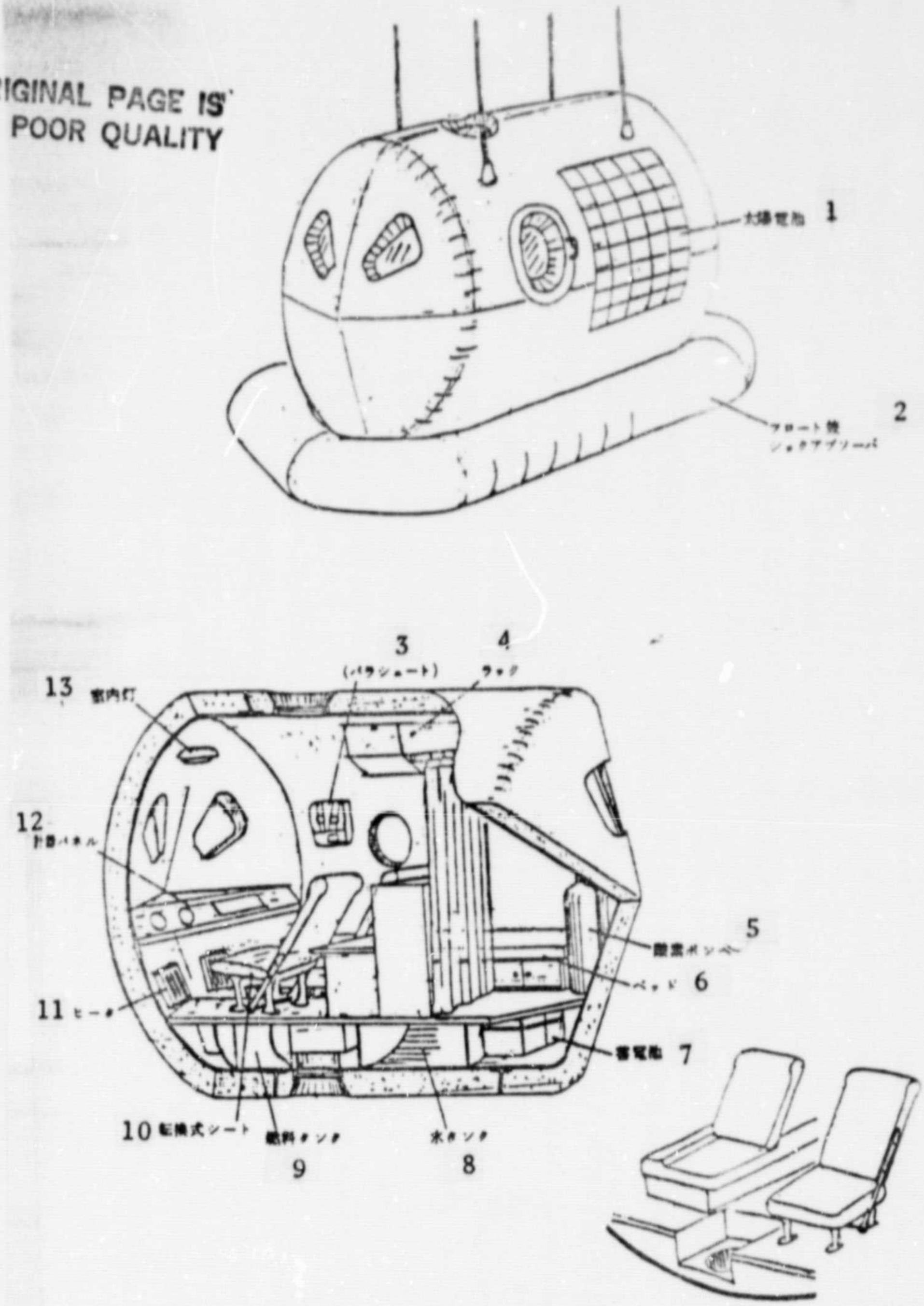


Fig. 5.6 Arrangement of equipment in cylindrical gondola

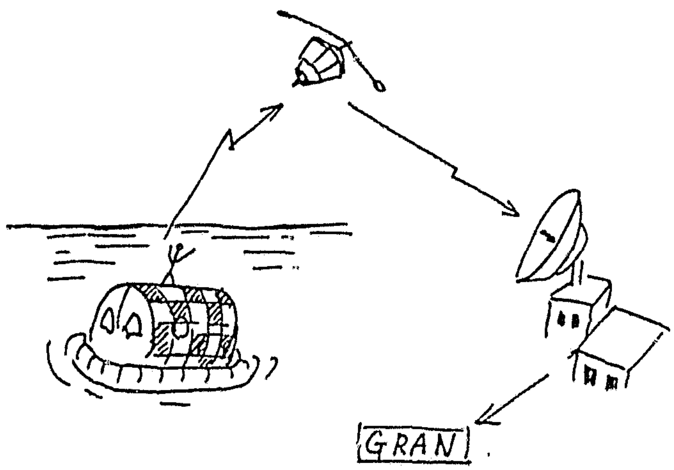
1 solar cells
2 float-shock absorber
3 parachute
4 rack
5 oxygen cylinder
6 bed
7 battery
8 water tank
9 fuel tank
10 adjustable seat
11 heater
12 instrument panel
13 reading light

5.8 Communications equipment, navigational equipment, distress signal equipment /46

The HF-transmitter receiver usually carried on long distance aircraft is on board as the communications equipment.

The navigation equipment receiving and using the signal radio waves sent by local stations is suitable as the simplest and cheapest equipment. This uses the so-called radio navigation method. Flight over ground by VOR using radio waves from a VHF (ultra-short wave) station would be possible, while omega navigation using radio waves from a VLF (ultra-long wave) station would be required when over water. This receiving equipment is the most commonly used navigational method at present since it is inexpensive. In the trans-Pacific project, VLF/Omega navigational equipment using radio waves from VLF stations and omega stations, as well as ADF equipment (automatic directional finder) using VOR (ultra-short wave) and NDB (intermediate wave) are to be on board if possible.

Notification of an emergency would be carried out by issuance of an S.O.S. by an HF receiver on board, but dispatches using artificial satellites may also be sent as used by N. Uemura in the polar expedition. This is termed EPIRB (emergency position indicator radio beacon). In the event of an emergency, when a distress signal is issued from this equipment, a satellite picks this up and relays it to a ground station where the position is calculated and GRAN (rescue organization) is notified.



5.9 Instrumentation, power source

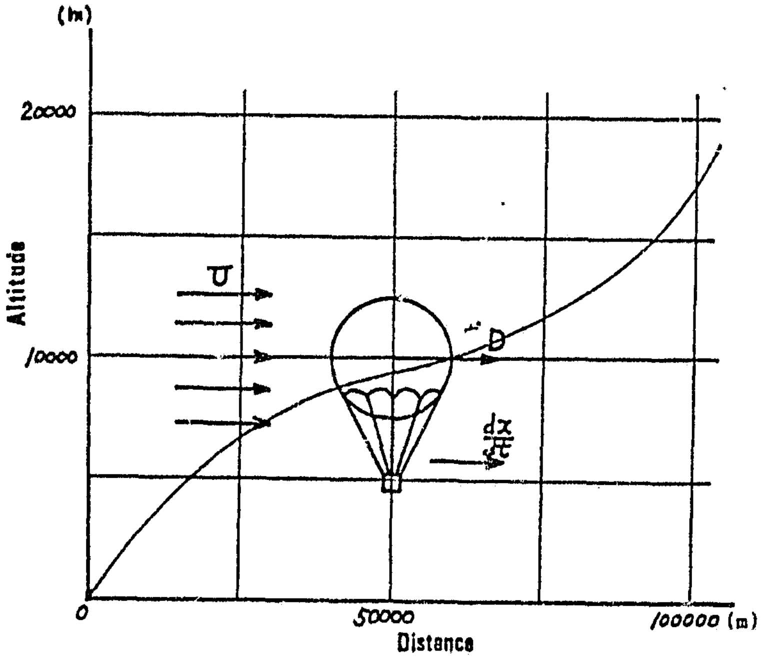
The instrumentation and power source are as follows.

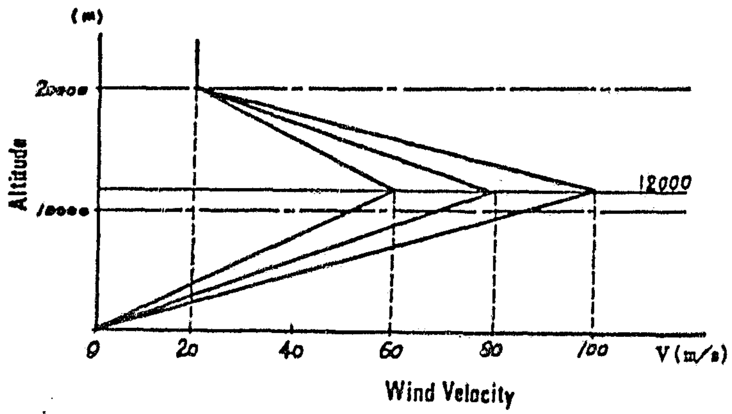
(1) altimeter (aneroid altimeter and radio altimeter)
(2) ascent meter
(3) barometer (for external pressure and pressure in gondola)
(4) thermometer (for external temperature and temperature in gondola)
(5) humidity meter (for external humidity and humidity in gondola)
(6) meter for gas pressure in balloon
(7) thermometer for gas in balloon
(8) clock
(9) magnetic compass
(10) flight camera

Power source:

(A) batteries for communications equipment, navigational equipment (24 V.D.C.)
(B) batteries for interior lights (12 V.D.C.)
(C) solar cells
(D) gasoline generator /47

[Data] Example of calculation of balloon course during ascent





In the case of a balloon of 30 m diameter, 900 kg weight and 174 kg of free buoyancy (fraction of buoyancy devoted to lift, the result following subtraction of weight from total buoyancy) (19.3% of weight), the course of flight if this balloon were to rise while subjet to winds was calculated, and the results have been depicted. The wind velocity on the ground is assumed to be zero, and it is assumed to increase linearly, reaching a peak of 80 m/s at an altitude of 12,000 m. This is followed by a linear decrease to 20 m/s at an altitude of 20,000 m (Figure 1).

It would take approximately 30 minutes for the balloon to reach an altitude of 12,000 m according to the calculations, and it would travel approximately 73 km from the starting point. (Fig. 2) /48

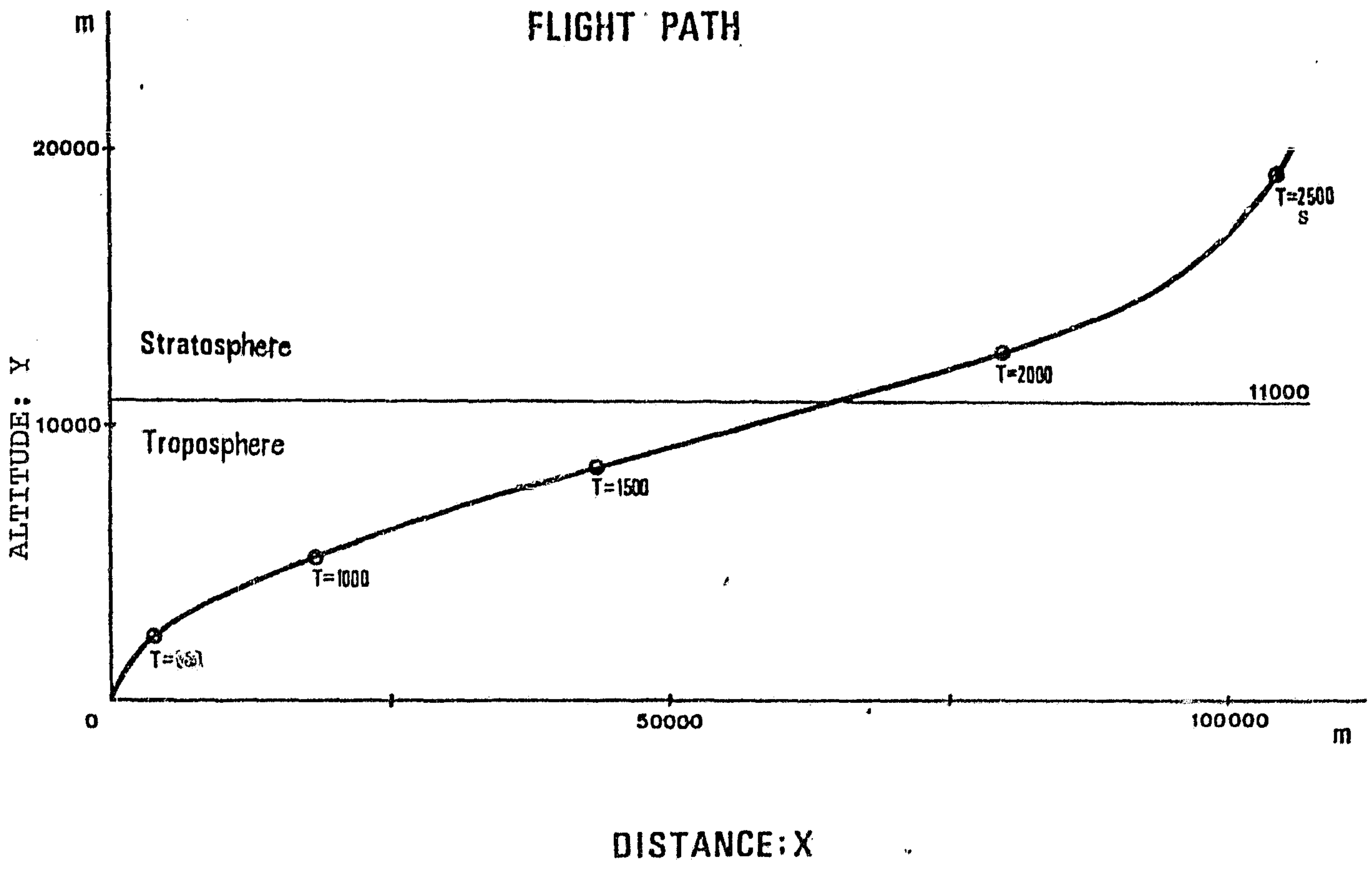
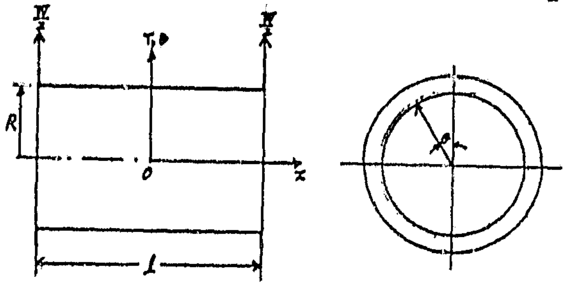


Fig. 2

Strength calculations based on membrane theory of cylindrical shell /49



The following proportional equations develop taking the differential pressure inside and outside of the cylinder as p, the weight per unit area as γ and the shear stress acting on the cross section in the circumferential and longitudinal directions (the sizes are equal) as τ.

$$\frac{\partial \sigma_m}{\partial x} + \frac{1}{R}\frac{\partial \tau}{\partial \theta} = 0 \qquad (1)$$

$$\frac{\partial \tau}{\partial x} + \frac{1}{R}\frac{\partial \sigma_t}{\partial \theta} = -\frac{\gamma}{t}\sin\theta \qquad (2)$$

$$\sigma_t = \frac{R}{t}(p - \gamma\cos\theta) \qquad (3)$$

The following results from equations (2) and (3)

$$\frac{\partial t}{\partial x} = -\frac{2\gamma}{t}\sin\theta$$

When $C_1(\theta)$ is taken as an integration constant and integrated, the result is

$$\tau = -\frac{2\gamma x}{t}\sin\theta + C_1$$

When the boundary conditions of $\tau = 0$ at $x = 0$ are used, the following results since $C_1(\theta) = 0$.

$$\tau = -\frac{2\gamma x}{t}\sin\theta \qquad (4)$$

When this is introduced in equation (1), the result is

$$\frac{\partial \sigma m}{\partial x} = \frac{2\gamma x}{Rt}\cos\theta$$

When this is integrated and $C_2(\theta)$ is used as an integration constant, the result is

$$\sigma m = \frac{\gamma x^2}{Rt}\cos\theta + C_2(\theta)$$

When both ends of the cylinder are assumed to be blocked, the result is as follows since $\theta m = pR/2t$ at $x = \pm 1/2$

$$C_2(\theta) = \frac{pR}{2t} - \frac{\gamma \ell^2}{4Rt}\cos\theta$$

Consequently

$$\sigma m = \frac{pR}{2t} - \frac{\gamma}{4Rt}(\ell^2 - 4x^2)\cos\theta \quad (5)$$

The aforementioned results are summarized and written as follows.

$$\sigma t = \frac{R}{t}(p - \gamma\cos\theta)$$

$$\sigma m = \frac{pR}{2t} - \underbrace{\frac{\gamma}{4Rt}(\ell^2 - 4x^2)\cos\theta}_{\text{(曲げ応力)}}$$

$$\tau = -\frac{2\gamma x}{t}\sin\theta \text{ torsional stress}$$

When the total weight of the gondola is taken as W and this weight is assumed to be uniformly distributed on the cylinder, the result is

$$\gamma = \frac{W}{2\pi R\ell} \quad (6)$$

Here, the result is as follows assuming W = 1,500 kg. R = 1,100 mm, 1 = 1,800 mm and t = 1 mm.

$$\gamma = 1.206 \times 10^{-4}\ kg/mm^2$$

The maximum value of σt occurs at $\theta = \pi$. The value is

$$(\sigma t)max = 11.5\ kg/mm^2$$

The maximum value of σ_m occurs at $\sigma = \pi$ in the center of the cylinder.

$$(\sigma_m)\ max = 5.77\ kg/mm^2$$

In addition, the maximum value of τ occurs at both ends of the cylinder, at $\theta = \pi/2$ and at $3\pi/2$

$$\tau max = 0.217\ kg/mm^2$$

In any event, the effect due to the gondola weight is slight and poses no problem.

6. Various problems in flight operations Saburo Ichiyoshi /50

6.1 Ground support

Ground support centers at Tokyo and San Francisco were established, and these support the balloon during flight through 24 hour surveillance. Both centers are capable of contacting the Civil Aviation Bureau, the Japanese Air Self Defense Forces, the U.S. Air Force, the Japanese Naval Self Defense Forces, the Maritime Safety Agencies, the U.S. Coast Guard, the Meteorological Agency, the Weather Bureau, the Ramos NASA computer or amateur radio groups. The position of the balloon is periodically received, the course is tracked, weather information

is received, weather forecasts are made, the ultimate course is projected and calculations of the ballast of the balloon are conducted independently of the balloon crew members, and these results are periodically conveyed to the balloon.

6.2 Preparations until lift-off

The lift-off site would be along the Pacific Coast of Honshu. A point was selected from which the winter jet stream could be easily boarded, and where protection from the wind would be possible. The time of lift-off would be the winter, from November through March, when a stable jet stream (polar jet) could be expected, and when the weather would be stable and the ground winds would be moderate. Deviations in weather conditions were also considered during the lift-off period.

6.3 Balloon master

The balloon master with considerable experience in launching of large capacity balloons and in gas injection is responsible. The balloon master has total responsibilty during gas injection in the balloon and until the balloon is safely launched. The balloon crew and other people work following the orders of the master.

The work begins with preparations of the sealed capsule. Instruments, power source, food, water, ballast, emergency provisions etc. are loaded, and various tests are conducted. After determination of "GO" based on the final weather information, the capsule is connected to the balloon by a winch while held down. This is to prevent spinning or other problems due to a strong ground wind. Next, gas is injected into the balloon. After the completion of gas injection, the crew boards and a final pre-launch check is conducted by the crew following a check list. The amount of gas, ballast and buoyancy are checked.

After the completion of the check, the crew receives permission from the control tower, and the balloon master orders lift-off at the moment of greatest meteorological stability. The winch rope is released and the balloon is launched.

6.4 Maneuvering

Maneuvering of a zero pressure balloon (balloon with virtually equal pressure inside and outside) is accomplished by virtually the same method as that of a conventional sport gas balloon.

The balloon descends by opening the valve at the apex of the balloon, releasing some of the gas, while it ascends by discharging some ballast. However, direct release of ballast or opening-closing of the valve by pulling on a rope is impossible because of the sealed capsule. All operations are carried out by remote control from within the capsulre by electromagnetic valves etc. /51

Lift-off at a rapid ascent rate is not carried out because it is a manned balloon. The balloon ascends at a controlled rate while excess gas is controlled by the ballast.

6.5 Lift-off

The balloon would ascend to the optimum flight level after approximately 30 minutes of ascent at a controlled rate of approximately 5 m/s based on analytical results of pilot balloons and meteorological data. The time of lift-off is evening when there is no effect of solar heat as in the day in order to economize on ballast.

The crew members would conduct ATC contact, monitor the instruments, observe the state of the balloon and would confirm the flight path until the cruising flight level is reached. After the cruising altitude is reached and the altitude is stabilized, all equipment is checked, and the results are relayed to the ground support center. The crew members alternate monitoring of the craft on four hour shifts.

6.6 During cruising

The greatest work during cruising is maintenance of the altitude. Contraction and expansion of gas due to the temperature difference in the day and night must be contended with. The overall flight project is affected by the amount of ballast ejected during this time and the amount of gas discharged. A stable flight for a longer period of time can be ensured by economizing the amount of balloon and gas discharged.

Equipment which issues alarms to the crew should the upper or lower limits of the cruising flight level or the standard ascent rate be exceeded are incorporated in the altimeter and the ascent meter.

The responsibility of the crew during usual flight is to prepare logs pertaining to the hourly position, altitude, balloon state and amount of ballast, as well as to maintain contact with the ground support center at regular intervals and to receive meteorological information, forecasts and flight advice.

Another important item with maintenance of altitude is to maintain strength and mental faculties while fighting fatigue

under severe environmental conditions for prolonged periods of time. The crew must rest as much as possible while off duty.

6.7 Flight profile

A trans-Pacific flight from Japan to North America is projected to take approximately 100 hours, covering approximately 10,000 km at an altitude of 12,000 m. Enough food for two weeks would be loaded to ensure enough in the event of recovery on the sea.

There would be a two man crew, with people experienced in balloon maneuvering, flight communications and the flight air control system.

The balloon would be launched from eastern Japan at night, would would ride on the stratospheric jet stream at an altitude above 10,000 m if favorable currents are boarded, and would fly across the Pacific to North America. The crew would spend three or four days in the capsule, and would land in Oregon or California.

6.8 Landing

The landing site can vary from Alaska and Canada in the north to the western coast of Mexico in the south due to changes in the meteorological conditions.

Landing at night is avoided due to night surveillance conditions. First, the balloon would descend to an altitude of 2,000 to 3,000 m following instructions of the nearest control tower based on ground conditions at the landing site and meteorological information obtained from the ground support center, and the wind direction would be monitored while flying at a constant level and a landing site would be sought visually. The balloon would then descend to an altitude of 1,000 m at a controlled rate, and it would then descend at a controlled rate while the concrete landing site has been determined. The balloon would then descend /52 to 30 m in level flying two or three times until the final landing approach is carried out, and the balloon would make an approach at the descent rate of approximately 1 m/s after confirmation that landing at the site would be safe. The drag rope would be dropped while opening the gas valve, and the balloon would be detached by quick release immediately after the capsule touched ground. Thus, movement of the capsule on the ground would be arrested. When the atmospheric state near the ground is very calm, the balloon need not be released and landing could be accomplished by the capsule alone.

6.9 Landing in water

Landing on the water has been envisioned due to unexpected circumstances. The capsule has been designed so that it can

safely land on the water. The procedures in that case would be virtually identical with those in the case of landing on the land. After touch down and separation of the balloon, a sea anchor would be thrown overboard and the capsule would be steadied. Neither sail nor engine for navigation on the water was provided. The capsule would be recovered by helicopter or ship in the event of landing on the water.

6.10 Rapid landing (landing in water)

In the event that safe landing is impossible due to tearing of the balloon or some other unforseen occurrence, the altitude would be gauged, the balloon would be detached and rapid landing would be effected by the capsule using the large parachute for the capsule which is attached outside of the capsule. In the event of emergency in the ocean, there are no provisions for individual parachutes for each crew member after escape from the hatch.

6.11 Practice

There are many cases in which reliance on the judgment of the crew members is required. Practice by the crew and by ground support crews is the most important key to success of the project.

The crew of the balloon must have the ability to make calm judgments under various circumstances rather than have extraordinary physical strength. Extensive training using the capsule, including activity training within the capsule, practice on various devices and simulated descent to a safe altitude while receiving air under low humidity, low pressure in a decompression chamber, as well as practice while the capsule floats on water is essential. The final suitability of the crew would be determined on the basis of these tests.

6.12 Flight traversing the Pacific

Success in this flight would break the existing record for distance of manned balloon flights and the record for long term duration in the stratosphere. A new record for manned balloon speed would also be set since the jet stream is used.

This project would serve as the opportunity for the concrete development of future super pressure balloons and infrared heated balloons in the field of LTA.

6.13 Conclusion

This balloon flight is a project to send a message to the President of the United States and the Secretary General of the United Nations in an appeal to them to halt environmental destruction and to promote world peace as we face the 21st century, beset with a variety of complex problems.

[Data]

"Figure illustrating the shape of the balloon for crossing the Pacific and the structure of the gondola", and "List of weights of balloon equipment", devices. /53

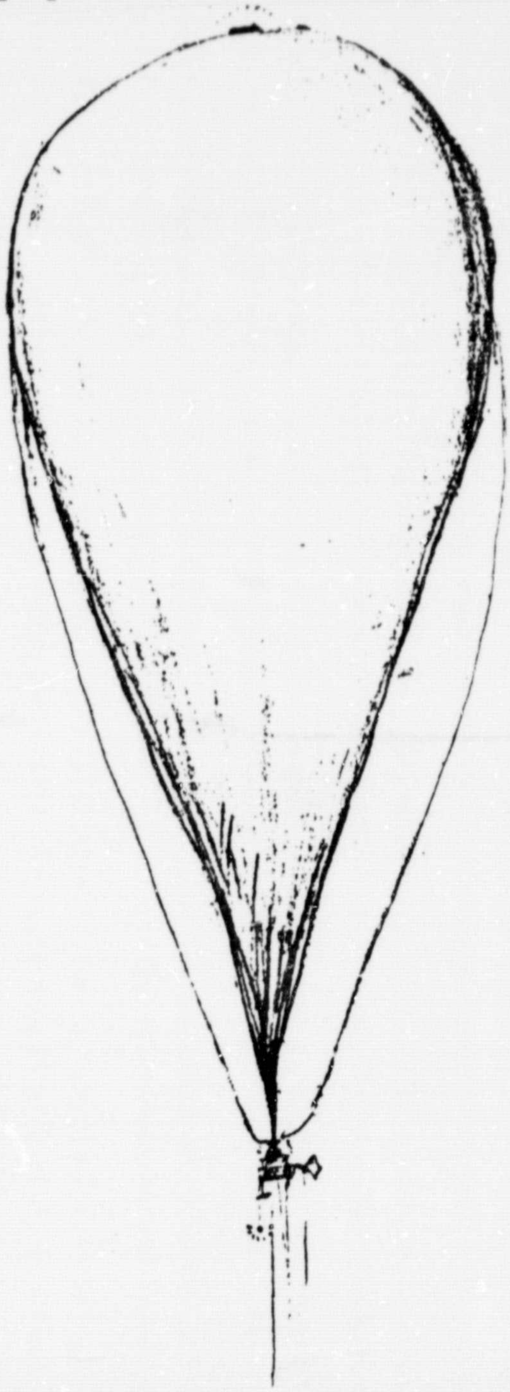


Figure illustrating the shape of the balloon for crossing the Pacific and structure of the gondola

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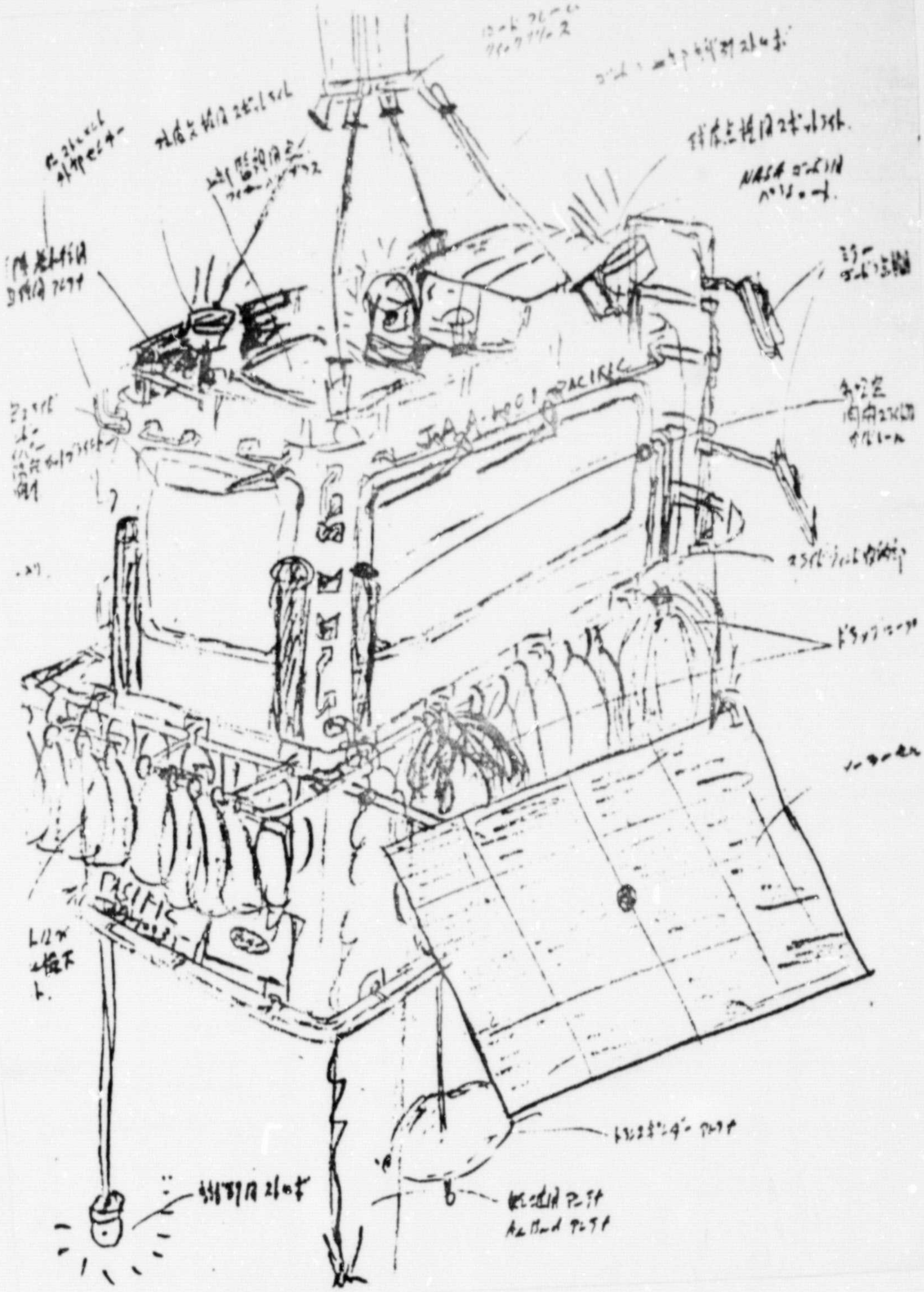

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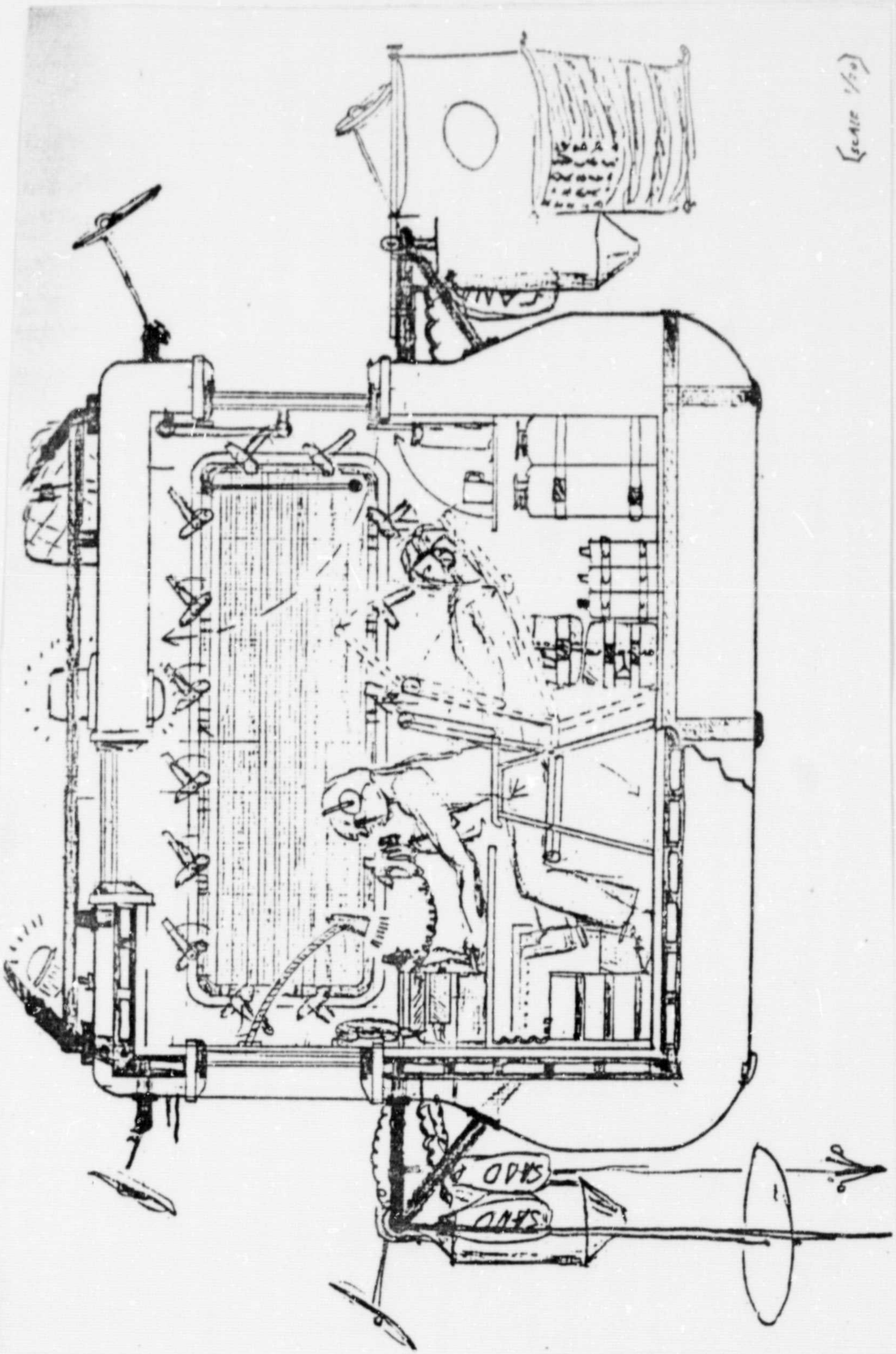

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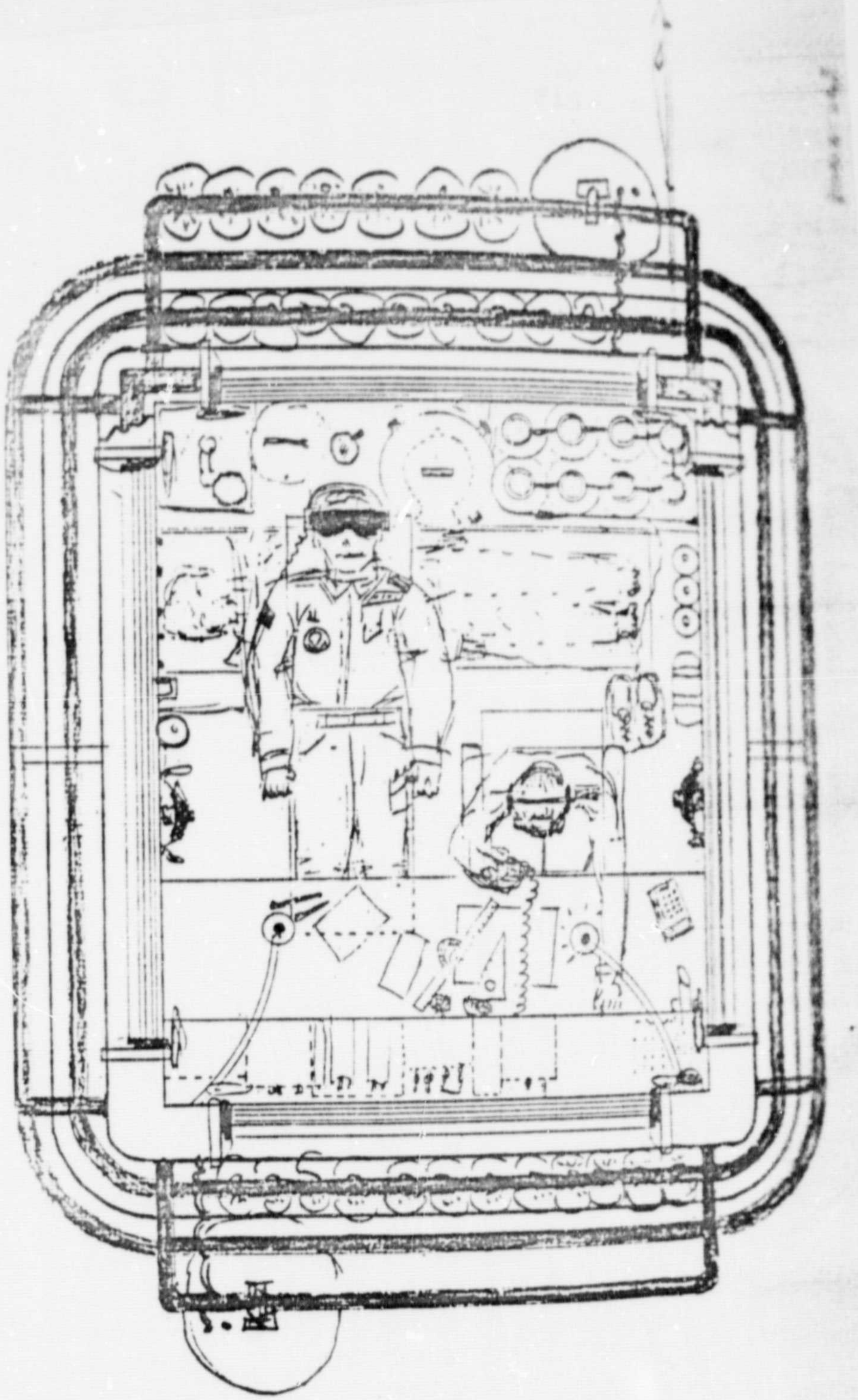

Table 2

Weight list balloon equipment, devices (units: kg)		
balloon skin B 15 (15,000 m^3)	80	
connection equipment, wires, valves	15	
quick release, four sets, 5 kg x 4	20	
load frame	5	
gondola wire	4	
Gondola		124
Duralumin or carbon fiber, frame	70	
FRP or GRP sealed wall	70	
foaming plastic, adiabatic, shock absorber, floatation material, air-tight windows, window frame	30	
double, sandwich structure, four layers, 10 kg x 4	40	
Crew		210
two men, 70 kg x 2	140	
clothes, installed machinery, shoes, harness, 5 kg x 2	10	
miscellaneous clothes for two men poncho, parka, down jacket, down pants, insulated cap, underwear, goggles, sunglasses, gloves	3	
schraf* 2 x 1.5 K = 3		
wet suit 2 x 4. K = 8		
helmet 2 x 1. kg = 2		
parachute (passenger use) 2 x 7 kg = 14	27	
Oxygen		180
liquid oxygen (with container) 5 liter capacity 36 lb (Gas 4150 l)		
mefabolicrate 800 ml/miss, 1152 l/day, taken as MAN		
6 day's worth x two men, 18 kg x 3	54	
regulator, valve 2m x 2	6	
mouthpiece, bellows pipe, body clip	4	
emergency use high pressure gas oxygen, mouthpiece, valve, tube 5 kg x 2	10	
Miscellaneous		74
two man lift raft, generator, survival kit	20	
fire extinguisher, three 3 x 3	9	
sea anchor	15	
parachute for descent of equipment 3 x 7 5 x 2	21	
folding mat, expandable, combined retractable aluminum ladder and temporary bed	10	
floor mattress for sleeping	2	
NASA parachute for capsule	25	
		102

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Communications, navigation support equipment,		
power source	5	
Ais Basd Radio (VHF)	3	
Ais Basd Radio, portable (VHF)	2	
ATC transponder	18	
omega	5	
HF radio, amateur band, marine band	3	
radio compass	1	
Emergency location transmitter	3	
antenna	15	
loran receiver	80	
power source, battery, AgZn, dry cell spare	20	
solar cell panel, + power source check circuit		
		155
Instrumentation		
altimeter two, 2 x 1 K	2	
ascent meter, fitted with audio two, 2 x 1.5 K	3	
altimeter in cabin two	1	
gas pressure sensor and indicator inside balloon	1	
thermometer, two systems inside balloon	0.5	
external thermometer, two systems	0.3	
internal thermometer, two systems	0.3	
O_2 partial pressure meter	5	
CO_2 partial pressure meter	5	
humidity meter, clock, tape recorder, tape spare	2	
flight recorder, two, compass	3	
		24
Tools A		
hammer, hatchet, saw, screwdriver set, large and small knives, air-tight sealing material, rubber tape, grease, silicon oil, grease, CRC, needle, cord	10	
Tools B		
soldering iron, radio bench, tester, fuse, various connector spares, spare wire, vinyl tape, measuring tape, green fuse, flashlight (large, medium, small)	5	
miscellaneous	4	
survival set 2 kg		
hood 2 kg		
cartridges, emergency set 1 kg		
binoculars 1 kg	6	
		25

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Stationery, calculator		
writing instruments, ballpoint pen, magic marker, paper, ruller, protractor, divider, cellophane tape, indicating sticker, slide ruler, calculator	2	
binoculars	1	
sextant	1.5	
conversion table		
air map, sea map, general map		
related frequency table, land bureau, sea bureau, aircraft bureau, meteorological communications		
log book		
weight, equipment list		
manual of flight auxiliary equipment		
radio manual		
IF NOT Q & A drill book		
almanac, constellation table	3	
		8
Water, food (for 10 days), lagging material, tray		
water, 20 liters	21	
food, delicacies, instant food, beer		
canned food, beverages, staples, side dishes, alcohol	20	
utensils, portable stove, fuel	10	
chemical warmer	5	
chemical refrigerant	5	
spare gloves	1	
tissue paper	1	
deodorant	1	
polyethylene bucket	1	
spare bags	2	
portable toilet	2	
		69
Separate stroboscope for night flight identification, 3 lamps x 4 kg	12	
Spotlight for illumination of balloon skin, equipment on basket	6	
Flag	1	
		19
Camera, 35 mm film, remote device, tripod	5	
16 mm film	15	
		20
Miscellaneous reserve weight		200
Total weight other than ballast		1210
Ballast: for automatic remote release		
for manual release	800	
lift-off ballast	800	

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7. Considerations pertaining to flight cost Chuta Wada /60

7.1 Selection of launch site

A basic condition is one where the high altitude jet stream can be easily boarded, but there are various other problems, including a site where the air control system would not be disturbed, a site where service is available from nearby, a site where transit is convenient etc. The most appropriate sites would be in north-eastern Japan (Figure 7.1).

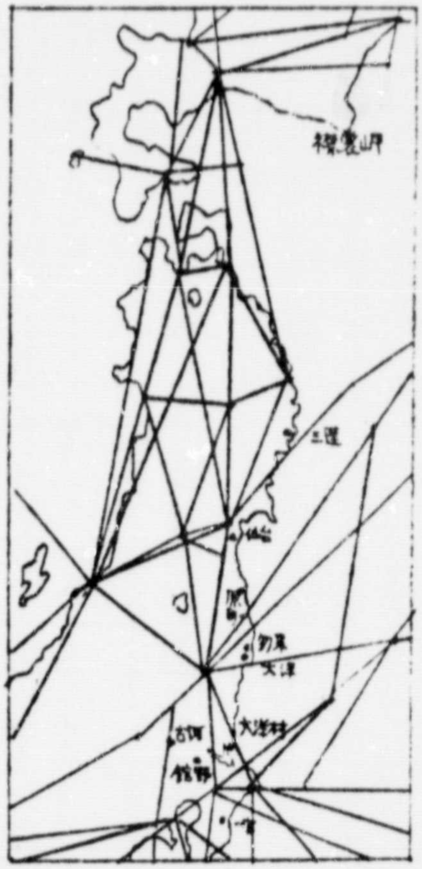

Figure 7.1 Air routes in north-eastern Japan (LOW/HIGH)

There were three sites where bombing balloons had been launched from Japan. According to the records, eastward movement began after ascent at a rate of 200 to 300 m/min.

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The balloon test site of the Space Flight Laboratory of Tokyo University was Taiyomura in Ibaragi Prefecture, followed by Haramachi in Fukushima Prefecture, and the balloon observation site in Miriku cho, Iwate Prefecture, was opened in 1971. It was selected as the site most remote from air routes, but today, even Miriku is only 20 km from routes (OTR1), and is becoming crowded. Only Cape Erimo in Hokkaido remains if the site were to be more than 100 km from air routes. Since there would be a tendency for the balloon to travel toward the Soviet Union if the site were too far north, caution is required just as in the previous case of bombing balloons.

The meteorological data are detailed at Sendai or Tateno (Ibaragi Prefecture) because there is a high level meteorological station where rubber balloons are launched periodically. For example, the indicated barometric pressure-mean wind direction (°)/wind speed (m/s) in the upper air at Tateno are as follows.

1 気圧面 \ 2 月	3 1月	4 2月	5 11月	6 12月
300 mb	267/46•1	270/49•9	258/50•2	262/59•4
100mb	267/35•5	267/38•2	261/36•1	262/42•6

1 barometric pressure
2 month
3 January
4 February
5 November
6 December /61

Tateno: 36'03' N, 140°08' E, mean values in 1971-1975 (21 hours) [Rika Nenpyo] 1981

The vicinity of Furukawa (Ibaragi Prefecture) expands broadly over ponds and fields, and it is a region of enthusiastic hot air ballooning. Ibaragi Prefecture, Tochigi Prefecture, Gumma Prefecture, Saitama Prefecture have common borders, the Tone River and Watarase River flow on the sides, and this region is north of the Kanto plain. It is situated in the middle of the practice air region for civil aviation "Kanto Koshinsetsu 1-1". (The height of this air region is up to 2,000 feet [Note 1]). In addition, the air route [B 14] in the upper air passes through in

[Note 1] The altitude is generally expressed in feet while the distance is expressed in NM (nautical miles) in current aircraft. Instruments also give such readings. The figures are converted to metric units below as required. (one foot = 0.305 m, 1 NM = 1,852 m).

the north-south direction, and lies on the KOGA point (KOG). The minimum altitude of B 14 is 5,000 feet on the north side and 4,000 feet on the south side.

A view of the complications in the air routes reveals that detection of a site further removed than this one would be very difficult. Consequently, past flights were made in close contact with control organizations while maintaining vigilance for gaps between aircraft. For that reason, balloons must allow for the rules of air control, and sufficient data must be sent to the control organizations, and the advice of the controllers must be heeded. However, beacons and transponders must be on board in order to facilitate identification, radar reflecting tape must be affixed to the outer surface of the air sac. In addition, the rate of ascent should be as great as possible, and reaching a high altitude in a very short period of time is desirable.

The conditions for selection of a launch site would be relaxed accompanying such measures. For example, the Furukawa area could be selected, and balloons could be launched from this area with the cooperation of aerial sportsmen. The vicinity of Tokyo would be advantageous in terms of support facilities.

7.2 Launch period

The meteorological conditions must be selected first because they determine the launching operations because of atmospheric disturbances on the ground as well as at high altitudes and on the way to such altitudes. In general, launching is preferable immediately after the passage of high atmospheric pressure. That is because ascending air streams behind a high pressure front can be utilized [Note]. Launching immediately after passage of a low pressure system or when such a system is nearby would be unsuitable because of the great disturbance.

Launching is generally not appropriate when a high pressure system is approaching, but these conditions can be reversed when flying at low altitude. That was the case in the Atlantic crossing of the Double Eagle II, when a launching site was selected intentionally before a a ridge of pressure. This was similar to surfing before a high pressure system. While this has no relation to the case when the high altitude jet stream is used, it is an interesting method of skillfully utilizing the wind force at low altitudes.

[Note] As for the properties of atmospheric pressure position, air eddys are greatest in a trough while they are slightest in a ridge. Consequently, there would be ascending streams on the eastern side of a trough (western side of a ridge) and descending streams on the western side of a trough (eastern side of a ridge).

In addition, the launching time should be after sunset if possible. The air is calm in the early morning and at sunset, but when economizing of ballast for flight is considered, launching in the evening followed by ascent is preferable because the flight can continue for prolonged periods without dropping ballast. Furthermore, the period from late at night until the following morning is the period when operation of airlines has ended and when the skies are fairly empty in terms of air traffic control. /62

7.3 Ascent and free buoyancy

Free buoyancy is that buoyancy in addition to the buoyancy of the gas which lifts the balloon. The balloon ascends at a higher rate with greater free buoyancy and the balloon merely floats if the buoyancy is zero which is the state when an equilibrium altitude is reached. Actually, this is determined by the amount of gas charged at the time of launch.

A view of actual results in observation balloons indicates that the ascent rate is slow when the free buoyancy is very low, the ascent rate declines at a height of several km and the preset level is not reached, but this is believed to be due to the fact that the reduction in gas temperature due to adiabatic expansion during ascent is far greater (a rate of 8°C/km with He) than the decline in the external temperature. In the opposite case, the entrance and removal of heat inside and outside of the air sac becomes extreme when the rate of ascent is too fast, and the air resistance due to reduction in the ambient pressure declines. Thus, acceleration occurs in the upper air and rupture takes place. The occurrence of accidents as in the case of observation balloons can be avoided since the rate of ascent can be finely adjusted in the case of a manned balloon.

Free buoyancy is usually expressed by a percentage of total weight. This is usually approximately 10% in observation balloons, and is selected so that the rate of ascent would be 250 m/min (weight 150 kg). Generally, a range of 200 to 300 m/min is used most often. The altitude reached if an observation balloon with a volume of 15,000 m^3 and a weight of 3,000 kg were planned would be 160 mg in the case of He, and the free buoyancy would be approximately 6.6% if the ascent rate were 300 m/min. In short, a figure of approximately 200 kg is required.

An altitude of approximately 15 km was reported to have been reached in approximately 25 minutes during the first ascent into the stratosphere in 1931 by Professor Piccard. The rate of ascent would have been 600 m/min based on reverse calculations, which would be very fast. The free buoyancy was approximately 30%.

A lower altitude than ours has been selected in the case of the project by Americans including Rocky Aoki, and the rate of ascent is also slow. The initial rate of ascent is 200 feet/min (60 m/min) to 20,000 feet (6,100 m), followed by a more gradual ascent, finally reaching the cruising altitude of 28,000 feet (8,540 m).

The rubber balloons launched at the Tateno high level meteorological station ascend at the rate of 300 m/min, and while there is seasonal variation, it generally takes approximately 40 minutes for the altitude of 12,000 m to be reached. A view of the horizontal distances traversed indicates movement of 20 to 40 km eastwardly. As a result, there has been no accident with aircraft. Furthermore, the time required to reach the desired altitude and the distance from the launching point would be far less if the ascent rate were the 600 m/min of Professor Piccard.

Based on the aforementioned points, the balloon of this project should have a high rate of ascent of 300 m/min to 600 m/min, and the set altitude should be reached in the shortest possible time.

7.4 Examination of direction of flow and arrival site

Since high altitude winds generally circumvent the globe centered on the poles while fluctuating considerably, flow occurs in directions lying on parallels. Consequently, the movement of a balloon which progresses on such winds would be isolatitudinal. This would differ considerably from HTA which would fly along a great circle course which would be the preferred shortest distance.

For example, a view (Figure 7.2) of the axial direction of the jet stream which moves at high altitudes of 300 mb in the winter reveals this. The jet stream which passes over the Japanese archipelago somewhat south of 40 degrees north latitude /63
reaches North America northward of the 40th parallel after crossing the Pacific Ocean.

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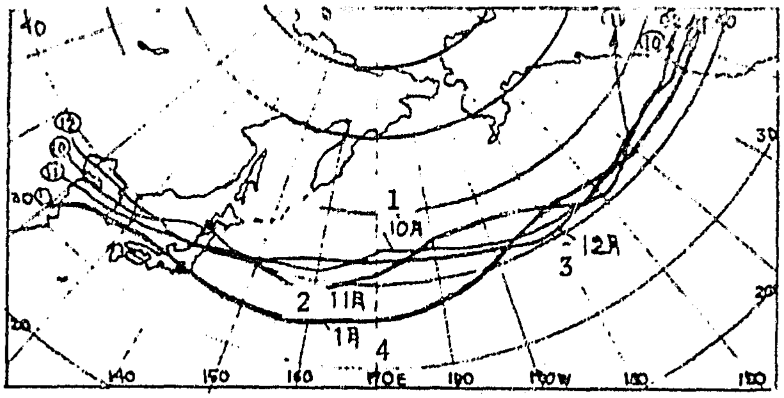

Figure 7.2 Example of axial changes in the jet stream (300 mb)

1 October
2 November
3 December
4 January

This can also be stated based on the records of the arrival points of bombing balloons sent by the Japanese army at the end of World War II or based on the "Angel Report" on the tests by the United States Army on trans-Pacific probes from 1957 to 1959. The route of balloons is concentrated in that direction.

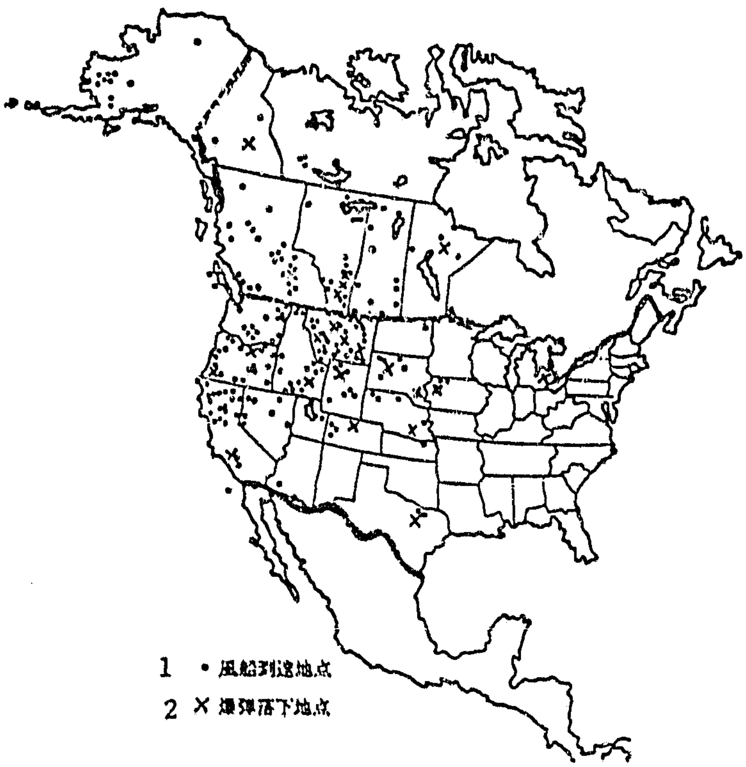

Figure 7.3 Traces of bombing balloons
1 point of arrival of balloons
2 point of descent of bombs

We will attempt analysis based on a figure (Figure 7.3) illustrating the points of arrival of the balloons and the points of descent of bombs. Here, North America has been divided isolatitudinally, and balloons from identical latitudinal /64
regions were concentrated in the same latitudinal group on the coast or in the center of North America. In short, the extent of balloon concentration and the region of concentration can be examined at any area of the arrival frontage viewed from the Pacific side.

The data [Note] regarding the details of arrivals in America of 285 bombing balloons have been confirmed, and appropriate

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[Note] "A Report on the Research of the Bombing Balloon (Oct. 1945)" and others.

divisions into isolatitudinal segments from Alaska to Hawaii would be appropriate for providing an understanding of the characteristics (Figure 7.4).

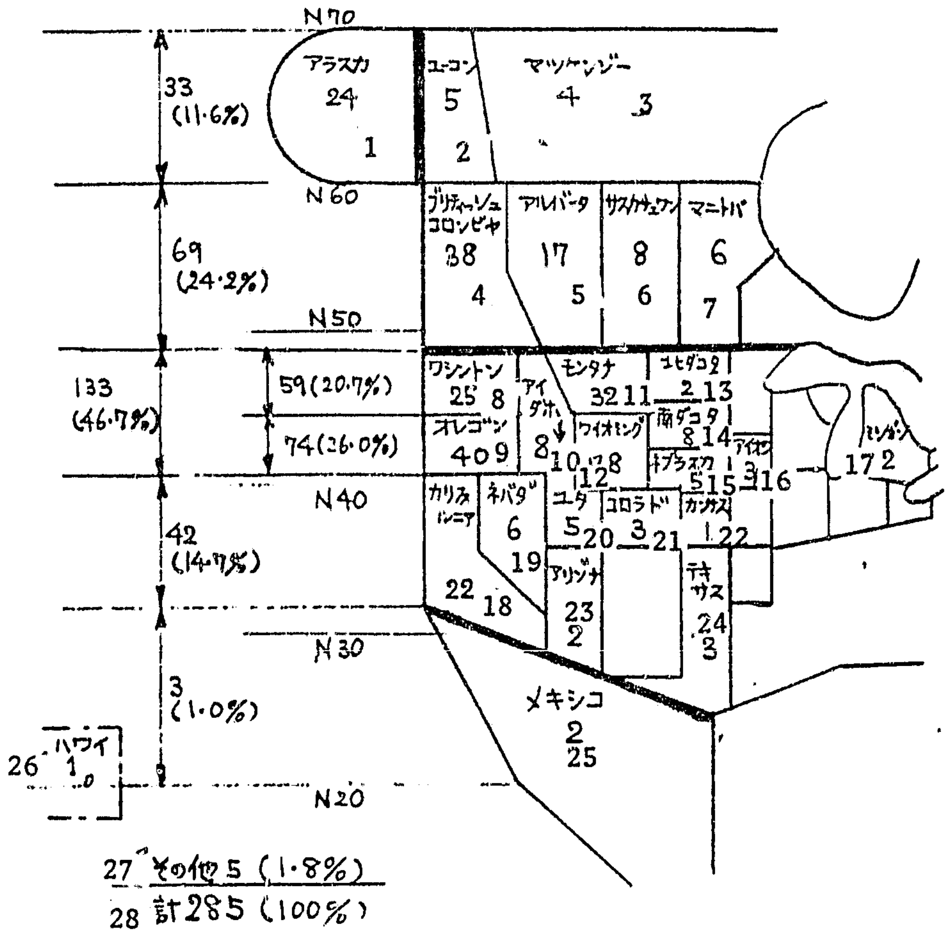


Figure 7.4 Arrival frontage of bombing balloons (rate viewed from Pacific Coast side)

1 Alaska	2 Yukon
3 Northwest Territories	4 Brit. Columbia
5 Alberta	6 Saskatchewan
7 Manitoba	8 Washington
9 Oregon	10 Idaho
11 Montana	12 Wyoming
13 North Dakota	14 South Dakota
15 Nebraska	16 Iowa
17 Michigan	18 California
19 Nevada	20 Utah
21 Colorado	22 Kansas
23 Arizona	24 Texas
25 Mexico	26 Hawaii
27 miscellaneous	28 total

Approximately half of the total, in short 133 (46.7%) were concentrated in the area from the 40th parallel to the 50th parallel. Washington and Oregon are the states facing the Pacific there, but the jet stream continues inward. Oregon received the highest number of bombs at 40, which was 26.0% of the total, virtually one out of four bombs sent. The north-south distance between the 40th and 50th parallels is broad, but the concentration tended to be on the north side. Specifically, the proportion of bombs drifting toward Canada was higher, and the possibility of arrival north of the 40th parallel is great.

If the target site could be narrowed, the vicinity of Portland (Oregon) would be a candidate. It is south of Seattle and lies 45° 35" north latitude. It is a center of transportation. If the vicinity of Furukawa (Ibaragi Prefecture) at 36° 10" north latitude were the departure site, the distance travelled would be 10,000 km. (It would be approximately 7,800 km if the great circle course were followed, but the isolatitudinal course is longer). The duration would be approximately 60 hours if a 180 km/h jet stream were boarded at a constant rate of 50 m/s. /65

San Francisco or Los Angeles are south of the 38th parallel, and the possibility of wind in that direction is slight, although landing in that vicinity may be possible if slight guidance of the direction near North America were effected.

Based on the prevailing wind direction, the region of arrival would be from the 40th to the 50th parallel in North America, and the possibility of movement farther northward is great. The desired region of arrival would be the 45th parallel.

7.5 Descent and manipulation

Preparations for descent were made from noon to allow a margin of error since the balloon gradually cooled as the sun approached the horizon when Piccard returned from the stratosphere. The rate of descent ranged from 1.5 m/s to 2.5 m/s, and the rate was finely adjusted when the earth surface was approached by discarding ballast, opening valves and operating the cords. Furthermore, electrostatic discharge occurred when lines were released.

The rate of descent was 1.25 m/s when traveling through clouds in the case of the Double Eagle II. A rate at which the clouds could be penetrated was selected since the heat of

the clouds would be reflected if the rate were too slow. When the ground surface was approached, the rate was reduced to 1.0 m/s, and fine adjustments were then carried out.

Use of the cargo parchute would be determined on the basis of various conditions, including the wind speed in the area, the state of the air sac and other systems as well as the state of the landing site/landing in the water. If the area is very tranquil, the descent rate may be finely adjusted without separation of the air sac, and soft landing using the float as a cushion could be carried out. A parachute is used to recover the measuring instruments in the case of an observation balloon, and descent from an altitude of 12,000 m at a rate of 5 m/s would take approximately 21 minutes*.

There is a seven hour time difference between Japan and the Pacific coast of North America. Consequently, if departure were at 5:00 P.M. from Japan, arrival in North America after a planned 60 hours would be at noon. Even if departure were at 10:00 P.M., arrival would be at 5:00 P.M.. A suitable margin of time for communications to find a landing target would also be required.

8. Present state of ATS (Air Traffic Service) and its utilization Chuta Wata /66

8.1 Actual ATS

There is a wide range of organizations assisting aircraft at present. For example, the Air Traffic Control (ATC) system prevents collisions and supports a regular flow of aircraft, the Flight Information Service provides weather and traffic information while the Emergency Warning Serivce provides support during emergencies. These may be summarized as the Air Traffic Service. Since the balloon of this project is not legally an aircraft, it is not subject to direct restrictions, but the ATS must be thoroughly comprehended and cooperation is essential to facilitate a smooth flight. This is also very important to ensure safety.

The air above the globe is divided into regions termed "Flight Information Regions" (FIR). The region controlled by Japan is divided into the "Tokyo FIR" and the "Naha FIR". As the United States is approached, the Pacific is divided among the adjacent "Honolulu FIR" and "Anchorage FIR", followed by the "Oakland FIR", Vancouver FIR" etc. (Figure 8.1)

When a balloon is launched and proceeds over the Pacific, the region from the sea level to 5,500 feet is the "Ocean Control

* trans note. Such a descent would actually take approximately 40 mins.

Region". For example, this region would be entered approximately 250 km east from a launch site at Furukawa (Ibaragi Prefecture) or south of Hachijojima. Regularly scheduled aircraft etc. advance to the next air route while reporting successive positions, but a balloon would first make contact with "Tokyo control", and would continue to float east while issuing a report every hour. The position could be accurately determined if Omega navigational equipment were on board, and the position could be automatically tracked on the ground if the emergency system utilizing satellites were on board. Furthermore, information could be relayed to the next control center responsible after leaving the Tokyo FIR, and the flight could be continued.

There are various rules depending on the altitude. For example, the altitude units used are the flight level (FL) above 14,000 feet (4,270 m). (For example, FL 140 would be an altitude of 14,000 feet exhibited by a number of three units). Moreover, a flight must be carried out with a transponder of VFR (visual /67 flight method) or IFR (instrument flight method) above 15,000 feet over Japan. The altitude of 24,000 feet is the seam in the control region, with higher altitudes termed the high altitude control region and lower altitudes termed the low altitude control region. The cruising altitude is precisely set. As a rule, at high altitudes above 29,000 feet (8,845 m) in the easterly direction (compass reading from zero to 180 degrees), altitudes of 30,000 and 4,000 feet multiples using VFR or altitudes of 29,000 feet and 4,000 feet multiples using IFR are the rule, while in the westerly direction (compass reading from 180 to 360 degrees), altitudes of 32,000 feet with 4,000 feet multiples using VFR or altitudes of 31,000 feet with 4,000 feet multiples using IFR are the rule. In short, a minimum vertical separation of 1,000 feet (305 m) is employed.

Furthermore, a protective region of 50 NM (92 km) is maintained on both sides of an air route in oceanic control, and two aircraft flying in parallel would be separated by at least 100 NM (185 km).

Current aircraft are controlled with such collision protections in mind. The flight of our balloon project must also bear these rules in mind.

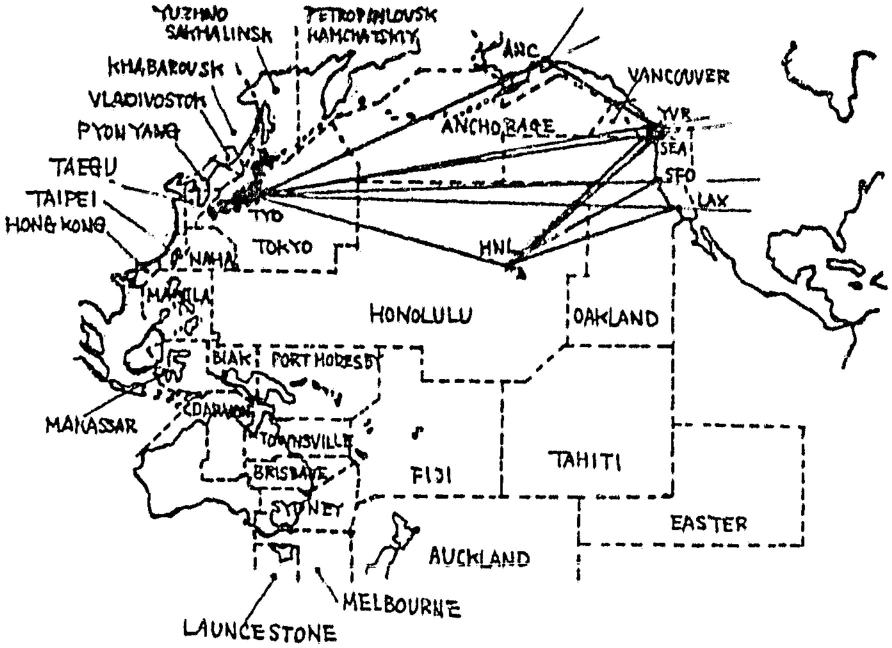


Figure 8.1 FIR (flight information region) over the Pacific Ocean and air routes from Japan to the United States.

8.2 Complicated air routes

The air routes over the Pacific linking Japan and the United States are complex. For example, there are great circle routes non-stop to New York and a route via Anchorage, routes to Vancouver, Seattle, San Francisco and Los Angeles as well as routes to various cities via Honolulu. Routes from the western Pacific other than Japan and from the south Pacific to the United States are also entwined with these. Judging from the wind direction, there is a great possibility that the course of the balloon of this project would be in the region between the northern air course linking Japan and Anchorage, and the southern air route linking Japan, Honolulu and California (Figure 8.1).

For example, there is a famous route [A90] in the eastward route toward Anchorage. Regularly scheduled jets fly by IFR, and
the altitude above the ocean is often FL 370 (11,285 m) or in /68
that range. Caution is required since they are at levels similar

to the cruising altitude of the balloon of this project, including adjacent FL 330 (10,065 m) and FL 410 (12,505 m). On the balloon side, the altitude must be adjusted as well as possible bearing in mind that the balloon is at the mercy of the winds. A level of FL 380 (11,590 m) or FL 420 (12,810 m) which is the easterly VFR altitude should be selected, and precise reporting of position to the control agencies must be carried out for safety. (Trials were first conducted in the northern hemisphere in the case of the ghost project (1966) in which long term observation around the south pole by balloon was conducted, but the south pole was ultimately selected due to the complexity of the air routes here. This indicates the absolute necessity of caution).

The effects of the jet stream are too great to be ignored by regularly scheduled jet aircraft flying the Pacific. For example, there is a time difference in service between Japan and Anchorage in the winter, with the eastward flight more than one hour faster. It is not unusual for a time difference of more than two hours to exist in the case of direct service to San Francisco or Los Angeles. While there are variations depending on the conditions, including altitude and season, the flights are generally faster in the direction of large atmospheric circulation.

The route usually chosen by single engine or twin engine light aircraft is Tokyo to Wake to Honolulu to Los Angeles or San Francisco. Since the altitude is only 5,000 to 6,000 feet, there is no line effect. Generally, extra fuel tanks are loaded in the fuselage, and there is a single pilot. The equation is primarily HF (short wave transmitter-receiver) and ADF (automatic direction finder). There are also cases of a sextant for back-up. Since VHF (very short wave transmitter-receiver) reaches only 250 NM even at an altitude of 40,000 feet, HF is used in flying the Pacific Ocean. Furthermore, an ordinary ADF would be adequate to receive radio waves from large power transmitters.

In addition, there are many cases of amateur pilots crossing the Pacific Ocean using single engine planes. That is because of the great advance in reliability of aircraft engines with the advance of technology following the war. There is also a case of a home-made aircraft with a 210 horsepower engine flying from the United States to Japan on the polar course (1976). Cold Bay, 850 km southwest of Anchorage, was selected as the starting point, and from there, a flight of 4,500 km while following NDB (nondirectional radio signal) was made. The flight was made at low altitude by IFR and the conjecture navigation method, and apart from the skill of the pilot, this illustrates the extent of ATS in modern aviation.

In sum, the conventional rules of aircraft must be thoroughly understood in balloon flying, and careful attention must be paid to avoid turbulence. Attention must be paid to contact with control organizations, thereby promoting safety.

8.3 Air rescue organization

When an airplane has not reported a position or arrived at a site by a predetermined time, an emergency state is issued and a search is automatically initiated. The details of this emergency state are divided into the following three stages:

(1) stage of uncertainty
(2) stage of warning
(3) stage of accident

The investigation and search widen as the state progresses /69
through these stages, and the countermeasures become more detailed.

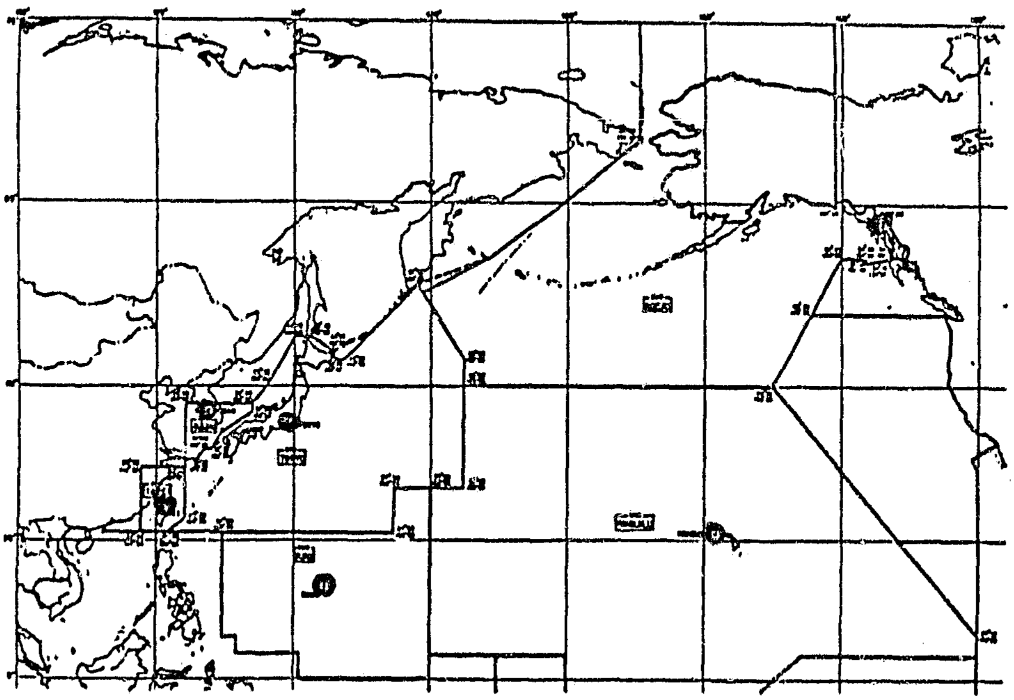


Figure 8.2 Locations of adjacent SRR (search rescue regions) and RCC (rescue coordination center)

Information pertaining to an aircraft in an emergency state is first collected at the air control center (ACC) with jurisdiction, and is relayed from there to the relief coordination center (RCC) where concrete measures are taken or contact is made with the U.S. Army relief organizations. The Pacific Ocean is divided into numerous search relief regions (SRR) (Figure 8.1) to strengthen an international relief system. The regions adjacent to the Tokyo SRR from north to south are the Juneau SRR, Honolulu SRR and Guam SRR. Each of these is responsible in its area.

A balloon flight can receive the same services if it is in close contact with these aircraft control organizations. Thus, a safe flight is possible without relying on coastal reserve units.

Professor Piccard carried an HF of 7 W output for contact-rescue during his ascent to the stratosphere 50 years ago, and contact was said to be excellent in Belgium even at a separation of 700 km. Maintenance of the transmitter in good conditions is very important for the case of an emergency. During the second flight in 1932, members of the Italian Army greeted the balloon upon its descent, and this may be considered to be part of international support activities.

A view of the state in 1978 when the Double Eagle II crossed the Atlantic reveals that the "amateur radio" played a major role. It was used not only for connection, but would have been used if a difficulty had been encountered. A ham radio was included among the items loaded in the "Trans-Pacific Flight /70
1981" in imitation of this. Furthermore, contact was maintained with the rescue unit of the military as well as with ATC in the flight of the Double Eagle II, thereby ensuring safety.

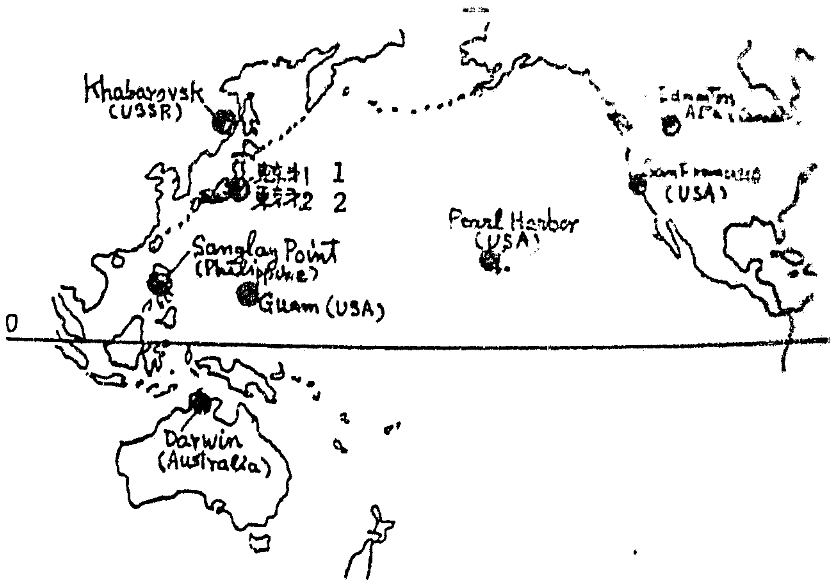


Fig. 8.3 Main FAX broadcast centers in the Pacific
1 Tokyo 1 2 Tokyo 2

In this project, emergency rescue equipment utilizing satellites such as the ARGOS system were loaded on the balloon. Thus, the precise location of the balloon could be automatically tracked by ground stations. Since this is a separate system from that of position reporting, it is expected to be very effective in a rescue.

8.4 Aviation meteorological service

Various meteorological information is provided to aircraft in flight by the control centers. For aircraft flying above the troposphere and below the stratosphere, anticipated weather maps based on 24 hour forecasts are provided at fronts of 300 mb (approximately 9,000 m), including the front at 500 mb (approximately 5,500 m), at 250 mb (approximately 11,000 m) and at 200 mb (approximately 12,000 m). The jet stream can be utilized based on two broadcasts daily. In the case of a balloon, the maximum height is judged considering the current position, and the balloon is assumed to ascend riding on winds at that level. The method generally used involves transmission of the altitude based on the judgment from the weather maps to the balloon in flight from the ground support organization, but the balloon carries the "Weather FAX" image receipt equipment. Thus, the altitude is selected with the judgment of the crew members. (In the case of conventional aircraft, the difference is that landing involves GCA or ILA.)

C-2

In the case of ships, most foreign vessels are provided with facsimile equipment, and they receive information in the form of weather maps. ("JAX-25 form" is well-known equipment.) This is far more active than mere acting in accordance with the indication of movement. This burdens small weather stations. If equipment for aircraft were developed in this project as well, it would definitely be carried on board. /71

There are many FAX broadcast centers around the world, and those in the vicinity of the Pacific Ocean which can be utilized in this project are as follows: (Figure 8.3).

The frequency is short wavelengths primarily from 3 MHz to 22 MHz, and each has its own call letters. Examples are JMH (Tokyo No. 1), JMJ (Tokyo No. 2), NPM (Pearl Harbor), NMC (San Francisco), RHB-RHO (Khabarovsk).

There are various types of weather maps, including analytical maps, forecast maps, average maps and high altitude data maps. Those maps believed to be of special relation to this project are high altitude analytical maps (AU) from AS (Asia), PN (North Pacific) and NA (North America). In addition, bands of upper level clouds accompanying the jet stream are easily determined by infrared (IR) images in cloud photographs by weather satellites. These provide good data for making conclusive judgments.

8.5 Omega/VLF navigation

The entire surface of the earth can be covered by the hyperbolic method using ultra-long waves of 10 kHz to 14 kHz. The radio waves are propagated from 15 m below sea level to an altitude of 60 km-90 km. At present, a compact device weighing more than 10 kg has been developed, and it can be carried on light aircraft and on helicopters.

The earth can be covered by eight broadcast stations, and networks of two series have been developed at present. One consists of eight Omega stations operated by the U.S. Coast Guard and one consists of eight VLF stations operated by the U.S. Army Figure 8.4).

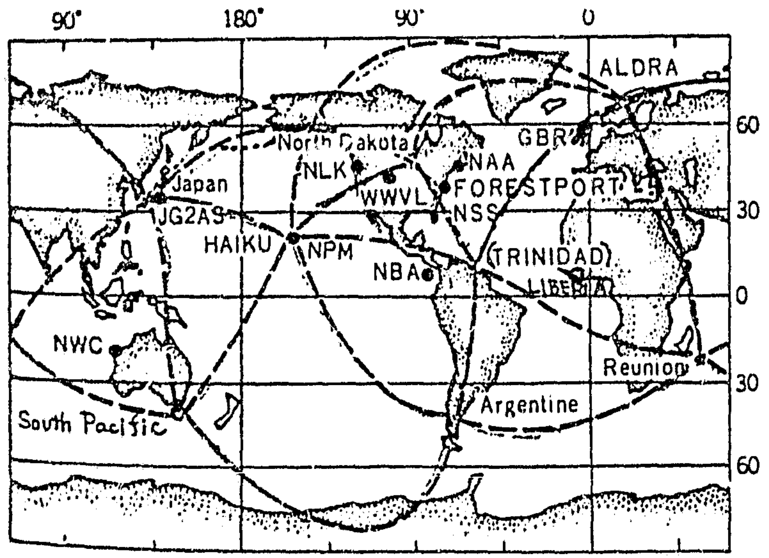


Figure 8.4 Omega broadcast stations and their base lines. Call signs for the VLF stations (•)

A view of the navigational equipment which has been produced (e.g. GNS-500) reveals it to be a completely automatic system in which the great circle course has been calculated and the compass bearings have been set. It has great capabilities. Initially, the current latitude and longitude are input, and the internal computer calculates the position every second using Omega stations and VLF stations. As the aircraft travels, the movement of the aircraft can be judged from the movements relative to the station, and the position can be determined. The capability is 72
comparable to that of INS (inertial navigation system). This equipment would also be carried on the balloon in this project.

There are examples of meteorological observation balloons which utilize Omega radio waves to determine their position. Radio waves are received by a doublet antenna suspended by rope from below the gondola in the case of a balloon floating at an altitude of 27 km. Subsequently, these are transmitted to earth via telemeter waves after amplification. Omega receivers for

ships are used virtually as is phase difference detection on the ground. There are five omega stations used; the Norway station, the Hawaii station, the North Dakota station, the Reunion station and the Tsushima station in Japan. Groups of curves can be formed by combinations of these, and the respective lane courses can be determined.

9. Anticipated problems and safety measures Chuta Wada /73

9.1 Accident in LTA vicinity

Professor Piccard ascended to the stratosphere twice, the first time on May 27, 1931 (altitude of 15,781 m) and the second time on August 18, 1932 (altitude of 16,201 m), and the problems encountered are indicated below.

[Problems pertaining to structure and design of equipment]

° The pulleys could not operate because the line system for the safety valve became tangled, rendering the valve inoperable (No. 1). ← Somehow actuated and landed.

° Internal humidity gradually increased (No. 1). → Frost inside cabin, → water ecaped and insulation was poor.

° The wiring system for the motor which turned the cabin shorted during lift-off (No. 1). → The interior became too hot and dry.

° The exterior of the cabin was painted white (No. 2). → Here, the interior became too cold and the temperature ranged from 0°C to -12°C.

° Air leaked in the vicinity of the ballast release equipment (No. 2). ← Became soaked in oil and stopped.

[Problems during lift-off and handling during mooring]

° Distortion in the cabin due to overturning from the stand and turning due to wind (No. 1). → Air leakage from seams and drop in pressure within cabin due to air leakage resulting from snapping of the mount for the electrometer. ← A putty of oakum and vaseline was covered with insulating tape. ← Liquid oxygen dribbled on the floor and raised the pressure in the cabin.

° The mercury manometer broke, leaking mercury (No. 1). ← Sucked to the lower atmospheric pressure outside of the cabin by a rubber hose.

° Adhesion of water with the night dew during mooring (No. 2). → Calculated loss of 200 kg. → Water dripped from the air sac during ascent. → Transmitted along the exterior of the cabin as water droplets during descent also.

° The wind swirled since the shape of the lift-off site was an open square (No. 1). → In the case of No.2, the site was modified to a depression which was enclosed by hills and which was not struck by the wind.

[Problems during flight for environmental reasons]

° The automatic recording barometer outside of the cabin ceases to operate because of the cold temperatures (No. 1).

Countermeasures would be instituted following an alarm, and the following measures would be effective:

° When water flowing along the air sac freezes at the gas pipe aperture, opening becomes impossible. A structure which does not collect water is essential.

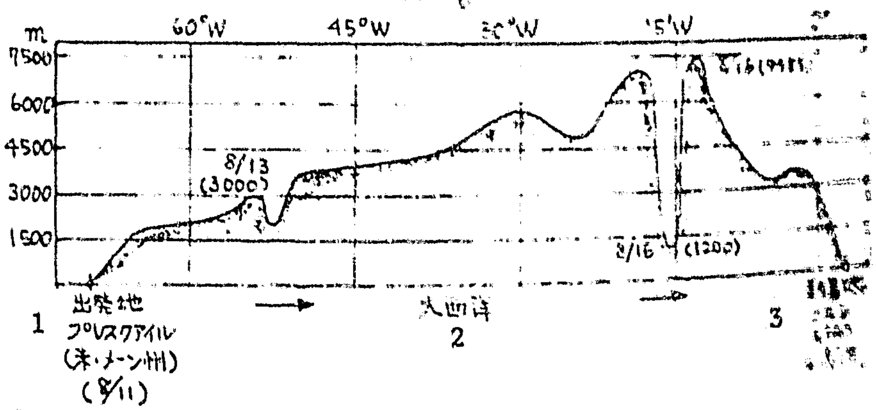
° The valve of the oxygen system can freeze and ice can block the passages, causing problems. Caution is required in the design.

° Since liquid oxygen has dangerous properties, discharge of excess amounts is preferable before landing.

° In No. 1, an aneroid barometer was used as the altimeter, but in No. 2, this was replaced by three mercury altimeters. There are also two automatic barometers (for FAI recording) on board.

° The aluminum panels of the cabin are painted with "white enamel". Corrosion due to mercury from a broken barometer on the floor would be prevented by this paint.

° A warning of "thunder" is issued in an H_2 gas balloon /74
especially. Precautions are taken to avoid thunderstorms during ascent and descent. Thus, a flight could be terminated without trouble involving static.



Change in state of Double Eagle II during flight
1 departure (Maine, 8/11) 2 Atlantic Ocean
3 arrival, (France 8/17)

A view of these cases indicates that back-up systems should be provided for unforseen circumstances. In addition, a dry state must be provided to avoid dew formation for ease of handling, and overturning or dropping must be prevented.

The first successful flight of the Atlantic by the Double Eagle II (August 17, 1978) was the second attempt after a failure the previous year. In No. 1, the flight ended in an emergency landing in the water after 65 hours, 14 minutes due to radio failure, extreme cold and rain in the open gondola. Based on that experience, the second attempt was made with equipment to protect against the cold, including thick clothing, electrically heated socks and button gas heaters, as well as water repellent radio equipment. The principal problemss were as follows.

[Cold!]

° It was extremely cold because of the open gondola.

° The sand in the ballast sac frozen. After smashing it with a hammer, the sand was dropped.

° Snow fell in the vicinity of the gondola in the morning. Particles of ice covering the air sac melted in the sunshine.

[Fight with the altitude]

° The balloon flew while being pursued by strong winds. It was lifted rapidly by ascending air streams to 6,000 m and then fell to a low altitude of 1,200 m on a descending air stream like a slide, followed by ascent to 7,500 m. Large amounts of ballast were lost through such sudden altitude changes. The hang glider, life raft, film cans, radio equipment etc. were all lost. A view of the flight altitude record published subsequently [Note] reveals that this was a true struggle. (Refer to figures).

[Communication impossible]

° The VHF (ultra short wavelength receiver) broke, and reception was possible but transmission was impossible. Since an amateur radio could be used, contact was made with British ham operators and they served as intermediaries.

[Mechanical defects]

° Since the oxygen masks which were provided used regulators rather than the compression type, intense drawing was required for use, and the crew became especially tired as a result. /75

A view of the aforementioned conditions indicates that an open gondola is unreasonable for long term flight at high altitudes. The conclusion that a sealed gondola is essential is inescapable from various angles.

According to "Historical Airship" and other data, eight of the twenty airship accidents from LZ 14 (1913) to LZ 129 (1937) were due to the explosive characteristics of H_2 gas (including

Note: Readers Digest "The Adventure of the Balloon Double Eagle" (June, 1980).

secondary causes). The overwhelming majority of the accidents were due to meteorological conditions such as storms or wind turbulence. The response is slow because the body is large, and sudden evasive maneuvers are impossible.

Since discharge of ballast and of gas is unavoidable when ascent and descent are repeated in severe wind currents, these stocks are lost in a very short time. Their loss is the limit of flight. This capacity would be greatly increased by adopting either a baronette (air chamber) structure or a super pressure mode in design, yet there would be no change in the great danger at low altitudes, especially near the earth's surface.

The essential measure which should be adopted is to direct our concerns to the problems of utilizing LTA for the behavior at altitudes above the troposphere.

9.2 Problems in Pacific Ferry

There are many examples of air transport via small aircraft from Japan to the United States via Guam, Wake, Midway, Honolulu etc., and of flights in the opposite direction from America. Those people termed ferry pilots generally fly one aircraft alone.

In general, westerly winds prevail from an altitude of 20 km and less, but virtually easterly winds are reported in spring at low altitudes of 1,500 m to 2,000 m at which ferry aircraft fly. The altitude planned in the balloon flight of this project is very different, but an examination of what happens during a ferry over the Pacific Ocean taking a long period of time would be very significant. A view of numerous reports indicates the following.

[Structural Problems]

° The attachments of the cargo may loosen during flight, shifting the entire center of gravity and inducing instability.

° The externally mounted antenna may become unstable and inoperative due to winds and freezing.

[Instruments, Radio Problems]

° The magnetic compass may fluctuate. → Since this may be affected by placement of peripheral metal parts, calibration must be conducted for each flight.

° Poor HF (short wave transmitter-receiver). → The suspended antenna is entwined about a reel. The antenna line becomes incapable of reflecting radio waves when it freezes and assumes an insulated state. Thus, noise due to static becomes extreme.

° The needle of the ADF (automatic directional finder) may fluctuate due to static even in the middle of the Pacific Ocean. ADF deviation occurs due to night error. + Dual ADF would be desirable. + A sextant and astronomical table should be provided should the direction become unknown due to abnormal readings, thereby ensuring safe progress at a known position.

[State of clouds over the ocean] /76

° There are thunderstorms which reach an altitude of 7,500 m. Detours should also be made about large cumulus clouds.

Judging from these conditions, countermeasures to freezing at low altitudes, including protection of HF, dual instrumentation and back-up by manual means, including sextants, are especially important.

9.3 Problem of mid-ocean forced landing

The gondola of the Double Eagle II is an open type gondola 5.2 m long and 2 m wide with a double hulled structure which could serve as a boat in the event of forced ocean landing. The principal materials were steel tubing and glass fiber. These were bonded using epoxy resin.

The gondola of the "Trans-Pacific Flight 1981" project of Rocky Aoki et al. is a double hulled boat similar to the Double Eagle II. It is 5.5 m long, 2.1 m wide and 2.6 m high. This form is the standard of the Royal Navy. It is maneuverable and stable in the ocean. It is fitted with a small sail and rudder, and is capable of self movement. The keel is lead, weighing 454 kg. While this is effective as a weight for stability on the ocean, it can also be used as ballast for the balloon and thereby acts to increase the duration of flight.

The gondola of the balloon in this project is a sealed capsule, and the interior is pressurized to provide a life-sustaining environment. There are expandable floats around the lower periphery, and these would enable the gondola to float in the water and also would act as shock absorbers in landing.

This capsule fitted with floats would float on the water surface while dangling an anchor or ballast. As in the American project, there would be no self movement using a sail or rudder. After signalling the position and making contact through the rescue system using satellites, the crew would await rescue by rescue organizations and would not move.

The capsule would be picked up similarly to the recovery of the command ship in the Apollo project. The capsule has an air-tight structure and is enclosed by adiabatic material and buffer material for this purpose. Even in the case of landing on land and not in the water, this structure would play a great role in implementation of a smooth landing.

9.4 Problems due to meteorological phenomena

Since the balloon of this project is directed to high altitude flight, it is not troubled by general meteorological phenomena during cruising, but it is subject to weather just like any ordinary aircraft even in the short periods during ascent and descent. For example, the following points require caution.

[Electrostatic charging and countermeasures]

Electrostatic charging occurs during flight due to friction with rain, snow or dust. ADF and HF are disturbed since corona discharge to the periphery occurs when the electric potential rises, giving rise to noise of various frequencies. The countermeasure in aircraft is installation of static dischargers which are sharp pins of low resistance which are aligned at the tip of the wind and which effect discharge to the periphery.

[Thunder and squalls]

These would be avoided. The clouds are observed and those posing little danger are traversed.

[Sudden gusts of wind]

Strong ascending or descending air streams dangerously increase the overall acceleration and have a great effect on the structure. Contact with the ground could be fatal. /77

[Rain]

Wetting of the film surface is desirable, but rainwater increases the overall weight. Disturbance could occur upon freezing.

[Snow]

Wet snow accumulates on the outer surface. The balloon should ascend and escape above the boundary with dry snow.

[Fog]

The vicinity must be scanned during flight and upon landing.

[Heat, Cold]

Cold air increases the buoyancy. The reverse is true during heating.

[Ultra-violet rays]

It promotes deterioration of the skin material (prevented by surface treatment).

Caution is especially required regarding electrical accidents associated with the weather. Spark discharge occurs in the following cases.

[Electric field disturbance]

The metal constituting LTA distorts electrical fields in flight, but spark discharge can occur between metal and certain high voltage sections right near electric lights especially during thunderstorms, melting the structure and causing destruction. ← The elimination of projections is a countermeasure. Each section in the periphery of metal should be completely bonded and electrically unified.

[Friction electricity]

Trouble can develop through spark discharges due to friction among the membranes, during severance or between membrane and metal structures as well as friction during release of dry ballast, during release of gas from the valve, during gas charging or friction between dust and the balloon. ← Countermeasures include the use of good conducting material for the air sac, metallic coating of the external skin as well as bonding of the valve and structures.

[Operation of radio equipment]

Spark discharge due to induced current during operations begins. All metal parts of related structures are bonded.

In short, all metal parts are bonded to form an electrically unified structure. Clouds are noted and thunderstorms are avoided. Valves and ballast are not operated when passing near thunderstorms. These are the principal points.

When inspecting the "bonding", the gondola should be housed in a dark hangar at night before the air sac is attached and the absence of sparks due to the radio equipment should be confirmed. This would be a very effective method.

← All metal parts of related structures are bonded.

9.5 Important points for safety

[Structure]

Removal of water around air sac, prevention of gas leakage, multiple equipment, manual back-up system etc.

[Handling]

Contact with night dew is avoided. A dry state is maintained. Overturning is avoided.

[Weather]

Thunderstorms and cumulus clouds are avoided. Caution involving turbulence, dew condensation and freezing is essential.

[Crew]

Problems include sudden illness, hallucination, fatigue (to cope with spinning)

[Controls]

Position notification, altitude deviation, traffic information.

Detailed consideration of such points is very important. For example, a view of the back-up systems reveals that provision of a sextant, binoculars, oxygen mask system and hand mirrors for signals would be desirable.

10. <u>Summation of implemented projects</u> <u>Chuta Wada</u> /78

10.1 Overall project

10.1.1 Flight project

The Pacific Ocean is to be crossed using the jet stream in the winter (November, December, January). A candidate for the departure point would be north-east Japan (for example, the vicinity of Furukawa). Rapid ascent would be during static periods from sunset through the night. Cruising would be at an altitude of 12,000 m to 13,000 m, and the arrival site would be a North American Pacific Coast city ranging from 40° to 50° north (for example, Portland,Oregon). (Figure 10.1).

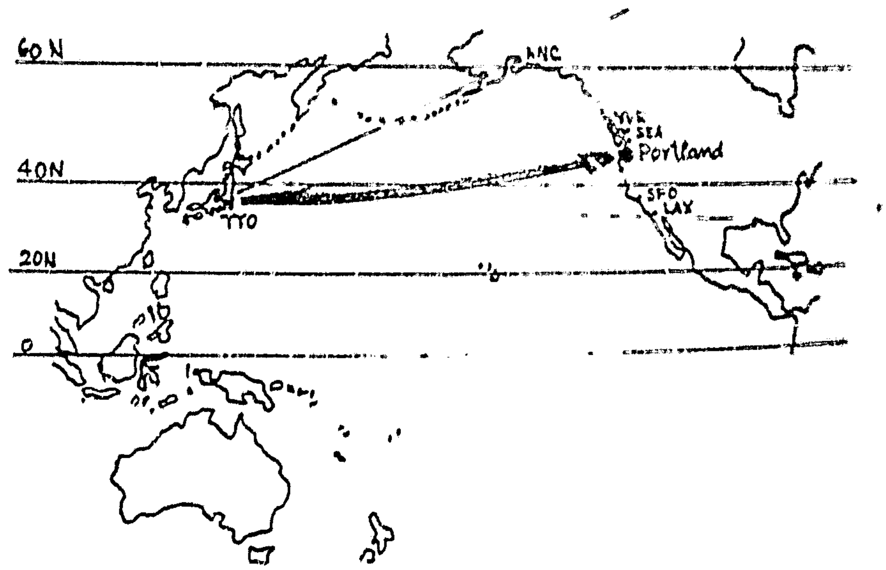


Figure 10.1 Estimation of arrival site

The distance is approximately 10,000 km. The flight time would be approximately 60 hours when the jet stream traveling at 50 m/s (180 km per hour) is boarded. The required equipment as well as air, water and fuel were carried taking the flight capability as seven days.

10.1.2 Balloon system and capacity

The balloon is a He balloon with a capacity of 15,000 m^3 and a weight of 3,000 kg (1,500 of which is ballast). It has a two man crew (operator/navigator). It is a zero pressure type. The altitude reached is 160 mb (approximately 13,000 m).

A comparison of this with similar balloons reveals the following.

/79

<名称(国)> 1	<容量 8	9	11	12
ピカール・FNRS号（ベルギー 2	14,130 m^3	H_2	2,000 kg	2人 13
ダブルイーグルII号（米 3	4,531 m^3	He	3,300 kg	3人
樋口敬二教授案（日 4	15,293 m^3	He	[illegible],000 ~ 4,000 kg	
ICI計画（英 5	21,240 ~ 28,320 m^3	He／熱空気 10		4人
ロッキー青木らの計画（米 6	11,327 m^3	He	6,124 kg	4人
本計画（日 7	15,000 m^3	He	3,000 kg	2人

1 name (country)
2 Piccard-FNRS (Belgian)
3 Double Eagle II (U.S.)
4 proposed by Professor Keiji Higuji (Japan)
5 ICI project (U.K.)
6 project of Rocky Aoki (U.S.)
7 this project (Japan)
8 capacity
9 gas
10 He/hot air
11 weight
12 crew
13 (2) people

10.1.3 Free buoyancy and gas charging capacity

In the case of Piccard (first flight in 1931), 2,800 m^3 of H_2 gas were charged in the air sac of 14,000 m^3 capacity at lift-off. Since the weight was 2,000 kg, the buoyancy was calculated at 800 kg (40%), but calculating back from the ascent rate of 600 m/min, the free buoyancy was approximately 30%. In this case, the ascent rate could be adjusted while releasing excess gas.

In the case of this project, assuming ascent at the rate of 600 m/min, free buoyancy of approximately 26.6% (approximately 800 kg) would be calculated as being required, but considering a rate of 40% (1,200 kg) for a reserve as in the case of Piccard, the initial amount of gas charged would be 4,200 m^3.

In addition, the gas buoyancy of He would be 0.25 kg/m^3 at an altitude of 200 mg (approximately 12,000 m) corrected for temperature and pressure, and would be 0.20 kg/m^3 at an altitude of 160 mb (approximately 13,000 m).

10.1.4 Navigation and prevention of collisions

The position is determined by Omega/VLF navigation equipment and navigation is conducted based on ATC contact by HF. Transponders and beacons are provided and radar reflecting tape is attached to the air sac in order to prevent collisions, but

/80

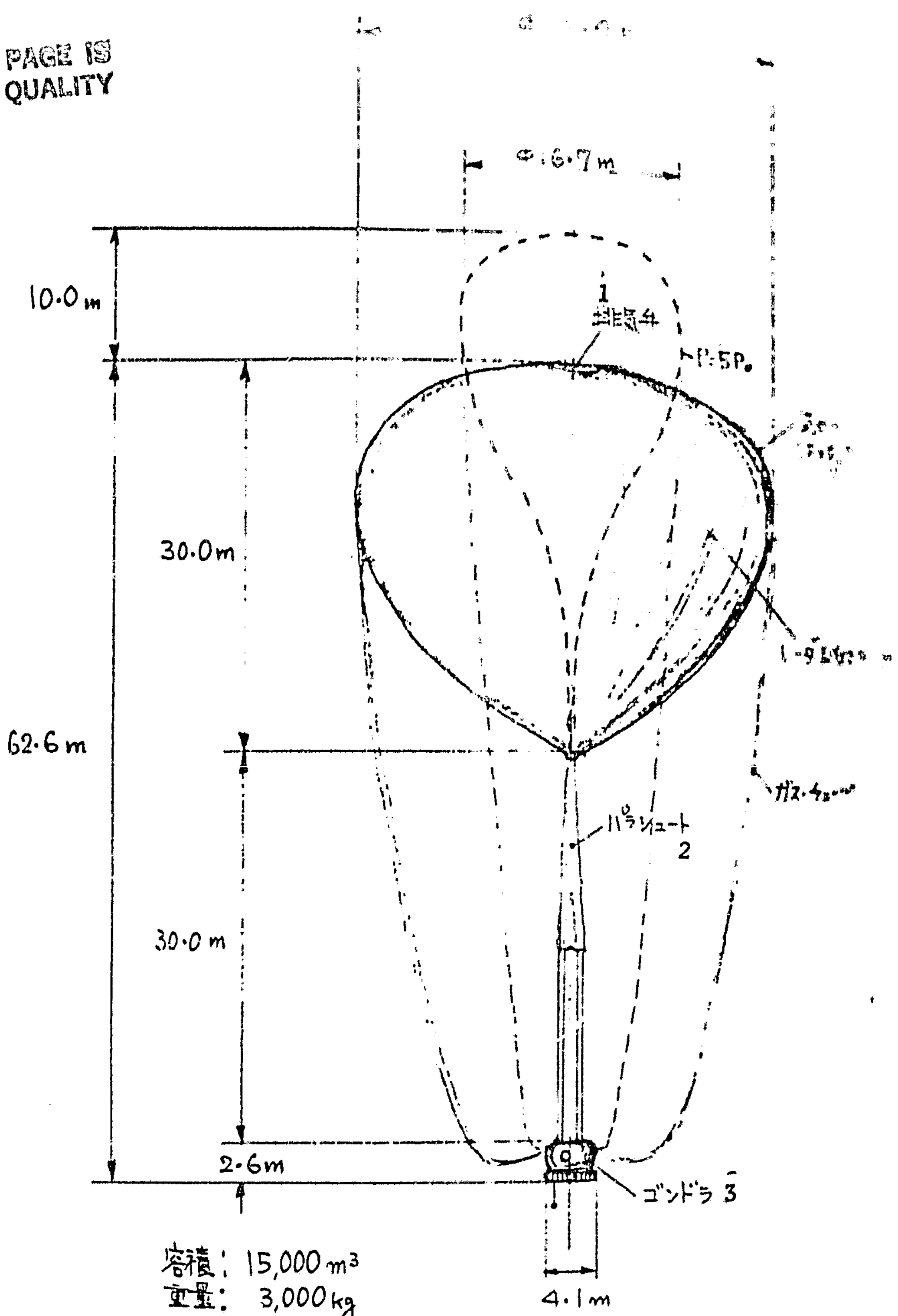


Figure 10.2 Total shape

capacity: 15,000 m^3
weight: 3,000 kg
1 vent valve
2 parachute
3 gondola

the flight altitude of FL 380 (11, 590 m), FL 420 (12,810 m) etc., which are the easternmost VFR navigation altitudes, were selected in cooperation with aircraft control systems.

10.1.5 Rescue

A cargo parachute is provided which dangles below the sealed capsule in the event of damage to the air sac. An emergency rescue system using satellites is provided which gives the accurate position during a forced landing.

10.1.6 Practice

Safety is anticipated through flight simulation, crew training and ground crew training. There are two air sacs, including a spare, and there is enough He gas for three inflations, including practice and a spare.

10.2 Method and form

10.2.1 External shape and foundation

An observation balloon was reinforced and designed to carry people. This involves large balloon technology with proven results. (Identical in size with the "B15" standard balloon of the Space Flight Laboratory of Tokyo University.) The diameter of the air sac when inflated would be 33.4 m at an altitude of 160 mb, and the total height of the balloon system would be 62.6 m (Figure 10.2).

A view of the results involving observation balloons indicates that spinning during ascent of the balloon is 1 or 2 times/min, and that one revolution occurs every 10 minutes to one hour during horizontal flight, at an average of once every 20 minutes.

10.2.2 Gondola

It is a sealed, adiabatic structure of reinforced aluminum alloy covered with foam. The total weight, including the two man crew and internal equipment, is 1,000 kg. There is a combination /81
inflatable float-shock absorber around the lower circumference. It is soft and supports the body while enabling floatation in the water for long periods of time.

10.2.3 Ballast

Ballast is necessary because of the zero pressure type of balloon. Assuming that 7 to 8% of the total weight would be released as ballast to adjust the buoyancy at each sunset [Note], a total of 1,500 kg of ballast was provided for seven sunsets.

[Note] Since the buoyancy would decrease 8.3% according to Charle's law assuming that the gas temperature falls 20°K from 240°K to 220°K, that amount of ballast would be discarded to maintain a constant altitude. A view of the results of observations balloons of the Space Flight Laboratory of Tokyo University indicates that this figure would be "2 to 3% of total buoyancy" per 20 km to 30 km of altitude. 500 kg of the 2,000 kg total weight in the case of Piccard (1931) was ballast, and only 150 kg were used. In the case of Double Eagle No. 1 in 1977 (failure), 1,550 kg of the total weight of 3,000 kg was ballast. The amount was prepared calculating a total of seven releases.

10.2.4 Power

An engine powered generator as well as batteries are provided for power for the radio and other equipment. The exhaust is used to heat the interior via a heat exchanger. (In the ICI project, the buoyancy is adjusted by hot air from the exhaust, and ballast is not used.) For safety, the small scale energy inside is restricted to one type of power.

10.2.5 Life support systems

The interior of the gondola is pressurized at one atmosphere pressure by a steady air supply system. Air is circulated via an air purification system containing a CO_2 scrubber and moisture absorption tubes. Oxygen masks are provided in the event of an emergency. Food and water are on board. Solar heated distillation equipment and survival kits are provided for emergency purposes.

10.2.6 Back-up system

A sextant, compass, manometer and other back-up devices for manual operation in the event of emergency are provided. Binoculars, mirrors, chemical body warmers etc. would also be effective.

10.3 Calculation of weight

The weight of the balloon system would be 500 kg for the air sac, 1,000 kg for the gondola, internal equipment and crew, and 1,500 kg of ballast for a total of 3,000 kg. The details are as follows.

(air sac) (total 500 kg, 5.5 million ¥)			
body (fitted with 15,000 m^2 of radar reflecting tape) (two sets, spare, main)	400 kg	Total 450 kg	4.5 million yen
load frame, gondola wire	15 kg		
valve, adhesive, connective equipment	15 kg		
quick release	20 kg		
cargo parachute (maximum weight during actuation 1,000 kg)	50 kg	50 kg	1 million yen
(gondola, empty) (total weight 370 kg, 20.3 million yen)			
structures (aluminum alloy, foam, FRP) (two man sealed form)	350 kg		20 million yen

drag rope (50 m) anchor /82

[Crew] (total weight 180 kg)
two man crew (at 200 lb x 2, working clothes) (weight standards of military aircraft)

[Ballast] (total 1,500 kg, 500,000 ¥)
ballast (7 nights worth, automatic remote release & manual release, two sets; main and training)

[Gondola equipment] (total weight 450 kg, 33.7 million ¥)
(1) Equipment (subtotal 196 kg, 9.94 million ¥) (7 days worth)
air supply system (tank, system)
air purification system (CO_2 scrubber, moisture absorbing tubes)
interior heating system (exhaust heat exchanger, radiator)
cabin control system (circuit, actuator)
ballast separating equipment (remote actuation)
toilet facilities (simple type)
steering seat, work table, seat equipment (cockpit structure)
interior rack (material, articles)
bed (one man)
interior light, thermos bottle, reserves
fuel & fuel tank (40 l) (gasoline)
float (combined shock absorber) (expandable type)
collision prevention beacon (two sets)

(2) Equipment and charts (subtotal 12 kg, 2.2 million ¥)
altimeter and spare parts (aircraft instrument)
ascent meter and spare parts (aircraft instrument)
automatic registering barometer (external type)
manometer (two types; balloon internal pressure, cabin internal pressure)
automatic registering thermometer (external type)
thermometer (two types; inside air sac, inside cabin)
humidity meter (two types; external & internal)
magnetic compass (aircraft instrument)
flight manual, charts, tables (one set)
sextant (for aircraft)
astronomical data (one set)
binoculars (wide angle, night glass) /83

(3) Recording (subtotal 7 kg, 300,000 ¥)
camera (35 mm, wide angle)
movie camera (16 mm)
stand, film, accessories

4. Radio/Power (subtotal 116 kg, 1.8 million ¥)
VHF (ultra-short wave transmitter-receiver, air band)
HF (short wave transmitter-receiver, air band)
ADF (automatic direction finder)
VOR (very short wave all directional range, for U.S. domestic flights)
DME (distance measurement equipment, for U.S. domestic flights)
ATC transponder (system response equipment)
ELT (emergency location transmitter) (two sets)
transmitter using satellites (ARGOS emergency rescue system)
omega/VLF navigation equipment (display, computer, power source)
antenna/cables (for VHF and HF, harness)
power storage system (NAV/COM, 24 V/12 V system)
engine powered generator (output 1 kW fitted with regulator and rectifier)
(meteorological FAX image receiving equipment) (for receipt of high level meteorological maps-examination of development of the equipment for aircraft)
(solar battery panel unit) (examination of layout outside of gondola-performance & price, practicality)

5. Clothing (subtotal 14 kg, 210,000 ¥)
sleeping gear (for two men)
cold weather clothing (wet suits) (for two men)
helmets (for two men)

6. Provisions (subtotal 41 kg, 240,000 ¥)
portable rations (14 days worth)
conventional instant food (14 days worth)
canned food, drink (7 days worth)
water and water tank (7 days worth) (30 l)
cooking set (electric)

7. Miscellaneous (subtotal 13 kg, 360,000 ¥)
medical set (one set)
lights/switched light (two sets)
gear box (one set)
leak repair kit (instant adhesive, grease, tape) /84
circuit tester (general type)
clerical items (calculator, pens, magic markers, ruler, sextant, straight edge, paper scissors, miscellaneous paper etc.)
alarm clock (one)
dry cell (for portable light, two sets)
sunglasses, work gloves (for two men)
buckets (two)
chemical body warmers (2 x 7)
mirrors (for signalling also)
tissue paper (one box)

flag (Japanese and American)

(8) Rescue/Safety (subtotal 51 kg, 2.35 million ¥)
rescue clothing (for two men)
fire extinguisher (three)
oxygen mask system (cylinder, accessories) (for two men)
illumination cartridge, smoke cartridge, firing pistol (one set)
survival kit (raft, accessories, SOS transmitter etc) (for two men)
solar heated distillation equipment (one set)
individual parachute (for two men) (Required by law. Little practical significance)

10.4 Estimation of expense

We will conduct a comparison of this type of project with the expenses of past projects.

[Piccard-FNRS (1932, 1932)]

Since the cost of constructing the balloon was 14,000 dollars at the time, the cost would exceed 100 million yen at present. (J. Nishimura "Balloon Launch", Iwanami Shoten).

[Double Eagle II (1978)]

The direct production expense for the trans-Atlantic flight was 1.25 million dollars, or approximately 30 million yen. Based on this, the direct expense for crossing the Pacific would be approximately 100 million yen, with hundreds of millions of yen required for support and indirect expenses.

[U.K. ICI project (1980)]

The direct expense was 250,000 pounds according to a pamphlet, approximately 150 million yen.

[Trans-Pacific Flight 1981 project (U.S.)]

Rocky Aoki has announced the cost to be one million dollars (approximately 230 million yen).

Consequently, the project would cost between 100 and 300 million yen.

A thorough examination of the details, including personnel, simulation, practice etc., is required when considering the expense because expenses involving personnel and duties assigned elsewhere can rapidly swell.

First, the expenses are divided into direct expenses, /85
support, related and reserve expenses. The details are indicated below.

[Direct expenses]
project (at 1 million yen x 2 months) 2 million ¥
design (at 2 million yen x 4 months) 8 million ¥
production-purchase (total of preceding sums) 60 million ¥
assembly, adjustment (at 10,000 ¥ x 400 MH) 4 million ¥
inspection, testing (at 10,000 ¥ x 400 MH) 4 million ¥
He gas supply (at 1,500 ¥/m^3 x 4,200 m^2 x 3) 18.9 million ¥
Direct Expenses Total 96.9 million ¥

[Support expenses]
office workers (at 30,000 ¥/month x 12 months x 3) 10.8 million ¥
office operating expenses (communications, meetings etc. at 3 million ¥/month x 12 months) 36 million ¥
activity expenses (negotiations with ministries, announcements, public relations etc.) 6 million ¥
flight simulation expenses (tests, research) 20 million ¥
service expenses (weather, rescue etc.) 6 million ¥
crew training expenses (environment, operations at 2.5 million ¥/month x 3 months) (two people) 7.5 million ¥
ground crew training/personnel expense (lift-off assistance 20 people x at 20,000 ¥/man x 5 times, expense of 2 million ¥, crowd control 20 people x at 10,000 ¥/man) 4.2 million ¥
support, cooperation personnel expenses (gas charging operation at 100,000 ¥/man x 10 men x 3 times) 3 million ¥
release site expenses (ground preparation, operation, lighting etc.) 8 million ¥
crew insurance (for two men) 3 million ¥
Support expenses Total 104.5 million ¥

Related expenses
activities in America (negotiations with U.S. officials, ground support center, international communications etc. 100 million ¥

[Reserve expenses]
reserve expenses (rescue etc.) (approximately 10% of the total of the direct expense and support expense) 20 million ¥

Direct, support, related, reserve expenses
Grand Total 321.4 million ¥

A summary of the balloon system weight/expense is illustrated below. (Table 10.1)

Table 10.1 Summary of the weight/expense of the trans-Pacific balloon /86

Equipment	196 kg	9,940,000 ¥
Instruments	12 kg	2,200,000 ¥
Recording	7 kg	300,000 ¥
Radio	116 kg	18,100,000 ¥
Clothing	14 kg	210,000 ¥
Food	41 kg	240,000 ¥
Miscellaneous	13 kg	360,000 ¥
Rescue	51 kg	2,350,000 ¥

(Details)	(Weight)	(Expense)	
air sac	500 kg	5,500,000 ¥	(15,000 m^2)
gondola	370 kg	20,300,000 ¥	(sealed cabin)
equipment	450 kg	33,700,000 ¥	(MAX 7 days)
crew	180 kg		(two men)
ballast	1500 kg	500,000 ¥	(7 times worth)
Total	3,000 kg	60,000,000 ¥	made or bought
		4,000,000 ¥	construct, adjust
		4,000,000 ¥	inspect, test
		18,900,000 ¥	He gas charging
		8,000,000 ¥	design
		2,000,000 ¥	project

(Direct expense) Total 96,900,000 ¥

(Support expenses) (office workers, office operating expenses, activity expenses, simulation expenses, service expenses, crew training expenses, etc.)
Total 104,500,000 ¥

(Related expenses) (negotiations with U.S. officials, ground support center, international communications, etc.) Total 100,000,000 ¥

(Reserve expenses) (rescue, etc.) (approximately 10% of the total of the direct expense and support expense) 20,000,000 ¥

GRAND TOTAL 321,400,000 ¥

10.5 Prospective Schedules /87

The work required in this project takes a total of nine months. If the project were begun in April, the flight could be implemented in January of the following year, and the precise date would depend on the weather.

In the case of the Honda project in 1965, preparations took a total of 16 months. This depended on technical consulations on the American side, as well as on time for providing special clothing. The project took an unusually long time.

The current project is expected to be completed in a much shorter period of time. The action on the American side especially is much quicker.

The details of the nine month period are as indicated below.

Reference Literature /88

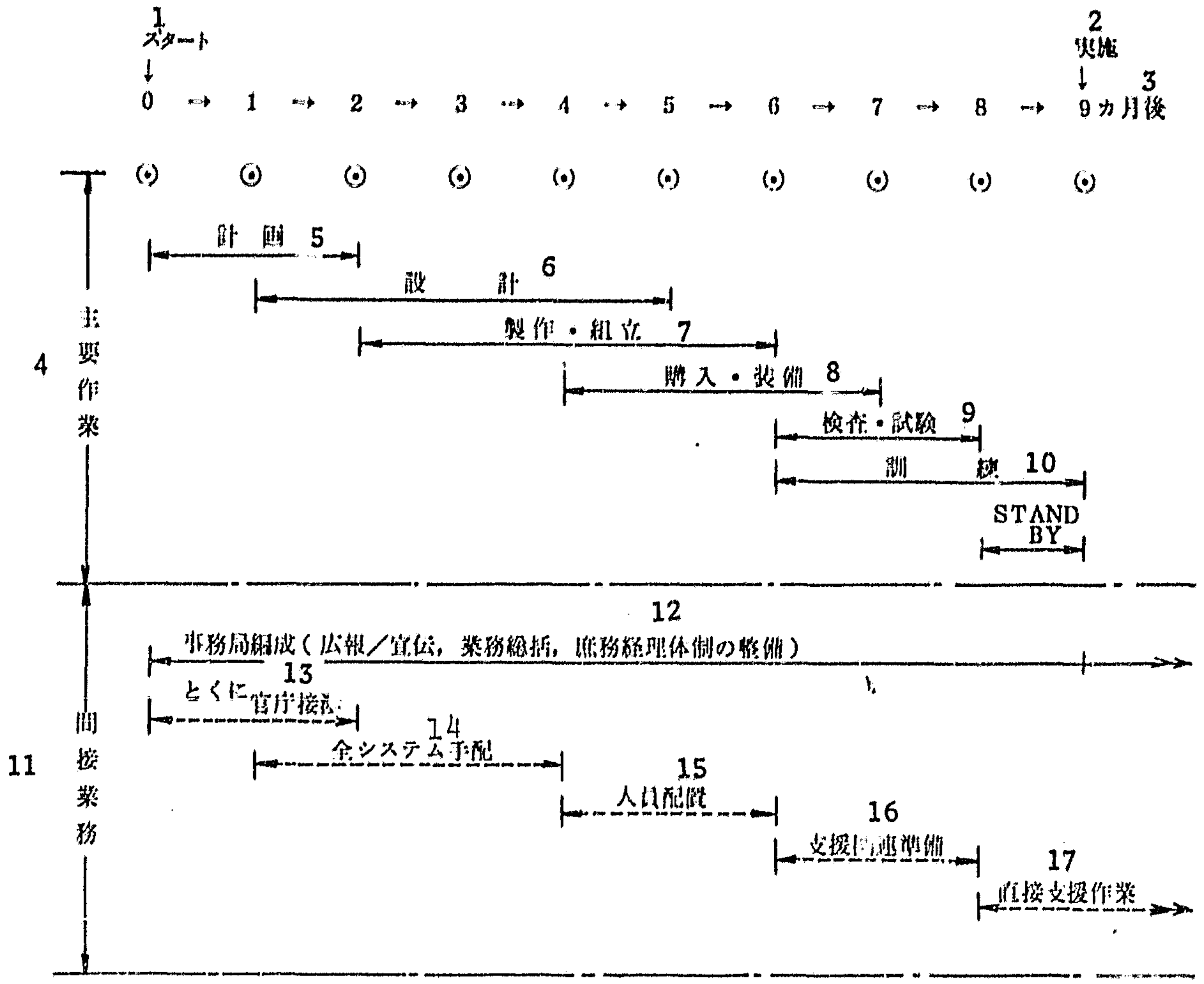
° "LTA aircraft symposium" (1979) Report (Published March 6, 1980 by the Space Flight Laboratory of Tokyo University). "On the concept of a trans-Pacific balloon flight" is contained at the end of the report. This is the introduction to the reference literature.

° The Last Great Adventure, "Around the World in 80!" Pamphlet (Published by ICI Magazine, 1980). A project to carry four people in a hybrid He-hot air balloon and to travel around the northern hemisphere at an altitude of 9,000 m to 16,500 m for 20 days. Sponsored by the U.K. ICI.

° "Trans-Pacific Flight 1981" Instructions (Data published October 16, 1980, introduction by Ben L. Abruzzo, December 3, 1980). Cruising by four people in a He balloon of 11,320 m^3 capacity at an altitude of 9,000 to 10,500 m. The maximum lift-off weight is 6,120 kg. The flight from Japan to San Francisco would take 3 to 4 days. Open gondola with Rocky Aoki participating. U.S. project.

° "Trans-Pacific Flight by Free balloon and Round-the-World Project" Report. (Honda project, August, 1965 report No. 1 issued). Three people in a sealed gondola crossing the Pacific in 2.5 to 3 days in the winter using the jet stream at an altitude of 10,000 m. 12 days to circumvent the globe. Research began in 1963. Expense approximately 200,000 dollars. Preparatory period 16 months.

Table 10.2 Daily schedule until implementation for 9 months



1 start
2 implementation
3 after 9 months
4 main operations
5 planning
6 design
7 production, assembly
8 purchse, outfitting
9 inspection, testing
10 training
11 indirect operations
12 office organization (announcements/publicity, total work activity, organization of general affairs)
13 especially ministerial negotiations
14 arrangements of total system
15 arrangement of personnel
16 support related preparations
17 direct support operations

Research Members

We conducted examinations from various angles through our 13 research groups, and issued a report summarizing the results. The research members and their responsibilities are as follows.

Buoyant Flight Association-Trans-Pacific Research Group

C. Ishii	(Chapter 3)
S. Ichiyoshi	(Chapter 6)
K. Terada	(Chapter 2)
K. Nagamatsu	(Chapter 4)
M, Makino	(Chapter 5)
C. Wada	(Chapters 7,8,9,10 and entire coordination
T. Nagasawa	(Liaison)
T. Yagibashi	(Editing)

Chapter 1 summarizes the intentions of all the members.

Part 2. Buoyant Helicopter System (BHS) Project

1. Research subjects
2. Research objectives
3. Outline of flying object
   (1) gas bag
   (2) propulsion mechanisms
   (3) support mechanisms
   (4) radio operational mechanisms
4. Flight experiments
5. Time schedule
6. Research personnel

(1) Research subject

Production of scale test vertical lift-off hybrid type LTA aircraft (Buoyant Helicopter System: abbreviated BHS).

(2) Research objectives

The trend toward development of a new type of LTA aircraft (Hybrid Lighter-than-aircraft), which would combine the buoyancy of a gas bag containing buoyant gas with the vertical lift off capabilities of the helicopter, has become active in various countries around the world recently.

In Japan as well, the Institute of Technology of the Ministry of International Trade and Industry has examined the development of this aircraft as a new candidate for large projects.

This research project has decided to produce a 1/10 scale model of the actual device as a part of the aforementioned development trends. This would clarify the possibilities of this type of hybrid LTA through flight tests, and would confirm its limits of mobility. The objective is to gain data for the development of this craft by the Japanese aircraft industry.

(3) Outline of flying object

The flying object (BHS) is composed of (1) gas bag, (2) propulsion mechanisms, (3) support mechanisms, (4) radio operational mechanisms.

Total length 9.5 m, total width 5.7 m, total height 2.7 m. The total outfitted weight is 50.8 kg and the maximum load is 10 kg. Approximately 50% of the total outfitted weight is the charge of buoyancy of the gas bag, and the remaining 50% as well as the power for movement are the charge of the four helicopters.

The maximum speed is 40 km/h and the cruising duration of a flight would be approximately 30 minutes while hovering would be possible for approximately 20 minutes. Take off and landing would be vertical. It would be capable of hovering in the air in a 5m x 5m range in a constant wind.

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Table 1. Main specifications

1	[illegible]	[illegible]
2	[illegible]	[illegible]
3	全高	2.7 m
4	[illegible]重量	388 kg
5	全備重量	[illegible]
6	[illegible]重量	[illegible]

1 total length
2 total width
3 total height
4 empty weight
5 total outfitted weight
6 fuel weight

Table 2. Main performance

1	最大速度	[illegible]
2	最大積載量	[illegible]
3	航続時間	20 min（ホバリング）6 30 min（巡航）
4	離着陸性能	垂直離着陸可能 7
5	ホバリング能力	5m/sの横風突風状態において機首方位を維持した場合，5m×5m内でのホバリング可能。8

1 maximum speed
2 maximum load
3 duration of continuity
4 lift-off, landing mode
5 hovering capability
6 20 min (hovering) 30 min (cruising)
7 vertical take-off and landing
8 capable of hovering in a space of 5m x 5m when mai[illegible] a bearing into a horizontal wind of 5 m/s

Regarding the structural parts of (1) to (4):

(1) Gas bag (Refer to Figs. 1, 2, 3)

It has the specifications illustrated in table 3. It is to be constructed by Taiyo Kogyo K.K. The same company is an institutional member of the Buoyant Flight Association.

(2) Propulsion mechanism (Refer to Figs. 4, 5)

It has the specifications illustrated in table 4. It is a modified version of the Hughes 500 helicopter made by Fujimaki Seiko Mfg. All four helicopters were newly purchased.

The modifications involved the rotor head, number of rotor blades, engine etc. In addition, the tail rotor was removed. Each rotor is provided with its own engine.

Rotation of the engine is transmitted to the rotor via a 10:1 speed reduction gear after passing through a centrifugal clutch.

The engine output is automatically regulated by an electric governor so that the speed of the rotor can be maintained at 950 rpm ± 5%.

Each rotor would be designed so as to turn in the direction opposite that of the adjacent rotors. By means of this, special /90 anti-torque mechanisms are unnecessary. Moreover, yaw would not develop during operation. This reverse spin by the rotor is accomplished by modification of the crankshaft of the engine so that the engine turns in the opposite direction. The mechanisms including the gear boxes are the same as in four helicopters.

(3) Support mechanisms

These are structural units linking the gas bag and the propulsion mechanism which have been newly designed and constructed.

These include the base attached to the gas bag, the forward and rear stays, the rigid hull frames connected to the forward and rear stays, and the rigid stays supporting the base and hull frame.

The materials used in the support mechanism are selected so as to fall within a specific weight (10 kg) range.

One helicopter is attached to both ends of the forward stays and to both ends of the rear stays. The tips of the stays are designed for easy attachment and removal, thereby facilitating transportation.

The mechanism supporting the four helicopters is designed to be strong enough to withstand even the worst imbalance, which would occur if only two out of four helicopters on a diagonal line were operating.

(4) Radio operational mechanisms (Refer to Figure 6)

The signal from the vertical gyros and rate gyros is incorporated in the control system. The transmitter-receiver required for radio operation as well as the electronic circuits required for this were newly designed and constructed.

Virtually all of the radio operational mechanisms were newly developed for this project. They are indispensable for stable control of the attitude in flight, and form the heart of this BHS project.

As illustrated in figure 6, it is composed of a unit on board the aircraft and a unit on the ground.

The ground unit has three components. The steering signals transmitted by the control stick to the three control boxes are sent to the transmitter via the mixing box.

The control laws are incorporated as electronic circuits in the mixing box, and the amount of the maneuvering signal, and rates of blending and apportionment of direction etc. can be altered by means of these. As a result, human operation is simple and the working capabilities of the BHS can be enhanced.

The signals transmitted from the ground transmitter-receiver reach the receiver on the aircraft, and are then sorted by each rotor, engine, manifold pressure and each control servo motor.

The cycle pitch and correct pitch of each rotor can be altered, and the engine speed can be regulated by the signals given.

Conversely, the vertical gyro (one) and the rate gyros (two) on board the aircraft detect the amount of change in the attitude accompanying movement as well as the forward-rear, left-right angles. The signals are sent to the pulse mixing box between the receiver and each servo motor which operates to automatically control the stability of the aircraft (Fly by Wire).

By incorporation of this automatic stability control system, the BHS can be operated by one person (on the ground) at high accuracy with complete movement in six directions. The BHS is stable even if the control stick is released or if one engine goes out, and it can continue flying stably without losing its attitude and can safely land. Moreover, various types of anticipated flying tests will be possible.

Various electronic devices planned for the craft will be carried in the center of the support mechanism.

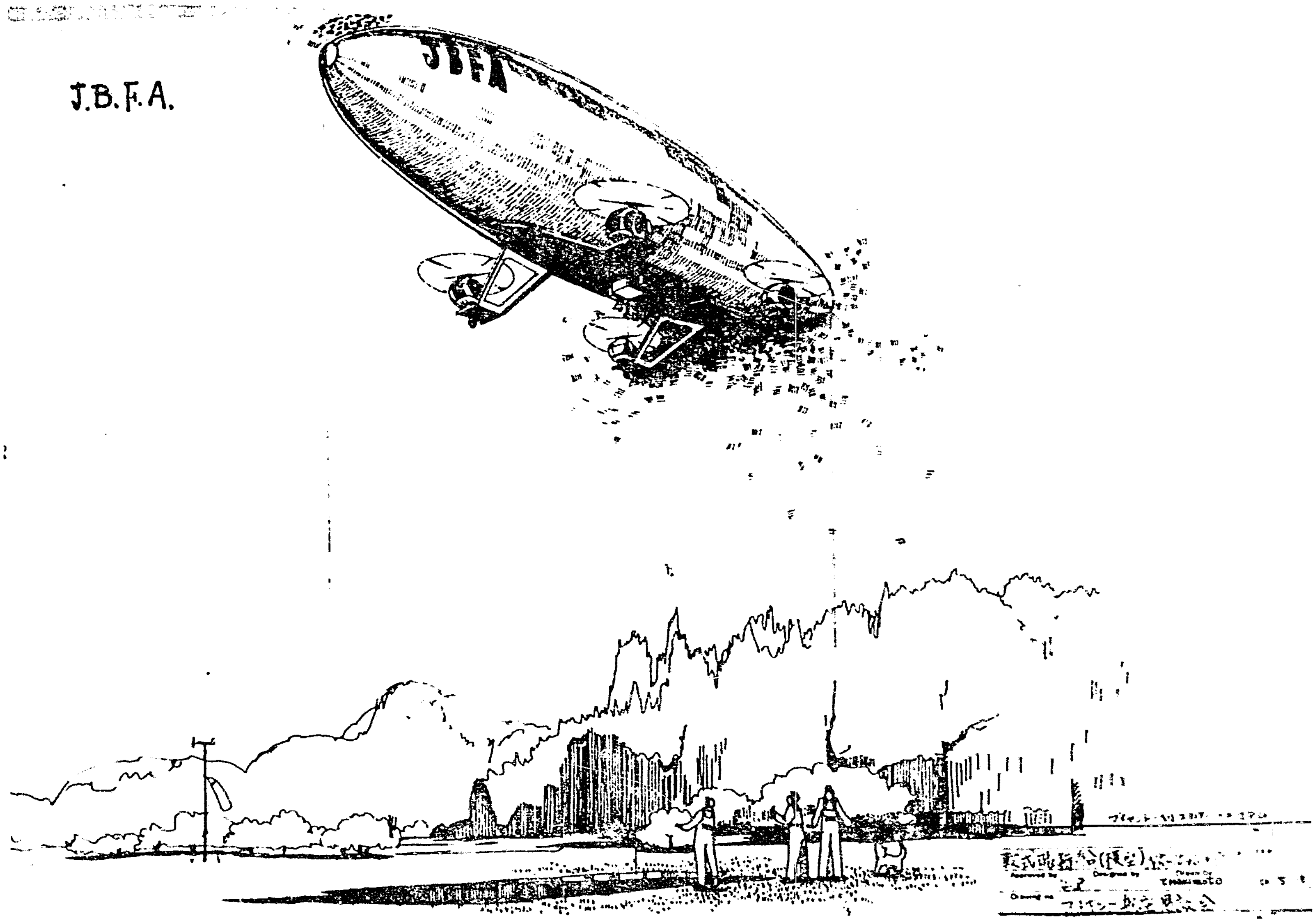

Fig. 1

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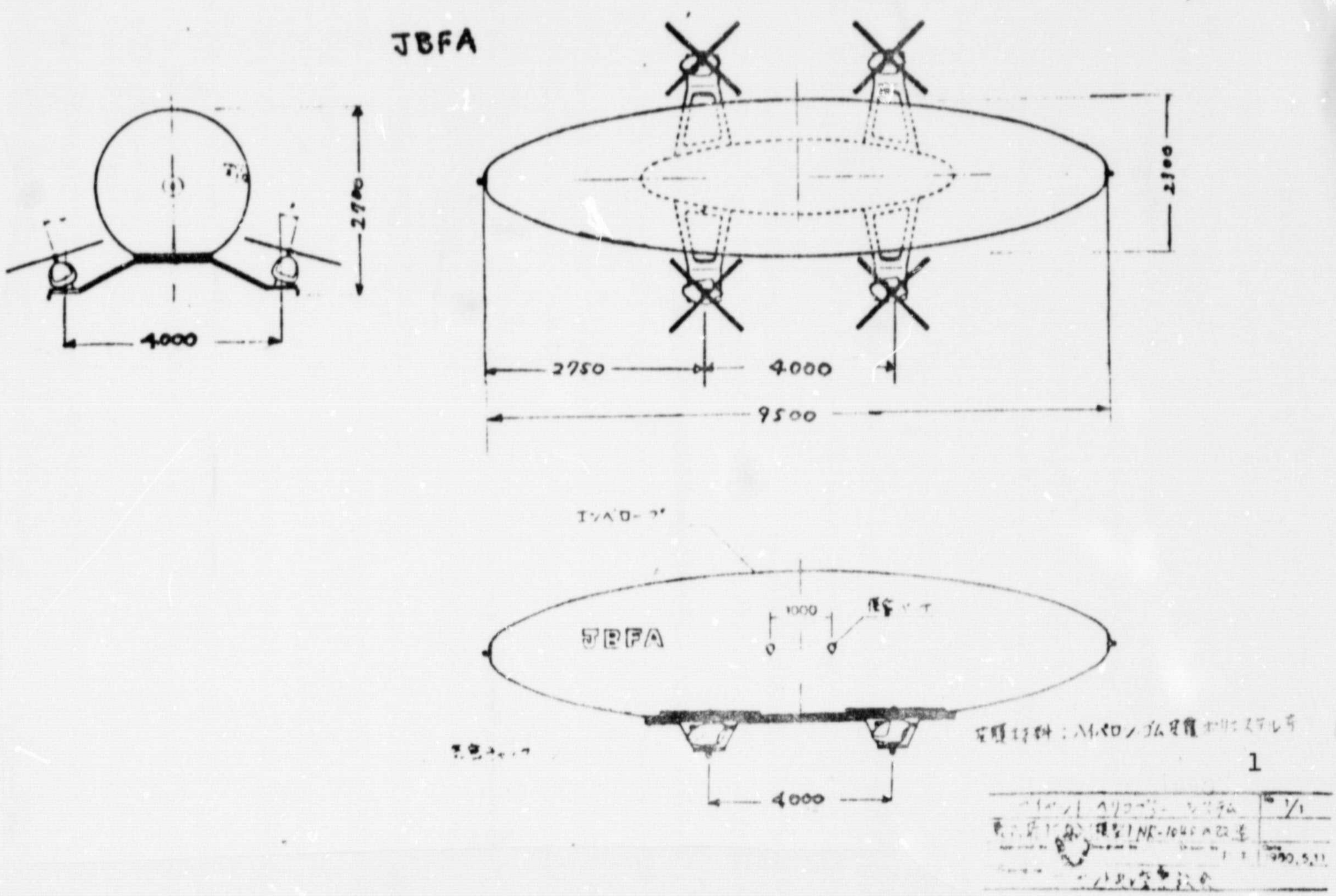

Figure 2. Buoyant Helicopter System
1 (all items illegible)

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Figure 3. Gas bag

Figure 4. Helicopter unit (four are mounted)

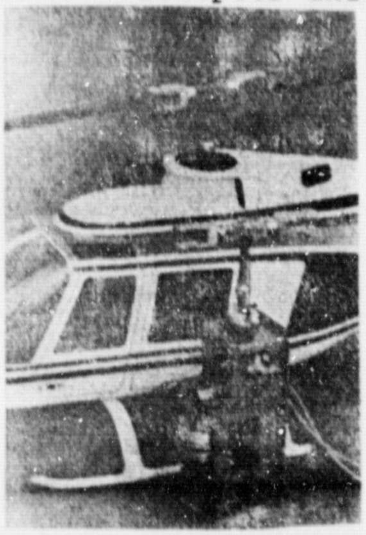

Figure 5. Engine unit of helicopter

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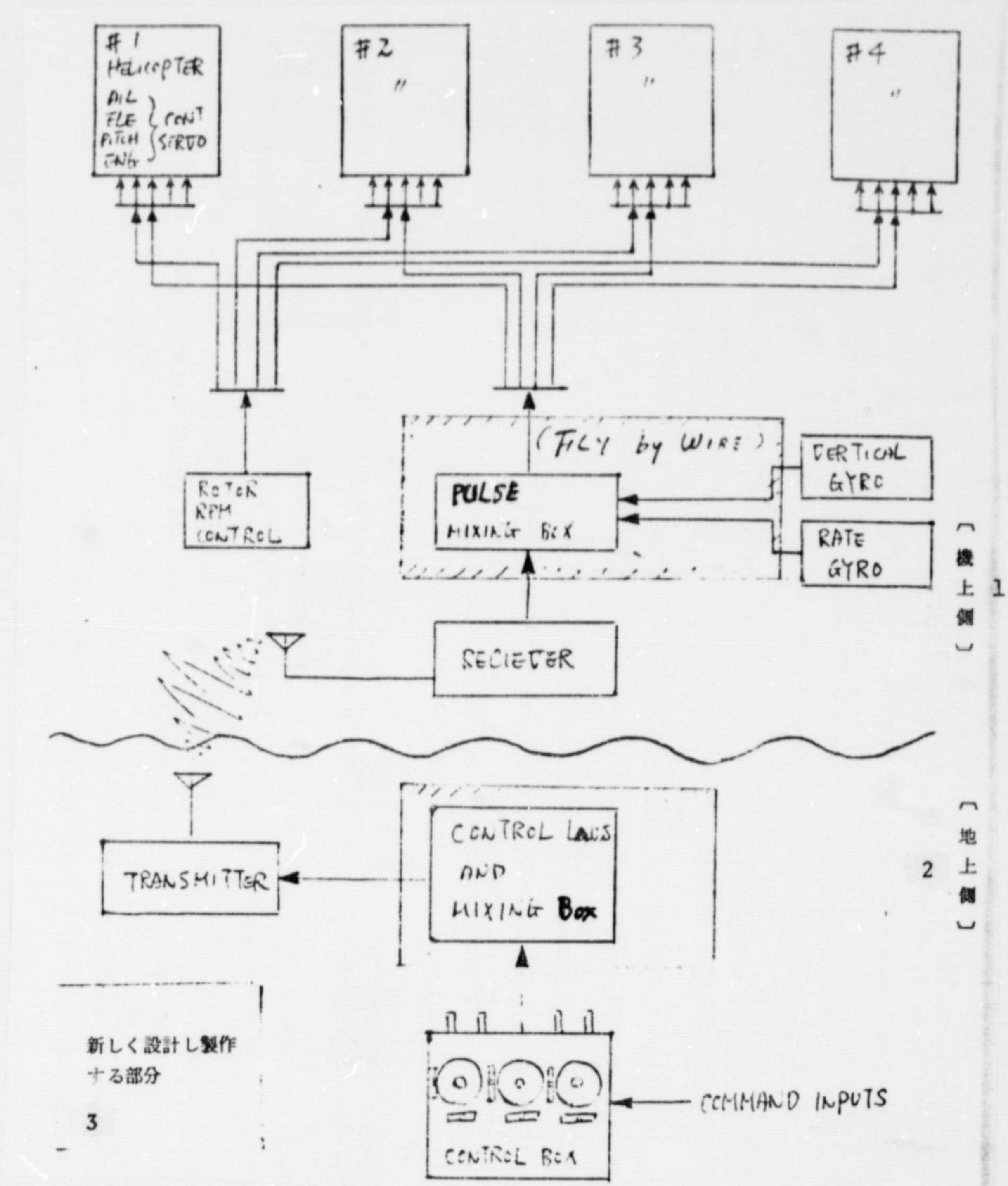


Figure 6.
1 on the aircraft
2 on the ground
3 units newly designed and produced

(4) Flight experiments /95

(a) Tests must confirm whether or not the overall BHS can be flown stably and precisely with four helicopters attached using the buoyancy of gas bags.

(b) The tests will be conventional vertical lift-off and landing performance tests as well as hovering tests.

(c) The attitude of the aircraft and the rotational movement of the tail will be confirmed in the hovering state.

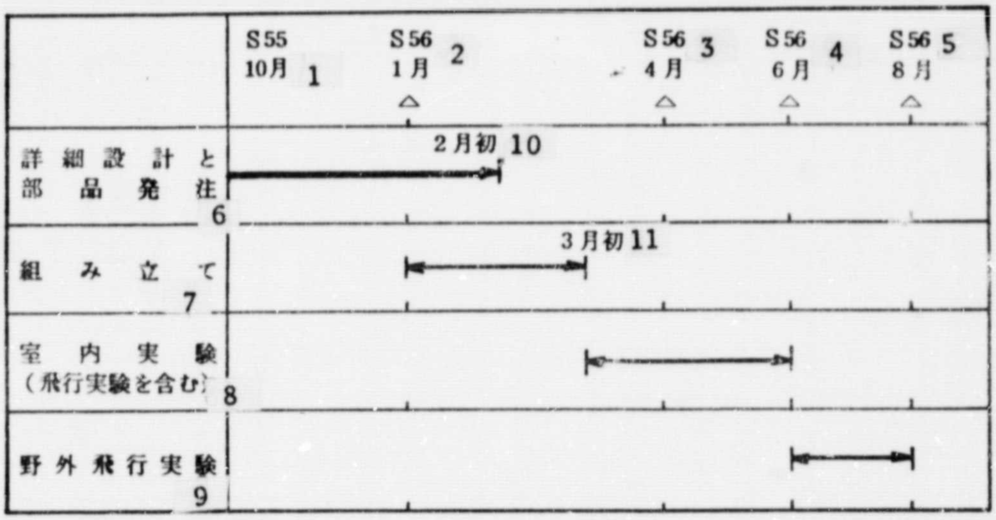
(d) Flight stability while one engine is out will be confirmed.

(e) Flight stability in unusual attitudes, such as forward or rear tilting, will be confirmed.

(f) The ability to control the instability in buoyancy due to loading or unloading by lift of the rotors will be confirmed.

(g) Other associated tests will be conducted.

(5) Time Schedule



1 October, 1980
2 January, 1981
3 April, 1981
4 June, 1981
5 August, 1981
6 detailed design and ordering of parts
7 assembly
8 indoor tests (including flight tests)
9 outdoor flight tests
10 early February
11 early March

(6) Research Personnel

Akira Higashi* (Space Flight Laboratory of Tokyo University, Professor, member of Buoyant Flight Association (JBFA))

Natsuo Hashimoto (Space Flight Laboratory of Tokyo University, graduate student JBFA)

Chiaki Oi (Toa Domestic Airlines, Crew Chief, JBFA)

Kazuo Kanazawa (Toa Domestic Airlines, Pilot, JBFA)

Susumu Mamiya (Technical Group Mamiya representative, JBFA)

Yoshihito Isono (Taiyo Kogyo K.K., Technical Director, JBFA)

Yasunobu Kasahara (Shobo Laboratory, Laboratory Director, JBFA)

Kazumasa Iinuma (Science Journalist, JBFA office director)

Appendix: Responsibilities

Higashi: Checking of total project

Hashimoto: Aerodynamic calculations of flight object and design of support mechanisms

Oi, Kanazawa: Overall design, assembly, flight testing

Mamiya: Assembly, flight testing

Isono: Design and construction of attachment sections of gas bag and support mechanisms

Kasahara: Design of support mechanisms

Iinuma: Adjustment and propulsion of entire project.

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* principal examiner

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	【ガス袋】 9		
1	型式	軟式	10
2	浮揚ガス	ヘリウム(He)	11
3	全長	9.5 m	
4	最大径	2.3 m	
5	長短比	4.1	
6	ガス容積	24.3 m^3	
7	ガス浮力	25.7 kg	
8	重量	12.8 kg	
	12.【材料】		
13	基布	ポリエステル,平織布	20
14	コーティング	ハイパロン・ゴム	21
15	厚さ	0.12 mm	
16	重さ	130 g/m^2	
17	引張強さ {タテa / ヨコb	16 kg/3cm / 23 kg/3cm	
18	破断時の伸び {タテa / ヨコb	22% / 23%	
19	ヘリウムガス透過性	2 ℓ/m^2/24 h	

Table 3. Various specifications (1)

1 type
2 buoyant gas
3 total length
4 maximum diameter
5 long-short ratio
6 gas volume
7 gas buoyancy
8 weight
9 gas bag
10 soft type
11 helium
12 material
13 base cloth
14 coating
15 thickness
16 weight
17 tensile strength (a, length; b, width)
18 elongation during tearing (a, length; b, width)
19 helium gas permeability
20 polyester, flat weave
21 high-blown rubber

1	ヘリコプタ（藤巻精工製（Hughes 500 改造型）4基	
2	全 長 （1基）	0.650m
3	全 高 （1基）	0.385m
4	全 幅 （1基）	0.300m
5	重 量 （1基）	3.0kg
6	【ローター】	
7	最大推力（1基）	12 kg
8	ヘッド型式	全関節式
9	直 径	1.70m
10	枚 数	3 枚
11	回転方向	右及び左
12	回 転 数	950 rpm
13	振り下げ	5 度
14	ピッチ可変範囲	−1 度〜＋10 度
15	ローター回転面可変範囲	全方向に最大15度
16	【エンジン】	
17	型 式	OS-FSR-H及び改造型
18	重 量	0.45kg
19	最大出力	2.5HP
20	常用回転数	2000 rpm〜15000 rpm
21	回転方向	右及び左
22	冷 却	強制空冷

Table 4. Specifications (2)

1	helicopter (Fujimaki Seiko Mfg. (modified Hughes 500) four	
2	total length (one craft)	
3	total height (one craft)	
4	total widthh (one craft)	
5	weight (one craft)	
6	rotor	
7	maximum propulsion (one craft)	
8	head type	' totally articulated
9	diameter	
10	number of blades	' three
11	rotational direction	'left and right
12	rotational speed	
13	downward twist	' 5 degrees
14	pitch variable range	' -1° to + 10°
15	variable range of rotor angle	' maximum 15° in all directions
16	engine	
17	type	' OS-FSR-H and modified type
18	weight	
19	maximum output	
20	usual speed	
21	rotational direction	' left or right
22	coolant	' forced air

1	タンク容量	600cc
2	燃料成分	3 アルコール 75% ニトロメタン 20% 鉱物油 5%
4	比重	0.8
5	消費率	6 ホバリング時において 2000cc/h

Table 5. Fuel

1 tank capacity
2 fuel composition
3 alcohol 75%, nitromethane 20%, mineral oil 5%
4 specific gravity
5 fuel consumption
6 2000 cc/h during hovering

1 [illegible]	2 ガス袋 [illegible] 3 ヘリコプタ(4基) 12.0kg 4 無線操縦機構 4.0kg 5 支持機構 10.0kg	[illegible]
6 燃料重量	2.0kg	
7 最大積載量	8 10.0kg (但しOne Engine Outを考慮した場合は 5kg)	
9 全備重量	10 50.8kg (但し,同上の場合は 45.8kg)	

11 (無線操縦機構の重量内訳…合計 4.0kg
• Vertical Gyro(1個)と Rate Gyro(2個) …… 2.3kg
• 無線受信装置 …… 0.7kg
• バッテリ …… 1.0kg)

Table 6. Weight details

1 empty weight
2 gas bag
3 helicopter (four)
4 radio control mechanism
5 support mechanism
6 fuel weight
7 maximum load
8 (when one engine is out)
9 outfitted weight
10 (45.8 kg in the above case)
11 details of weight of radio control mechanism Total 4.0 kg
vertical gyro (one) and rate gyro (two) 2.3 kg
radio transmitter-receiver 0.7 kg
battery 1.0 kg