II. The Rockoon

-- Osamu HIRAO and Tomo OKAMOTO --

Penetrating a dense layer of air at supersonic speeds causes a strain on the rocket fuselage and affects its flight performance. Several methods to overcome this difficulty have been conceived. One such method is the ROCKOON, first tested by Professor Van Allen and the Rockoon Research Group at the University of Iowa in 1952. A rocket was suspended from a balloon, and after the balloon had slowly drifted up to a comparatively thin layer of air, the rocket was ignited and launched. It was a complex task because a large polyethylene balloon was used and the rocket was ignited several minutes after launch at a low temperature and low pressure. The first rocket used, the DEACON, had a total weight of 90 kg and only reached an altitude of 30.5 km. When the rocket was launched from an altitude of 20 km, it reached 91 km. Therefore, the balloon system certainly is worthy of consideration.

In Japan, several plans for a Rockoon were outlined since 1956. Since this is described in detail in an article by Shigeo Nakagawa (Vol. 12, No. 3) I will not go into it here. Instead, I will outline the progress from 1959, the year I took over the present program at the Institute. Also, I will mention some objectives for the future.

From the beginning, we had three objectives:

I: To launch a rocket accurately and safely without letting the rocket or timer strike the ground.

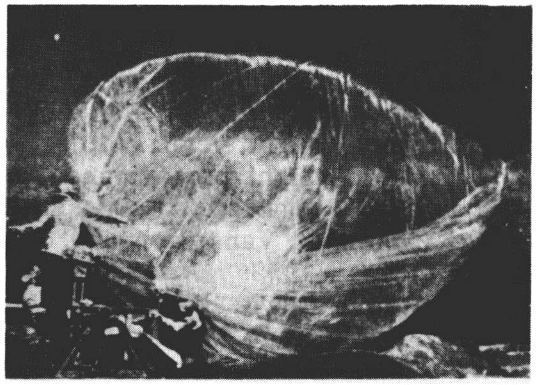
II: To study the temperature of the rocket propellant when floating in the air and when launched from the balloon; in other words, devise a method for maintaining the temperature of the propellant at about 20° C.

III: To manufacture a safe and accurate timer and telemeter.

During the experiments we encountered several problems. The experiments, which were performed over a two year period, are listed in Table 1.

1. Launching Test

This experiment corresponds to No. 1 of Table 1. The large balloon used for the rockoon was made of polyethylene with a fixed capacity. The hydrogen, which is put into the balloon before it is released from the ground, takes up only about 1/10th of the total capacity (reached when the floating altitude is 20 km). The method of checking the buoyancy by weight and balance was difficult because the slightest gust of wind proved dangerous even though the balloon was tied down with control ropes. At the present time only the small balloon method (which was almost inflated while on the ground) was used as a counter-measure. The large balloon was attached t a balloon launcher, and at the same time that buoyancy was being measure it was prevented from being blown away by a considerable gust of wind.



Picture 1. The large balloon being blown about by the wind (4-6m/s).

The next and most troublesome problem was that from the moment that the large balloon was released until the main rope extended to its full lengt and the rocket and timer were charged, the balloon would be moved even b the slightest wind. When the rocket and timer were finally released, they crashed to the ground because of the swinging motion. It was almost impo sible for the rockoon project to materialize as long as accurate, safe and economic measures were not taken to compensate for this swinging motion at the time of releasing the balloon. It was also difficult to overcome this difficulty by using a device for unwinding the main rope. At the time that we took over the project, we discussed this problem with those personnel previously involved. They had several suggestions including: using an aux- iliary release device, in the form of a catapult, which would move auto- matically in respect to wind direction and velocity; a method for releasing while sliding along the water surface; and even a balloon bomb system.

Finally, finances and time were taken into consideration, and an agreement was reached to study the small auxiliary balloon method, accord- ing to the proposal made by Mr. Jun Nishimura, who was a member of the rockoon committee conducting nuclear research. Then the concept and con- ditions were indicated for the necessary rocket launcher, and the design of Toyobumi Goshiro of Fuji Precision Industries was received. This is shown in Figure 1.

Figure 2 illustrates the launching method using an auxiliary balloon and a rocket launcher. Using this method, the rocket and suspended pack- age are fastened to ring which opens to either side of the launcher, and is

Table 1

Calendar of Progress in Rockoon Tests

Item	Purpose	Results
1. Launching test (2/3/59, Institute)	Examine launching method using rocket launcher and small balloon.	Found that we can safely launch balloon even at wind velocity of 3-5m/s.
2. Dummy test (2/19/59, Honjo Hatano)	Study method of maintaining propellant temperature at 20° to 25° C when rocket floating suspended from balloon.	Found that propellant temperature stayed at 20° for 1 hour during climb if the rocket engine section is painted black and covered with a double sheet of polyethylene. We are doubtful about temperature after floating begins. New problems arose regarding balloon strength, reliability of release for small balloon reliability of Sonde, rationalization of handling H_2.
3. Ground test (7/20-21/59 Institute)	Examine small balloon release, pressure-burst test of actual $450m^3$ balloon.	Decided to use method of burning off rope by igniting heating element with fuse. Ascertained that balloon strength about equal to designed value.
4. Dummy test (7/20-21/59 Obuchi)	Determine rocket propellant temperature after floating state begins. Understand conditions to which balloon exposed while adrift.	Found it possible to maintain propellant temperature at 25° C even after entering floating state. Found it necessary to improve balloon strength after discovering that a load several times greater than estimated by static tests, was acting on balloon.

Table 1 (continued)

Item	Purpose	Results
5. Rockoon test (1/10/59, Obuchi)	Launching test of Rockoon rocket. Measurement of rocket attitude angle. Determination of rockoon spin while floating.	Propellant ignition certain. Ascertained burning characteristics coincide with ground burning test results. Could not obtain data on attitude angle. Observed that there was an average of 1 spin/min. while floating. Believed balloon not sufficiently reinforced. Found it necessary to consider temperature of H_2 gas used for inflation.
6. Measurement of electric potential of balloon. Pretest (3/2, 4, 6/60 Hatano)	Examine use of meteorological radiosonde as method for measuring static electric behavior of polyethylene balloon.	Suitable position of radiosonde 10 m below large balloon. Electric potential greatest when balloon attached to launcher and moved about by wind, if conditions poor danger of electric discharge, but overall potential apparently drops at high altitudes. Polarity still unknown.
7. Dummy test (7/21/60, Obuchi)	Test of new type balloon. Command test. Measurement of electric potential of balloon.	No results besides radiosonde due to errors in launching operations.
8. Dummy test Rocket test (10/18/60, Obuchi)	Test of new type balloon. Command test. Cosmic ray observation by rockoon.	Confirmed reliability of command system. Believe uncertainties eliminated in strength of new type balloon. Could not make actual launch of rockoon. Find it necessary to protect balloon from wind when inflating with H_2.

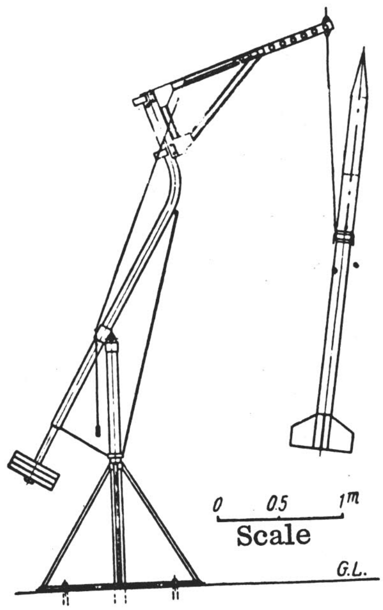


Figure 1. Rocket launcher.

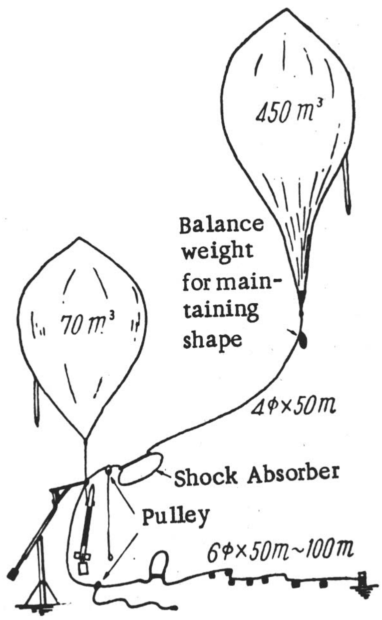


Figure 2. Explanatory drawing of launching test.

hoisted as shown in Figure 1. The main rope is coupled to the large balloon and a short auxiliary rope with a release mechanism is at the center. As shown in Figure 2, the small auxiliary balloon has ample bouyancy to support the weight of the rocket and suspended payload.

During the launch the large balloon is released, and just before the main rope has paid out, the arms of the launcher are opened (either by hand or by remote control using the gas pressure of an explosive charge). The rocket and suspended payload are supported by the bouyancy of the small balloon and the entire rig ascends without swinging about or crashing to the ground.

After attaining a desirable altitude, the small balloon is released by using the release device attached to the previously mentioned short auxiliary rope, and the rig becomes a regular rockoon system. When the small balloon is released the loop in the main rope acts as a shock absorber.

This method, which was being used for the first time, had to be proven. Therefore several launching tests were conducted. Nine tests were made using a pulley and a guy rope for pulling down the gear as shown in Figure 2, but were not actually used in the final test. As a result, the balloon after having been partially inflated with hydrogen could be safely launched even with a wind velocity of 3-5 m/s. On the day of the actual experiment, the weather was 100% perfect.

It was discovered that the most suitable time for disengagement from the rocket launcher was just before the main rope paid out. The dead weight attached to the bottom of the large balloon during the launching test, was constructed 1/3 the size of the original. In a later experiment in Aomori this dead weight proved to be especially valuable. Since a safe, reliable launching system was now in sight, experiments were encouraged on the problems relating to the temperature of the solid propellant for the rocket engine.

2. Dummy Test

The dummy test was made because although previous flight tests had been made to measure the temperature of the propellant, and ignition firing tests also carried out, combustion in the rocket engine was incomplete. Since the use of a restricted burning polyester composite propellant was anticipated in the method, a polyester resin with the same heat conductivity as the propellant, was used. Two dummy rockets were constructed, each half full of propellant. Sixteen thermistors were buried at every observable heat measuring point and a telemetering system was used to record temperatures at various points. Since reliable ascent and float data were desired, we chose the grounds of Nishi elementary school in Honjo City in Saitama Prefecture, where we had conducted preliminary rockoon tests at the end of 1956. We also selected the Kumagaya Meteorological Observatory annex which was located next to the school, and as a second telemeter receiving station, we selected the Hatano Station for the Meteorological Observation of the Troposphere. We were grateful to obtain the cooperation and the convenience of the above station. On February 19th at 5 a.m., the time schedule for the experiment began according to plan and with little or no wind the balloon was successfully launched at 7:56 a.m. However, 1 minute 36 seconds after launching, the line of the large balloon snapped. The dummy rocket fell by parachute onto a tree in the school yard and our objective was not achieved. The chief reason for this was that due to economy measures; we used a large balloon made in June 1957, and we discovered that the lines, that were together at the air escape exit at the bottom of the balloon, were made of hemp and had deteriorated after two years. We also discovered that the release mechanism for the small balloon was not constructed sufficiently well to resist shock. Since there was nothing wrong with the dummy rocket itself or its instruments, we took immediate measures and 20 days later conducted the second test. Fortunately, at 7 a.m. the rain and wind, which had occurred the previous night had disappeared, and there were many open spaces in the clouds through which the sky was visible. Therefore, we scheduled the launching for 9 o'clock, just before the wind would begin to blow again. Fortunately, everything went according to schedule. As a result of the close cooperation of the entire crew, it was possible to release the balloon 5 minutes before schedule at 8:55.

The temperature measuring instrument and telemeter remained in good condition throughout the experiment. Although the small balloon received the switch-on signal 2 minutes 58 seconds later, it was not released, but ascended together with the large balloon right to the end. It was assumed that some damage occurred to the nichrome wires. Thirty minutes later at an altitude of 4,000 meters, the sonde transmission stopped. From there the altitude and consequently the rate of climb could not be known, but fortunately with a 6 inch equatorial telescope, the balloon was seen in the sky with no clouds surrounding it, and after 63 minutes, we saw it dilate and burst. Although data was obtained on the temperature of the propellant during ascent, we obtained no information concerning conditions while the apparatus was floating. We painted the outside of the aluminum alloy chamber and the tail black, and when the polyethylene cover was doubled over and covered the chamber, the temperature of the propellant, which was over 10° C on ground approached 20° C as the rocket climbed. Although there was some difference in the temperature in each part, it is practically negligible if one takes into consideration the fact that the heat coefficient of the composite propellant is comparatively small. Consequently, it was felt that the double-sheet polyethylene cover system would be best for maintaining the temperature of the propellant. The necessity arose, however, for confirming this under flight conditions (floating conditions).

As a result of the experiment, the following problems have arisen.

a) To construct a safe and reliable releasing device for the small balloon.

b) To examine the strength of the large balloon.

c) To speed up and simplify the transport of the hydrogen cylinder and the hydrogen inflation operation.

d) To examine the reliability of the sonde.

e) To reduce the time required for preliminary preparations in the time schedule.

f) To study the temperature of the propellant when floating. Also, we gained confidence in the small auxiliary balloon launching system.

3. Ground Test

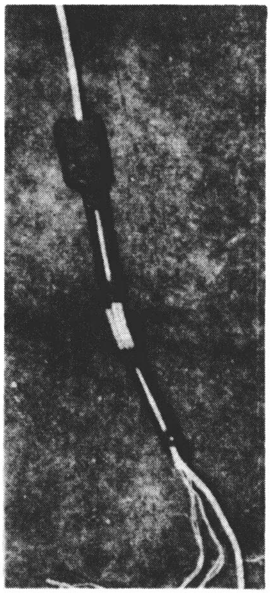
This was a countermeasure for a), b), and c) above. For the solution to a), tests of the following three proposals were made.

(1) A system combining aneroid, micro-switch and nichrome wire, and melting off the nylon rope.

(2) A system combining the displacement of the aneroid with a perfect mechanical release mechanism.

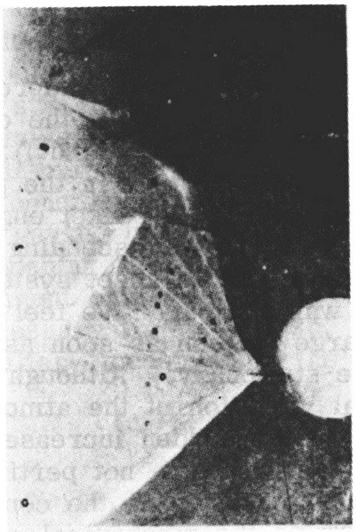
(3) A system combining electric fuse and igniter.

All three proposals were tested and the third method, as tested by the Fuji Precision and Imperial Fire Works group proved the most practical and rational from the standpoint of flexibility with the rocket launcher release, reliability and cost. For this reason the No. (3) method was chiefly used for releasing the small balloon from then on.

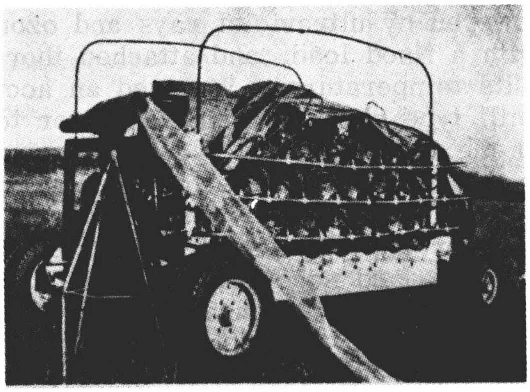


Picture 2. Release device.

Research data on the strength of the balloon in b) is insufficient. At present, as a result of simple theoretical calculations, we have constructed a water model about 1/30th the size of the balloon, and can only estimate its actual strength. In order to verify whether the actual balloon had the strength anticipated, the 450 m^3 balloon used in launching and ground tests was tested by blowing hot air into it. Just as anticipated, the rupture point indicated was approximately a value of a 10 mm column of water. However, judging from the form and location of the burstholes, regardless of



Picture 3. Balloon rupture holes due to applied pressure test.



Picture 4. Dolly with cylinders.

the strength of the materials, it was felt necessary to examine the balloon from the standpoint of the technique used in processing it. Furthermore it should be borne in mind that warm air measuring 30° C was used, which was not identical to high altitude conditions. As indicated in the photograph in the front (P. 11, picture 1) we measured the balloon at double its original size, putting markers on all important spots. For c) tests were made of a carriage for transporting cylinders capable of supplying a total flotation weight of 100 kg.

4. Dummy Test

Due to the fact that the telemeter was improved and it was possible to predict its range, a trial test was made at the original firing and testing ground scheduled for autumn and tests on b) and f) above were carried out. In testing f), the same method was used as in the previous dummy test in order to estimate the temperature of the rocket engine propellant while the rockoon was drifting in the air and while ascending. We discovered that it was possible for the polyethylene double sheet system to provide sufficient and practical heat insulation while afloat. We feel that it is difficult to explain the bursting of the large balloon as soon as it is fully inflated, by considering its strength while stationary. Although there is in this regard an old theory of the abnormal vibration of the atmosphere, and the theory advanced by Powell recently on the sudden increase in the rate of climb, it is felt that these two explanations were not pertinent to our experience.

We thought it necessary to ascertain the condition of the large balloon when climbing. To measure the mechanical conditions of the large balloon, an accurate pressure difference gauge sensitive to a 1 mm column of water was attached to the top of the balloon, in order to measure the difference in pressure between the outside and inside. A windmill type air escape velocity indicator, and thermistors to measure the temperature of the exhaust air were attached to the appendix value. Also, thermistors were affixed to two spots on the balloon in order to estimate the temperature of the balloon sheet. Considering the fact that polyethylene deteriorates and its resistance is lowered by ultraviolet rays and ozone, we took a test piece of polyethylene with a fixed load, and attached thermistors to it in an attempt to estimate its temperature. We used an accurate manometer (altimeter) and a windmill type climb velocity indicator to discover the variations in the motion of the rockoon while ascending. In addition, a solar battery was attached to the instrument pole for test purposes and in this manner we decided to try to measure 53 items.

The material used for the polyethylene sheet is macromolecular, being a mixture of crystalline and noncrystalline substances, since there was uncertainty as to its electrostatic behavior and some doubts concerning unexpected electrical phenomena in the upper air. Plans were made to clear up these points by conducting tests at Honjo after the dummy tests, but since this would exceed 50 test items and become too complicated, it was decided to postpone the matter to a later date. In spite of this, the device was very complicated as shown in Figure 3. We feel that much was gained by the very fact that we achieved the objectives hoped for, namely, attempting many measurements with many instruments, and mastering the technique of launching such a complicated apparatus. Although it is estimated as a result of experiments that the polyethylene sheet will remain stable down to -30° C, we discovered that its tensile strength would not go below half that. When the exhaust air of the large balloon passes an ascent velocity of 400 m/min in the stratosphere jet stream, we discovered that the air, (not the hydrogen) sucked into the balloon up to that time was ejected while indicating a pulsation of several times a minute as shown in Figure 4, (1) and (2). Considering the facts mentioned above, when one calculates the pulsatory rise in the internal pressure (which we consider inevitable), it is gauged to approach approximately a 7 mm column of water, and the internal pressure still reaches this value when the required value of the area of the appendix value opening is increased four times. It is presumed that the balloon will burst as a result of only the pulsatory rise in internal pressure, if one considers that the maximum pressure before rupturing while stationary is gauged by a column of water, and that the value of the area of the value opening is usually doubled. Although we should have conducted the experiment only after a full examination of the balloon's design, we lacked the necessary time to do so, and consequently we had to resort to all possible auxiliary measures in the experiments following.

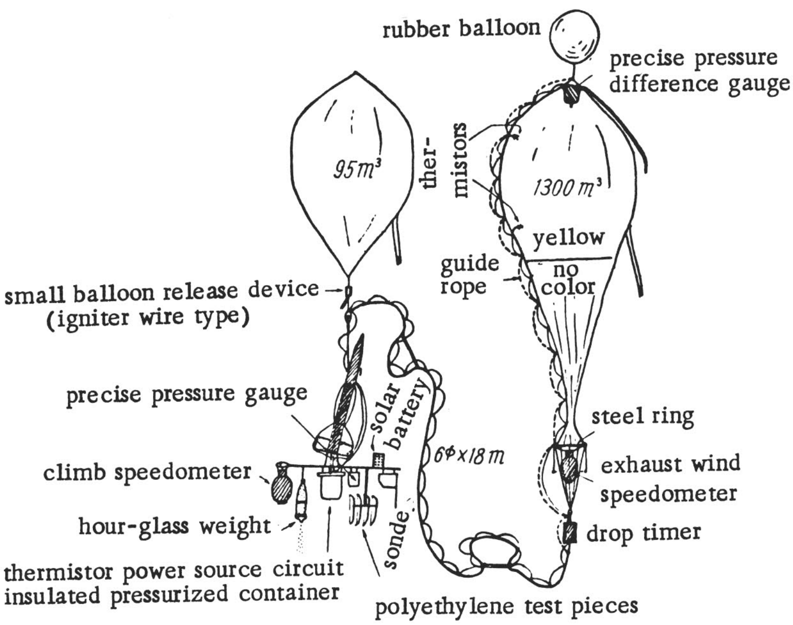
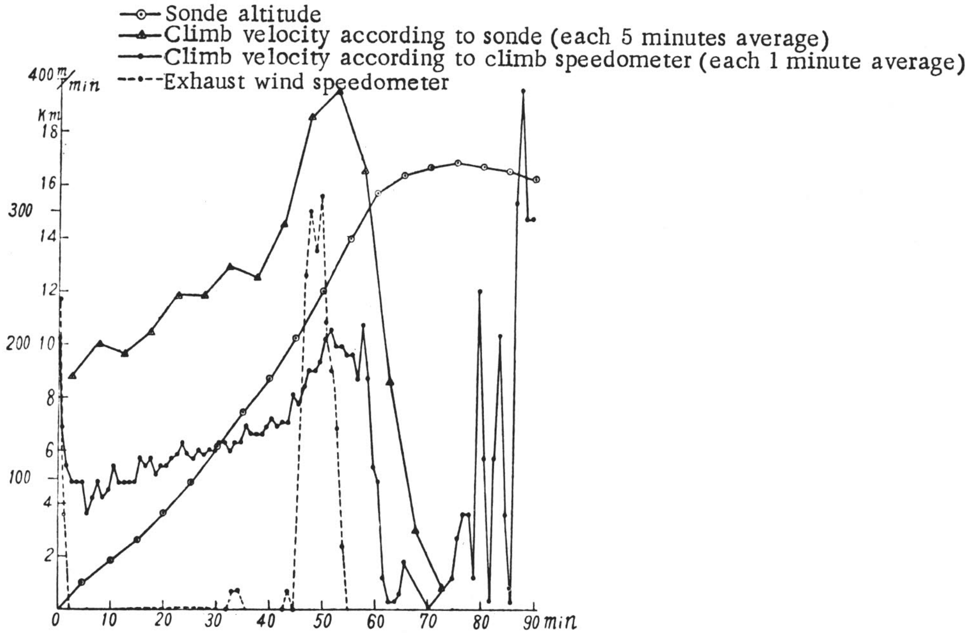


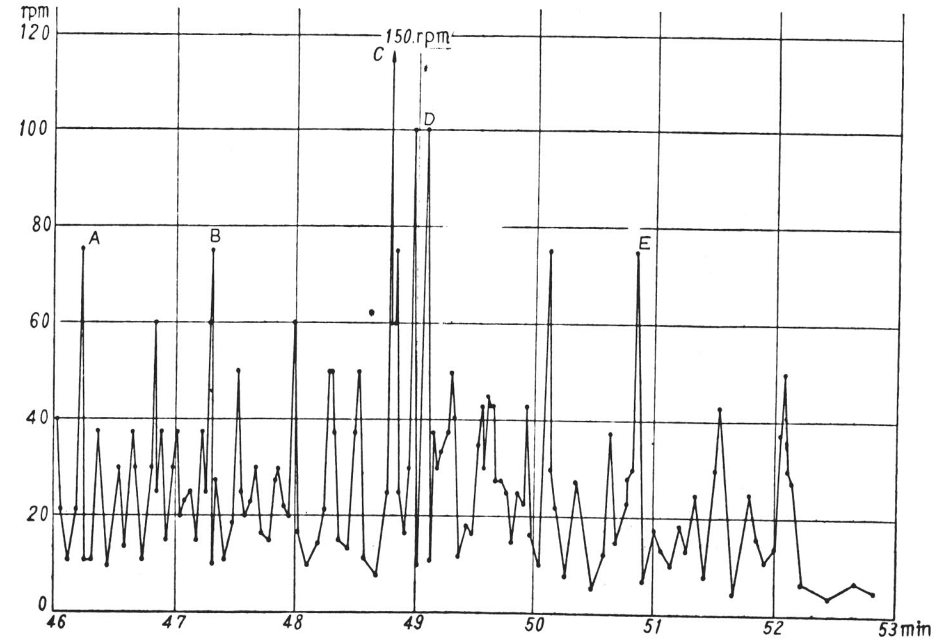
Figure 3. July Dummy Test in Aomori.

In this experiment for want of a better one, we borrowed a balloon launcher which had been designed and constructed for other experiments. However, the clamp was not strong enough, and just before we finished inflating it with hydrogen, while the rocket launcher was still in the process of being readied, the large balloon broke loose and began to ascend. Fortunately, the rope was caught on the launcher bolt and everything turned out satisfactorily. However, this made us realize the necessity of exercising further caution in this matter, so we decided to use an anchor rope when preparing the large balloon. Nevertheless it is felt that a special rockoon balloon launcher is absolutely necessary.

5. The Fist Rockoon Experiment in 1959



(1)



(2) Speed of Rotation of exhaust wind meter windmill when wind is escaping.

Figure 4. Balloon data during climb of dummy tests.

Since we cleared up all the problems left to us in the beginning by our predecessors (Nos. I, II and III) and those arising while solving them, we put main emphasis on the final goal for this year, which was complete combustion in the rocket engine, and secondary emphasis on experimenting with the flight attitude of the rocket, and sounding. We used two SIGMA-3 rockets. In making definite plans for the experiment, we discovered that we had only considered the propellant temperature problem in the ignition and combustion of the engine propellant, to the complete neglect of the problem of pressure decrease in the upper atmosphere. For the time being, we exerted our efforts to create conditions as close as possible to those of the ground test and decided to conduct the experiment after testing the nozzle closure for an airtight seal.

From excellent records made by the accelerometer in rocket No. 1, we learned that the engine burning was identical with that of the ground combustion test. Although No. 2 dropped after the large balloon burst prematurely just before firing, we learned that complete combustion took place as in the case of No. 1. We were unable to obtain any data on attitude during flight, since the gryo carried in the rocket was in poor operating condition. Due to the poor operation of the Pirani gauge, we have no direct data on the altitude reached, but judging from the period of flight, it was considerably less than that anticipated from a firing angle of 80°. It is estimated that the most probable cause was that there was no attenuation of vibration in the rocket after the suspended payload was cut off.

Moreover, the reason that the large balloon for No. 2 burst after reaching an ascent velocity of 550m/min, was because the hydrogen gas was put into the balloon before schedule and then, just before launching, the telemeter equipment was not functioning properly and the balloon was exposed to the direct rays of the sun for about 30 minutes. The temperature of the hydrogen increased, and it is believed that there was an increase in free buoyancy. Thus we felt it absolutely necessary to employ a device for raising the temperature of the hydrogen to that of the atmosphere, and reconsider a method for designing more than just a makeshift device for strengthening the balloon.

6. Preparatory Experiment in Measuring the Electric Potential of the Balloon

As explained previously, since the static electrical behavior of the polyethylene sheet was obscure, we decided to measure the field intensity occurring as a result of the electric potential of the large balloon, in order to estimate by way of precaution the electric potential itself. Obtaining the cooperation of Professor Saburo Okazaki and Mr. Koichi Aihara of the Institute of Aeronautics, we were in the process of making preparations. By chance we learned from Meisei Electric Company of the existence of an electric sonde for meteorological observation, and decided to make a preliminary experiment with it. We obtained permission from Mr. Chihiro Ishii, chief researcher of the SR (sounding rocket) group, to

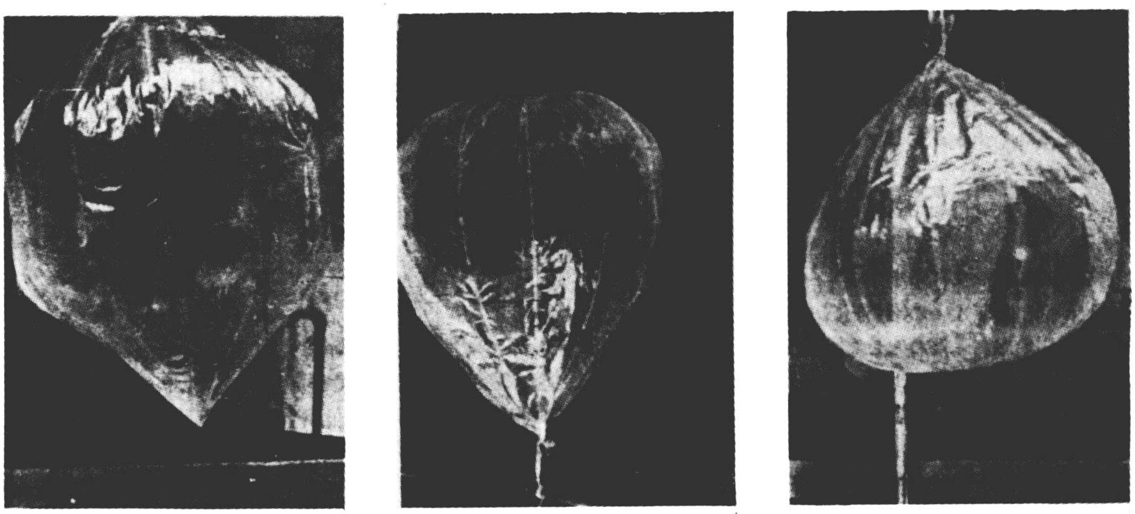
Picture 5. Radiosonde for Meteorological Data.

use a radioactive sonde in the large balloon test. We measured conditions close to the ground with a rotating electric collector constructed at Professor Okazaki's laboratory. (see photograph 2, center of page 10.)

The results of this test are being compiled with the assistance of Professor Okazaki. In general, the electric potential generated in the large balloon is applied to the balloon launcher and is at a maximum when blown around by the wind and at the moment of launching. At this time, if an adverse condition such as the contact of a metallic edge occurs, there is possible danger of an electric discharge, and we discovered that as the balloon ascends into the upper atmosphere, there is a tendency for the potential of the balloon to decrease as the conductivity of the atmosphere increases. We also discovered that by suspending the electric sonde about 10 m below the large balloon, it was suitable for measurements. If the potential of such a huge balloon is always this way, then we believe it permissible to disregard the problem of static electricity occurring in the problem of rupture when the balloon is inflated to the bursting point. However, questions still remain as to whether the potential is steady, whether it varies daily, and what the nature of the minute polarity and potential is.

7. Dummy Test

The large conventional SARDINIA type pyramidic and prismatically joined balloons are easily processed as the lines of fusion are all straight, and there is no waste in cutting. Also from the standpoint of conditions of use, there is an advantage in that even when attached to the statically most severe balloon launcher, they are more favorable than other forms. There is a disadvantage in the last point, however, in the condition occurring when the balloon dilates in the upper atmosphere. The problem with our large balloon at present is this same disadvantage. As a result of several deliberations on what would be a more rational balloon shape, it was felt that rather than suddenly adopt the American SKYHOOK which is flat in appearance, the AKUA, which has at its top the same curve as a conventional parachute, would suit our needs satisfactorily (the AKUA is used by Fuji Rubber as a salvage balloon for raising sunken ships, who apparently adopted this name since it is made and used by them). We constructed water models of the conventional polygonal type and the two new types and conducted comparative strength tests of them. We learned



(1) Hexagonal configuration (2) AKUA type (3) SKYHOOK

Picture 6. Water models of three types of balloons tested.

as a result that the two new types were 30 to 50% stronger when fully inflated than the conventional one. A problem arose in the selection of one of the two new ones, since it was difficult to detect any difference in the static tests, and it was only reasonable to choose that one which showed an advantage in respect to dynamic conditions. However, the dynamic conditions that the large balloon would encounter were unknown, so there is a need to carry out basic theoretical and experimental research. At the present stage progress is negative and moving slowly due, I believe, to a lackadaisical attitude. As described before, we have taken the problem of hydrogen temperature into consideration and employing a hydrogen heater, we decided to perform a launching test of the actual AKUA balloon.

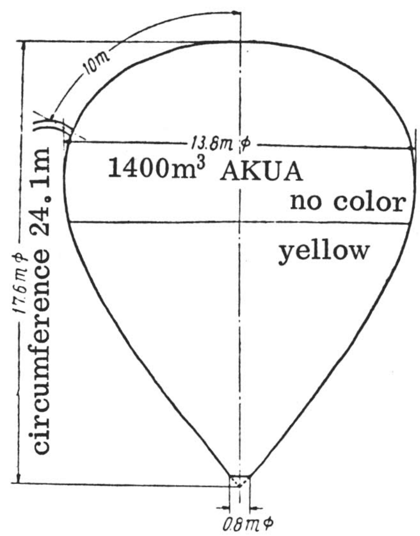
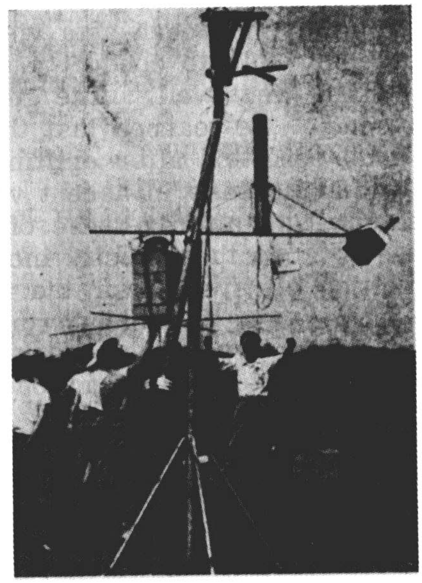


Figure 5. Large AKUA balloon used in (8).

Since the horizontal range of the ROCKOON rocket launched at the usual firing angle of 80° was too great, as a countermeasure we chose a firing angle of 85° in order to reduce the horizontal range to half and doubled the main rope to 100 m in order to keep the rocket from coming in contact with the balloon.

Since we planned to command the firing operation from the ground, we had to conduct a pretest. We combined the above with the final experiment, which was to measure the electric potential of the balloon. Although two launchings were made, we were not completely successful in achieving our goals. Although we should have moved the balloon launcher just before the first launching in the direction of the wind, since we were using the time in between meteorological observations at the meteorological station, we had to save time. Also since it was difficult to move about in a short time with only a minimum of crew members in a disorganized area, we were forced to carry out an abnormal, disorganized experiment. As a result the instruments were caught on the rocket launcher and dropped as shown in picture 7. Since the instrument pole used in the the first test was so long that it obstructed the view, we did not take the



Picture 7. Horizontal instrument pole used in dummy tests (7).

The Zenith photometer fell.

overall load into consideration in the second test, and as soon as we began the second one, without economizing at all, and the sandbags to be used for ballast were not attached, the crew did not give its undivided attention, and the pole was moved by the main rope. The free bouyancy of the small balloon became 7 kg too great, and although it should have been less than the 10 kg of the zenith photometer which was dropped the previous day, the small balloon reached a different altitude than the large one and ascended in a different direction. Its release device and the main rope were cut off and fell to earth. The only test which was at all satisfactory in either test was sounding with the radiosonde. The reason for the failures was not inherent in the small balloon launcher itself, but was due to failure in observing operational rules.

8. Dummy Tests and the Rockoon Experiment

Not having achieved our goals in 7, we employed a dummy rocket of exactly the same form and weight as that used in the final firing test, made the main rope into two strands and machine processed the attached section beforehand in order to avoid as much as possible loss in strength. We reexamined the shock damper, improved it, and restored the release and timer. Also we used a hydrogen warmer using warm water, just as that used in the Hatano experiment, for filling the balloon with hydrogen.

Since we had planned to employ a command system for firing, we also used a spinmeter to control the firing direction and attempted to cause the assembly to fall into the ocean at a visible place. Due to inclement weather we were only able to conduct a dummy test, and outside of the spin meter, everything went well. The guidance (command) showed good performance to the end. We learned that the large AKUA balloon continued to ascend in good condition after drifting upward and releasing the payload. Previously the increase in ascent velocity at high altitudes reached 100% of the velocity just after release of the balloon, but at this time we found it possible to keep the velocity increase under control. Instead of the previous melting off system for the nichrome wire in the release mechanism, we changed over to a gunpowder method and this also functioned perfectly. The clock type timer manufactured by Toshiba that we used in place of the micromotor also functioned well. Figure 6 shows the system in its entirety.

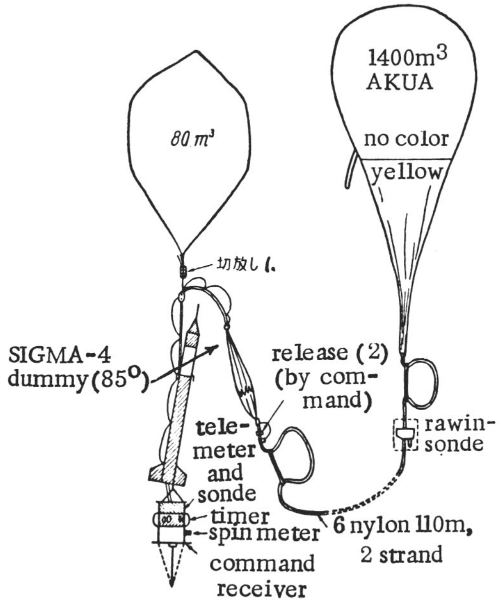


Figure 6. Equipment in (8).

Although it was unfortunate that we were unable to actually fire the SIGMA-4, its propellant was an improvement over that of the SIGMA-3 and its comparative thrust was improved 5%. The amount of propellant was increased 12% due to the fact that the outer diameter of the engine chamber was increased 5 mm to equal the 125 diameter of the nose section. The overall length was 2,772 cm as the design of the nose section was rationalized, and the transmitting antenna of the telemeter was attached to the tip of the nose cone. In place of signal sheet aluminum alloy, a honeycomb structure was used and the rocket was lightened. However, the tail had 4 sheets. The estimated performance was a range of 96.5 km fired at an angle of 85° at an altitude of 20 km.

Summary

Although we did not reach the point of carrying out an actual flight experiment, in view of the above results we learned that under favorable climatic conditions, it would be possible to launch safely and reliably a rockoon several kilograms heavier than the rocket itself. It is possible to anticipate a range of 100 km for the SIGMA, when the payload of the rocket is less than 6 kg. Also it is possible to limit the fall and direction to some extent to a desired area.

Future Problems

Although it became clear through the launching test that it is possible to launch a rockoon safely even with a wind of 3 m/s to 5 m/s after the hydrogen has been introduced into the balloon, it is required that there be almost no wind during inflation. At present it is necessary to expect that, if a gust of wind arises at this time, the balloon will rupture. Although the several ways of avoiding this danger were examined, due to economic and time considerations the method adopted was to introduce the hydrogen in the shortest time possible after waiting for a lull in the wind. Since this method is inadequate, the time required for the experiment was often prolonged while waiting for suitable weather conditions, and the balloon was often ruptured by gusts of wind. However, it is felt that the planning of the performance of the rockoon experiments can be greatly improved by constructing an inflation chamber, or at least by constructing a shield against the wind.

One other problem with the balloon is its rupturing at high altitudes when dilated. Experience has shown that an extremely efficient countermeasure is to measure accurately the free bouyancy acting on the balloon and to restrain the rate of ascent below a certain limit. It is also extremely desirable to provide facilities such as those mentioned above to avoid errors in bouyancy orientation, when the balloon is acted upon by the wind after being inflated with hydrogen. The resistance against rupture of the newly tested AKUA balloon has been improved about 30%, but we feel that in order to bring to light the real causes of this rupturing, we shall have to understand the conditions undergone during ascent and prepare data on a more rational design of a large balloon through theory and experiments. It is also necessary to examine further the shape, sheet materials, and processing techniques. Moreover, we believe that it is necessary to shorten the time schedule by omitting the leak test, by having a thorough examination made by the factory, since the flight time (at most) of the large balloon is no more than 2 hours. Also, since it is necessary for the balloon launcher to be easily movable in the direction of the wind at launching time, we feel that a new rockoon balloon launcher should be produced and tested.

At the present stage where a small balloon is being used, the rocket launcher functions perfectly as a balloon launcher, but it should be improved to function as an operation tower for making final flight preparations and for attaching the payload of instruments to the bottom of the rocket.

As mentioned above, the rockoon rocket is fired at a high altitude in a low density layer and the aerodynamic conditions undergone by the fuselage are much less harsh than when fired from the ground. We should design and produce a fuselage that can be fired within 12 minutes after launching. Also it should be possible to fire future rockets vertically for the convenience of instrument measurement to reduce the sea area in danger of a falling rocket, and to improve the climb performance of the rocket. Another problem remaining is that we did not obtain reliable data on the flight altitude of other rockoon rockets.

As far as rocket propellants are concerned, not only should the specific impulse be improved, but also when increasing the charge filling weight, the length — diameter ratio should be made suitable, and plans should be made to improve the maximum altitude by improving the quality-quantity ratio. Also, examination is under way at present of a way of increasing both the specific impulse and the amount of propellant charge by 10%. If realized, it will be possible to increase the rocket's flight range 40% by the above and by shortening the combustion time. If one considers lightening the fuselage, one can expect the SIGMA rockoon's maximum range to be 150 km, with a payload of 6 kg. It is also necessary to insure ignition combustion at low pressure, since the rockoon rocket is ignited at high altitudes. Also, if it becomes possible to develop a propellant that can be used at low temperatures, then a rockoon can be constructed for night launching.

Conclusion

The results of 2 years of rockoon development and research, still lacking data on various problems are generally as given above. All the accomplishments made thus far are the result of the understanding and cooperation of personnel from each level, and to them many thanks are due.

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