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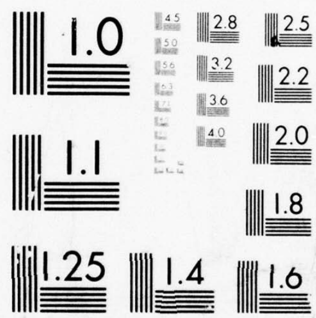

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FOREIGN TECHNOLOGY DIVISION

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AERONAUTICAL KNOWLEDGE
(SELECTED ARTICLES)

FOREIGN TECHNOLOGY DIVISION

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Hsinhua News Agency: On Nov. 17th 1976, our country successfully conducted a new hydrogen bomb test.

OUR COUNTRY HAS AGAIN LAUNCHED AN ARTIFICIAL SATELLITE SUCCESSFULLY

Hsinhua News Agency: On Dec. 7th 1976, our country again launched an artificial earth satellite successfully.

OUR ARTIFICIAL SATELLITE RETURNED TO EARTH ACCURATELY

Hsinhua News Agency: News Bulletin on Dec. 10th 1976.

Our artificial satellite, launched on 7th December, has returned to earth accurately according to plan.

According to the directions of "thoroughly organized, delicately managed" of Chairman Hua, all tracking, measuring, control tower and recovery personnel are operating seriously and completing the recovery mission successfully.

The Central Committee of the Chinese Communist Party, State Council, and Central Military Commissions sincerely congratulate all comrades who participated in this recovery mission.

IN MEMORY OF PREMIER CHOU, SCIENCE MODERIZATION MUST BE CARRIED OUT WITH AN EFFORT

CHIEN Hsueh-shen

Our beloved Premier Chou En Lai passed away more than a year ago. Reading articles by people who remember him, listening to the songs that people write about him, and watching stage shows in which people laud him, it again flashes into our minds to think of him. The fact that twenty-two years ago, our family could fortunately return to the bosom of the sosialist homeland is inseparably linked with Premier Chou who firmly executed Chairman Mao's revolutionary diplomatic direction. My whole family wholeheartedly respected and loved Premier Chou. Every time we think of him, we feel so close to him. After the death of Premier Chou, we framed the picture of Chairman Mao and Premier Chou who took the picture in 1945, and hung it on the wall, and every day we look at the picture that gives us tremendous encouragement and strength in order to convey the endless sad feelings of our family. We also cut out pictures of Premier Chou's activities in recent years from magazines and pasted them in a scrapbook so we can read it often, learn of the Premier's great revolutionary practice, and combine it with the eulogy at Premier Chou's memorial service. We learn especially from the phrase "we want to follow his pattern". Now we will not see Premier Chou En Lai anymore. However, Premier Chou did not leave us, but still encourages and teaches us to do good revolutionary work. The Wang, Chang, Chiang and Yao "Gang of Four" struck and persecuted Premier Chou, chimerically erased the brillian image of Premier Chou, and aroused our incomparable righteous indignation!

I have received a lot more education from Premier Chou En Lai. The great leader and teacher, Chairman Mao, gave me a lot of attention and many times showed me the marching directions of revolution, but, I may say, Premier Chou is the one who held my hand and taught me how to walk the road of revolution.-----------

Premier Chou En Lai had made indelible contributions to the revolution and construction of our country and established perpetual achievelments. ----. In 1957, at the fourth meeting of the First National People's Congress, Premier Chou pointed out in his "Report of Government work": "In order to develop our scientific and technical work effectively, the principles of coordination must be carried out. All related departments must work in a coordinated manner". "The scientific research strength of the entire country should be planned in an overall manner and arranged for the division of work on one hand, and most important is close coordination on the other hand". Later, as work gradually developed, Premier Chou pointed out at a conference in early 1963: All from the top down must have high political thoughts, high scientific planning, and highly organized discipline. In 1970, Premier Chou emphasized again that scientific and technical work on a broad scope need long term planning and should have a ten-year plan, and a presupposition; it must be rapid, but must follow in proper sequence, make steady progress, and there must be plans and preparations. In May 1974, when Premier Chou was very ill, he still wrote on a report of scientific and technical research items that guide lines must be made for the manufacturing, coordination, and use; then divide the work, amke a plan, and enforce it, which inspired me very much.------

"The Gang of Four" is something else.-------------

During the revealing and critizing of the antirevolutionary criminal acts of the "Gand of Four", I longed even more for the beloved Premier Chou En Lai. Under the direction of Chairman Mao's revolutionary line, he led the scientific and technical work on a national scale, and not only established this work, but also laid the foundation for the modernization of the science and technology of our country.

Now, the perspicacious leader and chief commander, Chairman Hua Kuo Feng has crushed the "Gang of Four" in one move to clear out the obstructions on our road to progress. Chairman Hua is very much concerned about our work. We must be closely united around the Party Central Committee headed by Chairman Hua, carrying out the bequeathed wishes of Chairman Mao, using the class struggle as the guiding principle, insisting upon the three basic lines of the Party, and insisting upon the three basic principles according to Premier Chou's directions of high political thoughts and highly organized disipline to complete all items with great efforts and to make the necessary contributions for the realization of agricultural modernization, industrial modernization, defense modernization, and the scientific and technical modernization of our country, catching up and passing the advanced level of the world.

SERVICE PEOPLE OF CAPITAL'S AIRPORT THINK MUCH OF PREMIER CHOU

News from this magazine: During the days of the first anniversary of the death of the beloved Premier Chou, people who work in the waiting room of the capital's airport are having numerous group discussion meetings to review the life of Premier Chou who was concerned about civil aviation and taught the people of civil aviation repeatedly, carefully and tirelessly. They also praised Premier Chou's great meritorious achievement and excellent quality and express their wholehearted love and sincere proletariat feelings toward Premier Chou.

The beloved Premier Chou's personal characteristics were plain and affable, modest and cautious. He was closely united with the people, interested in the sufferings of the people and left a very deep impression on the civil aviation service people. Comrade Lee Shui-chin said: In 1960, the first time I gave Premier Chou a haircut I was so excited and very nervous.------------.

Premier Chou worked very properly and demanded very strictly. He lived very frugally and modestly, which is very educational for all of us. The restaurant service attendant, Liu Hui-min, said: Premier Chou came to the airport, ate very simply, and never had anything special---------------.

The criminal activities of the "Gang of Four" have been seen by the civil aviation service people and are hated in their hearts. ----- The behavior of the "Gang of Four" formed a striking contrast to the outstanding character of our beloved Premier Chou. To think of Premier on the first anniversary of his death we all decided, under the great leadership of the Party Central Committee headed by Chairman Hua Kwo-feng, to do our very best in everything, to criticize the criminal acts of the "Gang of Four", and to carry out the proletarian revolution started by Chairman Mao.

THINKING OF PREMIER CHOU TO CARRY OUT THE EDUCATION REVOLUTION

SHEN Yuan

The great proletarian revolutionary of our people and outstanding communist warrior, our beloved Premier Chou, has bidden farewell for a year. During this year, whenever I think of Premier Chou who established the perpetual achievements of the peoples' revolution of our country and of the world, I think of Premier Chou who was boundlessly devoted to Chairman Mao and Chairman Mao's revolutionary line; I think of Premier Chou who exhausted this energy in serving the Party and the people, worked day and night with the revolutionary spirit, was humble and frugal, dignified and courteous and had a magnanimous quality of conscientiousness; I think of Premier Chou who was sincerely concerned about the educational revolution of the higher educational institutions and the thought reform of the intellectuals; and I cannot repress the endless grievous memories and endless reverence in my heart.

In Feburary 1958, Premier Chou called an educators' conference at the Purple Hall in Chung Nan Hai, and asked us to report the development of the practice of working while studying in Peking Aeronautical Institute.---------. When I mentioned that our teachers and students had a plan to design and build a light airplane but could not solve the problem of finance in my report, Premier Chou immediately asked me how much money was needed, supported our plan, and told the authority of higher education to help us.--------. On the eve of National Day in 1958 the "Peking No. 1" light passenger airplane, designed and manufactured by teachers, students, and workers of our institute and financed on Premier Chou's personal approval made a test flight successfully at the Capital's Airport; some other models also had successful test flights and some had good results.------------------.

In 1972, Premier Chou was very ill, but still insisted upon working. One night in December of this year, Premier Chou wanted to be briefed on some work in the aviation industry.-------, he still mentioned the educational revolution in making the airplane in 1958, ----- still remembered this little achievement made 14 years ago. We were very touched by the fact that Premier Chou was so concerned about educational revolution in the higher educational institutions.

It was after ten o'clock at night when he received us as soon as he had received some foreign guest. Without any rest, he walked into the waiting room in good spirits. This conference lasted until after three o'clock in the morming. Premier Chou had people prepare hot evening meal for us, but he only had a few peanuts. The premier, this respectable old man, worked for the revolution day and night, and did not know what fatigue was, even during his sickness. When I think of this, I could not hold my tears, I was extremely sad. Premier Chou's life is the life of brilliant struggle for communism, the life of permanent revolution. The Wang, Chang, Chiang and Yao "Gang of Four" were in opposition to Premier Chou like mad,----------.

We must learn the proletarian revolutionary spirit and high revolutionary quality of Premier Chou, closely unite with the Party Central Committee headed by Chairman Hua, carry out the bequeathed wishes of Chairman Mao and the proletarian revolution started by Chairman Mao and struggled for during his entire life by Premier Chou, and carry out the proletarian educational revolution.

A CARRIER USED TO TRANSPORT A SATELLITE AND SPACE SHIP

CHI Teng

(A satellite and space ship that can leave the earth to travel in space depend on space carrier rockets. This article is a simple introduction emphasizing their usage, characteristics, main components, flight orbit, and prospects. This is a long article and will be published in two issues.)

In our daily life, common transportation uses different vehicles, ships, and airplanes. Following the developments of space techniques, and based on the guided missile in the latter part of this century, the carriers used to transport a satellite and space ship have been made and the activities of human beings are entering outer space from near earth. The carrier rocket is an important part of space flight systems. So, what is its use, what are its components? How does it differ from a ballistic missile? What are its future prospects?

USE OF CARRIER ROCKET

We know that an artificial satellite circles the Earth and does not fall down, which is due to its centrifugal force that cancels the Earth's gravitational force. In order to satisfy this requirement, it must reach a velocity of 7.9 km/s; this is called orbital velocity. If the velocity is higher than this value and reaches escape velocity (11.2 km/s) the satellite will then leave the Earth, circle around the Sun, and become an artificial planet of the solar system. It is necessary to have solar escape velocity (16.6 km/s) in order to leave the gravitaitonal field of the solar system. How the satellite and space ship attain the necessary velocity is an important question.

Up to now, only a rocket can fly to outer space. Because it does not need as much oxygen from air as a regular engine does, it carries its own fuel and oxidizing agent and can work in a vacuum. But according to the present technical level and the characteristics of the rocket propellent, the velocity which is necessary to launch a satellite cannot be attained by a single-stage rocket, and a multistage rocket must be used. It has been predicted that the reusable single-stage rocket which can send a satellite into orbit repeatedly will come to the market in the 80's.

The space carrier generally means a multi-stage rocket launched from the ground. It provides sufficient power to the satellite so that it attains the necessary velocity to enter the Earth's orbit; or to the spacecraft so that it attains the velocity to leave the earth's orbit.

CARRIER ROCKET AND BALLISTIC MISSILE

In developing the space flight systems, the ballistic missile is in a very important position, as it is the prototype of a space flying vehicle. Missiles of the late 30's had impregnated the shape of modern missiles. In WW II, fascist Germany was the first to use missile weapons, but could not escape defeat. Since the mid-50's, for seizing a greater range of power and dominating the world, the USA and USSR have expended much manpower, material, and money to expedite the research of missile nuclear weapons. The ballistic missile came into being in the late 50's. Due to military necessity and engineering requirements of the weapon, the development of the missile laid a broad technical foundation for the development of space flight systems. During the same period, the first artificial satellite was launched into orbit. Space techniques developed very rapidly during the period of the 60's and large space carrier rockets were made. The two American and Soviet tyrants launched quite a number of military reconnaissance satellites, communication satellites, and weather satellites, among which many were synchronous satellites (orbital altitude from the ground - 35,860 km).

For the low-orbit earth satellite at an orbiting altitude of about 300 kilometers, the warhead of a ballistic missile is replaced by a satellite with minor changes to satisfy the launching requirements. But the carrying power of the ballistic missile is insufficient for a high-orbit satellite and it is necessary to add one more rocket stage. For launching manned moon landing spacecraft or other probes to distant planets, larger carrier rockets have to be made.

To design the carrier rockets and missile weapons, not only is the effective payload different, but also the carrying power and use conditions. Since a missile is an expendable weapon with a long storage life, it should possess a longer survivability. It must have mobility and be launched from a concealed site. The time for launch preparation must be short, and the propellent must be added very rapidly and be in a good ready state before the lauch. Thus, a storable propellent must be used. And the outside dimensions and weight should not be too large or too heavy; otherwise, it is not suitable for mobility. Under the circumstances, in order to increase survivability it is better to sacrifice the carrying ability to satisfy the requirements for war.

FOR THE SPACE CARRIER ROCKET

The emphasis is placed on increasing the carrying capability.

It has no need for storage, and the time for preparing the launching is not restricted. Therefore, the low-temperature propellent with high energy but low storability can be used; the weight and the outside dimensions are not limited by the launching condition.

The flight orbit of the carrier rocket is more complicated than that of a missile. It has a long operating period and some times it ignites twice at the last stage. It is in the weightless condition in the flight orbit and the propellent is in the weightless state, thus cause some problems in the transportation and control of the propellent.

No matter how the missions of the carrier rocket and missile weaponery may differ, the emphasis in design consideration and the technical problems encountered are not the same, but methods of design, manufacturing, and testing are basically the same.

MAIN COMPONENTS

A carrier rocket is generally composed of several single-stage rockets. These rockets are usually connected in series, the head of each stage being connected to the tail of the other (Fig. 1). There are also parallel connections made with the lower stages, and series connections with the upper stages (Fig. 2). The whole carrier rocket is divided into three parts: the structure, power plant, and control system.

The structure portion has an instrument cabin, propellent tank, and tail (some large carrier rockets have a tail fin). The propellent tank occupies a large portion of the rocket. It is a container of the propellent, and also the body of the carrier rocket which supports the load during the flight. In order to reduce the structural weight, the tank is made by chemical milling to cut off the surface metal of the inner wall of the tank and make the wall mesh-like, then it is welded together as a tank

(Fig. 3). The oxydizing agent and propellant use two separate tanks. In order to reduce the length of the carrier rockets, they can be made into one tank, and a partition is used to divide the tank into two parts at the middle (Fig. 4). A damper is installed in the liquid propellent tank to reduce the sloshing of the propellent during flight. For a low-temperature-propellent tank, a layer of insulation is needed to reduce evaporation, since the amount of evaporation loss of the propellent is quite large. The engine is installed right at the rear of the body. The position of the instrument cabin is often in the front of the carrier rocket. The main instrument facility of the control system is placed in the cabin.

The power plant includes the rocket engine and the liquid-propellent supply system. The common chemical rockets are of solid and liquid types. The specific thrust of a solid rocket engine is lower than of the liquid one (specific thrust - the thrust produced by consuming 1 kg of propellent in 1 second). However, due to the simplicity of the structure and high reliability of the solid rocket engine, it is most suitable for launching long-range satallites, or for connection in parallel with lower first stage of the carrier rocket as a booster (Fig. 2). The liquid rocket engine is always the main propelling system of the carrier rocket. Usually the high-energy propellents (such as liquid hydrogen - liquid oxygen, etc.) are used in the two upper stages; the regular propellents such as liquid oxygen - kerosene are used in the one lower stage. Liquid hydrogen - liquid oxygen are high-energy low-temperature propellents, the specific thrust of which reaches more than 400 seconds - 100 to 200 seconds more than the regular type, The boiling point is too low, and the storability is poor, so this type of propellent is not suitable for guided missile weaponry, but it is suitable for use in space carrier rockets.

The control systems of the carrier rockets include the guidance system, attitude control system, ground telemetry, testing, launching systems, power supply, and distribution facilities.

Inertial guidance and radio guidance are generally used as guidance systems in the carrier rockets. Inertial guidance depends on an instrument which measures the acceleration of the carrier rocket, in the carrier rocket to perform. The main units are the gyroscope, accelerometer, computer, etc. Radio guidance measures the direction and velocity of the rocket carrier by radar or radio on the ground. After computation and comparison the order for the flight error correction is sent to the carrier rocket. Through the control system on board the carrier rocket, the flight orbit is corrected, and the engine is cut off by receiving the engine cut-off signal from the ground. The actuating mechanism of the control system generally uses a swinging or moving engine to generate the control power and moment of force so that the carrier rocket will turn according to the sequence and maintain the stability of its attitude during the flight.

The carrier rocket also has different separation systems, including the separation of each stage; the separation of the satellite, spaceship, and the last stage of the carrier; the separation of the satellite cowling. The separation systems between the stages should guarantee a firm connection of the stages, but must be able to release the lower stage after its work is completed and, at the same time, start the engine and control system in the upper stage.

THE CHARACTERISTICS OF EACH STAGE

A multistage carrier rocket is a whole body, but each stage has its own characteristics. The first stage flies a precipitous ascending orbit in the atmosphere, the ratio of takeoff thrust and the takeoff weight being about 1.2 to 1.5. If the ratio is larger than 1.7, it may cause greater aerodynamic heating during the flight. Stage separation takes place at an altitude of about 40 kilometers in the atmosphere. Problems of stability and control of the carrier at separation may arise due to the effect of aerodynamic drag and wind at the upper atmosphere.

For the upper stages at a high flight altitude, the ratio of thrust and the "takeoff weight" is usually close to one. An altitude nozzle can be used with the engine to further increase the efficiency.

The last stage of the carrier rocket should have the capability at flameout to adjust the velocity of the satellite or spacecraft to the predetermined precision. Most engines have an after effect impulse deviation after flameout; if the deviation is rather large, a small moving engine or small nozzle must be used to provide precisely regulated velocity.

The satellite, and spaceship are installed in the last stage of the carrier. A cowling is used to cover the satellite and reduce the aerodynamic drag while passing through the atmosphere and to avoid damage to the satellite by aerodynamic heating and aerodynamic pressure. The cowling is separated and jettisoned at near vacuum. (To be continued.)

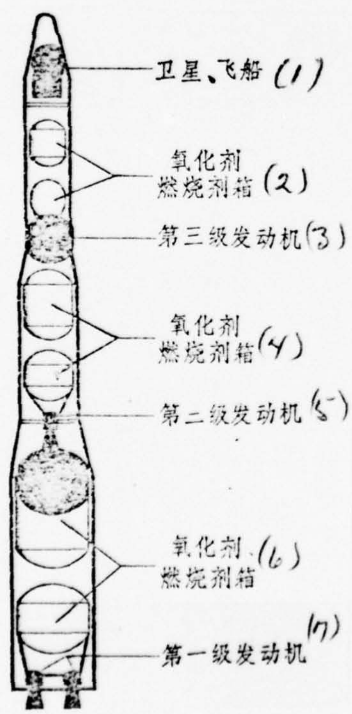

Fig. 1. Series connection type.

Key: (1) Satellite, space ship; (2) Oxidant, fuel tank; (3) Third stage engine; (4) Oxidant, fuel tank; (5) Second stage engine; (6) Oxidant, fuel tank; (7) First stage engine.

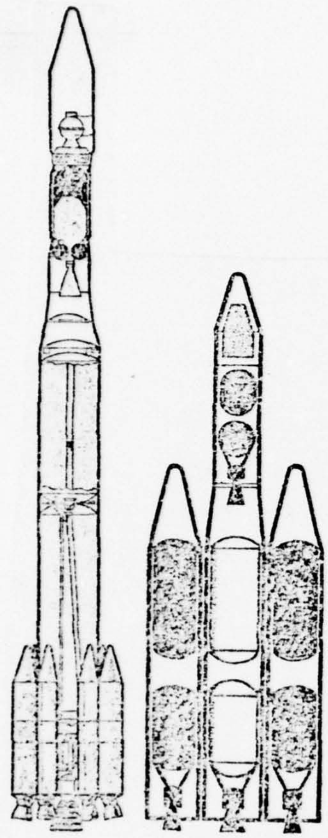

Fig. 2. Series and parallel combination type.

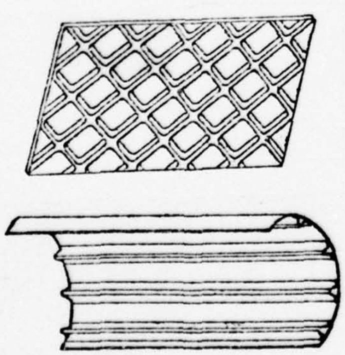

Fig. 3.

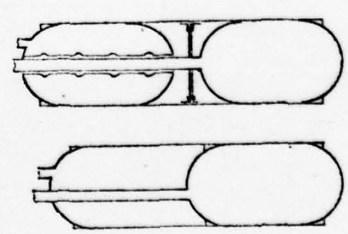

Fig. 4.

THE TESTING OF LIQUID ROCKET ENGINES

FAN Shun-fa

The testing of a rocket engine is an important practice in engine research and a means of checking the quality of engine production. Problems related to rocket engine testing are very broad. This article only gives a simple introduction to the testing contents, methods, and facilities of the liquid rocket engine on the test bench.

Everybody knows that the rocket engine is becoming popular in practical use among the power plants in flying vehicles. For military purposes it is used as the power plant of various rockets and missiles; for civilian purposes, it is used as the power plant of different spaceships and the artificial earth satellite carrying instruments. When you see that cars park on the highway due to engine trouble, you may think: would a missile fail while flying to an enemy target or during launching of an artificial satellite because of the poor quality of the engine? It is possible. In order to prevent these conditions from happening, it is required to provide a good and reliable engine as the power plant of the flying vehicle. Therefore, the quality of the engine must be totally and correctly tested and checked during research and production. To test the rocket engine is one of the effective methods to solve such a problem.

WHY TESTING IS NEEDED

The rocket engine is a complicated heat engine whose parameters affect each other. It is very difficult to guarantee the engine's high performance and reliable operation totally on the basis of theory and calculations. It must pass a number of repeated tests. In the test, the internal discipline of the engine at work is investigated in order to adjust and to improve the performance of the engine; to check the parts, the work reliability and technical quality of the engine; and to verify the correctness of the design theory. Therefore, before using the rocket engine, certain procedures must be followed for making different rigid tests.

A test of a rocket engine under the no-ignition condition is called a "cold test". A test with ignition on by burning the propellent in the generator or thruster is called a "hot test." A hot test is performed on the basis of a cold test. It can check the working reliability of the engine close to the practical working condition and obtain more accurate parameters. But the facility for the hot test is complex and expensive, and the hot test is only used as a supplement to the cold test or is used in a comprehensive test. The ground static hot test of the liquid rocket engine has been introduced.

TEST CONTENT AND METHOD

The static hot test of a liquid rocket engine consists of fixing the engine on the test platform, supplying the propellent from the supply system of the test platform to perform the hot test, and measuring the necessary working parmeter. Generally speaking, three different tests are made before the rocket engine is put in use: scientific research test, adjustment and steady test, and production test.

Tests during the research are scientific tests. The object of the tests is very broad, and tests are many. Many repeated tests are made on every part and the whole engine in order to choose the design parameters and the main characteristics of the engine, and to check the working reliability and other possible defects. Scientific tests also include environmental condition simulation tests based on certain requirements such as high and low temperature, vibration, overload, humidity, rainfall, vacuum, etc.

For the newly designed (or remodeled) engine, adjustment and model determination tests are also required. First, the working performance parameters of the engine are adjusted to the technical index of the design requirements, then the engine is installed in the flying vehicle and coordinated with the supply system and control system, and a static overall test is conducted. After the static test is passed, there is another flight test. If they all meet the requirements, then the model of the engine will be determined (the design blue print, technical index of the performance parameters, manufacturing technology, raw material selection, etc. will be determined). Then, it is put into mass production.

The mass produced engines should also have technological inspection tests of the parts and the whole engine. Most rocket engines are designed for one-time use, so this type of testing uses the sampling test method (also called sampling test). Tests must be done according to the specification of the model, that is, the basic parameters are measured (thrust, flow rate, pressure, working time) while the engine operates within the limit of allowable tolerances. If the samples pass the test, then the whole lot is considered passed. When the sample test does not satisfy the design requirements, one method is to double the samples. If they pass the test, then this production lot is considered passed; otherwise the whole lot does not pass.

TEST FACILITY AND TEST PLATFORM

Some test facilities of the rocket engine are simple, some are more complicated. The large liquid rocket engine test platform is especially complicated. During the test, the engine generates tremendous thrust (several dozen tons to several hundred tons to even more than a thousand tons), generates a very long flame (may reach from several dozen meters to more than 100 meters) with a temperature over 2,000°C, and makes a loud noise. These characteristics bring many difficulties for construction of the test facility and test platform. A series of requirements are also made for the test facility, test organization, safety, fire, and industrial hygiene. Now, we shall introduce the following aspects:

1. The types of Test Platform

According to different methods, there are several types as follows: there are platforms of large size, middle size, and small size according to the thrust of engine; there are platforms that use liquid, solid, hybrid, or nuclear fuel or electric power to propel according to the fuel; there are platforms that simulate high altitude, ground, or underwater conditions according to working conditions.

2. The Composition and Structural Model of a Test Platform

The basic compositions of different types of test platforms are nearly the same, but different in structure. The main composition are the fixed engine thrust test frame, propellent feed system, measuring system, maneuvering system, and control system. All facilities, equipment, and construction of these systems are called the "test platform." With the additional facilities (such as water, electricity, gas, communication, fire, maintenance, storage, cafeteria, dormitory, etc) for accommodating the technical personnel and workers, the whole place is called a "test station."

The engine is installed on the test frame horizontally (Fig. 1), vertically (Fig. 2), or inclined. The testing workship has open and closed structural types. The so-called open-type testing workship is to install the engine in a structure that has one side or three sides open to the air. The closed type is to install the engine test frame inside a closed room equipped with sound absorbent and sterilizing equipment. The structural type of the test platform is designed according to the size and use of the engine being tested. Generally speaking, a large or medium size engine is suitable for use on open and vertical type test platforms, and a small-size engine uses a closed and horizontal testing platform. Now, let us see the following two examples.

Assuming that the thrust of the engine does not exceed five tons, the test platform can use the type shown in Fig. 1. The engine is installed on a horizontal thrust test platform. The storage tank, maneuvering, control, observation, and measuring of the propellent feed system are separately installed at both sides or at the back. They are separated from the engine by a concrete cement explosive-proof wall, and a reflection wall is built opposite to the direction of the jet of the flame.

If the thrust of the engine is several dozen tons or over one hundred tons, a vertical-type platform is built (as shown in Fig. 2). With this type of installation, the combustion chamber does not accumulate fuel easily and the danger of causing an explosion is less. For safety's sake, the components of the test platform must be separated. The storage tank of the propellent feed system in the whole building should be built as an independent section. The maneuvering, control, and observation room should be far from the platform. The test platform should be built on a hill with a steep or a tall engine frame, and it needs an exhaust reflection installation and sufficient water to be sprayed to the center of the flame. These types of test platforms should be built far from residences.

3. Safety Items During Test

During the testing of rocket engines, regardless of the control of high engine temperature, the process of high-pressure combustion, or treatment of the dangerous propellent, any accident could happen unexpectedly. Therefore, strict technical safety measures must be taken during the construction of the test platform and during the test. So, in arranging the test station, a sufficiently safe distance must be considered between the test platform, propellent storage, control room, and the main warehouse buildings. The basic construction must take into consideration explosion safety and fire prevention. Test personnel must have a strong safety room. Technical equipment should try to use all remote maneuvering, remote control, remote observing, and automatic measuring and recording facilities. The fire system and alarm system should be reliable. Test personnel should have complete and reliable protection equipment; test regulations should be made and implemented strictly. In addition, attention should be paid to industrial waste treatment.

MEASUREMENTS DURING THE TEST

Parameters to be measured in the rocket engine test are usually thrust, flow rate, pressure, and testing time. After the data are processed, the parameters such as specific thrust, mixing ratio, and so forth can be determined. There are two measuring methods: direct measurement and indirect measurement. For some measurements general measuring techniques and instruments could be used, but for some specific measurements of rocket engines, special instruments must be used. The measuring instruments and methods are briefly introduced as follows.

Thrust Measurement: A force-measuring device which is a combination of a movable force-transmitting frame and force-measuring meter is used to measure and record the thrust generated during the working process of the engine. In the test, the commonly used force measuring meters are hydraulic dynamometer, spring dynamometer, and strain resistor dynamometer. The hydraulic dynamometer actually measures thrust by converting the pressure through a plunger of a cylinder (as shown in Fig. 3). The precision of the division scale of the dynamometer (such as 100 kg, 1 ton, 2 tons) should be calibrated. Before the test, the dynamometer and calibration equipment are "matched", so that the precision of the division scale of the dynamometer coincides with the calibration equipment. In order to refine the precision of the test, calibration equipment of higher precision is required. For instance, in the factory we often use the micrometer. When a part is processed, it is measured by a micrometer and it is immediately known whether the dimensions of the part agree with the dimensions shown on the blue print. The micrometer is much more accurate than the straight ruler or sliding caliper. But, every matter has two sides, and for many reasons there are always errors. In order for the micrometer to measure the dimensions of parts accurately, some other equipment (such as a gauge block) with greater accuracy must be used to calibrate the micrometer. The gauge block is graded according to accuracy. The higher the accuracy of the gauge block, the higher the precision with which the micrometer is calibrated. Thus, the dimensions of the parts can better reflect reality. In the measurement of various parameters of a rocket engine, thus calibrated, the dimensions of the parts measured in this manner can reflect reality better. The same logic applies in the measurement of various parameters of rocket engine; in order to increase the accuracy, much more accurate calibration equipment is required.

Flow Rate Measurement: This method measures the consumption of propellent in unit time during an engine test. This measuring method is to install an amperite (such as orifice-plate, nozzle, or Venturi tube), turbine-type flowmeter or other types of flowmeter in the duct where the flow is measured. The easiest way is to use an orifice-plate, differential-pressure-type flowmeter (Fig. 4), to measure. The orifice-plate, differential-pressure-type flowmeter uses the relationship of the flow and the differential pressure of the fluid when passing through the convergent cross-section of the orfice-plate to increase the flow rate and to produce a pressure differential before and after entering the orifice-plate. The size of flow is proportional to the square root of the differential pressure. If the difference of the pressure before and after entering the orifice-plate is found, the flow rate passing through the orifice can be obtained by means of calculation.

Pressure Measurement. This method measures the working pressure of different main parts of the engine at a hot run. The magnitude of the working pressure is closely related to the performance of the engine. The main measuring instruments are spring manometer or inductive, pressure trandsucer of potentiometric, capacitive, strain electrical resistive types, etc. What is a pressure transducer? Generally speaking, the pressure transducer is an element which changes a non-electrical quantity to an electrical quantity. For instance, the strain electrical resistive type of pressure transducer transforms the pressure variation to the corresponding electrical resistance variation which is turned into an electrical voltage signal after passing through a bridge to move the indicating instrument, and passing through a recorder to record the pressure data.

Besides, there are measurements of other parameters such as temperature, stress, vibration, fuel gas composition, etc. They will not be introduced here one by one.

In recent years, many newer and higher demands are brought forward in the testing techniques by following the speedy development of rocket technology. Thus, the testing techniques and test facilities are continuously stimulated to develop and to improve.

We should study the rocket engine testing technique further and in a more general way (broader), and at the same time, try to set up a reasonable, accurate testing program, try to reduce the number of tests, and try to increase the reliability of the tests, so that the test base can be constructed and the test work can be organized more economically, more reliably, and much faster and better.

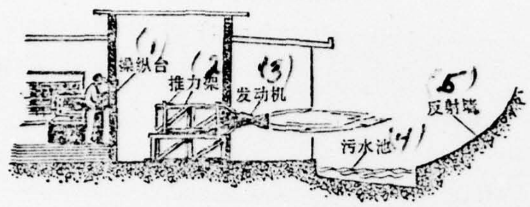

Fig. 1.

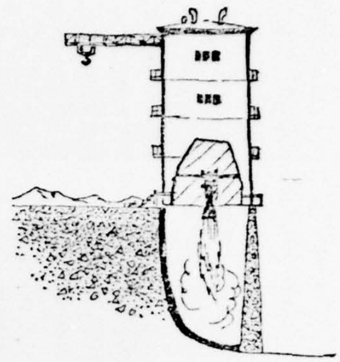

Fig. 2.

Fig. 1. Diagram of horizontal test platform.

Key: (1) Control panel; (2) Thrust frame; (3) Engine; (4) Waste water pool; (5) Reflection wall.

Fig. 2. Diagram of vertical test platform.

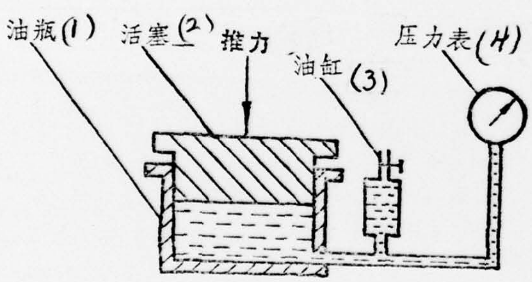

Fig. 3.

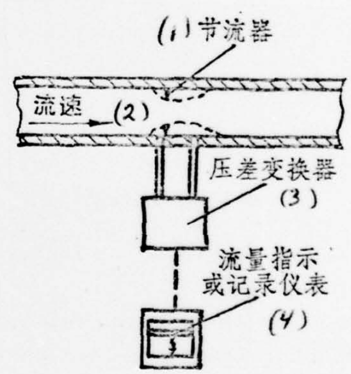

Fig. 4.

Fig. 3. Diagram of hydraulic dynamometer.

Key: (1) Oil cylinder; (2) Piston thrust; (3) Oil container; (4) Pressure gage.

Fig. 4. Diagram of orifice plate differential-pressure-type flowmeter.

Key: (1) Amperite; (2) Speed of flow; (3) Pressure transducer; (4) Flow indicator or recording meter.

SPACE FACTORY

> The development of space technology has significant scientific meaning. It enables human beings to develop knowledge of the Earth, the atmosphere, and the whole universe from outside the atmosphere, and to enlarge continuously our new field of activities. At present, the world is searching for a space production technique which is a new field. But it should be realized that scientific technology serves for the profit of a certain class. The Soviet Union and United States are two supercountries that started an unprecedented competition for the aggressive military purposes. They use the space technique as their world-wide strategic element and a means of seizing and swindling wealth. They are now researching the space fabrication technique for this purpose, too.

In boundless space, there are some conditions which are difficult to obtain on Earth; for instance, high-magnitude vacuum in space; the Earth's gravitational force is very weak, almost near zero; noise caused by vibration is also low; environment is pure; the spectrum of sunlight outside the atmosphere is all natural; and there are still other special conditions. All of these have drawn much attention to scientific research. Some people want to utilize these excellent conditions in space for fabricating rare materials and products and are thinking of erecting a space factory in the sky. According to the published material in foreign newspapers and magazines, some production problems of the imaginary space factory are introduced as follows.

Everything in space (it indicates things inside the spacecraft which flies along the Earth's orbit or out of the orbit) will have a weightlessness phenomenon. What is weightlessness? When a spacecraft makes a coasting flight along the Earth's orbit, the object in the spacecraft affected by the Earth's gravity which is cancelled out by an inertial force, will float; this phenomenon is called weightlessness. But, if this phenomenon is strictly analyzed, one would discover that the object is absolutely weightless at the center of gravity of the spacecraft. It is not completely weightless at places other than the center of gravity of the spacecraft, but is affected by a smaller acceleration (that is the gravitational acceleration $g \neq 0$).

When a spacecraft flies around the Earth, there exists weak gravitation, no matter how weak. Therefore, if the phenomena on the spacecraft or space station were strictly analyzed, we could not say that there is no gravity (Earth's gravitation) at all. It should be said that there is a tiny bit of gravitational force or the gravity is nearly equal to zero. It has been proven by test and calculation in the spacecraft that the gravitational acceleration near the Earth's orbit is approximately equal to 10^{-3} g.

If production is expected in a space factory, we must study what changes in the properties of a liquid take place under the condition of very weak Earth's gravitation or zero gravitation.

Under no gravitational force, the state of a liquid is determined by the attraction among molecules, especially the action of suface tension. If we melt metal under this condition, we shall discover that the viscosity and fluidity of the molten metal are same as that of the water; however, its surface tension is 7 to 20 times higher than that of water. Now, the rate of deformation of the metal is very high. Take iron as an example.

Its deformation rate is 3.7×10^4 cm/s, but that of water is 0.7×10^4 cm/s. Therefore, the molten metal under the weightless state can form a sphere in a very short time.

Now, the absolute value of the internal force which acts on the liquid metal is very small. Even if a very small external force is applied (mechanical or electrical), the shape of the liquid metal could be easily deformed. According to this physical characteristic, under the weightless condition we could form some metals in the space factory while in other places it would be very difficult to process otherwise. The major problem is how to use the external force to control the main process. These external forces could be obtained by electro-magnetic field, artificial gravity, contact by a mechanical device and some other methods.

WHAT CAN BE PRODUCED IN SPACE?

The kinds of products that could be manufactured in a space factory will be discussed below.

Melting Metal. We know that the main difficulty and limitation on melting metal is due to the container used for melting the crucible, which is made of refractory material. The metal, when melting, can get dirty from the fire resistant material, that is, contaminated; therefore, the quality of the metal is lowered. If we work under the condition of very weak Earth's gravitation, without a container, this defect could be overcome. During production in a space factory, this condition could be obtained. If a raw metal is shipped to an orbit and then to a space factory for the containerless melting process, the raw products are heated by electric or solar energy and melted to a metal liquid. Since there is no container, the shape of the raw product must be controlled, and must be maintained at a certain volume. In order to satisfy the requirements, the melted metal could be suspended by an electromagnet.

How to suspend the metal? A laboratory of a company in the United States came up with an electromagnetic system. The first model was composed of two electromagnetic coils and a servo-controlled mechanism. The electromagnetic coils induce an eddy current which can melt metal and act as suspension. When the gravity is very weak, one coil could be used (Fig. 1a). However, an electromagnetic suspension system with three pairs (six) of coils might be used for practical purposes in space in order to keep the solid shape of the molten metal. By using six coils, the position of the metal could be adjusted three-dimensionally (Fig. 1b).

Producing Glass. To produce glass in space could possibly be one of the first group of test production items. Because, the production of glass in space is different from that on Earth, it does not need large facilities. High-performance optical glass could be produced in space but not on Earth. What kind of material shall be used to produce glass in a space factory? It is considered that oxygen compounds of aluminum, hafnium, zirconium, titanium, and some other oxygen compounds are likely to be used. These oxygen compounds could provide extremely valuable properties to the glasses produced in space. Lenses made of these materials possibly possess better focusing property than lenses made on Earth. But it is very difficult to use these materials to make glass on Earth because there is still no such container to melt these oxygen compounds today.

Raw Materials and Casting. Probably it is possible to produce raw materials and castings in space in the future. Actually, utilization of the characteristics of a weightless condition to produce casting did not only happen after developing space technology. A long time ago, there was production technology which utilized a partially weightless phenomenon. Pouring molten lead through a sieve which is installed on the top of the tower to make lead pellets by letting the liquid lead fall down is an example.

A lead pellet is formed under the weightless condition during the falling of the liquid lead. Other examples are crushing a metal as well as a non-metal to a powder to make glass spheres --- balls and even making a hollow glass ball -- "micro type flask". But, it is impossible to obtain the weightless condition throughout the entire process while manufacturing these types of products on Earth; thus their precision is affected.

In an orbit in space, all objects with different specific gravity have no weight when they are in the weightless condition; thus, the deformation of material takes place intensely. On the ground, we know that the molten metal of lesser density floats on top of other liquid metal. This physical characteristic is generally utilized to refine pure metal. All kinds of impurities enter the metal during solidification. The processes are also different due to the buoyancy and thermal convectional functions of different compositions. The flow of liquid metal is irregular, therefore defects such as liquation, non-homogeneity, etc., exist inside the casting and some requirements are not satisfied. In order to solve these types of problems, methods like metal refining or a pressurized process (cold or hot rolling, forging) are used to make the interior of the metal homogeneous. Obviously, these methods need large facilities and investments. If we would develop the space metallurgical factory, we could solve these problems. We might see that phenomena in space differ from those on Earth. In space, liquid metals are in the weightless state, and we do not see floating and heat convection phenomena. Thus, a casting with an ideal characteristic could be obtained without internal defects and internal strain. Then, how can metal be processed in space? The molecular force could be used as a means of processing the metal when it is melted under the weightless condition. Making parts by this method, the tolerance could be greatly reduced. Besides, there are other methods which are the beneficiary of space smelting, such as metal hardening. We know that the metal crystallization has two phases, nucleation and crystal growth. The existance of the unmelted particles, speed and direction of heat dissipation, and the liquid thermal convections among other factors have the determinant effects on the above two processes. If the cooling of the metal is assured not by thermal convection, but by controllable radiation cooling, the microscopic defects could either be controlled or be eliminated, and the quality of the material could be improved. Then, what kind of method should be used? In space, we depend on adding powder or fiber of some other material to control the nucleation process in the crystallization of metal. We could obtain high temperature material with our required characteristics by using this method. For instance, a chromium base alloy used for manufacturing turbine blades. If some oxygen compound of cesium or titanium is added to this alloy when smelting, the life span of this alloy may be greatly extended.

Ball Bearings. Solid balls may be produced in space. The surface tension of metal under the weightless condition is very high; by using this characteristic, we could manufacture ideal balls. But, as the size of a ball increases, the manufacturing tolerance also increases. Therefore, the shape of the product must be controlled. To control the shape of the product we depend mainly on the inertial force, electromagnetic force, the surface tension of the body itself, etc. If we want to make some ellipsoidal products, we could use a rotating electromagnetic system to produce an electromangetic field to rotate the metal. Upon the action of inertial force, metal changes to an ellipsoidal shape. If some other shapes are desired, the principle of an electromagnetic system also applies. That is, if all electromagnetic coils are installed around the molten metal, and the strength of the electromagnetic field is adjusted in different directions, it will give us the shape we wanted.

High-Pressure Container. If we use pressure to put air into a solid sphere, we could inflate and obtain a hollow sphere (Fig. 2). A rare characteristic of this hollow sphere is its perfect and homogeneous microscopic structure, which we are unable to obtain on the ground. Such hollow spheres could be used as a high-pressure container.

Hollow Balls. Production of precision hollow balls in space might have a maximum economical impact. We could use this type of product to make high-quality bearings. When the thin hollow balls carry a load, they have the ability to resist elastic distortion, and can insure the automatic adjustment of the bearing, thus compensating the errors of different dimensions. This property has a possibility of increasing the lifetime of a bearing eight-fold. A hollow ball with such complete smoothness as this is very difficult to manufacture on Earth.

All Kinds of Thin Films. Very thin film, metallic strips, spring diaphragms, and very thin metal fibers can also be manufactured under weightless conditions. Their thickness could be that of a molecule. The main production technology is to have the metal mecahnically elongated while it is crystallizing from liquid form (solidification).

Metal Refining. Properties of many metals, such as ultimate strength and plasticity, can always determine their purity. For instance, a "single crystal of metal" is a very pure metal unit crystal; it is much purer than the "industrially pure" metal of the same kind. By using the refining method the metal tungsten could be separated accurately from oxygen and other materials and can be made into forged tungsten. To make these types of superpure material on the ground, a superpure facility must be established (generally a high vacuum is used). This requires a large investment; therefore the refining cost is very high. In space, we can have a high-vacuum condition, and the size of the container is unlimited.

Producing Crystal. Since the appearance of transistor and solid laser technology, there has been an urgent need for growing crystals. At present, silicon transistors are commonly used in electronic equipment. However, the cost of these types of transistors is very high, so these transistors could be considered for the first batch of products of the imaginary space factory.

SPACE PROCESSING TECHNOLOGY

To install or repair orbital space stations (Fig. 3), it is necessary to cut and weld metals and to bend sheet and section material. At present, the processing method of vacuum metal cutting has been tested successfully and been selected for use, and will fit the needs of space production, such as electron-beam cutting and low voltage plasma arc cutting. In order to reach this goal, it provided the basis for the application of lasers. If a solar focusing facility could be designed, it is also possible to use the solar focus to cut metal. This cutting method is obviously the simplest and most economical one.

Recently, the application of the technology of deforming metal by electromagnetics has become popular. The specificity of this technology is to deform the metal raw product by the mechanical force produced from a pulsed magnetic field. By using this method, parts of any complicated shape could be manufactured. After the raw material is punched into parts, it has a polished surface. At the same time, it also is possible to perform the deformation process on complicated glass work and raw material which is covered with plastic. It is estimated that to use this method will not cause any problems; the only hindrence is how to build a facility that has a minimum structure and provides maximum electricity. By using the pulsed magnetic field, many operational procedures could be carried out in space: pulling, blanking, piercing, expanding, extruding, and tube blank adjustment are among those operations necessary for the installation of space station and space production.

At present, space production is still in the research stage, and some aspects are also still assumptions. In particular, to install a space factory in space (orbital space station), it is necessary to deliver the material to space piece by piece, so the problem of capability and cost of transportation should be solved first Based on the situation that has developed at present, it needs further effort.

The research of production technology of the imaginary space factory is based on the development of space technology. With the knowledge, struggle, and utilization of the nature of the universe gained by human beings, the field of human production activities could have possibilities to expand from Earth to space.

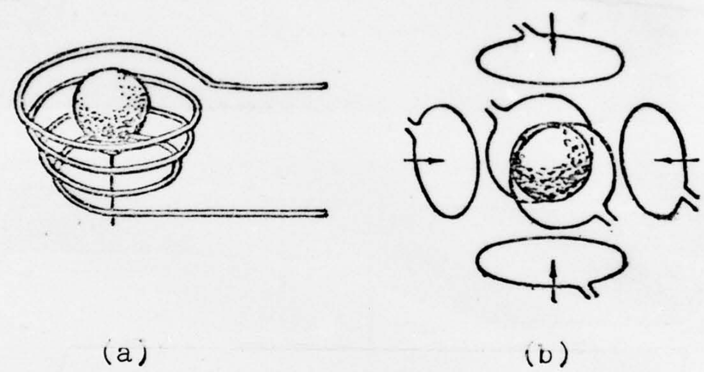

Fig. 1. Diagram of suspending and melting metal with electromagnetics (a) single coils, (b) 3 pairs (6) coils.

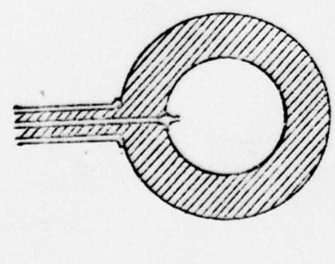

Fig. 2. Air entrance of an inflated hollowed thin wall ball.

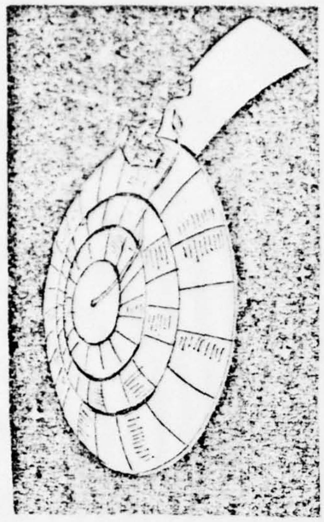

Fig. 3. Installation of an orbital space station.

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