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CONSTRUCTION AND LAUNCHING OF SCT-1 AND SCT-2 ROCKETS

[redacted]

by P. B. Buitron [redacted]

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CONSTRUCTION AND LAUNCHING OF SCT-1 AND SCT-2 ROCKETS

Early in November 1957, a little less than one month after the first sputnik was launched, engineer Walter C. Buchanan discussed with this writer some of the aspects of the launching of the US Atlas rocket.

His interest in and knowledge of this subject were revealed by the books on astronautics and rockets on the desk of engineer Buchanan who was deputy secretary of what at that time was the Secretariat of Communications and Public Works. Engineer Buchanan said that it was very necessary and advisable for Mexico to study and experiment in this field, within the scope of available resources. He said that it was indispensable for Mexico to keep up to date on these aspects of modern research.

A few days later, roughly in the middle of November, engineer Buchanan had obtained approval from the President and confidentially informed us that we were going to hold a number of meetings which, among others, would be attended by engineers Jorge Ruelas Tejeda and Joaquin Durand.

These meetings were held before the end of November; the first of them was held actually on 25 November. The enthusiasm of the participants at these meetings was tremendous and we quickly found out that we had enough information on theory and that we therefore were not going to have any problems on that score. At our second meeting, engineer Buchanan gave us the procedures for the deriving of flight equations; the equations checked with those found in various works on rockets. Engineer Buchanan also developed a graphic method for determining the vertical flight characteristics.

by Engineer Porfirio Becerril Buitron,
Deputy Director General of Operational Railroads

We made such rapid progress that we decided at our fifth meeting that we had talked enough and that we could now proceed to applying the theory of design, in a concrete form, in order to build the first rocket.

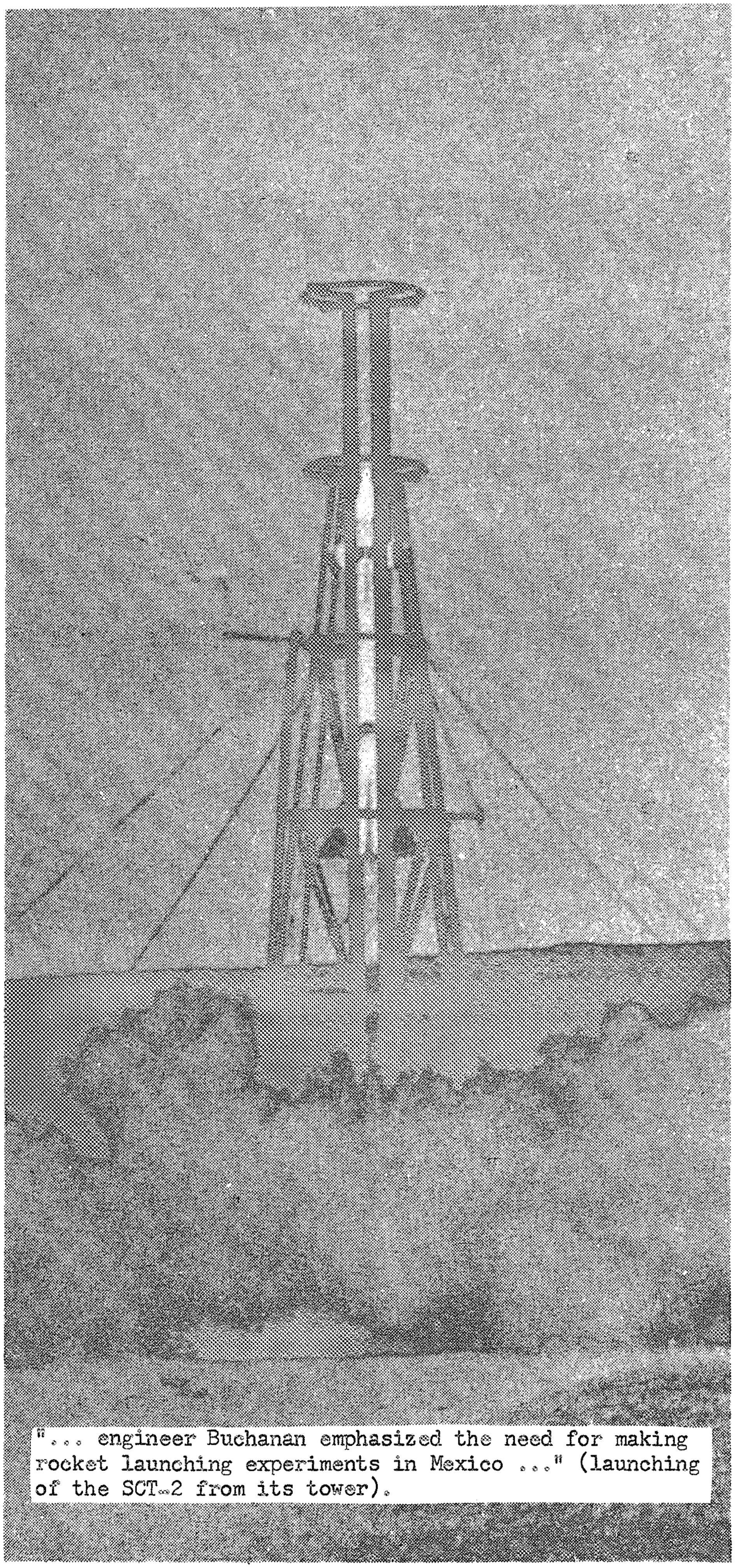
Engineer Duran was commissioned to design a solid-fuel rocket and engineer Becerril was given instructions to design a liquid-fuel rocket in which we would use ethyl alcohol and liquid oxygen. As its principal characteristic, it would burn 1 kg of 75% alcohol per second; in accordance with technical information available on the V-2 rocket the pilot model for the SCT-1 would essentially be based on the characteristics of this German rocket. Engineer Ruelas was put in charge of the aerodynamic shape of the rocket.

As we inject 75% ethyl alcohol into the combustion chamber, the heat, which required 25% water to evaporate, reduces the temperature to 2,000° C; at that temperature, the dissociation of water vapor molecules and CO_2 is at a minimum; therefore the average molecular weights of the gases is at a maximum, which is very good for obtaining maximum thrust at takeoff without expansion.

The rocket was designed with the help of technical and specialist personnel from the Director General of Operational Railroads and was supervised by our instructor, engineer Walter C. Buchanan. After the completion of the design phase, we proceeded to the construction phase; for this purpose, we set up a modest and simple workshop at Colonia Portales in Mexico City. The engine, the alcohol tank, as well as the liquid oxygen tank, and the pressure accumulator, were constructed of inoxidable chrom-nickel steel; the outer body was made of laminated aluminum. Everything, including the injection system, was built in our workshop.

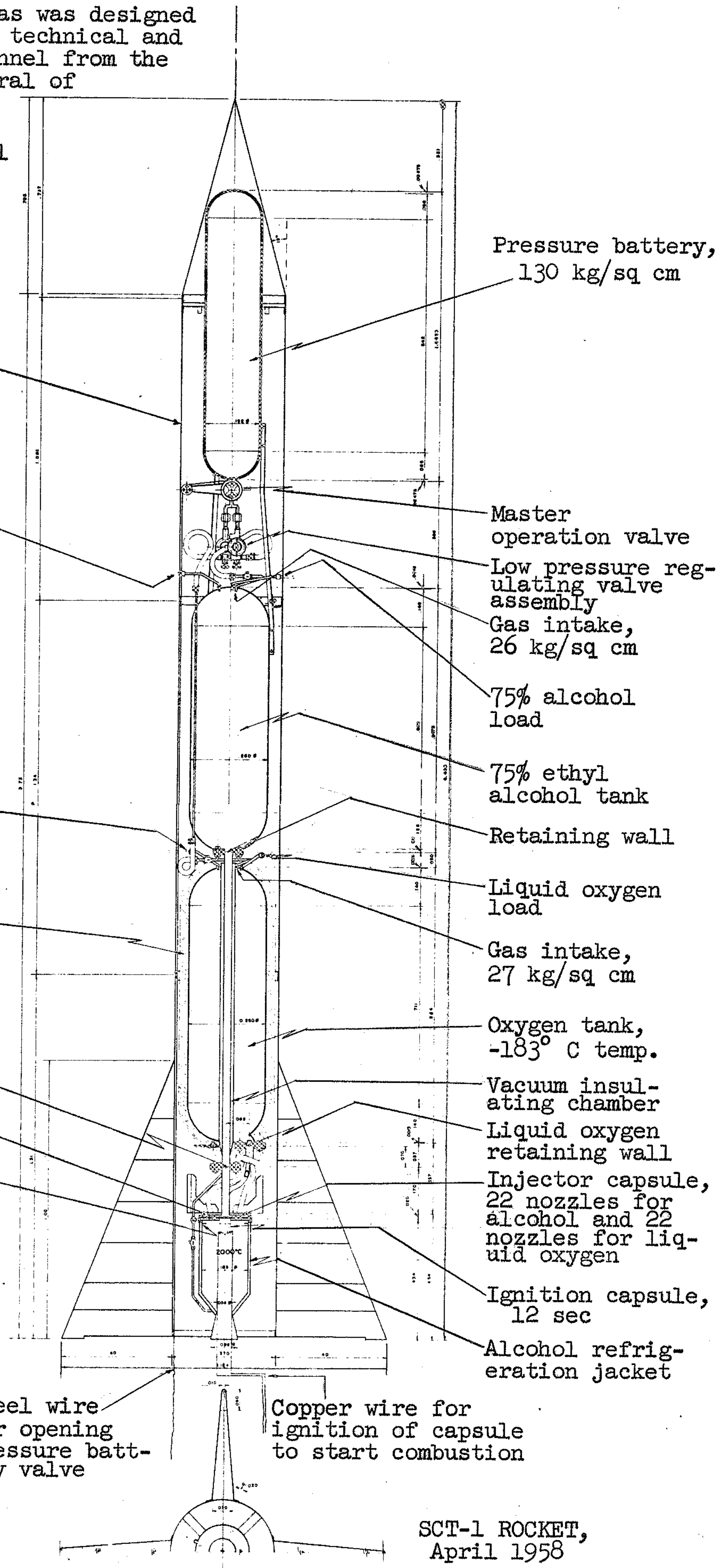
We must point out that all the materials used were obtained in Mexico and that it was not necessary to import any material; besides, all material used have the required quality which enabled it to take the stresses required and the very low temperatures (the temperature of liquid oxygen at atmospheric pressure is about -183° C). One thing that took a lot more time was the adjustment of the injection pressure nozzles we planned to install; we wanted the combustion chamber pressure to be 15.14 kg/sq cm (215 lbs/sq inch); we were trying to get the characteristics necessary for maximum utilization of 75% ethyl alcohol.

Before we could finish the construction of the rocket, we had to measure the power of the engine prior to the launching of the rocket. We also had to build a gantry tower to give the rocket initial direction on takeoff; because of the way the rocket was designed, it was going to have to be controlled from the ground. One of the attached illustrations shows the launching tower which looked like a gun barrel with a length of about 10 m.



"... engineer Buchanan emphasized the need for making rocket launching experiments in Mexico ..." (launching of the SCT-2 from its tower).

"...the rocket was was designed with the help of technical and specialist personnel from the Directorate General of Operational Railroads..." (Diagram of SCT-1 rocket)



SCT-1 ROCKET, April 1958

TECHNICAL CHARACTERISTICS OF ROCKET ENGINE

Fuel: 75% ethyl alcohol

Combustion agent: liquid oxygen at temperature of -183°C

Pressure battery: air at 130 kg/sq cm (1850 lbs/sq inch)

Regulating valves for injection of alcohol and of liquid oxygen, adjusted for:

(a) oxygen injection pressure 26 kg/sq cm (370 lbs/sq inch)

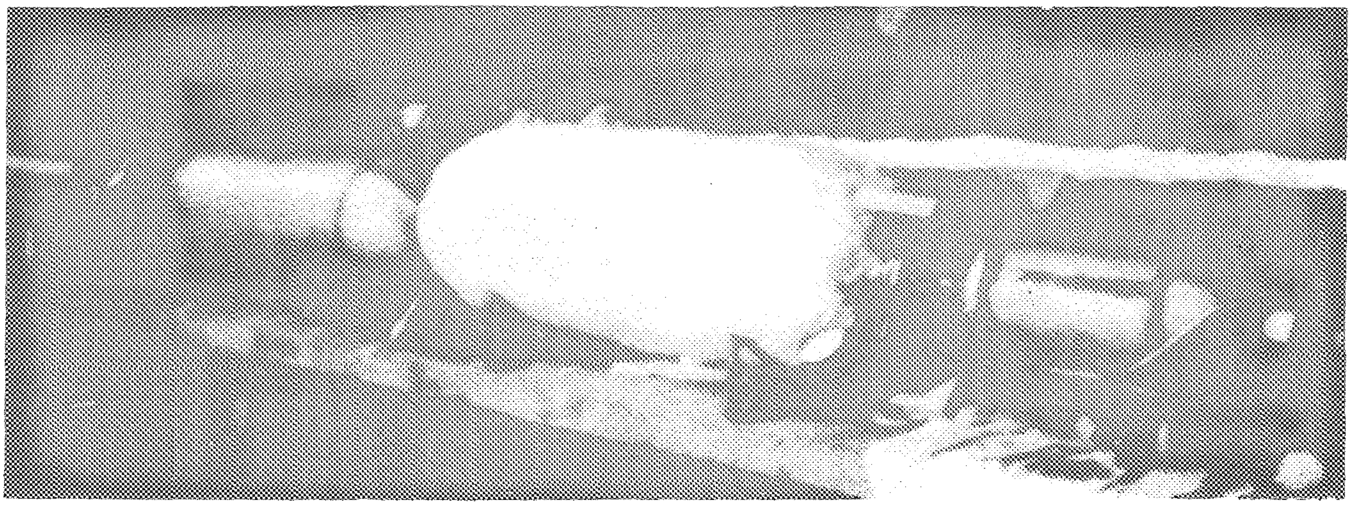
(b) alcohol injection pressure 24.65 kg/sq cm (350 lbs/sq inch)

Pressure in combustion chamber 15.14 kg/sq cm (215 lbs/sq inch)

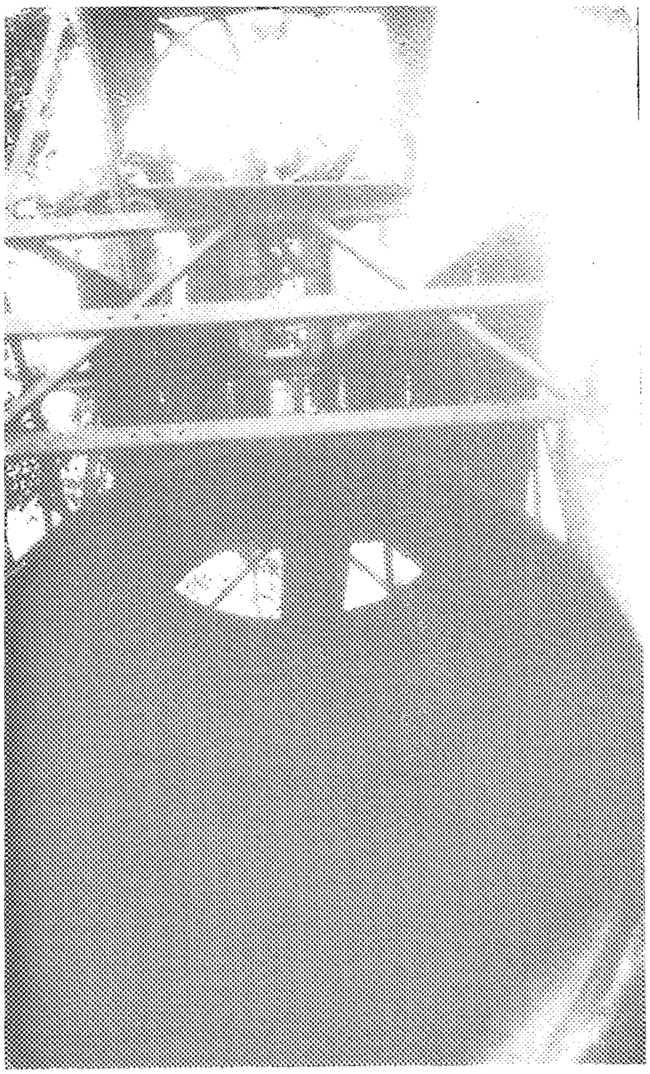
Escape speed of combustion gases at sea level: 2,000 m/sec (6,560 ft/sec)

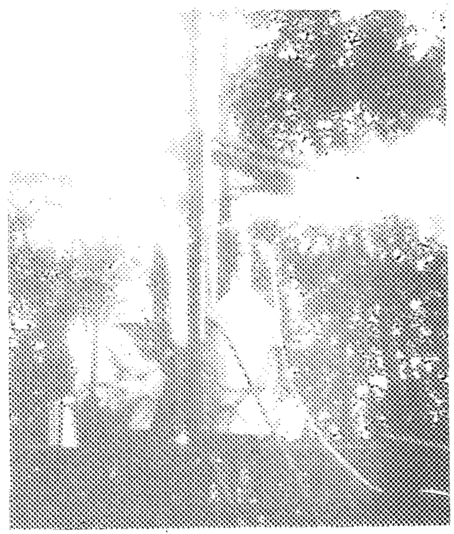
On the basis of the above data, the SCT-1 was built with the following characteristics:

Deadweight of rocket as such	102.7 kg
Weight of alcohol, oxygen, and compressed air	113.3 kg
Total weight	216.0 kg
Outside diameter of body	0.375 m
Total height	4.48 m
Total width of wings	1.184 m



"... the impulsion motor, alcohol tank ..., and pressure battery were made of inoxidizable steel with chrome nickel ..." (note the oxygen tank covered with insulating material).





Left: Guide shaft for engine combustion gases.
Top: Charging liquid oxygen at a temperature of -183°C.
Bottom: "... we built a protective wall and put shockproof windows in it ... we read off the power and pressure by means of electronic gauges ..."

To measure the power of the engine, we set up the launching tower and attached to it the core of the rocket with its tanks and engine; the power was first determined by means of dynamometers and then by means of hydraulic gauges.

The test site was set up near a highway in the vicinity of the town of San Bartolome, in Sierra de Xochimilco; that is to say, it was located at the outskirts of Mexico City. We thought that this place was very good because of the surrounding hills and gullies which could serve as protection for nearby settlements if the rocket should, by some misfortune, blow up on the pad.

About 50 m from the launching tower, we built a protective wall which had shockproof windows through which we could observe the operation of the rocket by means of a telescope; the engine power and pressure were read off from electric gauges.

For our first test, we did not complete the refrigeration system because we wanted to use these tests to get a precise visual localization of points exposed to high temperatures.

Also, during our first test it was impossible to achieve ignition because some of the parts were clogged which stopped the flow of ethyl alcohol. During the second tests however we did achieve ignition, although possibly due to the presence of certain defects resulting from lack of continuity, there were strange noises and strong vibrations which caused the earth to tremble; similarly, we must note here that this was a completely new experiment and that many of us had never been present at the launching of any rocket; therefore we really experienced some very intense emotions; for this reason, the precautions we took were perhaps a little bit exaggerated though we did this only in order to prevent accidents. We must remember that the combustion gases leave at a velocity 5 times the speed of sound.

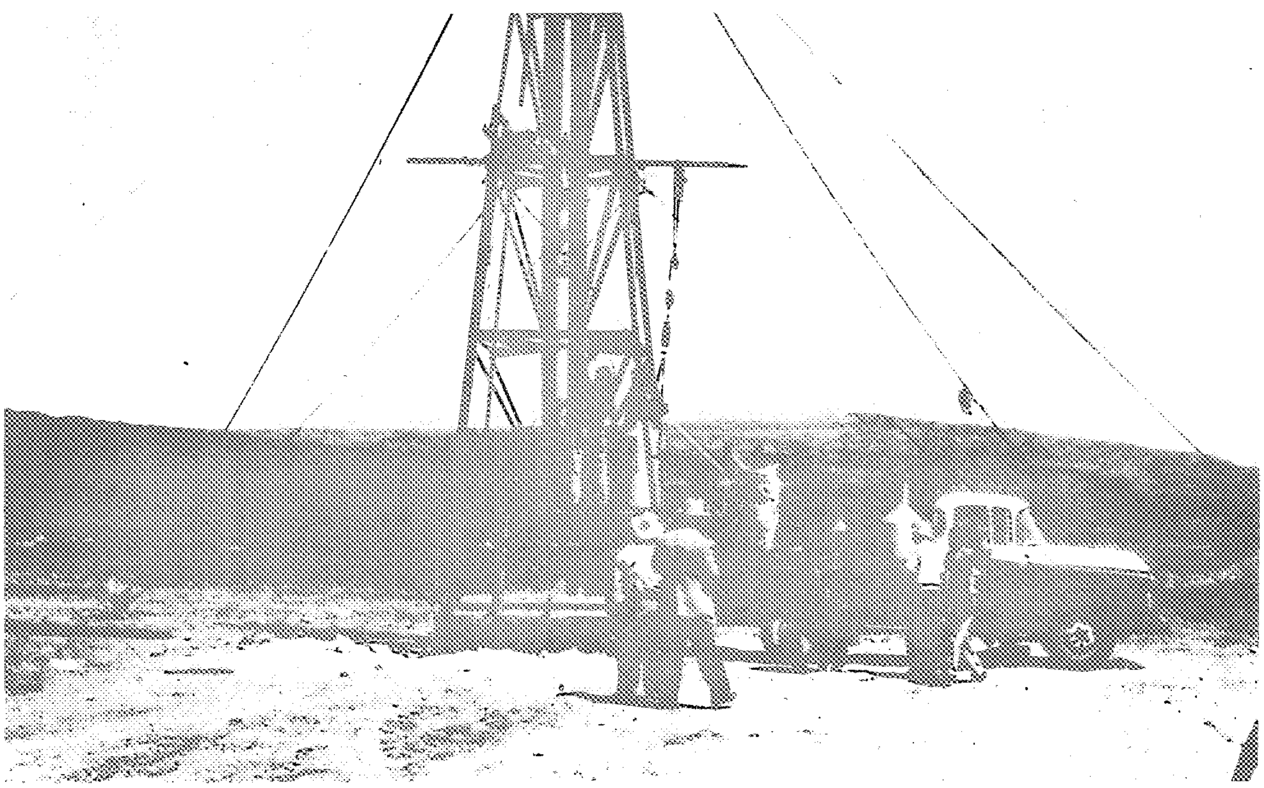
The inhabitants of San Bartolome had been explained the details of the operation; they were told about the protection offered by the surrounding gullies and they realized that we were making our observations from no more than 50 m, protected by nothing more than a wall; however we did not tell them about the occasionally very strong vibrations which occurred in the ground. As an extra precautionary measure, we also closed the highway leading to San Bartolome about 5 minutes before the test.

The last test -- it had to be the last one because during an earlier test a part of the engine was blown to bits -- was conducted on 25 September 1959. On that occasion we measured a rocket power of 531 kg; this was 440 kg more than we had calculated; this was due to the fact that the rocket burned up all the alcohol in only 40 seconds, instead of the 44 seconds we had been planning on.

On the basis of the results, engineer Buchanan decided that we would build another engine (during the last moments of each test, the combustion chamber, principally the escape nozzle, were deformed, which meant that we could never use the same engine again; everything was built on the assumption that the operation would last no longer than 4 seconds); engineer Buchanan decided that we would assemble the rocket completely in order to make the necessary adjustments; we also decided that, as soon as the necessary adjustments had been made, we would prepare for the launching along the boundary of "La Begonia" Ranch in the State of Guanajuato. Here we set up the same tower we had used for the tests at San Bartolome.

One of the problems we ran into before we could launch the rocket at Guanajuato involved the transportation of liquid oxygen. We solved this problem with the help of the AGA Company, which supplied two suitable tanks; it was also necessary to make special modifications in one vehicle in order to prevent the oxygen from being jarred, which would involve great danger because the bottles containing 113 kg of liquid oxygen might blow up any time. To prevent this, we moved the liquid oxygen as slowly as possible and it took us 10 hours to cover the distance of 330 km; we also tried to see to it that as little oxygen as possible would evaporate during the trip.

"... at 1200 we began to charge the liquid oxygen ..."
(picture taken shortly prior to launching of the SCT-1).



In the course of our launching tests, we had to make three adjustments. The air in the pressure accumulator, upon passing into the oxygen tank, greatly reduced its temperature; this increased the time required to achieve the pressure at which the retention diaphragm of the liquid oxygen breaks; this caused the ignition capsule to be extinguished before the injected oxygen arrived there.

On 24 October weather conditions were not good; however, it appeared that the weather would improve within 12 hours and we therefore immediately started putting in the liquid oxygen. However, one hour later conditions had not improved and, since the liquid oxygen had already been put in, there was a possibility that conduction in alcohol might lead to congealing. We wanted to prevent this from happening and engineer Buchanan therefore decided to launch the rocket. Although weather conditions were far from favorable, the fact that we were now going to go ahead with the launching would at least tell us what the liftoff characteristics of the rocket were going to be. There is no need to mention the tension that prevailed among all of us on that occasion when the rocket was finally launched at 1325 hours.

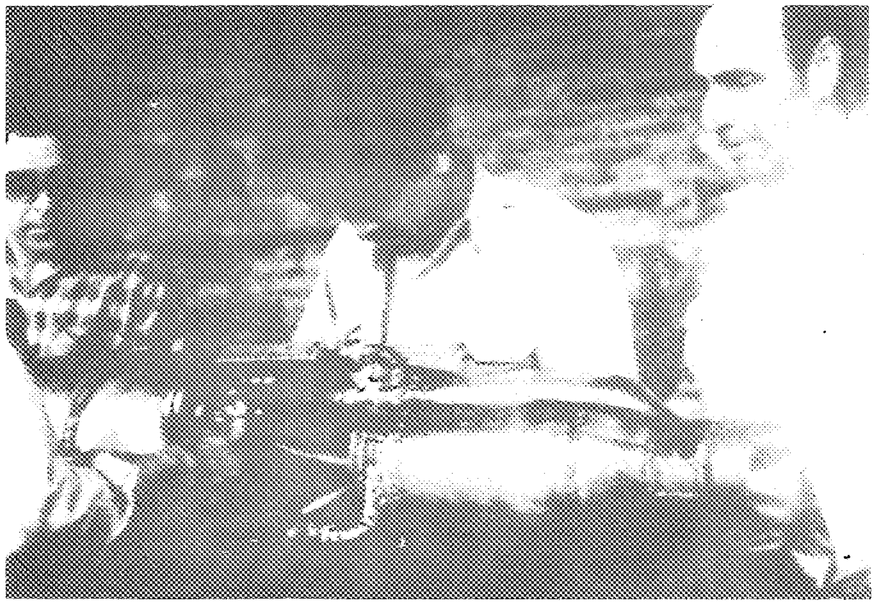
The launching took place in the following phases: after the liquid oxygen had been put in, we closed all valves and then put all covers in place on the outside. Then the order for ignition was given; ignition was achieved on the basis of a mixture of powder and phosphorous and took place inside the engine. The capsule was adjusted for 12 seconds; after ignition, we actuated the general valve of the pressure battery in order to obtain the pressure necessary for breaking the previously adjusted retention diaphragm; in this manner, we began the injection into the combustion chamber while the capsule was ignited; 7 seconds after rocket engine combustion in the normal manner, we were able to see the results of our labors; there was great joy and much pleasant surprise when the rocket began to lift off from its pad with what to us appeared like majestic slowness; the trail of flame and smoke left behind the rocket told us that combustion had been perfect.

The launching tower had an inclination of 2.5° toward the North. Because of the bad weather prevailing at the time of the launching, the rocket began to incline at an altitude of 4,000 m until it assumed a horizontal position against the direction of the wind; because of the design of the battery, this meant that the engine would not be working at the efficiency we had calculated in advance.

Despite these contrary circumstances, the launching proved successful and we all were very happy to have had a part in this undertaking, especially since this was the first time we were able to see a rocket rise into the sky with the help of liquid oxygen. This meant that we had taken the first step because we now knew the initial flight characteristics of this type of rocket and we were sure that we could go on with our study of these rockets at moderate cost.

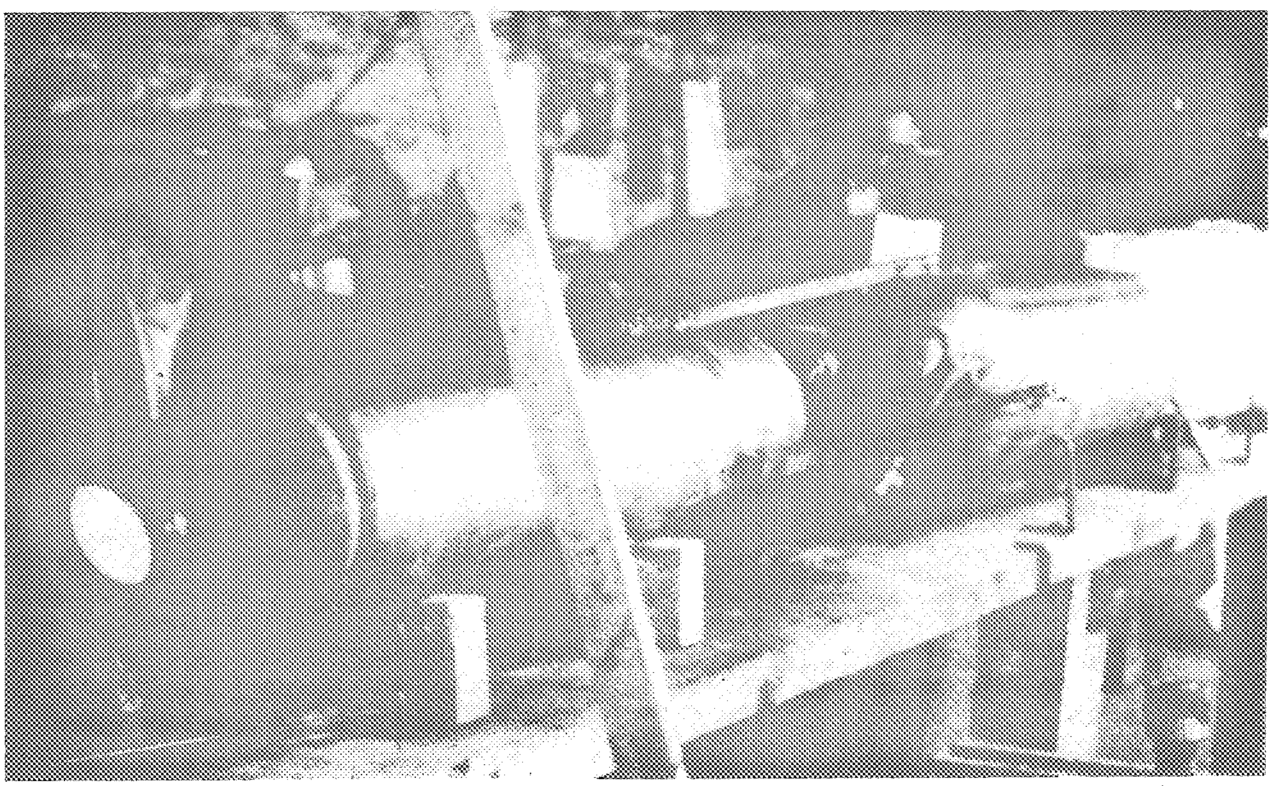
The SCT-2

On the basis of the experience acquired with the launching of the SCT-1, engineer Walter C. Buchanan now ordered the construction of a new rocket. With renewed and even greater enthusiasm, we now proceeded to correct the shortcomings in the combustion mechanism and we designed wings for vertical stabilization. The design of the SCT-2 differed in the following principles: (1) immediate combustion, (2) selection of gas for pressure battery which would not become liquefied at -183° C temperature, (3) improve the directional stability of the rocket.



"... with the experience gained in the launching of the SCT-1 ..." (outside view of impulsion motor for SCT-2).

"... we used helium in the pressure battery ..." (tank and impulsion motor assembly for SCT-2).



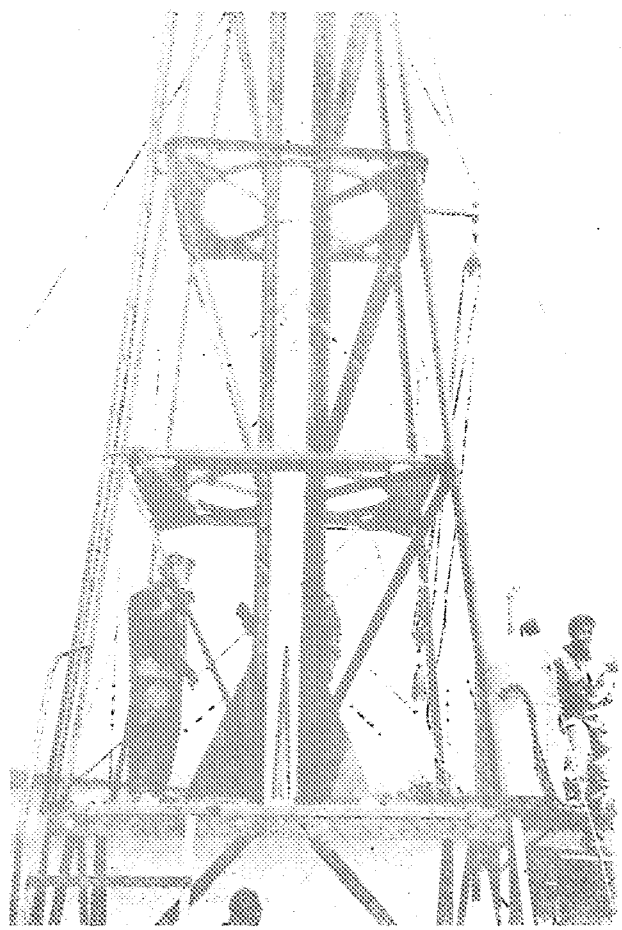
Characteristics of SCT-2 rocket

Deadweight of structure:	103.000
Weight of alcohol, oxygen, and helium (44 sec)	115.600
Weight of alcohol for refrigeration chamber (4 sec)	1.400
Total weight	225 kg.
Combustion time:	44 sec.
Outside diameter of body:	0.375 m.
Total height:	4.480 m.
Total width of wings:	1.184 m.

Characteristics of launch tower

Guide shaft length: 10 m
Base: 4 concrete foundations
Number of landings for assembly: three
Materials: structural steel

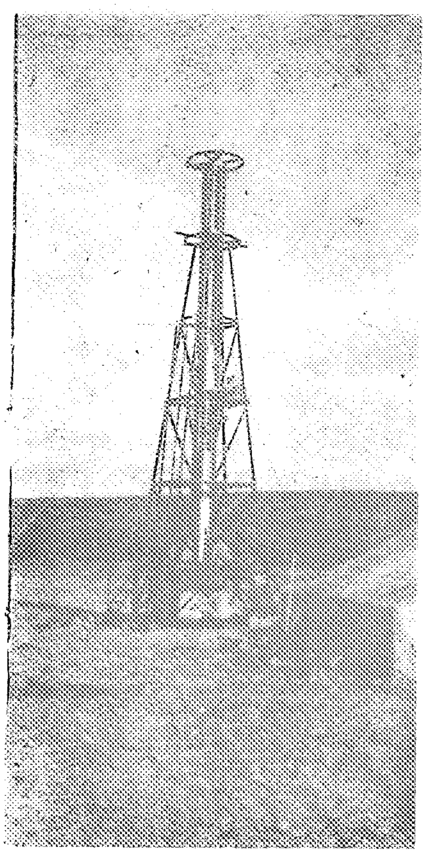
"... after we had built the SCT-2 ... we proceeded to launch it ... (three views of launch preparations).

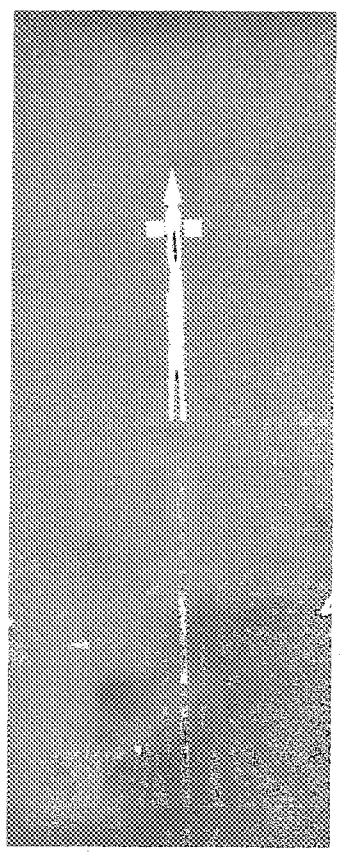


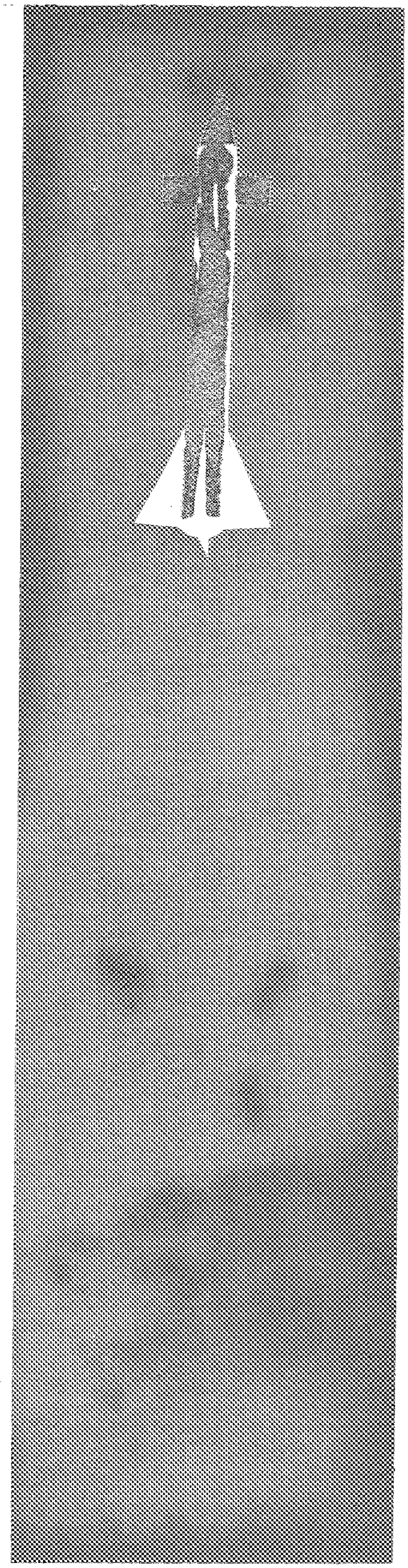
In order to achieve all this, we used helium in the pressure battery because this gas, in the liquid state, has a temperature of -292° C, which is much lower than that of liquid oxygen; the latter, as we said before, has a temperature of -183° C. Combustion can occur immediately in the usual manner when we use helium. We put fins at the top of the rocket in order to keep it in its vertical position.

After we had built the SCT-2 and after we had made the necessary tests near the town of San Bartolome, we were ready for the next launching. During our first attempt, we had a failure due to the breakage of one of the liquid oxygen pressure control switches. After we had corrected this defect, we launched the SCT-2 from the same site in the State of Guanajuato on 1 October 1960.

"... injection adjustment was perfect ... good combustion ... was indicated by the traul left by the rocket ..."







The ignition phase took place in exactly the same manner as before; the capsule was adjusted for 12 seconds, we opened the helium battery valve which was at a pressure of 130 kg/sq cm; then we injected both oxygen and alcohol.

The attached illustrations very clearly show that the adjustment of the injection was perfect; we can also see that combustion was perfect because of the trail left by the rocket.

As regards protective measures taken at the launching site, we might say that we erected an earth wall about 50 m away, with a steel and timber retaining wall, on the top of which we placed shock resistant windows for operational control. Of course, there is always the possibility of an explosion due to some malfunction, especially since we are working here with this liquid oxygen at a temperature of -183° C. The latter is injected into the interior of the combustion chamber and develops a temperature of 2,000° C.

At the launching of the SCT-2, we achieved an altitude of more than 25,000 m; the effective ground-to-ground flying time was 180 seconds.

At this time, we are continuing our study of the characteristics of this type of rocket and we are now planning on using electronically remote-control models; we are also thinking of equipping the rocket with characteristics that would enable it to break the sound barrier because these are the moments when the rocket encounters the most resistance, which in turn leads to greater fuel expenditure.

Engineer Walter C. Buchanan had given instructions for the study of the construction of a rocket which, instead of having a pressure battery, would be equipped with gas turbines and centrifugal injection pumps. This meant that we were going to have to solve a number of very complicated design problems, but we certainly can handle this both theoritically and materially in Mexico.

Once we get practical and effective results from the injection system we have just described, we will be able to launch multi-stage rockets; this would be our next objective. But we will need more financial resources for this although the cost should not be prohibitive and would certainly be within our range of capabilities.

We have thus described the development of the construction and launching project for the SCT-1 and SCT-2. In subsequent articles we shall take up some mathematical considerations which must be undertaken parallel to the other phases of this project.

List of collaborators of engineer Walter C. Buchanan, Secretary of Communications and Transportation, in the SCT-1 and SCT-2 rocket launching. launching projects.

A. Engineer Porfirio Becerril Buitron worked with the following personnel from the Directorate General of Operational Railroads:

Technical Bureau:

Engr. Jesus Aguilra Avila, structural assistant.
Engr. Ramon Moysen Morales, injection study assistant.
Engr. J. Manuel Reyes Anguiano, fuels assistant.
Engr. Jesus Vargas Cuevas, climatology assistant.
Mr. Jesus Flores Damian, projects assistant
Miss Bertha Rosas Pardavell, supply control.
Miss Martha Galduroz Arredondo, technical statistics control.

Laboratory and Work Shop:

Mr. Joaquin Garcia Jurado, electrical machine-building expert, chief of laboratory and shop.

Note: In addition to their regular work with the Secretariat, the above individuals worked on their rocket studies in the evening.

B. Engr. Jorge Ruelas Tejeda worked on aerodynamic studies.