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THE HISTORY OF THE FIRST A. I. S. ROCKET

by G. Edward Pendray

(*An address delivered before the American Interplanetary Society, November* 18, 1932)

When we first began the construction of our rocket, nearly a year ago, we had little in the way either of experience or data to guide us. In fact, it was that lack of experimental material that caused us to undertake a project for which we were little equipped either with training, machinery, material or money.

We drew up our first plans, with more courage than judgment, perhaps, little expecting at the time that they would ever come to the successful fruition which I have to report tonight. We had as guides the little information obtained from the work of the German experimenters at the Raketenflugplatz, the suggestions contained in such books as Esnault-Pelterie's "L'Astronautique" and other theoretical works, and finally faith in certain principles of our own.

Our first motor was designed somewhat like the motors of the German Miraks, except that it was larger, heavier, and supplied with certain improvements with regard to fuel intake.

The rocket itself was really no rocket at all, but rather a portable proving stand for testing out the motor. This we now realize, though in the beginning we were under the impression that we were designing a piece of apparatus capable of high altitude flights. It consisted, you will remember, of two long, cylindrical tanks of aluminum, one to hold liquid oxygen, and the other gasoline. On a tie-rod or shackle at the forward end of these tanks the motor was mounted. At the rear were four fins.

The motor was jacketed in a small tank of aluminum, which was intended to hold water for cooling. Surmounting the whole apparatus was a cone-shaped hood in two sections, designed to hold the parachute.

But to get back to the experiment—the design of this rocket is due mostly to Mr. H. Franklin Pierce, who proved a genius at accomplishing the engineering work required for putting the apparatus together. Mr. Pierce, in addition, did all of the assembly, and to him belongs a major part of the credit for our successful test.

The rocket was completed around the first of January this year, and thereafter began a series of preliminary tests. It was first necessary to learn whether our tanks would hold the pressure of three or four hundred pounds to which they would be subjected during firing. For these pressure tests we had a tank of nitrogen gas under 3,000 pounds pressure, supplied by the Air Reduction Company for this experiment. In addition, the Air Reduction company gave us several feet of pressure tubing and a pressure guage —equipment which would have cost thirty or forty dollars had it been necessary for us to buy it.

With this equipment, and with the aid of special pressure valves supplied us by the Schrader Tire Valve Company, we were able to demonstrate to our own satisfaction that the tanks would hold not only the required three or four hundred pounds, but that they would safely withstand a pressure of at least a thousand pounds.

We were now ready for actual tests with oxygen and gasoline. These required a proving stand in the open, preferably in a secluded spot and one which would be large enough, for a small rocket flight, should our rocket prove able to lift itself.

This search lasted all summer—and in fact the lack of a suitable proving field is still one of the most serious handicaps confronting our experimental program. A farm was obtained in New Jersey, nearly a hundred miles from New York City.

Work Begins

Beginning late in August, a small group of members of the society, including Mr. Lasser, Mr. Schachner, Dr. William Lemkin, Mr. Laurence Manning, Mr. Alfred Best, Mr. Alfred Africano, Miss Lee Gregory, Mr. Pierce and myself, worked several weekends at the rocket field.

Two bomb-proof dugouts were prepared, one about thirty feet from the site for the proving stand, for close observation and photography, and the other about 150 feet away, for the controls.

Meanwhile, other members of the Society built the proving stand, which consisted of two rounded upright members of wood, held in place by a stout framework of planks. The upright members, constructed to guide the rocket in the event of an actual flight, were fourteen feet high. The span of the supporting framework was a little under twelve feet. The whole apparatus stood on the ground as an independent unit, the lower parts protected from flame by sandbags, flat stones and banks of earth.

Guides had been placed at the sides of the rocket to engage the upright members of the proving stand. In order to facilitate the movement of the guides, the uprights were copiously soaped. The rocket was held in place for the tests by a light pole about twelve feet long, pivoted to an upright post at its outer end, and held down at its inner end by a coil spring which was in turn fastened to the base of the proving stand.

This apparatus was so arranged that any upward push exerted by the rocket in firing would be communicated to the pole and thence to the spring.

The first actual test consisted of filling the gasoline tank, and putting three hundred pounds of nitrogen pressure over the gasoline. This was done successfully, the valves and connections all holding perfectly. The second, and more difficult test consisted of loading the rocket with liquid oxygen.

At this point we learned one of the most serious difficulties with our rocket as an experimental apparatus. The opening into the oxygen tank was about half an inch in diameter. The tank itself was five feet long and one and a half inches in diameter, inside measure. To cool this long pipe sufficiently to hold oxygen required the evaporation of nearly a quart of the liquid.

Even this would not have been of great consequence, were it not for the extreme difficulty of pouring the oxygen into the tank. Liquid oxygen, when poured on metal at ordinary temperatures, behaves somewhat like water spilled on a white-hot stove. It spatters and sputters, droplets of it bouncing about in the most unpredictable manner. When it comes to pouring such a liquid through a hole half an inch in diameter, even with the aid of a funnel, it requires sometimes as long as fifteen minutes to empty a quart, most of which either evaporates from the furiously boiling supply in the funnel, or spatters down the sleeves of the operator, inflicting innumerable tiny frostbites, like little scalded spots.

Moreover, the ingoing liquid is met by an upward rushing stream of oxygen gas, seeking to leave the tank. Several expedients were tried for introducing the oxygen, until we made a funnel with a long copper tube for a spout. This worked fairly well, but very slowly, and often became plugged with frost during the pouring operation. It required about three quarts of liquid oxygen to get a full quart of liquid in the tank. When a quart of liquid had finally been induced to remain in the tank the oxygen pressure test began. With all hands in the dugouts, and a member timing the performance, I screwed in the safety valve and promptly ran for shelter, to await the building up of oxygen pressure by boiling inside the tank.

The safety valve has been set to go off at three hundred and twenty pounds pressure. We had been sure that the oxygen would build up to this pressure in a few seconds, and the last man scurried away from the rocket with considerable alarcity, once the safety valve had closed off the free escape of the gas. Actually, after considerable suspense, the safety valve popped off at four and one half minutes.

It was obvious that there was plenty of time for the last man to screw down the safety valve and walk calmly back to the dugout without danger.

A Successful Test

But in the ensuing test the second important weakness of our rocket appeared—in the system of releasing the turn-on valves. The valves were turned by powerful springs, and were held in the closed position by tiny pieces of fuse wire. When the operator was ready to release one of these valves he threw a knife switch in the dugout, operating a relay which in turn threw a heavy current through the fuse wire, burning it out and permitting the spring to pull the valve open.

I am convinced that this is the best possible arrangement for opening the valves of a small rocket from a safe distance, but the weakness in our apparatus was that the connections on the fuse wire were made directly by long wires from the battery and relays. These temporary connections, made hastily, loosely and under unpredictable field conditions, could not be counted upon to give good contact. The result was that sometimes the fuses would blow, and sometimes not. Unfortunately they did not in our first oxygen pressure test, and Mr. Pierce at length went up to the rocket and pulled the wire out with a long stick, releasing a beautiful cascade of liquid oxygen and gas.

We returned to the rocket field Saturday morning, November 12, determined to finish our tests and to shoot the rocket if possible. Cold and rainy weather had already given us some miserable hours at the field, and there was plenty of evidence that winter would soon end our experimentation for the season.

Bad luck seemed to follow our footsteps on that last week-end—ill luck which was really attributable, I think, to the extreme cold weather, the rain which was falling by starts and stops, the gusty wind, which made work difficult. The pits of the bombproofs were full of water, an accumulation from the heavy rains during the week. By the time these had been baled out and made habitable, the storage battery and the wiring put in place, and the rocket made ready for a test, it was getting late in the afternoon. Nevertheless, we were determined upon making a ground firing test, preparatory to trying the shot the following morning.

We filled the gasoline tank with a pint and a quarter of gasoline, using ordinary filling station gasoline, half ethyl and half clear gasoline. The object of the ethyl was to slow down the burning, since we felt that we would have less chugging and backfiring with this type of fuel.

The oxygen tank was filled, as nearly as we could tell from the frostline on the outside of the tank and our previous experience with this liquid, with a quart of oxygen.

We had previously worked out the part each man was to play in this test, since the handling of these fuels under fire is attended by no little danger. The rocket guides had been freshly soaped. Mr. Pierce attached his fuse wires carefully, then took his place at the controls in the dugout. My part was to finish pouring in the oxygen, screw down the safety valve, and retire to the dugout, to call out the firing orders.

Miss Gregory was charged with timing the pressure period. Dr. Lemkin was ready with a box of matches and a gasoline soaked torch, and Mr. Lasser was waiting the signal to go forward with this torch and light the fuse between the tanks of the rocket.

This last expedient had been adopted as a result of earlier failures with our electrical apparatus, a third weakness in our rocket. This distant firing control was a complete failure, and something must surely be devised to take its place in the next rocket. The expedient of going forward and lighting the fuse is too risky, and somewhat uncertain as well.

We allowed the pressure to build up for two and a half minutes, then Dr. Lemkin lit the torch, which Mr. Lasser carried out to the rocket, igniting the fuse.

We had previously decided that the fuels should be turned on almost simultaneously, the oxygen first, the gasoline close behind. I judged that the fuse was going properly to light the fuels. About three minutes had passed since the final turning down of the oxygen valve. Enough pressure should have been built up to start the firing —after that the heat would certainly accelerate this process sufficiently to give us the power we needed.

In the last half hour before the test the sky had partly cleared, and the sun had set. It was about five o'clock, already too dark, unfortunately, to permit the taking of pictures. The Acme Newspictures cameraman who had accompanied us, had already returned to the shelter of his car.

We were now ready. Mr. Pierce threw his switches rapidly. The fuse apparatus worked to perfection. For an instant there was a great flare, as the pure oxygen struck the burning fuse. In an instant the gasoline was also pouring into the rocket. The fuse, the flare, and the uncertainty about the performance of our rocket motor all disappeared at once, as, with a furious hissing roar, a bluish white sword of flame shot from the nozzle of the combustion chamber, and the rocket lunged upward against the retaining spring.

It is impossible adequately to describe that sight, or to convey the feeling it gave us. I suppose we were excited; but there was a certain majesty about the sound and sight which made it impossible for the moment to feel excitement as such. We forgot to remain behind the shelter of our earthworks. Moreover, we forgot to count the seconds as they passed in that downward pouring cascade of fire.

The flame was about twenty inches in length, clear and clean, of a bluish-white color, and quite steady. There was none of the chugging, choking or backfiring we had expected. The sound was even and powerful throughout the test. At the last, just before the firing ceased, the noise changed a little in quality—an indescribable change, perhaps a little less powerful. For a moment most of us thought the motor was hot, and about to burst. Now we believe this change in sound indicated that the liquid oxygen had been exhausted, and that the flame thereafter was supported for a second or so by the oxygen gas which flowed under pressure from the tank.

Suddenly we knew that the oxygen supply had been exhausted. There was an excess of gasoline, as we had planned. This now came spurting out, throwing a shower of fire all around the foot of the rocket and proving stand.

The Lessons Learned

We hurried out at once, fearing that the stand would burn up. Fortunately it had been thoroughly rain-soaked. When the gasoline had been consumed the fire was put out without trouble.

With the aid of a flashlight we made an immediate examination of the rocket. The water in the cooling tank was hot, but not too hot to touch. The nozzle of the motor was clean and bright, showing no sign of scoring or pitting. Inside the narrowest part of the nozzle there was a little soot, which very probably was left there by the final charge of gasoline, since it could hardly have remained in the choke during the actual firing.

But most important—the marks made by the rocket on the soaped guides indicated that it had registered a lift of about sixty pounds. Judging by the appearance of the marks, this lift had been pretty steadily maintained throughout the firing.

The unfortunate failure to time the firing accurately was something of a difficulty, but we were able to calculate, from the known flow of the fuels and other circumstances, that the firing had lasted between twenty and thirty seconds. With a lift of sixty pounds, our fifteen-pound rocket would, in a vacuum, have ascended to a height of sixteen miles. Discounting liberally for air resistance, a well designed rocket, flying perfectly straight, ought with so much power to reach an altitude in air of five to eight miles.

We had planned to make an actual shot the next morning, but we were disappointed. The day was rainy and windy, so much so that a shot would have been extremely dangerous and hard to control. Moreover trouble developed in the oxygen and gasoline feed lines, probably plugs of frost had gathered in them as a result of water finding its way into the fuels. Finally, the rocket was accidentally dropped while being placed in the proving stand for a final test. It proved too fragile to stand even so small a shock, and the parachute apparatus and trusses were badly bent.

As a matter of fact, the troubles of Sunday morning were in large measure due to the inclement weather. Had it been warmer and less windy, I feel that the attempt to shoot the rocket would have been a success. However, we believe we learned from this rocket all it had to teach us. The shot would have been spectacular, but probably not particularly important from an experimental point of view.

Here are some of the more important points learned from the tests:

1. The oxygen tank should be so constructed that the liquid is concentrated in large body, and is exposed as little as possible to contact with bare metal. It should, in fact, be insulated by some kind of heat-resistant packing. The fill plug should be easy of access, and at least an inch in diameter.
2. The entire rocket should be built as sturdily and compactly as possible, able to withstand considerable shocks without bending or breaking.
3. The fuel control valves should be operated by strong, self contained springs. They should be large, simple, leak-proof and sure in action.
4. The igniting of the rocket should be accomplished by some kind of electrical apparatus from a distance, but it should be simple, dependable and unfailing. As an experiment, a sparkplug in the top of the motor is suggested.
5. The electrical fuse-blowouts and all wiring on the rocket should be permanent, running from the various parts of the rocket to clip binding posts, or simple, but positive connections which easily can be broken as the rocket rises away from the ground. Such a wiring system must eliminate the danger of poor connections at the fuses or sparking apparatus.
6. The rocket should be sharply streamlined to withstand great acceleration, true flight probably being promoted better by long fins, extending more than half the length of the rocket, than by wide, short ones. It is also suggested that short fins be attached to the nose of the rocket, to aid in guiding the rocket and in cooling the motor.
7. The parachute apparatus should be placed at the rear of the rocket, rather than at the nose, so that the parachute, upon being thrown out, falls clear of the fins, no matter at what part of the flight the ejection takes place. It is suggested that experiments be made to do away with the parachute altogether, adopting instead some adaptation of glider or autogyro wings which can be opened automatically at the height of the flight.
8. Finally, every piece of apparatus connected with the rocket must be sturdy, and so designed as to avoid uncertainty of operation, liability to minor accidents, etc. In order to make sturdiness practicable, more experience needs to be gained with the light metals, particularly with magnesium alloys and beryllium, which are considerably lighter than aluminum, and equally strong.

Our rocket is now being rebuilt, with these lessons in mind. We hope to be able to shoot it in the spring, if a suitable place can be located near New York for the launching. In view of our experiences with the rocket and the fuels, while I do not in any way wish to give the impression that they are dangerous, I believe it would be practicable to invite the active members of the Society at least to be present at the shot, provided suitable bombproofs can be built to accomodate those who might insist upon being close to the launching rack.

NEWS OF THE MONTH

1,000-MILE PLANE SPEED NEAR TEST

Theories of General Crocco, Italian aviation leader, for the development of airplanes to race through the stratosphere at a thousand miles an hour will be tested in miniature by professors of the Guggenheim Aerodynamic Laboratory and mechanical engineering division of the California Institute of Technology.

The plane would be powered by a new type of jet or rocket propulsion engine, being a combination of principles of rockets and internal combustion engines. Analytical studies by J. M. Nordquist, aerodynamic research worker, describe this type of motive power as necessary to propel an airplane at speeds greater than sound travels.

These studies show the present type of aviation engine is valueless for flying ten miles above the earth at speeds which would outdistance the sound of one's voice. Necessary supercharging would use all the engine power of present types at such altitudes, and there is no known means of developing a cooling system which would permit combustion engines to withstand the terrific heat developed at such speeds.

General Crocco's proposed engine would be a hollow cylinder running lengthwise through the center of the plane, looking something like a fish with its mouth open.

A funnel-shaped intake, with the wide end out, would permit air to enter at the rate of a thousand miles an hour. Theoretically this would compress the air, which would generate a heat of 500 degrees centigrade, the heat igniting fuel which would be fed continuously through jets. The pressure of the air in the narrow part of the cylinder would furnish the combustion chamber, where heat would be about 1,500 degrees centigrade. The exhaust would be a widening funnel.

No cooling system would be used, the walls being insulated and constructed of firebrick or similar material. Two operators would sit in air tight compartments. The take-off would be by rockets or catapult.

Professor Robert T. Knapp, mechanical research engineer, doubts whether the air pressure would be sufficient—a great deal of it being lost in heat—to furnish the necessary motive power.

TILING ROCKET MAKES 2600-FOOT FLIGHT

Although from an aerodynamic point of view solid fuel (powder) rockets are of little value experimentally, yet for purposes of control of direction, etc., the recent flight of a rocket by Rudolf Tiling at Berlin is of much interest. The shot was made from the Tempelhof Airdrome Oct. 23 and height was limited to 2600 feet, because of objections on the part of authorities to higher flights. (Herr Tiling made 6000 feet last April). The rocket was 12 feet in length and upon reaching its altitude wings unfolded, letting the rocket spiral gently down to earth. It landed 1200 feet from the point of departure.

SUN CANNOT BE MUCH OLDER THAN 7.55 MILLION MILLION YEARS

The age of the sun cannot be much more than 7.55 million million years. So declares Dr. Ludwik Silberstein, research physicist of the Eastman Laboratories in the international scientific journal, *Scientia*.

Dr. Silberstein bases his conclusions on a mathematical study of astronomical researches made in part by other scientists. The luminosity of a star is proportionate to the cube of its mass. That is to say, a star twice as big as our sun gives off not merely twice as much radiation, but eight times as much. The older a star grows, the smaller it gets, because it is all the time converting its matter into energy and radiating the energy away. But the smaller it gets, the more slowly it shines itself away, by that same rule of the cube. When the sun shall at last have dwindled to one-half its present mass, it will be radiating only one-eighth as much energy.

The mass radiated away by the sun at present is 4,200,000 tons per second; the sun's mass in tons is expressed by a 2 followed by 27 naughts, Dr. Silberstein says. The application of a suitable mathematical formula to these two figures gives 7.55 million million years as the sun's age.

"If we know the present mass of a star," Dr. Silberstein continues, "the equation enables us to predict what its mass will be at any future time and, reaching back into the past, to tell how much time has elapsed since the star had a mass so or so many times greater than now. Thus, for example, if we ask what time has elapsed since our sun had twice its present mass (if such ever was the case), the answer is 5.66 million million years. Similarly, for the time since the sun had 4 times and 10 times its present mass (again if this was ever the case) we find 7.08 and 7.47 million million years respectively.

We see, incidentally, that these figures differ less and less from each other and approach very rapidly indeed the original time-coefficient, viz. 7.55 million million years, and the remarkable thing is that even if we asked about a hundredfold, a thousandfold mass, and so on, we would never exceed the length of time (T) which thus is the upper limit of the sun's age, if we are yet to keep to our concrete example. In plain English, the sun as such cannot be older than 7.55 million million years. If we asked what mass the sun had before that time, say 8 billion years ago, the equation would give us an absurd answer, an imaginary mass, as a mathematician would put it."

LIQUID OXYGEN

By Joseph H. Kraus

Associate Editor Everyday Science and Mechanics

(An Address delivered before the American Interplanetary Society October 21, 1932.)

It is not my purpose in my talk this evening, to enter upon a long and technical description of the possibilities of the use of liquid gases, for the propulsion of rockets or other devices, calculated to rise to heights to which the members of the American Interplanetary Society aspire. Rather, I will confine myself to a few general remarks and a series of demonstrations calculated to show you the difficulties under which this society labored to finally develop a rocket which may, within the next weeks, break all altitude records.

If I were to take the air in this room and subject it suddenly to a temperature of —193.5° C. (316 degrees below zero F), it would no longer remain a gas, but instead, it would become a liquid. This statement may sound preposterous to some of you. Well,—let me be permitted to give you another example with which you are all more familiar. Steam is a gas. If I were to take a quantity of steam and suddenly cool it, I would get water. The same is true of any gas.

Water, as everyone knows, boils at a temperature of 100° C, at a pressure of 1 atmosphere. This pressure is an important factor. If I increased the pressure to 50 atmospheres, water would not boil until a temperature of 265° C. had been reached. At this temperature, tin would melt (170 to 232° C.) Thus we have water, hot enough to melt tin. On the other hand, if I were to apply a vacuum pump to the kettle in which I was boiling the water, and if I maintained a pressure of about half an atmosphere, water would boil at a temperature of only 80° C.

This combination of pressure and temperature at which a gas becomes a liquid, is called the critical temperature and pressure.

At a temperature of —193.5° C. or —316° F. air would turn to a liquid. But this low temperature is difficult to attain. If we increase the pressure to 24 atmospheres, air will liquefy at —150° C. Further increasing the pressure to about 40 atmospheres will liquefy air at a temperature of —140° instead of 193.5. This is its critical temperature. Above this temperature, air will not liquefy regardless of the applied pressure.

These natural phenomena are found put to practical use in the refrigerators which you have at your homes which work on the same principle, namely, an easily liquefiable gas is subjected to pressure. But, every pumping operation produces heat (as you all well remember if you ever had to pump up a tire for the car and found that the barrel of the pump became quite warm). In the refrigerator, the gas, now under pressure, has also become quite warm, so it runs into some sort of a container, where it is allowed to cool and then turns into a liquid, thus you have seen that a vapor being liquefied, gives up a great quantity of heat. But when this liquid again turns into a gas, it absorbs heat, keeps the refrigerator cool, freezes ice cubes, and goes back to the pump to repeat its cycle.

You may wonder about this cooling effect, produced by a liquid turning into a gas.—Well,—do you not remember how cool an alcohol rub feels. The reason is the same; a liquid when turning into a gas, absorbs a great amount of heat. If we wish to bring this alcohol back into a liquid state again, we have to cool it or increase the pressure upon it. It is for the latter reason that, in order to keep alcohol, we stopper the bottles, to increase the pressure. You see, some of the alcohol evaporates, increasing the pressure in the bottle and the balance no longer is able to "boil" away, so to speak.

If I were to place a quantity of alcohol into the palm of your hand, you would tell me that it felt cold. If I were to fan the alcohol, and speed up evaporation, you would say that it felt colder than before. Again, a liquid, turning into a gas absorbs heat. On the other hand pumping air produces heat, expansion of the same air, if rapid enough, reduces temperature.

Have you ever let out some air from a bicycle or auto tire and remarked how cold it felt? A thermometer in the tire would undoubtedly show you that the temperature of the air *inside* is the same as the surrounding air, yet, its rapid release, through a small aperture reduces the temperature. This is the way the low temperature for the production of liquid air is obtained. Air is first pumped into a suitable container where it is allowed to cool to room temperature. Some of this air then passes through a small nozzle and sprays upon coils of tubing, lowering the temperature of the air which follows. The colder air, so formed passes through the same nozzle, further lowering the temperature until the gas is converted into a bluish liquid, slightly heavier or lighter than water.

Of course, the apparatus is much more complicated than I have just described, but the principle is the same as in the average household refrigerator.

The work of the American Interplanetary Society in developing a rocket for attaining great altitudes is perhaps already familiar to you. Their attempt at developing a fuel to drive such a rocket is not so popularly known. This society proposes to use liquid oxygen, obtained from liquid air, as one of the fuels, together with gasoline.

Now, in one pound of liquid air is stored 139,000 foot pounds of energy. If one pound of this air could be evaporated in one second, it should, if perfectly harnessed, raise a pound weight to a height of 139,000 feet, more than 26 miles per second, the equivalent of a speed of nearly 100,000 miles per hour, liberating 253 HP. Above a temperature of —140° C, air will not remain in a liquid state, and will pop into a gas instantly. This gas might attain a pressure of 800 atmospheres, since the density of liquid air is 800 times that of air, or about the same as water.

But, you might ask, why not allow liquid oxygen to boil at ordinary temperatures and expel it through a nozzle? Why use gasoline? Because, while liquid oxygen will boil, it will not do so rapidly enough to make available the great source of energy needed. If dynamite were permitted to burn slowly, it could not be used for blasting. Furthermore, the longer liquid air remains in contact with the object, the more heat has it absorbed from that object, the colder the object gets, and the slower the remainder of the liquid air evaporates. By uniting oxygen and gasoline a tremendously hot gas is obtained. Pure oxygen makes the gasoline burn with a hotter flame.

In more than one respect, the work of the society is pioneering. While it is true that some Germans and Dr. Goddard used gasoline and liquid oxygen in rockets, literature on the subject is sadly lacking.

To give you but a slight idea of what the experimenters are up against, I am now going to give you a few demonstrations of what it means to play with a liquid at a very low temperature.

This thermos jar contains liquid oxygen. It was obtained from liquid air which should be four parts of liquid nitrogen to one part of liquid oxygen,—when first manufactured; but since the boiling point of liquid nitrogen is —195.5° C, the nitrogen boils before the oxygen, which needs a temperature of —182.5°. Boiling at a lower temperature, nitrogen is more volatile, that is to say, it evaporates quicker; just as a mixture of alcohol and water, when heated, will first give off the alcohol.

The thermos bottle is used, because it prevents the liquid oxygen from absorbing heat too rapidly. I place some of the liquid in a kettle and put it on this block of ice. It boils violently, as you can plainly see. The smoke is due to the carbon dioxide and moisture in the air, which are condensed. If I pour it on the floor it disappears. (experiment follows:)

I told you before that liquid air had a density the same as water, more or less. If I poured liquid air into this glass of pure water, it would first boil at the surface. When the nitrogen, which boils off first, leaves, the liquid becomes heavier and is seen to go to the bottom of the glass, this is oxygen and slightly heavier. An envelope of gas prevents the liquid from making contact with the water.

While the cold is intense, I can pour liquid oxygen on my hand without doing any damage; if the liquid is left in contact with the hand long enough for the hand to give up its heat, I get a severe burn. The skin blisters as if I were burnt with a red hot iron.

On the other hand, if I were to allow the liquid air to remain in contact with the finger, it would be frozen so hard that, well we shall see—

Let us assume that this frankfurter is a finger. Its interior is, or rather should be, mostly meat, flesh. It may have a bone in it, although I doubt that. I place it into this beaker, add the liquid, and strike it with a hammer so—(experiment) That's what would happen to a finger, it breaks solidly off.

An ordinery pork chop, and an iron frying pan should show the housewife how to fry chops rapidly for friend husband. Pour liquid air over it and— If the iron pan were frozen long enough, it would shatter when the pork chop is dropped. Liquid gas has an important use here. It is almost impossible to reduce meat to powder, yet with this system it can be done.

Eggs fare just the same, they become as brittle as glass.

A banana dipped in liquid oxygen makes a good hammer, and may be used to drive nails.

Grapes make good bullets.

Rubber tubes may not be used in liquid air or oxygen rockets, the cold freezes the hose as hard as glass . . . .

And here we have an ordinary rubber ball. Note that there is no sleight of hand, yet if I drop the ball, it shatters as if it were a glass object. To convince you that I resort to no trickery, I'll pass out a few of the shattered pieces; when they thaw out, they will be soft again.

A pencil plunged into liquid air, loses its capacity to write, due to the extreme hardness of the lead . . . . .

While this liquid is cold, one should remember that it is not the low temperature but the liquid state that is important. From one horsepower of energy, we procure only 100 degrees of cold in the form of liquid air, but 2,000 degrees of cold, in the form of ice. A pound of liquid air will absorb only 2/3 as many heat units, calories, as a pound of ice. (liquid air, 50 cal. per kilo ice, 79 cal. per kilo).

Even the cohesion of metals is completely altered when immersed in liquid air. A piece of lead wire is rolled into the form of a spring, and a hook made at the end to support a weight. It is then immersed in liquid air. Note that it responds the same as a steel spring. Blowing on it thaws the metal out and it stretches.

A bell of lead will ring as if it were made of silver.

Here is an ordinary flower, which quickly changes in accordance with the old proverb "Dust thou art". It becomes as brittle as glass.

The power of liquid oxygen, I place some in this metal tube, add a rubber balloon, and we will observe the change, as the liquid turns into a gas. Again you will observe that I do not care to come in contact with the metal.

You remember the saying, "You can't drive a nail with a sponge, no matter how hard you soak it". That's all wrong. If the sponge is soaked hard enough in liquid oxygen, a nail may be driven or a plate broken . . . . .

With all this intense cold, liquid air does not destroy all forms of life. Thus the pyocyanic bacillus (*Pseudomanas pycyanea,* called the "bacillus of blue pus" although it produces a green pus, and a green pigment called pyocyanin), will survive treatment with liquid air. It follows that, under a condition of celestial catastrophe, it is quite possible for germs to be transported through the intense cold of space, to other planets, to start life anew.

Liquid oxygen is magnetic, and may be supported across the poles of a powerful electromagnet. It compares with iron about 1 to 1000.

Mercury and alcohol will freeze solid with liquid air. Yet, if we do not add enough liquid air, we may only partially freeze the alcohol which then acts like a rubber band. Here is an ordinary cocktail. We have many guests, so one cocktail is not enough to go around, yet, we can stretch this one . . . . and have enough for every guest.

There is no law against freezing a cocktail and eating it with a fork. . . . .

How would you like to pass a forkful of cocktail to your guests?

And as my last experiment, although a liquid intensely cold, liquid oxygen will support combustion. When confined, it is as dangerous an explosive as dynamite. I throw this lighted cigarette into the liquid and . . . . .

I trust that these few examples have demonstrated to you the powers ,dangers and difficulties with which members of the American Interplanetary Society have had to deal. If their rocket even rises from the ground in the first trial, a few weeks hence, they will have performed a great service, a pioneering engineering conquest, for which their names should go down to posterity.

PURE BERYLLIUM'S STRENGTH NOT YET MEASURED

The physical strength and other mechanical properties of pure beryllium, one of the possible metals for rocket construction, are still unknown because as yet even sublimation in vacuo, the most effective of the methods tried, has not yet yielded enough metal to allow its physical testing, H. A. Sloman, of the National Physical Laboratory, Teddington, England, reported to the joint meeting of the Iron and Steel Institute and the Institute of Metalsof London.

However, comparatively thin films of the metal of more than 99.9 per cent. purity that have been obtained, suggest that the pure metal should resemble iron in being ductile, strong and of medium hardness. Evidence was brought forward that beryllium undergoes some transformation at room temperatures, but it has not been determined if this is due to impurities.

R. J. M. Payne and Dr. J. L. Haughton reported negative results from attempts to produce alloys of beryllium and magnesium, but suggested that it might just be possible to solve the problem by simultaneously depositing them electrolytically both on the same cathode.