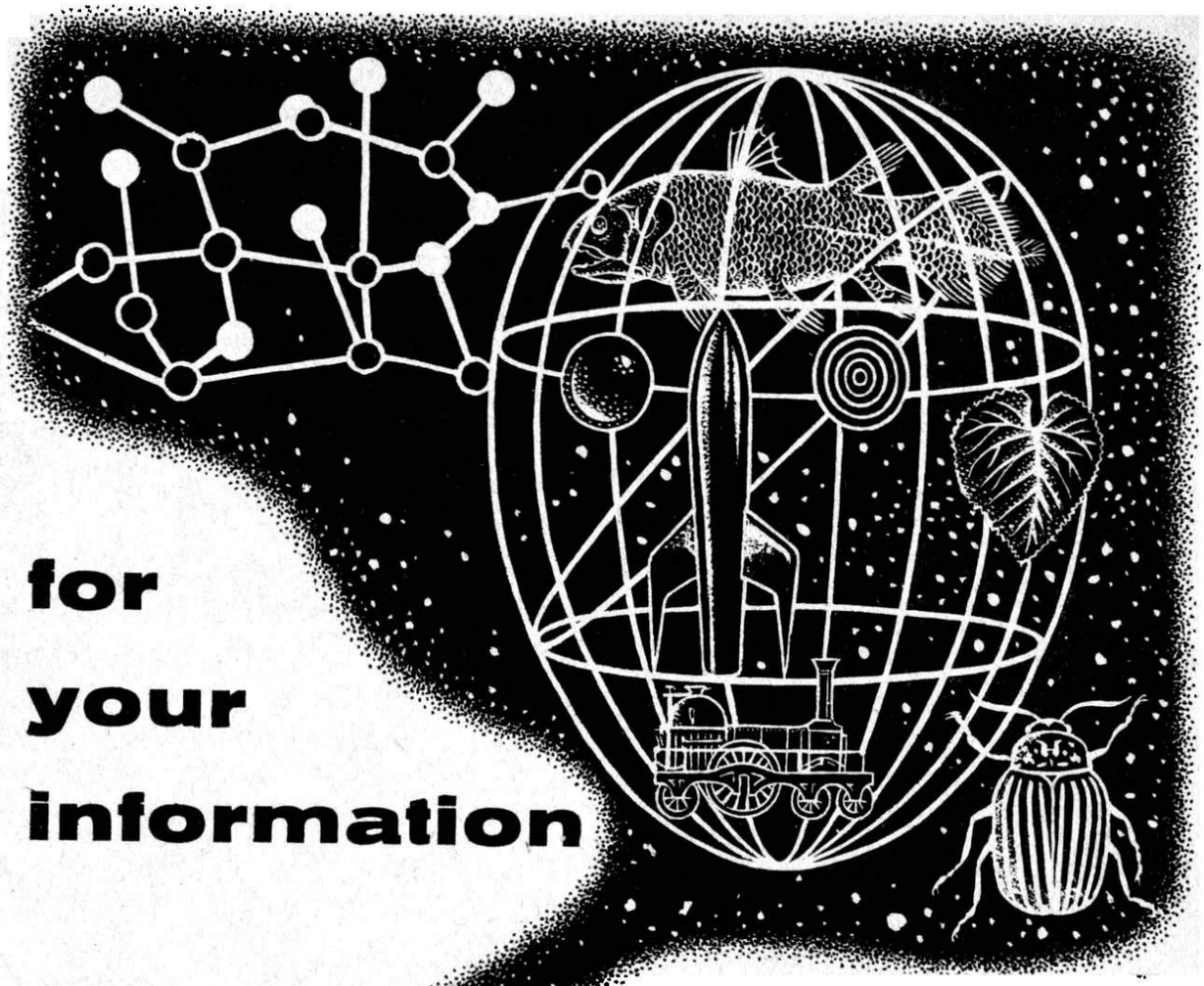

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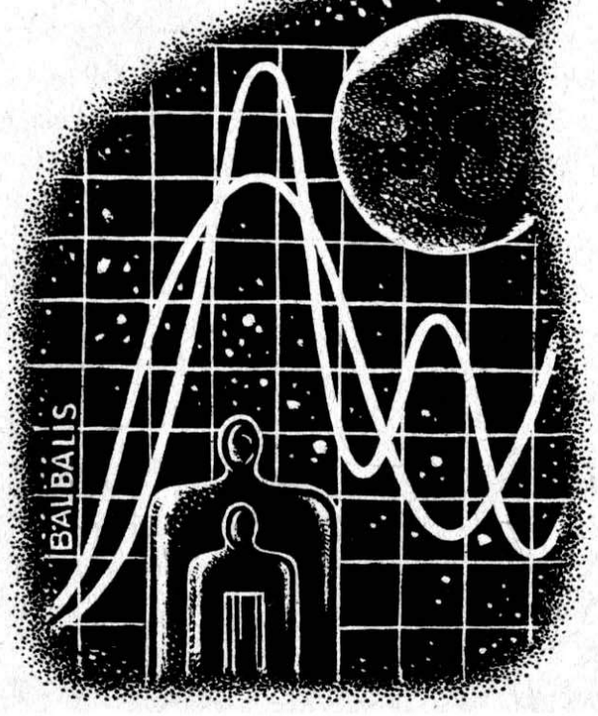


BY WILLY LEY

FUELS GALORE

THIS issue's column is once more devoted exclusively to questions from readers. This also applies to this opening section, which unfortunately cannot be credited to individual readers, for questions about rocket fuels were the most frequent item during the last few weeks. They ranged from the simple but pretty unanswerable "Please tell me what they put into solid fuels" to a rather long and confused letter from a lady in New Jersey who

said all kinds of things that simply aren't so.

To begin with, she "knew" that the Russian successes in the space field were all due to the use of solid fuels, while our explosions at Cape Canaveral occurred because of liquid fuels. She then went on to say that this solid fuel was indubitably a German invention and that we could probably find about it if we read all the patents taken out by the German company of *I. G. Farbenindustrie* — I may add that she misspelled the name. Since this situation is unbearable, she was writing to her senator, and she urged me to write to the President, asking him to order our chemists to go ahead and invent a solid fuel.

I don't know what her senator said to all this, but I tried to straighten her out as best I could in a letter: namely, that the Russian space rockets burn refined kerosene with liquid oxygen, as suggested by Konstantin Eduardovitch Ziolkovsky in 1903, and that they use solid-fuel rockets only, as far as is known, to boost their smaller high-altitude research rockets off the launching pad, but that these rockets, too, are liquid-fuel devices.

I also wrote that our chemists probably learned all *I. G. Farben* patents by heart as a matter of routine — and that we do have several companies which are in the business of concocting solid rocket fuels — without requiring a special order from the President.

LESS confused letters dealt with the question of why solid fuels are "superior" — "They must be or else the armed forces would not specify that they want solid-fuel rockets from now on" — and just what is meant by the term "families of fuels."

Though I have touched on some of these questions in the past, it is necessary to go over the whole problem in a more systematic manner to explain what is really involved.

What 99 per cent of the people who worry about the "secret" of solid fuels — Russian, German, Japanese, Yugoslav or what have you — do not seem to realize is that *all* rockets started as solid-fuel rockets. When the English fireworks maker of the 17th century or the naval architect of the 18th century, or the German gunnery master of the same period retired to his laboratory to make some rockets, he concocted a mixture of 60 per cent saltpeter, 25 per cent charcoal and 15 per cent sulfur. The proportions varied by one or two per cent from case to case, and there were special trade secrets as to how the saltpeter should be refined, how to obtain pure sulfur, and which kind of wood to burn into charcoal. But

the recipe was the one just given. It worked. And it was the only recipe there was.

In the language of modern rocket engineering, the men made a "mixed composite" which had a number of advantages. It was simple, the ingredients were not expensive, and it was reasonably safe to make. That the rockets had a tendency to deteriorate in storage was another problem. And that they could not be made very large was still another one.

It was due to these two drawbacks of poor storability and restricted size that inventors scouted around for other possibilities. Hermann Ganswindt in Germany (around 1880) and later Dr. Robert H. Goddard in the United States (1913 and following years) thought about the possibility of a machinegun-like firing mechanism, using solid-fuel cartridges. Ziolkovsky (1898 or 1903, depending on whether you have the year of writing or the year of publication of his first treatise in mind) wondered about the possibility of using liquid fuels. Goddard (patent of 1914) and Hermann Oberth (publication of 1923) followed suit.

Goddard was the first to actually experiment with liquid fuels. His first test-stand run took place on November 1, 1923, his first free flight on March 16, 1926. In both cases, gasoline and liquid oxygen were used. The first liquid-fuel rocket in Europe rose on March 14, 1931; it had been built by Johannes Winkler and used liquid methane (CH_4) and liquid oxygen. The first Russian liquid-fuel rocket (built by Blagonravov, fuels probably kerosene and liquid oxygen) rose sometime in 1932.

Of course each of these flights had been preceded by test-stand runs, most of which took place in spring and early summer 1930.

AT about the same time, an inventor tried his hand on a liquid-fuel rocket motor in which the oxidizer was *not* liquid oxygen. He was Friedrich Wilhelm Sander who, sometime during 1929, demonstrated a test-stand run with nitric acid as an oxidizer and an unnamed substance (probably fuel oil) as the fuel proper.

Sander's accomplishments are a difficult job for the historian for a very simple reason. Friedrich Wilhelm Sander was one of the very few people who, at that time, were in the rocket *business;* he made his living manufacturing rockets for signaling purposes, line-throwing lifesaving rockets and so forth. They were all still based on the old blackpowder formula mentioned, but he tried to make new inventions in his field, preferably before any competitors would come up with the same idea. Sander, as he made perfectly clear

in a letter to me, was not interested in furthering science. He wanted to enlarge his business.

While this is understandable, it leaves a few gaps in the history of the whole. One cannot even ask him to tell what he did and when he did it, because he disappeared early in the Second World War (rumor has it that he was arrested by the Gestapo and put into a concentration camp) and must be presumed dead.

My reason for stressing this gap in our historical knowledge is that Sander may have been the first to experiment with a new solid fuel too. There is, as has to be explained first, a "family" of solid rocket fuels which is called the "double-base powders." Their original inventor is Alfred Nobel and the invention itself is based on the fact that guncotton and nitroglycerin can be kneaded together into a jelly-like substance. This substance was, for many years, the most powerful explosive known and was sold under the name of "blasting gelatin" and half a dozen other trade names. Because each of the two ingredients is an explosive itself, the term "double-base explosive" was natural.

Later, Alfred Nobel developed this original "double-base" explosive into safer solid double-base powders which received trade names like "ballistite." It goes without saying that the "ballistite" of today is not the "ballistite" that Alfred Nobel and his chemists put together. But the one is the offspring of the other. In fact, most of the "smokeless powders" in rifle cartridges are offsprings of the double-base experiment too.

What I don't know is who was the first to try a double-base smokeless powder for rocket propulsion. It is known that Nobel himself experimented with rockets on and off, but the scanty descriptions that exist stress that his rockets carried a payload of nitroglycerin which produced a blinding flash even in daytime and a very sharp report that could be heard for several miles. Whether Nobel used his new substances for propulsion or whether he stuck to the old formula is something I would like to learn.

GODDARD, at the time of the First World War, did make laboratory experiments with smokeless powders (commercial types) in order to measure their exhaust velocities, but to the best of my knowledge he never produced a smokeless-powder rocket charge of any duration. It is logical that he didn't, because he had his machinegun-type firing mechanism in mind.

It is, therefore, very likely that Sander was the first to use double-base powders for rocket propul-

sion (unless Nobel did), but he did not arrive at a commercial product. This being his goal, he did not talk about his experiments. I know about it only because he once permitted Max Valier to watch a series of test-stand runs, and Valier told me about them — just a few months before his own death, when a liquid-fuel rocket motor blew up on him.

Naturally Sander, though probably the first, was not the only one to think of Nobel's double-base powders for rocket propulsion. The British Military Establishment did. So did the Ordnance Corps of the U.S. Army. So did the *Waffenprüfamt* (Weapons Research Office) of the German Army. And when the Second World War came, everybody blossomed out sooner or later with double-base rockets, propelled by sticks of "cordite" or "ballistite."

Just as the old "mixed composite" had a standard composition from which the individual manufacturers did not deviate much, the new double-base sticks also had a standard. Half of them was nitroglycerin, between 40 and 42 per cent was guncotton, while the remainder were additives with special functions. Main additive was diethyl-diphenyl urea, which was a gelatinizer. Carbon black was another additive, after it had been found out that an optically opaque charge burned more reliably than a translucent one.

Now the double-base charges were superior to the old black-powder in not deteriorating in storage — or at least much more slowly, for these things are relative too — in being more powerful and safer all around. But they still could not be very large. It was necessary, for the bigger types of war rockets, to put several "sticks" into the rocket.

The breakthrough to what is claimed to be a theoretically unlimited size (personally I am still sitting back waiting to see whether limits of some kind will not show up) did not come until after the war. Of course secrecy still prevails here. But the secret seems to be mainly in the manufacturing process, not so much in the composition. The composition, in fact, is familiar.

There is a cast double-base type (40 per cent nitroglycerin, 40 per cent nitrocellulose, 20 per cent additives). There is a mixed composite with ammonium nitrate as the oxidizer. And there are several which are actually synthetic rubber, with an oxidizer kneaded in.

So we do have solid fuels galore.

WHAT prompted most of the questions from readers were newspaper stories dealing with specific items as, for example, that the Army's liquid-fuel Redstone

rocket is to be replaced by the solid-fuel Pershing, and that the liquid-fuel Atlas and Titan are eventually to be replaced by the solid-fuel Minuteman.

The Minuteman is to be a three-stage rocket with the warhead in the third stage. The third stage, used by itself, would be a 200-mile rocket. The third stage on top of the second stage would be a 1500-mile rocket. All three stages together would add up to a 5000-mile rocket.

Well, newspaper readers ask somewhat belligerently, if they are going to replace both the Redstone and the Atlas by solid-fuel rockets, doesn't that prove solid fuels are better?

The answer, and this is really the key to the whole discussion, is that it does *not* prove anything like that. The choice is not one of "superiority" as the layman thinks of the term, but one of superior convenience.

A solid-fuel rocket is much like a cartridge: once it has been made, it can be used at almost any time. A liquid-fuel rocket is more comparable to an airplane: it needs servicing, fueling and so forth. Naturally, for military purposes, the simpler version is the better one — not because it is inherently "better" but because it is more convenient in every respect.

Actually the best solid fuels of today are still somewhat less powerful than the customary liquid fuels. This is admittedly a transitory talking point, for next week the fuel chemists may come up with a solid which is somewhat more powerful than the liquids in use. And whether there really is no limit to the size of solid-fuel units is something that still has to be proved, whereas we know right now that there is no limit to the size of a liquid-fuel unit, provided you have the skill and experience to build it.

The trend toward solids for miltary purposes is due to ease of handling and storage. But even this trend is not unanimous.

Recently the Air Force made the interesting discovery that a certain solid-fuel missile has to be replaced by a liquid-fuel missile. It is a missile which is carried "externally" under the wings of a fighter or bomber. Carrying rockets and missiles externally is old, of course. It always worked fine and was expected to work fine for all time to come.

But one point had been overlooked. If the plane which carries the missile cruises at 400 mph, there is no problem. If it cruises at supersonic speeds, one factor changes — the missile is heated up. Being heated changes the performance of a rocket charge, but *especially* of a solid-fuel charge. Liquids are far less sensitive in that respect, and for this reason a

solid-fuel job is now being replaced by a liquid-fuel device.

And the liquid-fuel engineers have gone over to a counterattack with new liquid fuels which allow a missile to be fueled and then stored as a sealed unit, just like a solid-fuel missile.

ASIDE from these special items, the military trend is in the direction of the solid-fuel missile, essentially for reasons of convenience.

This being so, what can be said in favor of the liquids?

Technological guessing is difficult, but it seems likely that the liquids will continue to be somewhat more powerful. If a new solid catches up with the current liquids in power, the new liquids will probably jump ahead again.

The liquid-fuel units are much larger now, and are likely to stay ahead in this respect too. Every once in a while somebody in Washington makes a news item by declaring that missiles should be smaller, because the warheads are growing smaller without being diminished in power. Well, yes — if the warhead can be smaller, and the rocket can be smaller and therefore easier to handle, and possibly even cheaper, this is fine for military purposes. But for space activities, things have to grow bigger, and bigger, and then bigger some more.

Finally, a solid-fuel charge will do what it has been designed to do, but nothing else. The thrust of a liquid-fuel rocket can be adjusted in various ways, and when it comes to manned flight, that is what is needed.

Being at the end of my answer to many different letters, I wonder whether I've made that answer clear.

The point is that one type of fuel is not inherently and in all ways "better" than all others. A certain type of fuel, or even a specific fuel, is likely to be better for a specific purpose. And as long as you have several sets of purposes, you'll need several kinds of fuels.

DECREASE OF GRAVITY WITH ALTITUDE

IT is pretty well known to everybody by now that a satellite in orbit does not have any weight in the ordinary sense of the word. It does have — a point which apparently cannot be emphasized often enough — mass and inertia, but it does not have any "weight." Almost inevitably this brings up the question of what it would weigh at a certain altitude if it did have weight — if, say, it rested on top of a tower of that height.

The general rule is, of course, the one given by Sir Isaac Newton. If the force of gravity is a

given amount one planetary radius from the center (which means at the surface of the planet), then it is one-quarter of that value at a distance of two radii from the center (or one radius from the surfact), one-ninth at a distance of three radii from the center, and so forth.

But what would the weight be at lower altitudes? Well, at the surface, the gravitational acceleration of the planet Earth is 32.18 feet per second squared. At a height of 3 miles this figure is still 32.15 ft. p. sec. squared. At 5 miles it has reached the value of 32.0 ft. p. sec. squared; at 25 miles it is still 31.8 ft. p. sec. squared. At 55 miles it is down to 31.4 ft. p. sec. squared and at 125 miles to 30.2.

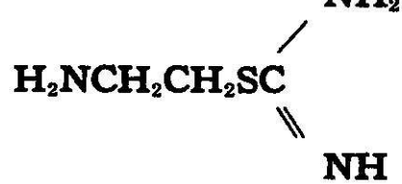
But 125 miles is not a satellite altitude; an artificial satellite placed in an orbit 125 miles from the ground would not last very long. The lowest feasible satellite altitude would be around 250 miles. The value for "g" at that altitude would still be 28.5 feet per second squared, only about 10 per cent less than at the surface.

ANY QUESTIONS?

Recently, in a radio broadcast, a reference to "anti-radiation drugs" was made. What are these drugs and how do they work?

Robert S. Stanley
Jacksonville, Florida

Yes, there some drugs which do help the body to overcome radiation damage. The one on which most work has been done has the chemical name of S- (2-aminoethyl) isothiuronium hydrobromide and the formula.



and even chemists refer to it by the shortened name of AET. What AET can do has been shown in an experiment with a group of mice. One-half of that group was not treated and subjected to 625 roentgens of radiation. Half of the untreated mice died within one month after radiation was applied. The other half of the original group was treated with AET and it took 1300 roentgens to kill off half of the treated mice. You might say that the resist to radiation was just about doubled.

An important point to remember is that AET is not a pill which will "cure" radiation damage. If such a pill is possible, we haven't found it yet. The AET must be present in the body before the exposure to radiation occurs, for it is a protecting chemical. It can be injected into a vein or simply swallowed. The method of introducing it into the body does not seem to make any difference.

The fact that such a protecting

chemical has been found makes it probable that others exist and can be made; presumably there will be some which are far superior to AET. The search for such other chemicals is somewhat handicapped at the present moment by the fact that nobody knows how AET works.

The majority opinion among the researchers has it that the harmful effects of radiation are caused indirectly, via a chemical detour. The radiation is believed to produce so-called "free radicals," chemicals which are highly active and for this reason do not exist for any length of time since they quickly combine with whatever is on hand. The "raw material" from which the free radicals in question are formed is the water of the body tissues, but some researchers feel that the presence of free oxygen increases the formation of free radicals. These researchers believe, therefore, that a lowering of the oxygen content of the tissues will be a partial answer.

Other researchers shoved the question of whether free oxygen plays such a role somewhat aside in saying that AET obviously acts as a trap for free radicals and makes them harmless, no matter how they were formed. The protection of the living cell by AET molecules would consist of "using up" the free radicals before they can attack the "living compounds" of the cell.

Still another group of researchers point out that if this were the whole story, any chemical which "uses up" free radicals should be an "anti-radiation drug." But quite a number of compounds are known that do use up free radicals, but that do not produce any radiation protection. These researchers think that the AET, modified by body chemistry, combines with the sensitive substances of the cell instead, forming substances which free radicals cannot attack. These researchers think that the body gets rid of the free radicals through other reactions and that afterward the combination of modified AET and cell constituents somehow falls apart so that the living cell can resume its functions.

Of course additional protective chemicals may be found even if it it not clear just how they work. But the search for such chemicals would be eased if it could be established just how they do, or should, work.

Please tell me whether any man has yet reached an altitude of more than 100,000 feet and how different space would be from whatever altitude has been reached.

William J. Gordon
Chicago, Ill.

The highest flight mentioned in professional literature is one by the late Captain Iven C. Kincheloe who took the rocket-propelled research airplane X-2 to a height of 126,000 feet in August 1954 and landed it safely after what he described as an uneventful flight.

Except for the air resistance experienced by a fast-moving body, conditions at 126,000 feet do not differ noticeably from free-space conditions. At about 100,000 feet, 99 per cent of the Earth's atmosphere is below the pilot; hence his cabin has to protect him as thoroughly as the cabin of a spaceship would.

One difference I can think of would be conditions of illumination. The contrast between illuminated objects and lightless background should be more pronounced and the space pilot would suffer if his eyes were not protected by light filters. This condition, however, would prevail to a large extent at 126,000 feet too. It is not stressed in the report on the flight, presumably because the time at the peak was so short.

A friend of mine says that "megabuck" means a million dollars. Is this true? Please answer in your column. I don't want to sign my name in case my friend was only joking.

Friend, you could have signed your name, because "megabuck" *does* mean a million dollars. But that does not mean that the term "mega" means "million." The word is an adaptation of a number of new terms introduced by the National Bureau of Standards denoting large and small figures so that they can be (A) easily pronounced and (B) avoid the confusion which always attends large numbers because the American method of naming large numbers unfortunately differs from the European system. For example, the figure 1,000,000,000 is usually called a billion in America; in Europe, it is called a milliard, and the figure 1,000,000,000,000 is named billion.

Readers of this column may have noticed that I never use the word billion for this reason, but instead use 1000 million. Now the National Bureau of Standards has picked the terms "tera," "giga" and "mega" for large figures. The word "tera" comes from Greek *terastios* meaning "monstrous." "Giga" is from Greek *gigas* which means either a giant or just "mighty." "Mega" is from Greek *megas*, meaning "large." The names denote:

Tera = 1,000,000,000,000 (European billion or American trillion); *Giga* = 1,000,000,000; *Mega* = 1,000,000. Then comes *Kilo* = 1000; *Hecto* = 100 and *Deka* = 10.

Below the decimal point you

have *Deci* = 0.1; *Centi* = 0.01; *Milli* = 0.001; *Micro* = 0.000,001 (or 1 millionth) and, as new additions, *Nano* = 0.000,000,001 and *Pico* = 0.000,000,000,001.

Is there a substance called gadolinium"? If so, what is it and what is it used for? I tried to look it up in a book on chemistry which my father has, but I could not find it. I presume it is quite rare and not listed for that reason.

Dolores Goldstein
Alameda Blvd.
Burbank, Calif.

If your father's chemistry text is more than a dozen years old, gadolinium may not have rated a separate paragraph because it was then mostly a chemical curiosity. But you should have found it in the periodical table of the elements. Gadolinium is element No. 64, one of the rare-earth elements, hence a metal. It is named in honor of Professor Johan Gadolin of the University of Abo in Finland. Gadolin, who died in 1852, discovered a substance he named "yttria" because it came from Ytterby in Sweden. Yttria later turned out to be a complex mixture of compounds of many of the rare-earth elements of which gadolinium is one.

In spite of the name attached to the whole group, it is not particularly rare; it was just difficult to isolate. The pure metal looks about like silver. The use of gadolinium as moderator rods in atomic piles was discussed several years ago, but I can't say whether it is actually so used now, nor do I know of any other uses.

THE HAIRS ON YOUR GIRL'S HEAD

ONLY about a week has gone by between the appearance of the February issue on the newsstands and the writing of this column, so there is very little mail as yet about the problem of the girls in the same town with the same number of hairs on their heads.

I have, in fact, exactly two pieces of mail, both of them postcards. One states that it could not possibly be the case. The other remarks philosophically that one should not deny that anything is possible, but that this certainly is not probable.

Well, this is one of the cases where "common sense" and mathematics are at odds with each other, and in these cases mathematics always wins.

Let's repeat the problem: the town has 220,000 inhabitants or more. Without going into fractional percentages of statistics, this means that 110,000 inhabitants are female. Subtracting 25 per cent of that number as being female children, we get an adult

female population of 82,500.

We'll postulate (in the hope of being mistaken) that one of these women suffers from an extreme case of what dermatologists call *alopecia totalis,* which means in plain English she does not have a single hair on her head. The number of her hairs therefore is *zero.* This is the one possible extreme. She can't have any less.

Now what is the maximum number possible? How many hairs are there in a really luxuriant dense-jungle-type head of hair? The estimates of the expert vary a little; the figure usually runs between 50,000 and 60,000, though some are willing to concede 80,000 as the possible maximum. Hence the girls in that town can have between zero and 80,000 hairs on their heads. Since there are more than 80,000 girls, not only one or two but several thousand will have the same number of hairs on their heads at a given moment.

— **WILLY LEY**

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