9

What Ivan Was Doing

When the Russians moved into Germany, they put the chemists at the Luena works of I.G. Farben to work at propellant research. True, these weren't propellant men, but to the Russians apparently a chemist was a chemist was a chemist and that was all there was to it. ARPA did something similar in this country a good many years later! At first the Germans didn't do much except determine the properties of the known rocket fuels, but when they were sent to Russia in October 1946 (some went to the State Institute of Applied Chemistry at Leningrad, the others to the Karpov Institute at Moscow) they were put to work synthesizing new ones, some to be used neat, some for additives to gasoline or kerosene. For the Soviets, like the Germans before them, were hunting for hypergols, and additives that would make gasoline hypergolic with nitric acid.

And, the nature of chemists and of chemistry being what it is, the paths they took were the same ones we took. They investigated the vinyl ethers, as the Germans had done before them, and then, in 1948, four years before NYU did the same thing, they synthesized and tried every acetylenic that they could think of. In 1948 they tried the allyl amines; Mike Pino at California Research was doing the same thing at the same time. They investigated the tetraalkyl ethylene diamines in 1949, two years before Phillips Petroleum got around to it. And, in 1948 and 1949 they worked over the mercaptans and the organic sulfides, just as Pino was doing. They investigated every amine they could get their hands on or synthesize, and they tried such mixed functional compounds as vinyloxyethylamine. And everything they made they mixed with gasoline—usually a pyrolytic, or high-aromatic type, in the hope that they could get a good hypergolic mixture. They even tried elemental sulfur, in some of their mixtures. But for a long time the most satisfactory fuel for their tactical missiles was the German-developed Tonka 250, mixed xylidines and triethylamine. The second stage of the SA-2 or Guideline (U.S. designations—we don't know theirs) surface-to-air missile used by North Vietnam uses that fuel, along with RFNA.

Home-made hydrazine hydrate (rather than captured German stuff) was available in the Soviet Union by 1948, but there was apparently little interest in hydrazine or its derivatives until about 1955 or 1956, when the Soviet chemists (all the Germans had been sent home by 1950) learned of our success with UDMH. The lack of interest may have been caused by the incompatibility of copper and hydrazine; and their engineers liked to make their motors out of copper, because of its beautiful heat-transfer properties. And, of course, the Russian climate has a tendency to discourage the use of hydrazine. UDMH, now, is one of their standard propellants.

Some work was done with high-strength peroxide, first with captured German material, and, after 1950, with Russian product, but there never was much interest in it, and finally the Navy took over all peroxide work. (It's very useful in torpedoes.)

The nitric acids used in the late 40's and early 50's were a 98 percent WFNA, WFNA containing 4 percent of ferric chloride as an ignition catalyst, and a mixed acid containing 10 percent sulfuric acid. And they had all the troubles with it that we had. They tried organic sulfonic acids—methane sulfonic, methane di and trisulfonic, ethane disulfonic, and ordinary disulfonic acid—as corrosion inhibiters in 1950 and 1951 (two years before California Research tried them) but used them in little more than trace quantities, a percent or so. They didn't work, naturally.

But in spite of the nitric acid troubles, one of the Germans bethought himself of Noggerath's equation relating propellant density to range, and decided to make a few points with his new bosses.*

* As a first approximation, the range of a missile is proportional to its boost velocity, squared. And Noggerath related the boost velocity to exhaust velocity and propellant density by the equation:

$$c_b = c \ln (1 + d\phi),$$

where c_b is the boost velocity, c the exhaust velocity, d the bulk density of the propellants, and ϕ a loading factor—the total tank volume of the missile, in liters, say, divided by the *dry* mass (all propellants burned) of the missile, in kilograms. So the range depends very strongly upon the exhaust velocity, but upon the density by a

He decided that a V-2 loaded with nitric acid and a really high-density fuel would have a range that would make him a Hero of the Soviet Union, at least, and set out to make that really high density fuel. So he mixed up 10 percent of toluene, and 50 percent of dimethylaniline, and 40 percent of *dibromoethane.* He got a high density all right—something like 1.4—but what those bromines did to the specific impulse was a crime. His Russian bosses, who were not fools, took one horrified look at what he was doing, and immediately took all his chemicals away from him. And four weeks later he was hauled up before a People's Tribunal, tried, convicted, and fined 4000 rubles for, in the words of the court, "Misleading Soviet Science." He was lucky. If I had been on the tribunal he'd have gone to Siberia for ninety years, and the charge would have been Exuberant Stupidity. The Russians were happy when he went back home. With an ally like that who needs enemies?

Other attempts at high-density fuels were made; 8 percent of colloidal aluminum suspended with aluminum stearate in kerosene was one of them. But it froze at −6°, and the investigators lost interest. And they tried various nitro-organics such as nitro-propene—the name alone is enough to scare me to death—as monopropellants, with no success to mention, and, as the Germans had before them, tried to use tetranitromethane as an oxidizer. And blew up a laboratory trying it.

Recently they have been showing considerable interest in mixtures of hydrazine nitrate and methyl hydrazine (like my Hydrazoid N) but whether they intend it for a fuel or for a monopropellant we don't know. Their first ballistic missile the SS-1A (NATO designation), was a carbon copy of the A-4, and burned 70 percent alcohol and liquid oxygen. Liquid oxygen was available in quantity, since the Soviets use the highly efficient and very fast air liquefier designed by Peter Kapitza. The larger missiles, SS-2, "Sibling" of 1954, and the SS-3 "Shyster" of 1956 used the same combination, except that the concentration of the alcohol was 92.5 rather than 70 percent.

But, as you may remember, the U.S. specifications for nitric acid, including the HF inhibitor, were published in 1954. So the next Soviet ballistic missile was a redesigned SS-1A, the SS-1B, or "Scud," and burned kerosene and IRFNA. They presumably used a starting slug—perhaps triethylamine—and the kerosene they use is a high

logrithmic function which, varies with the loading factor. If ϕ is very small, as it would be in a plane with JATO attached, the density is almost as important as the exhaust velocity. If it is very large, as an ICBM, the density of the propellants is much less important.

naphthenic type, very similar to RP-1. They prefer this to other types since it is much less liable to coking than, say, a high-olefinic mixture when it is used for regenerative cooling. Suitable crudes are abundant in the Soviet Union. There are two "rocket" grades of IRFNA commonly used in the U.S.S.R., AK-20, containing 20 percent of N_2O_4, and AK-27 containing 27 percent.

From the advent of "Scud," the presence of two design groups in the Soviet Union has been apparent, and the Soviet high command, presumably to keep peace in the family, splits development projects between the two. This procedure is not exactly unheard of in this country, where a contract awarded to Lockheed may be followed by one to General Dynamics.

One group remains wedded to liquid oxygen, and designed the SS-6, SS-8 and SS-10. SS-6, the monstrous 20-barreled beast that lifted Yuri Gagarin and Vostok I into orbit, burned oxygen and the equivalent of RP-1. SS-8, "Sasin," and SS-10 burn oxygen and, apparently a hydrazine–UDMH mixture equivalent to our 50–50.

The other group swears by storable oxidizers, IRFNA or N_2O_4, using the latter in the big strategic missiles which live in steam-heated silos, and the former usually in shorter range tactical missiles which have to cope with the Russian winter. The SS-4 "Sandal" uses IRFNA and apparently a mixture of RP and UDMH (compare U.S. Nike Ajax), while the SS-5 IRBM "Skean" and the SS-7 ICBM burn acid and UDMH. The recently deployed SS-9 ICBM "Scarp," a kissing cousin to the U.S. Titan II, but somewhat larger, burns N_2O_4 with, probably 50–50. There has been some conjecture that it may burn MMH, but that appears unlikely. Fifty-fifty is much cheaper, gives the same performance or a little better, and with a strategic missile you don't have to worry about the freezing point of the fuel. The smaller SS-11 uses the same propellants, and the SS-12, a tactical missile more or less equivalent to the U.S. "Lance," burns IRFNA and RP. (To bring things up to date, the SS-13 is a three-stage solid propellant equivalent to "Minuteman," and the SS-14 is essentially, the two upper stages of SS-13.) The Soviet naval missiles comparable to "Polaris," use IRFNA or N_2O_4 with UDMH or 50–50, or are solid propelled. And the Chinese ballistic missiles under development are based on the SS-3, modified to burn IRFNA and kerosene.

As for more advanced, or "exotic" propellants, the Soviet practice has apparently been more conservative than that of the United States. The Russians did some work with boranes in 1949–1950, but had sense enough to quit before they wasted a lot of time and money. There were some firings with 10 percent ozone in oxygen in East

Germany in 1952, but there is no evidence that this work was followed up. Nor is there any evidence of extensive work with halogenated oxidizers. In a long review article on perchloryl fluoride in a Soviet chemical journal recently, all the references were to western sources.* There has been some mention of OF_2, and of the alleged virtues of metal slurries, but nothing to indicate that it amounts to more than words. Nor is there any indication that they have done much with liquid fluorine or with liquid hydrogen, although it would be surprising, to say the least, if the use of the latter in their space program had not been considered.

In short, the Russians tend to be squares in their choice of propellants. Oxygen, N_2O_4, IRFNA, RP, UDMH and its mixes – that's about the lot. When he wants more thrust, Ivan doesn't look for a fancy propellant with a higher specific impulse. He just builds himself a bigger rocket. Maybe he's got something there.

* Of course this *may* mean that they are about to start working with it. Such review articles, in the U.S.S.R., frequently signal the start of a research program.