

hundreds of miles of membrane-filled pipes, a method so expensive in its capital and operating costs that, so far, plants have been constructed by only five nations, the United States, Britain, France, the U.S.S.R., and China. These plants are probably the costliest single manufacturing facilities of any type on earth. The U.S. plants, three in number, are reported to have cost nearly \$2.5 billion, and the French plant is priced at over \$1 billion.

With enrichment plants so limited in number, and with the U.S. the only country outside the Soviet bloc having significant surplus capacity, it has been relatively easy to obtain assurances that fuel sold to other nations for power reactors would not eventually wind up in the form of nuclear weapons. There are no guarantees, of course, since the plutonium formed in these reactors can be processed into explosives, but the limited number of sources for fuel simplifies the verification of nonproliferation agreements and makes it nearly impossible for a nation to build a bomb undetected.

Despite American concern and French mutterings, it is not at all clear how centrifuge technology is likely to do anything but give the U.S. some stiff competition and demonstrate that Europe can cooperate in important atomic matters without French participation. As things now stand, even the element of competition is somewhat uncertain, since the rapidly growing market for enriched uranium is likely to exceed present U.S. capacity by the mid-1970's. It is doubtful that the U.S., given its tradition of trying to discourage foreign self-sufficiency, will idly permit the market to outgrow its production capacity. But European planners apparently figure it might turn out that way. Euratom, for example, sees a production gap developing in the next decade and has proposed construction of an enrichment plant, but that organization has been virtually immobilized by French intransigence and various squabbles among the other partners.

As for the possibility that European success with the centrifuge process may give small powers—or, possibly, insurgent groups—a clue for developing cut-rate nuclear weapons, the evidence is quite weak. It is true that centrifugation does not require the vast power-generating facilities or mile-long structures that make it impossible to conceal a gaseous diffusion plant from

Commerce Committee Endorses Steam Car Engine

A Commerce Committee report last week endorsed the steam cycle propulsion system in motor vehicles as a "satisfactory alternative" to the present internal combustion engine. It claims that the Rankine, or steam propulsion system, is "superior" to the internal combustion engine both in terms of performance and emissions. The report, "The Search for a Low Emission Vehicle," is based on joint hearings held last May (see *Science*, 5 July 1968) by the Commerce Committee, chaired by Warren Magnuson (D-Wash.), and the Air and Water Pollution subcommittee, chaired by Edmund Muskie (D-Maine). Its conclusions are based on investigations by committee members, consultations with industry representatives, reports by members of the Society of Automotive Engineers, and studies conducted by engineers in the Transportation Department. The report, which calls for federal legislation to encourage the development of a viable steam car propulsion system, recommends specifically that the Health, Education, and Welfare Department devote a greater portion of its research funds to "inherently low-polluting propulsion systems." It also recommends that the Transportation Department finance demonstration projects which test various transportation applications of such systems.

Authorities say that the automobile, with its present internal combustion engine, now accounts for more than 60 percent of the nation's air pollution and in cities the amount is as high as 85 percent. The Commerce Committee report claims that the steam engine burns an inexpensive fuel, which "produces almost no pollution," and gets better fuel mileage. The report claims that the Rankine engine also has a better maintenance and reliability potential. The committee's report is highly critical of the automobile industry for "dragging its feet" in the development of a low-polluting propulsion system.—M.M.

aerial or space reconnaissance. But centrifugation, which requires engineering that is probably as difficult as any in the world today, is not a backyard undertaking. Furthermore, it is a long way from enriched uranium to an explosive device of any sort. For anyone wishing to build a nuclear bomb, there are easier and probably less conspicuous ways than a venture into the complexities of centrifugation.

Though British officials decline to provide any engineering details, it is widely suggested that the centrifuge plants will provide a market for a marvelous, but so far profitless, achievement of British scientific research—carbon fiber. Now in the category of a solution looking for problems, carbon fiber is many times stronger yet many times lighter than steel. Though Britain has pioneered in its development, its only significant use to date is in the turbine blades of Rolls Royce aircraft engines. In the absence of other markets, production is limited. Meanwhile, as has been the case with many other British developments, aggressive American firms are buying licenses and doing

all the things that must necessarily precede the reaping of what everyone involved foresees to be a great profit. Carbon fiber for light but strong rotors, plus new Dutch designs for durable bearings, are said to be the three-nation solution to the centrifuge problem. If that is the case, then Britain has all the more reason to be enthusiastic over the agreement.

According to British officials, the plants for manufacturing the centrifuges will be adjacent to the uranium-enrichment facilities. In Holland, it is expected that the site will be near a major industrial chemical complex. In Britain it will be at Capenhurst, where the Atomic Energy Authority's gaseous diffusion plant is located. The centrifuge plant will share Capenhurst's services but will otherwise be operated independently. Many details remain to be worked out, and the agreement is yet to be formally approved by the three governments. But work is going forward, and it is expected that one or both of the plants will be producing enriched uranium by 1973.

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