we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite."

George B. Kistiakowsky, who served as Eisenhower's science adviser during his final 2 years in the White House, says that Eisenhower had the problem of the military-scientific establishment very much on his mind and was concerned with the reaction to his speech. After the speech Kistiakowsky, in fact, took the trouble to issue an explanation of the references to science (*Science*, 10 February 1961), making it clear that Eisenhower was not referring to basic research but to industrial research of a military nature.

Kistiakowsky told *Science* a few months ago that Eisenhower was much in favor of academic science, but that the President perceived that a kind of technological momentum takes over in weapons development. "Once it appears possible to do something," said Kistiakowsky, "there is a tremendous urge to do it. That is what worried President Eisenhower."

Kistiakowsky concurred strongly on this point, but like many other academic scientists, did not agree with Eisenhower's views on everything while he was in the White House. In summing up his own feelings, however, he probably comes close to a national consensus on President Eisenhower when he said he had "enormous admiration and fondness for him as a person. He was a thoughtful and sincere patriot who put the welfare of the American people above everything else. . . ."

—JOHN WALSH

Uranium: Three European Nations Plan To Build Centrifuge Plants

London. Among U.S. government policy makers, "centrifuge" is one of the naughty words of nuclear nomenclature—so much so, in fact, that several years ago the AEC banned public references to it and also asked America's allies to keep quiet about whatever they might be doing in the field. The reason is that centrifugation is a cheaper, though technically very difficult, process for producing enriched uranium. And, since the United States has unswervingly tried to discourage nuclear self-sufficiency in any other nation, it has long looked upon the centrifuge process as something it would prefer not to see come into being.

That preference, however, is now on the verge of being rendered irrelevant, for, last month, ministers of Britain, West Germany, and the Netherlands met here and announced that the technical problems have been solved and that their countries intend to cooperate in building two centrifuge plants for the production of enriched uranium. No costs were discussed, but it is expected that the plants will not be any cheaper to build than gaseous diffusion plants—now the sole source of enriched uranium—of comparable capacity. The advantage lies in the fact that centrifugation requires about one-tenth as much electric power as gaseous diffusion does, and in Europe, where power costs are high, this difference is crucial. Also, unlike the gaseous diffusion process, it is possible to start on a small scale and simply add more centrifuges as more production is required.

The announcement was accompanied by strong assurances that the tripartite undertaking would adhere to existing agreements against the spread of nuclear weapons, and it was stressed that the plants would be constructed in Britain and the Netherlands. Germany, whose big, high-quality nuclear industry raises worrisome suspicions, especially to the east, will house the administrative headquarters for the undertaking but, for the present at least, will be out of bounds both for the manufacture of the centrifuges and for the enrichment plants that will employ them.

Thus, the centrifuge agreement is unlikely to produce any short-term effects of military significance—the stated cause of U.S. concern over the process. But, in its political and economic implications, it may well be one of the most important technological developments to take place in Europe for a long time. For, all at once, it offers the possibility of Europe's ending American domination in the booming worldwide market for enriched uranium, which is expected to reach over $1 billion a year by 1980. To those concerned, the centrifuge agreement offers a reasonable assurance that Germany will move no closer to a wholly independent nuclear capacity, though it should be pointed out that, in view of Soviet sentiments on this issue, the Germans more than anyone else recognize the suicidal implications of a step in that direction. Finally, against a backdrop of France keeping Britain out of the Common Market, the agreement ties Britain into a major European endeavor that makes economic sense—in contrast, for example, to the Concorde supersonic project or to European space efforts, both of which must rely in large part on the dubious banner of "prestige" whenever they run into trouble.

The French, who have followed their own nuclear development program to the detriment of European cooperative efforts, are said to be furious over the three-nation deal and are suggesting that Britain is acting irresponsibly in making Germany a partner in the production of enriched uranium. What this ignores is that the Germans are widely reported to have developed a centrifuge system on their own but, under the agreement, will forego having any of the plants on their own territory.

In view of the fact that a centrifuge plant is neither easy to build nor at all indispensable for a would-be bomb builder, U.S. touchiness on the subject suggests the possibility that commercial rather than military considerations underlie its longstanding concern about the process becoming feasible. Or it may reflect America's self-righteous belief that she alone is sufficiently sensible and trustworthy to possess all the means and materials for building a nuclear arsenal. In any case, for nearly three decades—in fact, since the Manhattan Project first headed toward a centrifugation process and then quickly abandoned it because of technical difficulties—the alternative gaseous diffusion method, because of its necessarily vast scale and matching operating costs, has provided the United States with a substantial competitive edge in the atomic marketplace. The U.S. plants, initially built for military purposes, have capacity beyond military and civilian requirements, and, accordingly, there has been no incentive for the U.S. to develop a centrifuge system. Rather, there has been incentive for it to emphasize the difficulties, of which there are many, and inquirers to the AEC would be told about these in ample measure.

To separate the fissile isotope from natural uranium through a centrifugation process, and on an industrial scale, involves the use of hundreds of thousands of long, narrow, revolving tubes, resistant to the highly corrosive gaseous uranium and capable of operating for long periods at 50,000 to 100,000 revolutions per minute. In the past, the British have reported laboratory models blowing to pieces under the stress, thus raising the image of great banks of these costly devices being shattered by flying fragments from a single failure. In sum, the American attitude was that it is an interesting but impractical idea. This confined enriched uranium production to the gaseous diffusion process, which produces separation by pumping uranium through

Industrial Innovation: How England Sleeps

London. Britain abounds with wonder and distress over why it is that American firms so often take the lead in developing and marketing technical ideas that originated in Britain. Students of the subject are invited to consider the following events, which recently came to the attention of *Science*:

In 1966, following the sale of a highly successful electronics firm of which he was a founder and director of research, a 30-year old British physicist was awarded a government-sponsored senior industrial research fellowship. (Since he prefers that he not be publicly identified in connection with this tale, let us refer to him as Williams.) These fellowships, limited to a small number, were offered as part of the government's efforts to promote a closer relationship between academic and industrial research. Williams took up the fellowship in one of the colleges of the University of London. There, with the encouragement of his section head, he proceeded to plan a device that could automatically scan cell samples and print out data on such things as number, size and contour, as well as size and shape of the nucleus in relation to the rest of the cell. Williams described the device as "a computer-controlled flying spot microscope," and felt that, if successful, it might have a variety of uses as a research and diagnostic instrument. In the latter category, he puts rapid screening of cervical smears. His section chief recognized that the project was a departure from the laboratory's basic research role, but, as he put it in an interview with *Science*, "There had been so much urging for universities to do something to help the economy, that I decided that we should cooperate with this project as much as possible." Higher officials of the college agreed, and also provided their support.

Once past the planning stage, Williams sought about $25,000 in development funds from the government agency that sponsored his fellowship. The request was turned down without explanation. Unofficially, however, it was learned that the review panel had decided that the proposed machine was impracticable, that the budget was unrealistically low, and that similar work was going on elsewhere. On the basis of his industrial experience and familiarity with the field, Williams rejected all three reasons, and proceeded to build the machine with what he describes as "salvaged" material and "borrowed" assistance. By September 1967, he felt he was far enough along to seek a patent. Application was made, and a provisional patent was issued several months later. Government literature had led Williams to believe that various agencies were on the lookout for inventions with possible industrial applications, and he hoped that industrial contacts might develop from the patent application. However, none did. And, since he was spending a great deal of his time personally soldering circuits and supervising his "borrowed" assistants, he did not pursue the quest for money or business connections. His section chief did seek assistance from an investment bank, but was turned down on the grounds that the project lacked backing from a business organization.

Meanwhile, a business organization did develop an interest in Williams' work—but it was an American organization. About a month after he applied for a patent, he received an inquiry from Sanders Associates, of Nashua, New Hampshire, an electronics firm with which he had become acquainted while he was in industry. A Sanders executive wrote that he had heard that Williams had taken a new job, and simply wondered what he was doing. Williams sent back a description of his project. He promptly received an invitation to visit New Hampshire, at Sander's expense, to describe the device to the firm's executives.

"Upon completion of my talk," he recalls, "they said they were interested and they asked how they could help me. I was flabbergasted."

Williams replied that he needed various items of electronics equipment—worth about $18,000—plus about $6,000 in direct financial assistance. Sanders agreed to lend the equipment, which is now en route, and to provide the money, which is now on hand for use over a 2-year period.

American interest in Williams' work was not confined, however, to just one organization. He also received an inquiry from a senior researcher at the University of Chicago Medical School. After Williams provided details of his work, Chicago ordered a copy of the machine, for which it has agreed to pay about $14,000 to cover the cost of materials.

Recently, Williams said, a British firm has shown some interest in his work; there is a possibility that it may provide some assistance.

Next fall, Williams will be leaving the college to join still another firm, where he has been offered a major post directing research. He hopes to work out a visiting appointment with the college so that he may continue work on the machine there.—D. S. G.

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 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.

—D. S. GREENBERG

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.