Атомная энергия – мирное использование
FOR DISPLAY (pp. 1–5)

E/W -- WILL MAN'S SUN EVER RISE? F.- 530

Munich, 19 August 1981 (CND) - The following article appeared in the Sunday Times, August 16, 1981.

The most important experiment in international scientific co-operation ever mounted—the search for fusion energy—is now under serious threat. Though free exchange between Britain, America and Russia has survived all the crises of the last 25 years, a crucial conference in Moscow next month will be boycotted by many Western scientists in protest at the Kremlin's exiling of the nuclear physicist André Sakharov and the invasion of Afghanistan. West German and French scientists have said they will not attend. Some British and Americans will go, but Washington has put a stop on all official exchanges since last autumn. As as result, the conference is expected to be a flop.

The research aim is spectacular: to reproduce on earth the workings of one of "God's gadgets"—the sun—and so create limitless, safe energy from that most abundant of substances—water.

In the 1950s scientists were grappling with the problem independently. The first suggestion for co-operation between the three nuclear nations came one frosty morning in the spring of 1956, and from the most surprising quarter.

Special report by ELAINE POTTER

ON APRIL 24, 1956, Igor Kurchatov, father of the Russian A-bomb, set off early from London for Harwell, Britain's nuclear research headquarters in Berkshire. There was still frost on the ground but the day promised to be sunny and warm. He was tense and asked for quiet in the car, concerned about the outcome of what he was convinced would be a momentous lecture to a group of Britain's top atom scientists.

For 20 years the Soviets under Stalin had been virtually cut off from all contact with other scientists. Now Russia's most eminent nuclear physicist, on a visit to Britain with his new political masters Khruschev and Bulganin, was about to push for re-entry into international science with a bold stroke: he would talk on a subject which was classified as top secret in every country where scientists had begun to look at it: Britain, America and Russia.

The subject was fusion—the attempt to produce, *in a slow and controlled way*, exactly the same kind of energy as is released *explosively* by the hydrogen bomb. By 1953 both America and Russia had exploded H-bombs, but research on the peaceful counterpart—referred to by scientists simply by its initials CTR (contained thermonuclear reactions)—was dragging.

Kurchatov's arrival at Harwell was preceded by a large brown-paper-wrapped package which most unusually passed unchecked through the perimeter security gates. It contained, in English translation, the full text of the talk Kurchatov was to give, and a copy was placed on each of the 250 seats of the large lecture theatre where he was to speak.

Many of the scientists present, including some working on the British H-bomb at nearby Aldermaston, were not even aware of the CTR work being done there. Dr Keith Roberts, then a top Aldermaston physicist, recalls that "the most significant thing seemed to be that the Russians were at Harwell at all."

Those more directly involved in CTR had received advance warning and discussed beforehand what sort of questions they might ask so as not to reveal their own work or even that they had any knowledge of such work.

The atmosphere was tense and exciting, particularly for those who knew that just 50 yards away from the lecture hall, Britain's most ambitious CTR project—a device called Zeta—was under construction.

Kurchatov made an immediate impact. A powerfully built man, with a baritone voice and long flowing beard, he described the Russian work in surprising and impressive detail.

"It was a fine exposition," says Professor Thomas Edward Allibone, a senior British fusion physicist at the time, "and we all felt the Russians had stolen a march on us. We were as much impressed by Kurchatov's description of their failures as by his description of their successes."

Dr Sebastian Pease, also there that day and now in charge of Britain's fusion programme, says that Kurchatov's revelations "made it clear that the Russians knew a great deal." So much, in fact, that British scientists decided they should redesign at least one of their CTR devices.

But the main significance of the talk was not in its scientific content: it lay in the fact that it was clearly intended to end the strict secrecy that had enveloped CTR research throughout the Cold War. The scientific and cost benefits of opening the subject up to an international exchange of information would be enormous, for at that time even America and Britain were keeping their CTR secrets from each other.

The post-Stalin thaw was then under way but East-West relations were still very tense. It was during this very visit by Soviet leaders that Commander "Buster" Crabb, a frogman, vanished mysteriously while apparently surveying Soviet ships in Portsmouth harbour.

Yet here was one of the world's most secretive societies taking the initiative to declassify a subject intimately allied to the development of the most destructive weapon in human history.

(P/10)

E/W (1) -- WILL MAN'S SUN EVER RISE?

FUSION is one of "God's gadgets," because it is nature's way of producing energy in the sun and stars. Their enormous gravitational pressure compresses and fuses together the nuclei of hydrogen's so-called "light" atoms at super-high temperature to produce the energy that lights our universe and keeps our world alive.

On earth, energy from coal, oil, wind or waves all derives originally from heat radiated by the sun. Each of these sources is merely a transient storehouse of the sun's energy.

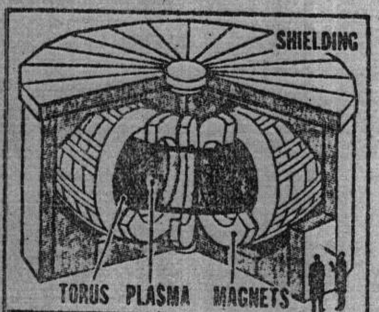
Scientists discovered how to release enormous energy by splitting the atomic nucleus—the process called fission—in the forties and produced the A-bomb. But *fusing* nuclei is far more difficult. For one thing, it demands unimaginably high temperatures: the temperature inside a blast furnace, for instance, can reach 1,700 degrees centigrade but fusion requires 100 million degrees and a method of containing the super-heated hydrogen—or plasma, as it is called.

Before the war most scientists thought it would never be possible to achieve the required temperatures on earth. It was the explosion of the atomic bomb in 1945 that produced for the first time the temperatures required for fusion. By 1953 both American and Soviet scientists had created a fusion bomb, the H-bomb, but the release of thermonuclear energy was, of course, explosive rather than controlled.

When Kurchatov spoke at Harwell, nuclear scientists had already spent a decade trying to design containers—usually called bottles—in which magnetic fields would trap the plasma long enough to produce fusion energy. But the difficulties were proving daunting—far more daunting than the pioneers in the field had ever imagined.

THE PIONEERS were in fact British and they were motivated not by high-minded notions of solving the world's energy problems, but by a combination of military and pure scientific interests. From the military viewpoint, for instance, CTR seemed to offer a copious source of the neutrons essential for weapons research.

In March 1946 George Paget Thomson, professor of physics at Imperial College, London, walked into the office of a junior, Dr Moses Blackman, carrying some scribbled notes that suggested a way CTR might be achieved.



● Thermonuclear fusion, in a bomb or reactor, is caused by fusing two hydrogen atoms to produce a helium nucleus. The new nucleus weighs less than the original atoms with the lost mass appearing—in conformity with Einstein's principle—as energy. But temperatures of hundreds of millions of degrees are needed to create a fusion reaction. In an H-bomb this great heat is provided by the A-bomb trigger. To make fusion energy the problem is to raise and contain the necessary high temperatures. The tokomak (above) is the most promising device. It consists of a vacuum chamber, like an inner tube, the "torus." Into it is introduced a puff of gas which is heated by an enormous electric current, which also produces a magnetic field. The gas is turned into plasma—a mixture of electrified particles—which is affected by magnetic fields. In the tokomak, the magnetic field confines the plasma into a snake in the middle of the tube to prevent the plasma touching the walls where it will be contaminated and cool. So far all the devices consume more energy than they produce through fusion. But optimists predict reaching break-even in the 1980s and commercial viability by the end of the century. If so, the rewards could be staggering. One gallon of water could produce as much energy as 300 gallons of petrol.

Thomson, the Nobel-Prize winning son of a Nobel prize-winner, had advised the American A-bomb builders and was familiar with early US work on hydrogen bombs. He now asked Blackman to do some calculations on how plasma might behave in the device his notes described. Remarkably, the device was a toroidal (doughnut-shaped) magnetic bottle similar in concept to the devices most commonly in use today.

Blackman, now emeritus professor, was initially cool. "It wasn't my sort of problem," he says, "but things were very different in those days. A request from the head of your department was an order. I had no option but to obey."

But Thomson himself was so convinced that solutions to the scientific problem would be found rapidly—with huge commercial benefits to Britain—that within two months he had lodged under his and Blackman's name a secret patent application for a thermonuclear device.

Before the calculations were even completed Thomson set two young PhD students at Imperial College (Stan Cousins and Alan Ware) to test the ideas. Their small under-equipped university laboratory became the first in the world to mount CTR experiments.

Later these efforts were combined with those of another group which had been working quite independently at Oxford's Clarendon laboratory. This group was led by a young Australian student called Peter Thonemann, an obsessive experimentalist, working under Churchill's war-time science adviser, Lord Cherwell.

Thonemann was not motivated by trying to solve the world's energy problems either—nor, in his case, by military considerations. "It was," he now says simply, "the problem itself and how to solve it."

Surprisingly, the work was not classified as secret until 1951. The Thonemann team then moved to Harwell and the Thomson team to the equally secure centre at Aldermaston. From then on personnel were positively vetted, the Official Secrets Act signed, safes secured to the floor and all the windows barred.

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IN RUSSIA, Kurchatov's enthusiasm for CTR was aroused in 1950 by two young scientists then working on the H-bomb—Igor Tamm and the young André Sakharov, whose fate now, ironically, is threatening the whole cooperative programme. Like G. P. Thomson, these two Soviet scientists produced theoretical descriptions for a containment device. And, like the original British design, it was doughnut-shaped and bound by a magnetic field. (The similarity almost certainly owed something to the fact that Klaus Fuchs, the spy who passed the A-bomb secrets to Russia, was head of theory at Harwell in the late forties and had been consulted about CTR by Allibone and Blackman).

Kurchatov's reaction was recorded by his assistant and biographer I. Golovin. Kurchatov, already the most powerful scientist in Russia, was sitting in his study on New Year's Eve 1950 when he turned to Golovin and said: "Sakharov has boosted us to tackle the second atomic problem of the twentieth century which is no less magnificent [than fission] —obtaining boundless energy by burning the waters of the ocean! That's a problem that one can give one's whole life to!"

That night, Kurchatov decided that CTR work should move from theory to the laboratory. According to Golovin, money was found immediately, and within months Lev Artsimovitch — later to emerge as the star of the Soviet and world fusion story—was in charge of a laboratory with more than 100 workers.

It was this group that developed a device called the tokomak (a refinement of the original doughnut-shaped bottle) which today dominates CTR research around the world. Sakharov laid the foundations for the tokomak —and was elected to membership of the Soviet Academy of Sciences for this work—although he personally remained on military projects.

America's CTR work started around the same time as Russia's. It began in a desultory fashion at Los Alamos "as something of a hobby" for A-bomb scientist James Tuck (an ex-Briton), but in 1951 it was jerked into life by a bizarre event.

On March 24 President Peron of Argentina announced to an astonished world that his scientists had actually harnessed the energy of the H-bomb. That "completely original system deals with creating artificial suns on earth," he declared.

In fact the claim turned out to be a hoax by an Austrian-born physicist, Dr Ronald Richte; but it did galvanise American physicists. Within months there were no fewer than three different methods of CTR under research—the so-called "pinch" system at Los Alamos, the "stellarator" at Princeton University, and the "magnetic mirror machine" at the University of California.

BY NOW all three nations' CTR programmes were top secret. The Berlin airlift crisis, the Korean war and an escalating arms race had raised East-West tensions high. How and why, then, did the Russians come to make that historic first step towards co-operation in 1956?

In fact it did not go completely against the grain of events. A thaw in the Cold War began after the death of Stalin in 1953. In the same year America's new president, Dwight Eisenhower, gingerly easing America out of the Red-baiting McCarthy era, called at the UN for a conference on the peaceful use of nuclear science. His call was heeded when, in 1955, the first international conference on Peaceful Uses of Atoms was held in Geneva.

Although no secrets were given away, it did become clear that there was no immediate prospect of a breakthrough to commercial fusion energy, and this—allied with the continuing political thaw—encouraged Kurchatov to make a bid for international cooperation. Since early profits were not at stake his chances were improved.

But what were his personal motives? Anna Livanova, a Soviet scientific journalist writing in the sixties, says Kurchatov "was very concerned about physics having become associated with the bomb. He thought physicists now had a great responsibility to use physics for peaceful purposes."

Even so he would not, of course, have taken his initiative without the approval of his political masters, and Anna Livanova records that Kurchatov "always had a very sharp sense of what the feeling of the time was, which way things were moving."

The way things were moving in the Kremlin at that time was towards opening up a variety of contacts with the West—if only out of self-interest. Khrushchev was deeply worried about Russia's lag in the technology and arms race and was putting out feelers about restrictions on atom bomb developments.

Kurchatov began his push for international scientific cooperation with an address to the historic twentieth congress of the Soviet Communist Party in February 1956, at which Khrushchev made his famous denunciation of Stalin and gave credibility to Russia's expressed desire to end the prevailing Cold War.

"We Soviet scientists," Kurchatov told the congress, "would like to work on this most important scientific problem together with the scientists of all countries of the world, including those of America, whose scientific and technological attainments we value so highly." Immediately after the congress Kurchatov began preparations for his visit to London.

Kurchatov met his British counterpart, Sir John Cockcroft, at the Athenaeum. Cockcroft takes up the story. "I had not met Kurchatov before but was greatly impressed by his intelligence and by his eagerness to talk about collaboration in atomic energy work. We had a very animated discussion at the top of the Athenaeum staircase where he was able to go much further than I could reciprocate, having no idea of the way the discussion would go. He suggested that he should deliver a lecture at Harwell and I agreed to arrange this."

There was nothing so discreet, though, after the event. The Soviets exploited it for its maximum propaganda value. On his return to Moscow, Kurchatov

P10/

boasted: "I am happy my country took upon itself this noble initiative and was the first in the world to remove the cloak of secrecy from these investigations."

The West was considerably embarrassed. Kurchatov's initiative made nonsense of continued secrecy on CTR. After all, the Russians were the very people that classification was supposed to keep information from. But the West realised it really had nothing new to tell the Russians in reply.

And the first effect of the Kurchatov talk was somewhat ironic. It brought about rapid declassification between the Americans and the British over an area much broader than CTR; agreements negotiated between Washington and London at that time concerned all nuclear matters, including military, which could hardly have been what the Kremlin had hoped for.

It took another couple of years for Britain and America to disclose their CTR secrets to the world. It was done via the unveiling of the Harwell device called Zeta (the acronym for "zero energy toroidal assembly") in January 1958.

Would the key fit the lock?

This was done with great ballyhoo—followed by some embarrassment when it turned out that the neutrons produced by Zeta were not the result of thermonuclear activity but of flukey accelerations of atomic particles in the device. Nevertheless, Zeta was a great advance on previous devices and the road to full international declassification was clear.

This happened formally at the second Geneva conference on peaceful atomic science in 1958. It was a historic occasion. In all, 111 papers were presented and both the Americans and Russians produced what Cockcroft described as "a dazzling display of model CTR devices."

Kurchatov arranged for his Moscow Institute, by now named after him, to be declassified and scientists were invited to visit, one of the first being Cockcroft.

In 1959 Britain decided to build a separate CTR research laboratory at Culham, near Oxford, specifically to escape Harwell's security fetters. As a contemporary press report put it: "Scientists will be able to invite foreign colleagues to their laboratories as easily as they would invite them for tea."

From that moment there deveoped an era of co-operation remarkable not only for its scientific content but also for its ability to survive frightening moments of political confrontation between East and West.

The tone was set from the beginning. The year Kurchatov went to Harwell tension was high over the Suez crisis and the Soviet invasion of Hungary, yet the initiative gained momentum.

There were to be many more examples. In May 1961, for instance, George Blake was sentenced to 42 years' jail for spying; but that very month Britain and Russia signed a formal five-year agreement for collaboration on peaceful uses of atomic energy and shortly afterwards America signed a similar agreement with the Russians.

Over the next 18 months came the building of the Berlin Wall and the Cuban missile crisis but neither prevented progress in the scientists' pursuit of CTR. More countries — France, Germany, Italy and later Japan—joined in and new structures were created to oil the wheels of international co-operation. The International Atomic Energy Authority began hosting triennial international fusion conferences and Euratom was created to ease costs and help co-operation between the fledgling fusion programmes in then non-nuclear Europe.

In the late sixties global politics were dominated by the Vietnam war, the Six Day War in the Middle East and the Soviet invasion of Czechoslovakia but CTR co-operation marched on.

In September 1971 Anglo-Soviet relations reached one of their lowest points when the prime minister, Sir Alec Douglas-Home, expelled no fewer than 90 Russian embassy staff from London for spying and Russia retaliated by expelling 18 of Britain's Moscow delegation. Yet at that very time British fusion physicists were being welcomed to Moscow.

The zeal of CTR scientists was clearly strong enough to override the most dangerous political crises. Yet there were problems in the laboratories—scientific ones—and many hopes were dashed.

When research began none of the pioneers imagined the problems would remain unsolved at the end of their lifetimes—witness, for example, G. P. Thomson's filing of a patent back in 1947.

Throughout the fifties, according to Theo J. Thompson, commissioner of the US Atomic Energy Commission, "fusion seemed to be only a matter of fitting a handful of keys, any one of which would work, to a lock. . . . But somehow the keys were rusty, or didn't fit. Somehow the right key got lost in a welter of abandoned approaches and discarded ideas."

The deepest gloom came in the mid-sixties, when as a result of a theory developed by David Bohm—which essentially said that heat losses from any magnetic bottle would always be too great—many physicists began to believe that fusion power was impossible. "Ban the Bohm" became the battlecry of CTR defenders, said Theo Thompson.

In Britain a secret government report to Tony Benn, then energy minister, recommended a 50 per cent cutback in the funding of Culham over five years, starting in 1967. Rumours were rife that a total shutdown was looming.

Foreign Office was horrified

But no sooner had the rundown of Culham begun when probably the most important breakthrough of modern fusion physics occurred.

At a conference in Novosibirsk in 1968 the Russians' top CTR scientist, Lev Artsimovitch, announced that the Soviet tokomak had achieved temperatures of some six million degrees C. This was more than *100 times* higher than the temperatures typically being achieved in the stellarators which were then the prevailing western CTR devices. The figures sounded so amazing that some American scientists, who had always been somewhat patronising about the Soviet research, simply did not believe them.

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E/W (4) — WILL MAN'S SUN EVER RISE?

To convince Western scientists, Artsimovitch made a bold move: although East-West tension was again high, this time over the Soviet invasion of Czechoslovakia, he invited a group of British scientists to his dacha outside Moscow to discuss, not just an exchange of information, but for the first time a joint experiment.

What the British had to offer was a new laser technique for precise measurement of the very high temperatures the Russians were claiming. The group included John Adams, the retiring head of Culham, Sebastian Pease, appointed to succeed Adams, and Nick Peacock, one of the best diagnosticians in plasma physics.

As Pease and Artsimovitch worked out how such a joint experiment could be set up, Pease says he felt sure that somewhere up the line obstacles would prevent it. "But everybody I took it to said 'yes' in disbelief, because they thought somebody further up the line would say 'no'." It was not until five tons of equipment and three British scientists landed in Moscow in March 1969 that anyone knew for certain that the joint exercise would actually take place.

Peacock, who headed the British group, says: "There were some, particularly in the Foreign Office, privately horrified about us going. The Foreign Office wouldn't even let us shop in their shop while we were there."

The scientists lived among their Russian colleagues and were even paid in roubles by the Russians. They were based at the Kurchatov Institute and attended all the seminars and colloquia on plasma physics and, as far as they could judge, were included in all relevant discussions.

Peacock and his group were at the Kurchatov nine months. Towards the end of their stay in September 1969, Peacock made public the preliminary results of their joint experiment: Artsimovitch's optimism about the Soviet tokomak was amply justified, he said—the temperature was even higher than the Russians had originally claimed.

"The Americans flipped," says Peacock. "They just dropped the stellarators and immediately converted them into tokomaks."

Artsimovitch tried in vain to persuade them to keep their stellarator programme going as he thought it might still prove the best solution in the end (a judgment which results now being obtained from stellarators, particularly in West Germany, are

But after the Peacock report everyone—Russia, America, Europe and Japan—reorganised their programmes towards bigger and bigger tokomaks.

Fusion is like Everest: there

During the seventies higher and higher temperatures were achieved and were sustained for longer and longer periods. The scientists' enthusiasm increased and so did the international co-operation with a new agreement between Nixon and Brezhnev in 1973.

The next major step came in January 1978 when the International Atomic Energy Authority put out feelers to see whether the time had arrived for a joint international fusion project to begin. The aim was to establish the world's first energy-producing reactor. (All the experiments so far are consuming far more energy than they are creating although break-even point is coming closer all the time.)

The response was good. In 1979 an INTOR workshop (the initials stand for International Tokomak Reactor) funded jointly by Russia, America, Europe and Japan was set up. Some 100 scientists, engineers and technicians from all these countries were allocated specific tasks to pursue in their own institute and four joint sessions were held in Vienna.

Last year INTOR produced its first, 650-page report. It recommended that work should proceed toward building an international reactor.

The sticky question of where it would be constructed was left open, awaiting the results of the giant experimental tokomaks currently being built in America, Russia, Japan and Europe (at Culham). But the preliminary estimate was that an INTOR reactor could be under construction at the guesstimated cost of £2 billion by the early nineties.

Whether this proves to be as unrealistically optimistic as so many other predictions in the CTR saga depends on governments providing sufficient funding —and whether the remarkable era of international cooperation will continue.

No one involved in CTR now seriously doubts that fusion will provide energy. Although immensely complex engineering and technology problems remain, the physics problems are essentially resolved.

Some physicists, such as Peter Thonemann, think that the economics of producing fusion energy might prove hard to support, but even he says: "Fusion is like Everest. It's there. The mountain had to be climbed. We will have fusion power."

But achieving it, even by the turn of the century, will certainly demand more money than governments currently seem willing to spend. Far more has been spent on refining the destructive characteristics of the atom than in taming it for the permanent and peaceful solution of man's energy problems. (Two examples: Britain plans to spend some £6 billion on the Trident missile project but its *total* spending on fusion at Culham so far is only around £120 million. And, although America last year decided to boost spending on fusion to about $1 billion a year, this is only a third as much as next year's nuclear weapons budget.)

And it will certainly demand a climate in which international scientific co-operation can continue.

Some observers believe that there is more behind the protests of Western scientists than their expressed distaste for the Soviet treatment of eminent colleagues like Sakharov and revulsion at the Soviet invasion of Afghanistan. The threatened break may also illustrate the belief held by many scientists that, the closer fusion gets to commercial feasibility, the less likely is the international pooling of information to continue.

But whatever the reasons, a unique and hopeful era is looking shaky. If it ends it will be a tragedy at several levels. An important point of contact between East and West will be lost; the achievement of fusion power will be delayed; and, in all likelihood, the smaller countries will have to drop out.

The danger is that a multinational effort that promised to help the whole world will degenerate into just another manifestation of rivalry between the two superpowers.