

BOMB APOLOGETICS: FARM HALL, AUGUST 1945

A little over a month after the ten German physicists had settled into Farm Hall, the British manor where they would be held and observed for six months (see the preceding article on page 27), they were astounded by the news of the atomic bombing of Hiroshima. Believing themselves far ahead of the Allies in nuclear research, the German scientists were suddenly shaken by the realization that they were in fact far behind. How had the Allies done it? Why had the Germans made so little progress in comparison? How could they explain this to themselves, to their countrymen, to their former enemies?

The British agents at Farm Hall transcribed and translated into English only those recorded conversations that proved of special intelligence value. Those conversations were then summarized and excerpted from the English in weekly or biweekly reports signed and compiled by the British officer in charge, Major T. H. Rittner. Copy number 1 went directly to the head of the Manhattan Project in Washington, DC, Major General Leslie R. Groves.

Groves apparently regarded the detention of the German scientists as a means of keeping them out of Soviet and French hands. An important additional factor in the decisions to detain Otto Hahn and Max von Laue, however, was a desire that those senior men should have an influence on the reconstruction of the scientific establishment in postwar Germany. Neither had played an important role in weapons-related fission research. Hahn's discovery of fission had set the enterprise in motion, of course, and he had continued to study the properties of fissionable isotopes; von Laue had performed absolutely no fission-related research.

Besides Hahn and von Laue, the ten internees included Erich Bagge, who had worked on isotope separation; Kurt Diebner, a leader of nuclear research in the German Army Weapons Bureau; Walther Gerlach, a distinguished physicist and chief administrator of nuclear

On hearing the news from Hiroshima, the incredulous internees came up with a self-serving story to explain their failures in nuclear research: To keep Hitler from winning, they had deliberately not developed the atomic bomb.

Jeremy Bernstein and David Cassidy

research in 1944–45; Paul Harteck, a professor at the University of Hamburg and very effective member of the German nuclear program, who had worked mainly on heavy water and reactor design; Werner Heisenberg, the most prestigious member of the nuclear program and its most influential scientist; Horst Korsching, who had worked on isotope separation under Diebner and Heisenberg; Carl Frie-

drich, Freiherr von Weizsäcker, an outstanding young physicist and protégé of Heisenberg, whose father had been the number-two man in Hitler's Foreign Ministry; and Karl Wirtz, an expert on heavy water and isotope separation.

The following excerpts, adapted from the forthcoming AIP Press edition of the Farm Hall reports, represent only a fraction of the rich history contained therein.

Afternoon of 6 August 1945

Shortly before dinner on 6 August, Rittner reported, he informed Hahn that the BBC had announced that an atomic bomb had been dropped. Hahn, Rittner wrote, "was completely shattered by the news and said he felt personally responsible for the deaths of hundreds of thousands of people, as it was his original discovery which had made the bomb possible. . . . With the help of considerable alcoholic stimulant he was calmed down and went down to dinner where he announced the news to the assembled guests."

HAHN: They can only have done that if they have uranium isotope separation. . . .

VON LAUE: [Uranium-235]

HAHN: Yes, 235.

HARTECK: That's not absolutely necessary. If they let a uranium engine [reactor] run, they separate "93". . .

HEISENBERG: Did they use the word "uranium" in connection with this atomic bomb?

ALL: No.

HEISENBERG: Then it's got nothing to do with atoms, but the equivalent of 20 000 tons of high explosive is terrific.

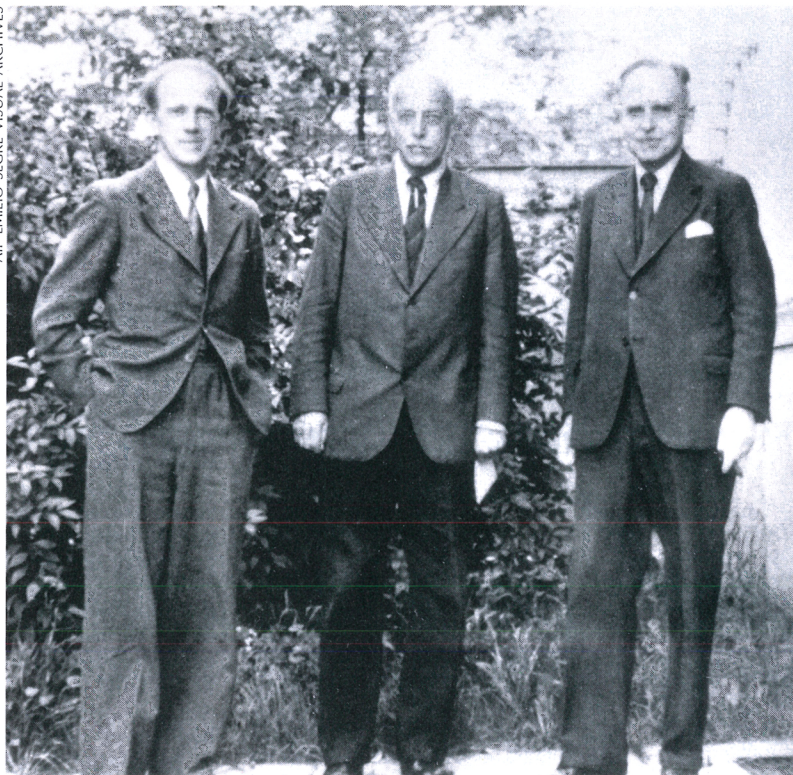
VON WEIZSÄCKER: It corresponds exactly to the factor 10^4 . [Probably what von Weizsäcker has in mind here is that 1 kilogram of uranium completely fissioned would correspond in energy to about 10^4 tons of exploding TNT.]

GERLACH: Would it be possible that they have got an engine running fairly well, that they have had it long enough to separate "93"?

HAHN: I don't believe it.

JEREMY BERNSTEIN was until recently a professor of physics at Stevens Institute of Technology in Hoboken, New Jersey, and a staff writer for The New Yorker. His latest book is An Introduction to Cosmology (Prentice Hall, 1995).

DAVID CASSIDY, an associate professor at Hofstra University, in Hempstead, New York is the author of Uncertainty: The Life and Science of Werner Heisenberg (Freeman, 1992).



WERNER HEISENBERG (1901–76), MAX VON LAUE (1879–1960) AND OTTO HAHN (1879–1968). All three were interned at Farm Hall, though neither Laue nor Hahn had an important role in weapons-related fission research.

HEISENBERG: All I can suggest is that some dilettante in America who knows very little about it has bluffed them by saying, "If you drop this it has the equivalent of 20 000 tons of high explosive," and in reality doesn't work at all.

HAHN: At any rate, Heisenberg, you're just second-raters and you might as well pack up.

HEISENBERG: I quite agree.

HAHN: They are 50 years further advanced than we. . . .

VON WEIZSÄCKER: I think it's dreadful of the Americans to have done it. I think it is madness on their part.

HEISENBERG: One can't say that. One could equally well say, "That's the quickest way of ending the war."

HAHN: That's what consoles me.

HEISENBERG: I still don't believe a word about the bomb, but I may be wrong. I consider it perfectly possible that they have about 10 tons of enriched uranium, but not that they can have 10 tons of pure U-235.

HAHN: I thought that one needed only very little 235.

HEISENBERG: If they only enrich it slightly, they can build an engine that will go, but with that they can't make an explosive that will—

HAHN: But if they have, let us say, 30 kilograms of pure 235, couldn't they make a bomb with it?

HEISENBERG: But it still wouldn't go off, as the mean free path is still too big.

HAHN: But tell me why you used to tell me that one needed 50 kilograms of 235 to do anything. Now you say one needs 2 tons.

HEISENBERG: I wouldn't like to commit myself for the moment, but it certainly is a fact that the mean free paths are pretty big. . . . If it has been done with uranium-235 then we should be able to work it out properly. It just depends upon whether it is done with 50, 500 or 5000 kilograms, and we don't know the order of magnitude. We can assume that they have some method of

separating isotopes of which we have no idea.

WIRTZ: I would bet that it is a separation by diffusion with recycling.

HEISENBERG: Yes, but it is certain that no apparatus of that sort has ever separated isotopes before. Korsching might have been able to separate a few more isotopes with his apparatus.

WIRTZ: We only had one man working on it, and they may have had ten thousand.

VON WEIZSÄCKER: Do you think it is impossible that they were able to get element "93" or "94" out of one or more running engines?

WIRTZ: I don't think that is very likely.

VON WEIZSÄCKER: I think the separation of isotopes is more likely, because of the interest that they showed in it to us and the little interest they showed in the other things. [Von Weizsäcker's observation must refer to a line of questioning after his capture by the Alsos mission.]

HAHN: Well, I think we'll bet on Heisenberg's suggestion that it is a bluff. . . .

[Heisenberg's conflicting statements to Hahn about critical mass suggest some fundamental confusion about atomic bomb physics. On the other hand, Harteck's opening observations are on the right track. The absorption of a neutron in a reactor by U-238 yields neptunium, element 93, in beta decay. Neptunium is unstable, decaying with a halflife of 2.36 days into element 94, which is fissionable.]

This was all known to the Germans. In 1940 von Weizsäcker suggested to the German Weapons Bureau that "93" could be used as a fissionable weapons fuel. A year later Hahn showed that this element was unstable and unsuitable for weapons. In the meantime, in August 1941 Fritz Houtermans suggested using the long-lived element "94", which the Americans called plutonium. The idea of using reactor-bred plutonium made its way into the German project, as indicated for instance by Heisenberg's lecture



WALTER GERLACH (1889–1979) was chief administrator of German nuclear research in 1944 and 1945.

before the Nazi dignitaries on 26 February 1942 (see the preceding article).]

Evening of 6 August

Rittner reported that at 9 pm all the guests assembled to hear the official BBC announcement of the Hiroshima bombing and the Manhattan Project. "They were completely stunned when they realised that the news was genuine."

HAHN: Of course we were unable to work on that scale.

HEISENBERG: One can say that the first time large funds were made available in Germany was in the spring of 1942 after that meeting with [Education Minister Bernard] Rust, when we convinced him that we had absolutely definite proof that it could be done [see the preceding article]. . . .

HEISENBERG: On the other hand, the whole heavy-water business, which I did everything I could to further, cannot produce an explosive.

HARTECK: Not until the engine is running [to produce plutonium].

HAHN: They seem to have made an explosive before making the engine, and now they say, "In future we will build engines."

HARTECK: If it is a fact that an explosive can be produced either by means of the mass spectrograph [again Harteck is on the right track, as this is precisely how the Manhattan Project produced its first highly enriched uranium]—we would never have done it, as we could never have employed 56 000 workmen. . . .

VON WEIZSÄCKER: How many people were working on [the] V-1 and V-2 [rockets]?

DIEBNER: Thousands worked on that.

HEISENBERG: We wouldn't have had the moral courage to recommend to the government in the spring of 1942 that they should employ 120 000 men just for building the thing up.

VON WEIZSÄCKER: I believe the reason we didn't do it was because all the physicists didn't want to do it, on principle. If we had all wanted Germany to win the war we would have succeeded.

HAHN: I don't believe that, but I am thankful we didn't succeed. . . .

[The claim by von Weizsäcker that the German physicists did not want to build the bomb may be seen as the beginning of what von Laue later called the German scientists' *Lesart*, or "version," of why the German project did not succeed: We could have done it, we knew how to do it, but we didn't do it on principle. If von Weizsäcker really believed this, then why did he voluntarily turn over his idea for using neptunium (93) to the German Weapons Bureau? The ineluctable fact, borne out by the documen-

tation, is that, at least in the beginning, von Weizsäcker and the others did want the project to succeed.]

HEISENBERG:

The point is that the whole structure of the relationship between the scientist and the state in Germany was such that although we were not 100% anxious to do it, on the other hand we were so little trusted by the state that even if we had wanted to do it, it would not have been easy to get it through. [While it is true that early in the war the scientists were not very

trusted, by 1942 they were, contrary to what Heisenberg claims. How else could Heisenberg and others have gotten permission to travel to occupied territories and even to neutral Switzerland?]

DIEBNER: Because the official people were only interested in immediate results. They didn't want to work on a long-term policy as America did.

VON WEIZSÄCKER: Even if we had gotten everything that we wanted, it is by no means certain whether we would have gotten as far as the Americans and English have now. There is no question that we were very nearly as far as they were, but it is a fact that we were all convinced that the thing could not be completed during the war.

HEISENBERG: Well, that's not quite right. I would say that I was absolutely convinced of the possibility of our making an uranium engine, but I never thought we would make a bomb, and at the bottom of my heart I was really glad that it was to be an engine and not a bomb. I must admit that. . . .

Late evening, 6 August

Later that evening, Rittner reported, Hahn and Heisenberg discussed the bomb one on one. "Hahn explained to Heisenberg that he was himself very upset about the whole thing. . . . Heisenberg stated that the people in Germany might say they should have forced the authorities to put the necessary means at their disposal and to release 100 000 men in order to make the bomb, and he feels himself that had they been in the same moral position as the Americans and had said to themselves that nothing mattered except that Hitler should win the war, they might have succeeded, whereas in fact they did not want him to win. . . . They then went on to discuss the feelings



CARL FRIEDRICH, FREIHERR VON WEIZSÄCKER (1912-) at Niels Bohr's Copenhagen institute in 1936. Einstein, in his famous 1939 letter to Roosevelt, warned that Weizsäcker was the son of the German Undersecretary of State.

of the British and American scientists who had perfected the bomb and Heisenberg said he felt it was a different matter in their case as they considered Hitler a criminal. . . ."

In the following conversation between Hahn and Heisenberg one is struck, on the one hand, by Heisenberg's admission that he had never calculated the critical mass of U-235 needed to make a bomb and, on the other hand, by his clear understanding of the difference between a reactor and a bomb.

This tête-à-tête, recorded unbeknownst to the two, succinctly captures what Heisen-

berg did and did not understand about bomb physics at the time of Hiroshima. We find absurd the idea that, as some have recently tried to argue, Heisenberg really had a deeper understanding but, even at that time in history, chose not to reveal it to Hahn or to anyone else.

HAHN: They can't make a bomb like that once a week.

HEISENBERG: No. I rather think Harteck was right and that they have just put up a hundred thousand mass spectrographs or something like that. If each spectrograph can make one milligram a day, they have got a hundred grams a day [of separated U-235].

HAHN: In 1939 they had made only a fraction of a milligram. They had identified the "235" through its radioactivity.

HEISENBERG: That would give them 30 kg a year.

HAHN: Do you think they would need as much as that?

HEISENBERG: I think so certainly, but quite honestly I have never worked it out, as I never believed one could get pure "235." I always knew it could be done with "235" with fast neutrons. That's why only "235" can be used as an explosive. One can never make an explosive with slow neutrons, not even with the heavy-water machine, because then the neutrons only go with thermal speed, with the result that the reaction is so slow that the thing explodes sooner, before the reaction is complete. It vaporizes at 5000 °C and then the reaction is already—

HAHN: How does the bomb explode?

HEISENBERG: In the case of the bomb it can only be done with the very fast neutrons. The fast neutrons in 235 immediately produce other neutrons, so that the very fast neutrons, which have a speed of, say, 1/30th that of light, make the whole reaction. Then of course the reac-

tion takes place much quicker, so that in practice one can release these great energies. In ordinary uranium a fast neutron nearly always hits 238 and then gives no fission.

HAHN: I see, whereas the fast ones in the 235 do the same as the 238, but 130 times more. [What Hahn had in mind here is that the cross section for fission produced by fast neutrons in U-238 is about a hundred times smaller than that for U-235.]

HEISENBERG: Yes. If I get below 600 000 [electron] volts I can't do any more fission on the 238, but I can always split the 235 no matter what happens. If I have pure 235, each neutron will immediately beget two children and then there must be a chain reaction, which goes very quickly. Then you can reckon as follows: One neutron always makes two others in pure 235.

That is to say, to make 10^{24} neutrons I need 80 reactions one after the other. Therefore I need 80 collisions, and the mean free path is about 6 centimeters. To make 80 collisions, I must have a lump of a radius of about 54 centimeters, and that would be about a ton.

[Heisenberg's first sentence is correct and is in accord with the observation that it takes a neutron with a kinetic energy of at least about one million electron volts to initiate fission in U-238, while neutrons of any energy can fission U-235. His next sentence is also correct and is based on the energetics of the situation. It is something any physicist who had read even the paper by Otto Frisch and Lise Meitner announcing fission could calculate. But then Heisenberg's calculation becomes unstuck. The picture he gives of how the bomb works is that a neutron fissions a U-235 nucleus, producing two neutrons that in turn fission two more 235s, producing four neutrons and so forth. It takes about 80 generations to fission the roughly 10^{24} (about 2^{80}) nuclei in a kilogram of 235—the amount needed to produce a yield of 10 000 tons of TNT. Heisenberg then notes that a neutron moves on the average about 6 centimeters between fission-producing collisions. (The actual number is closer to 17.) Since the spread of fission is analogous to a random walk, the size of the lump would be the square root of the number of random steps times the mean free path, $6\sqrt{80} \approx 54$ centimeters. Using the density of uranium, this yields a mass of 13 tons, not the 1 ton Heisenberg cites. Such a value for the critical mass alone would have been three tons heavier than the total payload capacity of any World War II bomber!]

But Heisenberg's whole calculation, even if he had done the arithmetic correctly, is irrelevant to how a bomb



PAUL HARTECK (1902–85) in England, 1934. He is considered to have been a particularly effective member of the German uranium project.

really works. Not only does he neglect the expansion and vaporization of the uranium, but he does not seem to know even how to define the critical mass. Once the fission reaction is initiated, then in any volume the reaction proceeds at a rate determined by the time it takes between fission-producing collisions. In U-235 this rate is about 10^{-8} seconds per fission. These fissions produce neutrons, some of which will produce more fissions, others of which will escape from the volume and be lost. A reasonable estimate of the critical radius is very roughly the mean free path. Using Heisenberg's 6 centimeters for the mean free path yields a bomb size of about 6 centimeters, which gives a critical mass of just 1 kilogram—much too small a figure. To do better, one must do a real calculation. Over the next week Heisenberg did take the time to think the problem over, and he presented the outlines of such a calculation to his colleagues on 14 August. But there is no convincing evidence, as far as we can see, that he had ever done this calculation earlier during the war, nor that he really understood bomb physics in depth and detail at Farm Hall or before.]

7 August 1945

On the morning of 7 August, Rittner reported, the guests read the newspapers eagerly. In a conversation with von Laue, von Weizsäcker said it would not be long before the names of the German scientists appeared in the newspapers and that it would be a long time before they would be able to clear themselves in the eyes of their own countrymen. Then he said:

VON WEIZSÄCKER: History will record that the Americans and the English made a bomb, and that at the same time the Germans, under the Hitler regime, pro-

duced a workable engine. In other words, the peaceful development of the uranium engine was made in Germany under the Hitler regime, whereas the Americans and the English developed this ghastly weapon of war.

[Thus the implications of the *Lesart* that the German scientists deliberately refused to work on a bomb are revealed in full form! This assertion has been repeated several times since 1945, most notably in 1956 in Robert Jungk's book *Brighter Than a Thousand Suns* (Harcourt, Brace, English translation, 1958) and most recently in Thomas Powers's work *Heisenberg's War* (Knopf, 1993); it has been refuted just as many times.]

Epilogue

Writing of Farm Hall in a letter to the German publisher Paul Rosbaud on 4 April 1959, von Laue recalled the origins of the *Lesart* in the days following Hiroshima:

After that day, we talked much about the conditions for an atomic explosion. Heisenberg gave a lecture on the subject in one of the colloquia that we prisoners had arranged for ourselves. Later, during the table conversation, the version [*Lesart*] was developed that the German atomic physicists really had not wanted the atomic bomb, either because it was impossible to achieve it during the expected duration of the war or because they simply did not want to have it at all. The leader in these discussions was Weizsäcker. I did not hear the mention of any ethical point of view. Heisenberg was mostly silent.

As the very brief excerpts presented in this article indicate, the German scientists were not content to admit they had misestimated what would be involved in making an atomic bomb. They introduced a subtle escalation: Not only did they work solely on the "peaceful" reactor but they did not "want to have it at all"; they had actually prevented the atomic bomb from falling into Hitler's hands. The implication was that the Allied scientists would have to bear the full responsibility for building "this ghastly weapon of war." This argument assumes, of course, that the Germans knew how to make an atomic bomb. What the Farm Hall reports also make abundantly clear, however, is that while they knew a few general principles—the use of fast fission with separated U-235 and the possibility of plutonium—they had not yet seriously investigated any of the details. All of the really hard problems were left untackled and unsolved. Rather than retreating from the bomb on moral principles, they had in fact convinced themselves that making a bomb in wartime Germany was simply unfeasible, partly because of sound economic considerations but partly also because they overestimated certain technical difficulties. In the end the Farm Hall reports speak for themselves. ■