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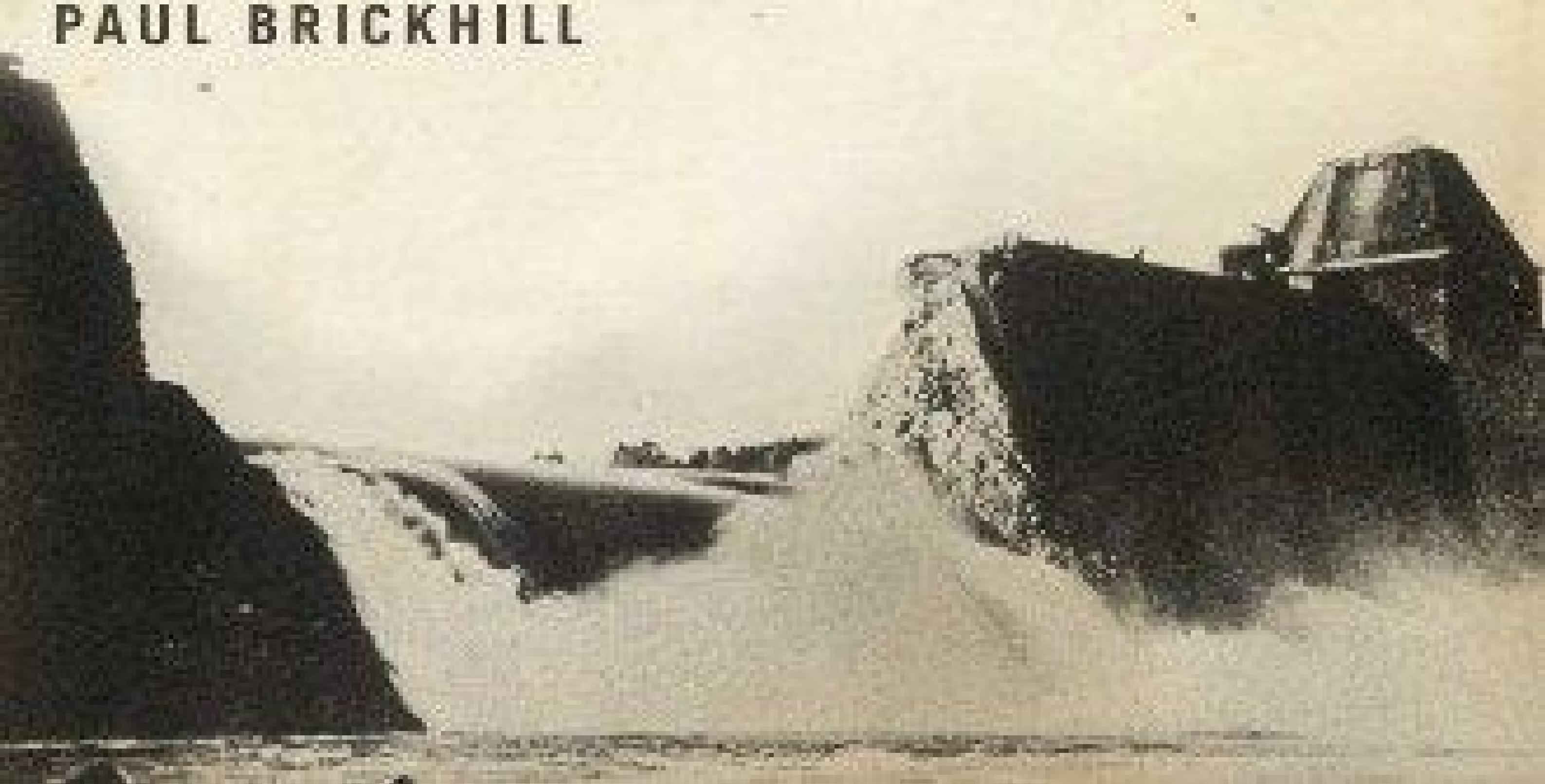
THE DAM BUSTERS

PAUL BRICKHILL



THE DAM BUSTERS

PAUL BRICKHILL

**To the men living and dead
who did these things**

LIST OF ILLUSTRATIONS

THE WAR-TIME LEADERS OF 617 SQUADRON

Wing Commander Guy Gibson, V.C., D.S.O. and Bar, D.F.C. and Bar

Group Captain Leonard Cheshire, V.C., D.S.O. and 2 Bars, D.F.C.

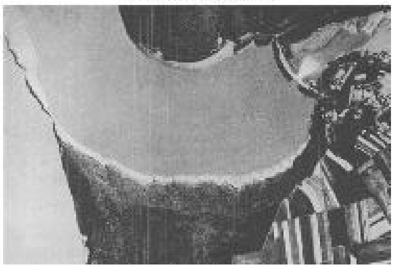
Wing Commander H. B. (Micky) Martin, D.S.O. and Bar, D.F.C. and 2 Bars, A.F.C.

Wing Commander J. B. Tait, D.S.O. and 3 Bars; D.F.C. and Bar

Air Commodore J. E. Fauquier, D.S.O. and 2 Bars, D.F.C.

Above: Gibson and his crew climbing into G for George just before they took off on the Dams raid. L. to R.: Trevor-Roper, Pulford, Deering, Spafford, Hutchison, Gibson and Taerum.

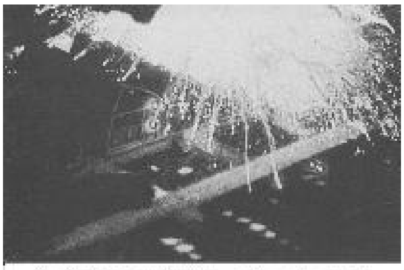
Below: The Eder Dam breached, photographed by our reconnaissance plane the morning after the attack.



Above: Gibson's crew tell their story at de-briefing after the dams raid. Standing at back: Sir Arthur Harris and Air Vice-Marshal Cochrane. Seated, L. to R.: Intelligence Officer, Spafford, Taerum and Trevor-Roper.

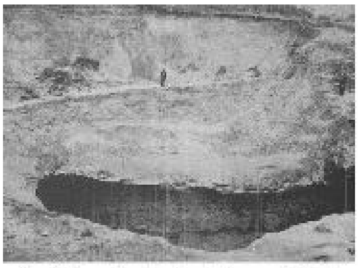
Right: The Moehne Dam breached, photographed by our reconnaissance plane the morning after the attack.

The moment at which H.M. King George VI selected the Squadron's badge. L. to R.: Air Vice-Marshal Cochrane, Gibson, H.M. King George VI and Charles Whitworth. In the foreground is a model of the Moehne Dam.



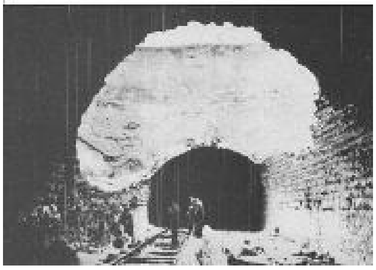
Above: One of the most remarkable photographs of the war—the moment at which Cheshire dropped his incendiary markers on the factory at Limoges. The incendiaries are showering over the factory roofs and, top-left centre, is the [illegible] of Cheshire's Mosquito.

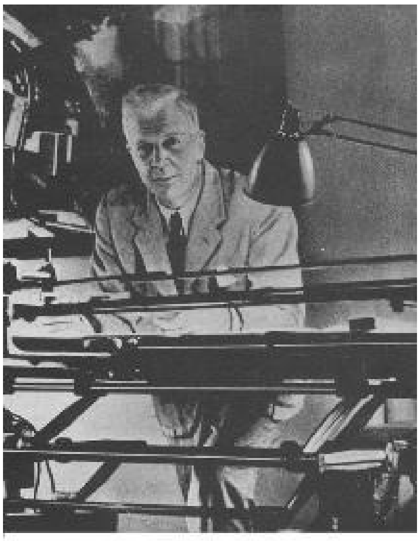
Below: The remarkable bombing of the Michelin factory at Clermont-Ferrand, when they were told to hit the two factory workshops and leave the canteen. Centre: the two factory buildings destroyed, and lower right, the large canteen, undamaged.



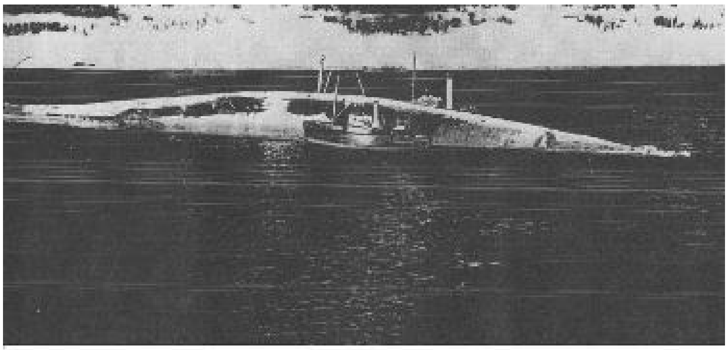
Above: The extraordinary direct hit on the Saumur tunnel obtained on the first "earthquake bomb" raid, showing how the bomb blew out the mountain over the tunnel. The tiny figures give an idea of the size of the crater.

Below: Shot from inside the Saumur tunnel after the Germans had cleared up the mess in time for the invading armies to take over.





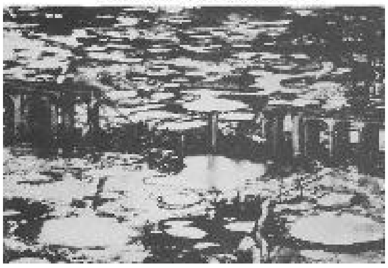
Barnes Wallis still working, after the war, on the drawing board where his ideas took shape.



The *Tirpitz* lying capsized in Tromso Fjord. Alongside her are salvage vessels.

Above: A ten-ton "Grand Slam" being taken from the bomb dump.

Below: The Bielefeld Viaduct, showing the [illegible] craters made by months of futile bombing and, in the shadow of the viaduct, the huge crater made by the first "Grand Slam", which brought it down.



CHAPTER I A WEAPON IS CONCEIVED

THE day before the war started Barnes Wallis drove for five hours back to Vickers' works at Weybridge, leaving his wife and family in the quiet Dorset bay where they had pitched tents for a holiday. He had that morning reluctantly decided that war was not only inevitable but imminent, and he was going to be needed at his drawing-board.

Wallis did not look like a man who was going to have much influence on the war. At 53 his face was unlined and composed, the skin smooth and pink and the eyes behind the hornrimmed glasses mild and grey; crisp white hair like a woolly cap enhanced the effect of benevolence. Many people who stood in his way in the next three years were deceived by this.

He spent the last night of peace alone in his house near Effingham, and in the morning, like most people, listened to the oddly inspiring speech of Chamberlain's. Afterwards he sat in silence and misery.

One thought had been haunting him since the previous morning's decision: what could he, as an aircraft designer and engineer, do to shorten the war? The thought stayed with him for a long time and through remarkable events before it was honourably discharged.

He had been designing for Vickers since before the first world war. In the twenties he designed the R.ioo, the most successful British dirigible. In the thirties he invented the geodetic form of aircraft construction and, using this, designed the Wellesley which captured the world's non-stop distance record, and the Wellington, which was the mainstay of Bomber Command for the first three years of the war.

Vickers' works, nestled in the baked perimeter of the old Brooklands motor-racing track, was turning out Wellingtons as fast as it could, and Wallis was designing its proposed successor, the Warwick. At this time he was on the design of the Warwick's tailplane, which was being troublesome. Clearly any additional work would have to be done in his own spare time and there was, also quite clearly, not going to be much spare time.

Bombers and bombs were the directions in which he was most qualified to help. Bombs, particularly, seemed a fruitful field. He knew something about R.A.F. bombs, their size, shape, weight and so on; the knowledge had been essential when he was designing the Wellington, so that it could carry the required bombs over the required distance. It was not knowledge which, in Wallis, inspired complacency. The heaviest bomb was only 500 Ib., and aiming was so unpredictable that the Air Force was forced to indulge in stick bombing—you dropped them one after another in the pious hope that one would hit the target. One hoped then that it would go off. Too many didn't.

R.A.F. bombs, too, were old, very old. Nearly all were stocks hoarded from 1919. There had been an attempt in 1921 to design a better bomb, and in 1938 they actually started to produce them, but in 1940 there were still very few of them. Both new bombs and old were filled with a mediocre explosive called amatol (and only 25 per cent of the weight consisted of explosive). There *was* a far better explosive called RDX, but production of that had been stopped in 1937. (It was not till 1942 that the R.A.F. was able to use RDX-filled bombs.) Meantime Luftwaffe bombs contained a much more powerful explosive than amatol—and half the weight of the German bomb was explosive.

Wallis knew there had been an attempt in 1926 to make 1,000-lb. bombs for the R.A.F. but they never even got to the testing stage. The Treasury was against them; the Air Staff thought they would never need a bomb larger than 500 Ib., and anyway Air Force planes were designed to carry 500-pounders. Not till 1939 (did the Air Staff begin to think seriously again of the 1,000-pounder, and six months *after* the war started they placed an order for some.

These shortcomings were not so obvious then, particularly as all air forces favoured small bombs designed to attack surface targets. The blast of bigger bombs was curiously local against buildings, and a lot of little bombs seemed better than an equal weight of larger ones. Even larger bombs needed a direct hit to cause much damage and there was more chance of a direct hit with a lot of little bombs.

To Wallis's methodically logical mind there was a serious flaw to all this. Factories and transport could be dispersed; in fact *were* dispersed all over Germany. Bombing (vintage 1939) would not damage enough factories to make much difference.

He started wondering *where* and *how* bombing could hurt Germany most. If one could not hit the dispersed war effort perhaps there were key points. Perhaps the sources of the effort. And here the probing mind was fastening on a new principle.

The sources of Germany's effort, in war or peace, lay in power. Not political power, but physical power! Great sources of energy too massive to move or hide — coal mines, oil dumps and wells, and "white coal" — hydro-electric power from dams. Without them there could be no production and no transport. No weapons. No war.

But they were too massive to dent by existing bombs. One might as well kick them with a dancing pump! The next step— in theory anyway — was easy. Bigger bombs. Much bigger!

But that meant bigger aircraft; much bigger than existing ones. All right then — bigger aircraft too.

That was the start of it. It sounds simple but it was against the tenets of the experts of every air force in the world.

Wallis started calculating and found the blast of bigger bombs *was* puny against steadfast targets like coal mines, buried oil and dams. Particularly dams, ramparts of ferroconcrete anchored in the earth.

Then perhaps a new *type* of bomb. But there Wallis did not know enough about bombs and the logic stopped short.

The war was a few weeks old when the dogged scientist dived into engineering and scientific libraries and at lunch-times, when he pushed the problem of the Warwick's tail-plane aside for an hour or so, he sent out for sandwiches, stayed at his desk and started to learn about bombs. At night at home he did the same, absorbed and lost to his family for hours. As the hard winter of 1939 arrived he progressed to the study of the sources of power.

Coal mines! Impossible to collapse the galleries and tunnels hundreds of feet underground. Possible, he decided, that a heavy bomb might collapse the winding shaft so that the lift would not work. No lift. No work. No coal. But that could soon be repaired.

Oil! Rumanian oil fields were too far for existing bombers, but a possibility for a future bomber. Germany's synthetic refineries were massive and well defended; perhaps a target for bigger bombers.

Dams! Three German dams stood out—the Moehne, the Eder and the Sorpe. All in the Ruhr, they accounted for nearly all the water supply to that monstrous arsenal. Wallis knew that the German method needed eight tons of water to produce a ton of steel. The possibilities were intriguing.

The Moehne dammed Moehne Lake where the Heve flowed into the Ruhr River, maintaining the level so that barges with coal and steel and tanks could go to and from the foundries. Moehne Lake held 134 million tons of water. The Eder dammed the Eder River in Eder Lake, 212 million tons of water. It controlled the level of Germany's second most important waterway, the Mittelland Canal. Even Kassel, forty miles away, got its water from the Eder. The Sorpe dammed another tributary of the Ruhr River in Sorpe Lake.

The Moehne was 112 feet thick at the base, 130 feet high and 25 feet thick at the top where a roadway ran; the Eder was even bigger. Wallis acknowledged that they were formidable. A 500-lb. bomb would hardly scratch the concrete. No less formidable the Sorpe, an earth dam, two sloping mounds of earth sealed and buttressed in the centre by a core of concrete.

In an engineering library Wallis unearthed accounts of their construction compiled by the proud engineers who had built them and found it hard to discipline his excitement as he read what the effects of breaching the dams could be.

It would not merely destroy hydro-electric power and deprive foundries of essential water, but affect other war factories which needed water for their processes. Disrupting them might cause a dozen critical bottlenecks in the completion of tanks, locomotives, guns, aircraft—almost anything one cared to name. It would deprive the populace of water too, which was no cause for joy in a gentle soul like Wallis but would at least induce in them a lessening of zest for the war.

There was still more to it. Breaches in the dams would send enormous floods ripping down the valleys, tearing away roads, bridges and railway lines, smashing factories and houses, so that some factories, rather than be deprived of water, would receive somewhat too much.

All this was fine, Wallis thought… logical ideas; but again one big flaw. The dams were so colossal that bombs twenty times bigger than existing ones were not going to hurt them.

His figures showed that when a 1,000-pounder exploded the charge expanded as a gas bubble, but at the end the bubble was only 20 feet across. A lot of damage was done beyond this 10-foot radius, however, by flying fragments, by blast and by the pressure pulse, or "shock wave." Wallis well remembered the pedantic description of Shockwaves… "there is no motion of the transmitting medium other than the usual oscillation of particles to and fro about their position of rest as the wave passes through them." Thin air gave scope to flying fragments and blast but the shock wave soon dissipated.

It would vibrate a structure, but not enough. To be destructive, shock waves had to travel through a more solid medium than air. And somewhere in Wallis's brain a little cell awoke and stirred restlessly, an old memory, locked up and almost forgotten. He felt there was something he knew about shock waves that he should remember, tried to think what it was—it was a long time ago—but the harder he tried the farther it receded. It was only when he put it out of his mind that it sneaked insidiously back to him again.

It was something he had read, something about concrete. And then it hit him. Waterloo Bridge! Concrete piles being driven into the bed of the Thames ! That was years ago. The piles had kept shattering mysteriously and there had been an investigation. He started searching his bookcases and in a quarter of an hour had found it, an article in a 1935 journal of the Institution of Civil Engineers. The great drop-hammers had been slamming the piles into the river-bed and the tops of the piles had been exploding upwards.

Investigation narrowed the cause to the shock waves. The sudden blows sent shock waves shivering down the piles; at the bottom they met the blunt resistance of the clay and bounced back up the pile at something like 15,000 feet a second, reaching the top just after the hammer had bounced off, so there was nothing to rebound from again and they passed out and away, and in their wake you got a tension after the compression. A sort of crush and then a sharp stretch, almost in the same moment; enough to make a structure split—to shatter it.

Concrete, the article concluded sagely, well resisted compression but poorly withstood tension. Wallis docketed the fact in his mind, thinking of dams.

You needed a solid medium to get destructive shock waves !

Of course, if you could bury a bomb *deep* in… But you couldn't slice a big bomb into ferro-concrete. No, but you might be able to inject it deep into some less solid medium before it exploded. You'd get the shock waves then. The expanding gas effects would be greater too; tamped by the encircling solids they would have to burst their way out.

He was aware that bombs and shells often buried themselves 3 or 4 feet in the ground before exploding, but that was so shallow the explosion forced its way easily to the top, causing a small crater, and the shock waves dissipated into the air. It was less effective than a surface explosion because the blast and shock waves went straight up instead of outwards.

But if you could *lock* the explosion underground so it could not break out you would get a sort of seismic disturbance… an earthquake! An earthquake bomb!

The idea shaped in his mind while he was sitting in a deep chair in his home at Emngham, an unspectacular setting for the birth of something so powerful.

But how to sink a bomb deeply into a resisting medium? You could not put one deep into a concrete dam. But a dam is set in water!

Water! It might not transmit a shock wave as well as earth but it would do so better than air. The tamping effect of water would produce a concentrated explosion and carry the “shock “punch. Wallis was starting to feel he might be getting somewhere.

And how about sinking the bomb in earth? A schoolboy knew the two principles. The heavier the bomb, the more power and speed it developed in falling. Wallis had learned the classic example in school. Drop a mouse down a well and at the bottom it will be able to get up and run. Drop a horse down and the horse will, probably burst. Because it was heavier it would hit *harder.* And the *farther* it fell, the *faster* it would fall!

So there it was : a bomb as heavy as possible (and as slim as possible) dropped from as high as possible.

Wallis looked up more books, studied the propagation of shock waves in soil, the effects of underground explosions at depth, and even found pages on the penetrative powers into soils of shells and light bombs. There was a piece about an enormous land mine exploded under a German-held hill at Messines Ridge in World War I. A colossal charge sent shock waves ripping into the earth, the hill was destroyed and the shock was felt in Cassell—30 miles away.

Wallis pulled out a pad and pencil and worked for a week, covering sheets with calculations, equations, formulas—and came up with a preliminary theoretical answer. A 10-ton bomb, with 7 tons of explosive in an aerodynamically-designed case of special steel, dropped from 40,000 feet, would reach a speed of 1,440 feet per second, or 982 m.p.h.—well over the speed of sound. At that rate it should penetrate an average soil to a depth of 135 feet.

A charge of that size should theoretically “camouflet” (not break the surface) at a depth of 130 feet. What it *would* do was cause a violent earthquake movement on the surface resulting in a hump forming.

“Such earth movements,” said a learned paper, “are capable of doing much damage at great distances.”

It looked as though Wallis had found his answer. Or part of it.

CHAPTER II —AND REJECTED

HE worked out theoretical effects, more pages of figures, and decided there was a chance that a 10-ton bomb exploding deep in water by a dam wall would punch out a hole a hundred feet across.

Supposing the bomb did not go as deeply into the earth as the figures predicted? Wallis worked out the effects of a 10-tonner exploding about 40 feet deep. In theory it would throw out the staggering amount of 12,000 tons of earth, leaving a crater 70 feet deep, with lips 250 feet across. He worked out the circumference of the crater and from that the maximum number of men and machines that could gather round the edges. Working day and night they could not fill it in under fourteen days ! Supposing one such bomb was dropped accurately in a marshalling yard! Or on a vital railway or canal or road where ground contours prohibited a detour!

Wallis did not get too excited. No bomber in the world would carry a 10-ton bomb. Or for that matter even a 5-ton bomb far enough to get it to a target.

Back to pencil and paper. He knew the limitations of aircraft design in 1940 and in a couple of weeks he knew it was possible to build a 50-ton bomber to carry a 10-ton bomb 4,000 miles at 320 m.p.h. and a height of 45,000 feet. He drew up rough specifications and christened it the "Victory Bomber."

And the aiming of bombs—notoriously hit and miss, mostly miss. Wallis found that increasing height did not greatly increase the problems and estimated that new bomb sights being developed and special training could put the bombs near enough to a target to destroy it.

That was the beauty of this 10-ton bomb. It should not have to be a direct hit! The earthquake shock would be so great that a near miss should shake a target to destruction. And another thing—a big bomb exploding 130 feet deep would not crater the surface but cause a huge subterranean cavern. Put such a bomb alongside a bridge or viaduct, and if the shock wave did not shake it to pieces the cavern underneath would knock its support away. An opening trapdoor—a hangman's drop ! The bridge would collapse into it.

There was one other possibility in it—perhaps the greatest of all. A few such bombs, accurately aimed, might shatter the roots of a nation's war effort. That could mean the end of the dreadful "Guernica" carpet bombing, which saturated an area with bombs so limited in effect that the area had to be saturated to make their use militarily worth while. Wiping out cities and civilians at the same time!

Wallis spent weeks setting it all out on paper and took it to people he knew in the R.A.F. and the Ministry of Aircraft Production. It was Dunkirk time. A potent new weapon had never been better timed.

Wallis's paper on the "earthquake bomb" roused three main emotions in officials: (1) Lukewarm interest. (2) Incomprehension. (3) Tactful derision.

One man understood and did what he could: Arthur Tedder, a quiet, intensely likeable man smoking a pipe, chained to a desk in Whitehall. But he was only an air vice-marshal then and did not have the influence he acquired later. He brought the bomb and Victory Bomber to the attention of several people in high places but the only result seemed to be a ubiquitous manifestation of courteous but implacable inactivity. Every machine in the country was working overtime on other vital things and the ambitious and excellent four-engined bomber project was just getting under way. It was a fair assumption that it might be disastrous to dislocate that in favour of the Victory Bomber, which would inevitably take much longer to develop. That automatically prejudiced the shock-wave bomb, because there was therefore no aircraft in sight which could drop it from Wallis's prescribed height of 40,000 feet. The new bombers would probably not be able to lift it or, if they could, to carry it far enough to drop it from higher than 20,000 feet, which was not likely to be enough.

And then on July 19, out of the blue, Wallis got an urgent summons to see Lord Beaverbrook, the bright-eyed firecracker who was Minister for Aircraft Production. With "The Beaver" interested anything could happen, and probably at speed. He caught the first: train to London, cooled his heels a few minutes in an ante-room and then the big door opened and a young man said:

"Lord Beaverbrook will see you now, sir."

Wallis jumped up, cuddling his calculations under his arm, and crossed the threshold, nervous with anticipation; and there was the little man with the wide, mobile mouth, sitting slightly hunched in his chair. It was the speed with which things happened that shook Wallis as much as the things themselves. No gracious, measured preliminaries. He was still in the middle of the floor, walking, when the little man barked:

"What's this about a ten-ton bomb?"

Wallis told him as concisely as he could; difficult for a scientist, who always feels compelled to go into technicalities, but he kept it short and lucid and Beaverbrook was interested.

"You know how short we are of stuff," he said. "This thing's only a theory. We'd have to stop work on other vital things to make it and then it might be a flop."

"It won't be that," Wallis said stubbornly.

"We'd still have to stop work on other things."

"It will be worth it."

"Take too long, wouldn't it?" said "The Beaver." "A ten-ton bomb and a bomber twice the size of anything else sounds like something in the distant future."

"We can do it in stages, sir," Wallis said. "I've got drawings for two-ton and six-ton bombs on the same principle. My Wellingtons can carry the two-tonner all right. The new four-engined ones can carry the six-tonner. They'll be operating in a year."

"Well, I'll see my experts about it," Beaverbrook said. "If it's going to mean diverting too much effort I don't like your chances."

Little seemed to happen for a while but behind the scenes things were moving in a ponderous government way. Little snippets filtered through to Wallis, particularly from that astute ally, Arthur Tedder. Nothing much; just that So-and-so had consented to look into the idea and that So-and-so had expressed mild interest. Wallis thought the prospects were still favourable. Sir Charles Craven, managing director of Vickers, was sympathetic and felt confident enough on November I to write to Beaverbrook suggesting he give permission to go ahead on both 10-ton bomb and Victory Bomber.

Then Tedder was posted to take over the R.A.F. in the Middle East and Wallis had lost his keenest supporter in the sacred and essential precincts of Whitehall. It was soon after that Craven sent for him.

"I'm afraid I haven't very encouraging news for you," Craven said as kindly as he could. "Air Council seem too wary of big bombs. They still believe stick bombing is necessary."

"But can't they *see* what a really big bomb would do?" Wallis said pleadingly.

"Apparently not. They say that from experience they would rather drop four 250-pound bombs than a thousand-pounder. Much less a 22,000-pounder."

"Could they understand my calculations, sir?"

Craven did not comment on their understanding. He said diplomatically that he doubted whether the members would have the *time* to go individually through all the calculations. Which was probably true. And then gently: "They say that anyone who thinks of ten-ton bombs is mad."

Wallis went back to Weybridge in anger, but in the morning the anger had mostly gone and in its place was outraged stubbornness. He started writing a treatise on his 10-ton bomb and called it "A note on a method of attacking the Axis Powers," the kind of obscure title so favoured by scientists; the word "note" being particularly misleading, as such things are often as long as a book.

Wallis's was. He started by outlining his theory of crippling an enemy by destroying the sources of energy, and went on to discuss in exhaustive detail the physical qualities of the targets, shock waves, blast, penetration, bomb design, aircraft design, charge/weight ratios, aiming problems, possible effects, repair potentialities, backed up with pages of graphs and formulae and equations. It was a *tour de force,* explaining step by step so lucidly that a layman could follow it if he took the mathematics for granted.

The "note" took Wallis several months, and then he had it roneoed and bound and posted copies to seventy influential men in science, politics and the services.

Results were not long coming. A secret service man called on him with a copy of the "note" under his arm.

"Did you send this to Mr.——?" he asked.

"Yes," Wallis said. "Why?"

“I’m afraid you shouldn’t have done so, Mr. Wallis.”

“Why?”

“It’s very secret stuff. This sort of thing must be handled very carefully and only reach authorised persons. Mr.—– was very surprised when this arrived in the post. We were concerned too. I quite realise you didn’t mean to be…”

“I sent out seventy of them,” Wallis said calmly, and the Secret Service was appalled.

“Seventy!” he said. “*Seventy!* Who? To whom? But you shouldn’t have. This is vital and very secret ! “

“Is it? “said Wallis mildly. “When I showed it to the authorised persons they said I was mad. I’m supposed to be a crackpot and this is regarded by authorised persons as fiddle-faddle.”

The secret service man said, “Oh ! “He asked for the names of the seventy. Wallis read them out and the secret service man, who seemed a little uncertain of his ground, went back to London to investigate further.

He appeared again a couple of days later.

“Well, it’s all right,” he said, “this time. We’ve decided that as so many were sent out so openly it’s actually rather a good form of security. No one will dream it’s all so secret. But please don’t do it again.”

Wallis bowed gravely. “I hope it will not be necessary again,” he said and the incident was closed.

A few days later there was another result. A copy had reached a Group Captain Winterbotham, who had an office in the City and was used to dealing with unorthodox aspects of the war. He had found it convincing, called on Wallis, and Wallis explained more fully. Winterbotham caught some of his enthusiasm. He knew Sir Henry Tizard, who was scientific adviser to the Ministry of Aircraft Production, and drew his special attention to Wallis’s paper.

Tizard read it carefully; as a scientist he could follow the intricate calculations. He went down to see Wallis at Wey-bridge and was impressed.

“I’d better form a committee to study this more fully,” he said. “It would have to have pretty solid backing from expert opinion. You’ll understand, I know. It would divert effort from other important things if we were to go ahead with it and we’ve got to be reasonably sure it would be worth while.”

“Of course,” Wallis said. He felt like singing.

Not long after, Wallis met the committee. At the head was Dr. Pye, Director of Scientific Research at the Ministry of Supply, and the others were scientists too. Wallis explained his ideas and described the probable effect on Germany’s war industries if the dams were breached. There was only one really worthwhile time of the year to breach them, and that was in May, when the storage lakes were full after the winter thaw and spring rains, and before the sluice gates were opened to water the country and canals for summer. Then you would get the greatest floods, the most serious loss of water and power. Dr. Pye said the committee would be a few days considering.

A week later Wallis faced the committee to hear theirfind-ings. His worst fears were soon over; the report was fa vour-able, but, as they read on, a little disappointingly so. They thought that the dams showed possibilities and the upshot was another committee. This one focused the aim more definitely; it was to be called "The Air Attack on Dams Committee."

The members were again scientists and engineers and in a mood to be interested in something new because even German bombs, though they were more efficient than R.A.F. bombs and killed thousands of civilians, had demonstrated the limitations of small bombs.

"With this big bomb," Wallis earnestly impressed on them, "you don't have to get a direct hit. I think a ten-ton bomb dropped fifty feet away stands a good chance of knocking a hole in a dam like the Moehne. A near miss like that ought to be simple enough to organise."

One of the members, Dr. Glanville, of the Road Research Laboratories at Harmondsworth, suggested building a model dam and testing the theories with scaled-down charges of explosive. Wallis accepted delightedly.

Over the next few months, whenever he could spare time from his arduous work at Vickers, Wallis helped Glanville design and painstakingly build a model dam one-fiftieth the size of the Moehne with tiny cubes of concrete, scale models of the huge masonry blocks in the real dam. The model was about 30 feet long, 33 inches high and up to 2 feet thick, a low wall arched between earthern banks, secluded from prying outside eyes in a walled garden.

They flooded the ground at one side to simulate the lake, and Wallis exploded a few ounces of gelignite under the surface 4 feet from the model to give the effect of a 10-tonner going off 200 feet away. There was a commotion on the water and a couple of patches of concrete flaked and chipped.

"Not so good there," Wallis said. "Let's try it closer."

He exploded more gelignite 3 feet from the dam, and there was a little more damage. He set off another charge 2 feet away and still found only minor chipping.

At a distance of 12 inches (representing a 10-tonner 50 feet from the dam) the gelignite caused a couple of cracks in the outer structure; but they were small cracks, not enough to harm the dam significantly. They tried several more charges but the cumulative effect was not encouraging.

Months had passed since the first hopeful meeting of the committee, and Wallis could see that their early co-operation was freezing. Glanville built another model, and Wallis tried bigger charges to see what *would* smash the models at a distance. One day a few extra ounces of gelignite a foot away sent a mushroom of water spraying over the wall round the garden and as the spume cleared they saw the water of the little lake gushing through the burst dam. Slabs of concrete had cracked and spilled out and there was the breach that Wallis had been wanting. He calculated the scaled-up charge which, dropped 50 feet away, would smash such a hole in the Moehne. The answer was something like 30,000 Ib. of the new explosive RDX, and the gentle scientist did not need pencil and paper to estimate the significance.

Thirty thousand pounds was nearly 14 tons. That was the explosive alone. Add the weight of the thick case of special steel—another 40,000 odd Ib. It meant a bomb weighing 70,000 Ib.—over 30 tons, and the Victory Bomber, still only on paper and straining the limits of feasible aircraft construction, would carry only a 10-tonner.

The next meeting of the Air Attack on Dams Committee was in a fortnight and it required little thought to foresee it would be the last meeting.

Wallis would not give up.

Supposing, he thought, a bomb could be exploded *under water against* the dam wall. The shock wave punch would be much greater. So the explosive needed would be smaller. So would the bomb casing.

But how to get a big bomb in the exact spot—deep enough for the shock punch and pressed against the wall to make the most of it? Or, as it might require more than one bomb, how could you get them all in the exact spot? A torpedo? But the dams had heavy torpedo netting in front of them, and so torpedoes were out. You could drop a bomb from very low level for accuracy, but bombs don't simply "drop ". Just after release they carry a lot of forward speed, giving them almost a horizontal trajectory for a while. If you dropped a bomb— even a whopper—from very low to get the accuracy it would simply skid *off* the water ; so that was no good. If you dropped it high enough to enter the water cleanly, you only had about one chance in a thousand of putting it right in the exact spot.

Wallis probed at this problem for days and every time he probed he came slap up against the same old problem—the only way would be to drop something from very, very low and somehow make it stay where it was supposed to. But that seemed to be impossible. He remembered his last holiday with the youngsters just before the war began when they had been skipping stones across the smooth water of a little pon,d. How on earth, he thought, could one toss a stone low like that and stop it skipping. Drop any shape of bomb very low at a couple of hundred miles an hour and heaven knows where it would skip to. When dams are full there is practically no space between the level of the water and the top of the dam wall and in his wry imagination he visualised a series of grotesque bombs hurdling over the dam wall and flying harmlessly downstream. What a pity, he thought idly, that you couldn't make a torpedo do a bit of hurdling—over an anti-torpedo net for instance.

Hullo! That was an idea! If a bomb could hurdle a dam wall it could also hurdle an anti-torpedo net. Such nets were a good hundred yards away from dam walls to keep any explosions at arm's length. A bomb didn't have to keep skipping for ever. May be it could be so judged to skip the torpedo net and not skip the dam wall. Hang it all, why not? He felt sudden excitement surging inside him. There would probably be three or four feet of dam wall above the water. Supposing the skipping of the bomb were timed (if it could be done) so that it was slithering to a stop on the water as it reached the wall. Why then, the wall would stop it dead and it would simply sink into the water, by the wall, as deep as you like. You could have the fuse fixed with a hydrostatic trigger so that the bomb would go off when the water pressure reached the right amount. Set in for fifty feet down or a hundred and fifty feet down. Please yourself. Hang it, the more he thought about it the more he liked the idea, even if it did sound a bit odd.

Wallis went home, dragged a tub into the garden of his house at Effingham and filled it right to the top with water. Then he rigged up a catapult a few feet away just a few inches above the level of the water. A few feet on the other side of the tub he stretched a string between a couple of sticks so that the string was also just above the level of the water. Then he borrowed a marble from his young daughter, Elizabeth, and shot it from the catapult at the water. It skipped off and cleared the string by several inches. Elizabeth and the other children looked on, wondering what he was up to. Elizabeth brought the marble back and Wallis fired it again, this time with a little less tension on the rubber of the catapult. The marble zipped off the water and only just cleared the string. “Ah,” thought Wallis, “that’s it.”

He and the youngsters spent the whole morning playing with the marbles and the water and the catapult and the string, trying different combinations of power and height while Wallis was finding out how much he could control the skip. To his deep joy he found out that with a regular shape and weight like a marble on smooth water he could control it quite well. At least well enough for it to be distinctly encouraging. But could he control several skips, which might be necessary? Aha, that remained to be seen. They went into lunch eventually, all thoroughly splashed. Wallis was very cheerful, and also, the children thought, very mysterious about it all.

Always sensitive to ridicule, Wallis told no one the details, not even his friend Mutt Summers, chief test pilot for Vickers and the man who had tested his old warhorse, the Wellington. Captain Summers was a hefty extrovert and not the type to take a freak idea seriously.

The day of the meeting of the Air Attack on Dams Committee Wallis went early to London, buttonholed the chairman, Dr. Pye, and privately explained his new theory, so earnestly that Pye did not laugh though he looked a little sideways.

“I’d rather you didn’t tell the others yet,” Wallis said. “They might think it a bit far-fetched.”

“Yes,” said Dr. Pye. “I see that. What do you want me to do?”

“Give me time to find out how much RDX will blow a hole in the Moehne Dam if it’s pressed up against the wall.”

Pye talked eloquently to the committee without giving Wallis’s secret away. The members were reluctant when they heard the results of the last model’s test and Wallis was like a cat on hot bricks till they consented to one more experiment.

Glanville built him a new model dam, and Wallis started with small charges, sinking them in the water and exploding them when they were lying against the slabs of concrete. The effect was shattering—literally. He smashed wall after wall seeking the smallest charge needed, and soon he knew that in a contact explosion tamped by water a tiny plug of a few ounces of gelignite blasted a satisfying hole through a concrete wall 6 inches thick. From that he calculated he would need only 6,000 Ib. of RDX to breach the Moehne Dam. With his new idea he could cut the case weight down to a little over 3,000 Ib., making the complete bomb about 9,500 Ib. Less than 5 tons. The new four-engined Lancasters would carry that to the Ruhr without trouble.

CHAPTER III THE GREEN LIGHT

ARMED with sums and theories, Wallis faced the task of convincing officials in their brick and stone lairs along Whitehall and other influential thoroughfares that he could put his bomb in the exact spot. He called on Professor Patrick Blackett, director of an "operational research" branch, and Blackett, a spare, rather intense man, listened to his ideas, carefully examined the calculations, riffled them back into a neat pile and said quietly:

"We've been looking for this for two years."

Wallis was electrified.

"I'd like you to leave these with me for a while," Blackett said. "There are one or two people I know who would be interested."

Blackett moved fast. As soon as Wallis had left he went to see Sir Henry Tizard and told him what he had heard. Tizard also moved with unorthodox haste, driving down to Weybridge next morning, where Wallis eagerly explained it all again.

"It seems," Tizard said when he had finished, "that the main thing to establish is whether this freak of yours will really work, and if so how we go about putting it into practice."

At Teddington, he said, was a huge ship-testing tank which would be ideal for experiments. He also thought there should be more tests to check how much explosive would theoretically punch a hole in a dam.

"I think I know just the thing," said Wallis, whose "damology" researches had been fanatical. "There's a small disused dam in Radnorshire; no earthly use any more as a dam and won't ever be. We could try and knock it down."

"Who owns it?" Tizard asked.

"Birmingham Corporation." Wallis knew all the answers.

"We'll try them," Tizard said, and Birmingham Corporation, with a little prodding, said yes.

It was a nice little dam, about 150 feet long and quite thick, curving gracefully across the mouth of a reach of Rhayader Lake, high in the Welsh hills west of Leominster. The corporation had built a bigger dam across the mouth of the lake to feed a little river that tumbled out of the hills.

Wallis estimated that the old dam would have a fifth of the resistance of the Moehne, an ideal test model. He calculated the smallest charge that should knock it down and set off with a packet of RDX and some explosives engineers. Wrapped against the raw mountain wind, he wasted little time, measured out the charge, tamped it in a sealed casing and lowered it deep into the water against the dam wall. Behind the rocks, his mouth dry with anxiety, he pressed the plunger and the lulls echoed with sound. Water