Barnes Wallis's Other Bouncing Bomb

Part I: Operation *Tirpitz* and the German dams

By John Sweetman

Tirpitz spent much of her service in the fjords of northern Norway

On 16 January 1942, the 52,600-ton German battleship *Tirpitz* with a formidable main armament of eight 15in guns and reputedly capable of up to 34 knots, entered Trondheim Fjord in Norway. She would anchor 35 miles inland, in the off-shoot Foetten Fjord, protected on three sides by steep cliffs. In the following months, four unsuccessful operations were mounted against her there by RAF Bomber Command and the Fleet Air Arm once narrowly missed sinking *Tirpitz* at sea.

In 1943 Winston Churchill demanded renewed air action. The powerful battleship *Tirpitz* remained a potent threat to the Arctic convoys carrying supplies to the USSR and raised the spectre of a foray into the Atlantic. To guard against these eventualities,

The Tirpitz in 1943

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the Home Fleet had a powerful array of battleships, cruisers and destroyers at Scapa Flow – ships that were urgently needed in other theatres of war. On 13 February 1943, the Prime Minister furiously minuted the Chief of Combined Operations, Paymaster-General, First Sea Lord, Chief of the Air Staff (CAS) and Commander-in-Chief (C-in-C) Bomber Command: 'Have you given up all plans for doing anything to *Tirpitz* while she is in Trondheim?… It is a terrible thing that this prize should be waiting and no one be able to think of a way of winning it'.[1]

From the aerial perspective, the omens were not good. Responding to another memo from Churchill on 27 February, ACAS (Ops) at the Air Ministry reported the lukewarm reaction of Bomber Command towards renewed attacks on *Tirpitz*: 'The ship in its present situation is virtually invulnerable to normal bombing methods. It is to all intents and purposes in a '*slit trench*'. The battleship's 'formidable and effective defences' prevented 'even moderate bombing accuracy'. Prolonged absence from main force operations of aircraft detached for duty to northern stations – where the weather often delayed projected air attacks – meant that only inadequate numbers could be spared. The pessimistic conclusion followed that any such operation 'would be yet another fruitless diversion of bombers from Germany'.[2]

WALLIS'S INITIATIVE

By now an unusual solution to the problem of *Tirpitz* had firmly come into focus. In 1941, the distinguished aeronautical engineer Barnes Neville Wallis, nominally Assistant Chief Designer (Structures) at Vickers-Armstrong's works in Weybridge, had drawn up a scheme for dropping a 10-ton 'earthquake' bomb at 40,000 ft from 'a stratospheric bomber' to destroy a wide variety of targets, including coal mines, dams, oil refineries and lock gates. Significantly, a 'water immersion' variation of the proposed bomb was also illustrated. However, this idea contained in a 117-page illustrated paper was turned down. The need to destroy dams then became a special focus of attention, and Wallis started to examine ways of projecting a missile dropped from a low-flying aircraft across the surface of a reservoir abutting a dam. This had obvious implications for attacking ships as well. During 1942 he therefore worked on two parallel versions of his so-called 'bouncing bomb' – one to destroy a gravity dam, the other a battleship.[3]

In Spring 1942, Wallis conducted initial experiments by bouncing marbles off water in a tub on the patio of his house in Effingham, seeking not only to prove the method workable but to establish consistency through a Law of Ricochet. He moved

on to trials with balls of different density fired from a special catapult at Silvermere Lake, near Cobham, and then to the National Physical Laboratory (NPL), Teddington, where active Admiralty interest was assured. On 22 April, seeing his proposal 'as essentially a weapon for the Fleet Air Arm', he outlined progress with his 'golf ball' experiments to Professor PMS Blackett, scientific adviser to the Admiralty.[4]

On 14 May, Wallis circulated more widely his thoughts in a persuasive, detailed paper, 'Spherical Bomb – Surface Torpedo'. A spherical bomb, he argued, was 'not susceptible to initial disturbance by the under-belly turbulence of the carrying aircraft at the moment of release'. Thus a more accurate flight path than for an 'ordinary bomb' resulted. The pilot would need to make a fast dive, then flatten out to release his load at a height 'not greater than 26 ft when travelling at a speed of 470 ft/sec in order that the impact angle shall not exceed five degrees'. Available data suggested that, given these constraints, a bomb would travel 3,500 ft (roughly 3/4 mi) in five bounces over water; the fifth just under 4 ft high, the first one-half the height of release. Double casing, bridged 'by a series of light timber beams or roughly welded steel girders', would permit any necessary adjustments. 'The charge should sink in close proximity and may be detonated by a hydro-static valve at any pre-determined depth, the rate of sinking being comparatively slow'. Suitable targets would be hydro-electric dams 'and floating vessels moored in calm waters such as the Norwegian fjords'. In a word, *Tirpitz*. No wonder Blackett responded quickly.[5]

Despite experiments with model dams at the Road Research Laboratory Harmondsworth and possibly because no practicable method of breaching one had yet been devised, Wallis regarded his project as primarily 'a naval weapon' and a means of attacking warships at anchor. But the relevance for dams – a special interest of the Air Staff since 1937 – determined that Blackett should contact his counterpart at the Air Ministry, Sir Henry Tizard, who visited Wallis at his temporary office in Burhill Golf Club on 23 April. Both Blackett and Tizard had an advanced draft of the 14 May paper and may have exercised some influence over the final version. Without doubt, though, Tizard was instrumental in securing permission for Wallis to conduct tests at Teddington, where he aimed 'to establish the feasibility of certain full-scale trials of a method of attacking ships'. To Ernest Relf of the NPL, on 19 May Wallis explained that 'the main difficulty may be to fly low enough at high speed as the angle of the first contact with the water is strictly limited'. Eight days later, he went to Teddington to finalise administrative arrangements, and on 30 June 1942 he outlined his programme 'to determine the performance obtained at varying aircraft speeds with varying mean density of bomb and height of discharge above the water'. Use of the water tanks and wind tunnel at Teddington would be followed by dropping tests from 55ft in the Vickers-Armstrong's shed at the RAE Farnborough, first with wooden dummies then a full-sized steel bomb of the correct weight. Finally, full-scale tests would be carried out with inert-filled bombs from an aircraft.[6]

ADMIRALTY INTEREST

Between 9 June and 10 September 1942, Wallis made use of one of the two large indoor water tanks at Teddington on at least 18 occasions, often all day. 'I moored a wax model of a battleship several hundred feet up the tank, broadside on. We fired 2in dia

(sic) balls at it, when of course after hitting the freeboard of the ship, the sinking velocity of the ball combined with back-spin to move it towards the ship, and by adjusting the mean density of the ball we were able to pass it right underneath 'the soft underbelly', to quote Winston Churchill'. By now, Wallis had added back-spin to his weapon for increased range and stability after release. There is evidence that he had always intended this, but for some reason excluded it from the 'Spherical Bomb' paper. Despite Blackett's earlier enthusiasm, it seems likely that the Admiralty only became actively involved in June 1942, after Lt LHM Lane RNVR from the Directorate of Miscellaneous Weapon Development (DMWD) visited Wallis about another of his ideas and learnt of this one. As a result, Rear-Admiral E de F Renouf, Director of Mine Warfare (DMW), went to Teddington and returned with other high-ranking officers who according to Wallis, were '*tremendously* impressed'. Representatives of the Air Staff and Ministry of Aircraft Production (MAP) also made the trek into Surrey. On 21 June the Controller of Research and Development (CRD) at the MAP, Air Vice-Marshal JF Linnell, wrote that 'the model experiments have established a clear case for an air test using full-scale bombs'. He authorised allocation of a Wellington for trials on the understanding that 'relatively small … structural modification 'to the bomb bay fairing would be necessary. Acknowledging that 'Wallis is an enthusiast for this scheme', he expressed concern that, 'as *the leading hand* in Vickers design staff' the replacement for the Wellington aircraft would suffer, if he were ' devoting too much of his time to his bombing project'. Subsequently, on 28 June, Dr DR Pye (Director of Scientific Research (DSR) at the MAP) did unequivocally inform Wallis that the aircraft must take precedence over 'this bombing project'.[7] On 9 July, Pye reflected: 'I think we can safely say that the gravity dam is a hopeless proposition', a view endorsed by other RAF visitors who, according to Gp Capt

Upkeep in static rig

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Production Wellington

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F W Winterbotham from Air Intelligence, doubted the concept of attacking ships as well. Winterbotham condemned Pye, chairman of a committee investigating Wallis's scheme for trying 'to prove that things *cannot be done*, rather than to find *how to do them*'. Wallis wrote bitterly on 21 July that 'the profound effect of water impact waves had not yet been realised by the Air Staff, but it is now appreciated by the Admiralty'. Without Admiralty – and specifically Renouf's – support, the 'bouncing bomb' may well have sunk without trace in a Teddington experimental tank. During June and July 1942, Air Ministry enthusiasm noticeably waned. Nevertheless, following Linnell's ruling of a month earlier, on 20 July a Wellington had been made available, and two days later Wallis learned that the Admiralty's request for 12 experimental weapons (4 ft 6 in diameter) to be dropped from it had been approved. This paved the way for a series of trials quite separate from those involving model dams.[8]

Underlining the naval dimension, Benjamin Lockspeiser (D/DSR at the MAP) sought advice from the Admiralty on what would be needed to 'damage various types of ships – i.e. size and charge weight'. RAF interest soon revived and a bureaucratic turf war between the Admiralty and MAP highlighted the Royal Navy's leading role at this stage. Lockspeiser complained on 8 August: 'DMWD is usurping our authority in this matter. I spoke to DMWD this morning and emphasised that these were our trials and that the responsibility for the conduct of them would rest with MAP'. Indeed, with so many agencies involved, friction seemed inevitable. On 2 October, HQ Coastal Command wrote to the MAP about DMWD working on a project 'which can best be described as a *spherical spinning bomb*', for which full-scale trials were soon due at Chesil Beach. Coastal Command could use such a weapon and wanted to send an observer to the trials. Wg Cdr EJ Palmer replied somewhat icily that the MAP was 'handling the scheme' with DMWD assisting only when required. Early flying trials were planned that week, but there was no need for Coastal Command to be concerned. This was a 'highly secret' affair. Sharply he added: 'The fact that knowledge of it has reached you rather surprises me and from your reference to them it would appear that DMWD are the culprits … I will let you know as soon as an interesting stage has been reached'.[9]

AUTHORISED TESTS

Such hiccoughs should not obscure the co-operation which did occur between Ministries and Services. On 4 June, £50 was agreed for preliminary tests at the NPL and a further £2,000 by Lockspeiser on 12 July for use of the water tank and wind tunnel, full-scale tests, modification of a Wellington and preparation of 'inert bombs' for dropping tests. This overall sum advanced to £10,000 on 4 August, indicating how seriously Wallis's idea was being taken. A report from RD Arm 4 (a) in the MAP underlined this on 18 August. Wallis intended to launch his 'novel' weapon from low level over the sea with a 'high rate of spin'. Model tests suggested that it would 'ricochet along the surface … for a considerable distance', but no full-scale tests had yet taken place. Summarising the concept of attacking ships by sinking a charge beside them and exploding it with an hydro-static pistol, RD Arm 4 (a) concluded that 'the expected performance of the weapon appears to present several tactical advantages', though 'a considerable amount of work' had still to be done before Service use. A week later, the two Services

and the MAP decided to carry out dropping trials the following month off the Dorset coast between Chesil Beach and 'the mainland known as East and West Fleet', though these did not actually happen until December. At the meeting on 25 August, it was agreed that Vickers-Armstrong's chief test pilot, Capt Joseph 'Mutt' Summers, Wg Cdr Palmer from the MAP and Wallis should reconnoitre Chesil Beach in connection with 'the Rota mine'. Lt Lane of the DMWD went with them on 2-3 September. They found that RAF Warmwell close-by would provide lock-up facilities and the Wellington could take off from its grass runway 'except in extremely wet weather'. However, variations in the water level at Chesil Beach caused concern, and Wallis agreed to further experiments at Teddington 'to see if approximately 1 1/2 diameters of the projectile would be sufficient depth of water to avoid drag or any other factors which may occur'. This would explain why dropping tests were delayed and indirectly through the plural 'diameters' that more than one version of the weapon would be tried. By November, detonation tests had determined that the new underwater explosive Torpex would be suitable for the proposed weapon, two aerial versions of which were under consideration: the larger (codenamed Upkeep) in a Lancaster against dams; two of the smaller (codenamed Highball) to be carried by a Mosquito in a simultaneous operation against surface vessels.[10]

Progress on the technical side and detailed arrangements for the Chesil Beach trials had not proceeded altogether smoothly. On 13 July, Lockspeiser complained that Wallis foresaw a 54in-diameter weapon 'to conform with the density and charge weight requirements against capital ships'. This would create problems of modification in the Wellington, and he believed that a 30in-diameter would suffice to check data extrapolated from the models tests. On 14 September the Director of the RAE Farnborough raised the question of responsibility for preliminary trials, which Wallis said would be conducted by his firm. 'These tests would begin with one bomb mounted in the aircraft, and the number would be gradually increased after handling trials had been satisfactorily completed'. Once Vickers-Armstrong was confident 'that the complete bomb installation caused no damage or serious difficulty in handling, the aircraft would be handed over to the RAE for a very brief confirmatory handling trial'. The following day, Wallis wrote to Lockspeiser explaining that the RAE could not provide a suitable airborne camera for the Chesil Beach trials, but had suggested 'a theodolite camera having a traverse in azimuth of 130 degrees' for which rising ground on the landward side of the East Fleet range seemed ideal. An automatic light signal, Wallis noted, was 'usual' to indicate release from the aircraft.[11]

That same day, 15 September, RD Arm 4 (a) summarised the 'progress of work on (the) Spherical Bomb'. One had been completed and would be filled with High Explosive (HE) substitute for static spinning trials within a few days. Eleven more

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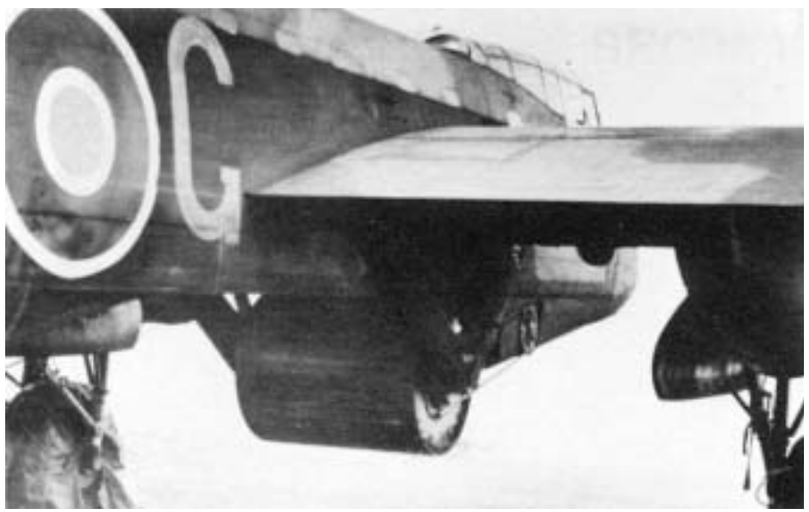

A Lancaster equipped with the Upkeep bomb

fillings were in hand, eight of which should be ready for dropping trials by the end of the month. Model tests (presumably after Wallis's visit to Chesil Beach a fortnight earlier) had shown the depth of water at the range to be sufficient. Then, on 1 October, Pye at the MAP revealed that aerial tests would involve spinning four of the practice weapons in an aircraft. Nearly two months later, on 21 November and a day after witnessing these spheres being spun in a static Wellington, Lockspeiser wrote: 'All indications are that he (Wallis) has got over his troubles with substitute fillings' so that dropping trials could start in 10-14 days. Yet, conversely and puzzlingly, on 23 November Mr CC Aston of RD Arm 4 (a) admitted that problems were still being experienced. Three days afterwards, a meeting at the MAP learnt that chemists from the Paving Stone Company at Weybridge had approved a suitable substance, which Mr Early of the Research Department at Woolwich thought very similar to Torpex. Furthermore, one container would be filled with Mineol II and spun in Richmond Park 'to ascertain whether the HE moved and upset the balance', but this could not take place before 3 December. Altogether more promising, but progress was in truth abominably slow.[12]

On 30 November, more signs of delay surfaced. The Ordnance Board needed both to check the feasibility of the outline scheme and Wallis's 'designs (sic) of the bomb'. Two days later Wallis wrote to Aston, enclosing Drawing No 45257 which showed the device proposed for using the standard D/C Pistol Mk XIV, and explained that 'the acorn which is mounted on the end of the fusing wire is quite free within the four members of the cap, so that relative rotation can take place'. However, Aston wanted more information, and on 7 December asked Wallis for 'a general arrangement drawing of the store showing the location required by the fuze'. Three days afterwards it became clear that, contrary to an undertaking on 26 November, Weybridge could not carry out preparatory work connected with the practice weapon designated for the spinning tests. A further two days elapsed before alternative arrangements were finalised.[13]

DROPPING TRIALS

The Chesil Beach trials eventually began two months late. On 2 December, Summers took the modified Wellington BJ 895/G over the Queen Mary reservoir near Staines and reported no adverse effects as four scaled-down weapons were spun at the same time. Two days later, Wallis acted as his bomb aimer when he flew the Wellington – its bomb-bay doors removed and special spinning apparatus installed – to Dorset and released two practice bombs. Both welded spheres burst on striking the water. Undeterred, Wallis arranged for the outer casings to be reinforced. Poor weather delayed the 'Second Trial' until 15 December. Both spheres (one with a dimpled surface, one with a smooth surface) were dropped from 60 ft after a steep dive by Summers and were apparently shattered on impact. However, after recovery they were found to be damaged, not broken. Renouf witnessed the drops, remained enthusiastic and chaired a review meeting at Vickers House on 17 December. On his advice, the Admiralty pressed for further trials. A planning meeting on 19 December agreed that 'there is good reason to believe that a sound mine will behave at least as well as models have indicated'.[14]

On 23 December, the DMWD summarised Project No 52 as conducting trials to determine the safety of carrying aircraft,

effectiveness of Highballs hitting water, strength of Mk XIV Type D/C pistols, 'length of travel over water, height of bounces and angles of incidence and reflection'. That same day, authorised expenditure on Wallis's scheme (strictly a contract from the MAP to Vickers-Armstrong) rose to £15,000. Once more, though, signs of bureaucratic dispute appeared. CRD scribbled in the margin of minutes for a meeting at Vickers House on 23 December that with six out of the 12 present, 'the Admiralty seem to have packed the meeting'. Darkly he added: 'Special steps may be needed to ensure that the experiments are kept under control'. On 29 December, Wallis asked and received approval for two further days at Teddington to conduct more tests connected with the 'rotating spheres' following the first two Chesil Beach trials.[15]

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From the Admiralty's point of view, 1942 ended on a positive note. Sufficient progress had been made for hopes of an attack with Highball in the New Year. Dropping trials at Chesil Beach gathered pace in January 1943, based on guidelines laid down on 28 December 1942: 'Smooth and dimpled Highballs' strengthened by extra welding would be followed by 'wooden Highballs fitted with cups designed to record impact forces' with the aim of confirming data from the NPL tests. The third and fourth series of trials occurred on 9-10 and 23-24 January 1943. Further drops on 5 February involved smooth wooden balls released from the Wellington at heights of 80-145 ft at an estimated air speed of 300mph and revolving at 425-450 rpm, the longest range achieved being 1,315 yds. To Lord Cherwell, Churchill's scientific adviser, on 30 January Wallis confirmed that the Chesil Beach trials had 'justified the hopes raised by the 2in-sphere trials' at Teddington. As a result, the Admiralty had given 'full priority' to develop a '3ft-sphere' for use by Mosquitoes against 'naval targets'. Independently summarising these trials, AD Grant (Wallis's administrative officer) explained that the first spheres comprised 'relatively thin steel pressings welded together and stiffened with diaphragms' and were dropped empty to make recovery theoretically easier. However, they were so severely damaged that some were then inertly 'filled with concrete'.[16]

INTENSIFIED RESEARCH

As these trials progressed, Wallis produced a 19-page paper which, despite its title *Air Attack on Dams*, included material relevant to an operation against *Tirpitz*. He sent a copy to Renouf on 9 January. After dealing with the German dams, in Part III he described 'the rotating sphere … as a means whereby aircraft may attack targets which are either water-borne or in contact with water'. During the next three months, 19 other people received copies, including Cherwell and Lockspeiser at the MAP. Capt FWH Jeans, Director of DMWD, had his on 20 January and Wallis believed that this was in turn copied and extensively distributed within the Admiralty. Figure 9 in the paper showed a 'spherical surface torpedo' released 1-2000 yds from the target attaining a 'mean velocity of about 150 mph', striking the side of a ship and, with the aid of its back-spin, penetrating the water to explode 'about 15-20 ft' below the hull. With the vessel in the illustration anchored close to a steep cliff, the similarity to *Tirpitz* in Foetten Fjord was marked.[17]


A PRU Mosquito

A combination of this paper and the Chesil Beach trials, plus Admiralty long-standing keenness, ensured that prospects for a Highball attack on *Tirpitz* did not die. Inevitably, though, a plethora of meetings filled the diaries and a procession of minutes and memoranda swamped the desks of busy men. On 2 and 4 January, the MAP drew attention to problems with the trials thus far and need to strengthen the weapon's casing. On 18 January the RAE was asked to arrange for a theodolite camera at the next series of drops connected with 'Operation High Ball' (sic) planned three days hence. The following day, a meeting chaired by Renouf looked at types of aircraft suitable to attack a warship with a weapon, which Wallis said would have a charge smaller than the 750 lb currently planned for the 46in-model. The MAP revealed, on 28 January, that it had placed 'a research contract for 250 of Wallis's spherical bombs' with Vickers-Armstrong's works at Crayford and that two Mosquito bombers were to be modified for further trials. Wallis was to liaise with the Mosquito's manufacturer, de Havilland, over the modifications as 'the essential requirement is that of the highest possible speed low down near the water'. At length, a division of labour was agreed between de Havilland and Vickers-Armstrong, though the latter warned that sub-contracting to Messrs Marshall of Canterbury might be necessary. Summers would be consulted about 'special radio devices' to determine the precise height above water. The following day, DSR expressed concern at 'the scientific problems involved in hydrostatic fuzing and sighting'.[18]

Two Mosquito IVs were formally put on contractual loan to Vickers-Armstrong on 30 January, though 10 days earlier Wallis had been asked to produce data so that Beaufighters could be considered for the operation. A meeting at the MAP on 2 February, 'to discuss the design of the Wallis Spherical Bomb for attack of Capital Ships with special reference to explodering (sic) arrangements', heard that Wallis currently saw Highball with a 35in-diameter, 1.5in-thick case, density of 75 lb per cubic foot, charge of 500 lb and total weight 950 lb. As shown in *Air Attack on Dams*, he anticipated that it would hit the ship at 150 mph and saw no difficulty with detonating the device. The Admiralty representative requested that the weapon should be able 'to jump a protecting section 6 ft high at 80yds' from a target. A meeting on 7 February learnt that three bombs filled with HE substitute would be dropped on concrete at Porton Down: woodmeal wax or soft white pinewood would be used as packing between the inner and outer casings. A week later, possible trials using Staines reservoir were ruled out for security reasons, and on 13 February, Air Vice-Marshal RS Sorley chaired yet another meeting 'to discuss the development and possible operational use of the spherical bomb'. Wallis repeated that he envisaged Highball comprising a 500 lb charge in a cylinder contained in a 35in-sphere with a gross weight of 950 lb and mean density of 75 lb per cubic foot. Two would be carried in a Mosquito and released 3/4 mi from the target.[19]

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On 16 February, Gp Capt FW Winterbotham of Air Intelligence (AI 1c) wrote a 'most secret and personal' minute to Air Vice-Marshal FF Inglis, ACAS (I), reminding him that he had spoken 'some months ago about an invention … which consisted of a spherical bomb that was made to reach its objective by Ducks and Drakes over the surface of the water'. He confirmed that it was 'originally evolved for attacks against Axis warships' about which the Admiralty, the Chief of Combined Operations and the Prime Minister 'became enthusiastic'. The code word was 'Highball' and 'the registered inventor BN Wallis of Vickers. I understand the Prime Minister has laid on the highest security measures'. Winterbotham outlined the different versions of Wallis's weapon, adding optimistically that 'the small anti-ship bomb is nearly ready'. Revelation that Churchill not only knew about the project, but strongly supported it, once more underscored his concern about *Tirpitz*. On 22 February, the MAP laid down that modifications to the two Mosquitoes contracted to Vickers-Armstrong for test purposes should not exceed £6,000. Four days afterwards, Flt Lt AD Green of the MAP revealed that the cost of 250 35in-Golf Mines (a generic term for all types of Wallis's weapon) depended upon the results of the dropping trials at Porton carried out on 17 and 23 February, which in turn would affect the final design. That same day, Air Vice Marshal JF Linnell (CRD at the MAP) chaired a meeting at which Mr A H Palmer of Vickers-Armstrongs said that Highball and Upkeep 'would probably not be in competition for machinery capacity due to the difference in their size'. The meeting learnt, too, that the first modified Mosquito should be ready by 8 April, the second a fortnight later. Slight qualms were raised the following day, 27 February, when Gp Capt W Wynter-Morgan admitted that the 75 Upkeep and 200 Highball 'Golf Mines' scheduled to be filled with Torpex would absorb the bulk of the RAF's allocation of explosive and deny its use in 860 1,000 lb Medium Capacity (MC) bombs.[20]

CLOSER AIR STAFF INVOLVEMENT

On the last day of February 1943, an Air Staff appreciation summarised the situation, still referring to a 35in-diameter weapon, 950 lb in weight to be released ¾ mi from a target. But it would now contain 600 lb of explosive and be back-spun at 500 rpm. 'Primarily' it had been developed to attack *Tirpitz,* and two Mosquito squadrons with 250 bombs were planned to achieve both this objective and attacks on other Axis capital ships. The prospect of a successful attack against the German battleship at Trondheim 'increased as a result of the superior performance of the Mosquito compared with current torpedo bomber types, and of the characteristics of the bomb'. Nevertheless, even in moonlight, an accurate night attack would be impossible '… in view of the navigational difficulties involved in a low-level approach to the target from outside of RDF cover … *a* problematical … *and* costly' daylight operation was the only option. Such an attack, whether successful or not, would compromise any operation against the German dams, so 'every effort should be made' to launch both 'at the same time'.[21]

On 3 March, the MAP confirmed that each of the bombs manufactured at Crayford cost £1,000. That same day Green laid down specifications for 250 Mk XIV D/C pistols, which must function in fresh water at 30 ft and 'may be subjected to severe side impact'. They were required by 30 April and should sink at 15 ft per sec. At its meeting on 8 March, the Chiefs of Staff established a sub-committee to report fortnightly on the progress of both Highball and Upkeep, and the Admiralty swiftly mounted a palace

Warmly, he argued that, as its squadrons would train for, plan and execute operations connected with Wallis's invention, the chairman ought to come from the RAF

coup to get Renouf appointed to its chair. Two days later, the RAF counter-attacked. Portal wrote whimsically to Pound: 'If his (Renouf's) name was mentioned at the meeting I apologize for not having heard it'. Warmly, he argued that, as its squadrons would train for, plan and execute operations connected with Wallis's invention, the chairman ought to come from the RAF. Air Vice-Marshal NH Bottomley, according to one staff officer adept at 'playing the Air Ministry organ more beautifully than anybody else', duly and rapidly replaced Renouf.[22]

Sir Charles Craven (Chairman of Vickers-Armstrong) announced on 9 March that the 250 contracted Highballs would be completed by 19 June and, if told 'immediately', a further 250 could be produced at 100 a month. This business proposition, despite further advances from Craven, was not taken up. Four days later, Lockspeiser complained that 'Highball' had come incorrectly into use; the proper codename was 'Golf Mine'. Sorley thought worse confusion would occur if the error were now pointed out, and 'Highball' stayed. At this meeting, Renouf pressed for an early attack on *Tirpitz*, fearing that defences around her would be heightened now that winter darkness had ended. On 16 March, Craven confirmed that 10 'Hi-Balls' (sic) had been despatched from Crayford, 120 would be ready by 26 April. The following day, the inter-Service Joint Planning Staff, referring to 'Operation Highball' concluded that 'the present arrangements for attacks in May on German dams and heavy units of the German Fleet should be pressed on with all vigour', but accepted that this would depend upon the technical findings of Bottomley's ad hoc committee.[23]

PROGRESS MEETINGS

That body produced its first report on 18 March 1943, identifying Trondheim, Narvik and Alten Fjord as the normal Norwegian anchorages for German heavy units; Kiel and Gdynia their repair ports. Of these only Kiel and Trondheim were within range of Mosquitoes from the United Kingdom. Noting that any attack on the German dams must be delivered before 26 May, the committee assumed that Highball would be used 'at about the same time'. Two days later, Bottomley received a sharp reminder from the CAS that his committee had been appointed 'to accelerate development and trials and to get the weapon into action as soon as possible'. It should not stray into operational matters which were the province of the Air and Naval staffs. The next day, 21 March, an Air Staff paper about an attack on 'enemy capital ships in Norwegian waters' pointed to the 'formidable' defences which would surround any of them at anchor. Carrying two Highballs, a Mosquito's range would be reduced to 1,140 mi, allowing Trondheim to be attacked from Sumburgh. Narvik and Alten Fjord were out of return range, 'but under most favourable conditions might allow of aircraft reaching Russian territory'. An alternative would be to 'abandon' (presumably bale out of) the aircraft over Sweden. A memorandum by Bottomley, dated 24 March, noted that a Mosquito unit for the purposes of attacking *Tirpitz* would be formed shortly and that

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Bomber Command had agreed to supply ‘an adequate number of trained crews and maintenance personnel’ to assist with its creation. Meanwhile, on 22 March, exercising overall professional responsibility for targets in the area of the enemy shoreline, Coastal Command took over the task of attacking *Tirpitz*. [24]

If dropped from 100 ft at 300 mph, the range would be 1,250 yds and its ‘primary purpose’ was to attack capital ships

Another meeting of Bottomley’s committee on 25 March heard that 30 ‘Highball bombs’ had been delivered from the factory and filling was about to start. Fifty of the total ordered would be inert-filled for trials, one go to Vickers-Armstrongs for spinning tests. Four days later, from the Air Ministry Air Vice-Marshal JC Slessor complained to Bottomley about expanding proposals to attack capital ships in Norway, *Graf Zeppelin* in Gydnia and the Italian fleet, which would require 2 1/2 dedicated squadrons and ‘wreck’ 2 Group operations. At best crews would need two months’ special training and then success could not be guaranteed. ‘It isn’t worth just taking any old squadron with its ration of P.O. Prunes and re-equipping it with Mosquitoes and arming it with this potentially decisive weapon’.[25]

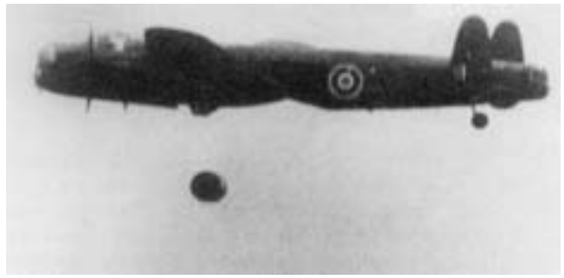
Clearly making use of Slessor’s comments, on 1 April Bottomley submitted a lengthy memo to the COS Committee in response to a minute of 27 March asking for analysis of the means required ‘to attack the German capital ships at present in Bogen Fiord (Narvik)’. After consulting Coastal Command, Bottomley believed that a squadron of 20 aircraft would be needed, but if the further idea of attacking Italian warships were pursued, a second Highball squadron should be planned. He held that the last week in June was the earliest date for an attack on *Tirpitz*. The following day, his ad hoc committee produced its second report, which held that 16 modified Mosquitoes would be operational by 8 May, the remaining 14 be ready at approximately four per week. This would allow 20 for *Tirpitz*, 10 for *Graf Zeppelin*. Yet another ‘progress’ meeting at the MAP on Saturday 3 April learnt that the first modified Mosquito would still leave Vickers-Armstrongs on 8 April, VHF be fitted on arrival at the operational unit and up to 500 Highballs, for inert and live use were now being considered.[26]

The Chiefs of Staff agreed on 7 April that Trondheim would be the most northerly location at which Highball could be used, and five days afterwards the Air Ministry sent the RAF delegation (RAF DEL) in Washington outline details of ‘Weapon A’ (Highball) and ‘Weapon B’ (Upkeep) with a warning that in ‘personally’ informing each member of the American Joint Chiefs of Staff ‘the absolute need for security’ be emphasised. Highball was 960 lb in weight including a 600 lb charge, with a 35in-diameter. If dropped from 100 ft at 300 mph, the range would be 1,250 yds and its ‘primary purpose’ was to attack capital ships. ‘The bomb is suspended in the bomb bay and given a backward spin of about 500 revs per minute before dropping. This initial spin lengthens initial flight before impact on water, increases the angle of incidence of ricochet and serves to counter the action of the water drag and the tendency of the sphere to roll under water. Investigations so far show that the spherical bomb will not be checked by booms carrying protective torpedo netting’.[27]

A progress meeting at the MAP on 14 April received more details about delivery by Air Transport Auxiliary pilots of Mosquitoes, for which additional wing tanks were on order. Next day, RAF DEL reported that General HH Arnold, Commanding-General of the US Army Air Forces, had displayed great interest in Highball and that it was 'very important that we get the plans for this device to the United States at the earliest possible date'. On 17 April, Bottomley's committee issued its third report, concentrating on the task of securing suitable drop tanks for the Mosquito to stretch its range by 200 miles 'under normal operational conditions'. The fourth report on 30 April confirmed that suitable, extra 42-gallon drop tanks had been made available and would be fitted to five aircraft a week. Ahead of schedule, 20 Mosquitoes were expected to be delivered by 15 May. Worryingly, though, that day Coastal Command recorded Vickers-Armstrong's observation that the Mosquito tended 'to sag' with an extra fuselage tank.[28]

HIGHBALL TRIALS

Highball trials at Reculver Bay



In fact, Highball dropping trials did not go well once a more specialised series, quite distinct from Upkeep, commenced in April. On 20 February 1943, Lockspeiser had warned Wallis of discussions between the MAP and Admiralty about 'the question of trials which will be necessary with the smaller version of your little toy to bring it into operational use as quickly as possible'. The final set of trials at Chesil Beach took place 8-9 March, but these exclusively concerned Upkeep. Although similar trials with a 46in-sphere were planned for eight days later, on 13 March the range was declared 'inadequate'. Due to lowering of the water level in spring and summer, even in ideal weather the Chesil Beach range would now be suitable on only three days a fortnight. Other locations were examined, including Shoeburyness, Orfordness and Port Madoc, but on 20 March the bombing range north of Reculver on the Kent coast was chosen and arrangements made to carry out separate Upkeep and Highball trials there from RAF Manston. It was, the MAP concluded, 'the best bet … for security purposes'. On 18 March, Bottomley's committee noted that the first Mosquito would soon be ready to commence the following programme: 'Trials to confirm the trajectory, range and dropping height will be undertaken immediately on delivery, these being followed by others against a target ship'. Next day, 19 March, ACAS (Ops) agreed that the first Reculver trial would be on 10 April, though during a meeting at the Air Ministry on 25 March this was put back to 11 April. The training and testing schedule now became clearer. 'Technical trials' would be at Reculver, and some operational crews would be trained there too in tandem with others at RAF Skitten in Scotland. The operational station for the special Mosquito squadron destined to attack *Tirpitz* would be RAF Sumburgh.[29]

By arrangement with Renouf, the former French warship Courbet would become the static target in a Scottish loch, and Mosquitoes practising against her would be based at RAF Turnberry. A meeting on 9 April recorded that inert-filled Highballs were to go to Turnberry, where Vickers-Armstrong would provide mechanics for aircraft maintenance. The previous day, a programme for Highball trials at Reculver was drawn up, aiming 'to determine the optimum range and trajectory of the 35in-sphere'. To establish the 'highest possible speed' commensurate with safety, the aircraft would dive up to 400 mph 'and parallel trials should be carried out at the maximum ground level speed without diving'. The sphere would be spun at different speeds up to 1,000 rpm, and modifications would be made to the sphere in the light of results.[30]

Static tests were conducted at Manston on 11 and 12 April, the inert filling being 'a compost of synthetic resin and sawdust'. On Tuesday 13 April Sqn Ldr C F Rose flying west to east dropped two Highballs at 0717 and 0720, both from 100 ft at 360 mph. One spun at 700, the other 1,000 rpm. As at Chesil Beach, the trials were filmed from a camera on shore, but for later ones at Reculver a second camera was positioned ahead on a spit of land below the old Norman church. Wallis recorded the outcome of Rose's efforts. 'In both cases the wood casing broke up on impact, but in the second run about 3/4 of the casing remained intact and gradually separated from the cylinder the latter apparently coming out axially. Casing and cylinder then continued flight together for a short distance, the casing striking the water and making a slight bounce. During the whole of this period, the undamaged portion of casing maintained its correct size and shape, so far as can be seen from the film'. On 16 April, three more Highballs (two from a Mosquito, one the Wellington) were dropped with similar results. Following the first failure, the metal bands restraining the outer wooden casing had been tightened. More drops on Sunday 18 April were unsuccessful, though: 'The cylinder also failed to run due to a section (or slice) of the wooden casing being cut off on impact'. Further adjustments were then put in hand with an 18in-wide metal band being fitted over the wooden casing. However, on 20 April, Air Marshal RHM Saundby at Bomber Command pronounced the trials so far 'disappointing'. Three days later, privately Wallis admitted that, although the tests at Porton had been 'successful', those from Manston were 'inconclusive'.[31]

The fourth trial at Reculver commenced on Wednesday 28 April, watched by Wallis and Renouf. At 7.30pm, flying parallel to the coast, Rose dropped the first steel-cased ('armoured with steel plates $^{5}/_{32}$ in-thick') Highball, spinning at 700 rpm, from 130 ft at 350 mph into a 15 mph head wind. Wallis recorded, despite a rough sea, 'a very successful drop, the store running well', '4-5 bounces' over 'about 1,000 yds'. The Highball was empty and therefore floated, but was 'slightly damaged'. The following morning Rose released a second, empty steel-cased Highball, spinning at 920 rpm, from 60 ft at 370 mph into a 5mph head wind. Again it bounced '4-5' times and travelled '1-2,000 yds'. 'Very successful. Casing quite undamaged', Wallis wrote. On 30 April, in flat calm Rose dropped two Highballs encased in wood (ash) not steel, spinning at 700 rpm from 60 ft at 360 mph. The first travelled 1,600 yds and bounced 12 times. Wallis professed only 'academic interest' in the performance, seeking merely to gain information about 'impact forces'. He had still not decided on the final composition of Highball, proposing to repeat the trial with steel plates. If successful, he would 'put on order' $^{5}/_{32}$ in-thickness plates for the remainder. He also considered 'plastic

mould casings' instead of wood. In its fourth report, issued on 30 April, Bottomley's committee noted that the two drops on 28 and 29 April, with a 'metal sheet over the wooden casing', had been 'successful'.[32]

Rose dropped two steel-cased Highballs on Sunday 2 May at 1230 in rough seas from 60 ft, one at 370 mph and 700 rpm, the other 380 mph and 520 rpm. In spite of an 'excellent performance' in terms of distance travelled, on recovery both were dented. Nevertheless, Wallis now opted for steel covering of the wooden casing. In a meeting at Manston on 2 May, chaired by Air Cdre B McEntegart, Wallis explained that 30 sets of steel bands had been ordered by Vickers-Armstrong from Messrs Sankeys, four of which had been delivered to Crayford on 1 May, thus revealing that Wallis's decision had been taken (and presumably officially approved) after the 29 April trial. The 'bands' were to be fitted to inert-filled Highballs by Vickers-Armstrongs and then sent to RAF Turnberry for trials against *Courbet*. Other inert-filled stores would be modified at Crayford and despatched to Manston for use at Reculver. The meeting, however, agreed that modifications to the full number of 250 Highballs would be postponed till after the anti-ship trials. As to those already delivered to RAF stations, 'all that would be required of the Service to modify existing stores would be to tighten up the bands, screw on steel plates provided and treat these plates and the exposed woodwork with a good quality paint'. They could then be kept in the open under a tarpaulin.[33]

Simultaneous operations against Tirpitz and the German dams remained theoretically feasible

Unlike Upkeep which had been stripped to its bare, internal cylinder, Highball now comprised a central cylinder for an HE charge or inert filling, and packing outside of that held in position by wooden slats. In turn, the slats were surrounded by metal bands (like a rainwater butt) and further encased by two, 18in-wide, $^{5}/_{32}$ in-thick steel plates. On 6 May, a meeting at the Air Ministry concluded that security problems would be 'reduced', with Upkeep now being cylindrical, Highball spherical with flattened poles. Meanwhile, on 5 May, another meeting at the MAP had reviewed the Reculver trials, considered the failure of the wood-covered Highball, looked at the option of a moulded plastic replacement and confirmed the Manston decision of 2 May in favour of steel plates. Highballs, modified in this way, should be ready for balancing at Turnberry on 9 May. Trials from there would aim to secure information about the ability to withstand impact with a target and, administratively, would be conducted by the Marine Aircraft Experimental Establishment (MAEE) at RAF Helensburgh. Two Mosquitoes would go to Turnberry for the preliminary trials.[34]

Simultaneous operations against *Tirpitz* and the German dams remained theoretically feasible. This article is concluded in the next issue.

NOTES

Explanation. Sir Barnes Wallis's papers contain a wide range of personal and official correspondence as well as copies of the minutes of meetings connected with his various projects, including Highball. When consulted at his residence in Effingham, the papers were not catalogued. They have since been dispersed mainly to the Science Museum, RAF Museum Hendon and Churchill College Cambridge. Some remain with the family, a few are in the possession of the Barnes Wallis Memorial Trust at the Yorkshire Air Museum, Elvington. Reference to the 'Wallis Papers' is made, therefore, only to identify the source of information and quotations.

Part 1

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25. Bottomley Committee, PRO Air 14/840; Slessor, PRO Air 15/442.
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27. PRO Air 8/1834.
28. MAP meeting, PRO Air 14/840; Bottomley Committee, PRO Air 8/1237; Coastal Command, PRO Air 15/442.
29. Lockspeiser to Wallis, Wallis Papers; trials details, PRO AVIA 15/3934; Bottomley Committee, PRO Air 14/840 & PRO Air 20/2619; 19 March 1943, Air 8/1234; 25 March, PRO Air 14/840.
30. Wallis Papers.

31. 17 Apr & 30 1943, Bottomley's 3rd & 4th reports and Saundby's conclusion, PRO Air 8/1237; Wallis comment, Wallis Papers.
32. Fourth trial, Wallis Papers; Bottomley, PRO Air 8/1237.
33. Wallis Papers.
34. Wallis Papers; MAP meeting, PRO Air 15/442.