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SELECTED ABBREVIATIONS

AAA	Anti-Aircraft Artillery
A&AEE	Aircraft and Armament Experimental Establishment
ADEN	Armament Development Establishment at Enfield
AFME	(HQ) Air Forces Middle East
ALG	Advanced Landing Ground
AUS(F)	Assistant Under-Secretary of State (Finance)
BIB	Baby Incendiary Bomb
BSA	Birmingham Small Arms (Company)
CRV	Canadian Rocket Vehicle
CS (gas)	2-chlorobenzalmalononitrile but identified by the initials of the chemists Corson and Stoughton
DEFA	*Direction des Etudes et Fabrication d'Armament*
ERA	Explosive Reactive Armour
FFAR	Folding-Fin Air Rocket
HEI	High Explosive Incendiary
HE MC	High Explosive, Medium Capacity (bomb)
HV	High Velocity
IAF	Indian Air Force
IFF	Identification Friend or Foe
LV	Low Velocity
MATRA	*Mécanique Avion Traction*
MG	machine gun
OR	Operational Requirements
ORS	Operational Research Section
OTR	Number of aircraft required Over The Target to achieve a specified level of damage
RAFME	(HQ) Royal Air Force Middle East
RL	Royal Laboratory
SEAC	South East Asia Command
SNEB	*Societé Nouvelle des Etablissements Brandt*
SOAF	Sultan of Oman's Air Force
TNA	The National Archives
UOR	Urgent Operational Requirement
VLR	Very Long Range

UNGUIDED WEAPONS

RAF MUSEUM, HENDON, 22 OCTOBER 2008

WELCOME ADDRESS BY THE SOCIETY'S CHAIRMAN

Air Vice-Marshal Nigel Baldwin CB CBE FRAeS

Ladies and Gentlemen - good morning

Welcome to our autumn seminar. Before I introduce our Chairman for the day, let me give my usual thanks to Dr Michael Fopp and his team here at the Museum for allowing us to use such excellent facilities. It is a double 'thank you' to Michael on this occasion because, as you will see as the day unfolds, in planning the day we have relied more than usual on his staff. The first three speakers this morning are all employed here at the Museum.

Our Chairman for the day – seen here – he's the tall one in the flying suit – is Air Marshal Sir John Kemball who has much experience of dropping things from the sky onto the ground: Hunters, and F-4C Phantoms (indeed he was the first RAF pilot to achieve 1000 hours on the Phantom). He then commanded a Jaguar squadron and then RAF Laarbruch (taking over from AVM John Price who I am delighted to see in the audience). He was then Commandant of the Central Flying School, Commander of British Forces in the Falkland Islands, and an Assistant Chief of the Defence Staff in the MOD. His final tour was as Deputy Commander-in-Chief at HQ Strike Command – not least during the Gulf War – so we could not have a more highly qualified man to lead us through the day.

Sir John, you have control

OPENING ADDRESS

Air Marshal Sir John Kemball KCB CBE BA

Thank you Nigel.

Ladies and Gentlemen, good morning. I am very pleased to be on the podium for this seminar today. As Nigel has briefed you, I have had considerable practical experience of delivering unguided weapons, from a variety of aircraft, and I, therefore, have a great interest in the topics that are going to be covered in our programme. So, without further delay, I will introduce our first speaker – AVM Peter Dye.

RFC BOMBS & BOMBING 1912-1918

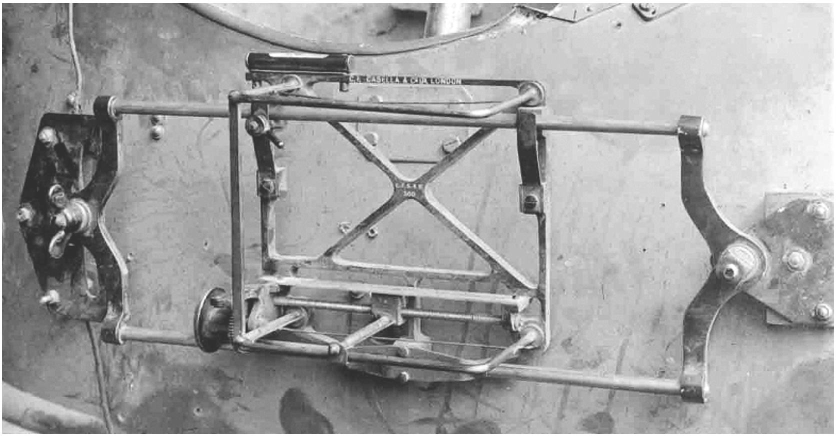
AVM Peter Dye

As an Engineering Officer, Peter Dye spent 35 years in the RAF, 20 of them supporting frontline operations, notably those involving the Jaguar and Tornado. Among his later staff appointments he was responsible, within the Defence Aviation Repair Agency, for the overhaul of all RAF, RN and Army fixed wing and rotary aircraft. As the third generation of his family to serve in the RAF, he has a passion for its people and traditions. He has written widely on aspects of the history of the Service and led the campaign to erect, at St Omer, a memorial to the British Air Services of WW I. Since April 2008 he has been the RAF Museum's Director of Collections.

As you will have gathered from the programme, Stuart Hadaway, Nina Burls and I have the unenviable task of describing the development of RAF bombs over some 30 years – including two world wars. If we are to keep to time we will have to skim parts of the story, and to avoid much of the general background. So please forgive us if not every aspect of this important topic is covered in detail.

I thought I would start, however, by showing you a short film clip made in about May 1917 of No 20 Sqn preparing for a bombing mission. (*The aircraft were FE2ds and the film featured sequences showing bombs being installed under the wings and fitted with fuses.* **Ed**) We know the approximate date because one of the aircraft depicted was shot down by a German fighter later that month. It is interesting because it shows how far the RFC had come in developing its bombs, and its bombing techniques, since the beginning of the war – certainly a far cry from simply throwing explosives over the side of the cockpit and hoping that they might land where you wanted and explode when you wanted![1]

I mention bombing techniques because it is impossible to discuss the development of aerial bombs without giving some consideration to the ways in which they were loaded, carried and dropped. Bombing operations of the sort we have just seen were just not possible when



The CFS Mk 4 bomb sight.

the RFC first deployed to France in August 1914. Adequate quantities of reliable bombs with sufficient explosive power were simply not available. There were no safe and effective methods of carrying them – such bomb carriers as existed were generally jury-rigged – and, until higher performance aircraft such as the FE2d were introduced, with their 250 hp Rolls-Royce engine, bomb loads remained modest – even when the observer was left behind.[2] Just as importantly, there were no reliable or accurate bomb sights until the introduction of the CFS Mk 4, invented by 2/Lt (later Colonel) Bourdillion when working with the CFS Experimental Flight in early 1915. Ultimately, nearly 4,000 CFS bomb sights would be produced.[3]

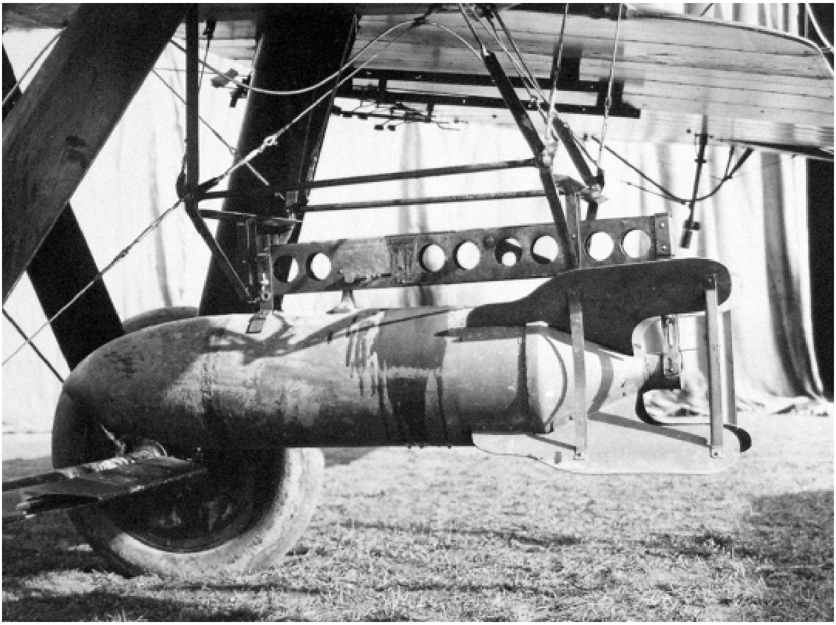
Pre-war interest in aerial bombs had largely been confined to the RNAS; the Military Wing of the RFC concentrated on reconnaissance and army co-operation duties. It must be said that in the development of bombing techniques, as in many other areas, the Naval Wing demonstrated a much greater appetite for innovation than the RFC.[4] By 1913, they had conducted a number of ground-breaking experiments and successfully demonstrated that bombs could be safely dropped from aircraft.[5] These trials had also revealed the importance of developing accurate sighting devices that would automatically cater for the speed and height of the dropping aircraft, as well as the wind speed and the bomb's aerodynamic characteristics.

The RNAS led the way in making bombing from aircraft a practical proposition, including the development of release gears and the introduction of a range of aerial bombs, notably the light case 100 lb bomb (designed for blast effective against submarines) produced by the Royal Laboratory (RL) that contained 60 lbs of explosive. A heavy-cased version was also developed, the RL 112 lb Mk 1, containing just 35 lb of high explosive but better suited for penetration or fragmentation effect.[6] These two weapons were supplemented by the smaller Hales 20-pounder, containing just 4.5 lbs of explosive, intended to be dropped on airships.[7]

Notwithstanding these pioneering efforts, at the outbreak of war the total supply of aerial bombs consisted of twenty-six 20-pounders, lying in store at RNAS Eastchurch.[8] Efforts to increase these numbers were not immediately successful, less than 700 high explosive bombs being produced by the end of the year. On the other hand, some 1,300 incendiary bombs were produced over the same period to a design developed by Flt Lt Finch-Noyes. The Petrol Bomb (Large) Mk 1, which was also adopted by the RFC, comprised a light casing holding a little over two gallons of petrol, together with a detonator and igniter. As primitive as this weapon may seem, it was substantially more effective than the *flechettes* and rifle grenades, that otherwise supplemented the meagre supply of aerial bombs in the first months of the war.[9]

During 1915, and well into 1916, these four bomb types represented the bulk of the ordnance dropped by the RFC and RNAS. In the Battle of the Somme, the RFC expended over 17,000 bombs, largely 20 lb Hales and 100 lb and 112 lb RL bombs. Total weekly production had now reached 1,900 bombs and would rise still further to 5,900 bombs by October 1917.[10]

As the war progressed both the RNAS and RFC introduced new and improved bombs, the latter in conjunction with private manufacturers and the Royal Aircraft Factory. This included, from the end of 1916 onwards: the RFC 230 lb bomb; the famous (at least to fans of Biggles) 25 lb Cooper bomb (replacing the Hales 20 lb bomb) fitted to a wide range of aircraft, including fighters;[11] the 520 lb light-cased RL bomb and the 550 lb heavy-cased RL bomb.[12] Other experimental bombs included the 40 lb phosphorous and 336 lb ‘Sweeper’ bombs. The former was designed to spread a shower of burning phosphorous over airships or balloons while the ‘Sweeper’

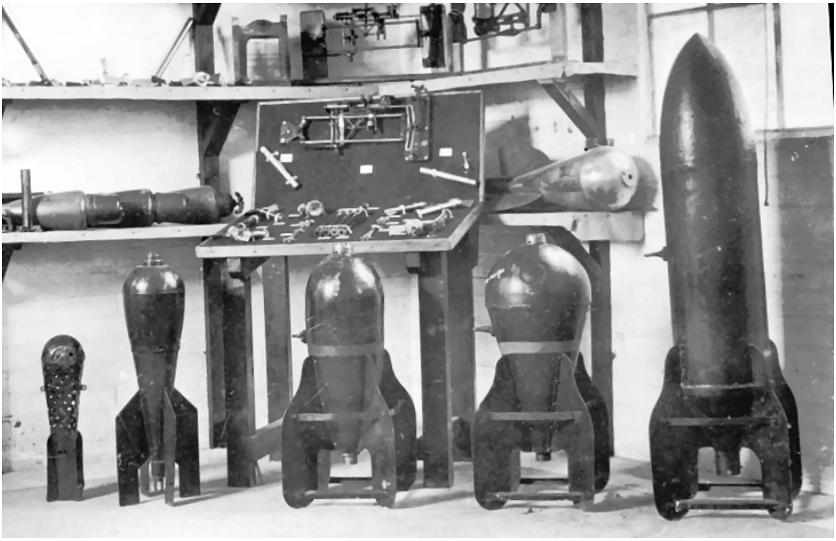


Skeleton carrier with a 230 lb bomb on an FE2d.

comprised manganese steel bars surrounding an explosive charge and was intended to damage industrial machinery, buildings and railway stock. Neither weapon proved particularly successful. The proliferation of bomb types led to efforts at standardisation from May 1917 onwards, although this did not slow the introduction of new types or of improved fuses and detonators.

With the production of heavier bombs came the development of more efficient and lighter bomb carriers and release gear. From 1916, the RFC standardised on the Skeleton type of carrier, built in three sizes to carry the 112 lb, 230 lb and 550 lb bombs. The Skeleton carrier offered considerably less resistance than previous types and could be readily modified to carry flares and lighter bombs as required. For the largest aircraft, such as the Handley Page O/400, internal stowage was developed, including the use of vertical cells to carry large number of smaller bombs and incendiaries.

In 1917, the RFC dropped an average of 58 tons of bombs each month but this rose to 394 tons per month by early 1918. In one week



From the left, an incendiary and 65 lb RL, 100 lb RL, 112 lb RL and 230 lb RFC bombs.

of March 1918, the number of bombs expended approached the total dropped in the entire Battle of the Somme, comprising:

25 lb Cooper	12,000
112 lb RL	2,000
230 lb RFC	120

Production was rapidly increased to meet these higher rates of expenditure and by the Armistice orders were in hand to supply:

25 lb Cooper	20,000 weekly
112 lb RL	5,000 weekly
230 lb RFC	750 weekly
520 lb RL	250 weekly
550 lb RL	500 weekly

The greatly improved performance of bombers such as the Handley Page O/400 (capable of carrying fourteen 112-pounders) and the Handley Page V/1500 with a bomb load of over 6,000 lbs, was matched by the development of even heavier bombs – including the 1,650 lb SN[13] – and the introduction of the Baby Incendiary Bomb

(BIB). The latter could be dropped from containers holding either 198 or 272 bombs. Each bomb ejected a burning thermite cartridge that burned fiercely. Used in conjunction with high explosive bombs they offered the prospect of creating extensive and sustained fires in built-up areas and factories.

The strategic bombing campaign undertaken by the Independent Force, in conjunction with the aircraft of 41 Wing and VIII Brigade, over the last thirteen months of the war, saw some 665 tons of bombs dropped on industrial centres, railways and airfields. The majority of these were 112 lb RL bombs and BIBs, although the total did include eleven 1,650 lb SN and fifty-four 550 lb RL bombs.

Subsequent Air Ministry reports, assessing the effectiveness of the Independent Force's operations, compiled in 1919 indicated that these bombs performed with varying effectiveness. The 112 lb and 230 lb bombs were found to have been generally satisfactory, although their blast effects were localised. The use of delayed action fuses, intended to allow the bomb to penetrate the target before exploding had not proved successful. Less effective still, was the 25 lb Cooper bomb which was said to have been useless against buildings, although it was conceded that it might have been more effective against soft targets.[14] More worrying, however, was the revelation that a great many bombs had failed to detonate. In most raids, a quarter, and sometimes as much as two thirds, had failed to explode.[15]

In summarising these findings it was argued that even heavier bombs, with greater penetrating power were required – larger than the 1,650 lb SN. It was also noted that bomb aiming was often extremely poor, even when there were no enemy fighters or AA fire.

Overall, it was concluded that the RAF's aerial bombs could not be said to have been more than moderately effective against railways, blast furnaces, aerodromes and industrial centres – the very targets that the Independent Force was intended to destroy.[16] I might add that a very similar target set would feature in the Combined Strategic Bombing Offensive of WW II.

I will end my brief paper at this point and leave Stuart to discuss how effective the RAF proved to be in addressing these problems during the inter-war years.

Notes:

[1] In his diary, Maurice Baring describes some early bomb dropping experiments conducted by Major Herbert Musgrave in September 1914, adding that 'one bomb was dropped, and it exploded, but not exactly where nor how it was expected to explode.' Baring, M; *Flying Corps Headquarters 1914-1918* (London: Bell & Sons, 1920) p44.

[2] In 1914, the RNAS, in their early raids on Zeppelin sheds in Germany, flew without observers and carried just four 20lb bombs. By 1916, the FE2b employed in the night bombing role, carried an observer and a 350 lb payload, made up of a combination of 20 lb, 112 lb and 230 lb HE bombs, as well as flares.

[3] The CFS bomb sight comprised a metal frame, mounted on the right-hand-side of the fuselage, with both a height and time scale, together with a levelling device. Using the foresight and backsight, the pilot was able to determine exactly when to drop his bombs. By 1918, it had largely been replaced by the High Altitude Drift sight for high level bombing and the CFS Mk 7 for low-level bombing. Colonel Bourdillion was awarded £500 after the war in recognition of the importance of his invention. TNA AIR1/22/15/1/111.

[4] For example, in 1912, the Admiralty's Air Department appointed Lt R H Clark-Hall to the RNAS specialising in armament duties and, in particular, bombing.

[5] Conducted at Eastchurch by Cdr C R Samson in early 1912.

[6] At the start of the war, TNT provided the explosive filling for aerial bombs but over time it was replaced by Amatol.

[7] Designed by Mr Marten Hale in 1913 and manufactured by the Powder Company at Faversham, Kent. The same inventor had been responsible for the Hale Rifle Grenade, patented in 1908.

[8] These were hurriedly supplemented by a large number of 6-inch shells which were fitted with tail vanes. Raleigh, *The War in the Air* (Clarendon Press: Oxford, 1922) p272.

[9] Ministry of Munitions, *Official History of the Ministry of Munitions* (HMSO, 1918-1924), Vol 12, Part 2, pp1-31.

[10] *Ibid*, p29.

[11] It was later redesignated as a 20 lb bomb.

[12] Although the 230 lb bomb replaced the 112 lb RL bomb as the RFC's standard heavy bomb, it continued to be used in large quantities until the Armistice. The Hales 20 lb bomb ceased to be employed on the Western Front after July 1917, once existing stocks had been exhausted.

[13] A thin-cased bomb containing approximately 800 lb of explosive. The 'SN' reportedly stood for Essen.

[14] It had, of course, proved extremely successful against massed troops and enemy supply columns during the German March Offensive.

[15] Rennles, K; *Independent Force* (London: Grub Street, 2002) p203.

[16] *RAF Museum B401*, Independent Force Report on Bombs, March 1919.

THE DEVELOPMENT OF RAF BOMBS, 1919-1939

Stuart Hadaway

Stuart Hadaway read History at Christchurch College, Canterbury 1997-2000, subsequently adding a Postgraduate Diploma in Museum Studies at the University of Leicester. He spent two years with the Museum of the Worcestershire Soldier before taking up his present appointment with the RAF Museum as Assistant Curator of its Department of Research & Information Services (DoRIS) in April 2004. He has recently published a book on the tracing of RAF aircrew who were posted missing during WW II.

The fifteen years that followed the war saw little real development in most areas of bomb development in the Royal Air Force, and indeed with hindsight it could be said there was some regression. There are various reasons for this; firstly, the inter-war years were lean, to say the least, and all of Britain's armed forces suffered from cuts and neglect. The money to invest in new equipment and its development was very tight. This had a knock-on effect in that aircraft development was also slow, and so the weight of bombs in particular, but also of ancillary equipment such as bomb carriers and sights, were all limited by the performance of the aircraft in use. Another was the lack of experience in the RAF and the Air Ministry, partly due to deliberate policy, which we will come back to later, and partly simply because air dropped ordnance was a very new form of weaponry, and one about which very little was really known. Similarly, aviation itself, and aerial warfare, were very new, and as yet no one was quite sure what exactly the role of an independent air force could or should be and, as a result, it was difficult to predict what tools this new trade would require.

The early inter-war years saw an attempt to essentially standardise what types of bombs were available. A wide range had been inherited from the RFC and RNAS, and an emphasis seems to have been placed on establishing standard types of bombs. Perhaps the backbone of the range would be the General Purpose, or GP, bombs. These were exactly that, high explosive bombs for general purpose use. They had to be proof against various eventualities, including penetrating the roofs of buildings, and so had thick cases. This led to a very low Charge:Weight Ratio, ie actual explosive content, of around 23-25%, making the resulting explosions small. The heavy casing meant that if the bomb was dropped on open or soft ground they tended to bury themselves, making large craters but doing little other damage. The specification for these bombs was put out in 1922, calling for 50, 120, 250 and 500lb bombs, and although the 50lb design was later cancelled, the other three types went into production in 1925 – despite a complete lack of any live drop testing.

This lack of proper testing would be the norm in the 1920s and early '30s. Bombs were submitted to few serious tests, and even then the bomb cases were usually fired from an artillery piece rather than dropped from an aircraft. This obviously left a lot to be desired. For one thing, the cases (or models of them) had to be modified to fit the barrel of the gun, which affected the aerodynamics of the bombs. For another, the fired casings tended to hit the targets on the ranges at right angles, or close to them, which did not always reflect the realities of how a bomb would actually hit a target. Quite often these tests would also be purely kinetic; they would not include any actual detonation of the bomb involved. To make matters worse, cuts and budgets also severely limited the live training of crews, so little information could be gathered from this source, either.

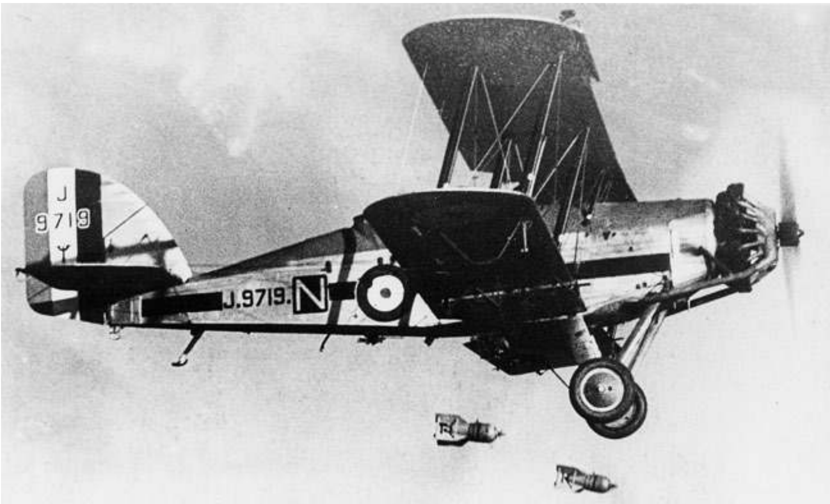
The GP range certainly had their flaws, but overall they suited the needs of the RAF at the time. Although in most years the grand finale of the Hendon Pageant would be the destruction by bombing of an enemy town or factory or port, the RAF was actually very unlikely to have to attack such a substantial target. The bulk of the RAF's work in the 1920s was colonial policing, and for this the design flaws were not so important. Targets were for the most part less solid, and destruction of property was not necessarily the aim of such operations. Take for example a series of raids carried out in Iraq in 1923; the various targeted villages were later visited by Flt Lt Horace Bowen, who reported on the damage done.[1] Although the bulk of the bombs used had been of WW I vintage, the report gives good examples of the

[1] RAF Museum AC73/19/49.

An armed Vernon of No 45 Sqn in Iraq circa 1924. Beneath the lower wing a 230 lb bomb is hung behind each undercarriage unit; there is a 520 pounder under the port inner wing and a pair of 112 pounders under the starboard inner wing. A container for BIBs is mounted under the starboard outer wing balanced by at least two 20 lb bombs on the port side. The five objects under the nose are spotlights to assist with night flying.

damage that the GP bomb would cause:

- No 2 target saw two 20 lb bombs dropped within the compound of a fort, and several more outside within 15 to 20 yards of the mud walls. The damage, Bowen reports, was negligible.
- No 4 target saw one large bomb dropped five yards from a substantial building. It made a crater 15 ft wide and 5 ft deep, yet had caused no damage at all to the walls of the building, while several more bombs between 30 and 50 yards away achieved the deaths of one villager, six cows and four donkeys.
- No 5 target, a village, had received at least three 500 lb bombs. One had left a crater 12 ft deep and 20 ft wide five yards from one building, cracking the wall. Overall, apart from blowing in



As in Iraq, so in India – a Wapiti of No 60 Sqn releasing a pair of WW I vintage 112 lb bombs somewhere over the North-West Frontier sometime in the 1930s.

> some windows and doors, there was little material damage, but ten people, twelve cows, six donkeys, two horses and about 200 sheep had been killed.

The list goes on through nearly twenty different villages, but these three suffice to show the problems that resulted from the limited blast effect of GP bombs, especially as, with their thick casing, they could bury themselves deep in the earth before exploding. However, some of this can be explained by the mud walls of the villages which were inherently flexible and shock-absorbent. On the other hand, Bowen reports that most of the villages were deserted; the shock of the bombings, carried out at night, had shattered the morale of the villagers. The hostile elements had been successfully dispersed, although the attacks had obviously also caused casualties among the population and their livestock. For more than half of our period, this was all that was required from this range of bombs, and they satisfactorily achieved it.

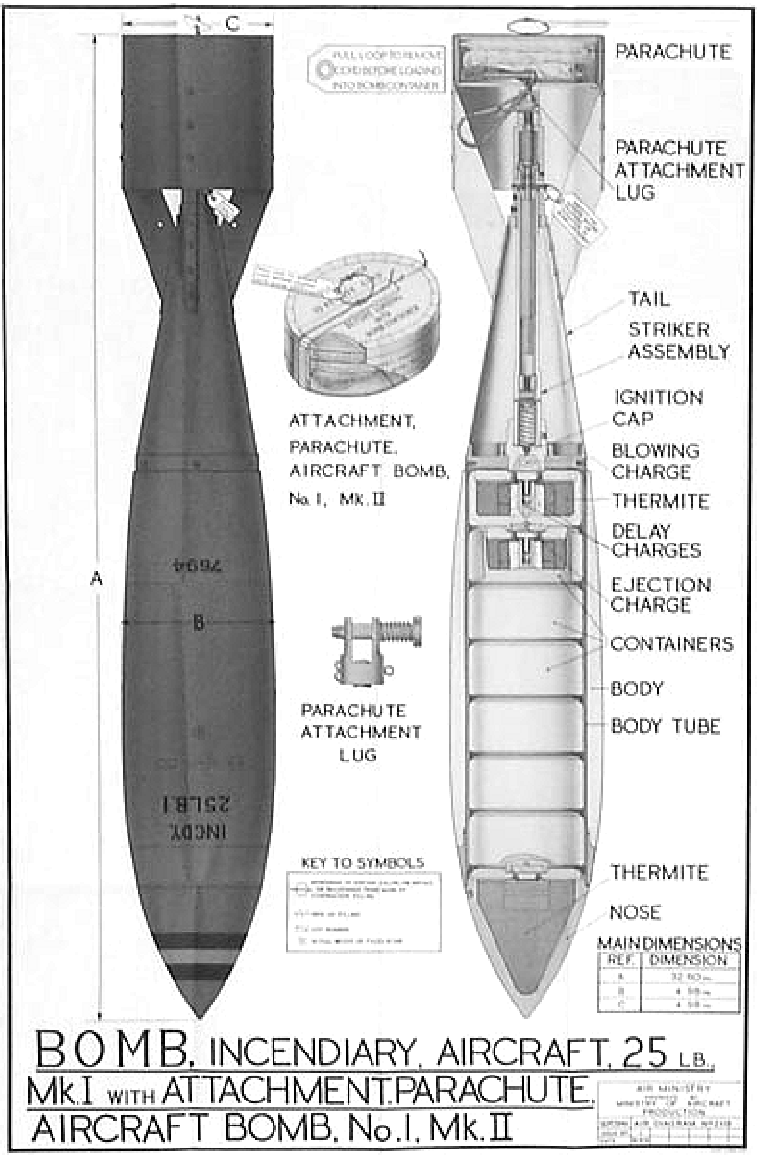
Where more destruction was required, incendiaries could be used. Large parts of villages that were targets Nos 3, 8 and 17 (in Bowen's

Report) and the whole of villages Nos 7 and 14 had been destroyed by fires started by incendiary bombs. These were WW I vintage designs, the so-called Baby Incendiary Bombs (BIB). No new Air Ministry requirement was put out for incendiaries until 1931, when a 20 lb (later increased to 25 lb) bomb specification was issued. A design was selected and put into production; entering service in 1937, it became one of the principle incendiary types used during the Second World War. By April 1939 some two-thirds of a million had been made – and at this point the Air Ministry finally decided actually to test them! These tests would demonstrate that the type was flawed in several ways, and numerous modifications over the next two years (leading to a 5 lb weight gain) had to be made for it to become a serviceable weapon.

In 1933 the Air Ministry had held open trials to find a new, lighter incendiary, and a specification was issued for a second type, the 4 lb model. Included in the specifications were exact size requirements, so that the new bomb would fit in the existing bomb containers already in use for the BIBs. The new 4 lb variant was, for once, properly tested, with numerous air drops to check trajectories and drift, although models fired from guns were still used to test penetration. The 4 lb incendiary proved to be effective, and would become one of the few success stories of the inter-war period.

The other main types of bombs concentrated on during this period were for maritime use, either anti-submarine or armour-piercing anti-ship bombs. The armour piercing bombs were, necessarily, thick cased. Three types were developed from 1921: 250, 500 and 2,000 lb, with, respectively, Charge:Weight Ratios of 17%, 18% and 8.8%. Naturally, these led to small explosions. The only test of any of these bombs saw one detonated below-decks on the target-ship HMS *Marlborough*. The damage was negligible. Also of note is that the bomb was placed there to be detonated, and not dropped. Indeed, none of these bombs were dropped during tests, and the only assessment of just how armour-piercing these armour-piercing bombs really were, was by firing them from guns at sheets of metal-plate.

The development of the anti-submarine bombs was even more slapdash. Three types were called for in 1924/25: 100, 250 and 500 lb. All were arbitrarily designed to a Charge:Weight Ratio of 50%. For these, air dropping tests were actually carried out, with five of the



Air Diagram of 25lb incendiary bomb.

100 lb bombs dropped simply to see if they would explode underwater or not. Four did, and this was judged satisfactory, although no studies were made as to how the bombs behaved in flight or underwater, ie trajectories or rate of descent, which might have helped with aiming. A sixth bomb was exploded underwater to asses the pattern of the explosion, although not against a representative target, which might have helped to assess its potential to inflict damage.

After this very scant testing, the bombs entered service in 1928, although it soon became apparent that the tails were unsuitable, and these were later replaced. Naturally, this upset the balance of the bombs, and further modifications were then needed. Finally, in 1934, with the Air Ministry becoming increasingly concerned about a possible European war, the entire range was tested and it was discovered that the fuses and detonators currently in use were also woefully inadequate. One reason for this would be that the fuses were modified from a design used for artillery shells, instead of from any of the specific anti-submarine designs produced by the Admiralty during the First World War. A redesign followed in 1936, even so by the outbreak of war all of the RAF’s anti-submarine bombs were under-powered, prone to bouncing off the water if dropped at the wrong height or speed, and around 40% failed to explode.

From the early 1930s attention turned increasingly towards a potential European war, and the development of suitable weapons. The idea of 1,000 and even 2,000 lb bombs had been toyed with in the late 1920s, and various models, based on scaling up 500 lb bombs, were made. This, incidentally, shows how little advance was made in the understanding of bomb aerodynamics and basic design over the period; most increases in bomb size simply saw the same shape scaled upward, regardless of how it performed. Returning to the 1,000 lb idea, given that the latest front line bomber of the time, the Handley Page Hinaidi, had a maximum bomb-load of less than 1,500 lbs, it is perhaps unsurprising that the idea was dropped. Even by 1938, with the much heavier Hampdens and Wellingtons entering service, larger bombs were not necessarily desired. Although each of these could carry (theoretically) four 1,000 pounders, they could also carry eight 500 lb, or sixteen 250 lb pounds. Given the imprecise nature of bombing, partly due to equipment – the standard bombsight was still the Mk IX Course Setting Bomb Sight, which was essentially a 1916

The Mk IX Course Setting Bomb Sight.

design – the delivery of fewer but heavier bombs served, in effect, only to reduce the number of available chances to hit the target.

In 1935 a reassessment of the GP bomb range was held, and the idea of bigger bombs again examined, although they were dropped in favour of 20 lb fragmentation and 40lb anti-personnel bombs. Again, this is perhaps understandable, and not just for the reasons already stated; the next European war was expected to see a protracted land campaign in France, like the last time, with the RAF offering close support to ground forces rather than the prolonged, long range heavy bombardment of Germany that actually occurred.

Even with the impetus of impending war, development of these smaller bombs was again somewhat chaotic. The 40 lb version, after trails of the empty casing in 1935, entered production in 1937. Proper evaluation was only begun the following year, when it was found that the pistol used in the type was utterly inadequate, and a redesign was needed. The 20 lb fragmentation bomb went through almost ten years of development, evaluating the American idea of using a case coated in extra rings of metal rather than a single sheet. This, theoretically, would have given the bomb a greater amount of shrapnel, but the idea was dropped because it would have been too expensive to mass produce, partly because it would have required the use of a different type of explosive than that which filled every other RAF bomb – Amatol. Amatol was a mixture of TNT and ammonium nitrate that had been developed in 1916 as a cheap alternative to pure TNT and was used for all High Explosive bombs until well into WW II. The 20 lb fragmentation bomb entered production in 1937. Yet again, however, full testing, including air drops, was not carried out until the following year, when the results (partly due to problems with the pistols) were very poor, the bombs being particularly prone to burying themselves too deeply in the ground before exploding.

The question remains as to why this state of affairs was allowed to develop. Partly it was the very newness of the RAF. Air Cdre Patrick Huskinson, who was involved in the development of bombs from the 1920s until well into WW II, believed that it was, at least in part, due to the way the RAF trained officers, in an ineffectual and slapdash way. Armament Officers, for example, were not required to have a technical background or even an in-depth knowledge of the weapons in use, their systems and the principles behind them. Most officers were still required to fly, and all too often this took precedence over their ground duties. The specialist knowledge simply did not exist, but neither did the broader service knowledge, or perhaps awareness is a better word, that could allow the system to change.

Huskinson says costs were also a factor. Most Ordnance Boards and Committees were tri-Service, and the RAF had to fight for support and funds against the larger and more experienced Army and Navy. There were not enough resources to go around, and it was harder for the RAF, with very little field experience to draw from, to justify its demands. Budgets also meant that bomb design had to be kept simple and the explosive used a standard one, to keep down production costs. The simpler they were, the quicker, easier and cheaper it would also be to set up new production lines should another war break out. Test sites and targets were expensive to erect, and (in the logic of the time) would simply represent a waste of money in the long periods between actual use.

General Purpose bombs and incendiaries were adequate for colonial policing, and this, mixed with inexperience and lack of

Old-style 112lb RL and new 250lb GP bombs, India, 1938.

resources, led to the stagnation of bomb design during the inter-war years. Whatever the reasons, so far as its bombs were concerned, the RAF was unprepared to fight a European war in 1939.

Sources:

TNA AIR41/81. AHB; *Armament, Vol 1; Bombs and Bombing Equipment*; (HMSO, 1952).

MacBean, Wg Cdr J & Hogben, Maj A; *Bombs gone: The development and use of British air-dropped weapons from 1912 to the present day* (Wellingborough, Patrick Stephens, 1990).

Huskinson, Air Cdre P; *Vision Ahead* (Werner Laurie, 1949).

RAF BOMBS AND BOMBING 1939-1945

Nina Burls

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Introduction

The Second World War was an unprecedented period of change in terms of bomb development. This, of course, had a direct impact on Bomber Command, which experienced a considerable increase in its striking power. This, when combined with advances in navigation and bomb-aiming equipment, together with the increased capability of its aircraft, permitted the Command to evolve from a force of very limited capability into a formidable war-winning one.

Snapshots

This development can be appreciated by comparing 'snapshots' of Bomber Command's campaign during the early stages of the war and its later capabilities.

Between 1939 and 1940 light and medium bombers such as the Battle, Blenheim and Hampden, with their maximum bomb loads of between 1,000 and 4,000 lbs, were flying essentially defensive or supportive sorties, using available stocks of the 250 and 500 lb General Purpose bombs which had been developed during the inter-war period. Navigation was reliant upon dead-reckoning and the available course-setting bombsights would have been familiar to the airmen of WW I.

By 1944/45 Bomber Command was conducting a large-scale area-bombing offensive, operating four-engined Lancaster and Halifax heavy bombers, several hundred of which were routinely dropping mixed loads of up to 14,000 lbs of high explosive and incendiary bombs on an almost daily (or, more often, nightly) basis. The accuracy of these operations was greatly assisted by radar navigation aids such as GEE and H2S which had been developed by this time and bomb-

Compare and contrast: above, the Hampden of 1939 with a typical load of GP bombs and, below, the Lancaster of 1945 with up to 14,000 lbs of HC and MC bombs.

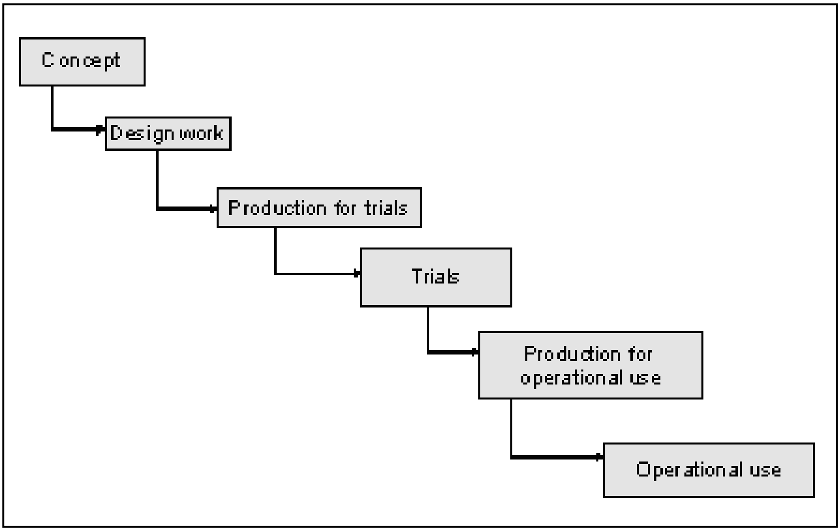


***Fig 1**. From drawing board to delivery.*

aiming was now being handled by a dedicated and specially trained crew member.

Drawing board to delivery

The British Bombing Survey Unit commented, when reviewing the history of bomb development during WW II, that it ‘was allowed to be influenced by strategic considerations’ and that ‘consequent armament development almost inevitably influenced strategy.’

This dichotomy becomes apparent if the process of how a bomb was produced from the drawing board to delivery over its target is considered. Each bomb had a unique production history but the simplified diagram at Figure 1 aims to illustrate the various elements involved in the process.

The concept for each new bomb reflected operational demands, as in 1940, when the Air Staff required a new 4,000 lb ‘mine-bomb’ which would need to be robust enough to permit dropping from heights of up to 1,500 feet at 200 mph without breaking up. To discuss the idea, a meeting took place on 18 September 1940 attended by representatives of the Admiralty, Air Staff, Ministry of Aircraft Production and the Ordnance Board.

The conclusions drawn at such meetings produced specifications

At least one of the concrete walls still stands on the old Braid Fell Range (Dumfries And Galloway).

leading to design work involving aerodynamicists, ballistic and fuse experts and the like whose proposals would eventually be vetted by the Director of Armament Development and the Ordnance Board.

Once a basic design had been approved it was further refined by, for instance, the Static Detonation Committee (just one example of a number of specialised armament Committees set up during WW II in order to oversee weapon development and production) whose specific remit was 'to study the scientific and technical aspects of the technique of static donation of bombs and shells; to interpret experimental results and consider their application to development.' In effect, they would decide on the appropriate explosive content and method of detonation. Once trials had been satisfactorily completed, production could begin, a two-stage process involving manufacture of casings followed by filling with the explosive content – all to be carried out in accordance with strict safety regulations. Meanwhile, further work would have been underway to ensure that existing bomb carriage facilities were capable of dealing with the new weapon or, if not, that remedial action had been taken to design a suitable alternative.

Live trials to investigate various aspects of a new bomb's behaviour were undertaken at sites such as Ashley Walk and Shoeburyness. Thus, for example, the pattern of, and the blast overpressure from, the explosion could be measured and recorded permitting problems to be identified and corrected. The creation of new range facilities, such as those at Braid Fell, which were ready for use in 1941, illustrates how the techniques of bomb development were refined during WW II, since this range permitted testing to be carried out under operational conditions for the first time. Testing of a new bomb was usually a five-stage process:

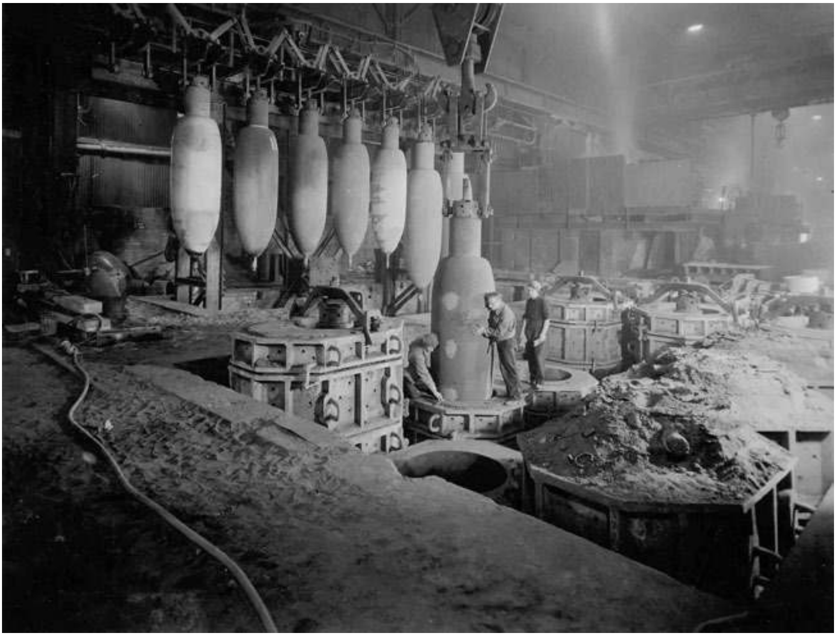
- inert bombs dropped from high-flying aircraft to check their flight and the appropriate settings for the bomb-sight;
- live bombs dropped to test fusing and detonation;
- inert bombs with live fuses were flung from aircraft against concrete walls;
- ‘rough usage’ tests, ie ground handling using standard RAF trolleys and winches to ensure that the bomb was safe and generally ‘airman proof’;
- finally, inert, but fused, bomb dropped from a high-flying aircraft on a representative target at Braid Fell.

All of this clearly represented a far more scientific approach to bomb development than had been the case during the inter-war years. Chemists, ballistics, fusing and filling experts all provided inputs and recommendations to the reports on new weapons that were routinely submitted to the Director of Armament Development and thence to the Air Staff who, along with the Ordnance Board, were the ultimate authority granting approval for a particular type of bomb to be introduced into service.

The ‘concept to delivery’ cycle has been depicted as rather linear but this is deceptive. A few more arrows back and forth would probably be more appropriate; perhaps a circular system inter-linking any of the various stages along the way would be more accurate. Furthermore, once a bomb had been used on operations, this was not necessarily the end of the story. Problems that were subsequently revealed by experience had to be solved; similarly, ideas for improvements were fed back to the Air Staff or the Director of Armament Development for their consideration. This would lead to modifications, perhaps an improvement to the means of attaching the tail unit, or a change to the type of fuse or pistol, resulting in an established type of bomb being produced in a series of mark numbers to indicate its modification state.

Supply

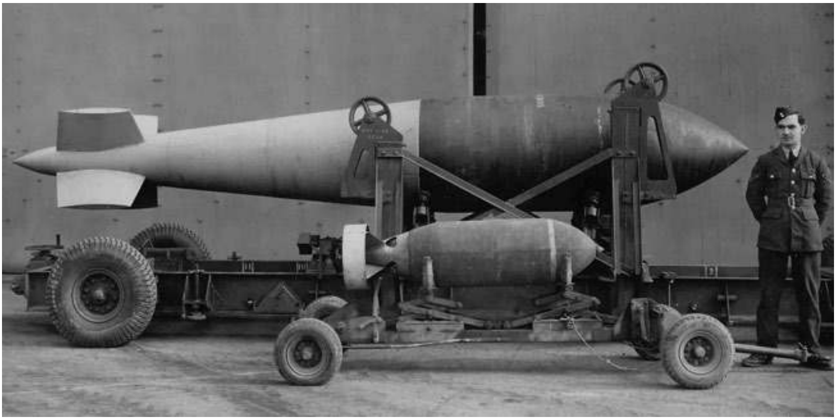
As with all technologies, bomb development, and production, was subject to certain pressures. In peacetime, these had been largely financial; funding was less of a consideration during the war when the



Casting cases for 12,000lb and 22,000lb bombs, 1944.

priorities became time, changing operational requirements and the issue of supply, both in terms of raw materials for manufacture and in the provisioning of stocks at unit level. Air Cdre Huskinson, in his book *Vision Ahead*, indicates that the genesis of a new bomb took about six months but, when researching the development of individual bombs for this presentation, two years did not appear to be unusual, if/when other priorities intervened or problems arose. The frustration caused by delays in the delivery of equipment is, incidentally, very evident from Sir Arthur Harris' tone in his *Despatch on War Operations*.

Supply, or rather the occasional lack of it, certainly had an impact. Trials could be delayed or even abandoned with existing equipment having to be accepted until such time as alternatives could be made available. The use of explosive fillings, a key factor in the effectiveness of a bomb, illustrates this point. Amatol, a mixture of ammonium nitrate and TNT, had been in use since WW I and it remained the standard filling until well into WW II. Its replacement



Bigger, better bombs. The 12,000 lb TALLBOY and the standard 1,000 pounder.

was RDX (cyclo-trimethylene-trinitramine) which was a much more efficient explosive. This became available only gradually, however, and at first its effectiveness was diluted by mixing it with Amatol to form Amatex. Later still, in 1943, came Minol (40% TNT plus 40% ammonium nitrate and 20% aluminium powder) which had both enhanced blast effects and a greater incendiary potential.

Bigger, better bombs

And so to the high explosive bombs themselves. It had soon became apparent that the 250 and 500 lb General Purpose bombs, available at the start of the war were inadequate. At 10-15% their detonation failure rate was far too high and with a charge to weight ratio of no more then 25% they simply lacked the explosive power to inflict much real damage. The late 1930s view, that there would not be a requirement for a bomb larger than 500 lbs, was soon eclipsed but early wartime efforts simply concentrated on producing large numbers of larger bombs in the same GP series.

By December 1940, however, analysis of the damage inflicted by the *Luftwaffe's* raids on the UK, particularly by the Germans' SC (*Spreng Cylindrische*) series of bombs with their higher charge to weight ratios and destructive power, had convinced the Air Staff that the RAF needed a whole new family of bombs. From then on, the overriding principle influencing development was to produce greater destructive effects. In short, to create bigger and better bombs.

This was effectively achieved with the development of the Medium and High Capacity bombs with their increased blast effects. The Medium Capacity (MC) series weighed from 250 to 4,000 lbs (plus the very specialised 12,000 lb TALLBOY and 22,000 lb GRAND SLAM, which are beyond this paper's remit). The MC bombs, with their charge to weight ratios of 40-50%, became the primary weapons of the bomber offensive from 1943 onwards. In all Bomber Command alone would drop some 253,800 1,000 lb MC bombs along with 403,000 500 pounders.

The High Capacity (HC) series, ranging from 2,000 to 12,000 lbs – the latter being the heaviest of all the 'mainstream' bombs – had very high charge to weight ratios of 70-88%. This was achieved by using a thin steel casing filled with high explosive (a combination of Amatol, Minol and Tritonal[1]). The relatively lightweight construction of these 'blockbusters' meant that they would collapse on impact so that they had to be instantaneously fused, delayed action only being an option with the MC series.

Design/Appearance

Most of the bombs produced in WW I had a rather bulbous appearance (*see page 12*) but these were eventually superseded during the inter-war period by the GP series which were quite gracefully streamlined throughout the entire length of the casing, the classic example being the 250 lb GP bomb (*which was similar to the 25 lb incendiary illustrated on page 20).* By contrast, and apparently taking as their inspiration, the German SC series, the body of the MC bombs of the later years of WW II had a tapered nose but parallel sides. With the HC series there was little attempt to reduce drag, the 4,000, 8,000 and 12,000 pounders all having a crude cylindical shape with virtually flat noses, although the latter did at least have a tail unit to provide a degree of stability in free fall. The HC series introduced the innovative concept of modular construction, the 8,000 and 12,000 pounders respectively being constructed of two and three 4,000 lb units bolted together (although these units were not, as is commonly believed, the same as the 4,000 lb HC bomb which was an individual design – still

1 Tritonal was a mixture of 80% TNT and 20% powdered aluminium.

a cylinder but one of 8" less diameter).

Markings and colours

Apart from their general appearance, shape and size, bombs were identified by colours and markings to indicate their purpose, content and so on. Some of the marking were highly unofficial, of course, and research into this *graffiti* might make an entertaining project for someone one day. High explosive bombs were originally painted yellow overall, but this was changed during the course of WW II to dark green. It was not unheard of to have two-tone bombs, because bombs that had been repainted green by being sprayed while in storage racks sometime retained underbellies which were still yellow.

Apart from the base colour, bombs carried a variety of coloured bands and stencilled data to indicate: weight; type and mark number; filling; date filled; filling station and lot number. The positioning of this information varied.

Incendiaries

Another key weapon in Bomber Command’s arsenal which should be mentioned is the incendiary bomb which had evolved over several years. The 4lb magnesium incendiary which had appeared during the inter-war years became the mainstay of this class in WW II. It was complemented by the 30lb phosphorous bomb, the 30 lb phosphorous ‘jet’ bomb and the 250 pounder. There were heavier models too, ranging as high as 2,700 lbs but these were less widely used. Their relative merits were much discussed but the overall impact of the incendiary bomb was indisputable. The destruction wrought by the firestorms that destroyed Lübeck in 1942, Hamburg in 1943 and Dresden in 1945 was largely attributable to the use of incendiaries. Indeed, they were considered to be so essential that they constituted a substantial element of many of the standard loads specified by Bomber Command, typically two thirds high explosive and one third incendiaries.

None of the bombs available was perfect, however, and problems with them were often reported. In the specific case of incendiaries being released from Small Bomb Containers (SBC), for instance, aiming was a problem, because mutual interference caused the load to disperse widely, diluting its effect. The answer to this one was to drop incendiaries in clusters. This innovation was very popular with

The end result – Düsseldorf, 1945.

armourers incidentally because, until then they had had to unbox the stick incendiaries and then re-pack them individually, hundreds of them, in the SBCs. When you consider that by 1944-45 the armourers serving a two-squadron station would have routinely loaded about 190 tonnes of armament – every day – and that does not allow for downloads following changes in plan or cancellations – one can understand why any relief was appreciated.

Ancillary equipment

The introduction of bigger and heavier bombs sparked parallel developments in the context of ancillary equipment, such as the tractors and trolleys needed to transport them and the hoists that were needed in order to load them, all of which had to be done safely, of course.

Prior to 1942 the Type A bomb trolley was in general use, although its maximum load was a mere 500lb. By that time, however, two additional models had already been produced: the Type B, which was capable of carrying four 500 pounders, and the Type D, which was particularly associated with the Wellington, Lancaster and Halifax and could handle a 4,000 lb HC bomb. With the increase in size and

Type	No	Type	No
Fragmentation (F)		**High Capacity (HC)**	
20 lb	5,000	2,000 lb	28,633
		4,000 lb	68,000
General Purpose (GP)		8,000 lb	1,088
40 lb	49,939	12,000 lb	193
250 lb	149,656		
500 lb	531,334	**Medium Capacity (MC)**	
1,000 lb	82,164	500 lb	403,000
1,900 lb	2,141	1,000 lb	253,800
4,000 lb	217	4,000 lb	21,000
		12,000 lb	854
Incendiaries		22,000 lb	41
4 lb	80,000,000		
25 lb	20,000	**Semi-Armour Piercing (SAP)**	
30 lb (phosphorous)	3,000,000	500 lb	11,600
30 lb ‘J’	413,000		
250 lb	7,000	**Armour-Piercing (AP)**	
		2,000 lb	<10,000

Table 1. *Breakdown, by type, of the 955,044 tons of bombs dropped by Bomber Command during WW II, ie these figures do not reflect the global picture.* Source: MacBean and Hogben.

weight of bombs the Type C trolley was introduced with a maximum load of 6,000 lbs and the Type F which could deal with 8,000 lbs. The design and construction of these various trolleys was pretty much the same and they could all be used to carry virtually any types of bombs, so long as their weight limits were not exceeded.

Conclusion

There were many factors influencing the design, development and production of bombs during WW II but the overriding philosophy was to create bigger and better ones. The scale of bomb development between 1939 and 1945 can be grasped from the figures shown in Tables 1 and 2. First, the variety of bombs employed by Bomber Command with new types appearing during this six-year period in unprecedented numbers. And secondly, the steady increase in weight of bombs dropped per aircraft.

Year	Weight of Bombs per Aircraft
1939	204 lb
1940	1,457 lb
1941	2,324 lb
1942	3,405 lb
1943	6,903 lb
1944	8,250 lb
1945	7,835 lb

Table 2: *Average weight of bombs dropped per aircraft by RAF Bomber Command during WW II.* Source: Official Report of the British Bombing Survey Unit.

This paper concludes our three-part review of bomb development during the 33 years, 1912-1945. It was not an entirely smooth process and a graph of progress made would have to feature significant peaks and troughs. Nevertheless, much progress *was* made and this permitted air power to evolve from being no more than a novel idea to become a weapon capable of seriously inhibiting an enemy's ability to wage war.

Sources:

TNA AIR41/81. AHB; *Armament, Vol 1; Bombs and Bombing Equipment*; (HMSO, 1952).

Huskinson, Air Cdre P; *Vision Ahead* (London, Werner Laurie, 1949).

Harris, Air Chief Marshal Sir Arthur; *Despatch on War Operations* 23 February 1942 to 8 May 1945 (London, Air Ministry, 1945)

The Strategic Air War Against Germany 1939-1945 – The Official Report of the British Bombing Survey Unit (Introduction by Sebastian Cox) (London, Frank Cass, 1998).

THE DEVELOPMENT OF RAF GUNS AND AMMUNITION FROM WORLD WAR 1 TO THE PRESENT DAY

Anthony G Williams

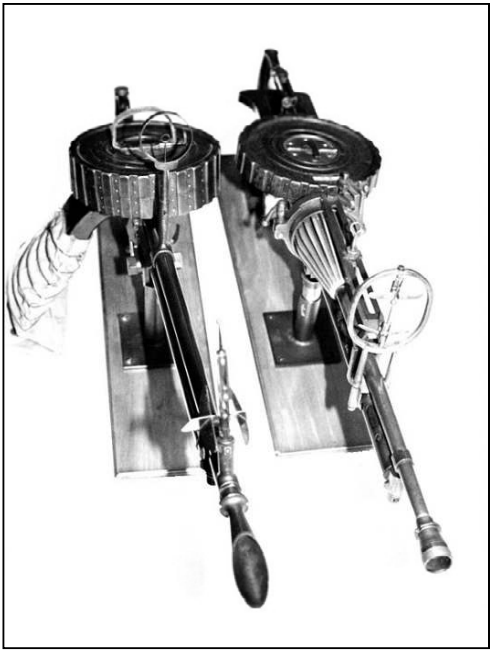
Tony Williams is a military technology historian with a special interest in guns and ammunition. He is co-editor of Jane's Ammunition Handbook *and has written many magazine articles and several books, notably the three-volume work* 'Flying Guns: Development of Aircraft Guns, Ammunition and Installations' *which he co-authored with Emmanuel Gustin. He maintains a website at http://www.quarry.nildram.co.uk*

As you might have gathered from the Chairman's introduction, my interests are in ammunition first, guns second, what the guns are strapped to third, and how they were used, and by whom, last. So my focus in this talk will be on the gun and ammunition technology used by the RAF and its precursors, and I hope you will forgive me for omitting any mention of squadrons or, indeed, much about specific aircraft.

World War 1

The initial use of aircraft in the Great War was for reconnaissance and artillery spotting. However, it was soon realised that if such flights were useful, it made sense to try to deny them to the enemy. Airmen therefore began to take guns aloft to take pot-shots at the opposition, but these were aircrew, rather than aircraft, guns; a variety of pistols, revolvers, shotguns, rifles and carbines were carried. Special ammunition was even developed for some of them: incendiary bullets for firing at observation balloons, and even a shotgun cartridge firing a type of chain shot for slicing through aircraft bracing wires.

It was soon realised that a machine gun was the ideal weapon for shooting at other aircraft, but at that time the standard British Army MG was the ·303 inch Vickers Gun; a heavy, water-cooled device weighing some 40 lbs which the primitive early-war planes struggled to lift off the ground. Fortunately, BSA had acquired a licence to manufacture the American Lewis Gun, which was far more suitable. It was much lighter at around 26 lbs, and its ammunition was held in a



Lewis Mk III (left) and a stripped Mk I.

pan magazine clipped to the gun, instead of the rather cumbersome fabric belt of the Vickers.

The Lewis was rather bulky because its barrel was surrounded by light-alloy fins which were themselves covered by an external sleeve, but such elaborate cooling arrangements were not required when the gun was mounted on an aircraft, so they were soon stripped away leaving it with a bare barrel. This, in conjunction with removing the stock, reduced the weight to about 17 lbs.

The Mk II version, used later by the RFC, had a smaller sleeve fitted to protect the mechanism. Two other changes made during the war were to increase the capacity of the magazine from 47 to 97 rounds and to speed up the rate of fire from around 550 to between 700 and 750 rounds per minute (rpm). The final Mk III version reverted to a stripped barrel with the double-height 97-round drum.

The light weight and magazine feed meant that the Lewis was particularly suited to flexible mountings designed to allow a gunner to move the gun around to point it in different directions. These will be described in Jeff Jefford's talk.

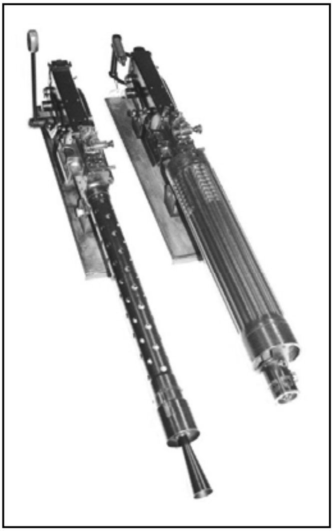
Mounting the gun for the pilot to use proved rather more problematical, especially as it was discovered that the optimum arrangement for a fighter aircraft was to have the engine and propeller in front of the cockpit. Early attempts to mount the gun to fire at an angle past the propeller were less than successful. It soon became clear that the most effective shooting could be done if the gun was


Nieuport with an upper wing mounting (left) and the much handier Foster mounting of a Lewis gun on an SE5a.

fixed to fire straight ahead. Some brave souls fixed the gun to fire through the propeller disk, hoping that a couple of bullet holes through the propeller could be tolerated, but there was always the risk of chopping off a propeller blade. The first satisfactory solution for biplane fighters was to mount the gun on the top wing, so that the bullets would miss the propeller.

With early mountings of this type the gun was fixed in place, which meant that the pilot had to stand up to change the magazine, leading to some exciting incidents. Eventually, the Foster mounting was developed: this allowed the pilot to pull the gun down towards the cockpit for magazine changes, and incidentally permitted the gun to be fired upwards. The top-wing mounting was not an ideal solution, however. The need to change magazines and to clear the frequent stoppages, mainly caused by poor quality ammunition, made this inconvenient. The French came out with a makeshift alternative solution in 1915 by mounting a gun in front of the pilot, where it could easily be reached, and fitting the propeller blades with deflectors to prevent bullets from penetrating them.

The Germans adopted a more sophisticated solution (actually first proposed before the war) of timing the shots from the machine gun so



Vickers Mk I (right) and the post war Mk III.

that they would pass between the propeller blades. These synchronisation systems involved converting the gun so that it could fire single shots each time the firing line was clear, thereby slowing the rate of fire to a degree which varied according to the relationship between the gun's reloading speed and the constantly changing propeller revs. This required precise timing of each shot and therein lay a major problem, for the Lewis Gun was not capable of this. It could only fire from an 'open bolt' (with the bolt held back and the chamber empty) so each time the firing signal was sent, there was a pause while the bolt started to move forwards, collected a cartridge from the magazine, loaded it into the chamber, locked the breech and then fired. Despite many attempts to modify the Lewis, this all took far too long for precise timing.

At this point the Vickers Gun came back into the picture. It fired from a 'closed bolt' – when ready to fire there was a round in the chamber, the action was locked and all that was needed to fire the gun was for the firing pin to be released. This was ideally suited to synchronisation. Furthermore, in a fixed mounting the belt feed was less of a problem and saved the pilot from having to change magazines. And by then, the aircraft were powerful enough to cope with the extra weight. So the Vickers became the standard fixed gun of the RFC and RNAS, although the Lewis was still preferred for certain purposes, which I will come on to.

The Vickers was modified, first by emptying its water jacket and punching holes in it to let cooling air through (the jacket could not be removed as it was needed to support the front of the moving barrel) reducing the weight to around 28 lbs, and subsequently by providing it with a slimmer and neater jacket, although the Mk 3 version was not adopted until after the War. Its free rate of fire was also increased from 550 to 850 rpm by fitting a Hazleton muzzle adaptor, although the actual rate of fire of a synchronised gun would have been much less than this. Synchronisation was always problematic and inclined to slip out of phase, but the Constantinescu-Colley, or C-C, hydrosonic system performed relatively well.

Fabric ammunition belts (used in Army Vickers guns until the 1950s) had the disadvantage that the empty section tended to flap around in the wind, plus the belt could get wet and then freeze. Steel disintegrating-link ammunition belts were perfected in the UK by Prideaux in mid-WW1 and became standard for aircraft guns thereafter.

The methods of sighting the guns also developed during the Great War. At first, only a couple of bits of metal were used to line them up, but the British developed the Aldis optical sight, mainly for fixed guns, and everyone worked on complex sights for flexibly-mounted guns, designed to compensate for the ballistic problems of shooting to one side. Even so, holding fire until as close as 50 yards or less was recommended.

I now want to turn to ammunition developments, since aerial fighting in the Great War prompted considerable development efforts, in two directions. One was to improve the variable quality of the ammunition (a problem affecting all combatants). A certain percentage of stoppages was acceptable in a ground gun, since the gunners could usually quickly clear the jam, but was a different matter in an aircraft, especially if the gun was mounted out of reach. In an attempt to resolve this, the British introduced in 1917 'Green Label' (or 'Green Cross') ·303" ammunition specifically for synchronised guns. This was taken from standard production lines, but carefully selected from batches which complied with tighter manufacturing tolerances and gave reliable ignition. This proved successful and was followed up in 1918 by establishing special production lines to make high quality ammunition for this purpose. This was known as 'Red Label' (also as 'Special for RAF, Red Label', 'Special for RAF' and finally 'Special').

The second line of development was the production of a variety of specialist bullets, initially prompted by the need to destroy hydrogen-filled spotting balloons and airships which were little affected by having small holes drilled through them. Several attempts were made

Examples of ·303" aircraft gun ammunition: PSA (Pomeroy) Mk I (HE); PSA Mk II; RTS Mk II (HEI); RTT (experimental HEI); and R Mk III (experimental HE).

to devise bullets filled with various explosive and/or incendiary chemicals. Initial work was in larger-calibre guns simply because the bullets were bigger, but this was soon replaced by ·303" ammunition. Some types of incendiary, such as the Buckingham which contained a phosphorous/aluminium mixture, were ignited on firing and burned slowly throughout their flight leaving a smoke trail, while others ignited on impact. The Pomeroy or PSA explosive bullet contained nitro-glycerine and was purely explosive, but the Brock, which contained potassium chlorate, and the RTS (Richard Threlfall and Sons) with both nitro-glycerine and phosphorous, had both explosive and incendiary effects, so were known as HEI bullets. Some of these bullets had Cordite propellant (so-called because it was extruded into cords), others had nitro powder. Use of these bullets was initially somewhat hazardous as the early versions had a reputation for premature detonations, and elaborate handling precautions were required.

These bullets were at first reserved for home defence, partly because they were needed to combat the German airships attacking British cities and partly because of concerns that they were technically illegal (explosive/incendiary bullets were banned as inhumane by international agreement). However, they were used by both sides, and after the war it was recognised that they were acceptable as they were intended to be used against aircraft rather than people.

The home-defence fighters retained the top-wing Lewis guns rather than the synchronised Vickers, for several reasons. First, the gun was lighter, which was an advantage given the high rate of climb needed to reach airship altitudes; secondly, it could be tilted to fire upwards; thirdly, its location meant that the pilot was shielded from the muzzle flash by the wing, which preserved his night vision; and, last but far from least, it was unsafe to fire the early explosive/incendiary ammunition from a Vickers because the bullet left in the hot chamber after firing a burst could ‘cook off’ from the heat. In this instance, the Lewis Gun’s open-bolt firing was an advantage.

The Interwar Period

By the end of the Great War the Vickers and Lewis guns in ·303" calibre were the established RAF armament and remained so until the late 1930s. They were also widely sold abroad, including to Japan, which was still using them at the start of WW II. However, many experiments had also been made during the war with large-calibre shell-firing guns, later known as ‘cannon’. Some of these were manually-loaded, including the recoilless Davis guns.

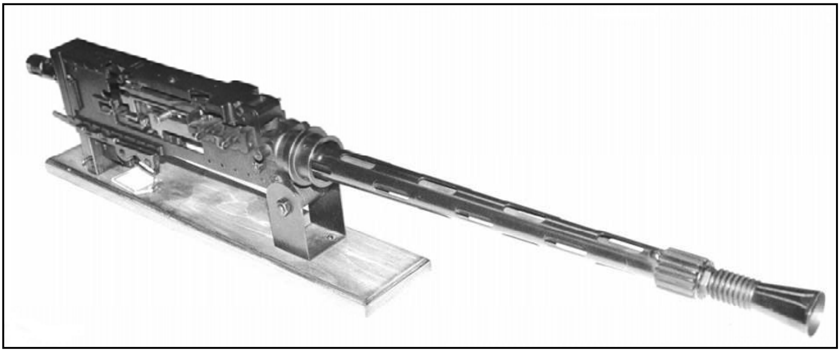
Others were big machine guns, notably the 1½ pounder (37mm) ‘COW’ gun (Coventry Ordnance Works). None saw significant use in the war. A few dozen of the 37mm COW guns were completed and these featured in various inter-war projects including aircraft specially designed to mount them, but they failed to generate much enthusiasm, although the COW enjoyed a swansong as an airfield defence gun in WW II.

There was little money to buy armaments after the end of the Great War, but that did not prevent theorising and experimentation, particularly in investigating the potential of larger-calibre guns. Three different classes of aircraft gun began to emerge in various nations: improved rifle-calibre machine guns; heavy machine guns; and automatic cannon. Rifle calibre guns were those which use the same ammunition as the standard military rifle, firing bullets of around ·30-·32 inch in diameter (7·5-8mm calibre). Heavy machine guns fired much bigger cartridges with bullets of around ·50-·60 inch diameter (12·7-15mm) which were three to six times as powerful as rifle-calibre ammunition. Cannon fired projectiles of 0·8 inch (20mm) or greater diameter, which was generally considered to be the smallest worthwhile size to use high-explosive ammunition, although some smaller HE shells were used by Germany, Italy and Japan during WW II.

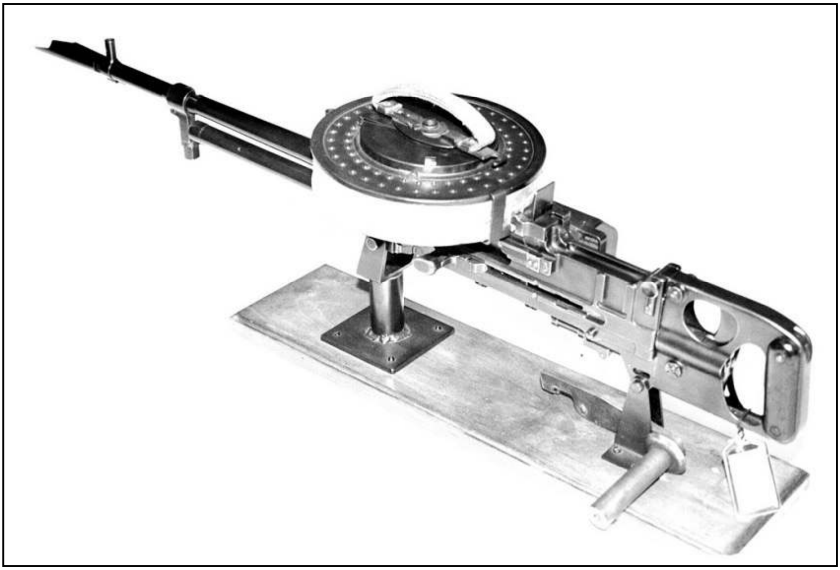
Vickers was in the process of developing a scaled-up version of their ·303" MG, chambered for a new ·5" (12·7mm) cartridge. This was produced in three versions for army, naval and aircraft use and was tested by the RAF in the mid-1920s against the new ·50" Browning heavy machine gun, which was bigger and more powerful. The conclusion was that neither offered sufficient advantages to replace ·303" MGs, since the slightly bigger hole they could punch was inadequate compensation for their greater size and weight and their lower rates of fire. The Swiss Oerlikon 20mm cannon, developed from the German Becker of the Great War, was also tested in the late 1920s and early ‘30s and proved more promising, since its explosive shells could do a lot more damage than just punching bigger holes, but it was big, heavy and slow-firing.

As a result of all of this, the RAF decided in the mid-1930s to stick with the ·303" calibre for the time being, while noting that a 20mm gun would be the preferred replacement if armour protection were applied to warplanes. After competitive tests, two new machine guns were selected; the US Browning and the Vickers Gas Operated (known also as the VGO or Class K), a modification of the Vickers-Berthier light MG.

The Browning was considerably modified over the American original. It was not just converted from ·30 to ·303 inch calibre but also modified to fire from an open rather than a closed bolt because the cordite-loaded ·303" rounds tended to explode if left in a hot chamber. The Browning was belt-fed and initially intended for fixed fighter installations (although later adapted for use in turrets). In

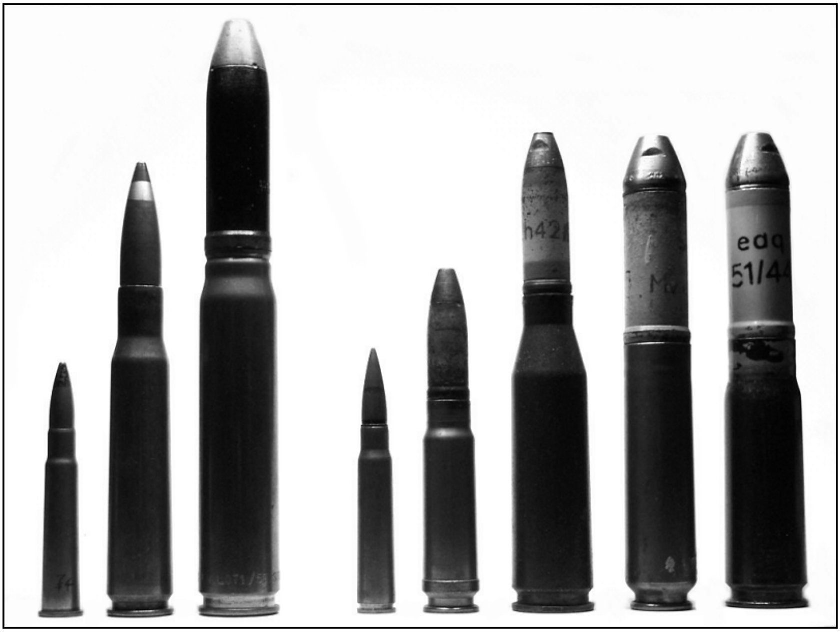


·303" Browning machine gun (above) and a ·303" Vickers Gas Operated machine gun (below).



contrast, the VGO used a pan magazine of 100 rounds and was for flexible mounting. It bore a close resemblance to the Lewis, although internally it was quite different. Rates of fire were around 1,200 rpm for the Browning, 950 rpm for the VGO. It was with these weapons that the RAF fought the Battle of Britain.

The rifle-calibre guns used by different air forces were quite similar in performance, weighing around 20-25 lbs and mostly firing



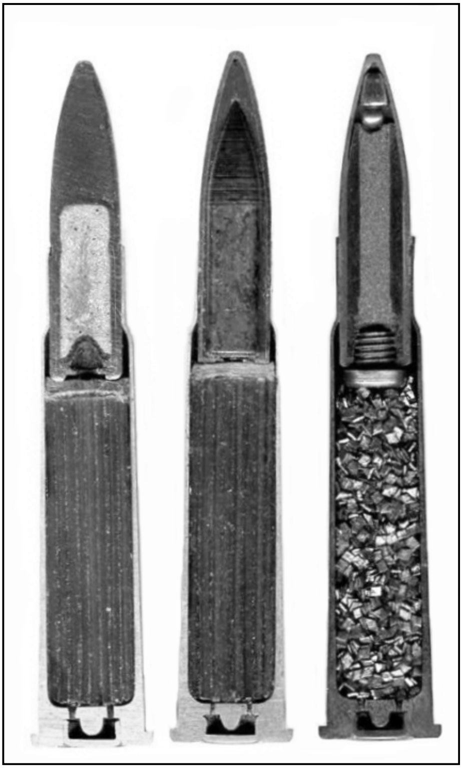
The three standard wartime RAF rounds: ·303", ·5" and 20mm Hispano (left), compared to representative German ammunition: 7.92mm, 13mm, 15mm and two varieties of 20mm ammunition.

at 1,000-1,200 rpm. There was more variation in the characteristics of heavy machine guns, with weights ranging from 40 to 90 lbs and rates of fire generally between 700 and 900 rpm. There was an even greater variation in size and power among the 20mm weapons (let alone the few even larger-calibre cannon), with weights from 50 to 120 lbs, rates of fire from 400 to 800 rpm, and considerable variation in muzzle velocities, which affected their hit probability.

The accompanying illustration indicates how the ammunition involved differed in size and power, comparing three famous cartridges used by the RAF during WW II – the ·303" rifle-calibre round, the American ·50" Browning heavy MG, and the 20mm Hispano cannon – with *Luftwaffe* ammunition in the same classes. The considerable power of the Hispano is obvious.

World War 2

In 1934 the Air Ministry had decided to accept the advice of the



Sectioned ·303" rounds, from the left: tracer, armour-piercing and incendiary (Dixon/De Wilde).

Operational Requirements Branch that, in view of the increasing speeds of both fighter and bomber aircraft, gun firing opportunities would be brief, so a six- or preferably eight-gun battery should be installed in fighters. This, of course, led to the specification which eventually resulted in the adoption of the Hurricane and Spitfire. Fitting so many guns around the engine was not feasible, so they were all mounted in the wings which overcame the complications of synchronisation. On the other hand, moving the guns away from the heat provided by the engine caused a gun freezing problem at high altitudes, which was addressed, not always successfully, with special lubricants and heating systems.

Work was also done on improved ·303" ammunition. The steel-cored armour-piercing and Buckingham incendiary/tracer (designated B Mk IV) rounds were based on old designs, but a new incendiary, the B Mk VI, was developed by Major Dixon, loosely based on the Belgian De Wilde design. In this picture you can see the steel core for the AP bullet and the construction of the famous B Mk VI incendiary.

In firing tests, the B Mk VI had a 20% success rate in setting fuel tanks alight, twice that of the Buckingham or the equivalent German 7·92mm round, and also had the happy side-benefit that the flash of ignition on impact told the pilot that he was on target. Incidentally, the Americans adopted the Dixon design in a simplified form for their

·30" and ·50" calibre incendiary ammunition, and the British subsequently copied the simplified design as the B Mk VII. Unlike the practice in other air forces, which used mixed ammunition belts, the RAF preferred to load each ·303" fighter gun with only one type of ammunition. The Dixon ammunition was first issued in June 1940 and was at first in short supply, the initial fighter loading being one gun firing Dixon incendiary, two with Buckingham incendiary/tracers, two with armour-piercing and three with plain ‘ball’ rounds with lead cores. By 1942 the standard loading for fixed guns was half with AP and half with incendiaries.

As a result of early battle experience, aircraft armour and self-sealing fuel tanks were rapidly applied and the ·303" guns lost effectiveness accordingly. In the Battle of Britain, the performance of ·303" ammunition was initially adequate but it was found that the German bombers often survived large numbers of hits. The reason became clear in further tests which involved firing ·303" and German 7·92mm armour-piercing ammunition against the fuselage of a Blenheim light bomber from behind – not the toughest of structures, and with only a 4mm armour plate protecting the gunner. This AP ammunition could normally penetrate up to 10-12mm of armour plate, but it was found that the aircraft structure it had to plough through before reaching the armour deflected, absorbed or disrupted the flight of the great majority of the bullets, and of those which reached the armour, very few had enough energy left to penetrate it.

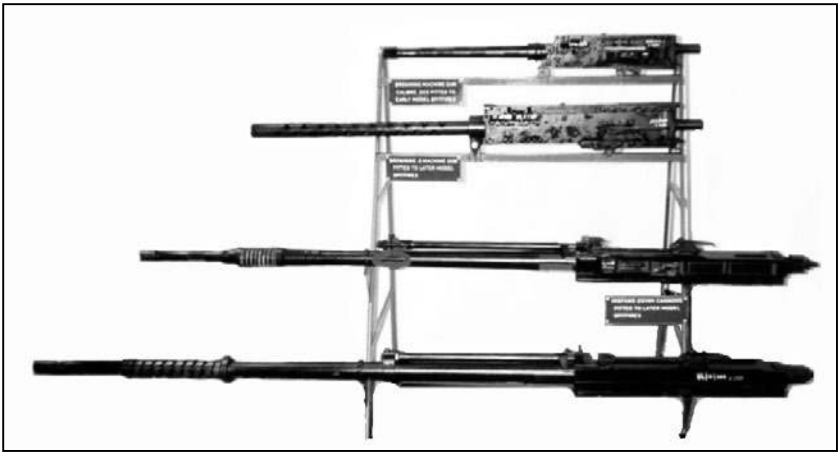
Some improvement was achieved by reducing the gun harmonisation range from 400 to 250 yards in order to concentrate the firepower of the RAF’s fighters, but it was clear that a more powerful gun was needed. This eventually arrived, just too late for the Battle, in the form of the 20mm Hispano. The Hispano (technically the Hispano-Suiza HS 404) was designed and developed at the French arm of the European Hispano-Suiza company in the mid-1930s. A firing demonstration of a prototype to British officers in Paris in 1936 banished all thought of the Oerlikon; the Hispano was similar in size and weight, slightly more powerful and fired nearly twice as fast. Unfortunately, the processes of obtaining approval to buy the gun, setting up a subsidiary Hispano factory at Grantham (the British Manufacturing And Research Company, or BMARCO), redrawing the gun to imperial rather than metric units, testing and debugging the

20mm Hispano-Suiza HS404 cannon (drum fed).

prototypes, then fitting them into aircraft and debugging the installations, all took too long for the cannon to achieve anything in the Battle of Britain.

A key problem was that the Hispano was designed for engine mounting, which meant that it would be bolted to a rigid crankcase. An aircraft wing is nowhere near as rigid, and this caused problems with all wing mountings, which had to be fine-tuned to achieve reliable gun functioning. In the initial Spitfire installation, which did see brief use in the Battle, matters were made worse by mounting the guns on their side in order to bury as much as possible of the bulky drum magazine within the wing thickness. The Hispano took a marked dislike to its unfamiliar environment and jammed as often as it fired. Much modification was needed to both the gun and the mountings before acceptable reliability was achieved. Even so, the stoppage rate by 1944 was still three times that of the US ·50" Browning. A major improvement was the replacement in 1941 of the original 60-round drum by a belt feed.

Work was also needed on the ammunition, as it was found that the fuze of the standard explosive shells was too sensitive, causing them to burst on the aircraft skin rather than within the structure where they would do most damage, and plain steel practice shells often proved more effective. By 1941 both a delayed-action fuze and an explosive with added incendiary filling had been developed, but the practice rounds remained in use alongside the HEIs until they were replaced by a new semi-armour piercing incendiary round (SAPI) which was essentially an HE shell filled with an incendiary compound and capped with a hard steel tip instead of a fuze. From 1942 on, the standard Hispano loading became 50% HEI, 50% SAPI. Compared with other 20mm aircraft cannon of WW II, the Hispano was a powerful and effective gun, but only averagely fast-firing and



Comparative sizes of wartime RAF guns. From the top: the ·303" Browning; the ·50" Browning; the short-barrelled Hispano Mk V and the standard Mk II.

unusually long and heavy. Its weaknesses were addressed in the late-war Mk V, shortened, lightened and speeded-up from 600 to 750 rpm.

The Hispano Mk V could lay claim to being the best aircraft gun of the war, but, in the main, it only saw action in the Hawker Tempest. What became the standard RAF armament of four Hispanos was also probably the best all-round fighter armament of the war, weighing more or less the same as the standard American armament of six ·50" Brownings but being about twice as destructive.

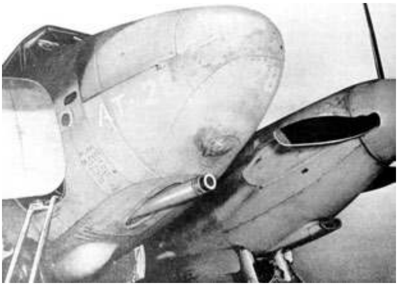
Sadly the same claims could not be made of the RAF’s bomber defensive armament. As you will hear from Jeff Jefford later, the initial advantage of the power-operated multi-gun turrets disappeared as the ·303" gradually lost effectiveness. Various attempts to introduce more powerful guns virtually all failed; the long and heavy Hispano, which needed substantial support, was far from ideal for the purpose and did not enter service in turrets until very late. The ·50" Browning was eventually fitted to some turrets by the end of the war, as well as being used in some fixed mountings, most notably in late-model Spitfires which carried two .50" Brownings alongside two Hispanos, apparently because gun heating arrangements were inadequate to keep four Hispanos functioning in sub-zero temperatures.

Hurricane armed with a pair of 40mm Vickers S guns.

These were not the only guns used by British aircraft during WW II. Two others deserve mention; the Vickers 40mm Class S and the Molins 6 pounder. The Vickers was designed around the same ammunition as the naval 2 pounder pom-pom, but the gun was based on a much-developed 1½ pounder COW gun. It was originally intended for aerial combat and fitted in a dorsal turret to a much-modified Wellington bomber, but this idea was abandoned. Later, a need arose for a gun capable of penetrating tank armour which could be fitted to ground attack aircraft. The S gun was duly dusted off and provided with armour-piercing ammunition. It saw service in the Hurricane IID (with one slung under each wing) and was an alternate armament for the Hurricane IV, which otherwise carried rocket projectiles, conversion between the gun and rocket armaments being quite rapid.

The S gun performed very well in North Africa, South-East Asia and in 1943/44 over northern France, flying from bases in England. Compared with the rocket projectiles more usually associated with ‘tank-busting’ the S Gun was far more accurate, scoring in practice shoots around 25% hits compared with 5% for the RPs (and according to Operational Research, the peculiar flight characteristics of the RPs made them very difficult to aim, which meant that in action, pilot stress caused the hit rate against tanks to decline to 0·5%). Unfortunately, the S gun was not powerful enough to penetrate the latest tanks, and the Hurricane IV was withdrawn from the European theatre only three months before D-day.

The RAF continued to show interest in airborne anti-tank guns,



Left, a 6-pounder Molins gun installed in a Mosquito and, below, the comparative sizes of a ·5" HMG and 20, 40 and 57mm cannon ammunition conveys some impression of their relative power to inflict damage.

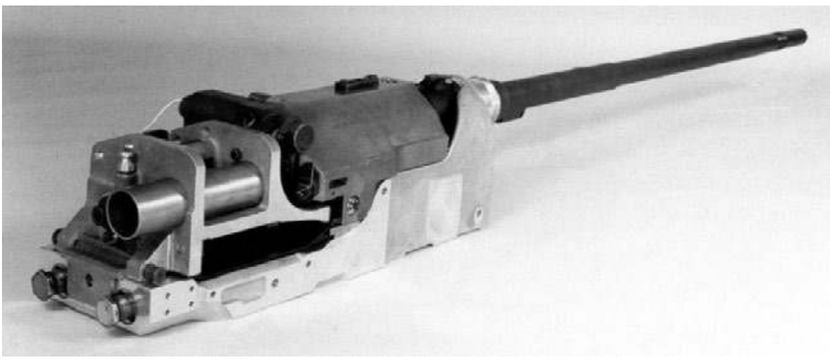
leading to the development of the Mosquito FB XVIII (better known as the Tsetse) which carried an army 6 pounder anti-tank gun fitted with an autoloader developed by the Molins company. This combination worked well, scoring a 33% hit-rate against tank-sized targets, and the 57mm ammunition was far more effective than the 40mm, but the RAF changed its mind and handed the aircraft over to Coastal Command for anti-U-boat work since it was the only gun which could reliably penetrate a pressure hull. In 1946 a Tempest fitted with a pair of Vickers 47mm Class P anti-tank guns was tested, but after that official RAF interest in powerful ground-attack guns disappeared for good.

Gunsights were also improved during the war, the pre-war reflector sights being supplemented by gyro sights which made deflection shooting much easier – without them average pilots were unlikely to score any hits unless they were directly behind their targets.

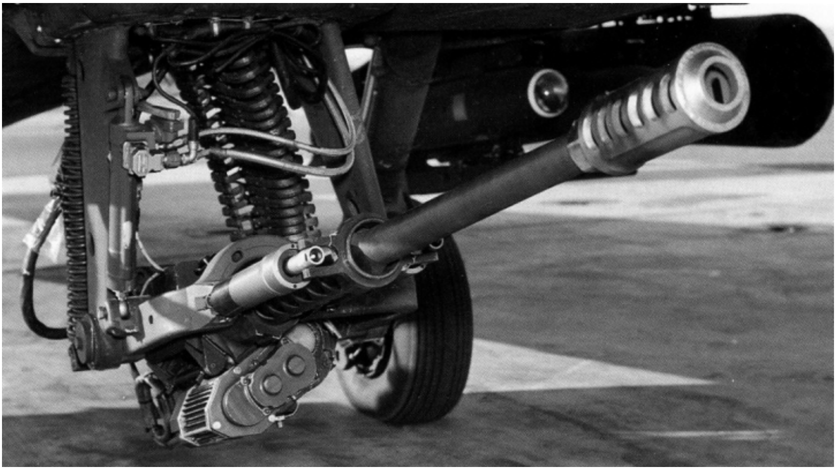
The Post-War Years

At the end of WW II, there was, as usual, very little money for new armament developments and the Hispano remained in service until the mid-1950s, not just in fighters but also in the Shackleton. However the Allies did have a new gun to play with; the Mauser MG 213C. The German firm had designed a new type of gun to meet a *Luftwaffe* requirement for a very fast-firing, high-velocity 20mm cannon. This addressed the main restriction on rate of fire – ammunition handling – by breaking it down into several stages. Instead of one chamber, formed as a part of the rear of the barrel, five chambers were used within a cylinder whose axis of rotation was parallel with the barrel, so that as the cylinder rotated, each chamber was brought into line with the barrel in turn, and its cartridge fired. At the same time, the other chambers were engaged with loading a fresh cartridge or ejecting a spent case. This allowed rates of fire of well over 1,000 rpm to be achieved. As this layout bore some resemblance to the traditional revolver type of handgun, it became known as the revolver cannon.

During the development of the MG 213C a low-velocity 30mm version, considered more suitable for bomber destruction, was also produced. This became the focus of interest in both the UK and France, who continued the development of the gun. It took several years before the resulting ADEN and DEFA guns were ready for service, but they were eventually introduced using slightly different versions of the 30mm ammunition. Further joint development saw the ammunition altered to fire a lighter shell at a higher muzzle velocity,



The ADEN cannon – in this case, the 25mm version.



The 30mm M230 Chain Gun – which arms the Army Air Corps' Apache AH 1s.

and this became the NATO 30mm round still used by the ADEN Mk 4 and DEFA 550 series guns, and by the M230 Chain Gun used on the AH-64 Apache attack helicopter in British Army service. However, the ADEN, DEFA and M230 all use slightly different versions of the ammunition which are not completely interchangeable.

The 30mm ADEN Mk 4 was the standard RAF and FAA gun from the late 1950s until the 1980s, and remains in service with the Hawk trainer (the last combat aircraft to carry it being the Sea Harrier and the Jaguar). It was exceptionally hard-hitting for its day, firing shells weighing twice that of the Hispano's at an only slightly lower muzzle velocity, but at a much higher rate of about 1,300 rpm. The difference in destructive effect compared with the Hispano was even greater than these figures indicate, because the Allies also benefited from another German development; the *Minengeschoss* or mine shells. These were high-capacity shells with very thin walls which permitted the HEI content to be approximately doubled. When used in the ADEN, this resulted in the 30mm shells having four times the blast effect of the Hispano's. ADEN ammunition also used another German development, tungsten-cored AP projectiles.

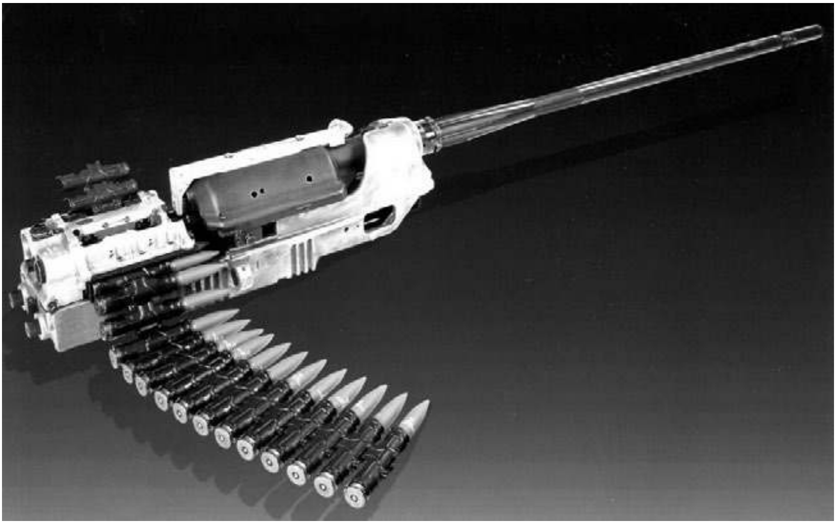
A 1955 paper compared the performance of the RAF's standard armament of four ADENs with the USAF's alternatives of four M39

The American 20mm M61 rotary cannon which saw service with the RAF in the form of the Phantom's SUU-23 gunpod.

20mm revolver cannon or one 20mm M61 six-barrel rotary 'Gatling' gun. The rates of fire quoted were 6,000 rpm for the US systems and 5,200 rpm for the ADEN fit. The 20mm guns also had a higher muzzle velocity. But in the weight of high explosive fired per second, the ADEN fit was six times higher. The RAF was still not entirely satisfied, however, feeling that a higher muzzle velocity would increase the hit probability. It was also noted in 1957 that 20% of ADEN shells would ricochet off the target and another 55-60% would detonate on the surface, seriously reducing their lethality. The RAF later greatly admired the 30mm Oerlikon KCA revolver cannon fitted to the SAAB Viggen fighter, which fired heavier shells at a much higher velocity than the ADEN and matched its rate of fire, at the cost of a relatively modest increase in size and weight. Despite the RAF's dismissal of the 20mm M61 rotary gun, it did see British service in a gunpod which could be carried by the Phantom FGR2.

The next gun to enter RAF service was the 27mm Mauser BK 27 revolver cannon which armed the Panavia Tornado. Similar to the ADEN, and weighing very little more, it uses 27mm ammunition of similar weight but fired at a muzzle velocity which is 30% higher and, at about 1,750 rpm, at a rate of fire which is 25% faster than the older gun. Modified for a linkless feed system, the BK 27 is also fitted to the Eurofighter Typhoon.

In the 1990s there was an abortive attempt to produce a new version of the ADEN gun, chambered for the NATO 25mm cartridge



The belt-fed 27mm Mauser BK 27 for the Tornado.

and known, unsurprisingly, as the ADEN 25. It was initially intended to use it to arm the RAF's Harriers from the GR5 onwards but the aim was defeated by various technical problems, the final and insurmountable one being the sharp curve required of the path of the ammunition belt between the magazine and the gun, which caused unreliable feeding. It was abandoned at the end of the last decade after about 100 guns had been built, and the Harriers have remained gunless ever since, which is reportedly proving a disadvantage in Afghanistan.

The proposed adoption of the Lockheed Martin F-35B Lightning II STOVL strike fighter could see another gun and ammunition entering the inventory: the General Dynamics GAU-22/A four-barrel rotary gun in the NATO 25mm calibre, which has been selected as an optional fit in a gunpod for this aircraft. This offers an even higher muzzle velocity than the BK 27 (albeit firing lighter shells) and will fire at a maximum of about 2,700 rpm.

Some final observations:

How useful are guns? In the days before guided missiles, guns were what fighter aircraft were all about: the sole purpose of the aircraft was to get some guns into a position where they could harm the enemy. The introduction of guided air-to-air missiles led to the rapid

Post-war RAF ammunition: 20mm Hispano; 30mm ADEN LV; 30mm ADEN HV; 20mm M61; 27mm Mauser BK 27; and 25mm NATO.

abandonment of guns in the 1960s, which was promptly regretted when experience in Vietnam revealed that, for various reasons, the impressive missile hit rates achieved in trials were not replicated in combat. Since then, missile performance, in both the air-to-air and air-to-ground roles, has greatly improved. Even so, new fighter designs still come with guns – or, at least, a gun. This is despite the problems which their vibration and noxious gas emissions cause to the aircraft, as well as the cost in purchasing, feeding and maintaining the guns plus training those who use and care for them. Indeed, the Ministry of

Defence did its best to cancel the acquisition of the guns for the RAF's Typhoon, but these are being fitted and were recently cleared for use in the ground attack role.

Why are guns remaining so popular? I think that several reasons can be identified. The current motivation is for aircraft acting in close support of troops in Iraq and Afghanistan to deliver very precise fire which is limited in effect, so that enemy forces very close to our troops can be engaged. This is likely to be a continuing need, as the present generation of guided bombs and missiles, while precise, have a considerably greater radius of destruction. Staying with the surface attack role, a gun also has the ability to fire warning shots or inflict limited damage – to a ship, for instance – in a display of determination. In the air-to-air role, a gun may also fire warning shots (when using tracer ammunition), may be used to destroy low-value targets such as Unmanned Aerial Vehicles, and provides a last-ditch backup should the missiles run out.

What of the future? Ultimately the gun may be replaced by a combination of small guided surface-attack missiles, such as the laser-guided 70mm rockets currently being developed for helicopters, plus lasers in the air-to-air role, but that day seems likely to be many years away.

Seen here firing an AIM-132 ASRAAM, at one time the BK 27 gun was to be retained only as ballast in the RAF's Typhoons – there was to be no ammunition. Happily this decision was reversed in 2006.

DEFENSIVE GUN ARMAMENT – TURRETS

Wg Cdr Jeff Jefford

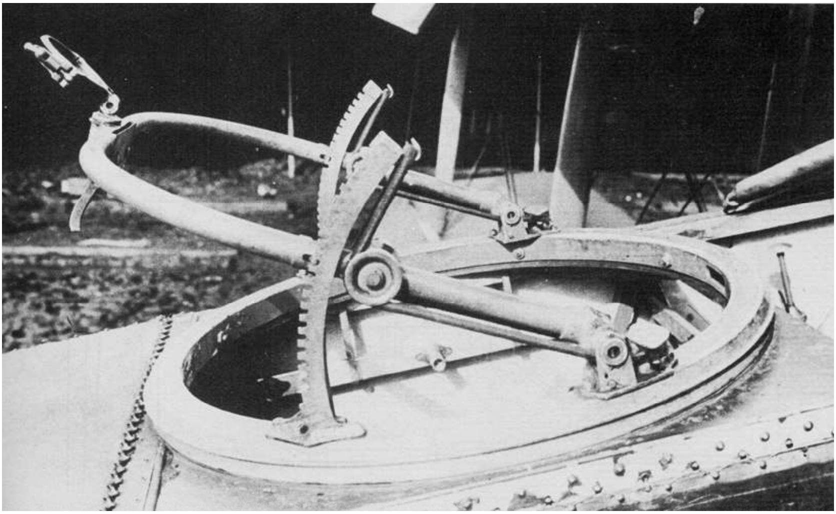
'Jeff' joined the RAF in 1959 as a pilot but (was) soon remustered as a navigator. His flying experience included tours with Nos 45, 83 and 50 Sqns and instructing at No 6 FTS. Administrative and staff appointments involved sundry jobs at Manby, Gatow, Brampton and a total of eight years at HQ Strike Command. He took early retirement in 1991 to read history at London University. He has three books to his credit and has been a member of the Society's Executive Committee since 1998; he is currently editor of its Journal.

As you have just heard, in the beginning, 'gentlemen' aviators anticipated taking sporting pot shots at each other with pistols and carbines but the 'players', who didn't see air warfare as a game, intended to play to win – which meant a machine gun. Unfortunately, the other team did the same thing, turning your machine gun into a <u>de</u>fensive, as much as an <u>off</u>ensive weapon.

This led to a second problem, because it was standard practice to put the pilot of an early tractor aeroplane – like the classic BE2 – in the back seat, where he balanced the weight of the engine in front, and to put the second crew member in between, more or less on the centre of gravity, so that the aeroplane could be flown with the front cockpit occupied or empty without introducing any issues of balance.

The problem with that was that the second crew member was the guy with the gun, but his field of fire was inhibited by the propeller in front, the pilot behind and a cat's cradle of struts and bracing wires. Many and various were the attempts to design a practical means of wielding a gun in the ubiquitous BE2, the best of them being the Strange Mount – named for its inventor, Lt Louis Strange. It was a simple pillar with the gun mounted on a horizontal arm which could be swivelled through 360°. Installed between the cockpits, it could, in theory, be handled by either crew member but, in practical terms, it was the observer.

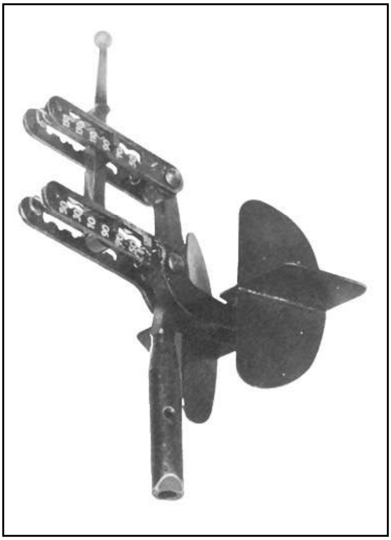
As air fighting developed, it became apparent that most attacks came from the rear, but these were particularly difficult to counter



The Scarff ring or, more formally, the 'No 3, Mk II barbette'.

because the pilot tended to get in the way. The answer to this one was to reverse the crew positions and in all later types the gunner occupied the rear cockpit, which provided him with an unrestricted field of fire over the most vulnerable sector. With his gun, always a Lewis, mounted on a Scarff ring – named for its designer, WO Frederick Scarff of the Admiralty Air Department – his ability to engage the enemy was much improved, but it was still no sinecure. I recently read the memoirs of an airman who flew as an air gunner between the wars. As he put it, 'Shooting at a moving target with a freely moving Lewis gun fitted to a moving aircraft was easy. Hitting that target was very difficult.'[1]

On the assumption that having two guns would double your chances of getting a hit, it was possible to mount two Lewises side by side but this was not as obvious a solution as it appears because, even with the assistance of a Scarff ring, it took a very strong man to heave more than 50 lbs of dead weight around against a 100 mph slipstream at 10,000 feet without oxygen, and in a dogfight involving harsh manoeuvres, that 50 lbs could easily be more than doubled. In the event most gunners in two-seat fighters, like the Bristol F2b, opted for a single gun, the double mounting being a more practical proposition in relatively staid artillery co-operation aircraft (RE8s and FK 8s) or in



The Norman vane sight. Mounted close to the muzzle, it was free to swing under the influence of the slipstream on the vanes, which displaced the sighting bead by (theoretically) the correct amount. In this instance there is a facility for adjusting the position of the bead to allow for the speed of the aircraft.

DH 4 and DH 9 day bombers which relied on maintaining formation in order to provide a concentration of defensive firepower, rather than on manoeuvrability – or at least, that was the theory.

If manipulating the gun was a problem, so was sighting, especially for beam shots, because the velocity imparted to a bullet has two components – one along the line of the barrel, the other the result of the fact that the barrel itself is moving at the speed of the aeroplane. If you failed to allow for this, at a range of, say, 200 yards at WW I speeds you were bound to miss by perhaps 50 feet. This error could be compensated for, or at least moderated somewhat, by the rather ingenious Norman vane sight – named for Lt Geoffrey Norman of No 18 Sqn. Mounted as the foresight, the vanes allowed it to 'weathercock' in the airflow, automatically offsetting the sightline by the required amount. At least, that was the theory – because it only really worked in smooth air, and there wasn't much of that in the whirling backwash from the propeller and the turbulent wake of the wings of a biplane. That aside, the gunner still had to deal with all the usual variables of range, deflection and bullet drop.

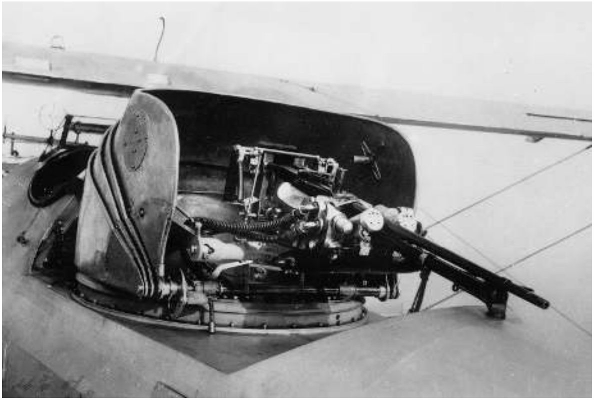
There was little change in the field of defensive gunnery until the later 1930s when the high speed monoplane began to make its appearance. They made it increasingly difficult, approaching the impossible really, to wield a hand-held machine gun at sub-zero temperatures in a 150 mph gale. If he was to be at all effective, the gunner simply had to be provided with some form of protection and

More usually associated with early Ansons, Armstrong Whitworth turrets were widely used on RAF marine craft. This one is armed with a Vickers Gas-Operated (VGO) gun.

Armstrong Whitworth were quick of the mark with an early form of turret. While it may have looked quite ‘turrety’, perched on the back of an Anson, it was actually not much more than a conservatory. There was no power involved – it was just a glazed housing to protect the gunner from the elements while he elevated and depressed his gun and rotated its mounting manually, as he always had done.

His seat was connected to the gun through a parallel-motion arrangement of struts, rather like a pantograph. His feet were on the floor and if he let them take the weight, the seat would rise up – and the gun depressed – or he could let his weight dominate, in which case the seat went down and the gun elevated. To rotate the turret, he simply did the ‘office swivel chair two-step’.

Meanwhile, while Armstrongs had dominated the early market with its manually operated greenhouse, more complex solutions were being explored by others. Boulton Paul was an early entrant in the race with the Overstrand and its powered nose turret. The single Lewis gun protruded through a vertical slot which was sealed by a fabric fastener,

Left – the Boulton Paul Overstrand's fully glazed, pneumatically rotated turret and right – the hydraulically operated FN1 in a Demon.

rather like a zip, and as the gun moved up and down, it opened and closed automatically. The gun was connected to the seat and elevated and depressed by the gunner shifting his weight, the movement being assisted and smoothed by hydraulic rams. But there was more – this turret was rotated under power – in this case pneumatic – provided by an air reservoir which was charged by an engine-driven compressor.

Even more sophisticated was the approach taken by Archie Frazer-Nash, of Nash and Thompson, who had devised an hydraulically-assisted means of controlling a gun that would overcome the problems being experienced manipulating a free gun at ever-increasing airspeeds. He built a demonstration rig that impressed Gp Capt Arthur Tedder, then CO of the Air Armament School at Eastchurch, to such an extent that it eventually resulted a production order for fifty units of a full-scale turret – the FN1 – tailored to fit the Demon two-seat fighter.

This more or less brings us up to WW II which was when the power-operated gun turret came into its own. There were one or two incidental manufacturers but only three made a substantial contribution.

First off were Bristols, who were virtually a self-contained outfit – they made their own aeroplanes, powered by their own engines and it sort of followed that they would build their own turrets. And so they did. There were some exceptions, of course, but in essence Bristols built the turrets for their home-grown Blenheims and Beauforts and then they rather dropped out of the production picture, although they were actually beavering away developing a whole series of sophisticated gun installations, notably for the Buckingham which, unfortunately, never really came to anything.

Bristol's turrets were hydraulic and driven by the main aircraft system. That had two drawbacks. You could have flaps and undercarriage, or the guns, but not both. That was not really a problem as you were unlikely to want flaps and wheels in a combat situation. The other drawback was more significant. Using the aircraft system meant long lines of piping carrying hydraulic fluid under pressure and, leaky joints aside, that was vulnerable to battle damage.

The second major player in the field was Boulton Paul. Their control system was electro-hydraulic. That is to say that the turrets had their own, electrically-driven, integral hydraulic pumps. All that was required from the aeroplane was a supply of 24 volts DC, which avoided the long hydraulic lines. This was not actually Boulton Paul's idea. It had originated with a Frenchman, called de Boysson, but the French Air Ministry had shown little interest. Boulton Paul's John North recognised the potential of de Boysson's turrets, however, and he ordered two and shortly afterwards purchased the design rights. After replacing the four original Darne machine guns with Brownings and anglicising the engineering, the turret went into production as the Boulton Paul Type A which saw widespread service in a number of types but most notably the Defiant and later production Halifaxes.

Boulton Paul also provided the sting in the Halifax's tail with its four-gun Type E turret, which was also fitted in early Liberators which were delivered without any defensive armament.

The third manufacturer, who produced far and away the largest number of turrets, was Nash and Thompson with its series of Frazer-Nash designs. Nash used engine-driven hydraulics but with dedicated pumps. That avoided the problem of having to choose between which services to have on line, but still left the battle-damage question, although the provision of separate pumps minimised the risk. In the Lancaster, for instance, the port outer engine pump drove the tail turret, the port inner the belly turret (if/when one was fitted); the starboard inner the nose turret and the starboard outer the mid-upper.

There were some variations on the themes but the three major manufacturers adopted individual approaches to the question of turret control (*see page 66*). Nash and Thompson provided a pair of grips which looked a little like motorcycle handlebars. The hand grips had built-in levers and these were squeezed to open the hydraulic valves which energised the turret. Pulling or pushing would then elevate or depress the guns and exerting pressure about the vertical axis rotated the turret. There was a trigger on each grip. The grips could be ganged together on a central pillar (as in the sketch) or mounted separately on either side of the turret.

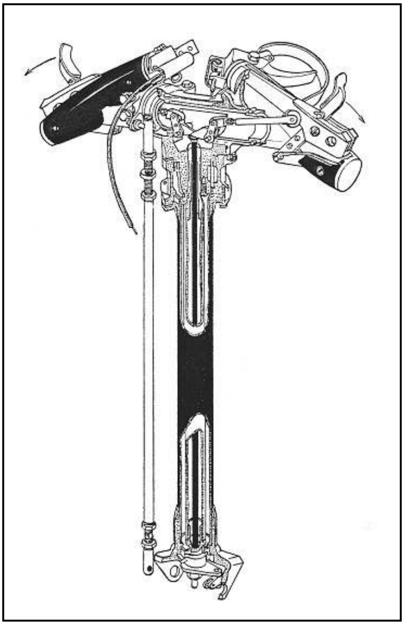
The Bristol system was quite similar, although in this case elevation and depression were controlled by twisting the hand grips, rather than pushing and pulling. There was a dead man's lever for the master hydraulic valve on the left and a trigger for the guns on the right.

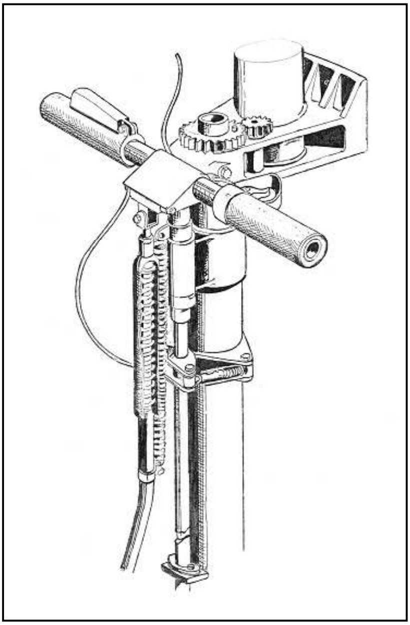
Boulton Paul opted for a control column. This incorporated a lever that one squeezed to energise the electrics and then simply moved fore and aft to control elevation and left and right for traverse – the firing button was on the top.

One last word on control – or to be more precise – aiming. We lack the time to go into any depth, suffice to say that air gunners had much the same facilities as fighter pilots. By 1940 the Barr & Stroud Mk III reflector sight was standard in most powered turrets. From 1944 onwards the reflector sights began to be replaced by a Ferranti gyro gunsight but when the war ended the Barr & Stroud was still the most numerically significant.

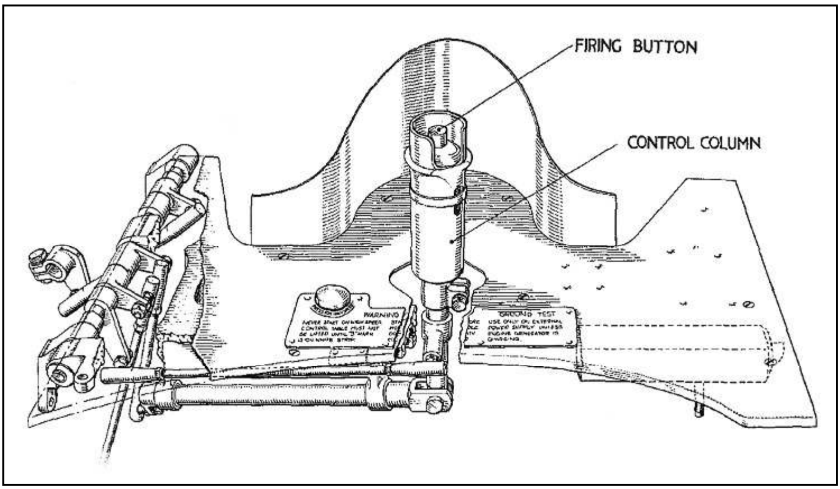
And now we need to consider the rather thorny problem of the lower defensive gun position. Bristols did their own thing on the Beaufort – and it was fairly basic. It consisted of a single ·303-inch Browning which the gunner lay prone to operate, facing the 'wrong' way, so that he had to aim backwards via a mirror while manipulating the gun by hand. It is extremely doubtful whether anyone ever shot anything down using this arrangement.

For the Blenheim IV, Bristols turned to Nash and Thompson who produced their FN54. There were no hydraulics or electrics; it was an entirely manual affair. The observer (as gunner) sat facing backwards on the integral seat, sighted through a periscope and moved the guns by rotating the whole contraption and by rocking it backwards and





Typical turret controls, top left, the Frazer Nash FN20, eg in the tail of a Lancaster; top right a Blenheim's Bristol B1 and below, the Boulton Paul Type C mid-upper as fitted to Hudsons and early Halifaxes.



The Handley Page Heyford with its retractable ventral 'dustbin' in the extended position.

forwards. Again, I doubt that it ever did anything more than perhaps scare someone.

So far as the RAF's heavy bombers were concerned, they had always, ever since the big Handley Pages of WW I, been provided with some means of firing downwards to deter attacks from below. By the mid-1930s the Heyford had been provided with a retractable 'dustbin' from which the hapless gunner was supposed to protect the entire lower hemisphere against all comers with a single hand-held Lewis gun.

In increasingly complex forms, this approach was followed by the Whitley, Wellington and Manchester, and the Stirling and Halifax were both intended to have had even more sophisticated ventral gun positions. Although, since the tail gunner could deal with stern attacks from below, the belly turret was intended primarily to deter attacks from the beam.

Unfortunately, early operational experience soon demonstrated that these turrets were of little practical value, because their robust metal construction meant that, apart from the section directly in front of the gunner, they were largely opaque and the restricted view meant that it was difficult to acquire and track a target. Worse still, when extended, the drag penalty could be as much as 20 mph – this when you were actually trying to run away. Furthermore, because a beam attack presented a fighter pilot with a very difficult firing solution, in terms

An example of a dorsal turret, the Boulton Paul Type A in a Halifax. Note the lack of space – a feature common to many turrets.

of deflection shooting, they failed to materialise in any case. The belly turrets in existing Whitleys and Wellingtons were soon abandoned, either locked in the retracted position or, because they now represented close to half-a-ton of dead-weight and seriously restricted access within the aeroplane, removed, and they were not fitted in later production aircraft.

This change in policy had a major knock-on effect on the second generation ‘heavies’ just as production was getting under way. In the summer of 1940 it was decided to discontinue the provision of ventral turrets and only a handful of belly turrets for Manchesters (the FN21), Halifaxes (the Boulton Paul Type K) and Stirlings (the FN19) were built and very few of these were ever fitted. Instead, for beam defence, both of the four-engined types were provided (as was the Wellington) with manually operated flank gun positions while the Manchester did without.

This was only a temporary arrangement, and in 1941 power-operated dorsal turrets were installed: FN50s for the Stirling and Lancaster, Boulton Paul Type Cs, and later Type As, for the Halifax and the rather unsatisfactory Frazer-Nash FN7 for the Manchester.

Thus far I have focused largely on the development of the

A Nash and Thompson FN20 in a Lancaster. Fully glazed when they left the factory, it was common practice, as here, to remove the centre panels to improve visibility. Perhaps surprisingly, this appears to have made little difference to the already freezing conditions within the turret.

hardware, but underpinning this there were a number of practical and doctrinal issues and we ought to look, at least briefly, at some of these by posing a series of questions.

Were turrets worthwhile? Among the wartime military community there was a small lobby of largely scientific, as distinct from uniformed, opinion that advocated the deletion of gun turrets. It contended that they were of doubtful value and that losing their weight and drag would yield an increase in performance that would result in a substantial reduction in losses and a significant saving in manpower (armourers as well as air gunners). While the math could be made to look attractive, it never overcame the ingrained experience of WW I – and never seriously questioned thereafter – which had demonstrated (to the satisfaction of the airmen who had to do it) that defensive gun positions were simply essential, nor did it take account of the impact on morale if crews, accustomed to having a self-defence capability, however limited, in which they were obliged to put their trust, were to be deprived of it.

Why *powered* turrets? In September 1940 Arthur Harris, then AOC 5 Gp, wrote to Bomber Command to say that he was 'convinced that a perspex turret in the tail is a mistake.'[2] He maintained that the most important feature had to be an unrestricted view and he wanted to save the weight and complexity of a powered turret by substituting a simple open observation station with three or four hand-held guns.

The infrared 'headlights' of the 'Z' IFF installation.

Perhaps unsurprisingly, this proposal made little headway – although it was a common (and, from the spring of 1944, in some quarters at least, standard?) practice for rear gunners to have the centre panels of the glazing removed to reduce internal reflections and any tendency for the eyes to focus on the perspex, rather than looking through it.

To shoot or not to shoot? It is not always appreciated that the core function of the air gunner was not to shoot down the enemy but to preserve his own aeroplane – which are not quite the same things. The very fact of operating in the dark provided a degree of, what we are now pleased to call, 'stealth'. If a gunner saw an enemy aeroplane he had two options, engage or evade – and the 'corkscrew manoeuvre' does appear to have been reasonably effective in throwing off a night fighter. On the other hand many crews maintained that if you opened fire first enemy fighters tended to break off and look for easier meat. This sort of conjecture was difficult to verify, of course. What one needed to know was whether the crews that had failed to return had been runners or fighters – and there was no way to establish that with any confidence. In late 1943 a comparative analysis of the records of Nos 1 and 5 Gps was carried out and this concluded that 5 Gp's aggressive 'shoot first' policy had increased the risk of attack and, worse, had resulted in an increase in the number of cases of gunners firing on other bombers.[3]

Nevertheless, while appropriate advice was offered, it was difficult to lay down the law in these circumstances, because, once a night bomber had disappeared into the darkness, despite the fact that there would have been several hundred others involved, each crew was effectively operating in isolation as an independent entity and it conducted its business as it saw fit. Several gunners were credited with a number of 'kills', of course, but I suspect that many more went through the war without ever firing their guns in anger.

No of guns of calibre	**Rate of Fire (rpm)**	**Ratio of probability of hits**
4 × ·303"	4800	4
2 × ·5"	1600	1.3
2 × 20mm	1200	1

Table 1. Probability of Achieving a hit

That said, the risk of mutual engagements between bombers was a very real one and its solution required a reliable form of IFF. This eventually turned out to be the infrared-based ‘Z Equipment’ which began to be installed from the end of 1944. In the Lancaster, this took the form of a pair of ‘headlights’ grafted onto the inner surface of the bomb-aiming blister.

What Calibre? The *Luftwaffe* had begun to arm its Bf 109s with 20mm cannon in 1940 and from then on the bombers were increasingly outgunned. By 1943 the standard armament of a German night fighter included at least two, and often four, 20mm cannon and the even more effective 30mm MK108 was beginning to appear. More to the point, armour plate, ‘bullet-proof’ windscreens and self-sealing fuel tanks meant that the German fighters were increasingly resistant to mere ·303-inch machine gun fire. The obvious solution was to introduce heavier calibre defensive weapons. But it is not quite as simple as that because there are several limiting factors associated with guns, especially larger ones:

a. The probability of getting a hit. It is axiomatic that a big bullet or a cannon shell will inflict more damage than a small bullet, but, because of weight limitations, you can have only two big guns versus four small ones and, as Table 1 shows, when rate of fire is factored in, you are about four times more likely get a hit with a ·303-inch machine gun than with a 20mm cannon.[4] So, four times more chance of a hit with rifle bullets, which don’t do much real damage, but may well cause the fighter to break off. It’s a quantity versus quality trade-off.

b. Duration of fire. Again, for a given weight of ammunition, a bigger gun means fewer bullets, and bigger guns tend to have

No of guns of calibre	Rounds per gun	Total rounds (weight of 660 lbs)*	Firing time
4 × ·303"	2500	10000	2 mins 5 secs
2 × ·5"	1000	2000	1 min 15 secs
2 × 20mm	540	1080	54 secs

* Limiting weight – 660 lbs – established by the standard 10,000 rounds of ·303 for the tail turret.

Table 2. Duration of Fire.

slower rates of fire. The upshot, as Table 2 indicates, is that the bigger the gun, the shorter the firing time – quantity versus quality again.[5]

c. Range. It is generally true to say that the bigger the gun, the greater its range but, while that is clearly an advantage, it is only of practical use if you can actually see a long way – as in a B-17 operating in daylight – but in a *night* bomber the limiting factor was visibility.

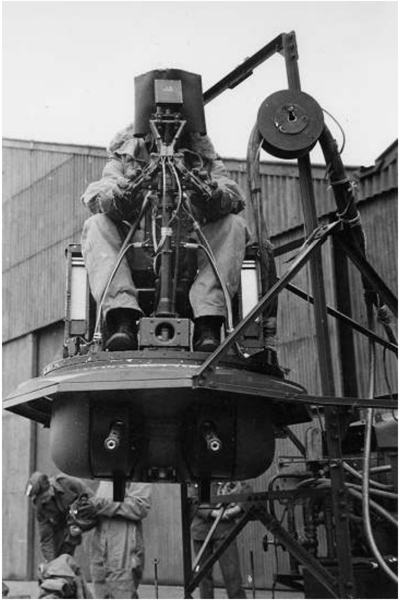
d. Muzzle Flash. Not significant in daylight, muzzle flash does become a problem at night and, while it is relatively easy to suppress on a ·303-inch gun, it becomes progressively more difficult to control as calibre increases. The point being, of course, that if the gunner is dazzled as soon as he opens fire, he is neutralised – making tracer of questionable value.

e. Weight. Broadly speaking, the bigger the gun the heavier it is which requires, in turn heavier mountings and heavier turrets. Adding weight, especially at the extreme tail, can introduce centre of gravity problems and, even if these can be tolerated, the increase in all-up weight may have to be offset by a reduction in ammunition, fuel (which is range) or bomb load. In order to alleviate the problems associated with the weight of defensive armament the main magazines were usually located close to the CofG and the ammunition was fed to the tail turret via ducts. There was also a tendency to overprovide ammunition; a Lancaster had storage capacity for a total of 18,000 ·303-inch rounds, which was far more than it was ever likely to need. The number of rounds did tend to be reduced later in the war, although this was offset by the

Air gunners checking the ducts, or tracks, which fed ammunition from the mid-fuselage magazines to the four-gun turret in the tail of, in this case, a Halifax but the arrangements were much the same in both the Stirling and the Lancaster.

introduction of 50-calibre guns, with their much heavier ammunition. In short, weight and balance was a factor that had constantly to be monitored and, sometimes provoked positive action. The most obvious instance of the latter was the Lancaster Mk VII which had the standard ·303"-armed FN50 mid-upper replaced by an electrically operated Martin 250-series turret armed with ·5-inch machine guns. With its much heavier ammunition, the American turret had to be mounted about six feet further forward in order to keep the aeroplane in balance.

f. <u>Drag</u>. Drag is something of a red herring, because big guns are not that much draggier than little one, but turrets are draggy and the answer to that lay in small, smooth, unmanned, remotely controlled barbettes. Some work was done on this concept, and in 1944 Boulton Paul actually produced a prototype installation for the Lancaster. Perhaps because it would have been a very challenging project technically and/or because introducing such an



The FN64 ventral turret specified for the Lancaster but which saw only limited service. Only the smooth, domed lower section housing the guns protruded into the slipstream.

extensive modification would have been very disruptive of production schedules, it never came anywhere near entering service, although the Americans managed to pull it off in the B-29.

So much for the pros and cons which, by the autumn of 1942 had swung the balance in favour of heavier armament, the stated aim being to introduce a pair of 20mm cannon for the mid-upper and twin ·5-inch machine guns in the tail. But Arthur Harris was still dissatisfied with the provision of defensive armament and still concerned about visibility and blind spots, particularly underneath. At a Ministry conference convened, at his instigation, in July 1943 it was decided to reinstate a formal requirement for an 'Under Defence' gun.

By June 1944 207 Halifaxes had actually been fitted with a single, hand-held ·5-inch machine gun in a Preston Green mounting and, by the same date, 48 Lancasters and 68 Stirlings had also been provided with a hand-held belly gun installation.[6] This programme had already been short-circuited, however, by a late 1943 decision to provide Main Force aircraft with mapping radar and the installation of an H2S scanner left no room for a gun position.

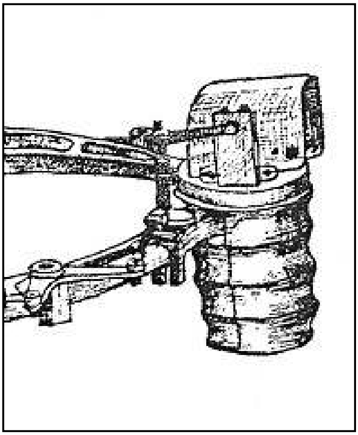
That said, some use was made of the FN64 turret in Lancasters. The FN64 was not retractable, but only the gun mounting actually protruded into the airflow, so it wasn't all that draggy. The gunner was housed inside the fuselage from where he sighted via a prismatic periscope. The guns could be depressed by about 80^{o} and traverse 100^{o} to either side, which encompassed a considerable volume of sky, but the view through the sight was only some 20^{o} and, with the pilot

The roomy and uncluttered Rose turret with its large unglazed area and its twin 50-calibre guns set wide apart.

taking evasive action by flying a corkscrew manoeuvre it proved to be almost impossible to acquire and track a target – especially in the dark. They were not really very practical and, as with the proposed hand-held under gun, most of them were displaced by an H2S scanner.

Meanwhile, much progress had been made with the up-gunned tail turrets and the new models began to appear in late 1944 in the form of the FN82 for the Lancaster and the Boulton Paul Type D for the Halifax. By this time there was a new player on the field, Rose Brothers of Gainsborough. Starting with a clean sheet, and drawing heavily on the experience and expertise of No 1 Gp, they had designed a twin-50 turret of their own and these had begun to be fitted to some Lancasters.

The Rose turret introduced a number of improvements: it was far less cluttered and had a large unglazed area – thus improving target acquisition and finally addressing Arthur Harris's long-term concerns about visibility – and it was much lighter than the standard FN20, although this was largely offset by the fact that all of its ammunition, 335 *big* rounds per gun, was stored within the turret.

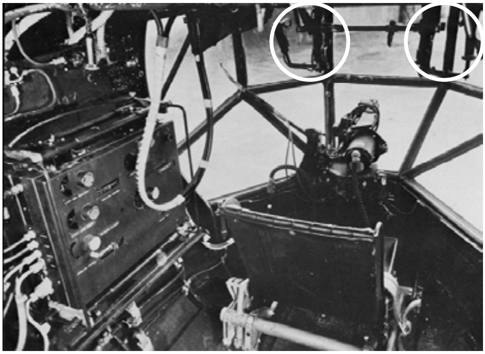


The Rose turret's Barr & Stroud reflector sight with its integral two-handed pistol grip

It was much roomier, so much so that it could even accommodate two people, which was an advantage in training. Furthermore, it was much easier to escape from. In the long-established 'traditional' tail turrets access was via a door at the back and the clip-on chest parachute was stored beyond it in the rear fuselage. In an emergency, the turret had to be rotated so that it was aligned fore and aft to permit the door to be opened to gain access to the parachute. Once this had been fitted, the turret had to be rotated through 90^{o} and the door opened to permit the gunner to roll-out backwards. All of this became problematical if the turret mechanism was damaged. In the Rose turret the available space meant that the gunner was able to wear a back-type parachute, permanently, and, since the guns were set much wider apart, he could simply roll forward between them, so that he could escape, even if the turret had jammed.

But the big innovation introduced by the Rose turret was in the way in which it was operated. There were two controls. One was a simple lever that allowed the gunner to swing the turret left and right in search mode. The other was a two-handed 'pistol grip' that was attached directly to the reflector gun sight. Once the gunner had a target in his sights he kept it there by moving the handgrip – the guns followed automatically. There was none of the interpretative control manipulation, in two planes, that was demanded by all other turrets; in the Rose turret control was instinctive – in effect, you just pointed your finger at the target and followed it, and with a gyro gunsight automatically laying off the correct amount of deflection it would arguably have been quite difficult to miss.

Only 320 had been delivered before August 1945, and 81 of those had been lost in action,[7] so you might think that I have spent a disproportionate amount of time on the Rose turret. But it was a very



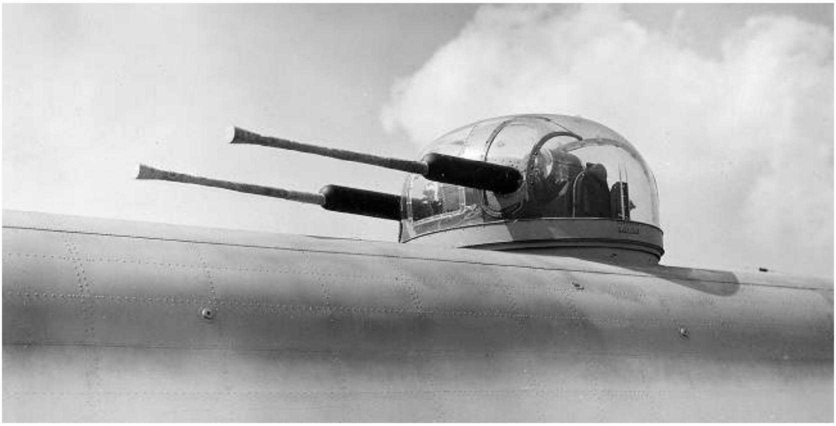
The controls for the Boulton Paul Type F turret in the Lincoln were led down beneath the guns, so that they could be operated from the bomb-aiming station.

considerable improvement on what had gone before and, had the war gone on into 1946, it might well have become the new yardstick.

In the event, of course, the war ended, somewhat abruptly, in August 1945. Precise production totals are elusive but it is safe to assume that that something in excess of 60,000 Frazer-Nash turrets will have been built during the war; Boulton Paul will have contributed at least 22,000 (many of them produced under sub-contract by Joseph Lucas) and Bristols must have made another 8,000 or so. The grand total of wartime turret production must, therefore, have been close to 100,000 units.

Which brings us to the last lap – a hasty canter through the first post-war decade during which turrets, and their occupants, gradually faded away.

During the later 1940s the standard heavy bomber became the Lincoln and its defensive armament reflected the policy decisions that had been taken during the war, back in 1942. Oddly enough, having dominated the wartime scene, Nash and Thompson dropped out of the picture and Boulton Paul provided the Type D (which had first seen service in late production Halifaxes) with its twin 50-calibre machine guns in the tail. Some of these were modified by the addition of a VILLAGE INN radar to create the Automatic Gun-Laying Turret (AGLT) which had begun to be fitted to the Frazer-Nash turrets of some Lancasters during the last few moths of the European war. The



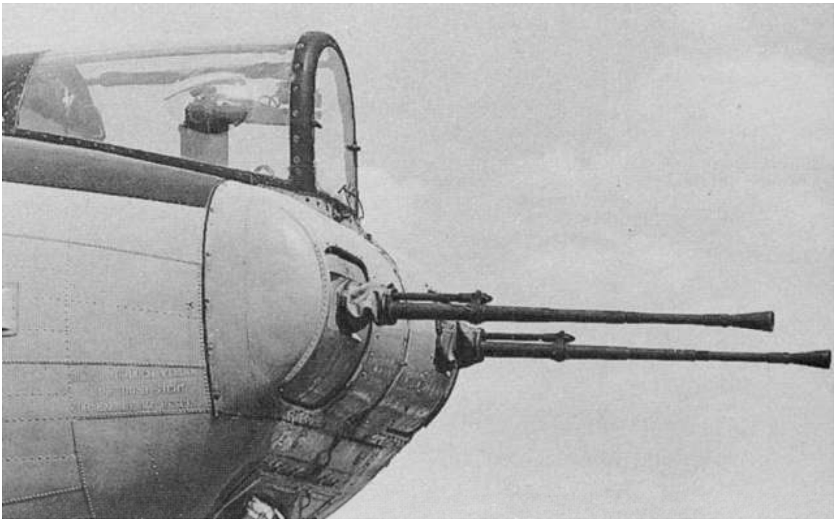
Standard dorsal armament of the Lincoln, the twin-20mm cannon-armed Bristol B17, the last of the RAF's classic gun turrets, was finally withdrawn from service in 1957 when it was deleted from the Shackleton.

AGLT saw limited post-war service in association with a series of stop-go trials but serviceability was a constant problem and the Ministry finally admitted defeat in December 1949 when the equipment was withdrawn without ever having really realised its potential.[8]

Boulton Paul also provided the Type F nose turret, which also had a pair of ·5-inch guns. In the Lancaster the air bomber could either be down on his belly at his bombsight or up in his turret, but not both. In the Lincoln the bomb-aimer was *seated* behind a magnificent bay window and the controls of the nose turret were taken down beneath the guns so that they were accessible from his normal work station.

Bristols had also come back into the picture and they provided the Lincoln's B17 mid-upper which mounted a pair of 20mm Hispano cannon. All of the Lincoln's guns were fired in anger, but for strafing in Malaya and Kenya rather than in air combat.

For a brief period, 1951-54, the RAF's air gunners were exposed to the sophistication of the B-29 and its General Electric Central Fire Control (CFC) system. The Washington had two dorsal turrets, two ventral turrets and a tail turret. All were low-drag installations, armed with 50-calibre machine guns, four in the forward upper turret, two in



The final iteration of a gun-armed big aeroplane in the RAF was the Shackleton which sported a pair of 20mm cannon in a Boulton Paul Type N installation..

all of the others, and all were remotely controlled from pressurised work stations. Rather like the Rose turret, the gunner tracked a target with his sight and the guns followed, but not directly, because a computer did the necessary calculations and laid off the appropriate amount of deflection allowing for such variables as ballistics, altitude, airspeed and parallax. This gave the guns an effective range of the order of 900 yards, well beyond that of most fighters. Control could be switched between sighting stations so that the top gunner could be allocated the upper rear turret and the upper front turret (normally controlled by the bombardier) allowing him to fire a broadside of six heavy machine guns at a single target.

At much the same time the RAF acquired another American aeroplane, the Neptune maritime patrol bomber and they effectively signalled the demise of the turret. When they were delivered in 1952 they had three turrets but when we gave them back in 1957 they had only one.

At much the same time, 1957, the Shackleton lost its mid-upper turret – it had had the same B17 as the Lincoln – leaving just the

Boulton Paul Type N mounting in the nose. The Type N had a pair of 20mm Hispanos which could be depressed a little, but they could not be traversed. They would have been of little use in air combat, of course, but that was not what they were for; they were provided to deter the bad guys on the ship or submarine that you were attacking from shooting back – and they did see some action strafing in the Aden hinterland, for instance.

So, to sum up, having started in 1915, the use of guns for defence had lasted for little more than forty years. Once an essential member of the aircrew community, the air gunner, and his turret, had been overtaken by advances in technology and they had become as obsolete as the English archers whose longbows had dominated the battlefields of the 14th Century. We do still mount free guns, of course – in helicopters – but for 'defence suppression', rather than 'air defence'. So aerial gunnery, in the traditional sense, has become a neat time capsule.

Acknowledgements. I am indebted to Les Whitehouse and Ron Clarke for their personal assistance in preparing this paper and recommend the latter's invaluable *British Aircraft Armament, Vol 1* (Yeovil, 1993) as a reference source.

Notes:

[1] Conroy, Denis; *The Best of Luck* (Victoria, Canada, 2003) p46.

[2] TNA AIR14/607. AOC 5 Gp Memorandum 2912/5/Eng to HQ Bomber Command, dated 27 September 1940.

[3] AP3368; Operational Research in the RAF (HMSO, 1963) p65.

[4] TNA AIR14/607. Figures extracted from a paper covered by Air Ministry letter S.2023/ACAS(T), dated 30 October 1942, from AVM Sorley to AOCinC Bomber Command.

[5] *Ibid.*

[6] TNA AIR2/2662. Minute DO(FP)/1034 dated 8 June 1944.

[7] TNA AIR14/991. HQ 1 Gp memorandum 1G/S.2014/18/Armt to HQ Bomber Command, dated 3 September 1945.

[8] TNA AIR14/3873. Work on AGLT was effectively terminated by Air Ministry memorandum, A.22705/49 of 5 December 1949.

MORNING DISCUSSION

Steven Mason: Reference was made to the operational assessment of the effectiveness of new bombs. How easy was that to do when bombs were being delivered in a mix with existing bombs?

Nina Burls: I think that I would need to have had notice of that one.

Wg Cdr Jeff Jefford: I am speculating here, but I would imagine that the answer would have to lie in post-strike photography. Put crudely, the idea of mixed loads was for the high explosives to blow the roofs off and for the incendiaries to set fire to the furniture. The most significant changes made during the war were in the size of HE bombs and I would have thought that the considerable blast produced by the much bigger 4,000, 8,000 and 12,000 lb bombs might have been apparent when compared to the well-established impact of the standard 500 and 1,000 pounders. But this may well have been more of an art than a science.

Nina Burls subsequently offered the following: I would agree that some feedback could be obtained from intelligence, either from the ground or, and more likely, from post-strike photography. Some very clever people were employed to interpret these photographs and they would have been able to tell, to some degree, whether the anticipated levels of damage were actually being inflicted. This was actually one of the ways in which we were able to conclude that the General Purpose range of bombs was largely ineffective. Perhaps more importantly, however, the characteristics of new bombs, or components (fuses, pistols, tail units, etc) were actually established, before they entered service, in the course of trials. The results were eventually made available in relevant Air Publications and manuals that permitted planners to match weapons against target types (armour, soft-skinned vehicles, reinforced concrete structures, residential accommodation, bridgeworks and so on) and to calculate the weight of effort/number of sorties required, allowing for the statistical accuracy of delivery and the forecast reliability of the weapons. All of this kind of empirical data was derived primarily from the analysis of specific trials, rather than operational research. That said, there was a feedback loop that recommended modifications and/or suggested further tests to overcome deficiencies that came to light after a bomb had entered service. Once a new weapon had been cleared for use, however, I suspect that the prevailing philosophy would have been that it was better to have an adequate bomb today rather than a perfect one next year, so a problem would have had to be pretty significant – perhaps an unacceptably high rate of failures to detonate – before taking remedial action that would disrupt production.

Mike Meech: A question for Tony Williams – what were the implications of using rimmed, as distinct from rimless, cartridges? Were rimmed ones more likely to jam?

Tony Williams: Jamming? Not, generally speaking, in the machine-guns used by the RAF. Rimmed cartridges were more prone to jamming, but only in guns using boxed magazines where the cartridges lay on top of each other, which made it possible for the rim to get 'on the wrong side'. But it was not a major issue and rimmed rounds are still in use today in Russian machine-guns.

AVM Peter Dodworth: Was our development of bombing during the First World War mirrored by that of the Germans?

AVM Peter Dye: Yes. The Germans produced a quite effective series of bombs early in the war, primarily intended to be dropped by Zeppelins, but, building on that operational experience, these were superseded by a completely new range of weapons for delivery by aeroplanes. I think that it would also be fair to say that we and the Germans learned from each other – most significantly by examining unexploded bombs. And the Germans were particularly interested in our bombsights – as were the French. So you could say that a kind of mutually self-improving community existed in which the developmental aspects and challenges were mirrored in *all* air forces.

Wg Cdr Ken Wallis: First, perhaps I could offer a short anecdote. During my time as an Armament Officer I came up with a number of ideas and inventions. One concerned the safety and efficiency of the 25 lb practice bomb. I produced the necessary drawings and submitted them up the chain. I eventually had a phone call from my Boss at Group HQ who said that my idea had been studied by the Ministry who had concluded that it was fundamentally unsound and couldn't possibly work. But he went on to say, 'Now Wallis, I know that you

A Kittyhawk of No 112 Sqn at Gambut in mid-1942 armed with a 250 lb GP bomb fitted with an extension rod.(Andy Thomas)

wouldn't have actually modified a Service store without authority – but *does* it work?' I assured him that it did and the idea was resubmitted. Believe it or not, it was nine years before it was adopted and, in the meantime, people continued to be injured unnecessarily and material damage continued to occur through avoidable incidents. The approval process had involved no fewer than seven Ordnance Board proceedings, although I – the originator of the proposal – was never sent a copy of any of them. Nevertheless, in the end they did give me £150!

And now a question. When I was flying Wellingtons in Italy in 1944 we were dropping 'rodded' bombs – 250 lb GPs bombs with a rod extending about two feet from the nose. When, many years later, I reviewed *Bombs Gone* I omitted to say that it made no mention of the rodded bomb. In fact I haven't been able to find a single piece of paper that refers to it. We were certainly using them in large numbers – two trips a night to the Anzio beachhead where the bombs would detonate above the ground to create the maximum anti-personnel effect. Was it perhaps banned by the Geneva Convention? Can anyone shed any light on the apparent absence of documentation on this?

Jefford: They were certainly widely used by fighter-bombers, by Kittyhawks in North Africa as early as 1942 and later in Italy, and I know that Vengeances and Mosquitoes dropped rodded bombs in

Burma from 1943 onwards. Since their use was so widespread, there has to be an AP (Air Publication) that deals with them – we just need to find it – and I would have thought that the fact that they were so widely used, and over such a long period, also suggests that they probably weren't illegal.

> ***Afternote****. Somewhat to my surprise, the RAF Museum was unable to come up with anything very substantial in the way of documentation and a day spent rummaging at The National Archives also failed to unearth what was required. There are several files dealing with trials of rodded bombs at Kew (AVIA22/844 is quite a good one), but one had expected to find chapter and verse in AP1661. There are copies, both at Hendon and at Kew, but, like many APs, it was a loose-leaf document that was subject to frequent amendment. It is possible, therefore, that rodded bombs had featured at one time but that the relevant Chapter was withdrawn when the technique was abandoned – the standard injunction to 'remove and destroy' the redundant pages ensuring that no copies of the superseded sections appear to have survived.* **Ed**

Wallis: One other thought. They were quite dangerous, because the bombs would jostle each other as they left the bomb bay and, perhaps because of the long rods, they would sometimes detonate and the explosion would ripple up the stick towards the aircraft. I also recall an incident in which I owed my life to an alert armourer. When we taxied back to our dispersal at Tortorella after a sortie, he made frantic hand signals indicating that I should keep the bomb doors closed and not open them, which was the normal thing to do. When we climbed out we found that we still had a rodded 250 lb GP bomb on board. It was 'live', in that the arming fork had been removed, but it had evidently been iced up on its carrier and had failed to drop off until we descended to a lower level at which point it had fallen onto the doors. If I had opened them, it would undoubtedly have gone off when it hit the ground.

Roger Hayward: I would just add that the RAAF used rodded bombs extensively against Japanese positions in New Guinea. This included Beauforts dropping American 2,000 lb bombs with rod extensions – these were said to be able to clear whole villages.

Air Mshl Sir John Kemball: From my own experience I know that they were also used later on in Vietnam – from F-4s.

Frank Angus: I was on No 18 Sqn and I recall that our Bostons used rodded bombs quite extensively. But I wanted to make a point about gun turrets. I think that, although I didn't know it at the time, I may be able to claim to have been the originator of the open windscreen on a Boulton Paul turret. I was on No 141 Sqn at the back end of the Battle of Britain and one of our gunners complained that he couldn't see because his turret tended to steam up. So I nipped into Gravesend to find a piano hinge and, having cut out a section of the perspex glazing, I used it to create a hinged panel with a catch to keep it closed or open. And it worked quite successfully. With hindsight, I was clearly breaking the law by making an unauthorised modification – but I got away with it.

Peter Hearne: Could you comment on the type of target used when they were evaluating the destructive power of the ·303 versus the ·5 before they chose the ·303. I ask because, in conversation with 'Winkle' Brown, he told me that when he first started flying early Martlets off a small carrier it was extremely difficult to shoot down a FW 200 with rifle-calibre bullets – it was only really possible if you were lucky enough to hit the pilot. When he eventually flew the Mk IV, with its ·5-inch guns, he found that they simply knocked bits off the other aeroplane and it was all over. Clearly, a very different level of destructive power as a result of the heavier calibre.

Williams: Well, the testing started in the mid-1920s, when aircraft were primarily of fabric-covered wooden construction and thus relatively easy to damage with a ·303 and a ·5-inch gun didn't really offer that much of an advantage. The stressed-skin all-metal aeroplanes of the late 1930s were a lot more robust, of course, but the RAF had already made its decision in favour of the ·303" in trials against an earlier generation of aircraft. But, of even more significance, when further trials were carried out in the 1930s, the RAF concluded that the ·5" was neither fish nor fowl, because it was much heavier and slower firing than the ·303" while lacking the real increase in destructive effect yielded by the high explosive content of a 20mm cannon shell which significantly amplified the power represented by simply increasing the calibre. So, when considering

Liberator VI of No 356 Sqn, complete with Sperry ball turret.

where to go after the ·303", the RAF deliberately decided to by-pass the ·5" – not because it wasn't more effective, but because the cannon was even more effective.

Richard Lambert: Would I be right in thinking that the ball turrets were removed from the Fortresses operated by the RAF?

Jefford: There are always exceptions to any rule, of course, but, yes, it is generally true to say that the ball turrets were removed from most of the RAF's Fortresses, although they were retained by many Liberators. In short, we didn't use the B-17 as a bomber and, since those that flew with Coastal Command were unlikely to encounter much in the way of aerial opposition, most of their belly turrets were eventually dispensed with. On the other hand, many of the B-24s that we used as heavy bombers in India, and perhaps those in Italy as well, did keep the Sperry ball turret, although, most of the large numbers of Liberators used as oceanic patrollers had their belly turrets replaced by a retractable ASV radar.

Lambert: So there were RAF ball turret gunners?

Jefford: Yes, must have been, especially for the Liberators. It is perhaps worth observing that American bombers were much more heavily armed than their British equivalents, which made them much more expensive in manpower. A Halifax or a Lancaster had a crew of seven, whereas the standard complement of an RAF Liberator operating as a heavy bomber in India was eleven (two pilots, a navigator, an air bomber, a WOp(air), a WOp/AG, a flight engineer and four air gunners).

Steven Mason: Turrets again. Am I right in thinking that there was some means of preventing you from shooting off your own tail from the mid-upper?

Jefford. Yes. It was most apparent on Lancasters and Stirlings fitted with the FN50 turret where it took the form of the so-called 'taboo fairing'. There was a feeler arm (that looked as if it might have been borrowed from a Dalek) below each gun and when these came in contact with the fairing they inhibited depression of the gun barrels to prevent the gunner shooting at the airframe; there were also interrupter cut outs to stop him shooting at the fins as the guns traversed across them. Similar, if less obvious, preventative systems were provided in other turret installations.

Interestingly, on the Defiant there was a facility that permitted the turret to be rotated forward and locked in that position with the guns elevated by 15^{o}. They had to be pointed upwards to avoid shooting off the propeller, but in that position it was possible for the gunner to transfer fire control to the pilot. This upward firing gun option was never exploited in service but, if it had been, it would have pre-dated the notorious German *Schräge Musik* installation that was so devastatingly effective against British night bombers in 1944. In point of fact, the upward firing gun concept that we tend to associate with the *Luftwaffe* was not a German idea. As was clearly shown by one of the pictures that Tony showed us, the COW gun could be fired upwards and a number of prototype fighters were built in the 1920s specifically to explore the potential of this tactic, although these never came to anything.

Richard Bateson: We heard something of the influence of the Mauser company on the development of post-war guns but I would be interested to learn about the work done by Rheinmetall-Borsig at Unterlüβ which was, I believe, virtually an out-station of the Ministry of Supply until about 1948.

Williams: There is a collection of papers, the Unterlüβ Reports, which used to be held in the Ministry of Defence Pattern Room; they are now in the library of the Royal Armouries at Leeds. At the end of the war, from about 1946, the German technicians who had worked on gun development, both Mauser and Rheinmetall, which had been the two main industrial concerns involved in the design of aircraft guns, were debriefed – or interrogated – and everything that they had to say about what they had achieved and what they had been working on next was recorded. These are the Unterlüβ Reports. They are still available (by prior appointment) and they reveal that the Germans had been working on some quite exotic concepts. Towards the end of the war, for instance, some heavy fighters – specifically intended as bomber destroyers – had been fitted with very large calibre cannon, up to 50mm, the idea being to engage American bombers from beyond the range of their defensive guns. It might have worked, if the Americans had not introduced long-range single-seat escort fighters that had no difficulty in dealing with these relatively cumbersome aircraft with their massive guns. Another project involved stabilised gun mountings for large-calibre cannon, to be carried by twin-engined fighters, with a gunner to aim them. These were calculated to be several times more effective than fixed guns, but were never tested in the air. In fact the engineers at Unterlüβ recommended a number of lines that were worth pursuing but, in the event, it was only the ammunition that I mentioned and the MG213 cannon that were picked up for further development by the allies.

Bob Fairclough: I first became involved with bombs at Warton more than thirty years after the end of WW II when I was designing the provision for external carriage of bombs on the Tornado. I was surprised to find that the primary weapon was still to be the 1,000 lb bomb of wartime vintage. At the time, I was told that the bombs available at the beginning of the war were ineffective and that the 1,000 pounder had been developed in a hurry by adding a suitable tail to a sixteen-inch naval artillery shell. Does anyone know if that is true? My point is that this weirdly shaped bomb, which was quite unsuitable for external carriage on a high-performance aeroplane, was still expected to be the standard armament. Because the Tornado was an international project, I was also required to cater for the full range of American bombs, particularly the Mks 82, 83 and 84 – all of which were of a decent shape for carrying externally. Is that still the case – do the British still use that 70-year old, inappropriately-shaped, bluntnosed 1,000 lb bomb?

Williams: Some bombs were certainly made by adapting battleship shells – the Japanese did it, for instance – but that would not have applied in the case of the British 1,000 pounder because a sixteen-inch shell weighed about 2,000 lbs.

Dye: This (hefting an actual example of a bomb that he had brought for display) is a 1914-modification of a six-inch naval shell to turn it into a bomb in the absence of any purpose-built weapons at the time. What they subsequently learned was that artillery shells required much higher quality materials and more robust fuses – you could get away with relatively low grade materials for an aerial bomb. It is possible that this is the origin of the 1,000 pounder story, of course – who knows? But there is clearly a long history of make do and mend when it comes to British aerial bombs.

Gp Capt Jock Heron: I was in the Tornado Project Office at MOD when the aeroplane was being conceived and we did query the use of the old 1,000 pounder as the weapon for this new aeroplane. We were told that we were to use it solely for dealing with notional drag, weight and performance issues but that it would not be the standard weapon for Tornado because something better would be available by the time that it entered service.

Wg Cdr David Herriot: I would just add that we are still using the classic 1,000 pounder today – indeed they form the basis of the Paveway II LGB.

PRESENTATION OF THE TWO AIR FORCES AWARD

It is customary to present the Two Air Forces Award at the Society's AGM in June but Service commitments prevented the winner of the award in 2007, Wg Cdr Harvey Smyth, from attending on that occasion. The opportunity was, therefore, taken for the Society's President, MRAF Sir Michael Beetham, to make the presentation on this occasion. Wg Cdr Smyth's paper, 'From Coningham to Project Coningham-Keyes: Did British Forces relearn historical air-land co-operation lessons during Operation TELIC?' was published in Journal 44.

A HISTORY OF AIR-TO-SURFACE ROCKET SYSTEMS

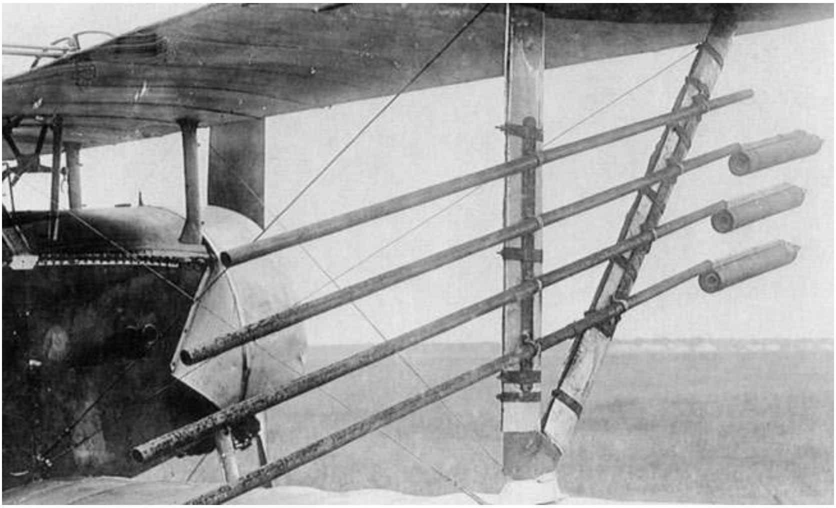
Wg Cdr David Herriot

David Herriot joined the RAF in 1969 and served for 38 years. His flying experience, as a navigator in the UK and Germany, amounted to six tours on Buccaneers and Tornados interrupted by staff appointments at HQ Strike Command and the MOD. Following a stint commanding the RAF element at Gioia del Colle in 1997, he became Wing Commander Cadets at the Department of Initial Officer Training and finally OC Air Warfare Centre, both at Cranwell. In retirement he has been appointed a Justice of the Peace and is the Honorary Secretary of the Buccaneer Aircrew Association.

Early Air-Delivered Rocket Development

Ever since man first took to the air, over 100 years ago, it was inevitable that, before very long, platforms would be developed that would provide the ability to deliver firepower from the air. The first aeroplane to be shot down by gunfire from another was probably a German Aviatik which fell victim to a French Voisin on 5 October 1914. But it was on April Fool's Day 1915 that another French pilot, Roland Garros, shot down an Aviatik using a Morane Parasol that had been specifically modified for the purpose of aerial combat. Thus it was less than a century ago that the first direct fire weapons came to be used in aerial combat albeit, and in the context of this paper, those first encounters were in air-to-air actions, rather than air-to-ground. However, it was not many weeks after Garros had fired his first rounds through his modified propeller that aircraft were being used to strafe troops.

Although rocket technology was utilised in a military context throughout WW I, it was mostly used in a non-combative role to propel line or cable from ship-to-ship or trench-to-trench. The accuracy and lightweight characteristics of the rocket, however, were not lost on the early pioneers of aerial combat who, thanks to a 31-year old French naval lieutenant named Yves Le Prieur, developed an air-delivered rocket system to attack observation balloons and



Le Prieur rockets, seen here on a French Nieuport 16, were fired from 1.5 metre-long steel tubes permanently attached to the interplane struts. (J M Bruce/G S Leslie collection)

airships. Le Prieur's invention was first used in April 1916 at the Battle of Verdun. However, because of the inaccuracy of the early rockets, they were initially limited to a firing range in the region of 125 yards, which resulted in some post-firing close encounters and steep manoeuvring to avoid a subsequent collision with the target! The rockets, which were fired from tubes fitted to the interplane struts, were initiated by an electrical impulse from the cockpit. Le Prieur rockets were fitted to a number of aircraft including Nieuports, SPADs, Sopwith's Pup and Camel, and the BE2 and BE12. A typical load was six or eight rockets per aircraft but the BE12 could take as many as ten.

Although successful against observation balloons, no airships were ever brought down by a rocket and, superseded by the incendiary bullet, they had been phased out of service before the war ended. Le Prieur rockets were used by the Belgians, French, British and, paradoxically, the Germans. When the war ended, however, the Royal Air Force, intent on retrenching and establishing its position as the junior service, forgot all about the potential use of air-delivered rockets. Little development took place in the United Kingdom during the inter-war years and, as a result, the RAF entered WW II without a ready means of killing armour.

During the Desert Campaign of 1941 it became apparent that in supporting the 8th Army, Coningham's Desert Air Force, was ill-equipped to damage, let alone destroy, Rommel's armoured fighting vehicles, particularly his heavy *Panzer* IIIs and IVs. The result, in April of 1941, was a study entitled 'Methods of Attacking Armoured Vehicles' which was led by Henry Tizard, a WW I pilot and Chairman of the Aeronautical Research Committee in WW II. Although no weapons were 'off limits' in Tizard's study, it soon became apparent that guns and their contemporary ammunition were only capable of dealing with soft-skinned and lightly armoured vehicles and that the weight of effort required to damage a tank with conventional bombs was far too great. Although some use was made of 40mm cannon, larger artillery-type guns were soon ruled out for fighter-bombers because of weight limitations and difficulties with coping with the recoil. It fell to Ivor Bowen, Assistant Director of Armament Research, to propose the use of rockets as a method of delivering a large warhead with sufficient punch to destroy or disable the German Army's tanks.[1]

Throughout the 1930s the Russians had been developing air-delivered rockets and Tizard and Bowen sought their assistance. Although the RS-82 and RS-132 did not officially enter Russian service until 1940, these 82 and 132mm rail-launched rockets had been used in combat as early as 1939, in both air-to-air and air-to-ground roles. However, like most unguided rockets, accuracy was a major problem. In tests of the RS-82, when fired at a single tank at a range of 550 yds, only two out of 186 rockets had hit the target and only 3.7% of rockets fired against a column of tanks scored a hit. The RS-132 fared even worse with no hits scored in 134 firings throughout one test. Nevertheless, both rocket systems achieved some operational success when fired in salvos against German forces invading the USSR during Operation BARBAROSSA in the summer of 1941.

At the end of August 1941, despite the deployment of a wing of Hurricanes to Murmansk and an undertaking to train the Russians to fly them, the Russians withdrew an earlier offer to send a delegation to the UK to assist in the setting up of a British rocket programme. Nevertheless, Tizard and Bowen put the information obtained from

The 'pigtails' of a load of 3-inch RPs with 25 lb warheads being connected up on a Coastal Command Beaufighter.

the Russians to good use and by September they had begun development of 2-inch and 3-inch Unrotated Rocket Projectiles. The 2-inch rocket was designed to carry a 23 lb plastic explosive warhead whilst the larger 3-inch rocket was initially intended to carry a 25 lb solid armour piercing warhead. During the development phase of the project, however, it soon became apparent that the 2-inch version was less effective than the 40mm Vickers 'S' cannon which first flew on the fighter-bomber variant of the Hurricane in September 1941. It was decided, therefore, to cease work on the smaller variant and to concentrate on the larger calibre rocket which would obviously carry more punch. The 3-inch rocket eventually entered service in 1943.

The 3-inch Unrotated Rocket Projectile

Although Dr Price's paper will consider the use of the 3-inch rocket by the Typhoon in some detail, it is appropriate to include some mention of it here to show how the effectiveness of the 3-inch RP in combat in WW II, eventually led to its use on Hunters in the Radfan campaign and subsequently to the development of podded rockets on fast jet aircraft in service in the later years of the 20th Century.

The 3-inch RP consisted of a steel tube of 3 inches (76mm) diameter, which was filled with 11lbs of cordite to propel the missile towards its target; ignition was through an electrical 'pigtail' initiated by a switch in the cockpit. A pretty rudimentary ignition system by

A 3-inch RP with a 60 lb warhead about to be loaded onto a Beaufighter in India.

today's standards, but effective enough at the time. To reduce the dispersion of strikes around the target, four small fins were fitted to the tail in order to spin the rocket, in flight, thus providing a measure of stability and improving accuracy.

Despite the urgency of the Desert Air Force's requirement, trials with the new weapon occupied the whole of 1942. Most firings were from Hurricanes but other types involved included the Hudson, Boston and Swordfish. It soon became apparent that the initial 25 lb Semi-Armour Piercing (SAP) warhead, was ineffective against the armour of the *Tiger* tanks that were coming into service with the *Panzer Korps* so a more lethal 60 lb SAP warhead was also developed, the latter being easily distinguishable as, at 6 inches, it was twice the diameter of the rocket tube. They were fully interchangeable, the warhead actually fitted being determined by the type of target.

Following the successful development and testing of the 3-inch RP, trials were conducted against representative U-boat targets. Results indicated that a shallow angle attack would result in a near miss being deflected upwards in the water to strike the target below the waterline. Before long, the rockets were in regular use with Coastal Command and the Royal Navy, which resulted in some notable U-boat kills. The first successful rocket attack against a U-boat took place in mid-Atlantic almost exactly half-way between SW Ireland and Newfoundland on 23 May 1943. A Swordfish of 819 Naval Air Squadron, from HMS *Archer*, fired a salvo of 3-inch rockets against the U-752, puncturing its pressure hull and rendering the vessel incapable of diving. The boat was eventually scuttled with the loss of 29 of its 46-man crew. Between its commissioning on 24 May 1941 and its sinking almost exactly two years later, this U-boat, under the command of *Korvetten Kapitän* Karl-Ernst Schroeter, had been responsible for the sinking of over 37,000 tons of allied merchant shipping. Five days after the FAA had sunk the U-752, the RAF followed suit when a Hudson of No 608 Sqn sank the U-755 in the Mediterranean. Its lethality as a maritime weapon having convincingly demonstrated, rockets soon began to be deployed with considerable success against land targets as well.

In the RAF, a typical 3-inch installation was four rockets under each wing on individual rails which could be fired as single-shots, pairs or salvos by means of a selector in the cockpit.

Rocket Ballistics

Rockets, like any other weapon released from an unstable platform (eg a moving aircraft), suffer from ballistic dispersion (the spread of the trajectories about a mean trajectory) and some, by their inherent design, suffer more than others. On the Typhoon, for example, rockets were carried on racks of four on relatively crude rails under each wing. Such a configuration had a significant aerodynamic effect on the ballistic dispersion of the weapons and although it was common to fire them in ‘rippled’ pairs, the launch of the first pair could significantly impair the accuracy of the second due to mutual interference. While it was possible to calculate what this theoretical disruptive effect might be, this could not be easily correlated with practical experience because other factors, eg operational stress, asymmetric loads on the airframe at the time of firing and less than ideal launch parameters, tended to distort the picture. Nevertheless, while many of these practical problems persisted, a significant improvement in overall accuracy stemmed from the replacement of launch rails by rocket pods in the 1960s.

Even with a gyro-stabilised gunsight, however, rockets, whether podded or not, can be inaccurate and it requires considerable skill to aim them properly. Although the Gravity Drop of a non-flight path weapon, a rocket or bullet, is much less than that of a bomb (ie a flight path weapon) other aiming errors, such as Velocity Jump (the angle of incidence measured from the rocket rail or launcher to the point where the rocket closes with the aircraft flight path) and Dip (the angle – measured at the target – subtended by the vertical distance between the pilot's eye and the rocket rail or launcher) can have a much more significant effect when firing rockets – the latter can vary depending upon how high the pilot decides to motor his seat up or down on the day in question! Moreover, because rockets are dependent upon the chemical reaction (burn time of their motor) required to project them forward, a 'slow-burner' can result in a significantly reduced time of flight, which will result in an undershoot. If the retractable fins of a podded rocket fail to deploy evenly, the resultant 'twirler' can cause mayhem for people standing nowhere near the target! These inaccuracies notwithstanding, the success of the Typhoon in WW II against soft-skinned and lightly-armoured vehicles, trains and small sea craft paved the way for the development of air-delivered RP for the rest of the century. Consequently, until the advent of 'smart' weapons, almost all of the RAF's post-war fighter-bombers have been equipped for, if not always armed with, rockets. Some examples are shown in Figure 1.

So what does the rocket bring to the battlefield that other weapons do not? First, and probably most importantly, it can be very accurate when compared to a conventional 'dumb' bomb. Moreover, because of its 'point and shoot' characteristic and its relatively short time of flight it has greater utility against agile or highly mobile targets in both land and maritime scenarios. Equipped with the right warhead, a rocket is far more likely to kill its target than a 'dumb' bomb which, despite its substantially greater explosive power, has a tendency to break up even if it were accurate enough to actually hit its target. In WW II, as indicated above, pilots found that considerable exper-

Aircraft	Rocket	Launcher Type	Rockets per Rail/Pod	Max No of Rockets
Hurricane II	3" RP	Rail	1	8
Typhoon	3" RP	Rail	1	16
Hornet	3" RP	Rail	1	8
Vampire FB5/9	3" RP	Rail	1	8
Venom FB 1/4	3" RP	Rail	1	8
Canberra B15/16	2" RP	Microcell	37	74
Hunter FGA9	3" RP	Rail	8	24
Hunter FGA9	68mm SNEB	Matra 155	19	38
Harrier GR3	68mm SNEB	Matra 155	19	76
Jaguar GR3	CRV-7	LAU-5003	19	38
Buccaneer S2	2" RP	Microcell	36	144
Buccaneer S2	68mm SNEB	Matra 155	19	76
Harrier GR9	CRV-7	LAU-5003	19	76

Fig 1: Representative RAF Rocket-Armed Aircraft.

The wartime '3-inch drainpipe' remained in service as the RAF's standard ground attack weapon until the end of the 1960s. This one is being fired at Song Song range off Penang by a Venom of No 45 Sqn in the late 1950s.

ience and expertise were required to deliver the 3-inch rocket with any degree of accuracy. Absolute accuracy in the delivery profile was essential to achieve success. Dive angle, true air speed, slant range, yaw (or lack of it) and angle of attack all had, and still have today, a direct bearing on the outcome. Add to these the fact that somebody might be shooting back, and the likelihood of success begins to suffer from the Law of Diminishing Returns!

From a positive stand-point, however, rockets are far less complicated than guns and do not suffer from issues such as recoil or the disposal of spent cartridges. The effect of the 60 lb warhead had a devastating impact on the morale of opposing troops. Post strike intelligence reports during WW II indicated that many enemy vehicles were abandoned intact or with superficial damage in the face of a probable rocket attack by Allied aircraft.[2] So, notwithstanding the problems of aiming and the accuracy of delivery, it is evident that the mere prospect of a salvo of rockets tends to have a demoralising effect on the enemy and, from that point alone, rockets are a valuable weapon to have in one's arsenal.

The 3-inch Rocket in the Radfan

After WW II, the 3-inch rocket was used in the Malayan Emergency, Korea, the Confrontation with Indonesia and, most notably, in 1964 by RAF Hunters in the Radfan in Aden where they

A couple of happy armourers about to load a 3-inch RP, in this case with a practice concrete warhead (and a mug o' tea), onto one of No 8 Sqn's Hunters at Khormaksar in 1963. (Ray Deacon)

were used to great effect.

Tension had risen in the Middle East between Aden and Yemen following the merger of the former into the Federation of South Arabia. Following an attempt to assassinate the British High Commissioner, by a grenade attack carried out at Khormaksar on 10 December 1963, a State of Emergency was declared. Attention turned to the Radfan where Quteibi tribesmen were regularly attacking traffic on the Dhala Road. On 4 January 1964, both the RAF and the Fleet Air Arm participated in Operation NUTCRACKER, providing air support to Army units that were engaging Yemeni insurgents. By mid-March, however, British troops were still engaged with the enemy and, on the 13th, a cross-border raid by armed Yemeni helicopters, supported by MiG-17 fighters, was carried out against the village of Bulaq and a Frontier Guard post. In response, RAF Hunters famously attacked and destroyed the Yemen Republic's Fort Harib with 3-inch rockets.[3]

From early May to mid-June 1964, Hunters continued to support the Radforce by countering Yemeni efforts to: close the Dhala Road; provoke revolt against the British presence in the region; and disrupt daily life within the Protectorate. During this six-week campaign, Khormaksar's Hunter Wing flew 642 sorties and fired 2,508 3-inch RPs.[4] Britain made a bloody withdrawal from Aden in November 1967, the Hunters being redeployed to Bahrain where, not long afterwards, the 3-inch rocket was withdrawn from service in favour of the 68mm SNEB podded rocket system.

Podded Rocket Systems

The weight and drag of the 3-inch RP's steel launch rails had a significant and detrimental effect on the performance and handling of the aircraft. As technology advanced, however, so did the design of air-delivered rocket systems. Experiments with anti-blast plates, which were fitted to some aircraft, merely increased the weight and drag problems. Aluminium rails, introduced in 1944, had some effect on reducing the flight limiting characteristics but the gains were relatively small. The next major improvement came with the introduction of podded launch systems, which required a more refined missile than the crude '3-inch drainpipe'. This was provided by the French, in the form of a 68mm unguided rocket that became known all over the world as 'the SNEB'. These were carried in significant numbers in pods, also of French design, made by both SNEB and MATRA. The podded approach conferred a number of major advantages, notably a substantial reduction in aerodynamic drag, and the capacity to carry many more rockets, because of the more efficient design.

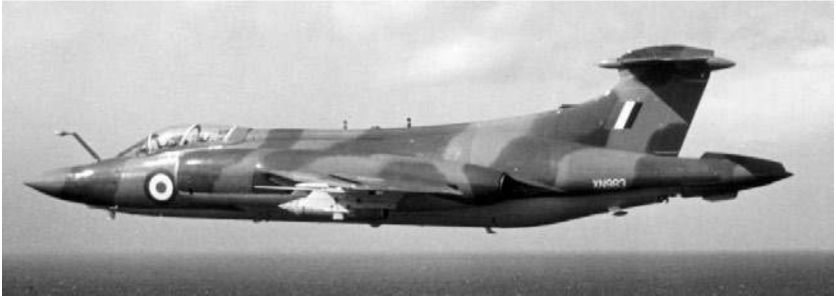
Manufactured by the *Societé Nouvelle des Etablissements Brandt* – hence SNEB – the new rocket had been developed in the early 1950s to provide the French armed forces with a weapon that could be employed by both fixed- and rotary-winged aircraft. Full-scale production began in 1955 and continues today. Based on the earlier 2.75-inch FFAR (Folding Fin Aircraft Rocket) developed in the USA, each missile had eight flip-out fins that deployed as soon as the rocket left its tube to spin it in flight, increasing its stability, reducing its lateral movement and thus increasing its accuracy. Each rocket had a single-stage solid propellant motor that would burn for 0.8 seconds to provide the boost required to sustain its trajectory to the target. The use of a single, rather than multiple, burn motor reduced the number of chemical reactions required, thereby reducing the number of possible misfires or shortfalls in trajectory. SNEB offered a number of

A Harrier GR3 loosing off a four-pod salvo of SNEBs.

warhead options: HE; fragmentation; smoke; and illuminating.

Within the RAF, the principal warhead was HEAT (High Explosive Anti-Tank) which, if it was to be effective, presupposed a direct hit. The damage inflicted by a HEAT warhead, which was initiated by a nose-mounted piezo-electric contact fuse, was derived primarily from its shaped-charge; there was relatively little kinetic penetration. While the rocket itself hit the target at about 1,700 fps, the resultant jet of hot metal had a velocity of some 30,000 fps and, assuming a strike at 90^{o}, could penetrate 10-15 inches of standard armour. Secondary effects of the warhead included blast and fragmentation, making it effective against personnel and lightly armoured vehicles. However, unlike BL755 which succeeded it, SNEB had little or no effect against ERA (Explosive Reactive Armour).

The RAF acquired two launchers for its SNEBs: the nineteen-round MATRA M116, intended for operational use, and the eighteen-round MATRA M155 for training. The M116 was a lightweight,



A Buccaneer of No 12 Sqn armed with a 36-round pod of 2-inch rockets under each wing.

single-shot disposable pod with a frangible, aerodynamic nose cone, which was shattered by gas pressure as the rockets fired. In practice, it was found that debris from the frangible nose cone could damage the launch aircraft and use of the M116 launcher was soon abandoned. The reusable M155 proved to be very satisfactory, however, and it was used both operationally and for training until it was finally withdrawn from service in 1998.

SNEB was cleared for use on Harriers, Jaguars and Germany-based Buccaneers. With two pods under each wing, 76 rockets per aircraft became a standard war load, which was a major increase over the, typically, eight 3-inch RPs of previous years. Even greater capacity was achieved on the Honington-based Buccaneers assigned to the maritime attack role. When the first unit, No 12 Sqn, was formed in 1969 it was equipped with ex-Fleet Air Arm aircraft armed with 2-inch rocket pods inherited from the Royal Navy. Similar in design to the MATRA pod, the 2-inch pod could carry 36 rockets thereby providing the Maritime Attack Wing with up to 144 rockets per aircraft, conferring a substantial probability of a kill against a Fast Patrol Boat.

Thus, with the demise of the traditional 3-inch RP, the firepower of the RAF's rocket-armed aircraft increased dramatically in the late 1960s and '70s and its lethality, coupled with a significant improvement in accuracy, was much greater than that offered by any other air-delivered weapon system of the day, especially against fast and/or manoeuvrable targets. That said, being very much a weapon of the Cold War years, there were few opportunities to subject SNEB to the ultimate test of operational use. It was fitted to some Army Gazelles during Operation CORPORATE in 1982, but it is not thought that any of these were fired in anger.

Ironically, because SNEB had not been cleared for storage in the ship's magazine, the Harrier GR3s on board HMS *Hermes* for Operation CORPORATE were fitted with the ex-Royal Navy Buccaneer 2-inch RP pods for war. The decision to do so was received by OC 1 Sqn, Wg Cdr Peter Squire, on 26 April 1982 and trials were immediately undertaken to prove the system before the aircraft deployed to the carrier via Ascension Island and the *Atlantic Conveyer*. [5] The squadron's Operation CORPORATE Diary indicates that the 2-inch RP was first used on 31 May against Argentinean troops dug-in on Mount Kent with further subsequent and successful missions being flown throughout the campaign.[6]

Figure 2, which compares the effectiveness of a variety of weapons delivered against typical manoeuvrable targets, shows that, whilst the rocket was far more efficient than the iron bomb, advances in technology and the arrival of BL755 would lead to the eclipse of the rocket, at least for a time.

BL755

Given the startling over-target requirement (OTR) numbers for SNEB in Figure 2, compared to BL755, it is not surprising that Hunting Engineering's first cluster weapon satisfied the requirements of the MOD staff officers seeking a solution to the problem posed by SR(A)1197 in the early 1970s. BL755's pattern size and the effectiveness of its shaped-charge warheads against representative Soviet armour indicated that the days of the rocket were numbered. Indeed, the company's 1975 MOD-endorsed sales brochure stated:

> 'The effectiveness of modern air defence systems in the field is such that the use of dive bombing or rocket attacks is likely to involve an unacceptable casualty rate.'

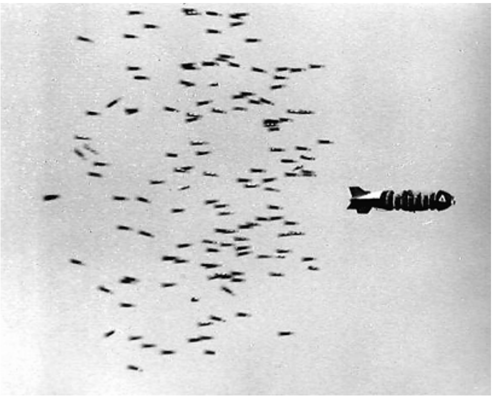
That short sentence summed up the case for a weapon, capable of being delivered from very low level and yielding a high kill probability, and, needless to say, Hunting's BL755 matched that requirement admirably.

The cluster bomb concept is based essentially on the 'shot-gun'

Target	Kill Required*	Weapon	Target Area	Dive Angle/TAS /Release Ht	No of A/c
Komar FPB	Sink	3 × SNEB	—	10°/500kts/700'	53
Komar FPB	Sink	2 × BL755	—	5°/450kts/300'	22
T-54 Tank	M- or F-kill	1 × 1000lb HE MC	—	8°/500 kts /500'	866
T-54 Tank	M-kill	2 × SNEB	—	10°/500kts/700'	20
T-54 Tank	F-kill	2 × BL755	—	5°/450 kts /300'	9
T-54 Tank	M- or F-kill	1 × 1000lb LGB	—	8°/500 kts /500'	1
T-54 Tanks	M- or F-kill	4 × 540lb HE MC	2000' × 1000'	5°/450kts/400'	693
T-54 Tanks	F-kill	2 × BL755	1000' × 500'	5°/450 kts /300'	28

* M-kill = Mobility Kill; F-kill = Firepower Kill.

Fig 2: Comparative Over Target Requirement (OTR) For Representative Weapons.

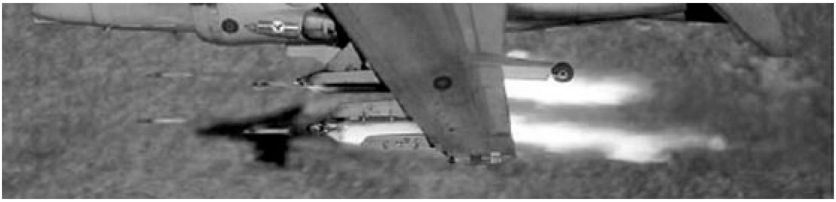


Left – a BL755 having released its flock of sub-munitions. Right – one of the 147 bomblets (in this case a parachute-retarded No 2, Mk 1) contained within each cluster bomb.

principle of compensating for aiming errors by covering the target area with a pattern of evenly distributed sub-projectiles. Externally, the 600 lb weapon looked much the same as any other general purpose bomb, with the same characteristic ogival shape. It was, however, the simple yet effective mechanical design of its Safety, Arming and Functioning Unit (SAFU) and the frangible petal sides, packed with 147 gas-ejected Armour Piercing bomblets, that made this weapon so devastatingly effective.

Nevertheless, just as new weapons enter service to counter a threat, so too does that threat gain enhancements to protect itself against the new weapon. Thus, to counter the BL755 No 1, Mk 4 (the initial in-service weapon), the Warsaw Pact (WP) increased the thickness of its tank armour to compensate. In response, by substituting the stabilising coronet with a mini-parachute, Huntings re-worked many of the bomblets to No 2, Mk 1 configuration. This new bomblet design increased the drag on the sub-munition upon release from its canister thereby increasing the striking angle of the shaped-charge with resultant greater penetration against the new WP armour. This status quo lasted throughout the remainder of the Cold War.

Experience with BL755 in the Falklands War had indicated that, when bullets were flying and the SAFU was set to its lowest level to allow for an ultra low-level delivery, the weapon was less reliable than



CRV-7 being fired by a Harrier GR7. Because it is a 2.75-inch rocket, it looks little different from SNEB but the secret lies in the substantial increase in performance conferred by the power of its Bristol Aerospace motor.

advertised in terms of its bomblet failure rate. Accordingly, when the RAF went to war in the Middle East in 1991, and eventually elected to drop all of its weapons from medium altitude, an Urgent Operational Requirement (UOR) was quickly identified that resulted in the majority of those BL755 No 1, Mk 4s that remained on inventory being modified to allow them to be released from medium altitude. The modification involved the provision of a Motorola radar altimeter that prohibited the deployment of the frangible side-petals until the weapon was close to the ground; the new BL755 became known as RBL755 – ‘R’ for radar.

BL755 entered service in its initial form with the RAF’s Harrier GR3, Jaguar GR1 and Buccaneer S2 in 1973 and the later models continued to serve well into the 21st Century. While still an effective weapon, however, in March 2007, following the UK’s acceptance of the principles laid down by the Oslo Conference on Cluster Munitions, a month earlier, it was announced that BL755 would be withdrawn from service before the end of 2008.[7] Most, if not all, have already gone.

CRV-7

The arrival of CRV-7 in the RAF’s inventory is less well defined than that of BL755. I am confident that it was acquired by way of a UOR but I cannot provide much more in the way of amplification. I do know that there were some very influential and inventive people working within the Jaguar Design Authority, which was by then autonomous and outside of the MOD, when CRV-7 entered service and that they may well have been responsible for the novel way in

Rocket	Gravity Drop	Slant Range	Average Flight Velocity to Target	Time of Flight
Le Prieur	NK	125 yds	NK	NK
3" RP (Rail Launcher)	2°20'	1,343 yds	1,574 ft/sec	2.6 secs
2" RP (Podded Launcher)	1°17'	1,787 yds	2,234 ft/sec	2.4 secs
68mm SNEB*	NK	1,750 yds	1,477ft/sec	3.5 secs
CRV-7	<1°	5,468 yds	4,466 ft/sec	3.7 secs

Fig 3: Historical Comparison of RFC/RAF Rockets.

which it was procured – perhaps by being tacked on to the Jaguar Mid-Life Update? For our purposes today, however, it does not really matter how it was acquired; suffice to say that it was an inspired manoeuvre by whoever was responsible.

CRV-7 is a Canadian-designed rocket, based, like SNEB, on the 2.75-inch FFAR, for use from fixed- or rotary-winged aircraft, against a variety of targets, including armoured vehicles, ships, fortifications and troops. This multi-purpose effect is achieved by a variety of warheads fitted to a universal rocket motor. The principle attributes of the weapon are its low ballistic dispersion and its high velocity, which permit its use at stand-off ranges of up to 20,000 ft. In current RAF service, CRV-7 is cleared for use solely from the Harrier. Like SNEB, the CRV-7 pod carries nineteen rockets but there the similarity ends. As Figure 3 indicates, while both rockets have a similar time of flight, CRV-7 can be fired from a slant range of more than three times that of SNEB at a speed three times that of the French weapon. CRV-7 is compatible with all pre-existing 2.75-inch warheads, but, in order to capitalise on the much higher velocities, high-mass versions have been developed to enhance the damage effect yielded by the considerably increased kinetic energy that has to be dissipated on impact.

What CRV-7 has brought to the RAF is a highly effective and accurate, but simple, weapon for the 21st Century. There is no requirement for a fancy guidance system of any kind. The weapon merely travels in a straight line in the direction in which it has been fired and at a velocity, provided by the sheer power of its solid fuel motor, that allows the delivery aircraft to stand-off and refute Huntings 1970s contention to the effect that *'. . . the use of [...] rocket attacks is likely to involve an unacceptable casualty rate.'* Best of all is the enhanced accuracy conferred by CRV-7's very high velocity, since its short time of flight minimises the effects of both the wind and gravity.

Significantly for the RAF, while Tornados flew mostly at night during Operation GRANBY, the Jaguars flew by day and employed CRV-7 to great effect, distinguishing themselves in the maritime attack role by destroying Iraqi naval targets, including patrol boats and landing craft.[8]

While public opinion and international protocols may have brought about the demise of the cluster weapon, almost a century after the first Le Prieur rocket was fired in anger, CRV-7 has seen a resurgence of the air-delivered rocket and, for the RAF in particular, the Harrier GR9 is operating successfully with it today in the War Against Terrorism and it is being used to knock down the cave doors of all those who would stand in the way of peace.

Notes:

1 Webb, D C; 'Rocket Attack' in *Aeroplane Monthly*, June 1995.

2 Gooderson, Ian; *Air Power at the Battlefront* (Cass, 1998) Ch 5.

3 Lee, Sir David; *Flight from the Middle East* (HMSO, 1980) Ch 11.

4 *Ibid.*

5 http://www.raf.mod.uk/falklands/1sqn_2.html.

6 http://www.raf.mod.uk/falklands/cr3005.html.

7 *Hansard* 20 March 2007. In a Written Ministerial Statement, in the wake of the February 2007 Oslo initiative, the Secretary of State for Defence (Des Browne) announced that '. . . we are withdrawing dumb cluster munitions from service with immediate effect.' This marked an abrupt change in policy, as it superseded a previous statement, made as recently as 4 December 2006, in which it had been declared that the UK was '. . . committed to withdrawing dumb cluster munitions by the middle of the next decade.'

8 http://www.raf.mod.uk/bob1940/operations.html

THE ROCKET-FIRING TYPHOONS IN NORMANDY

Dr Alfred Price

During a sixteen-year career as an AEO on Vulcans and Canberras, Alfred Price became an expert in the theory and practice of electronic warfare before leaving the Service in 1974 to become a writer; he is now a Fellow of the Royal Historical Society with more than forty titles to his credit and has been published in ten languages. His reputation is such that he was invited – as a Brit! – to write the three-volume history of the United States' involvement in electronic warfare from its inception in the 1930s to the end of the Century.

One film sequence that is almost obligatory for any TV documentary on the 1944 Battle of Normandy, shows a squadron of rocket-firing Typhoons peeling off in succession into their steep attack dives. Cut to the camera-gun film taken from a fighter-bomber, showing its rockets streaking away leaving dense smoke trails. Before the rockets reach the ground the aircraft pulls out of its dive, leaving the watcher to assume they hit their intended target. But is it likely they did so?

As anyone who has studied the subject will know, hitting a small target, like a tank, from an aircraft is difficult enough even using modern high-velocity unguided rockets. Could it have been any easier during the Second World War, with the relatively low-velocity weapons that were then available?

In 1943 the 3-inch rocket projectile entered service with the RAF. It was a crude weapon. The body consisted of a 3-inch diameter cast iron pipe, which housed the cordite rocket motor and carried the four cruciform stabilising fins at the rear end.

The variant of the rocket originally intended for use against armoured vehicles was fitted with a 25-pound armour-piercing solid steel warhead. For use against ships, a quite different 60-pound semi-armour piercing warhead was also developed, containing 17 pounds of high explosive. Tests revealed that the solid shot warhead was not very effective against land targets, although its stable underwater

Summer 1944 – armourers preparing a Typhoon for a sortie.

trajectory made it effective against ships and U-boats. Conversely, and fortuitously, the high explosive semi-armour piercing warhead was found to be more effective than the solid shot weapon against tanks and other vehicles.

Fitted with the semi-armour piercing warhead, the rocket projectile weighed 91 pounds. During operations over Normandy the Typhoon carried eight of these weapons on external launchers mounted on the wings. After launch the rocket projectile accelerated to a velocity of about 1,600 feet per second in 500 yards, in addition to the speed of the aircraft. The motor then burned out and thereafter the weapon coasted towards the target, losing speed gradually due to air resistance.

At the time of the invasion of France on 6 June 1944, the 2nd Tactical Air Force possessed fifteen squadrons of Typhoons. These were committed to action on a large scale, and during the actions that followed the rocket projectile achieved great prominence.

For attacks on heavily defended targets, pilots were instructed to commence a 60° dive at about 8,000 feet and fire all eight projectiles in a salvo as they passed through 4,000 feet. That placed the aircraft at a slant range of about 1,700 yards from the target at launch. After firing its complement of rockets, the aircraft was to pull into a steep zoom climb with a turn, to get outside the range of automatic *Flak* weapons as rapidly as possible.

For attacks on lightly defended targets, pilots were advised to enter a shallow dive of about 25° at 3,500 feet and ripple fire the rockets in

A salvo of 3-inch RPs with 60 lb SAP warheads fired, in this case, at a small coastal vessel.

pairs as they passed through 1,500 feet. That placed the aircraft at a slant range of about 1,000 yards from the target at launch.

The Shortcomings of the 3-inch Rocket

If a 3-inch rocket scored a direct hit on a tank, the latter invariably suffered serious damage. Yet the weapon was not accurate enough to do so on a regular basis, and a miss by as little as three or four yards served merely to blow a shower of mud over the vehicle.

The 3-inch rocket projectile was not what we would now call a ‘user-friendly system’. The pilot had to judge the firing range to within quite fine limits, ‘by eye’. An error of ±150 yards in the range at the time of firing would cause the rockets to impact 15 yards short of the target or a similar distance beyond it. Moreover, after launch the fins at the rear caused the projectile to ‘weathercock’ and align itself with the airflow. Thus if the aircraft had sideslip on at the time of launch, or was pulling ‘G’, that caused inaccuracies. Four degrees of sideslip produced a 50-yard sideways error at a firing range of 1,000 yards. If the aircraft was pulling 2G when its pilot fired the rockets, that caused them to impact about 30 yards short of the target. Unless the proper allowance had been made, a 20 mph side wind created an error of 33 yards in line. Any of those errors would cause the projectile to impact far enough from a tank for the latter to escape serious damage. When the effect of enemy AA fire was included in the equation as a distracting factor, the projectile's inaccuracies were compounded. A report on the results of operational rocket attacks on ground targets during April and May 1944 concluded that the 50 per cent zone for the rockets was 75 yards. That meant that the chances of scoring at least one hit with a salvo of eight rockets on a tank of 200 square feet in area was about 0.7 per cent.

The Battle of Mortain

Any assessment of the overall effectiveness of the rocket projectile must mention the weapon's effect on enemy planning, however. In the two months following the Normandy invasion, German armoured units never came into the open in force during the day to launch a counter attack against Allied forces. The fear of triggering large-scale air attacks, particularly from the rocket-firing Typhoons, was undoubtedly a major factor in inducing this timidity.

All that changed during the early morning darkness of 7 August 1944, when the 57th *Panzer Korps* comprising elements of 1 *SS Panzer*, 2 *SS Panzer*, 116 *Panzer* and 17 *SS Panzer Grenadier* divisions launched Operation *Luettich*. This powerful thrust was aimed at punching through the exposed left flank of US troops which were then advancing rapidly southwards after their breakout from the Cherbourg Peninsula. The intention was to reach the sea at Avranches, thereby severing the American supply artery. *Jagdkorps* II of the *Luftwaffe*, which included all fighter and fighter-bomber units in France, was ordered to put up a maximum effort with some three hundred sorties, to support the offensive on the first day.

When dawn broke on 7 August, the Mortain area was shrouded in mist. That allowed the attackers to advance steadily despite stubborn resistance from US ground forces. One problem the German troops did not yet have to face, however, was attack from the air. But from 11.00 hours the mist began to clear, and the Allied aerial riposte was not long in coming.

In his post-war despatch Air Mshl Sir Arthur Coningham, AOC 2nd Tactical Air Force, wrote:

'It was agreed [. . .] that the Typhoons, armed with rocket

> projectiles, of the Second Tactical Air Force, under the local control of AOC 83 Group, should deal exclusively with the enemy armoured columns, while the American fighters and fighter-bombers should operate further afield to prevent enemy aircraft from interfering with our air effort and, in addition, to destroy transport and communications leading up to the battle area . . .’

That left the Typhoon force in Normandy, with nineteen squadrons based within 50 miles of Mortain, a free hand to deal with the German armoured columns. At noon Wg Cdr Charles Green, commanding No 121 Wing, returned after leading an armed reconnaissance over the battle area by six Typhoons. He reported a large concentration of enemy tanks and motor transport at St-Barthelemy to the north of Mortain. Within minutes the first two squadrons loaded with rockets were airborne. Their pilots found between 50 and 60 tanks and about 200 other vehicles lining the road from St-Barthelemy to Cherence. The Typhoons began their attack by knocking out the vehicles at the head and the tail of the column, to bring it to a halt. Then they set about those trapped in between. A shuttle-service was then set up, with fresh squadrons of Typhoons arriving at 20-minute intervals.

For the next 8½ hours the German armoured columns came under almost non-stop pounding from relays of Typhoons. That day the Typhoon squadrons flew a total of 69 missions with 458 sorties, of which 294 sorties were sent against targets in the Mortain area.. Total munitions expenditure was 2,088 rockets and 80 tons of bombs.

The Typhoon attacks, coupled with a stubborn defence on the ground by the US 30th Infantry Division, quickly brought the German advance to a halt. As the fighter-bombers scored their first hits on the tanks, others pulled off the roads and hid under whatever cover was available. The enforced halt gave time for US troops, with armoured support, to move into blocking positions. Once the German advance had stalled, it never resumed.

In the event *Luftwaffe* put in far less than the promised 300 fighter sorties to cover the German thrust. A mission at around 1400 hours involving more than a hundred Messerschmitt 109s and Focke Wulf 190s, set out for the battle area from airfields around Paris. The fighters of the US IX Tactical Air Force carried out their blocking role with resolution, however. They intercepted the would-be raiders and, in the brisk skirmishes that followed, losses were light on both sides. But the important point was that the German formations were broken up, and not a single aircraft reached its objective. A further attempt by the *Luftwaffe* to reach the battle area later in the day, in similar force, suffered a similar rebuff.

In its daily report 57th *Panzer Korps* complained that: ‘Continuation of the attack during the midday hours was made impossible because of enemy air superiority.’ Later that day it reported: ‘The attack was bogged down since 1300 hours because of heavy enemy fighter-bomber operations and the failure of our *Luftwaffe*.’

Werner Josupeit, an NCO machine-gunner with 2nd *SS Panzer-Grenadier Regiment*, described what it was like to be on the receiving end of the Typhoon attacks. He wrote:

> ‘The fighter-bombers circled our tanks several times. Then one broke out of the circle, sought its target and fired. As the first pulled back into the circle of about twenty planes, a second pulled out and fired. And so they continued until they had all fired. Then they left the terrible scene. A new swarm appeared in their place and fired all their rockets . . . Black clouds of smoke from burning oil climbed into the sky everywhere we looked. They marked the dead *Panzers* . . .’

One battalion commander who fought with the 2nd *SS Panzer Division* in Normandy told me: ‘Your fighter bombers simply nailed us to the ground’, and, to emphasise the point, he pressed his thumb hard against the top of the table. He then repeated a catch phrase coined by German soldiers to sum up their predicament: ‘If the aircraft above us are camouflaged, they are British. If they are silver, they are American. And if they aren’t there at all, they are German!’

During the Mortain action the advancing German troops had relatively poor cover from AA weapons. That day only three Typhoons were shot down, and two of the pilots survived. For their part the Typhoon pilots claimed 84 enemy tanks destroyed, 35 probably destroyed and 21 damaged. They also claimed 112 other vehicles destroyed or damaged.

After the battle a careful examination of the area around Mortain

Claims against tanks by Typhoons

Tanks destroyed	84
Tanks probably destroyed	35
Tanks damaged	21

German tank losses

To RPs	7	(16%)
To bombs	2	(4%)
To ground ant-tank weapons	19	(44%)
Destroyed or abandoned by crew	11	(25%)
Unknown	4	(9%)
Total	**43**	

Table 1. Battle of Mortain.

revealed only 43 German tanks left behind, however. Of these, 19 were assessed as having been destroyed by ground anti-tank weapons, 7 by air-launched rockets, two by bombs and four to causes that could not be assessed. The remaining eleven tanks were abandoned intact or had been destroyed by their crews to prevent capture.

Why the large discrepancy between the two sets of figures? The huge pall of smoke and dust in the sky over the battle area certainly made damage assessment difficult while the action was in progress. Also it is likely that some tanks, probably the most conspicuous ones sitting in the open, were attacked and claimed more than once. It is not known how many damaged German tanks were recovered from the battle area, although it is unlikely that any that had taken a direct hit from a bomb or an air-launched rocket would have been reparable. It should also be pointed out that the Typhoons' rockets would have destroyed many more German tanks, had the latter continued to advance in the open.

The Effect on Morale

The physical damage the Typhoons inflicted on the German tanks was not, by itself, sufficient to halt the German advance. The effect of their attacks on enemy morale was far more severe than the actual damage they caused, however. One RAF report on the action, based on reports from prisoners, stated:

While a direct hit on a tank with a rocket was difficult to achieve, when it was the target was comprehensively destroyed, which is what happened to this Pz Kpfw IV.

> 'Interrogation of prisoners has shown without question that German tank crews are extremely frightened of attacks by RP (rocket projectiles). [...] Crews are very aware that if an RP does hit a tank, their chance of survival is small. It is admitted that the chances of a direct hit are slight; nevertheless, this would hardly be appreciated by a crew whose first thought would be of the disastrous results if a hit was obtained.'

German Army reports attributed most of the tank losses during the Mortain battle to air attack.' Yet from subsequent analysis we know that ground anti-tank weapons caused more than twice as many tank losses as those caused by aircraft. Part of the error was undoubtedly due to the inevitable confusion of battle, and the dense smoke columns rising from the many burning vehicles. And part of it stemmed from an understandable wish to ascribe the halting of the offensive to the Allied air attacks (which the German Army could do little about) rather than to US ground forces. The *Luftwaffe* had made few friends during the battle of Normandy, and it could safely be blamed for the failure of the German counter attack. That faulty assessment helped strengthen the already formidable reputation of the rocket-firing Typhoon in the minds of German soldiers.

To quote once more from Air Mshl Coningham's post-war despatch on 2nd TAF's part in the action:

> 'It was the first occasion in Normandy when the air forces had the opportunity of striking a German armoured concentration. It was a situation which required the speed and flexibility of air striking power. [...] The fighter bombers of the Second Tactical Air Force adopted a 'shuttle service' of attacking formations, and as the day developed it was becoming clear that air history was being made. As the tempo of the attacks increased, so did the morale of the tank crews diminish, and at the height of the battle it was observed that the enemy were not waiting to stand up to our fire. The action of the Typhoons made many of them abandon their tanks and take cover away from them.'

The Battle of the Falaise Gap

The failure of Operation *Luettich* left the German Army units around Mortain in a difficult situation, and one that became progressively worse with each day that passed. Powerful US armoured forces drove south of Mortain, then swung north east threatening to envelop the entire German force. On 14 August Hitler authorised a large-scale withdrawal, which quickly developed into a rout. As units attempted to move east, they were subject to almost incessant air and artillery attacks. Large numbers of troops escaped from the pocket, but many were forced to abandon their heavy equipment.

After the action the Operational Researchers of 21st Army Group searched the area between the Falaise Pocket and the German crossing points on the Seine, and recorded details of the tanks and other vehicles found destroyed and abandoned there. Those results were set down in a detailed analysis of the results of the Falaise Pocket action.

The searchers found 667 German tanks, self-propelled guns and armoured vehicles left behind. They did not claim to have found every enemy vehicle in the area, and it is likely that many were missed in the narrow lanes, orchards, farmyards and woods that occupied much of the area. Of that total, 385 vehicles – or just under 60 per cent – were

RPs	14 (4%)
Bombs	4 (1%)
MG/cannon fire	21 (5%)
Destroyed by crew	148 (40%)
Abandoned undamaged	121 (31%)
Other causes	77 (20%)
Total	**385**

Table 2. Battle of the Falaise Gap –
German armoured vehicle/tank losses.

examined to determine why they had had been left behind.

The size of the sample was large enough to show the effectiveness of the various types of weapon used by the Allied air forces: 385 tanks and armoured vehicles represented roughly the complement of two full-strength *Panzer* divisions. By that stage of the battle some German divisions were down to nearly 60 per cent of their establishment of armoured vehicles, so a figure of 385 came close to the complement of three divisions.

An analysis of the causes underlying the destruction and/or abandonment of these 385 armoured vehicles is at Table 2

The two largest categories are significant: those armoured vehicles destroyed by their crews to avoid capture, and those that were abandoned undamaged. Together these amounted to 269 vehicles, or 71 per cent of the total. The great majority of those vehicles had to be left behind because the Germans troops lacked the fuel to move them. Most of them spent the land battle stationary under camouflage, and when the retreat began they had to be left behind.

The 21 vehicles knocked out by machine gun or cannon fire from the air were lightly armoured scout cars or half-tracks; 87 of these vehicles were examined, of which the 21 represented just over 24 per cent. As was to be expected, no tanks or self-propelled guns were recorded as having been knocked out by machine gun or cannon fire from the air.

The first thing to come out of this, once again, is the near-ineffectiveness of the 3-inch rocket in direct attacks on armoured vehicles. This weapon accounted for only 14, or 3.6 per cent, of those examined. That was a meagre total, considering the large number of Typhoons involved in the action.

RPs	6 (>1%)
Bombs	52 (4%)
MG/cannon fire	377 (28%)
Destroyed by crew	27 (2%)
Abandoned undamaged	502 (37%)
Other causes	397 (29%)
Total	**1,361**

Table 3. Battle of the Falaise Gap – German vehicle losses.

From the many German accounts of the land battle, however, there can be no doubt that their troops in Normandy suffered greatly from the Allied tactical air forces. Although the direct air attacks on the German armoured vehicles were not very effective, the indirect effects of the attacks were powerful indeed.

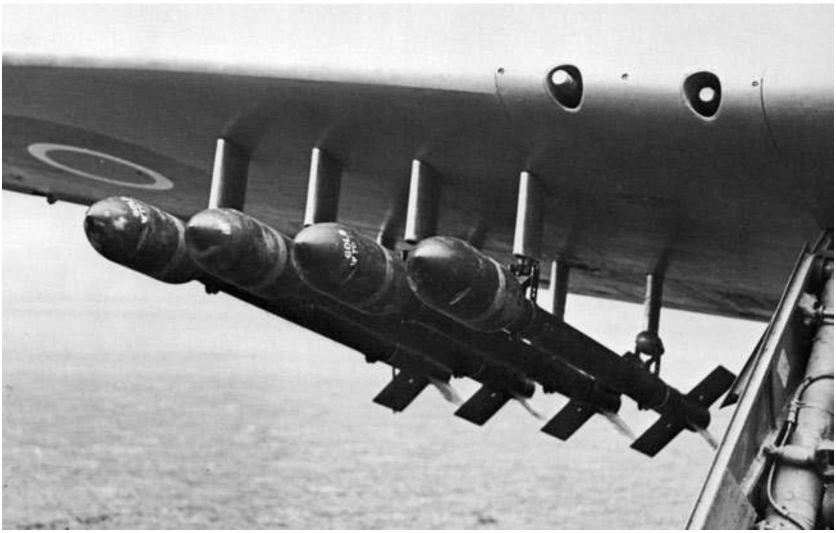
During the 21st Army Group ORS count, a total of 6,656 German soft skinned vehicles were found abandoned. Of these 1,361 were examined and categorised; the causes of these losses are at Table 3:

An effective way of preventing a *Panzer* division from operating was to shoot up the soft-skinned lorries that brought up its vital supplies of fuel and ammunition. The tactical air forces caused considerable mayhem amongst these. There again the rockets were not all that successful. The bombs did slightly better, but even so they accounted for less than 4 per cent of the lorries and cars examined. Machine gun and cannon fire were the most effective of the aerial weapons in this context, though they accounted for only 28 per cent. It was however a commonly used tactic for fighter-bombers to concentrate on the vehicles at each end of the convoy, to box-in those in the middle. So it is probable that fighter-bombers were responsible for the loss of somewhat more vehicles than these figures would suggest. Vehicles stuck in traffic jams were listed under the ‘abandoned undamaged’ or ‘destroyed by crew’ headings.

To sum up: machine gun bullets and the cannon shells aimed at the soft-skinned supply vehicles played a major part in inhibiting the operations by the *Panzer* divisions during the Battle of Normandy. When Allied ground forces broke through, and forced the German Army into a full-scale retreat, large numbers of armoured vehicles were left behind for want of fuel.

Due to its inherent inaccuracies, the 3-inch rocket projectile was barely effective against small targets like tanks or individual vehicles. The weapon destroyed relatively few of these. Yet the effect of the rockets on the morale of tank crews, particularly those lacking combat experience, could be devastating. Moreover, throughout the Battle of Normandy, the presence of several squadrons of rocket-firing Typhoons imposed severe constraints on the German strategy for fighting an aggressive defence.

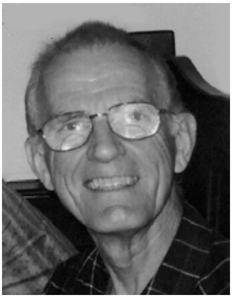
On its glory day, 7 August 1944, the rocket-firing Typhoon played a major role in halting a powerful thrust by major elements of five *Panzer* divisions. Any weapon that could achieve that, well deserved its place in the RAF's armoury.



While the 3-inch RP had its drawbacks, it made a critical contribution to success on 7 August 1944 and it remained in the RAF's armoury for another twenty years. Seen here on a Tempest, these are suspended from hooks, one of a number of much cleaner mountings that superseded the original crude and aerodynamically draggy rails – see page 109.

BRITISH AIR-DROPPED DEPTH CHARGES AND ANTI-SHIP TORPEDOES

Roger Hayward



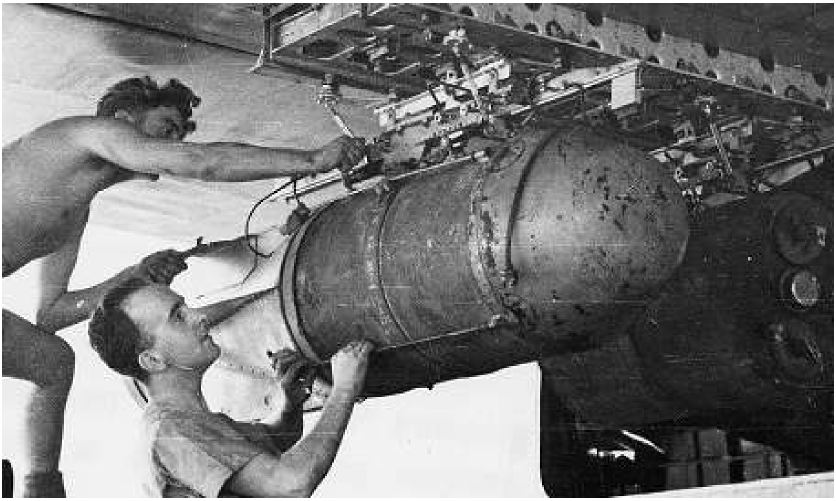
Following National Service with the RAF, Roger Hayward's subsequent career was spent in the Civil Service mostly with the Admiralty/MOD Navy in Portsmouth, London and Bath. During his final stint with the Ministry he occupied the Naval Heritage desk, which involved his having a watching brief over, among other things, the Fleet Air Arm's splendid Museum at Yeovilton. He has a number of books dealing with maritime warfare and weapons to his credit, most significantly in the context of this seminar, The Beaufort File, *which was published by Air Britain.*

Depth Charges

Depth charges were not available to British aircraft during World War One or during the following years of peace. However, the eventual shock realisation that the available anti-submarine bombs were unfit for purpose led to the hurried adaptation of the Royal Navy's Mk VII depth charge for aircraft use.

As it had not been designed for release from aircraft, this weapon, which contained 290 lbs of Amatol (a mixture of TNT and ammonium nitrate), had three major disadvantages: it was not sufficiently robust to withstand dropping from a reasonable speed; it lacked a sufficiently shallow setting for use against surfaced or diving targets (initially 50 feet, twice the optimum depth for a surface kill); and its bulk (450 lbs in weight and almost 17.5 inches in diameter) restricted its usefulness. For flight-in-air the basic Mk VII was fitted with a nose cone and a stabilising tail, both of which detached on striking the water. Its size was a particular disadvantage, as the numerically important Hudson could not accommodate it. The London and Stranraer biplane flying boats could carry two externally – reduced to only one on the latter if a long-range petrol tank was fitted – and the Sunderland and later the Catalina could take four.

Nevertheless, the introduction of this heavy depth charge on 6 July 1940 brought with it the start of an increasing run of successes against



A Mk VII Depth Charge being armed on a Sunderland.

enemy submarines. The first of these was against U-51, which was damaged by a Sunderland on 16 August.

Trials to determine the maximum safe dropping speed for the Mk VII depth charge were conducted as late as 8 October 1940, when it was found that it would break up if it struck the water at over 160 mph.

A more suitable weapon was clearly needed, and the answer was found in the purpose-designed Mk VIII depth charge, which initially had a minimum depth setting of 25 feet. Of only 11 inches diameter and 250 lbs in weight, it could be carried in larger numbers by a wider range of aircraft, usually: four on light bombers, such as the Hudson; six on mediums, such as the Wellington and Whitley; and eight on large aircraft, such as the Liberator and Sunderland. This potent new weapon, which featured a plain drum tail, came into use in early 1941. It contained 170 lbs of Amatol (later changed to the 30% more powerful Torpex – a mixture of RDX, TNT and aluminium dust) and could initially be dropped at up to 200 mph. Its slightly domed nose proved a disadvantage, as it allowed the weapon to sink quickly, which was undesirable in an attack on a surfaced or just-diving target, and it created the risk of ricochet.

An improved depth charge, which emerged as the Mk XI in 1942,

Mk 11 Depth Charges about to be loaded into a Neptune.

featured a slightly concave nose to address the two aforementioned problems, although even this would ricochet at 300 knots or 345 mph. Early versions of this new model could be recognised by their Mk III corrugated drum tails. Later, a bomb-type tail was fitted, featuring a vane of modified cylindrical shape supported by fins – three on the Mk IV tail and four on the later Mk V tail. The advantage of these two later tails was that the weapon was not fused until in its flight-in-air after release, thereby reducing the risk of explosion if the carrying aircraft ditched with depth charges on board. Both single and twin suspension lugs could be fitted.

Throughout the history of the air-dropped depth charge there have been the insuperable contradictory requirements for slow sinking and early detonation when attacking a shallow target and for the opposite when a submarine has been located at depth. These, plus release-speed restrictions, may mean that depth charges are currently more suitable for use from helicopters in shallow water where a homing torpedo could not run.

More modern versions of the Mk 11 (no longer XI) have incorporated significant constructional changes. A manufacturer's sales brochure described its Mod 3 version, designed for use against both submarines in shallow water and against surface vessels, as comprising a 4mm mild steel case containing 176 lbs of unspecified explosive. It featured a solid steel nose plate of apparently some

30mm thickness, for a total weight of 320 lbs. The now-elderly Mk 11 depth charge still appears to have something to offer, as it has been observed on the Navy's new Merlin helicopter.

Torpedoes

'To sink a ship it is better to let water in at the bottom than to let air in at the top.' So observed some naval luminary in the early days of torpedoes, and his perception was later as true of torpedoes v bombs as it had been of torpedoes v gunfire. However, achieving success proved far from easy.

Torpedoes proved much more difficult than depth charges to adapt for air dropping, and as aircraft became faster and more powerful, and the torpedoes heavier, so the problems worsened.

For convenience, all torpedo-carriers, such as the Sopwith Cuckoo, and torpedo-fighters, such as the Bristol Beaufighter, ie those torpedo-carrying aircraft that lacked facilities for a bomb-aimer with a proper bomb sight and could thus not be employed on normal level bombing duties if the need arose, are here referred to as torpedo-bombers. The era of the torpedo-bomber and therefore of the air-dropped anti-ship torpedo, lasted from just before WW I to the early 1950s, a period of only some 40 years. During this time air-dropped torpedoes more than doubled in weight and the speed of torpedo-bombers increased sixfold. The role was in fact being rendered obsolete, ie suicidal, by about the end of WW II by radar-controlled anti-aircraft guns firing proximity-fused ammunition. In recognition of this truth the planned introduction of the Brigand as a torpedo-bomber to follow the Beaufighter into Coastal Command squadrons, was abandoned. The Royal Navy persevered with the fast but unloved and very late Firebrand, and did not finally bow to the inevitable until just before the torpedo-capable Wyvern became operational.

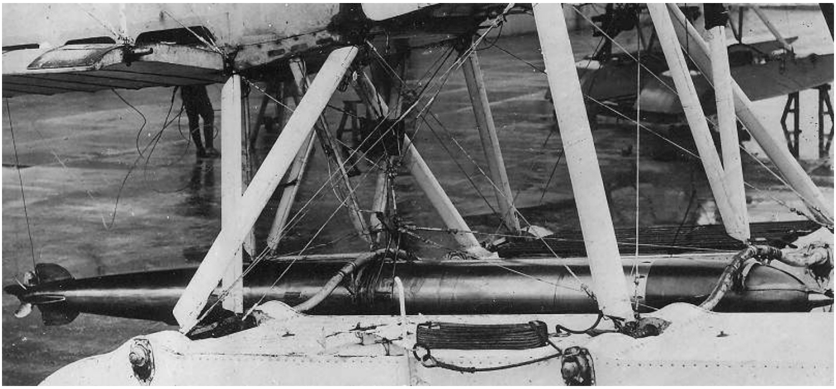
Following trials in 1914 the torpedo-bomber emerged as a practical weapon of war in August 1915, when Short 184 floatplanes from the seaplane carrier HMS *Ben-My-Chree* momentously destroyed three Turkish vessels during the Dardanelles campaign. The torpedo used was the 1897 vintage 14-inch Mk X of 812 lbs weight, which could run for 800 yards at 30 knots. The underpowered (225 hp) Short 184 and the light torpedo formed a clearly inadequate combination, and replacements were quickly put in hand. These emerged as the Short

A Mk VIII torpedo fitted with a drum-type drogue on a Vildebeest.

320 (ie 320 hp) floatplane and the purpose-built Mk IX torpedo. This was the first of a long line of so-called 18-inch air-dropped torpedoes, all of which were, like their RN and foreign counterparts, actually of 450mm or 17.7-inch diameter. This new torpedo weighed 993 lbs, including 170 lbs of explosive, and was only 12ft 10in long. It could run for 1,200 yards at 29 knots. The capability of the new Mk IX torpedo was almost immediately viewed as inadequate, and in late 1917 a lengthened warhead containing 250 lbs of explosive was introduced.

Developed by Sopwith, better-known for its fighters, another new torpedo-bomber appeared before the end of the war, the smaller and handier aptly-named Cuckoo. This was a ground-breaking machine, as it featured a normal wheeled undercarriage that rendered it suitable for operating from both shore bases and the flight decks of aircraft carriers. In fact the Cuckoos of No 185 Sqn embarked on HMS *Argus* on 10 October 1918, with the express intention of attacking the German High Seas Fleet at Wilhelmshaven. Delays and missed opportunities meant that neither of the two new aircraft nor the new torpedo were involved in any torpedo operations.

The existing naval Mk VIII torpedo was seen to offer even more promise, if an aircraft capable of lifting its 1,425 1b weight could be produced. This torpedo was 16ft 7in long and carried 317 lbs of explosive for 2,500 yards at 35 knots. Blackburn produced the Dart, the first of many torpedo-bombers from that company, in the early 1920s to carry this large weapon, which was later carried by successive aircraft until well into WW II. As the missile was intended for submarine use, the steel shells of the detachable heads (both blowing and operational) for this torpedo were only 0.05 inches thick, and therefore really too fragile for air dropping: anything but the



A 14-inch Mk X torpedo slung between the floats of a Short 184.

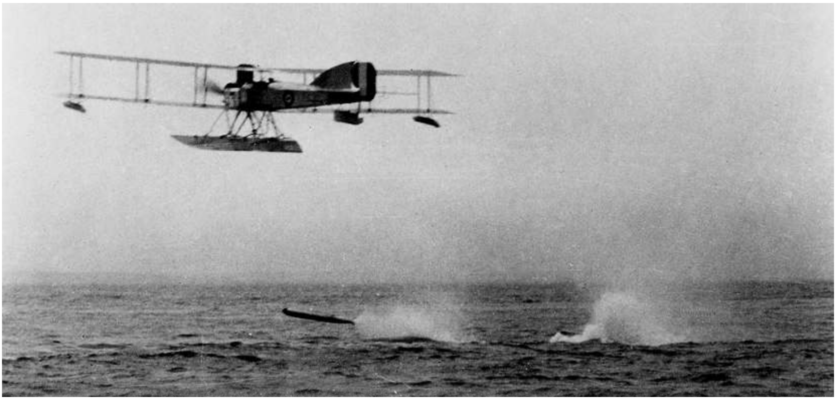
smallest dent would knock at least 4 knots off a torpedo's running speed.[1] An interim torpedo, the Mk X, was produced by mating the warhead of the Mk VIII to the body of the smaller Mk IX, but service use has proved difficult to verify.

With no experience or precedents to draw on, many trial-and-error schemes were tried in attempts to control the torpedo's deep initial dive. Drogues attached to the rear of the missile, to move the centre of pressure aft on entry, proved effective: a mushroom-shaped fitting that unwound from the exhaust pipe on the Mk IX and a drum-shaped fitting mounted above the fins of the Mk VIII.

Torpedoes up to the Mk X featured the Woolwich-pattern tail, on which the propellers are mounted aft of the rudders, whereas the Fiume-pattern tail was adopted on air-dropped anti-ship torpedoes from the Mk XII onwards. On this the propellers were mounted within the fins. This change was made for strength reasons because, as aircraft speed slowly increased and torpedo weight rose, so did the stresses imposed on the torpedo's delicate mechanism.

These stresses were not the only problems working against the satisfactory use of aircraft torpedoes, because, as their weight and release speed increased, their angle of entry into the water had to be increasingly controlled to ensure satisfactory running. Unless the torpedo remained at the correct, slightly nose-down, angle to the

[1] In a blowing head (used for training), ballast water was expelled at the end of the run in water, allowing the torpedo to float and thus aid recovery.

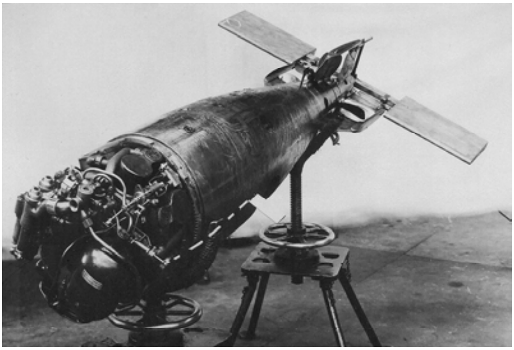


A bad drop of a torpedo, as in the case of this 14-inch Mk X from a Short 184 in 1916, could result in its playing 'ducks and drakes'.

horizontal throughout its trajectory, whose angle was constantly increasing throughout the time of flight (the rate of increase being inverse to the horizontal speed), there would be problems.

These problems would be exacerbated by any errors in height, speed or attitude made by the pilot at the moment of release. If the torpedo dropped tail-high, if the release height was too great, or if the speed was too low, then the torpedo would dive too deep and could strike the sea bed. On the other hand, if the torpedo fell tail-down, if the drop was made too low, or if the release speed was too high, then the torpedo was prone to porpoise or play 'ducks and drakes' on the surface, either of which could prevent a successful run. A torpedo that struck the water flat from more than a few feet at low speed would probably break up. And if these potential problems were not enough, any bank, yaw or other deviation from level flight in all planes would cause the torpedo to deviate from its intended course. Sometimes circumstances dictated the actual dropping position, but ideally it would be from about 800 yards out and a little ahead of the calculated impact point on the target's track, so that the torpedo would be closing on the target and not chasing it.

On top of all of that was the very difficult matter of correctly aiming the torpedo after having assessed the target's size, range, speed and bearing, and solving the resulting triangle of velocities to assess the necessary aim-off deflection. And then there was enemy action to

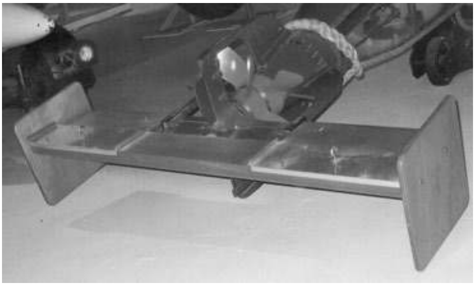


A sectioned Mk XIV torpedo fitted with Bull Gear.

consider: all of these problems to be solved in the pilot's head without mechanical aid within a few seconds. To aid pilots there was a series of torpedo sights, but these were generally distrusted and ignored or even removed, as some would scalp a pilot in a crash. Another factor was dropping range, and RAF pilots initially suffered from having been trained to drop at 1,500-2,000 yards range, whereas half that distance proved ideal, and from having had no opportunity to practice against (or even see) large high speed targets. This shortcoming was made good after the Channel Dash fiasco of February 1942, the movement of the German battle squadron from Brest to Kiel, but pilots already in service remained badly prepared.

To reduce drag, many aircraft, especially the more modern ones, carried their torpedoes horizontally and, as mentioned, a flat drop was undesirable. Air tails and Drum Control Gear were eventually developed to raise the torpedo's tail and control roll. The first mechanical aid employed for this purpose was Bull Gear. Invented by Capt J A Bull of the Royal Norwegian Navy, this comprised aerofoil-section winglets mounted on the torpedo's tail and controlled via pivoted rods from small air vanes on the sides of the torpedo's rear section. The vanes reacted to any change in the torpedo's fore and aft trim and moved the winglets to keep the torpedo at the correct angle to the horizontal. This expensive and complicated fitting was mainly associated with the fast but equally complicated and therefore disliked Mk XIV torpedo of 1935 and was associated almost exclusively with the RAF's Vildebeest biplane. The Mk XIV torpedo was some 220 lbs heavier and 30% faster than the Mk VIII it replaced, and carried slightly more explosive.

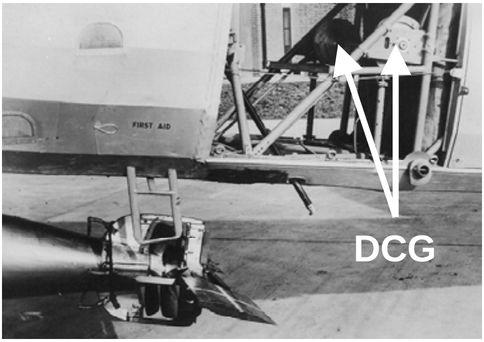
From the introduction of monoplanes, British aircraft torpedo development lagged behind the performance of RAF aircraft. The



A MAT Mk III, fitted to a Mk XII torpedo, is on display at Hendon beneath the RAF Museum's Beaufort.

Mark XII, used by the Beaufort, matched the performance of the Albacore, the Mk XV for the Beaufighter matched the performance of the Beaufort and the Mk XVII, intended for the Brigand, matched the Beaufighter. The Mk XV was in step with the navy's Barracuda only because the latter was late. These anomalies arose because the Admiralty controlled torpedo design and production, which meant that torpedo weights, which affected their capability, were limited to what RN aircraft could lift from the relatively short flight decks of their parent carriers. Admiralty control also meant that the RAF suffered regular torpedo shortages until the aftermath of the inquiry into the Channel Dash.

The most important device for controlling the torpedo's flight-in-air to ensure a good water entry was the Monoplane Air Tail (MAT), mounted on the torpedo's tail. The Mk I version was a 50-inch span neutral aerofoil, and appears to have been favoured by the RN. The MAT Mk III, which comprised a wedge-section 'wing' with adjustable flaps and rectangular endplates, was principally associated with the Mk XII torpedo of 1937, and was the combination used by the RAF and RN almost exclusively until mid-1943. This very important torpedo was 16ft 2in long without its nose pistol and carried 388 lbs of TNT or 432·5 lbs of Torpex in the standard short warhead for 2,000 yards at 40 knots. It is difficult to give an accurate weight for this and the two subsequent operational torpedoes, as a confusing variety of weights are quoted in numerous official documents. Apparently-reliable figures are 1,620 lbs (TNT) or 1,664·5 lbs (Torpex). Although widely-used, it was weak and monoplanes had to slow down to 180 mph in the face of the enemy at an ideal height of 70 feet to avoid a bad water entry. Nevertheless, all the individually-important torpedo successes by RAF and RN aircraft during WW II were achieved with this torpedo and air tail combination.



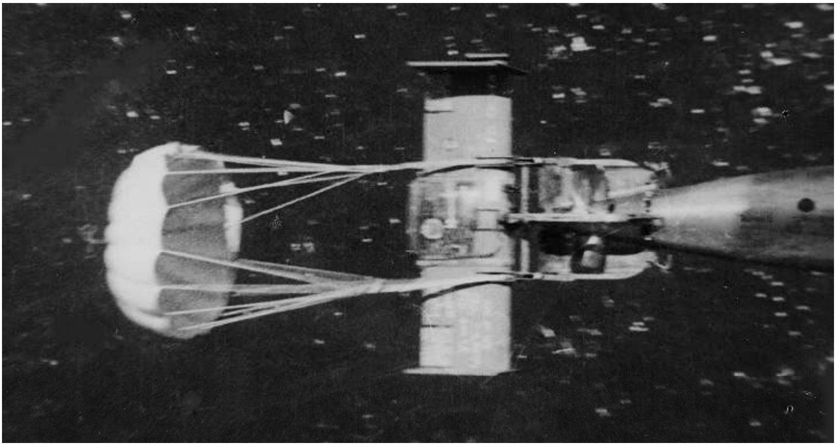
A Mk I Monoplane Air Tail (MAT) fitted to a Mk XII torpedo on a Swordfish with its Drum Control Gear (DCG) discernible within the fuselage.

The RAF achieved its first-ever torpedo hit on 18 September 1940, when No 22 Sqn severely damaged the 7,600 ton *Kriegsmarine* supply tanker *Ill* off Den Helder. The first RAF sinking was the 763 ton *H J Kyvig*, hit off Haugesund by No 42 Sqn on 26 October.

Torpedoes carried internally on the Wellington were fitted with a Hinged Air Tail (HAT) and torpedoes fitted with either this or MAT Mks I-III were steadied on initial release by Drum Control Gear (DCG), which was developed during the first half of 1938. This comprised a pair of wires some 18ft long (only one on HAT) that unwound from spools on the aircraft and prevented the torpedo's tail from initially falling as fast as its nose, thereby achieving an improved angle to the horizontal that the air tail then maintained until it broke away on water entry. DCG also controlled initial roll. A disadvantage of DCG was that the pilot could not commence avoiding action for a few seconds after release while the wires wound off.

To overcome this disadvantage a new air tail, the MAT Mk IV, was introduced, together with the strengthened Mk XV torpedo. The great advance incorporated in MAT Mk IV was its gyroscope, which controlled flight-in-air via small flaps, thereby rendering DCG unnecessary. The gyroscope was started by the withdrawal of a fid[2] when the torpedo was released. The new torpedo, which was only 9·5 lbs heavier than the corresponding Mk XII, carried the Torpex-filled warhead and could be safely dropped at 220 mph from 150 feet. The new combination was occasionally used by Barracudas and was the standard weapon of torpedo Beaufighters.

[2] Fid – a nautical term for a pin or spike used, eg in splicing rope or to support a topmast, or, in this case, as a lock to inhibit the operation of a mechanical device until withdrawn. **Ed**



The last British anti-ship torpedo, a Mk XVII with its MAT Mk V.

A means of making a torpedo attack a little safer was Gyro Angling, which allowed the torpedo to run in water at a pre-set angle to port or starboard of the line of flight at launch. Aiming became complicated and the method was little used.

The last British anti-ship torpedo was the Mk XVII, which featured strengthened components and structure, shortened propellers and a bronze tail in place of steel. Without its pistol it was 16ft 11in long and, with an 834 lb lengthened warhead containing 600 lbs of Torpex, weighed 1,871·5 lbs without its air tail. This latter was the new MAT Mk V, which was basically the Mk IV fitted with a drogue parachute to reduce the speed of its flight-in-air. This had become necessary because the new Brigand, Firebrand and Wyvern aircraft were faster than the Beaufighter (the Wyvern Mk I had a maximum speed of 440 mph with a torpedo). However, the Mk XVII/MAT Mk V combination remained unsatisfactory, the heavier and therefore longer, new warhead being itself the cause of many problems. This warhead was actually unnecessary, as the power of underwater explosions did not increase in direct proportion to the charge size. This all led to the CinC Home Fleet ordering in September 1951 that the speed of practice drops must not exceed 190 knots because of damage being caused to the torpedoes, and that war drops, if the need for them arose (this was during the Korean War), must be limited to 240 knots or 276 mph! This completely negated the Firebrand's performance and left

Although the FAA persevered for a little longer, in 1947 the RAF recognised that radar-laid naval AAA had made conventional torpedo attacks unrealistic and the Brigand, the intended successor to the Beaufighter, never entered service in the torpedo bomber role.

the relationship between aircraft and torpedo development back where it had been in 1939!

Until the late 1930s all torpedoes relied on impact for detonation, but then it was decided that a non-contact explosion could be more damaging. The additional non-contact device in what was termed a Duplex pistol was a proximity-influence exploder triggered by the magnetic field of the target. The device was tested successfully against HMS *Bruce* on 22 November 1939 but, although it worked at Taranto, it proved unreliable until mid-1943, thus allowing many Axis vessels to escape damage. The theory, that an explosion under a ship would prove more dangerous because it would flood its unprotected bottom, proved fallacious, as a ship was more likely to capsize and sink due to instability caused by asymmetric flooding after a hit on one side

For training, dummy torpedoes were steel or concrete shapes weighing the same as operational torpedoes but without any mechanism, and were intended to give pilots the feel of a laden aircraft and of the subsequent change of trim at the moment of release. Practice torpedoes were standard torpedoes fitted with either a collision (steel-covered wood) or a blowing head in place of a warhead.

With one or more complete squadrons on board each fleet carrier, as well as at some shore bases, Naval torpedo-bombers could

By 1944 the standard armament of the 'Torbeaus' of the UK-based Strike Wings was the Mk XV torpedo with a Torpex warhead, a Duplex pistol and a MAT Mk IV.

generally attack in force. The RAF was originally weak by comparison, having only two torpedo-bomber squadrons to cover the European coast from Biscay to Norway until the latter part of 1941, and there were no fighter escorts until about the same time. Coastal Command aircraft received no fighter escort during the chaotic Channel Dash operation, which saw all three torpedo-bomber squadrons operating against the same target, but poorly briefed and in an unco-ordinated manner. There were no RAF torpedo-bombers in the Mediterranean until 1942. The need for improved tactics was obvious, and the concept of dedicated anti-*Flak* and anti-fighter escorts emerged.

First to benefit regularly were the Mediterranean-based Beauforts from mid-1942 onwards, although there was never a Strike Wing as such. In the UK dedicated Strike Wings were formed, using Beaufighters for both *Flak* suppression and torpedo attack. The first outing was by the North Coates Strike Wing on the disastrous mission of 20 November 1942. The wing's next operation was delayed until April 1943 by the obvious need for further rigorous training. From then on there was no looking back. Prior to the advent of the Strike Wings, aircraft shortages led to torpedo attacks being made piecemeal, often by single aircraft. The Strike Wings at last enabled ideal tactics to be employed, with several aircraft simultaneously dropping torpedoes off both bows of a target,. However, timing robbed the Beaufighters of a key role in either the Battle of the Atlantic, as its turning point was passed in May 1943, or in the North African campaign, which in the same month ended in victory – torpedo Beaufighters did not become operational over the Mediterranean until June.

Some 'Also Ran' projects

Toraplane was the first of two torpedo remote-attack schemes. The risks faced by torpedo-bombers when approaching a target close enough to drop their weapons successfully were well understood and a means of overcoming these was sought. The inventor, Sir Dennis Burney, believed that a torpedo could be dropped from beyond the range of AA fire by fitting it with detachable wings and tail permitting it to be released some miles from the target (depending on visibility) and then glide down to sea level in stabilised flight. Development of this device, known as Toraplane, or Tora for short, began in August 1939, initially using the Mk XIV torpedo as the payload. The metal or wooden wings of the Mk I version had 3 or 4 degrees dihedral and spanned 11ft 4in. Intended for use by Albacore, Beaufort, Botha and Swordfish aircraft, all of which dropped it on many trials conducted by the Torpedo Development Unit, Tora I was never satisfactory and was replaced by the Mk II.

Tora II was intended for the Albacore, Barracuda and Beaufort only, as Toraplane could not be carried by the Hampden or Wellington adapted for torpedo dropping. This had metal wings spanning 14 or 15ft set at 6 degrees dihedral. Weight with a Mk XII torpedo, the standard load for wartime trials, varied between 1,790 lbs and 1,840 lbs. Recommended launching speeds for Tora II were about 135 mph for the Albacore and some 170 mph for the two monoplanes.

For an attack the optimum release height was 2,500 ft from an aircraft flying at a steady speed and completely level in all planes, after which the Toraplane's flight-in-air involved a 5,000-yard glide to sea level. A pendulum, suspended just below the wings, struck the

Toraplane II on an Albacore.

water an instant before main impact, releasing the Toraplane from the torpedo. The latter would then run normally. The many trials failed to perfect this theoretical approach, as the slightest anomaly at release or the effect of any adverse wind would be magnified during the long glide. Also, it was difficult to estimate a distant target's bearing, range and speed, and an alert target had plenty of time to manoeuvre onto an avoiding course.

Toraplane was never used in action and despite the huge cost and effort involved, was cancelled on 15 October 1942.

The other torpedo remote-attack scheme was a radio controlled project initiated by the inventive Gp Capt W Helmore. By 1944 it had become an airborne weapon of gigantic proportions called the Helmore Projector, and scale models of the operational device were constructed by Messrs Stone. By about mid-1944 the weapon became Helmover.

This was a giant torpedo with a diameter of 38½ inches and a length of 29 feet. Weighing 11,500 lbs overall, its warhead contained a ton of RDX explosive. Powered by a 700 hp water-cooled Rolls-Royce Meteor engine, based on the Merlin, Helmover had a speed of 40 knots both surface-running and submerged, but its surface range of 50 miles dropped to only three miles submerged. A retractable mast carried an air intake and the receiving aerial for radio control from a Mosquito, which had to fly a pattern of figures of eight to keep the missile's wake or smoke plume in sight. In the final stage of an attack the mast would be lowered and Helmover would submerge.

Stone's first prototype featured a tapered nose when used for loading trials, but before the first drop it was modified to typical

The prototype of the enormous Helmore Projector being loaded into a Lancaster in 1944.

torpedo shape. This complete, but non-running, prototype was dropped off the Isle of Wight on 21 May 1944 from Lancaster ME570/G of the Torpedo Development Unit. By September control of the project had passed from Messrs Stone to Rolls-Royce at Hucknall. There, production and testing of true prototypes began, with the first running prototype becoming available on 4 February 1945. A successful demonstration to VIPs on 4 April led to a production order for 100 Helmovers, which it was hoped would be used against the Japanese fleet.

Unfortunately, further trials revealed that the visual range of Helmover from the controlling aircraft was rather less than the desired 10 miles. Also, the Mosquito was not ideal for tracking, as Helmover was lost to view for some 50% of the time, owing to the speed and wide turning circle of the aircraft: but there was nothing better. The vulnerability of the controlling Mosquito resulted in the need for a fighter escort, but even then probable operational losses were expected to be unacceptably high, and other means of control were being examined when peace brought the cancellation of the project.

AIRBORNE SEA-MINING OPERATIONS IN WORLD WAR TWO

Air Cdre Graham Pitchfork

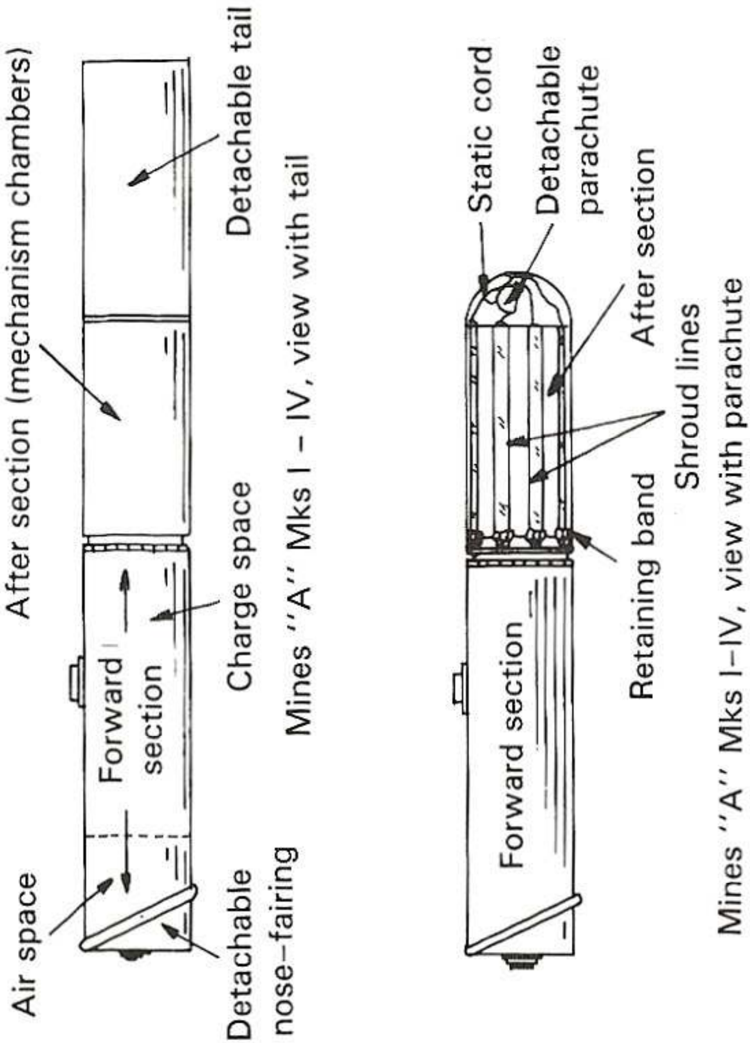
Following an initial Canberra tour in Germany, in 1965, Graham Pitchfork, a Cranwell-trained navigator, was seconded to the FAA to fly Buccaneers. Thereafter his career was inextricably linked with that aeroplane, culminating in command of No 208 Sqn. He later commanded RAF Finningley and RAF Biggin Hill before a final tour as Director of Operational Intelligence. Since retirement he has written several books on aviation-related topics and is a regular contributor to the Daily Telegraph's *obituary column.*

When I undertook to produce a short presentation on the various RAF sea-mining operations in the Second World War, I assumed that it would be a straightforward project and that information would be readily available. I was wrong on both counts. There was a great deal more mining activity than I had realised and it was very difficult to find a single authoritative source. Indeed, I never did and this presentation has been compiled by reference to numerous official documents that have covered aspects of aerial mining.

I intend to concentrate on the mining campaign in north-west Europe but it would be invidious not to cover the successful campaigns in the Mediterranean theatre and the Far East where considerable success was also achieved.

Initially, the sea mine was seen purely as a defensive device, but its development and use in the Crimea, and later during the American Civil War, firmly established it as a major weapon of war. By the beginning of WW I the sea mine had become an essential weapon for a major maritime power. The Royal Navy's mines of that period, and later, were the spherical, moored, horned type that we are all familiar with. Direct contact with any of the horns initiated an electrical circuit, which detonated the mine. Early experiments with magnetic mines, which rested on the seabed, were not particularly successful.

Between the two World Wars there was little development of the



Mines ''A'' Mks I – IV, view with tail

Mines ''A'' Mks I–IV, view with parachute mine but with German rearmament in the late 1930s, the Admiralty authorised work to develop a moored magnetic mine to be used against U-boats. By 1939 it was recognised that there was also a need for a ground mine and an order for thirty trial mines to be air dropped was placed with a view to their being laid by the RAF's Beaufort and Swordfish and Albacores of the Fleet Air Arm.

The long-range of some aircraft created an opportunity for the mine to be used *offensively*, thus creating a valuable option for attacking enemy ships in their own waters. To reach these more distant waters it was decided to give Bomber Command's Hampdens a mining capability. This required a major modification of the mine, including fitting a nose fairing and a drogue parachute, to allow it to be dropped at an increased height and speed.

The trial programme was completed in March 1940 when the mine went into production. Known as the 1,500 lb A (for airborne) Mk I, it became available in April. Robustly designed to withstand drops in excess of 200 mph and from heights that varied from 100 to 1,500 feet, and, as we shall see later, eventually 15,000 feet, the mine was modified three times in the first few months of its life, becoming variously the 1,500 lb A Mks I-IV. Approximately 750 lb of its weight was taken up by high explosive. A slightly smaller 1,000 lb mine was introduced in 1941 and these two became the RAF's standard mines throughout the war, although a more versatile 2,000 lb Mk VI, which contained more explosive and even more sophisticated fusing devices was introduced in 1944. They included various time delays, and the mine could lay dormant, sometimes for a matter of months. All mines incorporated a number of triggering options, initially magnetic, but later an acoustic system was introduced and, later still, a mix of both. To safeguard friendly shipping, the mines could be set to neutralise after a fixed period.

The mine was a cylindrical steel case 18 inches in diameter and 10 feet long, including the parachute pack and the nose fairing. The forward section housed the 750 lb of Amatol explosive and the after section contained the triggering system and hydrostatic safety switches which armed the mine when it sank to an appropriate depth. All mines were designed and supplied from naval sources, but the RAF experimental establishments were involved in the 'air aspects' of aircraft laid mines.

The Admiralty had overall control of the direction of the minelaying campaign which, since most were actually laid by the RAF, called for very close inter-Service co-operation and joint planning.

The North-West Europe Mining Campaign

The main plans for minelaying operations in North-West European waters were drawn up in the Admiralty, irrespective of the method of delivery or the Service involved. A very high degree of co-operation between the Royal Navy and the RAF was established for the laying of mines by RAF aircraft. A Captain RN, with a small naval staff, was part of the staff of the Commander-in-Chief at Bomber Command and a naval officer was appointed to each of the Bomber Group Headquarters. Specialist naval ratings, and occasionally some officers, were attached to bomber stations to assist operations and armament teams. In his War Despatch, Air Chf Mshl Sir Arthur Harris paid fulsome praise to the naval staff attached to Bomber Command and the various headquarters and bomber stations.

Aerial minelaying by UK-based aircraft of Coastal and Bomber Commands accounted for the great majority of all mines laid offensively in European waters. Most importantly, they were able to attack fruitful areas, which could not be reached by naval forces. This campaign, which eventually extended from the Norwegian fjords to the Franco-Spanish border, inflicted significant losses on the movements of Germany’s own shipping, and that of neutrals that continued to trade with Germany, in addition to greatly extending the

When Bomber Command first became involved in the minelaying campaign the task was assigned to No 5 Gp's Hampdens, each of which could deliver a single mine.

enemy's minesweeping effort. The coastline of Europe was divided into six areas:

Area 1. The Western Baltic.
Area 2. The Kattegat, Kiel, the Sound and Belts.
Area 3. The south coast of Norway.
Area 4. The North Sea; Danish, German and Netherlands coasts.
Area 5. The Belgian and northern French coasts.
Area 6. The French Biscay coast.

Within these areas, specific locations were identified and called 'gardens' and, for security reasons, each was given the name of a garden product such as a flower or a fruit. The mines were called 'vegetables'. Hence the common term in Bomber Command parlance for mine laying operations of 'gardening'.

Hampdens of No 5 Gp, commanded at that time by AVM Harris, each carrying a single mine, carried out the first British aerial minelaying operation on the night of 13/14 April 1940 when thirteen Mk I magnetic mines were laid in the Great and Little Belts off the Danish coast. The following night, Beauforts of Coastal Command, also carrying a mine each, laid six mines off the Ems and Weser Rivers. These first aerial minelays coincided with the German occupation of Denmark and Norway. The German invasion of the Low Countries, which followed a few weeks later, extended the choice of targets to the waters off the Frisian Islands and the Dutch coast. For the next few months minelaying operations continued at a modest rate, but spread over a much larger area after the fall of France. At this stage of the war, Bomber Command was reluctant to divert aircraft to the task and Fleet Air Arm Swordfish supplemented

By 1942 Bomber Command's second generation of four-engined 'heavies', in this case a Stirling, were increasingly committed to 'gardening' operations, delivering up to six mines per sortie.

the modest Coastal Command effort.

This initial attitude of Bomber Command to mining operations is well illustrated by their instructions early in 1941 to HQ 5 Gp – the only Group employed on mining operations at the time – which decreed that sea mining operations were to be undertaken only as a method of crew training. Exceptionally, when the weather prevented bombing, up to fifteen aircraft manned by experienced crews could be used. Needless to say, this aroused concern at the Admiralty and at Coastal Command and, following discussions at high-level, Bomber Command was given responsibility for mining operations in all areas north of the Elbe. Even so, during 1941, only 1,369 mines were laid in total by both Commands.

At the end of 1941, the Beaufort squadrons were committed almost entirely to the torpedo-bomber role and the onus of minelaying devolved on Bomber Command, supplemented by a very small effort by the Fleet Air Arm. In February 1942, the Command's capability increased significantly with the introduction of the Manchester, which could carry four mines, and during the summer these were replaced by Wellingtons, also carrying four mines, and the Stirling, which could carry six. Halifaxes and Lancasters joined the campaign in the autumn. On 25 March, Bomber Command was given the responsibility for *all* RAF mining operations. Air Mshl Harris, the Command's new CinC, immediately committed all of his Groups to the campaign. In May, the Command was able to top the 1,000 mark for the first time. By the middle of the year, the deployment of mines increased to 1,300 a month, rising to 1,600 in September – a total that exceeded the number laid throughout the whole of the previous year

The weight of this attack highlighted the enemy's shortage of minesweeping craft, and a three-fold increase in casualties brought urgent demands from the German Naval Command for more vessels. The sudden introduction of the acoustic circuit into some of the mines in September, undoubtedly contributed to the general increase in casualties. In November, Bomber Command mounted intensive operations outside the French Biscay ports and this severely hampered U-boat movements during Operation TORCH, the Allied invasion of French North Africa.

By the end of 1942 nine new 'gardens' had been planted, raising the number visited to 61, and 9,669 mines had been laid. The air minelaying campaign had assumed major proportions and enemy and neutral casualties rose steeply with 163 ships of 173,049 tons sunk and a further 110 damaged.

The average of 1,200 mines laid each month continued into 1943 with a peak of 1,809 in April. This very high total came about because a new triggering unit in the mines, incorporating both acoustic and magnetic fuses, had become available, and the Admiralty wished to exploit the factor of surprise. On the night of 27/28 April, 123 Bomber Command aircraft laid 458 mines off the French Atlantic ports and around the Frisian Islands for the loss of just one Lancaster. The following night, an even bigger venture fared less well. Over 200 aircraft took off and 167 succeeded in laying mines off the German and Danish coasts. Between them they dropped 593 mines – the highest total on any single night of the war but, with the opposition considerably greater in that area, twenty-three aircraft were lost.

During 1943, mines laid by Bomber Command sank 133 ships and damaged 92 others at a cost of less than 3% of the sorties. This reduction in the casualty rate arose primarily because in June the Command had developed the capability of dropping mines effectively from a greater height – 6,000 feet instead of the previous lower levels where the light *Flak* was a serious threat.

Parachute-retarded mines being fused.

During the last quarter of 1943, trials were carried out to perfect high altitude mining and these culminated in an operation on the night of 30/31 December when three Stirlings laid eleven mines in the mouth of the Gironde off Bordeaux, from a height of 12,000 feet. The average error was less than 1,000 yards. Mining from 15,000 feet was successfully developed two months later using H2S and this became the primary method used. The aircraft lost-to-mines laid ratio fell to one aircraft for every 97 mines. The figure for shipping casualties improved to a ship for every 62 mines.

The Allied invasion of Europe was largely responsible for a heavy upward surge in minelaying during the first seven months of 1944 with over 5,000 mines laid in April and May alone. This significant increase was achieved in fewer sorties since greater use was made of the Stirling and Lancaster, each able to carry six mines. The sheer weight of this assault swamped the already fully extended enemy defences and shipping casualties mounted steeply to a record of 61 in June.

With the Allies advancing into the Low Countries, the mining effort was concentrated on the three northern areas. With fuel becoming increasingly scarce and the greater number of mines to deal with, the German minesweeping effort fell behind the task and so, not surprisingly, the shipping casualties-to-mine ratio improved to one in 34, almost twice as good as the previous year’s figure.

Mention should be made of a spectacular operation on the night of

12/13 May when thirteen Mosquitoes of No 8 Gp made a daring low-level attack on the Kiel Canal – the first time since they had entered service that Mosquitoes had been loaded with mines. The mines laid that night closed the canal for seven days, holding up 63 ships with their vital raw materials. A few days later, it had to be closed again for a further three days. The disproportionate result achieved by such a small effort was, in its way, as remarkable as when a small force of Lancasters breached the German dams – it was an equally striking instance of the effective use of air power.

During 1944 a record number of 17,493 mines was laid and the very economical figure of 74 aircraft lost points to the efficacy of the high-level mining method in reducing casualties. The ratio of aircraft lost-to-mines laid fell from the previous year's figure of 1:97 to 1:235. Furthermore, enemy casualties were much higher, amounting to 204 ships of 146,981 tons sunk and a further 216 damaged.

As the Russians advanced from the east, and Holland was liberated in the west, much of the effort turned to the Baltic and the Kattegat where aerial mining once again had a major impact on Germany's war-fighting capability. Many of the new, more capable U-boats were unable to exit to the Atlantic, and perhaps just as important, the vital training waters for the U-boat crews off Danzig had to be abandoned. Danzig Bay was once closed for fifteen days and in a single operation, Lancasters dropped mines, which closed for thirteen days the eastern Baltic ports of Königsberg and Pillau. As a result, the movement of desperately needed German troop reinforcements to the Russian front was very severely affected.

The Naval Liaison Officer at the German Air Force Operations Division summed up the catastrophic position which the minelaying in the Baltic had brought about when he said,

> '. . . without training in the Baltic, and safe escort through coastal waters and the routes to and from operations in mid-ocean [Atlantic], there can be no U-boat war. Without sea-borne supplies, it is impossible to hold Norway. […] Already, we no longer command the sea routes within our sphere of influence, as is shown by the day and week long blocking of shipping routes in the Baltic approaches.'

By the middle of April 1945, the mining campaign was virtually over; the last operation was on 3 May when eleven Lancasters mined the Kattegat.

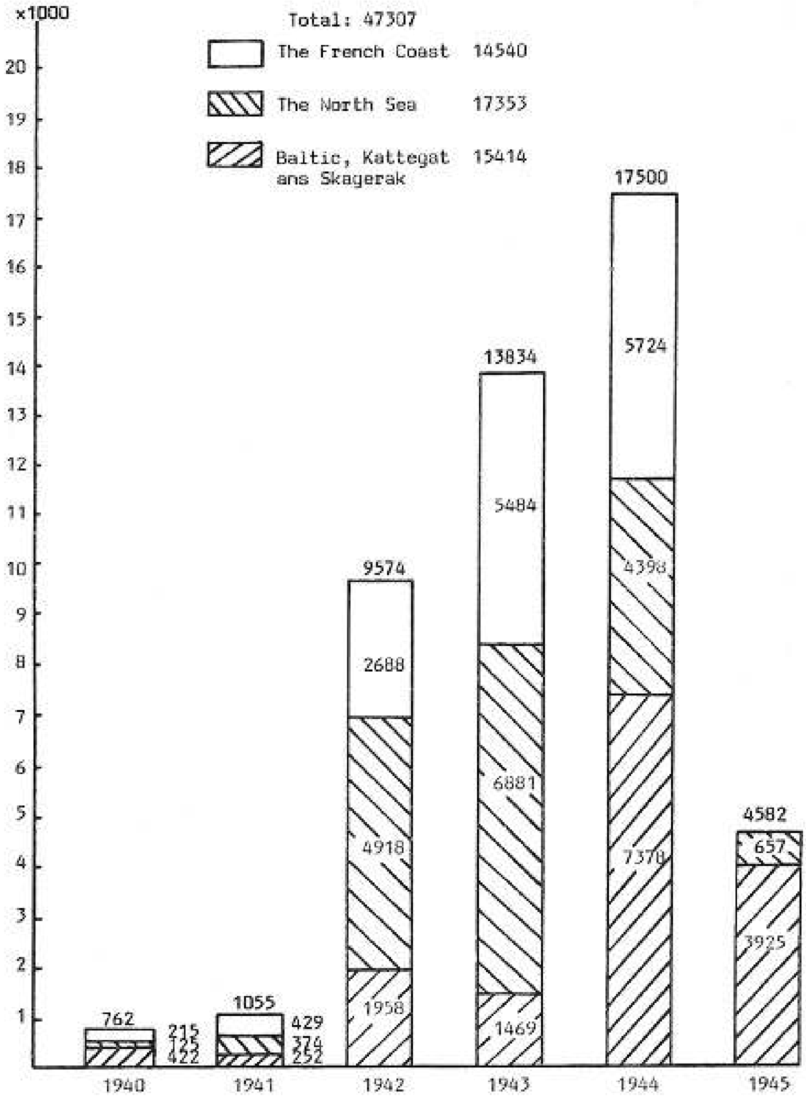
Summary

48,060 mines were laid offensively in enemy controlled waters, 47,152 by aircraft of Bomber Command. The air mining campaign in NW Europe played a major part in the general offensive waged against enemy controlled shipping and was the only means of carrying the attack to many remote and important sea areas, which would otherwise have remained almost untouched by hostile action. The very substantial results of the campaign – 717 vessels of 688,153 tons sunk and 565 damaged – far exceeded the results obtained by any other weapon. Mines accounted for 40% of the total sinkings of enemy controlled vessels. Contrast that with 17% by surface ships and submarines, 23% by direct air attack, such as the Strike Wings, and 20% during RAF and USAAF bombing raids.

Air mining also proved to be outstandingly economical in terms of effort and aircraft losses. From 19,523 sorties, just 507 aircraft were lost – compare that with the loss of 96 on one night in March 1944 when Nuremburg was bombed for little result.

Apart from its obvious success in sinking and damaging shipping, the air minelaying campaign also gave rise to many less tangible and often equally important effects, some at the strategic level, all of which contributed towards the final disintegration of the German war machine. Every delay to an important cargo contributed to the dislocation of basic industries, which relied on a planned flow of raw materials. This was compounded by the difficulties the Germans experienced in persuading neutral crews to sail into war zones, due almost entirely to the air mining campaign. This led to a total embargo in September 1944, at a time when Germany was becoming increasingly short of shipping space to carry the crucial raw materials, notably from Scandinavia, to feed the German industrial war machine.

The success of delaying the emergence of U-boats from their Biscay bases during Operations TORCH and, much more significantly, OVERLORD, owed a great deal to air mining. Staying on the U-boat theme, preventing most of the new, and much more capable, U-boats from reaching the Atlantic, and denying them their training waters in the Bay of Danzig, helped to ruin Admiral Doenitz’s



Mines laid by Bomber Command, 1940-45.

chances of operating them in significant numbers before the end of the war.

The interference of the movement by sea of troops and military equipment, particularly towards the end of the war when reinforcements could not be sent to Russia and to Scandinavia, was largely due to the air mining campaign.

In addition to these direct influences, the enemy was forced to maintain an ever-increasing multitude of minesweeping craft – the provision of ships, equipment, fuel and crews. During the last year of the war, 40% of all the men in the German Navy were employed in minesweeping and escort duties. Yet, despite this heavy expenditure on resources for mine countermeasures, the defences were generally unable to prevent the major disruption of traffic.

Few, if any of these results could have been achieved by any other form of attack, so, for a relatively modest outlay and losses, the air minelaying campaign in NW Europe must be considered to have been an outstanding success.

Mediterranean Theatre

In the Mediterranean area, the Fleet Air Arm's Swordfish and Albacores led the campaign as soon as Italy declared war on 10 June 1940. The North African ports were the initial targets but the effort was small with just 32 mines laid before the end of the year. However, one operation was particularly noteworthy. On 17 September six Swordfish each dropped a mine 600 yards off the entrance to Benghazi harbour. An Italian destroyer and a cargo ship detonated mines and both sank. Nine days later, a further ship struck a mine and sank. Six mines – three ships sunk, which must be the best result in the history of mining.

In May 1941, it was decided that the RAF would enter the mining campaign and on the night of 15 July Wellingtons of No 38 Sqn carried out the first attack when they mined Benghazi. During the rest of the year, Wellingtons based in Malta and in Egypt laid 172 mines in 38 operations against the ports in North Africa, Sicily and Greece that were being used to resupply the Axis armies. 1942 saw a significant increase in mining activities when the RAF assumed the major role. Most sorties were directed at interrupting the enemy's supply lines, particularly those supporting Rommel's troops in North Africa.

By 1943 Liberators, as here, and Wellingtons provided the bulk of the Italian-based minelaying effort.

During the year, 649 mines were laid, the majority outside Tobruk and Benghazi.

The range of targets was extended in 1943 when Beauforts, Liberators and Marauders began to lend a hand, albeit on a small scale. Activity was most intense during the successful Eighth Army battles in the latter half of the year culminating in the Tunisian campaign. Later in the year, mining activity switched to Sicily and Italy in preparation for the Allied landings.

An interesting operation was mounted on the 13/14 April, and repeated four nights later, when Lancasters of No 5 Gp, operating from their airfields in Lincolnshire, mined the important Italian Navy port of La Spezia under the cover of a major bombing attack. Sixty Mk V mines were laid.

By the end of 1943, Liberators and Wellingtons were busy mining Greek waters and, once Italian airfields became available, it was possible to mount a mining campaign that would become one of the most successful of the war and by far the most significant in the Mediterranean Theatre – the mining of the River Danube.

The Danube, the second largest river in Europe, had 1,500 miles of navigable water stretching from Germany to the Black Sea. It was a crucial link for the transport of raw materials from the Balkan and East European countries to Germany, particularly oil from Romania. In the opposite direction it was a strategic route to the Russian front and it was estimated that the Germans needed to move 12,000 tons of supplies eastwards every day to support the fighting. As the war progressed, and the Russian army advanced and Allied bombers attacked the railway system, the Danube became Germany's 'lifeline' and crucial to their war effort, so the German High Command assumed control of the river.

During the second week of April 1944, the RAF opened the campaign against the Danube when Liberators and Wellingtons laid the first mines in the river. Over the next six months, another seventeen operations were mounted when 1,382 mines were laid, the vast majority being Mk Vs with magnetic fusing, which were more effective in shallow water. The cost was just ten bombers lost.

The attacks had a devastating effect on the ability of the Germans to move supplies and priority traffic was cut by at least 60%, some estimates put it higher. The supply of the German armies of the south east was at first drastically reduced and later it virtually ceased. 156 ships and barges were sunk and a further 120 were damaged, and the threat of mining alone caused great congestion and hold ups. Efforts to clear the river resulted in the loss of five minesweepers and two Ju 52 mine clearance aircraft, which were blown up by detonations they had triggered. Salvaging the wrecked barges from the shallow river also created huge disruption.

The aerial mining attacks against the River Danube were a startling success.

Far East

The first offensive mining operation in the Far East was mounted in February 1943 by Liberators of the USAAF's 10th Air Force when they laid 40 British Mk V mines outside Rangoon. During the rest of 1943 the Americans laid 125 British mines and 272 of their own. The effect was immediate and shipping using the port dropped dramatically.

The RAF's minelaying operations began in earnest in January 1944

A Liberator of No 159 Sqn, the first unit to be committed to minelaying operations in SEAC.

when Liberators of No 159 Sqn, later to become the Eastern Air Command's chief minelaying unit in the area, operated against Rangoon, the main port of entry for Japanese supplies to the Burma Front. A second Liberator squadron (No 355) joined the campaign and during the year over forty long-range operations were flown to such targets as the Andaman Islands, Bangkok and the river estuaries south of Rangoon. The emphasis of operations was to disrupt the enemy's lines of communication. Although few ships were sunk, the presence of mines, and the threat that they represented, caused the Japanese to close the port of Rangoon from April to September. The mining of Penang in October 1944 forced all German U-boat operations to be transferred to a new base in Batavia. By the end of the year, 1,149 British and American magnetic mines had been laid successfully and a number of ports and river crossings were closed.

The mining campaign was extended in 1945 and the arrival of No 160 Sqn with its VLR Liberators allowed targets at extreme range to be attacked. This created acute supply problems for the Japanese, and although they attempted to keep going by using new ports in the Gulf of Siam, these were added to the target list as soon as they were seen to be in use. The USAAF introduced the B-29 Superfortress and these mined the Sumatran oil port of Pelambang. The Liberators of No 160 Sqn were able to reach Singapore and this involved a round trip of 21 hours, much of it flown at low level. These operations interfered considerably with the transport of bauxite and oil to Japan and the route was eventually closed in March.

Aircraft in South East Asia Command laid 4,374 mines. Although relatively few ships were sunk, the enemy was increasingly forced to use indifferent railway systems and these came under constant attack from interdictor and bomber aircraft. Stubbornly though the Japanese army fought in Burma, it was eventually defeated by a constant reduction in the level of supplies reaching the ground troops until they were quite inadequate for operations. The SEAC mining campaign stands out as one of the most successful of the war.

Conclusion

There can be no doubt that the air delivered mine became an established and highly effective weapon of war. From its traditional use as a defensive weapon it became the most lethal offensive weapon in the maritime war. Triggering systems became increasingly complex, creating major problems for the minesweeping force, which was never able to keep up with the developments. In addition to the destruction of shipping, the threat of mines was sometimes sufficient to halt operations as in the Baltic, the River Danube and the port of Rangoon.

The 13,500 mines laid in the Baltic, Kiel Bay and the Kattegat had strategic implications such as denying access to the open oceans for U-boats, disrupting critical supplies of raw materials to German industry, and disrupting, sometimes preventing, essential troop movements. Mining of the Kiel Canal, the Königsberg Canal and the River Danube gave ample proof of the vulnerability of inland waterways and in the Far East the use of very long-range aircraft demonstrated that even the remotest waters could not be considered mine-free.

The mining of enemy waters by aircraft was an outstandingly economical and successful operation, which far outweighed the comparatively low loss of aircraft and their crews. Perhaps the campaign should have been much bigger.

AFTERNOON Q&A

Mike Meech: First a comment. I recall a quote from an American infantryman during the break out from Normandy. He said that when the RAF's Typhoons were overhead, the Germans took cover, but when they were American P-47s, everyone went to ground – which must say something positive about the accuracy of the Typhoon's rockets.

Dave Herriot spoke about the increasing thickness of the armour plating on Soviets tanks and also alluded to the introduction of the explosive reactive armour which became increasingly common on T-55s, T-64s, T-72s, T-80s and the like– you could see it on the tanks that the Russians recently deployed in Georgia. Can the CRV-7 defeat that armour?

Wg Cdr Dave Herriot: I imagine that that one is directed at me but I'm afraid that I can't actually answer it, as I never had any dealings with CRV-7. That said, in view of the possible security implications, I'm not sure that I would want to answer the question, even if I could – but perhaps there is someone in the audience who could comment?

Wg Cdr Harvey Smyth (currently OC IV Sqn): Yes – the CRV-7 will deal with the ERA on anything up to a T-72. Indeed I last fired one last night on Holbeach Range – and they work quite nicely thank you! (*Laughter*)

While I have got the mic, I would like to take this opportunity to thank the Society for having me here. This has been my first seminar and it has been an excellent experience. Once I have got my membership sorted out, I hope to attend a few more.

Reverting to CRV-7, and just to amplify what David Herriot said, the RAF came very close to loosing it just prior to Operation TELIC (ie the British involvement in Iraq since 2003 – **Ed**) when it was slated to be deleted as a weapon option for the Harrier. We fought a very strong case to keep it, in conjunction with UK Special Forces who regard it as their weapon of choice for close air support. Interestingly, the use of CRV-7 has changed somewhat and today we would not consider using it against a tank, mainly because, despite its accuracy, you would still have to fire quite a lot of them to guarantee a hit – and we have established through trial firings that in order to guarantee that you will 'kill' a tank you do actually have to get a direct hit. With more modern weapons, using laser or GPS guidance, we can simply 'plink' a tank with a laser spot from our own cockpit – and that is the way that we would always prefer to go.

There is, however, still a place for rockets, as one can see in Afghanistan where they permit us to deliver a graduated response to whatever is going on on the ground. The latest MOD buzz word for this approach is 'a tuneable effect' and it has become the focus for the way in which we are endeavouring to pursue our counter-insurgency campaign. In short, one doesn't simply drop a couple of 1,000 pounders on a problem and hope that the local population will continue to support you. CRV-7 is extremely effective in this context as it permits you to fire just one rocket, and to fire it accurately at a point that *isn't* the enemy. For instance, if you have a Taliban sniper in a house within a compound occupied by local villagers, it is not helpful to destroy the whole compound. Firing a single CRV-7 at Mach 3 *over* the house, to impact harmlessly 500 yards out into the desert, will produce a supersonic shock wave that will let your man know that he has definitely been spotted and that we have 'intent'. This is generally enough to make him move on, or, sometimes, even to surrender – because he probably knows that you still have another thirty-seven of those rockets up your sleeve – and the 1,000 pounder option is still there.

Having monopolised the mic for too long, perhaps I could ask a question myself. In recent years we have seen a steady shift towards 'smart' weapons. Do you think that we have reached the stage at which unguided 'dumb' weapons are no longer of any practical use?

Herriot: As the most recent retiree, and having spent some time involved in weapons procurement at the MOD, albeit about ten years ago, I think that the answer to that is probably – yes. Not because the weapons themselves have lost their utility – it is more to do with the collateral damage that they can cause. We all know that an unguided bomb, at the wrong angle, can skip and detonate in quite the wrong place, and even if it is a dud, the size, shape and weight of it will be enough to wreak havoc. So – yes – I think that we are moving into a 'smart' world. Indeed before I left the MOD we were looking at non-lethal weapons. For instance, believe it not, one project involved a gun that fired 'glue' that would coat the enemy aircraft's surfaces to such an extent that it would gum up his controls, leaving him with little option other than to eject. Another idea was to fire a net over the opposition to achieve a similar effect. A bit far out, I know, but the point is that both schemes were attempts to avoid the use of high explosives and to achieve the aim by non-lethal means. So, given the inherent inaccuracy of iron bombs and the political climate governing the sort of campaigns that we are involved in today, if their days aren't over, they are probably numbered.

Going back to a point that was raised this morning – it certainly surprised me to learn, when I first began to fly Buccaneers in 1972 that the bombs that we were strapping on underneath the aircraft were the same as the ones that had been dropped by Lancasters in WW II. Even more remarkably, those weapons were still in use when I left the air force after almost forty years. The fact that they lasted so long indicates that there was nothing really wrong with them – but I think that they have finally had their time.

Anon: We had a lot of them.

Herriot: We certainly did – and we were so fond of them that we used to fish the inert ones out of Holbeach Range, scrub them down and go back and drop them again!

David Wilson: David Herriot referred to the slightly unconventional way in which we acquired CRV-7 in time for the Jaguar to use it the first Gulf War. I can confirm that it was via a UOR. It was making very slow progress – the Ordnance Board was deeply unhappy with CRV-7 and Boscombe Down had been conducting trials and tests on it for some considerable time. I was at Bahrein, running the weapons effort, when a Jaguar returned from a sortie having used a very expensive AIM-9 Sidewinder in order to destroy a single truck. With the incident recorded on film the Jaguar CO went back to the Air Commander and said, 'Now can I have my rockets?!' They arrived on a C-130 from Canada three days later.

Herriot: Nice story. So it was definitely through the back door.

Peter Symes: Were there any mining operations specifically aimed at bottling up ships in Norwegian Fjiords. I'm thinking of the *Tirpitz* in particular.

Air Cdre Graham Pitchfork: I don't think that there was ever an attempt to bottle-up the *Tirpitz* by using air-delivered mines. The RAF evidently preferred to use bombs – ultimately successfully – so any mining that was carried out would have been done by the Navy, probably using submarines. That said there were extensive mining operations in Norwegian waters, notably in the south towards the end of the war. Once it had become evident that there would not be a direct Allied assault on Norway, it became necessary to mine the harbours, particularly Oslo, in order to prevent the Germans from withdrawing their troops to reinforce the Eastern Front.

Steven Mason: You referred to Bomber Command's attitude towards mining, the way in which it was initially regarded as little more than a training sortie. At what point did the Command change its view, and to what extent did it do so voluntarily?

Pitchfork: It would have been in late-1941/early-1942 and they had little choice. With the Beauforts concentrating increasingly on torpedo work someone else had to take on the mining task and the job was simply given to Bomber Command. That said, it would not have been all that difficult a pill to swallow because Harris became AOCinC in February 1942 and his previous experience as AOC 5 Gp – the only Group with a mining commitment at that time – meant that he appreciated the potential value of a mining campaign – and its cost effectiveness. He also made extensive use of mining sorties to give inexperienced crews their first exposure to an operational trip – going through the briefing process, planning the mission, flying it – with the adrenaline pumping – and quite possibly getting shot at – and these sorties were not carried out without losses. If you look in the log book of a Bomber Command veteran you will often find that his first operation was a 'Gardening' sortie.

AVM Nigel Baldwin: Did all mining sorties count as an operational mission?

Pitchfork: Yes, they did. After all, they were not a sinecure. Some of them were very long range missions; Königsberg, for instance, was a ten-or-eleven hour round trip.

Air Mshl Kemball: We have a long-standing member of the Society in the audience today, AVM John Price, who had a central role in the

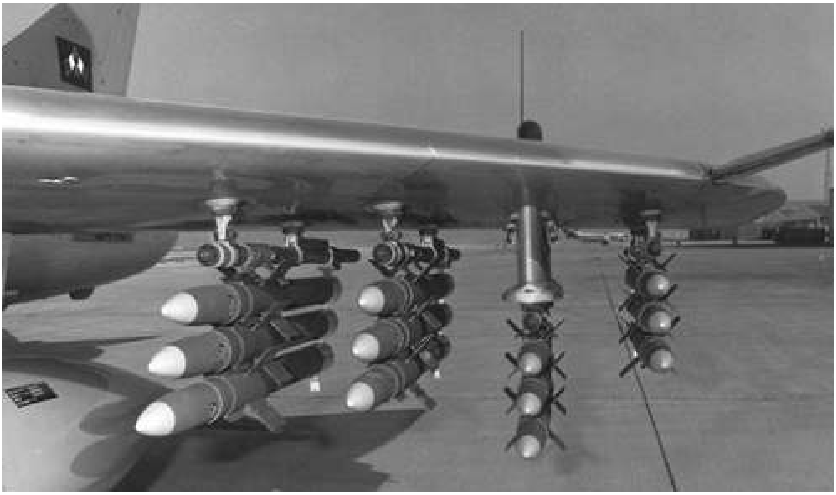
RAF's acquisition of SNEB in the 1960s and I invite him to tell us of his involvement.

AVM John Price: In January 1961, as a newly promoted squadron leader, fresh out of Bracknell, I was posted to the Air Ministry as Ops 4a, responsible for overseas operations, particularly in Air Forces Middle East (AFME), with its Headquarters in Aden. After a few months, presumably as a result of CinCs complaining about the performance of the 3-inch RP, I was tasked to write a paper identifying a suitable replacement. I do not know why it came to me, rather than to someone in OR – perhaps they were too busy with TSR2?! Anyway, although I was fond of the old '3-inch drain', having used it to good effect in Korea against trucks, supply dumps, the Pyongyang power station – most impressive that one – and some guns in a cliff cave, and having a very small personal error against targets on the range, I knew that with an average squadron error of 10 to 20 yards, doubled by the operational fright factor, as used by the Chief Scientist's (CS) staff, whom I consulted, we needed something better for use against T-34 tanks. But, as an aside, I was, only recently, sitting next to a retired army officer who, finding that I had been in the RAF, spoke in glowing and grateful terms about the rocket-firing 'Tiffies' that he recalled from his days in Normandy in 1944.

In correspondence with the various Commands, the following weapons were those which were most frequently suggested as possible replacements:

The 2-inch rocket, as used by the FAA
The 80mm Hispano Suiza Sura R80 rocket
The 68mm SNEB, singly or from pods
The 5-inch Zuni FFAR

Contacts with the various manufacturers, via the then Ministry of Aviation, produced a lot of data – often, in effect, sales pitches, but sufficient to allow me, with guidance from CS staff, to come down in favour of the Hispano R80 (also, as I recall, AFME's preferred option), although I hedged my bet by noting that, if it proved unsuitable for some reason that I could not then see, SNEB would be my next choice. I discovered later that there was an upper temperature limit on the R80's motor which rendered it unsuitable for storage in



Originally the front runner, the Hispano Suiza R80 was apparently ruled out on temperature limitations – although, as seen here on one of its Hunter FGA 78s, the Qatar Emiri Air Force seems to have made it work. (QEAF)

Aden and/or for holding at readiness on an armed aircraft in hot climates. With the Hispano Suiza rocket no longer in contention, there was a green light for SNEB which did not suffer from such constraints. I made contact with the French manufacturer, while working with Command and Ministry staffs to determine consumption rates in peace and war for the SD98 and TSD784.[1]

A demonstration in France of a Mystère firing SNEB with hollow charge 'squash' heads against 12-to-15-inch thick armour plate salvaged from the battleship *Richelieu* showed holes right through the plates, providing convincing evidence that it would be able to deal with Russian hardware. So the final version of my paper recommended SNEB along with projected costings. With someone from F6 holding my hand, we crossed Whitehall to the Treasury to make our case. As I recall, we were asking for about £3M but the wise old Treasury man gave approval for £5M, as he thought we needed

[1] The Secret Document 98 (Data for Calculating Consumption and Wastage in War) and the Top Secret Document 784 (Data for Calculating Expenditure in War) were (and may still be) classified documents used for planning purposes. **Ed**

more for contingencies. Neither I nor F6 dissented and his approval saw the programme safely embedded within the budget – happy days!!

The next hurdle to be cleared was to secure approval from the Ordnance Board, but they had problems. The first one concerned the fuse, a piezoelectric device that was new to them and they did not know how it worked. Neither did I, so we asked the manufacturer. They gave a corporate Gallic shrug and said that they didn't know either, but, since it clearly did, what was the Ordnance Board's problem? To get a precise answer to the question would take them time, and cost us a lot of money. I eventually succeeded in persuading the Board to accept that the fuse performed as required, albeit in some mysterious fashion, and they agreed that SNEB could be used by the RAF. We had no subsequent reports of fuse failure in service – perhaps the Board is still endeavouring to discover why it works.

The Board's second concern was that the weapon should not detonate, and should still be safe for operational use, after being dropped, in its transit packaging, onto a concrete surface from a specified height. This elicited another Gallic shrug and remarks to the effect that no one but *les Anglais stupide* would even think about using a rocket after they had been careless enough to drop it! Again, the company contended that trials to find an answer to this quite unnecessary question would inevitably increase the cost of the programme. They recommended instead that we should simply tell our people to be more careful and not to attempt to use inadvertently dropped weapons. I gave an edited version of the company's comments to the Board and spoke privately to its RAF member. The Board, with some misgivings, and holding me wholly responsible, finally approved the introduction of SNEB.

From then on it was merely a question of modifying Hunter F6s to carry and fire the weapon. Hawkers came up with the necessary modifications, but the Hunter's cockpit was already very crowded and the additional switchery aggravated and increased the existing confusion so that misfirings from, what now became, FGA9s were, to say the least, not uncommon. When, after converting from helicopters to Hunters, I eventually flew a Mk 9 and fired SNEB at Brawdy in July 1976, I discovered the switchery problem for myself, and found that one certainly needed to focus in order to avoid mistakes:

Back to 1962, when the A&AEE at Boscombe Down cleared the

Hunter 9 to carry and fire SNEB; the results were very good and showed that we now had a good tank buster. The only problem arose when firing from pods when rockets in flight could interfere with each other and thus impair the anticipated beaten zone. This problem was overcome quite easily by altering the setting on the intervalometer which adjusted the rate at which the individual rockets rippled out of the pod.

In closing, perhaps I could mention another, and far more obscure, project that came across my desk at much the same time – the CS Grenade Launcher. AFME and SOAF had another problem in that they needed a means of quietening crowds of dissident locals. The crews of helicopters, Beavers and Single and Twin Pioneers were asked, in what amounted to a reversion to 1915 practice, to throw out CS grenades after, of course, removing the safety pin with their teeth. The dangers of self-inflicted incapacity were obvious and we were asked if we could find a safer way of doing this. It was suggested that a number of grenades could be carried in an open-ended tube, with all of the safety pins already removed but with the operating levers still held in the closed position by the tube walls. The tube would be tied to the aircraft so that, when it was thrown out, it's fall would suddenly be arrested with enough of a jerk to overcome the limiting friction of the tube walls, allowing the grenades to fall out and the operating levers to spring open and activate the fuses. I asked the Ministry of Aviation to get a company to design and price such a launcher, of which I thought we might need about one hundred. The answer was that, manufactured in light metal, they would cost about £60 each. That proved to be too steep for the financiers so I asked for an alternative which turned out to be a tube made from *papier-mâché* at about £6 apiece, although the minimum order would have to be for a thousand units – so the total cost would still have been the same at £6,000. This was clearly a much better deal, however, and I was able to persuade the financiers that an overorder was justified on the grounds of total cost compared to unit cost – evidently a new concept to AUS(F). Boscombe cleared them for use, but I lost track after that. I have no idea whether any of them were ever used, or of what happened to the surplus.

CHAIRMAN'S CLOSING REMARKS

Air Mshl Sir John Kemball

First of all I would like to thank all of the presenters for their contributions to the day. A day which covered such a broad spectrum that I am not even going to try to pull it all together in what would be a vain attempt to create a coherent summary. Many of the techniques, tactics and equipments that we have considered are no longer of any real consequence, of course, which also makes it a little difficult to draw any lessons for today's air force. But, if I had to find some sort of theme, a common thread, it would, I think, have to be – inadequate preparation followed by the inordinate length of time required to develop satisfactory solutions – and I don't think that we have made a great deal of progress in that respect. It still seems to take forever to design, develop, test and introduce a piece of kit and, when we do eventually get our hands on it, it no longer fits the bill because the operational environment has changed and we have to start modifying it to match the current threat..

So, to all of you who are young enough – we do have *one* in this audience – to go on to be a staff officer in the MOD, the future will be in your hands. So it will be up to you to 'unblock the ministerial drains' and keep things moving at a reasonable pace.

And with that, I will wish you all a safe journey home and bring these proceedings to a close.

THE SCI

Wg Cdr 'Jeff' Jefford

In the aftermath of the seminar on unguided weapons, and in the light of a recent brief burst of publicity associated with the release of documents related to a proposed wartime use of chemical weapons,[1] this short supplementary paper may be of some interest.

Once the navy had switched from sail to steam, the fact that there was always a substantial fire on board ship made it relatively easy to make smoke and, if appropriate materials were burned, enough of it to make a smoke screen. The advent of aeroplanes provided the possibility of laying such a screen from the air, and very rapidly. Work began on this concept in the 1920s and by the end of the decade the FAA had an operational capability based on spraying titanium tetrachloride from an altitude of 600 feet from a tank slung beneath, typically, a Blackburn Dart or a Fairey IIIF.

Titanium tetrachloride is a corrosive liquid which hydrolyzes in contact with moist air to produce a dense white 'smoke' consisting of hydrochloric acid droplets and titanium oxychloride particles. Clearly, a very dangerous substance to handle, it required protective clothing and meant that both the structure and the fabric covering of the aeroplanes involved needed to be thoroughly decontaminated after each practical exercise.[2]

Perhaps inspired by the unpleasant nature of the chemicals involved, and/or the recent experience of gas warfare in the trenches of France, the programme took a more sinister turn. In 1924, while the smoke screen trials were still under way, it was noted that '[w]ith reference to various spraying experiments which are being carried out at Porton by the aircraft of Old Sarum, it has now been decided that some form of apparatus should be evolved for spraying mustard gas so as to be available if required.'[3]

Work progressed steadily with a number of issues needing to be resolved. For instance, it was necessary to determine the sizes and densities of droplets that would be required to create specified degrees of contamination and to correlate these with the results achieved under varying dispensing conditions, chiefly the height and speed of the aircraft at release. It was also necessary to compare the results of spraying under pressure, as distinct from by gravity alone, and to

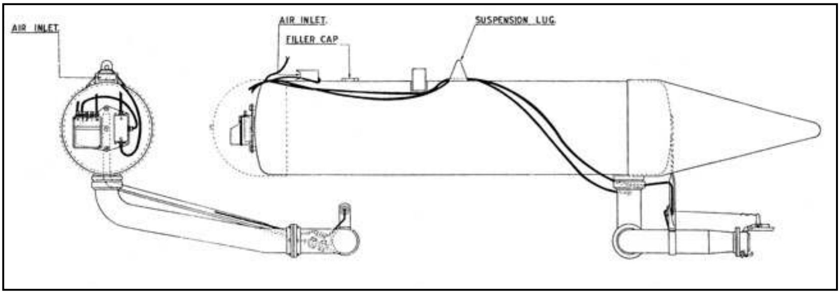
A spray tank, similar to those used by the FAA, fitted to a Bristol Fighter engaged on trials work.

establish the effects of wind on the spray patterns. By the end of 1930, much of this work had been done and the results were published in a classified report which included diagrams of spray patterns and related tabulated data.[4]

Having resolved the basic physical issues (although it would later become apparent that atmospheric temperature and humidity were major factors influencing the effectiveness of a chemical attack) the next stage was to develop a practical means of dispensing the gas and by 1938 this had emerged as the, euphemistically named, Installation, Smoke Curtain, 250 lb – or SCI for short. To be fair, this was not quite as misleading as it sounds, as the device could indeed be used for laying a smoke screen, using the well-established titanium tetrachloride method. Nevertheless, while laying a smoke screen was actually a secondary application, it would seem that, even in the more politically robust 1930s, SCI was deemed to be a more appropriate label than, say, 'PGD' – Poison Gas Dispenser.

By the late 1930s, 250 lb SCIs were being delivered against an initial order for 500 (at a total cost of £7,000), and plans were being drawn up for the production of 500, 1,000 and 2,000 lb versions to be carried by, respectively, Battles and Beauforts, Wellingtons and the projected Stirling and Halifax.

Irrespective of size, the design and operating principles were basically the same; the differences were merely a matter of scale. In essence, the SCI was a lagged, mild steel cylinder. Because it was expected to be mounted under the wings on a Universal Bomb Carrier, it was provided with optional detachable streamlined aluminium front and rear fairings to minimise drag. There was a discharge pipe, sealed with a Bakelite plug. Operation involved either the detonation of a cartridge within the cylinder which created an overpressure, breaking



All SCIs were similar in design, the main difference being in their length. This is a 500 lb model, which was 7 ft 9 ins long, including the nose and tail fairings.

the plug and forcing the liquid out in about 5 seconds (in the case of the 250 lb model) or firing cartridges which both broke the plug and opened an air intake allowing the liquid to be discharged under atmospheric pressure and gravity, which took twice as long.

It is evident that the possibility of large-scale gas warfare was being taken very seriously in the later 1930s. It is not suggested that procurement was actually undertaken in these quantities, but when considering future provisioning under Expansion Scheme F, for instance, the staffs were basing their calculations on the assumption that 'the gas effort would be 25% of (but in addition to) bombing

Hinds of No 50 Sqn fitted with 250 lb SCIs in 1938.

Left, a Lysander of No 208 Sqn fitted with a 250 lb SCI and, right, one of a number of locally produced extension pipes employed during field trials involving a Blenheim – both in Egypt in 1939.

effort'. When the sums had been done on that basis it produced a theoretical requirement for a total of 24,403 SCIs of various sizes, not to mention more than half a million gas bombs.[5]

Using some of the first 250 lb SCIs to be delivered, the first squadron-level field exercises were flown in August 1938. Employing a benign substance, of course, these were intended to familiarise aircrew and armourers with the procedures involved in handling and dispensing corrosive liquids and partly to give troops practical experience of being exposed to attack by air-delivered chemicals.

By 1939 SCIs had been deployed as far afield as Egypt where they were used by the Lysanders of No 208 Sqn as early as March, spraying a harmless liquid over an Army convoy and again in August on ships of the Royal Navy.'[6] Later in the year HQ RAFME began to build on this experience by adapting the SCI for carriage by Blenheims, which proved to be rather less straightforward than had been anticipated. The tank itself was easily accommodated within the bomb bay but this required a major extension of the dispensing pipe. Various modifications were tried in order to solve problems that were encountered with distortions to the theoretical spray patterns, due to non-standard nozzles, and contamination of the airframe, especially the tailwheel.

The upshot of this, and other trials work being conducted in the UK, was a steady proliferation of sub-types of SCI, each of the various weights becoming available as Mks I, II and/or III depending on the type of aircraft for which they were intended, whether the dispensing pipe was of the original design or had a later streamlined

The ultimate design of streamlined discharge pipes, seen here on a Blenheim.

profile and/or a non-drip nozzle, and whether or not it had had a variety of technical modifications incorporated. Large scale production was well underway by early 1940, orders for 5,030 500 lb and 4,462 1,000 lb units having been placed by February.[7]

By 1941 substantial quantities of SCIs were available and in-service trials were being carried out with a view to increasing the uplift. To this end an exercise was mounted at Feltwell on 23 March which involved fitting two 500 lb SCIs in a Blenheim of No 139 Sqn and a pair of 1,000 lb SCIs in a Wellington of No 75 Sqn.

Although no operational use was being made of the SCI, it was now a standard weapon option within the inventory and, as such, when a new basic training syllabus for observers was introduced in

Armourers in full protective clothing manhandling a 1,000 lb SCI towards the bomb bay of a Wellington during a trial carried out at Feltwell in 1941. Note the long extended and articulated discharge pipe.

A Blenheim of No 13 Sqn laying a smoke screen during an Army Co-op Press Day held on Salisbury Plain on 19 March 1942.

June 1941 it allocated four hours to the equipment and its installation, the theory of spraying, the calculations involved to cater for high and low-level dispensing and the effects of the wind.[8] In the event, however, while supplies of poison gas were produced and stockpiled within the UK and the option of using them was retained, both sides forbore to resort to chemical warfare and when the syllabus was revised again in October the SCI had been deleted.

Since gas warfare never happened, the only practical use made of the SCI was for dispensing smoke. Thus, for example, No 516 Sqn specialised in laying smoke screens for Combined Operations training exercises in Scotland. Instances of operational use include Blenheims of No 614 Sqn laying a screen for the Dieppe raid in August 1942, No 88 Sqn's Bostons doing it during Operation STARKEY in September 1943 and again on D-Day in June 1944, and Hurricanes of No 4 Sqn IAF doing the same to cover a landing at Kangaw during the third Arakan offensive in December of that year. Confirmation is lacking, but it seems likely that when Vengeances of No 110 Sqn were deployed to the Gold Coast for an anti-malarial spraying campaign in 1944, they would have used SCIs to do it.

In this general context, there were two also-rans. The first was the Installation, Smoke Curtain, 400 lb. Despite its name, however, this device had nothing to do with smoke; it was intended solely to dispense mustard gas. Later, known as 'Flying Cow', it was released, like a bomb, and while in free flight it ejected a 'rod' of liquid which then broke up into droplets and dispersed as it fell. The second device

Trial installation of an M10 Smoke Tank on a Tempest V.

was the American (Douglas) M10 Smoke Tank. Intended to be fitted under the wings of smoke screen-laying fighter-bombers, it saw some use by Typhoons and Mustangs in exercises during 1944 but it was not used operationally by the RAF.

Notes:

[1] *Daily Mail*, 26 June 2009.

[2] Titanium tetrachloride (FM) is not the only chemical that will produce a 'smoke', an alternative being sulphur-trioxide (FS), but neither of these would be used today; modern smokes are more likely to involve white phosphorous (WP), zinc chloride (HC), diesel fuel or other petroleum-based products, like fog oil (SGF2). The bracketed designations are the recognised short-hand for these chemical agents, drawn from a system originally devised by the British during WW I and since adopted internationally and much extended to include, for example, phosgene (CD), mustard gas (H), Lewisite (L), Sarin (GB) and Tabun (GA).

[3] TNA AIR2/1089. Minute from DDR(Arm) to the Secretary of the Chemical Warfare Committee, 16 December 1924.

[4] *Ibid*. Porton Report No 846 of 13 November 1930 'The Casualty Producing Power Of Mustard Gas When Sprayed From An Aeroplane Directly On To Personnel.'

[5] *Ibid*. Minute from F4 to AMSO dated 15 June 1938.

[6] Conroy, D; *The Best of Luck* (Trafford Publishing, Vancouver, 2003) pp 94 & 89-91.

[7] TNA AVIA 15/51. RDArm6(a) memo of 20 February 1940.

[8] TNA AIR14/16. Basic training syllabus for Air Observer, covered by HQ 25 Gp letter 25G/4/49/Air(6) dated 10 June 1941.

THE MEMORIAL AT NOYERS-BOCAGE

Listening to Dr Alfred Price's excellent analysis of the rocket-firing Typhoons in Normandy in 1944, I had a vague memory of the story behind a memorial placed in the village of Noyers-Bocage in 1994. I have now reminded myself of the detail.

I am indebted to Air Cdre J W Frost CBE DFC DL RAF(Retd) for the following. Surviving Typhoon pilots – especially General Paul Ezanno of the French Air Force and the late Flt Lt Denis Sweeting, who were Squadron and Flight Commanders respectively of No 198 Sqn, based in the beach head area during the battle – determined, with M. Jaques Brehin, the representative of the French Association that remembers the campaign, that a memorial to the Typhoon force should be erected in Normandy. That memorial, dedicated on 8 June 1994, stands in the village of Noyers-Bocage.

In May 1944, the ground attack Typhoon force consisted of twenty squadrons totaling about 450 pilots. During the Battle of Normandy, 151 pilots were killed in action and a further 120 either crash landed or bailed out; 38 of them became prisoners of war.

In the associated Book of Remembrance, the point is made that the losses of 151 Typhoon pilots was proportionately as great as RAF fighter pilot losses in the Battle of Britain. Of the 151 killed, seventy-eight were British and forty-one were Canadian; three were Americans

The Memorial at Noyers-Bocage.

The only surviving example of the Typhoon is now in the RAF Museum at Hendon.

in the RCAF; eight were Australians, six New Zealanders, five Rhodesians and four South Africans; two were Belgians and one each came from India, Ceylon, France and Norway.

The late Air Chief Marshal Sir Harry Broadhurst is on record as saying: ‘I suppose that flying one of these aircraft was the most dangerous task the Air Force has ever asked anyone to do.’

AVM Nigel Baldwin

TONY RICHARDSON – AN OBITUARY

It is with regret and a sense of loss that we record the passing of Tony Richardson. He was a Founder Member of the Society and was, first as a Member of the Publications Sub-Committee and then as Editor, responsible for the production of the Society's Journal from its first appearance in January 1987 until the 17th edition in 1997. He took up this role with the customary energy and enterprise, which were his hallmarks, and helped to lay the foundations for the authoritative and soundly established Journal that the society has today.

Tony Richardson was born in 1924 and joined the Royal Air Force in 1940 at the age of 16. He began flying operationally as a sergeant air gunner in Egypt on the Wellingtons of 108 Squadron, following a stint on instructional duties he transferred to Coastal Command for a tour on Sunderlands with 228 Squadron. Commissioned in 1943 he switched to the Air-Sea Rescue in November 1944 and he flew in the Walruses of Nos 277 and 279 Sqns until the end of the war. He was demobbed in 1946, three weeks before his 22nd birthday.

His civilian career began with the Rank Organisation, followed by sales and marketing for Michelin and Firestone where he became Head of Public Relations. Later he turned freelance and became a consultant for the Spanish Grand Prix. With his wife he had a house in Spain and both there and in the UK he must have done much to sustain sales of Rioja (red — always red. He never touched white wine.) His last job was as Managing Director of Eurolink International Ltd.

Tony would have been an eligible candidate for ‘The Most Unforgettable Character . . .’ With his abiding smile and the cheerful look in his eye he was a heartening person to be around. He brought a ‘can do’ attitude to everything he turned his hand to, and was always honest and up-front with his counsel. We are grateful to him for the yeoman service he gave in helping to set the fledgling RAF Historical Society on its feet.

RAeS AERONAUTICAL HERITAGE AWARDS

In late 2007 the Royal Aeronautical Society (RAeS) launched its Heritage Awards Scheme to commemorate **people, places or things that have made contributions of world-class significance to the art and science of aeronautics**. The Awards are recognised by placing bronze plaques in an appropriate place that has public access.

The scheme works bottom-up. The RAeS will accept nominations from anyone. However there is no central funding for the scheme; so proposers have to secure local funding and or sponsorship for the plaques (currently about £800 per plaque). All nominations are reviewed by the Scrutiny Committee, which comprises a broad cross-section of heritage experts from the Society and other organisations. The scheme was launched initially in the UK, but is now being extended to those other parts of the world where the RAeS has Divisions or Branches.

To date nine awards have been agreed. These include: Sir Arthur Marshall, who among his many achievements made a crucial contribution to the training of RAF pilots before and during the Second World War; the magnificent Shuttleworth Collection of flying historic aircraft and replicas; the Barnwell Brothers, who were the first to fly in Scotland and went on to become important aircraft designers at Bristol and Vickers; and Royal Air Force Leuchars to mark sixty years of maintaining Quick Reaction Alert.

The RAeS is keen to encourage nominations from members of the RAF Historical Society. Wing Commander Colin Cummings has kindly agreed to act as the point of contact within the RAFHS.

For more information and a nomination form see the RAeS website www.aerosociety.com (follow the 'Medals and Awards' button).

The scheme is administered by Mr Sam Phillips at the RAeS headquarters (0207 670 4371 sam.phillips@aerosociety.com) who will answer any queries or provide nomination forms. Air Commodore Bill Tyack (01252 622894 billtyack@btinternet.com) chairs the RAeS Steering Group that oversees the scheme. He is also happy to answer queries.

BOOK REVIEWS

The Relentless Offensive – War and Bomber Command 1939-1945 by Roy Irons. Pen & Sword, 2009. £19.99.

It is something of a metaphor for the content of this book that it contains no illustrations. Instead, it is densely written, passionately argued and makes for demanding – and rewarding – reading. Forty years ago, the classrooms of the RAF Language School rang with the assertion by *émigré* Russian teachers that 'repetition is the mother of learning' and that technique is apparent in the pages of *The Relentless Offensive*. It is none the worse for that, because its arguments are complex and, ultimately, highly convincing.

Roy Irons develops a consistent theme of dereliction in the application of Trenchard's doctrine of the offensive – the doctrine central to the survival of the Royal Air Force in the inter-war years. Those so charged failed to perform adequately in several discrete areas of the equipment and training of Bomber Command. This book identifies key instances in which such failures were allowed to happen as a result of dogmatism, muddled thinking and bureaucratic lethargy. He is broadly even handed in his censure of the Air Staff and of the specialist Armament Departments and the tale that he tells has a resonance even today.

Three main areas of criticism emerge from Roy Irons's researches, along with a number of cognate issues. He is not the first historian or commentator to highlight the weaknesses of defensive armament in Bomber Command's principal aircraft types, right to the end of the Bomber Offensive. He employs a wealth of technical information to demonstrate his case, but he also illustrates the extent to which entrenched belief in the ability of the bomber to 'get through' clouded logical thought and analysis. In passing, it should be noted that he gives Tizard and Ludlow-Hewitt an unexpectedly good press, not least in their recognition that aircraft and crew losses would ultimately cause huge damage to the potential of Bomber Command. Tizard's use of the measure of *bombs on target per aircraft loss* earns his especial approval and is fundamental to his assessment of the effects of inferior defensive armament and of the resulting aircraft losses.

Irons is equally critical of the lethargy and indifference of those charged with the development of effective bombs and, especially, of the failure of staffs to produce an incendiary cluster weapon. His detailed arguments are backed up by the typically colourful and acerbic comment of Sir Arthur Harris! Again, though, this is no mere outpouring of mere opinion on the part of Irons: his case is carefully argued and supported by fact.

The enforced recourse to night bombing that followed early failures by day leads Roy Irons to revisit the vexed question of escort fighter support for the bomber force. Here, he contrasts the effects of ultimate American success and the achievement of air superiority by day, with what he regards as British neglect. Inevitably, he returns to the Tizard formula to contrast bombing accuracies by day and night, the effects of electronic navigation and bombing aids notwithstanding. The measure *bombs on target* is fundamental to his case.

The Relentless Offensive paints a compelling picture of a dysfunctional procurement system that continued on its uncertain path right until the end of WWII. Many would argue that the structures and attitudes that led to such a conclusion remained in place for many decades to follow. His particular bile is reserved for the Armament Departments of the Air Ministry and the Ministry of Aircraft Production, but he is strongly critical of the Air Staff and of the part played, or not played, by its officers.

This is not a light or easy book to read, but its arguments are compelling and relevant even today. Irons argues that dogmatism, muddled thinking and bureaucratic lethargy caused unnecessary human loss in 1939-45 and flew in the face of the very compelling yardstick of *bombs on target per aircraft loss*. As a cautionary tale, *The Relentless Offensive* deserves a place on the bookshelves of many engaged in Defence Procurement today.

AVM Sandy Hunter

3 Group Bomber Command – An Operational Record by Chris Ward and Steve Smith. Pen & Sword, 2008. £25.00

5 Group Bomber Command – An Operational Record by Chris Ward. Pen & Sword, 2007. £19.99.

Each of these hardbacks (the 3 Group book has 320 pages and the other 266) sets out to present an account of Bomber Command’s war as seen through the prism of just one Group’s operational activities. Each book comes in two parts, the second, and larger, part consisting of hard statistical facts: a list of AOCs with dates; a list of stations with dates of occupancy by individual squadrons; VC winners and some basic numbers – sorties flown, broken down by aircraft type, and selected records of the ‘highest % losses’, ‘most raids flown’, ‘greatest tonnage dropped’ variety. Each squadron is then dealt with in a similar fashion – COs, bases, statistical data and ‘pecking order’, in the sense that No 9 Sqn, for instance, is noted (among some fifteen such comparisons) as having flown the 15th highest number of sorties in Bomber Command, the 21st highest number of Lancaster sorties in Bomber Command and the 10th highest number of sorties in 5 Group. All of this number-crunching is rounded off, for each squadron, with a list of every individual aircraft that it took on charge during WW II with a note on its fate/disposal. These numbers are remarkable; No 50 Sqn for example, worked its way through 169 Hampdens, 35 Manchesters and 227 Lancasters.

The first part of each book is a chronological narrative which draws heavily on its own annexed data, in that it records the comings and goings of COs and the movements and re-equipment of units, along with a varying amount of detail on the operations mounted and the losses sustained. The author(s) openly acknowledge that much of the information on individual raids, has been drawn from Middlebrook and Everitt’s *Bomber Command War Diaries* and the bulk of the details of individual aeroplanes will surely have been derived from the publications of Air Britain. Both books feature an extensive bibliography but, oddly enough, neither includes Webster and Frankland’s official history, which is, I think, a rather strange omission.

Since both books are telling essentially the same story, there is a great deal of duplication. Indeed some passages describing, for instance, the 1,000 bomber raids, the attack on Saarlouis in mistake for Saarbrücken, Dresden and so on are reproduced (almost) verbatim in both books. Apart from being rather repetitive, which is almost inevitable in view of the nature of the material, I found relatively little to complain about in the writing of the narrative section of the volume dealing with 5 Group. That said, there are a handful of typos that the publisher really ought to have sorted out, and I don’t think that you can get away with describing the operating principles of OBOE in terms of radar ‘beams’; the key word has to be ‘pulses’. There are, however, some curious inconsistencies; why, for instance, does each OC 617 Sqn get a potted biography (Holden has two full pages) while most other COs are simply named in passing. When it comes to names, the text, in both books, suffers badly from my personal bugbear, the ‘and his crew’ syndrome, which effectively consigns six out of every seven men to anonymity.

I found the 3 Group volume to be less well-written, more given to clichés for instance, than its companion – a consequence perhaps of co-authorship. Furthermore we have, for example, marshall (for marshal – twice); a missing ‘1’ in No 1 Group; the second AOC 3 Gp as Air Cdre Thompson (for Thomson – twice – and he could not have flown with No 14 Sqn in France during WW I, because it was never in France); No 107 Sqn in 3 Group at Leconfield in 1937 (which it wasn’t – I am guessing that this should have been No 102 Sqn at Finningley?); No 88 Sqn at Mildenhall in 1937 (presumably a typo for 38 Sqn) – all of this in the first two pages! These errors aside, I found the 3 Group presentation less satisfactory because it concentrates on the activities of Nos 149, 218 and 115 Sqns as representative of, respectively, a Wellington, Stirling and Lancaster unit. This was a conscious decision on the part of the writers, but it seems to me to have rather defeated the object of presenting a Group-based account.

Are these books good, bad or indifferent? Well, they are good, in that, being largely based on reputable, albeit secondary, sources, it is, I think, safe to assume that the annexed data will be accurate. But there is no really new information, and no attempt at analysis so no significant new conclusions emerge. Rather than, ‘are they any good?’ therefore, a better question might be, ‘what are they for?’. In his Foreword to the 3 Group book, Chris Ward says, ‘When I write a book, I do so as if it were specifically for me.’ Clearly, he likes to compile factual information – dates, numbers, statistics – and he likes to rearrange, collate and present it. These books are an exercise in doing precisely that, and they do it well, making the second part of each a potentially useful, if somewhat esoteric, reference source. But, for the rest, my impression was of an oft-told tale told yet again – twice.

So – should you buy them? Well, if you simply enjoy facts and figures and/or need to have readily available the sort of specialised information tabulated in the mega-annexes, then yes (although most of

it is already available elsewhere). But not if you are looking for a new interpretation or a deeper understanding of the bomber offensive, because you will find that the narratives add little in this respect.
CGJ

2nd Tactical Air Force, Vol 4 by Christopher Shores and Chris Thomas. Classic Publications; 2008. £35.00.

Members will recall that I reviewed the three volumes of this trilogy, very enthusiastically, in Journals 33, 35 and 37. While that completed the operational history, the authors had accumulated a large amount of ancillary information and this has been presented in a fourth volume. This provides: potted histories, including dates of movements and COs, of all of 2TAF's squadrons (while assigned to 2TAF); descriptions of the available weapon options and their use; an essay on dedicated role training; another on the problems caused by dust on beachhead ALGs, and their solution; *Luftwaffe* Orders of Battle on selected dates; and, to ring the changes from the exploits of pilots, two personal reminiscences provided by airmen.

A major portion of the book is devoted to a well-informed discussion on the application of paint schemes, including an attempt to nail down the, seemingly undocumented, rash of unit markings (mostly to do with coloured spinners and/or tail bands on Typhoons) that broke out shortly after the cessation of hostilities.

As described in the 2nd TAF book, many squadrons indulged in non-standard markings in the immediate post-war period. This Spitfire XIV (TZ112) of No 416 Sqn sports a part-chequered tail band, white-painted canopy frame, cowling panels and spinner and a large image of a lady called Yvonne beneath the exhaust stubs.

TZ112's 'Yvonne'.

The format and production quality maintain the excellent standards set by the first three books, so Vol 4 (which, because it extends the series' coherent pagination, covers pages 583-752) is very generously illustrated with extensive use of colour, including more than fifty of Chris Thomas' excellent profiles of individual aeroplanes – mostly Typhoons, Spitfires, Mustangs and Tempests, but including the odd Boston, Auster, Hurricane and even an Fi 156. The photographic content is extensive and includes many examples of wrecked and/or repossessed *Luftwaffe* aeroplanes. Errors? I found a few typos, Acklimngton (*sic*), Pouton (for Poulton) and Melksbroek (for Melsbroek), for instance. On page 583 the reader is referred to Fig 3 on page 589, which doesn't work, and on the same page I have a problem with a statement to the effect that echelon starboard would be the appropriate formation prior to a break into a right hand circuit. But these are mere pinpricks in an otherwise immaculate presentation – and the 242 well-reproduced pictures alone justify the price. As with Vols 1-3, strongly recommended; operational histories just don't come any better than this.
CGJ

Dowding and Churchill – The Dark Side of the Battle of Britain by Jack Dixon. Pen and Sword; 2008. £25.

The author of this book, a 256- page hardback with 58 b/w photos, flew with the RAF at the end of the Second World War. In 1949 he went up to Merton College, Oxford, to read for an Honours degree in Modern Languages, and in 1952 he emigrated to Canada. He served for five years with the RCAF before taking up an appointment as lecturer in French Literature at what became the University of Winnipeg, from where he retired in 1990. Before then his published works had been mainly in his academic field of French Literature. But it soon becomes clear within the first few pages of the present book that the subject does not represent for him a new departure. (It is in fact his second book on this same theme. The first, *The Battle of Britain, Victory and Defeat: The Achievements of Air Chief Marshal Dowding and the Scandal of his Dismissal from Office* was published in 2002 and reviewed in these pages – see Journal 31.) The story of the shabby treatment of Dowding, before, during and after the Battle of Britain has been a *cause célèbre* for the author that must have been smouldering for decades and his sense of outrage and resentment is almost incandescent.

But this is not a journalistic outburst and the author's disciplined academic background is plainly in evidence. The book has been comprehensively researched and there is no source he appears to have overlooked. The references to sources, published and unpublished, are backed by exhaustive footnotes recording *inter alia* the author's interviews and correspondence going back for decades with many of the key players of the period. (The arrangement of the Bibliography though is confusing in that it superimposes categories onto the works listed. Thus, while Robert Wright's book *Dowding and the Battle of Britain* is one of his sources it is not given a separate entry and his name appears only in the section 'Night Fighting' after 'Rawnsley', Wright's co-author of *Night Fighter,* or under 'Biography' as one of the only three entries listed there for Dowding himself. Appendix D to the present book, 'Where would we have been . . . ?' is the concluding chapter taken verbatin from Robert Wright's book, but appears here without attribution.

Unsurprisingly, there is little here that is truly new, though much of it will be new to a large number of readers. It is a damning indictment and one of its great values is that it collates all the segments of the story between one set of covers, and also quotes the views of some eminent people, like Harris and Freeman, not usually associated with it. This is an outright polemic and none of those who set themselves against Dowding come out of it well. Even some of the less culpable catch glancing blows along the way. Do not look here for balance. On the other hand the author would no doubt claim – and with justification – that balance doesn’t come into it since no countervailing evidence has ever been entered into the lists. (Your reviewer concedes that if there is any published rebuttal to the author’s account he has yet to encounter it.)

That points to one criticism that can be made of the book. The author doth protest too much, and to do so can diminish the impact overall. There is no need to labour a case that is already convincing. The facts will speak for themselves. As an example, the lengthy discussion of the application of the Principles of War to the Battle of Britain is unnecessary. On the other hand there are places where the presentation of facts provides one of the great strengths of the book, especially when they are expressed in the considered words of Battle of Britain pilots such as Alan Deere and others who were there.

Al Deere was at one time an RAF boxing champion. He once said, ‘Stuffy knew he could not go for a knock-out. The best he could do was to try to go the distance. The trouble is, he could not know what the distance was.’ Well, Stuffy went the distance, and the rest is history. Sadly though there was a dark side to it and that is amply portrayed in this book.

Gp Capt Ian Madelin

ROYAL AIR FORCE HISTORICAL SOCIETY

The Royal Air Force has been in existence for over 80 years; the study of its history is deepening, and continues to be the subject of published works of consequence. Fresh attention is being given to the strategic assumptions under which military air power was first created and which largely determined policy and operations in both World Wars, the inter-war period, and in the era of Cold War tension. Material dealing with post-war history is now becoming available under the 30-year rule. These studies are important to academic historians and to the present and future members of the RAF.

The RAF Historical Society was formed in 1986 to provide a focus for interest in the history of the RAF. It does so by providing a setting for lectures and seminars in which those interested in the history of the Service have the opportunity to meet those who participated in the evolution and implementation of policy. The Society believes that these events make an important contribution to the permanent record.

The Society normally holds three lectures or seminars a year in London, with occasional events in other parts of the country. Transcripts of lectures and seminars are published in the Journal of the RAF Historical Society, which is distributed free of charge to members. Individual membership is open to all with an interest in RAF history, whether or not they were in the Service. Although the Society has the approval of the Air Force Board, it is entirely self-financing.

Membership of the Society costs £18 per annum and further details may be obtained from the Membership Secretary, Dr Jack Dunham, Silverhill House, Coombe, Wotton-under-Edge, Gloucestershire. GLI2 7ND. (Tel 01453-843362)

THE TWO AIR FORCES AWARD

In 1996 the Royal Air Force Historical Society established, in collaboration with its American sister organisation, the Air Force Historical Foundation, the *Two Air Forces Award*, which was to be presented annually on each side of the Atlantic in recognition of outstanding academic work by a serving officer or airman. The RAF winners have been:

1996	Sqn Ldr P C Emmett PhD MSc BSc CEng MIEE
1997	Wg Cdr M P Brzezicki MPhil MIL
1998	Wg Cdr P J Daybell MBE MA BA
1999	Sqn Ldr S P Harpum MSc BSc MILT
2000	Sqn Ldr A W Riches MA
2001	Sqn Ldr C H Goss MA
2002	Sqn Ldr S I Richards BSc
2003	Wg Cdr T M Webster MB BS MRCGP MRAeS
2004	Sqn Ldr S Gardner MA MPhil
2005	Wg Cdr S D Ellard MSc BSc CEng MRAeS MBCS
2007	Wg Cdr H Smyth DFC
2008	Wg Cdr B J Hunt BSc MSc MPhil

THE AIR LEAGUE GOLD MEDAL

On 11 February 1998 the Air League presented the Royal Air Force Historical Society with a Gold Medal in recognition of the Society's achievements in recording aspects of the evolution of British air power and thus realising one of the aims of the League. The Executive Committee decided that the medal should be awarded periodically to a nominal holder (it actually resides at the Royal Air Force Club, where it is on display) who was to be an individual who had made a particularly significant contribution to the conduct of the Society's affairs. Holders to date have been:

Air Marshal Sir Frederick Sowrey KCB CBE AFC
Air Commodore H A Probert MBE MA

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