

Disaster in Harbour: The Loss of HMS *Vanguard*

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Lying peacefully at anchor in the sheltered waters of Scapa Flow, the battleship HMS *Vanguard* suddenly blew-up on a quiet summer night in July 1917, leaving but a handful of survivors. Accident or sabotage? While the trail of evidence uncovered by the Court of Inquiry furnished no definitive answer, the conclusion that it was an accidental cordite explosion makes the most sense and has not been seriously challenged to this day. Her remains are still in the Flow, but it is unlikely that even a full archaeological survey could determine anything other than that it was indeed an explosion in one of the amidships magazines which sank the ship. The records of the Court of Inquiry shed light on the internal routines of the Royal Navy's capital ships: even in such basic (and vital) procedures as the taking of magazine temperatures, each ship handled matters in its own way. Of equal interest are the many improvements which resulted from the loss of *Vanguard*.

Surprisingly little has been written about the sudden, catastrophic sinking of this powerful man-of-war - it is not even mentioned in the official History. 'Typical is the simple "destroyed by internal explosion at Scapa 9 July '17" in Oscar Parkes' *British Battleships*.² Other later references provide little more: even R. A. Burt in his detailed *British Battleships of World War One* only summarises the evidence.³ In his book about the loss of the armoured cruiser HMS *Natal*, Cecil Hampshire discusses the *Vanguard* tragedy but the description is marred by his attempt to use very circumstantial evidence to find a saboteur.⁴ The paper before you is an in-depth look at *Vanguard's* destruction and the lessons learned from it, with emphasis placed on the technical tidbits that are of value when trying to learn about the day-to-day habits of the wartime Royal Navy.

***Vanguard's* Career⁵**

On 22 April 1909, the Royal Navy's seventh dreadnought battleship slid down the ways at Vickers in Barrow-on-Furness. Along with her sister ships, *St. Vincent* and *Collingwood*, *Vanguard* was a slightly improved version of HMS *Dreadnought*, the most noteworthy alteration being the adoption of a new twelve-inch gun, lengthened to fifty calibres, instead of the forty-five-calibre weapon that had hitherto been used (see table 1).

Vanguard's career in the RN was similar to most of her contemporaries. Commissioned in March 1910, almost all of her time was spent in northern waters as part of the RN's concentration against the German naval threat. Perhaps the most notable peacetime activity was participation in the test firings against the old HMS *Empress of India*, which was of some significance to the gunnery community.⁶ When war broke out in August 1914,

Vanguard was part of the 1st Battle Squadron, and with the rest of what would become the Grand Fleet moved north on 29 July. Home was Scapa Flow in the Orkney Islands - the "Northern Base," as it was often called. Popular misconception has the battleships lying quietly at anchor for most of the war, but the reality was frequent sea time, in all weathers: gunnery shoots, tactical exercises and sweeps of the North Sea. Upon their return to Scapa, the paramount task was coaling, back-breaking labour for all hands. The Orkneys are treeless, windswept and sparsely settled, and initially the opportunities for off-duty entertainment were limited at best. Realising that "occupation and interest are the surest antidotes to discontent and unrest," the Fleet went ahead and built its own sporting facilities and much effort was devoted to keeping morale high.⁷ The storeship *Gourka* even provided theatre facilities.

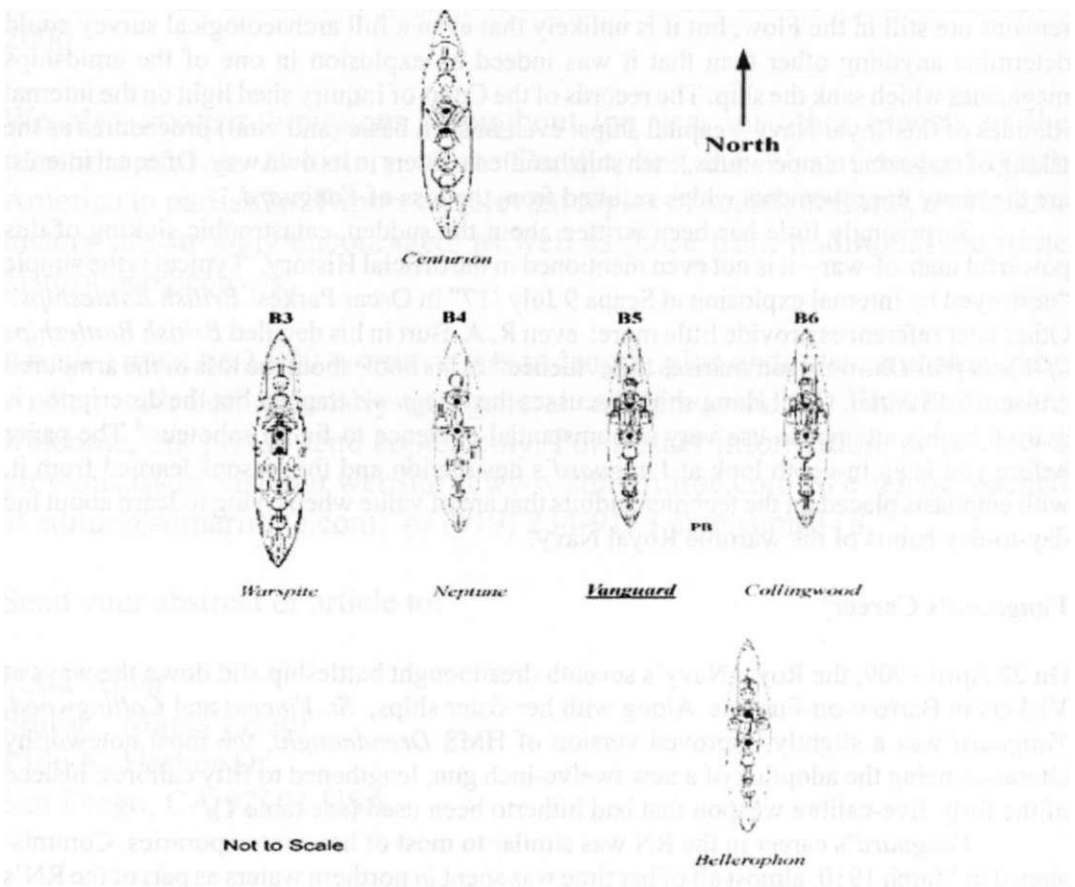


Figure F. The relative positions of the witness' ships. Evidence from the ships' logs indicate that *Warspite*, *Neptune*, *Vanguard* and *Collingwood* were in berths B3 to B6. The position of *Centurion* and *Bellerophon* is more approximate. All ships were roughly facing north, with their sterns towards Flotta. The picket boat was some 120 yards off *Vanguard's* starboard quarter (indicated by "P B" on the drawing).

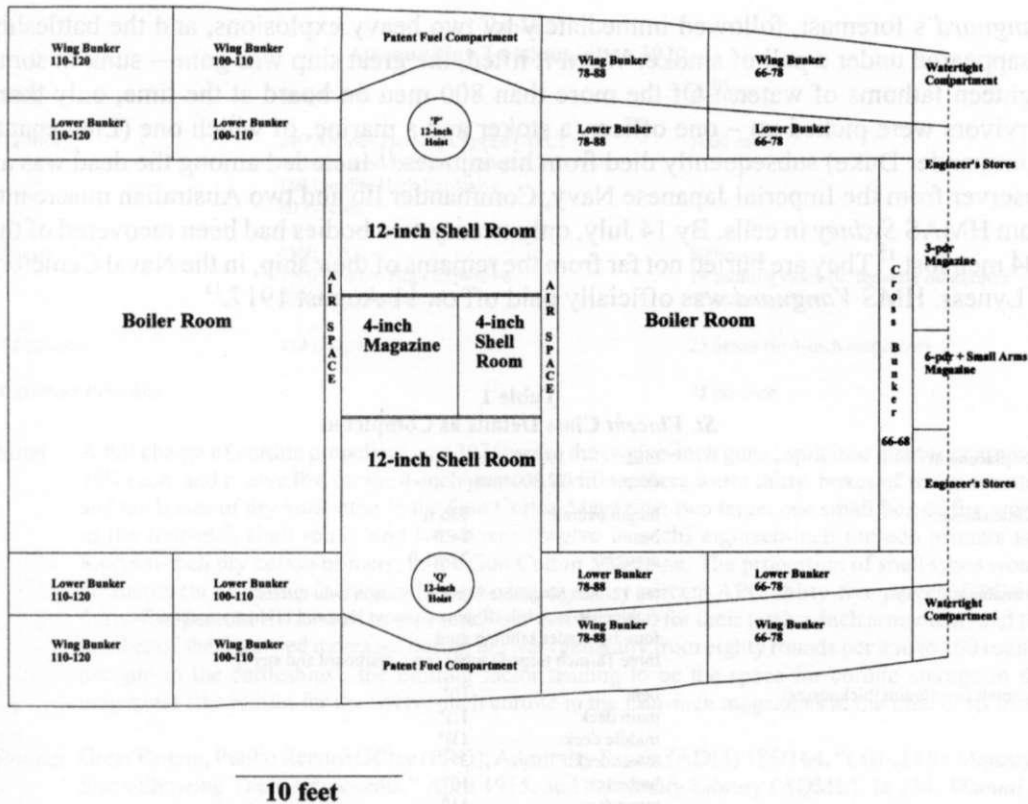


Figure 2: Sketch of a section of *Vanguard* at the centre of "Q" turret, looking forward (based on sheet "HMS *Vanguard* - Forward Sections as Fitted, April 1910," National Maritime Museum, Greenwich).

The first and only time that *Vanguard's* guns spoke in anger was at the Battle of Jutland on 31 May 1916 when, as part of the 4th Battle Squadron, she stood sixteen in the British battleline. No German capital ship came within reach, but *Vanguard* did open fire on the disabled light cruiser SMS *Wiesbaden*, hitting with her fourth salvo. At other times, the ship fired on German destroyers with both main and secondary batteries. In total, fifty-seven rounds of twelve-inch and ten rounds of four-inch were fired (see table 2). Enemy shells landed nearby, but *Vanguard* was never hit and suffered no damage or casualties.⁸

***Vanguard's* Death**

All was peaceful in the Fleet anchorage in Scapa Flow on the evening of Monday, 9 July 1917. It was overcast, with a gentle wind out of the northeast; both air and sea temperatures were in the low fifties Fahrenheit.⁹ Earlier that day, *Vanguard* had been anchored on the north shore of the Flow and had practised "abandon ship" in the morning. After a quiet afternoon, she weighed anchor at 5pm and exercised paravanes on the way to her berth near Flotta, anchoring at 6:30. *Vanguard* and her neighbours carried out their usual evening routines until about 11:20pm when, without warning, flames became visible abaft

Vanguard's foremast, followed immediately by two heavy explosions, and the battleship disappeared under a pall of smoke. When it lifted, the great ship was gone - sunk in some eighteen fathoms of water.¹⁰ Of the more than 800 men on board at the time, only three survivors were picked up - one officer, a stoker and a marine, of which one (Lieutenant-Commander Duke) subsequently died from his injuries." Included among the dead was an observer from the Imperial Japanese Navy, Commander Ito and two Australian miscreants from HMAS *Sydney* in cells. By 14 July, only twenty-two bodies had been recovered of the 804 men lost.¹² They are buried not far from the remains of their ship, in the Naval Cemetery at Lyness. HMS *Vanguard* was officially paid off on 11 August 1917.¹³

Table 1
St. Vincent Class Details as Completed

Displacement	load:	19,700 tons
	deep:	22,800 tons
Dimensions	length overall:	536 ft
	beam:	84 ft
	draught:	27-31 ft
Armament	ten 12-inch 50 calibre Mark XI guns in twin turrets	
	eighteen 4-inch Mk III guns on turret tops and in superstructure	
	four 3-pounder saluting guns	
	three 18-inch torpedo tubes (port, starboard and stern)	
Armour (maximum thicknesses)	belt:	10"
	main deck:	1½"
	middle deck:	1½"
	lower deck:	3"
	barbettes:	10"
	turret face:	11"
	turret roof:	3"
Machinery	18 boilers (235 psi), mixed firing (2,700 tons coal, 850 tons oil)	
	Parsons turbines	
	24,500 (designed) SHP	
	21 knots maximum	
	radius 4,690 nm at 10 knots	
Complement	823 (<i>St Vincent</i> , 1915)	
Cost (including guns)	<i>St Vincent</i> :	£1,721,970
	<i>Collingwood</i> :	£1,680,888
	<i>Vanguard</i> :	£1,606,030
Dates	<i>St Vincent</i> :	ordered 26 October 1907
		laid down 30 December 1907 (Portsmouth)
		launched 10 September 1908
		completed May 1909
		disposal list 1921
	<i>Collingwood</i> :	ordered 26 October 1907
		laid down 3 February 1908 (Devonport)
		launched 7 November 1908
		completed April 1910
		disposal list 1922
	<i>Vanguard</i> :	ordered 6 February 1908
		laid down 2 April 1908 (Barrow-in-Furness)
		launched 22 April 1909
		completed 1 March 1910
		blown up in Scapa Flow 9 July 1917

Source: R. A. Burt, *British Battleships of World War One* (London, 1986), 75-88.

Table 2
Ammunition Loadout, circa 1910¹

Gun	Projectiles	Cordite
12-inch	240 Armour Piercing Capped (APC) 400 Common Pointed Capped (CPC) 160 Lyddite High Explosive 80 Practice	1600 cases
4-inch	1500CPC 1500 Lyddite High Explosive 200 (later O) shrapnel	500 cases 14 saluting cases (in separate magazine) 47 cases practice
12-pounder	250 shrapnel	25 boxes (in 4-inch magazine)
6-pounder Hotchkiss	-	73 practice

Notes: A full charge of cordite propellant was 307 lbs. for the twelve-inch guns, split into quarter charges of 76³/₄ each, and twelve lbs. for the 4-inch guns. In addition, there were: thirty boxes of wet gun cotton and ten boxes of dry guncotton in the Gun Cotton Magazine; two large, one small box of fire works in the four-inch shell room; and two boxes (twelve in each) eighteen-inch torpedo primers and fourteen-inch dry cotton primers, in the Gun Cotton Magazine. The proportion of shell types would be altered (in 1915, the *St. Vincent's* were carrying thirty percent APC, thirty-five percent CPC and thirty-five percent HE as well as six rounds per gun shrapnel for their twelve-inch armament) and the number of shells carried increased during the war (generally from eighty rounds per gun to 100 rounds per gun in the battleships), the limiting factor tending to be the space for cordite storage in the magazines (the reason for the twelve-inch cordite in the four-inch magazines at the time of its loss).

Source: Great Britain, Public Record Office (PRO), Admiralty Papers (ADM) 186/164, "List of His Majesty's Ships Showing Their Armaments," April 1915; and Admiralty Library (ADML), Ja 254, *Manual of Gunnery for His Majesty's Fleet* (3 vols., London, 1915), III, 107.

The Fatal Explosion

The immediate worry was that *Vanguard* had fallen victim to an enemy submarine - at 11:30pm, the order was issued to "take up stations for protecting anchorage from Submarine attack according to plan," and ten minutes later the Admiral Commanding the Orkneys and Shetlands was asked if the hydrophones protecting the harbour had heard anything mysterious. The response was negative, and the instruments were reported as "working well."¹⁴ The defensive measures were cancelled at 07:25 the next morning. But as early as 00:35, the Admiralty was informed that *Vanguard* had been blown up, "apparently from an internal explosion."¹⁵

Eyewitness accounts were roughly consistent and have been summarised in appendix 1. There are a few discrepancies that can be attributed to different viewing angles, but the common thread is that there was a bright flash or flame, followed by two heavy explosions and then a third smaller explosion, or multiple blasts going off in quick succession. Most observers felt that the seat of the initial explosion and flame was somewhere between the foremast and the two turrets amidships ("P" and "Q"). The obvious conclusion was that at least one of the amidships magazines had blown up, followed by others. This was supported by the single significant piece of physical evidence: a metal plate five or six feet long and three to four feet wide that landed on the deck of HMS *Bellerophon*. It contained a number of openings for electric wiring and other purposes, sufficient for it to be tentatively identified

as coming from the fore-and-aft bulkhead in Number 2 Hydraulic Room on the starboard side of the ship, immediately abaft " A " barrette.¹⁶ The way the plate was buckled, and the fact that it showed no indications of having been exposed to heat, was consistent with the explosion not having occurred in " A " magazine.¹⁷

Satisfied that the loss was due to an explosion in a magazine, the Court of Enquiry - which consisted of Rear-Admiral W. C. M. Nicholson of the 1st Battle Squadron; Captain V. H. G. Bernard of HMS *Neptune*; and Captain James C. Ley of HMS *Canada* - considered that there were four potential causes: cordite as supplied becoming unstable; an existing instability in the cordite being worsened by its treatment onboard the ships of the Fleet, in particular since the outbreak of war; unrealised dangers which may arise in ships and which would bring about the ignition of cordite; or the act of an enemy agent or "dangerous lunatic."¹⁸

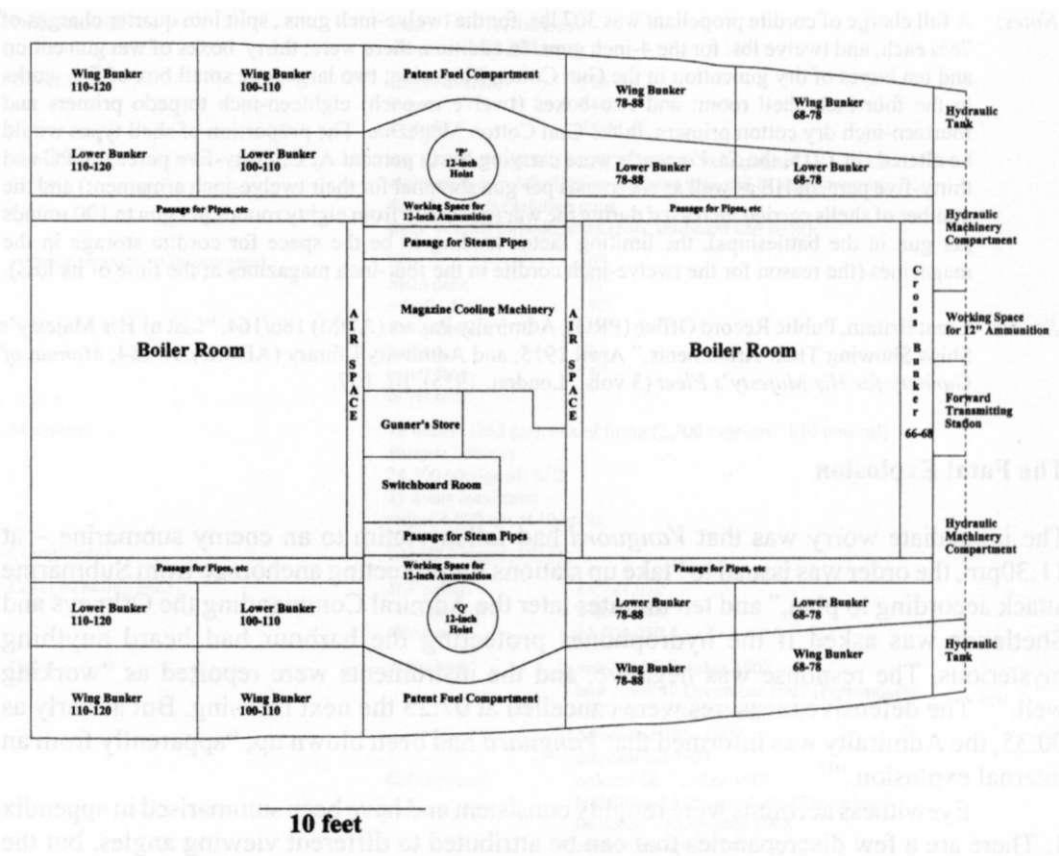


Figure 3: Sketch of the Middle Deck amidships layout of *Vanguard* (based on sheet "St. Vincent - Plan of Middle Deck as Fitted," National Maritime Museum, Greenwich). In 1918, the two four-inch, ready use magazines appear to have been converted to four-inch ammunition hoists (based on a note drawing dated July 1918), but in July 1917 they held a few four-inch shell (no cordite). The plan runs from aft to forward (left to right).

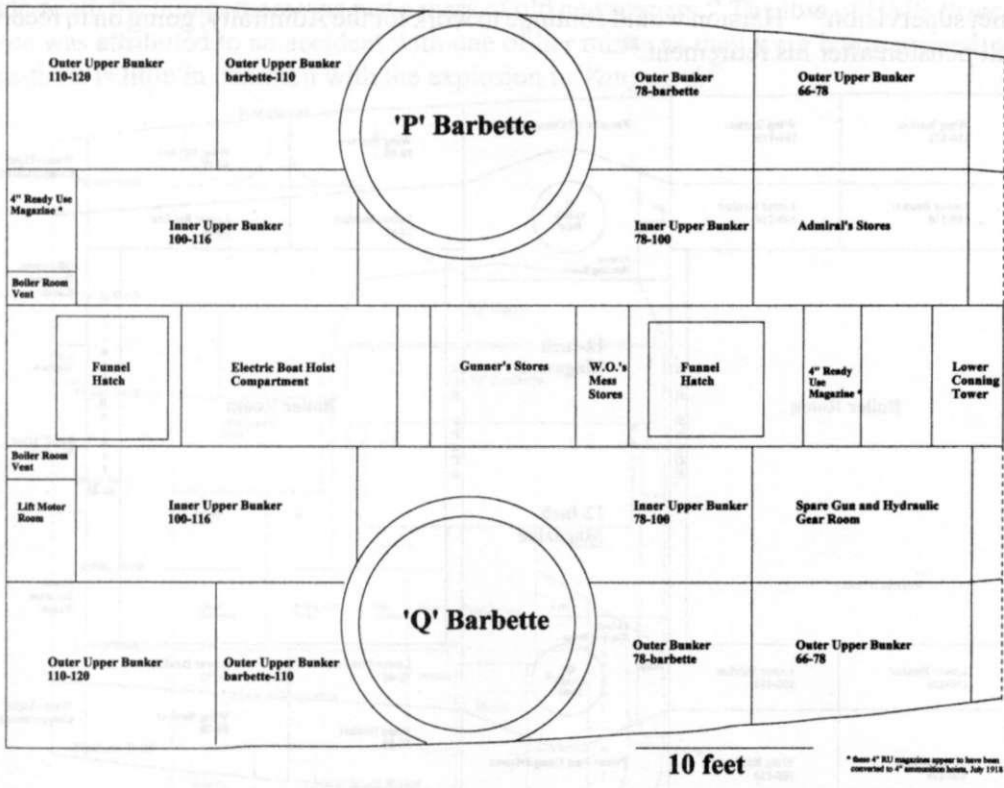
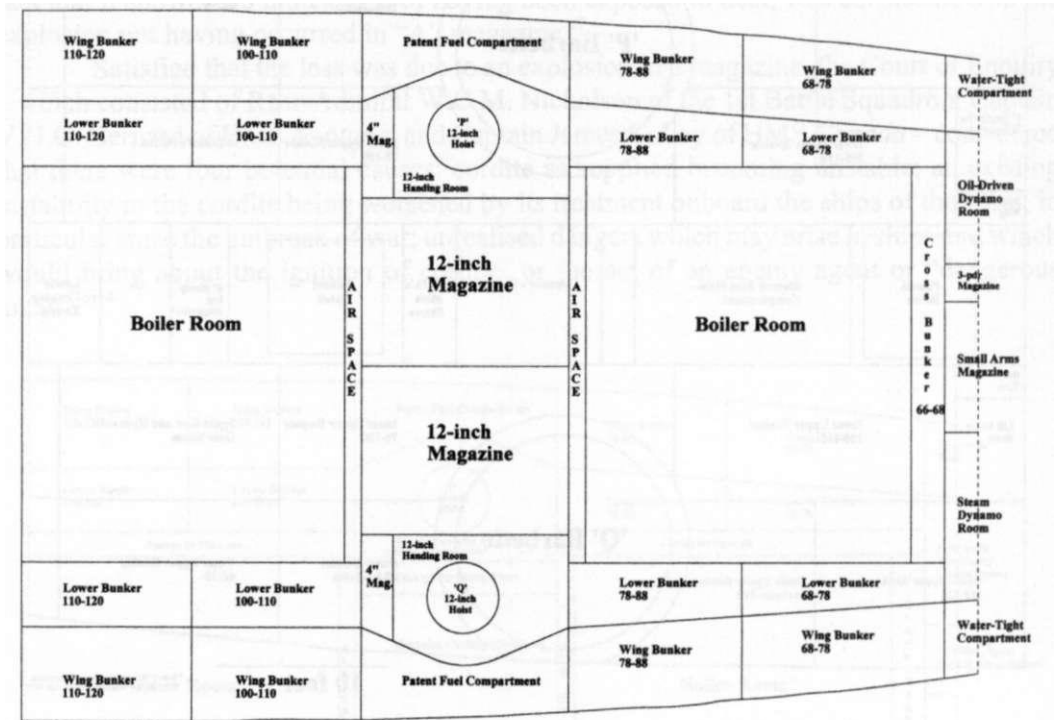


Figure 4: Sketch of the Lower Deck amidships layout of *Vanguard* (based on sheet "*St. Vincent - Plan of Lower Deck as Fitted*," National Maritime Museum, Greenwich). The plan runs from aft to forward (left to right).

Skulduggery?

Today's popular culture assumes perfidy behind every misfortune, and modern conspiracy theorists would find *Vanguard's* loss a fertile source. It was wartime - and we now know of German agents who were using simple devices to start fires on ships leaving New York.¹⁹ There were Irish Republican sympathisers in some of the naval ports who could be assumed to have an interest in the destruction of British warships. Best of all, there was one man, an Ordnance Fitter, who had only just left *Vanguard* and had been working in the armoured cruiser *HMS Natal* just before it blew up at the end of 1915. Chargeman John (Jack) A. Harston had been adjusting gear in "A" turret and sleeping in the Armourer's Mess since the previous Thursday, along with his assistant Robert Williams, the pair leaving *Vanguard* only a few hours before the disaster.²⁰ Harston denied all knowledge of anything that could have caused the explosion, and the Court decided there was nothing in either man's testimony to cause suspicion. Noteworthy, however, was Rear-Admiral Nicholson's message to Admiral Beatty: "the ignorance displayed by Harston, however, concerning general details of magazines was remarkable." He went on to recommend that a detective should be sent for further investigation, although the men should be allowed to continue their work under

"quiet supervision."²¹ Harston would continue to work for the Admiralty, going on to receive a full pension after his retirement.²²



10 feet

Figure 5: Sketch of the Platform Deck amidships layout of *Vanguard* (based on sheet "St. Vincent - Plan of Platforms as Fitted," National Maritime Museum, Greenwich). The three-pounder magazine was used to hold three-inch High Angle ammunition, and the four-inch magazines held cordite for the twelve-inch armament. The plan runs from aft to forward (left to right).

The fact remains that no factual evidence has ever been uncovered to support the sabotage theory. Including *Vanguard*, the RN lost five ships to internal explosions during the First World War: the pre-dreadnought HMS *Bulwark* (launched 1899) on 26 November 1914; the minelayer *Princess Irene* (taken over from the Canadian Pacific Railway) on 27 May 1915; the armoured cruiser HMS *Natal* (launched 1905) on 30 December 1915; HMS *Vanguard*; and the monitor HMS *Glatton* (launched 1914) on 16 September 1918.²³ *Glatton* was the only new purpose-built warship so lost. She had originally been ordered as the coast defence battleship *Bjorgvin* for the Royal Norwegian Navy, and subsequently was taken over by the RN for use in shore bombardment. In this instance, the evidence is solidly in favour of an accident: the six-inch magazine was immediately adjacent to the boiler room, and it had been the practice to pile ash and clinker flush against the separating bulkhead. When her sister, HMS *Gorgon*, was surveyed, it had been found that the wood lining inside the magazine was blackened, and in place of the cork lagging that was supposed to be

underneath the lining, there was just a mess of old newspapers.²⁴ The loss of HMS *Princess Irene* was attributed to an accident with one of her mines as they were being primed, and thus there is little in common with the explosion in *Vanguard*?⁵

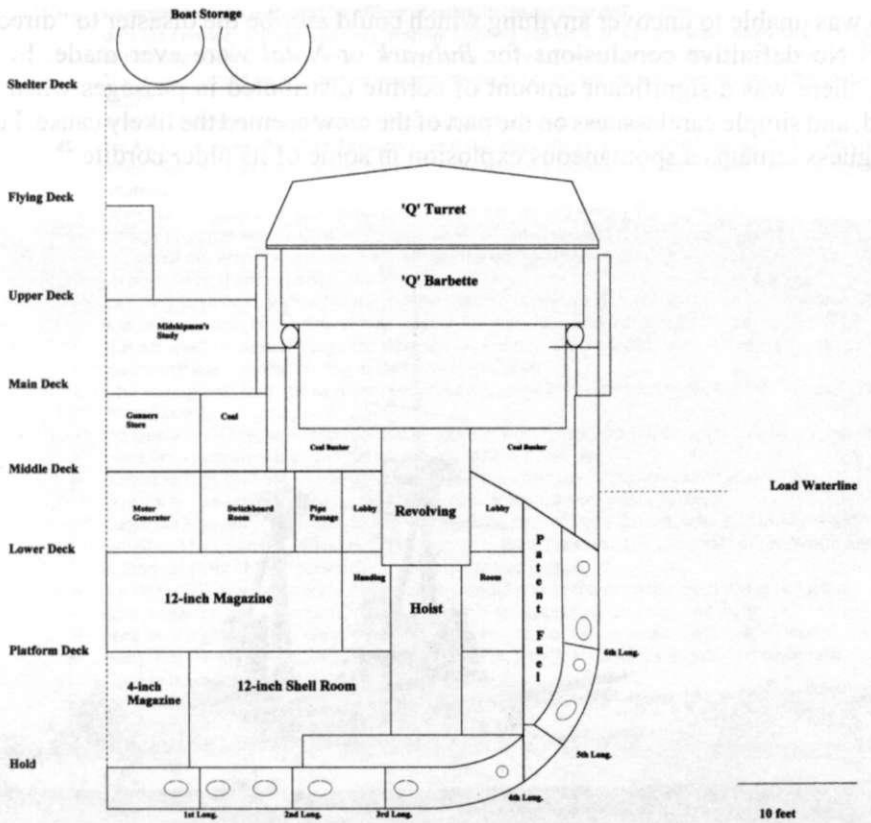


Figure 6: Sketch of the Hold amidships layout of *Vanguard* (based on sheet "St. Vincent - Plan of Hold as Fitted," National Maritime Museum, Greenwich). In this case, the four-inch magazines held cordite for the 4-inch armament. The plan runs from aft to forward (left to right).

Of the three other ships, *Vanguard* was at best obsolescent and the others certainly obsolete. Although less than ten years-old, *Vanguard* was much inferior to the newer, faster battleships: oil-fired, twenty-five knots designed speed; fifteen-inch guns; and improved armour and anti-torpedo protection. It should also be remembered that several examples of naval high technology (albeit of sometimes less than stellar combat value) had recently joined the Fleet: the battlecruisers *Renown* and *Repulse* (in January 1917 and September 1916, respectively); the light battlecruisers *Courageous* and *Glorious*, with four fifteen-inch guns and almost thirty-two knots speed (January 1917); HMS *Furious* (one eighteen-inch gun aft and a flight deck forward), which arrived in the Grand Fleet only a fortnight before *Vanguard's* demise; and the *Revenge-class* battleship *Resolution* December 1916.²⁶ When it is remembered that there was no distinction in the level of security for these newer ships compared to the original classes of dreadnought, it is obvious that any agent capable of

triggering a magazine explosion would have chosen a much more valuable target. A German prayer book, a photograph of a woman of "most fascinating appearance" and a letter in German were found, but nothing developed from these trivial items. The Naval Intelligence Division was unable to uncover anything which could ascribe the disaster to "direct enemy action."²⁷ No definitive conclusions for *Bulwark* or *Natal* were ever made. In the first instance, there was a significant amount of cordite distributed in passages when the ship exploded, and simple carelessness on the part of the crew seemed the likely cause. For *Natal*, the best guess remains a spontaneous explosion in some of its older cordite.²⁸

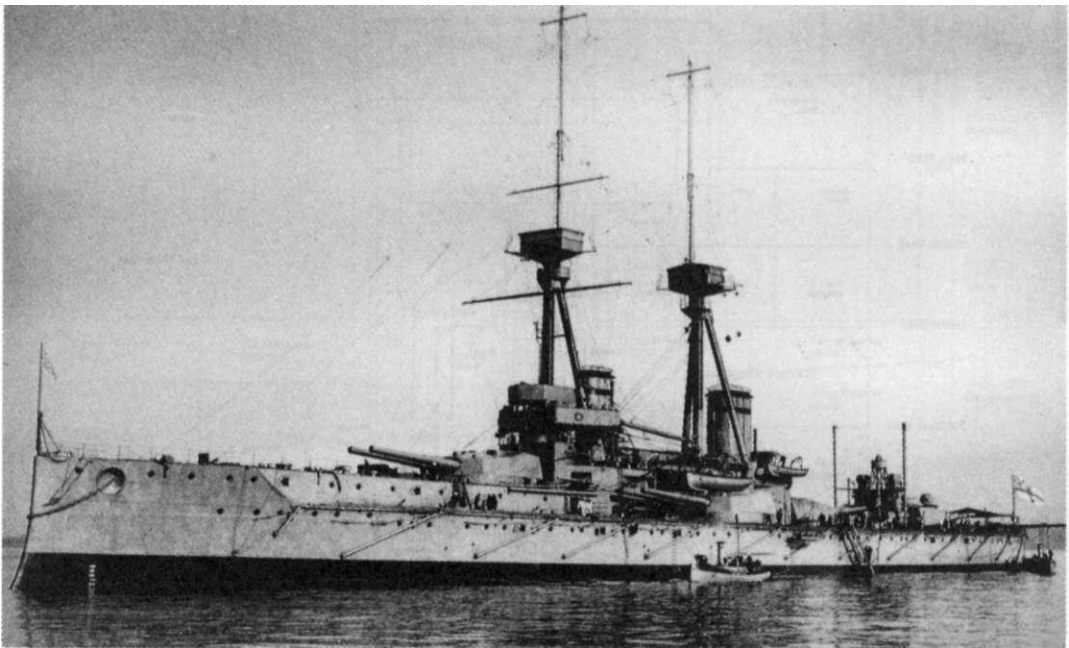


Figure 7: HMS Vanguard, 1910.

Source: National Maritime Museum, Greenwich, negative N754.

To date, no one has ever claimed responsibility for the sinking of *Vanguard* (or the others), and no evidence has turned up in British or foreign archives which could be used to support such a theory. Although there have been rumours of an outside saboteur, no serious case has ever been made to substantiate one. The principal of "Occam's Razor" must never be forgotten: the simplest solution to a mystery is usually the correct one. And in the case of *Vanguard's* loss, that means that the cordite explosion was accidental.

Nevertheless, some flaws in magazine security were uncovered by the Court of Inquiry - and there was wide variation between ships as to who had access to ammunition spaces and who could get keys, as shown in table 3. In some ships, it was possible to get into the magazines via the hoists and/or handing rooms, and not all the padlocks were sufficiently strong. Also, up until 1915 all magazines and other ammunition spaces used the same type of padlock, the keys for which were interchangeable.²⁹

Table 3
Magazine Security Procedures

Ship	Magazine Security
Vanguard	<ul style="list-style-type: none"> - magazines always inspected by officer or rating in charge after drill or firing - only the Gunnery Officer, Gunnery Warrant Officers and Gunner's Mates were authorised to obtain the keys to the magazines, the list of names being posted on the keyboard for checking by the keyboard sentry. However, it would appear that the magazine sweepers could get the keys themselves in the course of their duties. - at times other than Action Stations, the drawing of keys was logged. - for Action Stations, the Chief Gunnery issued the magazine keys to selected ratings, and he received them when "Secure" was sounded and reported to the Gunnery Officer and Commander when all keys were returned - other than Captain's Rounds, magazines were never opened simply for inspection. - Officer of Turret <i>not</i> responsible for cleanliness of the associated magazine. - Officer of the Watch was responsible for visiting one gunhouse and working chamber on every watch (or make-and-mend afternoons). - men may have been allowed to sleep in the handing rooms, working chambers and shell rooms, but there was only one man (the sweeper) who slept in the gunhouse, and that was in 'X' turret.
Collingwood	<ul style="list-style-type: none"> - Gunner was to visit each magazine three times each day, although this was not done if the magazine cooling machinery was running. No log of these visits was kept. - keys were gotten from the keyboard under the keyboard sentry's supervision, but the Gunnery Officer was not informed.
Si Vincent	<ul style="list-style-type: none"> - the Gunnery Officer would inspect each magazine weekly, and the Captain periodically, no log being kept. - magazine sweepers allowed to get the magazine keys themselves.
Monarch	<ul style="list-style-type: none"> - magazine keys kept on keyboard, which was locked (that key in the possession of the Corporal of the Watch), but no sentry placed on the keyboard, it being in a very public place. - magazine keys not to be issued to anyone under the rank of Petty Officer, who was to have been verbally authorised by Gunnery Officer or Chief Gunner to draw the keys. The Corporals of the Watch knew each authorised Petty Officer personally. Issue of keys was logged. - the Petty Officer who drew the magazine key would stay in the magazine until it was re-locked. - each magazine had a Warrant Officer responsible for inspecting the magazine daily. - once each night, the duty Gunner's Mate would ensure that all magazine hatches were locked.
Centurion	<ul style="list-style-type: none"> - other than for Action Stations and Divisional Drills, the Chief Gunner was required permission from the Captain before opening a magazine - for cleaning, a Gunner's Mate would be allowed to open a magazine, and would stay in the magazine while the cleaning party was working there - there was no system of rounds at night or during the day with special reference to the magazines.
Resolution	<ul style="list-style-type: none"> - only Officers, the Chief Gunner and Gunner's Mates were allowed to draw magazine keys, except for "Quarters Clean Guns," when the Petty Officers of magazines were allowed access. - the officers were required to obtain the keys in person, and this access was logged - Petty Officers were <i>not</i> required to remain in magazines while they were being cleaned. - Officers of Turrets (or their Second Officers) were required to visit their magazines twice daily at odd hours, this being logged. - nightly, the Officer of the Watch would visit one turret or the vicinity of a magazine once.
Emperor of India	<ul style="list-style-type: none"> - magazine keys kept under charge of the Sentry. - only Officers and specific ratings allowed to draw keys, which were signed for. - person drawing a key was responsible for the magazine until it was relocked. - special "Magazine Rounds" had been in force since the start of the War: each magazine was inspected daily by the Chief Gunner, who reported to the Gunnery Officer. - exterior of magazines inspected by Leading Hand of magazine daily between 4pm and 7pm, this being logged in the "Rounds Book." - one Gunner would inspect the exterior of each magazine nightly, reporting to Officer of the Watch and logging same. - the Magazine Rounds Book was inspected by the Gunnery Officer daily, and the Captain each Sunday.

Notes: "Sweepers" were men employed for cleaning the magazines. In January 1916 orders were issued that magazine sweepers were *not* to be employed unsupervised. Some of the dust inside the magazines had been found to contain cordite and/or power dust and was very inflammable, and it was ordered that no-one was to enter the magazines with boots having nails or iron tips.

Source: PRO ADM 137/3680; PRO ADM 137/293, "Grand Fleet Gunnery and Torpedo Orders," Orders 116 and 121, 13 and 20 January 1916.

Another security loophole was in the ventilation system leading to the magazines. In HMS *Collingwood*, vegetable peelings had found their way into "P" and "Q" magazines, and men had been smoking near the supply for "X" and "Y" magazines. There were wire mesh gratings in the trunks, but not small enough to prevent cigarette ends from passing through. Indeed, HMS *Bellerophon* reported finding a half-filled tobacco pipe inside the ventilation supply trunk, *inside* the magazine! In *Vanguard*, the magazine air supply came straight from the upper deck, and although there were manholes for cleaning the ventilation trunks, they do not seem to have been often opened. There had even been instances of "considerable quantities" of coal dust getting into magazines during coaling, even though the ventilation was supposed to be cut off and the inlets covered.³⁰

Problems with "quality control" and security when the cordite was manufactured and shipped were discovered. Orders had been issued on 18 July to inspect all cordite cases. HMS *Bellerophon* discovered two cases of twelve-inch cordite (manufactured in 1908) that had slips of paper inserted between the tear-off discs and the igniter. Worse still, a box of matches was found between two quarter charges of cordite in HMS *Thunderer*?

The new science of Wireless Telegraphy (W/T) was even called into question. Commander James Somerville, ultimately an Admiral of the Fleet, reported that the chance of sparks being produced in the magazines from W/T transmissions was almost nil. Moreover, the last transmission from *Vanguard* had been made at 9:54 pm. It should not be thought, however, that the RN was heedless of the danger of explosives on board. Indeed, appendix 4 is a sample of the precautions in force long before the *Vanguard* disaster.

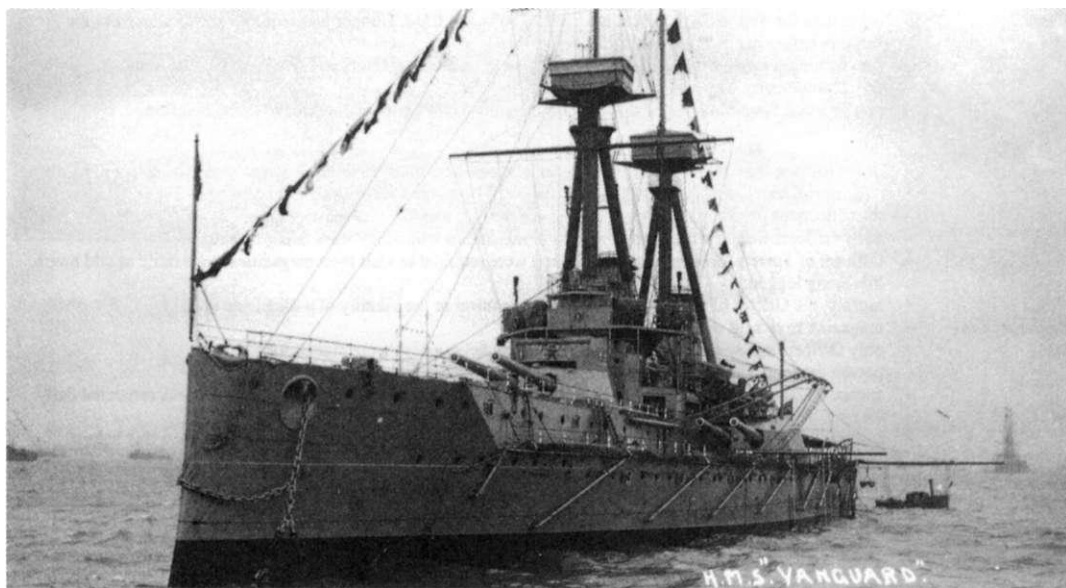


Figure 8: Port bow, 1911. Note the rangefinder on "A" turret - a blast screen would later be fitted immediately behind it. Barely visible is a circular crest on the bridge front, which is enclosed and glassed-in, with an open compass platform above. The vertical objects on either side of the bridge wings are the semaphores.

Source: National Maritime Museum, Greenwich, negative N755.

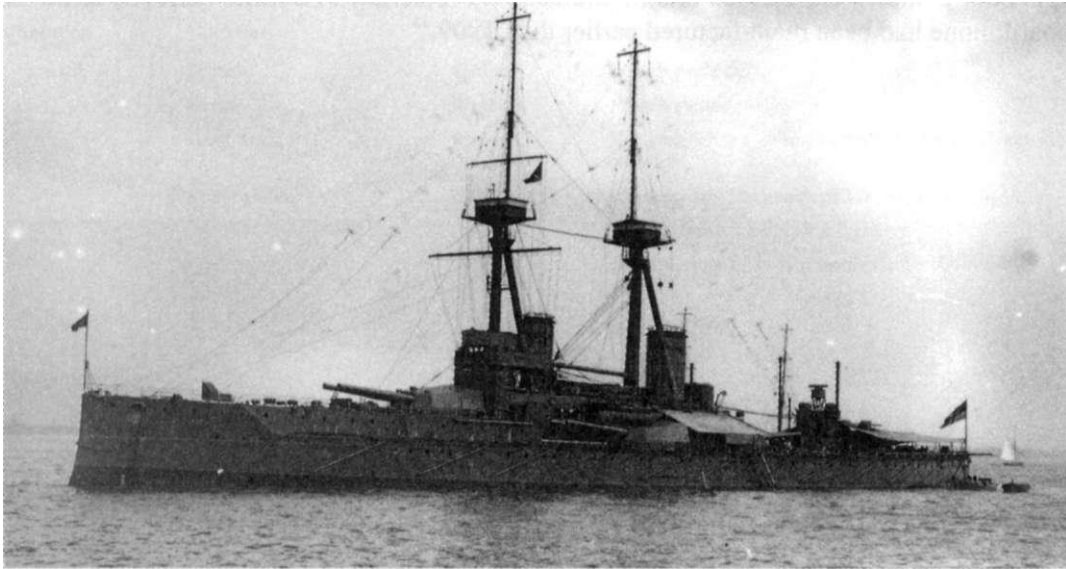


Figure 9: *Vanguard* in 1912. The simplistic fire control arrangements are very obvious - the canvas screens in the tops mask the probable location of small rangefinders, although there is a small one visible on the after superstructure, abaft "X" turret. The object visible on the forecastle near the fourth scuttle (not present in photo 2) is a canvas cover to a hatchway.

Source: National Maritime Museum, negative N752.

Cordite Quality

With enemy action discounted there remained two slightly different causes of the cordite explosion to be considered: either it detonated spontaneously or something within the ship caused it to go off. The most worrying case was the older cordite that had degenerated with time. Cordite had been used as a propellant by the Royal Navy from the end of the nineteenth century. It was a mix of gun cotton (shreds of raw cotton soaked in a solution of nitric and sulphuric acids), nitroglycerine and petroleum jelly (vaseline), with acetone used as a solvent. The mixture was pressed out into cords (hence the name) and then bundled together and packaged in a silk covering. Over time, sulphuric acid would be liberated (from the sulphate groups attached to the cellulose molecules), which would attack the cellulose and generate heat, further accelerating the process.³² If this was too fast or went on for too long, the cordite could burst into flame. This decomposition would be hastened if the cordite was exposed to high temperatures.

Vanguard had last embarked a complete load of cordite in December 1916 after a refit in Rosyth. Subsequently, after having expended charges in various practice firings, the ship received roughly fifty cases in February 1917 and a further seventy in June. Table 4 lists the probable contents of the various magazines as of July. All the cordite on board was

believed to be of "A" or "B" grade, and none was listed as "first-use" or "fire-first." appendix 2 shows the various lots (manufacturers' batches) of cordite believed to be on board; none had been manufactured earlier than 1909.³³

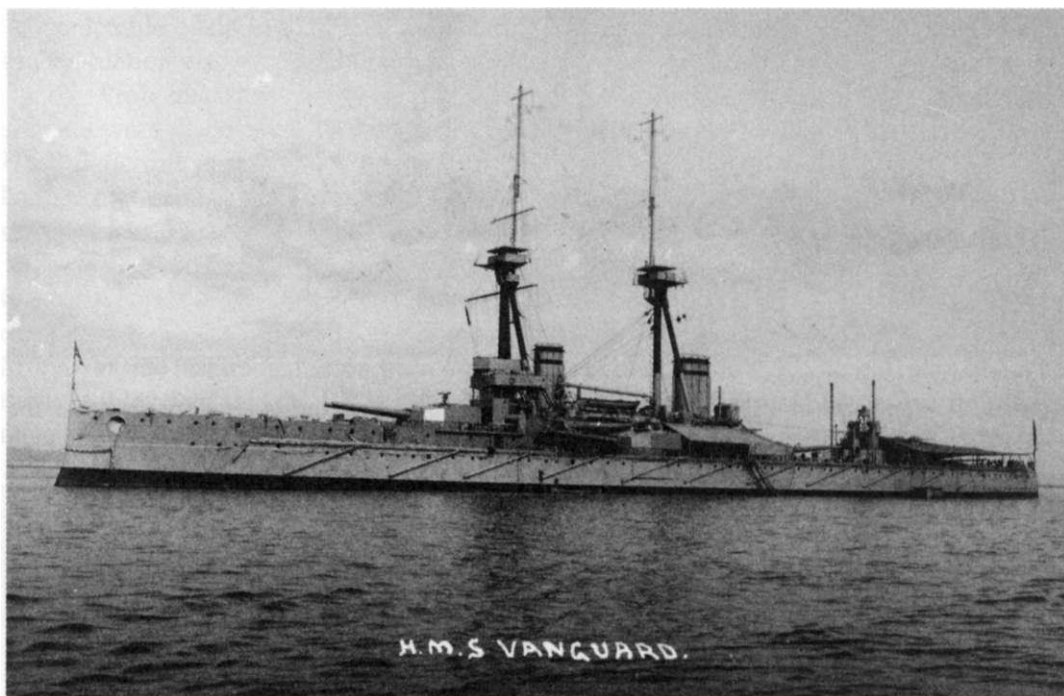


Figure 10: A fine picture of *Vanguard* at anchor. The rangefinder on "A" turret suggests that this was taken in 1911. A round crest appears on the bows of all the ships' boats, as well as the bridge front. When looked at under magnification, it appears as if there are letters (undoubtedly HMS *Vanguard*) written on the "kisbee ring" on the bridge wing.

Source National Maritime Museum, Greenwich, negative N20140.

Table 4
Probable Cordite Stowage in *Vanguard*, July 1917

Location	Magazine	Deck	Contents
Forward	12-inch	Platform	12-inch cordite
	4-inch	Platform	12-inch cordite
	Small Arms	Platform	"full complement" of small arms and aiming rifle ammunition
	3-pdr Saluting	Hold	approximately 180 rounds of 3-inch High Angle
	6-pdr and Small Arms	Hold	1 partly-used box of 6-pdr sub-calibre
	4-inch Ready Use	Middle	no cordite, but 20 4-inch Common and 60 4-inch lyd-dite
Amidships	12-inch	Platform	12-inch cordite
	4-inch	Platform	12-inch cordite
	4-inch	Hold	4-inch
	4-inch Ready Use (Port and Starboard)	Middle	about 11 4-inch shell and no cordite in each
'X' Turret	12-inch	Platform	12-inch cordite
	4-inch	Platform	16 cases of 12-inch cordite as well as 30 cases of 4-inch
"V" Turret	12-inch	Platform	12-inch cordite
	4-inch	Platform	12-inch cordite
Each 4-inch Gun		Boat Deck	six rounds Common shell and 1 box of cordite (stowed in a 1" steel box) at each gun

Source: PRO, ADM 137/3680, Minutes of the Court of Enquiry, various testimonies.

There were no smoke shells (the fuses of which were considered too sensitive to allow the shell to be stored below the upper deck) on board. Note that the regulations forbade stowing black powder and cordite charges in the same magazine.³⁴

In April 1917, the Admiralty had ordered the withdrawal of some lots of cordite. There was no real concern about its stability, but it was considered opportune to upgrade the quality in the Grand Fleet with the much increased stocks that had been manufactured with more modern processes (such as the increase to 2½-hours nitration of the cotton, improved cleanliness of the cotton, etc.), which were believed to have significantly improved stability. *Vanguard* may have had as many as 249 cases of this soon to be withdrawn cordite onboard. In theory, the spontaneous ignition of a single charge should *not* have led to the destruction of the ship; the cases in the magazines were stowed with the lids in a "weakened" state so that they would give way before the cordite exploded. In addition, the cases were flame resistant and the magazines fitted with venting arrangements sufficient to prevent an explosion.³⁵ The flames seen before the first explosion in *Vanguard* undoubtedly passed through these venting arrangements, but they were obviously insufficient to deal with a fire involving large quantities of cordite. The "flash trials" in HMS *Vengeance* would confirm that as long as the lids of the cases were in the weakened position, "spontaneous ignition of the contents of one cordite case in the magazine will not necessarily blow up the magazine."³⁶ The lids of *Vanguard's* cordite cylinders were "always" set to the "stowage" (i.e., weakened) position when struck below.

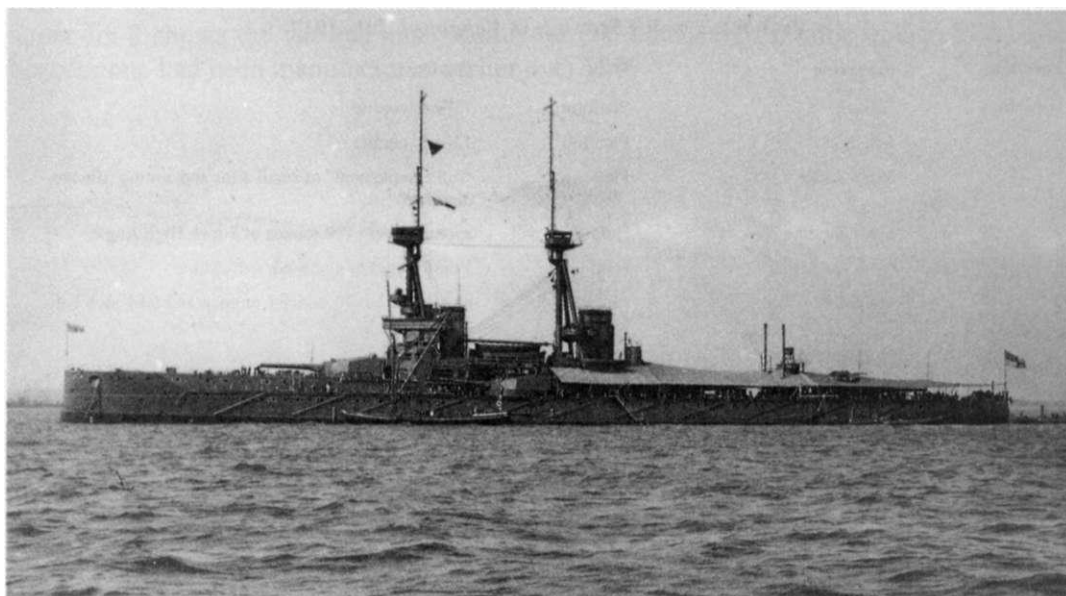


Figure IF. She has been slightly altered: the four-inch guns on the superstructure which were originally open are now in casemates; the bridge is slightly more elaborate than in earlier photos, now being cut away immediately above the conning tower and not having an enclosed structure, the searchlights have been raised and there is a new searchlight platform on the forward leg of the foremast. There are several pairs of searchlights clustered around the after funnel and mainmast, while those formerly mounted on the platform between "X" and "Y" turrets are gone. The 4-inch guns are still mounted on "P," "Q" and "Y" turrets (the awning over "X" makes it impossible to see if any are mounted there).

Source: National Maritime Museum, Greenwich, negative N753.

Magazine Temperatures

If the cordite did not explode "spontaneously," there was a risk if it became overheated while stored in the magazines. In RN ships, machinery was installed to cool the magazines, temperatures were to be taken daily, and thermographs placed in the hottest magazines.³⁷ One of the major findings of the *Vanguard* Inquiry is that there was no consistent procedure in all ships; table 5 shows the variety in routine among several ships. In *Vanguard*, all cordite magazines were taken every morning via the temperature tubes (small metal tubes down which a thermometer was dropped), and every Monday the thermograph chart was inspected by the Gunnery Officer. Shell, rooms and ready use magazines had their temperatures recorded weekly, and perhaps (the Gunnery Officer was unsure) were checked daily. If the temperature in a magazine reached 67°F, then the cooling machinery was started. Generally, "A," "P" and "Q" magazines remained between 65°F and 67°F at Scapa Flow during the summer, while "Y" and especially "X" magazines required cooling. It was "X" magazine that was affected by having steam up in the main engines.

Although disparate procedures were followed, each battleship was organized in such a way that *overall* increases in magazine temperatures would be discovered. Every ship had at least a general knowledge of which parts of each magazine might be hotter than the rest, but the regular monitoring of such "hot pockets" could not be considered especially rigorous. There was forced-air ventilation into the magazines, the ducts being led overtop the various ammunition bays. But post- *Vanguard* tests in HMS *Queen Elizabeth* and HMS *Lion* showed that certain bays could have a temperature higher than the rest of the magazine, even with the cooling machinery running, which would never be detected by the existing system of temperature tubes. Tests were conducted in other classes of ship, and no serious temperature variation was found.³⁸

Table 5
Magazine Temperature Routines in Certain Ships of the Grand Fleet

Ship (Class)	Temperature-Taking Routine	Magazine Temperature Trends
<i>Collingwood</i>	temperatures were taken at 7am, noon and 8:30 pm not running, and every watch when the cooler was running temperatures taken via the temperature tubes when coolers running, otherwise magazines opened up the same procedures were followed for all magazines there was a log of magazine temperatures kept thermographs in "X" and "Y" magazines, the charts being renewed weekly	"A" group of magazines only needed cooling in hot weather, both at sea and in hot weather (67°F being the temperature sought) - the cooling equipment always started when the temperature rose above 68°F "P" and "Q" magazines needed cooling at sea, and in harbour in warm weather the Chief Gunner reported that the 4" magazine beneath "P" and "Q" magazines had reached 81°F once because of a reserve feedwater tank, the cooling machinery being started immediately this was discovered "X" magazine always had the highest temperature, and almost always needed the cooler: it was seldom kept below 70°F when at sea or when steam was up in 'C' boiler room 'Y' magazine could be kept to about 70°F, and the cooler was started under conditions similar to the two amidships magazines it probably took 4 hours or so from lighting the boilers until the temperatures started to rise - the Gunnery Officer was always informed when these boilers were lit

St Vincent
(*St Vincent* class)

temperatures taken at least three times daily by one of the mates of the Chief Stoker and logged

temperatures also to be taken by one of the Stokers Mates when certain boilers were alight

it was a Chief Stoker's Mate's responsibility to take the temperatures, and they would only be shown to the Chief Stoker himself if there was something "abnormal"

log of magazine temperatures studied weekly by Gunnery Officer

there were also thermographs placed in the warmest places in 'X' and 'Y' magazines (the two hottest)

'A' magazine kept to 70°F, occasionally the cooler would be started when the hydraulic pump and/or dynamo were started (the state of steam in the boiler rooms had no effect on 'A' magazine)

'P' and 'Q' magazines were affected by the lighting up of boilers, and required that the cooler be run - the Chief Stoker starting the cooler when the temperature reached 68°F, and it would be run until the temperature dropped to 65°F

in winter, the temperature would be allowed to drop as low as 40°F, but in fact the log showed they never dropped below 50°F

'X' magazine was affected by 'C' boiler room and needed cooling when under weigh or even when at anchor in the summer months

'Y' magazine was affected by the engine room and one of the hydraulic rooms and needed frequent cooling, but it did not get as warm as 'X'

Monarch
(*Orion* Class)

temperatures taken thrice daily by the Gunnery Office Writer (3-badge Able Seaman) and logged, being inspected daily by the Gunnery Officer

the Stoker in charge of the cooling machinery would take the temperatures via tube every hour, and recorded in the Engineer's Office - if the temperature rose above 65°F, the cooling machinery for that magazine would be started

thermograph records from 'Q' and 'X' inspected by Gunnery Officer weekly

'Q' and 'X' magazines the two hottest (all magazines could be cooled correctly)

Centurion
(*King George V* Class)

taken at 8am, 11:30 am and about 6pm by an Able Seaman (Seaman Gunner) of the Gunner's Party, the temperatures being logged and inspected weekly by the Gunnery Officer

temperatures would be taken more frequently if the Gunnery Officer suspected that the temperatures might rise

the Gunnery Officer was informed if there was any indication that the cooling machinery needed to be started (65°F being the threshold) - the GO being the one who decided to start cooling

'Q' magazine was particularly susceptible to getting hot

Resolution
{**Revenge** Class)

taken at "Quarters Clean Guns" each morning by the Petty Officer in charge of the magazine by thermometers in the magazine, not via temperature tubes

cooling machinery would be stopped at different temperatures, depending on the magazine, but generally between 56°F and 63°F

if cooling machinery was running, the Engineering Department would take the temperatures every 3 hours until it had become low enough to stop cooling

cooling would be started if the temperature rose above 70°F

the temperature tubes would only be used when the cooling machinery was running

'X' magazine the hottest, and impossible to keep the temperature below 70°F when at sea, with the doors to 'X' space closed (the usual situation when manoeuvring)

thermographs in the 6-inch and 'X' magazines

Emperor of India
(**Iron Duke** Class)

taken morning and evening via temperature tubes

'A' and 'B' magazines usually 10°-15° higher than outside temperature, so that in winter they could fall as low as 50°F

thermographs in all magazines, the chart being examined each morning

Chief Gunner responsible for the magazine temperatures, they being taken by one of his party

'Q' and 'X' magazines the warmest, and difficult to get cooler than 60°F

cooling started if a temperature was greater than 70°F, or if there was more than a 10° difference between any magazine ("because of Director Firing")

Gunnery Officer would order cooling to be started

cooling stopped if temperature falls to 66°F, although this depended on the difference between magazines

Source: See table 4.

Heating In Adjacent Compartments

As can be seen from the sketches of the *St. Vincent-dass* internal layout, numerous coal bunkers and machinery spaces surrounded the magazines. *Vanguard* had steam up earlier in the day for the return to berth B.5: boilers 2, 3, 4, 5 and 6 in "A" boiler room and 1, 2, 3, 4, 5, and 6 in "B" boiler room for her passage from the North Shore. After securing, two boilers in "A" and the six same boilers in "B" were kept lightly banked, while boilers 4, 5 and 6 in "A" supplied steam for auxiliary machinery. "C" stokehold had not been used. Two bunkers on each side had been used while on passage. The cross-bunker between "A" boiler room and the forward magazines had not been used on 9 July, and it was rarely employed, being considered an "action bunker." If a fire had broken out there, it was likely to have been discovered because smoke would probably have found its way into the accessway used by the stokers. It is interesting that *Vanguard's* sister ship, *Collingwood*, had a fire in this cross-bunker before the start of the war because of hot ash in "A" boiler room being placed against the bulkhead. The coal in the bunker caught fire. It was extinguished, but not before the lower part of the bulkhead (at station 66) in the Blank and Saluting and Small Arms magazines had gotten hot. There was no insulation ("lagging") between the cross-bunker and the magazines in the vicinity. Supposedly *Vanguard's* stokers were "always careful" not to pile ash against the stokehold bulkheads, instead damping down the ash near the furnaces. In *HMS Collingwood*, there were orders forbidding the piling of ashes against the bulkheads of bunkers.

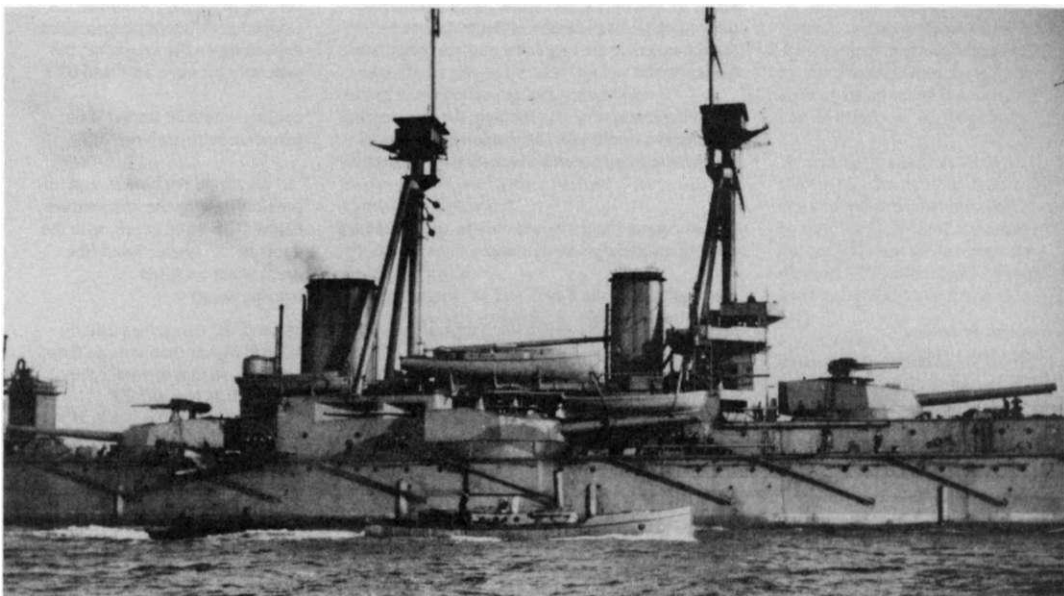


Figure 12: A view of the starboard side, amidships ("A" turret being to the right of the photo), taken shortly after completion. The foretop is noticeably smaller than in the later photographs. At this early date, pairs of four-inch guns were mounted on all turrets. It was in this part of the ship that the fatal explosion occurred.

Source: National Maritime Museum, negative N751.

There were procedures in place to monitor temperatures in the coal bunkers. In *Vanguard*, they were taken once every watch, when boilers were alight, twice a week otherwise. In *Collingwood*, bunker temperatures were also taken every four hours while steaming and every twenty-four hours when not under steam. As in the magazines, the temperatures were taken via temperature tubes, which were thought to be an accurate representation of the state of the entire bunker. Nevertheless, bunker fires were common. There had been one in *Vanguard* a few years before, in the starboard reserve bunker, between stations 140 and 147, probably caused by spontaneous combustion of damp coal bags.

The patent fuel spaces, adjacent to certain magazines, were another potential hazard.³⁹ In *Vanguard*, those on either side of "P" and "Q" magazines held shovels and empty coal bags, while those near "X" magazine were empty. At the time of the loss, these bags were believed to be dry, as *Vanguard* had not coaled in damp weather "for a considerable time." When the manholes to the patent fuel spaces were closed, there was no ventilation at all to them. If the same routines were followed in *Vanguard* as in *Collingwood*, the doors to these spaces would be opened every day.

Another minor fire risk involved the Engineer's Stores on the Hold Deck, located underneath the Dynamo Rooms. There were tanks into which oil from the floors of the Dynamo Rooms drained, but at least in *Vanguard* these rooms only contained firebricks.

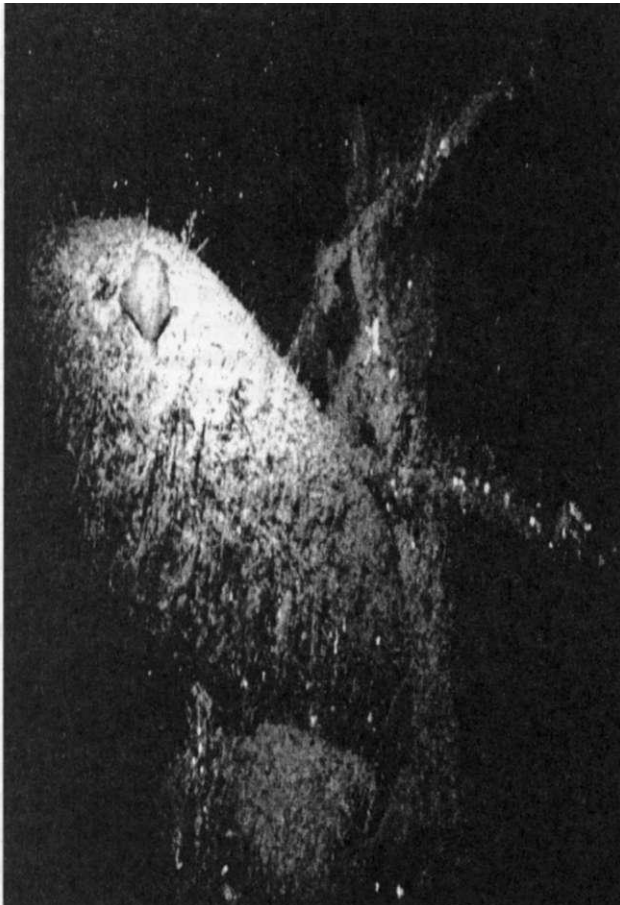


Figure 13: One of *Vanguard's* twelve-inch shells sitting amid the wreckage.

Source: © William Schleihauf, 1987 and 1999.

Conclusions of the Court of Enquiry

Convened hurriedly, with the urgent need to discover any major flaws in the Royal Navy's cordite stocks or magazine arrangements, and with very little solid evidence to go on, the Court of Inquiry was unable to determine any definite cause to the explosion in *Vanguard*. It was only able to conclude that the explosion may have been due to the ignition of cordite from an "avoidable cause," or the deterioration of perhaps unstable cordite.⁴⁰ The Court was "impressed by the good organisation and thoroughness which obtained on board that ship," and could not attribute blame to any one person.⁴¹ This was sensible and entailed no finger-pointing at scapegoats. With that, the members of the Court returned to their wartime duties.

No new information has been uncovered in the years since *Vanguard's* sinking, and the strongest statement that can be made for any potential cause is "not proven." The most unlikely reason remains sabotage. The two main contenders are spontaneous detonation of the cordite, or the cordite having caught fire from heating in an adjacent compartment. When it is remembered that none of *Vanguard's* cordite was more than eight years-old, the strongest possibility for the fatal explosion was a fire in a bunker or patent fuel compartment that went undetected long enough for cordite on the other side of the bulkhead to reach a critical temperature.

Lessons Learned

The Court of Inquiry did make thirteen recommendations, as well as recognizing that there was a serious risk of spontaneous combustion in the coal bags stored in the patent fuel spaces. The recommendations were:

1. The procedure for the taking of magazine temperatures needed to be standardised for all ships, and that the Gunner of the ship (under the direction of the Gunnery Officer) should take these temperatures and actually inspect each magazine two or three times each day.
2. Whenever the cooling machinery was running, temperatures should be taken by the temperature tubes more frequently. These tubes needed to be made smaller, and the openings fitted with lock and key.
3. Attention needed to be paid to temperature hot pockets, which might be at any level in the magazine.
4. All magazines in all ships should be supplied with thermographs.
5. Alternative openings to ventilation supply trunks below deck should be securely closed, and the trunks should be examined and cleaned periodically, the inspection plates being secured.
6. The openings of ventilation exhaust trunks should be better protected against the introduction of foreign material.
7. No oil whatsoever should be used on the floors of the magazine.
8. The lids to the cordite cases should be better secured, so that there was no risk of them coming adrift when set to the "stowage" position.
9. Arrangements should be made so that a "considerable" rise in temperature in any compartment adjoining a magazine or shell room should be discovered within two hours of it taking place.
10. When ammunitioning, every cordite case should be opened and examined, and that there should be stricter precautions in place in the Ordnance Store Depots, ammunition ships, and while in transit.
11. Efficient locks and doors to ammunition spaces (including the submerged torpedo flats) should be used.
12. Officers and men should understand the rationale behind the regular routine of "Rounds."
13. Although in the case of *Vanguard* there was no possibility of an "infernal machine" in the Canteen Stores having caused the loss (these spaces being well-removed from the magazines), a policy should be

instituted that Canteen Stores should not be stored in proximity to magazines.⁴²

In addition, a number of measures were introduced (some before the explosion) to improve magazine safety in British warships. It had already been approved in April 1917 to use clean "carded sliver" cotton and cracked mineral jelly, plus the minimum 2.5 hours nitration process in the manufacture of cordite - and as mentioned above, as new stocks of this improved cordite became available, some 6000 tons of cordite was withdrawn from the Fleet in April, May and June of that year.⁴³ Most categories of "Restricted Cordite" (see appendix 3) were removed from ammunition ships. Improved Naval Cordite Regulations were issued, including discontinuing the issue of "1st Use" and "Fire First" cordite and the practice of grading cordite; destroying all re-worked cordite reaching the age of five years; banning the re-issuance to the Fleet of suspicious cordite after testing; withdrawing any cordite made with less than 2.5 hours nitration at the age of eight years, and 2.5-nitration cordite after twelve years; and using special labels to identify any cordite which had been subjected to abnormal storage conditions. In addition, a system of inspectors and examiners was instituted in April 1917 for cordite, guncotton, and cotton factories, as well as bleaching mills, spinning mills and packing centres, and instructions were promulgated that any cordite which had been issued to the Auxiliary Patrol was not to be re-issued to the Fleet proper.⁴⁴

A large number of improvements to the shipboard ammunition stowage arrangements were also made. Revised regulations (CB 759) were issued in March 1918. Improved ventilation arrangements were mandated, including measures to prevent "deleterious matter" from passing through the ventilation trunks. Insulation was required around magazines in new construction, and improvements in lagging were mandated in existing ships. Consideration was given to increasing the space between magazine bulkheads and cordite cases in new construction. Similarly, studies were made of cooling and improved ventilation in compartments near magazines. Regulations were instituted to control stowage in compartments adjacent to magazines. There was reconsideration of the provision of "distant-reading" thermometers in magazines. Torpedo primers were no longer allowed to be stored on bulkheads adjacent to magazines. Revised instructions required alterations to existing ships in regard to electric cables running through magazines.⁴⁵ Better stowage, including flooding arrangements for high-angle and sub-calibre ammunition, were instituted, and explosives of "uncertain stability" had to be stowed separately. As ships were refitted, drenching arrangements for the magazines were installed. Existing types of cordite cases were subjected to trial and improved cases considered. Special footwear for use in magazines was introduced. HM Ships *Agincourt*, *Indomitable* and *Inflexible* had their unweakened cordite cases removed. The supply of magazine thermometers and thermographs was increased. More frequent and better regulated temperature-taking procedures were ordered, as was the regular inspection of magazines and adjacent compartments. Certain explosives were to be disembarked before ships went into drydock. Provision was made for a magazine log for a permanent record of inspections, temperatures and the issuance of keys, and an improved type of magazine lock was introduced. Orders were issued for the locking and securing of all compartments containing explosives, their approaches and adjacent compartments, and instructions were revised regarding responsibility for magazines. Closer supervision of men employed in magazines was specified, and rules as to who had access to magazines laid down. More stringent regulation of unauthorised persons in regard to access

to compartments containing explosives was introduced, as were regulations permitting the search of civilian workmen employed in magazines or their vicinity. Packages containing explosives were to be sealed prior to issue, and their inspection upon receipt approved. Locking arrangements were modified on all valves on ventilating, cooling systems, and temperature tubes. Searching and sealing of air spaces and unused watertight compartments contiguous to magazines were ordered. Provision was made for a separate magazine key board. And an overhaul of compartments prior to the embarkation of explosives was newly required.⁴⁶

It would take time for all these measures to be introduced. By 1919, all magazines were supplied with: two thermographs, one in the hottest, the other in the coolest part (small magazines only had one); two maximum and minimum thermometers; one hygrometer to record the saturation with water vapour; and two thermometers in tubes, for the continual observation of change in temperature without actually having to open the magazine (the tubes were placed in the crowns of the magazine, in positions where it was thought extremes of temperature might be encountered). All these temperature readings were recorded in a magazine log, and the weekly average maximum used to estimate the conditions under which those lots of cordite were being stored. The use of distant-reading thermometers was considered once again, but the "formidable" amounts of electrical wiring required, combined with the fact that the existing and new procedures would discover a gradual rise in temperature (and if a fire did start, it was too late) meant that these devices were not considered cost effective. Still under consideration in 1920 was the provision of a satisfactory seal to the cordite cases. Paper, fabric and various mechanical devices would be tried, but none would prove completely satisfactory.⁴⁷

Vanguard Today

Some eighty years and another World War later, the bones of HMS *Vanguard* still lie on the bottom of Scapa Flow. There are rumours of salvage having taken place immediately after the First World War. More substantially, in 1957 a Glasgow scrap firm (Nundy Marine Metals) purchased the wreck from the Admiralty, and it was believed at the time that *Vanguard* had never been "officially surveyed" by a salvage firm.⁴⁸ Their goal was non-ferrous material (the blown-open engineering spaces being an obvious target) to be retrieved by a small team of divers in standard diving dress. Some unknown agency has recovered her turrets; while several barbets still stand some fifteen feet proud of the bottom, the guns and gunhouses have vanished. Nevertheless, most of the ship is still there. Amidships is just a heap of rubble, with the occasional twelve-inch shell scattered about. Some sixty feet of the stern and most of the forecabin are fairly intact and upright - the black and white tiles in the seamen's wash places can be seen if you peer through the correct scuttle. Wood planking still covers the decks.⁴⁹ To anyone who knows her story, *Vanguard* is a very impressive memorial.

Today of course, HMS *Vanguard* is recognized as a war grave and any unauthorised diving is strictly forbidden: this seems to be enforced, no doubt in part to the nearness of the oil terminal on Flotta and the attendant security concerns. The diving charters stick to the remains of the German Fleet, scuttled in July 1919.

The name "Vanguard" has graced the Navy List twice more: during the next war, the last and perhaps greatest British battleship was christened HMS *Vanguard* but was

completed too late to ever fire a gun in anger. The current *Vanguard* is the nuclear ballistic missile submarine completed in 1993, and it is fortunate for all of us that she has never seen action."

NOTES

* William Schleihau is an underwater photographer and avocational naval historian whose current research interest is the art of gunnery as practised by the Royal Navy during the era of the Great War. A shorter version of this paper was presented at the "Merchants and Mariners of the Northern Seas" Conference in Comer Brook, NF, in August 1999.

1. Sir Julian S. Corbett and Henry Newbolt, *Naval Operations* (5 vols., 2nd ed., London, 1997).

2. Oscar Parkes, *British Battleships* (Hamden, CT, 1970), 506.

3. R.A. Burt, *British Battleships of World War One* (London, 1986), 83-86.

4. A. Cecil Hampshire, *They Called it Accident* (London, 1961).

5. Unless otherwise noted, details of *Vanguard's* history and specifications are based on Burt, *British Battleships*, 75-88.

6. Great Britain, Public Record Office (PRO), Admiralty Papers (ADM) 1/8346.

7. Admiral Viscount Jellicoe of Scapa, *The Grand Fleet 1914-16. Its Creation, Development and Work* (London, 1919), 86.

8. *Vanguard's* part in the Battle of Jutland has been taken from the report of its Captain, J.D. Dick. RN, in *Battle of Jutland 30th May to 1st June 1916. Official Despatches* (London, 1920), 356-360.

9. Weather data are consolidated from the 8 pm and midnight records in the logs of HM Ships *Warspite* (PRO, ADM 53/68210); *Neptune* (PRO, ADM 53/52418); *Centurion* (PRO, ADM 53/37451); and *Collingwood* (PRO, ADM 53/38188), 9 July 1917.

10. All times are Greenwich Mean Time.

11. Admiral Sir Doveton Sturdee, the commander

of the squadron, narrowly escaped the disaster, as he was away on leave instead of transferring to another ship while his flagship (*Hercules*) was refitting, as had hitherto been the case; see Sir Roger Keyes, *The Naval Memoirs of Admiral of the Fleet Sir Roger Keyes* (2 vols., London, 1935), II, 97.

12. Burt, *British Battleships*, 86.

13. PRO, ADM 137/3680, Board of Admiralty to the C-in-C Grand Fleet, 6 September 1917.

14. *Ibid.*, Signal from C-in-C to Ships of the G.F. in company, 11.30 pm, 9 July 1917; signal from C-in-C to ACO&S, 11.40 pm, 9 July 1917; and signal from ACO&S to C-in-C, 11.50 pm, 9 July 1917.

15. *Ibid.*, Signal from C-in-C to Admiralty, 12.35 am, 10 July 1917.

16. The dynamo room was immediately below the hydraulic room on the lower deck and shared a bulkhead with the Transmitting Station (TS). See National Maritime Museum, Greenwich (NMM), Drawing of HMS *Vanguard* - Forward Sections as Fitted, 1910.

17. PRO, ADM 137/3681, *Report of the Court of Enquiry Into the Circumstances Attending the Loss of HMS "Vanguard" on the 9th of July. 1917*, 30 July 1917.

18. PRO, ADM 137/3680, Interim report of Court of Enquiry into the Loss of HMS *Vanguard*, 26 July 1917.

19. See Captain Franz von Rintelen, *The Dark Invader - The Wartime Reminiscences of a German Naval Officer* (1933; reprint, London, 1997), 95. He arranged for lead pipes, filled with picric acid on one side and sulphuric on the other (separated by a copper disc, which would eventually be eaten through) to be placed in the holds of various Allied merchant ships.

20. PRO, ADM 137/3680. Hairston was living at 2 Bankside Villas, Upper Luton Road, Chatham,

according to a telegram he sent stating "quite safe on old address."

21. *Ibid.*, Message from the Rear-Admiral, First Battle Squadron to C-in-C, Grand Fleet, 14 July 1917.

22. Hampshire, *They Called it Accident*, 176.

23. Corbett and Newbolt, *Naval Operations*, II, 400.

24. Admiralty Library (ADML), Technical History Section, Admiralty, CB1515 (24), "The Technical History and Index, Part 24: Storage and Handling of Explosives in Warships, October 1919;" and Ian Buxton, *Big Gun Monitors* (Tynemouth, 1978), 96-99.

25. Norman R. Hacking and W. Kaye Lamb, *The Princess Story: A Century and a Half of West Coast Shipping* (1974); and Captain J.S. Cowrie, *RN Mines. Minelayers and Minelaying* (Oxford, 1914). I would like to thank Rick James and Peter Beeston for drawing my attention to these sources.

26. See Burt, *British Battleships*.

27. ADML, JaO1, Admiralty, Gunnery Branch, CB01429, "Report on Matters Arising Out of the Loss of HMS *Vanguard*, March 1918."

28. ADML, CB 1515(24), "Technical History, Part 24," 51-53.

29. *Ibid.*, 47.

30. PRO, ADM 137/3680, testimonies of Chief Gunner Frederick S. Gidley (HMS *Collingwood*); Engineer-Commander Harry Williams (HMS *Collingwood*); Chief Carpenter Frank T. Vernon (HMS *Vanguard*, who also pointed out that the ventilation trunks were the responsibility of the Engineering Department, not the Ship's Carpenter); and Commander Henry S.M. Harrison-Wallace (HMS *Emperor of India*); and Captain, HMS *Bellerophon* to Admiral Commanding, 4th Battle Squadron, 12 July 1917.

31. PRO, ADM 137/3680, "Statement Regarding the Possibility or Otherwise of the Explosive Carried in HMS *Vanguard* being Ignited by the Working of the W.T. Installation."

32. George F. Dale, "Stability of Nitrocellulose-based Powder," *Warship International*, No. 4

(1980).

33. PRO, ADM 137/3680, testimony of Commander Wilfred Custance, *Vanguard's* Gunnery Officer, who was attending an entertainment in *Gourka* and so avoided the explosion.

34. ADML, Admiralty, Technical History Section, CB 1515(29), "The Technical History and Index, Part 29: Ammunition for Naval Guns," 33; and Ja 254, Admiralty, *Manual of Gunnery for His Majesty's Fleet* (3 vols., London, 1915), I, 203.

35. "Technical History and Index, Part 24," 33-36.

36. PRO, ADM 186/229, CB 1451 *Vengeance* Flash Trials, 1917 and 1918, August 1918.

37. *Manual of Gunnery*, I, 197.

38. "Technical History and Index, Part 24," 42.

39. "Patent fuel" were briquettes made of a proprietary mix of coal and coal dust pressed together in a flammable matrix. I would like to thank Kevin J. Foster for this information.

40. PRO, ADM 137/3681, "Report of Court of Enquiry," 30 July 1917.

41. *Ibid.*

42. *Ibid.*

43. ADML, JaO11, Captain F.C. Dreyer, "Report," 26 February 1918, 8, Part II of CB01429, "Report on Matters Arising Out of the Loss of HMS *Vanguard*, March 1918." Priority was given to ships armed with fifteen-inch guns.

44. *Ibid.*, 9.

45. This was a potential hazard: some ships had cables run through the magazines, and experiments in HMS *Princess Royal* had shown that a "blow-out" in a 220-volt cable could burst thin steel sheeting and ignite the cordite on the opposite side.

46. "Technical History and Index, Part 24," 62.

47. *Ibid.*, 48-49; and PRO, ADM 186/244, Admiralty, Gunnery Branch, "Progress in Gunnery Matériel," July 1920, 65.

48. *The Orcadian*, 9 and 16 May 1957.

49. This description of the wreck is based on the author's four dives in the summer of 1987 and 1988; and Peter I. Smith, *The Naval Wrecks of Scapa Flow* (Kirkwall, 1989), 82-86.

50. Robert Gardiner (ed.), *Conway's All the World's Fighting Ships 1947-1995* (London, 1995), 533.

Appendices

Appendix Table 1: Summary of Eyewitness Accounts

Ship	Witness	Location	Description
<i>Neptune</i>	Lieutenant-Com- mander Yonge	inside superstructure	<ul style="list-style-type: none"> - "comparatively small" explosion, 3 second interval, "very big explosion," 5 second interval, "big explosion, but smaller than the second one" - all three explosions sounded similar - black and whitish-green smoke
	Able Seaman Peek	inside looking out through scuttle on star- board side	<ul style="list-style-type: none"> - bright flash of light like a searchlight fol- lowed by "the sky becoming one red mass" - very short interval, less than a second, be- tween the flashes
	Able Seaman Place	on quarterdeck, signalling boat passing between <i>Neptune</i> and <i>Vanguard</i>	<ul style="list-style-type: none"> - "great red flame and almost at the same moment heard a great explosion followed by two smaller explosions" - first explosion was from close abaft the foremast, the other two from farther aft - perhaps a 5 second interval between the first and second explosions, and 3 seconds between the second and third explosions - saw flame between the funnel and the fore- mast, about twice as high as the mast
	Able Seaman Robinson	forecastle, look- ing to port	<ul style="list-style-type: none"> - very bright light "like a searchlight" that went to a great height with a hissing noise - the light originated at the foot of the fore- mast, both before and abaft - big explosion followed by two smaller ex- plosions, 5 seconds between first and sec- ond explosion, 2 between second and third
	Signalman Frost	after part of sig- nal bridge, looking to port	<ul style="list-style-type: none"> - flame, followed by a large report, then an- other large flare and two reports - flare came from just abaft the foremast - perhaps an 8 second interval between first and second explosions, 1 second between second and third
	Signalman Ditch	after part of fore bridge, looking in direction of <i>Vanguard</i>	<ul style="list-style-type: none"> - large flare from the fore waist, just abaft foremast, followed by a loud report - did not observe any other explosions or flashes of light

	Bugler Barker, RMLI	port side on upper deck abreast 'B' turret, looking across to starboard	heard an explosion, followed by a burst of red flame out of the superstructure by the foremast and then flame shooting up near 'X' turret perhaps 6 seconds or less between the two flares much black smoke only heard 1 explosion
<i>Bellerophon</i>	Leading Signalman Williams	port side of bridge	large 'V'-shaped flash, 2 second interval, then 4 or 5 reports which sounded similar to a 4-inch gun much black smoke
<i>Collingwood</i>	Lieutenant Pears	inside superstructure, amidships	- 3 distinct explosions, the last two heavier than the first - 4 second interval and 2 second intervals
	Petty Officer Roberts	port side of superstructure	- soft muffled noise from off the port side of <i>Collingwood</i> , followed immediately by a big report - saw flames from 'X' turret to the forebridge, the fire seemingly even in intensity and height
	Leading Signalman Burt	exiting chart-house on bridge	• two big explosions "two or three seconds" apart, followed by two smaller explosions • the second big explosion was in the area between 'P,' 'Q,' and 'X' turrets, accompanied by a very high sheet of flame
	Ship's Corporal J. Stevenson	outside after superstructure on port side	• knocked through door into superstructure by a big explosion, followed a couple of seconds later two more explosions "in very rapid succession" and a second later another explosion
	Able Seaman S. Bailey	at No. 2 port searchlight	saw flash before the first explosion, followed almost immediately by "the loudest explosion of all" accompanied by a big column of smoke and flame, very quickly followed by two small reports almost together - smoke and flame from the first explosion came from just abaft 'Q' turret, more towards the centre of the ship - the second explosion appeared to come from all along in between the two masts, accompanied by much wreckage
	Ordinary Signalman M. Brown	port side of bridge	- heard two explosions, the second very much greater than the first - very bright flame with the first explosion near 'Q' turret - second explosion from between the two masts with much smoke

	Private A. Field, RMLI	aft on upper deck	<ul style="list-style-type: none">- heard three explosions, the first the largest, followed after a slight pause by the second and then almost immediately by the third- very high flame between the two masts with the first explosion, unchanged by the next two explosions
	Signalman T. Calvert	port side of bridge	<ul style="list-style-type: none">- heard two explosions, the first very much smaller than the second- flame appeared with the first explosion, just abaft the bridge, the second explosion (about 1 second after the first) caused flame and smoke extending the whole length of the ship
<i>Warspite</i>	Private L. Cook, RMLI	upper deck, starboard side	<ul style="list-style-type: none">- saw bright light that looked like a searchlight or night signalling lamps, on <i>Vanguard</i> that lasted for several minutes followed by one big flash that became red coloured followed by the sound of an explosion- the first explosion was followed by two more explosions, a couple of seconds apart- the initial light appeared to be between the mainmast and 'X' turret, immediately above the turret, that was steady and remained small
	Petty Officer C. Lidstone	starboard side of quarterdeck	cloud of smoke followed by a flash near 'X' turret about a second later, the smoke and fire was followed by an explosion, then almost immediately a second explosion with more flame
	Able Seaman E. Wride	starboard super- structure, for- ward	saw a light like a single lamp or scuttle opening between mainmast and 'X' turret that broke into a brighter light like a searchlight two or three seconds later - this light then became a "great flame" perhaps as high as the masts, and was followed by the sound of a big explosion a second explosion followed almost immediately
<i>Conqueror</i>	Private W. Munro, RMLI	quarterdeck	large cloud of black smoke that came from amidships between the two masts, followed about 2 seconds later by a very heavy explosion with "an enormous amount of flame", much higher than the masts only other explosions were small ones saw the bow and stern of the ship come a little way out of the water while the centre of the ship dropped and then she disappeared, perhaps 7 seconds after the first flame was visible

<i>Thunderer</i>	Leading Signalman A. Jolly	fore bridge	after watching a "light in the water" abreast 'V' turret, saw a bright whitish flash like a searchlight around the turret, of about 'A' second duration, followed by a big explosion and then 2 or 3 seconds later two or three small explosions
<i>Téméraire</i>	Leading Signalman T. Waye	on bridge	very heavy and sharp explosion, and saw a great sheet of flame, much higher than the masts, that originated around the foremast followed by rumbling noise and then a duller explosion 3 or 4 seconds later, with much black smoke near the mainmast heard a third smaller explosion
<i>Colossus</i>	Leading Signalman A. Coleman	fore bridge, looking in direction of <i>Vanguard</i>	great flame near the forward funnel, then a very big explosion, followed by a second sheet of flame, as large as the first, between fore and main masts
<i>Centurion</i>	Petty Officer T. Brush	starboard side of quarterdeck, looking in direction of <i>Vanguard</i>	flash "like a searchlight" followed by a big flame from about the middle of the ship which enveloped the entire vessel very heavy explosion after the flame - only 1 explosion heard
	Able Seaman E. Jones	harbour lookout	first flash amidships, 15 ft high
	Able Seaman W. Lester	harbour lookout	- first flash amidships, 15 ft high
<i>Monarch</i>	Gunnery E. Bailey, RMA	watching <i>Vanguard</i>	- explosion amidships
<i>Ajax</i>	Leading Signalman E. Williams		explosion before mainmast
Picket Boat	Petty Officer L. Driscoll	about 120 yards off starboard quarter of <i>Vanguard</i>	a rumbling noise and large flame that seemed to come from amidships between 'X' turret and the after funnel on the upper deck, followed by a large explosion, followed 4 or 5 seconds later by two smaller explosions

Notes: The intervals between explosions reported by some witnesses are their own estimates, and are probably reasonable approximations of the relative spacing between explosions. They cannot be considered accurate time measurements. It is most unlikely that eyewitnesses in the same ship were isolated before their testimonies were heard, and thus it is quite possible that they had discussed what they had seen: this may explain the similarities between their accounts. It should not be forgotten that at a distance, the sound of an explosion will be heard by the witness after the blast has occurred.

Sources: PRO, ADM 137/3680, Minutes of Court of Enquiry, 11-22 July 1917, 1-22, 51-61; and ADM 137/3681, "Report of Court of Enquiry into the Circumstances Attending the Loss of HMS *Vanguard* on the 9th July, 1917," List of Witnesses.

**Appendix Table 2
Cordite Lots Believed to be Onboard *Vanguard* When Lost**

Size	45 (MD)	Size	16 (MD)	Size	4 7/8 (MD)
Lot	Date	Lot	Date	Lot	Date
WA 1220	11/09	WA 1379	9/10	WA 3339	4/14
WA 1225	11/09	WA 1712	3/12	WA 3904	2/15
WA 1227	11/09	B343	2/11	B 1112	11/16
WA 1235	11/09	B418	1/13	B 1207	1/17
WA 1258	2/10	B932	7/16	C 1036	1/14
WA 1276	3/10	C 1390	10/15	E686	2/14
WA 1290	4/10	D 1181	4/11	E689	3/14
WA 1370	8/10	D 1204	6/11	H 1685	10/16
WA 1380	9/10	D 1351	7/12	RN 222	1/17
WA 1389	10/10	E843	8/15		
WA 1516	4/11	E 1204	11/15		
WA 3746	12/14	E 1623	9/16		
WA 4005	4/15	E 1706	11/16		
B 577	1/15	S 158	2/12		
B598	5/15	S 300	4/15		
D 1247	10/11	RN 138	11/16		
D 1459	12/12	RN 2923*	2/13		
D 1679	6/14	WA 3086*	7/13		
D 1712	7/14	N 1131**	9/15		
D 1924	2/15				
D 1978	2/15				
D2798	10/16				
E501	9/10				
E685	2/14				
H 438	1/11				
H 458	5/11				
H 594	1/13				

Notes: * denotes Size 16, MC cordite; ** denotes Size 11, MD cordite (it was believed that the thirty-two cartridges of lot D 2716 had been expended). "Size 45" was for the twelve-inch guns, and when freshly extruded had a diameter of 0.45 inches. "Size 16" was for the four-inch guns. "Size 4 7/8" was for the three-inch, high-angle guns. There were two types of cordite in use by the RN during World War I. Mark I cordite, which was the original composition. By 1918, this was considered obsolete, and stocks were not being replaced. MD cordite had a reduced proportion of nitroglycerine (the proportion of guncotton increased), which increased stability and reduced the wear of the guns. The following lots were ordered to be withdrawn in a letter dated 29 June 1917, but were probably on board: E 501 (September 1916), five cartridges; E 685 (February 1914), ninety-four cartridges; H 438 (January 1911), 188 cartridges; H 458 (May 1911), 122 cartridges; E 686 (February 1914), 112 cartridges; and E 689 (March 1914) thirty-two cartridges.

Sources: PRO, ADM 137/3680; PRO, ADM 186/244, Admiralty, Gunnery Branch, "Progress in Gunnery Matériel, 1920," 54; ADML, Admiralty, Technical History Section, CB 1515(29), "The Technical History and Index, Part 29: Ammunition for Naval Guns," 46; and PRO, ADM, Gunnery and Torpedo Division, Naval Staff, Admiralty, CB902, "Progress in Naval Gunnery 1914 to 1918," July 1919, 16.

Appendix Table 3
"Restricted" Cordite

Category	Description
1	MD cordite manufactured by "the trade" prior to the 1910 introduction of the Nobel system of boiling (ie "the modern system")
2	MD cordite manufactured by Waltham Abbey prior to September 1905
3	MD and Mark I cordite which gave unsatisfactory heat test results when first made
4	MD and Mark I cordite made by Curtis's and Harvey containing guncotton made by the Colnbrook Company
5	MD cordite manufactured by Waltham Abbey prior to the "modern system" of boiling not already covered by Category 2
6	MD cordite manufactured by "the trade" prior to the "modern system" of boiling not already covered by category 1
7	MD cordite manufactured by "the trade" containing guncotton made otherwise than by the displacement process and not already covered by category 1
8	all Mark I cordite 12 years of age or on becoming 12 years old
9	MD cordite containing guncotton nitrated for less than 2 hours on becoming eight years old
10	MD cordite made with guncotton nitrated for 2 1/2 hours on becoming 12 years old

Notes: Categories 1-7 had been withdrawn from the Fleet by February 1918. Category 8 had been withdrawn from the Grand Fleet by February 1918 and was to have been removed from all other ships by July of that year. Category 9 will have been replaced in all Grand Fleet ships by March 1918, and all other ships by September 1918.

Source: "Table 'A'" of DNO's Minutes of 13th July 1917 on Admiralty Docket G.02962/17, reproduced in CB 1429, "Report on Matters Arising Out of the Loss of HMS *Vanguard*, 12.

Appendix Table 4
Precautionary Orders Regarding Ammunition, 1916

- (a) Matches are not to be taken into magazines and shell rooms or into gun-houses or gun-positions where cordite is kept as a ready supply, except in cases where matches are required for lighting secondary lights, when they are to be kept by an officer or a responsible petty officer detailed
- (b) Smoking is to be prohibited in or near all positions where ammunition is stowed or kept
- (c) Wandering [electrical] leads are not to be taken into magazines; they are not to be used in shell rooms without the authority of an officer
- (d) The magazines are to be opened only by the direct authority of responsible officers, and there is no necessity for such constant work in a magazine as to require a sweeper permanently detailed for the purpose. Before any magazine is closed it is to be searched for the presence of oily waste or other unauthorised substance.
- (e) Officers in charge of magazines and shell rooms are to be held personally responsible for the opening and closing of the doors and hatches.
- (f) Magazines, shell rooms, and ready stowages are to be visited two or three times daily to ensure that they are not being used for improper purposes.
- (g) Officers and men are not to enter magazines unless they are wearing magazine shoes, or they have fearnought overshoes over their boots.
- (h) Magazine floors, battens, etc., are to be swept periodically.
- (i) When ships are refitting, sufficient sentries are to be placed on magazines and shell rooms to ensure their security. The orders to these sentries should direct that parcels or boxes are not to be allowed to be left near magazines.
- (j) Great care is to be taken that no charges that have been wetted or have been in contact with an oily cage are returned to the magazines; they should be kept apart and returned to the local ordnance store officer at the first opportunity, and if this is not possible they must be thrown overboard.
- (k) Magazine and safety hand lamps are not to be stowed in the immediate vicinity of magazines or shell rooms.
- (l) Charges with torn igniters should not be loaded into the main cages in the handling rooms; working chamber crews are to be instructed as to the possibility of this accident and the precautionary measures to be taken should it be seen that an igniter is torn, or loose powder present on the cordite trays.

The above orders are to be strictly enforced, and no laxity whatever in regard to magazine precautions is to be permitted. The fact that it is necessary to keep some ammunition on deck renders it essential that familiarity with the presence of explosives does not breed that contempt which is so dangerous and may easily lead to disastrous consequences.

Source: PRO, ADM 137/293, Order 194, "Grand Fleet Gunnery and Torpedo Orders," 6 December 1916.