PROGRESS IN GUNNERY MATERIAL, 1921.

CONTENTS.

Section 1.- Fire Control Instruments.

(C458) Wt.11059/Pk3861 10/21 300 Harrow (Gp. 1) 112

Section V.- Guns and Gun Design.

Section X_B.- Armour

Section XX.- Firing Trials with Live Shell.

LIST OF PLATES FOR PROGRESS IN GUNNERY MATERIAL, 1921.

List of Illustrations.

List of Illustrations – *continued*.

NOTICE.

This book is not to be considered as authority for demanding stores or altering material or methods.

SECTION 1.

FIRE CONTROL INSTRUMENTS.

1. Dreyer Table Fitted in H.M.S. " Hood " – Experience gained during the past twelve months has shown that it is a great improvement on all previous Marks of Dreyer Table. This table is based on a design which is now several years old and may be said to have reached finality on this basis.

In order to meet new requirements a fresh design is required, which is now under preparation at the Admiralty. (G.2401/21.)

Gyro Director Training Gear. – In order to ascertain the best method of carrying out indirect fire from light cruisers, comparative trials will be carried out in light cruisers fitted with Henderson's Layers' Telescopes and other light cruisers fitted with gyro director training gear.

The sketch Figure 1 shows the additional gear which is being fitted to the Mark III* Dreyer Tables in " Delhi." "Dunedin " and " Durban." This gear is similar to that fitted in " Hood " modified to suit Mark III* tables. (G.904/21.)

2. Langley Automatic Inclinator. – This instrument has been fitted for trial in H.M.S. " Malaya " instead of " Queen Elizabeth."

Figure 2 gives an outline arrangement of the instrument manufactured by Messrs. Elliott Brothers and is placed in the transmitting station. (G.726/21.)

3. Rangefinders. – Trials are being carried out at Fort Cumberland, Eastney, with all types of long base rangefinders, and will include trials with stereoscopic rangefinders and captured German instruments which include a 7.8 metre base stereoscopic instrument which was salved from B turret of " Hindenburg." On completion of these trials, the information obtained will be issued to the Fleet.

The first series of trials were carried out with 15 ft. F.X.2, 15 ft. stereoscopic, and 15 ft. F.T.24 rangefinders. Detailed reports have not been received, but the general conclusion is that the coincidence instruments are more accurate than the stereoscopic rangefinder, and the greatest accuracy throughout the trial was obtained from the 15 ft. F.T.24. For light gathering qualities the stereoscopic rangefinder was superior and the F.T.24 inferior to the F.X.2 rangefinder. In this respect the stereoscopic rangefinder operator was able to take ranges for 20 to 30 minutes after the remainder in failing light, but the inaccuracies increased to such an extent that the ranges taken during the last five or ten minutes were of no practical value.

Several instances occurred in which all three rangefinders would give inaccurate results, and their errors, which varied from 50 to 100 yards, increased to 800 or 1,000 yards. The visibility was apparently good, and this error generally occurred when a bright reflection from the sun was thrown on the sea between the rangefinder and the target. (G.11729/21.)

30 ft. Rangefinders.- Trials have been carried out in the Atlantic Fleet with 30 ft. coincidence and stereoscopic rangefinders, but these instruments are handicapped by an unsatisfactory type of mounting. The general conclusions are:-

(1) Under good conditions the 30 ft. rangefinders of either coincidence or stereoscopic type are more accurate than other rangefinders of shorter base length when mounted in similar positions.

(2) The 30 ft. coincidence rangefinders are more accurate :-

(*a*) When the visibility is good.

(*b*) When taking " snap " ranges.

(*c*) When taking initial ranges.

(3) The 30 ft. stereoscopic rangefinders are more accurate :-

(*d*) In poor visibility or failing light.

(*e*) When affected by vibration. (G.5615/21.)

(C458)

30 ft. Rangefinder Mountings. – The design of these mountings has proved unsatisfactory in (*a*) The method of support ; (*b*) Elevating gear ; (*c*) Training gear.

(a) The method of support is insufficient to overcome the vibration when steaming at high speed.

(b) Elevating gear is a type of lever gear, and it has been found that the weight of the 30. ft. instrument is too heavy for the operator. A design of wheel elevating gear has been fitted in " Repulse " and " Queen Elizabeth " for trial and is satisfactory.

(c) Training gear fitted has too small a leverage and the long base of the instrument causes excessive backlash. This defect has been partly overcome in the mountings as fitted in " Hood."

Messrs. Barr and Stroud are preparing a new design which will overcome the above defects and two mountings will be manufactured for trial. (G.1555/21.)

Rangefinders in Light Cruisers and Torpedo Boat Destroyers.- All rangefinders in Light Cruisers and Torpedo Boat Destroyers suffer from vibration at high speed to such an extent that the results obtained are practically useless.

Trials are being carried out with various types of mountings in ships of the 1st L.C.S., which included an "Argo" mounting which compared unfavourably with the Barr and Stroud type of mountings. (G.5007/21/)

Comparative trials were carried out with a 3 metre German Stereoscopic Rangefinder and a 9 ft. Barr and Stroud Coincidence Rangefinder mounted in the destroyers "Verity' and "Whitshed" and the general conclusions arrived at were:-

For initial ranges at ranges of 10,000 and above the coincidence rangefinder is superior.

Under ordinary conditions and steering up to 25 knots there is little to choose between the two types.

At Full Speed the stereoscopic gave the best results, which was partly attributable to the heavier weight of this rangefinder and mounting (especially the mounting), which was 2,144 lb. compared with 1,005 lb.

Interference from funnel gases, the coincidence gave the best results.

Smoke Screen stereoscopic alone could range on the screen. Not much difference in ranging through smoke.

During Firing stereoscopic gave the best results.

Low visibility, stereoscopic gave the best results.

Ranging on a Searchlight. No particular difference.

Ranging on a ship illuminated by searchlight, stereoscopic gave the best results.

Further trials will be carried out from "Winchester" and special attention will be given to obtain the causes and reduction of vibration. (G.0902/20.)

Bennet type Barr and Stroud Rangefinder Instruction Device.- Five instruments of the above type have been ordered and will be supplied to the following ships for trial:-

One 30 ft. to H.M.S. “Hood.”
One 15 ft. to H.M.S. “Resolution.”
One 15 ft. to H.M.S. “Hawkins.”
One 15 ft. to H.M.S. “Excellent.”
One 15 ft. to H.M.S. “Delhi.”

In arranging the designs for the above ships endeavour has been made so that the cumbersome parts may remain permanently rigged and the amount of erection necessary before use may be reduced to a minimum. (G.16883/20.)

Rangefinder Periscopes.- The present type of trainer's periscope for 9 ft. mountings in Torpedo Boat Destroyers requires to be lowered every time the rangefinder is covered, and afterwards has to be readjusted each time before use; in addition no movement in elevation is available, and the object rolls out of the field of view, causing unsatisfactory training. Three sets of special brackets so that the periscope can be secured to the body of the rangefinder have been supplied for trial, and this it is hoped will overcome these disadvantages. (G.15370/20.)

Future design of Rangefinders and Mountings.- Experience has shown that the efficiency of any rangefinder depends to a very great extent on the position in the ship in which it is mounted.

Investigations are now being carried out in order to obtain a double mounting, so that two rangefinders may be mounted in director control towers, one of these may be stereoscopic. (G.4725/21.)

SECTION II.

SIGHTS AND SIGHTING.

4. Gun-Sighting Telescopes.- Exhaustive tests and examinations have been carried out at the National Physical Laboratory, Teddington, of various types of German gun-sighting telescopes.

The advantage of the British type is a better definition over the whole of the field. The field of view in the German telescopes is larger, and the definition, except in the centre of the field, is not so goo, being very poor towards the edges.

The great advantage of the German telescopes was the degree of water-tightness obtained. One telescope was salved from a sunken submarine and when opened up the interior was free from moisture.

Messrs. Ottway modified two telescopes which were forwarded to "Excellent" for trial. The following is an extract of the report of the trial carried out with the two modified telescopes :-

Watertightness of G.S. Telescopes.- The two further telescopes mentioned in Messrs. Ottway & Co.'s letter dated 22nd October, 1920, referred to "Excellent" in Admiralty Letter G.16295/20 of 2nd November, 1920, have been received and tested.

2. They are :- one G.S. Telescope, Pattern G.327, and one G.S. Telescope, Pattern G.330.

3. A representative of Messrs. Ottway & Co. was informed of the date of the tests and witnessed them throughout.

4. Trial I.- The telescopes were exposed to steam in a hot bathroom and then subjected to a cold douche. This was carried out twice during a total period of about 30 minutes. Difference of temperature to which the telescopes were exposed is estimated at about 40° F.

5. Trial II.- The telescopes were submerged eyepiece down over the change of focus collar for 4 hours.

6. Trial III.- The telescopes were submerged eyepiece down over the change of power collar for 4 hours.

7. Trial IV.- The telescopes were submerged horizontal in 1 foot of water for 16 hours.

8. After each of these tests the telescopes were carefully examined without opening up, and both the change of focus and change of power collars were worked and found to move freely.

No fogging, penetration of water, or other loss of efficiency could be observed and in view of the severe nature of the tests compared with the probable treatment at sea, it is considered that this design of telescope may be regarded as thoroughly watertight. (G.17747/20.)

In view of these satisfactory results, approval has been given for the above modifications to be carried out to 3-9 V.P. gun-sighting telescopes supplied to Torpedo Boat Destroyers. (G.1995/21.)

Binocular Eyepieces for Gun-sighting Telescopes.- Trials are being carried out in H.M.S. "Excellent" with two designs of binocular eyepiece proposed by Doctor Hanson and Captain Goodyear, with the object of relieving eyestrain and affording protection from blast and flash. (G.2655/21. G.1107/21.)

SECTION III.

DIRECTOR FIRING.

5. Henderson's Director Layer's Telescope.- Details of this instrument are shown in plates Figs. 3, 4, 5 and 6, which include the modifications on the original design to allow for application of deflection spotting corrections.

Fig. 3 shows the general optical arrangements including the collimator which produces the illuminated cross wires, and shows the point of aim relatively to the object which is stabilised in the field of view.

Figs. 4 and 5 show the internal arrangements of the appliance, with details of the gyro and its belt connection to the stabilising prism.

Fig. 6 gives an external view showing the means of applying deflection (by means of the collimator) and also the scale for bearing rate.

Fig. 7 shows diagrammatically the principle of the instrument.

Routh outline of **principle** of Henderson Layer's Telescopes as used for **training** (see Fig. 7).

A. Telescope stabilised in space by gyro (B).
Telescope has a black grid in it (C).
F. Spider's web mounted on gunsight (G) so that it partakes of all movements of the gun and its range and deflection adjustments.
Note.- This grid is really reflected lines from a collimator.
D. A black pointer, mounted in the telescope, which can be moved by hand.
J. The target.
J.K. The line of sight.

The telescope and its grid (C) is stabilised, but the target (J) moves according to rate of change of bearing, and to make telescope and its grid (C) follow it, a method of precessing the gyro at the same speed as the rate of change of bearing is provided, lever (E).

If lever (E) is adjusted to the right rate, then grid (C) always follows the target and on looking through telescope the target appears to remain stationary in the centre of grid whilst the spider's web (F) moves about as the ship rolls.

The operator is provided with handles (H) by which he can move the gun so as to align the spider's web (F) on to target and when aligned he presses his trigger and fires.

If the rate of change of bearing has not been correctly gauged the target will move slowly across the stabilised black grid (C), but this does not matter so long as the spider's web (F) is aligned before the trigger is pressed.

To prevent target moving right outside the black grid, the gyro must be pushed round (with another gear not shown) until the target is in the centre of black grid and a new adjustment of lever (D) made to keep it there. Lever (E) will then show the new rate of change of bearing which can be read off on the graduated arc.

Further satisfactory trials have been carried out with this instrument, both in H.M.S. “Valiant” and also in H.M.S. “Dauntless,” including actual firings in indirect fire.

The results of these trials have shown that :-

(a) **For Direct Fire.-** The instrument is of undoubted assistance to the director layer, and also facilitates picking up the target after brief periods of obstruction to the line of sight from cordite smoke, enemy’s splashes, etc.

A considerable amount of practice is, however, required before the director layer can obtain full value from this instrument.

The director layer has also added to his duties the adjustment of the bearing rate as applied to his telescope, and has to precess the gyro occasionally to keep the object in the centre of his field of view ; this latter operation is only necessary when the bearing rate is wrongly adjusted and when first picking up an object.

These two additional duties correspond to the adjustments of the Henderson Firing Gear as fitted o the trainers’ telescopes in all ships, and are equally simple to operate.

The procedure while in direct fire is as usual, viz. :- The director layer operates the elevation wheel as necessary and fires when his cross wires are on, or if using Henderson’s Firing Gear presses his trigger when his vertical cross wire is on while the trainer keeps on for line.

The great advantage of this telescope is the steadiness of the point of aim, which is not affected by motion of ship.

(b) **For Indirect Fire.-** The instrument enables single ship indirect fire to be carried out with good accuracy and maintains a very steady point of aim for line in spit of alteration of our ship’s course and speed.

If alteration of enemy’s course and speed are reported by aircraft, the corresponding bearing rate can be applied and hitting should be possible for several salvos depending on the accuracy of the bearing rate applied. If this is only slightly in error the aircraft should be able to spot and correct the error without losing the target.

The procedure whilst in Indirect Fire differs considerable from the normal procedure, viz.:-

The director layer has to perform all duties and his main duty is **training** and firing (hence ht name “Layer’s Telescope” originally chosen for this appliance is rather unfortunate).

For preference he allows the Henderson Firing Gear to actually make the circuit so that he can devote his whole attention to training and pressing the trigger when his vertical cross wire is on, whilst ensuring that ht elevation will cause the horizontal cross wire to pass the horizon with the roll of the ship.

As the target is invisible he has nothing to do in the way of adjusting the bearing rate on precessing the gyro. In the event of a change of bearing rate being detected, either from aircraft reports or from results of fall of shot, the new bearing rate is calculated by the rate officer and set on the instrument by the phoneman or by an additional operator.

The director trainer is freed from all training and can devote his whole attention to adjustment of the Henderson Firing Gear Telescope and the elevation. If the front horizon is invisible he must have some means of adjusting on the rear horizon, and for this purpose provision has been made in 1921-2 estimates for purchase of a combined “sight inverting attachment and collimator” for use in all ships fitted with means of indirect fire.

Application of spotting corrections for line when in Indirect Fire.- While in direct fire deflection spotting corrections are pot on the deflection dial as usual.

When in indirect fire the gun deflections should be kept continually on the sight thereby applying the necessary correction due to any alteration of own ship or reported alteration of enemy. In the event of the enemy becoming visible the director sight is immediately ready for the continuation of direct fire.

Spotting corrections other than the above should not be put on the deflection dial.

Provision is being made in instruments now under manufacture for spotting corrections to be applied to the luminous cross wires in the collimator, provision being made for 5° each way.

Henderson's Layer's Telescope Mark II.- A new design of Henderson's Layer's Telescope has been designed for trial in H.M.S. "Valiant," and is now under construction at Greenwich.

The design is generally similar to the Mark I, but the gyro not only stabilises the director line of sight (with provisions for applying bearing rate) but also operates the director training transmitter through a relay be means of differential gear. This is necessary in order to obtain the full value out of the gyro turret training gear when fitted, since with this latter appliance the gyroscopic control automatically eliminates yaw from the turrets, but the displacement control *which causes the turrets to automatically follow the director training pointers) will tend to put it in again, because yaw cannot be eliminated from a **hand-trained** director. Yaw can, however, be eliminated from the director layer's line of sight by means of Henderson's Layer's Telescope, and if this can also be made to work the director training transmitter, hand worked director sights can then be used in conjunction with the tyro turret training gear without detracting from the efficiency of the latter.

Difficulty has been experienced in the design of Henderson's Layer's Telescope Mark II so that it may work in conjunction with Carslake's Auto Synchronism Transmission Gear ; but it is anticipated that the trial instrument will be completed during 1921.

The following extracts from the report of a Conference held at the Admiralty in April, 1920, deal generally with the subject of the Layer's Telescope, Henderson's Gyro Turret Training Gear, and also with Gyro Direction Training Gear.

1. A Conference was held on Tuesday, 27th April, 1920, to consider the Commander-in-Chief, Atlantic Fleet's letter No. 441/A.H. 835 of the 31st March, 19120, forwarding a report from the Commanding Officer, H.M.S. "Valiant," on the seagoing trials of Professor Henderson's Layer's Telescope, and the remarks thereon by the Vice-Admiral, 2nd Battle Squadron.

2. The conference had under consideration the proposal of the Vice-Admiral, 2nd Battle Squadron, to fit an improved design of Director Sight to Aloft Towers of Capital Ships armed with 15 in. guns, embodying as its primary consideration a form of Henderson's Layer's Telescope (modified as proposed in his letter No. 513.D/7 of the 26th March, 1920).

3. The Conference considered the value of the H nderson Laying Telescope under the separate headings of :-

Direct Fire and Indirect Fire.

A. **Direct Fire.**

4. After examining the report of H.M.S. "Valiant" and its enclosures, it was considered by the Conference that evidence exists that Henderson's Laying Telescope is of value in direct fire in a heavy ship as –

(i) A help to the layer.
(ii) A bearing rate finder.

And the Conference noted that in these respects it is reported to be superior to the G.D.T. Gear.

Consequently it is recommended that the proposed design of trial director control tower should be adapted to allow such an instrument to be fitted for the sole purpose of finding the bearing rate.

5. It is necessary, before a decision can be come to as to whether this invention should be fitted in all 15 in. ships, that extended trials should be carried out in a number of heavy ships. For this purpose it is recommended that four additional sets of Henderson's Laying Telescope with improved precessing arrangements should be constructed and fitted in H.M. Ships "Queen Elizabeth," "Barham," "Warspite," and ":Malaya" in order that more extended trials may be carried out to establish its value and to familiarise officers with the principles involved.

6. It is also recommended that he design of Henderson's Layer's Telescope should be developed in the directions proposed by H.M.S. "Valiant," viz., to enable the gyro to be utilised to eliminate yaw from the director line of sight and spotting corrections to be applied and that Professor Henderson should be asked to make alterations on these lines. This new design of instrument to be fitted in H.M.S. "Valiant" for trial with the Henderson Gyro Turret training system now fitted to one turret and already proposed to be fitted in all turrets of that ship, and also for trial in comparison with the "Valiant's" power-trained armoured director tower fitted with the Henderson Turret Gyro Training Control.

Note.- It has already been approved to fit the director system of H.M.S. "Valiant" with synchronous transmission to enable the armoured director tower of that ship to be fitted with the Henderson Turret Gyro Training Control, referred to above, and the fact that synchronous transmission is available will permit of the fitting of the proposed new design of Henderson's Layer's Telescope to the aloft director tower.

When the above, if approved, has been completed, H.M.S. "Valiant" will be fitted as follows:-

Aloft Director.- Henderson's modified design of layer's telescope, with gyroscope providing both "displacement" and "velocity" control of training transmission, *i.e.*, keeping the training transmitter set for both change of bearing and as necessary to eliminate yaw, so that the director layer's foresight or "spider's web" should never be off the target for training if the bearing rate is correct.

Note.-See Description of Henderson's Layer's Telescope attached.

Turrets.- Henderson's constrained gyro turret training control and displacement control, training the turrets so as to eliminate yaw and following the director pointers, so that the "turret director trainer" has nothing to do except to set the convergence corrector and possibly get the Slewing pointers into line on larger rapid alterations of bearing.

Armoured Director.- Director sight secured to the armoured director tower and the whole trained by power with Henderson's constrained gyro turret training control fitted to the tower to provide "velocity" control, *i.e.* , to relieve the tower trainer of the work of training except for change of bearing and spotting corrections.

This should permit the two systems to be compared, but it is recognised that difficulties will be encountered in the essential work of rendering the armoured tower races and training mechanism respectively true and delicate enough to meet the requirements.

B. **Indirect Fire.**

7. The Conference consider that it is important that the relative value of various methods of establishing an aiming point for **indirect** fire should be thoroughly investigated, in order to enable the Admiralty to decide on future lines of progress in this matter.

With regard to this point of view, the President of the Fire Control Table Committee had forwarded to the members of the Conference the following analysis of the "functions required of any complete system of gyro training gear."

8. **Functions required of any Complete system of Gyro Training Gear.**

I. Direct Fire.

(*a*) To obtain the bearing rate :-
For setting on the fire control table.

(*b*) As an aid to spotter :-
To assist Director Layer to keep on the correct target, especially during alterations of course, and when the target is temporarily obscured by smoke, splashes, etc.

Indirect Fire.-

(*c*) Single ship indirect fire :-
Which necessitates :-

(1) Providing a steady datum line.
(2) Training the guns from this datum line with minimum lag.
(3) Applying rate.
(4) Applying spotting corrections.

(*d*) Indirect fire from several ships :-
Which necessitates :-

(1) For sequence firing – all requirements mentioned in para. (*c*).
(2) For massed or Master Ship firing – as for (1), and in addition the datum lines provided in each ship should be comparable.

(e) Arrangements for pointing out targets.
For either direct of indirect fire.

II. Gyro Director Training Gear (Fig. 7_A).- This was the first arrangement designed, and owing to war conditions existing gear was made use of.

It is capable of dealing with all the above functions, but a large number of relays have been employed as shown in Sketch I. Each relay detracts from the accuracy of the gear.

The tyro datum line employed (Sperry Compass) is of the "fixed azimuth' type and is situated below.

Note.- Reports from fleet show that G.D.T. gear as at present fitted is not sufficiently accurate in bad weather, and the backlash due to relays will cause a large proportion of rounds missing for line except under the best conditions.

III. Layer's Telescope.- The layer's telescope was originally designed by Professor Henderson to compete with functions (*a*) and (*b*), paragraph I.

Only two relays are employed between the Gyros and the guns as shown in Sketch II.

The Gyro is situated aloft and is precessed according to the bearing rate, so that its axis should always be pointing towards the target.

IV. Future System.- (To be used in conjunction with the new Fire Control Table.)

The present intention is to make use of a "fixed azimuth" gyro situated below.

Only two relays need be employed as shown in Sketch III.

V. Improvements to Existing Ships.- The conclusion reached from the result of "Valiant's" trials is that the layer's telescope is more accurate than existing gyro director training gear for :-

(*a*) Measuring the bearing rate.
(*b*) As an aid to spotter.
(*c*) For single ship indirect fire (if suitable arrangements can be provided for applying spotting corrections).

The reason why it performs these functions with greater accuracy is because fewer relays are employed.

The gyro has a level control and so has a much slower rate of wander than the sperry against which ti was tested.

Note.- The Henderson modification to the sperry will give the slow rate of wander to the sperry.

VI. Neither the layer's telescope nor gyro director training gear have as yet been tested for (*d*) Indirect fire from several ships.

Although single ship indirect fire may be useful for detached ships, the former problem must be solved if indirect fire is to be carried out in a Fleet action.

In view of the great advantages which would accrue to a Fleet whose ships were capable of carrying out simultaneous indirect fire, it is considered that the final solution of this problem should be the ulterior motive of all improvements and trials in existing ships, so long as the efficiency of single ship firing is not impaired.

VII. The "fixed azimuth" gyro principle (*i.e.*, gyro compass below) is believed to be the most promising method :-

(*a*) Because there is less difficulty in lining up on the target to start with.
(*b*) Because a large gyro situated below can be employed, which is likely to be more accurate that a small one aloft.
(**Note.**- An equal number of relays are required in each case.)
(*c*) Errors due to bearing rate do not come in.
(**Note.**- If the layer's telescope were used for concentrated indirect fire, intercommunication of the bearing rate would be necessary.)

This is one of the principal arguments in favour of adopting the "fixed azimuth" principle for the future design apart from the other advantages of a master gyro system.

VII. Trials in H.M.S. "Rapid."- Trials of various types of "fixed azimuth" gyros have now been carried out in H.M.S. "Rapid," from which it appears that a Sperry Compass with Professor Henderson's modification provides the best available datum line for armament purposes.

It was apparently unaffected by rolling and alterations of course ; the maximum rate of wandering under all conditions did not exceed three minutes of arc per minute of time.

The relative wandering between similar datum lines in several ships (of a Squadron) might be even less.

Four sets of this gear are now on order and are to be fitted to four 15 in. ships.

The arrangements in these four ships would, therefore, be as shown in Sketch IV.

It would be observed that fewer relays are employed by using an Altham Receiver for this purpose than if the necessary dials were fitted to existing gyro director training gear.

This arrangement can only be regarded as a temporary one owing to:-
(1) Complication of the director tower.
(2) Difficulty in applying bearing rates and spotting corrections, but it will provide whatever ships are fitted with the best arrangements at present available for performing the functions required of gyro training gear, and should enable experimental work to proceed on the right lines.

IX.- The principles put forward by the fire Control Table Committee are concurred in by the Conference, and further action is recommended as follows :-

(*a*) To fit four Altham Receivers in the alfot director towers of the 2nd Battle Squadron ships, in order to provide a datum line for use in employing Henderson's Layer's Telescope.

(b) To carry out aiming trials of G.D.T. Gear (Sketch I) in one ship of the 2nd Battle Squadron as soon as the Henderson Controlled Sperry Master Gyro Compasses are fitted.

X.- The system proposed in Sketch III may eventually be fitted in existing ships for trial, but it is desirable to press on with such experiments as can be continued with existing gear in the meantime, and it is not considered that the advantages of any system have yet been proved sufficiently conclusively to justify its installation on a large scale.

6. Gyro Turret Training Gear.- With reference to previous remarks on this gear, little further experience has yet been obtained, but it has been decided to equip all turrets in H.M.S. "Valiant," and also those in the Capital Ships selected for the trial of the new Main Armament Director Control Tower, which should be completed in 1922.

Owing to delay in manufacture the gear has not yet been installed in "Valiant." Correction for yaw and alteration of course will also be applied to the director control tower to be built for trial.

7. Local Director Sights.- It has been approved in principle that for all future power worked mountings gun-sights shall be dispensed with and one local director sight for each turret shall be substituted.

The local director sight will be similar to aloft director sights as regards elevation but will be fixed to the turret for training, having provision only for application of deflection ; thus the trainer at the local director sight will actually train the turret, while the layer's will operate elevation receivers at the guns.

The sight will be as simple as possible in design and such complications as Henderson Firing Gear and Cross Laying Gear will be omitted. (G.4249/21.)

The advantages of this system over previous ones are :-

(*a*) Reduction of material provided for alternative methods of fire, one local director sight being provided instead of 4 gun-sights and an open director sight in twin gun turrets, and a proportionally greater saving where triple turrets are adopted.

(*b*) Better protection to turret and crew in that holes in roof of turret are reduced in number.

(*c*) Better watertightness.

(*d*) Saving of personnel in sight setters.

(*e*) Simplification in training of personnel, as the number of men who have to be taught individual laying will be reduced.

(*f*) Better facilities for using simultaneous firing of all guns in a turret if required.

(*g*) The local director sight can be placed close to the officer of the turret, who will be provided with a look-out hood.

The disadvantages are :-

(*a*) If the local director sight is damaged, means of firing any gun in the turret in local control are lost. This is not likely to occur unless the turret armour is defeated ; the periscope if damaged can be replaced.

(*b*) Difficulty in finding a suitable position for the local director sight which will be clear of wooding both from guns at all elevations and from ship's structure. This is not serious, however, and only means the loss of a very few degrees on one extreme bearing.

As these disadvantages only occur when the primary director circuits are damaged they were considered to be of too small importance to outweigh the advantages gained.

Experiments are now being carried out with periscopes in order to obtain a suitable periscope which will look through the side armour in the case of heavy turrets, and which will not suffer from the deficiencies experienced in older pattern gun-sighting periscopes due to loss of light.

There is every reason to suppose that a much improved type of periscope has been designed, and trials are to be carried out.

The use of a periscope with the local director sight has great advantages in reduction of size of holes in armour.

8. The Director Control Tower.- The director control tower is a combination of the director tower and the spotting top and is to be tried in a Capital Ship and H.M.S. "Enterprise." It is to be embodied in the design of the new capital ships.

(G.0386/21.)

Drawings of the general arrangement for heavy ships are shown on Fig. 8.

(G/01307/20.)

Arrangements for Light Cruisers and 2nd Armament of Capital Ships are generally similar, but in the latter provision is only made for two control officers and the rangefinder is of 12 ft. instead of 15 ft. base, and is mounted out of the centre line.

The advantages to be gained by combining the director tower and the spotting top are :-

(1) All the essential observes are trained together in one tower, thereby avoiding necessity of aids to spotting, etc., giving greater comfort to control officers, and providing greater certainty that director, range-finders, and all control officers are on the same object.

Sir James Henderson's method, on the other hand, effects a compromise as regards elimination of errors due to the two causes, and by this compromise he hopes to limit errors to something of the nature of 10 ft. or arc as a maximum. Sir James Henderson, however, considers that any gyro for producing a horizontal datum line should be connected up to an optical instrument from which a clear view of the horizon can be obtained, so that the accuracy of the gyro can be checked and adjusted from time to time.

11. Cross Levelling Gear.- This gear has now been fitted to the following ships :-

"Hood." Aloft and armoured director.
"Ramillies." Aloft director.
"Dauntless."
All repeat "W" Class Destroyers.
10 older Destroyers and Leaders.

and in addition, the original, made up for light cruisers, was converted into a working model and fitted in "Curacoa" (now in reserve.)

In the case of the first 11 vessels of the repeat "W" Class, the cross levelling correction is applied direct to the transmitters operating the training receivers at the guns, and is therefore not apparent to the director layer. In all other ships, including the remaining seven of the class, *i.e.*, "Wanderer" and vessels still building, "Wren," "Witch," "Whitehall," "Worcester," "Keppel" and "Broke," the correction is applied direct to the director sight, so that the application of the cross levelling correction is apparent to the director layer.

2. Further comparative trials have been carried out between the two methods of application as fitted in "Wild Swan" and "Mackay," but the results were not conclusive, trials so far having on been carried out under easy conditions. The result of the trials showed that, when cross levelling corrections are small, there may be advantages in applying the correction direct to the guns, and avoiding disturbing the director layer and thereby reducing the rate of fire. Under more difficult conditions, it is probable that many bad shots will results from this method, owing to the inability of the guns to follow their pointers, and to the director layer being in ignorance of the difficulties of the gun trainers. Further trials are to be carried out between two ships of the repeat "W" Class, where the director system fitted is identical except as regards application of cross levelling correction, observing that at the previous trials "Mackay" had the older and less complete type of director system, whereas "Wild Swan" had the later installation.

It appears from a later report that at the time of this trial "Wild Swan" had a considerable amount of backlash in her director sight, which would affect "line," and investigation of this defect as in fact shown that the design of the gear as now fitted is defective and needs to be reconsidered. This matter is now in hand.

3. Firing trials carried out by "Dauntless" confirm the necessity of cross levelling gear, but it was found that the rate of fire was reduced as a result of using it ;

this was partly due to inexperience of the cross levelling operator and shows that practice with the gear is essential.

4. It has been approved to fit a different form of cross levelling gear for trial in “Valiant,” in conjunction with automatic gyro turret training gear.

This will be done by canting the constrained gyro situated below the armoured deck fro gyro turret training control, so that its axis is elevated and trained to be parallel with the axis of the guns.

Cross levelling correction will then be applied automatically to the training of the turrets. Unless, however, the cross levelling correction is also applied to the director sight aloft, the displacement control (by which all turrets automatically follow the director pointers) will be in opposition to the application of the cross levelling correction. It is therefore necessary to fit cross levelling gear to the director sight aloft in “Valiant” as well.

“Valiant” is also to be fitted with a Henderson’s Layers Telescope Mark II, with means for transmission of the stabilised line of sight to the turrets by director receivers, consequently the turrets will be stabilised in space (including cross levelling corrections), and the director will be similarly stabilised, so that the two should work together satisfactorily.

(b) Similarly, Henderson’s Layer’s Telescope could not be adapted to operate the training and slewing transmitters.

(c) The method of applying cross levelling correction direct to the receiver in turrets would cause instruments to get out of step under extreme conditions of elevation and roll.

(d) Similarly also the practicability of the director control tower will be largely dependent on Carslake Synchronous Gear for the following reason. The D.C.T. trainer merely controls the training engine, and therefore movement of his hand wheel is a measure of rate of training and not of amount of training. Consequently his hand wheel can no longer directly operate the director transmitters, which therefore have to be geared to work off the training rack. This would have introduced great difficulty had it still been necessary to unclutch the training gear before slewing the D.C.T. As explained in paragraph 3 above this, however, will now be unnecessary.

Without auto synchronism it would be necessary to have the director trained by hand entirely independently of the tower as in existing armoured towers.

5. Two sets of this gear will be fitted in H.M.S. “Valiant” and “Revenge” for trial. A further set will be fitted for trial in conjunction with the new director control tower.

7. A recent French invention of Auto synchronous transmission has been brought to the notice of the Admiralty through Messrs. Elliott, who hold the rights of this invention in England. Complete instruments are not at present available for trial, but if this device is favourable it would cover all of the advantages above mentioned in paragraph 4, owing to the high speed of transmission possible ; it would also obviate the necessity of having two motors, one for training and one for slewing, and the receiver could be similar to existing elevation receivers with two pointers geared off one receiver motor.

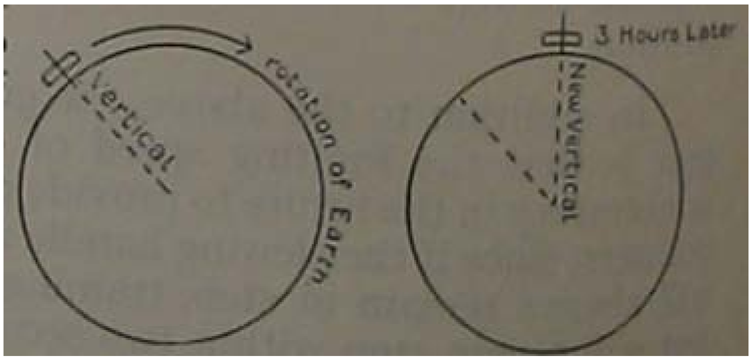
For the purpose of changing over from one control position to another some form of Carslake’s device would, however, be necessary.

10. Gyroscopes for giving a Vertical Datum Line.- No definite progress has been made in design of gyros to give a horizontal datum line.

Dr. Gray’s Gyro (previously referred to) has been given a trial at sea, but did not meet requirements, being upset by alterations of course and other factors. Sir James Henderson also has a design of gyro for this purpose, but is not at present ready to submit his instrument for official trials.

The difficulties of the problem may be explained briefly as follows. There are two factors to contend with:-

1. Rotation of the Earth.- To maintain the horizontal accurately the gyro must be made to wander in space in order to allow for rotation of the earth and to keep normal to the earth as is shown by attached diagram. This is further complicated by any movement of the ship (or aircraft), *i.e.*, if the ship is steaming east or west.



This compensation can be easily arranged be means of a gravity control, but such a control presents difficulties due to :-

2. Alteration of Course or Speed of the Ship.- This in effect upsets the vertical as far as gravity is concerned, *i.e.*, a plumb line would not remain vertical while ship is altering course or speed, and in order to avoid large errors from this cause the gravity control must be small. Consequently a compromise has to be made.

Dr Gray is still carrying out experiments on his own device, and it is anticipated that further trials will be carried out during the present year with either Sir James Henderson's Gyro or Dr. Gray's, or both.

Dr. Gray's method of dealing with the problem was to temporarily lock the controlling mechanism during alterations of course.

(2) Owing to the heavy tripod mast being dispensed with, a small amount of weight is saved in spite of the direct control tower being armoured with splinter proof armour (2 in. and 1 in.), and the director control tower being mounted on the top of the bridge structure, approximately 100 feet above the water line.

(3) Having all the essential observers in one tower also facilitates the application of gyroscopic inventions for eliminating effect of yaw, so that one instrument will eliminate yaw from the director layer and trainer, the rangefinder, and all the control officers.

The director tower already fitted in H.M.S. “Hood” also carries a 15 ft. range-finder and is trained by power (Williams Janney), and is therefore an intermediate step between the old director tower and the new director control tower. Trials of the power training in “Hoods” tower have so far been very satisfactory, and show that the control of the power training is sufficiently delicate to enable range-taking and director firing to be carried out without independent training of the rangefinder or director sight.

Provision is being made in trial director control towers for independent training of both the director sight and the rangefinder, but if the power training and gyro-scopic control meet expectations, independent training of the rangefinder may be omitted entirely in the future, and possibly also independent training of the director sight, but this latter will depend upon a further series of trials to be carried out on the proposals of the Fire Control Table Committee to apply all deflection including cross levelling in the transmitting room, so that it is never put on the director sight.

9. Carslake’s Auto Synchronous Transmission Gear.- 1. This device is mainly an electrical device, and further details will be found in C.B. 1569, “Annual Report of Torpedo School,” 1919, pages 244 to 246, and in “Vernon’s” Quarterly Letters to the Fleet.

Mention is made, however, in this book owing to the great importance of this invention from the point of view of director receivers.

2. Briefly the arrangement is such that the director training and elevating wheels on the director sights operate one side of hunting switches which control motors situated in the transmitting station. These motors in turn drive the transmitters of the director slewing, training and elevating circuits to the various director towers and turrets, there being separate transmitters for each of these positions. The other side of the hunting switches in the director tower are centred by repeat receivers in this position.

3. What is claimed for this invention is :-

Possibilities of instruments going out of step are reduced, and in particular on changing over from one position to another no lining up is necessary and on putting over the change-over switch all receivers will automatically line up to new controlling position.

In addition to the above, the great advantage from the point of view of director gear is that the limiting speed of transmission can be ignored, and it should be unnecessary in the future to provide clutch gearing between the slewing and the training pointers, since if the slewing handle always drives the training handle slewing receivers will always remain in step, training receivers will get out of step while slewing fast, but will regain step within two seconds of stopping the slewing wheel. The training repeat indicator will show at any time when the speed of slewing is too great for the training repeat to keep in step, and also will indicate when step has been regained.

An incidental advantage of this gear is that each turret and director tower is electrically separate and consequently damage to the circuits in one position will not affect the remainder.

4. Without this device it would be difficult, if not impossible, to utilise several of Sir James Henderson's inventions, *i.e.*:-

(*a*) Application of velocity control to the director tower (to allow for motion of ship in alteration of course and yaw) could not be adopted owing to the certainty of instruments getting out of step if velocity of alteration of course exceeded a certain limit.

Bearing rate, etc., is also applied to the director line of sight, and the turrets automatically follow due to displacement control.

This method of application will only suit power worked mountings fitted ith gyro turret training control, and involves the use of an additional constrained gyro situated below the armoured deck.

If this device proves successful it will be used in new Capital Ships in conjunction with the new Fire Control Table and provision for indirect fire.

5. There is no doubt whatever as to the necessity of having some means of correcting for errors due to cant of trunnions, and as the elevation of the mounting increases so the need increases ; for example, with a 45º mounting, firing at extreme range right ahead or astern, the error in deflection is exactly equal to the list of the ship, *i.e,* if the ship is listed 1º to starboard when a salvo is fired, that salvo will miss by 1º to the right if no correction is applied.

Under extreme conditions of bearing and 15º of roll each way it would be possible for the cross levelling correction to vary at the rate of 6º per second in a Capital Ship, which is not only more than any gun could follow, but also causes risk of the pointers getting out of step due to speed of transmission. It may therefore be necessary to limit the speed at which the cross levelling correction is applied down to that speed at which guns can follow the pointers, and under extreme conditions of roll, range and bearing, accuracy of cross levelling correction would not be obtained during certain parts of the roll and some means would have to be provided for informing the director layer when the correction was **not** being applied.

6. Another consideration in the problem of application of cross levelling correction is that of Indirect Fire. With existing G.D.T. gear, cross levelling correction cannot be applied unless direct to the training receivers at the guns. If, however, indirect fire s being carried out by means of Henderson's Layer's Telescope the cross levelling correction is included, whether applied to the sight or to the training receivers direct.

7. The policy at present is as follows :-

(*a*) **Modern T.B.D.s** are already provided for, and it is not proposed to provide for older ones at present.

(*b*) **Existing Light Cruisers** (with 30º mountings) to be fitted with cross levelling gear as in "Dauntless."
Money has been approved for supplying certain ships during the current financial year.
Existing Capital Ships. Two sets to be provided, one for "Valiant" and one for trial on the sight fitted in the new Director Control Tower, to operate the director sight direct, and for trial in conjunction with automatic gyro turret training control.

Supply for remaining ships to be deferred pending results of further trials.

(*c*) **Future Ships.** To be fitted with some form of cross-levelling correction for the director system ; the type will possibly follow the lines indicated in the final clause of paragraph 5, but will depend on results of further trials.

Note.- As stated in paragraph 2, recent investigation has shown that existing design of cross levelling gear is defective and therefore, until this is remedied, no further sets will be ordered.

SECTION IV.

PROGRESS IN EXTERNAL BALLISTICS.

12. Computation of Range Tables.- The method referred to as Bennet's turned out, after making enquiries through the U.S. Naval Ordnance Department, to be Moulton's method, which has already been considered. It appears unlikely that any further simplification of the step-by-step method of computing trajectories will be made, and the quest for one has been given up. The computation of range tables by present methods is regarded as the application of an elaborate formula to firing results that the formula does not quite fit. This is shown by having to use a variable value for the factor "$K\sigma$ " in the ballistic coefficient. Failing a more rational formula, the next best thing would appear to be a frankly empirical formula that has the merit of fitting results and does not require step-by-step integration. There is a suitable formula on a rational basis for small elevations, but one that would be of general utility has not been suggested.

13. Motion of Projectile in Flight.- The theoretical results of the trials carried out at Portsmouth in 1918 and 1919 have now been published in the Philosophical Transactions of the Royal Society, Series A, as a separate pamphlet entitled "The Aerodynamics of a Spinning Shell," by R.H. Fowler, E.G. Gallop, C.N.H. Lock and H.W. Richmond, F.R.S. Methods of obtaining and solving the equations are given. It is hoped to confirm the results by further experiment, but, in any case, before we can make practical use of such formulae, the initial disturbance that starts the wobble should be determined.

14. The Principal Problem.- The theoretical solution, or partial solution, given in "The Aerodynamics of a Spinning Shell" has been the subject of a certain amount of argument between well-known mathematicians, and it is rather beyond our powers of comprehension. So far as it is understood, it is not complete in the sense that the nature of the impulse that starts the yaw is not known. There are several theories as to what this is, and further experiments have been proposed to elucidate the matter. The difference between Prescott's treatment of the initial disturbance (see *Philosophical Magazine*, Vol. XXXIV, p.332) and Fowler's treatment is not quite clear, no whether either method would account for Dr. Mann's experiments with rifles.

Fowler's paper (for short) was criticised by Sir James Henderson and Professor Burnside, who considered that he had omitted one force, namely, the friction couple set up by the rotation of a shell in the air ; a couple similar to the friction couple at the point of a spinning top. Henderson and Burnside argue that this couple is important, since, on the analogy of the top, it is essential to have a rough blunt point so that the force will be large and the precession damped. Fowler's argument is, roughly, that the couple referred to by Henderson is comparatively unimportant and the experimental results can be adequately interpreted otherwise. The paper was referred to the Royal Society for Professor Lamb's arbitration. The latter agreed generally with Fowler's solution, but he did not think that the experimental results were good enough to establish definitely the various damping forces. To be able to argue backwards from the results to the causes producing them requires a high order of consistency between calculation and observation, and the experiment was too rough for this. We are, therefore, still uncertain about Henderson's couple and Fowler's damping forces, though in the main it may be taken that Fowler's solution is a good representation of the facts. On reading the paper, one cannot help remarking upon what has been achieved a small cost from such a simple experiment as firing a few rounds of 3 in. through jump cards on a 600 ft. range which a chronograph. Permission was given to publish results, which is good for progress in these matters.

The initial disturbance.- In last year's number this was called the "muzzle force," but the term "initial disturbance" used by others seems preferable and will be used in future. Experiments to determine the nature of this disturbance have been devised and put before the Ordnance Committee in December, 1920, but since they require rather special arrangements, which are indicated in paragraph 29, some time must elapse before we shall know what the initial disturbance really is.

15. Resistance of the Air.- The new ballistic range at Shoeburyness will be completed this year, and the solenoid chronograph will be used on it. The statement in the last number, that the resistance of the air forms the basis of the ballistic tables from which the range tables are calculated, does not imply that when we obtain a precise determination of the resistance as a function of velocity, yaw and shape of projectile, we shall therefore be able to construct more accurate range tables, because the value of the yaw throughout the trajectory is not known. In other words, it will still be necessary to determine the range-elevation for a gun by experiment. Moreover, the firing will have to be a series of different elevations, because the range obtained at one elevation is an insufficiently accurate criterion of the range that will be obtained at another. Nevertheless, it is important to determine the laws of air resistance, especially the elasticity corrections, and the effect of the external contour of the projectile.

Wind channel.- Mr. Dobree's design of quick acting valve for the discharge of air from a reservoir at a pressure of 120 lb. per square inch was completed by the Ballistic Air Resistance Committee in April, 1921, and is now being made. A compressor for charging the reservoir has also been obtained and small scale experiments will be carried out at the national Physical Laboratory. The idea of constructing a high velocity wind channel at Cambridge has fallen through on account of the noise of the exhaust, and under the present financial conditions it seems doubtful if this wind channel will materialise for some years to come. We have no information of what is being done in France and America.

16. Grain Island Range.- Steady progress is being made. It may be possible to use it for 7.5 in. and 6 in. guns this autumn, and it is ho[ped that the range will be completed by June, 1922.

17. Allowance for Meteorological Conditions.- Experiments are about to be carried out in H.M.S. "Canterbury" with a view to determining the wind at various altitudes from a ship by firing a high angle gun and observing the drift of the shell smoke with a stabilised mirror. More accurate weighting factors than those given in the Gunnery Orders of December, 1918, are being computed by the Meteorological Section at Shoeburyness.

18. Allowance for Rotation of the Earth.- Mr. Gallop's paper has been studied. His formulae are not in a form for direct application, because certain functions he uses are not given in the range tables. The formulae have been approximated to by other formulae which will be published, but for ordinary purposes the Gunnery Manual formulae are good enough. Sir James Henderson has examined Mr. Gallop's work and considers the corrections should be half, or possibly less than half, those given by Gallop's formulae. It is difficult to know what to advise when eminent scientists differ, and the question cannot be settled by a simple experiment. The matter will be given further consideration when the Grain Island range is ready for firing.

19. Photographic Range.- A 50 ft. range in the form of a tunnel to exclude the light is nearing completion at the National Physical Laboratory. The idea is to study the laws of air resistance by photographing a 1 in. shot in flight. The experiment should be an advance upon the methods hitherto employed with rifle bullets.

20. Loss of M.V. with Wear.- The cause of the sudden jumps in velocity of the cordite proof guns has not been established, but he wear and ballistics trials being carried out with some L.S. guns, in the course of which some thousands of rounds will be fired, may throw light on this question. The statistics of velocity, wear and E.F. rounds referred to in last year's progress have now been plotted. The published data for loss of M.V. is, generally speaking, in fairly good agreement, and no material revision will be necessary. The impracticability of estimating M.V. from a measurement of the wear on board a ship is apparent, but there seems to be no reason to suppose that basing estimates on the E.R. rounds fired is any less accurate : rather the reverse. The problems that concern us most, however, are (i) whether cordite proof data for loss of M.V. is the best guide, (ii) whether the introduction of tinfoil will alter the relation obtained before its use, (iii) how can the data be provided by the time that a new type of gun gets afloat, and (iv) how many guns and how many rounds must be fired to fix the mean relation sufficiently accurately. The above needs to be considered together with (v) how many guns and how many rounds should be fired to obtain a reliable range-elevation relation for the range table and R. and E. scales. The whole really amounts to defining what is necessary in the way of experimental firings for the determination of complete range table data, so that we have, not merely the range-elevation relation for a new gun, but a knowledge of the ballistics of the gun throughout its useful life. This aspect of the problem is dealt with in Article 21, pages 25 and 26.

21. Ballistics of Projectiles.- The relative ranging of recent types of 7.5 in., 5.5 in. and 4.7 in. projectiles has now been determined and the results published. Representative mixtures for H.E. and powder-filled shell have been brought into use for weighting projectiles, and, so far as can be seen, the relative ranging as determined at Shoeburyness is now truly representative of what may be expected with filled shell afloat. The policy of designing in the first instance the various natures of projectile to range the same at a selected fighting range for the gun has been adopted for all calibres down to 3 in., and in certain cases where there were found to be large differences in ranging the designs of existing projectiles are being altered and future supplies will be to the new designs.

The weighting of shell converted to practice with the new H.E. or powder substitute necessitates the provision of special plant at the depots for boiling the pitch used in the H.E. substitute. There are large numbers of these old shell that have to be used up for practice, and for the present endeavour is being made to fill as many as possible of the H.E. shell as Woolwich, where the plant exist, and to supply sufficient practice shot, or shell filled with the new substitute, for the allowance of full charges for practice. Any difference cause by the old method of weighting with sand and shot is less when firing with a reduced charge, and it will also be less with a small cavity shell such as an A.P.C. It should, of course, be understood that with shell converted to practice the difference in ballistic coefficient should be taken for the type and mark of shell that the projectile was before conversion. A converted shell should not be regarded as a practice shot which may range quite differently.

Generally speaking, the information with regard to the relative ranging and drift of projectiles is not quite as complete as is desirable. The 6 in. gun is the worst case : the data for the more important calibres and marks of shell is good, but we want to wait until the Grain Island range is ready before re-determining ballistics on a large scale so that it can be done at ranges above 16,000 yards. A range for each type of gun has been selected as the critical fighting range at which different natures of projectiles should be designed to range the same. They cannot be made to drift the same, and small differences in range at other ranges will have to be accepted.

Difference in M.V. of different Projectiles.- In last year’s number, the difference in M.V. which has been observed in some cases between proof shot and shell or between different types of shell was considered fictitious, because there was no apparent reason why shell of the same weight and same driving band should give different M.V.s with the same charge and gun. It was put down to the error of method that exists in determining M.V.s by the Boulange chronograph, but it has been pointed out that in another experiment it was found that the pressures confirmed the difference in velocity, and that the difference in velocity and pressure may be due to a difference in the yield of the shot or shell. This seems reasonable, and the previous opinion is therefore cancelled. The matter is only of consequence in allowing for M.V. and B.C. differences determined at one range when firing at another, and since, in any case, the figures given cannot be expected to hold precisely at all ranges, the practical consequence as to whether the whole difference in range observed in the trial is put down ot B.C. or partly B.C. and partly M.V. is small.

Re-determination of Ballistics for revision of Range Tables.- In the last number it was considered desirable to defer the re-determination of ballistics for revision of range tables until the Grain Island range was ready. Since then, practices afloat and some trials at Shoeburyness, which were called "Endurance and Ballistic Trials," have indicated the desirability of making a start with the smaller guns for which the Shoeburyness range is adequate. Moreover, it is probable that information obtained from small guns would be of advantage later in drawing up a programme for the larger guns. The following is the proposal at present under consideration. It will be seen that it aims at an all-round improvement in the accuracy of ballistic data. Generally speaking, no radical improvement can be obtained without a considerably larger expenditure than was hitherto considered necessary.

First of all it is necessary to obtain some idea of what expenditure will be required. A good deal, of course, depends upon whether it is essential to wear out one or more guns for the special purpose of determining a wear curve. Some ballistic and wear trials with L.S. guns that are nearing completion may indicate this, but in case they do not, a programme has been sketched out for 4 in., 4.7 in. and 5.5 in. guns with a view to seeing:-

(*a*) How closely the average gun can be expected to shoot to a range table, allowing for loss of velocity according to E.F. charges fired, and, or course, for the meteorological conditions, etc.

(*b*) How many rounds (or guns) should be expended in determining the range-elevation and velocity-round relations for the precision of the data to be consistent with (*a*).

(*c*) Whether it is advisable to determine the velocity-round relation at Shoeburyness instead of using cordite proof statistics from the point of view of obtaining a better guide.

The idea is to fire two of three guns of each calibre under strictly comparative conditions, in some cases up to 1,000 rounds a gun. The guns have been selected so as to obtain comparisons in the case of those in which we think we have goo range tables and adequate cordite proof data, as well as in the reverse case. From the practical point of view of getting several guns of the same calibre to shoot together afloat, it seems an important point to know just how closely they can be made to shoot together on an experimental range on shore with every refinement. The same, or course, applies to knowing how closely two calibres with recent range tables will shoot together, and, generally, to form an idea of the value of ballistic data such as it is.

Future Policy.- Besides the objects of the trial indicated above, it appears desirable to initiate a new policy on the introduction of a new type of gun, and we want to know whether this will be practicable and of any advantage. The following is what is under consideration at present (June, 1921) :-

(*a*) To determine complete ballistic data on the introduction of a new type of gun before the gun gets afloat.

(*b*) To improve ballistic data by firing under service conditions as to gun, mounting, ammunition and rate of far so far as is possible at Shoeburyness, also by firing more rounds and using two or more guns if necessary. This will also provide a good test of the mechanism and mountings under prolonged rapid fire.

(*c*) To apply the principle of standardisation with regard to projectiles as is done in the case of charges : to determine the ballistics of different types of gun on a more strictly comparative bases, and, generally, to maintain continuity of ballistic data.

(*d*) To design different natures of projectile to range, and so far as practicable, to drift the same as a standard projectile for each type of gun at the selected fighting range for the gun.

The idea underlying (*c*) and (*d*) is to adopt a standard projectile for each gun on which the range table will be based and sights graduated, and against which all other natures of projectile, or new designs that come forward in the course of time, will be fired. Also, in determining the ballistics of one calibre of gun, it is proposed to try firing it against a gun of another calibre, or “control” gun, whose ballistics are well established. This may afford some sort of check, and should, in a sense, maintain continuity from calibre to calibre as well as from shell to shell of the same calibre.

Shape of Head of Projectile.- From the ballistic point of view, a precise definition of the shape of head is of little consequence because different natures of shell with identically shaped heads do not necessarily range the same. In fact they generally differ. Therefore, designing them to range the same generally requires different shapes of head. Moreover, nose fuzes, caps and other considerations preclude the heads of all natures having a simple geometric contour. A precise definition of the contour of the head is, of course, necessary for purposes of design and manufacture, and new definitions were recently introduced for such purposes. For practical purposes, however, it has been decided to retain the old nomenclature by which ballistically different projectiles are known as 2, 4, 6, or 8 c.r.h., although these numbers do not precisely define the radius of the contour. All that is wanted for practical purposes is to divide up the projectiles that have radically different ballistics into different groups. Those in the same group and of the same calibre have, or should have, the same ballistics. At the present time there is little possibility of confusion, because nearly all guns are equipped with 4 c.r.h. projectiles alone. These are denoted by having the letter "A" following the mark of the projectile. The 6 c.r.h. has a "B" and the 8 c.r.h. a "C," thus, if the stamping on the base is "H.E. IA," we know that it is a 4 c.r.h. projectile, and the range table and gun-sights should also be marked 4 c.r.h. In other words, the thing to go for is the letter A, B or C, and not attempt to decide what the projectile is by measuring the radius of its head.

Manufacturing Tolerances.- The limits decided upon in the last number for the heavier natures refer to projectiles for 12 in. guns and above. For projectiles below 12 in., it has now been decided to double the limits given for 12 in. and above. This should give amply sufficient accuracy from the ballistic point of view, and, so far as can be seen, the manufacturers will be able to keep within the limits proposed.

Reduced Clearances.- Further experiments in this connection have been included in a programme referred to further on.

Rifled Shell and Hyper-Velocity Guns.- No results to report yet.

22. **Experimental Range Equipment.**- When the recording apparatus that we have been in quest of since 1917 had been designed by Mr. F.E. Smith, F.R.S>, and preliminary trials had indicated that the various instruments and methods would function correctly, the requirements for both land and naval ranges were put before the Ordnance Committee in December, 1920, together with an outline programme for the development of the apparatus and for the determination of the causes of dispersion and certain empirical ballistic relations referred to further on. The Committee agreed with the programme in March, 1921, and the development of the solenoid chronograph and the construction of a special sub-calibre range, required for part of the programme, is now under consideration.

Solenoid Chronograph.- Early in 1920, Mr. Smith made a change in the method of using his chronograph. Instead of energising the coils, the shell are transversely magnetised before firing. Besides experimental simplification in doing this, it enables the position of the shell in space to be determined as it passes through each coil. By another invention of Mr. Smith that was made and tried in October, 1920, single wires run parallel with the trajectory for the first few hundred feet instead of solenoids. By this arrangement it is possible to record each revolution of the shell, from which the velocity can be determined. It also gives the position of the shell in space as it travels along its helical path, and the inclination of its axis or yaw from instant to instant. For velocities alone only one wire is necessary ; the other items require four wires. By this arrangement it will be seen that the chronograph has now been developed into an apparatus that completely determines the velocity, angle of departure and yaw : in fact, it gives all that we want to know of the initial portion of the trajectory and the motion of the shot in flight. This constitutes a great advance on the elementary methods of jump cards and Boulange chronographs.

In December, 1920, Mr. Smith gave the conditions for critical damping of the galvanometer strings and critical damping has been obtained in practice. In March, 1921, he gave formulae for determining the displacement of the shot from the centre of the solenoids, but these formulae have not yet been confirmed experimentally. The solenoid chronograph has been in use fro determining the velocities of shell fragments and the times of ejection of the shots from the muzzles of the guns in the "Lord Clive" experiments. Further experiments are being made by the Ordnance Committee.

Recording Velocities on board a Ship.- If the ship is alongside, solenoids or the parallel wire method can be used, but for determining velocities without apparatus beyond the muzzle, as in a ship under way, there are now the following methods :-

(*a*) Coil, say, on roof of turret or on deck in the vicinity of the gun, using magnetised projectiles. Devised by Mr. Smith and tried in April, 1921. The rotation of the shot is recorded, which gives the velocity.

(*b*) Muzzle coil and breech contact giving time from commencement of recoil to ejection of shot. First tried in July, 1919.

(*c*) Time expansion wave along gun by solenoids at intervals. First tried in 1919.

The first seems a remarkable achievement : (*b*) was mentioned in last year's number, (*c*) is also being tried by the Americans. Both (*b*) and (*c*) are what may be described as "calibration" methods, because the relation between what is measured and the velocity will have to be established empirically for each type of gun. A string galvanometer and electrically maintained tuning for is used in all these methods.

23. Angle of Departure.- Besides the instrument referred to in the last number, there is now the 4-wire method mentioned in Article 22, "Solenoid Chronograph," page 27. With both instruments it should be possible to determine the angle of departure (elevation and line) and to determine the separate effects due to jump, whip, droop, throw-off, etc. These instruments also feature in the programme in connection with the initial disturbance and the causes of dispersion.

Origin of Trajectory in undisturbed air and actual M.V.- The first is important to know so that chronograph screens or solenoids can be put at the right distance. The second is required in connection with the methods of determining M.V. given at (*b*) and (*c*) in Article 22, "Recording Velocities on board a Ship," page 27. both are included in the programme.

Causes of Gun Dispersion. – Suitable recording apparatus having now been designed, we ought to be able to determine the primary causes of dispersion in the fall of shot, and proposals to do this have been put before the Ordnance Committee. For the purpose of the proposed experiments, the primary causes are assumed to be variation from round to round in the M.V., in the angle of departure, and in the retardation in the initial part of the trajectory due to variable yaw. It is thought that these things could be determined by firing an ordinary gun at Shoeburyness. The secondary causes of dispersion have been taken as engineering limitations in the design of gun, mounting or projectile, such as droop, jump, clearance and balance of shot. For determining these causes and their effects, a special range, specially designed small calibre guns, mountings and ammunition have been proposed, and the Committee are now considering the question of providing the range.

Empirical Ballistic relations.- As the principal problem in ballistics has not been solved, gun, projectile and gunmounting design is rather in the dark. We want to know roughly the best twist of rifling, the best weight of shot, and any characteristics of the gun and mounting, such as droop and jump, that affect dispersion. Design has had to be based upon such experience as is available. True, it is a process of trial and error, but in practice the process cannot be carried far enough, as is evident from a consideration of the cost, say, of a single big gun, or even one round. Moreover, we now require good results at ranges beyond the 16,000 yards to which previous experience is limited by the range at Shoeburyness.

In June, 1920, it was considered that the chances of obtaining a solution to these problems by further theoretical research, or along the lines afforded by the wind channel, if or when it materialises, were rather remote. For the progress of research and tis application to design more experimental data is essential. The recording apparatus, for which the requirements had been foreseen at the end of 1917, had now reached the state at which successful development appeared certain. The obvious practical solution of determining cause and effect by means of sub-calibre guns was put forward on the assumption that results would either be directly applicable to large calibres, or that they could be satisfactorily interpreted with the help of an occasional full calibre experiment. The requirements in the way of a range, sub-calibre guns, and mountings, together with an outline programme of experiments, was drawn up in the latter half on 1920 and put before the Ordnance Committee in December.

The general idea is to design the experiments so that the various factors affecting ballistics, such as the velocity, pitch of rifling, spin of shot, weight, shape and moments of inertia, can be varied at will, and so that the other items given in the above paragraph (Causes of Gun Dispersion) as the primary and secondary causes of dispersion can be varied through large limits than would be practicable with service guns. The whole process may be regarded as firing sufficient rounds, which is rendered possible by the small calibre used, and ringing the changes with all the variables until definite effects can be associated with definite causes. In this way we ought at least to obtain the information required for practical application to design. The Americans have embarked upon somewhat similar experiments on a larger scale, using some of our instruments and methods. They have further to go, but from the fact that even in our case design is not on a rational bases, that we have no entirely satisfactory solution to the problem of calibrating, and from unaccountable results of practice that are sometimes experienced, it is evident that some experiments of the kind indicated will be useful.

24. Rapid Cinematograph.- It is expected that the trials of this apparatus will take place shortly. Enquiries are now being made about the Jenkins continuous motion camera, which is on a new principle, the lens being in the form of a glass disc rotating at constant speed.

25. The Solenoid Experiment of July, 1919,- The analysis of this experiment, more particularly the employment of the theory of error has been the subject of discussion. It was referred to two independent scientists, Messrs. R.H. Fowler and D.R. Hartree, who agreed with it generally, and the results, which were briefly indicated in the last number, may be taken as not far wrong.

Calibration.- There is nothing further to report in this connection, except a point that was noticed in "Lord Clive" trials which probably accounts for a cause of failure in calibrating on differences in range observed between guns. If the guns are worn to about the same extent, and only a few rounds be fired by each gun, their differences in range will be of about the same amount as the probable errors of their M.P.I.s. In other words, an observed difference in range of perhaps 50 yards may not be significant, and basing a correction upon it may be of doubtful utility, if not unreasonable. The amount depends upon the mean error, the number of rounds, and other things that can be taken into account by the theory of error. The best advice to make guns shoot together is for the present, to be guided by the loss of M.V. according to E.F. rounds fired, and not to apply other corrections unless a gun differs from others by more than, say, 100 yards on two or more occasions of practice.

Naval Range.- It is hoped to visit the site and prepare a lay-out this year, but in view of general financial circumstances the actual construction of a range may be somewhat delayed. The present scheme is to fire to the northward from the vicinity of Broadford Bay (Ross-shire).

26. Trial of Simultaneous Firing.- A trial to show the effect of simultaneous firing from triple gun turrets was commenced in February, 1921, with 15 in. guns specially mounted in the monitor "Lord Clive." The ship was moored off Shoeburyness, the range being 17,500 yards. The object of the trial is to compare two and three gun salvos (fired simultaneously) with single shot firing. A total of about 180 rounds will be fired altogether ; so far, about 8 triple salvos have been fired in comparison with about 8 rounds per gun fired singly, the remainder of the trial having to be postponed on account of a premature occurring in one gun. The results of the first portion of the trial given below are therefore provisional Previous trials with double gun turrets had taken place in the years 1907 to 1911, the results being rather inconclusive or interpreted as showing no increased dispersion with simultaneous firing. The Americans are stated to have put bad results down to the use of triple turrets, but examination of some of their recent experiments shows that their single shot firing is as bad as their triple salvos, the spread being about 700 yards in either case. Their experiments have also been rather inconclusive. We anticipated a small increase in dispersion with simultaneous firing ; and to study the consequences in any detail, it was considered essential to identify the shots from each gun and to record the instant at which each shot leaves the muzzle. The first was satisfactorily accomplished by using plugged shell in one gun, non-delay fuzed shell in another, and delay fuzed shell in the other, the experimental staff at Shoeburyness being able to distinguish the splashes of each kind without doubt. The relative times of ejection in "simultaneous" firing were accurately recorded by the solenoid chronograph, the solenoids being round the muzzles. Other recording apparatus that would have given the M.V., jump, and throw-off had to be dispensed with but the guns started new, were fired round for round and identification of the shots enables calibration errors to be eliminated.

The Results.- When fired singly, the mean error of range was about the same as is ordinarily obtained afloat, *i.e.*, 70 yards, the mean error expected from R. and A. trials at Shoeburyness being 40 yards. This increase is larger than expected, but it does not point to bad ammunition or bad laying. The lateral mean error was 6 yards, the same as usually found at Shoeburyness. In the first place, taking the salvos as a whole, it was found that the effect of simultaneous firing was :-

(i) To shorten the mean range by 72 yards.
(ii) To increase the lateral mean error from 6 to 24 yards.

The longitudinal mean error was in fact slightly smaller for the salvos than for the single shots, but after a more detailed analysis, which cannot be gone into here, he conclusion has been reached that in the long run the dispersion with simultaneous fire will be rather greater than with single shot firing, notwithstanding the actual result of these rounds. The analysis of the salvo firing also shows that while the first shot ejected in each triple salvo is not affected by simultaneous firing,

(iii) The second and third shots to fire have their range reduced by nearly 100 yards, and their lateral mean errors are materially increased.

It is thus the effect upon the second and third shots in order of ejection that shortens the mean range of the whole salvo, increases the lateral dispersion considerably, and will in the long run increase the longitudinal dispersion. The increase in lateral dispersion was so apparent in the trial because the lateral dispersion with single shots was small. On service, the lateral dispersion would presumably be greater and consequently the increase would not be so noticeable. From the limited results so fare obtained, it is considered that simultaneous firing will be acceptable.

It may be of interest to give here briefly the ways in which it is thought that one gun firing shortly after another may be affected. :-

(i) The initial disturbance that starts precession is increased either by the impact of blast on the projectile just emerging or by increased muzzle vibration. Result, increased and more variable yaw, consequently shorter range and larger longitudinal mean error.
(ii) Increase of the angle f departure by jump resulting in a longer range.
(iii) Throw-off in line of departure (as distinct from what is ordinarily called the throw-off of a turret which occurs after the shot has left resulting in larger lateral dispersion. From this firing the mean error of throw-off appeared to be ± 5 minutes.
(iv) The shot passing through the gun wave, or shot wave, of the first to fire might cause a small decrease of range.

27. Consequences of Coppering and Rusty Bore.- The Ordnance Committee have carried out a series of trials with 6 in. guns to investigate the cause of some erratic shooting that occurred afloat. The bores of the guns ere found to be in a very bad state from rust and coppering. The actual guns and shell used by the ships were experimented with, together with other guns, and with the use of tin-foil. The shooting with the ships’ guns was erratic. The “toppling” reported by the ships could not, however, be reproduced, but it was established that the bad state of the bores was the chief cause of the trouble. With an increasing twist of rifling as with Marks I and III rifling in 6 in. VII, there is little margin in the C.N. bands and any extra adverse conditions in the gun means that the margin is passed. The trials also showed that after decoppering a gun with a rough and uneven bore the first few rounds were bad, but the shooting subsequently improved, and two further series using tin-foil gave normal errors.

27a. Foreign Progress.- The Germans have been experimenting with a microphone method for determining velocities on the lines we tried in 1918 and abandoned for solenoids The precision obtained in the experiments they published was bad and there was nothing to learn from them. The United States Navy are carrying out elaborate experiments afloat and on shore. They are chiefly with a view to determining the causes of dispersion with triple turrets and empirical ballistic relations between pitch of rifling, shape of projectiles, velocity, etc. They have an elaborate outfit of electrical apparatus that fills a ship's galley and they are using the solenoid chronograph. We have some of their earlier reports and results which give a good deal of information that is chiefly useful in showing the magnitude of the effort being made to thrash out ballistic problems. The French have been photographing projectiles in flight by a new process. We have no recent information as to what is being done in French or American wind channels.

German Guns.- Captured guns about 6 in. and below have been tried at Shoeburyness, but there is no remarkable accuracy or other feature of interest. A trial of their 38 cm. gun is under consideration.

SECTION V.

GUNS AND GUN DESIGN.

28. Auto-Frettage.- Preliminary experiments are being continued with a view to constructing a trial gun on this system in the future.

E.O.C. are carrying out a programme of experiments with two forgings of 12 in. bore. (O.C./B.3793.)

Methods of measuring the expansion of gun barrels under hydraulic pressure are being investigated by D.N.P.I. (O.C./B.3654.)

Approval has been given for the manufacture of a plant in R.G.F. which should be capable of dealing with guns up to 6 in. 50 calibre. (O.C./B.3701.)

29. Super-Velocity Guns.- The value of such guns, as far as the Navy is concerned, is limited to their use in special ships for bombarding large areas, such as Dockyards or Works, at ranges beyond the reach of any shore Batteries. The life and accuracy of such guns is limited.

It has been arranged, therefore, with the Army Council that the further development of these weapons will for the present rest in the hands of the Land Service, the Admiralty being kept informed of progress made.

The Delamare-Maze Turbine gun.- Experimental firings have been carried out with a weapon constructed to the inventor's ideas.

While showing that the theoretical drawings made by the inventor as to the value of the dynamic effect of high velocity gases on base of projectile in keeping up the pressure down the bore are more or less substantiated, these trials have clearly shown that the application of the idea to service weapons is impracticable, the main objections being :-

(a) Heavier charges required for same velocity in comparison with those of service ordnance.
(b) Difficulties in loading and consequently a much reduced rate of fire.
(c) High muzzle pressures resulting in serious irregularity in velocity and inaccuracies in range.

The last objection appears to be insurmountable and inherent with the principle involved.

It should be observed that the recoil is very largely reduced owing to effect of gases escaping to the rear, but troubles with blast effect on gun's crew would be difficult to deal with and have not been dealt with in these experiments which were only for trying out the basic idea.

The further trials of the gun have been discontinued. (O.C./B.3818.)

It is interesting to note that after comprehensive trials the Belgian Military Authorities have arrived at conclusions very similar to our own.

30. Rifling and Driving Bands.- In order to determine the most efficient type of rifling and driving bands investigations are still proceeding. In connection with the former, trials with 4.7 in. H.A., 6 in. Mark VII and XI and 15 in. guns, with different types of rifling, have been or are being carried out, but it may be some time before the results obtained can be fully made use of in the construction of new ordnance.

The position of the driving band and what steps should be taken to improve it is being taken up both n connection with the above trials and in special ones that have been arranged to compare the effect of variable physical properties in the band itself, different forms of band, and different material in the band. The results of all these trials must also necessarily be awaited and summarised before their application to future designs can be considered. (See also page 4, “New Designs of Guns.”)

31. Reduction in Wear of Guns, Lubrication of Bore.- The question of the use of a lubricant for the bore of guns is at present being considered.

Trials of spraying apparatus for applying graphite to the bores of heavy guns have been delayed owing to H.M.S. “Commonwealth” paying off. The question of modifying this gear for trial in larger guns is being investigated. (G.2168/21.)

Decoppering.- Trials are now in progress in the Fleet with a view to ascertaining the best means f applying the tin-foil alloy to B.L. and Q.F. (separate loading) guns. There are three alternative methods :-

(1) The alloy in the form of foil, to be crumpled by hand and thrown in after the projectile has been rammed home, but before the charge is loaded.
(2) As (1) but the foil to be supplied in a shalloon bag.
(3) The alloy as foil or in disc form attached to the cartridge. As this method complicates storage and supply arrangements in the handing room (since, to avoid wast, only one quarter charge in each half chare would include tinfoil and the tin foil to be effective must be close to base of projectile) it will only be resorted to if (1) or (2) above cannot be accepted by Fleet.

For fixed ammunition guns, the alloy in the form of foil will be threaded into the forward end of the cordite charge. The foil will be lacquered and wrapped in shalloon and in rounds fitted with shell filled lyddite or shellite, a glazed board disc, or washer in the case of base-fuzed shell, will be inserted between base of shell and top of charge to prevent the foil coming in contact with the base of the shell with possible danger of the formation of lead picrates.

Rough usage and firing trials, to confirm that this method of applying the foil is satisfactory, are now being carried out.

The use of tin-foil rings on projectiles is objectionable owing to the risk of shellite or lyddite fillings forming lead picrates with the lead of the tin-foil. It has therefore been decided not to proceed with this.

It has now been suggested that zinc-tin alloy might be used instead of tin-foil and trials have been arranged to test what effect this alloy will have, as it is thought probably that zinc vapour will be deleterious to the bore.

Ovality of Wear.- This question is assuming considerable prominence, as the effect of a gun wearing oval is to greatly decrease its life.

Various theories as to the cause have been put forward and followed up, but have not been borne out by practice.

The phenomenon is not confined to any particular type of gun, nor is ovality always in the same direction in any one type of gun.

It seems that some unsymmetrical influence must be sought to account primarily for the varying results obtained. The only factors that it seems possible to influence unsymmetrically are those connected with the recoil arrangements and mountings. By adding weights it is possible to change the already unsymmetrical position of the centre of gravity of the recoiling mass.

To test this theory practically, a trial has been arranged with two 4 in. B.L. IX* guns to which a weight of about 5 cwt. Has been attached eccentrically, in one case above, and in the other to one side of the centre of gravity of the recoiling mass.

These guns will be used fir firing the large number of routine rounds necessary at P. and E. establishment, and subsequent measurements may throw some light on the correctness or otherwise of the theory put forward.

(O.C. Min. 41680.)

32. Comparison between British and German Gun Designs.- (*a*) The design of German 38 cm, 42.4 calibre Naval gun mounted in “Baden” has been carefully investigated and compared with that of the British 15 in. Mark I 42 calibre gun.

(b) The main points of difference between this design and British designs are as follows :-

- (i) The gun is not relinable.
- (ii) Factors of safety are lower. In calculating the strength of the gun at any point, the Germans allow the steel to be stressed much nearer to its elastic limit that we do in our designs, also the figure of elastic limit which they take for purposes of calculation is higher than ours. The gun is not serviceable with barrel split.
- (iii) The gun s a Q.F., which permits of radical differences in construction from those necessary at the breech end of a B.L. gun.
- (iv) All-steel construction as against wired type.
- (v) Much smaller chamber (Capacity 18,000 cu. In. as compared to our 30,590.)

The effect generally of (i), (ii) and (v) is to lighten the gun considerably.

(iii) is a matter of general policy ; there are reasons both for and against .F. guns of this calibre

(iv) The advantages of all-steel versus wire-wound guns have been the subject of discussion for a great many years, and opinions still differ as to which is better than the other from point of view of strength and ballistics ; more recently, however, it has been considered probable that the smaller droop and greater rigidity of the all-steel type may be a very important factor in effect on accuracy. The German gun is noticeably stiff in the region of the centre of gravity, making for small droop and whip ; this is undoubtedly a good point.

(*c*) As regards (i), the life of our guns (about 325 E.F.C.) is apparently considerably less than that of German heavy guns owing to their use of cooler propellant. They evidently considered that the life of their guns was long enough to justify the simpler lighter design which is possible when relining is not intended. Experiments with propellants generally similar to the German are in hand, but some time must elapse before any can be adopted to replace cordite M.D. in the Service. Until then it is considered that we should certainly continue to design our guns for relining.

(*d*) As regards (ii), apparently German designers placed greater reliance on their steel forgings than we do on ours, and consequently stressed them much more highly. In all large steel forgings there is always a certain factor of uncertainty which we have allowed for and the Germans have been content to neglect. This is not confined to gun construction, but it is to be found throughout British engineering practice generally. The high factors of safety used in this country are considered to be partly due to the above and partly to caution, which may have been brought about by a few failures of guns in the past caused by faulty building or poor steel, also because there has been no special demand for light gun. We now call for a factor of safety of 1.5 over the chamber and of 2 forward before the steel is stressed up to a figure well below the specification yield point (20 tons as against the German 27). Consequently according to German ideas our factor of safety is 2 or 2.7.

The possibility of reducing the factors of safety in our gun designs has been the subject of discussion recently, and trials to test whether they are unduly great have been arranged for. Doubtless some reduction will now be possible in view of the great advance in machining operations and steel treatment made of late years, but improvements materially affecting our designs can only be adopted gradually. It is confidently anticipated that the forgings for the 16 in. designs will be much superior to what we have had in the past and fully equal to the German, the chief advance being in improvement in elastic limit and resistance to shock, which latter as evidently been specially attended to by German steel makers and is now provided for in our specifications for steel forgings.

The effect of these two points (lower factor of safety and high stress in the steel in the German design) is very marked over the chase with consequent reduction in weight and therefore decrease in the droop – a point already referred to in para. ().

(*e*) As regards (iii), a movement between breech bush and inner tubes in a Q.F. gun with cartridge case is of much less importance than with B.L. gun and obturator pad in maintaining an effective seal, and this has permitted the longitudinal stresses being taken direct by the jacket, the breech bush screwing into this instead of into the A tube as in our designs. This simplifies design and manufacture. It has also permitted the use of short hoops in lieu of a long B tube, a form of construction that offers many advantages in accuracy of building shrinkage, though at the same time providing less longitudinal strength, which is poor in the German design according to our ideas.

The fact that the Germans accepted this longitudinal weakness shows that they had great confidence in the workmanship and skill of their gunmakers, as good results depended entirely on these. Our guns are undoubtedly easier to build and are so strong circumferentially due to the wire that the accuracy in building shrinkages, necessary in the German design has not been called for.

(*f*) As regards (iv), steel and wire construction will be tried out in the trial 16 in. designs, also in trial 6 in. guns to be manufactured this year.

(*g*) As regards (v), the small size of chamber is not suitable for a solid cord propellant which we have hitherto adhered to. The question of adopting a tubular … various experiments are in progress.

The opinion is now held that the tubular shape makes for higher M.V. but reduced accuracy as regards mean differences in M.V.

It is more difficult to manufacture to accurate dimensions than cord or oval. Also, with a propellant such as M.D. cordite which has a volatile solvent (acetone) there would be less uniformity of stick than is obtainable with a propellant (like the German) with non-volatile solvent. Ardeer cordite has a non-volatile solvent. Again, owing to its form, a tubular propellant is inherently more susceptible to the influence of variations in ballistic conditions, and thus, though actual wear may be less, loss of velocity for a fewer number of rounds may be greater.

It is, however, one of the many things that requires further investigation before we can be in a position to decide finally what to adopt in the future. It is quite certain that we shall be able to improve on cordite M.D.

(*h*) Apparently the Germans consider it unnecessary to fire proof rounds in testing guns for supply, and, to take this gun as an example, this certainly permitted them to cut down factors of safety, and therefore weight.

(*i*) Summarising, the main lessons to be learnt from study of the German design are :-

(i) The possibility of reduced factors of safety being introduced into our designs, especially towards the muzzle.

(ii) The reduction of droop by (i) combined by the use of all-steel construction with a view to obtaining greater rigidity and consequently improved accuracy. At the same time distance of centre of gravity of gun from breech end would probably be decreased, and this would be advantageous as affecting diameter of barbette and size of mounting generally.

(iii) The need for taking advantage of manufacturing progress and greater knowledge obtained by experience in ordering trial guns of new designs from time to time, so that when new guns are required in supply they can be ordered to the most up-to-date designs. Unless this is done, our gun designers cannot acquire confidence in their designs nor can the gun makers gain experience in building.

(iv) The necessity for constantly revising our specifications to obtain the best possible gun steel, and for ensuring by strict inspection during manufacture, that specifications are adhered to and that the workmanship is of the highest standard.

The trial 16 in. guns and experiments in hand on other guns will test some of these points, but the trial guns have chases with a large factor of safety and the droop is therefore not the smallest obtainable.

(*j*) It may be of interest to mention here that the trial 16 in. gun under manufacture by E.O.C. weights practically the same as a gun of similar calibre that has been designed working to German figures and methods. It will be clear, therefore, that a good deal has been done already towards reducing weight ; but, although this is very desirable, it can certainly be overdone, and if the gun is not sufficiently **stiff,** its accuracy will be less good than one where weight has been subordinated all through to gunnery considerations. There is no doubt at all as to the importance of stiffness in a gun.

(*k*) It is the intention to build, next year, a 6 in. gun to the German design, so far as this can be done without adopting the Q.F. principle, and to try this gun against our guns of similar calibre.

New Designs of Guns.- 16 in. Three trial guns are now under manufacture, one of all-steel and two of wire construction. It is hoped to obtain valuable information from these as to dimensions of chamber and rifling for embodying in design of guns for new capital ships, but time may not permit of all-steel guns being adopted for supply should the trial gun of this type prove successful.

6 in. Manufacture of two trial guns has commenced. These are both guns of 50 calibres, on of wire and one of all-steel construction. A higher steel specification is to be worked to and guns are designed for a 108 lb. projectile. 6 in. guns designed for new capital ships will embody some of the above features and will be more powerful than the existing Mark XII.

5.2 in. A specially light type of Q.F. gun is being designed for use in submarines. M.V. will be about 2,400 f.s. Weight of projectile, 70 lb.

4.7 in. Q.F. VII and VII*. Two H.A. guns of this calibre have been completed with different types of rifling for comparative trials, which have not yet been completed. These guns take fixed ammunition.

2 pdr. sub-calibre guns. Orders for manufacture of trial guns have been placed, but the guns have not yet been delivered owing to difficulties with the steel, which must be of special quality. These guns are required for 4.7 in., 4 in. and 3 in., and for H.A. guns of the same calibre.

33. Recent Gun Accidents.

"Lord Clive" – Premature in 15 in. Mark I.- Whilst carrying out experimental firing off Shoeburyness on 21st February, 1921, a premature occurred in the left gun. The gun was being fired with service full charge, A.P.C. projectile, filled lyddite and plugged.

The explosion occurred about five feet from the commencement of rifling.

The jacket of the gun was shattered for about five feet all round, exposing the wire (Fig. 10). The rear portion of the jacket was cracked to the breech, while the material detached was found to be broken into a large number of small fragments, indicating a lack of toughness in the steel, which is being guarded against in steel specification for new gun design. Bolts securing the trunnion cap were sheared, and trunnion cap and saddle piece blown overboard.

The lock and portions of the box slide were blown to the rear.

The front cradle and slide were also damaged. No casualties occurred, with the exception of one man who sustained a slight injury to the foot.

Full investigation has been held to endeavour to elucidate the cause of the premature.

The possible causes of this accident may be summarised as follows :-

(1) Break-up of the shell.
(2) Set-back of the filling, with consequent ignition and detonation.
(3) Obstruction of the bore.
(4) Failure of the plug due to-

(a) Faulty material.
(b) Faulty construction, *i.e.*, manufacture.
(c) Faulty insertion.
(d) Absence of copper gas-check.

(1) It is most improbable that a shell which has been some seven years away from the Contractors' works, where it originally underwent keeping trials, would develop or have present flaws or defects sufficient to cause a break-up in the bore, although, as the shell was painted, it was possible that such defects were present. At the same time, the fact that the cap might separate from the shell immediately on firing must be borne in mind, and an obstruction caused by the cap jamming in the bore would be sufficient to set off the shell. A cap of this type is an old pattern A.P.C. is unlikely to be detached ; it is, in fact, less likely to do so than are the caps on present-day shell ; and as any appreciable looseness is readily detected at the ordinary overhaul of shell, it is considered most improbable that the separation of cap from the shell was the cause of the accident.

(2) The set-back of the filling. There is much evidence to show that the filling of shell of this type was by no means satisfactory. Considerable spaces have been found from time to time in A.P.C. shell as between the base of the explosive and the face of the adaptor, while cavitation has also been detected at the periodical and special examinations carried out at Ordnance Depots ; moreover, on a recent occasion, a steel spanner was found inside a filled A.P.C. shell 15 in., thus indicating that a lack of care was prevalent in the filling factory at the time this particular shell was filled. Having these facts in mind, it is possible that the accident was caused by a set-back of the filling.

(3) Evidence goes to show that the bore was clear, and obstructions such as might be caused by the presence of crusher gauges are most unlikely to have been present.

(4) (a) Faulty material forming the body of the fuze, and this particular plug was converted from a number 16 fuze (evidence goes to show that the mark of fuze was not Mark I, but rather Mark II or III), would readily lead to an accident of this nature, as unsoundness of the base of the fuze would give free access to the flame of the charge from the chamber of the gun right into the cavity of the shell. It may be mentioned that a large amount of defective material was met with during the War in connection with the manufacture of base fuzes. In some of it the presence of defects could only be determined by etching and special tests. In others it was visible to the naked eye, but it would be unwise to assume that all unsuitable material was eliminated ; in fact faulty material is thought to be only one of the probable causes.

(*b*) Construction of the fuze or plug. Assuming that the drawing was strictly complied with, then defects due to shell threads or improperly cut threads on the exterior or in the holes and side-plugs of the fuze below the flange need not be taken into consideration.

Examination carried out on the remaining shell and plugs indicates that the condition of threads of both shell and plugs was satisfactory, and it is therefore reasonable to assume that they were so in the shell the prematured.

As to the condition of the plug filling the copper pressure plate recess (which is fitted as a part of the conversion from fuze to plug), it is highly probable that if this plug had not been properly fitted and inserted with cement, as provided by the drawing a flash through might occur. Water-testing under a pressure of 60 lb. per square inch has been carried out on the balance of plugs remaining in shell supplied to "Lord Clive," and from the results of this pressure test it appears that full sealing as between the base of the plug and the interior, from which ready access to the cavity of the shell is obtained, was not satisfactory, and a complete absence of Pettman cement was noted. Five out of the twenty-five plugs tested failed to pass this test, the water passing from the base end of the plug out through the flash holes into the cap. **It is considered that this particular fault is the most probable cause of the accident.**

(*c*) Insertion. Full enquiry has been made, and it has been ascertained that the plugs were inserted at Priddy's Hard by experienced men who have been on the same class of work for some 15 years ; they used the authorised tools for the purpose, and their work was watched by A.I.N.O. and his staff. It cannot be said that the tightness of every individual plug was checked, as to have done this would have practically necessitated the carrying out of the work by the examiner, but there is every indication that all ordinary precautions were adopted. On the other hand, an examination of the remaining shell now at Chatham shows that the plugs were not as tight as they could be made, and, while it may be argued that the difference between the condition that these were found in and the condition in which they should be is a matter of opinion and dependent largely on the strength of the individual testing the tightness, it has been ascertained that, in certain cases, nearly a third of a turn could be made by a strong man. A third of a turn represents a space of approximately .04 between the seating of the flange of the fuze and the recess in the adaptor of the shell ; and although this is a very small amount, it might conceivably permit of the passage of gas to the side closing plug which exists in the fuze immediately under the flange. This side closing plug, if of correct thread dimensions, etc., would offer considerable resistance to the passage of gas ; but it would not be impossible for gas to force its way past although, meanwhile, the flange of the fuze would probably have seated itself into the recess. It is possible, therefore, that this was a cause, or contributory cause, of the accident. On the other hand, it must be recollected that the men who inserted these plugs have, in their time, inserted probably tens of thousands of base fuzes under identical conditions, and it is highly probable that failures on service would have resulted before now in appreciable quantities had the extreme tightness or otherwise of the fuze in the recess been of vital importance.

(*d*) Gas-check. These plugs were not fitted for a gas-check, and none was employed. Had one been present it would have mitigated the danger if it existed, due to faulty material, faulty construction and improper insertion ; but the presence of a gas-check would not necessarily have prevented an accident in the presence of such faults. Certainly, with badly-flawed material, a gas-check would offer but the very slightest resistance.

It may be mentioned that all shell allocated to this trial were opened out at Priddy's Hard previous to despatch, they were examined for condition of cavity, and new exploders were fitted ; and from the full enquiries that have been made, it is considered that all reasonable care was exercised in the operations connected with the insertion of the plugs and closing of the shell.

Conclusion.- There is little doubt that the plug was the cause of this premature (para. (4) (*b*) above).

Previous Accidents.- A premature occurred in a 13.5 in. gun of "Marlborough" at Jutland, when firing A.P.C. (old type) filled lyddite, fuze 16. No cause was assigned, and the accident was not subsequently fully investigated.

Action.- As a result of the accident it has been decided :-

(a) That no more base fuzed shell 12-pdr and above, filled H.E. shall be fired or issued unless fitted with gas-check and base cover plate to protect the fuze and fuze hold.

(b) To withdraw the 6 in. and 5.5 in. C.P.C. converted from powder to shellite filling which are without the protection referred to in (*a*), pending their alteration to a fully safe design.

(c) Not to fire filled H.E. shell with a plug in lieu of a base fuze unless with a gas-check and cover plate as used with the fuze.

(d) To introduce a special "firing plug" suitable for use for proof and experimental firings with filled shell where fuze action is not desired. The plug to be covered as in (*c*).

SECTION VI.

BREECH MECHANISMS.

34. Future Heavy and Medium Mechanisms.- For the 16 in. guns being manufactured for trial, it has been decided to adopt the E.O.C. short arm mechanism which is identical with that fitted to 18 in. Mark I guns. The time required to open or close the breech with this mechanism is three seconds, compared to five seconds with the existing 15 in. Mark I breech mechanism.

A 15 in. mechanism has been manufactured by Messrs. Vickers, on the Asbury principle, operated by air pressure or hand. Modifications are now being carried out to enable the mechanism to be operated hydraulically. It is claimed that this mechanism can be operated in one and a half seconds.

Very thorough comparative trials have been carried out by H.M.S. "Excellent" with the following designs of mechanisms for medium calibre guns :-

(1) Service (Vickers) type.
(2) Asbury type.
(3) Holmstrom type.

It has been shown that while both the Asbury and Holmstrom types have certain advantages over the Service type, the balance of advantage rests with the latter, and it is considered that for general service the mechanisms may be placed in the order of merit shown above.

In addition to these, a Universal Link Breech Mechanism, manufactured by Messrs. Beardmore, has been under trial.

This mechanism was very simple in construction and operation as originally supplied, but deficient in essential safety arrangements. Modifications to improve safety have been carried out, thereby doing away with much of its simplicity. Further trials are now being carried out.

Recent Breech Mechanism defects. 15 in. Mark I.- Failure to catch retaining breech screw open.- Cases have been reported in which the "catch retaining breech screw open" of left guns has been forced in with the first motion of the carrier in closing the breech by power.

A modification to the catch has been approved for trial and adoption if successful. (N.O.34802/20.)

Failure of latch retaining breech screw closed.- Cases have also occurred in which the "latch retaining breech screw closed" has failed to prevent the breech block from rebounding.

It is considered that this defect is due to wear of the flange of the breech screw. The parallel bearing surface on the flange of the breech screw is only .15 in. and may have become tapered off by use.

It has been approved to carry out trials with a hardened steel piece fitted to flange of breech screw.

4.7 in. B.L.I.- Fracture of link actuating lock.- Chemical analysis and mechanical tests of the fractured link were taken. These show that the material was within specification limits. No sign of a flaw appeared.

The cause of the fracture is considered to be as follows : It s possible to ship the lock with the breech mechanism lever half open so that the link guide bolt is to the right of the hole in the link actuating lock. If the breech mechanism lever is further opened the rib on the link will come up against the link guide bolt, and if any pressure is applied to the breech mechanism lever considerable strain will come on the rib.

This is likely to happen with an inexperienced person shipping the lock.

With the rib badly strained and cracked from this cause (not necessarily on one occasion only) it is possible that the final complete fracture was caused by the shock of firing.

It is not considered that the extra strain involved in rapid loading had anything to do with the primary cause of fracture.

No modification to the design is considered necessary with a view to preventing this defect. (G.19256/20.)

Box slide K-Modification.- The large number of cases of "jammed tube" which have been reported when using box slide "K" has led to investigation of the cause, and the following points have been considered :--

(a) The force required to press extractor home and overcome the tube retainer is too large, requiring greater effort that can be applied with the thumb of one hand, thereby necessitating the breech block being

held to the rear and tube forced home by both hands, or, alternatively, tube has not been forced right home, causing a jam on closing the breech.

(b) Tube forced to the rear on breech being swung to, due to insufficient strength of the tube retainer spring or incorrect overlap of tube retainer over base of tube.

Approval has been given to modify a lock and box slide for trial and to test the efficiency of fittings for holding breech open when inserting tubes. Interim action has been taken in C.I.O.1117/20.

SECTION VII.

POWER WORKED BUN MOUNTINGS.

35. "Baden's" 38 cm. Turret.- Owing to the great difference in the general arrangement of the machinery from that used in the British Navy, it is not always possible to draw a direct comparison between the two systems. The more important features of the German turret at variance with the British are as follows :-

(a) Electric power used exclusively in shell room and also for the following operations: training, alternative for working main cages, working auxiliary cage.

(b) Hydraulic power is self-contained in the turret.
(c) Direct ammunition hoist from handing room to gun-house.
(d) Loading wagon used in gun-house.
(e) The loading arrangements to the main cages are designed to load both guns simultaneously.
(f) There are no anti-flash arrangements between the magazine and handing room and stowage for charges in cases is provided in the handing room. The charges in brass cylinders were stowed in bulk in the magazine, cases being provided for the front portions only.
(g) A special auxiliary loading compartment is fitted below the gun house.
(h) The charge for the gun is in two parts, the rear portion being contained in a brass cylinder.

(*a*) *and* (*b*) **Use of Electric Power and Hydraulic Power Self-contained in Turret.**- There are points both for and against the use of electric power as opposed to hydraulic power in turrets, the principal disadvantage of hydraulic power being the necessity for walking pipes.

On the whole, it is considered tat the advantages of the German system are not sufficient to justify such a radical alteration as its adoption in the British service at the present time would entail.

(*c*) **Direct Hoist from Handing Room to Gun-house.**- As the "Baden" was laid down in 1914, the principle of the direct hoist is probably not based on war experience.

Anti-flash doors are fitted at the top and at the handing room level ; these doors are not properly flashtight from an explosion inside the trunk. The trunk is open at the shell room level, and it is therefore possible to get a flash direct to the shell room should an explosion take place when the flash doors at the top of the trunk are open.

This opening in the shell room is due to the type of transported used for loading the main cages in the shell room, which is withdrawn from the trunk after the cage has started to go up and, therefore, requires an opening in the trunk.

(*d*) **Loading Wagon in Gun-house.**- This seems to be as quick a method of loading as could be devised and trials show that each gun could be fired every 30 seconds, which is better than is obtainable in any existing British mountings. To do this, however the risk of having two exposed charges in the gun-house was possibly accepted, or it may have been the practice to keep the charges in the main cage at the top of the hoist and then transfer them to the wagon as soon as the gun was fired.

The loading wagon required a considerable amount of space in rear of the breech of the gun.

The wedge breech block is advantageous for rapid loading, as there is no danger of the block fouling the loading wagon, consequently it is not necessary to wait until the breech is fully opened before starting to place the wagon in rear of the gun.

It is also capable of being opened and closed very quickly.

(*e*) **Simultaneous Loading.-** This appears to be wrong in principle but is probably incidental to the revolving ring arrangement used in both handing room and shell room, so that the rings are maintained in an evenly balanced state.

Moreover, by good drill it enable charges to be exposed in the handing rooms and magazine for the minimum of time and avoided keeping charges in waiting positions.

(*f*) **Anti-flash arrangements in Handing Room.-** It is considered that the safeguard of keeping the magazine flash proof to the handing room is in any case necessary and that the German system is not to be recommended.

Undoubtedly the Germans made full use of the flash proof qualities of cartridges contained in brass cases and took risks that would not be permissible when handling bare charges. It is to be remembers, however, that the front part of the German charge was "bare," but it had not igniter and was enclosed in a double bag.

(*g*) **Auxiliary Loading Chamber.-** This is considered to be both a poor and an elaborate arrangement.

A considerable amount of gear is provided to enable an alternate supply of six projectiles per gun to be sent to the gun-house by means of an electrically driven hoist. There is no ready means of replenishing the secondary loading compartment from the shell room.

(*h*) **Use of Brass Cylinder for Charge and Size of Charge.**- The fact that the charge is in only two parts is largely responsible for several good points in the German design. It facilitates the handing room arrangements and the small total length enables the whole charge to be rammed in one motion from the wagon into the gun.

Owing to the excellent transporter provided in the magazine there is no difficulty in handling the heavy Q.F. cylinder. The weight of the brass cylinder when empty is 140 lb. and that of an “M” case is 160 lb.

As each holds approximately half a charge, the German method would save about 6½ tons in weight of stowage.

The use of the brass cylinder did not lead to any delays in the loading, and the fact tat these cartridges were stowed in bulk in the magazine saved time that is otherwise required to open up cases.

The total length of the German charge is estimated to be 63 in. as compared with 104 in. of British 15 in. charge.

The great advantage of having a short charge was very marked throughout the German loading arrangements.

36. Points of Detail that are of Interest :-

(*a*) **Method Employed of Transporting Shell from the Fixed to the Moving Structure in the Shell Room. –** The system used for this ensures that the shell is under control during the operation. The general arrangement is somewhat clumsy and occupies a great deal of space ; also the weight of the revolving trays, etc., is not wholly taken n the trunks, so it is not considered that the system has on the whole advantage over similar arrangements in British turrets.

(*b*) **Transporters in Magazine and Handing Room.**- The magazine transporter is considered to be a particularly good fitting, which enables cartridges of about 500 lb. eight to be handled with ease.

The weight of the two parts of the charge makes it impossible to carry the cartridges by man power, therefore the revolving ring in the handing room is required.

A system of power conveyors is under consideration for future British designs.

(*c*) **Shell Grabs.**- These are of a particularly good type which, after trial, has been adopted for future British designs.

(*d*) **Use of Wire Woven Bands for lifting Shell.-** These are used in the shell room in connection with the lifting and traversing gear, the wire woven band being wound upon a drum to lift the projectile. The arrangement is somewhat neater than the Service system of using a lifting wire, but, on the other hand, it requires a long driving shaft to operate the drum.

(*e*) **Embarking Arrangements.-** The arrangements for embarking ammunition have the advantage that the openings in the decks through which the hoist passes is reduced to the minimum size.

The projectile is first lowered horizontally to the main deck and then transported to the embarking cage.

This cage lies horizontally at the top and bottom of the hoist and turns to the vertical when passing through decks.

An anti-flash steel roller shutter is fitted at the top and bottom to close the opening when the cage is in movement. This elaborate fitting is presumably to meet the possibility of having to use this hoist in action to replenish the auxiliary shell chamber.

Power hoists are embodied in new British designs for embarking shell and cordite.

(*f*) **Floor Plating.-** The foot grip plating provided in the gun-house is very efficient. A similar type of floor plating is being tried in British Service.

(*g*) **Working of main cage lever and interlocks.-** During the operation of loading cages at the bottom of the hoist, and until a number in the shell room aligns tow pointers, the main cage lever is entirely free.

A controlling lever is fitted in the shell room which enables the cage to be controlled from this position in an emergency.

The interlocks in the gun-house between the main cage, flash doors and rammers, also between the wagon and rammer, are troublesome.

The interlocks are partly hydraulic and partly a system of stops which necessitates very accurate positioning of moving machinery to ensure that they are freed.

There did not appear to be anything to learn from the interlocking system.

The position in which the main operating levers are placed in rear of the turret is a good commanding position.

Illuminated tell-tales are fitted which show the position of the main cage and are considered to be a good fitting.

(*h*) **Chain and telescopic rammer.-** A purely chain rammer could not be used as the rammer head is not always supported. The rammer worked well.

(*i*) The turret was less mistake-proof than is usual in British practice. It is possible-

(a) To foul the projectile conveyors in the shell room by the revolving trunk if the former are not replaced.
(b) The gun could be fired when the wagon is foul of the recoil.
(c) There is no positive means of stopping the gun being elevated during the loading operation. There is, however, a stop provided for this, but it has to be operated by hand on each occasion. In all probability the guns were merely laid to a mark.

(*j*) **Jointing.-** The absence of air and water leaks was remarkable. The air supply to the hydraulic accumulators was found to be fully charged although it cannot have been looked at for over a year. The jointing material used for fixed piping was usually white metal washers. Similar material is now being tried in British Service.

The hydraulic pipes belonging to one particular machine were painted in a distinctive manner throughout their length. This was very helpful in tracing out the lead of the pipes.

(*k*) **The breech mechanism** (horizontal wedge type) could not be tried by power as an essential pinion was removed at all guns. The mechanism could be worked by hand, ant eh operation was easy when the heel of the ship favoured the direction of movement ; in fact there was a tendency for the mechanism to take charge. The operation was correspondingly difficult when the mechanism had to be moved uphill.

The firing arrangements consisted of a form of solenoid which released the firing mechanism in the breech block.

The elevating wheel was fitted with a loose ring, so that whatever position a layer's hands might be in he could always press on the loose ring and so fire the gun.

(*l*) **The sights** have been examined in detail and it is not considered that there is anything to be learnt from them. In several respects the mechanical details are crude and the absence in the design of any serious attempt to prevent or eliminate backlash is marked.

(*m*) **Air blast arrangements.-** In lieu of air blast and wash-out arrangements as fitted in British turrets, the Germans used suction trunks led from an electric fan. The mouth of the suction trunk is in line with the breech on the inner side of the gun when the latter is in the loading position.

When the empty cylinder is ejected, the gases in the gun are drawn through the suction trunk and discharged through the rear of the shield.

A cap is put over the open end of the cylinder, on ejection, to prevent the gases contained in it from escaping into the gun-house.

Wash-out arrangements were not provided in "Baden" owing to the use of Q.F. principle and absence of igniters. With the British system these fittings are essential for safety.

It is to be noted that cases have occurred in British 15 in. turrets in which a strong wind down muzzle has overcome the force of the air blast and gases have been force back into the gun-house.

It is considered that with the German system of suction trunks there is more likelihood of this occurring.

(*n*) **Stowage of spanners.-** Each spanner has a stowage bracket and the outline of the particular spanner is painted on the bulkhead. This enables the spanners to be mustered at a glance and ensures that they are stowed in their correct position.

(*o*) **Lubrication** is almost entirely by grease caps, which appear to be very satisfactory and worth of more general adoption in British Service. Generally speaking the German lubricating system was extremely good.

(*p*) There was a remarkable absence of precautions against sabotage in the German turret.

37. Loading Trials in "Baden's" 38 cm. Turret.- Loading trials have been carried out by H.M.S. "Excellent." These trials confirmed the loading times obtained from Germany.

The following table shows the comparative loading times for "Baden" and "Queen Elizabeth."

Times in gun-house only are shown.

"BADEN."	Secs.	"QUEEN ELIZABETH."	Secs.
Fire, recoil, run out and return to loading position	2½	Fire, recoil, run out	6
Bring down tray for ejecting cartridge	1	Open breech	5
Open breech and eject cartridge	1½	Raise G.L. cage	5
Wagon behind gun	3	Ram sell and two half charges	12
Ram shell and withdraw	6½	Lower G.L. cage	3
Cartridge tray down	1	Close breech	5
Ram cartridge and withdraw, at same time partially close breech	4½	Total	36
Finish closing breech, wagon back to transfer position. Elevate gun to firing position.	3		
Total	23		

It should be noted that gun-house times do not necessarily govern the rate of **continuous** fire.

While, generally, the cycle in magazines and shell rooms of "Baden" and "Queen Elizabeth" corresponds with that of gun-house, the rate of continuous fire would probably depend upon shell room supply in the latter and an additional 3 secs. would be required in the case of short-arm and 1½ sec. for Asbury.

The time for recoil and run out is reduced by 3 or 4 secs. by the adoption of pneumatic run out.

In "Baden" the cycle commences with wagon in gun-house loaded. If this system were adopted for future British designs, this wagon would have to be made flash proof, thereby adding considerably to complication and weight, or alternatively, wagon not to be loaded until required, which would add about 3 secs. to gun-house cycle.

The general arrangement of future design British turrets will differ considerably from existing turrets, and a loading time in continuous fire of under 30 secs. is being aimed at.

38. Flash Trials carried out in "Baden."- The object of the trial was to ascertain the extent to which the ammunition trunk from handing room upwards is flashtight ; also to test the efficiency of the handing room flash doors.

(G.0186/21.)

2.(*a*) The trunk as fitted is a rectangular structure with a central division to separate the two main hoists. This division is not entirely built of solid plating but has sections of perforated plate at intervals. A central compartment is fitted as far as the auxiliary loading chamber to contain the electric cables.

(*b*) The flash doors at the top of the hoist open outwards and are hinged horizontally. During the trials these were held closed by the hand operating gear.

(*c*) The flash doors in the handing room are of the chopper type, working in a vertical plane, and are held in place close to the trunk by guide strips.

(*d*) No flash doors are fitted in the shell room, but the top of the projectile cage fills the greater part of the trunk and forms a fairly good baffle to prevent flash passing into the shell room.

(*e*) An adequate flashtight joint is provided between the fixed and revolving structures at the levels of the floor and crown of the handing room.

There is no attempt made to maintain a flashtight fitting around the moving structure at deck levels above the crown of the handing room.

(*f*) Hatches are fitted to the ladder ways inside the turret and also to the gun-well at the crown of the working chamber. These hatches are fitted with an overlap and open outwards, so that they are fairly flashtight from above and would also vent freely should an explosion occur in the handing room.

(*g*) The magazines are separated from the handing room by W.T. doors, but these doors are open when a magazine is in use and stowage is also provided in the handing room for cases containing 36 front cartridges. The orders found in the handing room show that the front cartridges in the handing room are the first to be used with a corresponding number of rear cartridges from one magazine compartment.

After these have been expended both front and rear cartridges are taken from one magazine compartment, starting with a compartment on the disengaged side. All other magazine compartments are kept closed.

3. **Trial 1. Conditions.-** (*a*) A full 15 in. charge was ignited in the cordite compartment of the left main cage, both main cages being down and with flash doors closed.

(*b*) Four special cartridges made up with a single layer of cordite over a wooden core and enclosed in the usual silk cloth bag with igniter and tear off disc were placed on the trays of the revolving ring in the handing room. Of these, two were turned with igniters towards the trunk and two with the igniters away from the trunk. The tear off disc was removed from one of each of the above. These special charges each contained about 12 lb. of cordite.

(*c*) The magazine doors on the port side of the ship were open and those on the starboard side closed.

(*d*) An igniter and some cordite were placed on the deck 5 ft. inside the open door of a magazine which was opposite the cage containing the charge which was ignited.

(*f*) Strips of calico were placed in various places and outside the flash doors at the top of the trunk to locate the path of the flame.

(*g*) The breeches of the guns were open and so also were the hatches for the ejection of empty cylinders from the gun-house, which is a condition that might occur during the loading operation. The only other exits for flash from the gun-house were the gun port, sighting port, small space between the revolving and fixed parts of the O.O.Q. look-out position in the rear of the turret, and the rangefinder ports. These latter were closed by glass windows.

(h) This trial was carried out in “B” turret.

4. **Result. Trial 1.-** (*a*) The steel top to the left main cage was bulged open and was foul of the side of the turret and would have jammed the cage.

(*b*) The cordite and igniter in the right main cage were ignited.

(*c*) All four flash doors in the handing room were forced outwards ½ in. at the top but could be forced open again. These doors were $^{3}/_{16}$ in. thick.

(*d*) Some flash escaped past the 12 in. x 15 in. inspection doors in the side of the trunk in handing room.

(*e*) Inspection doors 14 in. x 18 in. on trunk in shell room each side were blown off and a considerable amount of flash had passed through the one on the left side.

(*f*) The flash doors on the left side in the gun-house were opened about 2½ in. at the bottom and signs of flash having passed all four flash doors in gun-house were evident.

Gun-house: (*g*) All the paint work on the left side of the rear part of the gun-house was badly scorched by the effect did not extend forward of the breech end of the gun.

(*h*) The calico outside the trunk flash doors was destroyed and a wooden ladder stowed in this vicinity was badly charred.

(*i*) The deck under the left ejection hole in the floor of the gun-house was scorched.

(*j*) A considerable amount of the gases vented through the guns.

Working chamber: (*k*) Some flame passed through the ports in the trunk for the main cage sheaves but the visible effect was limited to a radius of about 3 ft.

Spaces between handing room and working chamber.- (*l*) No signs of flash.

Handing room: (*m*) All four special charges were ignited and the wooden core was charred.

(*n*) Paint on the trunk and all around the crown of the handing room was scorched but there was no evidence that this paint caught fire.

Magazine : (*o*) The cordite and igniter were undamaged and the woodwork inside the open doors showed no signs of flash. It must be remembered that the special charges which ignited inside the handing room contained only a small amount of cordite.

Shell room : (*p*) No sign of flash except around the left inspection door to trunk.

(*q*) Inspection door to trunk for electric cables was blown off but the cables shewed no signs of damage.

5. Trial 2. Conditions.- General arrangements were the same as for trial 1 except that the main cages were at the top of their hoist, *i.e.*, at the gun-house level, and the charge ignited was in the right cage.

The breeches of both guns were closed and the left cylinder ejection hatch was closed and the right hatch open.

(*b*) This trial was carried out in "X" turret.

6. Result of Trial 2.- Trunk : (*a*) A slight amount of flash escaped past the flash doors in the handing room and one of the inspection doors to the trunk was blown off. This was not sufficient, however, to ignite the special charges in the handing room.

(*b*) Neither cage was damaged.

(*c*) Flash doors in gun-house were opened about 3 in. at bottom except cordite door of main cage, which was opened through 45º.

Cordite in the opposite main cage was ignited.

Gun-house : (*d*) The gases vented through the right ejection hatch, also through the gunports and around the joints of the O.O.Q. hood in the rear of the turret, a small fire being started on the wood deck under the ejection hatch.

(*e*) Some gases escaped past the breech through the gun.

(*f*) The rangefinder port windows were undamaged.

(*g*) The paint work on the right side of the rear part of the turret was burnt, the effect extending up to about 3 ft. on the muzzle side of the breech of the gun.

(*h*) One glass shade in the crown of the gun-house was broken.

(*i*) The lagging of the exhaust suction pipe was badly burnt.

Working chamber : (*j*) The calico inside the ports for main cage sheaves was singed on the trunk side only, showing that only very little flash passed into the working chamber.

Spaces between working chamber and handing room : (*k*) No signs of flash.

Handing room : (1) No signs of flash except in the immediate vicinity of the flash doors.

(*m*) Special charges undamaged.

Shell room : (*n*) No sign of flash.

7. **Conclusions.-** (*a*) The trials show that if a charge is ignited in a cage at the bottom of the hoist the flash doors as fitted in the handing room are inadequate, but that these doors in conjunction with the protection afforded by the cage itself, give good protection if a charge is burnt at the top of the hoist.

(*b*) The trunk is not flashtight from the shell room or working chamber, but, owing to the ease with which the flash doors at the top of the trunk can be forced open, the amount of flash which passes through these openings is not considerable.

(*c*) The isolation of the important machinery spaces and the protection to the electric cables from flash appears to have been well considered and to be satisfactory.

(*d*) The damage to material caused by these trials was small, and, so far as could be seen, both turrets could have remained in action when casualties had been replaced. The only machine which sustained any appreciable damage was the left cage of “X” turret.

(*e*) On the result of this trial it is considered that a direct hoist from the handing room to the gun house can be introduced without any considerable risk, provided that the trunk is fitted with well-designed flash doors at the top and bottom.

(*f*) During trial 1, the personnel in gun-house, handing room, and probably a proportion in the magazine and shell room would have been killed by flash or asphyxiation.

(*g*) During trial 2 the personnel in the gun-house would have been killed, but the remainder of the turret’s crew might have survived.

(*h*) Generally, the trials show that the German anti-flash arrangements as fitted in “Baden” were not flash-proof, but that, nevertheless, they were decidedly good, taking into consideration the additional safeguards provided by their brass cartridge cases, absence f igniters and the drill used whereby both cages were loaded and sent up together. The most probably condition for ignition of a charge being when cages were up it is considered that the likelihood of the handing room being affected were small. The German practice of keeping a magazine open to the handing room in action was, however, a risk which we should not consider justifiable in the light of experience.

(*i*) The trials also indicate the great value of a vet which will allow an explosion to escape out of the trunk and away from the magazine, if possible into the open air.

(*j*) Flash arrangements now in H.M. ships as the result of the 1917 trials are considered to be a great improvement on those adopted by the Germans as fitted in "Baden," and we have little to learn from them in this respect.

SECTION VIII.

TRANSFERABLE GUN MOUNTINGS.

(No further progress to report at present.)

SECTION IX.

ANTI-SUBMARIME WEAPONS.

39. Stick Bombs and H.V. Fuzes.- "Cyklop" trials. There is no progress to report on the actual development of stick bombs and fuzes, but trials have been carried out by the Mining School with submarine charges of different sizes detonated under water at various distances from the hulls of ex-German submarines, both submerged and on the surface. These are known as the "Cyklop" trials because the surrendered German submarine salvage vessel of that name was used to carry out the experiments. (G.0645/21.)

The submarines have not yet all been salved, and therefore, the results await full analysis. So far as gunnery weapons are concerned, the following appears to be the state of affairs :-

A 43 lb. charge, such as forms the burster of the 7.5 in. howitzer shell, if it bursts below water about 8 ft. from a submarine of the U. or U.C. class, may cause effective damage to the pressure hull. A 300 lb. charge at about 25 ft. is likely to be fatal to a submarine. This indicates that the stick bombs and howitzer shells developed during the war were suitable for their work. A final decision as to the precise sizes and natures of these weapons which will be retained, and as ot he future development of stick bomb throwers or howitzers has not yet been given, and trials with certain of the existing weapons may first be carried out. (G.0130/21.)

Gas-checks for stick bombs.- A satisfactory form of gas-check for stick bombs has been produced and tested, and the design is available for future manufacture. The annular erosion of the bore is not entirely prevented by this gas-check, but, provided a large number of rounds with stick bomb are not fired, the erosion is slight and unlikely to necessitate condemnation of the gun.
(G.43307/18.)

Howitzer trials.- Target practices with a 4.7 in. howitzer have been carried out to investigate the hitting capacity for this type of weapon against a "submarine" target. The advantage of plunging fire against a submarine is obvious (*vide* Section X, page 50), but the chances of obtaining direct hits with a howitzer against a submarine on the surface are poor, on account of the very small danger space.
(G.0913/20. G.01034/20.)

SECTION X.

PROJECTILES.

40. Production of A.P.C. Shells.- After the Armistice it was evident that the rate of production of large A.P.C. shells must be slowed down on the score of economy. As soon as the contracts which had been placed with Messrs. Hadfield, Vickers, Firth, Armstrong and Cammell during the war were completed, it was arranged that only 15 in. and 13.5 in. (H) shells should be provided to complete the outfits and reserves of existing ships ; the manufacture of 12 in. and 13.5 in. (L) was stopped accordingly (G.0575/19. G.11307/20.)

It was also decided during 1920 that only Messrs. Hadfield and Firth should continue to produce large A.P.C. shells for the present (C.P.156966/19). By giving these two firms a guarantee of a minimum order per annum their plants are kept in being and their expert personnel are kept together. Otherwise, in the face of the small orders which were being placed, there would have been some danger of the whole of the country's capacity for making these special high grade steel products being dissipated during the years of the post-war reconstruction period.

The question of manufacturing large A.P.C. shells at the Government factories at Woolwich has been considered. It seems clear that to attempt this would be uneconomical. The production of large shells and caps with special alloy steel,

requiring special treatment and tempering to give them the physical properties required for successful attack on armour at oblique impact, is a specialist's business. The shill and knowledge required are obtained from the funded experience of years, a large amount of which is gained in making articles for the commercial market.
(G.0210/19.)

Improvement in A.P.C. 13.6 in. and above. Improved specifications for plate proof. (G.3845/21), (G.3391/10), (G.5199/21), (G.6389/20), (C.P. 14385/20).- Trials have continued throughout 1920-21 to try and get into supply 15 in. and 13.5 in. heavy A.P.C. shells capable of passing a more severe plate proof than that originally introduced by the Shell Committee. Meanwhile failures at the existing proof have been not infrequent.

A small and temporary advance in the plate proof was made on a recent contract for 15 in. A.P.C. placed with Messrs. Hadfield (G.15036/20), but all the proof rounds except one failed and we have been compelled to revert to the original conditions of proof for the present. (G.3845/21.)

Trials of large A.P.C. shells in connection with, or bearing upon, the new proposed specifications are progressing.

Trial 15 in. shells have penetrated 12 in. armour plate under action conditions (Fig. 11), but we are not yet in a position to raise the specifications governing supply.

Trials for improvement in designs, caps and other experimental matters are also in hand.

It may be remarked here that experiment and research upon which improvement ultimately depends, are largely dependent on the money available for these services. The price of armour early in 1921 was about £235 a ton ; a 35 ton plate, capable of taking, say, 4 rounds of 15 in. A.P.C. shells, therefore costs some £8,000. Thus, apart from the cost of the shell, which is about £120, and the overhead costs of the proof butts, a sum of £2,000 is expended on armour plate alone for every round of proof or trial shell which is fired through thick armour.

Trials to determine the best weight (W/D^3) for future shells of heavy guns.- The length of a projectile, other things being equal, depends on its weight. A short shell tends to be steadier in flight than a long one and the nearer the centre of gravity is to the base the better. It is also probably that the length of a shell has something to do with a very frequent cause of failure during oblique perforation, that is, the tearing off the base of the shell. It is suspected that a short shell tends to escape this rupture more easily than a long one.

In the past British shells have, on the whole, been heavier than those used abroad. For instance, our 15 in. A.P.C. weights 1,910 lb. and the relation W/D^3 is therefore 0.566, W being weight in lb. and D the diameter in inches. The German and American shells are usually of approximately $W/D^3 = 0.5$. The German 15 in. weighs about 1,654 lb.

Trials were carried out to decide the question of the best weight of shell, form the armour piercing point of view, by firing 15 in. A.P.C. shell of the same quality but of three different weights as follows :-

15 in. A.P.C. heavy (service)	..	..	1,910 lb. W/D^3 0.566
15 in. A.P.C. medium ..	..	..	1,688 lb. W/D^3 0.50
16 in. A.P.C. light ..	..	..	1,519 lb. W/D^3 0.45

Twenty-one shells were fired and, as far as the trials went, the capability of the three shells to perforate armour fit to burst at various angles of impact differed hardly at all. The results, if anything, slightly favoured the "Medium" shell with W/D^3 of 0.5. This W/D^3 has been adopted for the shells of new turret guns (G.062/21). Further W/D^3 trials are in progress (G.0356/21). Ballistically, advantage rests with the lighter shell as M.V. and ranges are increased ; reduction in length and weight is also advantageous both to the gun mounting machinery and stowage arrangements.

41. Performance of Large A.P.C. Shells at Calibre Plates, Trials arranged.- Information has been received of certain successful foreign large A.P.C. trials at plates of approximately calibre thickness.

To compare with these reported results it is intended to fire at 13¾ K.C. plates taken from the "Baden" with our service 15 in. and 13.5 in. A.P.C. shells, to see at what angles and velocities the shells will perforate whole. (G.01159/20.) The resistance and quality of this German armour is considerably inferior to that of contemporary British K.C. plates, but its use will afford an economical means of carrying out comparative tests of shell designs and the qualities of shells.

(See also results of 15 in. A.P.C. at 13¾ in. turret armour on board "Baden" in Section XXc.)

41a. General Statement of the Armour Piercing Quality of Shells.- At medium battle ranges and angles of impact up to 20º to the normal shells of a suitable type and of the calibres shown may be expected to perforate armour and go on in a fit condition for bursting as follows :-

Calibre of Gun	*Armour penetrated – shell whole.*
15 in.	12 in. K.C.
13.5 in. Hy. or Light	10 in. K.C.
12 in.	8 in. K.C.
7.5 in.	6 in. K.C.
6 in.	4 in. K.N.C.
4.7 in.	2 in. H.T. steel
4 in.	2 in. H.T. steel

No details of the actual proof specifications of shells nor of the trial results obtained will be printed in the "Progress in Gunnery Material" because of the necessity for secrecy in such matters. A special pamphlet containing this information is being prepared for a very limited issue.

42. Proof of Shells.- In addition to the plate proof of weighted shells at armour of plating the following proofs are carried out :-

(a) **Recovery proof.-** A "weighted" shell is fired over sands for recovery, with high chamber pressure, to test the banding of the shell and attachment of cap and to see that the shell walls are not deformed under the pressure in the gun.

(b) **Fragmentation proof.-** The shell recovered from (*a*) is then filled and fragmented with the service filling and fuze to see that the explosion is satisfactory and the fragmentation of the right degree. (G.6592/19.)

(c) **Proofs of filling.-** (1) A filled and fuzed shell from each batch of filling is fired at a thin plate to test the efficiency of the filling and the delay given by the shell as filled and fuzed for service.

(2) A filled shell either plugged or fuzed is fired over water with high chamber pressure to test the safety of the filled shell.

(*d*) There is at present no routine test of batches of filling, as regards insensitiveness to shock, although exhaustive trials have been done with shellite up to 80/20. The introduction of a further routine proof for the "Insensitiveness of Filling" is under consideration. (G.7326/21.)

The above proof tests apply to A.P.C. and S.A.P. shells. Proofs on the same lines, so far as applicable, will be applied to all natures of shell to ensure that our material, as delivered in bulk for supply, continues to be satisfactory and does not differ from the shells tested at trials. (See C.B. 1561, pages 45-6.)

Outfits of shells for turret guns.- As the result of the "Swiftsure" trials the decisions given on pages 88 and 89 of the 1920 edition of this book (C.B. 1561) were reached.

This outfit of battleships was approved to be 100 per cent. A.P.C. with delay fuzes, and that of battle cruisers 80 per cent. A.P.C. with delay fuzes, and 20 per cent. C.P.C. (filled powder) with non-delay fuzes.

The firings at "Baden" (see Report in Section XXc) have not yet been fully dealt with, but the following are the probable lines along which these last experiments will direct progress. (G.0330/21.) In general, the conclusions reached at the "Swiftsure" trials were entirely confirmed. Our large A.P.C. shells, filled 70/30 shellite and fuzed with delay, are proved to be a very efficient weapon against capital ships **as at present designed.**

If an "optional delay" fuze can be obtained (the trials of which are very promising), it is probable that this device will be applied to the A.P.C. shells both in battleships and battle cruisers. This would enable a short delay instead of a long delay to be used at will, when firing at light craft, without changing projectiles in action. Alternatively, a proportion of A.P.C. shells can be supplied with non-delay fuzes. Our present base fuzes for all sizes of shell are insufficiently sensitive and are liable to go blind through thin structures. It is hoped to overcome this, and trials with new designs of fuzes are in progress. Improved sensitive base fuzes can also be made t embody the optional delay fitting. The question of whether a larger capacity shell, in addition to the A.P.C. type, is required for turret guns is still under consideration. It is clearly desirable for many reasons to have only one type of shell which will meet all requirements but this policy in unacceptable unless we can be sure that such is the case.

It has been clearly proved that the efficiency of the existing C.P.C. shell is improved by substituting a shellite for a powder filling, but the expense of conversion of the fillings and fuzes of existing shells would be great and there are other practical objections to the use as H.E. shells of our existing large C.P.C. shells.

If the designs of foreign capital ships develop in the direction of improved deck armour protection to an extent which makes it unlikely that such ships can be successfully dealt with by direct attack on their vitals by an A.P.C. shell, we may then have to reconsider the whole matter and revert to a large capacity shell designed to penetrate into the ship and explode with the most devastating effect in order to wreck girder strength and destroy the structures above the main armour deck. This possible development, however, lies in the future. So far as is known, the designs of foreign capital ships now built or building do not afford adequate protection against our 15 in. A.P.C. shell, provided the delay fuze functions correctly. Improvement in the regularity and reliability of the delay portion of fuzes is a very important matter, which is being pursued at the same time as the endeavours to improve the sensitiveness of fuzes in general, to introduce optional delay and to make our fuzes such that they can be filled in a manner which will cause either violent explosion or actual detonation, according to the nature of the exploding substance carried in the magazine of the fuze (*vide* Section XII, Fuzes). (G.6299/21. G.0330/21.)

Size of armour plates used for shell trials or proofs.- It is considered that relatively light armour plates of small area are more severe on a shell than larger and heavier plates of the same thickness. (G.0409/21.)

Under the conditions of erection at the proof butts a certain amount of "jump" of the plate when hit by the shell is unavoidable. Larger and heavier plates jump less than light ones and, being of larger area, they tend to dish or "give" more than smaller plates. It is now being arranged that plates of as nearly as possible 40 tons weight shall be used in future for tests of large shells, this weight being governed by the lifting capacity of the new crane at Shoeburyness. The actual size and weight of the plates will be arranged to take a maximum number of rounds without wastage of plate. (G.0409/21.) A definite distance of the point of impact of a shell from the edge of the plate and from the centre of any adjacent shell hole is imposed so as to standardardise the conditions for the shells. For the larger shells these distances are 2½ calibres from the edge and 3 calibres from the centre of adjacent hole.

Trials are in progress to test the extent to which large plates vary in quality and uniformity compared to small plates, and the final decisions as to sizes of plates to be used will depend finally on these trials. (G. 6694/21.)

Unsteadiness of shells at plate proof.- When firing shells with reduced charges to obtain the required S.V. for the proof or trial of shells or armour, particularly with the larger natures, there is a tendency for shells to be unsteady in flight, as shown by the shape of the hole made in a jump card erected in front of the armour plate. This unsteadiness tends to vitiate the result of the trial. As each round at thick armour may cost as much as £2,000 or more, it is a serious matter to reject the evidence of a round and to repeat it on the score of unsteadiness, although this has sometimes to be done.

Trials are in hand with 6 in. shells to try and discover some practical method of overcoming this difficulty at the butts. (G.6975/21.)

The difficulties of making such a weapon a practical success are obviously great and were not entirely overcome by the Germans.

Wear was excessive and the life of the guns extremely short, and there is evidence that the above system, of varying the dimensions of their shells as the guns wore, was in operation.

45. Variations in Weight of Shells in Supply. (G.12305/20. G.19727/20).- The whole question of "tolerances" allowed in the weights of shells as delivered empty from the makers and as finally filled and fuzed for supply has been under consideration.

A certain variation ± from the weight as actually designed has to be allowed to the maker of the shell and of the fuze. The tolerance allowed on the cavity also causes a variation in the actual weight of the explosive filling. The greatest variation in weight of the complete article will occur when all the tolerances of shell, fuze and filling weights have the same algebraic sign and, therefore, add up in the same sense.

It has been arranged that, in future, the tolerance in weight allowed in a service shell shall be-

For 12 in. and above	± 0.5 per cent. of the designed weight.
Below 12 ″ ″	± 1 ″ ″ ″ ″

It has been found that large A.P.C. 12 in. to 15 in. as actually filled 70/30 shellite and fuzed 16 D., have actual average weights as follows:-

12 in.		$855\,^{13}/_{16}$	instead of	854 lb. as designed.
13.5 ″	Hy.	$1,413\,^{5}/_{16}$	″	1,410 ″ ″
13.5 ″	Lt.	$1,259\,^{9}/_{16}$	″	1,257 ″ ″
15 ″		$1.917\,^{5}/_{16}$	″	1,910 ″ ″

It has been decided to adopt these actual average weights as the standard designed weights, so that future supplies of these shells shall average the same as those already in supply.

Until the Range Tables are corrected, a small ballistic correction for the difference between the Range Table weight of the shell and this actual weight should be applied in making accurate calculations for external ballistic problems.

45a. Fillings for Shells.- 70/30 shellite is the present approved filling for our large A.P.C. shells. Trials have shown that 80/20 shellite is satisfactory (*Vide* C.B.1561, pages 48-9.) Investigations are going on into the question of alternative fillings which shall avoid the difficulties caused in the workshops by the poisonous nature of shellite. We shall certainly not abandon shellite, however, until we get something equally satisfactory as regards insensitiveness to shock, safety and explosive effect. Another disadvantage of shellite, which is shared by lyddite, is the necessity for using metals completely free from all traces of lead in the vicinity of these explosives. It is proved by trials that, if a suitable fuze is used, shellite fillings can be detonated just as well as lyddite or T.N.T. The question, however, is a very complex one as it is affected by at least four factors, viz.: The fuze (whether detonating or igniferous) ; the filling (whether capable of detonation or not), insensitiveness being essential ; the size of the shell cavity ; and the thickness of the shell walls. What we want to obtain is the greatest possible “stopping” effect, for which large fragmentation is required in order that the fragments shall be in a condition fit to carry through bulkheads and decks and, by virtue of their weight shall retain their velocity well. Explosion (which is of a violent order) of the present weight of shellite filling in a heavy A.P.C. shell gives very satisfactory fragmentation, but it seems probable that the velocity of fragments can be improved. If the same weight of filling be detonated, fragmentation is considerably smaller and the fragments are too much strained to have much “carry” ; the effect is therefore too local. At the present time, we have no detonating base fuze of suitable type, consequently there is no option but to adhere to an igniferous fuze, although this could probably be used to initiate detonation through the medium of the gaine. But the adoption of a detonating filling means also reduction in size of cavity in order to reduce the effect on the shell.

Investigation of all these matters is in hand, but it will be realised that time is required and that many trials may have to be carried out before sufficiently definite results are obtained to justify large changes in shell design. In the meantime, it has been conclusively shown by numerous trials that our heavy A.P.C. shell filled 70/30 shellite, and fuzed No. 16 D are very efficient which is a strong reason for not departing from that combination unless on very sure grounds.

Fig.12 shows three 15 in. A.P.C. shells, two filled 70/30 shellite, one of which was detonated with a special fuze and the other exploded with a Service

The special rifling of guns for the purpose has been ruled out as being unlikely to cure unsteadiness. The present trials are to test whether using shells with a much reduced “clearance” between the shell body and the bore will achieve out object. If it does we may have to arrange for proof rounds to be machined to a specially high diameter.

7.5 in., 6 in and 5.5 in. shells.- The completion of proof ground shell trials which have been in progress since 1918, culminating in the firing at “Nurnberg” (Section XXB), has enabled decisions to be made as to the future requirements for the shells of these guns. These trials show that the 7.5 in. C.P.C. filled shellite with a delay fuze is an efficient projectile against light cruisers of any existing design. An armour piercing type of shell may be required when the protection of light cruisers improves, as it probably will do if larger vessels are constructed. Fresh trials are therefore being started so as to be ready with designs and specifications for ordering such shells for supply when the necessity arises. (G.01289/20.) Meanwhile the C.P.C. shells will be shellite filled with delay fuzes for supply to 7.5 in. guns. The 6 in. C.P.C. shells cannot be depended upon to reach the vitals of a light cruiser. It has been decided therefore, to introduce an armour piercing type of shell to replace the C.P.C. shell for the 6 n. guns of new aircraft carriers and of the newer light cruisers.
(G.7862/21. G0306/21. G.0648/20.)

These three calibres of gun are to carry, in addition to the C.P.C. or A.P. shell, a proportion of H.E. shells nose fuzed. The H.E. will have powder fuzes (45 P.) for firing against ships and a percentage may be supplied with a graze detonating nose fuze (when a satisfactory fuze of this type is produced) for barrage or bombardment purposes.

The powder D.A. fuze in an H.E. shell gives sufficient delay to allow the shell to penetrate and explode inside instead of detonating on impact as it does if fuzed with a D.A. detonating fuze, but this only applies against plating up to about 1 in. in thickness. In the former case the shell is broken up into larger pieces and the explosion inside the ship causes far greater damage than the detonation outside on the hull plates or deck.

Vide Submarine, T.B.D. and “Nurnberg” firing trials in Section XX_A & $_B$.

NOTE.- When H.E. shells with P. fuzes are tested at a rock at sea complete detonation is not to be expected.

The guns of the secondary armament of capital ships will carry C.P.C. filled shellite and fuzed with delay and H.E. shells as above.

Until a more sensitive base fuze is available a proportion of nose fuzed shells must form part of the outfit of 7.5 in. guns and below. When such a fuze s produced we shall perhaps be able to abolish nose-fuzed shells (except H.A. time fuzed) for new guns. (See remarks on “Nurnberg” trials in Section XX_B.)

Shells, 4.7 in. and below.- The prolonged proof ground trial of 1918 onwards, culminating in the firings at ex-German submarines and T.B.D.s, have enabled conclusions and decisions to be reached as follows. (See also Section XX_A.)

(G.0327/21. G.01256/20.)

For attack of ships.- The S.A.P. shell filled lyddite with fuze No. 12 is the most efficient for "stopping power" against T.B.D.s and is considerably better than the C.P. filled powder, which has been made obsolescent.

The H.E. shell is also efficient and for all-round purposes is better if fuzed with a powder filled than with a detonating fuze.

For attack of submarines.- H.E. shells fuzed with D.A. powder fuze are the most efficient shells for all-round use against submarines. This s largely due to the lack of sensitiveness of No. 12 base fuzes and also to the insufficient violence of burst of the S.A.P. shell with No. 12 fuze which, although originally developed with the idea of giving "coup de hache" effect on the pressure hull, very seldom achieves this object. Only at ranges at which plunging hits on the pressure hull of the submarine can be expected is the S.A.P. better than the H.E. For both natures of shell a short delay fuze is required (delay about 8 ft.) which the existing fuzes, No. 12 or D.A. do not give us.

Outfits of 4/7 in. and below.- These will consist, at present, of S.A.P. shells fuzed No. 12 and H.E. shells fuzed No. 45 P. for use against ships and submarines, and a proportion of H.E. fuzed with a sensitive graze for fuze barrage or bombardment. For the present both these natures of shell will be filled with lyddite. The C.P. powder shell becomes obsolescent and will gradually be replaced by S.A.P. (G.0265/21.)

Future Lines of Progress.

(i) **Shells generally.-** Until a more sensitive base fuze is available we must adhere to a proportion of shells with nose fuzes for 4.7 in. guns and below. (As for 7.5 in., 6-in. and 5.5 in. see page 50.)

(ii) **S.A.P. Shells.-** The present quality of shell is deficient in penetrating power. Future supplies will be made of high quality treated alloy steel and be subject to a more severe plate proof than existing shells. This will improve their effectiveness for plunging fire against the thick pressure hulls of modern submarines and against the sides of light cruisers. But this improved penetration power **must not be at the expense of their bursting effect.**

The development of a base detonating delay fuze may enable us to obtain that "coup de hache" effect, for flat trajectory fire against a submarine, which is wanting with our present shells and fuses.

(iii) **Filling of S.A.P. and H.E. Shells.-** At present this is to be lyddite in order to obtain as great a violence of explosion as possible with these small shells and with the powder fuzes available. (G.0210/20.) Lyddite is objectionable as a filling for several reasons of which the most important is that it reduced the penetrative power of the shell owing to its sensitiveness. For instance, a 1½ in. nickel chrome plate will cause the lyddite filling of a 4.7 in. S.A.P. shell to explode while the shell is passing through the plate. With the advent of delay detonating fuzes the necessity for the use of lyddite for the filling of small shells will disappear and an insensitive H.E. filling such as shellite, which is capable also of being detonated, can be used instead.

(iv) **Delay required.** (G.0327/21.)- The length of delay required for the best results, particularly against submarines, with shells 4.7 in. and below has now been decided. Whether base fuzes or D.A. fuzes can be made to give a short delay of the order required with any reasonable regularity remains to be proved.

To sum up, the lines of progress for these small shells are:-

1. To improve the quality of S.A.P. shells.
2. To develop improved fuzes.
3. As soon as practicable, depending on 2, to suppress lyddite as a filling.

(See also the remarks on the anti-submarine firings in Section XX_A.)

43. Utility of A.P. Caps – Velocity for "Cap Action."- It has always been recognised that there is a velocity for any given size and weight of shell below which the A.P. cap is of no value. Under these conditions "cap action" does not take place when the plate is struck.

What the lowest striking velocity may be at which caps cease to assist the shell is not known, but for large A.P.C. shells it certainly lies well below 1,500 f.s., and may be below 1,300 f.s., which isles than the least R.V. of these large guns. For smaller gun, 7.5 in. and below, however, this question is of practical importance owing to the lower striking velocities of the shells from such guns at fighting ranges. An uncapped shell is of greater weight than the shell body of a capped shell and, therefore is capable of doing more work in perforation, particularly if there is no necessity for a cap to destroy the hard face of the plate before the shell body starts pushing its way through.

It is probably, therefore, that the new A.P. shells and S.A.P. shells for 7.5 in. guns and below will be "uncapped," *i.e.* will have only a ballistic cap above the head of the shell proper.

44. Rifled Shells.- In connection with the trials of "Hyper-Velocity Guns" rifled projectiles are being used.

The ordinary sort of driving band is not capable of giving satisfactory rotation of the shell under the conditions of acceleration up to the great velocities used in this type of gun.

The shell is rifled on its body with ribs which accurately fit the rifling groove in the bore. It may be found that projectiles of increased diameter and slightly different rifling are required after each few rounds as the gun wears. It is believed that this procedure was adopted by the Germans for their long range guns.

fuze, and one filled T.N.T. and detonated. Of the collected fragments shown in the photo, a larger quantity is missing from the exploded than from the detonated shell. The reason is that when the shells are fragmented under water, the energy of the smaller fragments of the detonated shell, although their initial velocity is higher, is more quickly absorbed by the resistance of the water than that of the heavier, though slower, moving pieces of the exploded shell. This fact is consistent with the greater structural effect caused inside a ship by the exploded shell.

In the case of smaller shells, 7.5 in. and below, the actual mass of the burster is so much less that, when ignited, 70.30 shellite does not burn to the same degree of violent explosion as do the large bursters of 12 in. shells and above of the same percentage capacity ; this is also partly attributable to the face that in the large shell, the shell body is so strong that it does not give until the pressure within has had time to rise and thereby increase the violence of the explosion. Bursting effects of these smaller shells (see “Nurnberg” Report) are not altogether satisfactory and it is probably that a detonating fuze will be used for these when a satisfactory delay detonating base fuze is produced (see page 50).

Alternatives to Shellite. (G.087/20.)- The possible alternatives to shellite at present under trial or investigation are T.N.T. and a mixture known as T.N.T./T.N.X. (tri Nitro Xuoluene). The Germans used T.N.T. in blocks deadened by cushioning with wax or other substance in the nose of the shell. These fillings are much less sensitive than our lyddite but are not so insensitive as our present shellite, which needs no special cushioning. British trials with deadened T.N.T. have not hitherto been a success (G.0385/20) ; they are being taken up again (G.01223.20). Trials of T.N.T./T.N.X. are also being started.

It is known that the Americans were having trouble with their pressed fillings, which are found not to be always satisfactory insensitive. (G.7326/21.)

These are believed to be of ammonium picrate.

Lyddite.- The only service shells which now retain a lyddite filling are nose fuzed H.E. 7.5 in. and below, both for H.A. and anti-ship purposes, and S.A.P. shells 4.7 in. and below.

To obtain the greatest possible violence of burst, as is aimed at in shells of these natures, it is necessary at present to retain their lyddite filling.

The reason why lyddite is sensitive and shellite is not is believed to lie in the nature of the crystalline structure assumed by these explosives when they solidify after being poured into the shell in a molten condition. Lyddite forms comparatively large crystals of long axis, and it is the fracture of these crystals by the shock of impact that causes the lyddite to detonate spontaneously. Shellite solidifies into a close grained granitic structure and has no long crystals to snap under the shock of impact. The total abolition of lyddite fillings is aimed at, but it depends very much on the development of fuzes.

Powder Fillings.- These are now obsolescent. The only Service shells thus filled are C.P.C. 12 in. and above, which form 20 per cent. of the outfits in battle cruisers, and C.P. shells for small guns which are to be replaced by S.A.P. The stock of powder filled C.P. shells is so large that some years will elapse before they are all finally scrapped. The C.P.C. shells for 7.5 in., 6 in. and 5.5 in. guns are being gradually altered with a view to their being refilled with shellite instead of powder. For new guns, if any shell other than an A.P. type is required, a large capacity C.P.C. or C.P. type of shell will probably be used, filled with shellite. It may, later on carry a base detonating fuze.

Effects of moisture in Shellite.- It has been proved that a high moisture content in a shellite filling does not interfere with the violent explosion and correct fragmentation of A.P.C. shells 12 in. and above. It is expected, however, than an undue proportion of moisture may affect the picric powder exploders and be connected with variations in the time taken for the shell to burst after the fuze is set in action, thus affecting the linear length of delay obtained. This is being investigated with the whole “delay fuze question.”

46. Liability of Shells to Explosion or Detonation in Action.

A.P.C. Shells.- The thick walled A.P.C. type of shell is practically immune. from sympathetic detonation or explosion. A shell, bursting in contact with a pile of shells of this type filled 70/30 shellite and fuzed, may scatter the pile or even break up some of the shells in the pile without any of them exploding.

These shells have also been blown up in a shell room by a mine exploded beneath it (Chatham Float Trials) without any sympathetic explosion of the shells.

One 15 in. A.P.C. shell filled and fuzed went blind into the turret of “Baden” during the experimental firings. All attempts to destroy it, with gun-cotton detonated against the sides of the shell failed. Finally it was burst by blowing in the fuze with gun-cotton placed on the base of the shell.

H.E., C.P.C. and C.P. Shells.- These thin-walled types of shell are liable to explosion by a shell detonating in contact with them. They are not necessarily exploded by a shell which explodes but does not detonate.

If shells are not in contact the risk of explosion or detonation being communicated from on to the other is greatly reduced.

A 6 in. H.E. filled lyddite and fuzed will detonate similar shells at 3 ft. but not at 4 ft.

If placed *en echelon*, with the nose of one in line with the base of the other without overlap, detonation is not transmitted. Hence the orders if force and the arrangements of racks for stowage of shells at gun positions.

47. Chemical Fillings for Naval Shells.- The naval requirements have been defined to guide the works of the Joint Chemical Warfare Committee as follows (G.0398/21) :-

Possible Naval Uses of Gas.

Anti-ship Shells.- Any gas employed must be of a very quick acting nature to be of much use. Pointed shells with considerable penetrating power, with base fuses and without any hole in their side for charging purposes, are essential for naval anti-ship shells. The fillings may be either :-

(i) High explosive arranged to generate poisonous gases in addition to their ordinary bursting effect.
(ii) Partial gas filling together with a major filling of high explosive.
(iii) Complete gas filling, provided sufficiently serious effects can be produced to make it worth while surrendering all the usual bursting effects of the shell.

Gas Cloud Shells.- No restrictions are necessary except that :-

(i) The gas produced must be suitable for sea conditions.
(ii) The shells must be safe in stowage.
(iii) The shells must be safe under firing conditions with Naval full charge chamber pressures.

A quantity of obsolescent A.P.C., C.P.C., C.P. and H.E. shells from 18 in. to 4 in. calibre has been set aside for the use of the Chemical Warfare Committee.

(G.01159.20.)

Gas Experimental Station.- Arrangements have been made to construct a suitable bursting cell at Porton into which Naval gas shells will be fired through plating, and when sufficient experience has been gained a similar, but much large, chamber butt will be built at Shoeburyness. This will allow tests to be carried out with the large sizes of A.P.C. gas shell fired through thick armour. Until the Porton establishment is a going concern and properly equipped, progress is bound to be slow.

Actual Trials in Hand for Gas Shells.- Trials are continuing to find out what proportion of the shellite filling of A.P.C. shells can be surrendered to make room for a partial gas filling, without unduly reducing the bursting effect of the shell. (G.0819/20.) Trials are also continuing to find out whether the prevention of the "secondary flash" will enable an H.E. filling to generate in the compartment where it bursts a sufficient quantity of lethal gas (CO, Prussic Acid, etc.) to be of any use. It appears very doubtful whether this is a feasible proposition. (G.04372/18.)

Smoke Cloud Shells.- No progress to report, and none is likely until the Porton Experimental Establishment is a fully going concern. The fuze trials (Section XII page 63), if they produce satisfactory water graze fuzes, will solve that part of the problem.

48. **Ballistic Caps.-** The adoption of a longer ballistic cap on all shells for new guns, to increase the range and remaining velocity, has been accepted, subject to satisfactory rough usage and ballistic trials. (G.0510/21.)

What was originally known as an 8 calibre radius contour will probably be adopted. The technical name for the actual design of contour is 6/∞.
(G.3701/21.)

Conversion of Existing Shells to Longer c.r.h. Contour.- The conversion to 6/∞ c.r.h. of existing shells for turret guns and 7.5 in. guns and below has been under consideration, but the expense involved in this conversion and in the corresponding alteration to sights, directors, hoists and other armament fittings prohibits any such action for ships already afloat. (G.031/20.)

15 in. shells with long false caps have satisfactorily withstood severe rough usage trials afloat, and it has been proved by trials that this form of ballistic cap does not affect the behaviour of the shell hen fired against armour.
(G.0510/21, G.4486/21, G/6649/21.)

6 in. A.P.C. shells of 6/∞ c.r.h. were tried but failed to stand the rough usage they may get under service conditions. (G.0901/20.) This may be overcome by improved design, but it may be necessary to adhere to a 4 c.r.h. contour similar to that of the existing shells. With modern high elevation mountings the gain in range obtained by the use of long ballistic caps is not of such great importance as appeared during the war.

Ballistic Trials with Long Caps.- As regards all these long capped shells we are waiting for the equipment of the new long range at Grain Island to carry out the necessary range and accuracy trials. It is by no means certain that at high elevations such as 30º such shells will be suitable spun by the pitch of rifling which is at present given to our guns. In general it may be seen, therefore, that the definite adoption of the 6/∞ c.r.h. shell for either new or existing guns is still uncertain.

Ballistic Caps on H.E. Shells. (G.0308/20.)- If we are obliged to retain a proportion of nose fuzed shells for new guns, as will be the case if we cannot obtain the hoped-for improvements in sensitiveness of base fuzes, the adoption of long ballistic caps for the shells of such new guns will be limited to the length of the largest practicable monobloc shell, where C.R.H. is rather less than 6/∞. The difficulties and complexities of getting a D.A. fuze to act correctly underneath a ballistic cap are great, and the only satisfactory way of overcoming this is to use a stick to transmit the blow from the nose of the false cap to the fuze. This feature is disliked for Naval purposes, both on the score of safety and improbability of such a fitting withstanding the usage, shell necessarily receives in transport on board ship.

49. **Accidents with Shells and Precautions to be taken.**

Cracking of Shells.- In order to emphasise still further the importance of carrying out the periodical examinations of shells with great care, the attached summary of A.P.C. shells found cracked in supply is given. None of the new shells have ever been found cracked in the body in such a way as cold endanger the filling of the shell, but cracked caps are fairly frequent and flakes have been found cracked off the surface of shell bodies. If a shell in such a state were fired, the cap might break up and jam the shell in the bore and cause the base fuze to function with serious results. In any case the damage to the rifling would probably condemn the gun. Cracked C.P.C. shells 12 in. and above are also being reported fairly often. (G.4961/21.) A premature with these powder filled shells will usually make it necessary to retube the gun, although the bore often remains fit for continued firing in action.

Thus, apart from the periodical examination laid down in the regulations, it is very desirable when time and conditions permit (*e.g.*, during a leisurely bombardment) to examine all shells before they are rammed home.

Steps are being considered to rearrange the conditions under which the Admiralty Inspecting Officers at Firms' works are able to oversee the processes of manufacture so as to try and minimise the risk of any batches of shells particularly liable to crack being passed out into supply. (G.496/121-G.0428/20.)

Summary of A.P.C. Shells, 12 in. and above, known to have cracked in body or cap from May, 1918 – *December,* 1920

Calibre	At hot and cold water test during manufacture		After hot and cold water test but before leaving works		After leaving works	
	Shells	Caps	Shells	Caps	Shells	Caps
12 in.	17	0	22	3	0	4
13.5 in.	96	103	53	2	6	42
15 in.	76	5	73	22	4	19
Totals	189	108	148	27	10	65

It should be remarked that a large proportion of the defective shells discovered "after leaving works" were found before the shells were filled and issued, but a considerable number have been detected afloat and the existing precautionary orders for periodical inspection are of great importance. Other references to A.P.C. caps cracking – G.144/20.

"Lord Clive" Accident.- During the triple turret firing with 15 in. guns in H.M.S. "Lord Clive" a 15 in. A.P.C. old type shell, filled lyddite and plugged, prematured in the bore and destroyed the gun, fortunately with only one minor casualty. (*Vide* full report and conclusions given in Section V.) (G.0467/21.)

These decisions entail fitting new adaptors to the 6 in. C.P.C. VII A.Q. and to the 5.5 in. C.P.C. shells before they can be issued to ships with their new shellite filling and delay fuses. Meanwhile ships will carry these shells filled with powder.

50. Target Shells. (G.0713/20.) – H.M.S. "Agamemnon" is now ready to use as mobile target ship. Our attempts to develop "target shells" which shall not cause excessive damage and necessitate costly repairs after each shoot have not been very successful.

Trials carried out with 6 in. practice shot and 6 in. H.E. shells, both weighted and filled and fuzed, at a target representing the decks of "Agamemnon" showed that a 6 in. H.E. weighted shell could be used up to ranges of about 14,000 yards, but not **exceeding that range,** with reasonable certainty that no damage would be caused below the armour deck. 6 in. weighted shells are therefore being issued to the Fleet for target practices at "Agamemnon" with full charges and at ranges not exceeding 14,000 yards. At longer ranges the pieces of broken shell are liable to penetrate through the armour deck and this risk of damage to the ship's engines or boilers cannot be accepted. Trials are continuing to develop some special patter of 6 in. target shell or target shot which can be safely used without any restrictions as to range. (G.0713/20, G.0370/21, G.0154/21.) In view of the above it will be realised that the problem of getting a satisfactory and sufficiently innocuous 15 in. target shell is still very far from solution. Two 15 in. trial target shells of the latest design and filling are ready to be fired at a hulk, until this has been done no more money is to be spent of proof ground trials with 15 in. target shells and "Agamemnon targets." G.0713/20.) As the matter stands at present, the certainty that a large sum of money would have to be spent on repairs and possibly for docking the ship after each shoot is so great that the risk cannot be incurred.

Diving Shells.- Trials have been going on since 1902 with various patterns of diving shell. None of them have been successful at any reasonably low angle of impact on the water. Two experimental patters are now under trial by the Ordnance Committee. The chief value of such a projectile would be to increase the virtual target of a submarine on the surface, because shots falling some way short, if they dive, may hit the hull below water : the small target offered by a submarine on the surface would be considerably increased thereby.(G.0623/20, G.0230/20.)

Target Smoke Shell. – Supplies of target smoke shell are now in supply for 3 in. and 4 in H.A. guns, and steps are being taken to produce those for the 4.7 in. calibre. Under favourable atmospheric conditions it has been found that a smoke cloud (target) can be obtained lasting 15 minutes. In addition, experiments are in hand to combine with the cloud a smoke "line" of sufficient definition that will enable the rangefinder observer to obtain an easy cut with his instrument.

51. Star Shell.- As the result of combined experiments it has been found that, with the star composition now in use, the time of burning is primarily related to the density of the magnesium, and the restrictions imposed to provide for this being as high as possible have enabled very favourable results to be obtained. Present filling of star shell is confined to 3 in. calibre, and times of burning show a gain of approximately 80 per cent. over early fillings of this calibre. It is probably that this improvement will be reflected on other calibres when it is necessary to replenish stocks.

The experiments to obtain a star shell that will satisfactorily function with full charges (as against the reduced charges now used) have not yet met with success. Great difficulties were experienced in evolving a parachute system that would gradually take the strains associated with high velocities, but fresh ideas are being tried and the trouble is not thought insurmountable.

SECTION X_A.

AERIAL BOMBS.

52. Aerial Bombs.- In collaboration with the Air Ministry, trials have been started to develop armour piercing bombs for the attack of ships' decks.
(G.D.62/21. G.0953/19. G.0207/19.)

To develop this material it is necessary to carry out trials at the proof butts on the same lines as those required to develop shells. It is not a practical proposition to drop experimental bombs from aircraft onto targets. Trials of this sort could only be "Full-dress" trials, carried out on special occasions with the developed service article. Arrangements have been made, therefore, to fire the bombs from a howitzer at the proof butts, with striking velocities similar to those obtained when bombs are dropped from different heights. In this way the penetration through ships' deck armour and the effects on targets representing ships can be tested and the designs and methods of manufacture of the bombs improved. It is probable, when A.P. bombs are produced for supply that they will be subjected to some sort of "plate proof" for acceptance and generally be treated in a similar way to A.P. shells.

Insensitive fillings and suitable delay fuzes, to enable the bomb to penetrate as far as possible before it bursts, will also have to be tried out.

Later on, trials at targets representing ships will enable the constructors to obtain a good knowledge of what horizontal protection is required by large ships t keep out modern bomb attack. Meanwhile trials are being arranged with existing bombs of various sizes which are to be detonated at rest in different positions on board a hulk (probably the “Baden”). These trials will enable the structural effects of large capacity bombs detonated on the upper deck and between decks to be investigated for the benefit of our constructors without waiting for the developments outlined above.

At present bombs really suitable for the attack of ships are in their infancy. They will always be handicapped by their low striking velocity, until aircraft can mount some sort of a gun for firing bombs downwards. This would not only increase their penetrating power but also, by reducing the time of flight, increase the probabilities of hitting which at present are not great from any reasonable height, particularly at a moving ship.

These disabilities do not justify us, however, in ignoring the future possibilities of aerial bomb attack on ships. In the near future this may become a really formidable menace.

Flame Bombs.- Trials of a bomb to give smoke and flame when dropped into the water, for the marking of a located submarine or of a torpedo at the end of its run, are in progress. (G.0865/20.)

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SECTION X_B.

ARMOUR.

53. Armour.

Preliminary Remarks.- The subject of armour was not dealt with in the "Technical History of the War" series, nor in the first volume of the "Progress in Gunnery material," 1920. Volume 1 of the "Gunnery Manual" is now being revised, and Chapter 6 of the new issue will deal with armour and Chapter 7 with the effects of shell fire. These two articles will bring the general information on these subjects up to date. Succeeding issues of the "Progress in Gunnery Material" will contain the necessary information to keep officers in touch with the progress made. In view of the wide distribution of the "Gunnery Manual," however, certain details are omitted from that book regarding the progress of armour, ship protection, projectiles and delay fuzes. These particulars are to be regarded as very secret. Such information concerning them as is required by officers afloat will be inserted in future in the "Progress in Gunnery Material," which has much more restricted circulation that the "Gunnery Manual." (G.D. 85/21 and G.D.389/20.)

In this connection it may be stated, in general terms, that the efficiency of the design of the armour or deck protection of a ship depends upon its ability to resist at battle ranges the attack of the type and calibre of shell carried in vessels of a similar class.

The armour protection may, broadly speaking, function as follows :-

(a) It may resist the shell without suffering serious damage, in which case the armour may be considered as having been completely successful.

(b) It may have a hole knocked in it, but the resistance may be sufficiently high to cause the shell to break up in the process or to explode outside the ship's vitals. In this case the armour may be considered as having been partially successful (or partially defeated).

(c) It may fail to prevent the shell passing through it and going on in a fit state for bursting. In this case the armour would be completely defeated.

Assuming condition (*c*) above, the danger of the attack on a ship's vitals also depends very largely on the length of delay and regularity of the behaviour of the fuzes.

It will therefore be seen that exact knowledge of the capabilities of the shells and fuzes of a potential enemy is of the greatest importance, to enable our ship designers to dispose the protection in the most efficient manner. It will be equally evident that every endeavour must be made to keep similar details of our ammunition secret. This armour section may therefore be regarded as supplementary to Chapter 6 of the "Gunnery Manual," Vol. I (now in preparation), and will be understood more clearly when read I conjunction with that chapter and its illustrations.

Existing Specification Tests for Armour.- At present our plates are tested with the pre-war standard A.P.C. shells at normal impact. These specifications will remain in force until the correct tests with new shells at oblique impact enable us to lay down more modern conditions for the proof of armour plates.

The following table gives the approximate values of K.C. armour against attack at normal impact of the standard (old type) shells shown :-

Shell.	To defeat a plate the shell requires a velocity of f.s. per inch of K.C. armour	Approximate limiting velocity.
15 in. A.P.C. I.A.	100 f.s.	Of a 15 in. plate 1,500 f.s.
13.5 in. A.P.C. I.A. Hy	90 f.s.	Of a 13 in. plate 1,170 f.s.
12 in. A.P.C. IV.A.	150 f.s.	Of a 12 in. plate 1,800 f.s.
9.2 in. A.P.C. IV	225 f.s.	Of a 6 in. plate 1,350 f.s.
7.5 in. A.P.C. III.A.	300 f.s.	Of a 5 in. plate 1,400 f.s.
6 in. A.P.C. VII	300 f.s.	Of a 4 in. plate 1,200 f.s.

In order to be accepted at armour tests the plate must withstand a certain specified limiting velocity without being "holed" or having any portion of it detached from the back and without serious cracking.

Roof Plates.- During the war it became apparent that our turret roof plates were not thick enough to resist attack at long range. This led to the fitting of reinforcing plates on turret roofs and to the adoption of 5 in. roof plates for H.M.S. “Hood.” Roof plates of a still greater thickness are now under trial. The proofs of turret roof plates will be standardised for attack at 60º to the normal, representing an angle of descent of the shell of 30º. These proofs will probably be equated to 16 in. A.P.C attack, observing that 16 in. guns are already mounted in foreign capital ships.

Deck Armour.- Hitherto our decks have been built up of laminated thicknesses of high tensile steel (H.T.). In future both the design and material of armour deck in large ships, and probably in light cruisers also, will be different. The new material will be what is known as special treatment (S.T.) steel.

The features of this deck armour are required to be :-

(a) Capacity to dish and bulge under impact without cracking or tearing.

(b) Facility of working the plates form the constructor’s point of view in shipbuilding.

(c) Relative cheapness, compared to armour such as roof plates are made of, because of the large areas involved and the very high cost of modern armour.

Roof Plate Butts.- The tests of these thick roof and deck armour plates at 60º to the normal require a special type of butt, usually known as a roof plate butt.

The present equipment of Shoeburyness range in this respect is not satisfactory, and up to date we have been largely dependent on Vickers’ private range at Eskmeals, where a very good butt of this pattern was built during the war. It is hoped to get an improved butt erected at Shoeburyness in 1922. (G.2781/21.)

Splinter Proof Protection.- It ha been decided that gun-houses for 6 in. guns in future light cruisers and larger ships and the hoods of director control towers for main and secondary armaments of capital ships and of light cruisers are to have “splinter proof” protection. (G.0590/21. G.1306/21. G.19000/20.)

The moral, physical and material benefits of having the 6 in. guns self-contained and protected from weather and from the devastating effects of the small splinters of H.E. shells are obvious. It is not intended to armour these positions against direct hits by projectiles. The weight for this cannot be afforded as nothing but the thickest armour would be sufficient. Trials are in progress which seem likely to lead to the adoption for the present of 2 in. nickel chrome fronts and 1½ in. to 1 in. sides and roof to the 6 in. gun-houses and similar protection for the director control tower. (G.0178/20, G.0700/20, G.0567/21.) Trials are in hand to develop a system of chronographs for measuring the velocities of shell fragments when shells are laid at rest, and it is intended to follow these with other trials of shell bursting in flight.

(G.0483/21.)

From these trials it is hoped to be able to obtain sufficient data to be able accurately to say what constitutes "splinter proofness" against the attack of shells of any gun calibre as to which present information is inadequate.

54. Tests of Protection to be used in New Ship Designs.- It is recognised that so far as practicable the degree of protection to be afforded to the vitals of ships in the design stage and the proposed methods of constructing the armour decks and other practical features of her construction should be tested under conditions representing probably attack before the ship is built (*vide* "Hood" trials, C.B. 1561, page 82 , and Chapters 6 and 7 of the 1921, Vol. 1, "Gunnery Manual").

H.M.S. "Superb" has been allocated for this purpose (G.1001/21. G.0566/21) in 1921-2, and it is probable that a hulk will in future always be held at the disposal of the Admiralty departments concerned for such important full scale trials, and also for shell trials such as those carried out on "Swiftsure" and "Baden," whenever the developments of material render them desirable.

German K.C. Armour.- Tests of 12 in., 10 in. and 8 in. plates taken off ex-German "Baden" are in progress. Under present British standard conditions of normal attack the plates of all these thicknesses have been found to be markedly inferior to contemporary British K.C. plates. Trials to compare them at oblique angle attack are also in progress.

Trials of "Nurnberg's" side armour of 6 cm. (2.36 in.) also demonstrated the relative inferiority of German K.N.C. armour to similar British plating.

(G.01388/20. G.01365/20.)

Trials for new Armour Specifications.- The conditions of oblique impact which are necessary for proving A.P.C. shells, to ensure that the projectiles will be efficient under action conditions of velocity and angle of attack, require to be applied also to tests of armour. Trials were therefore started in 1918, but it will be some years before enough trials have been done to lay down definite specifications under these new conditions.

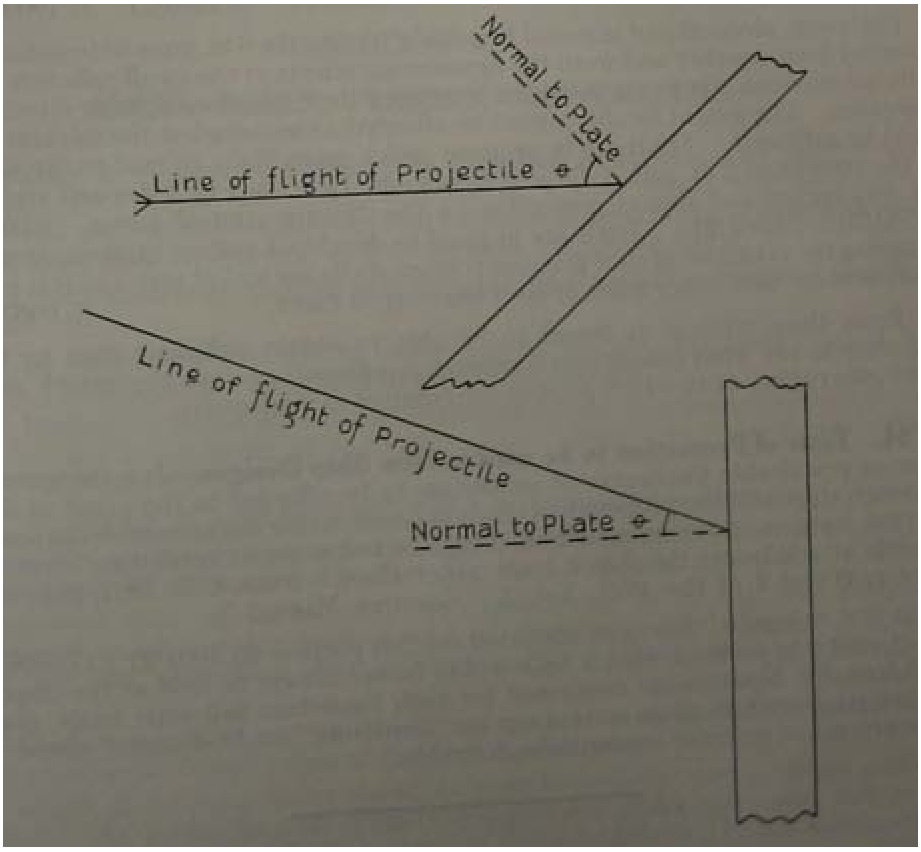
These oblique angle trials of armour have shown that the "limiting velocity of holing" a plate, under the new conditions of attack, is increased approximately by the following percentages :-

The "Limiting Velocities" of holing K.C. Armour at normal are increased-

by 20 per cent.	at 20 deg.	impact to	normal
″ 40 ″	″ 30 ″	″	″
″ 65 ″	″ 40 ″	″	″
″ 90 ″	″ 45 ″	″	″
″ 300 ″	″ 60 ″	″	″

and these facts a made use of whenever possible to increase the effectiveness of armour protection in the design of ships. A discussion of the theoretical aspects of oblique armour penetration and of the formulae now in use for calculations will be found in the "Gunnery Manual," Vol. 1921 (now in preparation).

NOTE.- The angle of attack to normal is the angle between the trajectory of the projectile and the plate normal at the point of impact $=\theta$ in diagrams.


Normal to Plate
Line of flight of Projectile θ
Line of flight of Projectile
Normal to Plate θ

SECTION XI.

PROPELLANTS.

55. Cordite.

R.D.B.- It has been decided not to proceed with this propellant for Naval Service owing to the difficulty in manufacturing it with regular dimensions. In this respect it is appreciably worse than M.D. (N.O.31711.)

Ardeer Cordite.- Investigation of this propellant has continued.

Numerous firing trials of the propellant as originally proposed have taken place and have been uniformly satisfactory. (N.O.32677.)

Trials are now in hand to test whether it can be relied upon to maintain its ballistics unchanged during years of storage. (N.O.265/21.)

Numerous samples have been, and are being. Subjected to climatic trial both in their normal state and after being deliberately contaminated with impurities such as might find their way into the cordite during manufacture.

Up to the present the results are entirely satisfactory.
(O.C.B.3652, N.O.52/21.)

The question as to safety in manufacture has not yet been entirely cleared up but experiments are in hand. (O.C.B.3808.)

The regularity of the dimensions of the sticks of this cordite has not up to the present been so god as was expected, and this is, of course, very important since irregular sticks make for irregular ballistics, but it is thought probably that this will be greatly improved with further research.

Oval Cordite.- It is not at present proposed to introduce this form for existing guns, but it will be required for the charges of new guns of the largest calibres.

Tubular Cordite.- Trials to investigate the ballistics of tubular cordite have been ordered.

SECTION XII.

FUZES, TUBES, PRIMERS, AND TRACERS.

56. Policy in respect of Fuzes to be Supplied in Future.- As regards percussion fuzes it is hoped, with the exception of a fuze which will be required for the special purpose of bombarding land defences at long range, to eliminate nose percussion fuzes from the Service, and to use only base fuzed shells.

Endeavours have been, and are still being, made to evolve a design of base fuze which will-

(a) Be sufficiently sensitive to ensure functioning on thin plate even in the largest calibre shell used in the Naval Service.

(b) Embody a device whereby the fuze can be set after insertion in the shell and before firing, so as to give either “delay” or “non-delay” effect as desired.’

(c) Be capable of being filled either as a detonating or as an explosive fuze.

As regards (*a*) a device has been suggested whereby the desired degree of sensitiveness may be obtained and preliminary trials have been promising.

An optional delay device to meet the requirements at (*b*) has been designed and submitted to trials which have proved its efficiency. The design in question possesses also the advantage that existing No. 16 D. fuzes can be modified to embody it.

The third requirement at (*c*) should not present insuperable difficulties but, of course, adds to the complication of the fuze mechanism.

The length of the delay to be aimed at must necessarily vary with the calibre of the shell. The actual lengths of delay required are under discussion still as a result of the trials at “Baden,” but it is expected that a decision will be reached shortly.

The difficulty of ensuring regularity in the length of delay given by the fuze is being investigated, the possibility of producing a delay powder, which will burn sufficiently slowly to allow a delay pellet of adequate thickness to stand the shock of hitting a heavy plate, is being looked into.

If it is decided that a fuze is required which will initiate detonation after the delay, this will necessitate either a delay powder which will burn to detonation or a second detonator which will function on the completion of burning of the delay pellet. Both of these lines of progress are in hand.

A type of fuze such as is being developed to meet the requirements set out above should not only be suitable for use in armour piercing and common pointed shell, but also in pointed H.E. shells and, possible, in shells required to function on water at low angles of arrival.

For shells supplied for bombardment of land defences a special type of nose detonating fuze will be supplied, and will probably be the same as that adopted by the land Service for similar purposes.

Several trials have already been carried out with a design which, while safer than the fuze which gave such greater satisfaction to the land Service during the war (No. 106), promises to be just as efficient. (G.1143/21.)

As regards time fuzes, it is hoped to replace gradually all existing powder burning time fuzes except No. 124 by mechanical fuzes, those for the heavier guns being arranged to run for 85 secs, and the remainder for 60 secs.

The present position as regards fuzes of various marks is as follows :-

57. Base Percussion Fuzes.

No. 12 Fuze.- It has been decided that further trials to obtain a satisfactory delay for No. 12 fuzes need not be proceeded with, such fuzes no longer being required. (G.19475/19, O.C.40138.)

A trial, however, was carried out in February, 1920, in which No. 12 fuzes, fitted with delays to F.L. design 25450M and R.L. design 25450m* and different makes of detonators were used, and the results indicated that a delay to the latter design would probably be satisfactory. (O.C. 39754.)

(This minute is actually quoted in the 1920 edition, but the letterpress indicates that the M type and not the M* type of delay was likely to be adopted.)

No. 15 Fuze.- The trials to obtain a satisfactory delay have been continued but without success further trials have, however, been cancelled for the following reason.

No. 15 fuzes fitted with delay were only intended for use in 6 in. and 5.5 in. C.P.C. shells when filled shellite.

It has now been decided that when such shells are filled with shellite they are at the same time, to be modified so as to enable No. 16 fuzes to be used in conjunction with copper gas-check plates and base coverplates.

With the unmodified shell and with No. 15 fuze, copper gas-check plates and base cover plates cannot be fitted, and in their absence the risk of premature due to the hot gases from the cordite charge finding their way between the threads of the fuze and the adapter cannot be accepted in H.E. filled shells.

(G.6794/20. B.0251/21.)

No. 16 Fuze.- As a result as the experience gained from firing trials against ex-German ships, it is possible that an alteration will be made to the delay pellet fitted to No. 16 D. fuzes for future manufacture.

Referring to the delay fuze approved for use in 7.5 in. C.P.C. shellite filled shells the nomenclature adopted is "No. 16 D.H." and not No. 16 D.R. as previously stated.

In the case of this fuze also, however, it is not unlikely that an alteration in length of delay will be required.

No. 16 D. type fuzes will also be provided, probably for any 6 in. and 5.5 in. armour piercing or C.P.C. shellite filled shells which may be supplied in the near future, but the type of delay which will be fitted will depend upon the length of delay required and the conditions under which that delay is necessary.

(G.01415/21, G.0330/21.)

58. Direct Action Impact Fuze.

No. 18 Fuze.- The trials carried out in respect of the fitting of shutters to No. 18 fuzes indicated that such modifications could be made, but that the result in fuze would not cost much less than newly manufactured No. 45 fuzes, and, having regard to this and to the obvious advantages of new articles over converted articles which do not contain all modern improvements, it has been decided not to proceed with the modification of No. 18 fuzes to contain shutters, but orders have been placed for the manufacture of No. 45 fuzes which, when available, will replace No. 18.

The New No. 45 fuzes will, generally, be filled with powder and be known as No. 45 P. Mark VIII fuzes.

(G.18783/19, G.4810/20, G.15079/20, G.01279/20, O.C.39028 *et seq*.)

59. Direct Action Fuzes.

No. 44 Fuze.- Trials have been carried out to ascertain the least angle of arrival on water at which No. 44 fuzes could be relied upon to function in 4 in. and 4.7 in. ogival headed shell.

These trials showed that functioning could be relied upon as below.

Gun	Shell	Minimum Angle of Impact	Minimum Range, Yards
4 in. Q.F. Mark IV	31 lb.	Just under 2 deg.	2,100 approx
4 in. Q.F. Mark V	31 lb.	1 deg. 49 min.	2,400 "
4 in. B.L. Mark IX	31 lb.	1 deg. 49 min.	2,400 "
4.7 in. B.L. Mark I	50 lb.	5 deg. 20 min.	4,100 "

(O.C.41826.

Trials to test the functioning of No. 44 fuze in flat-headed shells have also been approved. (G.7163/20, O.C.40728 *et seq*.)

No. 49 Fuze.- This fuze has now been declared obsolete for Naval Service.

(G.13721/19.)

60. Time Fuzes.

No. 124 Fuze.- No advance has been made in respect of powder filled time fuzes, but it has been suggested in respect of No. 124 fuze that an improvement in burning regularly when the fuzes are set full should be obtained if the full setting is reduced from 10 to 9.75, but sufficient trials have not yet been completed to determine whether this is the case or not.

Another cause of irregularity in No. 124 fuze which has been suggested is that the fuze was not tensioned sufficiently, and trials with fuzes tensioned more tightly have been arranged, both in respect o functioning in the gun and as regards setting by the automatic fuze setter in 2 pdr. Mark II guns. (O.C. 40150 *et seq*.)

61. Mechanical Fuzes.- As regards mechanical fuzes a drawing to govern manufacture has been approved and C.S.O.F. has commenced the manufacture of 500 fuzes. (G.1305/21.)

The order has been confined to this small number in order that any improvements necessary may be determined before the manufacture of the full Naval Service supplies is taken in hand. It is certain that one or two alterations in the approved drawing will be required, but these cannot be made until experience has been gained.

It has been decided that Naval Service requirements will be met by manufacture of new fuzes and not be adapting German fuzes, but about 5,000 German fuzes have been prepared for use at trials which will probably be carried out before a sufficient number of British made mechanical fuzes can be available.

If trials of the device are completed in time, it is hoped to embody in these 5,000 German fuzes a special anti-premature safety device of the same type as will be embodied in British made fuzes.
(G.10005/19, G.15408/20, O.C.40794 *et seq*.)

62. Hydrostatic Fuzes.- No progress has been made and trials of experimental designs have been suspended pending the results of the experiments being carried out against ex-German submarines. These have since been recommenced. (G.8420/20.)

63. Tubes.- New methods of filling service designs of tubes have been approved after trials which showed that they result in amore powerful flash effect and will ensure ignition over a larger air space. Current filling of tubes is on these lines.
(G.2109/20, O.C.40151.)

The combination of the new methods of filling and of manufacturing the bodies of tubes should result in more satisfactory tubes being supplied in future.

Percussion Tubes.- A certain amount of progress has been made with the new design of percussion tubes referred to in paragraph 57, and has shown that the design under trial promises to be satisfactory and

Further trials are necessary before it can be definitely decided to adopt the new design and have been arranged for. (N.O.29998. G.2080/19.)

Electric Tubes.- The withdrawal of lots of tubes which have become inefficient due to corrosion in the centre pole by the cement which was applied to it when being filled is proceeding.

Tubes which have been withdrawn are being converted to the current design in which no cement is applied. (G.4337/20.)

64. Primers.- Trouble in respect of misfires with No. I Mark II primers still continues, and investigations are still proceeding with the object of determining the cause and eliminating it.

Some misfires which have occurred may possibly have been due to the fact that it has been the custom only to require new primers to fire under a blow of 25 in. lb. whereas in the Service the striker springs are not condemned until the blow falls as low as 20 in. lb.

The specification governing the manufacture of Primers has been amended to permit the acceptance of primers which fire under a blow on 20 in. lb.

Primers of such lots and dates as are considered from reports received to be inefficient are being withdrawn as opportunity offers, and general withdrawals are proceeding on the following lines: (G.42400/18.)

Primers No. 1, Mark II, which are fitted with a glazeboard disc instead of a brass one to close the top of the magazine, since it is found that the sticks of cordite break up the glazeboard disc and allow the powder in the magazine to work down among the sticks.

Primers No 1, Mark IIa, No 2, IVa, and No. 5, Ia, which instead of a solid anvil have a ball which acts as the anvil ; this latter type, indicated by the "A" following the Mark, is considered liable to be dangerous in view of the possibility of the ball working loose and breaking up the composition. (C.M.O.830/20 and 105/21.)

SECTION XIII.

FIREWORKS.

65. Deck Flares.- In view of the danger of premature ignition due to excessive rise in temperature in the presence of moisture, all stocks of these flares have been destroyed.

Experiments are being carried out to obtain a new composition for filling such flares as may be required in the future.

V.B.S. Lights.- Satisfactory trials in the Fleet of new pattern V.B.S. Lights have been carried out but, owing to the length of time that elapses between actually firing and the complete functioning of this signal, it has been decided not to proceed with them.

Flares Signal Distress.- (Based on Crundall Distress Signal.) A new design of this signal consisting of a flare and thirteen stars ejected at intervals has been evolved by the Air Ministry. Rough usage trials to ascertain whether the signals are safe for stowage in ships are being carried out.

Wing Tip Landing Flares for use by Aircraft have been produced and satisfactory trials carried out by the Air Ministry. Their design has been concurred in as being suitable from a safety point of view for storage in the Naval Service.

SECTION XIV.

MAGAZINES AND SHELL-ROOMS.

66. Magazine Temperatures and Cooling Machinery.- Further reports received during the year from battleships of the Mediterranean Fleet and of the Atlantic Fleet during their stay in the Mediterranean show that the situation is not as satisfactory as it was thought to be and the possibility of the fitting additional cooling machinery is being considered.

67. Water Jacketing of Magazines.- This is still being investigated, as great advantages may be gained if the application of the idea is finally found possible.

These advantages are:-

(a) Immunity from loss of ship due to spontaneous ignition of a charge.
(b) Immunity from loss of ship due to explosion of mine or torpedo or penetration of cases by hot fragments from a bursting shell.
(c) Retention of cordite at an even temperature.

Trials have now been approved to test a new method which may be termed water jacketing under pressure.

In this method the cordite cases are stowed inside tubes built into tanks. The tanks are kept full of water and are connected by a large diameter pipe with a reservoir. The reservoir is partly filled with water and partly with compressed air and consequently the whole system is under pressure.

The great drawback to this and other methods that have been suggested is the serious reduction of stowage or a corresponding increase in the space occupied by the magazines.

68. Sealing of Cordite Boxes and Cases.- Two methods of sealing have now been approved.-

(a) For wooden boxes certain screws are countersunk, the space above the screw head being undercut, filled with sealing material and sealed.

(b) For brass powder cases a tape is first rove through holes in the lid, in such a manner that the lid cannot be removed without breaking the tape, but can be changed from the "transport" to the "stowage position." The ends of the tape are then passed through a small spiral metal spring which is compressed and the ends sealed. If the tape becomes cut the spring expands and straightens, rendering the fact evident. (G.18208/19.)

SEECTION XV.

CARE AND HANDLING OF AMMUNITION.

69. Protection of B.L. Charges.- The preliminary trials of the system of covering B.L. charges with two thicknesses of silk cloth instead of one only, and of covering the igniters with a cap or "igniter cover" consisting of a double thickness of silk cloth are described in Art. 67 of the 1920 edition.

2. A number of firing trials have now taken place at Woolwich. As a result of these it appear undesirable to use two thicknesses of silk cloth on cartridges 6 in. and below, as its use in these guns produces irregularity of ballistics. For guns above 6 in. the use seems unobjectionable.

3. It is now in contemplation to reduce the number of igniters fitted to one per half charge at heavy guns, each igniter being protected by a cap. There will thus in each cordite case be two quarter charges, one with igniter and cover, the other without igniter, and it will be necessary in loading to ensure that an igniter is next the vent. The cover of this latter igniter must of course be removed, but the cover of the other igniter can be left on.

4. For 6 in. guns and below the number of igniters will be unaltered, viz, one on each end of the full charge. Each will be protected by a cover but only the rear cover need be removed.

5. Before adopting these precautions trials on sea-going ships are being arranged to ensure that they are acceptable from the point of view of complication in ammunition supply to the guns and loading complications. (G.4252/21.)

70. Venting of Cordite Cases.- Efforts are being continued to obtain suitable designs of cordite cases.

Cases require to be :-

(a) Airtight.
(b) Capable of venting easily and at such a pressure as will not produce explosion.
(c) Able to withstand the rough usage to be expected on service.

The difficult is that (*a*) and (*c*) directly conflict with (*b*). As regards cylindrical cases M.Mk. II are considered as satisfactory, as this particular design can be made.

As regards Cases Powder Rectangular, the existing types of rectangular case have not proved satisfactory as regards opening freely if the contained charges become ignited and so avoiding a violent explosion.

A new design is now under trial in which the lid is made much larger, as large as the side f the case will take, and is fitted on the same lines as the lids of cylindrical cases. (G.01296/20.)

SECTION XVI.

FIELD AND BOAT GUNS.

71. Field Gun Equipment of the Fleet.- The issue of 12 pdr. 8 cwt. Field guns as allocated in C.I.O. 567/20 is completed.

The series of trials carried out with the 13 pdr. 6 cwt. Gun mounted on a carriage practically identical with that of the 3.7 in. howitzer have not been completely successful. The carriage provides for a traverse of 15 deg. and endeavour has been made to eliminate the necessity for relaying the gun after each round fired at all angles of elevation and traverse. At low angles of elevation and extreme traverse the jump is still found to be excessive. Attention is now being paid to the question of introducing modifications in order to overcome this defect ; no great difficulty is anticipated.

72. **Boat Armaments.-** The .303 Maxim Gun remains for the present the only armament to be carried in boats.

It has not been found possible to design a satisfactory boat mounting for the Q.F. 2 pdr. Pom-pom.

The .5 Vickers Machine Gun if adopted for Naval Service will most probably be employed for boat work.

SECTION XVII.

MACHINE GUNS AND SMALL ARMS.

73. **Future Machine Gun Policy.-** The functions for which a Machine Gun is required for Naval Service are :-

(1) For boat work.
(2) For us on shore by Naval landing parties in the form of Light Artillery.
(3) As a purely infantry weapon for use by Royal Marines on shore.
(4) For repelling attacks by low flying aircraft, though it may prove that the .303 machine gun will have to be discarded for this purpose.

Taking these functions into consideration, and in view of the stocks of Machine Guns now held, it has been decided that the policy of supply of Machine Guns in the future shall be :-

(a) **The Vickers Gun** to be adopted in place of the Vickers Maxim as the service Machine Gun. The Vickers Maxim Guns are to be retained in the Service and to be gradually replaced by the new Vickers Guns, as new ships have to be supplied or replacements become necessary.
(b) **The supply of Lewis Guns** in the present proportions shall be continued for Anti-Aircraft purposes for the present, and that these guns shall be supplied to Royal Marine detachments for Infantry work in the existing authorised proportions.

The .5 in. Vickers Machine Gun is being developed at present in conjunction with the War Office. Such a gun is required for the following purpose :-

(a) As the main armament for both H.A. and L.A. purposes in C.M.B.s, Motor Launches, and Picket and other boats.
(b) For use as the H.A. Armament for any other small vessels not normally armed with Machine Guns for Aerial defence.
(c) In lieu of, or in addition to, the .303 in. Lewis Gun Armament now carried by Capital Ships, Light Cruiser, Destroyers and other vessels, for defence against low flying aircraft provided that trials show that the .5 in. Machine Gun is superior to the .303 in. for the purpose, taking into consideration conditions for weight and space.
(d) Possibly in lieu of the projected 2 pdr. Multiple Pom-pom, if it is shown that weight for weight of equipment the .5 in. gun has superior

or equal stopping power to the 2 pdr. Multiple Pom-pom when mounted for defence against low flying aircraft, D.C.B.s or C.M.B.s.

SECTION XVIII.

GAS AND SMOKE.

74. The present position as regards gas and smoke is fully stated in the "Handbook on Chemical Warfare," which is being published this year.

A great deal of research is now in hand at the Universities and also at the Experimental Station at Porton, near Salisbury, the results of which are not yet available.

The new Naval type Anti-gas apparatus has not yet been perfected and is still in the research stage ; the type illustrated in the edition of "Progress in Gunnery Material, 1920," has not been adopted. For remarks on Gas Shell (**see Section X, page 54**).

The reports are arranged in the following order :-

SECTION XX_A.

H.M.S. "Excellent's" report of (*a*) and (*b*) with photos and diagrams.

Summaries of "Excellent's" remarks on (*a*) and (*b*) with Admiralty comments thereon.

Admiralty remarks *re* structural damage caused in (*b*).

SECTION XX_B.

H.M.S. "Excellent's" report of (*c*) with photos and diagrams.

Summaries of "Excellent's" remarks on (*c*) and Admiralty comments thereon.

Admiralty remarks *re* structural damage caused in (*c*).

SECTION XX_C.

H.M.S. "Excellent's" report of (*d*) with photos and diagrams.

Admiralty remarks *re* structural damage caused in (*d*).

The "Baden" firings are not yet completed, as the ship sank and had to be salved. Therefore the lessons to be learned from these experiments are not complete. The probably lines of development, as confirmed or suggested by these trials as well as by the preceding ones at H.M.S. "Swiftsure," will be found in the text of the sections above dealing with projectiles, fuzes and armour.

SECTION XX_A.

H.M.S. "EXCELLENT'S" REPORT OF THE FIRINGS AGAINST U.B.21 AND U.141.

With reference to Admiralty letter G.0618/1919 dated 22nd May, 1919, and Admiralty letter G.0729/19 of 5th May, 1920, firing trials have been carried out with U.B.21 on 30th September, 1920, and U.141 on 7th October, 1920. The trials were carried out on the Horse Tail Bank, the firing ship being H.M.S. "Terror."

2. U.B.21 sank as a result of the damage caused to her pressure hull. U.141 was damaged to a considerable extent, but has been safely berthed in Portsmouth Harbour

3. The firing was carried out at a range of 300 yds., the submarines being on an even keel at the beginning of the trial.

4. The guns used were 4.7 in. B.L., 4 in. B.L. and 12 pdr. 18 cwt., from each of which S.A.P., C.P. and H.E. shell were fired.

The 4.7 in. gun used heavy (50 b.) shell throughout the trial.

The H.E. and S.A.P. shell used were filled lyddite and the C.P. shell were filled powder.

The conditions reproduced during the trials were :-

(a) Attack on the conning tower using charges corresponding to a striking velocity of 2,000 yds. And 5,000 yds.

(b) Attack on the pressure hull using charges to give a striking velocity similar to that obtained when the angle of descent is 12½ deg. The submarine was not heeled for this trial, owing to the increased difficulties that this would have imposed on the execution of the trial and also that the circular nature of the hull of the submarine rendered it doubtful whether any additional realism would be gained.

5. The report is drawn up in the following manner :-

Appendix I. General Remarks on the Trial.
Appendix II. Detailed Report of the Trial with U.B. 21.
Appendix III. Detailed Report of the Trial with U.141.

SECTION XIX.

PROGRESS IN ANTI-AIRCRAFT GUNNERY.

The Naval Anti-Aircraft Gunnery Committee will shortly be dissolved, and its final report on the progress made and the present state of development of A.A. Control and material is in course of preparation.

75. Control of the Main A.A. Armament.- Experiments to enable the best temporary system of H.A. Control employing existing material to be decided on were recently carried out at the Nore.

The systems under trial were those embodying the use of :-
(a) Modified Holland Fuze Indicator.
(b) Hill's Predicting Fuze Indicator.
(c) Fuze Indicator of Gun.
The target employed was a Drogue towed from a Kite Balloon.

The trials proved that (*a*) was the most suitable Control Instrument, and that Drogues provided suitable targets for Fleet A.A. practice.

The future H.A. Control Installation for ships will comprise a Director, Height-finder, Angular Velocity Metre, and Calculating Instrument. Trials still await the designing and construction of instruments, which is proving to be a lengthy process.

Control must depend primarily on the Height-finder and two types (1) the 12 ft. M.B.2 Coincidence finder and (2) the Metre base Stereoscopic finder, are in course of construction. A 2 Metre V.B.2 is already available. It is hoped to carry out sea-going trials with all three types, and to purchase a number of these instruments for the Fleet this financial year.

A.A. Guns.- The theoretical superiority of the larger calibre guns was pointed out in the Interim Report of the N.A.A.G.C.

The 4.7 in. gun is considered to be the largest calibre gun which can be efficiently handworked, and the first gun and mounting of this nature are now under trial.

It is probably that this gun will be employed for L.A. as well as H.A. work in certain ships.

A brief description of the gun and mounting is as follows :-

Breech trunnions have been adopted, and muzzle preponderance is compensated for by means of springs.

The mounting is of the central pivot type.

Fixed ammunition is employed, and the gun can be loaded at all angles of elevation. A loading tray and toggle worked rammer are fitted.

A variable recoil system and run out springs are employed.

The sight, which has not yet been completed, introduces the following new principles :-

The action of setting the sight for fuze or range operates the gun only in elevation, and the gunlayer's elevating gear operates both gun and sight in unison.

Vertical deflection settings operate the fuze range dial, and are applied to the gun by a resetting movement of the latter.

Lateral deflection settings which are applied in the plane of sight operate the sight through sliding rod connections, and the deflection dial can thus be mounted in a fixed position.

Drift is applied automatically as an additional movement transmitted to the lateral deflection dial as the gun is set for fuze or range.

Complementary error, *i.e.*, the error introduced in elevation by the application of lateral deflection in the plane of sight.

76. Aldis Telescopic Ring Sight.- This sight, in which the ring is in the form of a ring of light of variable size, has been completed in trial form and is undergoing experiment. The sight is proposed for use with a simple system of control suitable for ships mounting a single gun H.A. armament.

77. Defence against Torpedo Carrying Aircraft.- The efficiency of a combined splash and explosive barrage is being investigated, and the use of flat nosed shell filled H.E. is to be tried.

It has been determined by trial that the 2 pdr. shell is the smallest sized shell which will stop an aeroplane by direct hit with reasonable certainty, and progress is being made in the design and production of a Multiple Pom-pom to fire this shell.

A six-barrel design *ex tempore* mounting in which the gun barrels can be set at varying divergences will be completed shortly, and it is intended to carry out sea-going trials at targets representing aeroplanes and D.C.B. targets. From the results of these trials the maximum number of barrels that can be efficiently mounted, and the fixed divergences of barrels required in future designs will be determined.

This design, however, bears little resemblance to what the final design will be, provided that it is decided to adopt this weapon for general use in the Service.*

78. Defence against Low-Flying Aeroplanes.- For this purpose forward-area sights are being supplied for Lewis Guns, and it is under consideration to increase the proportion of tracer ammunition.

The .5 Vickers Machine Gun is in course of development in conjunction with the War Office as a possible reply to low-flying armoured planes.

Experiments with aeroplanes firing machine guns at bridges and spotting tops will be carried out shortly, H.M.S. "Agamemnon" being employed as target ship. It is under consideration that bridge shelters, spotting tops, and director towers should be protected from aeroplane machine gun fire by bullet proof plating. The probable increase in calibre of machine guns carried by aircraft necessitates the production of highly efficient plating for this purpose. A maximum thickness of plating of .5 in. is being allowed for in future construction for protection of bridges, etc.

79. Targets.- Various types of targets for A.A. practice are being developed and it is hoped that some or all of the following may be found suitable for adoption :-

(*a*) **Balloons.-** The Air Ministry are producing a Kite Balloon with the minimum dimensions of 20 ft. by 16 ft., capable of obtaining a height of at least 10,000 ft.

(*b*) **Gliders.-** Trials are in progress with Glider Aeroplanes of 9 ft. span, gyroscopically controlled and capable of being released from an aeroplane as desired to provide a target similar to that presented by torpedo dropping aircraft.

(*c*) **Smoke Shell.-** Shell whose smoke burst will be in the form of a line instead of a cloud as at present are being designed to provide a target more suitable for ranging on.

(*d*) **Controlled Aeroplanes.-** Aeroplanes controlled by W/T are still in the design stage. At present the Air Ministry are unable to state definitely when they will be able to produce such a target.

(*e*) **Kites.-** Experiments with Service balloon kites are being carried out with a view to testing their suitability as targets for A.A. machine gun practice. Trials with Cody's Man-lifting Kites may be carried out if the results of the present trials are satisfactory.

80. Aeroplane Detection.- Detector of aeroplanes by aural and visual methods is being investigated.

An aural detector of the disc type which has given satisfactory results during shore trials will shortly be mounted in a ship for further sea-going trials.

SECTION XX.

FIRING TRIALS WITH LIVE SHELL.

81. Important Firing Trials with Live Shell at Ship Targets.- These trials comprise :-

(a) Firings at ex-German Submarines U.B.21 and U.141.
(b) Firings at ex-German Torpedo Boat Destroyers V.82 and V.44.
(c) Firing at ex-German Light Cruiser "Nurnberg."
(d) Firing at ex-German Battleship "Baden."

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* With a view to preserving secrecy, it has been decided that this weapon should be referred to as the "Mark M. Pom-Pom."

6. Photographs and target diagrams are included in the report so far as they are of interest.

Cinematograph films were obtained from the firing ship and also from a ship stationed at right angles to the line of fire. These are retained in H.M.S. "Excellent."

APPENDIX I.

82. General Remarks on the Trial.- The trial may be considered under the following heads :-

(a) Conning tower attack.
(b) Superstructure attack.
(c) Pressure hull attack.

I. Conning Tower Attack.- The conning tower of U.B.21 consisted of a single thickness 2 cm. thick ($^{25}/_{32}$ in.).

The conning tower of U.141 consisted of two plates, the outer being 6 cm. (2⅜ in.) and the inner 3 cm. (1¼ in.). These plates were 8 in. apart on the beam and 10 in. apart in the fore and aft line.

(*a*) Up to ranges of 5,000 yds. The following may be expecting when firing at a weak conning tower :-

S.A.P. Shell 4.7 in. and 4 in. will go right through and burst on the far side of the conning tower.
C.P. Shell 4 in. may burst in the remote wall of the conning tower.
H.E. Shell with No. 18 P. fuze will probably burst inside the conning tower.

(*b*) At a range of 5,000 yds. when firing at a strong conning tower :

Shell smaller than 4.7 in. will not penetrate into the inside of the conning tower.
S.A.P. Shell from 4.7 in. gun may penetrate into the conning tower under favourable conditions of impact.
H.E. and C.P. Shell from 4.7 in. gun will not penetrate, and of these two shells the H.E. has the greater effect on the surrounding structure owing to its wider cone of dispersion.

(*c*) At a range of 2,000 yds. when firing at a strong conning tower :

Shells smaller than 4.7 in. are not likely to penetrate inside the conning tower.
S.A.P. Shell 4.7 in. may be expected to penetrate inside the conning tower, but damage inside the conning tower will not be very great.
C.P. Shell 4.7 in. is not likely to penetrate into the conning tower.
H.E. Shell 4.7 in. will not penetrate.

The rounds fired provide sufficient data to show that when considering the effect of gunfire against submarines in the future when it may be expected that the strength f the towers will be comparable with that of the U.141, the only type of shell that may be expected to penetrate will be S.A.P.

So far as the actual trial is concerned no shell less than 4.7 in. heavy S.A.P. obtained penetration and then only when very close to normal impact. At 16 deg. from normal both 4.7 in. and 4 in. S.A.P. failed to penetrate.

II. Superstructure Attack.- The pressure hull of U.B.21 was 1¼ cm (½ in.), and that of U.141 was 3 cm. (1¼ in.).

The superstructure of U.141 was more substantial than that of U.B.21, and in both submarines there were a considerable number of obstructions such as air flasks, exhaust pipes, etc., contained in the superstructure.

For the purposes of the trial some targets were marked off in positions where the shell would only have to pass through the superstructure plating and other targets were marked off where the shell would meet greater resistance.

The results show that penetration of a 1¼ in. pressure hull be “coup de hache” effect is not to be expected.

Under favourable conditions penetration of a ½ in. hull by “coup de hache” effect may be obtained with H.E. 4.7 in. shell using number 18 P. fuze.

The behaviour of the shell depends almost entirely on the nature of the obstruction encountered. Generally speaking, C.P. and S.A.P. shell are likely to go blind or burst beyond the submarine if they meet the superstructure plating only. H.E. shell with No. 18 P. fuze will almost certainly burst in the superstructure and cause the greatest effect of the three types.

The chances of obtaining penetration of the inner hull by "coup de hache" effect being so remote, the objects to be attained by firing at the superstructure are to damage some essential pipe or fitting which may be exposed outside the pressure hull. For this purpose H.E. shell with No. 18 P. fuze may be expected to give the best result.

III. Attack on Pressure Hull.- The trial was carried out with velocity corresponding to an angle of descent of 12½ deg. This represents the following ranges :-

4.7 in.	7,140 yds.
4 ″	6,500 yds.
12 pdr. 18 cwt.	4,800 yds.

Under these conditions penetration into the submarine by direct attack on a 1¼ in. pressure hull may only be expected with S.A.P. shell of 4 in. or 4.7 in. calibre, and only then under favourable conditions of impact and provided that the fuze does not function too soon. For example :-

4 in. S.A.P. blind round penetrated at 48 deg. from normal.
4.7 in. S.A.P. shell failed to penetrate at 60 deg. from normal.

C.P. shell 4 in. or above may do some damage to the hull but will not penetrate.

H.E. shell 4.7 in. to 12-pdr. will not penetrate the hull, but the larger types of H.E. shell have considerable local effect and may do important damage to ballast tanks, etc.

12 pdr. shell of all natures will probably burst before reaching the pressure hull if they have to pass through any plating before reaching the hull ; they are therefore unlikely to do much damage.

The only reasonable chance of success that is to be expected from this form of attack would be with S.A.P. shell of 4 in. and larger calibre.

General conclusions are :-

1. For conning tower attack, the chances of effective gunfire are small, and S.A.P. shell 4.7 in. calibre and above are the only type likely to be of any use. Possibly, additional penetration could be obtained so that 4 in. S.A.P. would penetrate by fitting caps to S.A.P. shells, which, it is understood, is under consideration.

2. The superstructure may well be the only practical target if the submarine is trimmed well down, or if at close range when the angle of impact of shell on the pressure hull is unfavourable. It is considered that it is useless to expect fragments of shell to penetrate the pressure hull of "coup de hache" effect, and that any future developments are unlikely to improve this, therefore the best chance of injuring the submarine under these conditions is to cause serious local damage to exposed fittings. For this purpose H.E. shell are the most effective.

3. Attack in the pressure hull direct is the best method of injuring a submarine, but to be successful, it is necessary that the angle of impact favour the projectile. Success is, therefore, only likely t be obtained at long range.

In any case, it is a luck shot which will hit the pressure hull of a submarine similar to U.141 without first meeting some substantial obstruction, particularly at short ranges.

For this form of attack S.A.P. shell are decidedly superior to C.P. or H.E., but it is considered that the delay should be increased so that it is at least 6 ft. to ensure that the shell burst well inside the hull.

4. C.P. shell have no particular advantages and might well be discontinued.

5. It appears, therefore, that two forms of attack are required :-

(a) Destructive fire on superstructure.
(b) Plunging fire into inner hull.

It would be difficult to combine the requirements of those two forms of attack in one type of shell and fuze, as for (*a*) a delay of not more than 5 ft. is required and for (*b*) a delay of not less than 6 ft. is required

Further, for (*a*), it is necessary to have a wide cone of dispersion, and also to ensure that the fuze will function on meeting a comparatively light structure.

The requirements of (*a*) are met fairly well with existing H.E. shell using No. 18 P. fuze ; the delay of this fuze is a little short of ideal conditions.

The requirements of (*b*) are best met by S.A.P. shell, but improvement in penetrating powers of these shells would be very desirable. The delay of No. 12 fuze should be increased.

For either form of attack, shell of smaller calibre than 4 in. are unlikely to achieve any appreciable success, and the trial points to the necessity of having shell of larger calibre than 4.7 in. if success is to be relied upon.

6. With shell now in supply, the recommended procedure would be at ranges where angle of descent, if less than 10º, use H.E. shell with No. 18 P. fuze. At ranges where angle of descent is greater than 10º use S.A.P. shell.

7. Points of interest in the construction of submarines arises from the result of round 24 at U.141.

This round removed a fitting which projected above and was bolted to the pressure hull, thus leaving a hole in the hull.

It seems that this fitting, which is believed to be a salvage suction, could have been arranged sot that it was flush with the pressure hull.

Round 25 at U.141 started some rivets in the pressure hull. This also points to the desirability of constructing the pressure hull of a submarine so that the external surface is quite flush, and that a riveted joint may fail when subjected to gun fire although the hull be strong enough to resist the projectile.

APPENDIX II.

83. Detailed Results of Firing at U.B.21.-

NOTE.- Roman figures denote order in which rounds were fired. Other figures and letters refer to programme number and series. Fuzes marked thus -*- were fitted to arm at a low chamber pressure.

Round I.- 4 in. S.A.P. with R.V. for 5,000 yds. range. Fuze No. 12* F special. Made hole 4½ in. by 6 in. in thin outer plating (2½ mm.) and hole 4½ in. by 5½ in. n conning tower (2 cm.). Passed out through light plate covering, hole cut in starboard side of conning tower, making hole 4½ in. by 4½ in.

Violent explosion just outside.

Inside conning tower periscope was cut and a voicepipe holed in two places.

See Figs. 13 and 15.

Round II.- 4 in. C.P. with R.V. for 5,000 yds. range. Fuze N. 12*.

Made holes 4½ in. by 4½ in. in thin outer plating (2½ mm.) and in conning tower (2 cm.). Knocked off light plate covering hole about 2 ft. by 18 in. in starboard side of conning tower and burst about 20 feet beyond, as is evident from cinematograph record. The thick wall of the conning tower (2 cm.) was bent outwards round the hole in the starboard side.

Inside the conning tower the only damage was three strikes probably caused by pieces of plate.

See Figs. 13 and 15.

Round III.- 4 in. H.E. with R.V. for 5,000 yds. range. Fuze No. 18 P.

Penetrated light outer plating (2½ mm.) and burst on conning tower (2 cm.) with partial detonation.

Blew away light outer plating about 4 ft. before and 4 ft. abaft point of impact. Made hole in conning tower 11 in. by 13 in. with edges turned inward 6 in. Periscope flattened to half its diameter but not perforated. Three strikes in control room. Fragments of shell recovered from inside conning tower and control room. Press hull (1.25 cm.) 2 ft. 4 in below point of impact undamaged.

See Figs. 13 and 15.

Round IV.- 4.7 in. S.A.P. Service Charge. Fuze No. 12*.

Through four thicknesses of superstructure (2½ mm.) and exhaust tank (2½ mm.). Very mild explosion on water beyond.

See Figs. 13 and 16.

Rounds V, VI and VII.- 4.7 in. C.P. Service Charge. Fuze No. 12*.

Through superstructure, fur thicknesses of 2½ mm. Blind.

Two repeat rounds were fired with the same result.

See Figs. 13, 14 and 17.

Round VIII.- 4.7 in. H.E. Service Charge. Fuze No. 18 P.

Penetrated two thicknesses of superstructure (2½ mm.) bursting in the inner thickness close above pressure hull (1.25 cm.) with partial detonation. Holes in superstructure 5 in. and 1 ft. in diameter. Hole in pressure hull 2 ft. by 1 ft., centre of hole being 1 ft 6 in. to port of centre line.

Inside the hull a torpedo transporting rail on the starboard side was cut and the torpedo dented in four places, four small holes in ventilating pipe starboard side, and three small holes in light plate covers over accumulator terminals.

Three fragments were recovered from inside hull.

Light superstructure considerably damaged by burst.

See Figs. 13 and 17.

Round IX.- 12 pdr. S.A.P. Service Charge. Fuze No. 12 Service.

Through superstructure, two thicknesses of 2½ mm. Mild explosion beyond.

See Fig. 14.

Round X.- 12 pdr. C.P. Service Charge. Fuze No. 12 Service.

Through superstructure, two thicknesses of 2½ mm. Burst on water beyond.

See Fig. 14.

Round XI.- 12 pdr. H.E. Service Charge. Fuze No. 18 P.

Penetrated superstructure port side (2½ mm.) and burst on fore end of exhaust muffler tank, damaging an exhaust pipe leading through pressure hull. Pressure hull undamaged. Violent explosion and yellow marking in superstructure. Large hole in superstructure starboard and a hole 6 in. by 3 in. in top of starboard saddle tank, 4 mm. thick.

See Fig. 14.

Round XII.- 4 in. S.A.P. Service Charge. Fuze No. 12 Service.

Penetrated superstructure and grazed pressure hull (1.25 cm.) bursting on graze with violent explosion. Blew hole 18 in. by 10½ in. in pressure hull.

See Figs. 13 and 16.

Round XIII.- 4 in. C.P. Service Charge. Fuze No. 12 Service.

Penetrated superstructure (2½ mm.) and burst inside. No effect on pressure hull. Angle round bottom of coaming to hatch slightly distorted and one revet knocked out. Coaming dented.

See Figs. 13 and 17.

Round XIV.- 4 in. H.E. Service Charge. Fuze No. 18 P.

Penetrated superstructure (2½ mm.) and burst inside with partial detonation. Dent ¼ in. deep in pressure hull. Saddle tank starboard side started from pressure hull. Superstructure in vicinity demolished.

See Figs. 13 and 18.

Round XV.- 4.7 in. S.A.P. Service Charge. Fuze No. 12 Service.

Penetrated superstructure, two thicknesses of 2½ mm., and burst just beyond with mild explosion.

See Figs. 14 and 17.

Round XVI (Repeat of XV).- Fuze No. 12 Service.

Penetrated superstructure (2½ mm.) passed through an air bottle (½ in. thick and 16 in. diam.), and burst inside a second air bottle 14 in. beyond with partial detonation. Head of bottle blown off and starboard saddle tank (4 mm.) holed.

See Figs. 14 and 17.

Round XVII (Repeat of V).- 4.7 in. C.P. Service Charge. Fuze No. 12 Service.

Penetrated superstructure (2½ mm.), passed through two air bottles and burst on water beyond. Holes in air flasks 5 in. by 5 in., 8½ in. by 7 in., 8 in. by 7 in. and 12½ in. by 11 in.

Starboard saddle tank (4 mm.) holed, probably by a piece of plate.

See Fig. 14.

Round XVIII (Repeat of VII).- 4.7 in. H.E. Service Charge. Fuze No. 18 P.

Penetrated superstructure (2½ mm.) and burst inside with violent explosion. Superstructure in vicinity demolished and dent in pressure hull $^{3}/_{16}$ in. deep, and two holes in starboard saddle tank 4 mm. thick.

See Figs. 14 and 19.

General view of U.B. 21 is shown on Fig. 20.

APPENDIX III.

84. Detailed Results of Firing at U.141.

Round I.- 4 in. S.A.P. with R.V. for 5,000 yds. Fuze No 12* F. special.

Hit outer plate of conning tower (6 cm.) at 16º to normal, and burst without penetrating. Dent in plate 3⅛ in. deep. Partial detonation. No effect on fittings inside conning tower. Slight damage to light structure outside and strikes on gun and mounting.

See A of Figs. 21 and 23.

Round II.- 4.7 in. S.A.P. with R.V. for 5,000 yds. Fuze No. 12* N. special.

Hit outer plate of conning tower (6 cm.) at 1º to normal effecting penetration and bursting on and penetrating inner plate (3 cm.) 8 in. behind with violent explosion. Base of shell found in hole in outer plate. Disc punched out of inner plate (4½ in. by 5 ½ in.) and pieces of shell found inside conning tower. Only minor damage inside conning tower.

See A of Figs. 21 and 23.

Round III.- 4.7 in. C.P. with R.V. for 5,000 yds. Fuze No. 12* S.

Hit outer plate of conning tower (6 cm) at 21º to normal and burst without penetrating. Dent in plate 2⅛ in. deep and 18 in. diameter.

See A of Figs. 21 and 23.

Round IV (Repeat of Round II).- 4.7. in. S.A.P. with R.V. for 5,000 yds. Fuze No. 12* N special.

Hit outer plate of conning tower (6 cm) at 16º to normal penetrating it and bursting between outer and inner (3 cm.) plates with violent explosion. Distance between plates 1 ft. Dent in inner plate ¾ in. deep and 18 in. diameter but no penetration.

See A of Figs. 21 and 23.

Round V.- 4.7. in. H.E.. with R.V. for 5,000 yds. Fuze No. 18 P.

Hit outer plate of conning tower (6 cm) at 1º to normal bursting with partial detonation. Dent in outer plate 2⅛ in. deep and 18 in. diameter. Vent pipes to number 3 and 4 ballast tanks below point of impact holed. Light plating abaft hit (2½ mm.) damaged. Strikes on gun and generally in vicinity.

See A of Figs. 21 and 23.

Round VI.- 4. in. S.A.P. with R.V. for 2,000 yds. Fuze No. 12* F. special

Hit outer plate of conning tower (6 cm) at 8º to normal and penetrated it, bursting on inner plate (3 cm.) one foot behind with violent explosion. A piece of the inner plate 4 in. by 2½ in. was detached and found in the conning tower, but there was no damage inside the conning tower. This hit was just below the roof of the conning tower and the inner plate was supported at this point by a substantial transverse box beam. Inner plate was cracked through at point of impact.

See A of Figs. 21 and 23.

Round VII.- 4.7. in. S.A.P. with R.V. for 2,000 yds. Fuze No. 12* N. special.

Hit outer plate of conning tower (6 cm) at 2½º to normal and burst between outer and inner (3 cm.) plates with partial detonation. The inner plate was holed, size of hole 8 in. by 6 n., and fragments were found inside the box beam behind the point of impact. No damage done inside the conning tower.

See A of Figs. 21 and 23.

Round VIII.- 4.7. in. H.E.. with R.V. for 2,000 yds. Fuze No. 18 P.

Went through hole made by VI and enlarged it. Burst between inner and outer plates with partial detonation. Fragments of shell recovered from box beam inside conning tower but no damage done inside.

See A of Figs. 21 and 23.

Round IX.- 4.7 in. C.P. with R.V. for 2,000 yds. Fuze No. 12* S.

Hit outer plate of conning tower (6 cm.) at 5º to normal and penetrated it and burst on inner plate (3 cm.). Dent in inner plate ¾ in. deep and one rivet knocked out.

See A of Fig. 21 and Fig. 25.

Round X.- 4.7 in. S.A.P. Service charge. Fuze No. 12 Service.

Hit edge of 2½ mm superstructure, grazed wooden deck and burst on bollard at centre line. Half of bollard blown away. Violent explosion.

See B of Fig. 21 and Fig. 26.

Round XI (Repeat of Round X).- 4.7 in. S.A.P. Service charge. Fuze No. 12 Service.

Penetrated 5 mm. superstructure and two 5 mm. bulkheads, bursting with violent explosion after penetrating third thickness, making a hole about 4 ft. by 3 ft. in starboard side of superstructure. Shell turned sideways after passing through first thickness.

See B of Fig. 21 and Figs. 26 and 27.

Round XII.- 4.7 in. C.P. Service charge. Fuze No. 12 Service.

Blind through superstructure holing 2½ mm. sides and a 5 mm. deck by graze at middle line.

See C of Fig. 21 and Figs. 28 and 29.

Round XIII.- 4.7 in. H.E. Service charge. Fuze No. 18 P.

Hit superstructure and burst just inside with partial detonation.. Cylindrical tank in superstructure for stowage of spare torpedo cut nearly in two. Hole 2 in. by 2 in. in port ballast tank (5 mm.). Port side of 2½ mm. superstructure started outwards. Five rivets of strap on pressure hull started. Three of tapped bolts securing motor embarking hatch sheared off. Considerable upward effect in superstructure and tank starboard side holed (4 in. by 4 in. hole).

See D of Fig. 21.

Round XIV (Repeat of Round XII).- 4.7 in. C.P. Service Charge. Fuze No. 12 Service.

Penetrated 5 mm. superstructure and burst 5 ft. short of far side in which a hole 2 ft. by 2 ft. was made. Practically no other damage.

See C of Fig. 21 and Figs. 28 and 29.

Round XV.- 12 pdr. S.A.P. with R.V. for 12º angle of descent. Fuze No. 12* F. special.

Grazed edge of one of the holes in free flooding superstructure (5 cm.), penetrated an air flask in superstructure (2 cm. thick) and burst with explosion only inside flask blowing a hole 12 in. by 14 in. in opposite side. Most of fragments found inside air flask.

See E of Fig. 22 and Fig. 30.

Round XVI (Repeat of Round XV).- 12 pdr. S.A.P. with R.V. for 12º angle of descent. Fuze No. 12* F. special.

Penetrated superstructure (5mm.) and burst about 2 ft. inside with partial detonation. Hole in end of anti-rolling tank (5mm.) 1 ft. by 9 in. and crack in top of oil fuel tank (5 cm.) 6 in. by ¾ in. A piece 2 in. by 1 in. chipped out of butt strap in pressure hull.

See F of Fig. 22 and Fig. 30

Round XVII.- 12 pdr. C.P. with R.V. for 12º angle of descent. Fuze No. 12*.

Penetrated anti-rolling tank (5 mm.) making a clean hole. Effect inside could not be seen but pressure hull was not affected.

See G of Fig. 22.

Round XVIII.- 12 pdr. H.E. with R.V. for 12º angle of descent. Fuze No. 18 P.

Penetrated anti-rolling tank (5 mm.) making a clean hole. Effect inside could not be seen but pressure hull was not affected.

See G of Fig. 22.

Round XIX.- 4 in. S.A.P. with R.V. for 12º angle of descent. Fuze No. 12 F. special (not certain if *).

Penetrated superstructure (5 mm.) and pressure hull (3 cm.) without bursting, grazing a butt strap on pressure hull and was blind. Angle of impact on pressure hull about 48º to the normal.. In passing through pressure hull shell turned about 30º towards the normal and then passed through light lining to pressure hull and light wooden middle line bulkhead in crew space, ricochetted off the deck and lodged in a pile of spunyarn on a bunk. It is possible that this shell was not fitted with the special fuze for aiming at low pressures.

See F of Fig. 22 and Fig. 30.

Round XX (Repeat of Round XIX.- 4 in. S.A.P. with R.V. for 12º angle of descent. Fuze No. 12* F. special.

Grazed top edge of oil fuel tank (5 mm.) and burst on bracket supporting superstructure plating. Violent explosion. Made hole 2 ft. by 1 ft. in top of oil fuel tank at point of burst, but no damage to pressure hull. Some effect by fragments in superstructure.

See F. of Fig. 22 and Fig. 30.

Round XXI.- 4 in. C.P. with R.V. for 12º angle of descent. Fuze No. 12*.

Penetrated superstructure (5 mm.) and burst on air bottle already holed by Round XV cutting it in half, and knocking aside a bracket connecting the superstructure to the pressure hull and tearing out three rivets in pressure hull to which water was thereby admitted.

See E of Fig. 22 and Fig. 30.

Round XXII.- 4 in. H.E. with R.V. for 12º angle of descent. Fuze No. 18 P.

Penetrated superstructure (5 mm.) and burst inside. Violent explosion. Small hole (about 1 in. by 1 in.) in top of oil fuel tank (5 mm.) port side. Minor damage in superstructure.

See H of Fig. 22.

Round XXIII.- 4.7 in. H.E. with R.V. for 12º angle of descent. Fuze No. 18 P.

Burst on anti-rolling tank and holed anti-rolling tank (5 mm.) and (by fragments) ballast tank (5 mm.) under it. Partial detonation. Hole in anti-rolling tank about 2 ft. by 1 ft. 6 in. and various minor damage in vicinity of burst.

See G of Figure 22.

Round XXIV.- 4.7 in. C.P. with R.V. for 12º angle of descent. Fuze No. 12* S.

Penetrated superstructure (5 mm.) and burst on a 10½ in. cast-iron pipe about 1 in. thick leading out of pressure hull. Pipe, which was secured by 12½ in. bolts, was knocked off, all rivets being sheared. The pressure hull was thus opened to the sea though not actually damaged.

See C of Fig. 21 and Fig. 30.

Round XXV.- 4.7 in. S.A.P. with R.V. for 12º angle of descent. Fuze No. 12* N. special.

Penetrated superstructure (5 mm.) and hit pressure hull (3 cm.) at 60º to the normal. Pressure hull, on which there was a butt strap at the point of impact, was dented to a depth of 4 in. Shell broke up after grazing pressure hull and burst with explosion only. Pressure hull was not holed but several rivets were started and this caused a slight leak when, owing to flooding of ballast tanks, water rose over point of graze.

See C of Fig. 21 and Fig. 30. Figure 31 shows a General View of U.141.

H.M.S. "EXCELLENT'S" REPORT OF FIRING AGAINST V.82.

With reference to Admiralty letter G.0118/20 of 26th July, 1920, firing trials were carried out against ex-German Torpedo Boat Destroyer on 13th and 15th October, 1920.

The trials were carried out on the Horse Tail Bank, the firing ship being H.M.S. "Terror" who was in position 300 yards from the target.

The Torpedo Boat Destroyer sustained some under water damage during the first three rounds of the programme, and it was necessary to discontinue the trial until this had been repaired, which caused a delay of 24 hours.

On completion of the trial, further under water damage was temporarily plugged by divers, and V.82 was brought into harbour. It has subsequently been found necessary to beach V.82 as she was making water and would otherwise have sunk.

This preliminary report is drawn up as follows :-

Appendix I. General remarks.
Appendix II. Detailed results of each round.
Photographs and diagrams.

Cinematograph records taken from the firing ship and flank observation ship are retained in H.M.S. "Excellent."

The gun used for the trial was 4.7 in. B.L. Mark I, and S.A.P., C.P. and H.E. heavy type (50 lb.) shell were used.

The conditions reproduced during the trials were for a range on 7,000, to do which the corresponding charge was used and the Torpedo Boat Destroyer was heeled 12½° towards the firing ship by filling suitable tanks with water.

APPENDIX I.

85. General Remarks on Trial against T.B.D. V.82.

I. The results may be considered under two heads.

(a) Attack against exposed position such as upper deck, bridge, etc.
(b) Attack against hull.

II. Attack against exposed position.- (*a*) Comparative rounds were fired at the forward forecastle side plating, using H.E. shells with No. 18 and also No. 18 P fuze. The H.E. shell using No. 18 fuze caused very little damage to the side plating or inside the ship. The fragmentation was complete but the fragments were of a very small size, the majority of the effect being expended outside the hull. This shell did, however, distribute fragments laterally up to 10 ft. from the burst.

The H.E. shell using No 18 P. fuze caused considerably more damage inside the ship, and the size of the fragments were larger. Both these rounds were fired immediately below a 5.9 in. gun and neither would necessarily have stopped the gun from firing, but the round with No. 18 P. fuze did remove some of the forecastle deck.

The results obtained by these two rounds are decidedly in favour of the use of No. 18 P. fuze. S.A.P. and C.P. shells were not fired under exactly the same conditions to the foregoing, but the results obtained from other rounds fired under somewhat similar conditions lead to the conclusion that neither of these would be so effective against exposed positions as is H.E. shell with No. 18 P. fuze.

III. Attack against Hull.- (*b*) The effect of gunfire on the hull of a Torpedo Boat Destroyer is dependent on chance as to what obstructions are met by the projectile in its path through the hull.

The possible forms of attack are :-

(a) Shell traversing a clear space is caused to burst so that fragments are likely to penetrate the remote side under water and the bottom of the Torpedo Boat Destroyer.

(b) Shell meeting an obstruction such as a boiler is caused to burst, so that it causes the maximum destructive effect to the obstruction and the compartment in which it is situated.

(c) Shell caused to burst shortly after piercing the side, so that the side plating be severely racked and possibly punctured under water.

The trials show that S.A.P. shell may be expected to fulfil the conditions (*a*) and (*b*) above, and in this respect are superior to either C.P. or H.E. shell. On the other hand, H.E. shell with No. 18 P. fuze is the most effective for condition (*c*), and is, in fact, the only type of shell likely to produce the desired effect.

Round 2.- 4.7 in. C.P. filled powder. Fuze No. 12+ F. S.V. 1,100 f.s.

Holed 5 mm. side and 2½ mm. wing bulkhead in engine room and burst on the top of the port turbine casing, hitting a spring leaded valve. Delay about 7 ft. Pipe from valve to casing smashed and eight ½ in. bolts securing it sheared. Blades of turbine exposed. Skylight over point of burst was blown open.

Round 3.- 4.7 in. S.A.P. filled lyddite. Fuze No. 12+ N. special. S.V. 1,100 f.s.

Holed 5 mm. side and 2½ mm. wing bulkhead in foremost boiler room before boiler bursting on some pipes with a delay of about 6 ft. Explosion only. Two pipes about 4 in. and one about 5 in. cut and also some rod gearing. Two holes in 2½ mm. trunk of escape to upper deck port side 5 in. by 2 in. and 1 in by 1 in., and two holes in upper deck (2½ mm.) 4 in. by 1½ in. and 2 in. by 12 in.

Two holes about 4 in. diameter in bunker bulkhead starboard and one in ship's side starboard below water line about 6 in. diameter which flooded boiler room.

Round 4.- 4.7 in. H.E. filled lyddite. No. 18 fuze. S.V. 1,100 f.s.

Hit side of forecastle under gun burst with nearly complete detonation. Effect mostly lateral though some fragments came back about 400 yards. Hole in turtle back port side of forecastle (2½ mm.) 2 ft. 6 in. by 1 ft. 10 in. No strikes on gun or mounting or anywhere inboard on forecastle. Water alongside churned up. Under point of impact there were 24 holes of various sizes up to 6 in. by 4 in. in 2½ mm. cabin bulkheads and door. Fourteen holes of various sizes up to 5 in. by 4 in. in 2½ mm. bulkhead and door of wash place starboard side. A hole 4 in by 3 in. in ship's side port (5 mm.) about 14 ft. abaft point of impact. One small hole through upper deck (2½ mm.) near centre line and two under point of impact. Two holes in ship's side starboard (5 mm.) 1 in. by 1 in. and 1½ in. by 1½ in. About 40 small holes in various structure on upper deck abaft forecastle, about 20 of these being in wheel house and galley below it and one in the after funnel. This latter being 100 ft. from the burst.

Round 5.- 4.7. H.E. filled lyddite. Fuze No. 18 P. S.V. 1,100 f.s.

Grazed 5 mm. overhang of turtle back at port after end of forecastle and burst with about 2 ft. delay. Violent explosion. Filling marks in the vicinity. Considerable forward and blast effect. Cone of effect about 100º. Four holes and several strikes in torpedo tube 2 ft. under point of burst. 2½ mm. bulkhead about 2 ft. forward of burst smashed in by blast and holed in 28 places. Hole in 2½ mm. forecastle deck over burst 5 ft. by 3 ft. Four small strikes on breech of forecastle gun (trained fore and aft). 2½ mm. transverse cabin bulkhead about 4 ft. before burst was bulged in. A hole 5 in. by 11 in. was made in upper deck starboard side (2½ mm) by a fragment which had passed through the 2½ mm. bulkhead port side and both sides of a 2½ mm. escape trunk.

Round 6.- 4.7 in. S.A.P. filled lyddite. Fuze No. 12+ N. special. S.V. 1,100 f.s.

Holed 5 mm. side and 2½ mm. wing bulkhead in No. 2 boiler room and burst with 4 ft. delay. Violent explosion. Holed side of boiler and perforated about 20 tubes. Two 3 in. pipes holed, also six holes in uptake from boiler. One small hole in 2½ mm. bulkhead to No. 3 boiler room just under upper deck. One furnace door and cover plate on a large cowl on upper deck blown off. One small hole 1 in. long in upper deck near centre line.

Round 7.- 4.7 in. H.E. filled lyddite. Fuze No. 18 P. S.V. 1,100 f.s.

Holed 5 mm. side abreast No. 2 boiler room and burst in wing compartment with partial detonation. About 1 ft. delay. Side plating below water line was bulged outwards and torn away from frames over an area about 3 ft. by 7 ft., so that water entered by some 30 to 40 rivet holes. The 2½ mm. wing bulkhead was bulged against side of boiler and holed in many places, including one hole about 2 ft. by 5 ft. Side of boiler was holed and several tubes damaged.

Round 8.- 4.7 in. C.P. filled powder. Fuze No. 12+ F. S.V. 1,100 f.s.

Holed 5 cm. side and 2½mm. wing bulkhead in No. 2 boiler room abaft boiler. Burst on 10 in. steam pipe about 1 ft. inside. Delay about 4 ft. Steam pipe cut through in two places. One large fragment holed upper deck over boiler and was found on top of boiler.

Hole in upper deck 4 in. by 2 in. Various small pipes and valve gearing rods were holed and cut.

Fig 34 shows a general view of V.82.

IV. General conclusions.- It is, undoubtedly, the ideal arrangement if one type of shell can be devised to meet the requirements of a Torpedo Boat Destroyer engaging another T.B.D.

So far the comparative value of the three shells may be summarised as follows:-

H.E. with No. 18 fuze. – Unlikely to cause serious structural damage, but may cause a number of casualties f burst in a fortunate place.

H.E. with No. 18 P. fuze.- Will cause very considerable effect on the side plating through which it passes, and may cause serious leaks. Is likely to cause casualties, but to a less effect that H.E. with No. 18 fuze. Cannot be certain of disabling a boiler or turbine which may lie in the imaginary path of its trajectory had the shell not burst.

S.A.P. Shell.- Will cause little effect near side plating or to exposed personnel, but will most probably hole the T.B.D. under water if burst in a clear space between decks. Will almost certainly disable any boiler or engine which it meets, resulting in serious casualties inside the compartment.

C.P. Shell.- Has no particular advantages ; C.P. will not be as effective as S.A.P. for causing damage to the remote side or to solid obstructions, and will not be likely to cause damage to the near side.

The choice, therefore, lies between H.E. shell with No. 18 P. fuze and S.A.P. shell, and final judgement will be reserved until the further trials are carried out.

Other points for consideration are :-

(a) Whether it would be of advantage to increase the force of explosion of H.E. shell with No. 18 P. fuze.
(b) Whether the present functions of H.E. shell and S.A.P. shell can be combined.

The present feeling about these latter points is :-

(a) That there is no strong case for this, and that it is not desirable that the fragmentation be too complete.
(b) It seems very unlikely that either shell can be modified to produce the present characteristics of both types, therefore, if it is desired to limit the outfit of shell to one type, it becomes a matter of policy as to whether it is preferred to cause damage on the near side and to exposed personnel, or to the remote side and boilers, engines, etc., and personnel in these compartments.

If it is decided to retain S.A.P. shell to perform the particular functions of which it is now capable, it is considered that the delay might be increased with advantage.

APPENDIX II.

86. Detailed Results of Firing at V.82.- Fuzes marked + were fitted to arm at low pressure.

For diagrams of rounds fired see Figs. 32 and 33.

Round 1.- 4.7 in. S.A.P. filled lyddite. Fuze No. 12+ N. special. S.V. 1,100 f.s.

Holed 5 mm. side and 2½ mm. wing bulkhead at after end of engine room abaft condenser and burst with violent explosion. Delay about 5 ft. Pronounced lateral effect. 2½ mm. transverse bulkhead abour 3 ft. abaft point of burst holed in 20 places over an area 6 ft. by 5 ft., largest hole being 15 in. by 8 in. End of port condenser was holed and tubes exposed. A pipe leading into the starboard condenser was perforated. A fragment perforated the floor plating at the centre line and a ragged hole 3 in. long was made in the bottom (5 mm.) to starboard of the centre line. Two small holes were made in the upper deck (2½ mm.) and there was a hole 7 in. by 6 in. in ship's side starboard (5 mm.) and one very small one

H.M.S. "EXCELLENT'S" REPORT OF THE FIRING AGAINST V.44

With reference to Admiralty letter G.0118/20 of 26th July, 1920, and "Excellent's" report No. 1042 (firing trials with ex-German Torpedo Boat Destroyer V.82) dated 4th November, 1920, firing trials were carried out against ex-German Torpedo Boat Destroyer V.44 on Wednesday, 8th December, 1920.

The trial was carried out on the horse Tail Bank, the firing ship being H.M.S. "Terror," who was in position 300 yards to the northward of the target.

2. The Torpedo Boat Destroyer was damaged extensively by a 6 in. H.E. shell and after the trial was brought into harbour and beached.

3. This report, which should be read in conjunction with "Excellent's" previous report quoted above, is drawn up as follows :-

Appendix I. General remarks.
Appendix II. Detailed results of each round.
Photographs and diagrams.
Cinematograph records taken from a ship at right angles to the line of fire are retained in H.M.S. "Excellent."

4. During the trial V.44 was heeled 12º towards the firing ship by flooding fuel tanks, the charges used being such as would give a striking velocity corresponding approximately to this angle of descent.

APPENDIX I.

87. General Remarks on the Trial against ex-German Torpedo Boat Destroyer V.44.

(a) The particular objects of the trial were :-

(1) To compare the stopping power of 4 in. shell with the results obtained on V.82 with 4.7 in. shell.

(2) To compare the stopping power of 6 in. shell with 4.7 in. and 4 in. shells.

(3) To compare the stopping effect of S.A.P. shell fuzed with No. 12 fuze and S.A.P. shell fuzed with base detonating fuze.

(4) To see the effect of Pom-pom fire on a T.B.D.

(b) The following shells and fuzes were used :-

6 in. C.P.C. filled 60/40 shellite	Fuze No. 14 Q.W.
6 in. H.E. filled lyddite ..	Fuze 18 P.
4.7 in. S.A.P. filled lyddite 50 lb.	Fuze No. 12 N. Special and base detonating
4 in. S.A.P. filled lyddite ..	Fuze No. 12 F. and base detonating
4 in. C.P. filled powder ..	Fuze No. 12.

4 in. H.E. filled lyddite .. Fuze No. 18 and 18 P.

Base fuzes were fitted with weakened base plates to ensure the fuze arming at low chamber pressure.

(c) The charges used were as follows :-

Gun.	Charge.		S.V.	Corresponding range.	Corresponding angle of descent.	Pressure
	lb. oz. drs.	Size.				
4 in.	1 5 11	15/13	987	6,400	12	4.2
4.7 in.	2 1 2	15/13	1,100	7,000	10	5.83
6 in.	4 13 4	15/13	1,126	9,000	12½	3.66

The target was heeled 12½° towards the firing ship. One belt of 2 pdr. Pom-pom C.P. shell fuzed with Hotchkiss base percussion Mark IV fuze fired between Nos. II and III guns. One belt of 2 pdr. Pom-pom H.E. shell fuzed with No. 131 fuze fired between No. 1 gun and the bridge.

(d) The guns used were –
6 in. B.L. XII on C.P. XIV mounting.
4.7 in. B.L. I on C.P. VI mounting
4 in. B.L. IX on C.P. I mounting.

(e) The rounds fired were as follows :-

Series No.	Calibre.	Shell.	Fuze.	Burst.	Target.	Remarks
1.	4 in.	H.E.	18	PD	Superstructure under Bridge.	Effect mostly outside ship.
2.	4 ″	C.P.	12		After E.R,	Passed through clear space and holed far side ship.
3.	4 ″	H.E.	18 P		Superstructure under bridge.	Burst in base of funnel.
4.	4 ″	S.A.P.	12		No. 2. Boiler Room	Burst in B. room holing boiler casing in several places
5.	4 ″	H.E.	18 P		″ ″	Burst on Blr. Room bulkhead. Cut one steam pipe and made a hole in boiler casing.
6.	4 ″	S.A.P.	B.D.		No. 1. ″	Burst between ship's side and B. room bulkhead. 7 small holes in boiler.
7.	6 ″	H.E.	18 P.	P.D.	Fx. plating.	Considerable local effect up to about centre line.
8.	4 ″	S.A.P.	12	E.O.	No. 2. Boiler room	Burst in Boiler room and perforated steam pipes and boiler casing.
9.	4 ″	S.A.P.	B.D.	N.C.D.	No. 1. Boiler room.	Burst between ship's side and Blr. room bulkhead. Small steam pipe cut, Boiler undamaged.
10.	4 ″	C.P.C.	15	Blind.	Fx plating.	Burst on water beyond T.B.D.
11.	4 ft. 7 in.	S.A.P.	12	P.D.	After E. room.	Burst in a tank inside E. room. Fractured main steam pipe and holed turbine casing.
12.	4 ft. 7 in.	S.A.P.	B.D.	N.C.D.	″ ″	Burst in E. room made large holes in turbine casing.
13.	4 ″	C.P.C.	15	V.E.	Fx. Plating.	Burst on deck in far side of ship. Considerable local

						effect. Ship's side holed on far side.
14	6 ″	H.E.	18 P.	N.C.D.	Fore E. room.	Ship's side opened up for 9-11 ft. and E.R. flooded.

(*f*) Remarks on the comparative effect of the various types of 4 in. shells.- The comparative results obtained when using No. 18 (1) and No. 18 P (3) and (5) fuzes in H.E. shell were similar to those obtained in former trials, the bursting effect when using No. 18 fuze being largely expended outside the ship if the side plating be attacked, whereas if 18 P. fuze be used the burst is less violent but takes place inside the ship.

Damage to the ship's side on the near side when using No. 18 P. fuze was not caused by round (5) as was the case at round (7) of the trial with V.82.

D.P. shell (2) caused damage on the far side of the ship, the delay being 26 ft. This shell had a clear passage across the ship and the bursting effect was mild. S.A.P. shell, when fuzed with No. 12 fuze (4) and (8), will carry their bursting effect well into the ship and will probably disable any machinery which happens to be in the path of the shell. There were no instances of the nose of the shell damaging the remote side of the ship, the particular round (8) at which this might have happened the nose of the shell was stopped by a small steam pipe ; it is improbable that the nose would have passed through both the boiler room bulkhead and the ship's side had it not met the steam pipe.

S.A.P. shell when fuzed with base detonating fuzes (6) and (9) have much less forward effect than when fuzed with N. 12 fuze, the majority of the bursting effect being expended between the ship's side and the boiler room bulkhead.

(*g*) Comparative Stopping Effect of 4 in. and 4.7 in. Shells. The effect of 4.7 in. S.A.P. is very considerably greater than that of 4 in. S.A.P. (Rounds 1, 3 and 6 against V.82, and Rounds 4 and 8 against V.44).

With the larger calibre shell there is a chance of serious damage being caused to the remote side of the ship or the ship's bottom, which seems to be improbable with the smaller calibre.

The comparative effect of C.P. shell is not brought out very definitely by the trials, but this type of powder filled shell is not recommended in preference to S.A.P. or H.E. shell.

Direct comparisons of H.E. using powder fuzes are between round 5 of V.82 trial and round 3 of V.44 trial; also round 7 of V.82 trial and round 5 of V.44 trial.

In both instances the effect of the larger calibre shell was much the greater, particularly in the latter comparison where the 4.7 in. shell damaged the ship's side on the near side with the 4 in. shell failed to do.

On the whole, therefore, the 4.7 in. shell showed a very marked superiority over 4 in. shell.

(*h*) Comparative Stopping Effect of 6 in. Shell with 4.7 in. and 4 in. Shell.- 6 in. C.P.C. filled shellite has a tendency to pass blind through light structures (round 10 on V.44), but if it bursts (round 13 on V.44), it can be relied upon to do extensive damage.

6 in. H.E. with 18 P. fuze (rounds 7 and 14 on V.44) will do extensive local damage, and if fired near the water line will destroy the ship's side.

One round of either of the above-mentioned shell bursting in a torpedo boat destroyer should be depended upon to cause important damage, the chances of this being greater in the case of H.E. shell.

One round on 6 in. therefore may cause structural damage sufficient to stop a torpedo boat destroyer.

One round of 4.7 in. may put one machinery compartment out of action by damage to machinery or possibly flood one important compartment.

One round of 4 in. may put one machinery compartment out of action by damage to machinery, but is unlikely to cause any serious leaks.

(*i*) Comparative Effect of base Detonating and No. 12 Fuzes in S.A.P. Shell.- The fragmentation and blast effect when using B.D. fuzes is much more complete that when using No. 12 fuze, but the forward effect is less.

When used in 4 in. calibre shell (6) and (2) the forward effect of B.D. fuzes is barely sufficient to ensure that damage to machinery, etc., will be caused, and for this size of shell No. 12 fuze is preferred.

When used in 4.7 in. calibre shell (12) the burst effect was carried well into machinery compartments, and the damage caused compared favourably with shell using No. 12 fuze (11) for the attack of machinery on the near side of the ship.

It is considered that the delay given by the base detonating fuze is too short, particularly in the case of 4 in. shell, but that the local effect in the vicinity of the burst is increased by their use. This latter, however, is at the expense of the forward effect, and there is less chance of damage being caused by large fragments of shell driving through the remote side of the ship when B.D. fuzes are used.

The use of B.D. fuze in S.A.P. shell does in fact effect a compromise between H.E. shell and S.A.P. shell as referred to in Appendix I, paragraph 4, of Report of Trials in V.82, but, taken on the whole, it is not considered that the chances of causing serious damage to a Torpedo Boat Destroyer is increased by this compromise when dealing with smaller calibre shells such as 4.7 in. and 4 in.

In considering the chances of B.D. fuzes causing damage inside the ship, it must be remembered that during these trials the wing spaces outside the machinery compartments were empty, whereas in practice they might be full, which would have a greater retarding effect on B.D. fuzes than on No. 12 fuze.

(*j*) Effect of Pom-pom Fire.- Both types of Pom-pom ammunition used proved to be very effective. The C.P. shell caused considerable damage to exposed material, and actually reached and damaged the vital machinery of the torpedo boat destroyer.

The H.E. shell made large holes in light structure which would have had a very serous effect on the T.B.D. had they been on the water line.

On the whole, the effect of the C.P. shell is considered to be the more dangerous, but both types were useful.

(*k*) General conclusions.-(*l*) The type of shell recommended for use against Torpedo Boat Destroyers are as follows :-

6 in. gun H.E. with No. 18 P. fuze.
4.7 in. gun S.A.P. with No. 12 fuze.
4 in. gun S.A.P. with No. 12 fuze.

As regards the use of No. 18 P. fuze in H.E. shell, the powder fuze serves the useful and necessary purpose of retarding the burst so that the effect is felt inside the sip, but it is not an economical method of utilizing the potential bursting effect of the filling. It would be desirable to attain the same amount of delay with a fuze capable of giving a higher order of burst.

(II.) The stopping effect of a 6 in. shell is much greater than that of a 4.7 in. shell, and that of a 4.7 in. shell is considerably greater than that of a 4 in. shell. It is considered that the trials entirely justify the policy of arming the latest Torpedo Boat Destroyers with 4.7 in. guns.

(III.) The use of base detonating fuzes in S.A.P. shell 4.7 in. and below is not on the whole, thought to be advisable, at any rate in their present condition.

(IV.) Pom-pom fire against a Torpedo Boat Destroyer can be highly effective.

APPENDIX II.

88. Detailed Results of Firing at V.44.

**For diagrams of Rounds fired see Figs. 35, 36, 37 and 38.
Figs. 39, 40 and 41 show photos of V.44.**

Round 1.

Target :- Superstructure under bridge.
Shell :- 4 in. H.E.
Fuze :- 18.
Filling :- Lyddite.
S.V. :- 987.
Delay :- Nil.
Nature of burst :- P.D.
Point of impact :- Side of cabin against ship's side 2 ft. 6 in. above upper deck.
Vertical angle of impact :- 74 deg.

A hole 4 ft. by 3 ft. was made in the side of the superstructure, but the forward effect was very small. Seventeen small fragments pierced the 2½ mm. funnel casing beyond. Ten strikes were made under the roof of the cabin.

The fragmentation was very complete, the water being churned up along the whole water line of the T.B.D. and one fragment came back 200 yds.

No incendiary effect was caused to wood lining of the cabin.

Round 2.

Target :- After engine room to hit turbine casing.
Shell :- 4 in. C.P.
Fuze :- 12.
Filling :- Powder.
S.V. :- 987.
Delay :- 26 ft.
Nature of burst :- Good explosion.
Point of impact :- Ship's side 9 in. below upper deck.
Vertical angle of impact :- 74 deg.

A hole 4 in. diameter was made in the 5 mm. ship's side plate. The shell then pierced the 2½ mm. engine room bulkhead (port), making a hole 4 in. by 5 in. and, after grazing the turbine outer casing on port side of engine room, in which it made a furrow 2 in. deep through the lagging, it pierced the engine room bulkhead (starboard) (hole 10 in. by 4 in.) and burst on impact with the 5 mm. ship's side.

A hole 2 ft. by 3 ft. was blown in the starboard side, but there was no back effect into the engine room.

The starboard side plating was blown away from an angle iron for 3 ft., all the rivets being sheared, and the starboard bulkhead of engine room was slightly dished inwards.

Round 3.

Target :- Superstructure under bridge.
Shell :- 4 in. H.E.
Fuze :- 18 P.
Filling :- Lyddite.
S.V. :- 987.
Delay :- 8 ft. 6 in.
Nature of burst :- V.E.
Point of impact :- Side of cabin under bridge, 3 ft. 7 in. above upper deck.
Vertical angle of impact :- 74 deg.

A hole 4 in. diameter was made in the 5 mm. plating on side of cabin. The shell then penetrated the 2½ mm. inboard side of the cabin (hole 6 in. by 10 in.) and, crossing the gangway, it burst against the 2½ mm. outer funnel casing, making a hole 2 ft. by 3 ft. in this and in the inner casing.

There was very little forward effect, but two holes 4 in. by 3 in. and 3 in. by 3 in. were made in the steam drum of the boiler.

Round 4.

Target :- No. 2 boiler room.
Shell :- 4 in. S.A.P.
Fuze :- 12 F.
Filling :- Lyddite.
S.V. :- 987.
Delay :- 4 ft. 6 in.
Nature of burst :- M.E.
Point of impact :- Ship's side 1 ft. 6 in. below upper deck. Red flame on far side of T.B.D.
Vertical angle of impact :- 74 deg.

A hole 4 in. diameter was made in the 5 mm. side. The shell then pierced the 2½ mm. boiler room bulkhead, making a hole 4 in. by 5 in. and burst 2 ft. further in.

A hole 12 in. by 9 in. was made in the side of the boiler, exposing the water tubes and ten smaller holes were made in the casing.

The nose of the shell was embedded in the tubes 4 ft. from the boiler casing ; many tubes had been cut. The boiler leaked after this round.

A large steam pipe in the direct path of the projectile was cut.

One large and one small steam pipe above the burst was penetrated by fragments.

Several strikes were made in the deck above but no holes were made.

Round 5.

Target :- No. 2 boiler room.
Shell :- 4 in. H.E.
Fuze :- 18 P.
Filling :- Lyddite.
S.V. :- 987.
Delay :- 1 ft. 6 in.
Nature of burst :- V.E. Thick, grey smoke.
Point of impact :- Superstructure 3 in. above the upper deck.
Vertical angle of impact :- 74 deg.

A hole 4 in. by 5 in. was made in the 5 mm. superstructure. The shell then penetrated the upper deck 1 ft. inboard in which it made a hole 18 in. by 13 in. and burst just after passing through.

The boiler room bulkhead was demolished over an area 5 ft. by 8 ft., and bulged inwards for the whole length of the boiler room.

The outer shell of the boiler was penetrated by a small fragment and was bulged inwards. One steampipe was cut.

There was no backward effect through the ship's side.

Four fragments were recovered from the platform under the burst

Round 6.

Target :- No. 1 boiler room.
Shell :- 4 in. S.A.P.
Fuze :- Base detonating.
Filling :- Lyddite.
Design :- 27650 L.
Delay :- Nil.
S.V. :- 987.
Point of impact :- Upper deck, 22 in. inboard
Vertical angle of impact :- 74 deg.
Nature of burst :- C.D. Black smoke.

A hole 10 in. by 13 in. was made in the 5 mm. upper deck, a hole 2 ft. square in the 2½ mm. boiler room bulkhead, and a hole 1 ft. square in the 5 mm. superstructure 1 ft abaft the burst. Two ¼ in. dents were made in ship's side from inboard.

In the W.T. compartment, an ejection pipe leading overboard was broken at joint of flange on ship's side, and as the ship was heeled, water leaked slowly in. Two 1 in. holes and one 3 in. hole were made in the lower platform of the compartment.

Two 1 in. holes were made in outer casing of boiler.

Round 7.

Target :- After end of forecastle.
Shell :- 6 in. H.E.
Fuze :- 18 P.
Filling :- Lyddite.
S.V. :- 1126.
Delay :- Nil.
Nature of burst :- P.D. :- Yellow flame, grey and black smoke.
Point of impact :- 1 cm. torpedo tube, 2 ft. 6 in. above upper deck
Vertical angle of impact :- 74 deg.

The side of the forecastle inboard of the tube was blown away over a length of 1 ft. 6 in. fore and aft, and the deck above this was blown off also.

Four 6 in. holes, three 4 in. by 2 in. holes, and six 1 in. holes were made in the upper deck under the burst, but none were made in the main deck.

The base of the shell hit an angle iron in the forecastle gun support in centre line just before capstan engine and dropped down a ladderway to the main deck.

The capstan engine and forecastle gun were untouched.

Round 8.

Target :- No. 2 boiler room.
Shell :- 4 in. S.A.P.
Fuze :- 12 F.
Filling :- Lyddite.
S.V. :- 987.
Delay :- 4 ft. 6 in.
Nature of burst :- E.O. Brown smoke.
Point of impact :- Side plating 1 ft. below upper deck
Vertical angle of impact :- 74 deg.

A hole 4 in. diameter was made in the ship's side. The shell then pierced the boiler room bulkhead (hole 7 in. by 5 in.) and burst on hitting a 9 in. steampipe 1 cm thick, making a hole 4 in. by 3 in. in the pipe.

Eight fragments penetrated the boiler 3 ft. forward of the burst, and four 1 in. holes were made in the 5 mm. bulkhead 4 ft. abaft the burst.

Many small pipes in front of the boiler were cut, and the nose of the shell was found embedded in one of these.

The round was fired so that it would not hit the boiler, but pass through the space between the boiler and the bulkhead abaft it.

Round 9.

Target :- No. 1 boiler room.
Shell :- 4 in. S.A.P.
Fuze :- Base detonating, design 27650 L.
Filling :- Lyddite.
S.V. :- 987.
Delay :- 2 ft.
Nature of burst :- N.C.D.
Point of impact :- Ship's side, 2 ft. below upper deck
Vertical angle of impact :- 74 deg.

A hole 4 in. diameter was made in the ship's side, the shell bursting 2 ft. further in.

A great many holes were made in the boiler room bulkhead, but very little damage was caused inside the boiler room. One 3 in. steampipe was cut.

The boiler was undamaged.

A 2 in. crack through the upper deck was made over the burst.

Round 10.

Target :- Forecastle side plating.
Shell :- 6 in. C.P.C.
Fuze :- 15 Q.W Mark IV.
Filling :- 60/40 shellite.
S.V. :- 1126.
Delay :-
Nature of burst :- Blind through ship, burst on water beyond. V.E.
Point of impact :- Forecastle side plating 23 in. above upper deck
Vertical angle of impact :- 74 deg.

The shell struck the side on a transverse bulkhead, a hole 7 in. being made in the 5 mm. side and a hole 12 in. by 10 in. in the 2½ mm. cross bulkhead. It then passed out the starboard side 1 ft. 9 in. above the upper deck, making a hole 7 in. by 7 in., and partly cutting through a 3 mm. angle iron.

A hole 3 in. by 2 in. was made in the ship's side by a bit of plating 1 ft. abaft the exit hole.

The distance between the entry and exit holes was 5 ft.

Shell burst on water beyond the destroyer.

Round 11.

Target :- After engine room.
Shell :- 4.7 in. S.A.P.
Fuze :- 12 N special.
Filling :- Lyddite.
S.V. :- 1,100.
Delay :- 3 ft 6 in..
Nature of burst :- P.D.
Point of impact :- Ship's side 5 in. below upper deck
Vertical angle of impact :- 74 deg.

A hole 5 in. by 5 in. was made in the 5 mm. ship's side. The shell then pierced the engine room bulkhead, in which it made a hole 7 in. by 7 in. and entered a 2½ mm. tank containing a very heavy lubricating oil bursting in the tank and demolishing it.

A 7 in. main steam pipe, 1 ft. from the bulkhead was completely severed.

Eight punctures were made in the turbine casing, and several small pipes secured to the crown were partly cut through and flattened.

A hole 7 in. by 4 in. was made in the upper deck.

Round 12.

Target :- After engine room.
Shell :- 4.7 in. S.A.P.
Fuze :- Base detonating R.L. 27,650. L.
Filling :- Lyddite.
Design :- 27,650 L.
Delay :- 4 ft.
S.V. :- 1,100 f.s.
Point of impact :- Ship's side 1 ft. 6 in. below upper deck
Nature of burst :- N.C.D.
Vertical angle of impact :- 74 deg.

A 4 in. hole was made in the 5 mm. side, the shell then piercing the 2½ mm. engine room bulkhead and bursting 2 ft. inside.

Two holes (2 ft. by 1 ft., and 9 in. by 8 in.) were made into the turbine, and 10 holes from 1 in. to 2 in. through the 5 mm. bulkhead 4 ft. abaft the burst.

The main steam pipe over the turbine and several smaller pipes were cut.

Much more damage was caused than by round 11.

Round 13.

Target :- Forecastle side plating.
Shell :- 6 in. C.P.C.
Fuze :- 15 Q.W. Mark IV.
Filling :- 60/40 Shellite.
S.V. :- 1,126 fs.
Delay :- 14 ft
Nature of burst :- V.E.. :- Yellow smoke.
Point of impact :- Ship's side 3 ft. above upper deck
Vertical angle of impact :- 74 deg.

A hole 7 in. by 7 in. was made in the 5 mm. side.

The shell then pierced two 2½ mm. bulkheads, making holes 9 in. by 10 in. and 8 in. by 8 in. respectively, and burst 14 ft. from the port side about 6 in. above the upper deck.

A hole 3 ft. by 1 ft. 6 in. was made in the upper deck, and a hole 3 ft. by 1 ft. 6 in. in the starboard side.

The after bulkhead in the washplace (4 ft. abaft burst) was pushed back about 1 ft. and holed in several places.

The forecastle and main decks were undamaged.

Round 14.

Target :- Fore engine room.
Shell :- 6 in. H.E.
Fuze :- 18 P.
Filling :- Lyddite.
S.V. :- 1,126 f.s.
Delay :- 1 ft.
Nature of burst :- N.C.D.
Point of impact :- Ship's side 1 ft. 3 in. below upper deck
Thick light brown smoke.

The shell burst in the W.T. compartment and blew a hole 11 ft. long and 6 ft. deep in the side and a hole 9 ft. long and 4 ft. deep in the engine room bulkhead. The engine room was flooded.

The upper deck was bulged upwards 1 ft. for 11 ft. fore and aft.

A great deal of local damage to small pipes and auxiliary machinery was caused in the engine room, but on account of the compartment being flooded up to the upper deck on the port side, a detailed examination was impossible.

Two small rivets through 5 mm. bulkhead to after engine room were blown through, and water leaked from fore engine room to after engine room.

The starboard propeller shaft gland was started in the same bulkhead and this also caused a small leak.

2 pdr. Pom-pom H.E., Mark II, Fuze 131.- (1) Struck door of port torpedo tube and burst, hole 5 in. by 4½ in.

(2) Struck bottom of starboard torpedo tube 8 ft. from the door and burst, making a hole 9½ in. by 7 in., and bulged in and holed upper deck, hole 3 in. by 2 in.

(3) Struck at bottom of vent to boiler room, burst on impact, hole 1 ft. 8 in. by 1 ft. 4 in., good all round effect from fragments, 16 punctures in casing.

(4) Struck half-way up vent and burst on impact, hole 15 in. by 8 in., also 22 punctures in casing, good forward effect.

(5) Struck top of vent and burst on impact, hole 18 in. by 18 in., also 20 punctures in casing, good forward effect.

(6) Struck on upper deck 4 in. from ship's side, burst on impact, making a slight bulge in deck ; good forward effect from fragments, making numerous holes through hatch skylight and galley casing.

(7) Struck ship's side plating under fore bridge, burst on impact, hole 12 in. by 7½ in.

(8) Cut through guard rail, then through upper deck, hole 6 in. by 4 in., partly severed two 2 in. diameter pipes and punctured funnel casing.

(9) Struck casing for rod gearing at front of galley, burst on impact, tearing away casing and gearing and making a hole in galley 12 in. by 12 in., numerous small holes in upper deck.

2 pdr. Pom-pom Common Pointed Shell fuzed Hotchkiss, Mark IV.- (1) Entered steering engine compartment under searchlight platform and burst on starboard side, severing five voicepipes and making a hole 1 ft. by 9 in. Two small strikes on gun muzzle.

(2) Passed through mast half-way up (blind).

(3) Struck and severed three-sixteenths of an inch angle support to searchlight platform, then through bridge plating sideways, hole 7 i. by 2 in. (blind).

(4) Through port side of bridge plating, struck and carried away a bracket and went through starboard side plating sideways, hole 7 in. by 2 in (blind.)

(5) Entered port torpedo tube 8 ft. from door, the nose of shell inside of tube (blind).

(6) Entered port torpedo tube 12 ft. from door, hole 4 in. by 2½ in. ; burst against starboard side of tube, hole 9 in. by 4½ in., and two small strikes nearly through close to main exit.

(7) Struck guard bracket for port torpedo tube firing lever, then struck starboard tube, hole 4½ in. by 5½ in. ; probably burst in getting through, making a hole 4 in. by 3 in. in starboard side of tube, also a small puncture just below it.

(8) Entered port torpedo tube 18 ft. 6 in. from door, hole 3 in. by 1¾ in., then through opposite side of tube, hole 3 in. by 2 in. (blind).

(9) Entered starboard tube, hole 1½ in. by 1½ in., and out opposite side, hole 3 in. by 2 in. (blind).

(10) Struck ready supply rack for 4.1 in. gun, then through top of starboard tube, hole 6 in. by 2 in.

(11) Struck upper deck 3 ft. 6 in. from ship's side, burst in deck making a hole 14 in. by 6 in., four small pipes and two electric cables cut through in engine room.

(12) Through upper deck, 3 in. from ship's side, and burst, holing upper deck 6½ in. by 3½ in., cut through a 3 in. steam pipe and three smaller pipes and four electric armoured cables. The turbine casing was holed in four places.

(13) Through ship's side plating into engine room, making a hole in end of starboard turbine 2 in. by 2 in.

(14) Through ship's side plating into engine room, burst and holed an electric radiator in rear of port turbine ; the after bulkhead of engine room was punctured in two places.

(15) Through engine room skylight into engine room (blind), nose of shell picked up starboard side of engine room.

89. Summaries of Remarks contained in the Reports of the Captain of H.M.S. "Excellent," with Admiralty Comments.

On Firing Trials against the following ex-German Vessels.

Part 1.- Torpedo Boat V.82. 13th October, 1920, 15th October, 1920.
Part II.- Torpedo Boat V.4. 8th December, 1920.
Part III.- Submarine U.B.21, 30th September, 1920; and U.141, 7th October, 1920.

Part I.

Firing Trials against ex-German Torpedo Boat V.82.

Summary of remarks by Captain, H.M.S. "Excellent," with Admiralty comments.

Conditions for trial.

Destroyer heeled to 12½º towards Firing Ship.- To represent attack by a 4.7 in. B.L. Mark I, at range 7,000 ; angle of descent, 10º ; S.V., 1,100 f.s.

Types of Shell and Fuzes used.

4.7 in. H.E. filled lyddite – No. 18 fuze.
4.7 in. H.E. filled lyddite – No. 18 P fuze.
4.7 in. S.A.P. filled lyddite – No. 12. N. special.
4.7 in C.P. filled powder – No. 12 F. special.

Remarks by H.M.S. "Excellent."	*Admiralty Remarks.*
Attack against Exposed Position.	
Comparative effect of H.E. shell fuzed with No. 18 and 18 P. fuzes. (Both rounds fired at forecastle side plating.) H.E. shell fuzed No. 18 caused very little damage to the side plating or inside ship. Fragmentation complete but fragments very small. Majority of effect outside the ship. H.E. shell fuzed No. 18. P. caused considerably more damage inside ship and size of fragments was larger. Considers that of these two rounds the results are considerably in favour of the use of the 18 P. fuze. S.A.P. and C.P. shell were not fired under exactly the same conditions but results obtained from other rounds lead to conclusion that neither would be so effective against exposed positions as H.E. shell with No. 1 P. fuze.	Considers that the behaviour of H.E. shell fuzed 18 and No. 18). Was typical. Remarks that on "Nurnberg's" report it has been agreed that a powder filled D.A. fuze is to be adopted for all existing H.E. shell, 7.5 in. and below for use against ship targets. Considers that "Excellent's" remarks on the relative effect of H.E. (fuzed 18 P.) and S.A.P. and C.P. shell confirm the opinions previously expressed that, at present, the S.A.P. is the best general service shell for small calibre guns because of its superior stopping power. Considers that the comparison bears out the view that what is required is an H.E. pointed shell with sensitive base fuze.

Attack against Hull.	
Considers that the effect of gunfire on the hull of a T.B.D. is dependent on what obstructions the projectile meets with on its path through the hull. Remarks that possible forms of attack are :- *(a)* Shell traversing a clear space is caused to burst so that fragments are likely to penetrate the remote side under water. *(b)* Shell meeting an obstruction such as a b oiler is caused to burst so that it creates the maximum destructive effect to the obstruction and the compartment in which situated.	Concurs with "Excellent." Remarks on previous paragraph cover this also.

Remarks by H.M.S. "Excellent."	*Admiralty Remarks.*
Attack against Hull – (*contd.***)**	
(c) Shell caused to burst shortly after piercing side so that plating is severely punctured under water.	
Considers that trials show that S.A.P. shell may be expected to fulfil conditions (*a*) and (*b*) and are superior to either C.P. or H.E. On the other hand, H.E. with No. 18 P. fuze is most effective for (*c*) and is the only type of shell likely to produce the required effect.	
General Conclusions.	
Considers that the ideal arrangement is if one type of shell can be devised to meet the requirements of a T.B.D. engaging another T.B.D.	Fully concurs with "Excellent." The ideal is to have one type of shell only for us against ship targets (including submarines).
Summarises the comparative value of the 3 shell as follows :-	
H.E. with No. 18 fuze unlikely to cause structural damage, but may cause a number of casualties.	Concurs in remarks comparing shell, and remarks : It is proposed definitely to threat the C.P. shell as obsolescent and to replace it by S.A.P. or H.E. as supply permits
H.E. with No. 18 P. fuze will cause very considerable effect on side plating and may cause serious leaks. Likely to cause casualties but to a less effect that H.E. with No. 18 fuze. Cannot be certain of disabling a boiler or turbine which may lie in the imaginary path of its trajectory had shell not burst.	
S.A.P. shell will cause little effect near side plating or to exposed personnel, but will probably hole the T.B.D. under water if burst in a clear space between decks. Will almost certainly disable any boiler or engine which it meets.	
C.P. Shell.- No particular advantage. C.P. will not be as effective as S.A.P. for causing damage to the remote side or to solid obstructions and will not be likely to cause damage to the near side.	
Considers that choice lies between H.E. with 18 P. fuze and S.A.P. shell and	Remarks with regard to points (*a*) and (*b*).

reserves final judgement until further trials.	
Other points for consideration are :-	
(*a*) Whether it would be of advantage to increase the force of explosion of H.E. shell with 18 P. fuze.	(*a*) Is impracticable.
(b) Whether the present functions of H.E. shell and S.A.P. shell can be combined.	(*b*) Has already been remarked upon and adds :- As regards the latter, however, the point is mainly to decide upon what is needed for future supplies ; present outfits cannot be altered except at great expense.
If it is desired to limit the outfit of shell to one type it becomes a matter of policy as the whether it is preferred to cause damage to near side and to exposed personnel, or to remote side and boilers, engines, etc., and personnel in those compartments.	
Considers that, if decided to retain S.A.P. shell, it is recommended that the delay might, with advantage, be increased.	The length of delay required and the conditions of target S.V. under which it should be obtained are under consideration.

Part II.

Firing Trials against ex-German Torpedo Boat V.44.

Summary of Remarks by Captain, H.M.S. "Excellent,"
With Admiralty comments.

Conditions for Trial.

Destroyer heeled to 12º towards Firing Ship.- To represent attack by following guns:-

(*a*)	(*b*)	(*c*)
4 in. B.L., Mark IX, and Q.F. 4 in., Mark V.-	4.7 in. B.L., Mark I-	6 in. B.L., Mark XII.-
At range 6,400 yds	7,000 yds.	9,000 yds.
Angle of descent, 12º	10º	12½º.
Striking velocity, 987 f.s.	1,100 f.s.	1,126 f.s.

Types of Shell and Fuzes used.

6 in. C.P.C. filled 60/40 shellite – No. 15 Q.W.
6 in. H.E. filled lyddite – No. 187.
4.7 in. S.A.P. filled lyddite – Fuze 12 N. special and base detonating
4.7 in. S.A.P. filled lyddite – Fuze 12 F. and base detonating.
4 in. C.P. filled powder – Fuze 12.
4 in. H.E. filled lyddite – Fuze 18 and 18 P.

Remarks by H.M.S. "Excellent."	*Admiralty Remarks.*

Remarks on Comparative Effects of the Various Types of 4 in. Shells.

Comparative results obtained when using No. 18 and 18 P. fuzes in H.E. shell were similar to those in former trials, the bursting effect when using No. 18 fuze being largely expended outside the ship if side plating is attacked, whereas if 18 P. fuze be used, burst is less violent but takes place inside ship. C.P. shell caused damage on far side of ship, delay being 26 feet. Shell had a clear passage, the bursting effect was mild. S.A.P. shell fuzed with No. 12 fuze will carry their bursting effect well into ship and will probably disable any	Considers the most interesting point is the comparative efficiency of the S.A.P. shell fuzed with experimental base detonating fuze and the ordinary service No. 12 powder fuze. After making allowance for the very short delay of which the B.D. fuze is capable, it is not clear that the bursting effect inside the target of detonating the 4 per cent burster of the S.A.P. is more satisfactory than when the shell is exploded by the present service fuze, at any rate as regards causing serious forward damage, and the stopping power of the detonating shell using a

machinery in the path of the shell. S.A.P. shell fuzed with base detonating fuzes have less forward effect than when fuzed with No. 12 fuze, majority of effect being expended between ship's side and boiler room bulkhead.	non-delay detonating fuze certainly seems to be less than that f the service shell as fuzed. This point was clearly brought out in previous trials at destroyer target at Shoeburyness with 4 in. shells similarly fuzed. Considers that unless detonating is combined with delay action the large fragmentation obtained with a powder fuze is likely to be more effective in causing vital damage than the greater blast effect of detonation, and its more violent and widespread projection of the much smaller fragments into which the shell is broken up. Remarks that this points to the probability that, when a satisfactory base detonating delay fuze is obtained, we shall have to re-design our shells and alter their burster capacities to obtain best results against ship targets.

Comparative Stopping Effect of 4 in. and 4.7 in. Shell

Effect of 4.7 in. S.A.P. is very considerably greater than that of 4 in. S.A.P. and that with the larger shell there is a chance of serious damage being caused to the remote side of the ship or ship's bottom, which appears improbable with the smaller calibre. Comparative effect of C.P. shell was not brought out very definitely, but this type is not recommended in preference to S.A.P. or H.E. shell.	Concurs with "Excellent." Considers that the results strongly favour the heavier gun for the armament of our Destroyers, observing that several foreign powers are now mounting guns heavier than 4.7 in. and up to 6 in. in Leaders.

Remarks by H.M.S. "Excellent."	Admiralty Remarks.
Comparative Stopping Effect of 4 in. and 4.7 in. Shell-(*continued*).	
Direct comparison of H.E. using powder fuzes was obtained. In both instances the effect of the larger calibre shell was much the greater. In one case the 4.7 in. shell damaged the near side which the 4 in. shell failed to do. On the whole the 4.7 in. showed a marked superiority over the 4 in. shell.	
Comparative Stopping Effect of 6 in. Shell with 4.7 in. Shell and 4 in. Shell	
6 in. C.P.C. shellite has a tendency to pass blind through light structures (one round of this nature fired at the forecastle side plating of V.4 passed through ship and burst on water beyond), but if it bursts can be relied upon to do extensive damage. 6 in. H.E. with 18 P. fuzes will do extensive local damage, and if fired near the water line destroy the ship's side. One round of either of the above-mentioned shell bursting n a T.B.D. should be depended upon to cause important damage, chances of this being greater in the case of the H.E. shell. One round of 6 in. may cause structural damage sufficient to stop a T.B.D. One round of 4.7 in. may put one machinery compartment out of action by damage to machinery or possibly flood one important compartment. One round of 4 in. may put one machinery compartment out of action by damage to machinery but is unlikely to cause any serious leaks.	The blind 6 in. C.P.C. is referred to in paper with "Nurnberg" report. Concurs with the remainder of "Excellent's" remarks. Considers that the existing 6 in. H.E. shells fuzed with a D.A. powder fuze are satisfactory for use against a Destroyer.
Comparative Effect of Base Detonating and No. 12 Fuzes in S.A.P. Shell.	
Fragmentation and blast effect when using B.D. fuzes is much more complete than when using No. 12 fuzes,	Covered by remarks already made.

but the forward effect is less. When used in 4 in. the forward effect of B.D. fuzes is barely sufficient to ensure that damage to machinery will be caused, and for this size of shell No. 12 fuze is preferred. When used in 4.7 in. shell the burst effect was carried well into the machinery compartment, and damage caused compared favourably with shell using No. 12 fuze for attack of machinery on near side of ship. Considered that the delay given by the B.D. fuze is too short, particularly in 4 in. shell, but that the local effect in vicinity of burst is increased by their use. This latter is, however, at the expense of the forward effect, and there is less chance of damage being caused by large fragments of shell driving through the remote side of ship when B.D. fuzes are used. Considers that the use of B.D. fuzes in S.A.P. shell effects a compromise between H.E. shell and S.A.P. shell, as referred to in report of V.82 trials, but taken on the whole it is not considered that the chances of causing serious damage to a T.B.D. is increased by this compromise when dealing with smaller shells such as 4.7 in. and 4 in. Remarks that during these trials the wing spaces were empty, whereas in practice they might be full, and that this would have a greater retarding effect on B.D. fuzes than on No. 12 fuzes.	

Remarks by H.M.S. "Excellent."	*Admiralty Remarks.*

Effect of Pom-pom Fire.

Both types of Pom-pom ammunition used were very effective. C.P. shell caused considerable damage to exposed material, and actually reached and damaged vital machinery of the T.B.D. H.E. shell made large holes in light structures, which would have had a serious effect on the T.B.D. had they been on the water line. Considers that on the whole the effect of the C.P. is the more dangerous, but that both types are useful.	Concurs with "Excellent," but remarks that opportunities for the effective use of destroyer Pom-poms are only likely to occur at short range. On this account favours the use of H.E. shell rather than C.P. on account of the former's greater effect on personnel and armament fittings and the demoralising noise of the explosion.

General Conclusions

The type of shell recommended for use against T.B.D.s are as follows :- 6 in. H.E. with No. 18 P. fuze. 4.7 in. S.A.P. " " 12 " 4 in. S.A.P. " " 12 " The use of powder fuze No. 18 P. in H.E. shell serves the useful and necessary purpose of retarding the burst so that the effect is felt inside the ship, but is not an economical method of utilising the potential bursting effect of the filling. Desirable to attain the same amount of delay with a fuze capable of giving a higher order of burst. Stopping effect on 6 in. much greater than 4.7 in. and 4.7 in. shell considerably greater than 4 in. Considers that the trials justify the policy of arming the latest T.B.D.s with 4.7 in. guns. The use of base detonating fuzes in S.A.P. shell, 4.7 in. and below, is not on the whole though to be advisable, at any rate in their present condition. Pom-pom fire against a T.B.D. can be highly effective.	Concur as regards 6 in. As regards 4.7 in. and 4 in. these are points both for the S.A.P. and H.E. fuzed No. 18 P., former having the greater stopping power, but may hit without bursting on board, whereas latter can always be relied on to cause damage.

Part III.

Firing Trials against ex-German Submarines U.B.21 and U.141.

Summary of Remarks by Captain, H.M.S. "Excellent,"
With Admiralty comments.

Conditions for Trial.

(*a*) **Attack on Conning Tower,** with striking velocities corresponding to the remaining velocities which obtain at 2,000 and 5,000 yds.

(*b*) **Attack on Pressure Hull,** with striking velocities corresponding to the remaining velocities which obtain when the angle of descent is 12½º which occurs for the various guns at the following ranges :-

B.L. 4.7 in.	7,150 yds.
Q.F. 4 in. V.	6,500 yds.
Q.F. 12 pdr. 12 cwt.	4,650 yds.

Guns used : 4.7 in. B.L., 4 in. B.L., and 12 pdr, 18 cwt.

Types of Shell used.-

4.7 in. S.A.P. filled lyddite	..	..	..	Fuze No. 12.
4.7 in. C.P. filled powder	..	..	..	Fuze No. 12.
4.7 in. H.E. filled lyddite	..	..	..	Fuze No. 18 P.
4 in. S.A.P. filled lyddite	..	..	..	Fuze No. 12.
4 in. C.P. filled powder	..	..	..	Fuze No. 12.
4 in. H.E. filled lyddite	..	..	..	Fuze No. 18 P.
12 pdr. S.A.P. filled lyddite	..	..	..	Fuze No. 12.
12 pdr. C.P. filled powder	..	..	..	Fuze No. 12.
12 pdr. H.E. filled lyddite	..	..	..	Fuze No. 18 P.

Remarks by H.M.S. "Excellent."	*Admiralty Remarks.*
Conning Tower Attack.	
Conning tower of U.B.21 – single thickness of $2\frac{3}{32}$ in. plate. Conning tower of U.141 – two plates, outer $2\frac{3}{8}$ in., inner $1\frac{1}{4}$ in. Plates 8 in. apart on bear and 10 in apart in fore and aft line. (*a*) UP to ranges of 5,000 yds. following may be expected when firing at a weak conning tower. S.A.P. shell 4.7 in. and 4 in. will go right through and burst on far side of conning tower. C.P. shell 4 in. may burst in remote wall of conning tower. H.E. shell with No. 18 P. fuze will probably burst inside the conning tower. (*b*) At a range of 5,000 yds., when firing at a strong conning tower, shell smaller than 4.7 in. will not penetrate into the inside of the conning tower. S.A.P. shell from a 4.7 in. may penetrate into the conning tower under favourable conditions of impact. H.E. and C.P. shell from 4.7 in. gun will not penetrate, and of these two shells the H.E. has the greater effect on the surrounding structure owing to its wider cone of dispersion. (*c*) At a range of 2,000 yds. when firing at a strong conning tower.	Remarks that the actual conning tower of a submarine is so small that it is not considered that its special attack should be allowed to influence the design of the "general service" anti-submarine shell. The best shell for supply is the one which is most likely to be effective whenever it hits. Hits on a submarine conning tower, even if effective in disabling the tower and its periscope or occupants, will not, without existing shells, filling and fuzes, inflict decisive injury ; the W.T. hatch in the hull or the hull itself will not be pierced. Improved results may be obtained by existing shells if filled with an insensitive H.E. filling in combination with a base detonating delay. If conning tower is thick (of about 3 in. nickel chrome steel or double walled) as in U.141. Shells up to 4.7 in. 50 lb. cannot be relied on to disable tower. At a conning tower similar to U.141 existing H.E. and C.P. shells will not perforate at any angle, and 4.7 in. S.A.P. will not do so at angles beyond 20º, if then. Remarks that the burst of any shell,

Shell smaller than 4.7 in. are not likely to penetrate inside the conning tower. S.A.P. shell 4.7 in. may be expected to penetrate inside the conning tower, but damage inside will not be very great. C.P. shell 4.7 in. is not likely to penetrate. H.E. shell 4.7 in. will not penetrate. Considers that the rounds fired provide sufficient data to sho that the only type of shell that may be expected to penetrate conning towers of future submarines (where it is expected that the strength of the tower will compare with that of U.141) will be SA.P. So far as the actual trial is concerned no shell less than 4.7 in. heavy S.A.P. obtained penetration, and then only very close to normal impact. At 16º from normal both 4.7 in. and 4 in. failed to penetrate.	particularly H.E. and S.A.P., outside the conning tower may cause severe damage to deck fittings pipes, etc., which are exposed above the pressure hull. Such damage e.g., destruction of deck flaps, valves and ballast tank vent pipes, might hamper rapid diving, or, if Kingston valves were open when hit occurred, may cause a rapid dive. Of the three types of shell tried the S.A.P. is the best for attack on conning towers. Its perforation powers could probably be increased by capping, but thought doubtful if the disadvantage of this in respect to "capacity" and cost would be balanced by the advantages. Use of an insensitive filling (with detonating fuze) which would not "go off" on impact with a thick plate should be an improvement.

Remarks by H.M.S. "Excellent."	*Admiralty Remarks.*

Superstructure Attack.

Pressure hull of U.B.21 was ½ in. and of U.141 1¼ in. Superstructure of U.141 more substantial than that of U.B.21. In both submarines there were a considerable number of obstructures such as air flasks, etc., contained in the superstructure.	
Results show that penetration of 1¼ in. pressure hull by "coup de hache" is not to be expected. Under favourable conditions penetration of a ½ in. hull by "coup de hache" effect may be obtained with H.E. 4.7 in. shell with No. 18 P. fuze. Behaviour of shell depends almost entirely on the nature of the obstruction encountered. Generally C.P. and S.A.P. shell are likely to go blind or burst beyond the submarine if they meet the superstructure plating only. H.E. shell with No. 18 P. fuze will almost certainly burst in the superstructure and cause the greatest effect of the three types.	A hit low down near water line may cause a shell to burst close enough to the hull to blow a hole and for this an H.E. shell of large capacity is best. If pressure hull is of about 1 in. nickel chrome steel and the submarine trims down as low as possible, she should be practically immune from any but plunging fire. Remarks that the presence of air flasks, etc., inside superstructure afford added protection from bursting shell, although the reduce liability of base fuzed shells to pass overboard blind through the thin superstructure plating.

Shells and fuzes as at present in Supply recommended for Anti-Submarine Purposes, 4.7 in. and below.

Useless to expect fragments to penetrate by "coup de hache" effect, and that any further developments are unlikely to improve them. Considers that the best chance is to cause serious damage to exposed fittings. For this recommends H.E. and No. 18 P. fuze. For attack on hull by plunging fire and attack on conning tower. Recommends S.A.P with No. 12 fuze. Recommends procedure to be :- At ranges when angle of descent is less than 10º H.E. shell with No. 18 P.	Of the three present types of shell and two types of fuze, the following are recommended :- (a) For short range attacks "coup de hache" effect on hull required, H.E. fuzed 18 P. But the desired effect cannot be expected with these small shells unless the burst is close to the hull. (b) For attack on hull by plunging fire, S.A.P. with No. 12 fuze. (c) For attack on conning tower, S.A.P. with No. 12 fuze. Decisive damage to hull cannot be

fuze. At ranges where angle of descent is greater than 10° S.A.P. shell. Considers that the chances of obtaining penetration of the pressure hull by "coup de hache" effect are so remote that the objects to be attained by firing at the superstructure are to damage some essential fittings. For this purpose H.E. shell No. 18 P. fuze expected to give best results.	expected from the violence and fragmentation of burst inside the superstructure of any of our present combinations of shell filling and fuze. Although at some proof ground trials we have "holed" the plate representing the pressure hull by "coup de hache," this cannot be relied upon with 4.7 in. shell or below.

Attack on Pressure Hull

Trial carried out with velocity corresponding to those occurring with an angle of descent at following ranges :-

B.L. 4.7 in.	7,150 yds.
Q.F. 4 in.	6,500 yds.
Q.F. 12 pdr. 12 cwt.	4,650 yds.

Under these conditions penetration into submarine by direct attack on a 1¼ in. pressure hull can only be expected with S.A.P. shell 4.7 in. and 4 in., and only then under favourable conditions of impact, and that the fuze does not function too soon, e.g. :- 4 in. S.A.P. blind round penetrated at 48° from normal. 4.7 in. S.A.P. failed to penetrate at 60° to normal. C.P. 4 in. and above may damage the hull, but will not penetrate.	Effective holing depends on the thickness of the plating and angle of impact, and whether the fuze delays long enough to allow shell to hit hull before it bursts. S.A.P. shell is the best of existing types for this purpose, but the fuze requires a delay sufficient to ensure above conditions. The present No. 12 fuze does not give this. Also to use of an insensitive H.E. filling with a detonating fuze appears desirable.

Remarks by H.M.S. "Excellent."	*Admiralty Remarks.*

Attack on Pressure Hull – (*continued).*

H.E. shell 4.7 in. to 12 pdr. will not penetrate, but larger types of H.E. shell have considerable local effect and may do important damage to ballast tanks.	
12 pdr. shell of all natures will probably burst before reaching pressure hull – they are unlikely to do much damage.	Concur.
Only reasonable chance of success to be expected from this form of attack would be S.A.P. shell of 4 in. and larger calibre.	
Destructive Fire in Superstructure	**Remarks as follows on Fuzes.**
The above is fairly well met with H.E. No 18 P. fuze the delay of this fuze a little short of ideal conditions.	(Fuzes used were in all cases No. 12 for pointed shell and No. 18 P. for H.E.)
Plunging Fire on Hull.	i. As was to be expected, base fuzes are liable to be blind against superstructure plating. No. 12 is not sufficiently sensitive, nor is it capable of initiating detonation.
The delay of No. 12 fuze. Should be increased.	ii. Shell which are required to give "coup de hache" effect must detonate, and they require a fuze which will be set in action by the thinnest plating. Of our present fuzes, D.A. No. 18 P. is considered the best on account of its slight delay.
	iii. For plunging fire the present type of base fuze is satisfactory as regards sensitiveness, but an increased delay is required to enable shell to reach the hull and pierce it (if possible) before bursting.
	Future Lines of Improvements of Shells and Fuzes for Anti-Submarine Purposes.
	A type of H.E. filled shell with an insensitive filling is required, having a

	base fuze of extreme sensitivity. With this combination "coup de hache" effect should be obtained by fragments and for effect by blowing in the plating of the pressure hull if the shell bursts close to it. The shell should preferably possess sufficiently good A.P. qualities to render it capable of penetrating thin armour (up to 1½ in. or 2 in.), but this is of less importance than the "coup de hache." The same shell should be equally effective against light surface vessels, and there would then be the very great advantage of having one nature of shell only for all purposes.

90. REPORT OF FIRING TRIALS AGAINST V.44 AND V.82.

Remarks, re Structural Damage, by Admiralty.

The hull damage has been tabulated and summarised in the attached sheets, separating damage to hull structure proper from that to machinery and fittings.

As far as possible the blast effect of the shell burst is distinguished from the fragmentation effect. The damage to machinery and fittings which occurred naturally protected portions of hull which would otherwise have been damaged.

Attention is drawn to the following results :-

(*a*) The blast effect of burst taking place in wing compartments seems to have been greater than elsewhere, and with these tanks filled or partially filled with oil fuel or water as in service condition more severe damage would probably result. (*Continued on p. 100.*)

V.44 and V.82. TABULATED RESULTS OF FIRING TRIALS, SHOWING DAMAGE TO HULL STRUCTURE.

	No. of Round.	Size of Shell.	Position of Burst						Compartment Flooded.		General Damage	
			Confined Space.		Large Compartment or Open Space		On First Impact.		Blast	Fragmentation	Blast	Fragmentation
			Above Upper Deck.	Below Upper Deck.	Above Upper Deck.	Below Upper Deck.	In Open.	Partially Enclosed.				
V.82.	1	4.7 in.	-	-	-	Aft. Eng. Rm.	-	-	-	Aft. Eng. Rm & Compts. Aft. Side.	Nil.	Extensive.
	2	4.7 in.	-	-	-	Engine Rm.	-	-	-	-	Skylight blown off.	Nil.
	3	4.7 in.	-	-	-	Fd. Boil Rm.	-	-	-	Fd. Br. Rm.	Nil.	Extensive.
	4	4.7 in.	-	-	-	-	-	-	-	-	Nil.	Extensive.
	5	4.7 in.	End of F'cle	-	-	-	Turtle of F'cle	-	-	-	Extensive	Moderate.
	6	4.7 in.	-	-	-	No. 2 Br. Rom.	-	-	-	-	Nil.	Slight.
	7	4.7 in.	-	Wing Compt.	-	-	-	-	No. 2 Br. Rom.	-	Extensive	Moderate.
	8	4.7 in.	-	-	-	No. 2 Br. Rom.	-	-	-	-	Nil.	Slight.
V.82.	1	4 in.	-	-	-	-	Side of Cabin	-	-	-	Nil.	Moderate.
	2	4 in.	-	Wing Compt.	-	-	-	-	Aft. Eng. Rm. (on impact and blast of sehll on shell plating on exit)		Moderate.	Nil.
	3	4 in.	-	-	Funnel Casing.	-	-	-	-	-	Nil.	Nil (moderate impact and burst.)
	4	4 in.	-	-	-	No. 2 Br. Rom.	-	-	-	-	Nil.	Very slight.
	5	4 in.	-	Wing Compt.	-	-	-	-	-	-	Extensive. (Wing Bhd. No. 2 B.R._	Nil.
	6	4 in.	-	-	-	-	U. Dk. Abreast No. 1 Br. Rm.	-	Small leak Wing Compt.	-	Very slight.	Slight. Considerable impact and burst.
	7	6 in.	-	-	-	-	-	Lip of Torpedo Tube A.E. of F'cle	-	-	Extensive	Considerable.
	8	4 in.	-	-	-	No. 2 Br. Rom.	-	-	-	-	Ni	Slight.
	9	4 in.	-	Wing Compt.	-	-	-	-	-	-	Slight	Considerable (Wing Bhd.).
	10	6 in.	-	-	-	-	-	-	-	-	Shell passed through ship without bursting.	
	11	4.7 in.	-	-	-	Aft. Eng. Rm.	-	-	-	-	Nil.	Slight
	12	4.7 in.	-	-	-	Aft. Eng. Rm.	-	-	-	-	Nil.	Considerable. Extensive Machinery
	13	6 in.	Mess Compt. (small)	-	-	-	-	-	-	-	Extensive	Slight.
	14	6 in.	-	Wing Compt.	-	-	-	-	Fd. Eng. Rm.	-	Very extensive	Not ascertained.

Total	22	-	2	5	1	0	3	1	4	2	-	-

The passage of a shell through hull or bulkhead plating causes a hole slightly larger than the diameter of the shell in the first obstruction and slightly increased in successive obstructions.

V.82. FIRING RESULTS. DAMAGE TO HULL STRUCTURE.

Round.	Shell.	Path of Shell.	Position of Burst.	Blast Effect of Burst.	Fragmentation Effect of Burst.
1	4.7 in. S.A.P. 12 Fuze.	Port shell plating (5 mm.) Port wing plating (2½ mm.)	2 ft. inside eng. rm. between condenser and after bhd. 4 ft. below upper deck and 3 ft. from after bhd. (a large compt.)	Nil	1 hole 3 in. long in floor plating and outer bottom (5 mm.) at centre of ship; 2 small holes in upper deck (2½ mm.) above burst; 20 holes in aft. eng. rm. bhd. prt side, area 6 ft. by 5 ft., largest 15 in. by 8 in. in compt. aft side of eng. rm.; 4 holes in lower deck (2½ mm.), largest 9 in. by 3 in., and 2 holes in std. hull plating (5 mm.) largest 7 in. by 6 in., just below upper deck.
2	4.7 in. C.P. 12 Fuze.	Port shell plating (5 mm.) Port wing plating (2½ mm.)	2 ft. inside eng. rm. on top of port turbine casing 3 ft. 6 in. below deck (a large compt.)	Skylight over burst blown open	Nil.
3	4.7 in. S.A.P. 12 Fuze.	Port shell plating (5 mm.) Port wing plating (2½ mm.)	2 ft. inside for. boiler room, 3 ft. below deck and between boiler and ford. bulkhead (a large compt.)	Nil	2 holes, 5 in. by 2 in. and 1 in. by 1 in., in port escape trunk (2½ mm.); 2 holes, 4 in. by 1½ in. and 12 in. by 2 in., in upper deck (2½ mm.); 2 holes, 4 in. dia., in wing bhd. std. at lower part; 1 hole, 6 in. dia. in std. bottom plating (5 mm.) at level of floor plates.
4	4.7 in. H.E. 18 Fuze.	-	On the turtle of f'cle deck port side abreast gun (at point of impact)	Nil	1 hole, 2 ft. 6 in. by 1 ft. 10 in., in turtle of f'cle deck (2½ mm.), port side; 24 holes, largest 6 in. by 4 in., in fore and aft cabin bhd. (2½ mm.), port side; 14 holes , largest 5 in. by 4 in., in fore and aft wash place bhd. (2½ mm.), std. side; 1 hole, 4 in. by 3 in., in side plating port (5 mm.), 14 ft. abaft impact; 2 holes, 1½ in. by 1½ in., in side plating std (5 mm.) between upper and f'cle decks; 3 small holes in upper deck (2½ mm.), one at M.L. and 2 under pt. of

					impact; 40 small holes in various structures on upper deck abaft f'cle, one 100 ft. from the burst.
5	4.7 in. H.E. 18 P. Fuze.	Port f'cle turtle (5 mm.) after end	2 ft. inboard, port side, 2 ft. below f'cle deck (a small area enclosed on 3 sides and top and bottom)	Fore and aft bhd. port (2½ mm.) 3 ft. inboard smashed in. F'cle deck (2½ mm.), hole 5 ft. by 3 ft. over burst. Transverse cabin bhd. (2½ mm.), 4 ft. before burst bulged in.	28 holes in smashed fore and aft bhd. port; 1 hole, 5 in. by 11 in., in upper deck (2½ mm.) std. side; ford. gun and torpedo tube struck in several places.
6	4.7 in. S.A.P. 12 Fuze.	Port shell plating (5 mm.) Port wing plating (2½ mm.)	1 ft. 6 in. inside No. 2 boiler room abreast boiler, 2 ft. 6 in. below deck (a large compt.)	Nil	1 small hole in No. 3 boiler room bhd. (2½ mm.), just under upper deck; 1 hole, 1 in. dial., in upper deck at M.L.; holes in boiler, tubes and pipes.
7	4.7 in. H.E. 18 Fuze.	Port shell plating (5 mm.)	1 ft. inside sell plating, 2 f5. below deck in wing compt., 3 ft. wide abreast No. 2 boiler room (a confined space)	Shell plating (5 mm.) bulged outward and torn away from frames, area 7 ft. by 3 ft. at bottom of wing compt. Water entered through 30 or 40 rivet holes. Wing fore and aft bhd. (2½ mm.) bulged inboard against boiler, max. 1 ft. 6 in. over whole depth of bhd., and 1 hold 5 ft. by 1 ft.	Wing bhd. port holed in many places; side of boiler holed and tubes damaged.
8	4.7 in. C.P. 12 Fuze.	Port shell plating (5 mm.) Port wing plating (2½ mm.)	1 ft. inside No. 2 boiler room abaft boiler, 2 ft. 6 in. below deck (a large compt.)	Nil	1 hole in upper deck (2½ mm.) port side of M.L., 4 in. by 2 in.; small pipes and valve gearing rods holed and cut.

(b) In general, fragments did not pierce more than one thickness of plating.
(c) Holes from fragments are small and from blast effect of moderate size, except from lat round (6 in.) against V.44.
(d) The damage from 4 in. shell (31 lb.) is noticeably less than the damage from 4.7 in. shell (50 lb.).
(e) To avoid the possibility of sinking the target prematurely the point of impact was kept above the water line so that results do not represent the average flooding effect of water line hits.
(f) No fires were caused, presumably due to the absence of oil or other inflammable material.

In remarking on these trial results from the structural and design point of view, it is observed that damage from small calibre guns is naturally much less than might be received during a fleet action from light cruisers or from the secondary armament or capital ships, or again from mine or torpedo explosion. It represents the punishment likely to be received from enemy craft of similar type from gunfire hits.

There is no question of stopping the shell with protective plating, seeing that some 2 in. to 3 in. at least would be requisite to resist penetration and that the weight involved in protecting armament, machinery, and personnel would be prohibitive.

The question then arises whether the hull structure can be arranged so as to protect machinery by ensuring the shell bursts taking place on impact or sufficiently far away from vital parts. The present trials show that shell fuzes have sufficient delay to carry the burst inside and ensure "stopping power" by fragmentation. It may be noted here that in most cases bursts took place in the engaged half of the hull sections and not necessarily from shell being stopped by some fitting in its path.

Wing compartments for stowage of coal, oil fuel or water extending over the machinery spaces are a distinctive feature in German T.B.D.s. By causing shell to burst in them this arrangement may prove disadvantageous from the greater possibility of flooding the main compartment owing to the greater blast effect.

Subject to (*e*) above, it is concluded that the damage caused to structural strength and to buoyancy was not vital. So far as hull arrangements can be adapted to limit the "stopping power" of this kind of shell fire, good transverse subdivision in the machinery spaces is the only practicable defence in the circumstances. German designs go further than British in this respect, boilers being placed in separate compartments and the main machinery being arranged in two separate engine rooms. This is done at the cost of increased length of hull devoted to machinery installation, and therefore increase in the size of vulnerable target. It is proposed to consider this arrangement of machinery subdivision for future T.B.D. construction.

(G.01414/20.)

SECTION XX_B.

H.M.S. "EXCELLENT'S" REPORT ON "NURNBERG" FIRING.

With reference to Admiralty Letter G.0118/20 of 26th July, 1920, firing trials were carried out against ex-German cruiser "Nurnberg" on 5th and 8th November, 1920.

The trials were carried out to the eastward of the Horse Tail Bank, the firing ship being H.M.S. "Terror," who was in position 400 yds. from the target.

2. During the trials carried out on 5th November the ship was heeled to 10º towards the firing ship, rounds being fired through the protective belt and also at various targets above the upper deck. This degree of heel was produced by trimming coal to the starboard side of the ship.

For the trial on 8th November, the ship was heeled to 20º and the majority of rounds were fired through the upper deck to reproduce plunging fire at long range. The additional heel was produced by flooding coal bunkers on the starboard side of the ship.

3. Under water damage on the remote side was caused by one round fired on 5th November; this, however, did not delay the trial, the damage being localised to one magazine and a wing compartment. Apart from this, the hull below the normal water line was intact after the trial.

4. The original proposals for the trial against "Nurnberg" included some 15 in. rounds. Since the trial, now under report, it has been decided not to fire these rounds.

5. This report is drawn up as follows:-

Appendix I. – General Remarks.
Appendix II. – Detailed result of each round.
Photographs and diagrams.
Cinematograph records taken from the firing ship and from a ship at right angles to the line of fire are available.

APPENDIX I.

91. General Remarks on the Trial with "Nurnberg."

(1) **The guns used for the trial were:**
7.5 in. B.L. Mark 1 on a special proof mounting loaned from Shoeburyness.
6 in. B.L. XII on C.P. XIV mounting.

(2) **The shell and fuzes under trial were:-** *Fuzes Used.*

7.5 in. A.P.C. filled 70/30 shellite	No. 16 D.H.
S.A.P.C. filled 70/30 shellite	No. 16 D.H.
C.P.C. filled 60/40 shellite	No. 16 D.H. and No. 15 Q.W.
H.E. filled lyddite	No. 18 and 18 P.
6 in. A.P.C. filled 70/30 shellite	No. 16 D.H.
S.A.P.C. filled 70/30 shellite	No. 16 D.H.
C.P.C. filled 60/40 shellite	No. 16 D.H. and No. 15 Q.W.
H.E. filled lyddite	No. 18 and 18 P.

All No. 6 and No. 15 fuzes used were fitted with weakened base plates to ensure that they armed at a low chamber pressure.

(3) **For the trials with the ship heeled to 10 deg.** the charges were adjusted to give the S.V. corresponding to angle of descent of 12½ deg.

These were:-

Gun	Charge		Pressure Tons.	S.V.	Range corresponding to S.V.
	lb. oz. dr.	Size.			
7.5 in.	12 15 8	M.D.T.15/13	5.23	1,223	10,500

6 in.	4 13 4	M.D.T.15/13	4.6	1.128	9,000

For the trials with the ship at 20 deg. the charges were adjusted to give the S.V. for a range of 16,000 yds. These were:-

Gun	Charge		Pressure Tons.	S.V.	Angle of Descent corresponding to S.V.
	lb. oz. dr.	Size.			
7.5 in.	9 13 0	M.D.T.15/13	3.77	1,050	29 deg.
6 in.	3 13 0	M.D.T.15/13	3.66	1.128	38 deg.

(4) **The rounds fired are shown in tabulated form as follows:-**

No of Round	Gun.	Shell.	Fuze.	Heel of Target.	Point of Attack.	S.V.
1	6 in.	C.P.C.	No. 15	10 deg	C.T.	1,128
2	6 in.	H.E.	No. 18	"	Bridge	1,128
3	6 in.	H.E.	No. 18	"	Gun-shield	1,128
4	6 in.	A.P.C.	No. 16 D	"	Belt	1,128
5	7.5 in.	C.P.C.	No. 16 D	"	C.T.	1,128
6	7.5 in.	H.E.	No. 18	"	Bridge	1,223
7	7.5 in.	H.E.	No. 18 P	"	Gun-shield	1,223
8	6 in.	H.E.	No. 18	"	Gun-shield	1,128
9	7.5 in.	A.P.C.	No. 16 D	"	Belt	1,223
10	6 in.	C.P.C.	No. 16 D	"	C.T.	1,128
11	6 in.	C.P.C.	No. 16 D	"	Gun-shield	1,128
12	6 in.	H.E.	No. 18 P	"	Gun-shield	1,128
13	6 in.	S.A.P.C.	No. 16 D	"	Belt	1,128
14	7.5 in.	H.E.	No. 18 P	"	C.T.	1,223
15	7.5 in.	S.A.P.C.	No. 16 D	"	Belt	1,223
16	7.5 in.	A.P.C.	No. 16 D	"	Belt	1,223
17	6 in.	H.E.	No. 18	"	Bulwarks	1,128
18	6 in.	H.E.	No. 18 P	"	Bulwarks	1,128
19	6 in.	C.P.C.	No. 15	"	Superstr	1,128
20	6 in.	C.P.C.	No. 16 D	"	Belt	1,128
21	6 in.	A.P.C.	No. 16 D	"	Belt	1,128
22	6 in.	S.A.P.C.	No. 16 D	"	Belt	1,128
23	7.5 in.	C.P.C.	No. 16 D	"	Belt	1,223
24	6 in.	H.E.	No. 18 P	20 deg.	Upper deck	1,000
25	6 in.	C.P.C.	No. 15	"	Upper deck	1,000
26	7.5 in.	H.E.	No. 18 P	"	Upper deck	1,050
27	6 in.	H.E.	No. 18	"	Superstr	1,000
28	6 in.	H.E.	No. 18 P	"	Superstr	1,000
29	7.5 in.	C.P.C.	No. 15	"	Upper deck	1,050
30	6 in.	S.A.P.C.	No. 16 D	"	Upper deck	1,000
31	6 in.	C.P.C.	No. 16 D	"	Upper deck	1,000
32	6 in.	A.P.C.	No. 16 D	"	Upper deck	1,000
33	7.5 in.	C.P.C.	No. 16 D	"	Upper deck	1,050
34	7.5 in.	S.A.P.C.	No. 16 D	"	Upper deck	1,050
35	7.5 in.	A.P.C.	No. 16 D	"	Upper deck	1,050

(5) **It is convenient to group the results under five series:-**

(a) Attack on conning tower.
(b) Attack on gun-shields.
(c) Attack against light structures..
(d) Attack on belt.
(e) Attack through upper deck.

(6) **Attack on conning tower. –** (*a*) Summary of rounds.

No.	Calibre.	Shell.	Fuze.	Target.	Burst.	Impact.		Result.
						Vert.	Hor.	
1	6 in.	C.P.C.	No. 15	10 cm. C.T.	E.O.	79	59	Failed to penetrate
5	7.5 in.	C.P.C.	No. 16 D.	"	V.E.	79	78	Penetrated
10	6 in.	C.P.C.	No. 16 D.	"	V.E.	79	90	Failed to penetrate
15	7.5 in.	H.E.	No. 18 P.	"	P.D.	79	46	Failed to penetrate

(*b*) These results show that C.P.C. shell of 6 in. and smaller calibre are not to be expected to penetrate a C.T. similar to that of "Nurnberg." C.P.C. shell fired from a 7.5 in. gun will probably penetrate the conning tower and damage the interior, but is likely to break up during the process of defeating the armour. H.E. shell 7.5 in. and below are not likely to penetrate.

(*c*) Round No. 14 was arranged so that the point of impact was at a joint in the armour; and joint was not opened up appreciably by the explosion.

(7) **Attack on gun-shields.** – (*a*) Summary of rounds.

No.	Calibre.	Shell.	Fuze.	Target.	Burst.	Impact.		Result.
						Vert.	Hor.	
3	6 in.	H.E.	18 P.	5 cm. gun-shield	E.O.	79	64	Penetrated
7	7.5 in.	H.E.	18 P.	"	P.D.	79	82	Penetrated
8	6 in.	H.E.	18	"	P.D.	79	70	Failed to penetrate
11	6 in.	C.P.C.	16 D.	"	V.E.	79	82	Penetrated
12	6 in.	H.E.	18 P.	"	V.E.	79	82	Penetrated

(*b*) A direct comparison was obtained between the behaviour of No. 18 and No. 18P. fuzes with rounds 8 and 12, it being shown that 6 in. H.E. shell, when fuzed with No. 18 fuze, did practically no damage to the gun-shield, but when No. 18 P. fuze was used, the explosion of the shell was retarded sufficiently to enable penetration to be obtained.

(*c*) The violent burst of round No. 7, which is classified as P.D., indicated that the explosion was primarily due to the impact of the shell on the gun-shield.

(*d*) Any of the rounds which penetrated the gun-shield would be expected to put the gun out of action.

C.P.C. shells have more forward effect than H.E. shells, but either type would be unlucky if they failed to damage some exposed essential part of the mounting, such as the sight or the training rack.

(*e*) Round No. 8 leads to one interesting point of gun design owing to the damage caused to the chase of the gun outside the gun-shield. In the German design this damage did not affect the recoil of the gun, the distance from the front of the gun-shield to the cradle being greater than the total recoil of the gun therefore the damaged portion did not enter the cradle.

It seems to be desirable to embody this principle in future design of mountings to which an armoured shield is fitted.

(8) **Attack on light structures.** – (*a*) Summary of rounds.

No.	Calibre.	Shell.	Fuze.	Target.	Burst.	Impact.		Result.
						Vert.	Hor.	
2	6 in.	H.E.	18	Bridge	P.D.	79	67	Fair local effect.
6	7.5 in.	H.E.	18	Bridge	P.D.	79	63	About 100 per cent. more effect than round 2.
17	6 in.	H.E.	18	Bulwarks	P.D.	81	70	Nearly all effect outside ship.
18	6 in.	H.E.	18 P.	Bulwarks	N.C.D.	81	77	Fair local effect inside bulwarks.
19	7.5 in.	C.P.C.	15	Superstructure	V.E.	79	90	Good local effect

								inside plating.
24	6 in.	H.E.	18 P.	Plating	V.E.	69	86	Good local effect. Fragments penetrated main deck above P.D.
26	7.5 in.	C.P.C.	18 P.	Plating	P.D.	68	85	Good local effect inside plating.
27	6 in.	H.E.	18	Plating	N.C.D.	68	77	Fair effect along upper deck
28	6 in.	H.E.	18 P.	Plating	V.E.	68	71	Poor local effect.
25	6 in.	H.E.	15	Upper deck plating	E.O.	68	-	Burst below upper deck with slight effect.
29	7.5 in.	C.P.C.	15	Upper deck plating	P.D.	68	-	Good local effect. Main deck perforated.

(*b*) Comparison of H.E. shell fired with No. 18 and No. 18 P. fuze is on the whole favourable to the latter fuze being used. When using No. 18 fuze it is possible that a shell hitting the bulwarks will do no damage inside the ship (17), whereas when using the 18 P. fuze the burst will certainly be carried into the ship.

In the event of the point of impact of the shell being inside the ship, as for example in the funnel casing, the danger to personnel on the upper deck is more widespread when using the 18 fuze as opposed to the 18 P. fuze (27 and 28).

(*c*) The comparative effect of 6 in. and 7.5 in. H.E. is shown by rounds (2) and (6). Both rounds were fitted with No. 18 fuze and the forward effect was small, very few fragments getting through to the remote side of the bridge.

The effect caused by the 7.5 in. was about 100 per cent. larger than that of the 6 in.

(*d*) The comparative effect of H.E. shell with 18 P. fuze and C.P.C. shell with non-delay fuze is given by rounds (19), (24), (26), (29(and (25).

Round (25) gave a poor result, but otherwise there is little to choose between the two types.

(9) **Attack on belt.** – (*a*) Summary of rounds:-

No.	Calibre.	Shell.	Fuze.	Target.	Burst.	Impact.		Result.
						Vert.	Hor.	
4	6 in.	A.P.C.	16 D.	6 cm. belt	V.E.	-	81	Grazed protective deck and burst with moderate effect in distilling room.
9	7.5 in.	A.P.C.	"	"	V.E.	-	75	Grazed and cracked protective deck. Burst in port bunker, fragments carrying through ship's side.
13	6 in.	S.A.P.C.	"	"	V.E.	78	81	Grazed protective deck and burst on gun support with moderate effect.
15	7.5 in.	S.A.P.C.	"	"	P.D.	78	80	Penetrated protective deck and caused considerable damage in engine room.
16	7.5 in.	A.P.C.	"	"	V.E.	78	58	Penetrated protective deck and burst on under side of slop of protective deck on port side, holing ship under water.
20	6 in.	C.P.C.	"	"	V.E.	80	79	Grazed protective deck but did not penetrate. Small local effect
21	6 in.	A.P.C.	"	"	E.O.	80	82	Penetrated protective deck and caused slight damage to engine room.
22	6 in.	S.A.P.C.	"	"	E.O.	80	85	Penetrated protective deck and caused moderate damage in engine room.
23	7.5 in.	C.P.C.	"	"	V.E.	80	85	Grazed protective deck

							and burst above it. Good local effect at burst.

(*b*) The rounds which damaged the ship below the protective deck were (15), (16), (21), (22). From these we get a comparison between A.P.C. and S.A.P.C. shell in both 6 in. and 7.5 in. guns, and for effective damage in the vicinity of the burst the S.A.P.C. shell gave better results than the A.P.C.

(*c*) Rounds (4), (9), (13), (20), (23) grazed the protective deck and burst above it. The effectiveness of the bursts for the 6 in. rounds under these particular conditions was in the order A.P.C., S.A.P.C., C.P.C., and of the 7.5 in. rounds in the order C.P.C., A.P.C.. The results are therefore more doe to the individual behaviour of each shell and fuze than characteristic of each type of shell.

(9) **Attack over belt.** – (*a*) Summary of rounds:-

No.	Calibre.	Shell.	Fuze.	Target.	Burst.	Angle of Entry relative to Horizontal plane	Result.
24	6 in.	H.E.	18 P.	Upper deck	V.E.	21	Burst on impact. Fragments holed main deck, but not protective deck. Considerable local effect.
25	6 in.	C.P.C.	15	Upper deck	E.O.	22	Burst just below upper deck with slight local effect.
26	7.5 in.	H.E.	18 P.	Superstructure above upper deck.	P.D.	22	Burst on P.D. with good local effect. Fragments penetrated main deck over P.D.
29	7.5 in.	C.P.C.	15	Bulwarks	N.C.D.	22	Burst in bunker. Fragments holed P.D. Good forward effect.
30	6 in.	S.A.P.C.	16 D.	Bulwarks	V.E.	22	Burst on and penetrated P.D. Effect below absorbed in two large tanks.
31	6 in.	C.P.C.	16 D.	Side plating	V.E.	22	Burst in and cracked P.D. No fragments below but some flash.
32	6 in.	A.P.C.	16 D.	Bulwarks	E.O.	22	Punched hole in P.D. and burst with moderate effect above.
33	7.5 in.	C.P.C.	16 D.	Bulwarks	V.E.	22	Burst on and penetrated P.D. Good burst. Considerable damage in eng. room
34	7.5 in.	S.A.P.C.	16 D.	Bulwarks	N.C.D.	22	Burst on and penetrated P.D. Considerable damage in boiler room.
35	7.5 in.	A.P.C.	16 D.	Lip of Torpedo Tube	P.D.	22	Burst on and penetrated P.D. No damage below P.D. considerable forward effect

							above P.D.

(*b*) The rounds which caused effective damage below the protective deck were (30), (33), (34) (*i.e.*, S.A.P.C. and C.P.C. of 7.5 in. and S.A.P.C. of 6 in. calibre). The failure of A.P.C. to cause damage below the protective deck is attributed to the fact that for these rounds (32) (35) the longer axis of the projectile was no longer in the line of the trajectory when the protective deck was reached. Both these shells hit an angle iron when passing through the ship's structure causing a semicircular hole. The unsymmetrical blows may have disturbed the flight of the projectile.

The degree of damage caused by 7.5 in. S.A.P.C. and 7.5 in. C.P.C. was similar.

Round 31 did not cause damage below the protective deck by splinters but there was evidence of flash having passed through the hole made in the deck.

Of the remaining rounds (29) merely holed the deck by fragments. (32) (35) both defeated the deck but failed to carry the burst effect through the deck.

(11) **Behaviour of the fuzes. –** (*a*) The use of 18 P. fuze in H.E. shell serves the useful and necessary purpose of retarding the explosion so that the effect is felt inside the ship. On the other hand, it is frequently found that a large amount of filling remains on the structure surrounding the burst, which indicates that this is not the most efficient method of utilising H.E. shell.

The ideal condition would appear to be between the detonating effect and corresponding minute fragmentation when using the 18 fuze and the low order burst and larger size of fragments obtained with the powder filled fuze, but with the delay given by the latter.

(*b*) The delay to No. 16 fuze is sufficient to carry all the shell through the belt at the low S.V. used for the trial. The fuze will, however, function if the shell be further retarded by any substantial obstruction such as the slope of the protective deck.

This would account for the variable length of delay obtained, which was between 10 ft. and 30 ft.

Similarly the rounds which were fired above the belt nearly all burst either on or just after reaching the protective deck, the retardation of the shell when attacking the protective deck presumably being sufficient to absorb the time of delay.

This points to the necessity when considering the time of delay of bearing in mind the remaining velocity at which the shell will be used.

(*c*) The No. 15 non-delay fuze used in C.P.C. shell give average delay of 7 ft., which was sufficient to carry the bursting effect into the ship.

(12) **General conclusion.** – (*a*) Under the conditions of the trial all types of shell are capable of penetrating a 5 cm. gun-shield and will probably put the gun out of action. There appears, therefore, to be two alternatives offered: (*a*) to provide armoured shields of sufficient thickness to defeat H.E. or C.P.C. shell, (*b*) to provide splinter-proof shields. The compromise between these two conditions does not seem to be justifiable.

(*b*) C.P.C. and H.E. shell from 6 in. guns and H.E. shell from 7.5 in. guns will probably fail to penetrate into or damage to any great extent the interior of a conning tower with 10 cm. walls. This suggests that armour to conning towers of sufficient thickness to withstand H.E. and C.P.C. shells at probably fighting ranges may prove to be useful.

(*c*) For attack against unarmoured positions good results were obtained with C.P.C. filled 60/40 shellite, and in the results of the trial this shell compares favourably with H.E. using powder fuze. H.E. using a nose detonating fuze creates considerable local damage, but cannot be depended upon to have sufficient delay to ensure that its bursting energy is felt inside the ship.

(*d*) For attack against a 6 cm. belt and 2 cm. protective deck, 6 in. and 7.5 in. A.P.C. and S.A.P.C. will probably cause damage below the protective deck if the trajectory strikes the slope of the protective deck at the angle of descent of the trial.

If the projectile hits the flat of the protective deck, the probability is that the force of the explosion will be felt above the deck.

The rounds fired did not prove whether C.P.C. would have penetrated the slope of the protective deck after passing through the belt.

The bursting effect of A.P.C. and S.A.P.C. was somewhat disappointing, that of the S.A.P.C. shell being the better.

It is now considered that A.P.C. have insufficient bursting capacity and S.A.P.C. are generally preferable to A.P.C. unless the latter have marked inferiority in penetrating power. The “Nurnberg” trial does not deal with the armour piercing qualities of the two types of shell, as both types defeated any armour which they attacked.

(*e*) For attack by plunging fire S.A.P.C. shell for 6 in. and 7.5 in. guns and C.P.C. for 7.5 guns succeeded, causing damage below the protective deck whereas A.P.C. failed to do so. This latter may have been due to the rounds in question being made unsteady by the upper part of the shell striking an angle iron.

(*f*) Conclusions as regards shell. On the results of the trial it would seem that S.A.P.C. is a better shell than A.P.C. but the bursting effect of both natures is not sufficiently violent.

C.P.C. filled shellite is a useful all-round shell, particularly from 7.5 in. guns.

H.E. shell when fired with powder fuzes did not make sufficient use of their potential bursting power to justify their supply in addition to C.P.C. filled shellite if fitted with nose detonating fuze are liable to waste their effect outside the ship. A compromise seems to be required which may possibly be effected by the use of a base detonating fuze.

(*g*) Under the conditions of the trial, it may be said that 6 in. S.A.P.C. shell are capable of inflicting serious damage below the protective deck to a ship similar to the "Nurnberg," and that 7.5 in. S.A.P.C. and probably C.P.C. shell are also capable of so doing. The effect of the burst of 7.5 in shell is naturally considerably greater than that of the 6 in. shell.

It is considered that the limit of effectiveness of a 6 in. gun at fighting ranges is about reached in a ship protected to the same extent as the "Nurnberg" and that for more heavily protected ships a larger calibre gun would be required.

APPENDIX II.

92. Detailed Results of Firing at "Nurnberg."

Figure 42 shows the results of Rounds 3 and 8.
Figures 43 to 46 show the results of all rounds omitting 1, 2, 3, 5, 6, 7, 8, 10, 11, 12 and 14.
Figure 47 shows a profile of "Nurnberg" and the location of all rounds.

Round 1.

Target: - Conning tower.
Shell: - 6 in. C.P.C.
Fuze: - 16 D.
S.V.: - 1,128 f.s.
Filling: - 60/40 shellite.
Nature of burst: - E.O.
Delay: - Nil.
Point of impact: - Side of conning tower 1 ft. 8 in. from top and 9 ft. 3 in. from centre line forward.
Angle of impact: - Vertical, 80 deg.; horizontal, 59 deg.
Ship heeled to : - 10 deg.

The depth of the dish at point of impact was ¼ in. and diameter of dish 1 ft. 6 in.

Two superficial circular cracks 12 in. and 34 in. long were made 12 in. and 14 in. from point of impact.

The plates on the starboard side of the conning tower opened slightly but there was no damage inside. Most of the glass fronted electrical instruments had been broken previous to the trial, so the damage to them could not be estimated.

The damage outside the conning tower was minor and local. Eight fragments of shell were picked up in front of the tower.

The deck in front of the tower was undamaged, but there were four small holes through the foremost breakwater.

Round 2.

Target: - Fore bridge.
Shell: - 6 in. H.E.
Fuze: - 18
S.V.: - 1,128 f.s.
Filling: - Lyddite.
Nature of burst: - P.D.

Delay: - Nil.
Point of impact: - Side of chart house 4 ft. 6 in. above the bridge deck.
Angle of impact: - Vertical, 79; horizontal, 67.
Ship heeled to : - 10 deg.

The door of the chart house was driven over to the port side, and the interior of the house was badly damaged both by fragments and by blast.

There was a little forward effect, the port side of the house being holed only in two places, but the roof above was holed in ten places, some of the fragments causing the latter pierced the rangefinder on platform above and would have put it out of action.

A hole was made in the deck under the burst, 6 ft. long (fore and aft) by 1 ft. wide, and 24 fragments passed through the foremost bridge screen, 12 of these being close to the steering wheel and compass.

There were 28 holes down through the forecastle deck, chiefly forward of the burst.

The funnel was holed in three places, the fragments passing out through the other side.

Round 3 (see Fig. 42).

Target: - After superimposed gun-shield.
Fuze: - 18 P.
Shell: - 6 in. H.E.
S.V.: - 1,128 f.s.
Filling: - Lyddite.
Nature of burst: - E.O.
Delay: - Nil.
Point of impact: - 5 in. below the lower inner corner of right sight port.
Angle of impact: - Vertical, 79 deg.; horizontal, 64 deg.
Ship heeled to : - 10 deg.

The shield was driven in and broken, the size of the damage being 10 in. by 20 in.

The front part of the roof was driven upwards sightly, four rivets being started, while the hinged flap which forms the upper part of the front of the shield was blown early off and much distorted.

The effect in rear of the shield was considerable, the right rear bracket supporting shield nearly cut through, training gear wrecked, many dents and strikes on the cradle and the deck in rear of the gun badly scored in a dozen places.

In front of the gun-shield there was a continuous fore and aft line of holes in the deck, extending from 4 ft. before to 1 ft. abaft the burst.

The chase of the gun outside the shield was badly scored in several places, and had these been further to the rear they would have jammed the gun in the cradle on recoil and prevented it from running out. This is of interest in designing shields, and shows it to be essential to place them where they will burst the shell so that strikes on gun will not enter the cradle on recoil.

The point of impact of this round being close to a sighting pot, the shield did not offer its maximum resistance to the projectile.

A good many fragments came back towards the firing ship, and some fell near a trawler 500 yds. 90 deg. to the line of fire.

Round 4 (see Fig. 43).

Target: - Fore engine room.
Fuze: - 16 D.
Shell: - 6 in. A.P.C.
S.V.: - 1,128.
Filling: - 70/30 shellite.
Nature of burst: - V.E.
Delay: - 31 ft.
Point of impact: - Side armour, 6 ft. 3 in. below the upper deck.
Angle of impact: - Vertical, 78 deg.; horizontal, 81 deg.
Ship heeled to : - 10 deg.

The shell made a clean hole 6 in. diameter in the side armour, and after grazing a light platform 5 mm. thick it hit the protective deck on the corner of the slope at the foot of the 5 mm. bunker bulkhead. A dent 1½ in. deep and 7½in. diameter was made in the protective deck, and a hole 6 in. by 10 in. in a bunker bulkhead, tow rivets in the angle securing this to the protective deck being knocked out.

A hole 2 in. by 3 in. was made in the bunker bulkhead, 18 in. forward of the path of the shell, by a bit of armour from the ship's side.

The projectile, after being deflected upwards, went through a 2½ mm. bulkhead, in which it made a hole 7 in. by 14 in., and then through a second 2½ mm. bulkhead making a hole 10 in. by 18 in., finally bursting in the distilling room.

The bulkhead between the distilling room and the gangway was much distorted, and was blown away from the deck in several places.

The deck over the distilling room was dented in many places and pipes of the distilling machinery were badly damaged, two fragments going forward through the 5 mm. bunker bulkhead into the port bunker.

Round 5.

Target: - Conning tower.
Fuze: - 16 D.
Shell: - 7.5 in. C.P.C.
S.V.: - 1,223 f.s.
Filling: - 60/40 shellite.
Nature of burst: - V.E.
Delay: - Nil.
Point of impact: - Side of conning tower, 3 ft. 6 in. from top and 11 ft. 4 in from centre line forward..
Angle of impact: - Vertical, 79 deg.; horizontal, 78 deg.
Ship heeled to : - 10 deg.

A hole 12 in. by 10 in. was made in the side of the tower, flaked off 18 in. by 21 in. on the inside, the shell probably breaking up while passing through the plate.

The shell fragmented well, but beyond slight scoring on the foremost and port sides no further damage was done to the armour.

Practically all the electrical instruments were wrecked and dislodged.

Several glass sighting ports remained intact in position, and the inside of the tower was heavily marked with filling.

The base of the shell was found against the port side of the tower.

Round 6.

Target: - Fore bridge.
Fuze: - 18.
Shell: - 7.5 in. H.E.
S.V.: - 1,223 f.s.
Filling: - Lyddite.
Nature of burst: - P.D.
Delay: - Nil.
Point of impact: - Outer weather screen abreast chart house.
Angle of impact: - Vertical, 79 deg.; horizontal, 63 deg.
Ship heeled to : - 10 deg.

The forward effect was considerable, and a hole 6 ft. square was blown in the side of the chart house, the interior of the house being crumpled up and riddled by numerous fragments. Twelve feet of the outer weather screen was blown away.

Fragments passed out through the port side of the chart house, and 14 went through the deck above, severely damaging the rangefinder.

A large downward effect was caused under the burst, the upper deck being holed in many places, and the breech of the gun underneath was badly scored in four places.

Round 7.

Target: - After gun-shield.

Shell: - 7.5 in. H.E.
Fuze: - 18 P.
S.V.: - 1,223 f.s.
Filling: - Lyddite.
Nature of burst: - P.D.
Delay: - Nil.
Point of impact: - 12 in. from centre line of shield and 6 in. from bottom.
Angle of impact: - Vertical, 79 deg.; horizontal, 82 deg.
Ship heeled to : - 10 deg.

The shield was split and turned back over an area of 1 ft. 7 in. by 9 in.

A large portion of the shell struck the base of the pedestal and lifted the front part 1 in., drawing two of the bolts securing the pedestal to the deck.

The training and elevating gear on both sides were much damaged, rendering the gun immovable.

The rivets securing the shield on the right-hand side were torn away for 4 ft. and the right rear bracket supporting shield was cut through, the shield itself being bulged outwards.

The deck and angle securing it to the gun support under the point of impact were torn away and driven downwards for 6 ft. fore and aft by 1 ft. 6 in. wide.

One hole 18 in. by 11 in., and five holes 3 in. by 2 in. were made in the main deck over slope of protective deck, but the latter was not damaged.

A large amount of damage was done to electric circuits and cabin bulkheads on the main deck.

Round 8.

Target: - Starboard fore gun-shield.
Fuze: - 18.
Shell: - 6 in. H.E.
S.V.: - 1,128 f.s.
Filling: - Lyddite.
Nature of burst: - P.D.
Delay: - Nil.
Point of impact: - 1 ft. 5 in. from bottom of shield and 1 ft. 7 in from centre line..
Angle of impact: - Vertical, 79 deg.; horizontal, 70 deg.
Ship heeled to : - 10 deg.

A dent 2 in. deep was made in the shield over an area 2 ft. in diameter.

There was very little effect in rear of the gun, and the training and elevating gear, sights, etc., were undamaged.

In front of the shield, the chase of the gun was scored ½ in. deep in several places 16 in. from the cradle.

The deck was torn away from the gun support for 5 ft. fore and aft and 14 in. wide, one fragment passing through the upper deck and making a hole 1 in. by 2 in.

Small strikes extended over the upper works from the bitts (30 ft. forward) to the conning tower (20 ft. aft).

Round 9 (see Fig. 43).

Target: - After boiler room.
Fuze: - 16 D.
Shell: - 7.5 in. A.P.C.
S.V.: - 1,223 f.s.
Filling: - 70/30 shellite.
Nature of burst: - V.E.
Delay: - 37 ft.
Point of impact: - The side armour 6 ft.1 in. below the upper deck.
Angle of impact: - Vertical, 78 deg.; horizontal, 75 deg.
Ship heeled to : - 10 deg.

A hole 7½ in. in diameter and a radial crack 9 in. long were made in the side, the shell then penetrating the 5 mm. cofferdam bulkhead and graving the protective deck between two manholes. The protective deck was dented 1 in. and a slight crack through was made.

The shell was then deflected slightly upwards and passed through five more bulkheads (of thicknesses 5, 2½, 2½, 2½ and 5 mm. respectively), finally bursting against the outer wall of the cofferdam in the port bunker.

In the port bunker, two holes (6 in. by 3 in. and 4 in. by 2 in.) were made in the deck above, and four holes (1 in. by 1½ in.) and one hole (8 in. by 18 in.) in the ship's side above the armour. Eight 2 in. holes were made through the 5 mm. transverse bulkhead into the next bunker aft.

In the starboard bunker, a hole was made through the 5 mm. transverse bulkhead into the next bunker aft.

Round 10.

Target: - Conning tower.
Fuze: - 16 D.
Shell: - 6 in. C.P.C.
S.V.: - 1,128 f.s.
Filling: - 60/40 shellite.
Nature of burst: - V.E.
Delay: - Nil.
Point of impact: - 12 ft. 6 in. from centre line forward and 2 ft. 8 in. from top.
Angle of impact: - Vertical, 79 deg.; horizontal, 90 deg.
Ship heeled to : - 10 deg.

A dent ¼ in. deep and 9 in. diameter was made in the conning tower, but beyond this no damage was done.

The damage in front was slight, and a small incendiary effect caused in corticene, handrails of ladders, etc.

Round 11.

Target: - After gun-shield.
Shell: - 6 in. C.P.C.
Fuze: - 16 D.
Filling: - 60/40 shellite.
S.V.: - 1,128 f.s.
Delay: - 1 ft. 6 in.
Nature of burst: - V.E.
Point of impact: - 1 ft. from centre line of shield and 1 ft. from bottom..
Angle of impact: - Vertical, 79 deg.; horizontal, 82 deg.
Ship heeled to : - 10 deg.

The shell penetrated the gun-shield making a round hole 6 in. diameter, and then struck the base of the pedestal, bursting on this.

A large forward effect in rear of the gun was created, the training and elevating gear being wrecked and 3 ft. of the training rack being torn off.

The shell fragmented badly, a portion consisting of the base and half the wall being picked up inside the shields.

The damage on the deck in front of the shield caused by a previous round was slightly increased.

Round 12.

Target: - Starboard fore gun-shield.
Fuze: - 18 P.
Shell: - 6 in. H.E.
S.V.: - 1,128 f.s.
Filling: - Lyddite.
Nature of burst: - V.E.
Delay: - Nil.
Point of impact: - 1 ft. from centre of shield and 1 ft. 6 in. from bottom.
Angle of impact: - Vertical, 79 deg.; horizontal, 82 deg.
Ship heeled to : - 10 deg.

A hole 8 in. by 17 in. was made in the shield and the left front brackets supporting the shield was broken, but otherwise very little damage was caused in rear of the shield.

The hole in the deck in front made by round (8) was enlarged, and several fragments went through the main deck over the slope of the protective deck. The latter was undamaged, the one nearest to the cradle being 16 in. to it.

Round 13 (see Fig 43).

Target: - Fore engine room.
Fuze: - 16 D.
Shell: - 6 in. S.A.P.C.
S.V.: - 1,128 f.s.
Filling: - 70/30 shellite.
Nature of burst: - V.E.
Delay: - 23 ft.
Point of impact: - Side armour 6 ft. 3 in. below upper deck..
Angle of impact: - Vertical, 78 deg.; horizontal, 81 deg.
Ship heeled to : - 10 deg.

A hole 7½ in. by 10½ in. was made in the side armour, flaked off to 12 in. by 13 in. inside.

After piercing this, the shell struck the protective deck at the join of the 5 mm. longitudinal bulkhead, this also being at the join of the crown and slope of the protective deck.

Three rivets were knocked out of the protective deck and it was bulged to a depth of 2 in., the hole in the bulkhead being 11½ in. by 8 in.

After passing through a 2½ mm. bulkhead, the shell hit a 2½ cm. circular gun support, knocking a piece 9 in. by 8 in. out of this and bursting on impact. A hole 18 in. square was knocked out of the far side of the support.

The nose of the shell was found embedded in the upper deck over the distilling room.

Round 14.

Target: - Conning tower.
Fuze: - 18 P.
Shell: - 7.5 in. H.E.
S.V.: - 1,223.
Filling: - Lyddite.
Nature of burst: - P.D.
Delay: - Nil.
Point of impact: - 8 ft. 2 in. from centre line forward and 6 ft. 4 in. from top at join of two plates.
Angle of impact: - Vertical, 79 deg.; horizontal, 46 deg.
Ship heeled to : - 10 deg.

This round was intentionally fired at the join of two plates, but very little damage was caused to them. A dent ¼ of an inch deep and 18 in. across was made and the plates opened out ⅛ in., while several radial cracks were formed, extending for 2 ft. 9 in. from centre of impact.

The hole in the forecastle deck in front of the conning tower caused by previous rounds was slightly increased, and the light platform around the tower was blown away fro 12 ft. on either side.

Fragments from the shell hit the fore bridge, holing the light metal screen round the steering wheel.

Round 15 (see Fig. 43).

Target: - After engine room.
Fuze: - 16 D.
Shell: - 7.5 in. S.A.P.C.
S.V.: - 1,223 f.s.
Filling: - 70/30 shellite.
Nature of burst: - P.D.
Delay: - 10 ft.
Point of impact: - Side armour, 6 ft. 6 in. below upper deck.
Angle of impact: - Vertical, 78 deg.; horizontal, 80 deg.
Ship heeled to : - 10 deg.

A hole 15 in. by 8 in. was made in the side armour, this being flaked off to 18 in. by 11 in. inside; the shell then penetrated the slope of the protective deck and burst on its way through, making a hole 37 in. by 24 in.

The main steam pipe on each side of the engine room was holed by fragments and the nose of the shell was picked up against the centre line bulkhead, this being cracked and penetrated (hole 6 in. by 2in.) and also having two strikes in it.

The lugging of the turbine was holed but the turbine was undamaged.

Round 16 (see Fig. 43).

Target: - Fore 15 cm. magazine.
Fuze: - 16 D.
Shell: - 7.5 in. A.P.C.
S.V.: - 1,223 f.s.
Filling: - 70/30 shellite.
Nature of burst: - V.E.
Delay: - 31 ft.
Point of impact: - Side armour, 19 ft. 4 in. below forecastle deck.
Angle of impact: - Vertical, 78 deg.; horizontal, 58 deg.
Ship heeled to : - 10 deg.

A hole 8 in. by 9 in. was made in the side armour, the shell then passing through the slope of the protective deck and making a hole 13½ in. by 10 in. in it. The upper part of this hole was lipped outwards and the lower part lipped inwards, the top being heavily marked with copper. Part of the cap was found just outside.

The shell traversed the lower conning tower, hitting the port slope of the protective deck 2 ft. above the deck of this compartment and then ran down under the slope of the protective deck, making an 18 in. hole in the inner bottom and bulging the protective deck upwards for 3 in. over a length of 4 ft. 6 in. The shell finally burst on hitting the ship's side at the food of the side armour.

A hole 1 ft. 6 in. by 3 ft. 3 in. was made in the ship's side below the armour and the lower edge of the armour was lipped outwards 3 in.

Ten holes varying in size from 10 in. by 6 in. to 1 in. by 2 in. were made by fragments coming back through the inner bottom into the port 15 cm. magazine.

No damage whatever and no signs of flash could be found in this magazine and the centre line bulkhead was undamaged.

Although this ship was heeled 10 deg. to starboard, the port magazine and W.T. compartment were flooded, and the lower conning tower half flooded, the hole in the port side of the ship just on the water line.

Round 17 (see Fig. 43).

Target: - Bulwarks at fore end of battery.
Fuze: - 18.
Shell: - 6 in. H.E.
S.V.: - 1,128 f.s.
Filling: - Lyddite.
Nature of burst: - P.D.
Delay: - Nil.
Point of impact: - 1 ft. 6 in. from top of bulwark.
Angle of impact: - Vertical, 81 deg.; horizontal, 70 deg.
Ship heeled to : - 7½ deg.

The bulwark was blown down for 4 ft. on either side of the burst, several strikes being made on the top edge of the side armour. Eight plates 1/16 in. thick which were stowed against the ship's side at the point of impact were all bulged in and distorted.

A dummy man at the break of the forecastle was hit twice in the legs and once through the body.

Two dummy men 20 ft. abaft the burst were knocked down, one being punctured.

Very little effect was noticeable inside the ship.

Round 18 (see Fig. 44).

Target: - Bulwarks over No. 2 boiler room.
Fuze: - 18 P.
Shell: - 6 in. H.E.
S.V.: - 1,128 f.s.

Filling: - Lyddite.
Nature of burst: - N.C.D.
Delay: - Nil.
Point of impact: - Bulwark 2 ft. above upper deck..
Angle of impact: - Vertical, 81 deg.; horizontal, 77 deg.
Ship heeled to : - 7½ deg.

The bulwark was truck abreast the torpedo stowage, the bulwark plating being torn away flush with the upper deck for 14 ft. abaft and 4 ft. before the burst. The torpedo stowage was wrecked.

A boat's davit 2 ft. before the burst was partly cut through and a skid beam overhead was also nearly severed.

Several punctures were made in the funnel casing and a hole (12 in. by 8 in.) was made in the upper deck 10 ft. from the burst.

Round 19 (see Fig. 44).

Target: - After superstructure.
Fuze: - 16.
Shell: - 6 in. C.P.C.
S.V.: - 1,128 f.s.
Filling: - 60/40 shellite.
Nature of burst: - V.E.
Delay: - 9 ft.
Point of impact: - Superstructure 3 ft. above the upper deck..
Angle of impact: - Vertical, 79 deg.; horizontal, 90 deg.
Ship heeled to : - 7½ deg.

An entry hole 7 in. by 8 in. was made in the superstructure and all light steel cabin bulkheads in the vicinity were blown down and crumpled.

Three small fragments pierced the upper deck, two of which also pierced the main deck above the slope of the protective deck. The protective deck was undamaged.

Three fragments penetrated the port side of the superstructure and a transverse bulkhead 2 ft. abaft the burst was punctured in many places by small fragments.

Round 20 (see Fig. 44).

Target: - After boiler room.
Fuze: - 16 D.
Shell: - 6 in. C.P.C.
S.V.: - 1,128 f.s.
Filling: - 60/40 shellite.
Nature of burst: - V.E.
Delay: - 16½ ft.
Point of impact: - Side armour 6 ft. 1 in. below upper deck..
Angle of impact: - Vertical, 80 deg.; horizontal, 79 deg.
Ship heeled to : - 7½ deg.

A round hole 6 in. diameter was made in the side armour, the shell being deflected slightly upwards, and after passing through the bunker bulkhead, in which it made a hole 1 ft. 6 in. by 1ft., it struck an armour grating on the protective deck in an uptake from the boiler room.

The upper surfaces of three bars in the armoured grating were slightly twisted, and the shell was again deflected upwards piercing the far side of the boiler room uptake and bursting in the gangway 1 ft. inside the 6 in. off the deck.

A dent 1 in. deep and 6 in. across was made in the protective deck under the burst. The damage in the gangway was small and local, all pipes and circuits in the vicinity being intact, but the bulkhead and W.T. door 4 ft. before the burst were bulged forward 3 in. One large fragment went forward, and after penetrating both sides of an air lock leading to the boiler room it lodged in the brickwork of a brick and cement store.

A hole 3 in. diameter, caused by a fragment of side armour was made in the bunker bulkhead 10 ft. abaft the path of the shell.

A small skylight, 1 ft. by 2 ft. with three 6 in. ports in it, 6 ft. forward of the burst was undamaged.

Round 21 (see Fig. 44).

Target: - After engine room.
Fuze: - 16 D.
Shell: - 6 in. A.P.C.
S.V.: - 1,128 f.s.
Filling: - 70/30 shellite.
Nature of burst: - E.O.
Delay: - 10 ft.
Point of impact: - Side armour 7 ft. 8 in. below upper deck..
Angle of impact: - Vertical, 80 deg.; horizontal, 82 deg.
Ship heeled to : - 7½ deg.

A hole 6 in. by 7 in. was made in the side armour, the shell then piercing the slope of the protective deck (hole 1 ft. 9 in. by 1 ft.) and bursting on its way through.

The damage in the engine room was small. The main steam pipe was hit by two medium-sized fragments which pierced the lagging, but this saved the pipe and it was undamaged.

Several small steam pipes were cut though and the corner of a 1 in. turbine base plate was broken off.

The nose and base of the shell were picked up under the burst. A great many circuits secured under crown of protective deck were cut through.

Round 22 (see Fig. 44).

Target: - After engine room.
Fuze: - 16 D.
Shell: - 6 in. S.A.P.C.
S.V.: - 1,128 f.s.
Filling: - 70/30 shellite.
Nature of burst: - E.O.
Delay: - 10 ft.
Point of impact: - Side armour 7 ft. 6 in. below upper deck..
Angle of impact: - Vertical, 80 deg.; horizontal, 85 deg.
Ship heeled to : - 7½ deg.

A hole 6 in. diameter was made in the armour, the shell then passing through the 5 mm. main deck and hitting the slope of the protective deck, where it burst on passing through making a hole 7 in. by 1 ft. 6 in. in this.

The joint of the circulator inlet was started, making a small leak into the engine room and the cylinder cover of the circulator pump was blown in.

A hole 6 in. by 8 in. was knocked out of a 9 in. steam pipe and several small steam pipes were cut through.

Round 23 (see Fig. 44).

Target: - After magazine.
Fuze: - 16 D.
Shell: - 7.5 in. C.P.C.
S.V.: - 1,223 f.s.
Filling: - 60/40 shellite.
Nature of burst: - V.E.
Delay: - 27 ft.
Point of impact: - Side armour, 8 ft. 3 in. below upper deck, at join of main deck.
Angle of impact: - Vertical, 80 deg.; horizontal, 85 deg.
Ship heeled to : - 7½ deg.

A hole 12 in. by 9 in. was made in the armour, the shell then turned towards the normal and ran along the main deck over the slope of the protective deck for 11 ft., splitting a channel 2 ft. wide.

The shell then glanced slightly upwards and pierced a 1 cm. gun support of flat section in which it made a hole 10 in. by 8 in., finally bursting in a cabin on the port side.

Considerable blast effect was made in the vicinity, all the light cabin structure being wrecked, but the protective deck was undamaged.

Three holes (5 in. by 5 in., 4 in., by 4 in., and 8 in. by 8 in.) were made in the ship's side above the armour.

Round 24 (see Fig. 45).

Target: - Upper deck aft.
Fuze: - 18 P.
Shell: - 6 in. H.E.
S.V.: - 1,000 f.s.
Filling: - Lyddite.
Nature of burst: - V.E.
Delay: - Nil.
Point of impact: - Join of superstructure and upper deck 4 ft. from ship's side.
Angle of impact: - Vertical, 69 deg.; horizontal, 86 deg.
Ship heeled to : - 20 deg.

The explosion made a hole 2 ft. 4 in. by 2 ft. in the upper deck and 2 ft. 4 in. in the superstructure. The main deck over the slope of the protective deck was holed in three places (10 in. by 4 in., 3 in. by 1 in., and 1 in. by 1 in.), the slope of the protective deck being only scratched.

The interior of the superstructure was badly damaged by fragments and blast, but the effect was only local and the port side of the superstructure was untouched. A great deal of yellow filling was found inside the superstructure.

The transverse bulkhead 6 ft. before the burst was bulged forward and holed in several places both above and below the upper deck.

Cabins on the main deck near the burst were badly damaged by blast, and a few holes in these were made by splinters.

Round 25 (see Fig. 45).

Target: - No. 1 boiler room.
Fuze: - Non-delay.
Shell: - 6 in. C.P.C.
S.V.: - 1,000 f.s.
Filling: - 60/40 shellite.
Nature of burst: - E.O. (Grey white smoke with a grey column.)
Delay: - 3 ft.
Point of impact: - Base of superstructure 6 in. above the upper deck.
Angle of impact: - Vertical, 68 deg.
Ship heeled to : - 20 deg.

A hole 7 in. in diameter was made in the superstructure the shell then penetrating the upper deck in the galley 1 ft. further inboard, a hole 10 in. by 7 in. being made in this. The upper deck at this point was covered by 1 in. of cement. The shell burst 1 ft. beyond the hole in the deck doing very little damage.

Three holes (2 in., 3 in. and 4 in.) were made in the upper deck 2 ft. inboard of burst, and two large fragments went forward across the gangway, and after traversing an air lock to the boiler room they lodged in a brick and cement store.

Round 26 (see Fig. 45).

Target: - After superstructure.
Fuze: - 18 P.
Shell: - 7.5 in. H.E.
S.V.: - 1,050 f.s.
Filling: - 60/40 Lyddite.
Nature of burst: - P.D.
Delay: - 1 ft.
Point of impact: - Superstructure 2 ft. above upper deck.
Angle of impact: - Vertical, 68 deg.; horizontal, 85 deg.
Ship heeled to : - 20 deg.

The shell hit the superstructure where a 5 mm. transverse bulkhead was secured to it by ⅜ in. angle iron, a hole 3 ft. square being caused in the superstructure by the burst. A large hole 8 ft. by 4 ft. was made in the upper deck under the burst, and a hole 8 in. by 8 in. in the upper deck 6 ft. further inboard was made by a fragment.

Five holes varying in size from 4 in. to 6 in. triangular were made in the main deck over the slope of the protective deck. None of these pierced the protective deck, but it was scored ¼ in. deep in three places.

The 2½ mm. deck above the burst was bulged upwards for a foot over an area 16 ft. square, and was punctured by small fragments in several places.

The transverse bulkhead on which the shell burs was badly damaged and cracked for 14 ft. inboard.

A large amount of local damage was caused to the light cabin bulkheads in the vicinity both on the upper deck and main deck and four large fragments went forward through the port side of the superstructure.

Round 27 (see Fig. 45).

Target: - Superstructure abreast after funnel.
Shell: - 6 in. H.E.
Fuze: - 18.
Filling: - Lyddite.
S.V.: - 1,000 f.s.
Delay: - Nil.
Nature of burst: - N.C.D.
Point of impact: - Top of bulwarks on ship's side.
Angle of impact: - Vertical, 68 deg.; horizontal, 77 deg.
Ship heeled to : - 20 deg.

The top of the bulwarks was grazed and lipped over for 6 in. on each side.

A widespread effect was caused by innumerable small fragments on the upper deck.

Dummies 5 ft. away were destroyed.

Dummies 10 ft. away were torn.

Dummies 15 and 20 ft. away were badly torn.

The upper deck was holed in seven places by small fragments and about forty small punctures were made in the funnel casing and funnel, the latter extending nearly to the top.

Round 28 (see Fig. 45).

Target: - Superstructure abreast foremost funnel.
Shell: - 6 in. H.E.
Fuze: - 18 P.
Filling: - Lyddite.
S.V.: - 1,000 f.s.
Delay: - Nil.
Nature of burst: - V.E.
Point of impact: - Superstructure 3 ft. above upper deck.
Angle of impact: - Vertical, 68 deg.; horizontal, 71 deg.
Ship heeled to : - 20 deg.

A hole 3 ft. by 3 ft. 4 in was blown in the superstructure and the door of an upper deck store just abaft the burst was blown off.

The shell fragmented well, and the funnel casing was punctured in many places by small fragments.

The near side of the superstructure was bulged outwards for 4 in. over an area 8 ft. square and many rivets were sheared both in this and the inner casing.

The steam pipe to the syren was cut in two places.

Round 29 (see Fig. 45).

Target: - After boiler room.
Shell: - 7.5 in. C.P.C.

Fuze: - 15 non-delay.
Filling: - 60/40 shellite.
S.V.: - 1,000 f.s.
Delay: - 11 ft.
Nature of burst: - P.D.
Point of impact: - Bulwark s ft. above upper deck.
Vertical angle of impact: - 68 deg.
Ship heeled to : - 20 deg.

A hole 7½ in. in diameter was made in the bulwark, the shell then piercing the upper deck 4 ft. inboard and making a hole 24 in. by 8 in. After grazing an overhead rail in the bunker the shell burst two-thirds of the way across.

A 5 mm. cofferdam over two manholes in the protective deck (used for trimming coal into the lower bunker) was blown in and three fragments passing through the open manholes pierced the inboard side of the chute and so into the boiler room. The largest fragment cut steam pipes 1 in. diameter in the boiler room. The manhole covers had been blown off by a previous round.

A temporary patch in the ship's side caused by a previous round was blown off and the bunker flooded, the water passing through the manholes to lower bunker, but there was not sufficient water to enter the boiler room through the holes in coal chute.

The bunker bulkhead was blown in, a hole 4 ft. by 6 ft. being made in it; and a large forward effect was made in the gangway, fragments entering the brick store on inboard side of the gangway, and bits of brick were blown out through a manhole on to the upper deck, the port side.

The upper deck over the burst was bulged upwards 3 in. over an area 12 ft. square.

Round 30 (see Fig. 46).

Target: - Fore engine room.
Fuze: - 16 D.
Shell: - 6 in. S.A.P.C.
S.V.: - 1,000 f.s.
Filling: - 70/30 shellite.
Nature of burst: - V.E.
Delay: - 23 ft.
Point of impact: - Bulwark 1 ft. above upper deck.
Vertical angle of impact: - 68 deg.
Ship heeled to : - 20 deg.

A hole 7 in. by 9 in. was made in the bulwark and a 5 mm. angle iron against the ship's side was sheared. The shell then penetrated the upper deck 1 ft. 10 in. from the ship's side, making a hole 6 in. by 10 in. in this, and then, after piercing the bunker bulkhead 9hole (10 in by 8 in.), it passed through an open doorway and struck the protective deck 20 ft. fro the ship's side, bursting on impact. A hole 19 in. by 17 in. was made in the protective deck and pieces of shell were picked up in this hole.

Very little effect was caused in the engine room, the only damage being done by a fragment which passed through the top and side of a 5 mm. tank in the starboard engine room, through the centre line bulkhead and into a tank in the port engine room.

The transverse bulkhead on main deck just abaft the burst was holed in several places, the W.T. door being blown open, and the port bunker bulkhead was holed by fragments in two places.

The distilling room bulkhead was badly crumpled.

Round 31 (see Fig. 46).

Target: - After magazine.
Fuze: - 16 D.
Shell: - 6 in. S.A.P.C.
S.V.: - 1,000 f.s.
Filling: - 70/30 shellite.
Nature of burst: - V.E.
Delay: - 21 ft.
Point of impact: - Ship's side above the armour and 2 ft. below the upper deck.

Vertical angle of impact: - 68 deg.

A hole 6 in. by 6½ in. was made in the ship’s side, the shell then striking the protective deck at the bottom of the superimposed gun support and bursting there, a hole 12 in. by 15 in. being made in the support.

The protective deck was split through a line of rivets running athwartships for 21 in. and torn away from the doubling plate at the foot of the gun support for 21 ft. fore and aft.

Nine rivets securing the protective deck to a beam under it were knocked out and the corner of a plate in the protective deck where it joins the doubling plate round the gun support was bent down for 6 in

An angle iron under the protective deck at this point was driven down on to and flattened a flooding pipe but did not burst it.

The wood lining in the corner of the magazine at this point was torn away but no fragments could be found inside, although there were filling marks on the centre line bulkhead for 3 ft. round the hole in the main deck.

The centre line bulkhead was undamaged but a large amount of damage was caused to cabin structure on the main deck.

Round 32 (see Fig. 46).

Target: - Fore engine room.
Fuze: - 16 D.
Shell: - 6 in. A.P.C.
S.V.: - 1,000 f.s.
Filling: - 70/30 shellite.
Nature of burst: - E.O.
Delay: - 34 ft.
Point of impact: - The bulwark 2 ft. above upper deck.
Vertical angle of impact: - 68 deg.
Ship heeled to : - 20 deg.

A hole 8 in. in diameter was made in the bulwark. The shell then passed through the inboard side of the torpedo stowage and penetrated the upper deck 6 ft. from the ship's side, making a hole 6 in. by 1 ft. 6 in.

The shell grazed and bent a 1 cm. coaming round the bunker lid, and after piercing the bunker bulkhead, in which it made a hole 8 in. by 14 in., it struck the protective deck in the middle of the distilling room, making a hole 189 in. by 1 ft. 4 in. with the flap turned down for 9 in.

The shell burst just after glancing up off the protective deck and no damage was done in the engine room.

In the distilling room, the damage created by previous rounds was slightly increased and the forward effect was large.

Thirteen fragments went forward into the port bunker, making holes varying from 2 in. to 10 in. square in the port bunker bulkhead.

One fragment dented the ship's side above the armour, making a crack 8 in. long just through the plate 5 ft. below the upper deck.

The pressure plate from the fuze was picked up in the distilling room and the base fuze complete and split nose were recovered from the port bunker.

Round 33 (see Fig. 46).

Target: - After engine room.
Fuze: - 16 D.
Shell: - 7.5 in. C.P.C.
S.V.: - 1,050 f.s.
Filling: - 60/40 shellite.
Nature of burst: - V.E. (White smoke).
Delay: - 26 ft.
Point of impact: - Bulwark 6 in. above upper deck.
Vertical angle of impact: - 68 deg.
Ship heeled to : - 20 deg.

The shell struck a 5 mm. angle iron in the bulwark, shearing this and making a hole 8 in. by 8 in. in the plate. It then pierced the upper deck 2 ft. from the ship's side, making a hole 9 in. by 1 ft. 9 in., and pierced the bunker bulkhead, in which a hole 10 in. by 1 ft. 2 in. was made, finally striking the protective deck 1 ft. beyond the centre line bulkhead.

The shell burst on impact with the protective deck and made a hole 3 ft. by 1 ft. in this, and a hole 1 ft. square in the centre line bulkhead, which was stiffened by a 5 mm. angle iron at that point.

No damage was discovered in the starboard engine room.

In the port engine room the main steam pipe and turbine casing were each holed once; several small pipes were cut, and holes were made in the lagging of other large pipes without holing the latter.

A light plate under the burst which carried pressure gauges was smashed up.

Fragmentation was good.

A fire was caused in the port engine room bilges by some oil which became ignited and a dense column of smoke was emitted for some hours in spite of efforts to put it out. This made the engine room inaccessible.

Three holes varying from 2 in. to 8 in. were made in the port bunker bulkhead above the protective deck.

Round 34 (see Fig. 46).

Target: - Fore boiler room.
Fuze: - 16 D.
Shell: - 7.5 in. S.A.P.C.
S.V.: - 1,050 f.s.
Filling: - 70/30 shellite.
Delay: - 30 ft.
Nature of burst: - N.C.D.
Point of impact: - Bulwark 6 in. from top.
Vertical angle of impact: - 68 deg.
Ship heeled to : - 20 deg.

A hole 8 in. diameter was made in the bulwark, the shell then piercing the upper deck 9 ft. 6 in. from the ship's side and making a hole 11 in. by 8 in.

It then pierced the bunker bulkhead (hole 8 in. by 12 in.), both sides of inner funnel casing (holes 8 in. by 12 in. and 17 in. by 15 in.), both sides of the starboard gangway (holes 18 in. by 21 in. and 14 in. by 20 in.), the bulkhead between air lock in access to boiler room and port gangway (hole 12 in. by 14 in.), and finally struck the protective deck at foot of bulkhead between the port gangway and port funnel casing, where it burst.

A hole 2 ft. by 3 ft. was blown in the protective deck, the outer shell of the boiler was blown away for 2 ft. by 3 ft., the steam drum being holed in two places (holes 10 in. by 5 in. and 6 in. by 4 in.), a piece of the protective deck being found embedded in the larger hole.

The inboard side of the funnel casing was blown away for 3 ft. square.

Two holes 9 in. by 3 in. and 7 in. by 7 in. were made in the bunker bulkhead under the protective deck.

Round 35 (see Fig. 46).

Target: - No. 3 boiler room.
Fuze: - 16 D.
Shell: - 7.5 in. A.P.C.
S.V.: - 1,050 f.s.
Filling: - 70/30 shellite.
Delay: - 28 ft.
Nature of burst: - P.D. (Black smoke.)
Point of impact: - Torpedo tube 2 ft. above the upper deck.
Vertical angle of impact: - 68 deg.
Ship heeled to : - 20 deg.

A 12 in. channel was cut in the 1 cm. torpedo tube, the shell then piercing a 1 cm. bunker lid 8 ft. 6 in. from the ship's side. The bunker lid was blown overboard and lost.

The shell, after grazing a 5 mm. coaming round the bunker lid manhole and a 5 mm. overhead rail, pierced the bunker bulkhead (hole 2 ft. 3 in. by 2 ft.), both sides of a wide ventilating trunk to boiler room (holes 2 ft. 1 in. by 1 ft. 8 in. and 2 ft. 2 in. by 1 ft.), and struck and burst on the protective deck in the port gangway.

The protective deck was holed (4 in. by 4 in.) and a 12 in. crack though was made, but no damage could be round in the boiler room. Several electric cables just under the protective deck close to the burst were undamaged.

A large forward effect was created and a manhole door into the port cofferdam was blown in and crumpled up. The top of the cofferdam was blown open and the far side of the cofferdam was pierced by many large and small fragments.

93. Summaries of Remarks contained in the Reports of the Captain of H.M.S. "Excellent," with Admiralty Comments

On Firing Trials against "Nurnberg."

Conditions for Trial.

(1) **Ship heeled to 10 deg. –** Conditions to represent attack by:-

(*a*) 7.5 in. B.L., at range of 10,500 yds., angle of descent 12½ deg., S.V. 1,223 f.s.
(*b*) 6 in. B.L., at range of 9,000 yds., angle of descent 12½ deg., S.V. 1,128 f.s.

(2) **Ship heeled to 20 deg. –** To represent attack by:-

(*a*) 7.5 in. B.L., at range of 16,000 yds., angle of descent 29 deg., S.V. 1,050 f.s.
(*b*) 6 in. B.L., at range of 16,000 yds., angle of descent 38 deg., S.V. 1,000 f.s.

Precis of Remarks by "Excellent"	*Remarks by Admiralty*
Attack on Conning Tower	
Not to be expected that C.P.C. shell of 6 in. and smaller calibres will penetrate a C.T. similar to that of "Nurnberg" (*i.e.* 4.1 in.). C.P.C. fired from 7.5 in. guns will probably penetrate and damage the interior, but is likely to break up. H.E. shell 7.5 in. and blow are not likely to penetrate.	Concurs with "Excellent."
Attack on Gun-shields	
Direct comparison between behaviour of No. 18 and 18 P. fuzes. Shown that 6 in. H.E. when fuzed with No. 18 fuze did practically no damage to shield, but when No. 18 P. fuze was used explosion of shell retarded sufficiently to enable penetration to be obtained.	Concurs with "Excellent," and states that on other papers it has been definitely agreed that, at present, we should re-fuze these existing shells in supply with powder fuzes as the best means of improving their stopping power against any sort of target.
The violent burst of one round classified as P.D. indicates that the explosion was primarily due to the impact of the shell on the gun-shield	Concur. Lyddite, on account of its sensitiveness, may perhaps not be used for new H.E. shell.
Considers that any of the rounds which penetrated the gun-shields may be expected to put gun out of action. C.P.C. have more forward effect than H.E. shell.	Concurs with "Excellent."
One interesting point of gun design was brought	This matter concerns design of guns and

to light by the damage to the chase of the gun outside the gun-shield. In German design this damage did not affect the recoil of the gun, the distance from the front of the gun-shield to the cradle being greater than the total recoil of the gun, therefore the damaged portion did not enter the cradle.	mountings and not shell efficiency. The point has been noted for future designs of gun mountings.
Attack on Light Structures.	
Comparison of H.E. shell fired with No. 18 and 18 P. fuzes is on the whole favourable to the latter fuse being used. When using No. 18 fuze, possible that a shell hitting bulwarks will no damage inside ship, whereas when using No. 18 P. burst will certainly be carried into ship. If point of impact of shell is inside ship, *e.g.* funnel casing, danger to personnel on upper deck is more widespread with 19 fuze than when using 18 P.	Concurs with "Excellent." H.E. shell are required chiefly for use against torpedo craft.

Precis of Remarks by "Excellent"	*Remarks by Admiralty*
Attack on Light Structures. – (*continued*)	
Comparative effect of 6 in and 7.5 in. H.E. were shown by one round of each nature, fuzed with No. 18 fuze, fired at the bridge.	Concur. The bursting effect relative to the weight of the burster appears, in this case, to have varied directly with the weight of the burster.
Forward effect was small in both cases. The effect caused by the 7.5 in. was about 100 per cent. Larger than that of the 6 in.	These shells, however, were detonated on impact in the open air. It is probable that when shells are burst inside a ship the damage caused by the large burst would be more marked. It is theoretically supposed to vary as some power (?cube) of the burster.
Comparative effect of H.E. shell with 18 P. fuze and C.P.C. shell with non-delay fuze was obtained. There was little to choose between the two types.	The great advantage which C.P.C. has over the H.E. is that it can be fitted with a delay action fuze which will cause it to explode in the centre of the ship and therefore nearer the vitals. The H.E. nose fuzed shell as at present filled and fuzed can only be expected to give a very short delay and will only do this behind thin plating. Consider that both types necessary at present because base fuzes cannot be obtained of sufficient sensitiveness to ensure them not going blind when fired against very light targets, *e.g.* parts of a Destroyer or submarine outer shell. For example, a 6 in. C.P.C. shell fuzed No. 15 went clean through the forecastle of V.44 and burst in the water beyond.
Attack on Belt	
Four rounds damaged ship below protective deck. From these a comparison is obtained between A.P.C. and S.A.P.C. shell in both 6 in. and 7.5 in. guns. For effective damage in the vicinity of the burst, the S.A.P.C. shell gave better results than the A.P.C.	Concurs with "Excellent," and remarks that so long as we are confined to igniferous fuzes (pending the production of base detonating fuzes) we must get as large a burster into our A.P.C. type of shell as possible consistent with obtaining sufficient powers of fragmentation.
Five rounds grazed protective deck and burst above it.	Proof ground fragmentations of 6 in. A.P.C. with detonating and powder fuzes generally confirm actual target results at "Nurnberg."

Effectiveness of these bursts for 6 in. rounds under these particular conditions was for 6 in. in the order of A.P.C., S.A.P.C., C.P.C., and of the 7.5 in. in the order of C.P.C., A.P.C. Results considered due more to the individual behaviour of each shell and fuze than characteristic of each type of shell.	Concur with "Excellent."
Attack over Belt.	
The three rounds which caused effective damage below protective deck were S.A.P.C. and C.P.C. of 7.5 in. and S.A.P.C. of 6 in. calibre. Attributes the failure of A.P.C. to cause damage below the protective deck to the fact that for these rounds the longer axis of the projectile was no longer in the line of the trajectory when the protective deck was reached. Both shell hit an angle iron when passing through ship's structure, causing semicircular holes. These unsymmetrical blows may have disturbed the flight of the projectile. These rounds both defeated the deck but failed to carry the burst effect through. Degree of damage caused by 7.5 inn. S.A.P.C. and 7.5 in. C.P.C. was similar.	Concurs in the conclusion drawn as to the greater tendency of the shorter (A.P.C.) type of shell to be upset in tis flight and to turn sideways after penetrating the side plate at an oblique angle. Notes this has been observed before, particularly with 4.7 in. S.A.P. shells as compared with 4.7 in. C.P. shells. Considers it an additional argument in favour of giving the shell as large a burster as is consistent with defeating the side armour protection of the target, as it seems probable that in light craft, including light cruisers, horizontal rather than vertical protection will be developed. In future the capacity of H.E. shell for perforating plates representing the latter must not be the only consideration in deciding upon "plate proof" requirements of shells for supply.

Precis of Remarks by "Excellent"	*Remarks by Admiralty*
Behaviour of Fuzes.	
Use of 18 P. fuze in H.E. shell serves the useful and necessary purpose of retarding the explosion so that the effect is inside the ship. But points out that it is frequently found that a large amount of the filling remains on the structure surrounding the burst, which indicates that this is not the most efficient method of utilising H.E. shell.	Concurs. *Vide* previous remarks.
Considers that the ideal condition would appear to be between the detonating effect and corresponding minute fragmentation when using the No. 18 fuze and the low order burst and larger garments obtained with the 18 P. fuze, but with the delay given by the latter.	
Considers that the delay to No. 16 fuze is sufficient to carry the shell through the belt at the low S.V. used for the trial, and that the fuze will, however, function if the shell be further retarded by any substantial obstruction such as the slope of the protective deck. Holds this to account for the variable length of delay obtained in these trials.	Concurs with "Excellent," and states that the appropriate thickness of the target and the striking velocity for which the fuzes should be tested to give the delay aimed at for 6 in. and 7.5 in. base fuzed shell is under discussion.
Similarly of rounds fired above the belt nearly all burst either on or just after reaching the protective deck, the retardation of the shell when attacking the protective deck presumably being sufficient to absorb the time of delay. This points to the necessity when considering the time of delay of bearing in mind the remaining velocity at which the shell will be used.	Points out that a delay sufficiently long to ensure the shell reaching the vitals of the target under conditions of extreme range is desirable, but that, if adopted, would probably entail having delays which would be considerably greater than half the beam, and may be greater than the full beam of a small ship, when the shell is fired a short range with corresponding high striking velocity.
The No. 15 non-delay fuze used in C.P.C. shell gives an average delay of 7 ft. which was sufficient to carry the bursting effect into the ship.	Concurs with "Excellent," and points out that the fuzing of the base fuzed shells for attack of small craft with the existing type of non-delay fuzes would be efficient were it not for the lack of sensitiveness of these fuzes.
General Conclusion.	

Considers that under the conditions of the trial all types of shell are capable of penetrating a 5 cm. gun-shield and would probably put the gun out of action. Appears to be two alternatives offered:- (*a*) To provide armoured shield of sufficient thickness to defeat H.E. or C.P.C. shell. (*b*) To provide splinter-proof shields. Does not consider any compromise between these two conditions justifiable.	Fully concurs with "Excellent," and considers that all we can afford for Light Cruisers is "splinter-proof" gun houses against shell not greater in than those fired by foreign ships of similar class.
Considers that C.P.C. and H.E. shell from 6 in. guns and H.E. shell from 7.5 in. guns will probably fail to penetrate into or damage to any great extent the interior of a conning tower with 4.1 in. walls. Suggests from this that armour to conning towers of sufficient thickness to withstand H.E. and C.P.C. shell at probably fighting ranges will be useful.	Concurs with "Excellent," but notes that this depends on future designs, size of ship, etc.
Considers that for attack against unarmoured positions, good results were obtained by C.P.C. shell filled 60/40 shellite, and that in the results of the trial this shell compares favourably with H.E. shell, using powder fuze.	Concurs with "Excellent," but points out that the disadvantage of the base fuzed shell lies in its insensitive fuze.
Considers that for attack against a 6 cm. belt and 2 cm. protective deck, 6 in. and 7.5 in. A.P.C. and S.A.P.C. will probably cause damage below the protective deck if the trajectory strikes the slope of the protective deck at the angle of descent of the trials. If the projectile hits the flat of the protective deck the probability is that the force of the explosion will be felt above the deck.	Concurs with "Excellent," and points out that the question of the design of shells, and of the necessary plate proofs for future supplies, is dealt with on other papers.

[Transcribers note. The final section (Conclusions as regards shell) of this table was misaligned in the original. It is believed that the original intention of the document is as transcribed below]

Precis of Remarks by "Excellent"	*Remarks by Admiralty*
General Conclusions – (*continued*).	
Bursting effect of A.P.C. and S.A.P.C. disappointing, S.A.P.C. being the better.	
Not considered that A.P.C. have sufficient bursting capacity, and S.A.P.C. are generally preferable to A.P.C., unless the S.A.P.C. have marked inferiority in penetrating power.	
Considers that for attack by plunging fire S.A.P.C. shell for 6 in. and 6.5 in. guns and C.P.C. from 7.5 in. guns succeeded, causing damage below the protective deck, whereas A.P.C. failed to do so. This latter may have been due to the rounds in question being made unsteady through striking an angle iron.	Concurs with "Excellent." See previous remarks on page 123.
Conclusions as regards Shell.	
Considers that, on the results of the trials, it would seem that S.A.P.C. is a better shell than A.P.C., but that the bursting effect of both natures is not sufficiently violent. That C.P.C. filled shellite is a useful all-round shell from 7.5 in. guns	Concurs with "Excellent" as regards relative effectiveness of S.A.P.C. and A.P.C., also that 7.5 in. C.P.C. did well. Notes the present approved outfit for Light Cruisers, viz.:- "Hawkins," 7.5 in. 6 in.Ship. C.P.C. shellite 105 120 H.E. 45 80 per gun
That H.E. shell, when fuzed with powder fuzes, did not make sufficient use of their potential bursting power to justify their supply in addition to C.P.C. filled shellite, and if fitted with nose detonating fuze are liable to waste their effect outside the ship.	Does not altogether concur in the remarks about H.E. shell, and points out that these shell were not really tried in comparison with A.P. and C.P. shell. Moreover, H.E. shell are, at present, the best for the attack of light surface vessels such as destroyers and of submarines at short range.
Suggests that a compromise seems to be required which may possibly be effected by the use of a base detonating fuze.	Concurs with "Excellent."
Considers that, under conditions of the trial, it may be said that 6 in. S.A.P.C. are	Considers that, with our present knowledge, we could improve on

capable of inflicting serious damage below the protective deck to a ship similar to the "Nurnberg," also that 7.5 in. S.A.P.C. and probably C.P.C. shell are also capable of so doing.	"Nurnberg's" protection without adding to the weight.

94. REPORT OF FIRING TRIALS AGAINST "NURNBERG."

Remarks, re Structural Damage, by Admiralty.

		6 in. Shell.		7.5 in. Shell
H.E. Shell	6	3 at Superstructure. 3 at Gun-shields.	3	1 at Superstructure. 1 at Gun-shield. 1 at Conning Tower.
C.P.C. Shell	5	2 at Conning Tower. 1 at Gun-shield. 1 at Superstructure. 1 at Side Protection.	2	1 at Conning Tower. 1 at Side Protection.
A.P.C. Shell		1 at Side Protection.		2 at Side Protection.
S.A.P.C. Shell		3 at Side Protection.		1 at Side Protection.

H.E. Shell. – the effect of the H.E. shell at the superstructure was to create a certain amount of local damage which would have affected personnel more than materiel, the damage by the 7.5 in. shell being greater than that by the 6 in. shell, as would have been expected owing to the difference in the weight of shell. The shell with 18 P. fuzes (slight delay) were also more effective than those with 18 fuzes.

The 6 in. H.E. at gun-shield broke up on impact with front plate; blast would probably have affected gun crews. The 7.5 in. round would undoubtedly have put the gun out of action.

The 7.5 in. H.E. at conning tower had practically no effect.

C.P.C. Shell. – The two rounds of 6 in. shell had practically no effect on the conning tower armour, whereas the 7.5 in round completely perforated the armour, bursting inside.

It is pointed out that British 160 lb. armour is tested with 6 in. C.P.C. shell. The standard limit of resistance of this attack is 1,260 f.s. at normal, but some of the firms produce plates as much as 300 f.s. above this standard. The velocity at the trial was 1,128 f.s. at 12½ deg. To normal.

The 6 in. round at gun-shield had little more effect than the H.E. rounds. The 6 in. round at the ward room had large local effect. The rounds at side protection, 6 in. and 7.5 in., both perforated side and burst inside vessel without penetrating to the ship's vitals.

A.P.C. Shell. – The 6 in. round pierced through all protection and into the engine room damaging steam pipes, and would undoubtedly have had some effect on slowing down the vessel and creating damage to engine room complement. The 7.5 in. round amidship struck on corner of protective deck and was diverted.

The 7.5 in. round forward would have had disastrous effect on the vessel by bursting in magazine, as well as holing vessel below water.

S.A.P.C. Shell. – Where this type of shell obtained a fair hit on the protective deck it perforated with results generally similar to that of A.P.C.

Trial (*b*).

		6 in. Shell.	7.5 in. Shell
H.E. Shell	3	1 at Deck.	1 at Deck.
		2 at Superstructure.	
C.P.C. Shell		2 at Deck.	2 at Deck.
A.P.C. Shell		1 at Deck.	1 at Deck.
S.A.P.C. Shell		1 at Deck.	1 at Deck.

H.E. Shell. – The rounds at the deck perforated it, but very little damage was otherwise done.

The two rounds at superstructure were similar in effect to those at previous trial, the round with fuze 18 P. being the more effective.

C.P.C. Shell. – The rounds with the non-delay fuzes were not so effective as those with delay fuzes. At the round with 6 in. delay flash would probably have affected the magazine; the 7.5 in. round with delay ignited oil in port engine room.

S.A.P.C. and A.P.C. Shells. – The S.A.P.C. rounds were more effective than the A.P.C. owing, probably, to the greater percentage of burster in shell of the former type.

> NOTES. **–** Most of the shell at side and deck passed through the upper bunkers. These bunkers were empty, consequently it could not be judged as to what protective value the coal would have had had the bunkers been full.

The A.P.C. and S.A.P.C. shell used at these trials were of new type, and not of the type used in the late war. This remark also applies to the “Shellite” filling.

The damage done to the ship as a whole was not excessive.

The results of these trials again raises the question of incorporating a protective deck in future Light Cruisers.

SECTION XXc.

H.M.S. "EXCELLENT'S" REPORT ON "BADEN" FIRING

With reference to Admiralty letter G.01413/20 of 5th January, 1921, firing trials were carried out against ex-German battleship "Baden" on 2nd February, 1921.

The trials were carried out to the eastward of the Horse Tail Bank, the firing ship being H.M.S. "Terror," who was moored 500 yards from the target.

(2) The Ship was heeled to 11 deg. towards the firing ship, this angle varying about 2 deg. either way due to the roll; also the ship grounded at low water, which reduced the heel about 1 deg. during that period. The amount of heel was produced by removing coal and armour plates on the port side of the ship and by flooding wing compartments on the starboard side. All oil fuel and bilge oil had previously been removed to reduce the chances of fire. This angle of heel kept the top of the 10 in. belt about 3 ft. above water amidships; and the trim of the ship had been previously adjusted by removing the revolving weight of "A" turret.

(3) On the night following the trial salvage operations were in progress, but were much hampered by heavy swell, and at 0530 on the following morning these operations were discontinued due to the state of the weather.

By this time the ship was rolling heavily and started to ship water through the rent in the upper deck caused by round 8, the repair work on this damage not being completed; subsequently the gun ports on the starboard side were rolled under water, causing the amidship part of the ship to fill and heel over to 25 deg., eventually settling down on the bottom with a heel of 10 deg. to starboard.

(4) This preliminary report is drawn up as follows:-

Appendix I. – General remarks.
Appendix II. – Detailed result of each round.
Photographs and diagrams.

Cinematograph records taken from the firing ship and from a ship at right angles to the line of fire are available in H.M.S. "Excellent."

(5) "Baden" was salved and docked three months after she sank and the examination of the damage in detail was then completed. The following report contains the full results of the final records obtained.

APPENDIX I.

95. General Remarks on the Trial.

(1) **The gun used for the trial was 15 in. B.L. Mark I,** being the left gun in turret of H.M.S. "Terror."

(2) **The shell fillings and fuzes under trial were:-**

Shell.	Filling.	Fuzes used.
C.P.C.	Powder	15 N.D.
C.P.C.	60/40 Shellite	15 N.D.
A.P.C.	70/30 Shellite	16 D.
A.P.C. (light, 1,520 lb.)	70/30 Shellite	16 D.
S.A.P.C.	70/30 Shellite	16 N.D.

(3) **The charges were adjusted to give a S.F. of 1,550 f.s.** corresponding to an angle of descent of 13¾ deg. These were:-

Charge.	Pressure in tons.	S.V.	Range corresponding To S.V.
172 lb. 4 oz. M.D. 16	9.14	1,550	15,500

To obtain the same S.V. when using the light shell, a charge of weight 147 lb. 15 oz. M.D. size 26 was used.

(4) **The rounds fired are shown in tabulated form below :-**

Serial No.	Admty. No.	Shell.	Filling.	Fuze.	S.V.	Target.
1	3	C.P.C.	Powder	15 N.D.	1,550	Roof plate, B turret.
2	4	C.P.C.	60/40 Shellite	15 N.D.	”	Roof plate, X turret.
3	21	C.P.C.	60/40 Shellite	15 N.D.	”	7 in. battery armour.
4	22	A.P.C.	70/30 Shellite	16 D.	”	7 in. belt at fore end.
5	1	A.P.C.	70/30 Shellite	16 D.	”	Roof plate, X turret.
6	2	S.A.P.C.	70/30 Shellite	16 N.D.	”	Roof plate, B turret.
7	20	C.P.C.	Powder	15 N.D.	”	7 in. battery armour.
8	11	A.P.C.	70/30 Shellite	16 D.	”	10 in. belt above engine room
9	5	A.P.C.	70/30 Shellite	16 D.	”	X barbette armour, 13¾ in.
10	6	C.P.C.	Powder	15 N.D.	”	B barbette armour, 13¾ in.
11	19	S.A.P.C.	70/30 Shellite	16 N.D.	”	7 in. battery armour.
12	23	A.P.C. (light)	70/30 Shellite	16 D.	”	7 in. belt at fore end.
13*	1	A.P.C.	70/30 Shellite	16 D.	”	Roof plate, X turret.
14	7	A.P.C.	70/30 Shellite	16 D.	”	B turret, first plate.
15	8	A.P.C.	70/30 Shellite	16 D.	”	Connint tower, thickest part
16	18	A.P.C.	70/30 Shellite	16 D.	”	7 in. battery armour.
17	12	A.P.C.	70/30 Shellite	16 D.	”	10 in. belt above boiler room

* Repeat of Serial No. 5.

(5) **It is convenient to group the results into series :-**

(*a*) Attack on turret roofs.
(*b*) Attack on barbettes, turret front plates and conning tower.
(*c*) Attack on 7 in. belt in battery and forward.
(*d*) Attack on 10 in. belt.

(6) **Attack on roofs of turrets** (4 in. thick). – (a) Summary of rounds.

Serial No.	Admty. No.	Shell.	Filling.	Fuze.	Com-Pounded Angle of Impact from Normal	Burst.	Delay.	Target.	Result.
1	3	C.P.C.	Powder	15 N.D.	75¾ deg.	-	-	B roof	Holed.
2	4	C.P.C.	60/40 Shellite	15 N.D.	79 deg.	E.O.	20 ft	X roof	Failed to penetrate
5	1	A.P.C.	70/30 Shellite	16 D.	79 deg.	V.E.	15 ft	X roof	Failed to penetrate
6	2	S.A.P.C.	70/30 Shellite	16 N.D.	79 deg.	P.D.	-	B roof	Failed to penetrate
13*	1	A.P.C.	70/30 Shellite	16 D.	78 deg.	E.O.	15 ft	X roof	Failed to penetrate

(*b*) These results show that the angle of impact is too small for any of the shell used to effect penetration by means of its velocity, but that the slightly more favourable angle of impact of round q coupled with the non-delay fuze functioning on impact caused a hole to be made in the 4 in. roof plate.

(*c*) It is noticeable that the damage caused to the roof plates by shell with fuzes which functioned on impact (1 and 6) exceeded that of shell fuzed with delay fuze (5-13). In the later case, and also for round 2, the explosion of the shell taking place in the air would be less likely to cause damage than if the shell be exploded in contact with the plate.

Therefore where penetration is unlikely owing to the oblique nature of the attack, a shell with N.D. fuze may be expected to do more damage than a delay fuzed shell.

(d) A point of interest arises from the damage to which a roof plate and girder supports are susceptible, in that a loading wagon such as employed in the “Baden” and which has considerable lateral travel is very liable to be jammed and so prevented from moving either in line with the main cage or the gun. Also, the wagon itself being in the gun-house and extending nearly to the roof must be more liable to be damaged than a cage which comes up from below.

(e) The angle of impact of round 1 is somewhat difficult to calculate owing to the shell having hit the eave plate instead of the roof plate : it can be shown, however, that :-

Angle of impact = Cos *a* sin B cos *c* cos *d*
+ sin *a* sin C cos *d*
+ cos *a* sin B sin *d*.

where a = Angle between eave plate and flat roof plate.
B = Inclination of flat plate roof to horizontal.
c = Angle of inclination of plate.
d = Angle of descent of projectile

(7) **Attack on Barbettes.** (Front plates of Turrets and Conning Tower, 13¾ in. thick.) – (a) Summary of rounds.

Serial No.	Admty. No.	Shell.	Filling.	Fuze.	Com-Pounded Angle of Impact from Normal	Delay.	Burst.	Target.	Result.
9	5	A.P.C.	70/30 Shellite	16 D.	11 deg.	3 ft.	E.O.	X bar-bette	Penetrated.
10	6	C.P.C.	Powder	15 N.D.	12 deg.	-	-	B Bar bette	Failed to penetrate
14	7	A.P.C.	70/30 Shellite	16 D.	18 deg.	Blind	-	B Front Plate	Penetrated (blind)
15	8	A.P.C.	70/30 Shellite	16 D.	30 deg.	-	P.D.	Conning Tower.	Failed to penetrate

(b) This trial shos that A.P.C. will penetrate 13¾ in. plate where C.P.C. will fail. Round 15 was fired at an angle of 60 deg., which serves to determine by comparison with round 14 the ange of impact at which perforation of 13¾ in. armour may be expected.

(c) The performance of A.P.C. shell as regards penetration would appear to be satisfactory.

(d) The insignificant damage caused by round 15 to instruments inside the conning tower, which were mounted on plates built up from the deck and not in contact with the side of the tower, shows that this method of fitting instruments is entirely justified.

(8) **Attack on deck over 7 in. Battery. –** (a) Summary of rounds.

Serial No.	Admty. No.	Shell.	Filling.	Fuze.	Com-Pounded Angle of Impact from Normal	Burst.	Delay.	Result.
3	21	C.P.C.	60/40 Shellite	15 N.D.	16½ deg.	P.D.	6 ft.	Considerable local and blast effect.
7	20	C.P.C.	Powder	15 N.D.	16 deg.	-	23 ft	Less general, but more forward effect than 3

(b) Comparison between these two rounds is not altogether easy, as the effect of the former was greatly taken up by blowing down the casemate bulkhead, whereas the late action of the fuze in round 7 allowed the shell to penetrate this before bursting.

The blast effect of round 3 was certainly greater than that of round 7, and taking into consideration the greatly increased strength of structure with which the explosion of round 3 had to contend, it is considered that its general effect was superior to that of round 7, and that round 3 gave a very satisfactory result.

(c) Both the above rounds were intended to hit the 7 in. battery armour, but owing to the movement of the target and firing ships both shells went high.

(9) **Attack on 7 in. Armour. –** (a) Summary of rounds.

Serial No.	Admty. No.	Shell.	Filling.	Fuze.	Com-Pounded Angle of Impact from Normal	Burst.	Delay.	Target	Result.
4	22	A.P.C.	70/30 Shellite	16 D.	22 deg.	V.E.	38 ft	7 in. belt for-ward.	Large local effect
11	19	S.A.P.C.	70/30 Shellite	16 N.D.	28 deg.	V.E.	20 ft.	7in. battery armour.	
12	23	A.P.C. (light)	70/30 Shellite	16 D.	27 deg.	E.O.	30 ft. (outside ship)	7 in. belt for-ward.	
16	18	A.P.C.	70/30 Shellite	16 D.	18 deg.	E.O.	53 ft	7in. battery armour.	

(b) No comparison can be drawn between the bursting effect of A.P.C. light (12) and ordinary A.P.C. (4), as the former burst while leaving the port side of the ship.

(c) A comparison between S.A.P.C. (11) and A.P.C. (16) is difficult, the former having great local effect amongst light structure ; this was, however, less than was obtained with C.P.C. shell. The A.P.C. shell (16) encountered more substantial structures and had less local effect. The path of the disc of the plate at this latter round is noteworthy.

The A.P.C. rounds (4) and (17) can also be compared with the S.A.P.C. (11).

Of the rounds under consideration, by far the most important damage was caused by round 17, which put three stokeholds out of action ; but this is attributable to the position of the burst rather than a particularly violent bursting effect. Round 16 (A.P.C.) was disappointing in bursting effect, but round 4 (A.P.C.) gave good results.

(10) **Attack on 10 in. Belt.** – (a) Summary of rounds.

Serial No.	Admty. No.	Shell.	Filling.	Fuze.	Com-Pounded Angle of Impact from Normal	Burst.	Delay.	Target	Result.
8	11	A.P.C.	70/30 Shellite	16 D.	18 deg.	P.D.	7 ft.	10 in. belt.	Fuze acted early. $1^{3}/_{16}$ in. bulkhead and protective deck stopped all damage.
17	12	A.P.C.	70/30 Shellite	16 D.	15 deg.	E.O.	38 ft,	10 in. belt.	Protective deck was penetrated, three stokeholds damaged by burst and two boilers out of action. Shell burst about 2ft. above armoured grating in funnel uptakes.

(b) These two similar rounds were fired under identical conditions and clearly show the necessity of a delay action fuze. By the fuze acting prematurely in round 8, practically no damage was caused to the vital parts of the ship, all effect being contained by the $1^{3}/_{16}$ in. longitudinal bulkhead. Round 17, on the other hand, damaged three stokeholds and actually disabled two boilers.

(C458)

(11) (*a*) **Behaviour of fuzes** :-

Nature of Fuze.	Serial No.	Thickness of Armour First penetrated.	Delay.	Remarks
16 D.	4	7 in.	38 ft.	
	5	4 in. roof plate	15 ft.	Did not penetrate.
	8	10 in.	7 ft.	
	9	13¾ in.	3 ft.	
	12	7 in.	30 ft.	Light shell.
	13	4 in. roof plate	15 ft.	Did not penetrate.
	14	13¾ in.	Blind	
	15	13¾ in.	-	Did not penetrate.
	16	7 in.	53 ft.	
	17	10 in.	38 ft.	
16 N.D.	6	4 in. roof plate	-	Did not penetrate.
	11	7 in.	28 ft.	
15 N.D.	1	4 in. roof plate	-	Did not penetrate.
	2	4 in. roof plate	20 ft.	Did not penetrate.
	3	Deck	6 ft.	
	7	Deck	22 ft.	
	10	13¾ in.	-	Did not penetrate.

(*b*) It will be seen that the 16 D. fuze should carry a shell through the thickest armour before the shell is burst.

(*c*) Omitting round 12, which was a light projectile and gave a delay of 30 ft., the delays obtained with 16 D. fuze were 37 ft., 15 ft., 7 ft., 3 ft., 15 ft., 53 ft., and 38 ft.,

(*d*) The 16 non-delay fuze did not function for 28 ft. at round 11.

(*e*) The 15 non-delay fuze did not function for 20 ft. and 22 ft respectively at rounds 2 and 7.

The irregularity of the behaviour of these non-delay fuzes is noteworthy.

(12) **General Summary. –** (*a*) The penetrating power of A.P.C. shell was satisfactory, but it must be borne in mind that the recent plate trials at Shoeburyness with armour from “Baden” show that the German armour can be defeated at a velocity somewhat lower than is required for a British plate of corresponding thickness.

(*b*) The A.P.C. shell under trial gave satisfactory penetration and appeared to be of very strong design.

(*c*) Further lines of development would seem to be to improve the fuzes so that the bursting effect should be at least up to the standard of V.E., and to ensure greater regularity in the delay obtained with delay fuzes under varying conditions of attack of armour.

(*d*) The behaviour of C.P.C. filled shellite was satisfactory, and this type of shell with N.D. fuze should be useful for attack against light cruisers, etc.

(*e*) The delay obtained with 16 D. fuze is variable, the results obtained with rounds at the turret roofs being considerably shorter than the average. In view of the shortening of the linear delay when heavy armour is penetrated, as shown by round 9, it is considered that the average delay aimed at should be lengthened.

(*f*) During the trial the $1^3/_{16}$ in. longitudinal bulkhead localised the damage in the enar side at round 8 and on the far side at round 16, whereas the ⅞ in. bulkhead was pierced on the near side at round 3 and on the far side at rounds 7 and 16.

Bulkheads of this nature may therefore localise the effect of shell with N.D. fuze, but should be at least $1^3/_{16}$ in. thick.

As regards the protection afforded to the far side of the ship from the burst of a shell with delay fuze, this is not very important as the compartments which are protected are relatively unimportant.

(*g*) Round 17 is an example of a shell doing damage to the vital machiner of a ship against which the thick 13¾ in. belt armour provided no protection, owing to the shell passing through the 10 in armour above it. It is, therefore, a comparatively easy matter for a shell to reach the funnel uptakes and, unless the middle deck is strong enough to prevent the bursting effect from reaching the vital machinery, very considerable damage may result.

In the round under consideration, the shell burst near an armoured grating, which was unshipped by the explosion and enabled the fragments of shell to reach three stokeholds.

(*h*) In addition to the armoured grating which became unshipped at round 17 (as in (*g*) above), there is another instance, at round 7, of a grating being unshipped by an explosion below it. These instances point to the necessity for armoured gratings to be rigidly secured.

APPENDIX II.

96. Detailed Result of each Round. – Details of damage, embodying results of examination after "Baden" was salved.

Round 1.

(Fig. 53 shows a profile of "Baden" with location of the rounds.)

Target :- Roof plate of "B" turret.
Shell :- C.P.C.
Fuze :- 15 N.D.
Filling :- Powder.
S.V. :- 1,550.
Delay :- On impact.
Nature of burst :- Thick cloud of white smoke.
Point of impact :- 20 ft. 10 in. to rear of turret and 20 ft. 4 in. to proper left of centre line of turret.
Angle of impact :-
Inclination of flat roof plate to horizontal :- 11 deg.
Inclination of plate :- 9 deg. 20 min. from normal.
Angle between eave plate and flat roof plate :- 22 deg.
Angle of descent :- ½ deg.
Compounded angle of impact :- 75¾ deg. From normal.

A hole 6 ft. 9 in. long and 1 ft. 11 in. wide in the centre, tapering to 1 ft. 4 in. at front and 9 in. at rear end, was punched in the 4 in. roof plate. The roof plate inside the turret was flaked off for 8 in.

The heads of four bolts at inner edge of sloping plate were sheared off, and the remaining bolts were slightly drawn, the inner edge of the plate abreast of the centre of the hole being lifted 2 in.

The roof plate detached and driven into the turret was broken into three parts as follows :-

(1) Piece 6 in. by 28 in. was jammed between the bed of left chain rammer and loading wagon, the latter being distorted and put out of action. The rammer head was undamaged, but prevented from being used until the piece of plate was removed.

(2) Piece 66 in. by 26 in. fell down gun well into the working chamber causing very slight damage.

(3) Piece 42 in. by 20 in. picked up in rear part of gun-house, having caused no damage and apparently having struck the back of the turret.

The left gun was put out of action by a heavy strike being made ont eh top of the open breech block.

Round 2.

Target :- Roof plate of "X" turret.
Shell :- 15 in. C.P.C.
Nature of burst :- E.O.
Filling :- 60/40 shellite.
Fuze :- 15 N.D.
Delay :- 20 ft.
S.V. :- 1,550.
Point of impact :- 22 ft. from rear of turret and 5 ft. 2 in. to proper right of centre line of turret.
Angle of impact from normal :- Vertical, 78 deg. 30 min.; horizontal, 14 deg. Resultant, 78 deg. 50 min. from normal.

At the point of impact the 4 in. roof plate was bulged 6 ft. long to a depth of 7 in., and cracked through the centre of the bulge for a length of 4 ft. 3 in.

Several strikes to the roof plate were caused by fragments of shell 3 ft. from the rear of the turret as far as the rear edge of the turret.

Six bolts securing the rangefinder hood to the roof were sheared, the remaining bolts lifted, and the butt strap was cracked through. The side of hood was cracked. Half of the rangefinder casing was blown off on to the upper deck.

Considerable forward effect was made and the shell broke up well.

Inside the turret the air trunk between the guns was burst and partly carried away. Several voicepipes and electric circuits were severed and driven down between the guns.

The bolts securing the rear cross girder were sheared from the centre line to the right slope, and the girder was driven down 2 ft. and fractured in several places. The bolts securing the girder to the right side of the turret were also sheared.

The fore and aft girder was hanging by a few bolts at the fore end near main trunk, the remaining bolts being sheared and the girder driven down 16 in. at the rear end.

A small girder carrying voicepipes, etc., was broken away from the brackets attached to the roof and driven down on to the right loading lever, on of the latter being badly bent.

The right gun was put temporarily out of action by this.

A Carley float secured to the right side of the turret was set on fire.

Round 3 (see Fig. 48).

Target :- 7 in. Battery armour.
Shell : - 15 in. C.P.C.
Fuze :- 15 in. N.D.
Filling :- 60/40 shellite.
S.V. :- 1,550.
Delay :- 6 ft.
Nature of burst :- P.D.
Point of impact :- Forecastle deck forming roof of casemate ; 3 ft. from outboard edge of casemate.
Angle of impact from normal :- Vertical, 12 deg. 30 min.; horizontal, 10 deg. 50 min. Resultant from deck, 16 deg. 30 min.

The shell struck the roof of the casemate and after ploughing a hold 12 ft. long and 3 ft. wide in this it burst in the roof just outside the superstructure, making a hole 7 ft. by 3 ft. 6 in. in the latter.

Practically all the damage was forward and downwards, some of the forward being above the roof of the casemate.

The ⅞ in. fore and aft casemate bulkhead was blown down for 15 ft., the rivets securing it at the top being sheared and the bulkhead being bent inboard from the foot, thus penetrating the deck of the starboard passage.

The inner bunker bulkhead was blown away from 37 ft.

The transverse bulkhead above the upper deck at fore end of casemate was blown down towards the burst, and the transverse bulkhead under this between two bunkers was blown down for 12 ft. wide and the whole height.

The transverse bulkhead abaft the burst was undamaged above the upper deck but was holed in four places (holes 6 in. to 2 in.) below this deck.

The 5.9 in. gun in this casemate was undamaged.

The light plating inside the funnel casing was punctured in numerous places and four ventilating fans put out of action.

Part of the should of the shell weighing 300 lb. and a smaller fragment weighing 20 lb. were recovered from the port inner bunker.

The protective deck and armoured gratings were undamaged.

The blast went forward along the starboard passage and smashed in a light bulkhead of a storeroom 100 ft. forward of the burst.

No damage occurred in the port gangway.

A hatch at outboard after end of the casemate was blown downwards.

Two holes 1 ft. square were made in the forecastle deck inside the casemate, probably caused by pieces of plate, and much local damage to light fittings was caused inside the casemate.

Round 4 (see Figs. 48 and 52).

Target :- 7 in. belt forward.
Shell :- 15 in. A.P.C.
Fuze :- 16 D.
Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- 38 ft.
Nature of burst :- E.O.
Point of impact :- 7 in. belt just above main deck.
Angle of impact from normal :- Vertical, 19 deg. 10 min.; horizontal, 11 deg. 50 min. Resultant from normal, 22 deg. 20 min.

The shell struck and penetrated the 7 in. belt just above the main deck, this latter being holed from a distance of 2 ft. from the ship's side, and then, after penetrating the longitudinal bulkhead between the starboard storeroom and the capstan engine room, the shell burst two-thirds of the way across the ship, demolishing the port longitudinal bulkhead. The ship's side port was badly dented but not pierced.

A hold 15 ft. square was made in the main deck over the burst, and several smaller holes over this in the upper and forecastle decks.

The starboard longitudinal bulkhead was bulged outwards and split along a line of rivets from top to bottom.

The outer thickness of armour plate port side was bulged outwards to a maximum depth of 3 in. this being at its join with the plate abaft it, which latter was undamaged.

The bulkhead on the after side of the capstan engine room and port storeroom was badly bulged and holed, and the bulkhead before the capstan engine room was slightly bulged in upper half.

The clutch gear at bottom of port cable holder spindle was slightly damaged, but no further damage could be round in the machinery.

No damage was made on the lower deck (armoured).

Round 5.

Target :- Roof plate of "X" turret.
Shell :- 15 in. A.P.C.
Fuze:- 16 D.

Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- 15 ft.
Nature of burst :- V.E.
Point of impact :- Flat roof plate at join of front plate and 6 in. from join of left slope.
Angle of impact from normal :- Vertical, 79 deg.; horizontal, 10 deg. 50 mion. Resultant from normal, 79 deg. 10 min.

The 4 in. roof plate was bulged 2½ in. for a length of 3 ft. 4 in. width 7 in., opening up seam between it and eave plate by 1 in.

The front plate at point of impact was flaked off in a segment 9 in. by 3 in., and several circular surface cracks were made up to 4 ft. from impact.

Seven large strikes about 5 in. diameter were made on the front of the range-finder hood, the angle iron securing the hood to the roof plate being broken away for 3 ft. 9 in., and all except nine of the securing bolts were sheared.

The rangefinder casing and supporting stand were blown on to the upper deck.

Round 6.

Target :- Roof plate of " B " turret.
Shell :- 15 in. C.P.C.
Fuze :- 16 N.D.
Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- On impact.
Nature of burst :- P.D.
Point of impact :- Roof plate 25 ft. 9 in. from rear of turret and 2 ft. to proper right of centre line of turret.
Angle of impact from normal :- Vertical, 79 deg.; horizontal, 6 deg. 50 min. Resultant from deck, 79 deg.

The roof plate was bulged for 8 ft. in length and 1 in. deep, and a through crack 2 in wide was made for 7 ft. 10 in. Twenty-one bolts round the bulge were sheared.

Inside the turret all bolts securing the cross girder to the roof were sheared from the right side of the turret to the left fore and aft girder, and cross girder being driven down 2 ft. 7 in.

All the bolts securing the right fore and aft girder were sheared and the girder was driven down between the breech of the gun and the rails of the loading wagon. This would have taken a considerable time to clear in action.

Voicepipe, air trunks, electric circuits, etc., were broken away and littered about the gun-house.

Round 7 (see Fig. 49).

Target :- 7 in. battery armour.
Shell :- 15 in. C.P.C.
Fuze :- 15 N.D.
Fuilling :- Powder.
S.V. :- 1,550.
Delay :- 22 ft.
Nature of burst :-
Point of impact :- Half inch coaming round forecastle deck at join of top of casemate and 7 in. belt.
Angle of impact from normal :- Vertical, 12 deg.; horizontal, 10 deg. 20 min. Resultant from deck, 15 deg. 50 min.

A hole 3 ft. wide by 6 ft. long was made in the forecastle deck over the casemate. The shell then pierced the ⅞ in. longitudinal casemate bulkhead, in which it made a hold 3 ft. 5 in. by 3 ft. 9 in, and burst in the passage outside the casemate.

Two holes 2 ft. by 1 in. each were made in the superstructure by bits of deck from entry hole. The fragment causing one of these holes pierced the boat deck and then entered the funnel, finally coming to rest by deeply denting the outer funnel casing on the port side. Three holds (6 in. by 2 in., 6in. by 10 in. and 4 in. by 3 in.) were also made in the upper deck inside casemate by bits of deck from the entry hole.

The deck in the passage immediately under the burst was bulged downwards 6 in. and the light bulkhead between this passage and the ventilation trunk was demolished.

A heavy strike was made under the forecastle deck immediately over the burst.

There was a large and far-reaching forward effect, eight holes (6in. by 12 in.) being made in made in the inner bulkhead ($^{5}/_{16}$ in.) of port passage, and two holes (5in. by 3 in. and 8 in. by 6 in.) were made through ⅞ in. bulkhead into port casemate.

Several dents were made in ⅞ in. bulkhead between port casemate and passage, and a dent 2 in. deep was made in this by a large piece of the wall of the shell. This piece was picked up in the port passage together with several other fragments.

Thin sheeting between funnel uptake and ventilators each side was blown down.

An armoured grating on forecastle deck in starboard ventilation trunk was unshipped but the funnel was undamaged.

No damage was done to the protective deck or boilers.

Round 8 (see Figs. 49 and 52).

Target :- 10 in. belt above engine room.
Fuze :- 16 D.
Shell :- 15 in. A.P.C.
S.V. :- 1,550.
Filling :- 70/30 shellite.
Nature of burst :- P.D.
Delay :- 7 ft.
Point of impact :- Top edge 10 in. belt.
Angle of impact from normal :- Vertical, 12 deg. 40 min.; horizontal, 12 deg. 50 min. Resultant from normal, 18 deg.

The shell struck the top edge of the 10 in. belt (making a hole 2 ft. by 3 ft.) and burst just in front of the 7 in. casemate armour.

A hole 8 ft. long by 2 ft. wide was ploughed in the upper deck.

A hole 1 ft. 6 in. by 2 ft. 6 in. was made in the 7 in. battery armour and four large fragments of shell were found inside the casemate.

A hole 1 ft. 6 in. by 6 in. was made in ⅞ in. casemate bulkhead. This was caused by a fragment of 7 in. armour which was found lying inside the casemate under the hole not having penetrated the bulkhead.

A hole 3 ft. by 4 ft. and several smaller holes were made in the main deck under the burst, and one hole 2 ft. square was made in the middle deck over the slope of the protective deck.

The protective deck was quite undamaged, fragments of the upper deck plating having made the holes in the main deck over the slope.

Fragments of shell, however, were found in the bunker.

The 1 $^{3}/_{16}$ in. longitudinal bulkhead was dented but not pierced.

Round 9.

Target :- Barbette armour of "X" turret.
Fuze :- 16 D.
Shell :- 15 in. A.P.C.
S.V. :- 1,550.
Filling :- 70/30 shellite.
Nature of burst :- E.O.
Delay :- 3 ft.
Point of impact :- 3 ft. 9 in. from top edge of fixed armour and 25 ft. 9 in. from midship line forward..
Angle of impact from normal :- Vertical, 11 deg.; horizontal, 0 deg. 30 min. Resultant from normal, 11 deg.

The armour was completely penetrated, a hole 17 in. diameter being made in it.

Apparently the shell burst when it was two-thirds of its way through the armour and the nose of the shell as far as the shoulder was found inside barbette 23 ft. from outer edge of entry hole.

Considerable damage was done to the roller path.

Some damage was caused to machinery in the pocket between girders where the nose of the shell was found.

Round 10.

Target :- Barbette armour of "B" turret.
Fuze :- 15 N.D.
Shell :- 15 in. C.P.C.
S.V. :- 1,550.
Filling :- Powder.
Nature of burst :-
Delay :- On impact.
Point of impact :- 5 ft. 3 in. above forecastle deck and 23 ft. 4 in. from midship line forward.
Angle of impact from normal :- Vertical, 11 deg.; horizontal, 5 deg. 20 min. Resultant, 12 deg. 10 min.

The shell burst on impact with the plate, penetrating 1½ in. over a diameter of 9½ in.

The angle connecting the upper deck to the armour was torn away and flattened for 7 ft.

The forecastle deck was bulged downwards for 9 in. and a hole 6 in. by 4 in. was made in this. A large piece of the base was found on the upper deck under the burst.

The thin liners between the plates were loosened and partly squeezed out.

Round 11 (see Fig. 50).

Target :- 7 in. battery armour.
Fuze :- 16 N.D.
Shell :- 15 in. S.A.P.C.
S.V. :- 1,550.
Filling :- 70/30 shellite.
Nature of burst :- V.E.
Delay :- 28 ft.
Point of impact :- 7 in. armour 3 ft. above upper deck midway between two 5.9 in. guns.
Angle of impact from normal :- Vertical, 11 deg. 30 min.; horizontal, 25 deg. 50 min. Resultant from normal, 28 deg. 10 min.

Projectile grazed under side of 5.9 in. gun causing the gun to swing round.

A hole 1 ft. 6in. by 2 ft. was made in the 7 in. belt, the shell entering the foremost end of the same casemate that was entered by No. 3 round, and burst when under the starboard fore and aft passage.

The upper deck over the burst under the fore and aft passage was torn away for 15 ft. in each direction.

The transverse bulkhead below upper deck 2 ft. before path of shell was blown down over an area of 15 ft. square.

The W.T. room and a storeroom on fore side of this bulkhead were destroyed.

Considerable effect was caused in the light plating dividing the ventilating trunks from the funnel, but no damage was done to the protective deck or boilers. Part of the base was recovered from an armoured grating in ventilation trunk on middle deck, and one bar of the armoured grating (6 in. deep and ½ in. wide) was broken.

The nose of the shell weighing about 500 lb. went straight forward, and after piercing several light plates and a $1^3/_{16}$ bulkhead it struck the ship's side port without doing any damage to this, and was found lying in the port outer bunker.

The blast effect did not appear to have been so large as was the case in No. 3 round.

Round 12.

Target :- 7 in. belt at fore end.
Fuze :- 16 D.
Shell :- 15 in. A.P.C. (light).

S.V. :- 1,550.
Filling :- 70/30 shellite.
Nature of burst :- E.O.
Delay :- 30 ft.
Point of impact :- 7 in. belt just above main deck.
Angle of impact from normal :- Vertical, 20 deg. 10 min.; horizontal, 17 deg. 30 min. Resultant from normal, 26 deg. 30 min.

A hole 2 ft. in diameter was made in the side armour and a hole 12 ft. long and 8 ft. wide was ploughed in the main deck. The shell then turned towards the normal, and after piercing the centre line bulkhead, in which it made a hold 2 ft. by 3 ft., it cut through an angle iron port side and finally burst in the port side plating from which the armour plate had previously been removed. This is established by the photographic record considered in conjunction with inspection of the compartments. An irregular hole 6 ft. square was made in the port side.

Four holes the largest being 20 in. by 14 in., were made in the upper deck by pieces of side armour from the entry hole, and two 6in. holes in the forecastle deck.

Many strikes from armour were made on the ship's side port above the main deck, and several pieces of armour were picked up in the Sick Bay there.

The lower deck under the clothing stores was not punctured.

A piece of the driving band was found in the port clothing store.

Round 13 (Repeat of Serial No. 5.).

Target :- Roof plate of " X " turret.
Shell :- 15 in. A.P.C.
Fuze :- 16 D.
Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- 15 ft.
Nature of burst :- E.O.
Point of impact :- Left centre roof plate 24 ft. from rear edge of turret.
Angle of impact from normal :- Vertical, 78 deg.; horizontal, 13 deg. 50 min. Resultant from normal, 78 deg. 20 min.

The shell made a bulge 6 ft. long by 7 ft. wide and 4 in. deep, and a through crack 3 ft. 10 in. long through the centre of the bulge.

The rangefinder hood was broken up and was blown overboard, with the exception of about a quarter of it which remained in place.

Inside the turret the rivets securing the left longitudinal girder to the roof were sheared, and the girder was driven about 2 ft. on top of the left loading wagon, putting this out of action.

Round 14 (See Fig. 52).

Target :- Front plate of " B " turret.
Shell :- 15 in. A.P.C.
Fuze :- 16 D.
Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- Blind.
Nature of burst :- Blind.
Point of impact :- Front plate of turret midway between the guns.
Angle of impact :- Vertical, 12 deg.; horizontal, 11 deg. Resultant, 18 deg. 40 min.

Shell completely perforated armour, making holes 18 in. in diameter flaked off to 36 in. by 48 in. outside and 24 in. by 35 in. inside.

Shell was found inside turret with nose resting against left girder of right gun-slide.

The centre position sight and apparatus in its immediate vicinity was wrecked.

The shell was eventually exploded by a gun-cotton charge with the following result.

The sound of the burst was indistinguishable from that of the gun-cotton detonating, and degree of rapidity of burst was therefore difficult to estimate. Thick black smoke was emitted from all holes in the gun-house.

The left rammer (main cage to transport wagon) was unshipped and damaged.

The nose of the shell and a large part of the body were found lying on a platform 2 ft. below the burst, and two large fragments were lying where the shell had been. Part of the base weighing 30 lb. went through the main cage trunk and was found lying in the gun-house just in rear of this trunk. Other small fragments were found lying about the gun-house and working chamber, but no other serious damage could be found.

It is of interest to record the steps taken to destroy the shell referred to above.

In the first instance information was received that the normal pre-war practice at Shoeburyness when destroying A.P.C. shell of large calibre was to explode four 15 oz. slabs of wet gun-cotton placed on top of the shell slightly in front of the driving band.

As it was desired to preserve the fuze if possible, an attempt to break the shell open by using a smaller charge was first tried ; this, however, was unsuccessful, and the following table shows the attempts made before the shell was finally destroyed, and it would appear that there has been a very great advance in the strength of projectiles during recent years :-

No. of Round.	No. of Slabs of G.C. wet 15 oz.	Dry Primers.	Remarks.
1	3	1	Small indent the shape of G.C. slab.
2	4	1	No change.
3	6	1	Small hole ¾ in. deep under dry primer.
4	7	1	Enlarged hole to 1¼ in.
5	8	1	Projectile turned over.
6	8	2	Hole increased to 1¾ in. and enlarged laterally.
7	10	2	Slightly increased to result of round 6.
8	10	2	Projectile moved 2 ft. to the rear.
9	25	12	Charges placed in a ring around the shell and tamped with sand bags. Hole mentioned above increased to 2in. depth.
10	25	12	Charges placed against base of shell, tamped with sand bags. Shell destroyed.

Round 15.

Target :- Thickest part of conning tower (13¾ in.).
Shell :- 15 in. A.P.C.
Fuze :- 16 D.
Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- On impact.
Nature of burst :- P.D.
Point of impact :- A 1 in. angle iron round the conning tower 6 ft. from top of tower and 9 ft. 6 in. from centre line forward.
Angle of impact from normal :- Vertical, 18 deg.; horizontal, 25 deg. 50 min. Resultant from normal, 30 deg. 10 min.

The shell burst on impact, making a bulge 4 ft. 6 in. by 2 ft. 6 in. and 4 in. deep, and opening out the plates half an inch at a join.

The inners side of the plate attacked was badly flaked and cracked, two cracks 6 in. deep and 8 ft. 10 in. long being made. No loosening of plates or of securing bolts was made inside the conning tower, but outside the join of the plate attacked was opened from ⅛ in. at bottom to ⅞ in. at top of conning tower. This was 3 ft. from point of impact. The plate attacked was driven in 1½ in. from the plate immediately below it, the join being 2 ft. below point of impact.

The starboard door was blown off, the upper hinge being broken.

The deck round the tower under the point of impact was blown away for 6 ft. 6 in. by 3 ft. 6 in. and a storeroom underneath was demolished.

The deck over the Admiral's cabin was holed and several pieces of shell were recovered from this cabin.

The diameter of the bulge inside the conning tower was 5 ft. and superficial star cracks were made on the bulge.

The damage to fittings inside the conning tower was very slight.

Round 16 (see Fig. 51).

Target :- 7 in. battery armour.
Shell :- 15 in. A.P.C.
Fuze :- 16 D.
Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- 53 ft.
Nature of burst :- V.E.
Point of impact :- 7 in. belt 4 ft. 6 in. above upper deck.
Angle of impact from normal :- Vertical, 13 deg.; horizontal, 12 deg. 40 min. Resultant from normal, 18 deg.

The shell struck the 7 in. armour belt making a hole 1 ft. 9 in. by 1 ft. 6 in. which was flaked off to 3 ft. diameter inside. It then pierced the upper deck at foot of inner casemate bulkhead, making a hole 2 ft. by 3 ft. in the upper deck and a hole 1 ft. by 1 ft 6 in. in the casemate bulkhead, and after penetrating four other light bulkheads it burst just above the main deck. The main deck was demolished just under the burst, and hole 8 ft. by 8 ft. was made in a lagged bulkhead in the coal bunker.

Fragments passed upwards into a store on the main deck and holed light structures before denting the 2 in. bulkhead.

Other fragments traversed the empty bunker and dented the 2 in. bulkhead on the outboard side of it.

A large piece of the base was found amongst the debris at the point of burst.

Some auxiliary machinery (with coils attached) close to the burst was damaged, but no other damage to machinery or to the middle (protective) deck could be found.

A disc of 7 in. armour punched out of the entry hole traversed the ship and dented 7 in. belt the port side, being recovered from the port casemate.

Three other holes (4 in. by 2 in., 4 in by 4 in. and 4 in. by 1 in.) were also made in the ⅞ in. bulkhead inside casemate by fragments of the 7 in. belt.

Round 17 (see Fig. 51).

Target :- 10 in. belt above boiler room.
Shell :- 15 in. A.P.C.
Fuze :- 16 D.
Filling :- 70/30 shellite.
S.V. :- 1,550.
Delay :- 38 ft.
Nature of burst :- E.O.
Point of impact :- 10 in. belt 3 ft. below upper deck
Angle of impact from normal :- Vertical, 13 deg. 40 min; horizontal, 5 deg. 10 min. Resultant, 14 deg. 40 min.

After piercing the 10 in. belt the shell pierced the outer bunker bulkhead (hole 4 ft. by 2 ft.), the main deck and the inner bunker bulkhead (hole 5 ft. by 1 ft. 6 in.), finally bursting against the funnel casing above the centre boiler of the foremost boiler room.

The armoured gratings over this boiler were unshipped and many fragments of shell entered the boiler.

Two of these entered the steam drum, and the remaining fragments severely damaged the tubes each side.

The nose of the shell weighing about 400 lb. went through the port electric cable passage (under the main deck, in the centre boiler room) and, after piercing the bulkhead between the two boiler rooms, it was found embedded in the tubes of the port boiler. Most of these tubes were broken.

A smaller fragment, after traversing the centre boiler, pierced the bulkhead and dented theouter casing of the port boiler without doing any damage to the atter.

The traverse bulkhead between the foremost and No. 2 centre boiler rooms was pierced in three places, two of these fragments piercing the outer shell of the centre boiler in No. 2 boiler room. One of these fragments traversed the boiler, making 3 in. holes in the casing each end, but did no further damage. The other fragment entered the outer casing, grazed the steam drum, and removed a 30 in. manhole cover in the after end of the casing without damaging the steam drum or tubes.

NOTE.- Fig. 52 shows photographs of " Baden " with an A.P.C. shell bursting inside the ship and outside the battery side armour to illustrate the difference in the visibility of these two hits, also a photo of the turret shield after round 14.

97. REPORT OF FIRING TRIALS AGAINST "BADEN."

Remarks, re Structural Damage, by Admiralty.

Turret Roofs. – The girders under the roofs were very inadequate as supports. In the design of our new triple turrets the method of securing and the support of the roof plates is receiving special attention with a view to perfecting the holding up arrangements and preserving the guns and fittings from damage when the roof plate " dishes " under a blow.

Blast Damage.- Rounds 3 and 7. Having regard to the severe damage caused by the blast of these C.P.C. shells, it is very necessary to compare the efficiency of welded joints with that of riveted joints. It is observed that a riveted joint of many feet in length is quite unable to hold up against a blast in a confined space.

Support of Armour Plates.- Round 8. The displacement of the 7 in. belt plate is evidence in favour of some kind of support being worked between two adjacent plates at the butts. A new method of butt support will be tested in the trials at H.M.S. " Superb."

Uptakes.- Round 7 showed the undesirability of working the uptakes so close to the ship's side as in "Baden.: This is being borne in mind for new designs.

Fire.- Round 2. Any article (such as a Carley float) which will burn or smoulder should not be stowed on a turret.

Damage to Decks and loss of Girder strength.- Rounds 3 and 8. The breaking up of the upper deck between the ship's side and the belting brings forward again a feature noticed during the war, namely, that a shell may plough up a considerable section of " strength deck," and if the vessel had to travel a long distance after the action this injury, with others, might result in her breaking her back. The common practice is to estimate the stress, after the structure above the thick deck is destroyed, in order to see if it is inordinately high. This will be arranged for in our new designs.

Turret Barbette arrangements. – Round 9, The German system of connecting the roller path support to the barbette armour was shown to be unsound.

Armour Doors.- Round 14. An armoured door is a danger unless its hinges are very strong and it is very securely fastened.

SECTION XXI.

MISCELLANEOUS.

98. Rapid Cinematograph.- The preliminary trials of the Heap and Grylls instrument have shown up various minor defects which are being remedied, but progress is slow. It is hoped to have the machine in operation at Shoeburyness during this year.

An elaborate and somewhat costly lay-out will be required for its successful use.

(G.7076/21, G.5553/21, G.2063/20.)

SECTION XXII.

GUNNERY PUBLICATIONS.

99. During the last twelve months the following books have been published:-

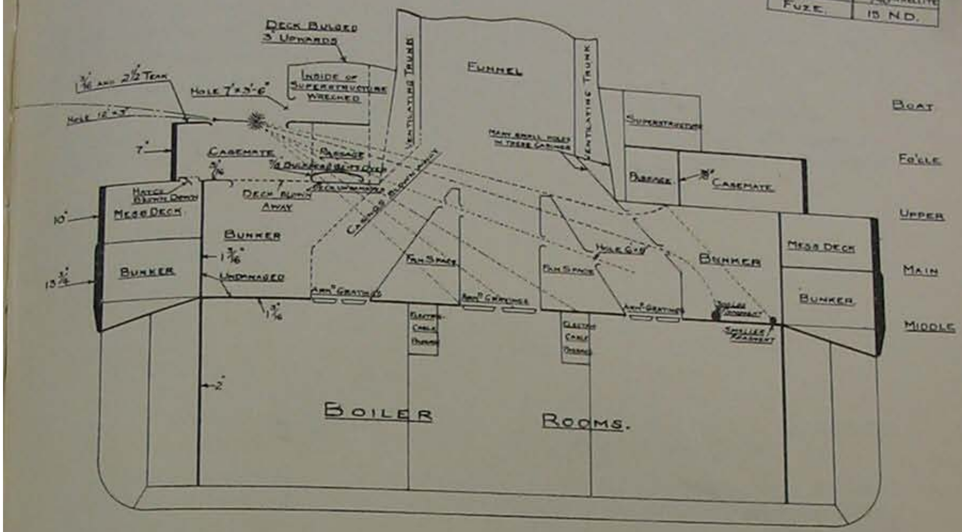
Royal Naval handbook of Field Training, 1920.
Notebook for Officers of Quarters Hand Worked Guns, 1920.
Manual of Gunnery, Vol. III, 1920
Pocket Book for Power Worked Mountings, 1920.
Handbook for 6-inch B.L. Mark XII Gun on C.P. XIV Mounting and the 5.5-inch B.L. Mark I gun on C.P. II Mounting, 1920.
Handbook for 15-inch Mark II Mountings, H.M.S. "Hood," 1920.
Turret gun Drill, 13.5-inch Mark V, Marks II, II*, and II** Mountings, 1920.
Turret Gun Drill, 15-inch Mark I, 1920.
Handbook for use at Fire Control Drills, 1920.
Interim Report of the Naval Anti-Aircraft Gunnery Committee, 1920.
Instructions for Ordnance Artificers, 1921.
Manual for Power Worked Mountings, Book I, 1921.
Manual for Power Worked Mountings, Book II, 1921.
Handbook of Bayonet Training, 1921.
Instructions for the Inspection of naval Armament Stores, 1921.

The following books are now in course of preparation :-

The Sight Manual.
Notes of Anti-Gas Apparatus.
Report of Naval Anti-Aircraft Gunnery Committee.
R.N. Handbook of Musketry and Pistol Practice.
Handbook for Naval Range-Finders and Mountings.
Handbook for 7.5-inch B.L. Mark VI Gun, C.P. V Mounting.
Handbook for Ammunition.
Fire Control Pocket Books.
Machine Gun Handbook.
Form S.1151 (Register of Non-Transferable Gun Mountings).
For S.295 (Gunnery Instructions to be complied with).
Optical Manual.
Gunnery Manual, Vol I.
Handbook of Chemical Warfare.

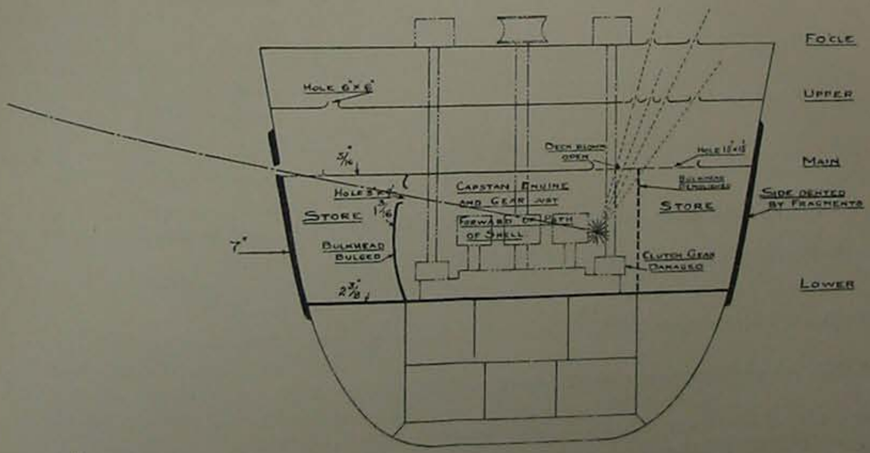
Printed by H.M. Stationery Office Press, Harrow

Shell	15" C.P.C.
Filling	60/40 Shellite
Fuze	15 N.D.



Round Nº 3.

Shell	15" A.P.C.
Filling	70/30 Shellite
Fuze	16 D



11059B/P.H. 3861.300 (1/2)

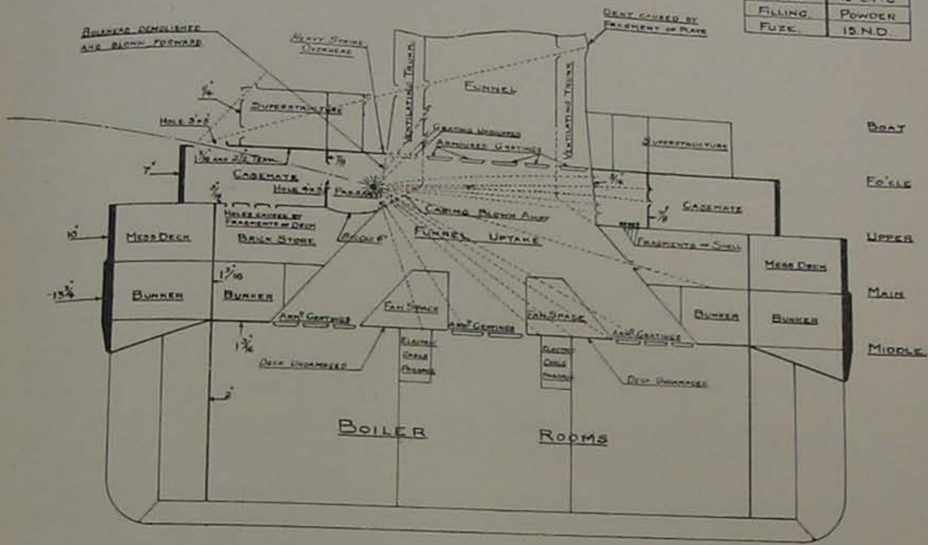
C.B.R. LTH 815.

Round Nº 4.

FIG 48

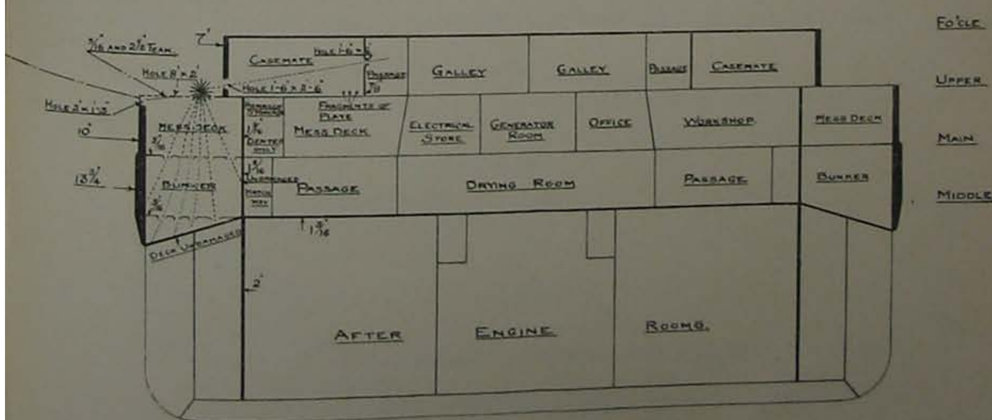
BADEN.

Shell	15" C.P.C.
Filling	Powder
Fuze	15 N.D.



Round No. 7.

Shell	15" A.P.C.
Filling	70/30 Shellite
Fuze	16 D.



Round No. 8

FIG. 49.