WASC 2019

Operational Procedure
Notes for
Ballistic Test Mortar
and
Ballistic Test
Pendulum
Note on Col.
Eardley-Wilmot's
13 in SS Mortar
of 5 ton 0 cwt 1 qr
of 1856

EXPLOSIVES SECTION	EXOP14
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Operational Procedure	Issue No: 2
THE BALLISTIC MORTAR	Issue Date: 30 October 1995
	Issued by:

1. Context and Scope

1.1 This procedure describes how to prepare and carry out strength tests on an explosive using the ballistic mortar in Building 25 of the Explosives Section.

1.2 The apparatus may be used for testing all types of commercially available explosives.

2. Policy

2.1 All tests on explosives using the ballistic mortar shall be carried out in a controlled and consistent manner.

3. Responsibilities

3.1 Only staff who have experience of, or have received instruction in the procedures for preparing charges and operating the ballistic mortar shall be allowed to carry out these tests. Other members of the Explosives Section staff, who have little or no experience in the use of the ballistic mortar, may operate the apparatus only under the direct supervision of an experienced operator. Support staff will have the skills and experience necessary for the provision of that support. (Refer to HSL Policy P7 "Staff competences", for further information).

3.2 The member of staff supervising the work is responsible for ensuring that the tests are performed in a consistent manner in accordance with this procedure.

3.3 The Section Calibration Officer is responsible for ensuring that the balance used for the preparation of test charges is calibrated regularly, bears a valid calibration label, and that appropriate records are kept.

4. Procedures

4.1 The Section's safety rules must be followed at all times and take precedence over all other considerations. Current safety rules for operating the ballistic mortar are contained in the Facility Documentation File, EX/01/034/93.

4.2 Clean the bore of the mortar and the steel projectile with hot water and detergent before use, and dry them with paper towelling or a jet of compressed air. If necessary, scour the small detonation chamber at the rear of the mortar using file card attached to a wooden rod, but do not under any circumstances use abrasives on the cylindrical surface of the projectile, or the part of the mortar bore into which the projectile fits.

4.3 Thoroughly wet the mixture of sawdust and limestone dust in the target bunker (to minimise the quantity of dust raised during firing) and cover the mixture with wet hessian bags.

4.4 Before preparing the first explosive charge in a series of tests, carry out the following procedure (refer also to EXOP28, "Use of balances"):

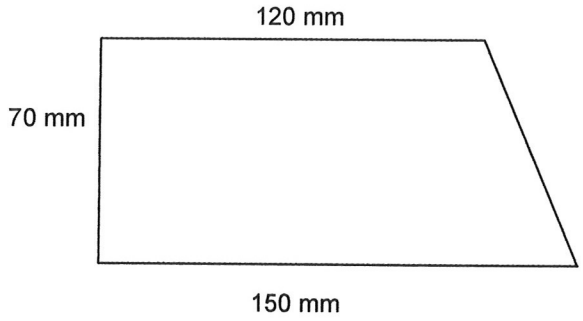
(i) Check that the balance bears a valid calibration label.

(ii) Check that the balance indicates zero when the pan is clean and empty.

(iii) If the checks are not satisfactory inform the Section Calibration Officer and request a re-calibration. Use an alternative balance for the preparation of charges.

4.5 Prepare a cartridge case for the each charge as follows:

(i) Take a sheet of 0.03 mm thick tin foil which has been cut to the shape and dimensions shown in the diagram.



(ii) Form the sheet of tin foil into a cylindrical cup with the aid of the 25 mm diameter tufnol former provided.

4.6 Follow the procedure given below to prepare and fire charges of explosive in the following sequence:

(i) a charge of Blasting Gelatine (the standard calibrating explosive for the mortar);

(ii) two charges of the explosive undergoing test (fire additional charges if the results recorded from the two shots are not in close agreement);

(iii) a second charge of Blasting Gelatine.

4.7 To prepare an explosive charge:

(i) Place the tin foil cartridge case onto the balance and add the explosive in small increments until the case contains exactly 10 g of explosive.

(ii) Place the cartridge case in the hinged cylindrical brass holder, for support, and tamp the explosive gently but firmly into the case using the 21 mm diameter tufnol rod.

(iii) Crimp a 30.5 cm (12 inch) length of safety fuse (having a burning rate of 1 cm per second) to a plain No 8 strength copper-cased detonator, using the bench-mounted crimping tool.

(iv) Insert the detonator into the open end of the cartridge case, so that the end of the detonator is in firm contact with the explosive, and fold the foil tightly around the detonator to seal the charge and hold the detonator in place.

4.8 To load and fire the ballistic mortar:

(i) Pass the fuse through the axial hole in the steel projectile until the foil-wrapped charge is in contact with the base of the projectile and the end of the fuse protrudes through the opposite face of the projectile.

(ii) Insert the projectile fully into the mortar so that the charge is positioned in the detonation chamber at the rear of the mortar.

(iii) Set the cursor on the curved scale, which measures the angle of deflection of the mortar, to the zero position.

(iv) After carrying out all necessary safety checks, switch on the warning siren and flashing beacons, and ignite the fuse by means of a safety match (fusee).

(v) After the shot has fired and the fumes have cleared, record the angle of recoil of the mortar from the position of the cursor on the scale.

(vi) Wash and dry the projectile and the bore of the mortar, as previously described, before loading another charge.

4.9 Repeat the procedure until all the shots have been fired in the correct sequence.

4.10 When all shots have been fired and the mortar has been cleaned and dried, liberally smear the inside and outside surfaces of the mortar, and the surfaces of the projectile, with oil. Place a container of silica gel inside the bore of the mortar and replace the muzzle plug.

4.11 Calculate the strength of the explosive under test, as a percentage of the strength of Blasting Gelatine, from the formula:

$$\text{Strength (\%BG)} = 100 \times (1 - \cos A) / (1 - \cos B)$$

Where A = angle of recoil for the explosive under test
and B = angle of recoil for Blasting Gelatine.

4.12 Record the following information in the laboratory record book for each series of tests:

(i) The programme number or test number.

(ii) The name or number of the explosive.

(iii) The manufacturer's name.

(iv) The date of manufacture.

(v) The date of the test.

(vi) The angle of mortar recoil for each shot.

(vii) The calculated strength of the explosive for each shot.

(viii) The mean strength of the explosive under test (as %BG)

(ix) The signature of the supervising officer.

EXPLOSIVES SECTION	EXOP15
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Operational Procedure	Issue No: 2
THE BALLISTIC PENDULUM	Issue Date: 30 October 1995
	Issued by:

1. Context and Scope

1.1 This procedure describes how to prepare and carry out strength tests on an explosive using the ballistic pendulum in Building 25 of the Explosives Section.

1.2 Although mainly used for testing mining explosives, this procedure may be used for assessing the strength of all types of commercially available explosives.

2. Policy

2.1 All strength tests on explosives using the ballistic pendulum shall be carried out in a controlled and consistent manner.

3. Responsibilities

3.1 Only staff who have experience of, or have received instruction in, the procedures for operating the ballistic pendulum shall be allowed to carry out these tests. Other members of the Explosives Section staff, who have little or no experience in the use of the ballistic pendulum, may operate the apparatus only under the direct supervision of an experienced operator. Support staff will have the skills and experience necessary for the provision of that support. (Refer to HSL Policy P7, "Staff competences", for further information).

3.2 The member of staff supervising the work is responsible for ensuring that the tests are performed in a consistent manner in accordance with this procedure.

3.3 The Section Calibration Officer is responsible for ensuring that the balance used for the preparation of test charges is calibrated regularly, bears a valid calibration label, and that appropriate records are kept.

4. Procedures

4.1 The Section's safety rules must be followed at all times and take precedence over all other considerations. Current safety rules for operating the ballistic pendulum are contained in the Facility Documentation File, EX/01/035/93.

4.2 Before preparing the first explosive charge in a series of tests, carry out the following procedure (refer also to EXOP28, "Use of balances"):

(i) Check that the balance bears a valid calibration label.

(ii) If the balance is fitted with a level indicator, check that it is level and adjust if necessary.

(iii) Check that the balance indicates zero when the pans are clean and empty.

(iv) If checks i and iii are not satisfactory inform the Section Calibration Officer and request a re-calibration. Use an alternative balance for the preparation of charges.

4.3 Follow the procedure given below to prepare the explosive charges:

(i) Take two cartridges of special gelignite, of nominal weight 113.4 g (4 oz), and make an identifying mark on each. Weigh each cartridge accurately and record the weight, making allowance for the weight of the cartridge wrapper (refer to EXOP8, "Preparation of explosive charges for official tests"). Use a previously etermined average figure for the weight of the wrapper rather than removing the wrapper from the cartridges to be used.

(ii) Prepare two cartridges of the test explosive by progressively cutting off the excess weight, making allowance for the weight of the cartridge wrapper, so that the net explosive weight of each cartridge is 113.4 g.

4.4 Load and fire the charges in the following sequence:

(i) a charge of special gelignite (the standard calibrating explosive for the pendulum);

(ii) two charges of the explosive undergoing test (fire additional charges if the results recorded from the two shots are not in close agreement);

(iii) a second charge of special gelignite.

4.5 For each shot weigh a quantity of dry granular clay stemming, and a single 43 mm diameter x 25 mm thick clay plug, so that the total quantity of clay is 910 g (2 lb). Note that it is not necessary to use a calibrated balance for weighing the clay.

4.6 Prime and load each charge as follows:

(i) Use a non-ferrous pricker to make a hole in one end of the charge and insert a No 8 strength copper instantaneous detonator fully into the charge, ensuring that the detonator end is flush with the end of the cartridge.

(ii) Insert the charge into the bore of the wheeled cannon with the detonator towards the rear of the cannon, i.e. in the inverse position. Push the charge to the rear of the bore using the wooden rammer.

(iii) Insert the clay plug from the weighed quantity of stemming into the bore and push it gently onto the end of the charge using the wooden rammer.

(iv) Load the remainder of the clay stemming into the bore incrementally using the special funnel and wooden plunger. Press each increment firmly into the cannon using the wooden rammer.

(v) Position the wheeled cannon so that its face is 51 mm (2 inches) from the face of the pendulum, using a wooden spacer between the two to check the separation.

(vi) Position the special sliding scale at the rear of the pendulum ensuring that the pegs at each end of the scale are located in the appropriate holes in the rear of the pendulum and the fixed post. Ensure that the scale reads zero when the pendulum is at rest and adjust the fixed post if necessary.

4.7 After carrying out all necessary safety checks, switch on the warning siren and flashing beacons, and fire the shot.

4.8 After the shot has fired and the fumes have cleared, read the linear deflection, or swing, of the pendulum from the sliding scale.

4.9 Repeat the procedure until all of the shots have been fired in the correct sequence.

4.10 As the standard pendulum swing for 113.4 g (4 oz) of special gelignite is taken as 83.1 mm (3.27 inches), corrections must be applied for discrepancies in either the weight of gelignite charge used or the pendulum swing recorded. Correct the recorded swing for gelignite and calculate a swing correction factor (to be applied to the recorded swing for the explosive under test), as follows:

(i) From the results of the two gelignite shots calculate the average explosive weight and the average swing for special gelignite.

(ii) Adjust this average swing for weight discrepancies, i.e. multiply by 113.4 and divide by the average charge weight of the gelignite (in grams).

(iii) Calculate the correction factor by dividing the "standard" swing for gelignite (83.1 mm) by the adjusted average swing determined in step ii.

(iv) If the charges of the test explosive were not prepared exactly to the correct weight as described in paragraph 4.5, make an adjustment to the recorded swing for the test explosive in a similar manner to step ii.

(v) Multiply the each recorded swing for the test explosive by the correction factor determined in step iii to give the corrected swing for the explosive.

4.11 Record the following information in the laboratory record book for each series of tests:

(i) The programme number or test number.

(ii) The name or number of the explosive.

(iii) The date of manufacture.

(iv) The date of the test.

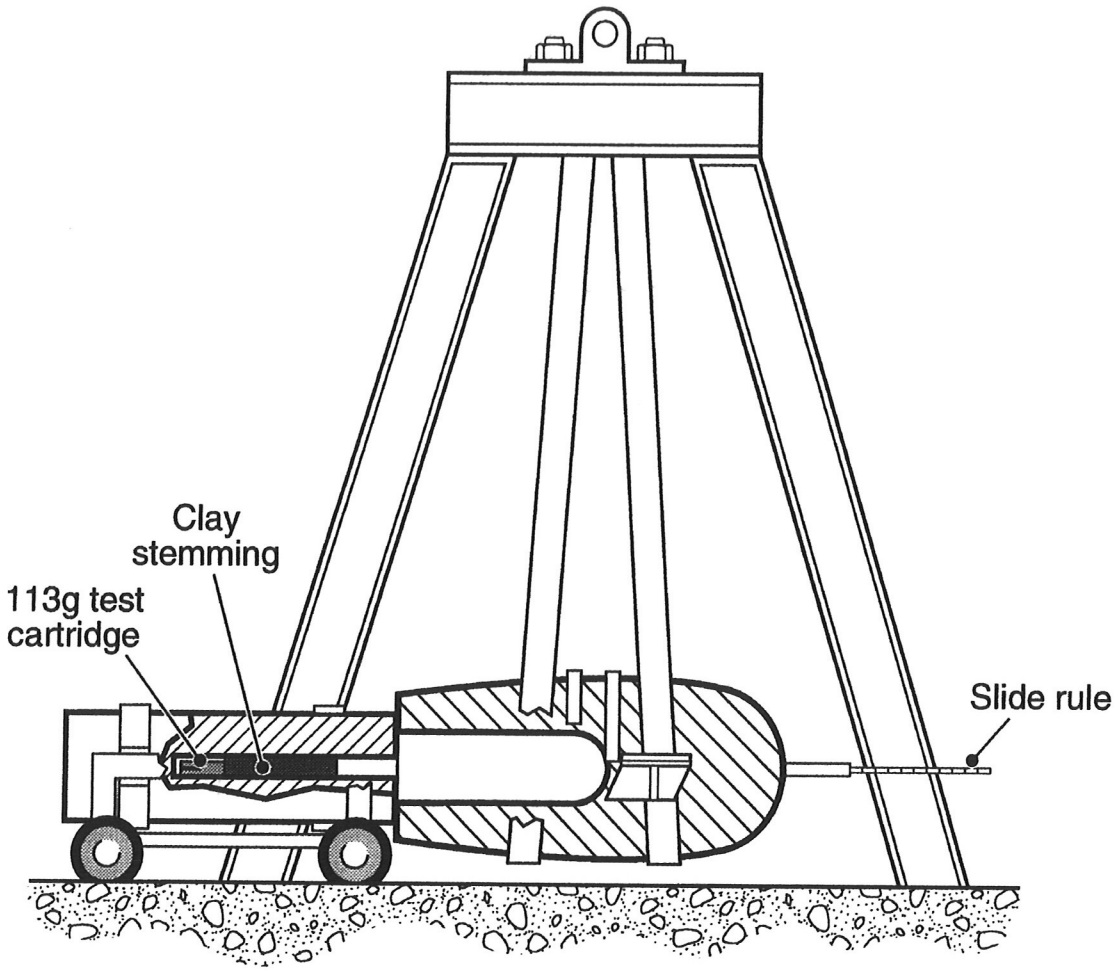
(v) The diameter of the cartridges

(vi) The weight of each cartridge (excluding the wrapper weight)

(vii) The actual pendulum swing for each shot.

(viii) The corrected swing for the test explosive.

(ix) The mean corrected swing for the test explosive.



THE BALLISTIC PENDULUM

BALLISTIC MORTAR AND BALLISTIC PENDULUM DATA

BALLISTIC MORTAR		BALLISTIC PENDULUM	
Mass (including suspension):	465 kg	Mass (including suspension):	5 Tonnes
Mass of shot	16.5 kg	Mass of dry clay stemming	0.9 kg (2 lb)
Mass of explosive sample	10 g	Mass of explosive sample	113 g (4 oz)
Calibrating explosive	Blasting Gelatine (BG)	Calibrating explosive	Special Gelignite (60 NS Gel)
Angle of recoil with BG	19° 25'	Deflection with 60 NS Gel	8.3 cm (3.27 in)

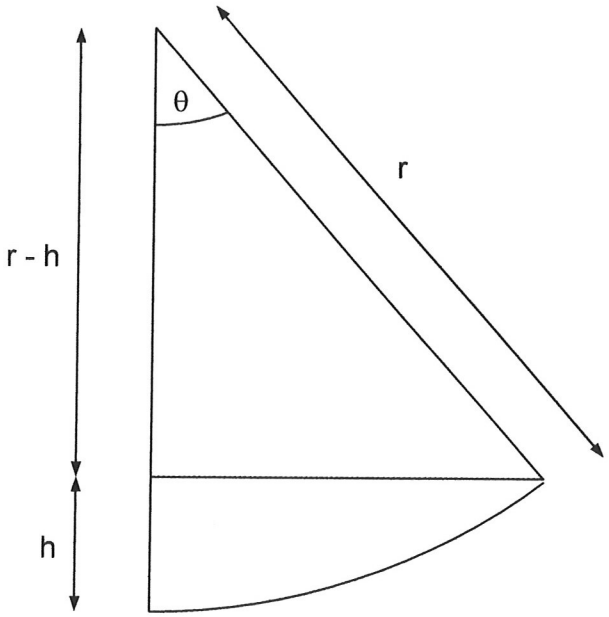
Composition of Blasting Gelatine		Composition of Special Gelignite	
Nitrogycerine	91.2 %	Nitroglycerine/nitroglycol	60.5 %
Nitrocellulose	8.2 %	Nitrocellulose	3.7 %
Chalk	0.6 %	Potassium nitrate	28.1 %
		Woodmeal	7.4 %
		Calcium carbonate	0.3 %

The ballistic mortar and ballistic pendulum assess the weight strength of an explosive by measuring the energy released by the detonation of a small quantity of the explosive and comparing it with the energy released by the same quantity of a powerful calibrating explosive.

With the ballistic mortar, the energy released by the explosive under test is proportional to 1- cos θ, where θ is the angle of recoil.

With the ballistic pendulum it can be shown that, for a small angle of deflection, the energy released by the explosive under test is proportional to the square of the linear deflection of the pendulum.

BALLISTIC MORTAR (principle of measurement)



r = radius of suspension

h = height to which mortar is raised

θ = angle of deflection at height h

m = mass of the mortar

g = acceleration due to gravity

$$\text{Cos } \theta = \frac{r - h}{r}$$

Therefore $h = r (1 - \cos \theta)$

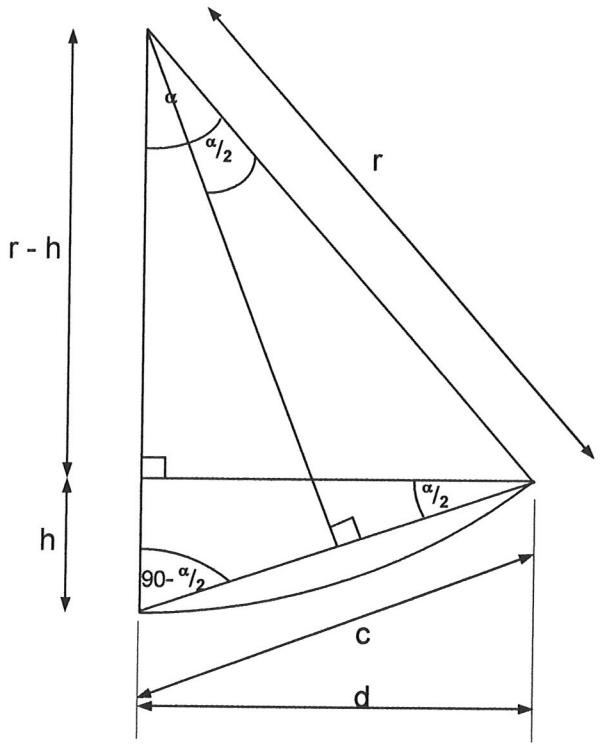
Energy to raise mortar to height h = mgh

Therefore energy = $mgr(1 - \cos \theta)$

$= K(1 - \cos \theta)$

where K is a constant for the mortar.

BALLISTIC PENDULUM



h = height to which the pendulum is raised

α = angle of deflection at height h

r = radius of suspension

d = linear deflection

c = length of the chord between the ends of the arc of swing

m = mass of the pendulum

g = acceleration due to gravity

$$\sin \alpha/2 = \frac{c}{2r} \qquad \text{\_\_\_\_\_(1)}$$

For a small angle α $$\sin \alpha/2 = \frac{d}{2r} \qquad \text{\_\_\_\_\_(2)}$$

$$h = c.\sin \alpha/2$$

Therefore from (1) $$h = 2r.\sin^2 \alpha/2 \qquad \text{\_\_\_\_\_(3)}$$

Energy to raise pendulum to height h = mgh

Therefore, energy $= mg.2r.\sin^2 \alpha/2$

But from (2) $$\sin^2 \alpha/2 = \frac{d^2}{4r^2}$$

Therefore energy $= \frac{mgd^2}{2r}$

$$= Kd^2$$

where K is a constant for the pendulum.

Colonel Eardley-Wilmot's 13 inch S.S. Mortar of 5 ton 0 cwt 1 qr of 1856

If you ask a member of the public whether Her Majesty's Government still has a use for Victorian cast-iron ordnance, outside a museum, he will laugh at you. If you ask a member of the Ordnance Society the same question, he will of course know better. Or will he?

The story begins during the Crimean war when in April 1855 the British Baltic fleet under Admiral Dundas bombarded Sweaborg in the Gulf of Finland. During this bombardment three 13 inch mortars split,having fired between 114 and 355 bombs. The remaining ten mortars, having fired between 129 and 311 bombs, ceased fire and the matter was refered back to the Board of Ordnance.

Colonel Eardley-Wilmot was instructed to design a new 13 inch mortar on more modern lines,eliminating the decorations of the old design by General Blomefield dating from 1805.

The design was approved in 1856 and Messrs Walker Co were instructed to cast one as a pattern for trials.

Trials were carried out in 1857 at Shoeburyness and the new mortar accepted for survice. The war being over, peace signed in March 1856, and the navy not having any mortar boats in commission, no further Eardley-Wilmot mortars were cast. Just the one was retained as a pattern for future reference.

In 1900 the Inspector of Explosives decided to copy the U.S.Bureau of mines and set up a ballistic pendulum for the testing the strengh of explosives for use in coal mines. The pendulum was set up at the Rotherham testing station using the Eardley-Wilmot 13 inch mortar. Between the wars pendulum and mortar moved to the Harpur Hill Research Establishment, near Buxton, to continue their working life.

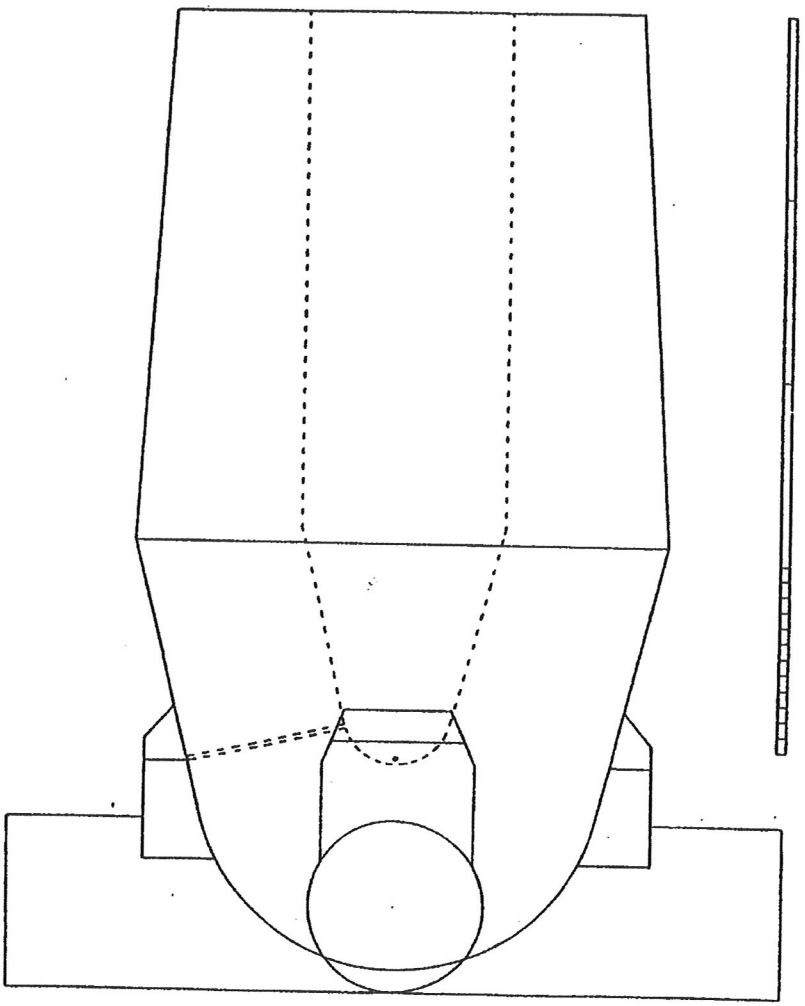
By kind permission of the Director of the Explosion and Flame Laboratory,H.S.E, Mr.B.J.Thompson, I was able to photograph and measure the Mortar. There I was shown this splendid piece of Victorian Ordnance, painted bright red and a bit splattered with clay, suspended in its harness.

It is 5 foot 4 inches long,compared with a Blomefield S.S. mortar's 4 foot 5 inches. There are no mouldings but like the earlier mortar it has a gomer chamber. It is clearly marked 100-1-0, 1856, and with the broad arrow proof mark. The vent issealed. On the left trunnion is "W.Co." and on the right "1". Clearly this is the original Eardley-Wilmot 13 inch mortar. Ninty years of use have left a small crater at the base of the chamber, but otherwise it's condition is excellent and it is clearly in good hands.

Although used only occasionlly these days it remains the only true link with the explosives of the past giving highly reproducable results. The method of use is to place a gun mounted on rails, with a 1.8 inch bore and loaded with a 4 ounce tamped charge, exactly two inches from the face of the mortar. On firing the gun recoils and the swing of the mortar recorded. For gelignite that swing today is 3.27 inches, just as it was in 1900.

The Eardley-Wilmot 13 inch mortar has had various names. The Wilford Wilmot mortar,(what Wilford's contribution was is not clear. He was, however, a senior officer which may be sufficient reason). The long sea service mortar,and the 101 hundredweight mortar.

It would be interesting to know whether the U.S. bureau of Mines or its successor still have their pendulum containing a 12.2 inch, 14.1 ton mortar. Perhaps one of our U.S. members can tell the society.



13 Inch Iron Sea Service Mortar, weight 100-1-0, cast 1856. Harper Hill, Bustow. ARC 91.