FURNACE BRICKWORK.

The development of refractory materials suitable to withstand the intense heat generated in the furnaces of oil-fired boilers has been dealt with in "Papers on Engineering Subjects," No. I, p. 8, where an account is given of the various tests to which the materials are subjected. The problems to be faced are somewhat different from those encountered in industrial furnaces where the refractories are not only exposed to the erosive action of molten metal and slag, but are also required to bear considerable loads due to the height of the structure involved, while in many cases their chemical composition requires special consideration in the light of possible reactions which may affect the purity of the product of the furnace.

The life of the furnace brickwork in oil-fired boilers is influenced by :—

(1) The high sustained furnace temperature.
(2) Rapid changes in temperature.
(3) Vibration caused by
  (i) Pulsation;
  (ii) Gunfire, &c.
(4) Incorrect or careless construction.

Gradual progress has evolved refractory bricks which will meet Naval requirements and under normal circumstances modern brickwork should last for several years without renewal, assuming that it has been properly built, has received proper care and that pulsation has been avoided.

The latest specification for the refractory bricks used in Naval boilers states that these must be made of the best fire-resisting insulating material, of good, sound quality and of the best description and capable of withstanding a temperature of 3,000° F. Further specified requirements are :—

> "Corners of bricks and tiles required square are to conform to this condition. No brick or tile will be accepted if buckled. No bricks which exceed specified dimensions by 1 per cent. or falls below the specified dimensions by $1\frac{1}{2}$ per cent. will be accepted.
>
> "Names of the makers of the bricks proposed to be fitted are to be submitted for approval and samples of the bricks are to be sent to Haslar Oil Fuel Depôt for examination and test if required.
>
> "Brickwork is to be constructed in an approved manner . . . the joints between the bricks are to be kept as thin as possible; the bonding material is not to exceed $\frac{3}{16}$ in. in thickness.
>
> "Sides of furnaces are to be bricked to a thickness of not less than $2\frac{1}{2}$ in. and for a distance of 6 feet from the front bricks 4 in. thick are to be used.

"Front and back casings are to be lined with bricks not less than 4 in. thick to the height of the highest combustion tubes and above this not less than 2 in.

"Brick pans are to have two layers of brick in the bottom, the top layer not less than $2\frac{1}{2}$ in. thick and the bottom layer not less than 2 in. thick."

The weight of the brickwork in a modern boiler is very considerable, amounting to some 7 tons in an average case. Much attention has therefore been directed towards the reduction of this item, but it has been found that the minimum weight per cubic foot of bricks that will satisfactorily withstand the necessary tests is about 115 lbs.

With regard to the general treatment given to fire bricks, it may be observed that as a rule insufficient care is taken in the stowing and handling of these articles and as a consequence a large number have edges and corners chipped, being then quite unsuitable for their intended use. These defects may be temporarily covered by pointing the finished brickwork, but service at sea quickly exposes them, and only undamaged bricks having sharp clean edges and corners should be selected for building new brickwork if a satisfactory life is to be obtained.

No description is required of the Service method of attaching the brickwork to the plating of the boiler casings other than to state that as far as possible each brick (except those laid on the horizontal floor or brickpan) is provided with a bolt recessed into the body of the material, the head of the bolt being protected by a plug of refractory material, while suitable material is introduced into the spaces between adjacent bricks.

The following terms, which are believed to be generally accepted, have been employed in this article in referring to the materials used for building up the furnace brickwork, viz. :—

"Bonding" is the material used as mortar between the bricks while "stopping" refers to that employed for filling the hole provided in the brick for the head of the securing bolt.

The nature and the method of application of the materials used for stopping and bonding merit some brief description in view of the unsatisfactory results which may obtain in the absence of the few necessary precautions, and these it is proposed to discuss in what follows.

Fireclay.—This material forms the essential basis of all bonding materials and no clay having a fusing point below 1,500° C. should be classed as fireclay. The best fireclays are obtained from the coal measures and after suitable treatment, including lengthy "weathering" or exposure to the air, are admirably suited for their purpose.

When used alone fireclay is subject to considerable shrinkage on being fired, and in order to reduce this effect ground bricks or potsherds (sometimes called " grog ") are often mixed with the clay to the extent of about one-third its weight.

Fireclay mixed with fresh or salt water sand has been used for bonding material in the past, but it has been decided that no sand of any description is to be used in future for " bonding " and " stopping." A small proportion of the right kind of sand may be advantageous when mixed with fireclay, but as sand is obtained from different sources, often without any form of inspection, it is a safer practice to avoid entirely the use of sand in any mixture required to withstand high furnace temperatures.

The effect of high temperatures on mixtures of fireclay and sand (the latter obtained locally at Malta) is shown in the photographs.

A special bonding and stopping mixture, consisting of fireclay, crushed brick and tough white clay, has been under trial for some time—*see* A.F.O. 1229/26. This mixture, known as the " Haslar mixture," when properly prepared and applied has given excellent results, but its success depends upon the careful drying and thorough mixing of the ingredients to a degree which has proved somewhat impracticable under service conditions.

Results, scarcely less satisfactory, have, however, been obtained from the use of a mixture consisting of equal parts of fireclay and crushed firebrick. The firebrick to be crushed may be selected from any used furnace brickwork provided neither glazed bricks nor those showing discolouration are used. The selected bricks should be crushed to the consistency of fine sand if required for " bonding " material and to that of coarse sand when to be used as " stopping " material.

It has been found that although mixtures of fireclay and crushed brick in the proportions 1 : 1 to 2 : 1 make a good " bonding " material, the proportion of 1 : 1 is preferable; it should, however, be noted that rigid adherence to these proportions is not absolutely essential, provided that the proportion of crushed brick is slightly less than that of the fireclay. The fireclay should be as dry as possible and should be intimately mixed with the crushed brick before water is added. The crushed brick should, if possible, be of similar material to that of the brickwork to be built up, preferably being manufactured by the same maker as the latter.

Bolt Hole Stopping.—When bricks are held in place by bolts, the result of any displacement of the stopping, that protects the head of the bolt from the flame, is serious, since if the bolt head becomes exposed, it may fuse, forming with the material of the brick a compound of comparatively low melting point, which will cut channels in the brickwork, so exposing the casing to the heat of the furnace.

In order to avoid this, it is essential that the " stopping " should be of the right mixture and carefully applied, the following procedure having proved effective. The coarse crushed firebrick should be mixed with the fireclay, sufficient water being then added to make a thick paste. The bolt holes should then be damped or washed with a thin wash of fireclay. Stopping should then be well rammed home, preferably by means of a suitable dished circular tool, and left with the "stopping" proud like a flush rivet.

It will be readily realised that if an air space is left the "stopping" will be forced out of place by the expansion of the air before a sufficiently high temperature to bake it has been reached, while if the "stopping" is too wet when applied, or of incorrect ingredients, the plug may shrink when fired to such an extent that it will drop out.

TESTS OF BONDING AND STOPPING MATERIALS.

The relative merits of various mixtures for stopping and bonding materials are well illustrated by the results of the tests here described.

Fireclay as drawn from Naval Store.

Sand obtained locally at Malta.

Crushed brick prepared from old used bricks from which glazing had been removed.

Experiment I.—Photograph 1.

Four pattern 25 bricks used.

Figures 1, 2, 3 and 4 show bolt hole "stopping".

Figures 5, 6, 7 and 8—"bonding" between the bricks.

The bricks were exposed to a temperature of about 2500° F. for 4½ hours in an oil fired furnace, then allowed to cool in the furnace.

Results as shown in photograph 1.

No.	*Stopping Material.*
1	Fireclay.
2	5 Fireclay, 1 Sand.
3	6 ,, 1 ,,
4	1 ,, 1 Crushed brick.

No.	*Bonding Material.*
5	6 Fireclay, 1 Sand.
6	Fireclay.
7	5 Fireclay, 1 Sand.
8	1 ,, 1 Crushed brick.

Experiment 2.—Results shown in Photograph 2.

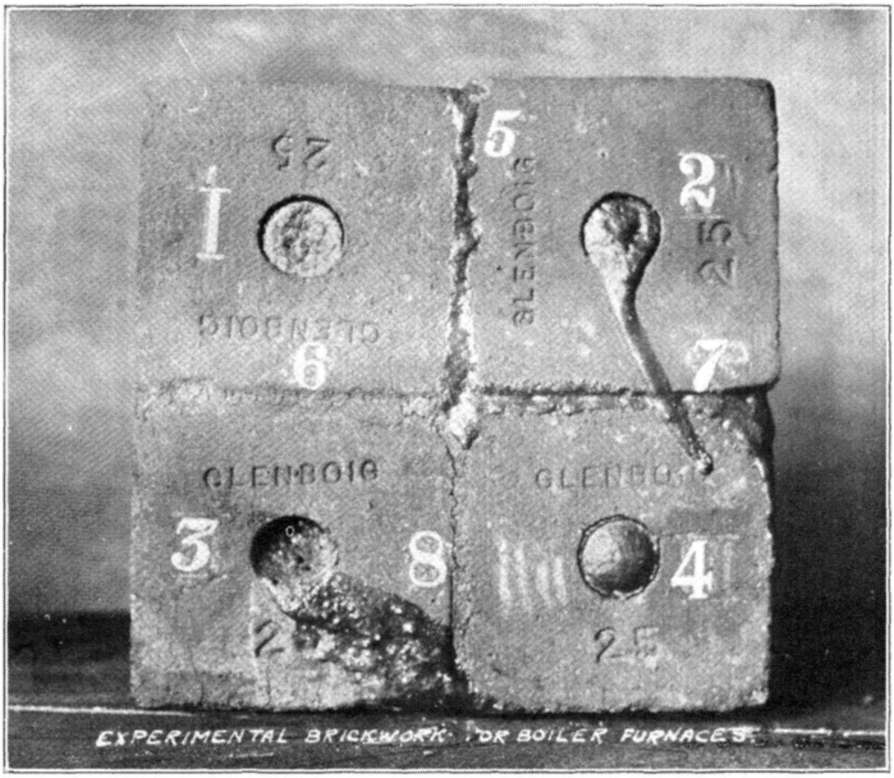
Same conditions as for 1.

No.	*Stopping Material.*
1	Fireclay only.
2	Fireclay, sand and crushed brick.
3	6 Fireclay, 1 sand.
4	5 ,, 1 ,,

[To face p. 6.

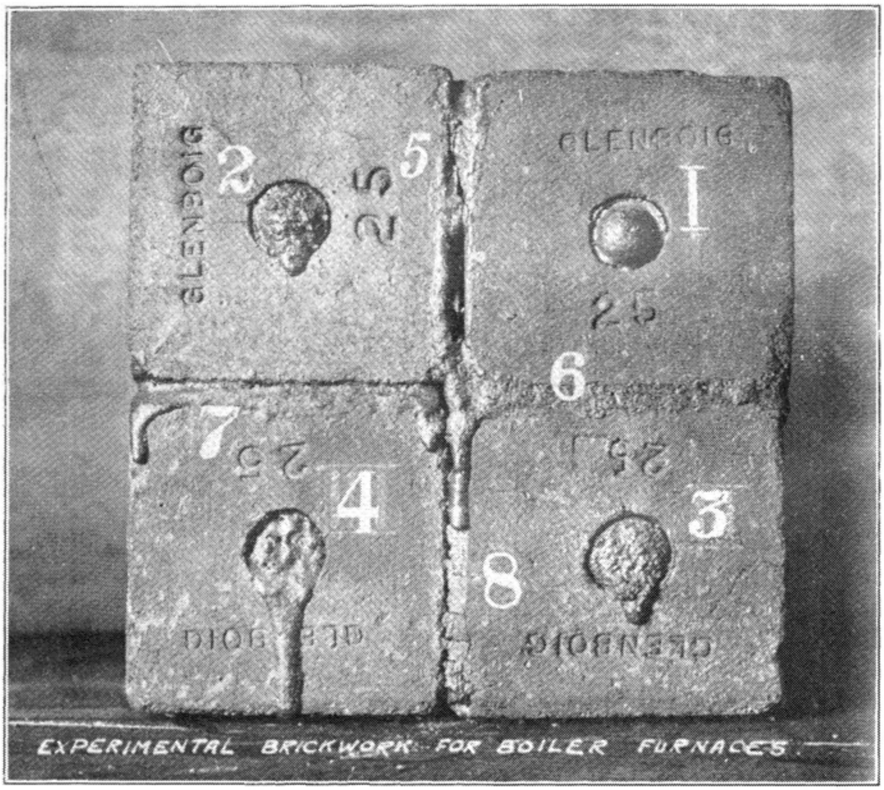
PHOTOGRAPH 1.

FRONT.



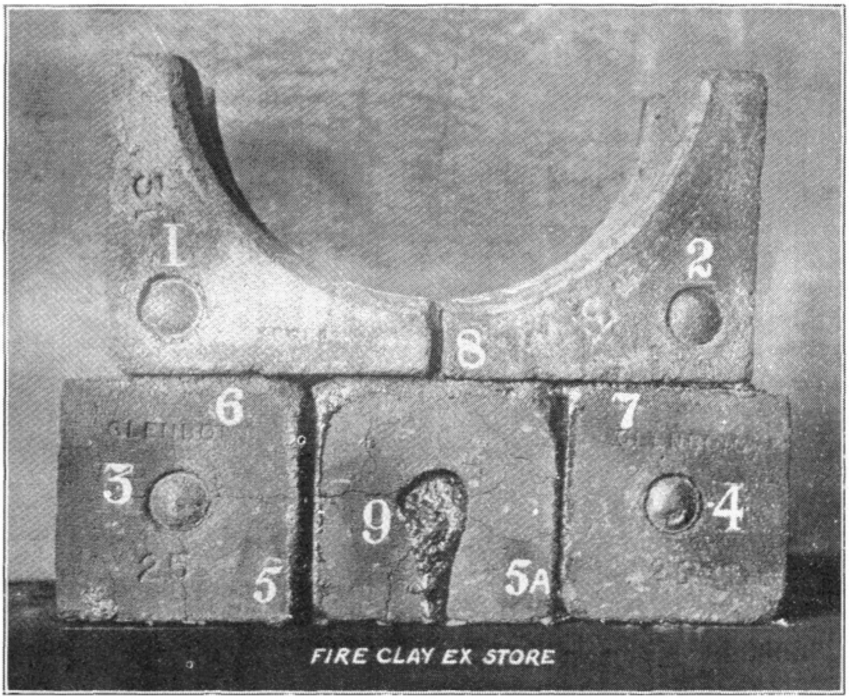
PHOTOGRAPH 2.

BACK.



Photograph 3.

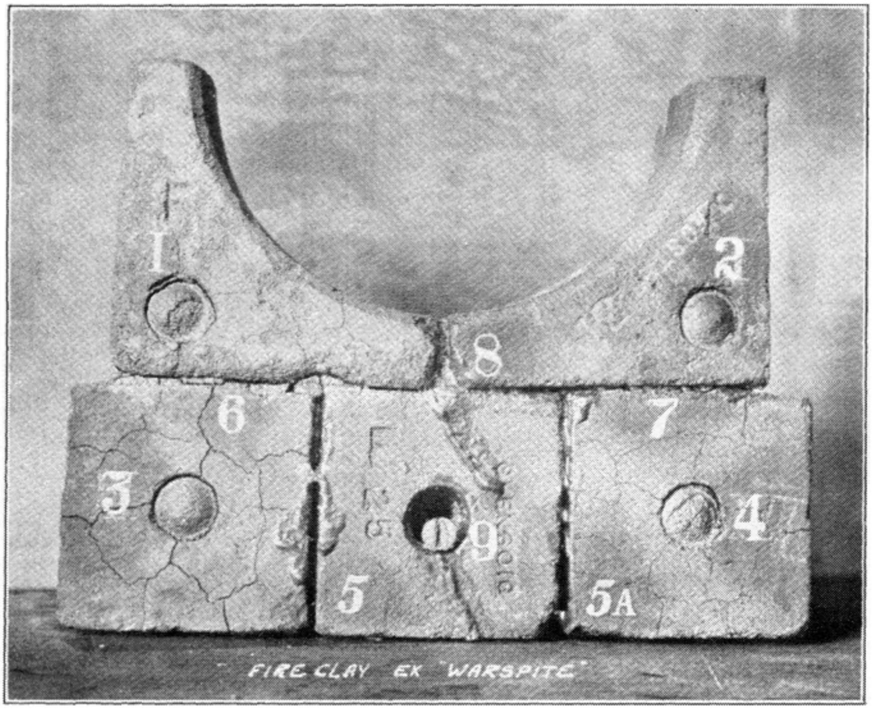
Back.



To face p. 7.]

PHOTOGRAPH 4.

FRONT.



No.	*Bonding Material.*
5	6 Fireclay, 1 Sand.
6	1 ,, 1 Crushed brick.
7	5 ,, 1 Sand.
8	Fireclay.

Experiment 3.—*Results shown in Photograph* 3.

Bricks were patterns 25 and 31 and treated as in Experiment 1.
Nos. 1, 2, 3, 4 & 9.—Bolt hole stopping.
Nos. 5, 5*a*, 6, 7 & 8.—Bonding between bricks.

No.	*Stopping Material.*
1	Fireclay.
2	1 Fireclay, 1 Crushed brick.
3	1 ,, 1 ,, ,,
4	Fireclay.
9	2 Fireclay, 1 Sand.

Note.—Plug fused.
Bolt burnt through shank.
Bolt head can be seen.
Channel cut in brick.

No.	*Bonding Material.*
5 & 5*a*	2 Fireclay, 1 Sand.
6	Fireclay.
7 & 8	8 Fireclay, 1 Sand.

Experiment 4.

Same conditions as for Experiment 1.
Bricks as in Experiment 3.
Results shown in Photograph 4.

No.	*Stopping Material.*
1 & 4	Fireclay.
2 & 3	1 Fireclay, 1 Crushed brick.
9	2 ,, 1 Sand.

No.	*Bonding Material.*
5 & 5*a*	2 Fireclay, 1 Sand.
6	Fireclay.
7 & 8	8 Fireclay, 1 Sand.

Bonding.—For this the Fine Mixture made up into a paste is used. The bricks are first damped, those on the floor of the furnace being laid as close together as possible in order to minimise the thickness of the jointing. In the case of bricks secured by bolts, care should be taken that these are not screwed up too tightly. The thickness of jointing for these bricks should be kept as small as possible and in no case should exceed $\frac{3}{16}$ in. The jointing material should be proud of the brick face and should be smoothed down in such a manner as to cover the edges of the bricks. If the bonding is not finished off in this manner the flame will tend to burn away the exposed edges of the bricks and eat in behind the bonding material which thus becomes loosened.

Patching.—This is done with the Medium or Fine Mixture, made up in the form of a stiff paste. Great care should be taken that all fused or glazed portions of the brick are chipped away, leaving only a good surface, while the bricks should be undercut where this is possible. The defective portion is then damped and the mixture rammed into place with a wooden wedge or other suitable tool. If after steaming slight cracks are observed it is advisable to fill them with a similar mixture made up into a slurry and the whole washed over with a brush.

Glass, Ganister and Iron.—The use of these materials in the stopping appears to cover the surface of the brickwork with a hard glazed layer; at the same time the glaze so formed penetrates the brick, this effect being most marked in the case of the iron and least in the case of glass. With continued steaming these substances, which have a lower fusing point than the brick, become molten, and tend to flux the brickwork: channels are thus formed in the walls by the molten material, which may also cut its way through the brick floor.

Fireclay Wash.—In order to protect the face of the brickwork from surface cracking, it is desirable to apply a thin wash of fireclay, which should be thin enough for application with a brush, its purpose being merely to fill the surface pores of the brickwork. If it is applied in sufficient thickness to form a surface layer on the bricks, it will merely harden and then crack off, removing portions of the brick face in the process.

"METHOD OF TEST OF FIREBRICKS EMPLOYED AT THE LIQUID FUEL EXPERIMENTAL WORKS, HASLAR."

A brief description of the methods employed for testing fire bricks is appended as a matter of interest, being divided into three main sections, viz.:—

(1) Cold Test.
(2) Hot Test.
(3) Conductivity Test.

"Cold Test."

On receipt of sample of bricks for test they are carefully examined, the points requiring particular attention being:—

(*a*) General finish and manufacture.

(*b*) Agreement with standard dimensions as laid down in Lithograph book of drawings, particulars etc., revised January 1919.

The bricks are dried over a slow fire till all the moisture has been driven out.

One sample brick is then taken for test of porosity, the test being carried out as follows :—

The brick when thoroughly dried is weighed, it is then soaked in a tub of water for 24 hours, so that it is completely saturated, and again weighed, the percentage of porosity is then taken as being :

$$\frac{\text{Weight wet minus weight dry} \times 100}{\text{Weight dry.}}$$

The percentage should not as a rule exceed 10.

A cold dropping test is then carried out. The brick in a thoroughly dry state is dropped on to a flat concrete floor from a height regulated according to the weight and structure of the brick.

Three drops are made, should the brick break at the first drop, the largest portion is dropped a second time, and similarly for the third drop. A brick, or part of a brick which breaks into eight or more pieces on any drop is considered "shattered," and its rejection is considered, further dropping tests being made on a fresh sample to confirm the results first obtained. Observations made during the dropping test allow estimates to be made of the general toughness and strength, and an inspection of the fracture is made for examination of the internal structure of the brick. (A brick that does not break during the dropping test is broken by force).

The bricks are then tested for their property of being cut or shaped.

This completes the cold test.

"Hot Test."

Samples of bricks which have not been treated in any way, except that they have been dried over a slow fire on first receipt, are placed on the floor of a specially constructed, bricklined, oil fired furnace.

The oil spray from the burners does not impinge on the bricks, but they are subjected to the heat of the furnace on all sides.

Procedure of burning Test.

Time.	*"Procedure."*
8 hours	Furnace lit up and temperatures gradually raised to 2500° F. and there maintained.
16 hours	Furnace died out.
8 hours	Furnace lit up and temperature gradually raised to 2700°F. and there maintained.
16 hours	Furnace died out.
4–5 hours	Furnace lit up and temperature gradually raised to 2850°F.
	Completion of burning test.

The bricks are under continual observation during the burning test, and are first examined in place, special attention being paid to flaking, cracking, fusing, glazing and distortion.

Seger cones are placed in the furnace, and are so graded that the temperature can be noted.

The bricks, after removal from the furnace, are subjected to a hot dropping test similar to that made when cold. Notes are made of the results and the bricks if not already fractured, are broken for the examination of the interior. Bricks after the hot test should be able to be cut without becoming friable.

In addition to the above hot test, it is the custom to test a sample of each consignment in the special oil fired crucible, in which a heat of over 3000°F. is quickly raised. This test, known as the "Fusing Test," is always applied to the initial supplies of bricks from any new source, and is used also as an occasional check on later consignments.

A retest is practically always made of any brick which shows grave faults, and no bricks are condemned unless two or more of the samples show similar defects.

Insulation Test.

The brick to be tested is placed in a lagged chamber. On the upper side of the brick a copper vessel containing water and a delicate thermometer is placed. A flame is applied to the under side of the brick and the rise of temperature of the water in the copper vessel noted at intervals for half an hour, care being taken to prevent heat reaching the upper side by leakage past the sides.

This test has proved to be very necessary in that some materials, which are pre-eminent in their refractory qualities, are unfortunately comparatively poor insulators of heat.