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The Properties and Service Performance of Quarl-block Materials

W. McCLIMONT, B.Sc. (Member)* and H. M. RICHARDSON, B.Sc.†

The chemical and physical properties of a number of refractory materials have been determined in the laboratory and the durability of mouldable, castable and pre-fired burner quarls has been compared in five steamships. After service trials extending over a period of 2½ years it has been concluded that mouldable materials gave better service than either castable or firebrick quarls, but that both castable and pre-fired sillimanite quarls gave better service than firebrick. The deterioration of the quarls was caused mainly by thermal spalling; attack by slags or fuel ash was not a major cause of quarl-block deterioration.

INTRODUCTION

In oil-fired marine boilers, the quarl blocks, surrounding the burner openings, normally give shorter service than other parts of the furnace refractory lining. Service trials have, therefore, been carried out with various refractory quarl materials, with the object of obtaining data whereby the performance of quarl blocks might be improved. At the time of initiation of these trials, the two major causes of quarl failure were considered to be slag erosion and spalling, i.e. cracking caused by thermal shock. Trials were planned, therefore, in cross-channel and ocean-going vessels, as it was considered that the cross-channel steamers would provide conditions of severe thermal shock and it was hoped that the conditions in the ocean-going vessels would emphasize the effect of slag erosion.

A number of castable and mouldable refractories have been tested in the laboratory and some of these materials have been used as quarl blocks and their behaviour compared with that of normal firebrick and sillimanite quarls in the various boilers.

PROPERTIES OF THE REFRACTORY MATERIALS

1) *Fired Bricks*

Two firebricks and a sillimanite brick were included in the experiments. Firebrick A was a 42 per cent alumina-content brick of refractoriness 1,760 deg. C. and percentage apparent porosity in the range 22 to 25. Firebrick B was a 38 per cent alumina-content brick of refractoriness 1,710 deg. C. and apparent porosity in the range 18 to 23 per cent.

The sillimanite brick was a 60 per cent alumina material with a percentage apparent porosity of 32 and a very high refractoriness (>1,800 deg. C.).

2) *Mouldables and Castables*

Samples of the mouldable and castable materials were examined in the laboratory. Both the chemical and physical properties were determined, and are given in Tables I and II.

The materials were classified by the manufacturers as medium, high-duty, or super-duty materials according to the recommended service hot-face temperature given in Table I.

TABLE I.—CHEMICAL ANALYSES

	Mouldable				Castable				
	C	E	F	X	G	H	J	Z	V
SiO_2	49·76	39·70	33·46	45·00	38·42	39·29	27·24	40·71	43·50
TiO_2	3·76	1·22	1·46	1·38	2·76	3·83	1·30	1·30	1·75
Al_2O_3	38·64	52·56	59·78	46·36	41·06	41·30	64·04	28·78	41·00
Fe_2O_3	3·64	1·16	1·26	1·65	5·64	6·14	0·96	6·59	4·40
CaO	0·22	0·31	0·09	0·24	8·87	7·46	3·88	10·18	6·00
MgO	0·51	0·37	0·23	0·56	1·42	1·15	0·22	0·90	0·90
Na_2O	0·18	0·21	0·66	0·22	0·17	0·18	0·13	0·34	—
K_2O	0·31	1·56	0·88	1·04	0·26	0·23	0·73	1·11	—
Li_2O	0·05	0·05	0·03	0·05	0·05	0·05	0·06	0·05	—
Loss	3·14	3·12	2·73	3·80	0·25	0·21	1·52	9·36	—
Service temp. (deg. C)	1,450	1,600	1,600	—	1,200	1,200	1,600	—	1,350

This paper presents the results of the work, after some of the trials had been in progress for 2½ years; it is interesting to note that it was soon observed that slag erosion was not a major cause of quarl deterioration.

The high-duty mouldable C was essentially a mixture of fire-clay and ground firebrick, but mouldables E, F, and X, classed as super-duty, contained a mineral of higher alumina content, as well as the clay. The medium or low duty castables G, H, and V, contained an iron-bearing calcium aluminate hydraulic cement, but the super-duty castable J contained a more refractory white calcium aluminate cement, as well as a mineral of high alumina content. Material Z was found in service in a

* Principal Assistant Marine Engineer, British Shipbuilding Research Association.
† Senior Principal Scientific Officer, Refractories Division, British Ceramic Research Association.

TABLE II.—SIEVE ANALYSES

Sieve size	Percentage remaining on each sieve						
	C	E	F	G	H	J	V
on 5's	8·2	3·5	15·3	17·0	18·7	7·2	9·2
—5 +10	26·1	19·6	28·4	30·4	32·3	19·0	25·3
—10 +16	10·9	23·0	12·3	9·9	5·9	12·2	12·0
—16 +30	7·6	8·6	10·4	4·7	5·2	11·8	14·6
—30 +60	4·5	6·6	8·1	3·7	3·7	11·7	9·5
—60 +100	2·1	2·8	3·7	1·7	2·1	5·2	4·3
—100 +200	2·3	2·1	2·6	4·2	5·2	4·7	5·4
—200	38·2	33·4	22·0	28·2	26·8	28·3	19·7

vessel and would otherwise not have been chosen as a trial material, its source was unknown and its refractoriness was very low (1,300 deg. C.).

3) *Physical Analyses*

The type of grading used in the various materials was generally very similar indeed and this was shown in the sieve analyses. All showed rather high percentages of coarse and fine, with a low percentage of medium-grade material.

4) *Behaviour on Heating at High Temperatures*

The two castables G and H began to soften at 1,400 deg. C. and were almost molten at 1,450 deg. C. Test pieces of the ramming materials C, E and F and the castable J were heated for 1 hour at 1,550 deg. C. and 1,600 deg. C. The results are shown in Table III.

TABLE III

Firing temperature, deg. C	Per cent contraction (—ve) or expansion (+ve)			
	C	E	F	J
1,550	+1·7	—1·5	+0·7	N.D.
1,600	Bloated	—2·8	+2·8	—3·6

5) *Resistance to Thermal Shock*

Spalling tests have been made on specimens, 5 × 3¼ × 3¼in., prepared from the mouldable and castable materials and fired at temperatures between 600 deg. and 1,400 deg. C. Specimens were heated from one end only and the heating rate, at which cracking occurred, was determined by use of a sonic method, the natural frequency of vibration of the specimen showing a marked change when the specimen cracked. The results obtained are given in Table IV.

TABLE IV

Material	Firing temperature, deg. C	Heating rate at which crack occurred, deg. C per minute
C	1,400	5
	1,200	5
	1,000	5
	800	10
	600	20
E	1,400	15
	1,200	20
	1,000	25
	800	25
	600	20
F	1,400	15
	1,200	20
	1,000	20
	800	20
	600	25
J	1,400	15
	1,200	25
	1,000	25
	800	40
	600	40

It will be noted that the safe heating rate decreased as the firing temperature was increased. Firebrick specimens of the same size cracked when heated in the range 5 deg. to 10 deg. C./min., but sillimanite materials may withstand heating rates of 20 deg. C./min. It should be realized that the safe rate of heating depends on the size of the test specimen, so that large quarl shapes would be expected to crack on heating, at slower rates than those listed in Table IV.

6) *Cold Crushing Strength*

Unfired castables may develop a cold crushing strength up to 7,000lb./sq. in. Firebrick and sillimanite bricks generally have crushing strengths greater than the values for mouldables and castables, which are shown in Table V, but it is significant

TABLE V.—CRUSHING STRENGTHS OF MOULDABLE AND CASTABLE MATERIALS

Material	Temperature of firing, deg. C				
	600	800	1,000	1,200	1,400
C	900	1,090	1,700	1,490	1,980
E	340	1,050	—	950	1,040
F	N.D.	1,140	1,770	1,370	N.D.
H	2,700	2,620	2,090	1,600	—
G	2,340	2,690	2,490	1,700	—
J	1,130	1,200	680	570	2,210

Values in lb./sq. in.

that at least one specification for the strength of firebricks demands a cold crushing strength of 2,000lb./sq. in.

SERVICE QUARL BLOCK TRIALS

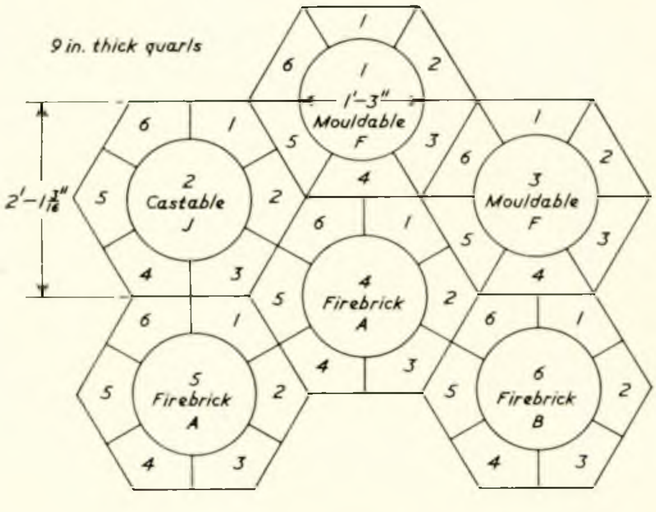
(Data on boiler performance is given in Table VI.)

Ship 1. Cross-Channel Steamer

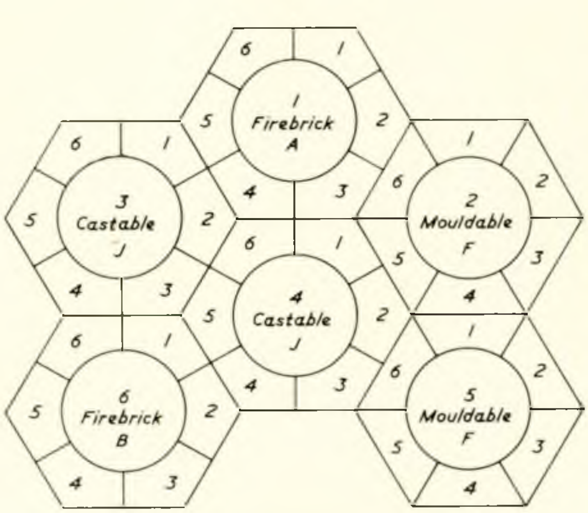
The steamer has two Foster Wheeler D-type boilers, each with six Wallsend burners; each burner usually has six quarl bricks. The arrangement and size of the quarls are shown in Fig. 1, which also gives the materials used at the commencement of the trial in May 1957. Firebricks A and B spalled after relatively short periods of service; it was therefore possible to replace these and, at later dates, the castable quarls with castables G and V, mouldable C, sillimanite bricks, and also a castable of type H. The condition of some of the quarls in December 1957 is shown in Fig. 2, and the condition of all the quarls of the starboard boiler in April 1958 is shown in Fig. 3.

The result of the trial is shown in Fig. 4 where the superiority of the mouldable materials can be seen readily. The firebricks A and B always had to be replaced, because of the severe damage caused by the spalling of the blocks. The castable J gave longer service than the firebricks, but became weak and friable during use. The castable type H developed strength during use and had spalled badly when inspected in January 1959, but castable G was in fairly good condition when inspected at the same time. It was thought, however, that it might not remain in sufficiently good condition for the 12 months that would elapse before the next repair period and it was therefore replaced by castable V. The sillimanite bricks also gave better service than the firebricks, although cracks developed during service. It was necessary to replace the sillimanite quarls because, when disturbed for refitting, or when other type quarls were removed during repair periods, the cracks opened up and the quarls broke into two or more pieces. The mouldable C in the port boiler, burner No. 2, was replaced because the anchorage had failed, although the refractory itself was still in excellent condition.

The quarl blocks were generally free from slag and no serious slag attack had taken place even after 2½ years service. There was some slag on the No. 1 burner quarls in both burners and this penetrated cracks in the sillimanite quarls, that were replaced in January 1959, but the failure had not been caused by the slag deposit. The mouldable F had also resisted the slag deposit; it developed strength gradually throughout the trial and the expansion cuts opened up slightly;

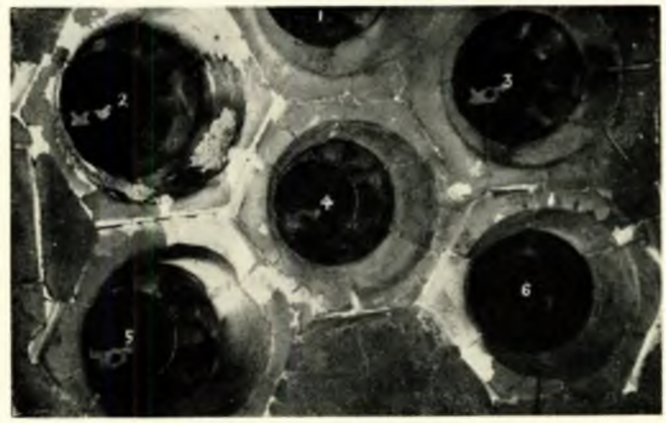


PORT-LOOKING FROM INSIDE FURNACE



STARBOARD

FIG. 1—*Ship 1. Arrangement and size of quarls*



Port boiler

Starboard boiler

FIG. 2—*Ship 1. Condition of quarls in December 1957*

Starboard boiler

FIG. 3—*Ship 1. Condition of quarls in April 1958*

after 2½ years some pieces had broken away and it was cut out and repaired using the same grade of material.

Ship 2. Cross-Channel Steamer

Ship 2 has two Foster Wheeler D-type boilers with a cluster of seven burners in each boiler. The burner arrangement is very similar to that in Ship 1, but with seven burners instead of six. The front walls of the boilers and the quarls were originally built with brickwork, but the bricks failed by spalling in a matter of weeks. The front walls and the quarls were then lined with a mouldable refractory (material X) which gave a life of six years, although the quarls did need patching from time to time.

It was decided to rebuild the quarl area in one of the boilers; the front wall from a distance of about 2ft. above the burners to floor level was removed and two mouldable refractories were used in the rebuild. Material X, which had been used previously so successfully, was again used for half the area, including four of the burners, and material E was used to build the remaining half of the wall, including three burners. There was a vertical joint between the two materials down to floor level.

The materials were supported with heat-resisting metal anchors and were both treated in the same way by the same

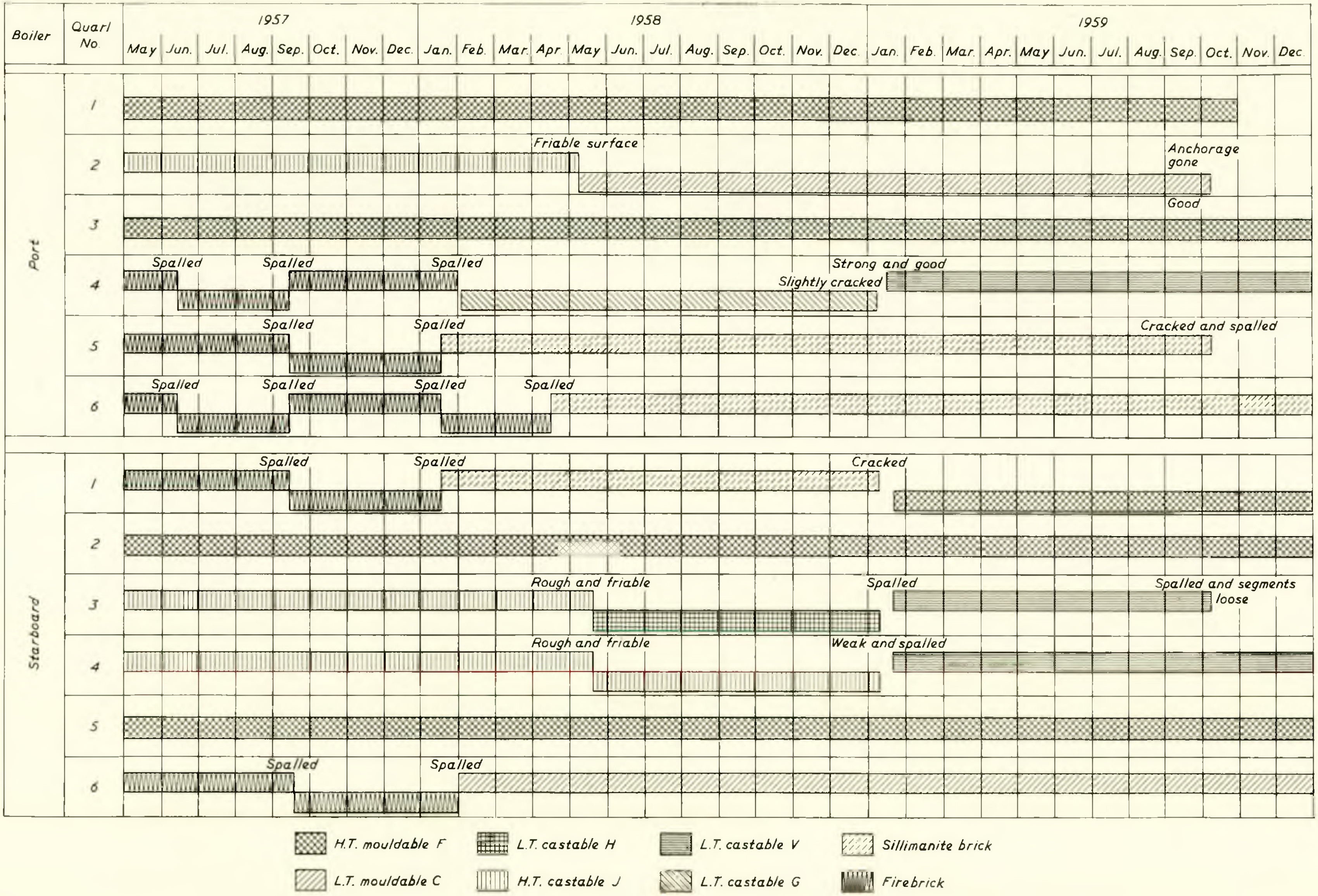


FIG. 4—*Ship 1. Quarl test. Staggered sections represent span of quarl life*

TABLE VI.—DATA ON BOILER TYPES AND PERFORMANCES

	Ship 1	Ship 2	Ship 3	Ship 4	Ship 5
Type of boiler	Foster Wheeler watertube type with water-cooled walls and superheater	Foster Wheeler watertube type with water-cooled walls, superheater, desuperheater, and economizer	Babcock and Wilcox singlepass watertube boiler with interdeck superheater and tubular air heater	Babcock and Wilcox marine sectional header singlepass, with interdeck superheater and tubular air heater	Babcock and Wilcox marine sectional header single-pass, with interdeck superheater and tubular air heater
Date of construction	1948	1949	1956	1953	1955
Output per boiler per hour	66,000 lb	95,000 lb	54,000 at service power	42,250 at service power	42,250 at service power
Furnace volume, cu. ft. per boiler	835	735	860	690	690
Projected radiant heating surface, sq. ft., per boiler	275	225	333	136	136
Oil-fired, lb./hr. per boiler at full power	4,300	6,000	3,800	2,910 at service power	2,910 at service power
Type of draught	Forced (closed stokehold)	Forced (closed stokehold)	Balanced	Forced and preheated	Forced and preheated
Type of burners	Wallsend pressure type	Wallsend pressure type	Wallsend-Howden centrifugal atomizers	Wallsend-Howden pressure system, Z-type	Wallsend-Howden pressure system, Z-type
Number of burners per boiler	6	7	5	5	5
Oil-fuel pressure: Builder's fullpower trial	166 lb./sq. in.	163 lb./sq. in.	—	—	—
On service	150 to 200 lb./sq. in.	150 to 250 lb./sq. in.	310 lb./sq. in.	150 to 250 lb./sq. in.	150 to 250 lb./sq. in.
Oil-fuel temperature: Builder's fullpower trial	182 deg. F	192 deg. F	—	—	—
On service	190 to 195 deg F	213 deg. F	210 deg F	Various, Redwood 1 viscosity 100 to 160	Various, Redwood 1 viscosity 100 to 160

workman. The wall was inspected after moulding and after the first firing and both sections appeared to be in very good condition when the ship went into service on 30th December 1957. Fig. 5 shows the condition of the front wall at this time and also serves to indicate the burner arrangement. After three weeks service, in which daily sailings across the Channel had been made, the boiler was again inspected. A crack had now appeared at the junction of the two materials, but both had behaved in a similar way. The wall was in good condition, but a few small cracks had formed down the quarl cone radially, but not parallel to the wall surface. The cracks appeared in about equal numbers in the two materials, in segments where the radial cuts had been made a fairly large distance apart.

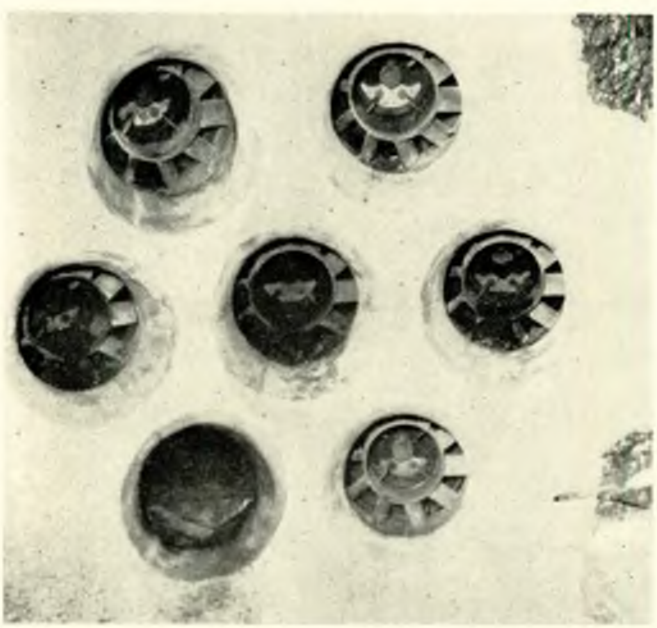


FIG. 5—*Ship 2. Condition of front wall in December 1957*

The boiler was again inspected on 17th April 1958; the ship was still in service, making one Channel crossing per day, except during the Easter period when extra sailings were required. Material X was still in very good condition, with some radial cracks at the quarls, but none parallel to the wall surface. Material E was now friable and weak; it had cracked parallel to the wall surface in at least two places, with the result that pieces of the rammed quarls were now loose. Carbon had been deposited on some of the cones and the poker had abraded some of material E away.

The chemical analysis indicates that material E contains less clay that material X because of its lower loss on ignition. The higher alumina content of E indicates that E would need a higher temperature to develop its maximum strength. The strength measurements indicate that E is a weak material. It is therefore suggested that the temperature in the boiler was not sufficient to strengthen mouldable E, but that X had sufficient clay to give it greater strength. Material E would possibly resist slag attack better than X, but there was no slag on this front wall.

Ship 3. Troop Carrier

This troop ship, making voyages to Hong Kong, has four Babcock and Wilcox header boilers, each containing five burners arranged in a straight line.

When the boilers were first inspected some of the quadrant-type quarl blocks were made from firebrick A (42 per cent alumina) and others were in a castable. A 42 per cent alumina brick had been built above the burner quarls. These bricks had spalled badly and were covered with slag that did not penetrate far into the bricks; the quarls were also covered with slag.

The ship was chosen for a trial because of the presence of the slag and also because the front wall generally needed rebuilding. The chemical analysis of a slag dropper taken from above the quarls was:

SiO_2	46·7	MgO	1·6
TiO_2	0·8	Na_2O	6·1
Al_2O_3	31·6	K_2O	2·1

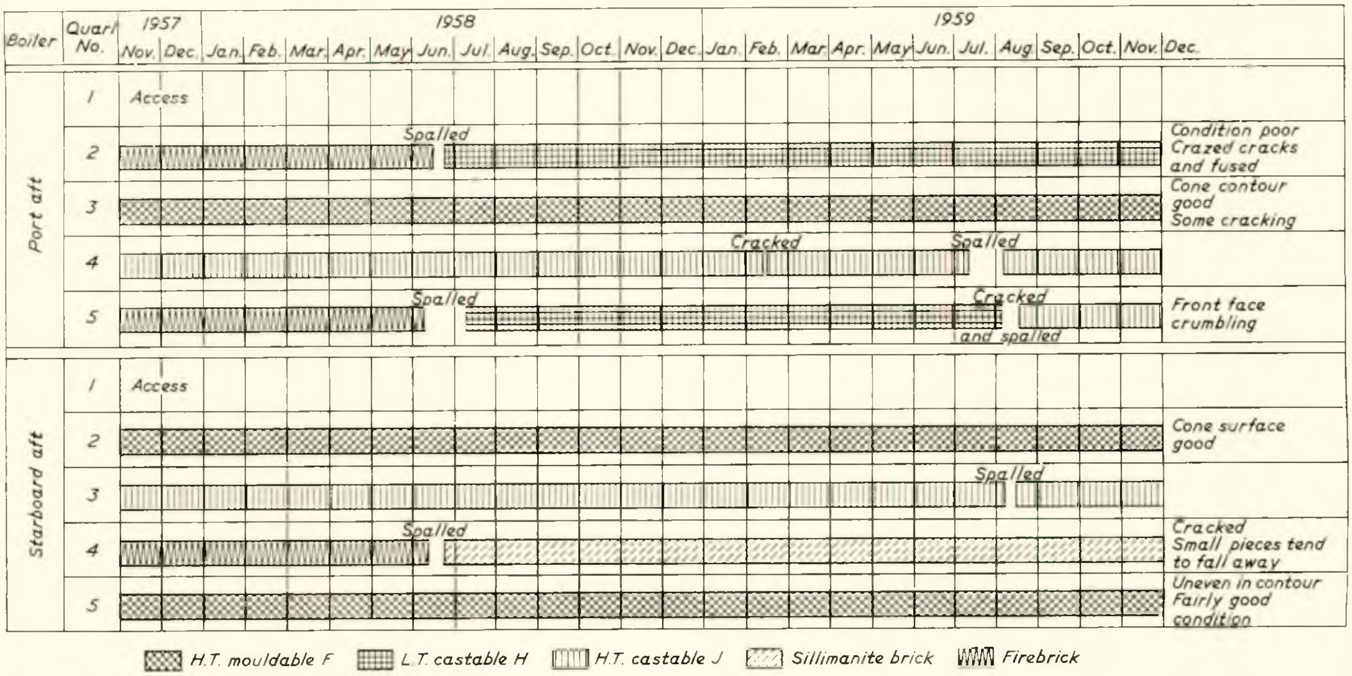


FIG. 6—*Ship 3. Quarl test*

Fe_2O_3	5·9	Cr_2O_3	0·3
CaO	0·8	V_2O_5	2·3

The two aft boilers were fitted for trial, with the front walls built in high-temperature mouldable F and the quarls arranged as follows:

Port aft: Burner No.
- 1 (access) Castable Z
- 2 Firebrick A
- 3 H-T mouldable F
- 4 H-T castable J
- 5 Firebrick A

Starboard aft: Burner No.
- 1 (access) Firebrick A
- 2 H-T mouldable F
- 3 H-T castable J
- 4 Firebrick A
- 5 H-T mouldable F

The results of the trials in the two aft boilers are shown in Fig. 6 and again the superiority of the mouldable material is apparent. The access quarls have not been included because they were different from the other burner quarls in shape and size, and cracked material could be easily displaced. However, it was very apparent at the first inspection, after only one return voyage, that castable Z was not refractory enough for the required service; the quarls had fused severely. The condition of all the quarls in January 1958 after one return voyage is shown in Fig. 7.

It was disappointing that the quarls were generally free from slag and no severe slag attack had taken place. At the end of the trial the mouldable F material was still in position. Although the front surfaces were uneven and tended to crack, the cone surfaces were generally in good condition. The sillimanite quarl had given much longer life than the firebrick, but was cracked and small pieces tended to fall away. The castable materials had cracked and spalled after giving longer service than the firebrick.

The two forward boilers had been fitted in April 1958 with castable J quarls, except that sillimanite quarls were used in No. 3 burner in the port boiler. Very little comparison of quarl materials could therefore be made. The sillimanite quarls were still in service in October 1959, although all the surfaces showed cracks and small pieces tended to fall away; some of the castable quarls had been replaced in February and August 1959 because of spalling damage, but many were still in service.

Ship 4. Cargo Vessel

The two Babcock and Wilcox single-pass header boilers, in this cargo vessel, were each served by five Wallsend burners arranged in a straight line. The vessel made trips to South African ports.

The quarl block trial commenced when quarls were fitted in June-July 1958, and inspection was made in October 1958 after the first return journey to South Africa and subsequent inspections of the quarls were made in March, August and November 1959. The condition of the quarls in November 1959 is shown in Fig. 8.

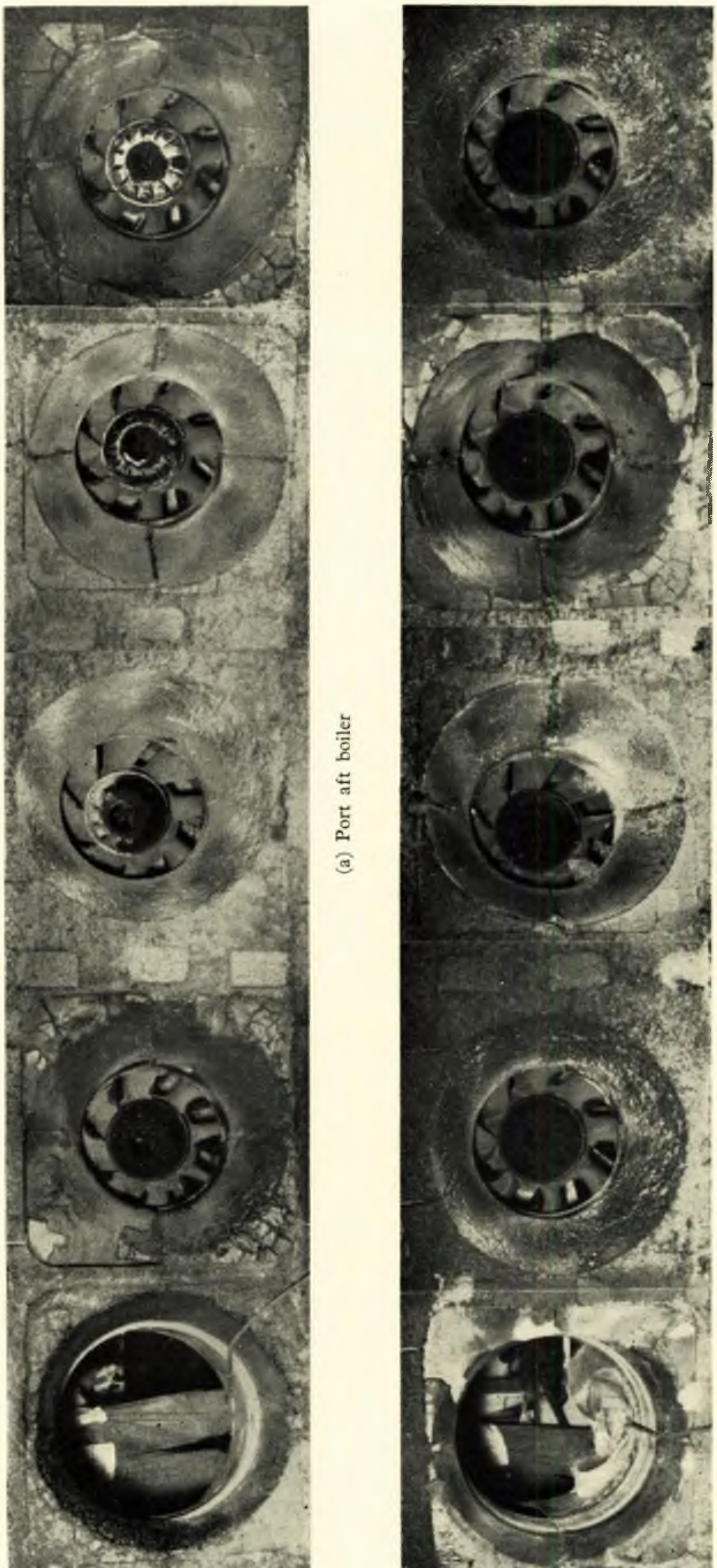
Each burner was surrounded by four quadrant-shaped quarl blocks and firebrick; mouldable and castable materials were fitted. During the quarl trials it was possible to take temperature measurements in the quarl blocks around the second burner in the port boiler, i.e. next to the access burner, and the maximum temperature recorded during trial coastal runs was 1,260 deg. C., but temperature fluctuations of up to 30 deg. C./min. were noted.

The various quarl materials were arranged as follows:

Port boiler: Burner No.
- 1 (access) Firebrick A
- 2 Firebrick A
- 3 Mouldable C
- 4 Castable G_1
- 5 Mouldable C

Starboard boiler: Burner No.
- 1 (access) Firebrick A
- 2 Castable G_1
- 3 Firebrick A
- 4 Mouldable C
- 5 Castable Y

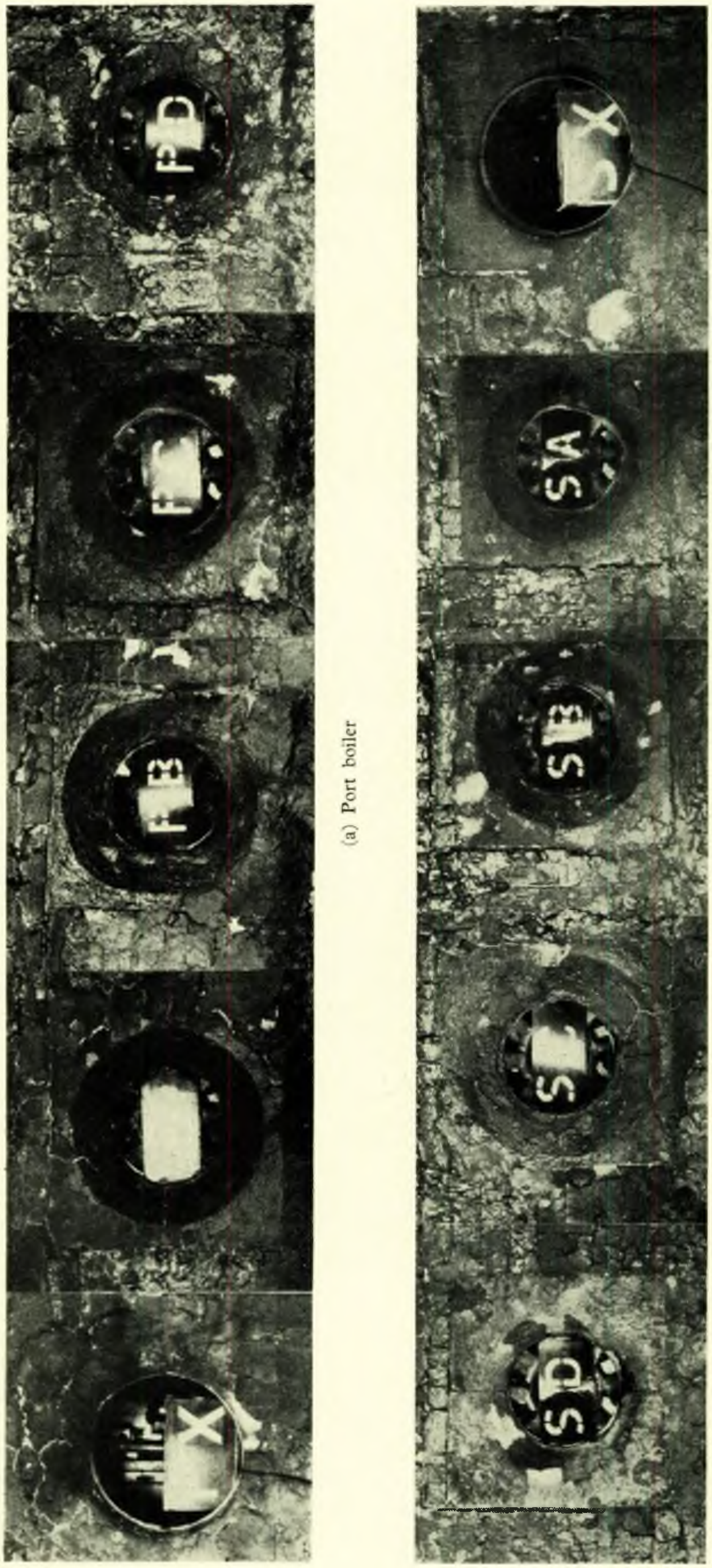
The castable G_1 was very similar to castable G, and consisted of the iron bearing aluminate hydraulic cement and firebrick grog of 42 per cent alumina content, but the recommended service temperature was 1,320 deg. C. The castable Y also contained the iron bearing cement but bauxite grog,



(a) Port aft boiler

(b) Starboard aft boiler

FIG. 7(a) and (b)—*Ship 3. Condition of quarls in January 1958 after one return voyage*



(a) Port boiler

(b) Starboard boiler

FIG. 8(a) and (b)—*Ship 4. Condition of quarls in November 1959*

(a) Port boiler

(b) Starboard boiler

FIG. 9(a) and (b)—*Ship 5. Condition of quarls in November 1959* i.e. high alumina content, had been used instead of firebrick grog.

During the quarl trials in this vessel, only firebrick A material had needed renewal, the mouldable and castable materials were still in service in November 1959. The firebrick A quarls in both access burners were renewed in March 1959 and the firebrick in No. 2 port boiler was renewed in November 1958. These quarls had been replaced by new firebrick A blocks and these again needed renewal in August 1959. The firebricks had spalled and pieces of brick had fallen away from the burner blocks. One brick quarl, starboard boiler No. 3, had given one year's service, but it was badly cracked and its condition was not good. Castable Y, of recommended service temperature 1,550 deg. C., had not developed sufficient strength during service, the surface of these quarl blocks was always friable and weak, but the blocks had not cracked although some granular material had worn away from the face of the blocks. The upper segments of castable G_1 quarls were in very good condition, but the surface of the lower segments had fused; heat reflected from the furnace floor or flame impingement with pick-up of fuel ash may have caused the temperature limit of this material to have been slightly exceeded. The mouldable C quarls had not spalled and had given good service; the material tended to vitrify and became very strong, but the lower surface tended to peel where a small amount of slag, or possibly wash from the upper brickwork, had been deposited. The castable and mouldable materials had been abraded away in the throat by the poker that was used to dislodge carbon; the poker had no effect on the firebrick.

The mouldable C, of similar alumina content to the firebrick A, had given better service than the latter, in spite of the fact that expansion cuts had not been made and some contraction cracks had formed. The castable materials had not spalled, but in this experiment they showed a limited tolerance to temperature; castable Y did not develop sufficient strength and castable G_1 tended to fuse. Practically no slag had been deposited on the quarls in this vessel and slag attack was not a cause of quarl failure.

Ship 5. Cargo Vessel

This vessel was a sister ship of Ship 4, but temperature measurements on No. 3 burner quarls showed a maximum temperature of 1,340 deg. C. although with very similar temperature fluctuations. This cargo vessel journeyed to Australian ports and the boilers were under observation for four voyages:

1) June to November 1958
2) November 1958 to March 1959
3) March to July 1959
4) July to November 1959

The various quarl materials were arranged in the following positions:

Port boiler:	Burner No.	
	1 (access)	Mouldable C
	2	Mouldable C
	3	Castable Y
	4	Firebrick A
	5	Mouldable C
Starboard boiler:	Burner No.	
	1 (access)	Firebrick A
	2	Firebrick A
	3	Mouldable C
	4	Castable G_1
	5	Castable Y

The condition of the quarls in November 1959 is shown in Fig. 9.

The trial in this vessel has been affected by the use of a fusible wash on the front wall; this wash contained zircon and calcium fluoride with small amounts of calcite, quartz or flint, felspar, and a glass.

In the port boiler the mouldable C quarls were still in position at the end of the fourth voyage, some contraction cracks had formed and the wash had caused the surface to become glazed. This glaze tended to peel away taking mouldable material with it. Expansion cuts had not been made in the mouldable quarl and therefore contraction cracks had formed; patches were necessary at burners 2 and 5 in March 1959. Castable Y was very friable and weak after the first voyage and the firebrick A material had spalled and cracked badly at burners 3 and 4. These were replaced by brick and by chemically-bonded mouldable quarls. The chemically bonded mouldable was of similar composition to mouldable C, but the addition of a chemical bond enabled preformed quarls to be made. After only one voyage the chemically bonded material was replaced by firebrick A because insufficient strength was developed at the service temperature and the quarls tended to crumble. At this time a second chemically bonded material (containing a different bond) was installed to replace spalled brickwork in the adjacent quarl. At the end of the fourth voyage both the firebrick A, which was cracked but glazed, and the chemically bonded material were still in position. The chemically bonded material was glazed, but abraded in the throat by use of the poker.

In the starboard boiler it was necessary to rebuild the front wall and, therefore, to replace the quarl blocks after the first voyage. At this time, the firebrick A quarls were badly cracked, but glazed by the wash, and the mouldable C was in good condition. Castable G_1 had been attacked by the wash and was now badly fused and castable Y was again weak and friable. On rebuilding, firebrick A quarls were used around all burners except No. 4 which was built with the original type of preformed mouldable quarls. These chemically bonded quarls were removed after one voyage because they lacked strength and tended to crumble. The firebrick A quarls were badly cracked, but the wash had glazed the surface so that cracked pieces were held in position.

In this vessel the castable materials were adversely affected by the fusible wash used on the front wall brickwork. The mouldable C material again gave good service, but tended to be attacked by the fusible wash. Firebrick A was aided by the wash in that spalled pieces were held in position by the glazing of the brick surface.

CONCLUSIONS

The service trials have shown that firebricks A and B spalled under the conditions in all the boilers and that the mouldable materials gave longer service and did not spall. Both super-duty and high-duty mouldable showed much improved spalling resistance over the firebricks. This result agreed with the indications of the laboratory spalling tests. The sillimanite bricks also showed better spalling resistance than firebricks A and B; this result agreed with the laboratory tests and with the known properties of sillimanite bricks. The castable materials also spalled less readily than the firebricks but the trials indicated that the choice of the correct grade of castable was very critical. Super-duty castables may not develop strength in service while medium-duty materials may tend to fuse or melt, especially in the presence of slag deposits or refractory washes. The use of a high-alumina grog in a castable may also inhibit the development of a ceramic bond under these service conditions. A ceramic bond was generally developed in the mouldable materials but material E was weak in Ship 2. The abrasion of castables and mouldables in the burner throats, by means of pokers used to dislodge carbon, indicated that these materials were not as strong as the fired bricks. Although this abrasion by a poker is not considered a serious fault, attempts will still be made to produce a stronger chemically-bonded mouldable material,

The use of wash on the brickwork was deleterious to the mouldable and castable materials, especially the latter, and the general absence of slag-erosion effects favoured the performance of both materials.

The main cause of quarl block deterioration was thermal shock, with the resultant cracking and falling away of broken blocks. The presence of the surface wash tended to keep broken firebrick in position.

From the results of the trials in the boilers of the five vessels, mouldable materials would be placed at the top of an order-of-merit table and firebricks A and B would be placed at the bottom, with sillimanite bricks and castable materials in intermediate positions.

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