

THE BABCOCK & WILCOX COMPANY
NEW YORK, N. Y.
REFRACTORIES DIVISION

PLAINTIFF'S EXHIBIT

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ENGINEERING BULLETIN 61-19

FACTORS AFFECTING THE PERFORMANCE OF CASTABLE REFRACTORIES
(Supersedes EL 60-27)

This entire Engineering Bulletin has been reviewed at this time and several changes have been made to enlarge the scope.

With the release of our new castable products such as B&W Kaogun-L, B&W Kaogun-HS, B&W Kaogun-BF and B&W Kao-Tab as well as the improvements made to B&W Kaolite-20, B&W Kaolite-22 and B&W Kaolite Aggregate, we have revised Appendix A.

Appendix B has also been revised to shorten the firing-in period for the thicker castable structures.

The section of previous letter which included the current printed instructions appearing on the bags has been omitted. This information will be released as a separate Engineering Bulletin.

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B&W

Refractories Division

FACTORS AFFECTING THE PERFORMANCE OF CASTABLE REFRACTORIES

EB 61-19
(Supersedes EL 60-27)

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FACTORS AFFECTING THE USE OF CASTABLE REFRACTORIES

INTRODUCTION

This informative has been prepared in order to cover in one place for ready reference the majority of information affecting the proper use of castable refractories.

Failure to understand some of the fundamental facts about castable refractories has in many cases led to installations in which the material has failed to perform as expected because basic considerations were ignored or violated.

Those points which are considered to be of prime importance are covered in this letter.

1. WATER CONTENT

The effect of variations of water content relating to strength is covered for several of our most widely used castables in Technical Letter 25. Of all the variable factors involved in the placement of castables, proper control of water content with thorough working into place is probably of greatest importance. Appendix A gives recommended water additions for our complete list of castables.

2. FORMS

Watertight forms, suitably braced, should be used whenever it is desired to contain the refractory castable until it takes its hydraulic set. Either metal or wood may be used for the forms. In any case a form oil should be used to prevent the castable from sticking to the forms. Although many types of oil and light grease have been used for this purpose, some of the major oil companies have developed special lubricants for this specific purpose.

Wherever possible, it is suggested that sectionalized forms be used of a type which will permit the height to be built up in successive convenient increments as the work proceeds. This permits the placement and working of the material to be performed more easily and more completely.

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to that of the main portion of the castable itself. If an internal mesh is required for a specific reason, such as a thin duct or stack lining, chickenwire is recommended with a 1-1/2" - 2" mesh approximately 18 gauge. Such a mesh is so formed that it is not able to exert the same type of positive expansion stresses as expanded metal lath or welded road mesh, and therefore does not have as pronounced a tendency to form a cleavage plane.

4. MIXING

Unless the castable is placed by means of a pneumatic gun, it requires a mixing operation with water before it can be installed into place. There are three general methods: (a) hand mixing, (b) mixing in a mortar mixer, or (c) mixing in a concrete mixer of a stationary or movable type.

(a) HAND MIXING

Hand mixing is the least desirable of the three methods. It takes longer, there is a greater chance of insufficient mixing, and it is usually more difficult to control the water content because the workman naturally tends to use excess water to make his job easier. Hand mixing is normally done in a mortar box, although it can also be done in a wheelbarrow or on a clean flat surface. To overcome the effects of segregation which may have taken place in handling and storage, the dry castable should first be dry mixed before water is added. After thoroughly dry mixing, the water should be slowly added and the material should be mixed sufficiently to obtain a uniform consistency.

(b) CONCRETE MIXERS

A concrete mixer operates on the principle of a drum with lifting vanes rotating on a horizontal axis. The vanes lift and drop the material in a manner to provide a complete mixing action. With many concrete mixers, including Transit-Mix trucks, it is often necessary to add sufficient water to permit the material to flow easily when being discharged. This frequently means that more water is required for purposes of getting the material from the mixer than is desired from a standpoint of achieving maximum strength. If a concrete mixer is used this characteristic should be investigated to assure that the mixer will handle a castable of the recommended consistency.

(c) MORTAR MIXERS

A mortar mixer is normally considered to be the most suitable type of equipment because it permits a close control of the water content. A mortar mixer is a cylindrical container mounted on its horizontal axis with a rotating shaft on the same axis. To the shaft are attached paddles or blades, which are designed to

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Once the mixing action has stopped, the material should not be remixed at a later period. To do so will adversely affect the strength.

5. CASTING AND HAND RODDING

Probably the majority of small and medium sized installations are made without special vibrating or pneumatic equipment. Under such circumstances it is necessary to thoroughly work the material into place by hand whether it be a flat surface, such as a floor, roof, soaking pit cover, or in an inclined or vertical surface behind forms.

The water contents should be as specified in Appendix A. After the wet castable is placed in position, it should be rodded or tamped into place. Tools used for such a purpose may be any of the following: (a) a spade, (b) an ice scraper, (c) a hoe with a straightened shank, (d) a metal rod or a wooden pole of 1/2" - 1" diameter and of suitable length, (e) any other suitable implement. The foregoing will work well with a mixture which has fairly free flowing characteristics. For a stiff mix, it is necessary to use a tool with a larger surface, which will permit the material to be pushed and tamped into place.

6. CASTING BY VIBRATING MEANS

The action of vibration sets the particles of the fresh castable in motion, reducing friction between the particles and thus giving the mixture the mobile qualities of a thick fluid which easily settles into place. The vibratory action permits the use of a stiff, heavy mixture which would not be practical with hand rodding and tamping.

EXTERNAL VIBRATING

When using vertical forms of suitable strength, it is possible to vibrate the form externally to assist in placement of the castable. The simplest method is to tap the outside of the form with a hammer or other suitable hand tool. This will cause the material to flow freely and to spread uniformly. The efficiency is improved by means of a regular external vibrator or by an improvised vibrator, such as a chipping hammer, air hammer or air rammer. With a large air hammer, merely leaning the tool against the form will produce effective results. For a chipping hammer, it is suggested that a heavy plank be placed against the form and in turn the chipping hammer be directed against this plank. The plank will prevent the form from being gouged. With vibration of this type it is possible to use water quantities as low as for internal vibrating. It has been found that when placing a castable by external vibrating

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Care should be taken when using an internal vibrator to move it slowly to prevent creation of voids. It is particularly important to remove it from the mass slowly to avoid formation of holes.

The question is frequently raised as to whether excessive vibration will produce segregation. While this is a danger with structural concrete having an extreme range of size between coarse and fine aggregate, it does not appear to be as important with refractory castables having a much smaller range of particle sizes. Vibrating should not be continued, however, any longer than is necessary to eliminate the air.

7. PLACEMENT BY PNEUMATIC METHODS

Applying castables by means of pneumatic guns is widely practiced.

This method offers particular advantages when it is necessary to handle large quantities of material through a small access area. In an ash hopper, for example, the physical problem of handling the castable through small doors poses many problems under conventional mixing techniques and can be expensive in terms of manpower. If a gun is used, the material can be charged at a convenient location a hundred feet or more from the point of placement and carried there through a hose by air pressure.

Pneumatic placement guns are generally classed as a dry gun or a wet gun depending upon the manner in which water is added to the dry castable.

(a) DRY GUN

The dry gun operates on the principle of pressure forcing the dry material from the charging chamber through a hose to the point of placement. Water is added at the discharge nozzle.

It is recommended that some prewetting be used with the dry gun to reduce rebound losses and dust. Instructions for suitable amounts of water to be used for prewetting are shown on the bag of B&W castable refractories.

Experience has shown that dense castables are best placed using a nozzle pressure of 25 - 40 psi and insulating castables at 20 - 25 psi. The water pressure at the nozzle should be about 10 psi higher than the air pressure.

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In cold weather the strength of a castable will be adversely affected if the dry material used is in the freezing range of temperatures and if mixed with cold water. It is desirable therefore, that both the dry material and the water be in a temperature range of 60 - 70 F if maximum strength is a consideration.

Provisions should be made to maintain a minimum ambient air temperature of 50 F when placing castable refractories. At the same time any steel that will come into contact with the refractory should be maintained at a temperature not lower than 40 F. Freshly poured castable refractory should be protected against freezing for a minimum of 48 hours or until thoroughly dried.

When the temperature is generally above 40 - 45 degrees F and below 60 degrees, the maximum strength of the material can be improved by heating the mixing water. The following formula may be used for estimating the temperature of fresh concrete:

$$X = \frac{Wt + .22 W't'}{W + .22 W'}$$

where W = Weight of water
 W' = Weight of dry castable
 t = Temperature of water
 t' = Temperature of solids
 X = Temperature of mixed castables

For example, assume that Kaocast at a temperature of 45 F is to be mixed with six quarts of water per bag. A desirable mix temperature would be 70 F.

$$\text{then } 70 = \frac{6 \times 2.08t + .22 \times 100 \times 45}{6 \times 2.08 + .22 \times 100}$$

$$70 = \frac{12.48 t + 990}{12.48 + 22}$$

$$t = 114 \text{ (temperature of water)}$$

For maximum strength development the dry castable should be heated if appreciably below 45 F. To eliminate this necessity it is suggested that the material be stored in a heated enclosure several days before use.

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With Kaocrete-D, Kaogun-HS, Kaocrete-28, and Hydrochrome a considerable amount of heat is liberated starting approximately 4 to 6 hours after placement under room temperature conditions. It will be noted that the surface tends to become dry at this time and is quite warm to the touch. Starting at this time, the refractory should be kept cool by means of fog nozzles, water spray, or some other suitable means. Covering with a static pool of water is unsatisfactory since the water becomes hot. Likewise, covering with damp sacks holds in the heat unless the sacks are continually wetted. This generation of heat will last approximately 18 hours and moist curing should be continued until heat is no longer generated.

When located behind forms, addition of curing water is unnecessary for any of our castables. In hot weather we would recommend wetting down the forms periodically for Kaocrete-D, Kaogun-HS, Kaocrete-28 and Hydrochrome.

The other B&W castables do not generate heat in the same manner. Unless the weather is hot and dry, it is sufficient to maintain a humid non-drying atmosphere by the simplest methods without special provisions for cooling.

Whenever wet sacks or burlap are used for curing, they should not be placed directly on the concrete before it has become hard, because soft spots can result. To avoid this possibility, place the sacks above the material by suitable spacers. Keep wet.

(Kaolite-LI is an exception to the foregoing recommendations on curing. First, it should never be cast behind forms. It should be gunned or slap troweled and exposed to the atmosphere. Second, Kaolite-LI should never be subjected to water curing or damp curing. It acquires strength with the application of heat and should be exposed to immediate air drying or subjected to heating immediately upon completion of application.)

13. AIR DRYING

Following the curing, the castable may be exposed immediately to heat or it can be air dried indefinitely. The longer it air dries before exposure to temperature, the more strength it will develop, although the increase in strength is negligible after several days. As soon as heat is applied, further development of strength ceases.

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RECOMMENDED WATER ADDITIONS

Material	Lbs/std bag	Lbs req'd/ cu. ft.	Recommended Quantity of Water In U. S. Quarts/Bag				
			Wet Type Cement Gun	Casting & Hand Rodding	External Vibration	Internal Vibration	Ramming
Kaocrete-A	100	122		7 approx.	6-6.5	6-6.5	3-4
Kaogun-L	100	125	6.5-7	7.5	6.5-7	6.5-7	---
Kaocrete-B	100	103		13	---	---	---
Kaocrete-D	100	132		7	6-6.5	6-6.5	3-4
Kaogun-HS	100	125	6-6.5	-(See note 6)	---	---	---
Kaocrete-28	100	131		7	6-6.5	6-6.5	3-4
Kaogun-BF	100	128	7-7.5	7.5	6.5-7	6.5-7	---
Kaocrete-32	100	134		7	6-6.5	6-6.5	3-4
Kao-Tab	100	153		6	5-5.5	5-5.5	---
Kaocrete-LI	100	130		7	6-6.5	6-6.5	3-4
Kaocast	100	126		7	6-6.5	6-6.5	3-4
Hydrochrome	100	170		6	5-5.5	5-5.5	2-3
Kromecast	100	175		6	5-5.5	5-5.5	2-3
Floorcast	100	150		6	5-5.5	5-5.5	2-3
Kaolite-LI	50	58		-(See note 4)	---	---	---
Kaolite-20	40	48		12	10-11	10-11	---
Kaolite-22	40	52		13	11-12	11-12	---
Kaolite-25	100	90		13	---	---	---

Notes:

1. One U. S. Quart = 2.08#
2. Water contents will vary slightly in accordance with method of placing and size and shape of job. In all cases use the least amount of water consistent with satisfactory placement.
3. Water additions should be carefully measured. Containers may be marked at the proper level with a China marking pencil which is unaffected by water. As an alternative, holes may be punched in the container at the proper elevation.
4. Kaolite-LI is recommended only for gunning and slap troweling.
5. Water requirements for slap troweling should be determined in field.
6. Kaogun-HS is recommended for gunning. B&W Kaocrete-D should be specified for casting. If Kaogun-HS is to be cast the Kaocrete-D water additions may be used.

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APPENDIX B

SUGGESTED HEATING RATES FOR VARIOUS WALL
THICKNESSES AFTER CURING AND AIR DRYING

- A. Over-all Refractory Thickness Up to 9"
8 hours hold at 250 to 400 F
8 hours raise at 100 F/hr to 1200 F
8 hours hold at 1200 F
8 hours raise at 100 F/hr to 2000 F.
8 hours hold at 2000 F
raise at 100 F/hr to operating temperatures
- B. Over-all Refractory Thickness - more than 9"
12 hours hold at 250 to 400 F
12 hours raise at 75 F/hr to 1200 F
12 hours hold at 1200 F
12 hours raise at 75 F/hr to 2100 F
12 hours hold at 2100 F
raise at 75 F/hr to operating temperatures

The above heating schedules are of a general nature for ideal conditions. These heating rates permit a slow uniform expelling of water with minimum expansion differences in the mass to retain maximum strength. Under many circumstances the heating periods can be greatly abbreviated without serious adverse effects.

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APPENDIX C

RECOMMENDED CASTABLE OVERAGES

Type of Installation	Overage - %
1. Casting and hand rodding involving minimum of waste	8 - 10
2. Vibrated installation - to allow for greater compaction	
Dense castables	15
Insulating castables	20
3. Slap troweling and plastering	10 - 15
4. Gunning	15 - 100

Gunning losses vary widely according to a number of variables. A floor may have less than 10% loss and a roof might have as much wasted as that which adheres, in other words, a 100% overage might be required. Losses run less on the inside of a stack than on the outside of a vertical cylinder or tank. Losses will also vary according to wall thickness, type of nozzle, air pressure, water pressure, prewetting of castable, rate of feed, experience of operators, stickiness of material, type of surface, etc. A gunning contractor is in the best position to determine required overages.

For gun placement on a vertical surface we would suggest that for these castables specifically prepared for gunning the following overages be applied.

B&W Kaogun-L	20%
B&W Kaogun-HS	15%
B&W Kaogun-BF	20%
B&W Kao-Tab	15%
B&W Kaocrete-B	15%

These allowances take into account the rebound losses as well as trimming losses. For other B&W castables suitable for gunning we would suggest that a figure of 35% be used for vertical surfaces. This overage may be adjusted based upon the individual past experience with the products to be gunned.

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APPENDIX D

MANUFACTURERS OF VIBRATORS

Berkshire Manufacturing Co., 1103 Power Ave., Cleveland 14, Ohio
Blaw Knox Division, Blaw Knox Co., Blawnox, Pa.
Chicago Pneumatic Tool Co., 8 E. 44th St., New York 17, N. Y.
Cleveland Vibrator Co., 2828 Clinton Ave. West, Cleveland 13, Ohio
Concrete Surfacing Machinery Co., Spring Grove Avenue & Platt St.,
Cincinnati 32, Ohio
Dart Manufacturing & Sales Co., 1246 Champa St., Denver 4, Colo.

Electric Tamper & Equipment Co., 1947 Ludington Ave., Ludington,
Michigan
Hill Pump Valve Co., 2728 Elston Ave., Chicago 47, Ill.
Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y.
International Vibration Co., 16702 Waterloo Rd., Cleveland, Ohio
Jaeger Machine Co., 920 Dublin Avenue, Columbus 16, Ohio
Maginniss Power Tool Co., 131 Distl Ave., Mansfield, Ohio

Remington Arms Co., 939 Barnum Ave., Bridgeport, Conn.
Master Vibrator Co., 149 Stanley Ave., Dayton 1, Ohio
Branford Co., 140 Chestnut Street, New Haven 7, Conn.
Roeth Vibrator, Inc., 9229 Chestnut, Franklin Park, Ill.
Stow Manufacturing Co., 400 State St., Binghamton, N. Y.

Syntron Co., 1938 Black Street, Homer City, Pa.
Viber Co., Ltd., 726 S. Flower St., Burbank, Calif.
Vibro-Plus Products, Inc., Stanhope, N. J.
White Manufacturing Co., 1941 McKay St., Elkhart, Ind.
Wyzenbeek & Staff, Inc., 223 N. California Ave., Chicago 12,
Illinois