PLAINTIFF'S
EXHIBIT
K-1573

Reprint from
BRICK & CLAY RECORD
May 1961

Johns-Manville Insulating Firebrick Are Different!

The combined skills of Johns-Manville research, engineering and production have developed a new method of producing insulating firebrick. This article describes the entire system.

JOHNS-MANVILLE
JM
PRODUCTS

FILE COPY

DEFENDANT'S
EXHIBIT
OI-144

The slinger machine depositing a thick layer of mix on slabs to form a column of clay.

Johns-Manville

They're made by entirely different processes—for example, brick are cut from fired slabs

Insulating firebrick at the Johns-Manville plant in Zelienople can best be described by two words: "They're different". These refractories are different because Johns-Manville makes them by entirely different processes than the standard accepted methods. Probably the biggest deviation in the process is that the brick are cut out of fired slabs.

These slabs are molded, fired rapidly through tunnel kilns and then cut into standard brick and special shapes The standard fired slab will produce five 9-inch straight brick or standard shapes. The advantages of this system are many.

Handling of the slabs throughout the process is easier, a more stable load is possible on the kiln cars with better spacing to permit removal of the burnout and to obtain uniform temperatures throughout the kiln cars. Finally, the use of slabs reduces labor and the trim in the sizing operation. Many special shapes can be produced directly from slabs, which normally would have to be molded and processed as special items.

But the difference goes beyond the method of producing from slabs. It also extends into preparation of raw materials, forming methods, and drying. There are no presses or extrusion machines in the factory. The entire process, while using some standard components, has been developed, engineered and constructed as a joint effort by the research, engineering, and production departments.

The slabs are formed in processes almost foreign to the clay products industry. The 1600, 2000 and 2300 brick slabs are formed in a casting operation, the 2600, 2800 and 3000 brick slabs are molded by a slinger type machine.

In addition to production economies and high quality obtained, the operation provides the flexibility and basis for giving quick shipment of standard and special shapes to its customers.

Raw Materials

Raw materials must be carefully selected for refractories and particularly the amount of iron and titanium.

Major ingredients for all refractories are fireclay, kaolin, sawdust and grog. The clays are unloaded from hopper bottom car or by scoop truck into a cross conveyor and elevated to drop into bins.

Ponderosa Pine sawdust is used because of its high bulking property, which reduces burnout problems in the kiln. Hard wood sawdust can be used, and although the hard woods increase plasticity, this property is not necessary in the processes used. The sawdust is unloaded from boxcars by a pneumatic system to a hammermill, which breaks down the sawdust to the desired particle size. The hammermill uses special type hammers which are more like blades and which have a shearing action as compared to the crushing action normally obtained in a hammermill.

The grog is the trim obtained during the sizing operations. The trim from each type is collected separately for use in the same type brick formula from which it was obtained.

The raw materials, except grog, are stored in large bins, which are equipped with dust collector systems. Grog is collected, transported and stored in Invert-a-Bins (a type of metal tote box holding 88 cubic feet). To empty them they are inverted above a conveyor leading to the use bin. The Invert-a-Bins provide a dust free method of collecting, storing and discharging the fine grog. Dust collectors are located at the finishing operations, raw material storage and batching operations to provide an extremely clean operation.

The dry portion of the mix contains clay, grog, sawdust, Gypsum

le Firebrick Are Different!

plaster is also included in mixes for the casting operation. The dry ingredients are weighed out in a batch car and dumped into a skip bucket which delivers them to a paddle type mixer. This mixer provides a homogeneous mixture known as the dry mix.

A major part of the clay is added to the batch as clay slip. This is made in blungers charged by a scoop truck. The slip contains about 40% clay and is screened carefully, before storage in tanks below floor level, which are continuously agitated.

Clay slip is pumped from storage tanks to a rather long pug mill, where it is mixed with the dry mix and additional water. The mix is then fed from the pug mill to a slinger type machine which forms a column from which the slabs are cut.

The slinger is a rotating machine which throws the mix, between the moving side belts, onto Transite pallets, moving on the molding conveyor. The slinger builds the column up to a thickness of 4 to 5 inches. The column passes under a rotary cutter, which cuts the column to the desired height. The trim from the cutter or evener, as it is called in the plant, is returned to the pug mill for remixing. The column proceeds to another cutter which operates like a guillotine, and cuts the column into slabs. The guillotine cutting must be timed exactly right, so that the slabs will be located in the center of the pallet. The dimensions of the slabs are approximately 26″ x 10″ x 3″.

Remove Slabs Automatically

The slabs are automatically removed from the conveyor belt onto dryer cars, which are positioned on the lowervator principle. The dryer cars are somewhat unusual in construction. They rest on legs after being moved to storage with a platform truck. They also have wheels for moving them along the loading truck and through the tunnel dryers.

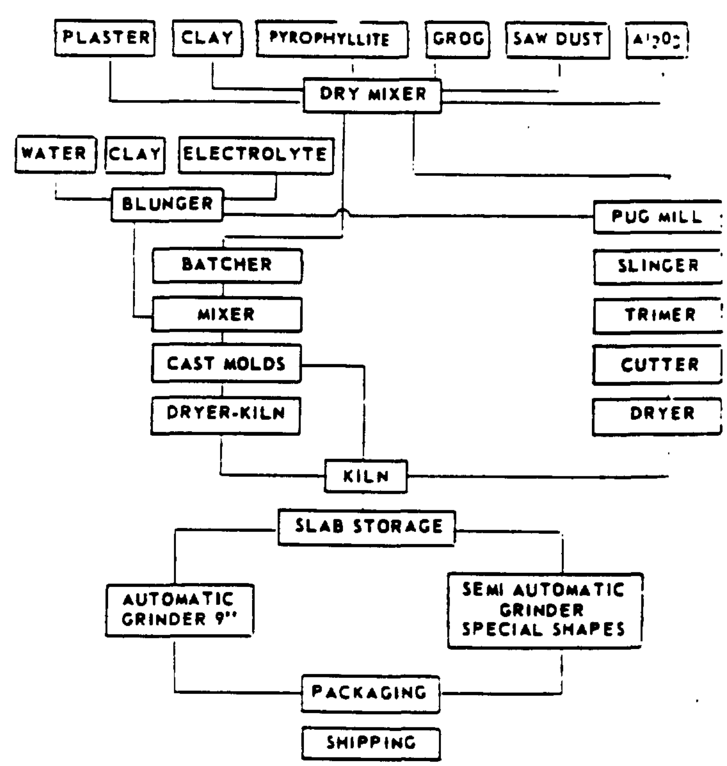
The slinger type slabs are dried in tunnel driers, which operate continuously. Molding is normally on a five day week to supply the driers and kilns for a seven day period.

After the slabs are dried they are removed from the Transite pallets and loaded onto kiln cars for the firing operation.

In this process the dry mix is weighed out from an overhead storage bin on a batch basis. Clay slip and water for the batch are measured volumetrically. These proportioned materials are dropped into a paddle type mixer, and mixed for a period of about ten seconds. The mixer is then tilted and the mix pours over the side of the mixer into a large steel gang mold. This mold will make thirty slabs, approximately 25″ x 10″ x 3″. Since the mix contains about 50% water it flows easily to fill up the mold cavities.

After about fifteen minutes, the gypsum plaster in the mix has ab-

Slabs are transferred from main conveyor to dryer car which automatically lowers on kiln cars.

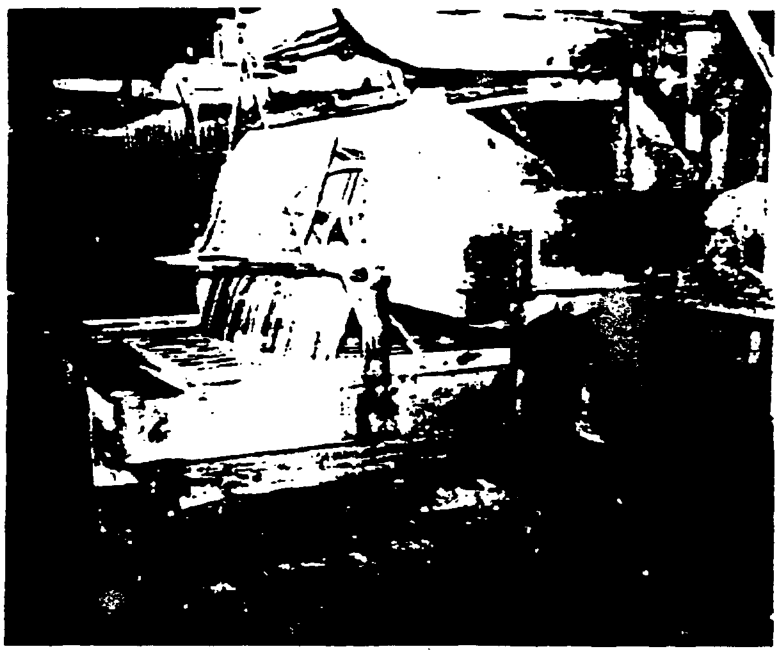


Flow Chart, Johns-Manville Zelienople Plant.

Typical Chemical Analysis—Insulating Fire Brick

Material Composition	JM-20	JM-23	No. 26	No. 28	JM-3000
SiO_2	44.2	44.2	57.4	39.0	29.4
TiO_2	1.29	1.29	1.7	1.25	1.0
Fe_2O_3	0.46	0.46	.8	.5	.71
Al_2O_3	38.0	38.0	39.7	59.0	65.6
CaO	15.2	15.2	0.2	—	0.3
MgO	.06	.06	.1	—	0.5
Na_2O	.02	.02	.1	.19	.1
K_2O	.27	.27	.1	.06	.1
P_2O_5	0.16	0.16	—	—	—
Al (Metal)			—	—	3.6

Corrected for Al_2O_3 equivalent of Al Metal present



Step three in the Johns-Manville process. After 10 seconds mixing the slip is poured into a metal mold.

PROPERTIES (Average values)		TYPE OF JOHNS-MANVILLE INSULATING FIRE BRICK					
		JM-3000	JM-28	JM-26	JM-23	JM-20	JM-1620
Temperature limit		†3000F	†2800F	†2600F	2300	2000	‡2000F †1600F
Approx. density, lb per cu ft		65	58	51	30	28	31
Transverse strength, psi		200	175	140	140	105	80
Cold crushing strength, psi		400	300	210	210	155	120
Linear shrinkage, percent		*0.8 at 3000F	1.0 at 2800F	1.0 at 2600F	.3	—	0.0 at 2000F
Reversible thermal expansion, percent		0.5-0.6 at 2000F	0.5-0.6 at 2000F	0.5-0.6 at 2000F	—	—	0.5-0.6 at 2000F
Conductivity (Btu in. per sq ft per F per hr at following mean temperatures)	500F	3.22	2.55	2.22			0.77
	1000F	3.30	2.80	2.44	1.20	1.14	1.02
	1500F	3.37	3.06	2.68			1.27
	2000F	3.44	3.32	2.93			—

*24-hr Simulative Service Panel Test: all others 24-hr soaking period †Back-up or exposed ‡Back-up only.

sorbed sufficient water to cause the mix to set or harden. After the mix has set, the filled mold is picked up by a crane and moved to a stripping machine. A kiln car is positioned at the stripping machine, which is operated to extrude the slabs from the mold directly onto the kiln car. This loads one course of slabs on the kiln car. Two additional molds filled and stripped in the same manner are used to load the car three courses high.

Charged Directly

The loaded kiln car is then charged directly into a high temperature dryer. Two types of drying treatment are available. The one method is to charge directly into a dryer operating between 500° and 700°, depending upon the schedule. This is a single tunnel dryer holding 9 kiln cars, and drying can be completed in 4½ hours, when operating at maximum schedule. After drying, the kiln car proceeds to a tunnel kiln where the firing is carried out.

A newer dryer method, which has just been completed and is expected to obsolete the method described above, consists of drying above 1000° in a combination dryer and kiln. In this method, the kiln car of molded slabs goes directly from the loading position into the combination dryer and kiln, and the slabs progress from the drying to the firing without interruption. This method reduces fuel, cuts down the cycle, and results in an improved control of the operation.

Cannot Stand Drying

Essentially the problem with the casting process is that this material cannot stand any drying of the ordinary type. If placed in an ordinary dryer and raised to say 350°, the cast slabs slump.

In the new drying and firing method, the slabs must be introduced into a temperature of approximately 1000° F. as rapidly as possible after they have been formed. The water has to be converted almost instantly into steam with a tremendous absorption of heat. If the temperature is allowed to drop at any point, cracking results. Therefore, the process has to be continued on a steadily advancing temperature until the firing portion of the kiln is reached.

This involved some very serious difficulties because of the enormous amount of heat required for the evaporation of the water. The design of the kiln includes four high temperature recirculation fans. These take hot gases out of the crown of the kiln and return them through passages in the side walls of the kiln to chambers located along walls which are provided with a kind of checkwork of openings through which the gases are moved into the loads at high velocity.

Excess Air Burners

The heat is made up by excess air burners installed in the side walls of the kiln in the moving stream of hot gases. Sufficient fuel is burned to maintain the temperature to the desired point of the gases entering the kiln. The capacity of the fans is great enough to recirculate the entire volume many times per minute. An exhaust fan was installed at the entrance of the kiln to take the gases out of the kiln and discharge them to the atmosphere. This draws upon the crown of the kiln just inside the entrance end.

The products of combustion from the high temperature section pass down towards the entrance of the kiln. They are picked up through openings in the crown and side walls of the kiln by a high temperature fan having the ability to be run at 165°F.

Discharged Into Flues

They are discharged into the flues in the side walls of the kiln and out into the ware space, being heated en route by the excess air burners in the walls of the kiln. They are then picked up by the intake of the [illegible] fan and returned again after being heated, and so go down to the entrance. In this way a high degree of recirculation is maintained all through the entrance end of the kiln, [illegible] the water, and the burnout of the sawdust is carried out.

Interestingly [illegible] so much water [illegible] is formed. Evidently [illegible] a water-gas reaction takes place in the presence of the great volumes of steam which are being evaporated from the body itself.

In order to carry out this process successfully a most careful control has to be established. As mentioned above, there can be no checking off in heat or the slabs are cracked, at least on the surface, or in more severe cases right through the entire thickness.

By the time the end of the preheating portion of the kiln is reached, all the sawdust has been burned out and the brick are clean of all [illegible]. They are then in a position to be fired to the desired maximum operating temperature without any further problems.

The cast method operates on a predetermined schedule 24 hours a day, seven days per week. It has the advantage of a minimum quantity of material in process and processing time to the fired slab state is less than 24 hours.

Very careful control in the tunnel kilns is required to regulate the [illegible] out of the sawdust and obtain the necessary oxidation of the product. The design [illegible] very high degree of [illegible] firing through [illegible] which produces [illegible] covery rate. Although sawdust originally presented a problem in firing, the firing method [illegible] so that the heat [illegible] burning of the sawdust is an advantage in helping to raise the temperature of the ware, and thereby reduces fuel usage at the [illegible].

In the new method of firing the cast type brick using the [illegible] combination, considerable research and experimentation [illegible] before a successful [illegible] obtained. In addition to the [illegible] it was necessary to move very high volumes of hot [illegible].

[illegible] Recirculating Fans

These have been obtained with the use of high-temperature recirculating fans in the dryer section. These recirculating fans consist of two 1650°F fans and two 1450°F fans. The exhaust fan is rated at 1250°F.

Another example of the complexity of the operation is the fact that each slab loses 15% of its weight in drying and firing.

After firing, the slabs are stored in the plant according to size and temperature type.

The slabs are ground and cut into brick and shapes by specialty built sizing machines, equipped with dust control equipment to maintain good working conditions and to collect the dust for use in [illegible].

Completely Automatic

The [illegible] machine for producing 9" straight and rectangular shapes is completely automatic from the point where the fired slabs are fed into the machine. In this equipment the slabs pass through two sets of grinders to grind to desired thickness; the slabs are then conveyed between the [illegible], which cut the slabs to [illegible], and finally pass through a set of gang slitters, spaced [illegible] to cut the slabs into five [illegible] brick per slab. Adjustments [illegible] the machine to produce [illegible] 2½" or 3" series brick in various widths. The largest finished [illegible] now produced on this equipment [illegible]. Other equipment is used to produce standard shapes, [illegible] and all types of special [illegible].

The equipment and operations described are used to produce insulating firebrick in the classes of 16, [illegible] and 28. In addition, a high alumina insulating fire brick for [illegible] is produced using the slinger method.

The plant also produces a complete [illegible] high temperature bonding mortars, and lightweight aggregates.

JOHNS-MANVILLE
PRODUCTS

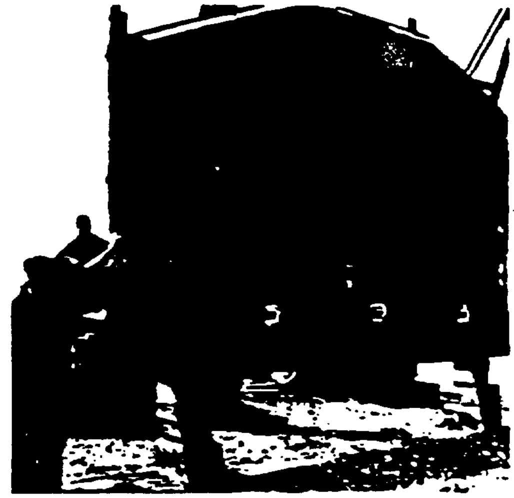
Johns-Manville

General Headquarters: 22 East 40th Street, New York 16, N. Y.

Offices In All Large Cities

CASTABLE REFRACTORIES

No Need to Wait for Special Refractory Shapes



Monolithic lining for giant furnace door constructed of Light Weight Firecrete, 9" thick

TODAY, WITH INDUSTRIAL plants bearing down on war production, it is important that furnace shut downs and outage hours be kept to a minimum. At this critical time J-M Firecrete is an unfailing guard against prolonged shut downs. Many readers of The Power Specialist already are using this refractory. To others, faced with ever increasing production schedules, a description of Firecrete and its application may be of help.

Firecrete is a hydraulic setting refractory used for furnace door linings, burner rings, baffle tile, header protector tile, pipe linings, furnace bottoms, special shapes of all kinds and for casting small monolithic furnaces. It is furnished dry and, when mixed with water on the job, can be placed as easily as ordinary concrete. If necessary, shapes and small monolithic linings can be put in service within 24 hrs. after being placed. Firecrete has practically no drying or firing shrinkage and is highly resistant to spalling.

It is furnished in three types:—

1. Standard Firecrete for temperatures up to 2400°F. This is the most generally applicable type of Firecrete.
2. High Temperature Firecrete for temperatures up to 2800°F. This is similar in properties and uses to Standard Firecrete but is composed of a higher heat-resistant base which makes it applicable for use against a higher temperature.
3. Light Weight Firecrete for temperatures up to 2200°F. This is similar to Standard Firecrete but much lighter in weight. It has unusually low thermal conductivity and is approximately four times as effective as fire brick in retarding heat flow. Its low heat storage capacity and high resistance to spalling make it an ideal insulating refractory concrete for lining doors of all sizes and for casting special shapes, furnace bottoms and small monolithic furnaces.

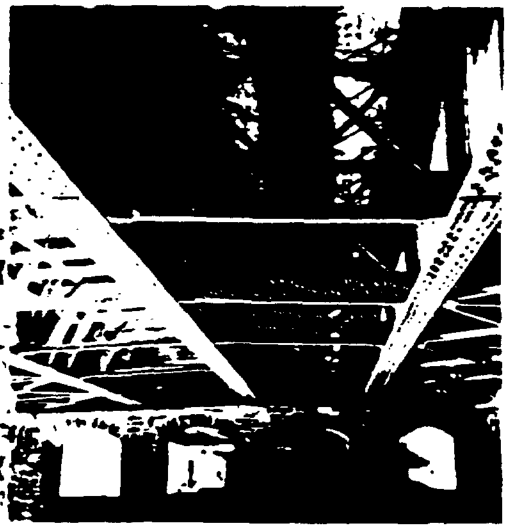
The type or types of Firecrete to be used depend upon the particular service requirement. Johns-Manville engineers, familiar with such problems, and with a thorough knowledge of their own products, are readily available at the nearest J-M office.

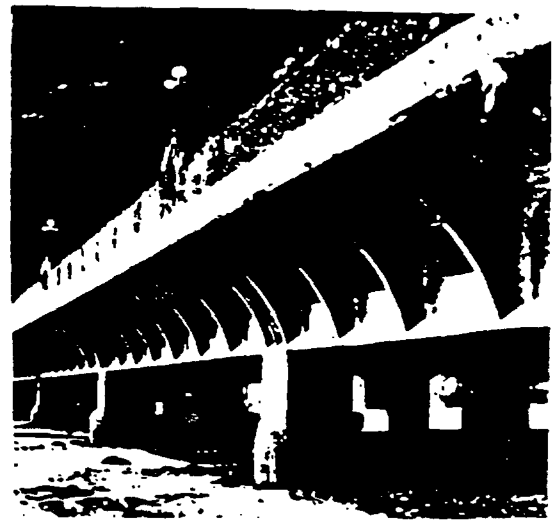
Application of Firecrete

As Firecrete hardens rapidly, water should not be added until the job is ready for application of the refractory. Directions for mixing with the amount of water required can be obtained with the material.

Firecrete may be tamped or rammed into place but where possible it is better to pour the mix into a mold as it makes more homogeneous shapes, requires less labor, and eliminates possibility of failure because of inadequate ramming. When casting it is preferable to make a complete section at one time to prevent stratification. If material has set, the surface should be well scarified to insure proper bond with fresh refractory. The mix should be shoveled into place immediately, and rodded with a blunt end tool until all corners are filled and air pockets eliminated.

FILE 431 HT brick & refractories





Left: J-M Insulated water supply pipe under Bow River bridge.
Right: The Bow River bridge from a more picturesque angle.

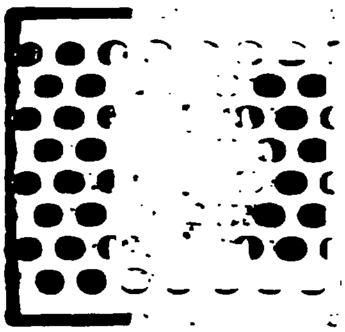
coldest winter nights. Here is where Mr. A. G. Ghent, Canadian Manager, Government Service Unit of Johns-Manville at Ottawa, should continue the story.

"Twenty-two years ago last September," said Mr. Ghent, "the Department of Public Works at Ottawa sent for me. Advice on insulation was desired. I was told that a 12" water main was to be erected to carry fresh water over the Bow River to the town of Banff. This pipe was to be hung on swing braces under the existing Bow River bridge. Temperatures in winter ran as low as 50 degrees below zero—sometimes lower. The water would have an all time flow through the pipe of one half foot per second. Could it be adequately insulated?

"Yes—by using the following J-M specification.

'Cover pipe with 2 plies of 15 lb. J-M Asbestos Felt, cement all laps, then a layer of Johns-Manville Standard Hair Felt, 1" thick, secured to the pipe with a wrapping of heavy jute twine on 2" centres, and over each layer shall be applied a layer of 15 lb. Asphalt Saturated Asbestos Felt secured in place with a wrapping of jute twine. This combination of Johns-Manville Standard Hair Felt and Asphalt Saturated Asbestos Felt shall be repeated until the necessary thickness is applied, and over the whole shall be applied a wrapping of 55-lb. Asbestos Felt secured with rings of copperweld wire applied on 4" centres. The laps on the horizontal pipe shall be placed on the side and turned downward to shed water. The whole shall be finally coated with two coats of cold asphalt coating.' "

"It is over a score of years since this specification was given. I had almost forgotten it until, during a recent conversation with Mr. J. M. Wardle, Director of Surveys and Engineering, Department of Mines and Resources at Ottawa, the subject of Banff was brought up. Mr. Wardle said that twenty-three years ago he was Chief Engineer of National Parks of Canada in which Banff was situated. He well remembered the installation of the water main, and its insulation according to J-M specifications. But what was of greater interest to me, as a Johns-Manville man, was to learn that Mr. Wardle had, shortly before our meeting, inspected this pipe line. He had found no defects in it. Judging from its present appearance it seemed likely to last another decade or so. In all the years since its installation the pipe had had no failure. The people of Banff had their water in all weathers, the Canadian government had made an excellent investment, and Johns-Manville had another job well done."

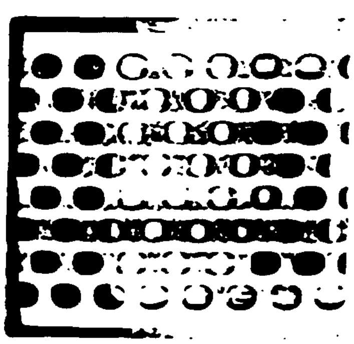


Forms for shapes may be made either of wood or metal. Wooden forms are used generally in emergencies, since they are quickly constructed and, if necessary, can be burned away without damage to the refractory. If a number of shapes are required, a heavy metal form, well coated with oil, which can be used repeatedly will prove more satisfactory. Such molds should be in 2 or 3 sections so that they can be easily removed, and made ready for another casting.

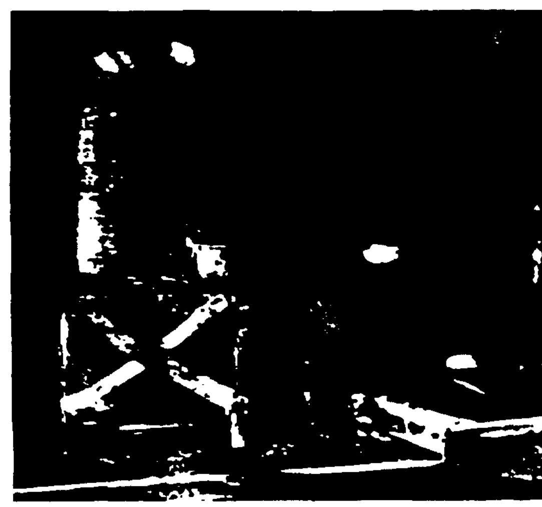
Firecrete hardens sufficiently in six hours to permit the removal of the forms if necessary. On small installations 12 hours curing is desirable before heat is applied. It is preferable, however, to let linings of Firecrete cure for 24 hours or longer before putting into service. The hardening can be accelerated by mixing Firecrete with hot water. This practice, however, is not recommended except when the shape is urgently required as it reduces ultimate compressive strength.

Because of its inherent advantages, a monolithic furnace door lining is a desirable construction for both new and old equipment. By using a castable refractory material, the labor and cost of cutting and fitting brick to the door frame is eliminated. For old doors which have become warped or distorted in operation, a monolithic material affords the only practical, economical method of relining. Firecrete, quickly prepared and placed the same as concrete, readily adapts itself to any irregularities in the frame and is ready for service after a few hours of air curing.

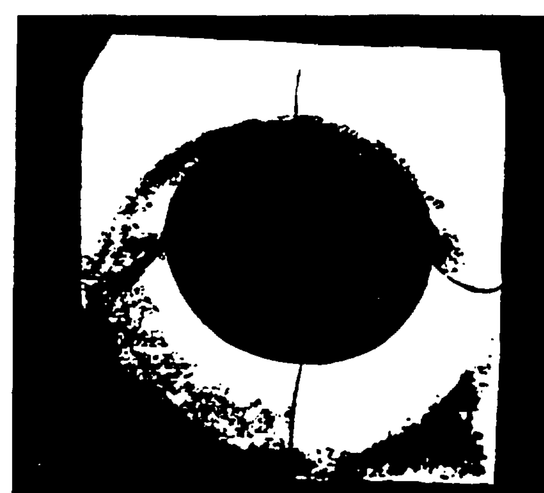
Firecrete is suitable for lining doors of practically any design. Doors less than 4 sq. feet in area generally require no reinforcing to hold refractory in place. On larger doors anchor rods with bent ends, or bolts with washers and nuts are generally used. Here again Johns-Manville engineers are available for advice on the layout and spacing of such reinforcement, or on any other question on the use of Firecrete Refractories.



Firecrete is handled as easily as ordinary concrete. Be careful to use the right amount of water.



Above: *Standpipe linings are quickly poured.*
Below: *Special shapes are easily constructed.*



Army-Navy "E" flag awarded to Johns-Manville factory workers at Manville, N. J. Left to right: Plant Mgr. John E. Begert, Claude Schollenberger, president of the A. F. of L. union at Manville, Miss Elizabeth Mozell, and Major General Thomas E. Robins.

ARMY-NAVY "E" AWARDED

Workers of J-M Manville Factory Receive Coveted Honor

OVER 4,000 Johns-Manville workers and members of their families assembled in Manville, N. J., on March 24th to celebrate the formal raising of the Army-Navy "E" flag over their factory.

Major General Thomas E. Robins, chief of the Construction Division, O.C.E., together with other Army and Navy officers, represented the Government. President Lewis H. Brown, in a short speech, pledged continued and unceasing effort in the production line from Johns-Manville and its workers.

The war production at Manville includes such essential items as asbestos textiles, packings, packing cups and gaskets, insulating materials, asbestos and asphalt building products, Transite pipe, brake linings and clutch facings.

Referring directly to some products not ordinarily linked with fighting equipment, Major General Robins told of the essential part they played. "Not only do you help make it possible for our armed forces to fight," he pointed out, "but you play a vital part in training millions more to join the more than a million and a half fighting men we already have overseas. Throughout the United States these young men, the flower of American manhood, are being sheltered in buildings in which your shingles, wall board and other building materials are to be found. All these—together with new war products and secret uses of materials that cannot be revealed now—make your part in the war effort one of which any group of men and women can well be proud."

The flag was accepted on behalf of the Manville factory workers by John F. Begert, plant manager. Commander Austin S. Kibbee, appearing for the Navy, presented the lapel insignia which every employee of the plant is entitled to wear.

Insulating Fire Brick in Modern Furnace Construction

By N. ALLEN HUMPHREY
District Engineer
Johns-Manville

INSULATION is playing its part in speeding up the wheels of industry as well as keeping them turning efficiently. Until recently insulation was employed for economy and to afford comfortable working conditions only. With the advent of insulating fire brick insulation can actually be used to speed up many furnace operations.

Periodic operating furnaces such as those for heating, forging and heat treating are ones in which insulating fire brick play their important role. In these furnaces losses due to heat storage within the walls become a greater factor than heat transfer through the wall.

With heavy refractory walls that soak up the heat like a sponge hours of valuable time and large quantities of fuel are required to bring the furnace up to the desired operating temperature. On the other hand light weight insulating fire brick walls heat up quickly and absorb far less heat. In fact about one-fourth as much heat is required to establish equilibrium conditions in an insulating fire brick wall as would be required in a fire brick wall of the same thickness.

Figs. 1 and 2 illustrate the equilibrium conditions of a 9-in. fire brick wall subjected to a furnace temperature of 2400 deg. F. Fig. 1 is for an uninsulated wall; Fig. 2 for a wall insulated with 4½ in. of 2000 deg. F. insulating brick. Note that the 4½ in. of insulating brick reduce the heat transfer by 1852 — 473 = 1379 B.t.u. per square foot per hour. With the equipment operating continuously for approximately 8000 hours per year, being fired with oil at 3 cents per gallon, there would be an annual saving by the use of the insulation of approximately $4 per square foot of wall area per year. The installed costs of the 4½ in. of insulating brick would not be over $1 per square foot. Therefore, for equipment operating continuously the use of insulation in back of fire brick is most desirable.

On the other hand a vast majority of heating, reheating, forging and heat treating furnaces are operated intermittently. With intermittent operations the heat storage within the walls becomes a more important factor than the heat transfer through the walls. In many instances the equilibrium conditions of heat storage and heat transfer are not obtained before the furnace is shut off for the night. In Fig. 2 the heat storage of 54,910 B.t.u. per square foot of wall area is equivalent to 9 gallons of fuel oil; compare this with a similar wall constructed of 9 in. of insulating fire brick with 1 in. of high temperature block insulation as shown in Fig. 3. In this wall the heat storage is reduced to approximately one-fourth of the amount stored in the insulated fire brick wall.

Unfortunately this comparison does not tell the whole story, or may not even serve to guide us in our choice of materials for furnace wall construction. What we should know is how much heat must be applied to the respective walls during a normal

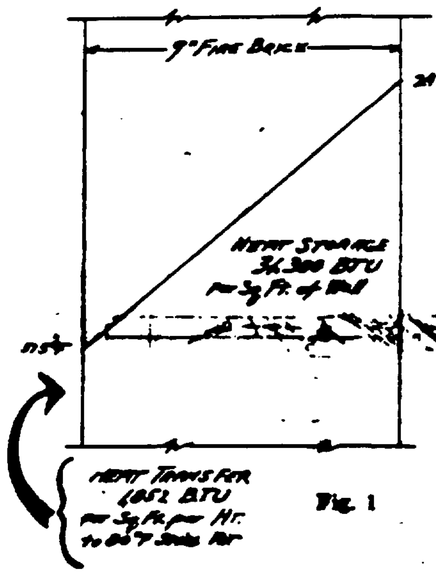


Fig. 1

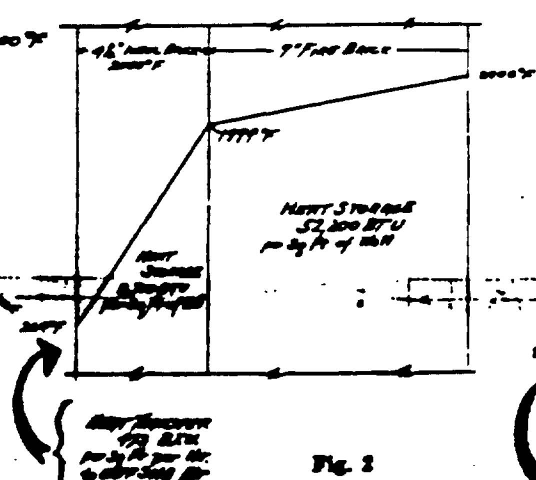


Fig. 2

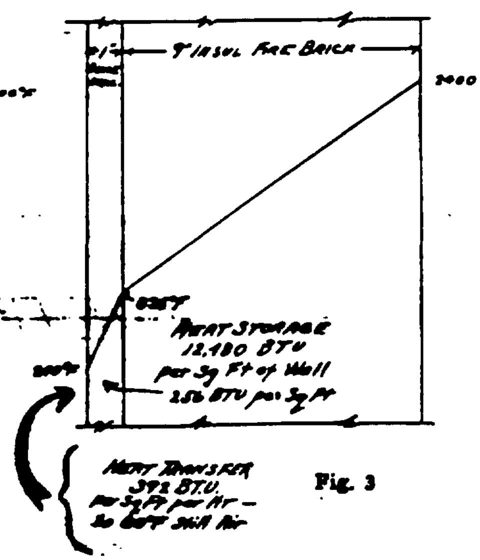


Fig. 3

Reprinted from Blast Furnace and Steel Plant for December, 1941

Printed in U.S.A.

FILE 431 HT brick & refractories

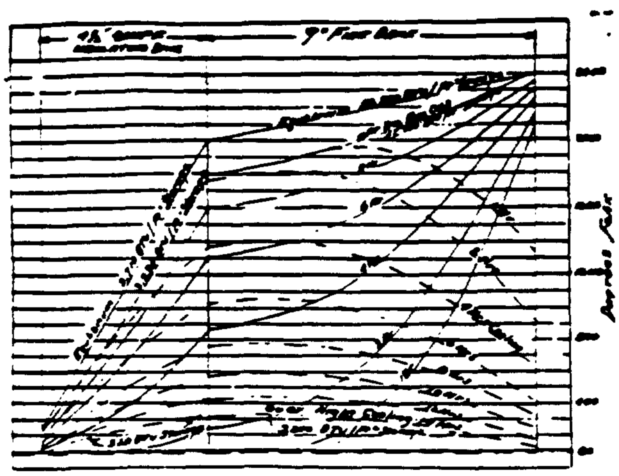


Fig. 4

cycle of operation.

As a guide in this direction we have constructed Schmidt Graphs* and obtained the data given in Fig. 4. This figure is the composite data obtained by construction of a series of the Schmidt Graphs on heating as illustrated by Fig. 6 and on cooling as illustrated by Fig. 7.

Insulating fire brick walls come up to the operating temperature in much less time than regular fire brick under the same firing conditions. This is illustrated by the Schmidt Graphs; compare Figs. 4 and 5-A. Only about one hour is required to bring the insulating fire brick wall face temperature up to the 2400 deg. F. operating temperature, while many hours are required to heat the inner face of the fire brick wall. This has to be compensated for by allowing more time in which to reach the full operating temperature or by harder firing. As a result much time and a considerable quantity of fuel would be saved, each time the insulating fire brick furnace is heated. No attempt has been made to estimate this saving except as a factor in comparing the losses in cooling because of the greater heat storage in the fire brick wall.

The advantage of this difference in time required to heat up is one of the chief reasons for the use of insulating fire brick in combustion chambers of domestic oil burners. Better combustion conditions and reduced heat losses often result in fuel saving of 10 per cent or more. See Measuring Losses from On-Off Firing by F. K. Ovetz and J. G. Nellis, Fuel Oil Journal, November 1938.

In constructing these graphs we assumed that the furnace would not be tightly sealed during the shutdown period and that the natural draft would cool the interior at the rate indicated in Fig. 8, Curves "A". In the case of a tightly sealed furnace the loss would be from the outside due to heat transfer through the wall only. This condition seldom exists except in electric furnaces which do not have flues. As the insulating fire brick heat up more quickly than fire brick we have assumed that the cooling will also be more rapid on the interior face.

To select the most economic furnace wall construction a Performance Cost Study can be made from the data obtained by the construction of the Schmidt Graphs in much the same manner that comparisons are made on various thicknesses and kinds of insulation to determine the most economic kind and thickness of insulation to be employed.

In order to make the analysis more complete we have also compiled similar data on 9-in. fire brick wall only, as shown in Fig. 9, and on a 9-in. insulating fire brick wall only as shown in Fig. 10. The tabulation shown in Table I is a Performance Cost Study comparing the data obtained above.

*Industrial Furnaces. Volume 1, Third Edition by W. Trinks. Appendix 2. John Wiley & Sons, Inc., 1934.

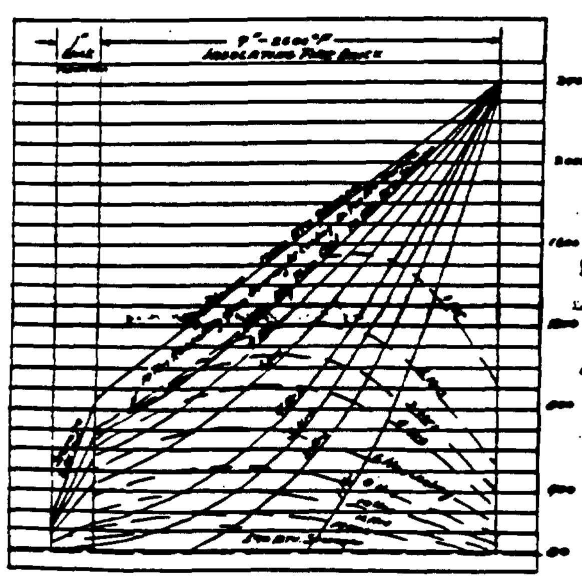


Fig. 5-A

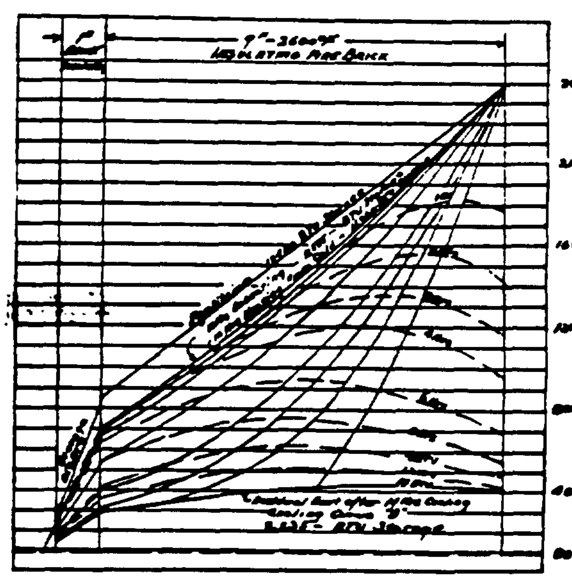


Fig. 5-B

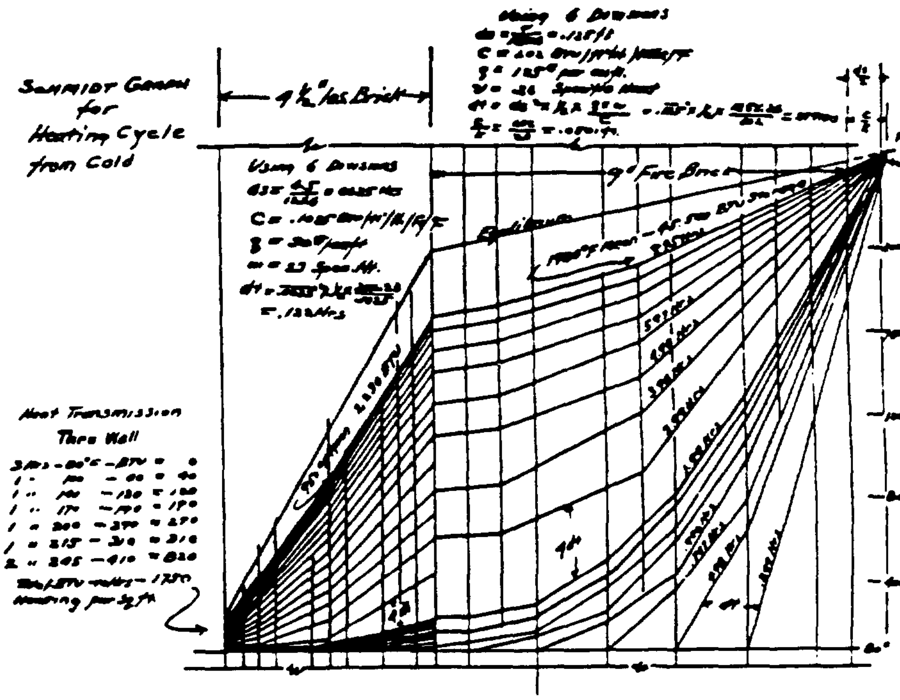


Fig. 6

The 9-in. insulating fire brick and 1-in. block insulation wall shows very good economy and affords the best construction. The 9-in. insulating fire brick only shows slightly better economy. However, the insulating block offers broken joint construction which is conducive to good tight furnace wall construction and is therefore the standard recommendation.

This study is, of course, based on a rather complete cooling of the furnace walls during the overnight shutdown. The design of the furnace would to a large degree govern the cooling rate. The rates chosen for these studies may be excessive for the better type of construction. With some experience records to serve as a guide studies should be made in the above manner in order to arrive at the most economic furnace wall design.

As an illustration we have supplemented the above study with another cooling cycle for the wall constructed of 9 in. of insulating fire brick backed up with 1 in. of block insulation. See Cooling Curve "B" for insulating fire brick Fig. 8 and Fig. 5-B for the composite data on heating and cooling. The performance cost study clearly indicates that with

Fig. 7

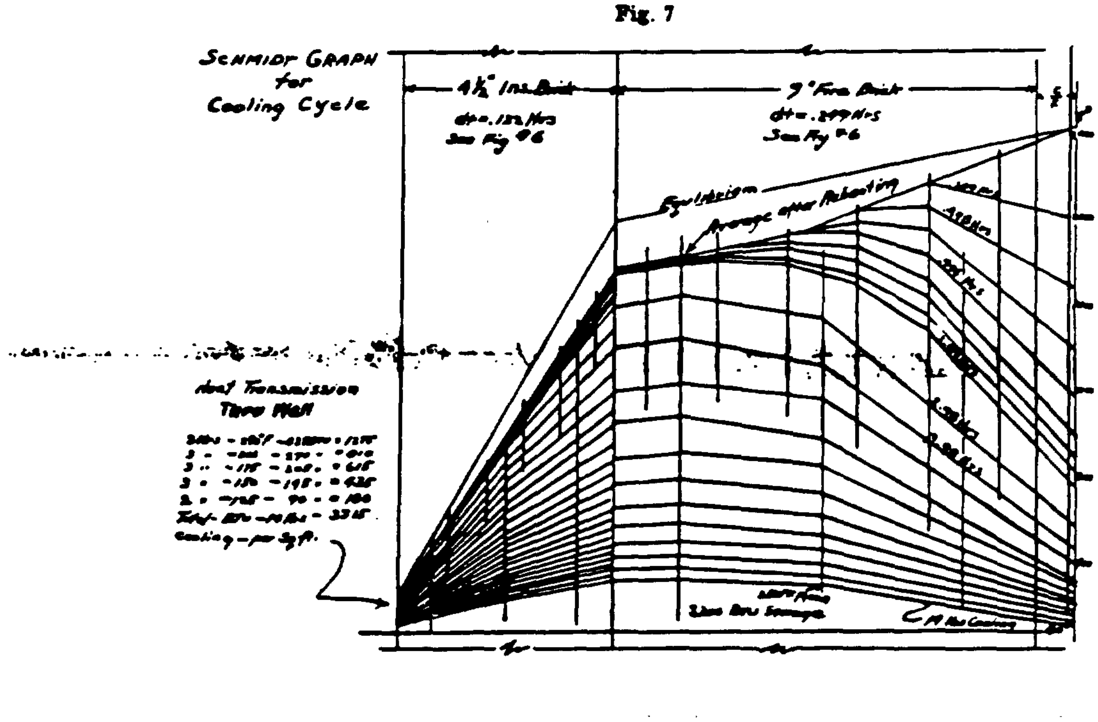


Table I—Performance Cost Study—Insulating Brick vs. Fire Brick

Furnace wall construction	9" fire brick only	9" fire brick 4½" insulation	9" insulating fire brick only	9" Insulating fire brick and 1" insulating block	
1—Heat transfer equilibrium, B.t.u./sq. ft./hr......	1852	473	537	392	392
2—Heat storage equilibrium, B.t.u./sq. ft..........	31300	52200	9975	12480	12480
3—Assured heating and cooling cycle.............	A	A	A	A	B
4—Heat transfer, 10 hours heating and operation..	10080	1750	2290	1455	1655
5—Heat loss transfer—14 hours cooling..........	8135	3315	3395	2795	3370
6—Heat loss to interior—14 hours cooling.........	22365	40935	5870	7535	5650
7—Total heat loss—14 hours cooling (5 + 6)......	30500	44250	9265	10390	9020
8—Total average heat loss per 24-hr. day (4 + 7).	40580	46000	11555	11785	10675
9—Total heat loss million B.tu./sq. ft./year*.....	10.22	11.44	2.88	2.94	2.67
10—Approximate cost of furnace wall per sq. ft....	$ .90	$ 1.67	$2.16	$2.36	$2.36
11—Normal fixed charges†—25 per cent...........	$ .225	$ .417	$ .54	$ .59	$ .59
12—Total yearly cost (9 + 11)....................	$10.44	$11.85	$3.42	$3.53	$3.26

Assumed Conditions

2400 deg. F. normal operating temperature.

*Eight hours per day operation—250 days per year—2000 hours per year.

Fuel oil, 3 cents per gallon—150,000 B.t.u. per gallon, 40 per cent efficiency = 50 cents per million B.t.u. available heat.

Fire brick cost $60 per M—Labor laying $20 per M.

2600 deg. F. insulating refractory brick—$145 per M—Labor laying $20 per M.

2000 deg. F. insulating refractory brick—$100 per M—Labor laying $20 per M.

1900 deg. F. diatomaceous earth block insulation—15 cents per sq. ft., 1 in. thick—Labor installing 5 cents per sq. ft.

†Normal fixed charges—Amortized in approximately 5 years with interest = Approximately 25 per cent per year

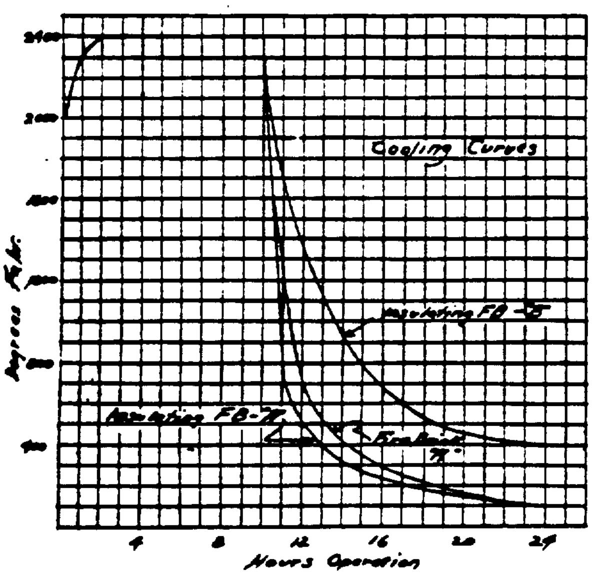


Fig. 8

less complete cooling during the shutdown period the insulating block in back of the insulating fire brick affords a good return on the investment. The same is true in the case of furnaces used for annealing where the cycle of operation extends over a longer period of time.

Insulating fire brick will replace ordinary fire brick as the lining for periodically operated furnaces as fast as the trade becomes aware of the improved economy and greater flexibility in heating and cooling that is obtainable by their use. The insulating fire brick must possess the refractory qualities of the better grade of fire brick. Even with a somewhat foreshortened life the economy of using the light weight insulating fire brick is apparent. Theoretical studies such as the above will guide us and actual performance will prove that insulating fire brick are a big contribution to modern furnace design.

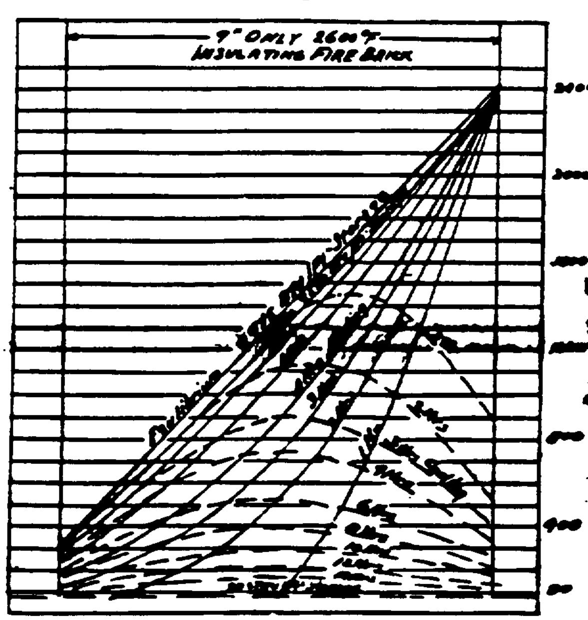


Fig. 9

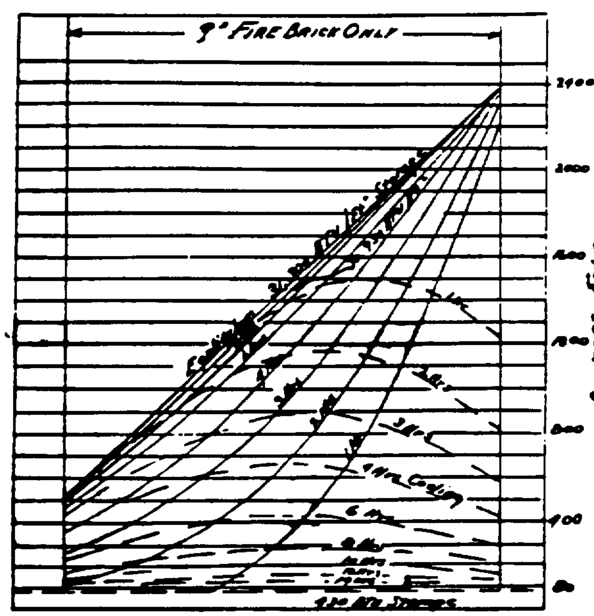


Fig. 10