THE MANUFACTURE OF KAYLO PRODUCTS

by

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Preface

The purpose of this manual is to serve as an aid to good practice in the manufacture of Kaylo products, and to provide information to those who may not be familiar with the nature of the operation. The material contained herein is the result of both laboratory research and plant experience over the years. Admittedly, some of what is written may still be classed as theory, and some statements may even be considered as controversial. There remains much to be learned. The manufacture of Kaylo products is still a relatively new and "green" industry. This is probably all to the good, because when something is no longer green it stops growing and rot begins.

Many, many persons have contributed to our present state of knowledge on the subject. This manual represents an effort on the part of the author to correlate and integrate the information available at this time.

It is not the intention here to describe in every detail, and step by step, the various aspects of a prescribed operation. This has been done in several manuals written by members of the staff at the Berlin plant. Rather, this manual is designed to attempt to explain why certain things are done as they are or why certain changes in operation are indicated.

THE MANUFACTURE OF KAYLO PRODUCTS

CONTENTS

Chapter I

THE NATURE OF KAYLO PRODUCTS

Kaylo is a registered trade mark employed to specify the hydrous calcium silicate products manufactured by Owens-Corning Fiberglas Corporation. Kaylo is an adjective and should never be used as a noun. Furthermore, it should always be capitalized.

As just mentioned, Kaylo products fall within the class of materials known as hydrous calcium silicates. Research over the years has revealed the existence of a large number of hydrous calcium silicates, but the majority of these are scarcely more than laboratory curiosities. That is to say, little or no use is known at this time for many of these compounds.

The term hydrous calcium silicate denotes a chemical compound composed of CaO (lime), SiO_2 (silica) and H_2O (water). A specific hydrous calcium silicate has, of course, definite physical and chemical properties. The formation of hydrous calcium silicates can be effected in one of two ways: 1) By the reaction of water with previously formed anhydrous calcium silicates, such as occurs in the hardening of portland cements when mixed with water; 2) The direct union of CaO, SiO_2, and H_2O. It is this method that is employed in the manufacture of Kaylo products.

The two hydrous calcium silicates that are of interest in connection with Kaylo products are: tobermorite, having the formula $4CaO.5SiO_2.5H_2O$; and xonotlite, having the formula $5CaO.5SiO_2.H_2O$. Other hydrous calcium silicates can be, and sometimes are, present in Kaylo products. But the majority of these are of an accidental nature, and most are detrimental for one reason or another.

Tobermorite, like so many minerals, can accommodate varying amounts of other constituents within its crystal structure. This, when controlled, can be used to an advantage. More will be said of this later.

Xonotlite apparently shows no tendency to incorporate any "foreign" oxides within its structure.

In the formation of hydrous calcium silicates by hydrothermal methods, the lime apparently first reacts readily and completely with silica to form lime-rich calcium silicate gels having variable compositions but characterized by CaO/SiO_2 ratios in excess of unity. These products in turn react with residual silica of the mix to form products poorer in lime. The order of formation and transformation is believed to be thus: lime-rich gel $\rightarrow 5CaO.4CaO.nH_2O \rightarrow CaO.SiO_2.nH_2O \rightarrow 4CaO.5SiO_2.nH_2O \rightarrow 4CaO.5SiO_2.5H_2O$ (tobermorite).

To achieve the desired end product in the above progression, it is necessary to have the proper batch ratio of lime and silica in such form as to be reactive under conditions of the process, and to permit sufficient time at a given temperature (pressure). If appreciable amounts of the intermediate products are present, the ware will show such undesirable properties as: high shrinkages upon drying, punky structure and low strength, and/or high shrinkages at elevated temperatures.

If the batch ratio of lime to silica is near unity, and if sufficient time is permitted at temperatures and pressures in excess of about 300°F and 52 psig, respectively, the reaction given above will continue as: $4CaO.5SiO_2.5H_2O$-- $5CaO.5SiO_2.H_2O$ (xonotlite). The composition of the intermediate product in the transformation of tobermorite to xonotlite has not been fully resolved as yet. X-ray diffraction patterns generally show some lines characteristic of the two end members, but certain other key lines may be missing. Relative intensities may also vary. It is generally the practice to refer to this intermediate product as "hybrid" material.

The advantage that structures of xonotlite have over those of tobermorite is higher temperature resistance. A structure of the hybrid material is intermediate in this respect.

The possibility still exists, however, that tobermorite is transformed directly into xonotlite, and the hybrid material is in reality a mechanical mixture of the two. In any case, the effect is the same.

As mentioned earlier, tobermorite can take certain other oxides into its structure. Alumina, Al_2O_3, in particular enters the structure readily. When this occurs to any appreciable extent, the transformation of tobermorite to xonotlite is retarded greatly; so much so that for practical purposes it may be considered as preventing the transformation. Because of this, batches intended for the production of xonotlite must be free of any substantial amount of reactive Al_2O_3. On the other hand, tobermorite containing Al_2O_3 apparently forms more readily than the pure compound, and also yields ware of higher strengths. However, high temperature resistance of the ware is decreased roughly in proportion to the amount of Al_2O_3. But it is possible to take advantage of the favorable characteristics imparted by a limited amount without the temperature resistance being lowered to a point that is critical for most installations of the product.

The positive identification of the various chemical combinations or phases, either desirable or undesirable, that can exist in hydrous calcium silicate products is not easy or simple. Generally, in other systems, products are formed which are readily discernible by means of the light microscope. Accordingly, optical properties and other characteristics can readily be determined. Because the crystalline products that are formed within reasonable times by hydrothermal means in the lime-silica-water system are so extremely fine, identification is not possible with the light microscope. Other means, such as X-ray diffraction and differential thermal analysis in particular, must be employed. Less certainty of positive identification results. Furthermore, the extreme fineness of the crystalline compounds results in behavior often more typical of a gel rather than a crystalline structure. In these cases, the water content and the distribution of this water throughout the structure has a distinct effect on the properties of the product.

Because of the above circumstances, it is the more common practice to attempt corrective measures based on certain assumptions as the cause of ware being off quality, rather than on the results of extensive laboratory tests. That is to say, diagnoses are often made without supporting laboratory data. In plant operation, time is all important and cures must be effected in the shortest possible time. It is not intended to imply that these assumptions are mere guesses and without foundation. They are made by trained personnel and are based on the findings of past research and plant experience. It is being emphasized that considerable art is involved in the manufacture of Kaylo products, and successful operations are largely dependent upon the presence and decisions of persons thoroughly trained in the art.

Chapter II

TYPES OF KAYLO PRODUCTS

In the previous chapter, it was pointed out that Kaylo products consist essentially of hydrous calcium silicate. The true density of these silicates is about 150 pounds per cubic foot. In fact, the over-all density of the constituent solids of Kaylo materials is about this value. The apparent density, which is considerably less, is determined and controlled by the ratio of water to solids employed in raw batch. By means of the proper selection of amounts and types of asbestos, together with further fiberization, dilute suspensions or slurries are obtained which do not settle or lose water by bleeding. Prescribed treatment is also followed in the hydration of the lime to assist in obtaining these stable suspensions.

With slurries of this nature, the volume of the hardened body is sensibly the same as that of the cast slurry. When the water is removed by drying from the interstices of the solid framework of hydrous calcium silicate that has been formed in the process, a product of low apparent density results. It is obvious that the higher the ratio of water to solids in the slurry, or the greater the percentage of total volume contributed by the water, the lower the apparent density of the product after the free water has been removed by drying.

Inasmuch as the synthesis of hydrous calcium silicates is involved, some water of the batch becomes fixed in that it becomes an integral part of the compound in question. But this amount represents a very small percentage of the original volume.

The chief products of the Berlin plant are generally considered as being of four types; characterized by two different apparent densities for each of two different hydrous calcium silicate compounds that constitute the structure of the product.

As mentioned in Chapter I, the two hydrous calcium silicates of interest in connection with Kaylo products are tobermorite, $4CaO.5SiO_2.5H_2O$; and xonotlite, $5CaO.5SiO_2.H_2O$. The tobermorite-type products are referred to within the organization as Kaylo-10, K-10, or regular Kaylo. In the literature Kaylo alone is employed; the products being called Kaylo Pipe Insulation, Kaylo Block Insulation, or Kaylo Core Material. The Pipe and Block Insulation have a nominal apparent density of 11.4 pounds per cubic foot, and the Core material 20.0 pcf. Thus, the two classes of Kaylo-10 products are distinguished from each other by their difference in apparent density and their end use.

The Kaylo-10 products of the lighter density are designed primarily to afford thermal insulation at elevated temperatures up to 1200°F, whereas the purpose of Kaylo-10 product of the heavier density is to provide a structural material whose strength and fireproof nature together with its insulating value, make it highly desirable as the core of panels and doors of sandwich-type construction. The facing material that is applied by the customer may be wood, metal, transite, etc.

Kaylo-20 ware is characterized by having a xonotlite, $5CaO.5SiO_2.H_2O$, structure. Included are Kaylo-20 Pipe Insulation and Kaylo-20 Block Insulation having a nominal apparent density of 12.5 pounds per cubic foot, and K-20 Core Material at 20.0 pcf.

Similar to the Kaylo-10 ware, the end use of the Kaylo-20 products dictates the production of two different densities. The advantage of Kaylo-20 ware in each case is its higher temperature resistance, the limit being 1800°F. instead of 1200°F.

The apparent density of the product in any case is chosen to yield a material having a hardness and strength demanded in its end service, or, as is the case with Kaylo-20 thermal insulation, is the natural result of the water/solids ratio required to give stable, non-settling slurries. In no case is a higher density employed than is considered to be a safe minimum under the circumstances.

The strength of both Kaylo-10 and Kaylo-20 products expressed as modulus of rupture tends to vary roughly as the square of the density. For example, the modulus of rupture for Kaylo-10 thermal insulation at 11.4 pcf density may be expected to be about 75 psi, and that for Kaylo core material at 20 pcf density is likely to be about 230 psi;

$$75 \times \frac{(20)^2}{(11.4)^2} = 230.$$

A modulus of rupture of about 112 psi is not uncommon for Kaylo-20 insulation of 13 pcf density, and about 265 psi can be expected for Kaylo-20 core of 20 pcf density:

$$112 \times \frac{(20)^2}{(13)^2} = 265.$$

Theoretically, for a given density the Kaylo-20 material probably should not be quite as strong as the Kaylo-10 product. The reason for this is that the structure of the former is more coarsely crystalline and presents less area of contact for the cohesive forces. Actually, however, in commercial production the reverse tends to be true in respect to modulus of rupture. The likely explanation is that Kaylo-20 material, being composed of crystals of greater size, behaves less like a gel and is more stable in the drying process. During the drying of Kaylo-10 ware, stresses are likely to be created and result in incipient cracks which adversely affect the tensile strength. Compressive strengths on the other hand, are not as seriously affected by these flaws in structures, and for a given density are generally higher for Kaylo-10 than Kaylo-20 insulation and core material.

It should be emphasized that these strength data represent general values and trends. A number of factors greatly affect the strength. These are discussed at greater length in a subsequent chapter.

Chapter III

FORMULATIONS

A number of things have to be taken into consideration in designing a formulation for a given type of Kaylo product. Perhaps of utmost importance is the combination of properties in the end product. Among these for thermal insulation are: modulus of rupture, compressive strength, hardness, handleability (resistance to abuse), apparent density, appearance, shrinkage at elevated temperatures, and thermal conductivity or "k" factor. It so happens that the optimum or ideal cannot be obtained for each and every property, at least at this time. A sacrifice in one is frequently made to benefit another. For example, the means that have been employed to bring about a reduction in "k" factor have resulted in some loss of strength. Efforts, then, are directed toward the attainment of the best combination of properties that are possible, as indicated by customer reactions.

The design of a formulation is further complicated by the fact that a slurry must result which can be handled most satisfactorily by existing plant methods and equipment. Furthermore, the formulation must lend itself to the greatest possible speed of processing throughout the various steps from mix to trim. Here again a compromise must be made between one or more of the desired properties and the ease or speed of processing. A case in point: it is known that shrinkage of the product at elevated temperatures can be reduced by employing less diatomaceous earth and more crystalline silica, but it is alsoknown that the rate of prehardening would be lowered and longer periods of autoclaving would likely be needed.

Further complications are introduced by efforts to keep batch costs as low as possible. The effects of a substitute material, an additional constituent, or a change in density, have to be carefully observed and analyzed to determine if the change has been favorable in respect to speed of processing, quality of the product, and the amount of off-ware. An addition to batch cost may in effect represent a saving in the long run.

Formulation for Kaylo-10 Insulation

The following formulation is currently (March, 1959) employed for both Kaylo-10 pipe covering and block, and has been in use since December, 1958:

Raw Material	Weighed Amount (Pounds)	Dry Weight (Pounds)	Percent
AW amosite asbestos	100	100	3.28
W-3 amosite asbestos	50	50	1.64
6D chrysotile asbestos	150	150	4.92
4K chrysotile asbestos	200	200	6.56
Quicklime	840	840	27.55
Tripoli	350	350	11.48
Celatom	850	816	26.76
Clay	100	100	3.28
Ground limestone	240	240	7.87
Air-float chromite	100	100	3.28
Wollastonite C-101	100	100	3.28
Tamol #731	12.5	3	0.10
Totals		3,049	100.00

Water - 16,830 lbs.
Water/solids = 5.53
Molar CaO/SiO_2 = .77

Factors:

CaO/quicklime = .94
SiO_2/Celatom = .83
SiO_2/tripoli = .99
SiO_2/clay = .45

At the time of writing, there are no basic changes indicated in this formulation. There is, however, continuing search for ingredients that would lower the "k" factor of the product without necessarily taking part in the chemical reactions involved in the formation of the desired product. If such an ingredient is found, the amount employed in the formulation will in all probability be minor in respect to the lime and siliceous materials.

Arrangements are underway to conserve the slurry carried by the water in the periodic wash-out of the mixers and lines, and to return this diluted slurry to the batch. It is also proposed to return at least a significant portion of the waste Kaylo material resulting from trim and off-ware to the batch at the earliest possible date. Certain adjustments will be made so that the proportions of the solids to each other and the ratio of total solids to water do not differ from those in the formulation given above.

Formulation for Kaylo-10 Core Material

Given below is the formulation employed in the manufacture of Kaylo-10 Core Material. It is sometimes referred to as Hydrate Core to distinguish it from another type of Kaylo-10 core produced earlier.

Raw Material	Weighed Amount (Pounds)	Dry Weight (Pounds)	Percent
6D chrysotile asbestos	150	150	4.11
4K chrysotile asbestos	300	300	8.23
Hydrated lime	1,800	1,386	38.02
Tripoli	1,400	1,400	38.40
Celatom	375	360	9.87
Clay	50	50	1.37
Totals		3,646	100.00

Water - 10,200 lbs.
Water/solids = 2.91
Molar CaO/SiO_2 = .82

Factors:

CaO/Hydrated lime = .73
SiO_2/Celatom = .83
SiO_2/tripoli = .99
SiO_2/clay = .45

This formulation yields a product that is satisfactory as to strength, but the ware is often subject to drying cracks in the process. The formulation for Kaylo-10 core material should be the object of further study.

The writer feels that more reinforcing, either asbestos fibers or the fibrous wollastonite C-101, should be employed. It is also felt that an improved product would result under conditions of practical autoclaving cycles if the molar CaO/SiO_2 ratio were to be lowered to about 0.75.

It will be observed that hydrated lime instead of quicklime is used. This is done to keep the consistency of the slurry low enough for it to be handled satisfactorily in the casting operation. It would be advantageous if quicklime could be employed. Hydrate is more expensive for a given CaO content, deteriorates much more rapidly, and represents an additional raw material to handle in the plant. Perhaps some combination of asbestos and wollastonite C-101 can be found that will provide adequate reinforcing and will contribute less to the consistency of the slurry, so that quicklime can be used for the Kaylo-10 core formulation.

Formerly, a Kaylo-10 core material that was satisfactory in most respects was made from a formulation in which portland cement supplied most of the lime and silica. It had been designed to fit into the Sayreville operation, which required a very rapid rate of prehardening. Early in July, 1957, complaints were received from a customer stating that Kaylo-10 core exhibited greater absorption of the adhesive in the laminating operation than did a competitive calcium silicate core material. The change to the above hydrate formulation in July 1957, resulted in a material showing considerably less absorption of glue, and equal to competitive material in this respect.

Formulation for Kaylo-20 Thermal Insulation

At the time this is being written, there are two schools of thought in regard to the optimum formulation for Kaylo-20 thermal insulation. Both groups can present data supporting their contentions. Some feel that the 1.017 molar CaO/SiO_2 ratio of the formulation currently employed is too high for the amount of autoclaving permissable at present rates of production. Others are of the opinion that the great quantity of excellent ware produced from formulations having this CaO/SiO_2 ratio indicates that it is satisfactory. The writer is inclined to feel that the 1.017 value represents just about the maximum, and if for some reason the ware does not receive the customary amount of autoclaving (the prescribed time, pressure, and temperature), higher than normal amount of shrinkage at 1800°F will likely result. For this reason, he feels that a molar ratio of about 0.95 would prove more satisfactory day in and day out.

Following is a formulation typical for the production of Kaylo-20 thermal insulation. The actual quantities vary depending upon the amount of slurry required for the particular train of molds to be filled, but the relative amounts of the ingredients are held constant:

Raw Material	Weight (Pounds)	Percent
W-3 amosite asbestos	375	13.00
6D chrysotile asbestos	150	5.20
4K chrysotile asbestos	50	1.73
Quicklime	1,025	35.52
Tripoli	1,025	35.52
Red iron oxide	11	0.38
Wollastonite P-1	250	8.65
Totals	2,886	100.00

Water - 13,515 lbs.
Water/solids = 4.71
Molar CaO/SiO_2 = 1.017

Factors:

CaO/quicklime = .94
SiO_2/tripoli = .99

It is possible that an inert ingredient may be added in the future to function as an opacifier to infra-red rays. Kaylo-20 thermal insulation is designed to serve at temperature ranges where radiation is an important factor in the conductance of heat. Extremely finely ground zircon is an example of a material that exhibits some opacity to infra-red. A trial run of Kaylo-20 thermal insulation containing 5% of zircon is awaiting test.

Formulation for Kaylo-20 Core Material

As is the case with Kaylo-20 thermal insulation, there is also a difference of opinion as to the best molar CaO/SiO_2 for Kaylo-20 core. The ratio was reduced to .977 from 1.00 in December 1958 with results that are not too clear cut. It is the writer's opinion that this ratio is still somewhat on the high side to be safe for plant production. In the current formulation given below, the computations are based on a CaO content of 73% for the hydrate. If by chance the CaO content for the lot actually used was 74% instead of 73% as found in the test sample, a molar CaO/SiO_2 ratio of .99 would obtain.

The hydrate content is varied in accord with the amount of available CaO found to be present in the test samples.

The following batch is based on a 73% CaO hydrate.

Raw Material	Weighed Amount (Pounds)	Dry Weight (Pounds)	Percent
4K chrysotile asbestos	550	550	14.83
Hydrated lime	1,880	1,448	39.06
Tripoli	1,520	1,520	40.99
Red iron oxide	15	15	0.40
Wollastonite P-1	175	175	4.72
Totals		3,708	100.00

Water - 10,005 lbs.
Water/solids = 2.81
Molar CaO/SiO_2 = .977

Factors:

CaO/hydrated lime = .73
SiO_2/tripoli = .99

Chapter IV

ROLE OF THE VARIOUS RAW MATERIALS

Asbestos

The term asbestos is not definitive of any specific chemical compound. It is a general term applied to any natural mineral that tends to occur in a fibrous form. Throughout the years, various minerals in this form have been tried in Kaylo formulations, but only two, chrysotile asbestos and amosite asbestos, have proved to be satisfactory quality-wise, or to be economically feasible.

Asbestos is employed for two purposes. First, it is an effective suspending agent. With proper fiberization, it is possible to obtain stable, non-settling suspensions of as little as 3 or 4% of asbestos in water. This jackstraw arrangement of fibers is capable of supporting and keeping other solids from settling out of suspension in dilute slurries. It makes possible the creation of the stable suspensions of high water content necessary for the production of lightweight products by our present process.

Second, asbestos fibers provide reinforcing. They not only tend to prevent cracks from originating, but they also tend to hold the piece together after a crack has occurred. The latter function is commonly referred to as hinging.

As recently as 1939, the role of asbestos as a reinforcing material was not appreciated, and it was even later that asbestos was employed to make light density products possible. The first hydrous calcium silicate products manufactured were of relatively heavy density. They were found to be subject to severe cracking, and even to disintegration with time when exposed to even moderate temperature changes, and to changes in humidity. The cementitious phase of Kaylo-10 products is essentially tobermorite. While this compound is crystalline, the crystals are so extremely fine that the structure tends to behave as though it were a gel. That is to say, there is significant swelling or shrinking with changes in moisture content brought about by change in surroundings. Reinforcing in the form of asbestos is necessary to stabilize this gel-like structure. On the other hand, Kaylo-20 products are composed of xonotlite. This material is more coarsely crystalline and the crystals themselves are needle-like. Heavy density Kaylo-20 products are not subject to the cracking tendency exhibited by Kaylo-10 ware.

Attempts have been made to substitute other fibers for asbestos in varying amounts. Glass fibers of alkali resistant compositions have been tried and these failed on two counts. In the first place, contrary to the behavior of asbestos, they tend to clump and ball-up, instead of becoming evenly dispersed throughout the slurry with mixing. In the second place, even the most resistant glasses exhibited an envelope of altered glass about the fiber. As a consequence, a satisfactory bond did not obtain between the hydrous calcium silicate and the unaltered portion of the glass fiber.

Fiberized bagasse has also been tried without success. This organic material undergoes some shrinkage in the processing and withdraws from intimate contact with the cementitious phase, rending it of little use as a reinforcing fiber.

Limited amounts of the fibrous mineral wollastonite are now being used for reinforcing in certain formulations. More will be said of this later.

Chrysotile

Chrysotile asbestos is essentially hydrous magnesium silicate of the same chemical composition as its mother rock, serpentine. The pure mineral has the formula $3MgO.2SiO_2.2H_2O$, but commercial fibers invariably contain varying amounts of other oxides as impurities. Chrysotile is rather widely distributed, but about 60% of the world's market is supplied by Canada and about 20% by Russia.

Most of the chrysotile coming from Canada is graded and labeled according to a uniform system which is universally recognized. The grading system is arranged to divide seven main groups of asbestos into more than twenty-five grades. Standardization of the various grades is produced and maintained by regular testing on the Quebec Standard Testing Machine. This equipment consists of a nest of 3 screens and a pan measuring 24½"x 14-3/4"x 4" deep, resting on a table which is movable and is driven by an eccentric rotating in a vertical plane at 328 rpm. The screen sizes are 2, 4, and 10 mesh, respectively. A timing device allows exactly 600 revolutions per test. Testing is done on a 16-ounce sample representative of the lot. The sample is divided into four fractions by the action of the testing machine. The weights in ounces of the fractions retained on each of the three screens and that caught in the pan are recorded. These weights define the quantity of the various fiber lengths in the sample, and in this manner establish a certain grade. The greater the proportions of longer fiber, or the greater the amounts on the coarser screens, the lower the number designation of the grade. Within the numerical grade there is also further gradation defined by a letter of the alphabet; the lower the letter in the order of the alphabet, the greater the proportions of the longer fibers.

Chrysotile fibers tend to be relatively short. The price increases rapidly with increase in fiber length. Certain grades of long fiber may sell for considerably more than a thousand dollars per ton.

In Kaylo formulations, grade 4K and grade 6D are currently used. The delivered prices are about $226 and $102 per ton, respectively. The distribution of the fibers in these two grades are:

	On #2 mesh	On #4 mesh	On #10 mesh	In Pan
4K	0	4	9	3
6D	0	0	7	9

Chrysotile of good quality is a soft, yet strong fiber. The individual fibers of a given grade are in reality bundles of much finer fibers. As such they have fine "hairs" protruding from the sides, and tend to exhibit broomed ends. It is this make-up that is responsible for their remarkable ability to stay in suspension, and to support other solids in dilute slurries. This structure also tends to hold water within it, and imparts non-bleeding characteristics to a slurry. The difference in structure between chrysotile and glass fibers accounts for their different behavior when incorporated in slurries.

Although the grading and labeling of Canadian chrysotile is rigidly controlled, there are differences in quality of supposedly the same grade from different sources, as far as being an ingredient in Kaylo products is concerned. The various chrysotiles may differ in suspending power, and differences in inherent strength may be reflected in differences in strength of the ware. The only means known at this time to detect these differences is in the testing of the resulting Kaylo slurries and products. To date no Canadian chrysotile has proved as satisfactory as that of J-M. However, the search is continuing, and it is likely that other sources of supply will be found.

The Canadian system of labeling does not necessarily apply to chrysotile from other countries. As a rule, samples of the various grades must be obtained and attempts made to classify them on the Canadian basis before choices are made for trial Kaylo batches. Limited amounts of Venezuelan chrysotile have been used with success when blended with J-M material. It is questionable that it could be used to the exclusion of the latter.

As mentioned above, chrysotile is a hydrous compound. That is to say, water is an integral part of its crystal structure. For this reason it begins to disintegrate and lose strength at relatively low temperatures in terms of thermal insulation. As recently as 1955, chrysotile was the only type of asbestos employed in Kaylo thermal insulations. The demands of the trade for greater stability at higher temperature, and for reduced thermal conductivity, led to the use of a blend of amosite asbestos with chrysotile in Kaylo thermal insulation.

Amosite

Amosite is essentially an anhydrous ferrous silicate. When pure it has the formula, $FeO.SiO_2$. Usually there is some MgO in the structure, along with a little CaO. The fibers tend to be very much longer than those of chrysotile. For the grades used in Kaylo batches, a large percentage of the fibers are longer than one inch, with some ranging up to about three inches or more. Almost all of the fibers are longer than 3/8". The delivered prices at Berlin for these fibers are about $196 to $210 per ton. In comparing these prices with that for 4K chrysotile, it is evident that a fiber of much greater length is obtained at a somewhat lower cost.

Africa is the only important commercial source of amosite asbestos. Each producer, who may buy crude from many sources, uses his own system of nomenclature for the various grades. Aside from fiber length, the quality of amosite in respect to strength, brittleness, gangue content, etc., may vary greatly from vendor to vendor. Prices for material of the same quality may also vary considerably. However, it has been found that the quality has remained quite constant of given grades supplied by North American Asbestos. Prices also have compared favorably. From what has been learned, we presently appear to be in a position of a preferred customer of North American.

As mentioned above, amosite is an anhydrous compound, which means, of course, that it contains no water as part of its structure. Partially for this reason, it can withstand higher temperatures than can chrysotile before breakdown begins. The substitution of amosite for chrysotile results in products having lower shrinkages at elevated temperatures.

Another factor in favor of amosite is that lower "k" factors, particularly at higher mean temperatures, result in the products when it replaces chrysotile. This is believed to be due to the fact that it is an iron compound and as such is more effective in blocking infra-red radiation. Some of the ferrous iron of the amosite apparently undergoes a base exchange with the lime of the batch, and becomes disseminated throughout the entire hydrous calcium silicate structure. That the entire body of the product becomes uniformly pink after being subjected to high temperatures is evidence of this. Kaylo products containing only chrysotile remain white. Just how much iron and lime are involved is not known. A study of this phenomenon would be most worthwhile. If the amount of lime that takes part in this reaction is significant, and if this lime is thus prevented from combining with the silica to form hydrous calcium silicate, the true CaO/SiO_2 ratio may be different from that designed and intended for the formation of the desired hydrous calcium silicate.

Still another argument for the use of a certain percentage of the asbestos as amosite, is the pouring characteristics imparted to the slurries. Being a stiffer fiber, its presence makes for a slurry less prone to result in eddies as it is being cast into the molds by present methods. This differential movement within the slurry, with one portion sliding over another, results in slip planes or discontinuities within the ware. On the other hand, too high a proportion of amosite results in a "harsh" slurry which tends to fold or tear as it is being cast in the mold. These patterns are carried over into the finished ware as defects.

While high amosite contents may yield a slurry that holds the solids well enough, this stiff and relatively open framework of fibers may permit the loss of water by bleeding. Consequently, a blend of amosite and chrysotile is employed in the production of Kaylo thermal insulation to take advantage of the favorable characteristics of each. However, in a process that does not involve the holding of the slurry for any length of time under quiescent conditions, bleeding is not a problem and solely amosite will most likely be used. This was true for the batch employed in the tubular molding operation, which was recently discontinued.

It is of interest in this connection, that J-M uses only amosite in its process. Since a very dilute slurry, 20 to 25 water/solids ratio is employed, harshness is not a problem. Nor does this slurry remain quiescent. Furthermore, the molding is a press and filter operation, which requires that the slurry possess a high degree of freeness. Thus J-M is able to take full advantage of the characteristics of amosite in both the slurry and the product.

The latest survey of competitive hydrous calcium silicates revealed that all but J-M Thermobestos contained a blend of two types of asbestos.

Only chrysotile is used for Kaylo-10 and Kaylo-20 core materials. This is done to obtain the optimum pouring characteristics with these slurries of lower water content.

Earlier it was stated that only chrysotile and amosite types of asbestos have been found to be satisfactory, or to be economically feasible. Crocidolite asbestos gives highly satisfactory performance, but prices have been too high to permit its use. Like amosite, it comes from Africa. In fact, deposits are frequently closely associated. It is commonly called "blue asbestos", and has the complex formula, $Na_2O.3FeO.Fe_2O_3.8SiO_2.H_2O$.

Wollastonite

Comments on wollastonite are inserted here because it is a fibrous material and is used for reinforcing of the hydrous calcium silicate in Kaylo products.

Wollastonite is anhydrous mono-calcium silicate, $CaO.SiO_2$. It may be made synthetically, but we are concerned here with the natural mineral. It is supplied in several degrees of fineness from a source in New York State by Godfrey L. Cabot, Inc.

It will be recalled from discussions of formulations in Chapter III that grade C-101 was used in Kaylo-10 thermal insulation, and grade P-1 in Kaylo-20 thermal insulation and in Kaylo-20 core.

The C-101 grade is a relatively coarse material having needle-like crystals up to 1/4" in length. It is used to replace a part of the asbestos in an amount of 100 lbs. for 100 lbs. per batch. It functions solely as reinforcing and does not contribute to suspension. Therefore, the amount that can be substituted for asbestos is limited. It has all of the properties of a good reinforcing material, being strong, having good adhesion to the binder, and being unaffected by heat up to temperatures far beyond the limit that either type of asbestos can withstand.

But perhaps the greatest advantage is to be found in its low cost, about $26 per ton delivered, compared with about eight times this amount for the asbestos it replaces. At a replacement of 100 lbs. for 100 lbs., a savings of about $10 per batch is realized. On a typical day, a total of 28 to 30 batches of Kaylo-10 light density slurry may be poured. Wollastonite C-101 first went into the batch the latter part of August, 1958.

Both Kaylo-10 and Kaylo-20 core formulations at present employ hydrated lime instead of quicklime in order to keep the consistency of the slurry low enough to permit it to be cast satisfactorily. The writer feels there is a strong possibility that if quicklime were substituted for hydrate, and wollastonite C-101 for a part of the asbestos, a satisfactory slurry and as good, if not better, product would result. Studies are indicated on this subject.

Wide use of wollastonite can be expected if and when the manufacture of specialty items becomes of consequence. This especially applies to relatively high density xonotlite, or Kaylo-20, bodies. Experimental pieces of a body composed of 50% xonotlite-50% wollastonite C-101 at a density of 50 pcf have shown a modulus of rupture of 390 psi. After heating at 1800°F for 24 hours, the modulus of rupture was 220 psi and the material had undergone a shrinkage of only 0.6%.

Wollastonite P-1 is an extremely fine, or pigment, grade. It is used in both Kaylo-20 thermal insulation and core batches. Being of pigment grade, it is, naturally, higher priced than C-101, but still is much cheaper than asbestos. Whether or not it is preferable to C-101 in Kaylo-20 batches is still a moot question, and should be resolved sometime. Plant personnel are reluctant to change because of satisfactory experience with the finer material. It should be mentioned here that no thickening of Kaylo-20 slurries occurs at any stage prior to autoclaving, so that these slurries remain in a fluid state for longer periods than do those of Kaylo-10 formulations. Bleeding, or loss of water, from the cast ware can be of major concern. This could be a determining factor in a choice between the finer and the coarser grades of wollastonite.

Lime

Lime, of course, supplies the CaO to combine with the SiO_2 of the batch to form the hydrous calcium silicate binder. It must be a high calcium lime. Highly impure limes, or dolomitic limes, containing appreciable amounts of magnesia are unsatisfactory. The magnesium silicates which result from the reaction of MgO with SiO_2 do not function as a cementitious material. But even worse, the delayed hydration of MgO to $Mg(OH)_2$ involves expansion and results in a disruptive force after the Kaylo mass has set up.

Fortunately, the composition of the product is closely controlled by reputable producers, and reasonably constant quality can be expected from any one source.

Quicklime

Quicklime is employed in both Kaylo-10 and Kaylo-20 thermal insulation formulations. By means of controlled conditions of hydration during the batch mixing operation, a "fat" lime putty results which contributes largely to the desired non-bleeding characteristics of the slurry. For this and other reasons, a very reactive lime is needed. To meet these needs, a "soft" burned lime, yet free from excessive amounts of uncalcined limestone, is required. Many producers cater to the steel manufacturers who prefer a "hard" burned lime. Such limes are not generally suitable. It has been the experience at Berlin that no readily available lime was quite as satisfactory as that produced by Warner Company from its Bellefonte, Pennsylvania plant.

Hydrated Lime

Currently, hydrated lime is used in the heavier density Kaylo-10 and Kaylo-20 core formulations. If quicklime were to be employed in the present formulations, the consistencies of the slurries would prove too high for satisfactory handling in the casting operation.

Commercial hydrate has certain disadvantages. The delivered price is higher for a given CaO content, and it is more susceptible to deterioration during storage. Small inventories and frequent analyses must be the practice. It is hoped that further studies of core formulations will result in modifications which will permit the use of quicklime.

Silica

Two forms of silica are used in the Kaylo-10 thermal insulation and core formulations. They are the crystalline tripoli and the amorphous diatomaceous earth. Kaylo-20 formulation contain only tripoli at the present time, but limited amounts of diatomaceous earth, up to about 20% of the siliceous fraction, have been used in the past. The amount of diatomaceous earth that can be employed in Kaylo-20 formulations is limited by its reactive alumina content. Actually, it was found in laboratory tests with a diatomaceous earth particularly low in Al_2O_3 that high quality Kaylo-20 products were formed more readily when the silica fraction consisted of 60% crystalline silica-40% diatomaceous earth than when composed of entirely crystalline silica. But larger shipments of this particular brand of diatomaceous earth proved to have higher alumina contents and to be quite variable in this respect. Consequently, advantage could not be taken of the characteristics shown by the laboratory sample.

Amorphous silica in the form of silica gel is suitable for both Kaylo-10 and Kaylo-20 formulations, but the cost is much too high for use as a raw material in production.

Tripoli

The term tripoli has different connotations in various countries and in the literature. In American usage, tripoli is a microcrystalline quartz. There are two extensive deposits located in southern Illinois and in Arkansas. Both are being exploited. The material being used at Berlin comes from the former, and is supplied by Illinois Minerals Company.

While it is in reality a quartz, the microcrystalline structure renders it much more reactive than ordinary quartz of the same screen fineness. The delivered price at Berlin is $28.06 per ton for 95% minus 325 mesh, compared to $15.60 for quartz ground to the same fineness. This represents a difference of $2.18 per batch of Kaylo-10 thermal insulation, but experience has shown that the reductions in cylinder time made possible by its use more than compensate for the added cost of the tripoli. For the autoclaving periods accepted as standard in plant operations, greatly inferior ware results when quartz replaces tripoli. Or stated differently, longer autoclaving is required to obtain ware of the same quality when quartz is employed.

Attempts have been made to increase the reactivity of ordinary quartz by grinding to extreme fineness, but the reactivity did not approach that of tripoli of a 95% minus 325 mesh fineness. This experience indicates that the processing of plate glass grinding wastes to provide a source of silica does not hold great promise.

In the formulation for Kaylo-10 thermal insulation, the tripoli constitutes 30% of the total silica. In the Kaylo-10 core batch, the tripoli accounts for about 79% of the siliceous fraction.

Celatom (Diatomaceous Earth)

Celatom is the trade name of the diatomaceous earth produced from Nevada deposits by Eagle-Picher Company. This vendor selects material from only certain strata and blends it for our use. Prior to shipment, each lot is tested by their quality control laboratory for organic matter content, using the method and standards prescribed by us, to assure that the organic content is safely below injurious levels (about 200 ppm). This tested and approved product is labeled Celatom N-370. The results of these determinations of organic content reach the plant by air mail before the Celatom arrives.

Diatomaceous earth, or diatomite, is the fossilized remains of diatoms. Diatoms are microscopic single-celled aquatic plants which have the ability to extract silica from the water in which they live, and with this silica build for themselves external skeletons. When the diatom dies, this skeleton settles to the bottom and remains after the organic part of the plant has disappeared. Over ten thousand different types of diatoms have been identified. Naturally, there are great variations in size, shape, surface area, bulk density, etc., among the diatomites. Furthermore, although all are composed for the most part of amorphous silica, they differ greatly in the amounts of impurities or other oxides that they contain. All of these different attributes have a bearing on the suitability of a particular diatomite deposit for use as a raw material in Kaylo formulations.

Diatomaceous earths other than Celatom N-370 have been given thorough trials. They have generally proved less satisfactory because of lesser reactivity, or because of variable composition from shipment to shipment. In one instance, a vendor's supply of satisfactory diatomite became exhausted.

While knowledge of the presence of gross amounts of impurities may eliminate a diatomite from further consideration, in many cases it is necessary to employ it in trial runs in order to evaluate it. Apparently many factors contribute to its measure of value as a Kaylo raw material. Certain diatomites, although pure enough and having high surface areas, do not react with lime as readily as others. Celite from J-M falls in this category.

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Diatomaceous earth is used in the batch for two reasons. First, as an amorphous form of silica, it reacts very readily with lime. This property permits the cast ware to set up or preharden in a relatively short time at temperatures in the neighborhood of 200°F. The preliminary setting or prehardening of the cast ware greatly facilitates the handling of the filled molds in subsequent operation, and also makes for easier stripping of certain sizes of ware after autoclaving. Also of importance is that scheduling of the cylinders is far less critical, because prehardened or set ware can stand for several hours on the floor if necessary before being autoclaved.

The second reason for using diatomite in the batch is its contribution to the thickening of the slurry, giving it greater water-retaining and non-settling characteristics. It is true that no diatomaceous earth is employed in Kaylo-20 formulations, but Kaylo-20 products cannot be made at as low apparent densities. The minimum density of Kaylo-20 ware that is now practicable in production is about 12.5 pcf. That is to say, the absence of diatomaceous earth in the formulation makes necessary the use of slurries of lower water/solid ratios.

Since the water/solids ratio of the Kaylo-10 core slurry is less than that for Kaylo-10 thermal insulation slurry, less diatomaceous earth is required to give the same rate of prehardening and the same water-retaining properties.

Clay

It was mentioned earlier that it was advantageous to have a limited amount of reactive alumina present to enter the structure of the hydrous calcium silicate which constitutes the body of Kaylo-10 ware. A fine grained china clay (kaolinite type) is a most satisfactory and constant source of reactive alumina, and the silica of the clay is also reactive. This type of clay is used in an amount of 3.28% of the solids in the Kaylo-10 insulation batch, and 1.37% in the Kaylo-10 core formulation.

These amounts appear to be about the optimum in each case from the laboratory studies and the plant trials that have been made. Strengths are greatly improved, and low shrinkages at elevated temperatures result in the product. The presence of somewhat higher quantities of alumina results in ware showing excessive shrinkage at high temperatures. Thus, it is essential that the alumina content of the formulation be closely controlled. Large variations in alumina content of the diatomaceous earth fraction render this control most difficult.

Clays other than a kaolin or china clay might be used, but the use of a high grade china clay insures that objectionable impurities such as organic matter, sulfates, chlorides, etc., are not a problem. There is evidence that bentonite clays increase processing shrinkage.

Alumina in the form of bauxite is not reactive in the Kaylo process.

Inert Ingredients

Studies have shown that the inclusion of extremely fine inert ingredients in the batch reduces the thermal conductivity of the product remarkably. Through the addition of 11% of fine inert materials to the batch, combined with a change to a blend of amosite and chrysotile instead of chrysotile alone, the "k" factor at 550°F mean of the plant product has been reduced about 0.14 from what it was in 1955. It is believed that this effect is mainly due to the increase in number of interfaces between dissimilar materials encountered as heat flows through the insulation. The studies have shown that combination of additives is better than a single inert substance.

A great number and variety of materials have been found to be effective, and the choice for use in production is dependent upon a number of factors. Requisites for a satisfactory additive of this nature are: it should be inert and not interfere with the formation of the desired hydrous calcium silicate; the finer the grain size the better; infra-red blocking properties give an added advantage; it should not impart undesirable color or shade to the product; it should be readily available and cheap.

Carbon black is by far the most effective additive found to date for lowering "k" factor, but its high cost and the darkening it gives to the product rule it out, for the present at least. On the other hand, limestone ground to pass 200 mesh is not as effective, requiring 10% addition to produce the same amount of lowering of "k" factor as 2% of carbon black, but it is by far the cheapest of all of the batch ingredients and does not cause a color change in the product.

The considerably cheaper ground magnetite, Fe_3O_4, has been found to be almc t as effective as ground chromite, $Fe(CrO_2)_2$, but the latter does not darken the product as much.

As to be expected, there is some reduction in strength of the product as the amount of fine inert material in the batch increases. Thus in lowering the thermal conductivity by this means, some strength is sacrificed. Consequently, a compromise must be reached in this matter. The present formulation calls for 7.87% of limestone and 3.28% of chromite for a total of 11.15% of additive. It is likely that 11% of limestone and 4% of chromite could be carried without reducing the strength to a danger point or where it would be objectionable to the customer. A reduction of .03 in "k" factor at 550°F mean could be expected. However, the plant experienced a period of low strengths in 1957 while employing 15% of additive, and may accordingly object to the return to this much. But the formulation has been changed in several other important respects since then which have all contributed to higher strengths, and reoccurrence of the low strengths of 1957 is not to be expected. A return to 15% of additives will not be proposed, however, until it has been first established that a product of more than ample strength can be made consistently with the return of waste slurry and of scrap Kaylo material to the batch. These two modifications to the batch are proposed for the immediate future.

Perhaps research will in the future reveal an additive more effective than any now known, and it will not be necessary to employ quantities to the extent the strength is seriously affected in order to obtain "k" factors that compare favorably with those of competitive materials.

Ground Limestone

As mentioned above, ground limestone is one of the inert additives now in the Kaylo-10 thermal insulation formulation. It is supposedly a by-product in the lime industry, being too fine for most purposes. Nominally it is 90% minus 200 mesh, but most of the grains are as fine as face powder.

Although it is added to the batch to decrease the thermal conductivity of the product, a cheaper batch results as a bonus. The delivered price of the bagged material at Berlin is only $11 per ton. The average of the prices for the other ten solids of the formulation is $4.778 per cwt., while that for limestone is only $0.550.

The present material is a high calcium limestone, but a dolomitic limestone would serve as well. The fineness is the important factor in this case.

Chromite

Iron chromite is the second additive being used to lower the "k" factor of the Berlin product. It has the added advantage of being effective in blocking infra-red radiation. This particular material is known as air-float chromite, and is available commercially, being a batch ingredient in certain glass container plants. The delivered price of bagged material is $2.653 per cwt., which is still cheaper than the average for the other ingredients.

Surface Active Agents

Tamol #731

Certain surface active, or dispersing, agents are effective in increasing the fluidity or flowability of a slurry. Tamol #731, which is supplied by Rohm and Haas, is of this class. The addition to the Kaylo-10 insulation batch was begun on November 10, 1958. It is employed in an amount of 0.10% of the weight of the solids. This addition has proved most valuable in imparting excellent pouring characteristics to a slurry that was otherwise too thick and stiff to cast properly. The incidence of air holes and folds has been greatly reduced in molded pipe covering. While it does add $2.34 to the batch cost, the saving resulting from a lower amount of off-ware more than compensates for this increase.

Tamol #731 is a new development, and Berlin was one of the first customers. Promise has been made of likely price reductions in the future.

A satisfactory dispersing agent for Kaylo slurries has been the subject of research for several years. Many have been tried in the past, but their use was soon abandoned for one of two reasons: either they were foam formers with a resulting unfavorable effect on the "k" factor of the ware, or they caused unsightly staining of the product. Tamol #731 has neither of these disadvantages.

Coloring

Red Iron Oxide

A small amount (about 0.3%) of fine red iron oxide is added to both types of Kaylo-20 batches to give a pink color to the product. This is done to distinguish the ware on sight from corresponding Kaylo-10 material.

Chapter V

RAW MATERIAL SPECIFICATIONS

The specifications as given here are not to be considered as being in final or standard form. They are actually compilations of the properties and requisites of the various raw materials, made to serve as the bases for the drafting of formal specifications.

It should be emphasized that passing a specification based on conformance to a limited number of chemical and physical properties is no assurance that one material will function as well as another in Kaylo formulations. Certain variables can exist that are not easily detected except by observations of behavior of the materials in trial runs of batches containing the material in question. The specification for each ingredient should contain a clause stating that it shall prove to be satisfactory for use in the production of Kaylo products. Final grounds for acceptance or rejection of a particular material should be whether or not it compares favorably with standard performance in respect to speed of processing and to the quality of the product.

No new source of any of the batch ingredients should be given final approval before runs of laboratory and plant trial batches have been made and favorable results are obtained.

Once a material has been approved, it is one of the functions of the Process Control Engineering Section to conduct the necessary tests in its laboratory at the plant to insure that no significant variation from specifications occurs. It is also the responsibility of this group to advise as to corrective measures to be taken when the character of material on hand has changed due to conditions of storage or other reasons.

Chrysotile Asbestos

Chrysotile shall conform to the following requirements and in addition prove suitable in plant trials for the production of Kaylo products.

Two grades of chrysotile are required for the production of Kaylo products, a shingle fiber and the shorter, stucco or plaster fiber.

The former shall prove to be the equivalent of Grade 4K or better in the Quebec Standard Test; the latter the equivalent of Grade 6D or better.

The vendor shall guarantee that each material is of the chrysotile variety of asbestos. Optical properties rather than chemical analysis are to be the basis for judgment in case of dispute on this point.

Maximum impurities:	Cl	.20%
	SO_3	.75%

The chrysotile shall be supplied in bags of uniform weight, with the grade of the material marked thereon. Compressed material in paper bags is preferred.

Approved vendors: Johns-Manville

Amosite Asbestos

Amosite shall conform to the following requirements, and in addition prove suitable in plant trials for the production of Kaylo products.

There is no uniform system employed in the grading of amosite asbestos. Generally speaking the grades of interest consist predominantly of fibers longer than 3/8 or 1/2", and about 20 or 25% longer than 1".

The amosite shall contain no more than 2.0% of non-fibrous material present as rock or dust.

The chemical composition shall conform roughly to the following: 50% SiO_2, 6% Al_2O_3, 37% FeO, 4% MgO, 2% H_2O.

Before a new and untried material is purchased, representative samples must be furnished for comparison with "standard" fibers as to brittleness, tensile strength, fiber length distribution, etc.

The amosite shall be supplied in burlap bags of uniform weight, with the grade and manufacturers name marked thereon.

Approved vendors: North American Asbestos Corporation

Pulverized Quicklime

This lime shall conform to the following requirements, and in addition prove suitable in plant trials for the production of Kaylo products.

Substantially all of the pulverized lime shall pass the No. 20 sieve and after slaking, not more than 1.0% by weight shall be retained on this size screen.

Requirements as to chemical composition on an air dry basis are as follows:

		When tested at	
		Plant	Place of Mfg.
CaO Total	Min. %	94.5	96.0
CaO Available*	Min. %	92.5	93.5
R_2O_3	Max. %	2.0	2.0
MgO	Max. %	3.0	3.0
SO_3	Max. %	0.3	0.3

*A.S.T.M. Designation C25-47 (sugar method)

The lime shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of lime in each bag shall not deviate more than one pound, plus or minus, from the average weight.

The bags shall be marked, "Pulverized Lime", and shall also comply with the A.S.T.M. requirements for marking.

Approved vendors: Warner Lime Company

Hydrated Lime

This lime shall conform to the following requirements, and in addition prove suitable in plant trials for the production of Kaylo products.

Not more than 1.0% by weight shall be retained on the No. 30 sieve, nor more than 15.0% on the No. 200 sieve.

Requirements as to chemical composition on an air dry basis are as follows:

		When tested at	
		Plant	Place of Mfg.
CaO Total	Min. %	72.0	73.0
CaO Available*	Min. %	69.5	70.0
R_2O_3	Max. %	1.5	1.5
MgO	Max. %	2.0	2.0
SO_3	Max. %	0.25	0.25

*A.S.T.M. Designation C25-47 (sugar method)

This lime shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of lime in each bag shall not deviate more than one pound, plus or minus, from the average weight.

The bags shall be marked, "Hydrated Lime", and shall also comply with the A.S.T.M. requirements for marking.

Approved vendors: Warner Lime Company

Tripoli

This material shall conform to the following requirements, and in addition prove suitable in plant trials for the production of Kaylo products.

Evidence must be presented that this silica flour is produced from a form of microcrystalline quartz commonly known in the U.S.A. as "tripoli".

Not more than 1% shall be retained on the No. 100 sieve, nor more than 5% on the No. 325 sieve. At least 50% by weight shall be finer than 25 microns.

Requirements as to chemical composition on "as received" basis are:

SiO_2	Min. %	98.0
R_2O_3	Max. %	1.5
Loss on ignition	Max. %	1.0

This silica flour shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of contents in each bag shall not deviate more than one pound, plus or minus, from the average weight.

Approved vendors: Illinois Minerals Company

Diatomaceous Earth

This material shall conform to the following requirements, and in addition prove suitable in plant trials for the production of Kaylo products.

Not more than 0.1% shall be retained on the No. 20 sieve, nor more than 8.0% on the No. 325 sieve.

Requirements as to chemical composition on "as received" basis are:

SiO_2	Min. %	80.0
Al_2O_3	Max. %	7.0
Fe_2O_3	Max. %	4.0
Total R_2O_3	Max. %	10.0
Loss on ignition	Max. %	9.0
Organics	Max.	200 ppm*

*As tested by OCF method, June 5, 1956 Revision, and employing color standards to be provided by OCF.

This diatomite shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of contents in each bag shall not deviate more than one pound, plus or minus, from the average weight.

Approved grades and vendors: Celatom N-370, Eagle-Picher Company

Clay

This material shall conform to the following requirements and in addition prove suitable in plant trials for the production of Kaylo products.

The clay shall be the china or kaolinite type, and uncalcined.

It shall be pulverized clay showing no more than 1.0% on a No. 325 sieve.

Requirements as to chemical composition on "as received" basis are:

SiO_2	Range %	40 to 50
Al_2O_3	Range %	35 to 45
$SiO_2+Al_2O_3$	Min. %	84.0
Loss on ignition	Max. %	15.0

The clay shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of contents in each bag shall not deviate more than one pound, plus or minus, from the average weight.

Approved vendors: Georgia Kaolin Company
Kraft Chemical Company

Limestone Flour

This material shall conform to the following requirements, and shall in addition prove to be suitable in plant trials for the production of Kaylo products.

Extreme fineness is a major requisite. At a given price, preference shall be given to limestone flour having the smallest particle size. In any case, there shall be no more than 5% retained on No. 325 sieve; 80.0% or more of the limestone shall be finer than 10 microns.

Both high calcium limestone and dolomitic limestone are acceptable. Requirements as to chemical composition on "as received" basis are:

$CaCO_3$ or $CaCO_3$+$MgCO_3$	Min. %	97.0
Moisture	Max. %	1.0
SiO_2	Max. %	1.0
R_2O_3	Max. %	1.0

This material shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of contents in each bag shall not deviate more than one pound, plus or minus, from the average weight.

Approved vendors: Warner Lime Company

Iron Chromite

This material shall conform to the following requirements, and shall in addition prove to be suitable in plant trials for the production of Kaylo products.

Extreme fineness is a major requisite. No more than 5% shall be retained on the No. 325 sieve. A suitable material is that known as "Air Float Chromite", and is of a purity comparable to that of the chromite employed as a colorant in the glass container industry.

This material shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of contents in each bag shall not deviate more than one pound, plus or minus, from the average weight.

Approved vendors: Frank Samuels and Company

Wollastonite

This material shall conform to the following requirements, and shall in addition prove to be suitable in plant trials for the production of Kaylo products.

The wollastonite shall be the natural mineral graded to give a definite particle size range. Two grades are of interest. They correspond to Grade C-101 and Grade P-1 as produced and labeled by Godfrey L. Cabot, Inc.

This mineral shall be shipped in paper bags strong enough to withstand normal handling without bursting. Weight of contents in each bag shall not deviate more than one pound, plus or minus, from the average weight.

Approved vendors: Godfrey L. Cabot, Inc.

Red Iron Oxide

This material shall be the pigment grade of red iron oxide.

Approved vendors: C. K. Williams Company

Dispersing Agents

A dispersing agent to be acceptable must be capable of greatly increasing the fluidity of Kaylo slurries when amounts no greater than 0.10% are added, must not cause the formation of foam during the mixing of the slurries, and must not result in the staining of the product. The standard of performance is that of Tamol #731.

Approved vendors: Rohm and Haas Company

Chapter VI

BATCHING AND MIXING OPERATIONS

The detailed procedures to be followed in this step of the process, and in subsequent operations, are given in a manual prepared by C. F. Silkwood, and approved by O. W. Pfeifer, titled "Kaylo Manufacturing; Process and Operational Control". This manual was issued June 11, 1958.

It is the intention here to refer only to the high lights of the above-mentioned manual, and to offer some further explanation where such is considered helpful.

Formulation changes may be made only upon authorization of the Plant Manager. It is the responsibility of the Chief Process Engineer to calculate the actual quantities of each of the raw materials and the amount of water required, to specify the temperature of the water, and to give detailed instructions to be followed in the treatment and mixing of the ingredients of the batch. All of this is recorded and published on a standard form.

Bagged, rather than bulk, raw materials are employed in the batching operation. Formerly, the Sayreville plant operated with a weighing and accumulating system for its raw material handling and batching, but experiences there indicated that the handling of bagged ingredients was to be preferred, both from the standpoint of over-all cost and control.

The specified weights of the principal raw materials for the batch are determined by using an equivalent number of bags. Where possible, the weight of a particular ingredient is chosen so as to represent some whole number of bags. In cases where this is not feasible, some easily defined fraction of a bag is chosen. It is necessary, of course, with this scheme to make a regular check on the average bag weight of the raw materials as they are received.

If a significant variation is evident, the material is isolated, and means are devised for using it. In such cases the vendor is advised and asked to correct the condition.

The batching and mixing operations begin with the measuring out of the predetermined amount of water at a prescribed temperature into one of the two tanks that are used to disperse the asbestos in water. These are cylindrical tanks with impellers located near the bottom. In the pumping from one tank to the other, the suspension passes through a Bauer mill, the plates of which may be set at a desired clearance.

The batching and mixing to be described is that for Kaylo-10 thermal insulation batch because the operation is the most complex. More ingredients are employed and the recovery of waste slurry is involved.

The amount of water used for the batch is determined by the amount of dry solids plus the amount of solids contained in the volume of waste slurry added. The volume of waste slurry to be used per batch is determined by the quantity that has been collected in the two salvage tanks (similar but somewhat smaller than the asbestos tanks), and the number of batches of Kaylo-10 light density scheduled to be run for the day.

The waste slurry is, of course, much more dilute than the batch slurry, since it consists of the batch remaining in the lines and mixers plus the water used to wash out the equipment.

After the prescribed amount of clear water for the batch has been metered into the No. 1 asbestos tank, and the Tamol #731 added, a measured amount is pumped to the No. 2 asbestos tank, and thence to the hydrapulper for the hydration of the quicklime. This quantity is about four times the weight of the quicklime.

To the water remaining in the No. 1 tank, a metered amount of the dilute waste slurry is added. To this tank is then added, all of the asbestos, the clay, and a half a bag or so of the quicklime going into the batch. (Asbestos disperses better in lime water than in straight water.) These solids are put into suspension by the action of the impeller at the bottom of the tank and pumped into No. 2 asbestos tank through the Bauer mill running at a clearance of 0.020".

The treatment given the asbestos in the Bauer mill, which is a fiberizing operation, is varied according to the blend of asbestos being used at the time and to the characteristics of the final slurry. If a higher consistency is desired, or if clogging of the pouring nozzles is being experienced, the plates of the Bauer mill may be set closer together, or several passes may be made through the mill, or both. Also, if the slurry is showing abnormal tendency to bleed, more work may be done on the asbestos by the Bauer mill.

While the asbestos suspension is going through the Bauer mill, the operator dumps the remainder of the quicklime and the wollastonite into the hydrapulper containing the water for the hydration of the lime. The hydrapulper is then set to run for about three minutes to thoroughly mix the lime and water, and to get the hydration of the lime well under way.

After the asbestos suspension has gone through the Bauer mill into asbestos tank #2, it is pumped from there to the hydrapulper on top of the lime putty. When this is complete, the hydrapulper is put in motion and the diatomaceous earth, tripoli, and additives added. The complete batch is allowed to mix for about eight minutes.

The hydrapulper is a piece of equipment primarily designed for the production of pulp slurries in the paper industry. The violent action imparted to a fluid results in very thorough mixing within a short time. Its action also is effective in further opening of the asbestos fibers. Because of this, the hydrapulping period must be controlled. The consistency of Kaylo slurries increases with increases in time of mixing in this equipment.

For all of its effectiveness as a mixer, there may be a disadvantage in the use of a hydrapulper. There is a possibility that an undesirable amount of air is entrapped in the slurry by the violent action. If this is true, and if these air bubbles are for the most part carried through the process to the finished product, the "k" factor of the ware is likely to be affected adversely. This should be a subject for study.

Following mixing in the hydrapulper, the slurry is pumped to a holding mixer, which is a Robinson ribbon mixer. At this point, samples of the slurry are taken for determinations of consistency, density, and temperature.

The consistency figure is the value obtained with equipment specially designed to measure the resistance that a revolving brass cone meets as it penetrates the mass of slurry. Consistency must be held within certain defined limits because of its effect during the filling of the molds. A high consistency causes the slurry to flow sluggishly in the molds, resulting in air holes, slip planes, and pouring folds or tears. Low consistency will result in bleeding after casting, water veins with subsequent cracks or separations, and shifting within the molds during handling.

The density of the slurry is reported as weight per cubic foot. It is determined simply by weighing a known volume. Control of slurry density is essential in the control of the density of the product. Determination of slurry density also affords a check on batching as to the solid raw material weights and quantity of water employed.

All of the pertinent data are obtained, and recorded at this point. Departures from normal are promptly reported to the Production Superintendent and the Chief Process Engineer. The latter attempts to determine the reason for the departure, and must decide if the proper correction can be made, or if the slurry must be dumped.

After it has been determined that the slurry is normal, it is held in the holding mixer on the batch floor, with just sufficient mixing action to maintain uniformity, until demands on the pouring lines call for it to be pumped to any one of the pouring mixers. There is one such mixer in the No. 2 pouring line (molded pipe covering casting), and there are two in the No. 1 pouring line (flat ware). These mixers are similar in type to the holding mixer on the batch floor.

The existence of only one holding mixer is a serious handicap to efficient operation, since it may be called upon to handle any one of four types of slurries. Scheduling, therefore, is extremely critical inasmuch as it must be free of any remnants of previous batch of different type at the time the new batch is ready to be pumped from the hydrapulper. The matter is further complicated in that its availability must be tied in with cylinder opening schedules.

Plant personnel have asked for assistance from General Engineering in planning for additional batch storage facilities. A holding mixer for Kaylo-20 slurries is especially needed, and would be of unestimable value in making for more efficient operation. Kaylo-20 slurries can be held practically indefinitely before casting. If storage facilities are available, mixing can be done when most convenient on the batch floor and independently of the cylinder schedules.

The entire batch mixing facilities should be the object of study and comprehensive planning in view of the greatly increased demands for production. Present batch mixing facilities are essentially the same as those that first went into operation on March 12, 1954. More than twice as much slurry per day is being mixed now than it was then. The ultimate capacity of the system under the most efficient operation was considered at that time to be about 32 batches per day of the same type of slurry. Not only has this "limit" been exceeded, but the plant has been called upon on certain days to mix three types of slurries instead of only one.

The exact manner in which waste Kaylo products will be returned to the raw batch has not been determined as yet. Nor is it known how much of the material presently sent to the dump can be safely incorporated in the batch.

The quantity of dust that results from the trimming, routing, and planing operations far exceeds the weight of the reject ware. This Kaylo dust is collected in dust arrestors, and usually amounts to more than 5 tons per day, or nearly 15% of the weight of the solids that go into the Kaylo-10 thermal insulation batches daily.

Laboratory results thus far indicate that it is likely that this much can be returned to the raw batch without serious degradation of the quality of the product. In utilization on a plant scale, this dust will probably be transferred from the collectors to a tank where it will be mixed with water at a definite water/solids ratio. Plans call for two such tanks. During any one day, the dust and water will be mixed in one tank, and the dust-water slurry prepared the previous day drawn off from the other as needed in the batching operation.

Chapter VII

FORMING

Casting Method

With a forming method dependent upon the casting of a fluid slurry to shape, such as used for by far the most of the production at Berlin, a great many of the defects in the finished product originate at the pouring or casting station. The person who performs the task of filling the molds is a key figure in determining the quality of the ware. A considerable amount of art is involved at this stage of the process. Accordingly, the plant has generally followed the practice of requiring that a man "work up" to the job of pourer. Also, training manuals, emphasizing the intricacies of the operation and describing in detail the procedure to be followed, are available and are required reading. The Shift Foreman is directly responsible for the performance of his pourer and other members of his crew.

In spite of all efforts to obtain uniform performance among the crews, this objective is rarely attained for any one month. Quite typical is the record for February, 1959. Of the four crews, one was responsible for 36% of the off-ware, whereas another was charged for only 16%. This high off-ware crew, which poured a fourth of the production, was charged with more than one-half of the ware rejected for air holes, and had five times as much ware lost for this cause than did the best of the crews in this respect.

The answer to this problem seems to lie in eliminating as much of the human element as possible in this operation. Efforts are now being directed along these lines, as further discussion will reveal.

There are two pouring lines: No. 1 where all of the flat ware is cast; No. 2 where only molded pipe covering is poured. Current demands for pipe covering are such that some must also be poured on the No. 1 line.

The pouring line actually begins at the station where the autoclaved ware is stripped from the molds. A summary follows of the operations performed on the No. 2 or molded pipe covering line.

A tier of filled molds (full car flight) is taken from a train that has been pulled from the cylinder and delivered by means of a lift truck to the end of the line, where the ware is stripped from the molds by the stripping gang of the crew.

Here the processed ware undergoes its first inspection. A piece of ware with gross defects is discarded at this point. A report of the ware discarded is made on the Pour and Strip Recap form which originated when that particular train was poured and which accompanied that train throughout the complete process, with all pertinent data at each step being recorded thereon.

As the ware is stripped, it is color coded to the proper pouring crew.

A most significant control check is made by the weighing of a representative sample to determine its moisture content. One piece of each size ware in each car is weighed and the weight recorded on the Pour and Recap form. By comparing with the preprinted maximum weight for "dry" ware of this size, it is determined whether or not the ware has to receive supplementary drying. These data are also employed in establishing the proper cylinder cycles.

It is the practice for a member of the Quality Control staff to make spot checks at the stripping station. Here the ware can be readily identified with a specific train, cylinder, and crew. Also of major importance is that faulty molds responsible for off-ware can be detected at this point and taken out for repair and/or cleaning.

After the ware has been stripped from the mold, the cavity and core are coated with a mold release. This is an emulsion of about 3% of polyethylene in a fairly heavy petroleum oil compounded at the plant. The oiling of the molds is performed by hand, the oiler rubbing a rag that has been dipped in the emulsion over the surface. All too often a poor job is done here. Incomplete coverage often results, as does deposition of excess oil in some parts of the mold. Mechanical application of the oil would, in all probability, provide a better job at a saving in manpower. This is one instance where the human element could be eliminated to an advantage. A project for the mechanical oiling of flat ware molds is now on the docket of General Engineering. This should prove to be a simpler arrangement than the one which would be required for the No. 2 line. Following successful installation and operation of the equipment for the flat ware molds, work will undoubtedly begin on a mechanical oiler for the pipe covering molds.

Following the oiling, the strippers reassemble the molds; that is, assure that the end spacers are in place, and reset the core into the cavity. This is done for all molds except those for K-segmental pipe covering. For this relatively flat ware the core is inserted by the pourer and his helper after the cavity has been filled with the slurry.

The molds are moved along the line by a chain conveyor. On the No. 2 line the pourer alone has control of the stop and go. He exercises this control by means of a pedal at his station.

As the molds move along the line they pass under a blast of compressed air before they reach the pourer. The purpose is to remove loose chips of old material that invariably fall into the cavity from sides and frames of the molds, etc. While the present arrangement accomplishes the purpose fairly well, it is costly to operate. It is estimated that the cost of the compressed air runs about $800 per month. There appears to be an opportunity here for more efficient equipment with lower operating costs.

When the molds arrive at the pouring station, the pourer adjusts the rate of flow for the slurry to a speed he considers proper for the size of the mold to be filled. The slurry is pumped from the pouring mixer through a hose with a pouring nozzle attached at its end. The pourer controls the rate of flow by adjustment of an outlet valve and by regulation of a variable speed pump. For ware of lesser thickness he employs a pouring nozzle 8" long and having a nominal slot opening of 3/8". For the thicker ware, he uses an 8" long nozzle with 5/8" wide opening.

The pourer has instructions to follow a certain prescribed pattern of operation during the filling. But there are, nevertheless, certain variations in mode of operation characteristics of the individual. This is, perhaps, typical of any field of activity where particular skills, coordination, and pride in the work being performed are concerned.

Efforts are in progress toward the development of a full length (approx. 34") pouring nozzle for pipe covering. There is reason to believe that a nozzle of this nature would eliminate much of the human element from the pouring operation. Furthermore, it should reduce the incidence of air holes, slip planes, and folds which occur to some extent when the much shorter nozzle is employed by even the best pourer.

For flat ware on the No. 1 line, the pouring nozzle is essentially an elbow on the end of a 3" diameter hose, having a rectangular shape at the exit of about 70% of the area of that of the hose opening. Development of a 54" long pouring nozzle is the aim in this case. A gang of three molds could be poured at the same time with a nozzle of this length. Better alignment of the asbestos fibers in the ware should also result.

As might be surmised, the first problem to be solved in the development of these much longer nozzles is that of obtaining and maintaining uniform flow over the entire length. The presence of asbestos fibers in the slurry makes the problem more difficult than if a perfectly homogeneous fluid were being dealt with. The second stage of development will be concerned with ease of handling on the line.

Following the filling of the pipe covering molds, the overflow is screeded off by the pourer's helper when he is available for the task or by the pourer himself when the helper is engaged with the hoist in lifting a gang of the molds off the line onto the car being loaded for entrance into the prehardener, the next step of the process.

The excess slurry that is screeded from the pipe covering molds on No. 2 line goes into a sump and is pumped into the pouring mixer for the No. 1 line. There are always some chips of hardened Kaylo material on the sides of the molds and frames which become loosened during the handling on the No. 2 line and then fall into the slurry in the sump. Formerly only flat ware was cast on the No. 1 line, and the effect of the presence of chips in the slurry on the flat ware was negligible. But when the practice was begun of casting pipe covering also on this line, the clogging of the nozzles with the narrow openings affected both production and the quality of the ware.

It is necessary, therefore, to pass the sump slurry through an attrition mill, such as a Bauer mill, before re-use. The plant is planning an arrangement whereby the sump slurry of both lines is emptied into a tank and then passed through a Bauer mill to the pouring mixer on either pouring line, depending on the slurry requirements at the time.

After the car is loaded with the filled molds, it is the responsibility of the pourer's helper to move the car into the prehardener. In the case of the first and last cars of the train in schedule, this person records the time of entry on the Pour and Strip Recap form. He also positions an empty car after a filled one goes into the prehardener.

As perhaps with any method of forming, there are advantages and disadvantages inherent in the method just discussed.

Among the advantages are: The actual casting is rapid; the molds are simple and easily interchanged to meet demands of production; forming equipment is simple and compact; considerable latitude in batch formulation is possible.

The major disadvantages are: The random orientation of the asbestos fibers that occurs is not as favorable as fibers oriented generally in the planes of the major axes, in respect to "k" factor and to strength contributed to the product; the surface is not as hard and resistant to abuse, and of as uniform appearance, as that obtained by certain other methods of forming; a large number of molds are required, and an individual mold must accompany the ware through processing.

Until recently, the casting method of forming did not permit the production of sectional pipe covering in sizes greater than that for 12" pipe. The use now of a dispersing agent in the batch, and other batch modifications that have been made, have resulted in changes in the pouring characteristics of the slurry such as to make possible the casting of sectional ware through 23" pipe sizes. The molds, which will be of the nested or piggyback type to avoid undue waste of space, are not yet available for production. When these sizes do go into production, it will be possible to eliminate all tri-segmental ware from the standard line of products.

A disadvantage that has been reduced in significance to a great extent by the use of a dispersing agent in the batch and which should be even less a factor when full length pouring nozzles are available, is the creation of air holes, folds, and slip planes in the ware. Air holes detract from appearance, and adversely affect the "k" factor. Folds also mar the appearance of ware. Slip planes are discontinuities in structure and as such cause the ware to be more prone to breakage.

There is another defect in many sizes of present production of molded pipe covering that is of concern to the plant and to Sales. Too frequently the ends are not square. When detected the ware is given an end trim by hand. While ware corrected by this means is acceptable to most customers, it is not to certain others such as the Navy for instance. The Navy has a specification calling for a length of 36 minus 0". Detection of this defect in each and every piece is most difficult, and occasionally some ware with out-of-square ends reaches the customer and is cause for complaint.

The casting method itself is not responsible for this problem. The specific cause can be one of several. Among these are: Premature and unequal drying of the ware, thin ware and small sizes in particular, while in the hot cylinder prior to the time that an atmosphere of saturated steam obtains, resulting in excessive and uneven shrinkage; excessive build-up on, or improper placement of, the spacers.

The length of the mold cavity for pipe covering is only from 36-1/8" to 36-3/16". This does not allow much for in process shrinkage (of which there must be some to permit stripping), and for end trim, if a 36" long finished piece with square ends is to be obtained. At the time most of the molds were purchased, several persons, including the present Plant Manager at Berlin, argued for longer molds with end trimming of all M.P.C., but the decision was made to use the shorter lengths. It is generally agreed now that this was the wrong decision. The same mistake should not be made again in the design of equipment for a new plant.

Of the various types of imperfections that cause rejection of pipe covering as off-ware, "broken corners" has almost always constituted the greatest percentage of the total. As would be expected, large sectional sizes of the lesser thicknesses are particularly susceptible to this damage during stripping and subsequent handling in the plant. The sizes 6" x 1" and 12" x 1½" are examples. Had molds of greater lengths been available, much of the ware with damaged ends could have been saved by end trimming.

In an effort to get out of the difficulty caused by out-of-square ends without going to the very great expense of replacing the present molds with longer ones, the plant is trying out three different thicknesses of stainless steel spacers as replacements for the old and thicker black iron spacers. The lightest gauge that will stand up will be used. The additional length that will be gained is from 1/8" to 3/8". General Engineering has the project for a conveyor to carry all molded pipe covering from the trim saws to the wrap and pack area. On this conveyor all pipe covering will be end trimmed. Perhaps some pieces will receive only a "kiss", but even this would help some to correct the out-of-square ends condition.

Routing of Billets

As the size of pipe covering decreases below that for 2" pipe, difficulties are experienced in forming it by the method discussed above. A major difficulty lies in the tendency of the thin cores to deform during repeated runs.

Accordingly, small sizes of pipe covering are now made at Berlin by cutting rectangular billets from flat ware, trimming outer surfaces to give a hemi-cylindrical shape, and routing to the desired inside diameter.

This ware has a rough and unpleasing appearance, and is more susceptible to breakage than cast ware. For these reasons, there are serious objections to it on the part of some customers, and absolute refusal to buy by some. From the standpoint of manufacture, the routing method is a costly and wasteful operation. Plans are to abandon this method of forming if and when the method discussed below proves successful.

Routing of I.D. in Solid Half-Round Billets

This method involves the casting of solid half-round billets and then form pipe covering by routing out the interior to the proper inside diameter. Thus the exterior has a cast surface and presents the same appearance as the other molded pipe covering being produced. Obviously, much less material is wasted in routing to the interior dimensions only.

The plant has demonstrated with trial molds that solid half-round billets can be produced successfully. In principle, the mold is a rectangular pan with a scalloped insert. Such an arrangement can be filled in the same manner as a flat ware mold.

Studies are in progress at the plant on improvements that will make for easier stripping, handling of the ware, etc. But of major concern is the design and building of routing and trimming equipment for billets of this nature. General Engineering has this project on its docket.

After having inspected a sample piece of ware that had had the I.D. routed by semi-mechanical means, Sales personnel have been pressing for the earliest possible production date.

Vertical Casting or Tubular Molding

For the past few years, and until January 21, 1959, certain small sizes were cast and prehardened in tubular form by means of original equipment developed for the purpose.

The use of this equipment was discontinued as the result of conclusions reached in a study of the economics involved.

There are three reasons why an unfavorable economic picture was obtained: 1. An abnormally high percentage of off-ware resulted for production over extended periods of time; 2. Maintenance costs were high; 3. The equipment was designed primarily for demonstration, and not for production; accordingly only a single bank of molds was available for use.

Conditions 1 and 2 above resulted because super-atmospheric pressures were involved. Elevated pressures were employed to reduce cycle times and increase rate of production per mold cavity. But in so doing the problem of maintaining seals and preventing leakage, day in and day out, became a major one. A leak could be responsible for loss of slurry from the mold, and for boiling and blow-ups in the ware. Also because elevated pressures were involved, control and proper balance of pressures and temperatures throughout the system were critical. For example, if at any stage the temperature of the ware was such that the vapor pressure of the water within the ware exceeded the pressure being exerted externally on the ware, the ware would crack or blow up.

When the equipment was in good repair, and the proper cycling, temperature, and pressures were in effect, ware of excellent quality was produced and the percentage of off-ware was exceptionally low. During the period it was in production, its behavior was similar to that of the little girl of nursery fame, "When she was good, she was very good; but when she was bad, she was horrid."

Previous experience with vertical casting at the plant should not rule out further consideration of the method with certain modifications. Perhaps the use of elevated pressures is not feasible for production equipment. It may be better to cast slurries at temperatures near the boiling point of water into vertical molds, maintain this temperature in the cast piece by means of hot water circulating around the mold and through the core, then eject the tubular piece after it has hardened sufficiently for safe handling. Equipment would be much simpler and easier to control than the former arrangement. Certain persons within the organization have some definite ideas on a process of this nature. Pabco Caltemp is made in all sizes by a somewhat similar method, so the principle is not new and untried.

The advantages of any vertical casting- prehardening-ejection method are: low mold inventory; and the fact that the mold does not accompany the molded piece through the cycle; with resulting saving of autoclave space and of heat that would otherwise be used in heating the mold steel.

Press and Filter Method

A press and filter method is employed by Johns-Manville for the production of Thermobestos. In this process a very dilute slurry (water/solids= approx. 18 to 20) is mixed at a temperature of about 165°F and then sent to tanks where the slurry is heated by the injection of live steam to about 200°F, and maintained at this temperature until a desired gel structure is obtained (2 to 3 hours). By the addition of the condensate from the steam employed in heating the water/solids ratio of the gelled slurry at the end of the gelling period is about 24 or 25 to 1. This slurry is then ready for the molding operation.

At each press station there is a tank to receive the amount of slurry required for the piece being molded. The exact volume of slurry being received is determined by a probe for level control. This amount of slurry is then pressed and filtered in an elaborate mold at a pressure of 75 psi to the desired size and shape. Through the loss of water by the press and filter action, the water/solids ratio in the molded article is about 5 to 1. Since the solids are in a gel state, the molded ware possesses considerable cohesion and "green" strength.

(Details of the J-M process is contained in the report, "Johns-Manville Thermobestos Plant Visitation", prepared by R. S. Grant, July 10, 1958.)

The advantage of this process is that it produces a product having excellent properties: low "k" factor, high strength and resistance to abuse, dimensionally true, and pleasing appearance. Also, because of the high state of mechanization, little of the human element is involved.

The disadvantages are:

1. Offers little flexibility as to formulation; workable formulation is costly.
2. Formation of a gel of required properties is critical.
3. Molding stations are expensive and space consuming.
4. Customer servicing is of concern because of the amount of labor and time required to make a mold change.

Other Methods That Merit Further Study

A number of other methods of forming have been tried in the past to varying extents in the plant laboratory and at the research laboratories. Certain ones, such as centrifugal casting, and continuous prehardening and forming, do not seem to merit further study for one reason or another. On the other hand, results with others have been sufficiently promising to afford reasons for further study. Among these are: Filter press method (Denny); extrusion of prehardened and plastic bodies to shape (similar to the forming of clay pipe); pressing of prehardened light density flat ware to core material densities. Undoubtedly ideas as to other methods will occur as time goes on.

Chapter VIII

PREHARDENING

Following the casting step in the Berlin operation, the slurry in the molds is partially reacted, and hardened to a state that considerable pressure with the finger must be exerted to make an impression. This is accomplished by exposing the ware to the conditions existing in one of the four steam tunnels called Prehardeners. Temperatures of about 200°F are maintained, which is near the optimum. Temperatures much in excess of this cause boiling of the slurry, and those lower than this decrease the rate of hardening to a point where it is slower than the pouring rate.

Prehardener temperatures are controlled by means of temperature recorders and controllers that actuate pneumatic steam values. Baffles prevent the direct impingement of the live steam on the molds, which would cause boiling of the slurry.

The length of time required to preharden the ware varies with the thickness of the piece inasmuch as penetration of heat into the mass is involved. The extremes are a minimum of 1.00 hour for 1" thick ware to a minimum of 2.50 hours for 3" thicknesses.

There are two main reasons for prehardening the ware before it enters the cylinder. It reduces handling problems, and it makes the interval of time between pouring and autoclaving much less critical.

When the molds contain a fluid slurry, extreme care must be exercised in transporting them to, and loading them in the autoclave. The facilities at Berlin are not conducive to smooth and gentle handling of the molds between the time they are filled and the time they come to rest in the cylinder. Kaylo-20 slurries do not preharden, and with the smoothest handling possible under the conditions existing, a great amount of off-ware results because the slurry shifts from one end of the mold to the other or actually spills from the mold. The defect appearing in the product is listed as "N.E.M." (not enough material). On the other hand, when the slurry in the molds is prehardened before the trip to the cylinder, it can withstand a reasonable amount of abuse. This is done for all Kaylo-10 ware both pipe covering and flat ware.

The other important reason for hardening the slurry soon after casting is to minimize bleeding of water from the cast piece and/or settling of the solids from suspension. The extent of this action, of course, increases with time, and is more pronounced in large sizes in which the head of the fluid slurry is high. Scheduling of the cylinders so as to have one available to receive a train of filled molds just as soon as it is ready for autoclaving is seldom possible if the cylinders are to operate at peak efficiencies without undue downtime. Accordingly, a train of filled molds may have to be held on the floor for periods up to about four hours before a cylinder is available for this train calling for a definite autoclaving cycle. Ware in a prehardened state can withstand this treatment without damage. In contrast, the length of time that non-prehardened ware in large sizes can remain outside the cylinder without adverse effects is extremely limited. Within a relatively short time, discontinuities appear in the form of veins of water, which carry over into the finished product as cracks, and tears or separations; or the slurry may subside to an extent that the prescribed dimensions are not met in the product.

There is still a third advantage to be gained by prehardening. At peak rates of production, a fresh train of ware enters the cylinder within minutes after a processed train has been pulled. Temperatures of the cylinder shell under these circumstances are in excess of 400°F. From the time of entrance until an atmosphere of saturated steam is created within the sealed cylinder, the mold metal receives a great amount of heat by radiation. If the slurry is still in a fluid state at this time, there is great danger of boiling occurring at the slurry-mold interfaces, resulting in pitted and rough surfaces of the product. When the slurry is prehardened, the risk of this happening is minimized.

Surface boiling is sometimes experienced with the Kaylo-20 slurries, but the other problems which are attendant in the processing of a fluid slurry under existing conditions at Berlin are far more serious. Every effort is made to get the cast slurries into the cylinder as soon as possible after pouring, but with the complications involved, too long a time frequently elapses. Since the Kaylo-20 products are made on the same lines as Kaylo-10 ware, the latter in all stages of the process must be out of the way and not act as an obstacle in the path of the Kaylo-20 material. Working back from the time that a cylinder is scheduled to be available to receive a Kaylo-20 train, the following must be taken into consideration: the mixers and lines must be washed free of Kaylo-10 slurry, the batch weighed out and mixed, molds stripped and available on the pouring line, the Kaylo-10 ware in process ahead sufficiently prehardened and moved out of the prehardener, and the cylinder emptied and made ready to receive the cars of Kaylo-20 ware. Granting that all of this may be done effectively in proper sequence with perfect timing, the molds containing the fluid Kaylo-20 slurry must still be transported over a devious, rough, 150-foot-long path to the cylinder.

If Kaylo-20 pipe covering is to be made consistently with low percentages of off-ware, a separate line from mixer to cylinder is essential. As it is now, it is produced on a line designed for a slurry of greatly different properties and behavior. Passage through the prehardener is an example of the incongruity involved. Heating of the Kaylo-20 slurries in the prehardener not only does not accomplish the ends for which the treatment is designed, but actually has a detrimental effect. Heating to temperatures in the neighborhood of 200°F results in more fluid slurries that are more prone to leak from the molds and also to slosh during movement of the molds.

Returning to the prehardening of Kaylo-10 pipe covering, this would not be essential in the production of many of the small sizes if it were possible to autoclave the ware within about two hours after pouring. Sizes up to about 8 inches exhibit relatively slow rates of bleeding, and can be transported without damage with a reasonable amount of care. This is mentioned because tests have shown that ware which has not been prehardened exhibits about 25% higher strengths than ware which has undergone this treatment. In a sense, then, prehardening is a necessary evil with conditions as they are.

Probably because there is no alternative in view of the limited space available in the Berlin plant, a car of molds is pushed into the prehardener as soon as it is loaded. In this manner, the train is made up in the prehardener. This is bad practice for several reasons. In the first place, full advantage is not taken of the purpose for which the prehardener is designed. The capacity of the prehardener is governed by the time required to preharden the last car loaded. Therefore, it is serving merely as an accumulator for all preceding cars. In as far as functioning as a prehardener, the time during which it is being loaded is wasted.

A second bad feature of car by car loading is the loss of heat during the time the door is open to receive each and every car of the train.

Third, it is not possible to achieve uniform prehardening throughout the train. Obviously, the ware in the first car receives more heat than that in the last car.

But perhaps of greatest significance is the bumping and jarring which soft, partially prehardened ware receives as each additional car meets and shoves those ahead of it in the prehardener. At an intermediate stage of prehardening, the ware has lost its plasticity and ability to move with and recover from mechanical shock, and does not yet possess sufficient strength to resist certain disruptive forces. Under forces that tend to move the partially prehardened slurry or to shift the core, cracks are apt to occur in the ware. Presently about 20% of the off-ware is due to cracks. There is every reason to believe that most of these originate in the prehardener. Naturally, the larger sizes of the lesser thicknesses are more susceptible to damage. This cracking of the ware during the prehardening step would not be the problem it is if means were available for smoother handling, such as perhaps a monorail system.

The obvious way to overcome the several disadvantages inherent in present practice would be to accumulate an entire train outside the prehardener and to move the train as a unit into it. This does not appear possible with the restricted space available at Berlin, but should be considered by all means in the design of a new plant.

Prehardener capacity pretty much controls the rate of production. An advanced state of hardness must be obtained; otherwise a high percentage of cracked ware results. Berlin has from time to time lengthened existing prehardeners to meet the demands of increased production. The limit as far as available space is concerned has been reached on 3 of the 4 units. In the design of a new plant, it should be made certain that prehardener capacity is in excess of expected demands by a safe margin.

The degree of latitude in formulation also is dependent upon prehardener capacity. The stiffening and hardening of the slurry at temperatures in the neighborhood of 200°F is the result of chemical reaction between the diatomaceous earth fraction and the lime of the batch. It follows that formulations containing less diatomaceous earth in proportion to crystalline silica, all other conditions being the same, will preharden at a slower rate. Studies have shown that the limiting temperature the product can withstand is raised by a decrease in the proportion of diatomaceous earth in the formulation.

Presently Kaylo-10 thermal insulation shows a shrinkage of about 1.3% after being heated for 24 hours at 1200°F. The ratio of diatomaceous earth to total silica in the batch is 0.7. Available data indicate that if shrinkages of this magnitude are to obtain at 1500° instead of 1200°F, only about 40% instead of 70% of the silica of the batch can be in the form of diatomaceous earth. This change would reduce the rate of prehardening, with currently available raw materials at least, to a point that the output of the present prehardeners would be drastically curtailed. On the other hand, if the prehardeners were longer, or there were more of them, making it possible for the ware to remain in the prehardeners for greater periods of time, reductions could be made in amount of diatomaceous earth without the prehardening step becoming the bottleneck in the process. In determining prehardening capacity for a new plant, the prehardeners should be deliberately over designed, perhaps two fold, on the basis of the rate of prehardening of the present slurry. This would eliminate the restrictions on formulation now imposed by existing equipment.

Chapter IX

AUTOCLAVING AND DRYING

Autoclaving of Kaylo products is accomplished in SID cylinders. SID is a convenient term coined to designate a cylinder in which simultaneous induration and drying of hydrous calcium silicate products can be accomplished.

The strict meaning of induration is hardening. In the processing of Kaylo products, it is the step in which the lime, silica, and water are combined to form the hydrous calcium silicate desired in the end product. The formation of this hydrous calcium silicate structure brings about the change from a soft, pliable mass to a rigid body; hence the term induration. The reaction of the three components to form the desired hydrous calcium silicate occurs under conditions of a steam atmosphere at elevated pressures and temperatures. Actually, it is the heat that brings about the combination of the components, but since water is one of these, a steam atmosphere is required to conserve this ingredient in the reactive mixture.

A comparison of the formulae of the two hydrous calcium silicates in question, $4CaO.5SiO_2.5H_2O$ and $5CaO.5SiO_2.H_2O$, with the batch formulations will reveal that the amount of water in the batch is greatly in excess of that present in either of the two compounds. This situation makes it possible to begin the drying phase of the autoclaving cycle before the combination of lime, silica, and water is complete without any danger of insufficient water being present for the reaction. Thus it is possible to carry on the induration and drying simultaneously - a "SID" operation.

Drying is accomplished by subjecting the ware to an atmosphere of superheated or unsaturated steam. Each cylinder is equipped with radiators heated by a flow of Dowtherm liquid at a temperature of about 600°F or somewhat higher and a fan at one end to circulate the heat through the train of ware. At a given point in the specific cycle being employed, the fan is turned on. The heat being thus supplied raises the temperature of the atmosphere surrounding the ware, causing water to evaporate from the product. In a closed system, an equilibrium would soon be established. That is to say, for any given temperature the pressure would rise to the value equal to that of saturated steam at that temperature. When the equilibrium, or saturated steam, condition was reached, evaporation of the water from the ware would cease. But in the SID operation, the pressure is maintained at a constant value by means of a control valve through which the additional steam being generated escapes from the cylinder. In fact, the SID cylinder during the drying phase of the cycle functions as a boiler, the water for the generation of steam coming from the ware. This is literally true because the steam generated in the SID cylinders is fed into a low pressure system which serves to supply steam for the prehardeners, to heat the plant, etc.

A SID cycle consists of four phases: time required to get up to pressure; time at pressure without the fan on (saturated steam atmosphere); drying time (superheated steam atmosphere); time required to bring the pressure down to atmospheric pressure.

The first, or up to pressure, phase is fairly constant for a given cylinder and load and varies from 25 to 30 minutes for pipe covering, and is 1 hour for flat ware trains. A controlled rate of pressure rise is accomplished by a pneumatic control system composed of a time-pressure cam which operates the set point of the pressure controller. The pressure controller throttles the steam inlet valves to obtain the pressure rise cut on the time-pressure cam.

The second, or indurating, phase is the period during which the ware is subjected to saturated steam at a constant and definite pressure and temperature. The length of this phase of the cycle is determined by a combination of many factors. Those that must be considered include: Nature of the hydrous calcium silicate desired - Kaylo-10 or Kaylo-20; the thickness of the ware; the type of product - core, pipe covering, or block; desired end moisture content - "wet" or "dry"; the physical structure of the train; the operating pressure and other characteristics of that particular cylinder.

The indurating phase may vary in time from zero to 1 hour. In general if conditions are such that an extended drying period, the next phase of the cycle, is to be in effect, the indurating phase is shortened accordingly. This is because there is ample water present for the chemical reaction that produces the hardening or indurating of the ware to continue far into the drying phase.

The theory of SID autoclaving presumes that, at the start of the cycle, conditions are favorable for the reaction of lime, silica, and water to advance to the point at which a rigid structure of hydrous calcium silicate has been set up before there is any significant loss of water. Actually, this condition does not obtain with certain sizes of pipe covering in 1 inch and 1-1/2 inch thicknesses under present plant practice and rate of production.

Within a matter of 20 minutes to one-half hour, the processed train is removed from the cylinder, a fresh train put in place, and the cylinder door closed for the next cycle. During this time, the hot Dowtherm continues to circulate through the coils, and, of course, the cylinder walls remain very hot from the previous cycle. Although saturated steam is employed to bring the cylinder up to pressure, the temperature of the atmosphere within the cylinder is considerably above that of saturated steam at the pressures existing at the beginning. Thus a saturated steam atmosphere is not created, and as a result, premature drying of the thin sections of pipe covering results. This often causes excessive in-process shrinkage, and sometimes soft ends, where drying is more pronounced.

Attention is now being given to means of correcting or minimizing this condition. It has been the practice to keep the steam trap at the bottom of the cylinder open at all times. It is now proposed to close the trap during the up phase and the indurating phase of the cycle, and to open it when the drying phase begins. This is an added operation and must be given close attention, but it is hoped that the results will justify it. The theory is that the incoming steam will condense on the relatively cool molds and cars, and this condensate then held in the cylinder to contribute to the humidity instead of being allowed to escape through the trap.

A great amount of attention must be given to the make-up of a train of ware going into a cylinder. Ware of the same thickness, for the most part, goes into the same train. But drying characteristics depend upon the shape and other dimensions, as well as on the structure of the loaded car. Ware on cars near either end of the cylinder is in a position more conducive to rapid drying than that on cars near the middle of the train. Consequently, the cars of ware more difficult to dry are placed at the ends of the train. Care must also be exercised in the location of the cars in the train so as not to create undue obstruction to desired flow patterns within the cylinder.

At the end of the prescribed induration period, the fan at the end of the cylinder is turned on to carry heat from the radiators containing hot Dowtherm fluid over the ware. The length of this phase of the cycle is determined pretty much by the same factors as those for the length of the indurating phase. The Process Control Supervisor and the Quality Control Supervisor jointly evaluate the cylinder cycles each day from a mass of basic data accumulated in the operation. Changes are made in the cycles where and when indicated to be advisable.

Of particular importance in this connection are the moisture contents of the ware throughout the train and the strength and high temperature shrinkage of the product. The percentage of shrinkage shown by ware after having been subjected to a temperature of 1200°F for 24 hours is an excellent measure of whether or not it has received adequate processing in the autoclave. High shrinkages are evidence that an opportunity had not been afforded for sufficient reaction to occur, and are even more sensitive than strength data in this respect.

The objectives in cycle design and adjustment are to produce ware of uniform high quality and of uniform moisture content. "Dry" cycles are employed for pipe covering in 1" and 1-1/2" thicknesses, which means that all ware as it comes from the cylinder should have a moisture content very close to 25%. Ware of greater thicknesses (except core material) is on "wet" cycles, which are designed to yield ware having a moisture content near 65%.

Ware from "wet" cycles must receive additional drying in one of the four auxiliary driers. These are rooms in which a flow of air at about 300°F is maintained by unit heaters. The sole purpose of this practice is to increase production from the cylinders that are available at Berlin. Drying is not as efficient in the hot air driers as it is in a SID cylinder, but this scheme does permit some shortening of the cycles in the cylinders, resulting in more cylinder loads or cycles per day. The end achieved by the use of the four driers is about equivalent to that which would result from the addition of another cylinder with all operating on "dry" cycles. Were this additional cylinder available, there is little doubt that the production of the same amount of dry ware could be accomplished more economically than is now the case.

Drying in the SID operation is more efficient than drying by hot air for a number of reasons. In the first place, superheated steam has a much greater heat content than air at a given temperature. It also has a great thirst or affinity for water; that is, it is the nature of steam to "want" to go to the saturated state. Also of great significance is that temperatures of 500 to 600°F are more feasible in the SID cylinder than in a hot air drier. High temperatures for the drying of Kaylo ware are advantageous because a lesser quantity of heat is required to evaporate a given amount of water (heat of vaporization decreases with increase in temperature), and also because the viscosity of the water is less, thereby permitting the water from the interior of the piece to migrate more readily to the surface where evaporation occurs. Drying in the cylinder has the advantage also in that the ware is already hot throughout at the start of the drying operation and does not have to be brought up from room temperature.

The mechanism by which Kaylo ware dries is not generally understood. Practically all of the moisture is evaporated at or near the surface. Within the structure of Kaylo products is a network of extremely fine, continuous capillaries, which at the start of drying are filled with water. The diameters of these capillaries are so small that the vapor pressure of the water in them is depressed tremendously. Accordingly, the boiling point of the water in these capillaries is extremely high. Therefore, there is every reason to believe that water does not evaporate from the surface of the water deep down in one of these fine capillaries. To escape it must migrate through these narrow tubes to the surface, and evaporate at this point.

This drying behavior explains why Kaylo-20 ware dries so much faster than does Kaylo-10 ware under the same conditions. The xonotlite structure of the former is more coarsely crystalline than the tobermorite structure of the latter. This results in capillaries of larger diameter that can deliver moisture to the surface more readily. Consequently, the Kaylo-20 product dries in from 1/2 to 3/4 of the time required for a comparable piece of Kaylo-10 ware.

The question has been raised as to why make-up air is not employed in the hot air, auxiliary driers at the plant to reduce the relative humidity of the drying atmosphere. The answer to this is it is more important from the standpoint of drying to maintain as high a temperature as feasible than to bring about a reduction in relative humidity. In fact, the maximum relative humidity that can obtain in the driers operating at 300°F and at atmospheric pressure is only about 20%. Under these conditions drying from the surface will be very rapid, and the time required to dry the piece as a whole depends upon the rate of migration of moisture from the interior to the surface. As mentioned earlier high temperatures speed up this migration.

For the reasons just discussed, a plant should not be designed to include auxiliary drying as an integral part of the processing. To be sure, provisions should be made for such drying in cases of emergencies, and for drying of a wet train or portions of a train that result occasionally for one reason or another. For cases of this nature, it does not appear feasible to reprocess a train in the cylinder. On the other hand it should prove economical in the long run to have a spare or stand-by cylinder that could be put into service when another is down for repairs or cleaning, rather than attempting to make up the loss of production by going to "wet" cycles on all the other cylinders. When no spare cylinder is available and auxiliary driers are already being used to near capacity (as is the present situation at Berlin), it is the natural tendency to continue using a cylinder long after a repair or cleaning job has been indicated. Prolonged operation of a cylinder that has lost much of its efficiency because of need of repair or cleaning, is, of course, costly.

Returning to the SID cycles, after the drying phase is complete (the moisture of the ware reduced to a prescribed amount), the timer starts the time-pressure cam which operates the vent to the low pressure system valve and starts to depressurize the cylinder. After the pressure reaches that of the low pressure system, the controls switch from the vent to the low pressure valve to the vent to the atmosphere valve to continue the lowering of the pressure in the cylinder. At this point the fan is also stopped. The pressure continues to decrease until atmospheric pressure is reached and the cycle completed. The standard down times with pipe covering loads are 25 minutes for each of the three 175 psi cylinders, and 30 minutes for the two 200 psi and the seven 250 psi cylinders.

The rapid rate at which the cylinder can be safely brought down from pressure is made possible by the ware being in a dry state. Formerly when ordinary saturated steam autoclaves were in use, the rate at which the pressure was reduced was held at 1 psi/minute; at faster rates the saturated ware would blow up. Herein lies another great advantage of the SID over ordinary autoclaves. With SID cylinders dry ware can be produced at a considerably greater rate than can wet ware by saturated steam vessels.

Then, of course, provision has to be made to dry all of the products from the latter type of cylinders. As mentioned earlier, hot air drying is a prolonged and inefficient means of accomplishing this for hydrous calcium silicate products. It is of interest that the J-M plant at Manville has 16 drying tunnels, 170 feet long, equipped with 4 tracks per tunnel, having a total capacity for 1,800 cars of ware. This plant has nine cylinders of the conventional type.

The 250 psi cylinders at Berlin are much more efficient than the 175 psi ones. The latter are remnants of early operation which have been converted to the SID type. On an average, the total cycles in the former are shorter by: 1 hour for 1-1/2" thick ware, 2 hours for 2-1/2" to 3" ware, and 5 hours for 3-3/4" to 4-1/4" thicknesses. Just what operating pressure would be the most favorable in plant practice remains to be determined. There is little doubt that it will prove to be higher than 250 psi, but how much in excess of this pressure is a matter of pure speculation. As the operating pressures (and temperatures) increase, the rate of reaction increases, as should the rate of drying. While the degrees of superheat at 600°F (difference between 600°F and the temperature of saturated steam at a given operating pressure) will decrease as the operating pressure increases, this should not in itself result in slower drying within practical ranges of pressures. The higher temperatures that will exist throughout the ware should more than offset the effect of fewer degrees of superheat.

On the other side of the picture is the longer time required to bring the cylinder up to pressure and to depressurize it at the end of the run. The time consumed in accomplishing these two phases of the cycle could be appreciable at certain high pressures, and more than balance the gain in time possible for the indurating and drying phases of the cycle. The Research Laboratory at Newark is obtaining an experimental SID cylinder capable of operating up to 500 psi. For the first time equipment will be available to conduct experiments to determine optimum SID conditions and to obtain some badly needed information.

It is likely that the limiting factor in regard to operating pressures will prove to be the cost of the equipment designed to handle such pressures as well as certain other added costs involved in operating at pressures which are uncommon for vessels of this size.

Chapter I

OPERATIONS SUBSEQUENT TO AUTOCLAVING

After the ware emerges from the autoclave, and is in a dry condition, it must undergo trimming and finishing, warping, packing, and storage in the warehouse. Of course, the ware is inspected by Quality Control at all of these stations. If discolored or rough surfaces are detected at the trim saw, this ware is taken out of the line for hand cleaning and smoothing of the surfaces before it is sent on for wrapping.

The handling of the ware after it leaves the autoclave is the most inefficient of all of the operations at Berlin. This is probably the natural result of the plant having evolved for the most part, from a sand-lime brick plant to one producing Kaylo products. The inefficiency is strikingly evident when one considers that a given piece of ware coming from a cylinder on a "wet" cycle is likely to be handled or removed from one location to another, singly or in a container of some sort, 16 separate times before it is on its way to the customer. A comparison of Berlin and Manville operations in this area reveals a startling contrast.

It must be said that management of Berlin is aware of these deplorable conditions and has given GPD Engineering the project for conveyor and equipment from trim saw to wrap and pack area. On the conveyor all pipe covering will be end trimmed, if for only a "kiss" to produce square ends. On the same conveyor, the pipe covering will be brushed to remove discolorations and bumps resulting from dirty molds. The adhesive will be applied mechanically. The wrapping will be done by hand, and carton sealing will be accomplished by top and bottom sealers.

This project is excellent as far as it goes, but a material handling engineering study should be made of the complete operation to determine how the general condition at Berlin could be improved, and to come up with recommendations in this respect for a new plant. That there are 23 lift trucks continuously moving throughout the Berlin plant in an apparent helter-skelter fashion, is illustrative of the problem. Aside from all other obvious undesirable aspects, a considerable amount of damaged ware results from this manner of handling.

Chapter XI

AUXILIARY OPERATIONS

Naturally, there are many supplementary operations connected with the production of Kaylo products that are more or less common in the manufacture of any article. These will not be discussed. There is, however, one such operation that is peculiar to the subject process. That is the cleaning of molds.

The method now employed involves the use of an inhibited acid to dissolve the adhering calcium silicate. Back in 1950, as part of the investigation of SID possibilities, O-I Research conducted studies of various mold cleaning methods. The recommendation was made that acid cleaning be dropped from any further consideration because of the many objections inherent in this method. For some reason, probably because of a relatively high initial cost of an alternative method that was recommended, this advice was unheeded by management and acid cleaning was put into operation.

The result has prompted the Plant Manager at Berlin to write on April 8, 1959: "The cleaning of molds with the use of acid must be eliminated at the earliest possible time for two reasons: first, the mold equipment has now been subjected to acid attack for sufficient years that the rate of deterioration is becoming greatly accelerated. Unless this is stopped, large replacement costs for molds will be encountered. Second, everyone is familiar with the aforementioned labor costs* incurred, which cause is based on the use of acid for mold cleaning. We had a Pangborn** representative in last Friday, and all past work that was done was covered in his files. This goes back as far as 1950, when Research of O-I conducted the experiments. The cleaning of the molds will be done by a soft abrasive blasting, using walnut shells. Pangborn has had many installations of this type of blast cleaning. They also have the design, which was designed long before and never followed through---. This reduces all of the etching of the shells (molds) and also eliminates the cost of acid and allied material cost. It will eliminate the manpower aforementioned, as well as reduce manpower in Mold Repair for cleaning and repairs necessary. It will increase the run life of the molds before cleaning is necessary. The blasting is done with rotating wheels throwing the abrasive against the mold rather than using high pressure air, which calls for a large air compressor cost of installation and operation.

We are sending out a shell (mold) for them to again check the buildup (deposit) to make sure that the machine will efficiently do the job.

*Cost of hand cleaning stains and removing rough surfaces, both the result of acid cleaning of the molds, from a large portion of the ware.

**The method recommended by O-I Research.

This is a four-wheel job and the cost is roughly $10,000 per wheel, which of course includes the entire installation, however, it should be in the area of $35,000 or a little less. The machine has to be set in a pit and will have conveyor holding of molds into, through, and out of the blast cleaning area.

We will follow this project diligently and with dispatch, and as soon as design cost, time of manufacture, installation time and cost are secured will follow through with a 901."

Along with the acid cleaning, the other methods studies by O-I Research, and not recommended for one reason or another, were: High pressure steam; high pressure water; mechanical brushing; supersonic vibration.

The cleaning of molds would not likely be a problem of any consequence if they were to be made of stainless steel. A few replacements have been constructed fairly recently of this metal, and the performance in respect to buildup and the surface of the ware has been remarkable. After about two months of service, the metal still exhibits a mirror-like appearance. If the present behavior continues over a prolonged period of time, the economics involved should be evaluated. An unfavorable answer would probably result in the Berlin situation, in that it would likely be poor economy to merely replace the black iron shells with stainless steel, thus duplicating molds that are too short. But it may be a different story if new frames and new molds were to be fabricated for use at a different location.

Chapter XII

INDICATED MODIFICATIONS OF PRESENT PROCESS AND EQUIPMENT

At no comparable period in the history of the Kaylo operation have so many changes and improvements been made as in the past few months and weeks. Although the writing of this manual has been done at intervals over a period of no more than six weeks up to this point, many of the changes indicated in previous chapters as being desirable have already been accomplished and in operation. Furthermore, several others are scheduled for early completion. On the assumption that these, too, will be in effect before this manual is in the hands of the reader, no further mention will be made here.

The items that are listed in this chapter are those likely not to be in operation in the very near future because of the magnitude of the project, lack of manpower and/or space at Berlin, or other valid reasons for the delay. At the risk of appearing repetitious and redundant, mention will be made of certain subjects for the sake of emphasizing their importance. They should be considered from the standpoint of feasibility of incorporation at Berlin, and should by all means be taken into consideration in the design of any new plant.

In this latter connection, Berlin experience is providing and will continue to provide, valuable information in respect to process and equipment. Contrary to the situation in many plants, there is very little or no conservatism in the attitude of the management of Berlin. Rather than being averse to any change, there is an expression of desire to try anything new if it has at least a 50-50 chance of being favorable from the standpoint of cost savings, increased production, or quality of the product.

With this foreword, further discussion of certain items follows.

Separate Production Line for Kaylo-20 Ware

In the present set-up, Kaylo-20 ware is made on the same line as Kaylo-10 products. This all too frequently results in an excessive amount of off-ware. The Kaylo-10 line is designed to handle prehardened material. Kaylo-20 slurries do not preharden. The long route that the molds filled with a fluid slurry must follow - including passage through the prehardener - results in shifting of the slurry, causing the end product to be out of dimensions. Not only this, but the Kaylo-10 slurry and ware in all stages of the process, from mixer to cylinder, must be cleared out of way before Kaylo-20 production goes through. This results in waste of time even under the best scheduling possible.

The line for Kaylo-20 products should, of course, not include a prehardener, but should provide a short, smooth passage from pouring station to the cylinder.

Separate mixers for Kaylo-20 slurries would eliminate the necessity for washing the mixers and piping free of Kaylo-10 slurries when runs are to be made. They would also make possible a reduction in the number of batching operations. Under the present practice, the size of the batch must be tailored to the volume of the molds in the particular train being processed at the time. Since Kaylo-20 slurries do not preharden and may be held indefinitely, a large quantity of Kaylo-20 batch could be mixed and drawn upon as needed.

Conveyors

It was mentioned in a previous chapter that movement of materials and ware throughout the Berlin plant is accomplished by a fleet of 23 lift trucks, and that a materials handling engineering study is indicated. Discussion here is limited to the handling of the filled molds from pouring to cylinder, because rough handling during this stage of the process contributes to off-ware. The sloshing of the fluid Kaylo-20 slurry was mentioned in the section above, but damage can also result to Kaylo-10 ware. At certain intermediate stages of prehardening, Kaylo-10 material has lost its plasticity but has not yet attained any appreciable degree of cohesion and strength. Mechanical shock can easily cause cracking. In the present practice, filled molds are loaded on cars with flanged wheels to run on a track through the prehardener. A train of cars is made up in the prehardener, and the ware receives bumping and jarring as each car is added to the train.

Once the Kaylo-10 ware has been prehardened sufficiently, it can withstand a reasonable amount of mechanical shock, so smooth handling of the ware in the prehardener is of greater importance than on the way from there to the cylinder. But smooth handling of the fluid Kaylo-20 slurries is required over the entire route.

A different and smoother means of carrying both Kaylo-10 and Kaylo-20 ware through the prehardener to loading in the cylinder is indicated. A monorail system, for example, may be the answer to the problem.

Accumulation of a Train Prior to Prehardening

The disadvantages inherent in the practice of making up the train of ware inside of the prehardener have been discussed in Chapter VIII. The favorable results likely from accumulating the train prior to entrance into the prehardener were also outlined.

Prehardeners have in the past been the governing factor affecting the rate of production, and can also limit the latitude of batch formulations if the capacity for output is restricted. Under present conditions of formulation and rate of production, the prehardeners are in fairly good balance with the rest of the processing. But conditions could change and the prehardener capacity could become a bottleneck. For reasons discussed in detail previously, a prehardener would function more effectively if it were to receive an entire train of ware as a unit instead of one car at a time. That is to say, a given prehardener could preharden a given train of ware in a shorter period of time if means were provided for the make-up of the train before entrance into the prehardener.

Along with an arrangement of this nature, means should be provided to permit the by-passing of the prehardener if and when the size of ware and availability of a cylinder indicate such is possible and advisable. This in itself would have the effect of increasing prehardener capacity in relation to the other production units.

Reserve SID Cylinder Capacity

At present, in an effort to obtain the utmost in production from existing cylinders at Berlin, most of the ware is taken from cylinders when the moisture content is about 65%. This ware then must be dried further in the much less efficient auxiliary driers. In addition to this loss in efficiency, the cost of extra handling of the ware must be considered. If an additional SID cylinder were available, the same amount of dry ware could be produced at less cost.

It would likely prove to be good economy to have a spare cylinder available for use when one of the others is down for repair or cleaning. At present, the withdrawing of a cylinder from production is postponed as long as possible because of the production problems involved. In other words, it is kept in operation long after a decline in operating efficiency is evident. With a spare available, all cylinders could be maintained at top efficiencies without interruption of production.

This spare cylinder need not be down all of the time it is not called upon to replace another, but could be used to receive at least a portion of the Kaylo-20 ware poured on the separate Kaylo-20 line mentioned earlier. However, there should be a clear understanding among all concerned that its chief function is that of a spare, and should not be inflexibly tied in with production.

Auxiliary Driers

It is not the intention of the preceding section to imply that some auxiliary drying facilities are not necessary. The point is that it is not good practice to employ this type of drying as a routine matter. On many occasions some of the ware coming from a "dry" cycle will have a higher moisture content than is permissible for dry ware and this ware will have to be given further drying. Mechanical failures, failures within the Dowtherm system, etc., could sometimes result in an entire train of wet ware. Under conditions such as these, it is more feasible to dry in an auxiliary drier than to return to a SID cylinder.

Mold Cleaning

The present method of cleaning molds with acid is costly, and after a time results in serious damage to the molds. An alternative method must be found. Studies of several years ago indicated that an effective and safe job could be done by blast cleaning with a soft, organic abrasive. The plant has just recently begun further investigation of this method.

Improvements on the Pouring Line

There are several improvements indicated on the pouring line, and concerted efforts are being made to put them into effect. Among these are: Means for accomplishing complete removal of Kaylo chips and dust from mold cavities prior to filling; mechanical oiling of molds; full length pouring devices; mechanical screeding.

Perhaps the greatest benefit to be derived from these items will be the elimination of much of the human element and the role it plays on the pouring line in respect to rate of production and the quality of the ware.

Molds

The major shortcoming of present pipe covering molds is that they are too short. If the molds were longer (in the neighborhood of 37"), all pieces of pipe covering could be given an end trim. Less off-ware would result, and even passable ware would generally be improved in quality.

The economics should be studied of constructing the shells and cores of pipe covering molds of stainless steel. Trials in progress indicate lack of attack and freedom from build-up. Preference of stainless steel over black iron may depend upon whether or not acid cleaning is continued.

Chapter XIII

PERTINENT REPORTS

Several detailed reports have been issued that are pertinent to the subject matter of this manual. Those that are most closely related are listed below. Copies are available at the desk of the author of this manual, and another set is on file at the Berlin plant.

Title	Author	Date
Development of and Experiments with the 6' x 21' SID Cylinders at Berlin	Clarence D. Pawlicki	8-1-52
Development of Kaylo Batch Mixing Procedure at Berlin Plant	Harold F. Zink	6-15-54
Effect of Asbestos Variations on Physical Properties of Kaylo Thermal Insulation	D. L. Bishop	11-4-55
Establishment of Cycles for 1", 2", and 3" Pipe Covering in the SID Cylinder at Sayreville, N. J.	Harold F. Zink	8-1-52
Factors Affecting High Temperature Shrinkage of Kaylo Thermal Insulation	D. L. Bishop	4-8-58
Factors Affecting Thermal Conductivity of Kaylo Insulation	W. C. Taylor	8-20-57
Factors Contributing to Off-ware at Berlin	Harold F. Zink	5-7-54
Investigation of the Effect of Variables in the Prehardener Operation on the Quality of the Ware	Harold F. Zink	8-5-54
Johns-Manville Thermobestos Plant Visitation	R. S. Grant	7-10-58
Kaylo Mold Design, Filling, Cleaning, Stripping, and Lubrication	Clarence D. Pawlicki	8-1-52
Kaylo Manufacturing; Process and Operational Control	C. F. Sillwood	6-11-58
Kaylo Raw Materials and Processes	G. L. Kalousek	10-13-52
Observations of the Flat Ware Process at the Berlin Plant During the Weeks of November 9 and November 30, 1953	Harold F. Zink	12-22-53

Physical and Chemical Properties of Kaylo Products	G. L. Kalousek	10-13-52
No. 1 Production Line Training Manual	A. D. Denny	5-17-54
No. 2 Production Line Training Manual	A. D. Denny	2-22-54
Review of Berlin Plant Operations	O. W. Pfeifer	8-30-56
Sayreville SID Demonstration Plant; Background, Design, and Performance	Clarence D. Pawlicki	8-1-52
Studies of the Effect of Reactivities of Various Diatomites in the Reactions of Formation of Kaylo and Kaylo-20	A. S. Ayish	1-28-58
Studies of Molded Pipe Covering Off-ware at Berlin Plant	D. L. Bishop	3-16-53
Study of Molded Pipe Covering Off-ware at the Sayreville Plant	W. C. Taylor	12-23-52
Study of SID Cycles at Berlin Plant and Other Factors Affecting the Quality of the Ware	Joseph Scovronek	1-21-54
The System Lime-Alumina-Silica-Water and Applications to Kaylo Products	G. L. Kalousek	10-13-52
The System Lime-Silica-Water	G. L. Kalousek	10-13-52
Trial Runs of Xonotlite Kaylo at the Berlin Plant, and Properties of the Product	W. C. Taylor	3-5-55
Vertical Casting, Prehardening, and Ejection of Kaylo Molded Pipe Covering	H. F. Zink C. D. Pawlicki	5-7-53
Vertical Casting, Prehardening, and Ejection of Kaylo Molded Pipe Covering Section II	C. D. Pawlicki H. F. Zink	10-19-53
Xonotlite and Lepisil Kaylo Products	G. L. Kalousek	10-13-52