Friday, May 17

CLAY AND CLAY PRODUCTS

Elec. Eng. Auditorium

1. Clay and Clay Products - Technologic Trends in the Production and Utilization of Mineral Products.
   F. L. Steinhoff, Editor, Brick and Clay Record, Chicago.

2. Mineral Composition of Clays as Seen under the Microscope.
   R. E. Grim, Sedim. Petrol., Ill. State Geol. Survey. Missing

3. Separation of Clay Minerals by the Supercentrifuge.
   W. F. Bradley, Ill. State Geol. Survey. Missing

4. Illinois Novaculite as a Refractory.
   A Light Weight Structural Material Prepared from Illinois Clays.
   Illinois Fluorspar as a Pottery Flux. Missing
   C. W. Parmelee, W. R. Morgan, C. G. Harman, Dept. of Cer. Eng. and State Geol. Survey.

Saturday, May 18

5. Trends in the Development and the Use of New Units and Materials for Building Construction.
   F. M. Lescher, Assit. Prof. of Arch., Univ. of Ill.

6. Reinforced Brick Masonry for Permanence (a motion picture - - -)
   Hugo Filippi, Gen. Super., Ill. Brick Co., Chicago; Consulting Eng.

7. Brick Houses - Cheaper and Better (illustrated).
   A. W. Luse, Secr-Mngr., Chicago Face Brick Bureau, Chicago.

8. Recent Findings on the Relation of the Constitution of Clays and Shales to Their Ceramic Properties.
   R. E. Grim, Seci. Petrol., Ill. State Geol. Survey.

9. Report of Progress in the Study of Illinois Face Brick.
   C. W. Parmelee, Head, Dept. of Cer. Eng., Univ. of Ill.

10. Report of Progress in the Study of Light Weight Aggregates.
    C. W. Parmelee, Head, Dept. of Cer. Eng., Univ. of Ill.

p. 2, line 12 - "that fewer measurements could be made, etc.," suggest this be amplified.

p. 4, "Soluble salts." Why mention this if nothing is to be reported?

p. 5, line 9, etc. - "The limited amount of data, etc." Suggest this sentence be deleted as it would seem sufficient to point of the superiority of Illinois brick.

p. 5, last sentence. - Suggest this sentence be deleted unless some statistical treatment is considered.

Table 6. - Suggest that "Most probable" values be defined.

Suggest that "Variation in dimensions" values be defined.

Suggest that each figure carries a descriptive notation assisting in its interpretation.

R. E. G. (Grim)

What publ.?

Dr. John W. Finch

Did his undergraduate work at Colgate University and received his Doctor's (D. Sc.) degree from the University of Chicago. He specialized in geology and mining engineering and has had wide experience in mineral exploration as well as in teaching. He has served as mining consultant in South Africa; Turkey and the Near East, and in the Orient; was professor Economic Geology at the Colorado School of Mines and Dean of the School of Mines at the University of Idaho. Before taking his present position he was Director of the Idaho State Bureau of Mining and Geology (since 1930).

This is the first visit of the Dr. Finch to Illinois since his appointment as Director of the U. S. Bureau of Mines. We are greatly indebted to him for ~~his~~ the special effort which he has made during these busy days to be present and to participate in our program.

TECHNOLOGIC TRENDS IN THE PRODUCTION AND UTILIZATION OF CLAY AND CLAY PRODUCTS

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Fred L. Steinhoff, Editor, BRICK & CLAY RECORD, CHICAGO

Six years of depression have not been without their effect on the clay products industry. The economic upheaval caused by the almost total cessation of building has tended to develop in the mind of the clay products manufacturer a different conception of his possibilities. During the building boom of the previous decade many manufacturers ~~eagerly and~~ vigorously pursued two tendencies in the development of their business~~. These were~~ - one, specialization to a high degree and - two, the theory of expanding trading areas through low cost mass production. These two tendencies did not work out ~~very~~ well ~~with the~~ exception ~~of~~ for two or three concentrated consuming areas, for the following reasons:

Clay of good quality is not scarce. High shipping costs effectively define markets. Efficient plants of moderate size can produce just as cheaply as plants of huge capacity. As the depression closed down upon the industry these facts became apparent and clay plants found themselves once again restricted largely to their natural trading areas in which they enjoyed a commercial advantage due to proximity and lower shipping costs.

As a result manufacturers have put more intensive thought on their two primary assets, their clay pits and their clay plants, in order to exploit to the utmost their possibilities in the production of wares which can be competitively sold within so-called local markets. The idea of mass production of a single item is rapidly giving way to efficient production of a diversified ~~line of~~ products.

Perhaps this is not strictly in line with my subject of technologic trends but it is essential to have this picture in order to understand the motivating forces behind the technologic trends ~~that I shall~~ to be discussed. These motivating forces can be grouped under six major heads:

(1) Economic influences (freight rates, general business, etc.)
(2) Competition
(3) Desire for additional profit
(4) Labor conditions
(5) Governmental actions (NRA restrictions on wages and hours, etc.)
(6) Natural desire to progress

All of these forces have affected and will in the future force important changes in the clay industry. ~~I say 'will' because I would be remiss indeed if I failed in this paper to point out a few of my own interpretations of future~~ Some of these trends ~~which~~ have not as yet manifested themselves because of the extremely low operating ratio of this industry but ~~which I feel~~ they will certainly ~~will~~ come to light with return to more nearly normal activity as a result of roots already sprouted.

Undoubtedly other speakers at this conference will deal more comprehensively with the above factors, and perhaps others, because several or all of these affect almost every branch of the mineral industry. They should, however, be kept in mind as the motivating forces behind technologic developments or trends.

Technologic developments in the ceramic industry naturally group themselves under three general heads:

(1) New equipment and processes
(2) New products
(3) New uses ~~of~~ for old products.

NEW EQUIPMENT

DE-AIRING.—

Undoubtedly the major development in new equipment is the principle of de-airing. It is perhaps the outstanding development of the century in the utilization of clay. De-airing removes air from a plastic clay mass by means of a vacuum pump applied to the barrel of the auger machine just preceding the formation of the bar or column.

The application of de-airing has made possible an improved body structure enabling better products to be made; development of new and formerly unusable clay deposits; and the production of products heretofore impossible from certain types of clays. Some 200 de-airing units have been installed in the clay industry. It has increased market possibilities of clay plants because it makes possible a greater diversification of products and therefore a greater utilization of existing clays and plant equipment.

MAGNETIC SEPARATION.—

New high-intensity separators give promise of solving the problem of eliminating such impurities as pyrites, mica, and other feebly magnetic substances. For certain Illinois clays this development may make it possible to produce higher refractoriness, and better color. This principle might be employed upon Illinois kaolins, stoneware clays and fire clays used in refractories, sewer pipe, and face brick production.

Higher freight rates - a governmental or economic influence as you might choose to call it - now makes it possible to spend additional money to further refine Illinois clays. By this I mean that repeated percentage increases in freight rates have increased the differential between eastern Ohio and western Pennsylvania brick and Illinois brick thus permitting the Illinois manufacturer to utilize this increased differential in product improvement. To a certain extent this also applies to other clay products such as refractories, stoneware, and terra cotta.

A prominent refractories manufacturer in the East is at present working with a magnetic separator in the expectation of utilizing a clay which cannot be used unless impurities are removed.

PREHEATERS OR ROASTERS.—

This is a comparatively new development similar to a rotary dryer in principle but claimed to be a cheaper and less ponderous machine. One installation (on an Illinois plant) is for the purpose of removing sulphur from fire clay and for rendering frozen or excessively moisture laden clay more easily handled. The clay is heated to approximately 1000° ~~deg.~~ F. which destroys part of the plasticity, reduces shrinkage and permits quicker processing in drying and firing. It is still experimental but indicates a new line of thought. The device costs little to build and to operate.

PACKAGE SHIPPING.—

Much thought has been put on the matter of shipping clay products in packaged units for handling by crane or other mechanical devices at the plant, enroute, or at the job. High handling costs after the product has been manufactured is one of the chief problems in this business. Therefore methods for lowering costs in this direction are looked upon with great favor. Package units being experimented with include crating with wood or paper plus metal strips. A mechanical brick-grab using the principle of ice tongs is also being marketed.

FACING MACHINES.

From England comes an idea of improving the texture, color, and quality of a brick made of clays of otherwise restricted utility. Several machines, one in this state, have been installed for the utilization of this idea. It involves the impregnating or imbedding of colored sand or other minerals and materials into the surface of a clay column as it issues from the die. Claims made for this machine are that it makes possible the utilization of clays for the manufacture of products considerably greater in value than otherwise possible.

I might mention here that a cheap sand or other mineral that would produce novel and beautiful colors when finely ground and fired to brick temperatures would find a ready market in the production of such a brick.

If I might be permitted a prediction I should like to include under equipment trends the very great possibility of the utilization of the efficient, relatively inexpensive small tunnel kilns which have been so successful in the whiteware industry. Because of their smaller capacity these kilns are more flexible than their large progenitors. As an example of what I mean I might cite as a possibility their use for the production of clear shades of face brick, leaving the flashing still to be done in periodic kilns.

Another, and perhaps somewhat more remote, possibility is the control of colors by artificial means rather than the more or less haphazard method of depending upon natural colors developed by flashing. Hudson River manufacturers have for years produced darker colors with the aid of hematite and colors in clay roofing granules are well controlled. The advantages in reduction of inventories alone are obvious.

NEW PRODUCTS

As I have stated, the trend is distinctly toward the fullest utilization of the raw materials and equipment available. Plants today are making a more diversified line than ever before. This is not so apparent as it will be with the return of business volume because many of the products that have been developed have had very little market. The tendency, however, is to develop products which will increase sales possibilities in local markets.

MORTAR MIX.

In Iowa some fifteen or more clay products manufacturers are utilizing their dryer waste and grinding it to produce what they call mortar mix. The dryer waste is ground so that 80% passes thru a 200-mesh sieve. It is recommended for supplanting 25% of the cement in a mortar mixture of three parts sand to one part cement. Economy, better working properties and equivalent bond strength are the claims for it. Hundreds of thousands of bags of this former dryer waste are being sold to building material dealers in Iowa with a nice profit to the clay products manufacturers.

Similarly, ground clay has been applied to bulk concrete work and a U. S. bulletin* issued on this subject.

As far as I know no Illinois manufacturer has utilized his dryer waste for such purposes. It would seem well worth while investigating. Most of the Illinois clays are of the type that will produce satisfactory mortar mix.

Incidentally this is an excellent subject for research on the part of our ceramic schools.

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* "Clay in Concrete" D. A. Parsons, Bureau of Standards. Write Superintendent of Documents, Washington, D. C. (5¢).

GRANULES. -

Manufacturers of asphalt roofing and siding use large quantities of fired clay granules as a coating and to give color to their product. Ground brick bats were formerly used but new processes for the manufacture of granules from raw clay give a much better and more uniform product.

SEWAGE FILTER RINGS. -

There has been developed at Iowa State College a new product of clay - a sewage filter ring similar to the Raschig ring used in the chemical industry.

These are small hollow cylinders of burned clay about 1" in diameter and 1" long for use as the filter material in sewage disposal plants. Due to the larger exposed areas they are said to be much more efficient than the crushed quartzite commonly used. Work is now in progress to develop an economical method of producing these rings.

INSULATION. -

So-called light-weight products, made porous either by a bloating process or by the introduction of chemicals or combustibles which are driven out in firing, open up an entirely new market. In the refractories field these products are used to make insulating refractories which can, in many cases, be used on walls exposed to heat with material savings in fuels.

In the construction field light-weight brick or tile offer opportunities as a backing up material in non-load bearing walls. In structural steel buildings they lighten the load as well as acting as fireproofing and insulation.

MULTICORED PRODUCTS. -

Brick are being made with as many as 60 small holes, reducing weight 25 to 30% and yet retaining ample strenght for ordinary building purposes. The holes are so small that mortar will penetrate only enough to give keying effect similar to that obtained with metal lath. The brick being lighter can be shipped more cheaply, thereby overcoming some of the loss due to increased freight rates.

OTHER PRODUCTS. -

Time does not permit more than a mere reference to other trends in the development of new clay products to meet competition, high labor costs, increased freight rates, or other influencing factors.

2" brick Veneer. - They are thin brick developed for veneering old homes, etc. They can be shipped more economically and because of their lighter weight require less expense in foundation construction.

Double Brick. - These are hollow units taking the place of two brick plus a mortar joint. Used for backing up and facing purposes. Saves as much as 17% in labor laying cost.

Flagstones. - Irregularly shaped slabs of fired clay resembling slate or colored stone flagging used for walks, porches, floors, patios, etc. Color possibilities are even great because of wide range of fired clay colors.

Ashlar Block - This is a product resembling ashlar stone in texture and size but having the advantage of a wider range of colors than it is possible to obtain in natural stone.

Floor Brick - This is a dense, impervious product for factory flooring to replace cement or wood. It is in demand by packing houses, food products plants, chemical plants, breweries, etc., where sanitation and cleanliness are important.

Brick Slabs - These are thin brick attached by means of a binder to a wall board base in groups of convenient handling size. These panels are then nailed to a wall giving the effect of a brick wall appearance. Other designs provide for the application of the individual slabs to a wall by means of staples, rods and other devices. They have been developed for economical veneering of exterior and interior walls.

Hollow Units - New designs for hollow tile which make for faster laying by providing a better mortar bed and a hand hold for the mason so that he can speed up the laying in the wall have been developed for low cost housing use. These tile are designed to be the complete wall requiring no further exterior or interior treatment.

NEW USES FOR OLD PRODUCTS

REINFORCED BRICK MASONRY.—

Perhaps the outstanding trend in the utilization of clay products is the development in reinforced brick masonry. A man who has played a major part in the engineering and promotion of this development is a speaker on this program. I recommend that you listen to his instructive and interesting message.

Reinforced brick masonry will undoubtedly stimulate its own trend in its use for engineering structures and in the form of slabs for low cost housing construction. These important subjects I understand are to be covered by other speakers who are prominent in their developments. I may say this, however, a large scale use of the principles of reinforced brick masonry might very possibly mean simply modifications in our present products to bring out the utmost in economy and utility. For those who are unfamiliar with reinforced brick masonry, I might briefly describe it as a slab, bar or column containing reinforcing rods imbedded in mortar joints to give the construction rigidity, tensile strength, and other properties not unlike reinforced concrete.

RESURFACING OLD ROADS WITH BRICK.—

A trend has been distinctly defined in the rejuvenation of old pavements by resurfacing them with paving brick. There are many who predict that with the return of normal business, and attendant increased motor freight traffic, the need for brick surfaced highways to withstand the increased wear and tear of the traffic will be imperative.

Improvements in brick road construction have been notable: for instance, the use of calcium chloride for surplus filler removal; improved fillers with reduction in slippery conditions; de-aired brick for stronger surfacing; and improvements in base design.

INCREASED USE OF GLAZED OR ENAMELED BRICK.—

Methods have been found to reduce the cost of a glazed surfaced brick or block. A self-cleaning, highly reflective, full color range product is finding increased use in gas stations, store fronts, building exteriors and interiors. With new construction in full swing, these products will undoubtedly find much larger demand.

INTERIOR USES.

All clay products are finding a larger acceptance for interior use. Homes with brick wall interiors are finding favor. Brick floors in homes, factories and offices are new trends. It is said that a reinforced brick slab laid on metal laths as the form and support will construct a floor costing but $40 more than wood construction in an ordinary size home. Glazed wall units of large size from 1½ to 2" thick are another development.

TRENDS IN MANUFACTURING.

I would fail in my mission were I to neglect to point out one significant trend at present somewhat obscure due to the low ebb of activity in the field.

I refer to the increased use of production control methods. I believe that we will see a distinct forward movement in processing control and in the absorption in the industry of technically trained men who can man this control processing.

One other thing. Strange as it may seem, I believe we are ~~aba~~ not very far removed from a problem of dire labor shortage and of higher priced labor. Millions of men now idle are, I fully believe, permanently disqualified for work. The disintegrating effect on the moral fibre of protracted idleness and open-handed relief has greatly increased our permant army of unemployables. So I am venturing a prediction - a prediction of a trend in clay products manufacturing that will be distinctly more mechanical than it is today.

Brick plant labor was always heavy, burdensome labor. It is going to be difficult to find enough men who will willingly perform this kind of labor. So when production increases and clay plants hire new men to fulfill their complement - look for difficulty in organizing crews who will work smoothly together and who can be molded into an efficient production machine. Look for further mechanization - a future trend in the technological utilization of clay and clay products.

TRENDS IN THE DEVELOPMENT AND USE OF NEW UNITS FOR BUILDING CONSTRUCTION

By Frank M. Lescher
Assistant Professor of Architecture, University of Illinois, Urbana

It is extremely dangerous to prophesy what is likely to happen, even in the immediate future, when changes of all kinds are as imminent in every business as they are at the present time; and more especially when an old, established, and tradition-bound industry such as building shakes off the draperies of its traditions, and steps forth in the freedom of what we call modernity, but what might perhaps more justly be called architectural nudism.

In my belief, this danger to accurate prophecy, as far as building is concerned, lies principally in two things. The one is the fact that so many scientific investigators are carrying on experiments which may result, intentionally or accidentally, in the production of new materials suitable in some respect or other for building work. As a result, ~~- investigation that is being carried on quietly, or even under cover - so that~~ some unusual product or products may change many of our ideas as to the suitability or fitness of some of our present materials to the purposes which they have been serving in buildings; especially as the new products may serve those purposes more directly, more accurately, or more cheaply. Similarly, new uses for, or changed appearance of, old products may result in the obsolescence of these present products or methods of production in favor of the new.

The other danger to accurate prophecy lies in the effort that is being made by so many men, not of scientific status, but of the business world, to make building better and easier, not only from the viewpoint of craftsmanship, but also from that of finance. There is an earnest group of believers in the theory that building, especially the building of houses, has in the past taken far too large a portion of the little man's income, whether it be paid for the direct purchase of a house, or whether it be paid in the form of rent; and this same group, together with many others, is as firmly convinced that far too large a portion of the little man's investment in a house is destroyed, or we might better say, deflated, by poor materials, or more particularly, by poor workmanship. The non-predictable efforts of this group of men in their entirely laudable endeavors to make a profit by bettering this situation, constitute the second danger to an accurate foretelling of the trends in the use of building materials.

I think it may fairly be said that the building industry is still the only large scale business in the country, or even in the world, which is still conducted largely on the basis, ~~at least for the most part,~~ of hand preparation of the material on the job. There are exceptions, of course. Factory preparation of part of the material is a common-place to most of this generation of the building industry; nevertheless, we still see most of our mortar and plaster mixed by hand - our bricks laid one by one in their places in the building - the lumber cut to fit in its place as it is used - and all the other hand processes of our present-day building carried on as they have been from the time the first cave man decided to improve his cave by rolling a few stones across the entrance to make his dwelling more commodious, and ~~more~~ better protected from the weather.

We are seeing a trend away from this situation, and I think that this trend, which leads more and more toward greater utilization of larger factory-prepared or pre-fabricated units is pointing the way toward the high-road of future building, especially in the vast field of the smaller house. Many architects are, either wilfully or ignorantly, keeping their eyes turned away from this signboard of the building times, believing that by so doing they are putting off the evil day when they will have to work in materials of a new kind or a different form. ~~So, too, the craftsmen of the building trades, equally blind to their own interests, not sensing the current setting toward the production of pre-fabricated units, are inclined to fight the new rather than adapt themselves to it, and gain the benefits to come from greater employment on larger scale, lower priced work.~~

Many observers of this trend are inclined to feel that building, taking the same road as the automobile industry, will develop a mass-production product, to be used for a few years, and then turned in on a new unit, or else thrown on the junk-heap. Another group, which includes many architects, takes the fearful view that this sort of development sounds the knell of residential architectural practice; that the architect, if he survives at all, will be but the minor adjunct of the building factory.

I cannot agree with the first group. We do not live in our automobiles, much as we use them, and the very fact of living makes, within a short time, a vital difference in our viewpoint toward the place in which we live. We Americans have been accused of being a nomadic people, especially of recent years, because of the peculiarly transient nature (as far as employees are concerned) of many of our large scale businesses, more especially the chain store and multiple factory groups. Nevertheless, in the mass, our people are home-loving, and, given the chance, we take root, little inclined by nature to move about constantly. Consequently, I believe firmly that the constant changing from one house to another that is an innate part of this first group's theory would so shock the natural home-loving instinct of the great body of the American people, that such a method of home-building or home-owning would never become truly popular in this country, even though the love of the new would become much stronger than it is at present. Natural obsolescence and depreciation take a sufficient toll, even of our present types of buildings, without developing a type which invites quick obsolescence.

With the second group I am equally at variance. We have at the present time in many of our industrial communities, a peculiarly atrocious type of mass-production small house which ~~never knew what an architect was, and~~, I ~~fear,~~ was never even in contact with a really competent builder. The proposed mass-production types of small houses which have so far been proposed, are so far superior to the usual type of industrial housing that no comparison can be drawn; so that even an "adjunct" architect may be of value in housing under the new thought.

The trend with which I am most concerned, however, leads directly from the idea of mass production, and that is the trend toward lower cost and consequently, toward greatly increased home ownership, with all that home ownership implies in stability, thrift, good citizenship, and an enlightened, liberal and reasonable conservatism. As people concerned, at least in part, with the production and use of building materials, we should do everything in our power to accelerate the trend toward lower-priced, substantial building. This implies a study of the subsidiary trends in the development of lower-priced building materials, and of methods of handling those materials so that labor costs may be lowered in the building itself.

The steel and lumber industries are moving rapidly into the arena of such construction with their large unit, quickly assembled buildings. The mineral industries are not far behind, and in many respects are abreast of these others, and by virtue of the many excellent qualities of their materials, should soon take the lead in many respects. It is my hope, modestly, to give an idea of what the architect thinks may be accomplished by the use of these materials.

Brick, by virtue of its many varied colors and color combinations, its textures, and its durability under all sorts of weather conditions, has long been a favorite building material, even in areas far distant from the natural beds of clay and shale from which it is made. However, ~~the fact that it is a small unit product, requiring high-priced, skilled labor for its use under the same old-fashioned hand methods that have been in use ever since the material was first developed,~~ the cost of brick construction has militated against its wide use in the very places where its excellent qualities of durability, slow depreciation, and low upkeep cost are most desirable - in the dwellings of the people whose finances make them think first of first cost, and not of the continuing cost of the building.

The brick industry has taken two progressive steps in the direction of remedying this situation. The one, as is well known, involves the use of reinforcement in connection with brick, to give it the same sort of resistance to bending that we have in connection with reinforced concrete. The other, of recent development also, involves the use of pre-fabricated brick panels, cast either on the ground at the site, or at a factory under factory conditions; ~~in either case, using lower priced, less highly skilled labor than is the case where the individual units are placed one by one in the wall.~~ These panels, then, are placed on, and attached to, a structural framework which forms the wall support.

To me, these two developments combine into the germ of a possible structural scheme which need not necessarily require the structural framework for the wall. It seems possible to cast these brick-faced panels in wall-high, or at least in story-high units, of sufficient width to contain an ordinary door or window, and with intermediate units of the same width, so as to become interchangeable with them. The backing could be, instead of concrete or mortar, some one of the insulating plasters, changed in chemical composition to gain strength and binding power, and made extremely porous to give additional insulating value, so that no other insulation need be used. The inside surface of the plaster could be troweled or floated smooth, so that no further treatment, other than decoration, would be required.

As for the interior walls, a modification of the same scheme could be followed, especially for the bearing walls, whereby reinforced brick panels of the same height as those in the outer wall could be cast with a thin layer of plaster on each side, of such size that all units, either blank or with openings, could be interchanged as desired. Floor and roof panels could be similarly designed, taking into account the possibility of designing the edges of the pre-cast slabs as beams reinforced to take care of the stresses which would develop. By leaving the brick floor surfaces exposed, a durable, easily cleaned floor would result.

Following a similar scheme, it seems possible to me that terra cotta face units could be used to give an outer surface to pre-cast slabs that would have all the beauty of color, texture and ornament inherent in terra cotta, while obtaining at the same time the lower cost values of larger size, factory-fabricated units which can be handled and set in place by machine methods. Such terra cotta units would have in addition the ability to show ornamental interior faces where desired, especially in such rooms as bath rooms and kitchens, where an easily cleaned surface is especially desirable.

Such ideas may seem ~~highly~~ fantastic to many of us, but in view of the many things now going on about us and accepted as a matter of course by everyone - things which only a few years ago were not even considered within the bounds of the most fervid imagination - I do not believe we can approach any idea with the thought that it represents the impossible.

Glass is another of the materials which no stretch of the imagination could have shown as reaching the amplitude of building use to which it is at present falling heir. Long in use as a means of admitting light to building interiors, glass has, in the last few years, attained to many other building uses which before then seemed almost impossible. Glass roofing tile have come into use, glass bricks and building blocks have become entirely practical, and structural sheet glass as an interior and exterior facing for other materials is seen on every side.

I cannot help but feel, however, that glass in building has but started its race. The developments already attained and pending in the manufacture of stronger, more elastic, and more heat-resisting glass open vistas to the imagination that seem to have no closure. Too, the types of glass that admit the more health-giving rays of the sun to the interiors of buildings have but started on their careers of usefulness. The moulding, etching, engraving, and sand-blasting of glass as a wall surfacing are proving it to be an aesthetic aid to building of the first class.

I see no reason why glass cannot be used as the beautifully decorated containing envelope of electrical lighting and heating panels which will bring about a new era in this class of building work. Further, it would seem entirely probable, that if glass can be so made as to pass certain light rays to the inside of the structure, while at the same time withholding others, it could also be made to keep heat rays outside of the building, thus solving one of the serious problems that confront the air-conditioning engineers. I confidently expect this discovery to be made, and brought to a commercial basis.

Light, porous insulating aggregate for concrete, made of brick shales, has been on the market for some years, and has proved a success both for blocks and as an aggregate for poured concrete. Why is it not possible to make a different development of this material, so that by admixture with some waterproof plastic compound which will become hard without being heavy, large structural units of the factory-fabricated type may be manufactured; light and easy to handle, sufficiently strong to carry ordinary residential wall loads, and by its own character, so full of minute air spaces as to be self-insulating. This, too, by careful design of reinforcement could be made at least as successful a floor and roof material as our present nailing concretes, and like them, would not require furring or other means of holding other materials in place where required to be held by nailing.

Our building material investigators have been particularly successful in their efforts to develop insulation materials which really accomplish their purpose efficiently. Rock wool and glass wool have achieved a well-earned triumph in the field of insulation and have taken the lead as a fire- and vermin-proof material for the purpose. For many years hollow clay wall tile were advertised (none too truthfully, I am afraid) as having a very considerable insulating value because of the dead air contained in the hollows of the tile. This was, of course, only relatively true; but nevertheless, these hollow tile formed a handy, light weight unit, sufficiently strong for most types of ordinary building, upon the inside surface of which, when used for outside walls, plaster could be directly applied.

If it is desired that a small wall unit such as this be continued in use, it might be possible to combine with the tile a very considerable insulating value, by packing the hollows with rock wool or glass wool, sealing it in place by an asphaltic diaphragm to keep out the dampness which tends to cause too great packing and settlement in the wool, and thus obtain a combined unit which might have a very distinct value in certain types of work for exterior walls, or for interior walls or partitions which should have soundproofing qualities, as in hospitals, doctors' or dentists' offices, or in music studios.

The steel enameling industry has made excellent use of its product in building by the development of the steel enameled tile and siding which attracted so much attention at the World's Fair during the two years of its operation. It would seem that there is a possibility that the use of this material might be extended to larger units by enameling the frameless steel wall units themselves instead of the smaller units of the outer covering. There has been such an advance in the art of enameling that it is entirely possible that large surfaces such as are constantly used in the type of construction just mentioned could be properly enameled without difficulty, thus giving a beautifully colored, smooth, weatherproof, rustproof surface without the addition of the outer covering which is now required. Not only would this serve for the exterior of the building, but, as in the case of the terra cotta units spoken of before, could be applied to the inside of such units as would be best served by such treatment.

As I recall the various trends which seem to me to be logically indicated, or the developments in materials which have been suggested, the latter, especially, may seem somewhat fantastic, as I have said before, and perhaps beyond our present vision of probability, or even of possibility; nevertheless, stranger things have happened in the building industry in the last few years.

There is one trend, however, that I would like to see well established; one which has nothing to do with building materials themselves, yet is vitally necessary to them, and to the building industry as a whole. The trend to which I refer is one toward some different practices in the social and financial aspects of building, and particularly of small residential building. The social aspects ~~to which I refer~~ are better control of zoning and planning in residential districts, and better inspection of small building projects for the protection of the owner himself, even against his will. The financial aspects refer to lowering building financing costs by the elimination of certain bonus and brokerage exactions all too common among some private lending agencies - exactions which, in company with improper amortization figures, sometimes force the small owner, unfamiliar with methods of financing, to pay what amounts to an extremely high rate of interest.

In closing, let me pay a compliment to the various industries connected with building for the way in which they have carried on against real and vital difficulties, and, with a lively and inquiring spirit, carried on research toward the production of better and more economical materials.

REINFORCED BRICK MASONRY FOR PERMANENCE

By Hugo Filippi
General Superintendent, Illinois Brick Company, Chicago

When the title of my paper was first suggested I was reluctant to accept it. Mentally I balked at the use of the word "permanence" but on further thought I concluded that I ~~would be committing no grave error since~~ the word "permanence", when applied to building materials, must of necessity be considered in a relative sense.

In the past we have heard much of the slogan, "Concrete for Permanence" and yet, at every hand, may be seen examples of its disintegration, both incipient and progressive. We are familiar with the so-called "permanent" structure of steel, and yet everyone knows that the demon corrosion takes a staggering toll in dollars each year. Wood construction may, in isolated cases, last a hundred years or more, but in general its span of life is a matter of decades. And finally brickwork, with an enviable record for service, likewise has a normal span of life usually measured in terms of much less than a hundred years, so you see that when one has the temerity to use the term "permanence" in connection with a building material exposed to the disintegrating forces of nature one is treading on dangerous ground, and especially so when comparison is made with Webster's definition of the word.

The trend ~~of the times~~ is definitely in the direction of more efficient, economical and intelligent use of all materials and toward the development of new uses for both raw materials and for finished products. Since time immemorial plain brickwork has been recognized and accepted as ~~a construction~~ particularly well adapted to wall construction because it has lent itself so easily to architectural treatment; because its color possibilities are so vast and satisfying and because of the dignity and character of the finished work. An internationally famous architect once made this statement "All of the ingenuity of man, through the ages, has failed to develop a substitute building unit which at once combines in a wall, utility, color, character, charm and beauty."

Strangely enough, down through the long centuries which record the history of brickwork, little thought has been given to its use for any purpose other than as a direct load-bearing material. Bending in brickwork has been avoided as one would avoid a pestilence and I say quite properly so under the old order of plain brickwork but today we are beginning to think in new terms--we are thinking of brick masonry reinforced with steel rods--we are combining the high compressive strength of brickwork with the high tensile strength of steel and we are doing it in such an effective way that reinforced brick masonry may safely be used for such representative structural members as beams, columns and floor slabs and of course in walls, as well. Thus, in a single stroke, the inherent weakness of plain brickwork in tension has been eliminated and its scientific combination with steel reinforcing rods has resulted in a type of construction capable of carrying heavy loads in flexure and in shear, as well as in direct compression, thus meeting the requirements of modern structural engineering practice. Surely this proves that the ceramic industry is alert to its responsibility to find new uses for its products and that it is keeping step with the trend of the times. Now, may I suggest to you, that such outstanding developments in the industry and in the field of construction marks a distinct step forward and presages for clay products a new era and a new realm of usefulness.

Scientific research during the past ten years establishes that the principles of reinforced brick masonry design are the same as those commonly accepted for reinforced concrete and that the same design formulas may be used. Today several hundred structures, such as buildings, bridges, trestles, retaining walls, storage bins, stadia, etc., have been built wholly or in part of reinforced brick masonry and the list continues to grow almost daily. It has particularly found an interesting and valuable field of application in residential construction wherein prebuilt slabs have been used in wall construction, as exemplified in the Model Farm House at A Century of Progress, and in prebuilt floor slab construction of which several examples are being built at the moment. And again, entire residences have been built, using this new system, as exemplified by the Exhibit Building of the Brick Manufacturers' Association at the World's Fair and by nearly 30 residences in the California earthquake area adjacent to the Calaveras fault line.

I could go on and on, telling you of the many uses to which reinforced brick masonry has been or may be put but time does not permit. The motion pictures which are to follow will demonstrate visually to you the integrity of this system of construction in a dramatic manner and far more effectively than I could do so.

You will see a structure that carried the weight of 2 million people - a building, the floors of which were tested to more than twice the design load with resulting insignificant deflections and stresses - a construction which, while under the test loads, was subjected to a two hour fire test at a temperature of 1625 degrees - after all of which it required air hammers and the repeated blows of a 2000 pound ball of iron swung from a 60-foot boon, the partial wrecking of the supporting walls and the complete removal of both front supporting columns, before the structure would fall. That, gentlemen, is a true history of the performance of the reinforced brick masonry building wrecking of which you will now see ~~wrecked~~ in motion pictures, and offers indisputable proof of the structural integrity of reinforced brick masonry construction and marks a new trend in the utilization of the ceramic products of our great State.

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Address of By Albert W. Luse, Secretary,
Chicago Face Brick Bureau, Chicago

Third Annual Mineral Industries Conference of Illinois
University of Illinois, May 18, 1935

Revised Copy, June 3, 1935

"BRICK HOUSES--CHEAPER AND BETTER"

Illustrating
Century of Progress Model Face Brick House
of Reinforced Brick Masonry Panels
Load-Bearing, of 4-Inch Thickness

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"Brick Houses--Cheaper and Better!"

These are not my words, but those of Mr. Thomas H. Beck, Chairman of the Board of the Crowell Publishing Company, at whose commission who, as you know, are Publishers of Woman's Home Companion, The American Magazine, Collier's The National Weekly, and The Country Home--reaching the farming communities.

Holsman & Holsman, Architects, were commissioned to build for the Crowell Publishing Company, built under the for the 1934 Century of Progress, a Model Farm House, under the auspices of their Country Home Magazine, that was to would be low in cost, low in upkeep, and practically fireproof. Using a slang expression--some commission, quite a commission a small house low in cost, low in upkeep, practically fireproof--to Architects, who, in the past, had been designers of cooperative apartments, that which housed as high as 25, or more, families.

When the House was completed and turned over to the Crowell people, Mr. Beck remarked:

"You have shown the people how to build houses cheaper and better. Both of these things must be done in America. I have no greater ambition than to spend my declining years trying to help the people accomplish it." I don't have to work for money any more."

I trust there are some here today who can match Mr. Beck's last remark. Probably some of us should be in the Publishing business, and not allied with the Construction and Material business, if this is to be so.

~~Well,~~ so much for the origin of the Brick House in which we are interested today.

This important question arises--why was Architect Holsman limited, in his commission, to three basic things--low cost, low upkeep, and practically a fireproof house? Most certainly, with more freedom in spending money, the Architect could have still secured low upkeep and fireproof. But there is a need today for houses meeting these three basic requirements. It is more than a need; it is a dire necessity, if thousands of our citizens are ever to own the roofs over their heads.

Using Illinois figures only, the Illinois net incomes for 1932, as released by the Treasury Department last December, 1934, on income taxes paid, give us these illuminating figures, in round numbers:

Net Incomes of	$ 5,000. and less	-- 259,000	Income Taxpayers
" " "	5,000.-10,000.	-- 20,000	" "
" " "	10,000.-20,000.	-- 5,500	" "
" " "	20,000.-40,000.	-- 2,000	" "
" " "	above 40,000.	-- small percentages	

Incomes above these figures, in the various brackets, are in small percentages, and really do not enter into our discussion now. You will see from these figures that really the $5,000. and less incomes--including the $10,000.--give us the potential new home owners. It is from this group we will expect the volume.

Even with all the impetus given to Home Building, recently through F. H. A., and other kindred methods, including new financing plans for homes, covering 10, 15, and 20 years, either Government or Insurance Companies loans, the problem with us is still to construct low cost housing. A man cannot acquire an expensive home--entirely out of proportion to his yearly income--even through a long term amortization. In 12 to 15 years, the debt has doubled. He never will be able to pay for it. There must be low cost houses for modest incomes.

Examining another set of figures, we learn that there are 10,500,000 urban homes--farm houses not included--in the U. S. 22% are priced from $3,000. to $5,000.;

21% are priced from $5,000 to $7,500. In other words, ~~over~~ 43% of the homes now in existence, run from $3,000 to $7,500. Homes above these values, to the $10,000 homes, amount to 10% and the percentage dwindles to 3½%, as we reach the $20,000 homes.

I think from these two sets of figures--one giving the latest incomes reported in Illinois; and the other giving 43% of homes prices between $3,000 and $7,500 in the U. S.--we show conclusively that low cost housing is the problem in the home field today.

It has been said that previous to the ~~starting of the~~ depression--1929 and 1930--no particular attention had been given to solve the problem of real low cost housing for the masses. It was because the Contractors and Home Developers could make greater profit on the better class of homes, costing more money.

Probably Ex-President Hoover's Home Conferences was the beginning of a period giving serious thought to Home Building in general. From that time on, and especially during the last two years, it has been a major problem in the Press, Halls of Legislation, and Economic Gatherings. Housing has come into its own as a subject of talk, but not as a reality.

In the two-year period previous to the opening of the 1933 Century of Progress, the Press carried columns, and almost pages, of copy about the types of homes with cost reductions which would be developed and displayed at the Century of Progress. The public was all keyed up, expecting to see home prices shattered.

Publicity writers stressed most strongly the wall construction. We would have steel sheets, steel panels, fabricated wood panels--something entirely new and at greatly reduced costs. It was intimated that 20 percent of the total cost of the house would be saved, and in most cases it would come out of the cost of the walls because of the new type of construction. It was perfectly absurd, because if this were the case, the walls of the house would be entirely eliminated on this basis. However, the public was led to believe this.

We made an exhaustive study of all the homes at the 1933 Century of Progress, and we did not find that this was true. In fact, we found just the opposite--no home on display, including those of sheet steel, also wood panels, costing less than $7,000 to $7,500, and others above this price. Thus the price was quite beyond the salaries of many that we have enumerated in the list of today's potential buyers.

In the light of what we have just set forth, we believe that Mr. Beck of the Crowell Publishing Company, did a wise thing in specifying a low cost house at the 1934 Century of Progress.

Thus you have the <u>why</u> of the low cost Brick home, which is under discussion today.

There may be some here today who visited our House. The location of it, on Leif Ericson Drive, at the extreme south end of the Grounds, slowed down attendance somewhat. However, this is an interesting fact. By actual count, more people passed through our House than would fill six Yale Athletic Bowls--that is to say, over 475,000 people. We believe the people were thoroughly interested, for over 10,000 descriptive booklets at 10¢ each, were sold. Some 75 to 80 working plans and specifications were purchased. Hundreds of thousands of pieces of descriptive literature were distributed gratis. One house at Huntingburg, Indiana was erected last Fall, duplicating our Century House. Hundreds and hundreds of requests have been received concerning some part of the house.

While Reinforced Brick Masonry is over a century old, as far as I can ascertain this is the first two-story house actually erected, using single, 4-inch thick, load-bearing Reinforced Brick Masonry Panels, with IPan Ferro Concrete floors. The house is built around the two basic ideas--4-inch Reinforced Brick Masonry Panels, and Steel IPans for floors and roof.

Probably I should have said from the outset that this method of construction needs an Architect at all times. It is an Architect's proposition, for it follows his blue prints and specifications. Panels are accurately specified, numbered, and fall into the construction plan automatically. You are building with Steel, Brick, Cement, with little need for the saw, hammer, and plane, in constructing the walls and partitions.

All of our publicity and effort has put the Architect into the picture. We believe it would be very detrimental to the success of Reinforced Brick Masonry Panel Construction to have the public assume that anyone can erect such a house without plans and specifications.

The plans and specifications, covering the engineering requirements, were most carefully drawn, and necessarily so, to meet the ~~careful~~ scrutiny of the Engineering Staff of the Century of Progress, also the Chicago South Park Commissioners. They required a 100-pound load ~~, also~~ resistance to an 85-mile per hour gale. They approved our data, showing it capable of resisting at least a 100-mile gale.

~~I am pleased to advise that~~ Mr. Filippi, our previous Speaker, was the Consulting Engineer in working out the problems of our Century House.

In this connection we might ~~advise~~ that under date of April 11, 1935, we have the Federal Housing Administration approval of this type of construction--Reinforced Brick Masonry Panels--two-story houses, utilizing Government insured loans. Mr. Miles L. Colean, Technical Director, F. H. A., and his Staff, were very critical, of our plans and specifications. They requested us to submit technical data answering their requirements. They specifically mentioned that <u>this was a new type of construction, and there were no reference data</u>. There were, however, R-B-M data, but not in the use of upright ~~Panels~~, 4-inch, load-bearing.

Being an Advertising and Promotion man, and not an Engineer or Architect, ~~as you have probably discerned before this, but~~ truly interested in both, maybe I am privileged to say that the Engineers giving the approval, could not rely on previous data, as they are wont to do. Such data were non-existent.

It was rather amusing, when in Washington last Fall, bringing this type of construction to the attention of P. W. A., one of the higher Specification Authorities remarked;

"Why, Luse, if what you are telling me is true, we will have to throw our books out the window."

I remarked;

"If the type of construction we are promoting meets all Architectural and Engineering requirements of safety, maybe you will have to."

They wanted to see a 4-story structure of this type of construction.

I further advised him that there had to be a first Suspension Bridge.

It is sometimes amusing, in the course of my occupation, mingling with Engineers and Architects, to get the reaction from the different professions. The Architect remarks that if the Engineer designs the house, it will have to be taken down; and the Engineer counters that if the Architect builds it, it will come down. I don't know just how much truth there is in this.

Most certainly, everyone is interested in Architecture with pleasing lines and of safe construction. The two must go hand in hand to make a finished picture.

Coming back to the construction of the Century House, as previously stated, everything is worked out from the Architects' blue prints and specifications. Panels are made and numbered to fit into a pre-conceived plan, as would be cut Stone coming onto a job.

Now let's see some of the pictures, showing the actual construction. The old Chinese proverb, "A look is worth 10,000 words", is true.

Thirty slides were used showing the various stages of construction of this House. Some of the colored slides vividly portrayed the colorful red Brickwork.

It is an 11-room house, two stories, including two baths, double garage, with a combination pitched and deck roof. The count does not include heater and fuel rooms.

The dimensions of the House are:

First Floor, Including Garage (Over All)	55'2" long; 26'6" wide
Second floor	29'10" " 26'6" "

There is no basement, because it is believed cheaper to build above ground than below.

Where skilled labor is not over $1.00 per hour, it is estimated the house can be duplicated for $5,000. This includes a good grade of plumbing, heating, and lighting--ready for the occupant to move in.

The Brick Panels were made at the building site, of Indiana-Illinois Red Colonial Brick, costing $26.00 per M, delivered. Panel molds were made of 2 x 4's, with holes on 8½-inch centers, for ¼-inch deformed Steel Rods to be inserted. Thus the openings between the Rods for the placement of the Brick are 8½ inches on centers. The sand bed is screeded smooth under the frame, forming a perfect plane surface for the face of the Brick. This sand bed absorbs any grout which would run through to the face of the Brick. In the mortar joints threaded bolts are placed, in the upper part of the Panels, which permit the use of a plate later in raising the Panels to the walls. These bolts also project through the floor IPans, thus aiding in anchoring the Panels.

A thin grout of Quick Hardening Portland Cement, 1 part
Hydrated Lime, ½ "
Clean Sharp Sand 3 "

is poured over the back of the Brick in the Panel. This is a very particular operation. The Cement, Lime, and Sand is well mixed dry; then slightly wetted and mixed and allowed to stand not less than half hour, or more than one hour. Then it is mixed with water to the thickness of thick cream,--total water not more than 7 gallons to a bag of cement.

A perfect bonding is an absolute necessity, and this operation must be rigidly adhered to, as it relates to the mortar content and the way of mixing.

The Reinforced Rods are perfectly embedded in this manner of using the grout. It is possible to use a deeper frame than 4 inches.

When the Panel is being made, Haydite mortar mix may be poured on, to the thickness required, thus giving a thicker wall, and at the same time providing for insulation. Panels as large as 7'4"--floor height--and 6'6" wide, were raised from the floor, using a single 20-foot pole derrick, operated by man power.

It is interesting to note that there was no failure of a single Panel during the entire construction. Panels containing approximately 240 Brick, weighing over 1,200 or 1,300 pounds, were set in the walls in the one Panel in one operation. Two men at the wall, one at the derrick--three all told--easily handled the Panels, erecting, and plumbing. Corner Panels are dove-tailed, and fit perfectly with just the mortar joint openings.

Interior partitions were also made of Brick Panels, in the same manner as we have described for the outer walls. However, instead of placing the Brick in the Panel forms on edge, they were placed bed-side, thus making our walls approximately 2½ inches thick. Six Brick are figured to the square foot when placed on edge; 4 Brick to the square foot when bedwise. Interior partitions for the first floor were placed in position by man power alone, and anchored.

In commencing this job, the masons had never worked on a house of a similar type, and they were very much of the opinion that they could work faster by trowel than our type of Panel making. In order to check this, several interior Panels were laid up with trowel. There was no comparison in quality of workmanship, time and cost--everything being in favor of the molded Panel.

Steel IPans were placed over the first floor walls, both exterior and interior. They were securely anchored and then filled with light weight Cement aggregate. The IPans were of 12-guage Steel, 4 inches deep, 18 inches wide. In some instances, as over the garage, they had a span of 15 feet.

Finishing off the cement fill of the ~~Pans~~ made them ready for a mastic covering, in preparation for a wood floor ~~or~~ linoleum covering, ~~or what have you.~~ The one operation of placing the IPan and filling it with Cement aggregate, made a second floor and an under-ceiling at once.

Second story walls were put in position in a similar manner to the first floor. The Steel beams of the roof framing are securely bolted at the ridge pole, with a beam extending to each corner, and in turn securely bolted to the channel plate. Over this Steel roof frame are placed 14-guage Steel IPans. These are not filled with a Concrete mix, but with Thermax Slabs. We thus have a fireproof and thoroughly insulated roof. Over the Thermax fill was placed an asbestos shingle roof, attached in the regulation manner.

Corner fenestration was used, because it gave more window openings than in the average house--there being some 8 feet in each room. It also permits cross circulation and a better arrangement of interior furniture.

The deck roof over the double garage is really a continuation of the floor Pans, as used in the second floor of the house proper.

From the exterior view, you will notice the house has cantilever construction in several places--the doorways and the porch. Because of the use of the IPans and the lighter weight retaining walls, it is possible for the Architect to use cantilever construction. Furthermore, the position of the first floor outer walls does not set the position of the second story walls.

Our labor costs, per Chicago Union Scale, were Masons--$1.50 per hour
Carpenters-- 1.31¼ " "
Laborers-- .82½ " "

Even with these labor costs, and being an experimental job all the way through, we struck an average of approximately 40¢ per square foot for the walls, including labor, material, and installation. We are quite confident that such costs on an organized job could be cut to 35¢ per square foot, or less, depending upon the price of Brick and other masonry materials, labor costs, together with the contractor's knowledge of this type of construction.

There are at least 15 advantages of this type of 4-inch load-bearing, Reinforced Brick Masonry Walls of Panels:

(1) Freedom of design.

(2) Variety--not stereotyped.

(3) Cantilever construction.

(4) Roof--pitched, deck, or combination of both.

(5) No factory fabrication.

(6) No machinery investment.

(7) No mass production to reduce costs.

(8) Panels cast at building site.

(9) Local labor and materials used.

(10) Speed, construction.

(11) Monolithic--rigid, permanent.

(12) Wide color palette.

(13) No painting exterior panels.

(14) Rust- Termite- Fire-Proof.

(15) Less material, low cost, low upkeep.

There was no wet plaster used in the home. Various wallboards and wall coverings--linoleum, etc.--covered the walls. It is proposed in this type of wall, that it have insulation and be treated as an ordinary wall.

Undoubtedly the question of leakage of 4-inch Panels comes to mind. We are pleased to advise that Panels were left exposed in certain places in the house, so that examinations could be made to see if there was any leakage. We found no leakage of the joints whatever, either of the individual Brick, or the vertical joints with the mastic fill.

The house is of monolithic construction, as mentioned by Mr. F. J. C. Dresser in charge of Chicago Housing, when he examined the photos and specifications in his office in Washington. It is strong and durable.

As high as 8,000 visitors passed through the house in a 10-hour day. This was an average of about 12 persons per minute, almost in lock step—a continuous procession, upstairs and downstairs, with the exit over the garage deck roof. The Attendants on the lower floor advised that they could feel no vibration of the house, neither was there any sound of footsteps overhead, even with this vast number passing through.

The savings in construction cost come partially from the fact that one entire course of back-up Brick is eliminated from an ordinary 8-inch solid masonry wall in all the outer walls. With Brick Veneer over wood studding type of construction, the entire studding, both upstairs and downstairs, is eliminated. In both cases, the 4-inch Reinforced Brick Masonry Panel is load-bearing, carrying the entire structure. Thus the cost of at least one-half the amount of Brick, plus the cost of installation, is eliminated. Rate of construction is also speeded up.

During the last few months, we have proved by alternate estimates on several houses that are semi-fireproof, low upkeep, that houses can be built on this method as low, or lower, in cost than in using all frame construction. With the Brick Panel interior partitions, the garage is built in, fireproofed.

Carrying this cost figure a point farther, over a 10-year period of upkeep, consisting of two or three paint jobs, depreciation, etc., the advantage is even more in favor of Brick.

The cost figure for reproducing this 11-room house, is $5,000, where skilled labor is not over $1.00 per hour. This includes a good grade of plumbing, heating, and lighting fixtures. The Reinforced Brick Masonry Panel House that we have just described to you, was the only house at the Century of Progress that could be built for $5,000. As Architects develop their plans, and as Contractors and their workmen become more familiar with this type of construction, it is believed that costs can be reduced. Contractors will come to the job with the needed equipment, and will be able to eliminate all lost motion, organizing their job from the very beginning.

Our Century House was built without a basement. It is contended that it is cheaper to build above ground than below. However, where basements are desired, the first floor can be built of Reinforced Brick Panels, the same as we have described. They can be on 24", 26", or desired centers, in units if 3', 4', 5', and 6' lengths, supported on Steel Junior I-Beams, or Pre-Cast Reinforced Concrete Joists, or Reinforced Brick Beams. Further, it is expected that such Brick Panels will become a standard item of the Material Dealer.

(*) Reinforced Brick Slabs, of $2\frac{1}{4}$-inch thickness, and 5-foot length, will carry an ultimate load of 200 pounds per square foot, and a safe load of 50 pounds per square foot. A $3\frac{3}{4}$-inch Reinforced Brick Slab, 8-foot length, will carry an ultimate load of 300 pounds per square foot, and a safe load of 75 pounds per square foot. A Reinforced Brick Slab $6\frac{3}{4}$-inches thick will carry a 100 pound load per square foot. *

When our work sheets now show that the entire exterior walls--23 Panels, 604 square feet--of the second story, were erected, completely, in 9 hours and 5 minutes, there is every reason to believe that Pre-Cast Brick Panels can be placed, as a first floor in any ordinary sized house, in less than a day's time. Such construction gives a fireproof basement, and should be used in the all lumber house, and the Brick Veneer over wood studding, as well as in the all Brick house. As a method of fireproofing the basement, where statistics show that most of the fires originate, Reinforced Brick Floor Panels would be a God-send in eliminating wood joists.

Where there is no basement, the over-all cement floor foundation makes an admirable place for the casting of the wall and partition Panels at the building site. The bed of sand gives you the levelling element.

Where a basement is required, the Pre-Cast Brick Floor Panels can be placed in position on the Steel Beams, and thus a place is made ready at no extra cost whatever, for the making of the wall and partition Panels.

(*) From Brick Engineering, Volume III.

There is much to be said in favor of this type of construction. Architects advise that because of the lighter exterior wall load of Reinforced Brick Panels, they have more freedom in placing the second floor wall Panels, both in cantilever and other construction. They do not require the heavy supporting wall beneath.

Cantilever type of construction was used in our Century House, without any additional cost, because of the Steel IPans in the second story floors.

In a word, the Reinforced Brick Masonry Panel is the Brickman's answer to Fabricated Homes. It is truly remarkable that one of the oldest building materials known to man, today, is used in the most advanced type of construction.

The small-home field is a large one, as we attempted to show through our two tables of statistics--the one giving incomes, and the present census of low-cost homes already in existence.

It is verified in the recent General Electric Home Competition, with its 2,000 competing designs. Class A alone, the small house for the North, had 1,000 entrants, which is approximately half the entire number of competitive plans submitted. It is also reported that probably 75 per cent of the plans, showed a trend toward the modern type--many with deck roof.

Reinforced Brick Panels are most admirably adapted to the type of construction shown in the General Electric Competition, the very latest home design competition in this country, awards just having been made.

"Cheaper and Better Homes" <u>can</u> be built with Reinforced Brick Masonry Panels. The coming Architect will undoubtedly brush aside the cobwebs of tradition and strike out boldly, developing new ideas in the method of utilizing construction materials, thereby giving us homes at a lower price, fireproof, with low upkeep cost, and within reach of the masses.

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RECENT FINDINGS ON THE RELATION ~~OF THE CONSTITUTION~~ OF CLAYS AND SHALES TO THEIR CERAMIC PROPERTIES

Ralph E. Grim
[redacted] Petrographer, Illinois State Geological Survey, Urbana

Introduction

The Illinois State Geological Survey for the past several years, in cooperation with the Department of Ceramic Engineering of the University of Illinois, has been investigating the mineral composition of Illinois' clays and shales in an endeavor to obtain a better understanding of the factors which control their ceramic properties. This research is leading to the accumulation of a body of fundamental information on Illinois' raw materials for ceramic purposes which should be of value in improving present products, in solving certain processing problems, and in developing new products. At the Second Annual Mineral Industries Conference held last year, a preliminary report[1] of this work was given. ~~Our researches in this direction have been continued, but are not yet completed.~~ The present paper is a progress report in which it is intended to present some results of our further work on this problem.

These results can be presented best under the heading of the following general variable factors of constitution which exert an important influence on ceramic properties, (a) variations in particle size, (b) variation in mineral composition, and (c) variations in the base-exchange capacity and the identity of exchangeable ~~ions~~ bases. It is not considered that these are the only

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1/ Grim, R. E., Clays and shales: Report of the Second Annual Mineral Industries Conference on Home Building in Illinois, pp. 101-109 (1934).

constitutional factors influencing ceramic properties although they are among the most important.

Influence of variations in particle size upon ceramic properties

The important influence exerted on ceramic properties generally by variations in the degree of fineness of the constituent particles of raw materials has been recognized and studied for some time. In investigating Illinois clays and shales a slightly different approach to the problem has been used, and specific data for these materials have been obtained. These data are important, not only for their own inherent value, but because the influence other factors of constitution exert on ceramic properties cannot be evaluated without them, i.e., unless the variations due to particle size are taken into consideration.

To study this problem, a series of Pennsylvanian shales used in brick making were selected, all of which contain the same mineral components[2], i.e., they are all composed essentially of a sericite-like mineral, micaceous in form, and quartz. By selecting such material, variations in ceramic properties caused by differences in the identity of the mineral components could be largely eliminated. The content of material existing in particles less than 2 microns in diameter, plus larger clay mineral particles which could be broken down to this size on working, was determined for each shale of the series by microscopic and

2/ Grim, R. E., Petrology of Pennsylvanian shales and non-calcareous underclays associated with Illinois coals: Bull. Am. Cer. Soc. 14 (1935).

sedimentation analyses. Likewise, the content of material coarser than 2 microns and not broken down to a smaller size was determined for each member of the series. The former fraction was designated for convenience as fraction A, the latter as fraction B. This procedure of fractionating the material at 2 microns (.002 mm) was followed for several reasons. Without a separation at 2 microns into one fraction (B) whose mineral composition could be determined microscopically and another fraction (A) which required X-ray and chemical data in addition to microscopic information for mineral analysis, these shales are too complex to permit satisfactory mineral identification. Further, 2 microns represents about the upper limit at which the constituents of these rocks possess to a pronounced degree the properties commonly associated with the term clay. Slightly coarser material partakes of the nature of silt. Ceramic tests were made on each member of the series, and the determinations of the values for various ceramic properties were plotted against the content of fraction A with the results shown in ~~the following~~ figures 1, 2, and 3.

sedimentation analyses. Likewise, the content of material coarser than 2 microns and not broken down to a smaller size was determined for each member of the series. The former fraction was designated for convenience as fraction A, the latter as fraction B. Ceramic tests were made on each member of the series, and the determinations of the values for various ceramic properties were plotted against the content of fraction A with the results shown in the following figures.

Titles for Figs 8pt

Fig. 1. Curve showing the relation between amount of fraction A and modulus of rupture without added sand for a series of Pennsylvanian shales. The locations of samples used in constructing this and the ~~following~~ figures 2 and 3 can be determined by reference to the sample numbers and the appendix to the author's previous paper in Bull. Am. Cer. Soc., vol. 14, No. 5 (1935).

Fig. 2. Curve showing the relation between the amount of fraction A and volume drying shrinkage for a series of Pennsylvanian shales.

Fig. 3. Curve showing the relation between the amount of fraction A and volume burning shrinkage for a series of Pennsylvanian shales.

Figures 1, 2, and 3 show that the modulus of rupture, the drying shrinkage, and the burning shrinkage decrease with decreasing amounts of fraction A. The decrease in modulus of rupture (Fig. 1) is most rapid in shales ranging from 100 per cent to about 70 per cent fraction A. As shown in figure 2, the decrease in volume drying shrinkage becomes increasingly less as the amount of fraction B increases. The burning shrinkage, as shown by figure 3, appears to decrease gradually as the amount of fraction A decreases. There is a suggestion that the rate of decrease is more rapid with less than 60 per cent fraction A (Fig. 3) but the data are not conclusive on this point.

An inspection of the figures 1 to 3 shows that the values for certain of the shales are not close to the curves drawn approximately through average values. Thus, shales number 241, 237, 239, 279 exhibit distinctly higher or lower values, as the case may be, for modulus of rupture and drying shrinkage than the average values for shales of similar fraction A content. Petrographic analyses ~~of the shales~~ show that textural characteristics are usually responsible for these variations. In general a shale possessing values below the average is found to contain aggregates and mineral particles which break down only with difficulty to particles as small as those in fraction A, i.e., 2 microns or less. Ordinary working processes do not reduce these aggregates and particles although they can be broken down to this size, and the designated content of fraction A has been determined on the latter basis. Since they are not broken down during working, the sample exhibits the properties of a shale with a smaller amount of fraction A. The cause of this difficulty in disaggregation is commonly a slight silicification. Similarly samples possessing values above the average are usually those very easily disaggregated and consequently on working an unusually large number of particles are reduced to the size limit of fraction A causing the sample to possess values characteristic of the average for shales of larger fraction A content. Shales that have been exposed to surface weathering conditions commonly exhibit this exceptional ease of disaggregation.

Influence of variations in mineral composition on ceramic properties

It has been recognized in recent years that all clays are not composed dominantly of kaolinite or a kaolinite-like mineral, but that they may contain any one or more of a group of minerals known as clay minerals. In this group are to be found such minerals as kaolinite, anauxite, halloysite, allophane, beidellite, montmorillonite, nontronite, a sericite-like mineral, and perhaps others. The ceramic properties of a given clay or shale will in part depend upon which of these minerals are present and their relative abundance.

The noncalcareous underclays occurring beneath the coals in Illinois are composed of a mixture of kaolinite, the sericite-like mineral and quartz.[3] As already indicated, the shales

[3] Grim, R. E., Idem.

associated with the same coals are composed of the sericite-like mineral and quartz. Thus by comparing the ceramic properties of these shales and clays in such a way that the influence of particle size and texture are held constant, the influence of kaolinite and the sericite-like clay mineral on these properties can be investigated. This has been done by determining the relative abundance of fraction A and fraction B for a group of underclays, by obtaining determinations of values for the ceramic properties for each member of the group, and by plotting the ceramic values against the content of fraction A. A comparison of curves (Figs. 4, 5, and 6) based on such plottings for similar properties for shales and underclays is in effect a comparison of the average ceramic values for shales and underclays of the same fraction A content. In this way the influence of particle size and texture can be eliminated and the influence of mineral composition studied.

Fig. 4. Curves showing the relation between amount of fraction A and modulus of rupture without added sand for a series of Pennsylvanian shales(———) and non-calcareous underclays (- - - -).

Fig. 5. Curves showing the relation between amount of fraction A and volume drying shrinkage for a series of Pennsylvanian shales (———) and non-calcareous underclays (- - - -).

Fig. 6. Curves showing the relation between amount of fraction A and volume burning shrinkage for a series of Pennsylvanian shales (———) and non-calcareous underclays (- - - -).

Figure 4 shows the values for modulus of rupture to be higher for the underclays than for the shales. This difference is greatest when the content of fraction A is large, and least when it is small.

As shown by figure 5, the underclays possess a higher drying shrinkage than the shales. The curves show further that the difference is greatest in material rich in fraction A, and that the rate of decrease of drying shrinkage with increasing amounts of fraction B is different for the underclays and for the clays.

Figure 6 shows the underclays to possess a lower burning shrinkage than the shales. As in the case of the drying shrinkage the rate of decrease of firing shrinkage with increasing amounts of fraction B is not the same for the underclays and shales.

The relative abundance of kaolinite and the sericite-like mineral is not the same in all underclays. In the underclays investigated, 271 and 232 contain the most kaolinite, 248, 225, and 256 the least. In the green properties, there is no close correlation between the relative amounts of these minerals and the values for these properties. From this it can be concluded either that in materials of this kind a minimum amount of kaolinite is ample to cause the differences in green properties shown in figures 4 and 5 with larger quantities exerting little additional influence, or that the divergence of values possessed by the shales and underclays are caused in part by factors which have not yet been analyzed. The solution of this problem is a task for the future.

As shown by figure 6, there is a relationship between the abundance of sericite-like mineral and kaolinite and the burning shrinkage. Underclays 256, 225, and 248 with the highest amount of sericite-like mineral possess values close to those of shales in which this mineral is the dominant constituent. Other data not here presented further emphasize a fairly close relationship between ~~mineral identity and burning properties generally~~ the abundance of these minerals and other burning properties.

A petrographic analysis providing data on the relative abundance of fractions A and B in a given shale or underclay, and on the identity of the essential mineral components can be made in a comparatively short time. Using these determinations together with data similar to that presented above permits a rapid and fairly accurate estimation of the ceramic properties without detailed ceramic analyses.

Influence of variations in the base-exchange capacity and of the identity of exchangeable ~~ions~~ bases on ceramic properties

It has been recognized for some time that many clays possess certain amounts of various alkalies which they will exchange under certain conditions for other alkalies. This is the phenomena of base-exchange made use of in zeolite water softeners in which the mineral zeolite exchanges its sodium for the lime of the hard water.

Different clays may possess the capacity to exchange different amounts of alkalies. Likewise, the specific identity of the exchangeable base is not the same in all clays. Recent work by Endell, Hoffman, and Wilm [4/] has shown that there is a

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4/ Endell, N., Hoffman, U., Wilm, D., Röntgenographische und kolloidchemische Untersuchungen über Ton. Zeit. f. angew. Chemie, 47, pp. 539-547 (1934).

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relationship between the exchange capacity of a clay and certain of its green ceramic properties. Thus, plasticity and drying shrinkage increase as the base-exchange capacity increases, i.e., the higher the capacity possessed by a given clay, the higher its plasticity and drying shrinkage will be. Within a given type of clay, such as kaolin, the breaking strength also increases as the exchange capacity increases.

Perhaps of greater importance is the further recent finding that the properties of the raw material vary also with the identity of the exchangeable base. It is now known that a given clay will have a slightly different plasticity and drying shrinkage depending on whether sodium or lime is the exchangeable component. Specifically as lime is exchanged for sodium, the plasticity is increased, and the drying shrinkage is decreased. Clays as they occur in nature usually carry calcium as the exchangeable base rather than sodium so that nature tends to provide the raw material in a condition of high plasticity and low drying shrinkage. The influence of these bases on other ceramic properties, and the influence generally of other bases such as potash and magnesium, are problems for future research.

The importance of this approach to clay and shale research is obvious when it is recognized that these data on base-exchange capacity and exchangeable constituents may hold ~~the~~ a key to the control and improvement of the ceramic properties of a given clay. This problem of the improvement of a clay is not as simple nor as unrelated to other factors as may be concluded from the foregoing statements. Thus, different clay minerals possess different base-exchange capacities, e.g., the base-exchange capacity for kaolinite is nil or very low, whereas for beidellite and montmorillonite it is very high. Therefore, a clay so constituted that its exchange capacity is low can have its properties changed very little by varying its exchangeable base. However, this difficulty probably can be surmounted by blending in another clay with high exchange capacity thereby increasing the possibility of varying the ceramic properties by varying the exchangeable constituent.

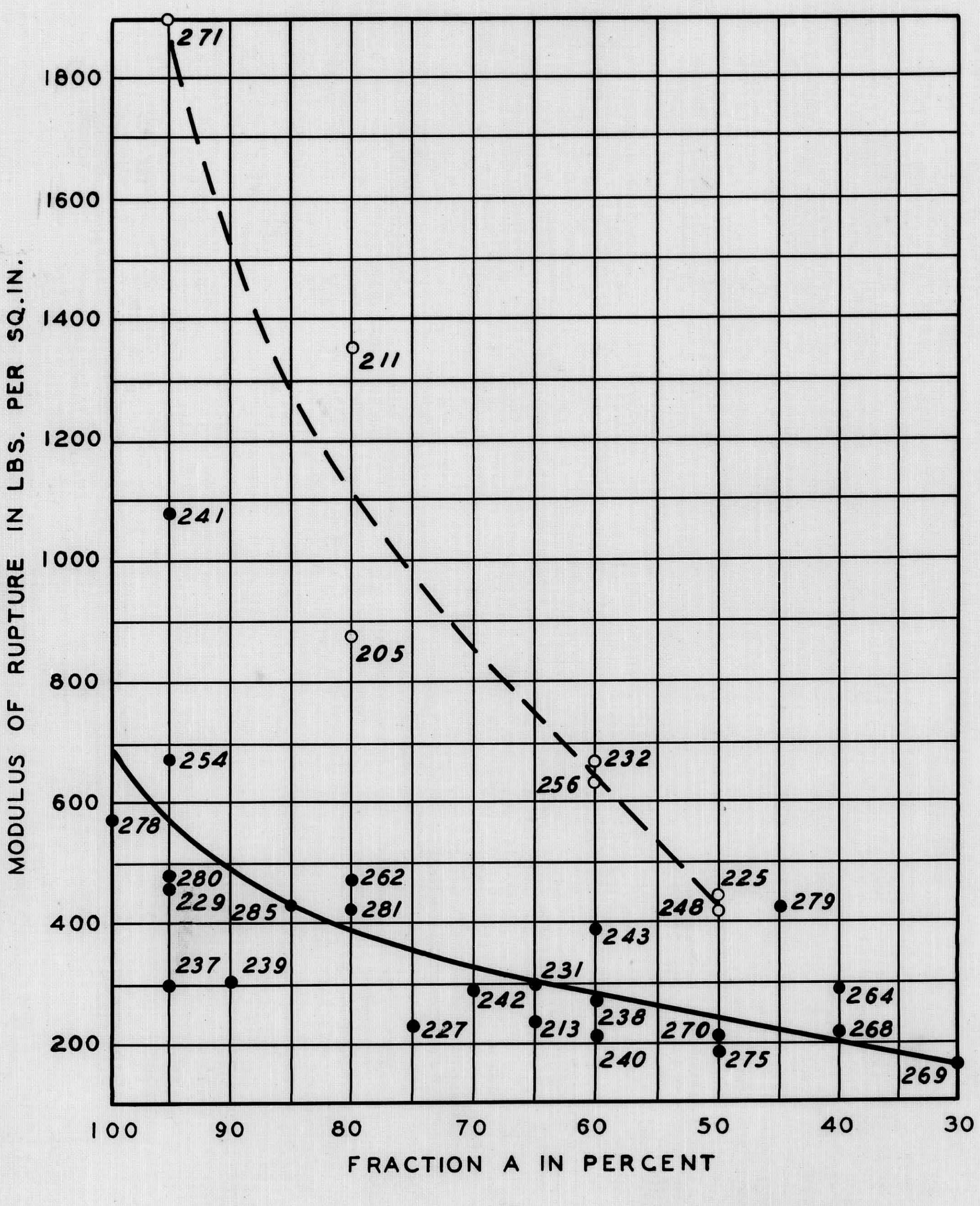
Various constituents of many clays such as free ferric hydroxide and free silica probably tend to reduce the base-exchange capacity of a given clay and consequently influence the ceramic properties. Also, there is evidence that the base-exchange ability of a given clay mineral varies with its particle size. Therefore, the problem of improving properties of clays from this point of approach may involve a consideration of the removal of certain constituents or a change in the size of the constituent particles.

Fig 1, 2, 3

3 tracings from Grim's paper removed by R. E. Grim, April 11, 1939

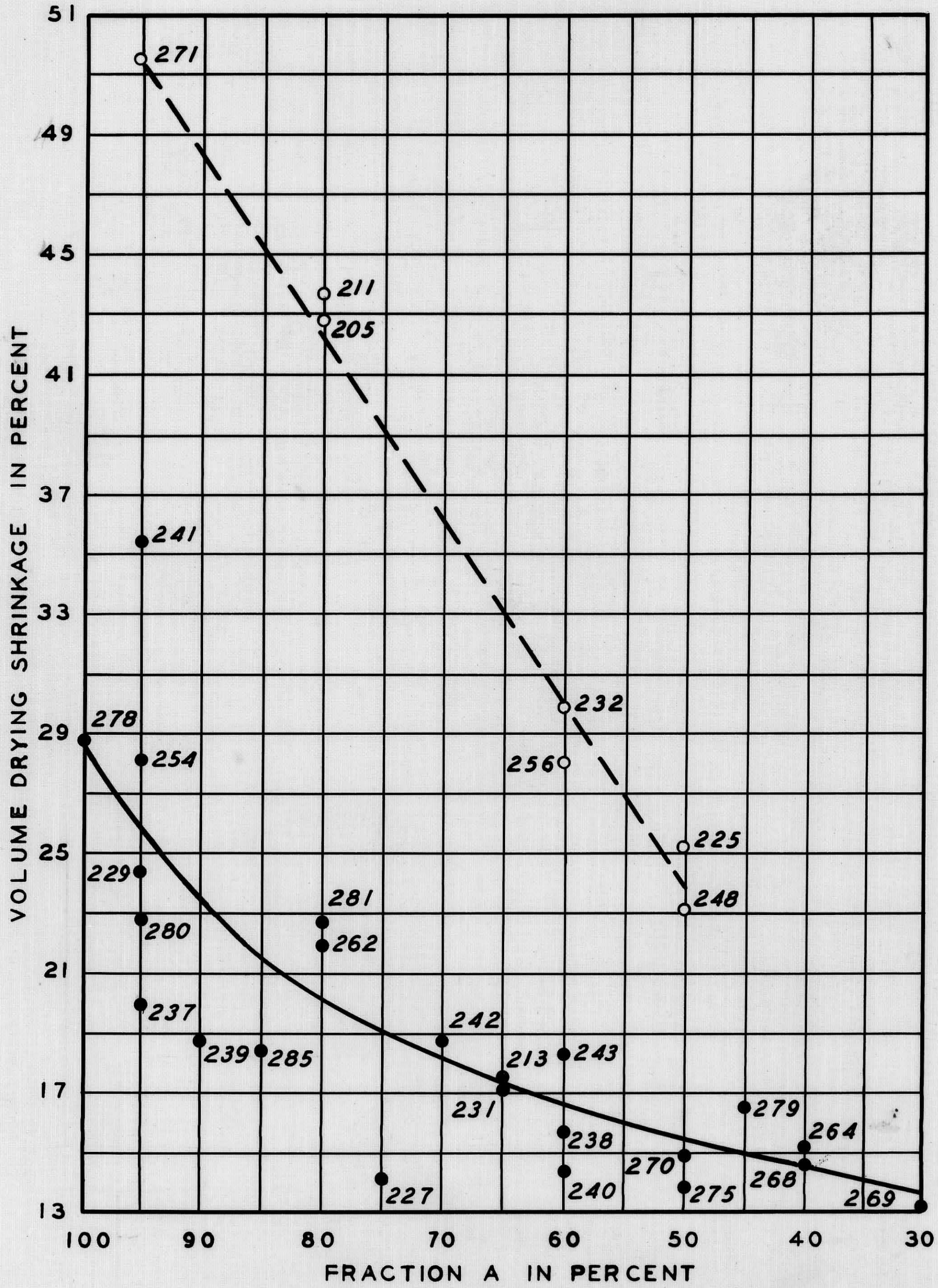
Green Fig 4

Reduce to 4 1/4"



Gunn Fig. 5

Reduce to 4 1/4"



Gunn Fig. 6

Reduce to 4 1/4"

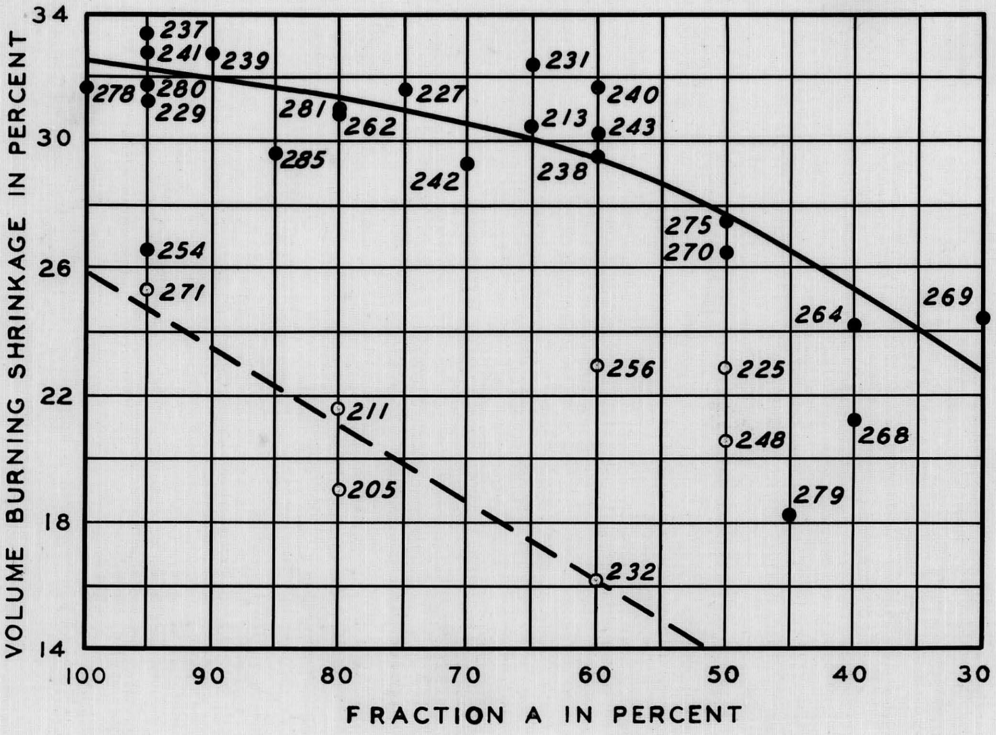
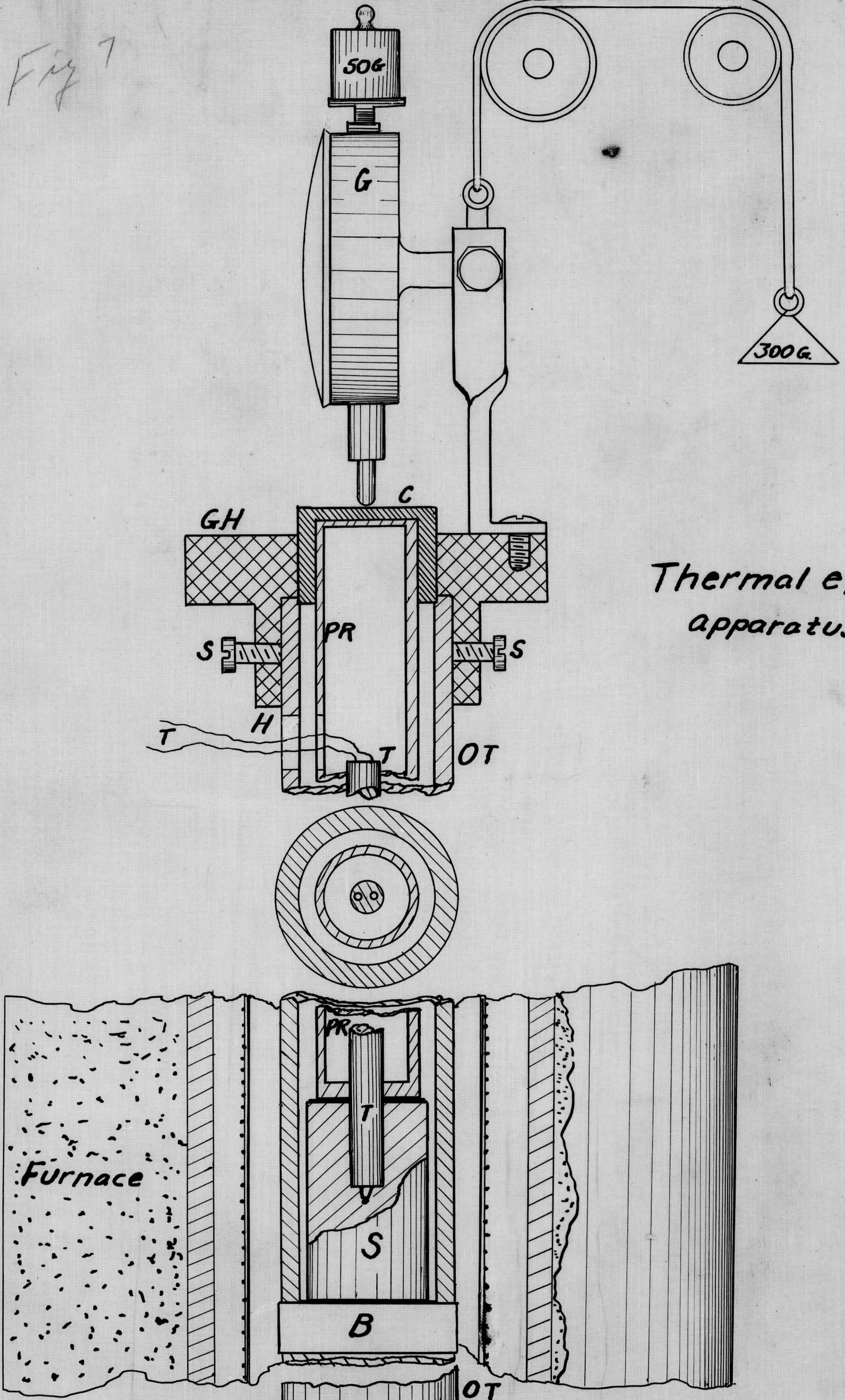


Fig 7



Thermal expansion apparatus

A Progress Report on an Investigation of Face Brick

By C. W. Parmelee
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University of Illinois

Introduction

The purpose of this investigation, made by the Department of Ceramic Engineering of the University of Illinois in cooperation with the State Geological Survey, was to determine the physical properties of face brick manufactured in the State and to compare these brick with face brick manufactured in other states. An investigation of the physical properties of brick manufactured outside the State but offered for sale in the State has also been started. The data herein presented have been gathered from the measurements made here and from publications* giving similar data taken under standard conditions.

Twenty-two brands of Illinois face brick and eleven brands of out-of-state brick offered for sale in Illinois have been tested. The published data, already mentioned, have been gathered from tests on nineteen brands of face brick manufactured in two states (Oklahoma and Virginia).

In order to conduct a uniform and fair test on all the brick, one man selected all the specimens for testing purposes. The Illinois brick were all gathered at the plant of the manufacturer, while the out-of-state brick were taken

*Physical Properties of Common and Face Brick Manufactured in Virginia, by J. W. Whittemore and Paul S. Dear, Bulletin No. 6, Engineering Experiment Station of Virginia Polytechnic Inst.
Physical Properties of Common and Face Brick Manufactured in Oklahoma, by L. F. Sheerar, Publication No. 8, Engineering Experiment Station, Oklahoma Agricultural & Mechanical College.

from the stock of dealers representing the out-of-state manufacturers in the Chicago area.

Description of Tests

Variations in size.- Uniformity of size should give, in some measure, an idea as to the amount of control exercised by the manufacturer. This, in addition to the technical value of uniformity, makes the test worth performing. The test, as performed on Illinois brick, consisted of measuring the length of one hundred brick and dividing the sum by that number to obtain the average. The variation from the average was found by measuring the individual length and subtracting from the average length; totaling all the variations and dividing by the number of tests gave the average variation in inches.

The per cent variation in length was found by substituting in the following formula:-

$$\text{per cent variation} = \frac{\text{average variation}}{\text{average length}} \times 100$$

The same computations were made for width and thickness.

It was observed, while conducting the variation of dimension tests on the Illinois brick, that fewer measurements could be made and still get the same numerical values. Therefore, in obtaining the variation data for out-of-state brick, thirty specimens of each brand were used.

Warpage.- Warpage measurements were made by laying a straight-edge along the length of a brick and estimating the warpage to the nearest 1/16 inch. One hundred specimens of each brand of Illinois brick and thirty specimens of each out-of-state brick were measured.

Compressive strength.- The compressive strength was determined on not less than five half-brick specimens according to the method of the American Society of Testing Materials designation C. 67-31. The brick were cut in half by means of an abrasive cut-off wheel and placed flatwise in the testing machine. The two bearing surfaces were in each case dipped in shellac and thinly coated with plaster of paris to insure uniform load distribution. The load was applied vertically at a uniform rate till fracture occurred.

Transverse strength.- The transverse strength was determined on not less than five whole brick of each brand according to A.S.T.M. test designation C. 67-31. Each brick was placed flatwise on knife edges spaced seven inches apart and the load was applied uniformly at mid-span. The knife edges used for this test were the type recommended by the A.S.T.M. The transverse strength was obtained by use of the standard equation.

Absorption.- The absorption values were found by allowing five brick of each brand to set in distilled water until constant weight was reached. This procedure varied from the test recommended by the A.S.T.M., specification C. 67-31, in which a definite five-hour saturation period in boiling water is specified. The standard formula

$$\text{per cent absorption} = \frac{\text{Sat. Wt.} - \text{Dry Wt.}}{\text{Dry Wt.}} \times 100$$

was used to obtain the values.

Rate of absorption.- ~~Some~~ an indication of the permeability of a face brick may be obtained by the rate at which it will absorb water at room temperature. Five samples from each brand were weighed with the accuracy of ±0.5 per cent, placed in distilled water, and weighed again at one hour intervals until the weights became constant. The rate of absorption in per cent was computed from the hourly value.

Bulk density.- The bulk density values were obtained from an average of five samples ~~determined~~ by the suspended weight method. The specimens were first weighed with an accuracy of ±0.5 per cent, and immersed in distilled water until ~~till~~ saturat~~ion;~~ed; the saturated and suspended weights were then determined. The density was computed from the formula:-

$$d = \frac{\text{Dry Wt.}}{\text{Saturated Wt.} - \text{Suspended Wt.}}$$

Brinell hardness.- Five specimens from each brand were taken for a Brinell hardness test and one surface of each sample was smoothly ground on a revolving steel disc with 200-mesh carborundum as the abrasive. The hardness was determined on a standard Brinell machine with a constant bearing load of 500 or 1000 Kg. The different loads were used due to extreme differences in hardness; soft and extremely vitrified brick breaking under the 1000 Kg. load. Carbon paper, interposed between the sample and ball, was used to more clearly define the mark of the steel ball. The diameter of the indentation was measured with a magnifying instrument. The Brinell index was obtained from the diameter by the equation given by McBurney, Jour. Am. Cer. Soc. 1930, 823.

The Brinell hardness test is not used extensively in testing ceramic products, and its value depends considerably on how the data are interpreted. It should be kept in mind that if the brick were homogeneous throughout there should be a definite correlation between Brinell hardness and the compressive strength. However, the condition is not fully realized. Therefore, the Brinell index data might be said to give the strength or hardness of a practically uniform portion of the brick in the region of contact with the ball. The compressive or transverse strength, on the other hand, gives the strength of the brick as a structural unit.

Soluble salts.- A qualitative test for the presence of soluble salts was made by half immersing the brick samples in a pan of distilled water. After evaporation was complete, the surfaces were examined for evidence of scumming and the resulting appearance recorded. These results are not reported at this time.

Color.- The color test was made by matching the brick with the colors of the Munsell charts. The results of this test eventually will be reported according to hue, value, and chroma. This is a very satisfactory method if too many tests are not conducted at one time since then the eyes of the operator become fatigued.

Results

The accompanying table no. 1 and figs 1, 2, 3, 4, 5 summarize the results thus far obtained relating to the standard brands of face brick manufactured in the State. The tests showed the superiority in these tests of Illinois brick as a group in nearly all physical properties. The limited amount of data available for direct comparison shows an apparent inferiority of southern and western brick compared to mid-western brick.

Although the variation of Brinell hardness in one brick is quite large there is a very distinct difference in hardness of various types of brick. A limitation in the method of Brinell hardness measurements is the indistinct boundary between the indentation and the surrounding surface; possibly some better method can be found to determine this property.

The following Table 1 shows some of the more interesting values obtained.

Further statistical treatment of brick data should be beneficial to both manufacturer and consumer.

Table 1.- Summary of Data

	Illinois	Others
Ave. compressive strength ---------------	11,320	8,800
Max. compressive strength ---------------	17,800	16,200
Most probable compressive strength ------	12,000	10,900*
Ave. Transverse strength ----------------	1,720	1,390
Max. transverse strength ----------------	2,860	3,140
Most probable transverse strength -------	1,600	1,300*
Ave. absorption -------------------------	3.65%	7.58%
Max. absorption -------------------------	9.5%	13.2%
Most probable absorption ----------------	5%	5%*
Ave. variation in dimensions ------------	2.72%	3.06%
Most probable variation in dimensions ---	2.2%	2.2%
Most probable maximum warpage -----------	.0625"	.0625"
Ave. warpage ----------------------------	.0159"	.0269"
Max. Brinell hardness index -------------	174	193
Min. Brinell hardness index -------------	34	56

*Most probable values for all brick

A Discussion of the Figures

Note on Frequency Scales

The frequency scales shown on Figures 1, 2, 3, 4, and 5 are those for Illinois brick; the frequency scale for "all brick" may be had by multiplying the given scale by the factors listed below.

Transverse Strength - - - $\frac{13}{5}$

Compressive Strength - - 2

Warpage - - - - - - - - - $\frac{6}{5}$

Absorption - - - - - - - - $\frac{11}{8}$

Variation of Dimensions - $\frac{20}{13}$

Since there were forty brands of out-of-state brick considered as against twenty-two from Illinois, the two sets of curves were adjusted to secure an easier comparison. The high points, or the most probable values, are adjusted so that they are the same height for comparison purposes, for both Illinois and "all" brick" curves.

The number of brands of brick and the intervals of measurements for each graph for Illinois brick are listed below.

Properties	Number of Brands Tested	Intervals on the Graphs (approx.)
Transverse Strength - - -	23	300 lb. per sq. in.
Compressive Strength - -	23	2,000 lb. per sq. in.
Warpage - - - - - - - - - -	33	1/16 inch
Absorption - - - - - - - -	23	1.5%
Variation in Dimensions -	33	1.%

Frequency curves have been employed to show graphically how Illinois face brick as a unit compare with all other brick tested or concerning which we have data. This method of presenting the result of experiments shows the relation which probably exists between the number of brands tested and the variations in the properties observed. In testing such heterogeneous material as ~~a~~ face brick, it is to be expected that there will be variations and the truly representative values may be had only by carefully analyzing the data. An arithmetical average of the results of a physical test of such wares is of relatively little value unless a very large number of samples is tested. ~~It~~ If only a small number is tested, then attention must be paid to the frequency with which certain values occur. From these, we may derive the representative values which may be accepted with confidence, whereas, very low values or very high values are only occasionally observed. For example, on Figure 1, Distribution Curve of Transverse Strength, the most frequent value for transverse strength attained by all brick tested (including Illinois brick) was about 1300 pounds per square inch, which is the Most Probable Value, whereas the ~~most frequent~~ corresponding value for transverse strength of the Illinois brick was nearly 1600 pounds per square inch. Further, inspection of the curve for the Illinois brick shows that the least transverse strength attained was more than 1000 pounds as compared with approximately 600 pounds for all the brick.

The summary of the data shows that the brand of brick having the highest transverse strength of this investigation is manufactured outside the state of Illinois, yet the frequency diagram indicates the probability of a brand of brick being manufactured in Illinois having this strength is greater than the probability of it being manufactured in "all" states" considered.

It should be noted that this part of the Illinois frequency curve is extrapolated and, therefore, gives the probable distribution in this range. Further, the next highest value for transverse strength for out-of-state brick is 2400 pounds per square inch. This value is also of very low frequency. If the data for out-of-state brick only were used in drawing a frequency curve, the value of 3,100 pounds would seem to be incorrect for any brick since it would be entirely out of line with the rest of the data, but the data from the Illinois brick show that it is possible and also that it is very nearly the maximum value one would ever expect to attain under the test conditions. Some of the data ~~is~~ are indicated on the frequency curve to show the trend and to make the explanation clear.

In general, the less the area under a curve, the greater is the uniformity of the physical property tested. The ideal condition would be represented by a point showing that all samples tested gave exactly the same strength. This point would be located by a straight line parallel to the frequency ordinate and running from the baseline to the point.

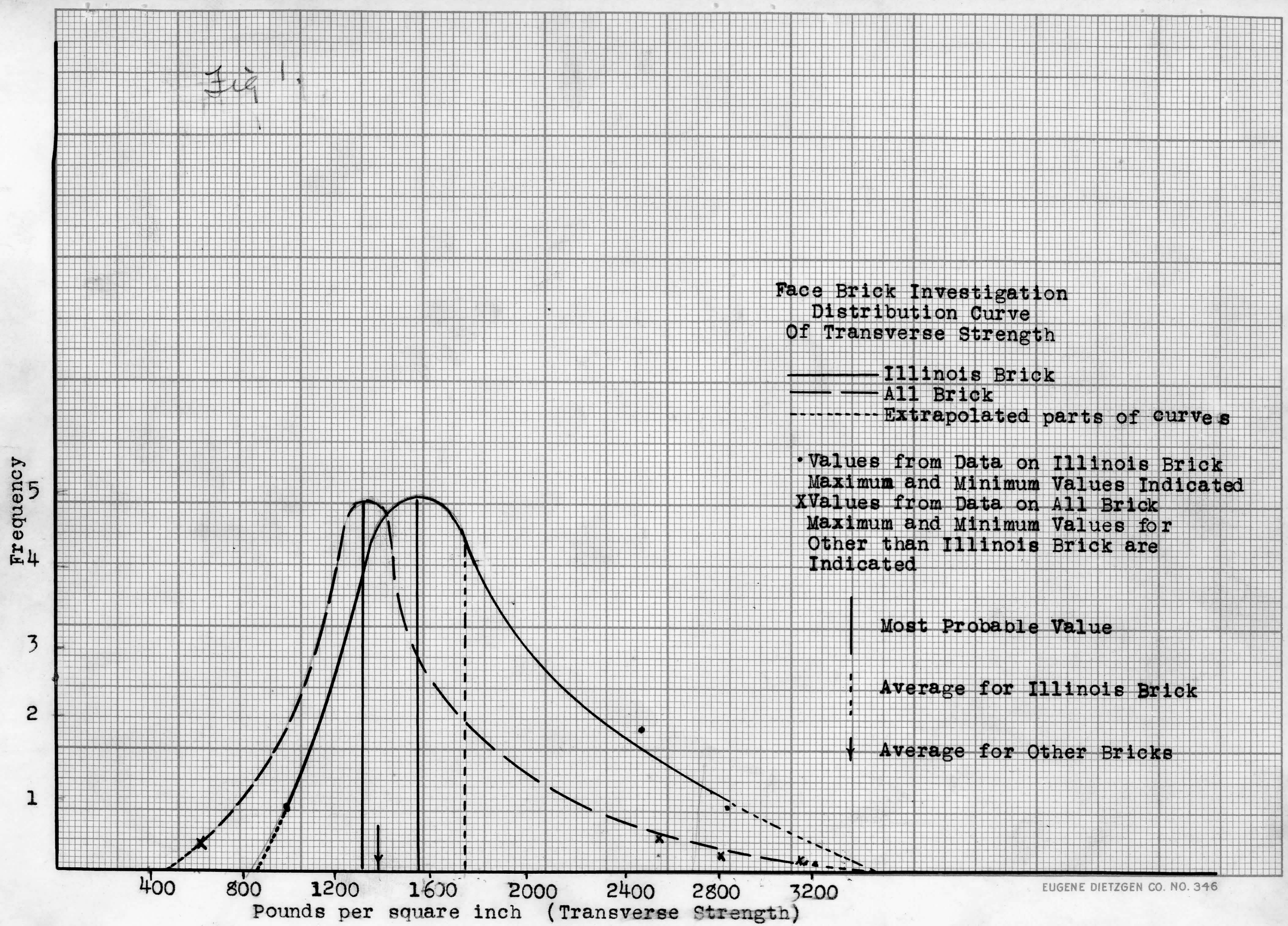
The frequency curves shown in Figures 2, 3, 4, and 5 may be interpreted in a similar manner. The Distribution of Maximum Warpage, Figure 2, shows that the Illinois brick as a unit show a somewhat greater probability for greater warpage than all the brick but the maximum warpage to be anticipated is not much different. It should be noted that the scale of warpage is in hundredths of an inch and the differences are very small.

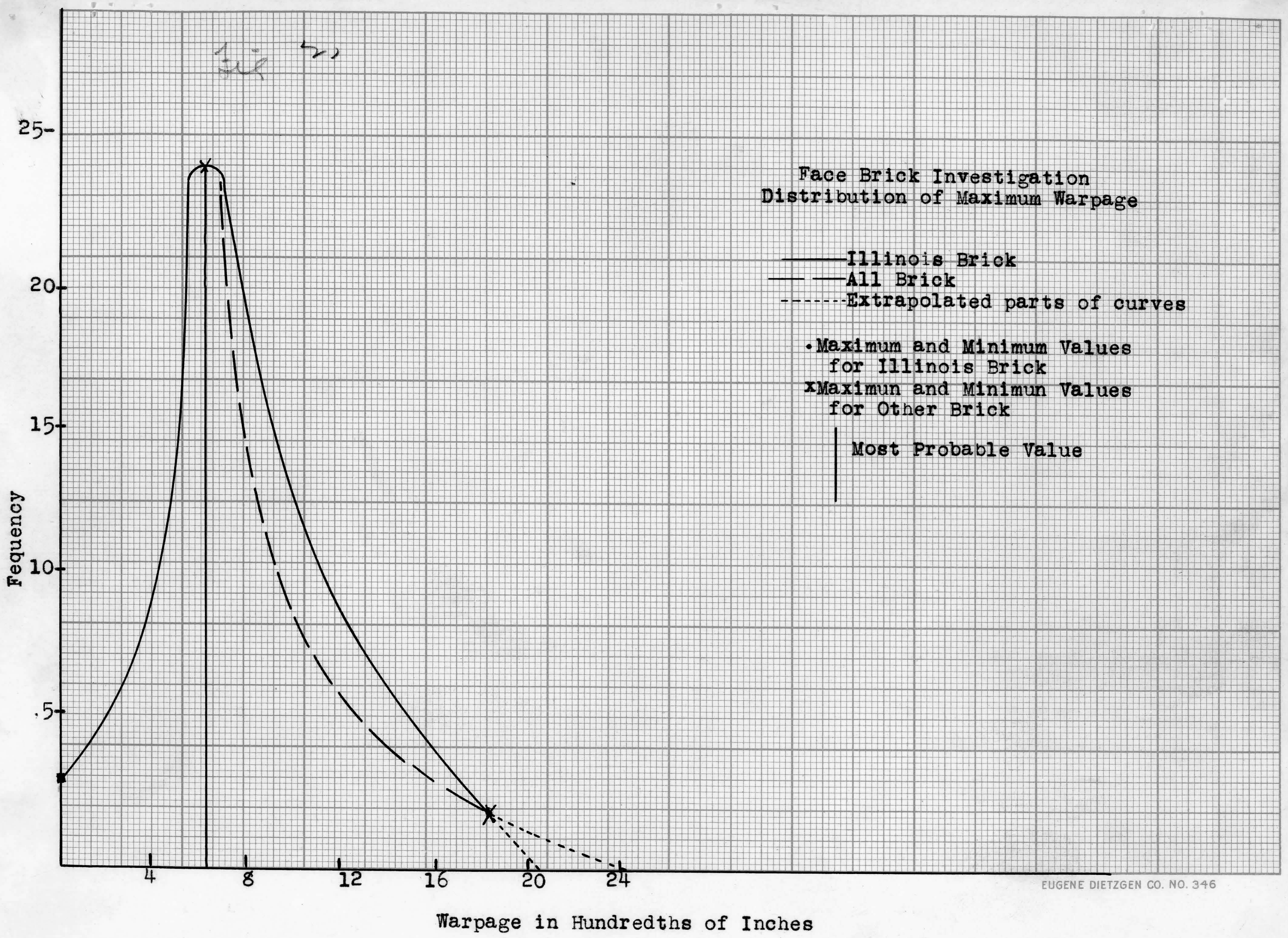
The Distribution of Absorptions, Figure 3, shows that the average absorption for Illinois brick is less than the Most Probable Value for all brick, whereas, the average absorption for brick other than Illinois is higher. The maximum for Illinois brick is less than the maximum for all brick and there is less probability that the Illinois brands of brick will vary as much as all brick considered.

The Distribution of Variations in Dimensions, Figure 4, shows that the average for Illinois brick is greater than the most probable value for all, but less than the average for brick from other states. In other words, the Illinois brick were found to show a slightly higher variation than the average variation of all brick but they are more uniform than out-of-state brick tested or of which we have data.

The Distribution of Compressive Strength, Fig. 5, shows that the average of the Illinois brick is considerably higher than the average of other brick, also that the Most Probable Value for the Illinois brick is greater than for all brick studied.

Fig 1.


Face Brick Investigation
Distribution Curve
Of Transverse Strength
Illinois Brick
All Brick
Extrapolated parts of curves
• Values from Data on Illinois Brick
Maximum and Minimum Values Indicated
X Values from Data on All Brick
Maximum and Minimum Values for
Other than Illinois Brick are
Indicated
Most Probable Value
Average for Illinois Brick
Average for Other Bricks
Frequency
1
2
3
4
5
400
800
1200
1600
2000
2400
2800
3200
Pounds per square inch (Transverse Strength)
EUGENE DIETZGEN CO. NO. 346



Face Brick Investigation
Distribution of Maximum Warpage
Illinois Brick
All Brick
Extrapolated parts of curves
•Maximum and Minimum Values for Illinois Brick
xMaximun and Minimun Values for Other Brick
Most Probable Value
25-
20-
15-
10-
.5-
Fequency
4
8
12
16
20
24
Warpage in Hundredths of Inches
EUGENE DIETZGEN CO. NO. 346

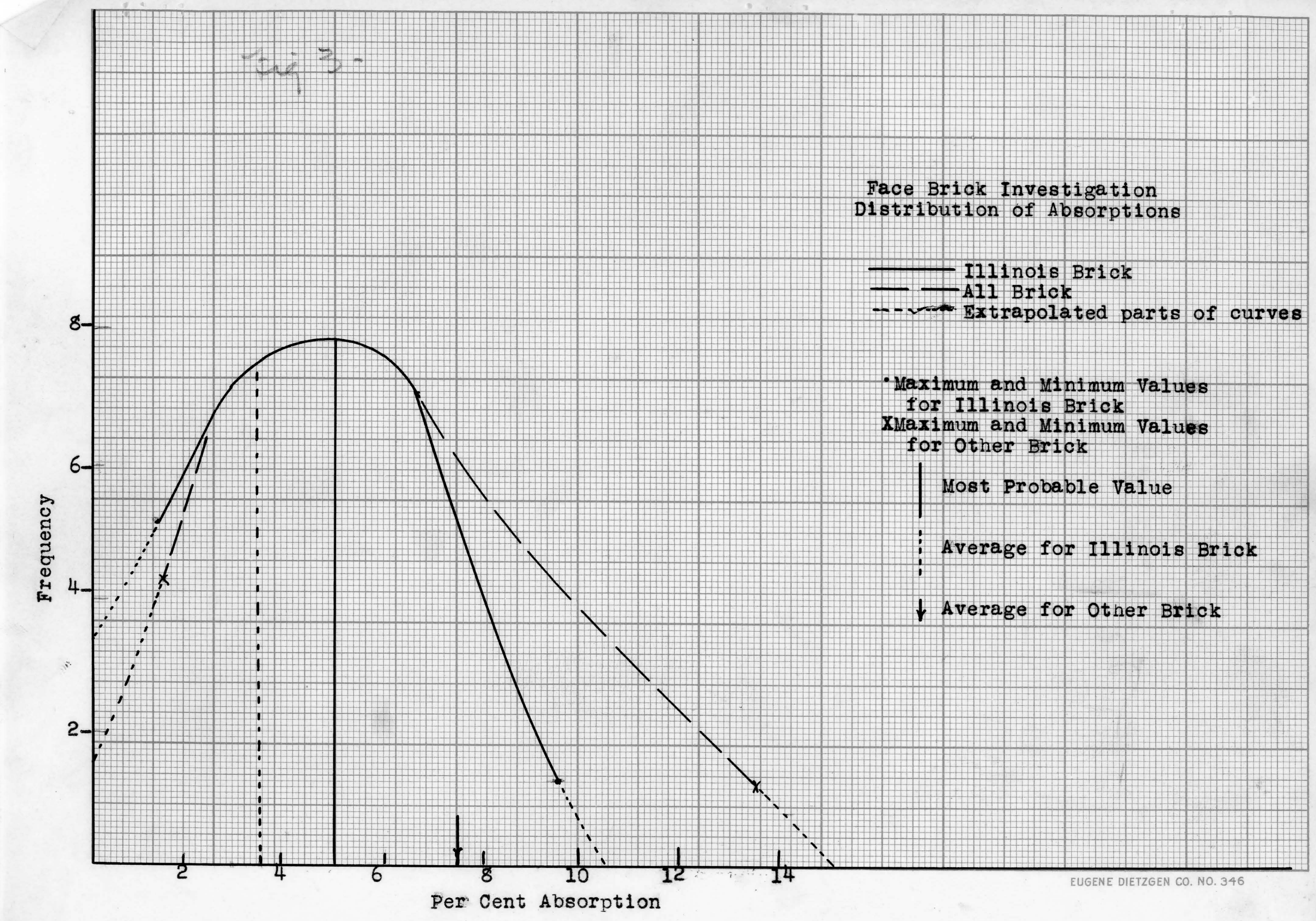


Fig 3 -
Face Brick Investigation
Distribution of Absorptions
Illinois Brick
All Brick
Extrapolated parts of curves
•Maximum and Minimum Values for Illinois Brick
XMaximum and Minimum Values for Other Brick
Most Probable Value
Average for Illinois Brick
Average for Other Brick
Frequency
8
6
4
2
2
4
6
8
10
12
14
Per Cent Absorption
EUGENE DIETZGEN CO. NO. 346

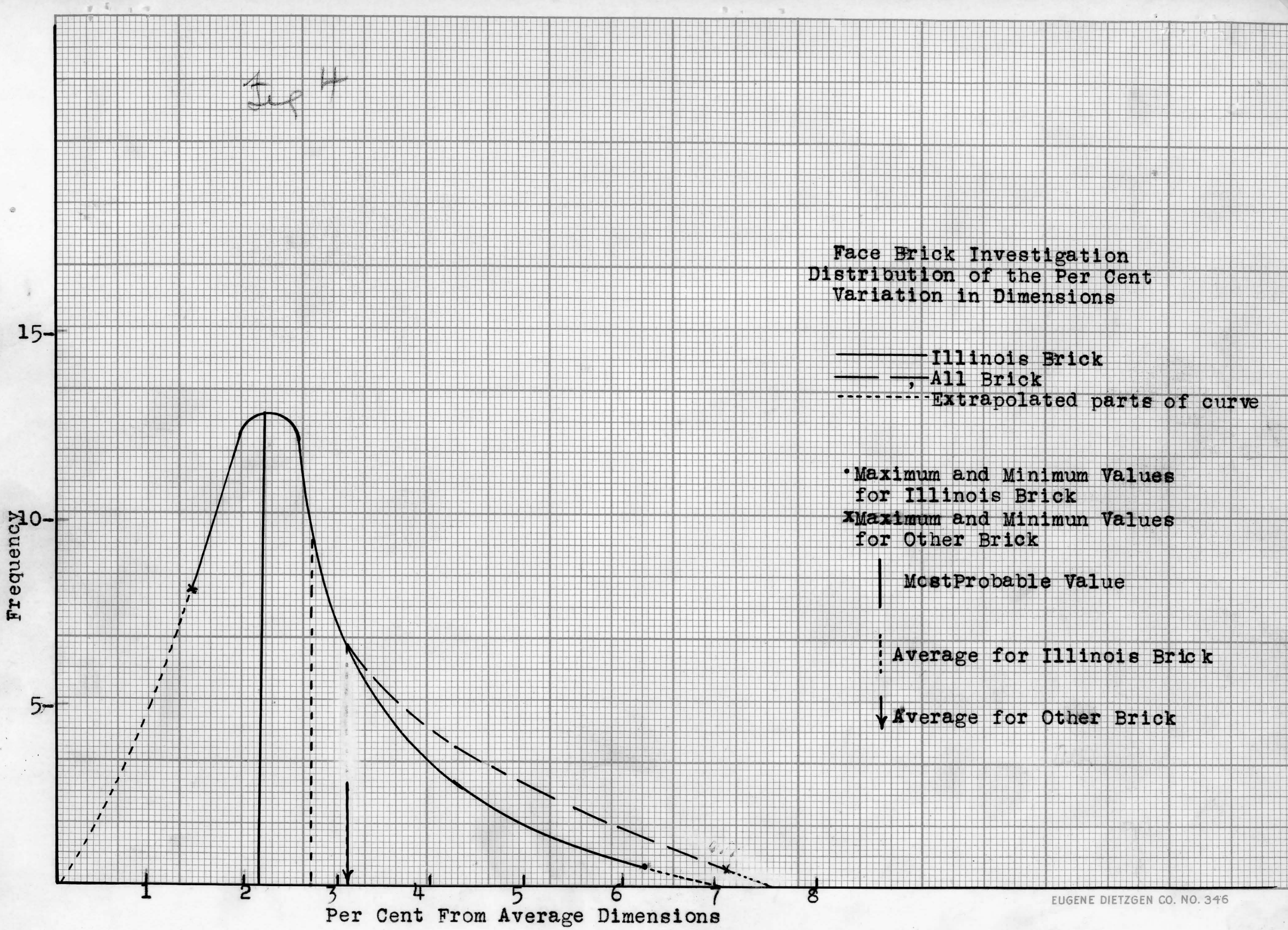


Fig 4
Face Brick Investigation
Distribution of the Per Cent
Variation in Dimensions
Illinois Brick
All Brick
Extrapolated parts of curve
Maximum and Minimum Values
for Illinois Brick
Maximum and Minimun Values
for Other Brick
MostProbable Value
Average for Illinois Brick
Average for Other Brick
Frequency
15
10
5
1
2
3
4
5
6
7
8
Per Cent From Average Dimensions
EUGENE DIETZGEN CO. NO. 346

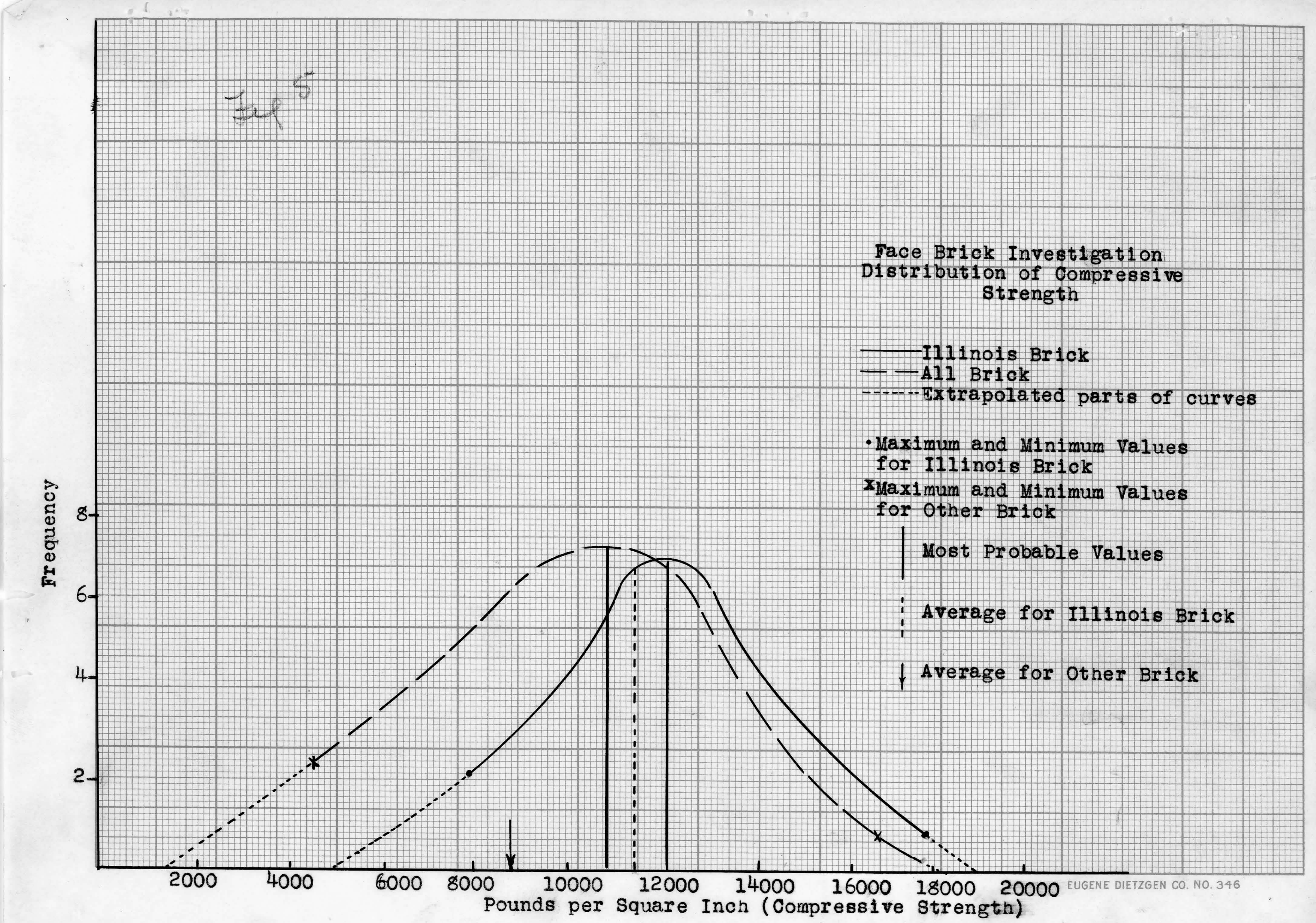


Fig 5
Face Brick Investigation
Distribution of Compressive Strength
Illinois Brick
All Brick
Extrapolated parts of curves
Maximum and Minimum Values for Illinois Brick
Maximum and Minimum Values for Other Brick
Most Probable Values
Average for Illinois Brick
Average for Other Brick
Frequency
8
6
4
2
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Pounds per Square Inch (Compressive Strength)
EUGENE DIETZGEN CO. NO. 346

Face brick studies - corrections

No scale is given for frequency on any charts.

On the graph "Variations of dimension" it is not shown what the solid and dashed lines respectively represent.

It is not evident how the graph "Variations in dimension" relates to any item given in "Summary of data."

The data given on warpage in "Summary of data" appears to be discordant with the data presented in the graph titled "Distribution of maximum warpage."

The heading "Description of tests" at the top of page 2 should be made continuous with the last paragraph on page 1, as they deal with the same subject.

The heading "Description of tests" should be inserted as a center heading just before the last paragraph on page 1.

Page 3, second paragraph. This paragraph should be started with the word "Absorption -" to denote the nature of the test.

Page 3, last paragraph. This paragraph should be started with the words "Bulk density -" to denote the nature of the test.

Page 5, paragraph 2 - the word "Results" should be a center heading.

Page 26. The heading "Face brick investigations" should be deleted.

DER

Comments on "Face Brick Studies"

p. 1. - Should there not be a footnote reference to the publications mentioned in lines 7 and 11.

✓ p. 2. - Line 15, starting "warpage" should be a new paragraph.

✓ p. 4. - First paragraph on p. 4 should begin with the title "Brinell Hardness" which has been crossed off.

p. 5. - Would suggest the section titled "Results" be changed somewhat as follows and that the statement regarding the limitations of the Brinell hardness method be transferred to the discussion of that test on p. 4:

Results

✓ The accompanying table and charts summarize the results thus far obtained relating to the standard brands of face brick manufactures in the State as a unit. The tests show the decided superiority of Illinois brick as a group in nearly all physical properties. The limited amount of data for comparison show an apparent inferiority of southern and western brick compared to mid-western brick.

p. 6. - Delete "Face brick investigations" and give a table number.

p. 3. - It is not clear how the rate of absorption is calculated. This involves (1) time, and (2) amount of water absorbed.

Chart "variations in dimensions" is missing. Presumably it has been deleted.

JEL
6/28/35

A Progress Report on the Use of Peat with Clay in the Production of Porous Brick

By C. W. Parmelee
Head, Department of Ceramic Engineering,
University of Illinois, Urbana

The purpose of this investigation, undertaken jointly by the Department of Ceramic ~~Department~~ Engineering of the University of Illinois and the Illinois State Geological Survey, was to attempt the production of highly porous brick suitable for insulation purposes. The introduction of organic material such as peat, straw, sawdust, coal, etc., in clay mixtures is an old practice which has been successfully employed at various times in the production of special products.

The raw materials used were peat obtained from near Elgin, Illinois; ~~fire clay from the~~ underclay from the Ottawa district ~~Chicago Retort and Firebrick Company of Ottawa~~; till or surface clay from the ~~pit of the National Brick Company at Deerfield~~ vicinity of Deerfield; shale from the ~~Herrick Clay Manufacturing Company~~ of Ottawa. Some tests have been made with the last named material but less completely so because of difficulties encountered in burning.

The peat and clays were mixed in varying proportions and the mass brought to a workable condition with the addition of water. Test pieces were formed by extrusion through dies.

These test pieces were burned at several different temperatures according to the nature of the clay. Special care was needed in order to accomplish burning successfully without damage by bloating. Using the experience gained with the small test pieces, full size bricks were made in the plastic condition by hand molding and repressing. These were burned to cone 01 and the following results were obtained:

8 pt

Percentage	Absorption (per cent)	Apparent specific gravity
Till - 100%	10.7%	1.70
90 till + 10% peat	30.9	1.41
80 " + 20% "	42.2	1.19
70 " + 30% "	57.8	0.98
Fireclay 100%	12.3	2.05
90% fireclay 10% peat	18.8	1.68
80 " 20% "	31.1	1.35
70 " 30% "	50.1	0.997

The brick were of good color and appearance. The very high absorptions and low specific gravities attained as well as the excellent color and appearance are very favorable indications of the possibility of producing brick of good insulating properties.

~~What is the strength of the bricks? - not determined~~

Friday, May 17

COAL RESEARCH

Elec. Eng. Auditorium

1. Fuels. - Developments in the Technology of Illinois Fuel.
   Samuel R. Lewis, Consluting Mech. Eng., Chicago.

2. Production and Utilization of Coal.
   G. H. Cady, Senior Geol. and Head of Coal Sect., Ill. Geol. Surv.
   F. H. Reed, Chief Chemist, Ill. State Geol. Survey.

3. Chemical Engineering Problems Relating to the Mineral Resources of the State.
   D. B. Keyes, Head of Chem. Eng. Div., University of Illinois.

4. Organic and Mineral Components of Coal as Seen under the Microscope.
   W. S. McCabe and C. G. Ball, Ill. State Geol. Survey. Missing.

5. Separability of Coal Components in Coal Fines.
   L. C. McCabe, Ill. State Geol. Survey. Missing

6. Coking and Gas-Making Properties of Illinois Coals.
   Gilbert Thiessen. Missing.

7. Smokeless Briquets Made by Impact Process.
   R. J. Piersol, Ill. State Geol. Survey.

Saturday, May 18

8. Illinois Coal as a Solid Fuel - Possibilities of Improving Its Competitive Position.
   The Economics of Coal Beneficiation, with Special Reference to the Problems of Smaller Operators.
   R. J. Lawry, Contr. Eng., Roberts and Schaefer Co., Chicago.

9. Possibilities of Improving and Extending the Use of Ill. Coal through a Study of its Constituents.
   G. H. Cady, Senior Geol. and Head of the Coal Div. State Geol. Survey.

10. Utilization of Coal Mine Waste.
    C. M. Smith, Res. Assist. Prof. of Mng. Eng., Univ. of Ill.

11. Furthering the Utilization of Ill. Coal Through Proper Equipment Design.
    H. Kreisinger, Res. Eng., Combustion Eng. Co., New York City.

12. Ill. Coal as a Source of Gaseous and Liquid Fuel - Looking to the Not Far Distant Future.
    From the Viewpoint of a Technical Man in Industry.
    M. D. Curran, Pres., Radiant Fuel Corp., St. Louis, Mo., and West Frankfort, Illinois.

13. From the Viewpoint of a Research Coal Chemist.
    Gilbert Thiessen, Assoc. Chem., Ill. State Geol. Survey.

Memorandum

To: Dr. M. M. Leighton

From: F. H. Reed

Date: September 5, 1935

Re: Publication of papers in coal (Mineral Industries Conference)

General comments

Dr. Cady has suggested that these articles should not be published. Before such a decision is reached, I believe it would be well to consult C. J. Sandoe and others in industry in regard to their views. Mr. Sandoe and others expressed themselves to me during the June boat trip as well pleased with the Mineral Industries Conference, and desirous of having copies of the papers, particularly Mr. Kreisinger's. Since this one is already published, it is possible that the abstracts now being distributed will fulfill their needs. I, too, would like to conserve our funds for publication, but if these papers are desired by men prominent in the Illinois coal industry, they should be published.

Detailed comments

Developments in the Technology of Illinois Fuel, by Samuel R. Lewis

p. 4, 2d paragraph, lines 17-20, incl. Sentence requires rewriting.

The Selection and Design of Equipment for Burning Illinois Coal, by Henry Kreisinger

p. 13, lines 1-7, incl. This paragraph should be rewritten in a manner similar to that in the abstract of this article.

Illinois Coal as a Source of Gaseous and Liquid Fuels, by Gilbert Thiessen

p. 14, lines 9-11. I suggest the deletion of this sentence.

The article by Mr. Kreisinger was published in "Combustion" June, 1935.

The article by Prof. Keyes was published in "Chemical Industries," July, 1935.

MML

ILLINOIS STATE GEOLOGICAL SURVEY

Date Stamped AUG. 20

ITEM Papers in COAL (Mineral Industries Conference)

Initials	Date Received	Date Passed On
Please have in mind that these are being published under the auspices of the State Geological Survey and you should therefore look out for points that might be questioned by producers, thus involving the Survey, and that can just as well be avoided. MML		
GHC	8-20	8/-28
FHR	8-28	9-5

Comment in blue pencil

See note inside cover

[D]o not recommend the publication of these papers. The money it would cost had much better be spent in the publication of results of Survey investigations

G.HC.

See notes p. 4, p. 6, p. 9, and Fig. 3.

The paper has been greatly improved.

C. F. Fryling
June 28 '35

See notes p. 4, p. 6, p. 9, and Fig. 3.

The paper has been greatly improved.

C. F. Fryling
June 28 '35

Could some experimental points be included?
I fear that the diagram gives a false impression of the accuracy of the determinations

C. F. Fryling

MINERAL INDUSTRIES CONFERENCE

		No. pp	No. illus
I			
1.	Leighton	13	10?
2. ✓	Lewis	14	
3. ✓	Steinhoff	12	
4. ✓	Rockwood	11	
5. ✓	Reed	13	
6. ✓	Parmelee & Lamar	8	
7. ✓	Keyes	11	
II			
8. ✓	Lawry & Roberts	11	
9. ✓	Cady	18	19?
10. ✓	Smith	4	1z ✓
11. ✓	Kreisinger	13	9z and 1c ✓
12.	Curran	12	
13. ✓	Thiessen	19	~~11~~ 9z - 2c ✓
III			
14. ✓	Lescher	13	
15. ✓	Filippi	4	
16. ✓	Luse	12	
17. ✓	Grim	10	6 z
18. ✓	Parmelee (Brick)	6	5 z
19. ✓	Parmelee (Aggregate)	2	
IV			
20.	Lamar	16	13 c
21.	Fryling and Wnite	17	
22.	Coghill (printed)		
23.	Goldbeck	18	
24.	Miller & Breerwood (printed)		
25.	Parmelee (Novaculite)	10	5 z
26.	Trainor	10	

Coal

Clay

Rock

Pass on to next if out of town or report to EJ.

ILLINOIS STATE GEOLOGICAL SURVEY

Date Stamped Aug. 3, 1935

ITEM **MS ILLINOIS MINERAL INDUSTRY IN 1934 - Voskuil**

Initials	Date Received	Date Passed On
GHC coal only	Aug 3 1935	Aug 3 1935
AHB oil only	Aug 6, 1935	Aug 6, 1935
FHR	aug 6- 1935	aug 9-1935
JEL	8-9-35	8/10/35
MMf	8/12/35 (vacation)	8-22-35
WHV	8-23-35	8/23/35

Substituted page 1

DEVELOPMENTS IN THE TECHNOLOGY OF ILLINOIS FUEL

By Samuel R. Lewis

The outstanding development in the preparation of Illinois coal seems to be in the improvements by the producers and dealers.

~~Thus~~ producers are sending the coal through a jet of air to remove all the loose dust, ~~are~~ washing it with water to remove all soluble material, and ~~are~~ coating it with a film of distillate to keep it from powdering.

Illinois producers of coal, under the present economic necessity, apparently have decided to deliver better fuel and not to leave most of the task of protecting an Illinois industry, as in the past, to the man who builds equipment to facilitate the burning, that is to say, to the builder of the stoker or furnace.

This delivery of better fuel involves crushing and screening and sorting so as to remove incombustibles and dust. Most of the dust, ~~removed at the mine by air jets,~~ now ~~is~~ being thrown away, ~~but this dust~~ probably will become a profitable by-product, just as the pyrites now picked from the sorting tables ~~are~~ is being absorbed by the chemical industry, whereas formerly ~~they were~~ it was wasted.

Washing coal with water removes not only the dust, but carries away also the particles of mineral heavier than coal. Washing may become nearly universal, for tremendous investments have been made to facilitate it at some mines.

I doubt the validity of the claim - as to "fusing" of oil treated coal -

C.H.

Next paragraph reads like propaganda -

Recent large scale tests have shown that in actual practice ~~have shown that the~~ water washing gave an improvement ~~of 15%~~ in the burning efficiency of the coal of 15 per cent. This improvement is in part accounted for by a 7 per cent increase in the heat value of the fuel per unit of cost, leaving 8 per cent as the net improvement ~~, this being made up for an increase of 7% in the Btu purchased per dollar of fuel cost and left a net increase of 8%~~ in the amount of steam produced per unit of ~~dollar of fuel~~ cost, because of the greater efficiency with which the fuel could be burned.

~~Due to processing with oil the~~ The particles of coal that has been processed with oil ~~as they burn~~ seem to burn to coke without fusing together into comparatively large masses, as ~~xxxx~~ do ~~es~~ some kinds of untreated coal. The treated coal does not hold as much occluded water and so does not cling to the sides of stoker hoppers or arch over above the ram or the screw, one of the weaknesses of wet, untreated coal having a considerable proportion of ultra fine particles when used in underfeed stokers.

~~The~~ The processing of ~~processed~~ coals also appears to prevent the formation of ~~reduce the tendency to permit~~ blow holes through the fuel bed when ~~of~~ large stokers are used. Since such blow holes, with the extremely high temperatures in the fuel around their edges, are responsible for excessive ash fusion and stoker maintenance, the processed fuel brings about a considerable improvement.

One large producer predicts that due to the super processing of Illinois coal, the present standard method of coal purchasing by large consumers ~~xxxxxxxxxx~~ on a B.t.u. ~~Btu~~ basis will be modified to allow properly for the increased burning efficiency.

The alternating side-firing manual method of burning Illinois bituminous coal has met with considerable favor. ~~I described this scheme here last year.~~ It involves the maintaining of

Why not call this "oil treatment" instead of "super-processing"?

The recently developed oil-coating technique bids fair to supersede the air-de-dusting process, and far surpasses the older calcium chloride process which may become obsolete. The warmed oil, is blown through the coal at high pressure forming a mist, sometimes as an emulsion with water, and the oil coating easily is applied by the dealer at his local yard or dock as well as by the producer at the mine tipple.

The oil must possess ~~very~~ definite characteristics; It must be of low surface-tension, so as to spread all around every particle of coal and so as to attract and hold and cover each dust particle. It must not be odorous and must not evaporate and disappear or wash off. There must not, of course, be enough oil to cause the larger particles of coal to cohere each to the other, or to impede air distribution.

An instance has been cited in which the dealer added a small amount of oil of cedar to the distillate which was applied to the coal, with the result that the basement to which it was delivered acquired an interesting scent of the North woods.

This super-processing applied to Illinois coal costs ~~around~~ about 10 cents per ton for removing the dust with air, a small amount more per ton for water washing, and from 7 to 13 cents per ton for the oil treatment. A small portable air compressor, a tank of the coating, and an atomizer comprise the dealers' necessary equipment for oil treatment.

Oil processed coal can be thrown into the air, as with a shovel, without any dust appearing and still gives no visible evidence of the oil.

a bed of ashes above the grates and when time for introduction of green fuel arrives this coal is placed in a triangular pile against one side of the furnace in a bed prepared by first havingworked the incandescent fuel into a similar pile against the opposite side of the furnace. Thus there remains in the center of the furnace a deep valley with one hill side red hot ready to ignite the volatiles and with the other hill side carried on ashes and ready to be heated from the top down. As the cooler hill side thus is heated gradually, the volatiles are burned and efficient and smokeless combustion results.

For almostall new large coal burning installations, mechanical feeding of the fuel into the fire, coupled with control of the excess air both above and below the fuel bed is employed. The underfeed forced draft automatic stoker has proved its ability to burn Illinois coal efficiently and smokelessly, in domestic applications as well as in large power plants.

A better understanding of the furnace volume required ~~so that~~ the chemical processes of combustion properly may be carried out is evident almost universally, and there is by long odds a smaller number of unsatisfactory installations being made. Improvements have been made in the distribution of the coal throughout the length of the retort by refinements of the screw in ~~that~~ type of underfeed stoker, and by auxiliary pushers in the ram type of underfeed stoker.

A dead plate behind the retort when the stoker is fed from the boiler front no longer is necessary, due to improved distribution throughout the length of the retort, and as a result of the omission of a dead plate there is much less difficulty with recent underfeed models, in removing clinkers.

Experience has demonstrated to manufacturers and salesmen of the smaller sized stokers that despite expense and trouble, old hand-fired boilers must have adequate furnace volume, and it has become a much easier task to induce owners either to excavate for deeper pits or to elevate the boilers.

In a great many instances high pressure salesmen have made such extravagant claims for increased output due to stokers that but one stoker has been installed in one of the boilers where there were two boilers.

While the single stoker usually could be forced to burn partially, enough coal to fulfill the demand, and on the fireman, the results, as to smoke and as to xclinkerxand wear and tear on the boiler, to say nothing of waste of heat up the chimney, were deplorable even though perhaps a reduced total fuel input compared with that for hand firing, was achieved. It is obvious to the initiated that a self contained firebox boiler, for instance, so overloaded that the doors at the back end are red hot could not be absorbing anything like the proportion of heat which it is capable of salvaging.

There is a definite tendency to correct this too enthusiastic request from boilers used for heating, by installing additional stokers, with the result almost always demonstrated that the boiler efficiency increases remarkably, the paint remains on the back end doors, and that the insulation, if any, on the breeching no longer is being cooked.

It follows, of course, that with a reduced heat release there is a reduced demand for furnace volume and an improvement in the escape of free carbon scattered around the neighborhood. There is noticed, also, a reduced labor demand from the fireman.

There are a few heating installations in which the boilers are over-size, but such cases are not common. As a general thing the boilers for heating systems are selected intelligently on the basis of their highest efficiency at the load demand, and when these boilers are stimulated far beyond their efficient point by forcing the release of excess heat the boilers fail to salvage a good part of the heat and there must be an eventual unhappy reaction on all parts concerned.

Many years ago a very simple type of coal stoker which batted the coal out above the fire bed like a spray, without introducing too much air, and which thus spread the pre-crushed small lumps evenly in such amounts as did not too rapidly or suddenly reduce the furnace temperature, was well known.

There was some sense to this idea, though it suffered an eclipse for some time. It was radically different in principle from the progressive firing of the traveling grate or from the gradual downward heating of the coal in an underfeed furnace. This ancient scheme has had a recent revival, almost parallel with the recrudescence of the equally ancient underfeed idea, popularized by heavy advertising. The power demand for the spreader type of stoker is small and the mechanism is simple.

~~A characteristic of~~ this type of stoker ~~is that~~ the fire bed must be exceedingly thin, since when the fire is thick clinkers ~~manifest themselves~~. The exceedingly high temperatures obtained lead to a considerable deposit of slag on the furnace walls and even in the boiler itself. Spreader type stokers are far better adapted to continuous steady moderate loads than to intermitten operation or to rapid fluctuations in demand.

Many of the smaller particles of coal may be burned in suspension in spreader type stokers and it may be that the revival of this type was suggested by the great success of pulverized coal burning apparatus.

Pulverized coal has proved satisfactory and efficient, and the fly ash problem is never as serious as proponents of other methods of burning coal would have their friends believe.

There has been ~~observed~~ a tendency to substitute plastic refractory material for the conventional standard firebrick shapes in ~~gkx~~ high-temperature furnaces, even though the basic material may be essentially the same. This may be due to the difficulties in securing the desired quality of workmanship in laying the firebrick and in inability to fuse the fire clay to the brick so as to present an unbroken barrier to the heat.

There is an interesting situation in Chicago concerning distribution of coal in the metropolitan district. The Illinois Tunnel Company during many years delivered coal to most of the large plants in hotels and office buildings, being equipped with efficient machinery for receipt of the coal from standard gauge cars above the surface, and with dumps and conveyors in the sub-basements of the buildings. The tunnel thus relieved the streets of a tremendous amount of heavy traffic.

During recent years, however, the coal distributors, equipped as they must be with motor trucks for delivery of coal to outlying districts and to buildings which do not have tunnel service, have taken the coal traffic almost all away from the tunnel. They are able to do this with the heavy duty modern self-dumping trucks now available and the dealers probably ~~achieve~~ derive more profit from the transportation ~~increment in the money which they collect for~~ of coal than they can achieve in [the narrow range of possible profit in the value] of the

the sale

commodity itself.

The Illinois Tunnel, therefore, has its traffic limited to hauling ashes and to an insignificant volume of package freight. ~~In some buildings the tunnel ix graciously is allowed to remove the rubbish along with the ashes.~~

Recently there has appeared propaganda in favor of utilizing the Illinois tunnel for central station heating, filling it with high pressure steam pipes from a ~~very~~ large, efficient and costly steam plant to be built near one corner of the metropolitan district.

Since there are several modern boiler plants ~~in loop buildings~~ now standing idle because of the block service system of the Illinois Maintenance Company, this new super power plant may be delayed in materializing.

The Illinois Maintenance Company contracts with building owners to furnish owners the steam at less cost or trouble than that for which the owner could make his own steam, and by improved efficiency in operating key plants often holds in reserve, unfired, thousands of horsepower in less favorable buildings. It appears reasonable to argue that all things considered these idle boilers and chimneys ought to be put to work, using the tunnel for intercommunication if necessary, before pouring millions of dollars into a new plant so close to the loop as practically to be in it.

The smaller sized domestic stokers of the worm-feed type can now be provided with arrangements for receiving the coal directly from the delivery truck in lots of from one to four tons at a time. The coal can be delivered automatically by means of an extended worm, as needed, directly into the heater. These extended conveyors can be furnished in any length up to 28 feet, and they do away entirely with any manual handling of the coal within the house.

In many cases it is practicable to have the conveyor enter the firepot from the side or rear, leaving the stoking and ash doors freely accessible. This arrangement is a great improvement over the earlier installations feeding from the front, with a short conveyor.

with which the handling of ashes and clinker was difficult.

An appreciated advantage of domestic stokers using bituminous coal over the usual oil or gas burning equipment ~~xixxxx~~ lies in the heat storage characteristics of a coal fire, which permits long intervals of reduced heat production ~~due to~~ by banking the fire, so that the heater and pipes and radiators are not subjected to sudden intense heat reception as when the oil burner starts after stopping, or as when the gas burning rate suddenly is increased in response to a thermostat. Serious expansion and contraction strains, difficulties with air venting and with condensation return thus are reduced greatly when the fuel is of the solid type.

Considering fuel oil, there seem to be fewer illusions than there were formerly, and the most nearly prosperous oil burner manufacturers are those with mechanisms for handling heavy oil such as the type which requires heated tanks and comparatively high temperature preheating close to the burner. As much as one third the price per gallon of the oil thus can be saved.

There is manifest a reduction in the number of new and not thoroughly developed oil burners which for a time ~~did~~ beset the unwary. The intricacies of secondary air and excess draft and adequate furnace volume are better understood, and many of the early installations which smoked and popped back and leaked oil on the floor and which perfumed the basements have been corrected.

In modern efficient plants the routine minimum automatic control comprises dampers for the secondary air, valves for the oil flow, barometric draft control at the chimney, arrangements to stop and shut off everything if the water line becomes unduly low or if the flame fails, and antisyphon devices in case the oil tank is higher than the boiler room floor.

Changes from light oil to heavier grades of oil in many cases have made sufficient savings to justify scrapping of earlier and far from outworn equipment. There has been such progress that heavy oil in some cases indeed, is operating large heating plants without smoke at less cost for fuel than was required with the hand fired coal formerly used.

This statement of course should be qualified by mentioning other cases in which, as in one large hotel, the saving by installing automatic stokers with coal over the cost of oil formerly burned ~~did pay~~ paid for the stokers in less than one year.

A comparatively new arrangement for small heaters burning oil consists of a water tank having a cylindrical interior furnace, into which the oil flame is introduced. The water occupies the annular space between the furnace and the tank drum. The oil flame is controlled thermostatically. It is practicable to use a near-by fan-equipped convector with this device for heating a room or a garage or a shop in a very economical and simple manner.

Anyone who has studied the performance of modern power steam boilers knows that to a very great measure the high efficiency of such boilers is due to the carefully arranged and thorough circulation of the water against and away from the heat absorbing surfaces.

All of the conventional cast iron sectional boilers ignore this studied and refined circulation except within each individual section, since there are only two connecting nipples, one above the water line and one below the water line. With only one small connection, or down at the bottom where the water is comparatively cold, there is a very limited circulation of water from section to section. The upper connecting nipple, above the water line in the steam space, is of no value in promoting water circulation. If a third connecting nipple or its equivalent were to be placed close to and below the water line, then water could circulate rapidly from the sections receiving the most heat to and from the sections which have cooler surfaces, with an immediate improvement in efficiency of heat absorption and in reduction of the priming and foaming to which cast iron boilers are so subject. Such an improvement would be reflected favorably in the fuel consumption.

There have appeared in the market very recently sectional cast iron boilers with connections from section to section such as allow this favorable water circulation, some by a third nipple, others by increasing the diameter of the upper nipple so that it is half submerged.

~~Concerning gas,~~ Most of the gas we know in Illinois is piped in from outside the State or is of the by-product variety.

The wonderful convenience and cleanliness of gas for residence heating cannot be denied. The savings by gas for space heating in Chicago have been very effectively advertised. There are, of course, isolated instances in which gas can be used in conversion burners at a fuel cost approaching or even eclipsing the cost of hand fired coal. My own home in Chicago burns coal in a round cast iron boiler, with hand firing. The ~~13~~ thirteen-room house has forced circulation hot water heating. The coal cost per season is about $160.00. A recent inspection was made and an estimate was developed for conversion gas heating by the Public Service Corporation. The fuel cost per year with gas would be more than double the cost for coal.

With hot water heating, ~~while~~ although there is a coal and ash dust problem in the basement there has never been any particular manifestation of dust in the upper stories of my house due to the fuel since the major housecleaning problem appears to be from dust which enters via the windows, which for the sleeping rooms are open all night every night.

A serious situation exists with efficient gas burning heaters, which is present only to a slighter extent with oil burning heaters, in that the products of combustion are heavily loaded with water vapor. This condenses in the chimney, especially in the parts of the chimney above the warmed ~~parts~~ walls of the house, and impregnates any porous material such as unlined masonry, with moisture. If the plant operates intermittently or in such manner that freezing of this moisture can occur, nature tears the chimney to pieces with astonishing rapidity.

Based on this experience it is wise always to have a non-corrosive metal lining for all chimneys which serve gas burning apparatus. In my own home, in which the relative humidity is rather high in winter, there are several old chimneys which serve fire places, and which are not metal lined. The mortar and sand absorbs moisture from the air passing up these chimneys left open for ventilating purposes, condenses and freezes, and after every thaw the sand and mortar manifests itself at the bottom in surprisingly large quantities.

This phenomenon has only an indirect application to technology of fuels, but is very directly a sign pointing to tighter and better chimney construction and to closely fitted joints between sections of flue lining, and to something better than ordinary sand-lime mortar to fill these joints. A cement which resists both water penetration and moderately high temperature seems to be needed.

I believe the summary already prepared for distribution is adequate

swc

Slides #A1499
A 1500

Mrs. Sweeney

THE VIEW POINT OF SCIENCE IN THE PRODUCTION AND UTILIZATION OF COAL*

By Frank H. Reed

As far as science is concerned, problems in the production and utilization of coal resolve themselves into the questions: Can research do anything to aid in the production and utilization of coal? And if so, what direction should the work take?

Before answering these questions, it is necessary that we define our understanding of research, get an idea of what it has done in this and other fields, learn how this has been accomplished, take inventory of our present state of knowledge in regard to the production and utilization of coal, and then see what course is suggested.

Research is of two kinds--scientific and applied. Scientific research is the orderly method by which the physical and chemical laws of the universe are learned. Industrially, research is the unbiased method of applying fundamental scientific information to the solution of purely utilitarian problems. In the words of the president of one of our largest research laboratories, applied research "must of necessity concern itself essentially in cultivating for profit those regions discovered and mapped out by the academic experiments in the fields of fundamental sciences." Applied research either creates a new product or enhances the value of the old one.

---

* Presented at the Third Annual Mineral Industries Conference of Illinois at Urbana on May 17, 1935.

That industrial research pays is amply demonstrated by the experience of those organizations which have invested in it intelligently. However, it must be borne in mind that even as an army crawls on its stomach and can proceed no faster than its food supply can be obtained and transported, so the application of industrial research crawls on the foundation of scientific facts accumulated by fundamental research and proceeds no faster than these scientific facts can be discovered and applied. While considering industrial research, one must remember that the success of any program of procedure is dependent entirely upon the ability of the executive personnel to select the right projects and research workers, provide adequate facilities and supervision, prosecute each project to a definite conclusion, coordinate the efforts of the various groups, and present the accumulated information in a manner intelligible to those responsible for its commercial acceptance and exploitation.

A word of caution is necessary in regard to research. It cannot be operated on the basis of a slot machine in which a coin is deposited, a lever pressed, and a piece of cake with the desired flavor of frosting is delivered to the customer. As one research director points out, direction from a corporation executive to a research worker must come from an intelligent and sympathetic interest in the problem assigned. He cannot expect satisfactory results if he merely sets up a rocky cave, so to speak, and says to his researcher, (quoting this chemical director), "crawl in there and think, and when you have solved the problems which you ought to know exist in my business (but which I have neither the time nor the inclination to outline for you) come out and tell me about it. In the meantime, I don't want to be bothered about how you are getting on, and--whatever you do in there--be quick about it."

Let us now consider the tremendous strides that have been made since the beginning of the present century in the use of raw coal as a fuel. This progress is well illustrated in the production of electric power from coal. In 1902 the average consumption of coal per kilowatt-hour was about 6.6 pounds; by 1917 this figure had been reduced to 3.3 pounds; by 1927 the figure was reduced to 1.84 pounds; and in 1934 we consumed an average of only 1.45 pounds of coal to produce 1 kilowatt-hour of electrical power. It is interesting ~~now~~ to ~~study~~ note the overall efficiency which the above figures represent on the established basis that 1 kilowatt-hour is equivalent to 3415 B.t.u.'s. If we assume that the coal consumed had an average value of 13500 B.t.u. per pound, then the overall efficiency becomes as shown in Table 1. It has more than quadrupled in a little over 30 years, and we have reason to expect that ~~it will still be~~ the present figure will be increased by 50%.

TABLE NO. I.

Production of Electrical Power from Coal 1/

Year	Pounds of coal consumed per kilowatt-hour	Efficiency 2/ in %
1902	6.6	3.8
1917	3.3	7.6
1927	1.86	13.6
1934	1.45	17.4
?	1.00	25.3

1/ Figures taken from reports by U. S. Bureau of Mines.

2/ Assuming 13500 B.t.u./pound of coal; using 3415 B.t.u.'s as equivalent to 1 kilowatt-hour,

e.g. $\frac{3415}{13450} = 25.3\%$.

This shows considerable progress over the last 30 years and also indicates that we are approaching a limit to the amount of electrical energy which may be produced from a pound of coal. Although certain plants have produced electrical power by consuming slightly less than 1 pound of coal per kilowatt-hour, it is not probable that the average will be lower than this figure in the near future.

While reviewing the progress that has been made in the production of electrical energy from coal, we cannot keep from asking what has made this progress possible, how ~~it was~~ was it accomplished, and what is suggested therefore in the solution of other coal utilization problems.

First of all it is highly significant that this development has been simultaneous with as notable advances in practically all fields of applied science. However, the application of scientific information to the solution of industrial problems cannot proceed faster than the accumulation of the scientific information upon which the applications are based. In fact, it is well known that there is a necessary lag between the establishment of scientific facts and their application to industrial enterprises. As industrialists and scientists have become better acquainted, and learned to appreciate the value of each to the other, this lag has become less and less until in many fields the industrialist is literally pushing the scientist for basic information upon which advances in industrial technique may be made. Probably one of the best illustrations of close cooperation between science and industry is that of the development of the synthetic organic chemical industry in this country. It is one of our most technical industries. Before the World War it was practically unknown; today, its annual sales exceed 100 million dollars. In order to reduce to a minimum the time lag between the discovery of basic scientific information and its industrial application, the abler companies in this industry maintain their own laboratories and scientific research workers, and some consider it a good investment to appropriate as much as five per cent of their gross sales to the maintenance of their scientific research activities.

Less than seventy years ago, there were no aniline dyes or synthetic organic coloring materials or synthesized fibers; today we can command any color of the rainbow on either natural or so-called artificial fibers, and obtain it at a price within reach of all. The chief instrument in this great change has been research. First, we experienced haphazard type of experimentation, and later a more scientific type of planned research directed toward the accumulation of fundamental information upon which to build our processes and industries.

For the promotion of a closer relationship between pure science and industry we owe much to Dr. Robert Kennedy Duncan. In 1906, while in Europe gathering material for chemical studies, he conceived the idea of the Industrial Fellowship Plan whereby either large or small manufacturers could receive the benefits of industrial research on specific problems, under adequate scientific guidance, at a nominal cost without assuming the responsibilities of manning and equipping a research laboratory. Dr. Duncan established his first industrial fellowship at the University of Kansas in 1907. In 1911 he was asked to establish his system in a department of industrial research at the University of Pittsburgh. The practical success of this experiment resulted in the establishement of the Mellon Institute of Industrial Research in 1913. The remarkable success and contributions of Mellon Institute in the solution of industrial scientific problems is too well known to need amplification here. This industrial fellowship plan has spread to most of our qualified institutions of higher learning and has contributed largely to a better and closer relationship between science and industry.

The last quarter century has also seen an increase in the establishment of federal and state laboratories to aid private industry by accumulating fundamental scientific data and aiding in the solution of problems of national and state importance. Also, cooperation within various industries has resulted in the formation of many trade associations for the purpose of financially sponsoring industrial research for the solution of problems peculiar to the particular industry. A well known example of such a trade association is the American Gas Association, which has spent as much as $200,000 in a single year on fundamental research, development of new uses for gas, overcoming difficulties, and technical service to customers. Within the last few months, Bituminous Research Incorporated has been organized to attack certain phases of research on bituminous coals.

In the United States today, 30,000 scientists are employed by American industry, and 1600 research laboratories are contributing to the advancement of science in satisfying our human needs. Is it, then, any wonder that during the past quarter of a century there has been a demand for and there has been produced more mineral products than in all previous world history?

In taking inventory of our present state of knowledge in regard to coal, we wish, first, to call attention to the fact that coal has been produced and used principally as a source of fuel. Due to the extensive and widely scattered deposits of coal throughout the world and to their ready availability, coal has secured and maintained first place as a source of energy for heat and power, which place it will probably hold for centuries to come. It seems highly probable, with our present limited information, that coal's chief use will continue to be as a fuel, either in the raw state as a lump or powdered fuel or as a raw material to produce coke, briquettes, and liquid or gaseous fuels, and certain by-products.

In Illinois the location, thickness, quantity, and approximate quality of the various coal beds is fairly well known. In fact, the quality of the coal is so well recognized that the thick seam of Franklin County has received so much attention that it is due for early extinction, leaving available the thinner coals of the State. The coals have been chemically analyzed and duly classified in accordance with the latest scheme of classification by rank and grade, now being used by the code authorities. Yet the fact remains that considerable foreign coal is being imported into Illinois, where the largest coal reserves in the country are available. Illinois coal also suffers from the competition of natural gas and oil. That this outside competition is actual and serious needs no elaboration. However, what can be done about it? To the scientist there is only one answer to this question, and that is by research, first obtaining the basic fundamental data and then finding its practical application.

In this discussion we are purposely omitting such items as wages, freight rates, etc., because these may not be so relevant after some researches are completed.

Now, instead of talking in generalities, let us consider specific cases where more information will lead to constructive suggestions and eventual solution of some of our problems.

Coal is frequently considered and treated as a homogeneous substance. We know that this is not literally true and that coal is a very complex and heterogeneous mixture of many substances. In the laboratory we have been able to separate coals into four groups based upon physical ~~appearance~~ properties. These four groups have been designated as (1) Vitrain, recognized on account of its vitreous lustre; (2) Clarain or bright coal; (3) Durain or dull coal, commonly called splint coal; and (4) Fusain or mineral charcoal. Fusain is largely responsible for the sooty smudge which makes bituminous coal so dirty to handle. Certain preparation plants are now removing about 85 per cent of the fusain content of the coal by simple dedusting processes, due, of course, to the friable nature of fusain and its accumulation in the finer sizes. Figure 2 shows the distribution, ash and specific gravity of the physical components of one of our coals. Note that vitrain and clarain have a low specific gravity--1.30 and 1.35 respectively--and a low ash content, 1.5 and 4.6 respectively. The mineral matter is concentrated in the higher gravity durain and fusain. Note also that vitrain and clarain comprise 82 per cent of the total coal.

TABLE NO. II.

Banded Ingredients
Washington County, Illinois, Coal

	Vitrain	Clarain	Durain	Fusain
Distribution in %	13.	69.	15.	3.
Ash in %	1.5	4.6	31.5	17.5
Specific gravity	1.3	1.35	1.59	1.62

We are immediately led to ask if there is a possibility of commercially separating the light 82 per cent from the heavy 18 per cent, and obtaining a coal having an ash content of around 3 to 5 per cent and being practically free from the dirty fusain. Would not such a product have considerable sales appeal in meeting the competition of coals outside of the State? Another question: If we separate the vitrain and clarain and obtain a coal producing from 3 to 5 per cent of ash, have we largely eliminated the troublesome clinkering problem? Again--would such a product be of premium value as a source for powdered fuel, thereby reducing the amount of fly ash? It is evident that such questions would never occur to us unless the fundamental scientific information in regard to the physical components of coal were called to our attention. To answer these and other similar questions, it is necessary that we obtain basic information in regard to physical and chemical properties, burning characteristics, etc., for each of the banded constituents. This fundamental information can then be applied to the solution of problems in design of equipment for mechanical beneficiation, combustion, etc.

The coal shown in Table 2 was purposely chosen because it is one of the few in Illinois containing appreciable quantities of durain or splint coal. Most Illinois coals do not contain much splint coal, and the vitrain plus clarain content would be higher than the 82 per cent shown, ranging upward to 96 per cent.

One of the nuisances in the burning of high volatile bituminous coals is the production of large quantities of smoke. What do we know about the chemistry of combustion of solid particles of fuel under the conditions existing in fuel beds, either in our industrial plants or domestic furnaces? It appears to us that fundamental information on this point is lacking. If we had this information we might get some new ideas which would lead to a change in the design of our combustion chambers. I wonder if you would feel safe in making the statement that it is impossible to burn in a domestic furnace a properly prepared high volatile Illinois coal without the smoke nuisance? When we purchase oil or gas for domestic heating, we are required to install equipment especially designed for the purpose, and are furnished directions for its suitable operation. If auxiliary air, special drafts, an electric blower, and specially designed combustion chambers are necessary for burning oil and gas, does it not suggest that some combination of these could be found which would give our properly prepared coal a chance to compete as a clean, desirable, and economical fuel? It certainly has no chance today when it is usually burned in a cracked iron pot which is leaky at every joint and receives a minimum of attention from all concerned.

Illinois coal may also be marketed as a clean domestic fuel in the form of coke. Probably the greatest contribution to the coking of Illinois coal was made by the late Professor Parr. Although his process is not in actual use, the only low temperature coking process in commercial use in the United States today--the Wisner process--is similar in principle to ~~the~~ Parr's ~~process~~ in that it is a two-stage process in which the coal is preheated before coking. Mention should here be made of the Knowles ovens, operated by the Radiant Fuel Corporation at West Frankfort, which have been producing domestic coke since December, 1933. In the production of coke by any process there is a question of the by-products formed. One of the problems is to remove the hydrocarbons from the hot oven as quickly as possible to prevent cracking of the hydrocarbons. So we ask the question as to whether or not there is an opportunity to improve the design of coke ovens for this particular purpose. Incidentally, the vertical coke ovens were first designed in this country for Eastern coals, which present less difficulty in coking than do the high volatile bituminous coals of Illinois. The Knowles ovens were originally designed for coking petroleum. Both types of ovens have been used in an effort to adapt Illinois coals to them. Is it not possible that better results would be obtained if a coke oven were designed to adapt itself to Illinois coals? May not the separation and scrutiny of the physical components have some bearing on this matter also?

Another field in which we do not believe that all is known is in regard to the chemical action of the various solids, liquids, and gases which come in contact with fire brick and furnace linings. While glibly stated, this would result in a whole series of problems of a fundamental research character which would require time and money, but which would probably lead to worth while results.

While oil and natural gas are now serious competitors of coal, it does not require a very active imagination to visualize a time in the not far distant future when these fuels will no longer compete with coal. It is probable, that coal in some form will then serve as the raw material from which oil is produced by hydrogenation as it is being done by experimental plants in Europe today. Again, we may find that closer study of the banded ingredients will prove profitable. Possibly by that time we will gasify our coal completely for domestic fuel. Who knows? The answer cannot be given today. One thing is absolutely certain, and that is that research will lead the way by supplying the fundamental information upon which our industrial applications are made.

No. 7

CHEMICAL ENGINEERING PROBLEMS RELATING TO THE MINERAL RESOURCES OF THE STATE *

5/27/35

Corrected

By D. B. Keyes
Head of the Chemical Engineering Division
University of Illinois

The utilization of the mineral resources of the State constitutes one of the most important fields of activity for the chemical engineer. Coal and petroleum are the two resources that seem to offer the greatest chance for industrial development.

The Chemical Engineering Division of the University of Illinois has always been interested in the State's resources and has spent many thousands of dollars in an attempt to lay a foundation for their greater utilization. It would seem worthwhile to review briefly not only the work that has been done in the last few years by this division, but to point out specific problems which should be profitable. The subject will be treated under four headings: coal, petroleum, stone, and silica.

...ndustries Conference at
... 1935.

No comment on text
[illegible]

I regard this as an inadequate presentation of the case - Should not be published.

Coal

Improvement of the Product. — It is well known that Illinois coal, when burned in furnaces for the production of power and for domestic heating, is apt to show a low efficiency of combustion due to certain chemical and physical characteristics. Slag formation on boiler, economizer and preheater tubes is an example of this inefficiency. This is distinctly a chemical problem in that it has been shown that the character of the ash and the slag can be materially changed by a chemical treatment of the coal before combustion.

A thorough scientific study of the complex silicates that are formed in the slag will undoubtedly indicate what can be done to prevent the formation of undesirable material which adheres to the heating surfaces.

It should be remembered in domestic heating that, owing to the high volatility of Illinois coal, there is a tendency to lose an appreciable portion of the fuel up the stack and that a marked increase in the efficiency of combustion would prevent this loss. Anything that can be done to improve the combustion characteristics of Illinois coal will materially increase the value of the product.

One of the impurities in Illinois coal is sulfur, which is present to the extent of 1 to 6 per cent. The sulfur dioxide formed by combustion is an irritating gas that is corrosive when present in a humid atmosphere. The removal of sulfur from Illinois coal would mean much in the prevention of air pollution in the cities and towns.

We have spent considerable time in an endeavor to devise some method of sulfur removal from the coal. Our experiments indicate that a combination of a coking and hydrogenation process may prove feasible. At the present time certain coals can be washed by a standard commercial process and over half of the sulfur removed, but it is highly desirable that a process be developed that can be utilized for the removal of sulfur from all coals marketed within the State. There is no question but what this is an outstanding research problem, because if most of the sulfur could be removed the value of the coal would materially increase. Furthermore, if the sulfur could be removed in a usable form and at a price such that it could compete in the present market, Illinois would have a new mineral resource in a quantity sufficient to make it a factor in the world market.

lf # Utilization of Coal. - Considerable work has been done, especially in Europe, on the hydrogenation of coal to produce oil and motor fuel. It is our opinion that coal could be first oxidized and then hydrogenated to produce a superior product, possibly solvents or intermediates for the synthesis of organic chemicals. We do not wish to give the impression that the problem could be solved satisfactorily in a short time, but undoubtedly the transformation of coal into liquid products is well worth the consideration of our mineral industries.

Beside the oxidation and reduction of coal, we should also consider the destructive chlorination of coal and coal ash to produce valuable organic chlorides and metallic chlorides, such as aluminum chloride. This is a field that has not been investigated, but is an excellent example of the possible formation of new compounds ~~which could be used in the industry~~, based on a chemical treatment of coal.

¶ Utilization of By-Products. - The Chemical Engineering Division has done considerable work on the chlorination of methane - one of the principal by-products formed in the coking of coal. The chlorinated hydrocarbon has a possible use as a solvent for cleaning textiles. One commercial concern is continuing the development of this process at the present time. Further fundamental work along this line would be desirable.

Benzol and tar, formed in the coking of coal, have long been used for raw materials for the production of dyes, medical products, and a great many synthetic organic chemicals. At the present time considerable interest is being shown in utilizing these raw materials for the manufacture of antioxidants to be used in rubber manufacture and the stabilization of motor fuels.

Carbon monoxide, which can easily be produced by the partial combustion of coal or coke, can be made the source for the synthesis of acetic acid. Considerable time and money have been spent by the Chemical Engineering Division on the reaction between carbon monoxide and methyl alcohol to produce this product. This operation takes place under high pressure in the presence of certain catalysts. Acetic acid, in turn, is the most widely used organic acid and is one of the chief raw materials for the manufacture of artificial silk. This particular product is growing in popularity and if acetic acid could be produced at a lower cost, undoubtedly its utilization, not only for this purpose but for the manufacture of non-inflammable film, plastics, etc., would materially increase. There is probably no single organic chemical at the moment which has a more attractive future than acetic acid.

Beside acetic acid, benzaldehyde has been made in our high pressure laboratory by the action of carbon monoxide on benzol.

Carbon monoxide will react with hydrogen, produced in the coking process, to form the higher alcohols so commonly used in lacquers and for various solvent purposes.

The Chemical Engineering Division has studied the reaction between carbon dioxide, another combustion product of coal, and benzol to produce benzoic acid. The sodium salt, known as sodium benzoate, is a common product used in our food industries.

Carbon dioxide and beta-naphthol react to produce beta-hydroxy naphthoic acid, a product and a process that is now of commercial significance. This product is the intermediate in the manufacture of many of our red dyes.

The production of urea by the interaction of carbon dioxide with ammonia is now a commercial success. This product can be made at a price so that it is attractive as a fertilizer.

We have spent over $60,000 during the last six years studying the recovery of sulfur dioxide from flue gas, and the present indications are that we will be able to produce liquid sulfur dioxide at a price far below its present value. The quantity of sulfur dioxide produced by this process in Chicago will be sufficient to meet the demands of that area. We hope, furthermore, to be able to produce this product at a price that will permit its conversion into free sulfur and to sell it in competition with the sulfur produced in Louisiana, Texas, and elsewhere.

Sulfur is one of the greatest raw materials for the production of sulfuric acid, which is the chief acid used throughout the world. It has often been said that the industrial prosperity of the United States is indicated by the amount of sulfuric acid consumed. If it were possible, as we hope it will be, to decrease the cost of this universal chemical, we will be able to create for the State of Illinois a new mineral industry of huge proportions and one that will have an effect on the economic structure of the industries within the State.

The importance of sulfur in agriculture should not be under-estimated.

Petroleum

Production. — The available supply of oil from our producing fields is being rapidly depleted. Several chemical processes have been proposed to make available oil which cannot be profitably extracted at the moment. Most of these treatments involve the utilization of some acid. One of the chief difficulties of these processes is the excessive corrosion of metal equipment. Research is now being done in several organizations to produce organic inhibitors to prevent this corrosion.

Another scheme for recovery of oil that is not now available is known as "repressuring". Gas is pumped into the ground and dissolves in the oil. Before the feasibility of this process can be determined, it will be necessary to know the solubility of gases in the oil under very high pressures. Work of this kind has been done by the Chemical Engineering Division.

Utilization. - Considerable interest is now being shown by our refineries in the polymerization of gases produced in the cracking process for the production of both motor fuels and lubricating oils.

The greatest organic solvent in the United States from the standpoint of production and utilization is ethyl alcohol. The present methods of production of this product are largely confined to the fermentation of agricultural products, especially black strap molasses imported from Cuba, Porto Rico, and Hawaiian Islands. One of the large chemical companies has recently built a plant at Whiting, Indiana, for the production of alcohol from waste gases purchased from the petroleum refineries. We have done considerable fundamental work on an improved method for the production of alcohol in which ethylene gas is allowed to react with water in the presence of a catalyst. It has been discovered that the equilibrium for this reaction is favorable at low temperatures. A catalyst which would operate under these conditions would solve the problem.

Acetaldehyde has been produced by a special air oxidation of petroleum and is easily recoverable. This product can be oxidized further by a commercial and standardized process to produce acetic acid, which has been mentioned above. It is thought by some of us that this will undoubtedly be one of the chief sources of acetic acid in this country.

Various research organizations in our refineries are producing anti-knock material from petroleum. Our own thought in the matter is that either by an oxidation process, referred to above, or by a dehydrogenation utilizing certain aerogel catalysts which have been developed in our division, we might be able to produce compounds in the product of high anti-knock value.

Acetylene, the source of many synthetic compounds and the gas which is used for cutting steel and for various other purposes, is now being produced by passing refinery gases through an electric arc. One well known organic chemist made the statement some years ago that acetylene will be the chief source of raw material for a gigantic chemical industry.

There are many other problems that are worth considering for research in connection with the utilization of petroleum. We will mention only a few: synthetic resins, for use in our new lacquers, varnishes, enamels, etc.; synthetic rubber; and fatty acids formed by the oxidation of kerosene and paraffin wax to be used in the compounding of rubber and in the preparation of special soaps, etc.

Synthetic Stone

The Chemical Engineering Division of Purdue University has treated the native shales with lime and water under pressure to produce a truly synthetic stone of unusual merit. This is one of the most interesting developments in the field that has occurred in many years. The State of Illinois has available in enormous quantities raw material for this type of product, and it is easily conceivable that further work along these lines will mean the production of a superior stone.

Silica

There have been developed in the Chemical Engineering Division here at the University of Illinois extremely porous materials known as aerogels made from mineral materials. The silica aerogel has been reported by outside organizations to be one of the finest heat insulators ever produced. Undoubtedly this product, which can be easily made from mineral resources within the State, should be studied thoroughly in order to determine its practical feasibility.

These aerogels are being investigated by us as catalysts. Owing to their enormous surface, they bring about a marked acceleration of many gas reactions.

less # light rule

The solution of all problems involving the utilization of our mineral resources depends on the successful application of chemistry, physics, and mathematics. The application of these sciences to industrial problems is the basis of work in Chemical Engineering.

aRS

#7

SMOKELESS BRIQUETS MADE BY IMPACT PROCESS

By R. J. Piersol

Presented before the Third Annual Mineral Industries Conference of Illinois

May 17, 1935

<u>Introduction</u>

Three and one-half years ago, in planning a research program on the increased utilization of Illinois coal, one problem which presented itself was the processing of slack coal into a product which would command a price comparative to that of lump coal. Success is such a project would be of importance since approximately one half of the sized coal produced in Illinois is slack coal (less than 2 inches).

Three years ago, an experimental investigation was initiated, the method of attack being the briquetting of slack coal without a binder - binder not only being expensive (about 70 cents per ton of briquets) but also adding the smokiness of the resultant fuel.

Preliminary attempts to briquet without binder by a steady pressure did not show promise of commercial success, but excellent briquets were formed in the laboratory by impact without binder as the result of a systematic investigation of the combined effect of temperature and impact blow.

It was fortunate that the original method of attack was without binder because it was discovered, subsequently, that this same process could be used in making smokeless briquets without binder from a coal product from which the smoke had been removed. If the binder method had been used in the briquetting of the smokeless product, the resultant briquet would not be smokeless.

The discovery that Illinois slack coal may be impacted into briquets (either ordinary or smokeless) is protected by U. S. Patent Application Serial No. 714,760 filed on March 9, 1934.

Estimated energy consumption

It requires 2000 foot-pounds (the blow of a 500-pound hammer dropping 4 feet) to make a briquet weighing 0.1 pounds), or 20,000 foot-pounds per pound of briquets, or 40,000,000 foot-pounds per ton of briquets. This is equivalent to 20 horsepower-hours per ton of briquets.

The fuel consumption for preheating the coal (250°C. for ordinary briquets and from 400° to 500°C. for smokeless briquets) is from 50 to 100 pounds of coal per ton of briquets, depending upon the type of briquet produced.

The shrinkage of coal in producing a ton of ordinary briquets is equal to the percentage moisture in the coal, all moisture being removed. The corresponding shrinkage for smokeless briquets is the percentage moisture plus 15 per cent, which is the amount of volatile removed in order to produce smokelessness.

Properties of ordinary briquets

Tumbling tests on impacted briquets show that they withstand handling better than the coal from which they are made. This is due in a large degree to the fact that briquets have a homogeneous structure, with no parting planes.

Both accelerated slacking tests and out door exposure tests show that impacted briquets do not deteriorate appreciably from weathering, whereas lumps of the corresponding natural coals weather very rapidly under similar conditions. This is due primarily to decreased pore space resulting from the increased density of the briquet - weathering being accelerated by absorbed moisture.

The ignition and maintenance temperatures of impacted briquets are the same as those of corresponding natural dry lump coal. The rate of burning is less due to their greater density, the burning being from their outer surfaces inwardly. There is a minimum of swelling and cracking during combustion.

Properties of smokeless briquets

In the demonstration just witnessed, smokeless briquets were prepared from a 50-gram sample of 4-mesh St. Clair County coal, prevolatilized for a 5-minute period to a coal temperature of 515°C. (with 15 per cent volatile loss), thereby resulting in a smokeless product. This was cooled for 5 minutes to an approximate temperature of 350°C. and briquetted in a die at 300°C. by the impact blow of the 500-pound hammer, dropped from a 4-foot height.

Figure 1 shows the effect of amount of naturally occurring volatile on smoke index of coal - smoke index being an accurate quantitative measure of the total quantity of smoke liberated in the combustion of a unit quantity of coal under controlled laboratory conditions of fixed air supply and temperature of burning. The top point represents a high volatile - 44 per cent - Illinois coal; the next lower point, a lower volatile - 38 per cent - Illinois coal; and the two lowest points, West Virginia Pocahontas coals - 16 and 17 per cent volatiles - referred to in trade literature as "smokeless coal." Attention is called to the straight line relationship between smokiness and volatile, the amount of smoke not decreasing as rapidly as the decrease in volatile; secondly, that these so-called smokeless coals contain 40 per cent as much smoke as the higher volatile Illinois coals and 50 per cent of that of the lower volatile Illinois coals.

Figure 2 shows the effect for higher volatile Illinois coal of the remaining volatile matter after successive removals of the low temperature fractions of the volatiles on the resultant smokiness of the product. Again there is a straight line relationship, but the reduction in smoke is far more rapid than the reduction in volatile, thereby showing that the smoky portion of the volatile has been removed and the smokeless portion retained. The briquet, containing 29 per cent volatile, has less than one-third the amount of smoke as Pocahontas coal, 16 per cent volatile.

Figure 3 shows similar results for lower volatile Illinois coal.

Figure 4 records the percentage of remaining volatile matter in higher volatile Illinois coal prevolatilized for a 5-minute period at various temperatures, showing a straight line relationship. Figure 5 is a graph for the same coal, using a 10-minute preheating period. Figure 6 shows similar results for a lower volatile Illinois coal.

Figure 7 presents the results of the mechanical strength, in terms of tumbling loss, of smokeless briquets made from a higher volatile Illinois coal, thereby showing smokeless briquets of excellent strength. Figure 8 shows similar results for the strength of smokeless briquets made from lower volatile Illinois coal.

Figure 9 shows that the optimum percentage (15 per cent) removal of the smoke producing volatile fractions, may be secured by a wide range (10 to 40 minutes) of preheating periods with a corresponding wide range of preheating temperatures (420° to 480°C

Commercial development

In the Illinois coal area, adjacent to the St. Louis market, a cooperative organization has been formed to manufacture and merchandise smokeless briquets. It is planned to adapt a present commercial machine which is being used to impact briquets with binder, each unit producing 250 tons per 24-hour day.

In the Illinois coal area, adjacent to Chicago, a large stripping organization is carrying on development on the manufacture of ordinary briquets. This coal possesses a high calorific value; is remarkably low in ash; but, due to its high moisture, necessitating immediate marketing. Therefore, the problem of this company is processing their coal in off season into a form which will withstand weathering.

Summary

In summary, it has been discovered that (a) Illinois slack coal may be impacted into briquets without binder, (b) Illinois coal may be transformed into a smokeless product by the removal of a small amount of low temperature fractions of the volatile matter, and (c) this product may be impacted into smokeless briquets without binder.

Demonstrations

A demonstration will be shown of the smokelessness of smokeless briquets as compared to corresponding natural coals.

There is an exhibit of 4-inch ordinary briquets.

The tumbling barrel, used for testing the mechanical strength of the briquets, may be inspected.

EFFECT OF AMOUNT OF NATURALLY OCCURING VOLATILE ON SMOKE INDEX OF COAL

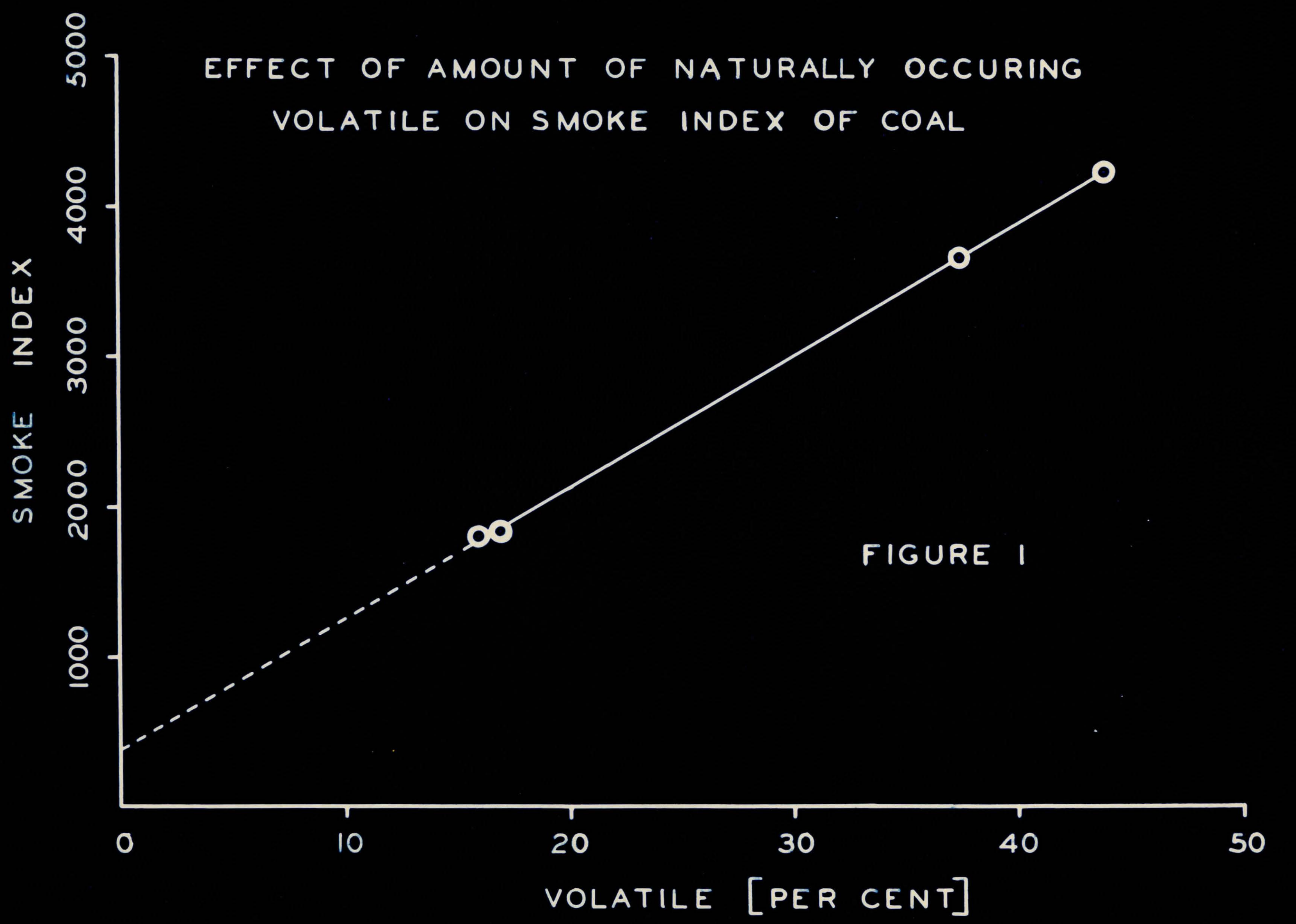


FIGURE I

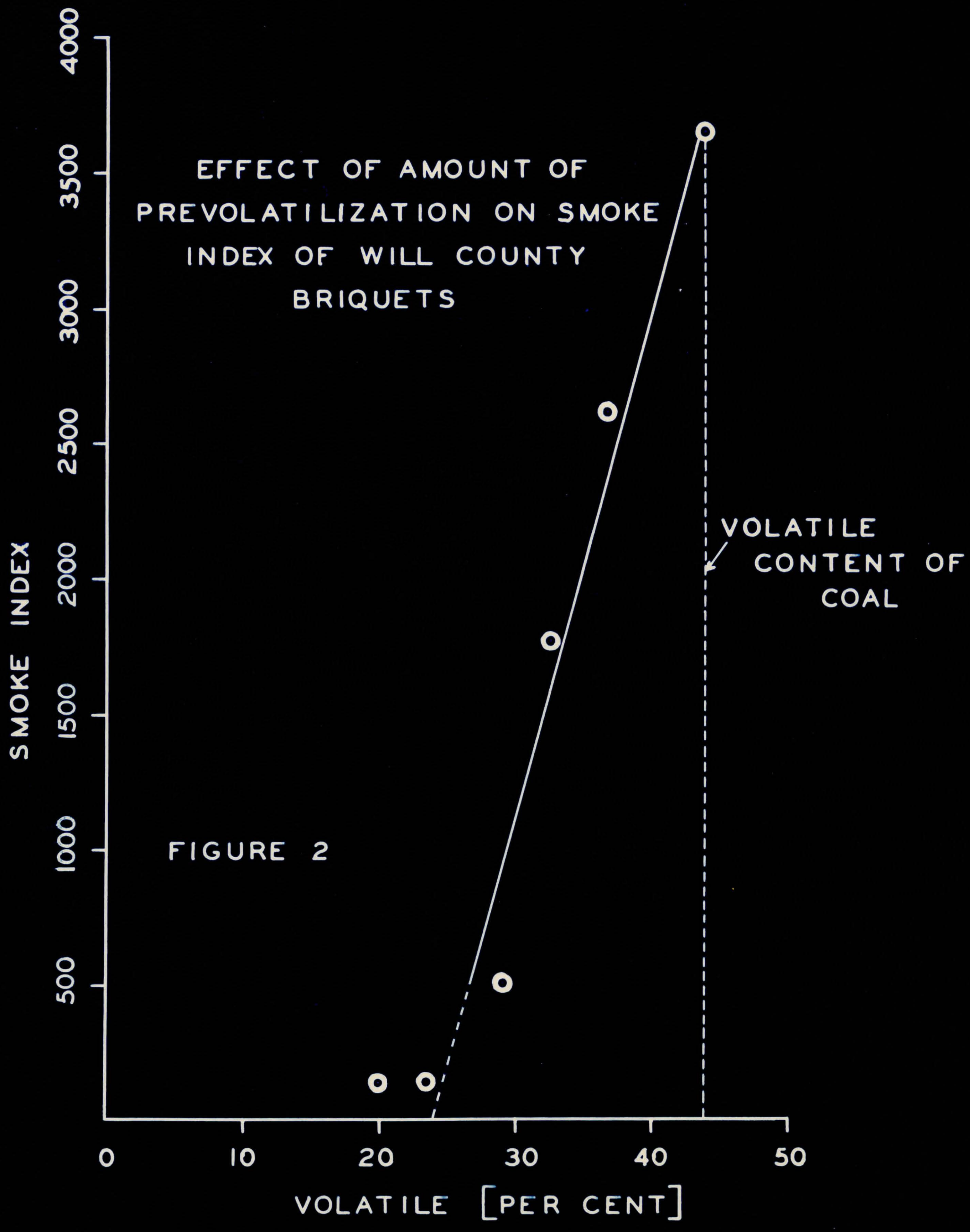

EFFECT OF AMOUNT OF PREVOLATILIZATION ON SMOKE INDEX OF WILL COUNTY BRIQUETS
SMOKE INDEX
4000
3500
3000
2500
2000
1500
1000
500
VOLATILE CONTENT OF COAL
0
10
20
30
40
50
VOLATILE [PER CENT]

FIGURE 2

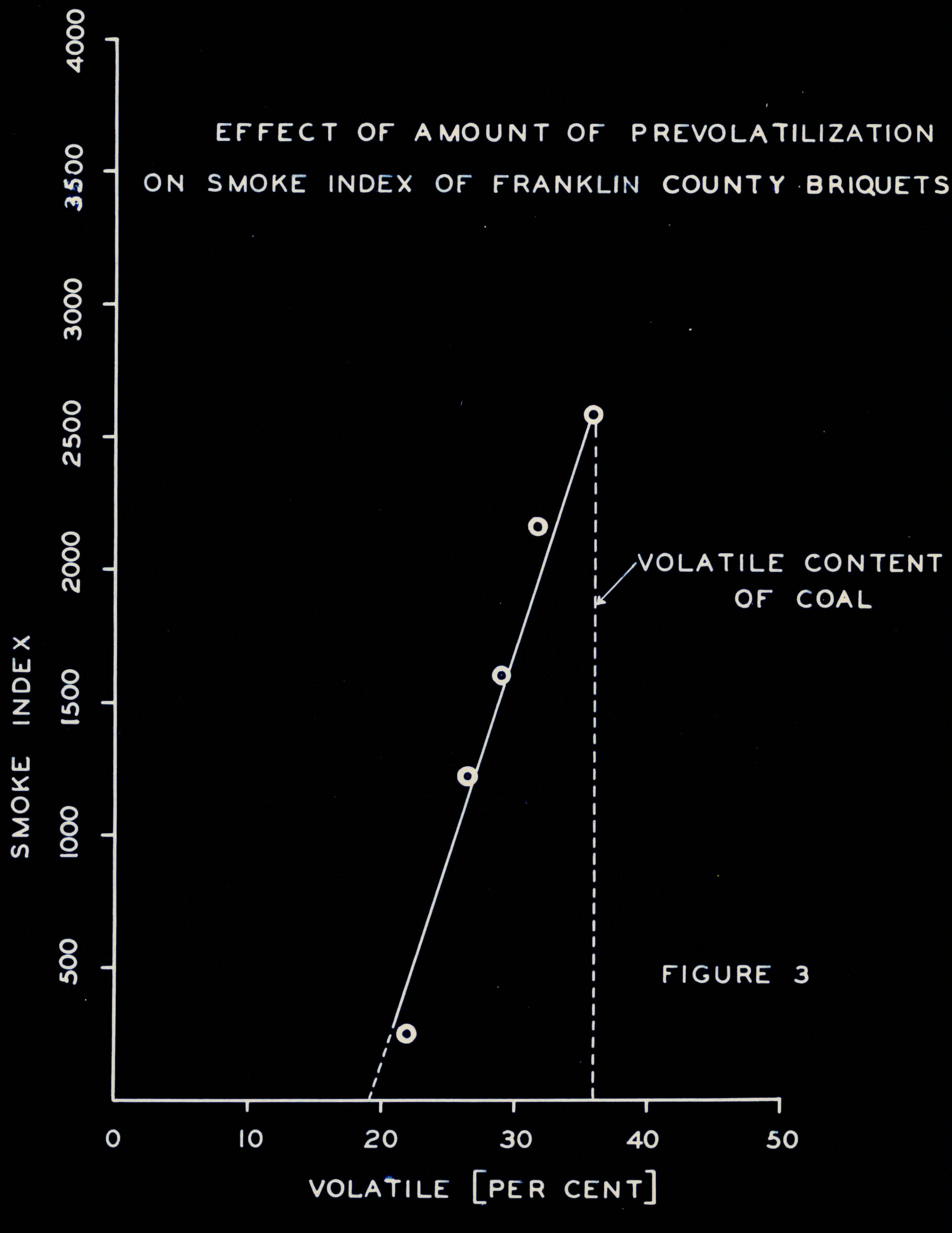
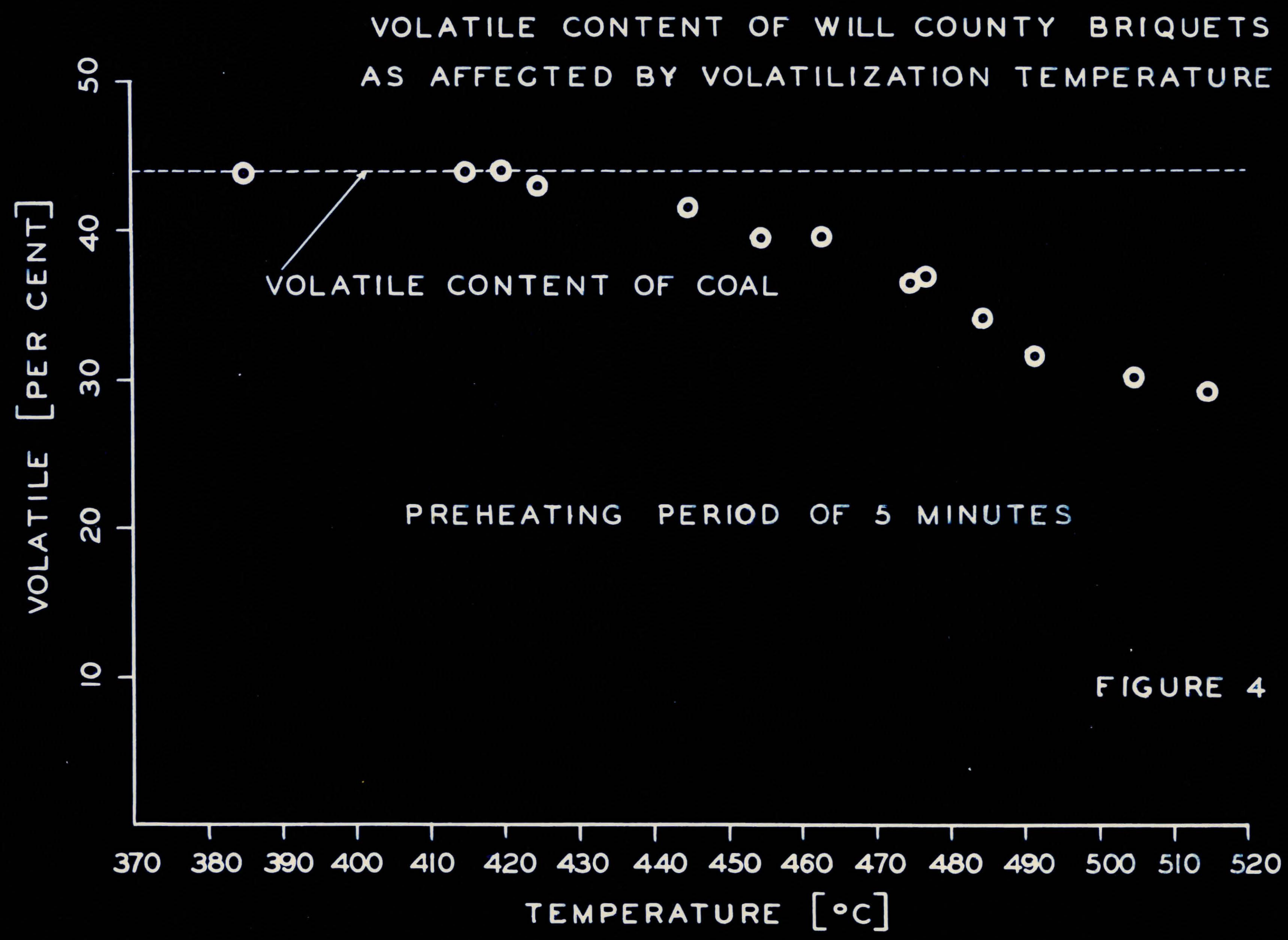

EFFECT OF AMOUNT OF PREVOLATILIZATION
ON SMOKE INDEX OF FRANKLIN COUNTY BRIQUETS
SMOKE INDEX
4000
3500
3000
2500
2000
1500
1000
500
0
10
20
30
40
50
VOLATILE [PER CENT]
VOLATILE CONTENT
OF COAL

FIGURE 3



VOLATILE CONTENT OF WILL COUNTY BRIQUETS
AS AFFECTED BY VOLATILIZATION TEMPERATURE
VOLATILE [PER CENT]
50
40
30
20
10
VOLATILE CONTENT OF COAL
PREHEATING PERIOD OF 5 MINUTES
FIGURE 4
370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520
TEMPERATURE [°C]

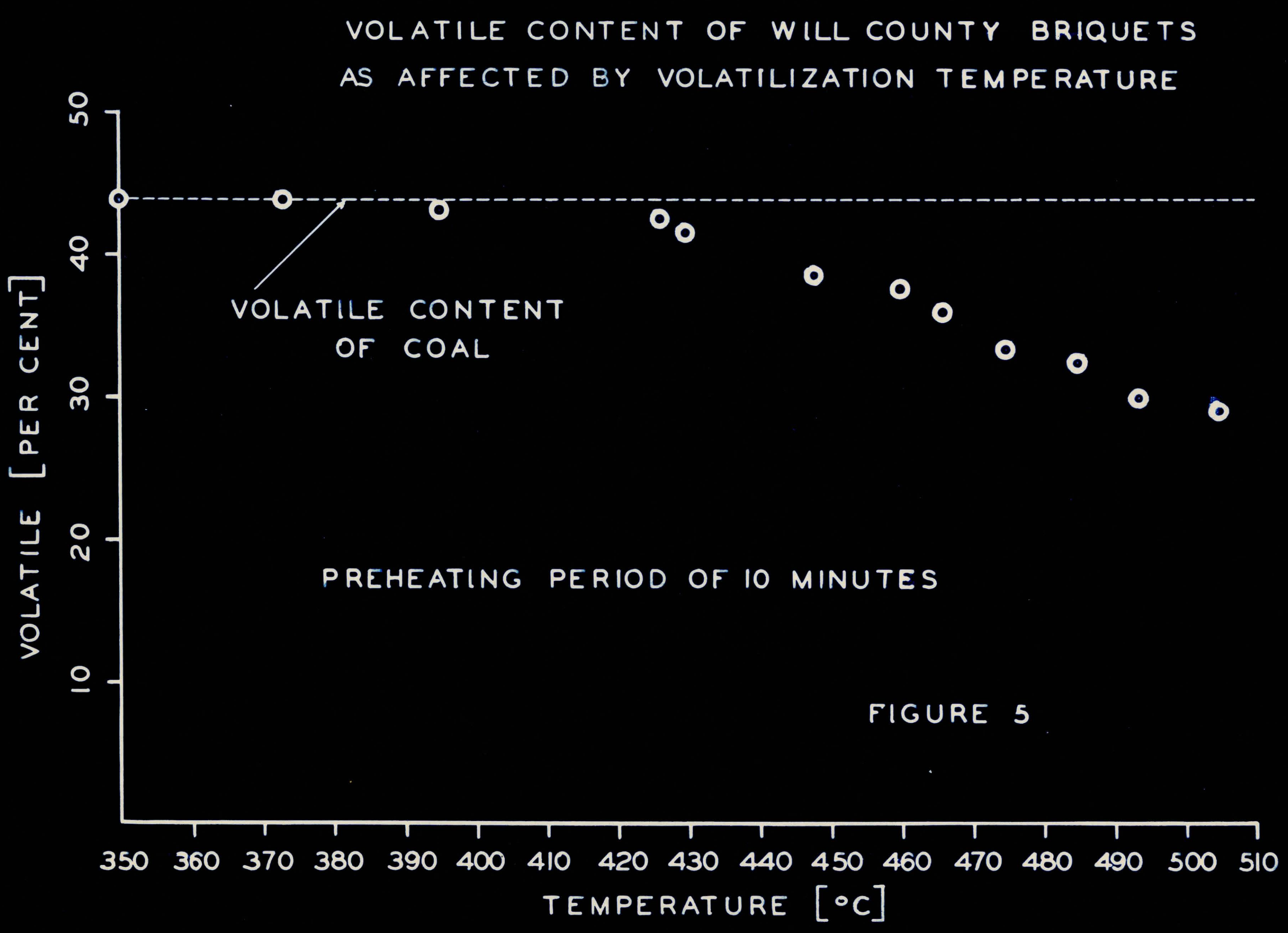

VOLATILE CONTENT OF WILL COUNTY BRIQUETS
AS AFFECTED BY VOLATILIZATION TEMPERATURE
VOLATILE CONTENT
OF COAL
PREHEATING PERIOD OF 10 MINUTES
VOLATILE [PER CENT]
50
40
30
20
10
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490
500
510
TEMPERATURE [°C]

FIGURE 5

VOLATILE CONTENT OF FRANKLIN COUNTY BRIQUETS
AS AFFECTED BY VOLATILIZATION TEMPERATURE

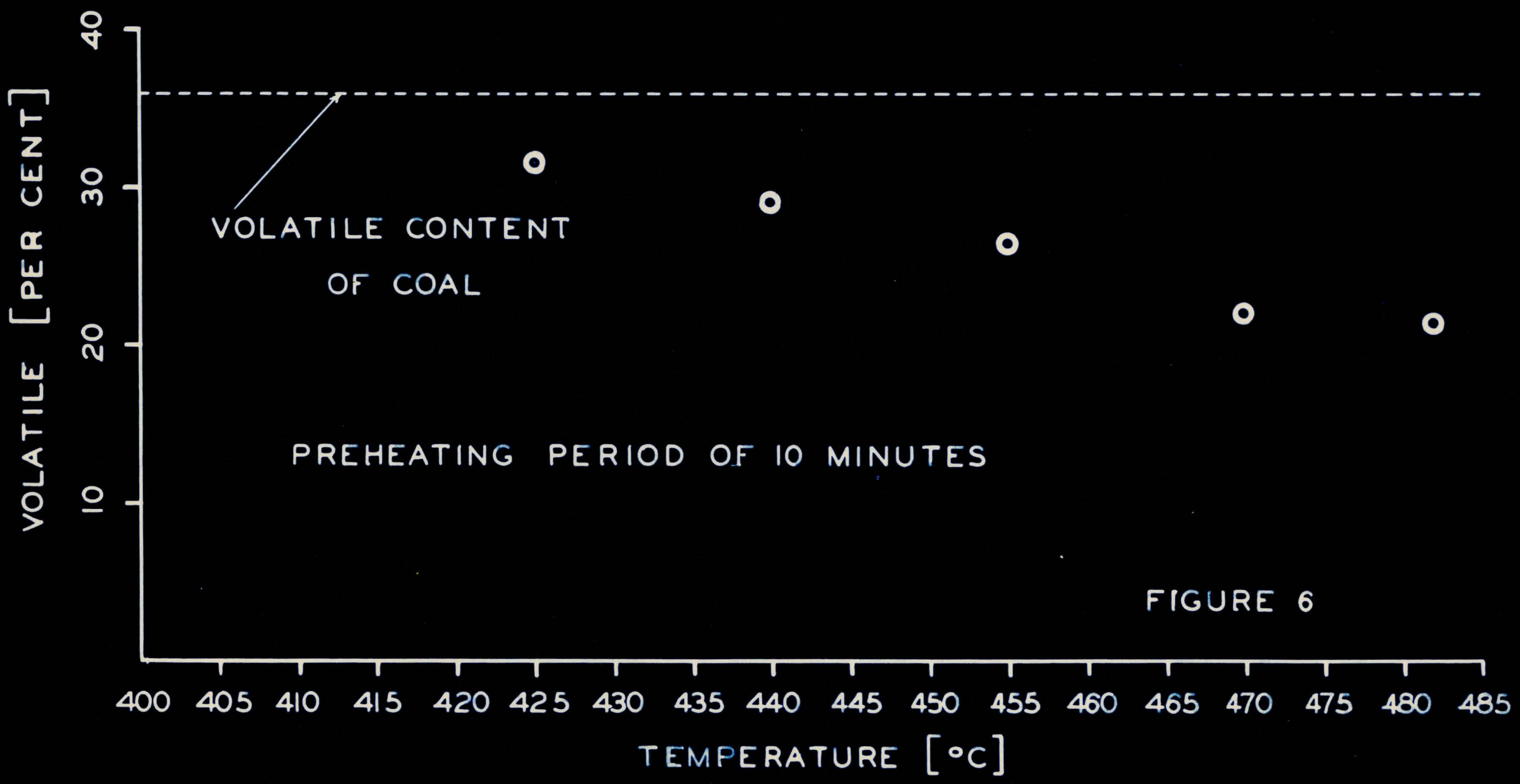


FIGURE 6

MECHANICAL STRENGTH OF WILL COUNTY
BRIQUETS AS AFFECTED BY VOLATILE CONTENT

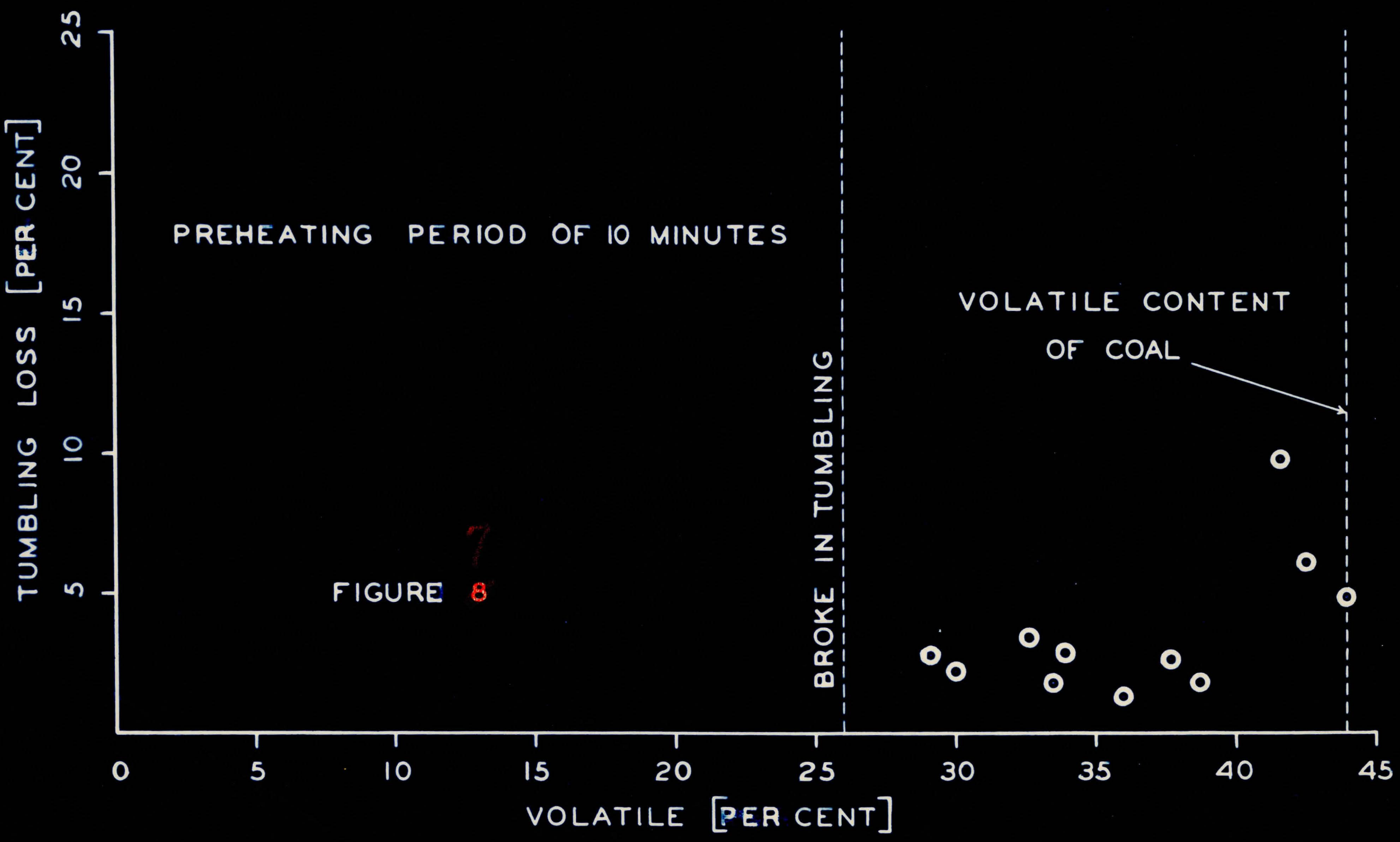
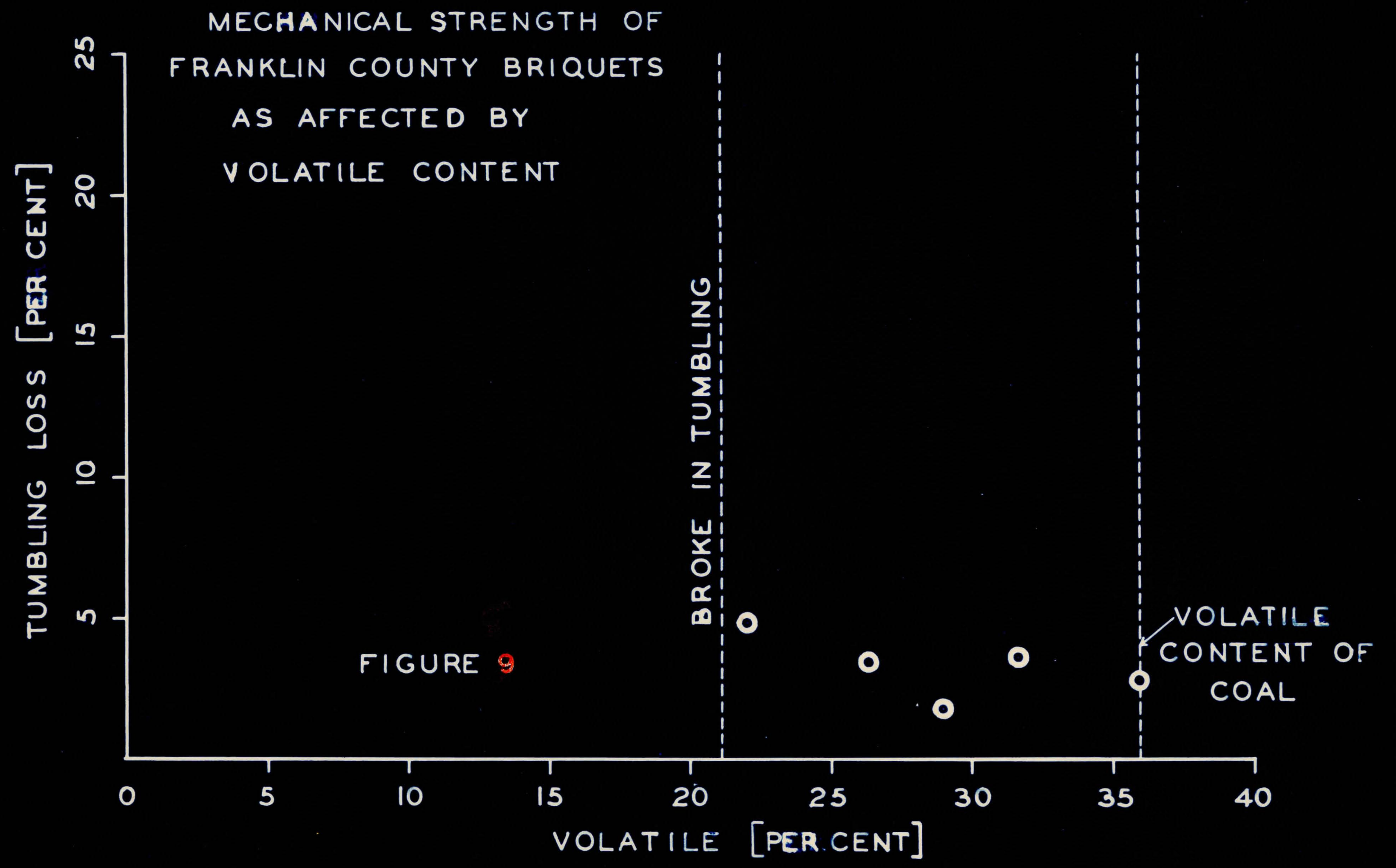


FIGURE 8


MECHANICAL STRENGTH OF
FRANKLIN COUNTY BRIQUETS
AS AFFECTED BY
VOLATILE CONTENT
TUMBLING LOSS [PER CENT]
25
20
15
10
5
BROKE IN TUMBLING
VOLATILE
CONTENT OF
COAL
0
5
10
15
20
25
30
35
40
VOLATILE [PER CENT]
FIGURE 9

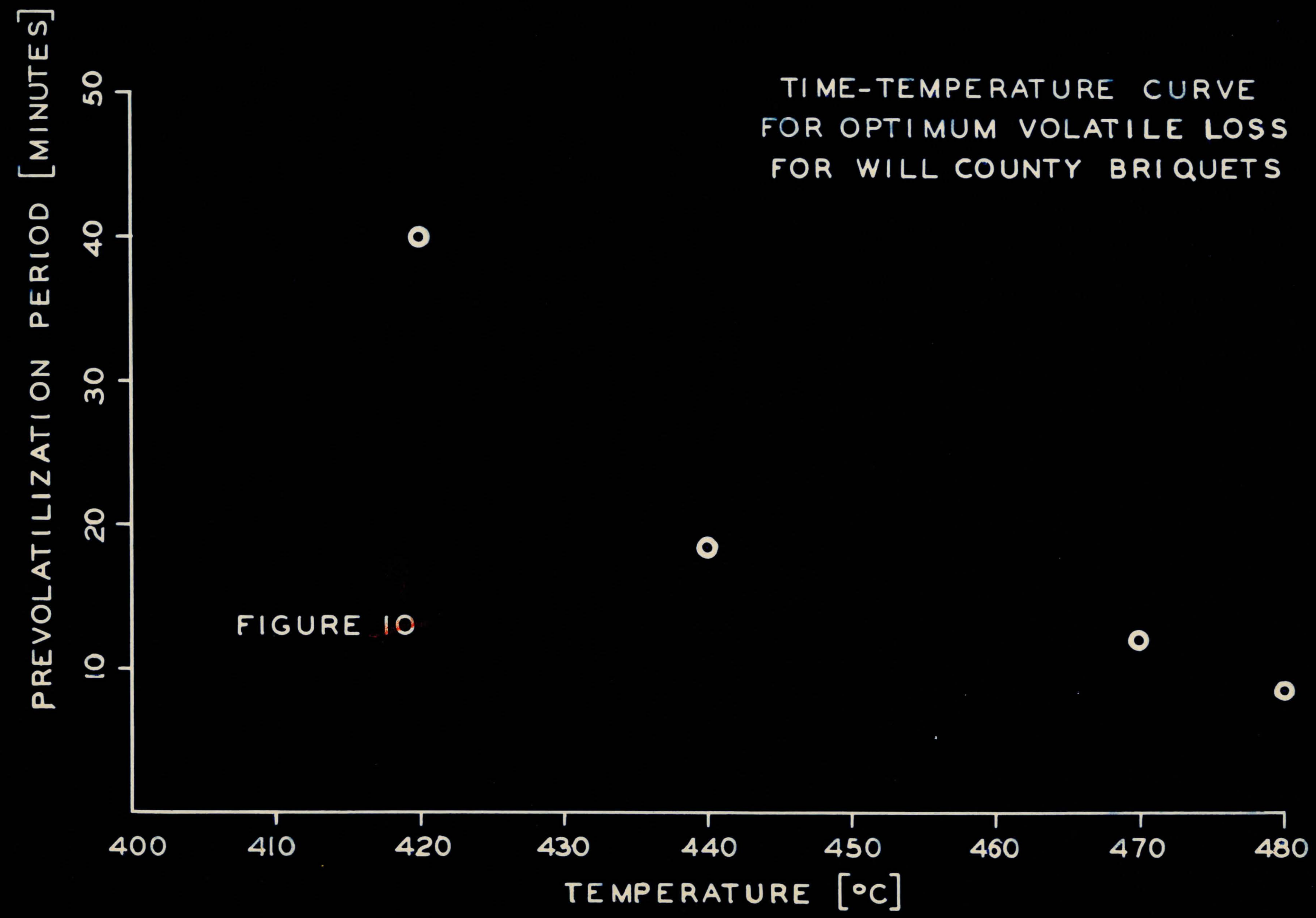

TIME-TEMPERATURE CURVE
FOR OPTIMUM VOLATILE LOSS
FOR WILL COUNTY BRIQUETS
PREVOLATILIZATION PERIOD [MINUTES]
10
20
30
40
50
400
410
420
430
440
450
460
470
480
TEMPERATURE [°C]

FIGURE 10

Apparently a hastily prepared paper, poorly organized, and valuable only in a general way. I believe the summary already prepared is sufficient to present the main points of the argument

THE ECONOMICS OF COAL BENEFICIATION WITH SPECIAL REFERENCE TO THE PROBLEMS OF THE SMALL OPERATOR.

By R. J. Lawry
Contracting Engineer, Roberts and Schaefer Company, Chicago

It is an accepted fact that coal, to command the best place on the market, must fulfill a certain standard of purity as regards ash and sulphur content.

~~A part of the~~ market demands reasonably low ash content and a certain minimum sulphur percentage; ~~but~~ other ~~markets~~ are satisfied with a comparatively high sulphur content and demand the absence of only visible ash producing impurities.

The present critical attitude of the buying public is due to their better knowledge of the fuel which they have to burn. Their increased interest of course is strengthened by the competition offered coal from oil and gas fuel.

As a result of the necessity of producing a more merchandisable fuel, many of the leading Illinois coal operators have built, or are building, quite complete and efficient Cleaning Plants, and many other operators are investigating and planning to build such plants as additions to their present screening and hand-picking facilities.

~~So it is believed that~~ the coal industry in Illinois is thoroughly alive to the present day needs regarding fuel, and we believe that the bulk of the demand in the future will be fulfilled with a well prepared product.

~~But~~ this statement applies especially to the large and also the moderate capacity mining operations, ~~and these~~ produce perhaps nine-tenths of the annual output of coal. The remaining tenth ~~of the coal~~ is produced by an equal number of small~~er mines and this section of the industry is composed of~~ wagon and small shipping mines. ~~The smaller shipping and wagon mines~~ are of importance to the community ~~where they operate,~~ in providing a livelihood for their employes.

-tence: "as a result etc is not clear

Possibly the meaning is:—

"As a result the small operator who cleans his coal never applies such preparation to sizes above about 3 x inches because of the relatively ~~sm~~ small quantity of the larger sizes produced."

The small wagon mine that operates usually only during the cold weather ~~only~~, and that sells its product as run-of-mine coal or after a crude screening, will seldom have to face the problem of mechanical cleaning, but the operator of the small tonnage ~~operator of the~~ shipping mine that produces about 100,000 to 150,000 tons a year~~, or perhaps as much as~~ ~~150,000 tons a year,~~ will have to face this problem ~~as~~ because he ~~will~~ must ~~come into~~ compete~~tion~~ with the product from the larger mines. A carload of coal is judged only by its quality and price, regardless of whether it is produced by a small operator or comes from a splendidly equipped mine.

(We are assuming that) coal beneficiation is more difficult for the small tonnage operator than for the larger one. There are many reasons why this is so. The large operator has or is served by an organized sales force or selling agency which has advertised the superior product and ~~xxx~~ is in a position to make good, large sized tonnage contracts for a steady supply of coal of a uniform ash content, ~~while~~ whereas the small mine cannot contract to furnish a ~~sufficient~~ certain amount of one size of washed or cleaned coal ~~so that he will have to~~ and must therefore depend on selling it on the open market.

The present trends in coal preparation and cleaning are to produce closer sizing, or more sizes of the complete product. In the large operation the amount of each size will be sufficient to supply some special use, but for the small producer the amount of each size, or grade of coal, is insufficient to sell to advantage to an industry.

As a result the small operator, if compelled to clean his coal, never extends the size above say a 3" inch size. ~~In case of the larger operations~~, ~~already~~ some of the larger Illinois mines are already washing or planning to wash sizes up to 6" inches.

~~The initial cost of a Cleaning Plant is usually expressed in dollars per ton hour--for example, a plant cleaning coal at the rate of 200 tons per hour, might cost $400 per ton hour, or $80,000 for the plant in operation.~~

Sentence - We are not etc - ~~Omit~~

Sentence rambling + seems to have three diff. unrelated ideas

Omit - as it is difficult to interpret what the author is trying to say

As is true with most industrial operations, commercial washing and cleaning units have been developed for average capacities for which they are most likely to be used. The unit capacities for the different sizes for the small mines would probably be much smaller than would be appropriate for the commercial cleaning units. A mine producing 100,000 tons per year would have an average daily production of about 500 tons, or not over 90 tons per hour. If the sizes below 3 inches were to be treated the capacity would amount to about 60 tons per hour. It is perfectly feasible to obtain a cleaning unit to treat this comparatively small amount of coal, but if this 3 x 0 inch coal were to be washed in two sizes, and also two more of the smaller sizes were to be treated with air, as is done in many of the large operations, the amount of these smaller divisions would be less than 15 tons per hour, which is an extremely small amount for a cleaning unit.

We are not now discussing the advisability or inadvisability of cleaning coal unsized or separated into several parts, but cleaning coal in a small size range has become very prevalent and this fact must emphasize the difficulty of treating small tonnages of coal economically.

There are also many mines producing less than 500 tons per day for which the problem of cleaning coal is especially difficult, because of the construction of the plant. In the foregoing we have been considering only the installation cost of a cleaning plant, but the expense of operation is another burden on the small operator. Two men can attend a plant that handles 200 or 300 tons per hour, while one handling only 50 tons per hour would require at least the attention of one man which would, of course, increase the cost of operation per ton.

Also, if the small coal operator is required to construct a simpler plant to clean his coal than the large operator, it is likely that he will not clean his coal as well and will probably have greater losses. If he does not clean his coal as efficiently, the return on his investment will be less.

In connection with the cleaning of coal there are a number of things which are appropriate to a large plant, but which would be a burden to a very small plant. One of these items is the heat drying of small sizes of washed coal which is quite often a necessity in our climate. The drying installation would be practically impossible for a small operator.

When and if coal beneficiation becomes a general practice in our coal industry, it will become apparent that certain coals, while of excellent quality, are difficult to treat. Neither coal washing nor air cleaning are exact sciences and many plants are put into operation with a knowledge that their methods may have to be changed. Such a change would have to be brought about by some sort of a technical investigation. Large cleaning operations usually employ a Test Engineer as well as a laboratory and chemist, or combination of the two. Keeping a check by means of an analysis on the product is absolutely necessary for the selling of the coal as well as a necessary method of maintaining the efficiency of the cleaning plant.

The small coal operator would be unable to afford the expense of a test laboratory or test engineer to benefit the operation of his cleaning plant. He can, of course, obtain consultation service and use a commercial laboratory, but in this respect he is at a decided disadvantage to the large operator with his own testing facilities.

While we are pointing out the economic difficulty of operating small capacity plants, there is, of course, a brighter side to the picture. A man with sufficient initiative and ability to operate a small mine successfully, might also combine in himself the job of superintendent, salesman, constructor and Preparation Engineer–in fact some men are doing all these things.

Those of us ~~actually~~ in the business of building Preparation Plants do not always take the time to classify the plants ~~they~~ we have built. My attention has been drawn to the fact recently, that while there are many very small cleaning plants, most of them have been built at good size mines and usually are confined to treating one size of coal only. ~~the small size installation will be either finally abandoned or enlarged.~~ There are very few cleaning plants at mines producing less than from 500 to 1000 tons per day.

One solution for cleaning plants for small mines is to build a central plant to prepare the coal to be cleaned from a number of small mines. This solution of the problem has been tried many times in the past, usually by companies owning a number of small mines and on the theory that it would be cheaper to build and operate a central cleaning plant than several small ones. In theory this solution is correct, but in practice it has never worked out very well. There are several serious objections to the central cleaning plant, some of the most important of which are the degradation of the coal by the extra handling; the additional cost due to transferring the coal from several small mines to one central plant, and the difficulty of obtaining ~~of~~ a constant and uniform supply of coal from several mines. ~~to a central plant.~~ Therefore, when all things have been considered, our company has usually advised against building a central plant. ~~However,~~ Some of our clients have, however, ~~in the past,~~ decided in favor of this method of solving their problems and we have built central plants, but the result ~~of such experiments~~ has usually been that they ~~these plants~~ were finally abandoned for one reason or another.

In addition to the objections pointed out above, we think there would be ~~the~~ still further difficulty ~~of~~ in applying this solution to a number of small mines with different ownership. ~~It~~ wherein it would be difficult to arrange operating schedules under such conditions to give a regular and continuous tonnage to the central cleaning plant. We therefore do not believe that this method will be successfully applied to small mines of different ownership.

To answer more definitely the capacity limitation in regard to the building of cleaning plants at small mines, I believe that unless a mine produces from 150,000 to 200,000 tons of coal per year, the cost of building and operating a coal cleaning plant will meet all the difficulties which have been mentioned above.

I might point out that there are some interesting exceptions to the conclusions drawn from the discussion of this subject. One of the most noted exceptions is the Birmingham Field of Alabama which is unique in having coal cleaning plants at ~~xxx~~ many small mines.

From the report of the Coal Inspection Department of this State for the year 1929, the production for that year was 18,415,000 tons. Of this total production some 74% was washed. This 74% was composed of the following products:

Run-of-mine Coal	40%
Nut and Egg Coal	6%
Slack Coal	28%

The total production (18,415,000 tons) was produced by 214 mines of which 75 had operating washeries. Of these 75 washeries, one plant was rated at 60 tons per day; 7 plants at 200 tons per day, and the other 66 at 300 or more tons per day. Of the 75 mines operating washeries, 25 produced less than 100,000 tons per year, and the product washed consisted entirely of slack coal.

It is important to consider the reasons why these small washeries in the Birmingham District of Alabama have been successfully operated for many years, and why such plants would be unsuccessful in any northern states. Due to the climatic conditions in the Birmingham District these small washing plants have practically no housing and therefore construction cost is almost entirely eliminated. Also, the coal being washed at these small plants is for special purposes and is consumed within the rather small radius around Birmingham. Therefore the success of these small cleaning plants in that district or other similar Southern districts does not apply in Illinois or other Northern states.

Another important factor that has bearing on the necessity for cleaning plants is that many, if not most of the larger mines, have reduced their mining cost by the installation of mechanical loading in some form and thereby have been able to operate at a profit during the time of low prices.

Mechanical loading makes necessary the better cleaning of the coal on the surface. Mechanized mines have therefore had to add to their cleaning methods above ground, either by improved facilities for hand picking the larger sizes or by hand picking the lump only and installing mechanical cleaning plants for the balance of the product. To what extent the smaller mines of the state have utilized mechanical loading I do not know, but in all probability not to any great extent.

Having discussed even thus briefly the situation of the operator of small mines, it remains to offer any suggestions which will be helpful and enable him to retain his place in the industry. There are two or three methods applicable to his situation any one of which we believe is practical of adoption and with intellignet installation and careful operation would be successful.

For the proper application of the methods to be suggested it is necessary to make first some general division of the small mines into classification according to daily and annual capacity. We would suggest three general, but not arbitrary, divisions, namely; 1st, the purely local mine, making deliveries mostly, if not entirely, by wagon and truck. 2nd, the smallest class of shipping mines, say having a daily capacity of 500 to 1000 tons per day; and, lastly, the next larger classification based on daily capacity, say roughly from 1000 to 1500 tons per day. Even the latter are small mines ~~based on~~ compared to the average daily capacity of the larger producing mines of the state. Referring now to the first classification, or the purely local mines, as has been pointed out above, these will not be considered in offering suggestions for preparation over and above simple preparation by hand methods. Even this, however, could considerably improve the product of these mines.

Referring now to the second classification of small shipping mines, with a daily production of say 500 to 1000 tons: There are two methods especially adaptable to this class of mines:

¶ FIRST METHOD: (a) A number of such mines in the same general locality- not, however, restricted to a small area, could be combined under a holding company composed entirely of the owners of these consolidated mines. Such a grouping of these small mines would overcome many of their difficulties not only as to ability to finance coal preparation plants, but would greatly facilitate and economize in the operation of such mines; and, lastly and very important, enable them to reach more diversified and continuous markets. In other words, they would be placed more nearly on a par with large operating mines. Such a consolidation of small, individually owned properties is entirely practical and would be highly beneficial to the owners of such properties.

There is ample precedent for the above statements as such consolidations have been made in the past but usually by outside parties who assumed entire responsibility for the consolidation and the operation of the mines; the selling of their product and furnishing the financial backing necessary for the improvement of the properties, etc. However, this method of grouping mines, just referred to, has been more beneficial to the outside parties who take over the operation and control of these properties, than to the original owners. It is for this reason that we suggest the method of consolidation through a grouping of such mines with the ownership and control to remain entirely in the hands of the present owners of the property.

For the successful carrying out of such a combination of small mines, and to be assured of obtaining the necessary financial assistance for the improvements required to place them on a competitive basis with larger mines, it is absolutely necessary that the owners of any mines to be so grouped, should approach some Engineering Company with the facilities and experience to first command the confidence of the owners of the individual properties--so that each would have confidence that only mines which would add to the ultimate success of the combination, would be included in the consolidation. Also, that a proper and unprejudiced valuation would be put on each property entering into the consolidation, according to its merit and value in the combination. Such a method of procedure will assure the owners, entering into such a consolidation, of securing the proper basic assets xxx essential to their success in competing with the larger mines and larger producing companies.

(b) Having completed the consolidation of such a group of mines, the next step is for their engineers, above referred to, to make a careful study of each and all the mines included in the group and recommend the improvements necessary to place each mine on a competitive basis on the market, and to reduce its cost of production, etc., and also an estimated cost of such improvements. Such report would also include the classification of each mine in the group, as to the quality of coal it would produce in relation to the other mines in the group and co-ordinate all these for a unified sales proposition; thereby enabling them to reach the largest possible diversity of markets.

(c) The first two steps having been properly accomplished, the same reports prepared by the Engineers, will command the confidence of Finance Companies which will enable such a consolidation to make the necessary improvements which is the final object of the consolidation.

There is plenty of precedent in the consolidation of small plants in many industries to convince anyone that with intelligent and experienced direction, such a combination of small properties would be highly beneficial to owners of such small mines.

SECOND METHOD: We will now consider another method of procedure which would apply more particularly to the next classification of mines, say from 1000 to 1500 tons daily production, but which can also be applied to some of the larger mines in the classification above discussed.

We wish to remark in passing that the above method of consolidation for the small mines into groups would also apply to the somewhat larger mines of the group now being discussed. However, the mines in this group now being discussed, having somewhat larger daily capacity, lend themselves more readily to individual beneficiation than the mines of smaller, daily capacity.

Mines in this group, having a daily capacity of 1000 to 1500 tons, per day can very readily be equipped with coal cleaning plants designed for and using equipment developed especially for mines of small daily capacity.

The company with which I have the honor of being associated for the past thirty years, has been very successful in building Coal Preparation Plants, either by the Wet or Dry Process, or the combination of both for medium small mines. We wish, therefore, to point out to the operators of such mines that their problem is within the practical application of present day equipment and design, which are giving eminent satisfaction to operators of many small capacity mines.

In closing, we wish to express our appreciation to this Conference, and especially to Mr. Leighton, who presented us this opportunity of offering encouragement to the owners for the small mines of Illinois regarding their problems in coal preparation.

May 8, 1935.

R. G. Lawry,
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Possibilities of Improving and Extending the Use of Illinois Coals through the Study of Their Constitution

By Gilbert H. Cady
Senior Geologist and Head of the Coal Division
Illinois State Geological Survey, Urbana, Illinois

Although the purpose of scientific investigation of Illinois coals is the discovery of facts, the immediate hope of such undertakings is that the facts discovered will lead to some means of improving the competitive position of these coals in the market.

The prospect that the efforts expended in research will be rewarded with discoveries are best of course in those fields that have been little explored and yet are sufficiently large to excite the imagination. One does not equip an Antarctic expedition to explore Nantucket. There is a desire also and above all to direct research toward fundamental considerations upon which rest the procedures of coal production and utilization.

There will probably be no general agreement on what constitutes fundamental research in the use of coal, because the problem will be regarded from various points of view. Indeed, there may be several varieties of fundamental research, but two at least are of outstanding importance. One line of research undoubtedly concerns the principles and processes involved in the conversion of coal into usable forms of energy after it has reached the devices of conversion. These principles and processes are commonly included under the general term, utilization. Another line of investigation of fundamental importance concerns the nature of the energy resource itself. A somewhat subordinate line of research concerns processes and principles involved in the removal of the coal from its bed and its preparation for use, that is, production. Undoubtedly the research into the principles and processes of energy conversion is of outstanding importance and has so been recognized. On the other hand the importance of investigations of the coal material itself has never, at least until recently, attracted the imagination of either practical men or scientists in spite of the fact that one would naturally suppose that the fundamental position of coal in the energy picture would attract consideration of its character. There appear to me to be two possible reasons for this.

Coal has been prevailingly regarded as an essentially uniform homogeneous substance. Its complexity of chemical composition has been realized, but in general it has been regarded as material composed throughout of fairly similar complex molecules, possibly pictured as coal molecules. This material varies slightly from place to place but is essentially the same within the given area such as a mine except for the mineral impurities with which it is mixed.

This generalized conception ~~of the nature~~ of coal conforms with and is sustained by the prevailing method of chemical description. The proximate form of analysis is a generalized method of describing coal as a material consisting of volatile matter, moisture, non-volatile, combustible matter or fixed carbon, and a residue called ash. This, of course, provides no picture of coal at all as a definite substance but pictures it entirely in terms of factors involved in its utilization.

The calorific determinations have the same effect. The B.t.u. value as determined in the laboratory represents essentially the total heat energy available by combustion from the available carbon and hydrogen in the coal. The experimental determination corresponds very closely with theoretical values so that presumably essentially complete combustion takes place in the calorimeter. It obviously makes no difference how the hydrogen and carbon are combined or occur in the coal in regard to the potential energy of combustion available. The enterprise operating an incinerating plant as a source of energy is unconcerned whether the raw material fed into the furnace is available carbon and hydrogen in the shape of discarded lilies or of the remains of the ally serenader. The same logical attitude is adopted toward coal considered as a source of available carbon and hydrogen.

This generalized conception of coal has resulted in a very characteristic attitude in regard to its production and utilization. Since its constitution is of little concern, preparation for its utilization other than removal from the bed involves simply removal of as much foreign material as possible and adjustment of size such as is required by the devices perfected for the combustion process. It is quite obvious that in adopting this point of view the major field of investigation is that of combustion, and once the principles of perfect combustion are understood there is nothing further to be accomplished by research except the perfection of methods for preparing the coal for use under such conditions. It seems to be a very reasonable point of view on the basis of the premises upon which it has proceded, and accounts for a general lack of interest in investigations concerning the nature of coal.

What it is my desire to do at this time is to bring to your attention the inadequacy of the conventional attitude toward coal and to indicate the implications with respect to preparation and utilization residing in a more naturalistic conception of coal.

First it would be well to explain what is meant by a naturalistic attitude.

From the standpoint of the naturalist, particularly the geologist and botanist, coal is a rock, or aggregate of materials which the botanist is able to identify as originally derived from plants. It is composed of these original plant parts, just as most other rocks are mineral aggregates, mixed with certain and varying amounts of mineral materials. It is consistent to call the plant parts in the coal <u>phyterals</u> just as the component parts of other rocks are called minerals. From the naturalistic point of view, then, coal is an aggregate of phyterals, not simply a generalized combination of moisture, ash, volatile matter and fixed carbon, or carbon and available hydrogen mixed with a lot of inert materials. This constitutes the naturalistic attitude.

The same attitude toward the ash residual from the combustion of coal finds it necessary to consider mineral matter from which the ash was derived and the nature of its occurrence in coal.

From the naturalistic point of view the conventional methods of considering and describing coal are entirely inadequate; from the conventional point of view the naturalistic attitude is unnecessarily complicated and impractical. The truth probably lies somewhere between these two points of view.

From the standpoint of the combustion technologist coal under conditions where complete combustion takes place is simply available carbon and hydrogen mixed with inert material. The conversion of the heat of this combustion into usable form of energy (that is, steam pressure) has reached a surprising degree of efficiency in some operations. Similar efficiency is generally impossible for all operations, and indeed is probably not to be expected in most operations. It is a practical impossibility. The combustion technologist may gnash his teeth over this condition but the fact of the inefficiency of most combustion apparatuses must be faced, which means obviously that possibilities of improvement of the combustion performance of such devices through possible adjustments in the character of the fuel must be considered. So far as the coal industry of Illinois is concerned it is of little importance to the marketing condition of these coals that certain steam generating installations presumably burning eastern coal, since they are located in the market area of those coals, achieve an efficiency of 90 per cent more or less. The adaptability of Illinois coal to the particular type of equipment is open to demonstration but what is more to the point is that this particular type of efficient equipment is entirely out of possibility of use by probably 90 per cent of users of Illinois coal or other fuel within the Illinois coal market area. The problem is one of modifying Illinois coal to make more efficiently utilization possible by these inefficient types of equipment.

The general point I wish to make is that there are definite limitations to the possibilities of benefit to the coal industry in the conventional generalized attitude toward coal as a material consisting simply of carbon available hydrogen and inert materials, and that when this limit is reached there will be a tendency to search the possibilities of relief residing in the naturalistic conception of coal. Indeed this is about the only source of enlarged possibilities of usefulness left, onee the conventional procedure attains an efficiency of 90 to 95 per cent when conditions are favorable. I am not forgetting, however, the possibility of re-

'insert to page 7'

I would regret being misunderstood to the extent that these statements in regard to the conventional generalogy conception carry the implication that I believe no further progress can be made by investigation along such lines, or that the Survey has abandoned assembling information that may relate to such utilization. Neither implication would be correct for much improvement on utilization of Illinois coal in the small industrial and domestic plant is possible, and the Coal Section of the Survey devotes three-fourths or more of its time on matters relating to the conventional conception of coal. This paper, however, concerns the significance of studies of the constitution of coals and necessarily that part of our studies is emphasized.

lief that resides in processing the coal by heat and briquetting to provide manufactured fuels.

Insert >

It is now pertinent ~~to the argument~~ to call attention more specifically to the meaning of the naturalistic consideration of coal, and to indicate the possibilities of modifying the character of coal or of employing it for special uses that reside in its constitutional character.

Coal must be considered as a rock material if viewed from a naturalistic point of view. It is composed of more or less coalified plant materials or phyterals, mineral charcoal (or fusain), and varying quantities of mineral matter, some of which is foreign mineral matter washed or blown into the bed, and some organic mineral matter. As a rock Illinois coal possesses the usual lithologic characteristics of normal banded bituminous coal to which type of coal it belongs. One of the first characteristics of Illinois coal that one observes ~~in viewing it as a natural substance~~ is its banded character, ~~(Figure 1). The fact that it is banded is an~~ indicating that it is composed of several sorts of material. In Illinois coal three varieties of material, each distributed in thin lenses, produce the banded appearance on the faces of the coal in the bed and on broken blocks. The ~~so-called~~ banded ingredients ~~of Illinois coal~~ represent very definite, distinguishable, and separable portions of the coal bed. There are four such ingredients in normal bituminous coals as a group, namely; vitrain, or the brilliant jet black coal; clarain, the bright, laminated coal which makes up the bulk of our Illinois coal beds, the mineral charcoal, or fusain, and occasionally splint coal, or durain. This latter is a dull variety of coal resembling clarain in general structure and texture but distinctly dull in luster. It is rare in Illinois coals but is occasionally found, particularly in Herrin No. 6 coal bed in southern Illinois, in thin layers rarely as much as two inches in thickness.

Very casual inspection should be enough to convince one ~~most anyone~~ that these ingredients are present in Illinois coals, and they have sufficiently different general appearance so that difference in chemical characteristics and behavior under similar conditions might reasonably be expected. Furthermore examination of one coal bed in southern Illinois has shown that the proportion of these ingredients in the bed differs considerably from place to place (Fig. 2).

That the physical dissimilarity of the banded ingredients of Illinois coal is paralled by dissimilarity of chemical character, even when expressed in the generalized terms of the proximate and ultimate analysis, is indicated by sixty analyses more or less that have been made of these ingredients separated by hand from various Illinois coals. There are very definite chemical differences among the ingredients (Fig. 3) that are consistent from coal to coal, but are not of the same importance in all coals. It is noteworthy that in general differences between ingredients in terms of the proximate values decrease with the rank of the coal, so that the higher the rank of the coal the less the

the importance of the variations in the relative amount of the ingredients in the coal.

It is possibly needless to say that evaluation of the character of the ingredients in the terms of such a generalized form of analysis as the proximate analysis is exceedingly unsatisfactory for it provides no basis for determination of the real differences that exist. All differences are expressed in the terms used in evaluating coal with respect to its available energy in combustion, that is in terms of available carbon and hydrogen. Some other basis of comparison is desirable.

Not only do the banded ingredients possess individuality in general appearance and chemical character as revealed by the proximate analysis but they possess individual physical characteristics so that they are differently affected by the mining and preparation processes.

The effect of blasting, handling, sizing, and gravity separation upon the proportion of the ingredients in different portions of the prepared coal has been under investigation by Mr. Louis C. McCabe of the State Geological Survey, in cooperation with the University of Illinois Engineering Experiment Station and the Department of Mining and Metallurgy, for some time. One report on this subject has recently been published[1] ~~by the Survey as Report of Investigations No. 34, under the title,~~ "Banded Ingredients of No. 6 Coal and Their Heating Values as Related to Washability Characteristics". In this investigation the segregation of the different band ingredients

[1] McCabe, Louis C., "Banded Ingredients of No. 6 Coal and Their Heating Values as Related to Washability Characteristics", Illinois State Geol. Survey Rept. Inv. No. 34, 1

in the different gravity fractions of the coal was very definitely demonstrated (Fig. 4).

At the present time an investigation is underway which involves the collection of samples of screenings from ten mines, screen, and float-and-sink analyses and a large amount of chemical work, and also physical analysis of the ingredients in each fraction of coal. This will result in an enormous amount of information concerning the segregation of the ingredients in the different specific gravity fractions by screen size that should be extremely illuminating as to the effect upon coal of preparation processes and the potential possibilities of segregation and blending.

When segregation of the ingredients takes place the effect is usually shown in at least three ways. There is a general tendency for concentration of fusain in the dust. This is now generally recognized in dedusting technique. This particular technique, by the way, has done much to attract interest to the segregating effect of the cleaning process. Segregation of vitrain takes place in light fractions of coal of fine size, although somewhat coarser than the fractions in which fusain is the prevailing ingredient. The coarser and heavier fractions vary in character from clarain (Fig. 5) with low ash content to clarain with high ash content, bony coal, and finally pure mineral matter. (Fig. 5).

Knowledge of the physical characteristics of the banded ingredients will make it possible to devise procedures of mechanical separation which may be fitted into the present scheme of separation without great difficulty. Fusain is the most easily pulverized of the three most common ingredients, hence aspirated material is largely fusain as has been previously noted. Vitrain is brittle and resiliant and generally characterized by fine cracks which tend to cause its segregation in the medium fine sizes. Clarain is relatively tough and not penetrated by cracks as is vitrain and hence is less likely to break down to small sizes than vitrain or fusain.

The ~~extent to which knowledge of the~~ possibili~~ty~~e of segregating and blending banded ingredients to supply definite blended types of coal ~~will be of~~ cannot be practical value ~~is impossible to~~ foret~~ell~~old. We know that the characteristics of the different ingredients differ greatly. Vitrain is characterized by an exceedingly low ash content and a tendency to swell greatly upon heating. Fusain is conspicuously high in fixed carbon, about 80 to 85 per cent in the dry condition, ~~and~~ it is commonly very inert under carbonizing conditions, and it possesses no binding properties such as are essential for the formation of good impaction briquets. Added to coal with much vitrain a little fusain improves the quality of coke over that produced from the raw coal. Both vitrain and clarain have positive coking reaction but apparently in some cases addition of vitrain to a natural coal improves the strength of the coke (Fig. 6). With only the criteria supplied by the generalized type of analytical data available for evaluating or indicating the nature of the ingredients there is a limited number of variable possibilities of designation, but even on this basis it is apparent that it is quite possible to produce coal material of widely different character on the one hand or a coal of very uniform character on the other by systematic segregation and blending procedure. The ability to control the nature of coal reaching the market is of significance because:

1. It permits close control over coking mixtures;

2. It permits segregation of those parts of the coal best suited for the production of manufactured liquid and gaseous fuels;

3. It permits blending to produce particular burning characteristics; and

4. It permits isolation of easily pulverized ingredients for use as powdered fuel.

The possibilities of variability in the coal residing in its banded constitution gives only part of the picture provided by the naturalistic consideration of coal.

The character of each of the banded ingredients varies from that of the other three in the nature of the phyterals of which it is composed. That is to say, vitrain (Fig. 7) is coalified woody material, and as such has been named anthraxylon by R. Thiessen. Clarain (Fig. 8) is attrital material, representing all kinds of plant debris, wood shreds, pollen, resins, spore exines, cuticular residues, and all the spindrift of the coal measure forest. Fusain (Fig. 9) is either actually fossil charcoal or carbonized wood produced by some other agency other than ~~by~~ fire. In general it is derived from the same sort of material as vitrain but is carbonized rather than coalified.

Clarain is characterized by great variation in the character of its phyterals. Some clarain contains a great many spore exines, ~~(Fig. 10)~~, others only a little. Vitrain likewise not uncommonly contains a great quantity of resin ~~(Fig. 11)~~, although other vitrain may show none.

Unless the process of coalification ~~levels off~~ diminishes the original differences that must have existed among the plant parts enmeshed in the coal swamp, it seems altogether probable that there are differences in the phyterals, particularly as so many of them appear to retain much of their original appearance~~s~~. Spores can be isolated intact (Fig. 12), crushed flat it is true but otherwise with their original characteristics preserved. Cuticles (Fig. 13) can be isolated from the coal by the exercise of some care, retaining many of their original characteristics and structural features. (Fig. 14, out). Resins (Fig. 15) have usually been somewhat carbonized but are readily recognized.

Observation of the phyterals found in the coal impresses the observer with the probability that the different entities commonly still retain some of their original individuality. If this is the case it is quite apparent that vitrain will vary in character as it contains much or little resinous matter, and that a considerable range of variation in the composition of clarain is possible, depending upon whether woody fragments, cuticular waxes, resins, or other materials are present. The effect upon the character of the coal because of variations in its phyteral composition can only be inferred. There is as yet no information in regard to what this effect may be except the information provided by analyses of the banded ingredients. We know that the vitrain is of woody origin, and that clarain commonly contains a much higher amount of waxy constituents than is found in the vitrain. The proximate or ultimate analysis, as has repeatedly been stated, provides a very unsatisfactory basis for differentiation, because as has been repeatedly pointed out, the whole purpose of these analyses is to indicate the composition of the coal in terms of its combustibility. On the other hand if we actually find resins, waxes, and humic materials in the coal it seems to be highly desirous to regard coal in terms of its actual composition, rather than its combustibility, if a true picture of its character is desired.

That knowledge of the immediate constitution of the coal will eventually prove of great practical value in planning uses for coal either through the possibility of segregation of coal of peculiar characteristics suitable for special uses seems to the speaker inevitable. At any rate this naturalistic conception of coal opens up a new field of speculation and experimental investigation. But I believe much depends on the development or a much more definite conception of the immediate chemical character of the coal than is supplied by analyses which indicate the combustibility characteristics and nothing else.

Before closing it is important that some reference be made to the investigations of the mineral matter of coal that are being carried forward in connection with other investigations of the immediate constitution of coal, since these investigations are quite different from the usual investigations of coal ash.

Much of the mineral matter in coal is extraneous in character, that is, it is not organic mineral matter. As a matter of fact the amount of organic mineral matter is probably relatively small, so that the source of most of the material that is left as a residue from combustion is present in the coal as discrete mineral particles. It has been our belief that the only satisfactory method of understanding the nature, occurrence of ash, and its behavior during combustion was through a study of the mineral matter present in the coal and capable of identification and to a certain extent of actual isolation by physical means.

In the strength of this belief a column of Herrin No. 6 coal collected in the New Orient mine at West Frankfort, representing the entire bed, was subjected to detailed study, to determine the nature of the minerals that could be isolated by precise gravity separation technique. As a result of study and the analysis of coal residues from which all possible mineral matter had been removed, the character

2/ McCabe, L.C., Mitchell, D.R., and Cady, G.H., Proximate Analyses and Screen Tests of Coal Mine Screenings Produced in Illinois: Illinois State Geol. Survey Rept. Inv. 38, 1935.

of the minerals and their distribution in the bed was determined with great detail (Fig. 16 Diagram). The results of this investigation ~~have just been~~ are being published.[2] ~~or will appear within a few days.~~ They give irrefutable evidence that the mineral matter in that particular bed of coal consists to at least 98 per cent of the four minerals, calcite, kaolinite, kaolinite as clay, and pyrite. All other minerals, traces of quite a variety being found, amounting to not more than two per cent of the total mineral matter, not of the coal. A considerable portion of this 2-per cent consists of silica. These data indicate very definitely that the behavior of ash in the fire box, that is, its fusion characteristics, is determined by the variations in the amount of a relatively small number of minerals. This, of course, makes the control of the fusion temperature a much simpler problem than if a large number of minerals were involved, it also explains very definitely why variations in the softening temperature of the ash have been observed as a result of mechanical cleaning of the coal, since by such practice selective elimination of the minerals takes place, resulting in the concentration of certain minerals in certain grades of coal with the resulting change of the softening temperature of the ash.

Since this investigation was completed microscopic study of thin sections prepared from the same and other columns of No. 6 coal in southern Illinois has been made to determine the nature of occurrence of the mineral matter in the coal. It has been ~~pretty~~ rather definitely shown that cavities rarely exist in the coal. The original cavities such as were present in fusain and the desication cracks in vitrain cavities in resin rodlets, etc., are commonly filled with kaolinite (Fig. 17). Calcite may also be present in such cavities but it is usually of later origin (Fig. 18). This disseminated material, because of its intimate association with the coal, is difficult to remove. A great deal of the pyrite is disseminated through the coal (Fig. 19), but it is much more commonly found in segregated masses that are relatively easy to remove. In general the cleaning process probably tends to greater loss of the minerals that are effective in lowering the ash softening temperature, thereby improving the coal in that respect.

These studies that have been carried on in the nature and distribution of mineral matter in Illinois coal are the initial studies of the kind so far as is known. I believe that they will be of great practical value in removing from the field of speculation many of the elements involved in an understanding of the variations in the behavior of the ash of Illinois coals under high temperatures. In speaking in commendation of this work credit for carrying it forward should be given to my colleague, Dr. C. G. Ball.

Conclusion

It is my hope that in presenting this explanation of the work on the constitution of coal being carried on by the State Geological Survey, I have given you a correct idea of the possibilities residing in the naturalistic conception of coal as compared with the traditional conception based upon the generalized picture of coal. Without such a naturalistic conception of coal I can see no hope of expansion in utilization except as it may be discovered by accidental means or undirected experiment. The traditional attitude toward coal ~~is~~ prohibit~~ive of~~s imaginative consideration of the possibilities of expanded utilization in so far as they reside in the coal itself. It is my thesis that a new attitude toward coal must be adopted and the adoption of such an attitude is possible only through recognition of resources of discovery residing in the naturalistic viewpoint.

~~Finis~~

Figure		Page

This merits publication as a separate pamphlet in cooperation with Eng. Exp. Station. Possibly as a progress report.

(10)

UTILIZATION OF COAL MINE WASTES

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Introduction

Within the past two or three years so many inquiries as to the possibility of procuring pyrite suitable for the manufacture of sulphuric acid from coal mine wastes were directed by acid manufacturers to the Engineering Experiment Station or members of its staff that it seemed advisable for the Experiment Station to look into the feasibility of utilizing such waste, for that or other purposes. For this reason the problem was given a project number in the Engineering Experiment Station and a preliminary field examination was made a year ago.

This examination was not encouraging from the standpoint of pyrite recovery but it did indicate that much good coal is going onto the dump in the form of table pickings at many of our mines, and that a thorough investigation of coal mine wastes was warranted from the standpoint of possible coal recovery, alone. Current production of waste includes not only the material that goes on the surface dumps, but a ~~very~~ considerable additional tonnage which is broken down but left underground in hand loading. All told, it is probable that as much as two million tons of waste material are developed at Illinois mines, annually.

Only one major phase of the problem of utilizing such material has been studied as yet. That is the characteristics of table pickings. These are all hand-selected materials, the criterion governing the rejection of a piece from a stream of coal as it flows over a picking table being a content of visible impurity. Presumably, every piece which includes a considerable amount of visible impurity goes into the reject (pickings) regardless of how much of it is coal. Although ~~While~~ an attempt is made to salvage the coal which adheres to the impurities in the largest pieces of pickings, most of it goes to the dump, where it constitutes not only a direct loss but in many cases a serious nuisance as well, due to spontaneous combustion.

Sampling

Pickings are highly heterogeneous both as to the size of particles and their composition. Tiny particles of coal are intermingled with huge pieces of rock, and all gradations of size and composition between these extremes are encountered in a mass of pickings.

This makes it extremely difficult to take a sample, and recourse was had to samples of large volume taken by small increments at frequent intervals, over a day's run. Where 6-inch or larger material was involved, as it frequently was, a ton or more of material was taken, with smaller sizes being sampled in proportion.

The typical tipple arrangement ~~is for~~ the pickings from the lump, egg and nut coals to go onto individual conveyors, each of which discharges onto a cross-conveyor, which carries all of the pickings to a dump receptacle. Wherever feasible, the stream of combined pickings was sampled, by cleaning off the material on a single flight of the last pickings conveyor, at regular intervals of a few minutes, throughout the working day. The material so chosen was sacked and shipped to the laboratory of the Department of Mining and Metallurgical Engineering at Urbana.

In some cases it was not possible to sample the main stream of rejected pickings, and separate samples had to be taken of the lump, egg and nut pickings. These were tested separately but an estimated composite sample was constructed by combining the results in the proportions of the estimated tonnages of lump, egg, and nut pickings, respectively.

Reduction and Testing of Samples.

Circumstances were such that it was necessary to store most of the material a few weeks, before it could be reduced and tested. One sample which was stored six weeks lost less than 2.5% per cent of its weight, presumably in moisture. None of them ~~should~~ showed appreciable signs of slacking or other deterioration as a result of storage.

Since, as has been indicated, much of the material consisted of mixtures of coal and rock, the samples were crushed to minus $1\frac{1}{2}$-inch, both to liberate the coal from the rock and to facilitate testing.

While coal-mine products are commonly crushed in roll crushers, the abundance of large modules of pyrite in some samples and of rock in all samples ~~is~~ led to the use of a heavy-duty gyratory crusher.

The steps ~~full~~ the flow sheet ~~which was~~ followed in reducing and testing the samples is shown in Fig. 1 which is self-explanatory.

Testing each sized product at two specific gravities (1.60 and 1.40) divided it into three products: 1.60-sink, or refuse; 1.40-1.60-middlings, and 1.40-float or clean coal. The latter should be marketable in all sizes tested, and the middlings should be usable at the mine, either as boiler fuel or for heating the surface plant and wash water. For this reason it will be referred to as boiler fuel. Any recoverable pyrite goes into the 1.60-sink or refuse fraction.

Three sizes of clean coal were produced by the tests, the $1\frac{1}{2}x\frac{3}{4}$-inch corresponding with commercial small-nut, and the $\frac{3}{4}x3/16$-inch with stoker coal. If produced in sufficient volume, as at a custom cleaning plant, the 3/16-inch x 65-mesh fines could be sold to pulverizing plants. Otherwise it could be mixed in with the larger sizes.

The minus 65-mesh coal is not considered ~~as being~~ of value, although it could be sent to pulverizing plants if ash requirements were not too rigid. This size constituted only a few per cent of each crushed sample, and it was not tested by float-and-sink methods.

Result of Float-and-Sink Tests.

The results of float-and-sink tests on screen samples of pickings are reviewed in Table 1 which includes estimates of the yield of coal and boiler fuel to be expected at each mine represented, were an efficient cleaning unit to be installed to treat its table pickings.

Roughly, one half the crushed pickings are small nut in size, 40% of them are stoker size, while the rest are fines. Without exception, the quality improves as the size decreases. However, there are marked variations in the per cent of clean coal in a given size, from sample to sample. For the nut size, this ranges from 17% clean coal in Sample 1 to 44% in Sample 6. For the fines the corresponding range is from 35 to 64% clean coal.

Considering the composite dust-free samples, their total content of clean coal ranges from 24% (Sample 2) to 51% (Sample 6) the mean for the seven samples represented in Table 1 being 37%. In addition, more than 10% of the material tested is suitable for local use as boiler fuel or for heating purposes.

While Table 1 indicates that only a comparatively small tonnage of coal might be recovered from the pickings at a given mine, it is clear that, in the aggregate, very large tonnages of clean coal are now being wasted in this state. If no more than one million tons of table pickings are being developed annually at present, the indications are that about one-third of this, or say 300,000 tons could be recovered as clean coal. If pickings could be treated at a cost of 30¢/ton or less, including all charges, either in individual units at each mine, or in larger custom plants serving the various producing districts, a net saving would result to the industry if the salvaged coal could be sold for as little as $1.00 per ton, at the cleaning plant. Since an appreciably higher average realization could reasonably be expected it appears that most of the Ill. coal which is now being wasted in table pickings might be conserved at a profit.

Analyses of Test Products.

Complete analyses of the test products are not available, but Table 2 gives the results for one of the more pyritic samples, which contained more than 43% ash and 16% sulphur. Just as Table 1 showed the quality of the sized products to improve with decrease in size, Table 2 shows that the same tendency holds as to the quality of the coal and boiler fuel fractions, i.e. each shows a decrease in ash and sulphur content, with decrease in size.

This probably means that the cleaner the coal the more friable it is and the more it tends to appear in the smaller sizes. Ash in the clean coal ranged from 5.1% in the fines to 8.8% in the small nut, averaging 7.8%. Similarly sulphur in this product ranged from 3.6 to 4.1, averaging 4.0%. In the boiler fuel sulphur averaged 6.0% and ash 22.3%. The greatest concentration of sulphur (27.4%) was in the refuse (1.60-sink) from the small nut size. The composite refuse from Sample 3 averaged 23.7% sulphur and 63.5% ash.

Pyrite Recovery.

Any pyrite to be recovered would come from the refuse or 1.60-sink fraction of the pickings. Inasmuch as pure pyrite is 54% sulphur, the refuse of Sample 3 must have been 44% pyrite if all its sulphur were pyritic. With proper crushing a concentration of pyrite, which has a specific gravity of 5.0, should be readily separable from the much lighter shales and residues with which it is associated in the refuse fraction from the sink-and-float tests. It is planned to determine the pyrite content of some of the more promising 1.60-sink fractions by retesting them in acetylene tetrabromide which has a specific gravity of nearly 3.0. The sink from this test should be nearly pure pyrite.

Although the indications are clear that considerable tonnages of pyrite could be recovered from Illinois picking-table refuse the economic feasibility of doing so in the near future is in doubt because the comparatively high cost of producing and shipping a pyritic concentrate of sufficient purity to meet the proposed specifications would hardly be covered by the quoted prices of only a few dollars per ton of concentrate, delivered at the acid plant. However, as the investigation proceeds better data will be developed for gaging the feasibility of marketing pyrite from Illinois coal mine wastes.

Summary.

Summarizing, the results of the investigation to date indicate that it would be technically possible to produce substantial tonnages of pyritic concentrate from the table pickings at many Illinois coal mines but the economic feasibility of doing so under present market conditions is highly doubtful.

However, the investigation has shown that thousands of tons of clean coal are being wasted annually in the pickings from Illinois coal. It is apparent that most of this valuable waste could, under efficient procedure, be recovered at a profit.

Table 1. Estimated Yield of Coal from Dust-free (+65-mesh) Pickings

Sample No.	Ill. Seam No.	Ldg. Meth. (a)	Size Symbol (b)	Size % Wt.	Composition (% by Weight) Coal	Composition (% by Weight) Fuel	Composition (% by Weight) Refuse	Estimated Yield (Tons per day) Pickings	Estimated Yield (Tons per day) Clean Coal	Estimated Yield (Tons per day) Boiler Fuel
			n	49	17	8	75	--	25	12
			s	41	31	12	57	--	38	15
1	6	m	f	10	35	12	52	--	11	4
			all	100	25	10	65	300	74	31
			n	50	18	14	68	--	9	7
			s	37	27	14	59	--	10	5
2	6	m	f	13	40	13	47	--	5	2
			all	100	24	14	62	100	24	14
			n	46	26	6	68	--	36	9
			s	42	34	8	58	--	43	10
3	6	m	f	12	45	8	47	--	15	2
			all	100	31	7	62	300	94	21
			n	47	31	9	60	--	23	7
			s	40	43	10	47	--	28	7
4	6	m(c)	f	13	57	6	37	--	12	1
			all	100	39	9	52	160	63	15
			n	51	33	15	52	--	10	5
			s	43	48	11	41	--	12	3
5	6	m	f	6	56	8	36	--	2	--
			all	100	41	13	46	60	24	8
			n	54	44	8	48	--	10	2
			s	41	58	9	33	--	9	1
6	5	m	f	5	63	8	29	--	1	--
			all	100	51	8	41	40	20	3
			n	49	31	15	54	--	4	2
			s	37	58	14	28	--	5	1
7	5	h	f	14	64	11	25	--	2	--
			all	100	46	15	39	25	11	3

(a) Loading method. h = hand loading. m = mechanical loading.
(b) n = 1½x¾-in. small nut; s = ¾x3/16-in. stoker; f = 3/16-in.x65-mesh fines. All is plus 65-mesh.
(c) Strip mine.

Table 2. Analyses of Test Products from Sample 3

Size	% of Sample*	Product	% of this Size*	Analyses (%) Moisture	Ash	Sulphur
small nut 1/ x ¼-inch	46	coal	26	2.8	8.8	4.1
		boiler fuel	6	2.0	23.6	6.1
		refuse	68	0.8	63.3	27.4
			100			
stoker ¼ x 3/16-inch	42	coal	34	2.8	7.7	3.9
		boiler fuel	8	2.5	22.0	6.0
		refuse	58	1.2	63.2	21.6
			100			
fines 3/16-inch x 65-mesh	12	coal	45	3.3	5.1	3.6
		boiler fuel	8	1.8	18.0	4.9
		refuse	47	1.6	65.0	15.0
			100			
all	100	coal	31	2.9	7.8	4.0
		boiler fuel	7	2.2	22.3	6.0
		refuse	62	1.0	63.5	23.7
			100			
composite				1.7	43.4	16.3

*from Table 1.

Published in "Combustion"
June 1935

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SELECTION AND DESIGN OF EQUIPMENT FOR BURNING ILLINOIS COAL

by

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The subject of this paper is the selection and the design of equipment for burning Illinois coal, and the paper limits itself to the use of Illinois coal as fuel for making steam. The physical and chemical properties that affect the burning of coal can be briefly stated as follows.

Hard

Dirt in fines

Layers cubes

Handles well

Illinois coal is hard; it is generally harder than the impurities that it contains. For this reason lump coal usually has lower ash content than slack. The coal is of laminar structure consisting of thin layers of shiny black material alternating with dull brownish substance. It breaks along the layers and at right angles to the layers. This tendency of fracture gives the lumps somewhat cubical shapes. Owing to its hardness the coal stands handling without excessive breakage.

High ash & S.

L.F.P

Free Burning

High Vol.

Storage

Compared to eastern coals the Illinois coal contains high percentage of ash and sulphur, and the ash fuses at low temperature. The coal is free burning, that is it does not soften and fuse into large masses of semi-coke, but the individual pieces keep their shape and remain separate until completely burned. When the coal is heated a large part of the combustible is driven off as gas, and when improperly burned produces dense black smoke. In storage the coal is inclined to spontaneous combustion and therefore does not store well.

Fig. 1

Of the different types of mechanical stokers now on the market the traveling grate stoker is the best suited for burning Illinois coal. Traveling grate stoker is a mechanical device for continuously feeding coal into the furnace and also continually removing the ash remaining on the grate after the coal has burned off. The moving grate is in the form of an endless belt running over two pulleys and located at the bottom of the furnace. As the grate moves over the pulleys coal comes in at one end, burns to ash as it moves across the furnace and/the ash drops off at the other end of the moving grate into an ash pit. ~~The upper part of the traveling grate is placed over air compartments to which air is supplied under pressure. Thus, the air can be supplied to the fuel in parallel zones extending across the width of the furnace at any desired pressure.~~

Fig. 1.

The traveling grate stoker is illustrated in Figure 1. The coal flows by gravity from the small hopper onto the grate and with it moves through the furnace. Air at various pressures is supplied through the compartments under the grate. ~~as shown in the illustration.~~ By the time the coal has reached the rear end of the furnace practically all of the combustible is burned off and only ash remains. The ash is dropped over the end of the stoker into the ash pit, from which it is removed through the ash pit door into the car which hauls it away. In the illustration is shown a device for returning the cinders caught in the two hoppers, ~~back in~~to the furnace. One of ~~these cinder hoppers~~ which is emptied through the arch of the furnace and the other through the rear wall.

Free from fines

The natural hardness of the coal keeps it comparatively free from excessive fines. This comparative freedom from excessive fines makes the resistance of the fuel bed to the flow of air nearly uniform over the entire grate, which in turn ~~This nearly uniform resistance~~ results in a uniform flow of air ~~over the entire grate~~ and freedom from burned-out holes in the fuel bed. It also prevents to a large extent short and long fires existing at the same time. ~~at the rear of the stoker.~~

uniform air flow

Free burning

Owing to the free burning property, the individual pieces of coal burn separately without fusing together into large masses of semi-coke, the air is nearly uniformly distributed over the fuel bed ~~grate~~ and the coal burns evenly over the full width of the grate. This is the principal requisite of a good traveling grate stoker coal. The opposite of free burning coal is caking coal. Such coals when burned on a traveling grate become pasty and fuse into large slabs of semi-coke. These slabs crack in few places and the air ~~supplied through the grate~~ flows only through the cracks and not through the center parts of the slabs, with the result that these slabs of semi-coke do not burn completely by the time they reach the end of the grate, and thus a large percentage of the combustible matter is wasted with the ashes.

[ash cover]

The comparatively high ash content of the Illinois coal is another requisite of a good traveling grate stoker fuel. The burned out ash on the rear part of the stoker forms a substantial cover over the grate and protects the latter against the reflected heat from the arch. Because of the fact that during the passage of the coal through the furnace the fuel bed is not agitated, the ash is not lifted into the hot fire and fused into hard clinker. Any clinker that is formed is soft and spongy and is not detrimental to the operation of the stoker.

[no hard slag]

[Coking coals agitation necessary]

When coking coals are burned on the grate the fuel bed must be agitated to break the large ~~masses~~ pieces of semi-coke. Such agitation lifts the ash into the burning fuel and ~~when~~ if the ash has low melting temperature ~~the ash~~ it is fused into sticky clinkers. The eastern coals are caking coals; they are generally burned on multiple retort underfeed stokers which ~~is~~ are designed for agitation of the fuel bed to break the large masses of semi-coke. The eastern coals, however, have ash with comparatively high melting temperature.

[Fig. 2]

[Combustion T. grate]

The gases rising from the fuel bed on the front part of the ~~chain~~ traveling grate stoker contain a high percentage of combustible which must be mixed with air and burned before it leaves the furnace, otherwise smoke is produced. The furnace above the grate must be designed to facilitate this mixing and combustion. The rear arch furnace design shown in Figure 1 gives very good results in this respect. The rear arch directs the air flowing into the furnace around the rear end and through the rear part of the stoker into the stream of combustible gas rising from the front part of the stoker. The two streams are mixed while passing through the comparatively narrow throat between the nose of the arch and the front wall, and the combustible burns in the combustion space ~~between~~ above the throat. ~~and under the boiler.~~

Figure 2 shows what is likely to happen in a badly designed furnace shown in outline in the lower part of the figure. The upper part of the figure contains two charts; the chart on the left gives the composition of gases rising from the fuel bed of ~~a~~ the traveling grate stoker. The chart on the right gives the gas composition at the section where the furnace gases enter the boiler. The composition of the gases rising from the fuel bed ~~were~~ was obtained by ~~collecting~~ the analysis of gas samples ~~of gases~~ collected 2 inches above the top of the fuel bed at various points indicated in the figure by the small circles. The~~se samples~~ analyses were ~~analyzed and the results~~ plotted on the chart directly above the sampling point. The composition of furnace gases entering the boiler were obtained by ~~collecting~~ the analysis of gas samples collected above the first row of boiler tubes at the points indicated by the small circles shown in the figure. The chart under the grate gives the pressures in the various air compartments under the grate. The gases at points 1 to 5 inclusive contain a large percentage of combustible and very little or no oxygen to burn this combustible. The gases at points 6 to 7a inclusive contain no combustible but very large percentages of free oxygen. Because the furnace was poorly designed the combustible gas was not mixed with the free oxygen, and the two streams flowed separately into the boiler. As indicated by the analysis of gases in the first pass the two points on the left of the second chart show very high carbon dioxide content, high carbon monoxide, and practically no free oxygen, whereas the two points near the rear wall show a very low percentage of carbon dioxide and a very high percentage of oxygen. The furnace smoked badly even at moderate ratings and the Smoke Inspector threatened to shut down the plant.

Figure 3 shows the same furnace as Figure 2 modified to eliminate the smoke. The modification consists of a provisional rear arch placed close over the grate. This arch directed the air passing around the end and through the rear part of the grate into the stream of combustible gas. The two streams were fairly well mixed by passing ~~between~~ through the throat formed by the rear and front arch. Most of the combustible gas burned before it entered the boiler. The composition of the gases in the first pass was nearly uniform across the whole pass, as is indicated by the two curves in the chart above the rear part of the furnace.

With a uniform bed of burning fuel no free oxygen passes through the fuel bed; all the oxygen is ~~combines~~ combined with carbon either as carbon monoxide or carbon dioxide. Free oxygen must be admitted over the fuel bed and mixed with the gases in order that the combustible may be burned. With a traveling grate stoker such free oxygen enters the furnace around the end and through the rear part of the stoker. Some air may be also supplied through holes in the arches. The furnace must be designed to produce mixing of the two streams of gases, and ~~combustible~~ combustion space must be provided so that combustion can take place. It may be suggested that the combustible rising from the fuel bed is mostly the volatile matter of the coal and that if the fuel did not contain the volatile matter the oxygen might possibly work its way through the fuel bed uncombined.

Figure 4 shows that the gases rising from a ~~fuel~~ bed of burning fuel contain large percentages of combustible even though the fuel is coke and the fuel bed only 6 inches thick. The figure gives the results of a study of combustion in the fuel bed of a burning coke, ~~This~~ which study was made at the Bureau of Mines nearly twenty years ago. The figure is a combination of five charts giving the composition of gases in a 6-inch fuel bed of burning coke at five different rates of combustion. The top chart represents the rate of combustion of 20 pounds of coke per square foot of grate per hour, the second chart below represents rate of combustion of 38 pounds, the third chart below represents rate of combustion of 51 pounds, the fourth chart the rate of combustion of 71 pounds, and the bottom chart the rate of combustion of 106 pounds. On the left the ordinates of the charts give the percentages of each constituent of the gases, the ordinates on the right give the temperature in the fuel bed. The abscissa gives the height above the grate in inches. The fuel bed was 6 inches thick and samples of gas were collected $1\frac{1}{2}$ inches, 3 inches and $4\frac{1}{2}$ inches above the grate in the fuel bed, also at the surface of the fuel bed and $1\frac{1}{2}$ inches from the top of the fuel bed. It is interesting to note that in every case there was no free oxygen at the top of the fuel bed, in fact most of the free oxygen disappeared $4\frac{1}{2}$ inches above the grate. Higher ~~The~~ rate of combustion was obtained by forcing more air through the fuel bed. For example, in test 42 with the rate of combustion 106 pounds the weight of air supplied through the fuel bed was $5\frac{1}{4}$ times the weight of air supplied in test 48 having rate of combustion of only 20 pounds. This means that the oxygen ~~will~~ combines with the carbon as fast as it is supplied, and the composition of gases in the fuel bed and above it remains practically the same for all rates of air supply and rates of combustion. It will be noted that the combustible at the top of the fuel bed is about 16 per cent with all rates of combustion.

Figure 5 shows a traveling grate stoker installation under a bent tube boiler, designed for burning high volatile Kansas coal. This furnace is characterized by rear arch narrow throat and large combustion space above the throat for burning combustible gases. ~~The furnace was~~ designed for burning high volatile Kansas coal. Both arches ~~of the furnace of Figure 5~~ are made of water-cooled tubes. The side walls above the throat are also water cooled and ~~Besides this water cooling~~ there is a water-cooled tube on each side of the furnace just above the grate. These tubes in the side walls prevent the ash from sticking to the side walls and dragging of the fuel bed along the walls. For Illinois coal, a water-cooled furnace is very desirable. It greatly reduces the maintenance and the outage of the furnace. The installations shown in Figures 1 and 5 are well adapted for burning Illinois coal without smoke.

Range 10M 100M

The traveling grate type of stoker is used for units varying in size corresponding to 10,000 to 100,000 pounds of steam per hour. For smaller boilers type E stoker or the so-called spreading stoker are used with satisfactory results. In such cases the selection of the equipment is made largely on the basis of low cost rather than on the excellence of performance. For units larger than 100,000 pounds of steam per hour the traveling type of stoker becomes too large and costly both in first cost and maintenance. Large stokers must be built very heavy to prevent distortion by driving mechanism or deformation by heat and the stalling of the stoker. The difficulty of keeping a uniform length of fire increases with the width of the stoker; the wider the stoker the greater the chance of having long and short fires at the same time.

Type E Spreading

Larger units than 100M

It does not mean that all installations with steaming capacity of 10,000 to 100,000 pounds of steam are to be traveling grate stokers and above 100,000 pounds of steam per hour all to be powdered coal. There are many powdered coal installations with a steam output in the above range. Such pulverized coal installations are put in because of special local advantages, personal likings, or some peculiar load conditions favoring pulverized coal. It means, however, that in this range of sizes 10,000 to 100,000 pounds of steam, the stoker partisan has ~~real~~ an argument in his favor.

With large steam generating units it is difficult to get in enough grate area to give the required high steam output. The capacity of the steam generating unit increases as the cube of the linear dimension, whereas the great area increases only as a square. The pulverized coal furnace, however, increases also as the cube of the linear dimension. The large steam generating units of today are fired ~~by~~ with pulverized coal. ~~Pulverized coal~~ which has a number of advantages ~~which~~ appealing to many engineers. A pulverized coal plant can use any coal that is available on the market and thus be independent of the coal supply. The plant can burn fuel oil or natural gas in the same furnace, and in fact, even with the same burners as pulverized coal; therefore, the change from one fuel to the other can be made on very short notice without any structural changes. The operating thermal efficiency of pulverized coal is usually higher than it is with stoker plant. This high termal efficiency is obtained because of lower ash pit losses and very small or no banking losses.

Illinois coal is well suited to pulverized coal firing. The high volatile matter content ~~makes it~~ causes the coal to ignite quickly, and stable fire is maintained even at very low rate of working. ~~Its~~ The natural hardness is somewhat against ~~it~~ the coal because it reduces the output of the pulverizer, and increases the power consumption per ton of coal pulverized. The maintenance of the pulverizers is also somewhat higher than it is with the soft eastern coals. However, with proper selection of ~~the~~ pulverizing mills ~~used for pulverization~~, this disadvantage due to ~~its~~ the hardness is negligible. The high percentage of ash and its low fusion temperature are also somewhat against the coal. The higher ash content increases the cost of pulverization and is apt to cause greater dust nuisance resulting from the large quantity of ash being discharged with the gases from the stack. The low fusion temperature is an advantage with slag tap furnaces because the ash is easily removed in molten state. It is also a disadvantage because molten ash is carried into the boiler and may be deposited on the boiler tubes thus clogging the gas passages and necessitating a forced shut down. This is particularly true of slag tap furnaces. However, with a proper design of the steam generating unit, including the boiler, the furnace, and the ash disposal system, the drawbacks due to high ash contents and low fusion temperature can be nullified.

P.C and oil & gas

High Eff

Suitability Ill. coal to P.C.

Slag Tap

Slag on boiler tubes

With pulverized coal firing, the entire process of combustion takes place in the combustion space. With stoker firing approximately half of the combustion takes place in the fuel bed and the other half in the combustion space. This means that the combustion space of the pulverized coal furnace must be at least double the size of the combustion space of a stoker fired furnace. The usual rate of combustion of Illinois coal when burned in pulverized form is one to two pounds of coal per cubic foot of furnace volume per hour. In a few installations the rate of combustion reaches 2½ pounds per cubic foot and in still fewer installations to 3 pounds of coal per cubic foot. These high rates of combustion are usually of short duration being used only during the peak loads. The rate of combustion is largely determined by the design of the furnace and the selection of material used in its construction. If the furnace is lined with refractories the rate of combustion is always under 1½ pounds of coal per cubic foot, and corresponds somewhere to a heat release of 14,000 to 16,000 B.t.u. per cubic foot of furnace volume per hour. If in ~~these~~ such furnaces higher rates of heat release ~~rates~~ are used, the refractory lining is rapidly wasted away by the molten particles of ash that are sprayed on it by the pulverized coal flame. Such wasting away of refractory lining results in frequent shut down of the unit and high cost of maintenance. Therefore, refractory lined furnaces should be designed with ample combustion space. The burners should be so designed and located in the furnace, as not to cause flame impingement against the refractory lined furnace walls.

~~The~~ Water-cooled furnaces should be used wherever ~~it~~ they can be economically justified. ~~The~~ Water-cooled furnaces permit~~s~~ higher rates of heat liberation and greatly lower~~s~~ the furnace maintenance, besides permitting the units to be in service for long periods of time. They are indispensable for large steam generating units because it ~~would be~~ is very difficult if not impossible to build and maintain in service wide and high refractory walls.

In water-cooled furnaces the walls simply consist of a row of steel tubes through which water circulates, the tubes of the walls ~~are~~ being connected into the boiler water circulation. In other words, the boiler is extended and built around the furnace. The tubes may be either bare or covered with refractory or cast iron blocks. The bare tube furnace walls are cheaper, have lower maintenance and the combustion of coal in the bare tube furnace can be made just as good as in a furnace with refractory or metal block covered water walls. As a matter of fact the bare tube furnace wall does not stay bare, it becomes covered with ash or slag. A large part of such accumulation of ash and slag drops off when the furnace is cooled. The covering on the refractory or metal covered water walls wastes away and requires replacement. Such replacement is costly and in many cases the cost of covering and its maintenance is not justified.

Figure 6 shows details of construction of a bare tube water wall. The tubes are 3 to 4 inches outside diameter and are so spaced that ~~there is~~ the space between them is about 2 inches wide. ~~space between them.~~ The space between the tubes is closed by two steel strips about 1 inch wide, each strip being welded to one tube. These strips when welded onto the tube resemble a fin on a fish and therefore a furnace wall of this design is called fin tube furnace wall. This design of water-cooled wall has many advantages. The tubes are easily replaced. The walls are light and are generally suspended from a steel frame. By cutting out the fins in any one spot a neat peep hole for observing the fires is easily obtained. Water-cooled walls are strongly recommended for burning Illinois coal.

Figure 7 shows a steam generating unit with water-cooled furnace walls on three sides of the furnace. The fourth wall is made of refractory because it contains the burners which are more easily fitted ~~and because it is easier to fit the burners~~ into a refractory wall than into a water-cooled wall. The flames move away from the burner wall and therefore do not impinge on it. There are six of these burners placed in two rows ~~and~~ of three ~~in~~ each. ~~row.~~ The long flame travel from the burners to the tubes of the boiler ~~results in~~ causes complete combustion and greatly reduces the chances of ash being deposited on the boiler tubes, and clogging the gas passages. The ash on its long path through the water-cooled furnace is cooled below its sticky temperature and does not adhere to the boiler tubes. Any ash that may be deposited among the tubes of the first bank ~~is~~ can be easily dislodged with a hand lance inserted through peep holes in the top part of the rear wall. The ash dropping to the bottom of the furnace passes through a water-cooled screen over the bottom of the furnace, is cooled down below its sticky temperature, and removed from the ash hopper in a granular form. This unit has a maximum capacity of 300,000 pounds of steam per hour and is installed in an industrial plant. Similar units can be built in various sizes ranging from 50,000 pounds to 500,000 pounds of steam per hour. It is a unit admirably suited to burning Illinois coal. The main points of merit are the water-cooled furnace, the location of the burner under the lower drums of the boiler, the long flame travel from the burner to the first bank of boiler tubes, and the easy access of the first bank of boiler tubes for removal of slag that may be deposited on the boiler tubes or on the superheater. The unit is supplied with coal by three pulverizing mills located directly in front of the furnace. These mills are of the high speed type, are compact and require small space for their installation. Other types of mills of good design could be used for the same purpose.

Figure 8 is another steam generating unit well adapted for burning Illinois coal. The furnace is completely water cooled including the burner wall. The boiler is of the sectional header type with an interdeck superheater. The unit is fired with eight horizontal burners placed in two rows one above the other. Coal is supplied from pulverized coal storage bin located in an adjacent lean-to building. This is so-called storage system of firing. The coal passes from the raw coal bunker to the pulverizing mill where it is dried and pulverized. The pulverized coal is then deposited in the pulverized coal bin from which it is fed by feeders to the furnace as the coal is needed. Attention is called to the fact that all the feeding and coal delivering apparatus is under the boiler operating floor so that to the observer on the operating floor there is nothing to suggest the presence of pulverized coal. The burners are of such design that either pulverized coal or fuel oil can be burned. The change over from one fuel to the other can be made one burner at a time without changes in the load on the boiler. The unit was designed for generating 550,000 pounds of steam per hour at 750 pounds pressure. It is installed in a central station. The ash deposited at the bottom of the furnace is removed in a granular form through a water sluice. Units of this design can be built in steaming capacity of 50,000 to 600,000 pounds per hour.

Figure 9 shows another powdered coal installation with completely water-cooled furnace wall adapted to burn Illinois coal. The pulverized coal is supplied from a pulverized coal storage bin to eight burners two of which are located in each of the four corners of the furnace. The streams of mixture of coal and air from these burners are tangent to a circle in the center of the furnace. Therefore, this form of firing is known as the tangential method of firing pulverized coal. The ash deposited on the bottom of the furnace is heated by the close proximity of the turbulent flames to high temperature and is removed in liquid state through a slag spout located in one of the side walls near the bottom of the furnace. In all cases where the ash is removed in liquid state it is absolutely necessary that the furnace be completely water cooled, the high temperature maintained in the furnace would damage any refractory. This unit is designed for 1400 pounds pressure and has a capacity of 300,000 pounds of steam per hour. It can be built in any size ranging from 75,000 to 750,000 pounds of steam per hour.

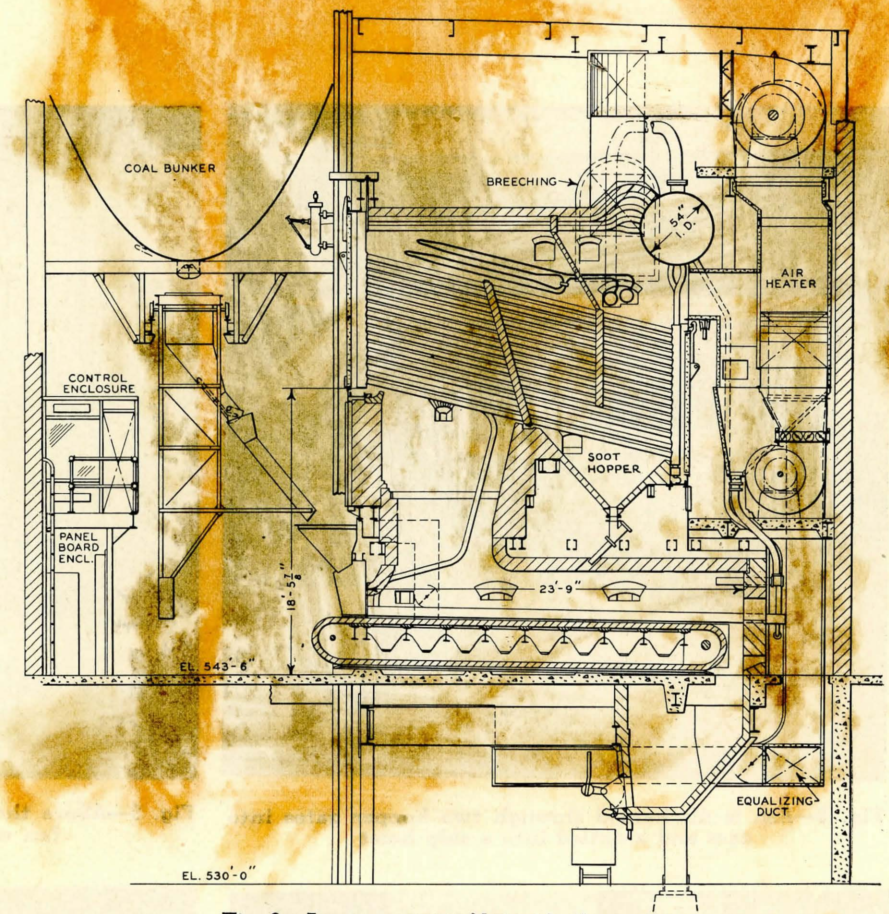
Illinois coal is hard and has a high ash content. These properties make it somewhat hard to pulverize. The capacity of all types of pulverizing mills ~~will be~~ is lower and the maintenance higher with Illinois coal than with most of the eastern coals. The maintenance is always higher with high-speed hammer type mill than with low-speed roller or ball type mill. Generally speaking the low-speed mills should be given preference when selecting mills for pulverizing Illinois coal.

ILLUSTRATIONS

Krauninger Fig. 1

Reduce to 4"

~~Fig 1.~~



~~Fig. 6—Arrangement of latest boiler unit~~

Fig. 1.– Arrangement of latest boiler unit

Kreisinger Fig. 2

No reduction

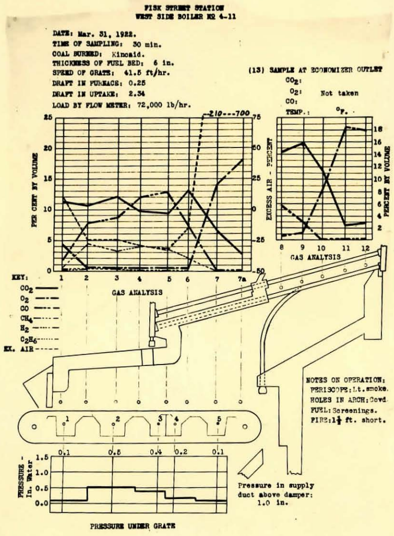


Fig. 2

Fig. 2

Fig. 3

No reduction

FISK STREET STATION

WEST SIDE BOILER № 4-11

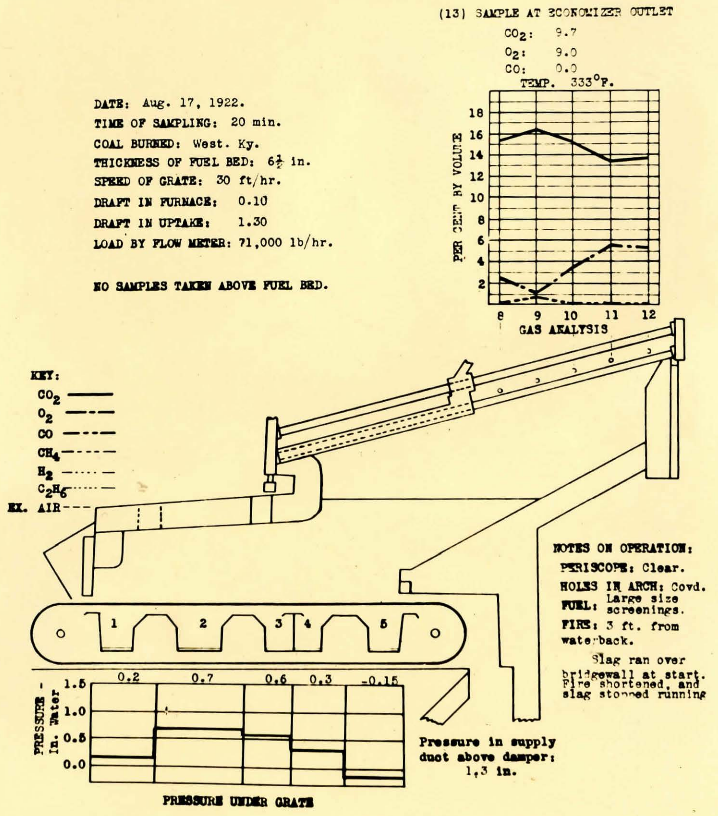
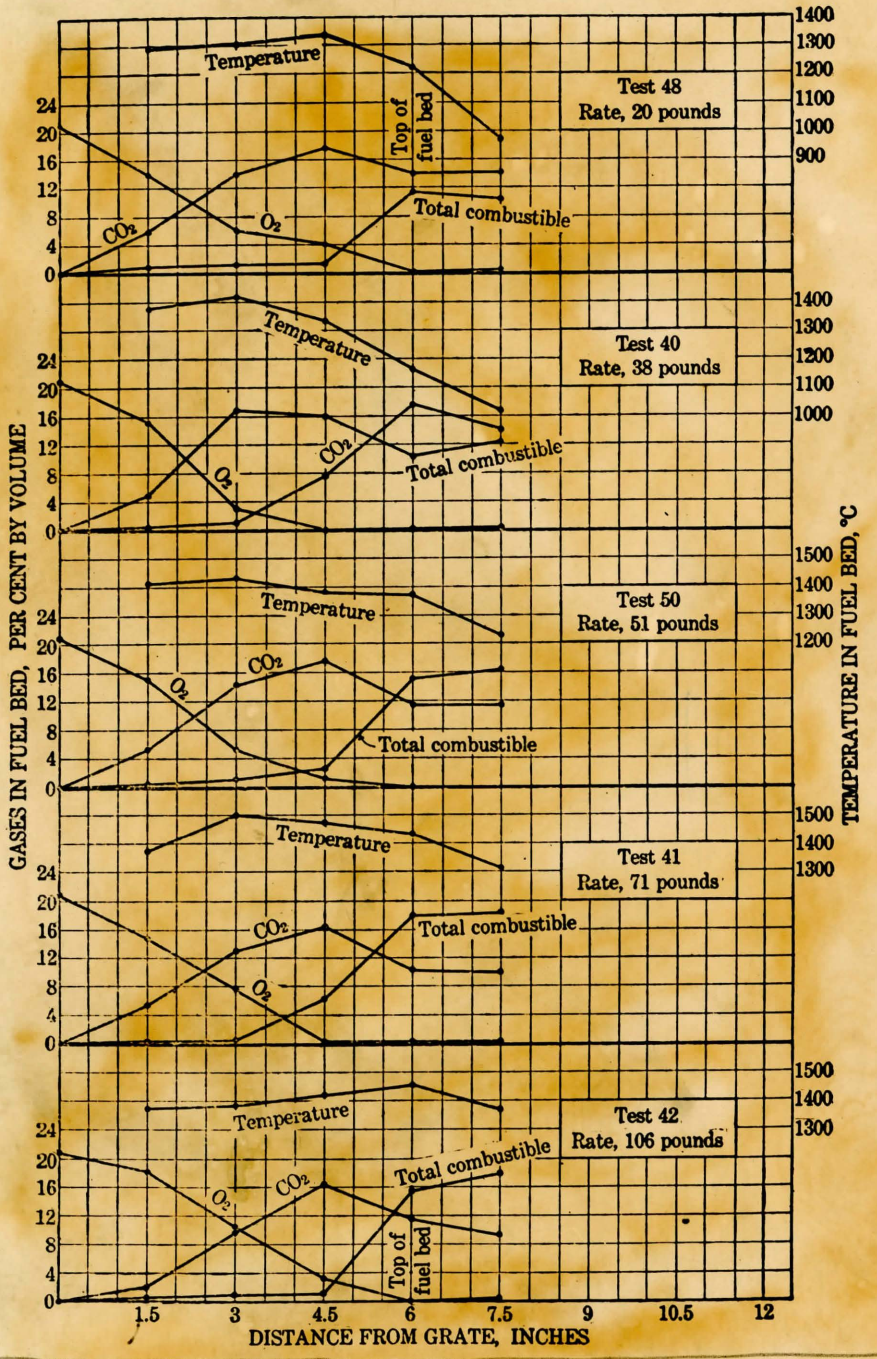


Fig. 3

Fig. 3

Kreisinger Fig. 4

Reduce to 4"



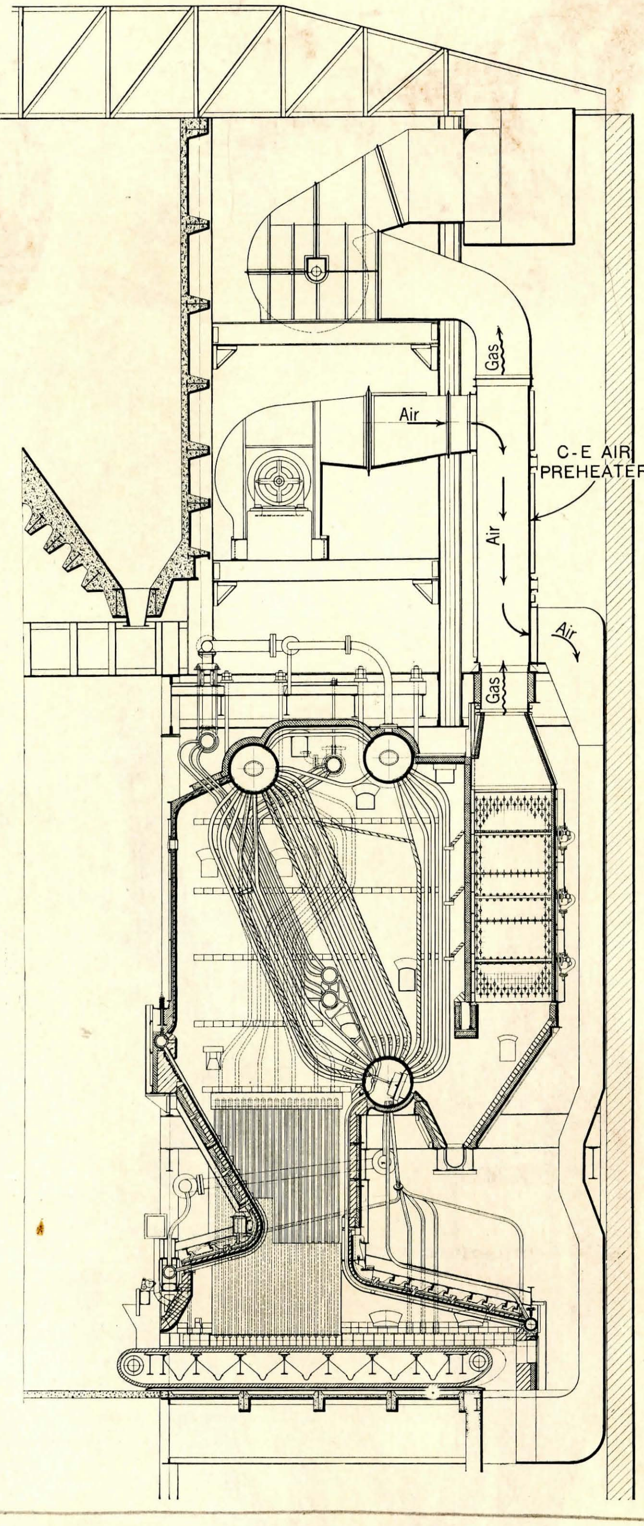
~~Figure 12.~~—Composition of gases and temperature in 6-inch fuel bed of coke in a small hand-fired experimental furnace. Rates of combustion, 20, 38, 51, 71, and 106 pounds of fuel per square foot of grate per hour.

off off

Fig 4.

Fig. 4.—

Kreisinger
Fig. 5



Reduce to 6"

OB

OB

Fig. 5

Fig. 5

Kreisinger Fig. 6

Reduce to 4 inches

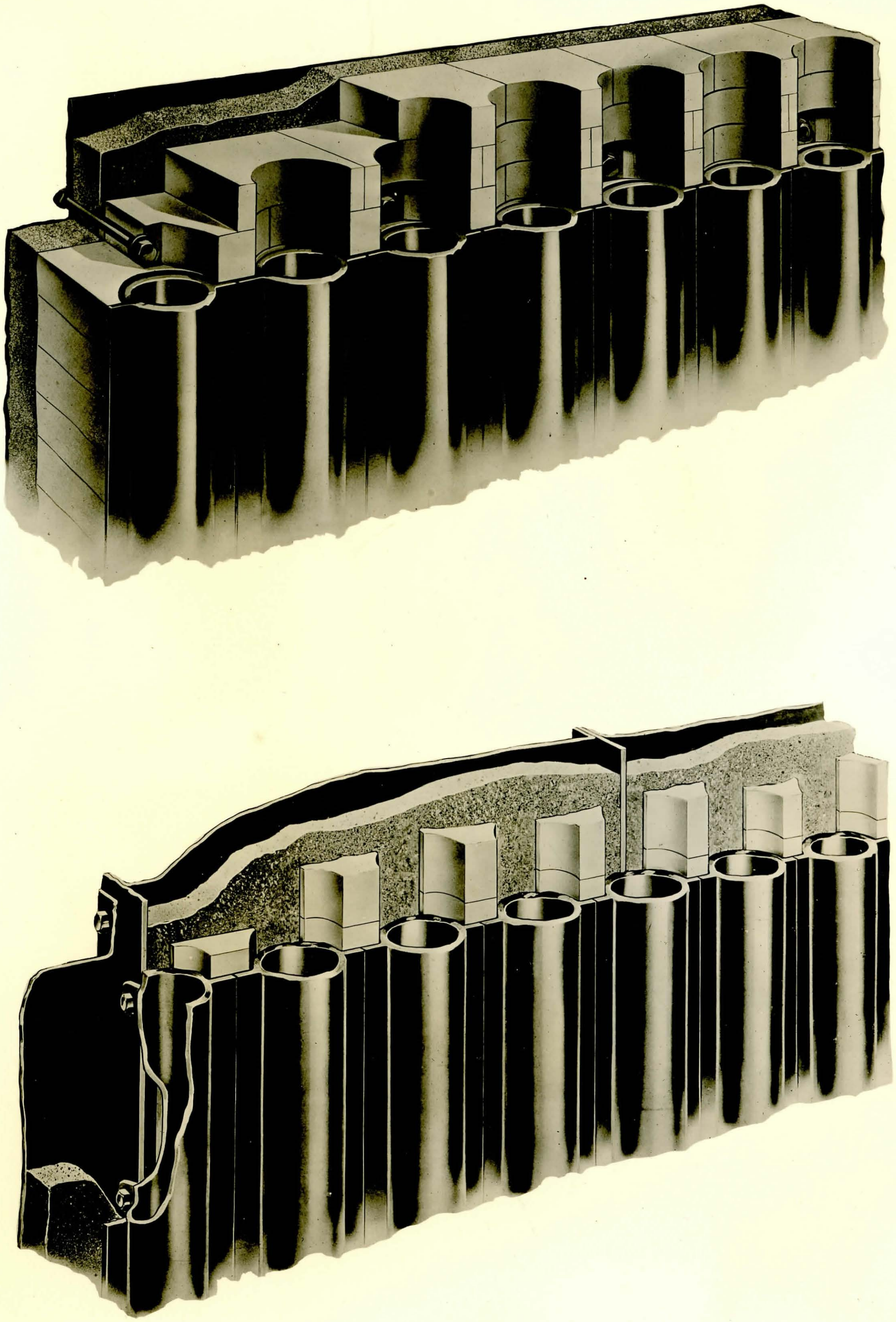


Fig. 6

Fig. 6

Reduce to 4 ½ inches

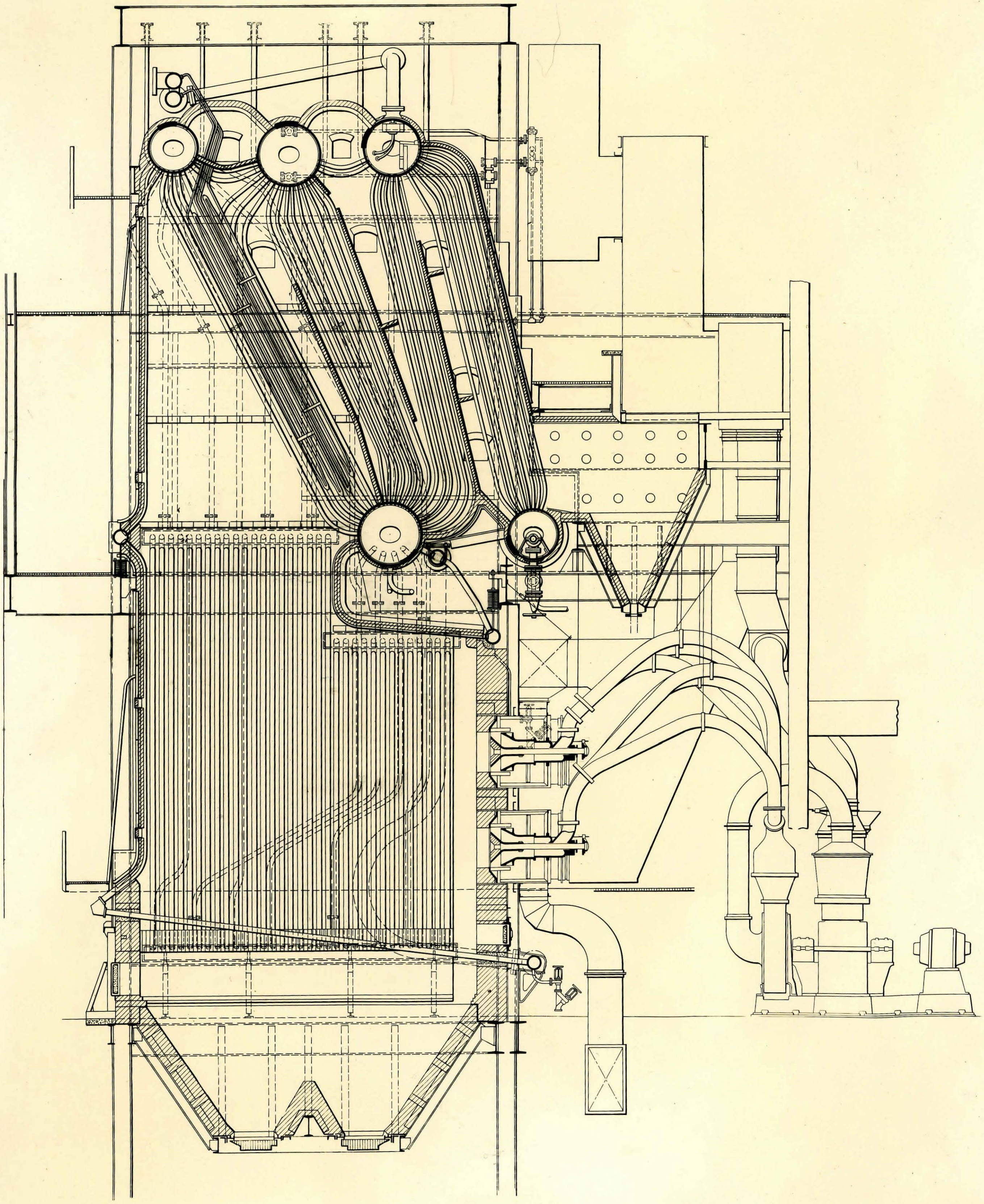


Fig. 7

Fig. 7

Reduce to 4 1/2"

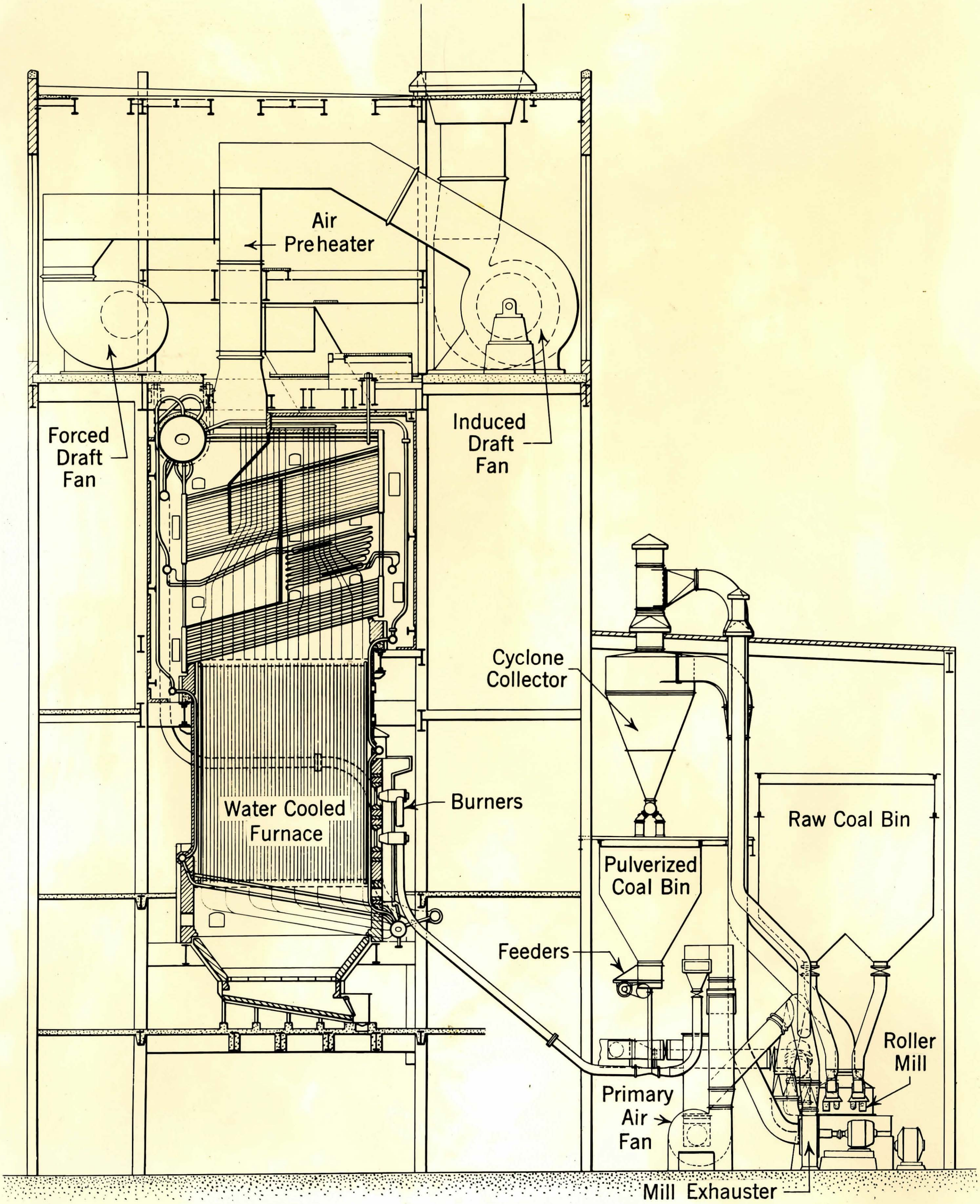


Fig. 8

Reduce to 4½"

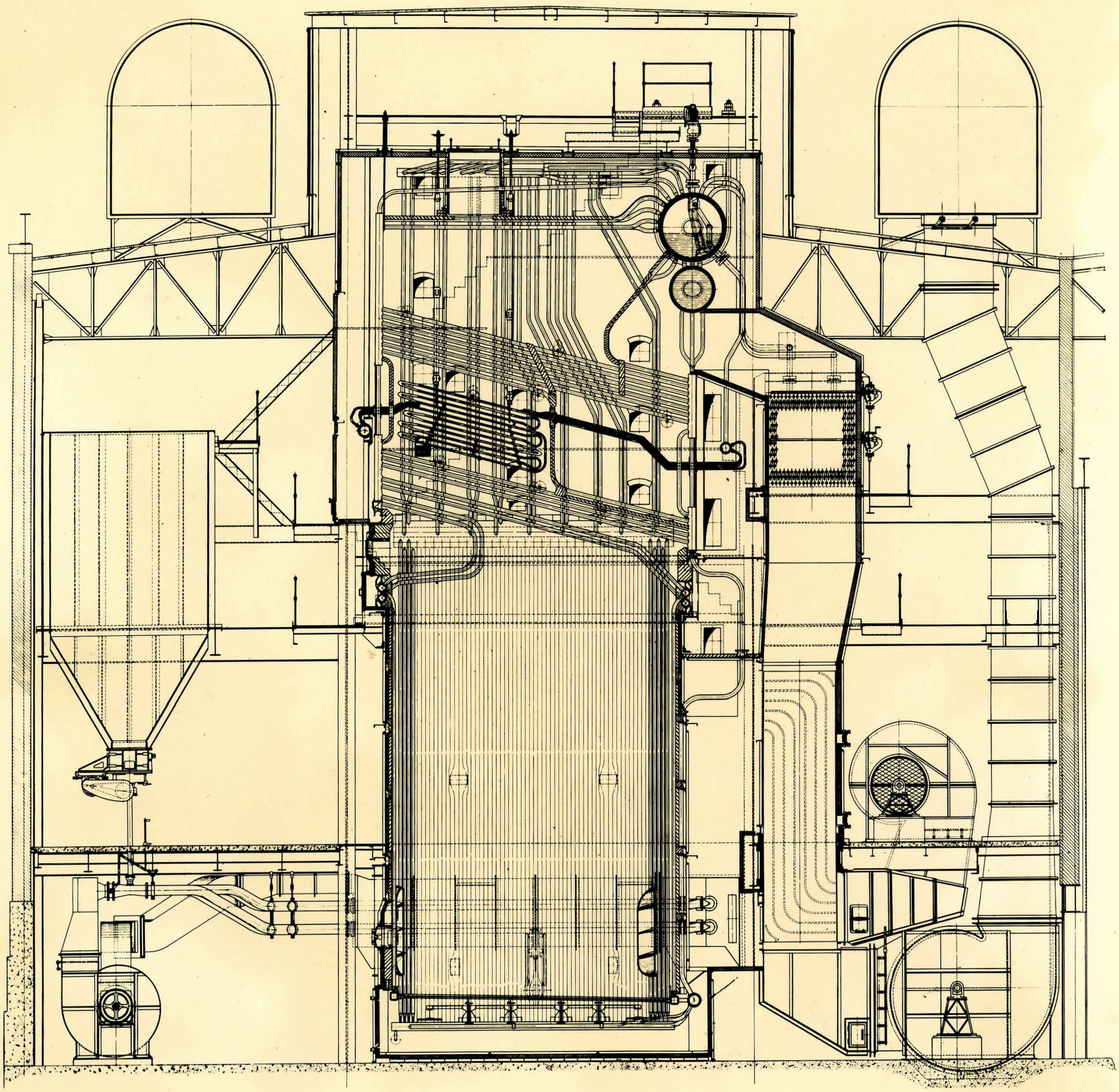


Fig. 9

This is so obviously an advertisement of the West Frankfort operation that I cannot see the justification of publication by a State Department

Its well written and acceptable otherwise

GWC

#12

ILLINOIS COAL AS A SOURCE OF GASEOUS AND LIQUID FUEL

LOOKING TO THE NOT-FAR-DISTANT FUTURE

From the Viewpoint of a Technical Man in Industry

by M. D. Curran, President,
Radiant Fuel Corporation,
West Frankfort, Illinois.

The production of gas and oil from coal in the United States has generally resulted from the destructive distillation of coal used in the metallurgical industries. The steel industry has been largely responsible for the development of by-product coking of coal, because their requirements of coke have been greater than all other metallurgical operations combined. The coal gas and tar oil produced have been considered as by-products for which markets had to be developed in order to permit expansion of by-product coking to meet increasing demands of the Nation for iron and steel.

Up to the present time the markets for Illinois coal have been almost entirely confined to its use for generation of steam and electricity, railroad fuel, industrial heating and domestic or house heating. During the last twenty-five years many efforts have been made to use it in the manufacture of metallurgical coke for the steel industry. In more recent years it has found a small and growing market in the gas industry, both for making producer and water gas.

Until rather recently, artificial gas plants throughout the Illinois coal trade territory used coke as a source of blue gas, but during the war years and for a short period thereafter, gas companies, being unable to secure adjustments of their rates in proportion to the exceptionally high cost of coke, were forced to devise ways and means by which they could substitute coal for coke in the water-gas operation.

As far as Illinois is concerned, this change has been of some help to the coal industry in that it permitted the sale of the prepared sizes of Illinois coal to gas utilities in its natural trade territory where coke, made from standard coking coals of other states, had theretofore enjoyed the business.

The increased use of producer gas in various types of industries has created increasing markets for nut sizes of Illinois coal. While this has not been a large outlet, it has been a substantial one and of considerable importance to the coal industry of the State. ~~of Illinois.~~ During recent years, however, much ~~a considerable part~~ of the coal used in the manufacture of industrial producer gas has been replaced by natural gas.

A brief statement, with regard to the efforts made to use Illinois coal in by-product coking ovens for the manufacture of blast furnace coke, is fitting and proper in this discussion. We have reason to wonder why the large steel-making operations in the Chicago district have been forced to import coals from other states for the manufacture of coke when ~~the State of~~ Illinois has such an abundant supply of coal so close to the center of the steel operations. The steel industry has spent many millions of dollars trying to substitute Illinois coal for Eastern coal, but has thus far failed to develop ways and means to do so economically. While it is generally understood by those identified with the industry that Illinois coals have a much lower coking index than certain grades of Eastern coal, the effect of this lower coking index on the usability of coke in the blast furnace, which was made from Illinois coals, may not be quite so generally understood. Briefly, it may be said that the physical strength of the coke produced in standard by-product coking operations from Illinois coal is considerably less than that obtained in the coals of higher coking index. However, this lack of strength can be, and is, offset to a satisfactory extent when Illinois coals are mixed with the low volatile coals of West Virginia. The natural structure, however, of coke made from Illinois coal is such that this coke, when used in the blast furnace, sustains severe loss by the solvent action of carbon dioxide gas in the stock column. In other words, a part of the carbon in the coke is converted into carbon monoxide gas and is lost with the gases leaving the furnace, so that the expected amount of carbon does not reach the smelting zone where it is to be used. Consequently, a higher consumption of coke is required to make a ton of pig iron than is the case where the ~~characteristics of the~~ coke ~~are such as to~~ withstands the attack of carbon dioxide gas in the stock column.

In by-product coking plants in common use today, Illinois coal gives lower yields of gas and by-products, due to the high percentages of moisture and oxygen contained, and when this lower by-product recovery is combined with the lower value of coke in the blast furnace operation of the steel industry, it has been found that greater economy could be had by using coals of higher coking index, even at additional cost.

It is therefore proper to say that up to the present time there has been only limited use of Illinois coals for production of gas and oils, and that such use has been restricted to producer and water-gas operation where complete gasification takes place with little or no recovery of oils. According to the Minerals Yearbook of the United States Bureau of Mines, there were some 36 million tons of coal produced in the State in 1933, of which only 318 tons were reported used in the coking industry.

By-product ovens, operating in connection with the steel industry, have been the largest consumer of coal for carbonization. Of the four largest coal producing states of the Union - West Virginia, Pennsylvania, Illinois, and Kentucky - Illinois alone has been unable to participate in the vast tonnages required in by-product coking operations, due to the peculiar coking characteristics of its coal.

Meanwhile, our present day social order is undergoing changes quite revolutionary in character. Peoples throughout the Western World are developing a new perspective of life. Predictions are made that the beginning of a new social order is at hand. In our own country people living in rural communities and on farms are demanding the many conveniences of life now common to city dwellers. On the other hand, large centers of population are determined to find a way to make available to their citizens some of the advantages common to rural life. Civic groups in our larger cities have been giving increasing amounts of time and effort to a study of means to improve their society. They have concluded that ways and means must be found to provide their citizens and their children with sunshine and a clean atmosphere in winter as well as summer. Political leaders have accepted their conclusions and are actively engaged in finding a solution. The most practical answer available at this time, in this section of the country, is the use of smokeless fuels, such as gas, oil, and coke, and the greater use of automatic stokers. It would be a mistake for the coal industry of this state to disregard this changing sentiment.

Fortunately for Illinois, the coking characteristics of her coal, which have prohibited its use in the steel industry, have been found to be desirable in the manufacture of coke for domestic use. While it is true that a new coking process had to be developed by which greater use of the natural coking properties of the coal could be obtained during carbonization, it has been found that combustion characteristics have been developed by the use of this process which are considered a fundamental requirement in coke to be used for household purposes.

During the course of our many years of study, certain rather definite ideas have crystallized, upon which our most recent development is based. We now believe that any large scale development in the manufacture of a low cost smokeless domestic fuel by carbonizing Illinois coal will reckon with the following considerations:

(1) The high moisture content of our coal must be disposed of prior to carbonization, if satisfactory coking efficiency is developed.

(2) Clinkering troubles in burning coke made from coals having low fusing ash are much more severe than when burning the coal itself. This is accounted for by the higher fire box temperature generated with the use of coke. While the fusion point of ash in our coal varies over a considerable range, the whole range is sufficiently low to provide a major obstacle in marketing coke made therefrom. These difficulties will be overcome only when carbonization takes place in such a manner as to produce combustion characteristics in the coke which permit it to burn freely at temperatures well below the softening temperature of the ash. In other words, the coke should have combustion qualities similar to the coal from which it was made.

(3) Any successful coking process developed must be of such a type and character that it can be used at the mines and operated in connection with mining operations in such a way as to utilize sizes of coal normally hard to dispose of and at the same time provide for carbonization before the coal becomes too highly oxidized. As the demand for stoker size coal

increases there will be a corresponding increase in fines produced by crushing. These fines are subject to more rapid oxidation than larger sizes of coal, due to greater surface exposed, and contain a larger percentage of inert Fusain substance due to concentration of this substance in the fines. Thus, it is necessary to carbonize the most highly non-coking part of the coal seam, if the mine operator shall be enabled to market his production to the greatest advantage.

(5) The coking process must be sufficiently flexible ~~as~~ to meet the fluctuating demands of the domestic consumer. Therefore, the apparatus used must be able to withstand heat shocks sustained by intermittent and irregular operation.

(6) Capital invested in processing apparatus must be limited to an amount which will not be burdensome to the processing cost, and which will be within the means of the mine operator to provide.

(7) A market for gas at its reasonable value must be provided. The natural one is the large centers of population within piping distance of coal fields.

When these considerations are complied with, it will be found that an entirely new product will have been created. A smokeless product from Illinois coal, which, while resembling coke in appearance, will have characteristics entirely different ~~than~~ from those common to by-product coke, and combustion qualities similar to those of coal. It will also be found that a new industry is created for the State; ~~which~~ one that will be identified with coal mining communities, and ~~which~~ that will provide a base for additional industrial development in those communities by making available coal gas and coal tar oils for rectification and industrial use.

It has been demonstrated by the operation of a commercial plant, ~~located~~ at West Frankfort, Illinois, during a period of one and one-half years, that a process has been developed which complies with the considerations set forth above. This plant uses the Curran-Knowles Process and is carbonizing 5/16" screenings, commonly sold as carbon size coal, and produces from this coal a new smokeless fuel which has been well accepted by the consuming public in a great many cities and towns throughout the natural trade territory of Illinois coal fields. Briefly, this process uses the Knowles Sole Flue Coking Oven, which operates with flue temperatures of about 2500° F. The yield of surplus coal gas runs about 3,000 to 4,000 cubic feet, and the yield of tar oil runs about 9 gallons per ton of coal charged. The gas has an average heating value of 500 B.T.U.'s per cubic foot, and the tar runs unusually low in free carbon and pitch. At the same time this tar has characteristic high temperature qualities, but differs from standard by-product coke oven tar in that it contains a much higher percentage of valuable tar acids.

In the design and construction of this pilot plant, special effort was made to reduce capital cost of not only the carbonizing chambers, but the auxiliary equipment as well. The power required for individual loads has been worked out to permit handling with small internal combustion engines using coal gas or benzol drips as the source of power. The surplus gas, which is sold to the Utility System supplying gas service to cities and towns in this coal field, is pumped into this system under fifty pounds pressure by gas engine operated compressors.

The carbonizing chambers are built entirely of fire brick, except the combustion flues and floor, where either carborundum, alumina or silica brick can be used. The coal to be processed is placed on the floor of the chamber in a layer 10 to 12 inches thick and heated by flues located beneath the floor. The products of distillation pass up through the coal. The gases leaving the carbonizing chambers have a temperature of 550° to 650° F., which is about 1,000 degrees lower than ~~is the case~~ in standard by-product coking operations using similar flue temperatures. The regenerative heat recovery provided beneath the combustion flues reduces the temperature of the waste gases to 450° F to 500° F., as they enter the stack. This results in greater thermal efficiency in carbonizing, and also permits considerable savings in gas handling and by-product equipment. The work to be performed in cooling the gas is materially lessened to the extent that the cooling water required is within the limited amounts usually available in coal mining districts.

This plant uses 100 tons of 5/16" screenings per day, or about 3,000 tons per month. Of special significance is the fact that it has demonstrated the practicability of by-product carbonization at the mines of small tonnages at a manufacturing cost well within the scope of market requirements in the Illinois trade territory. Of equal importance is the fact that carbon size coal, containing very limited coking properties, and susceptible of rapid oxidation, can be carbonized to form a sturdy coke substance.

Without going further into detail, it may be ~~safely~~ said that a basis for the manufacture of a new smokeless fuel from Illinois coal has been established by means of which the mining industry of the State can look forward to expanding its markets through a channel heretofore closed to it.

Considering the competitive situation of the producers in the Illinois coal field, it will be found that a large tonnage of coal from other states is imported into our natural trade territory. If an analysis be made to determine the reason for this situation, many contributing factors will be found to be responsible, among which is the preference of people for using smokeless coal and coke, regardless of the additional cost. This personal preference has been responsible for a large importation of smokeless coal. Furthermore, increased efficiencies developed in combustion apparatus used in power plants have resulted in reduced sales of screenings, due to the lower ash fusing temperature of our coal. Where forced draft stokers are used, the dust particles in the screenings are carried along with the products of combustion and often form slag deposits on the boiler tubes, causing a reduction in efficiency. If these smaller particles are removed from the screenings used for this purpose, this handicap is removed. It, therefore, appears that any process which will utilize dust or carbon size coal will permit the coal industry to recover at least a part of this class of business.

With the changing social sentiment, one of two things will happen; namely, there will be either an increased importation of smokeless fuels, including gas and oil, or the mining industry of this State will process a portion of its coal in such a way that it will merit the domestic business. The coal industry needs two sources of help in order to undertake the development of this new trade outlet:

(1) It needs capital; and

(2) It needs and adequate outlet for the gas which it will produce in the processing of its coal.

As to the first requirement, the industry is, generally speaking, unable to help itself with its present means. This new social demand has come at a time in the life of the industry when it is, perhaps, least able to finance new undertakings. If this new step in the marketing of coal is undertaken, financial help from without the industry must be provided. Unless and until money for new undertakings becomes easier to get through private channels, or Federal assistance is given, the progress of this development may be rather slow.

As to the second requirement, it will be entirely practical to run gas lines from the coal fields to the nearest large centers of population, where the gas produced can be sold at prices equal to, or less than the present costs of producing gas in those communities. I say quite frankly that if these large communities want smokeless fuel for heating their homes, they must assume the obligation of consuming the gas produced in the production of smokeless solid fuel. While it will undoubtedly be found that the Utilities serving these communities have adequate production capacity, and certain obligations and commitments, which might temporarily prevent them from taking large quantities of gas from this new source, it is safe to assume that there is likely to be an equilibrium established between the rate of growth of this new industry and the annual increment in gas requirements, which will permit absorption of this additional gas without any great disadvantage to these Utilities. Furthermore, such additional amounts of gas made available at low cost should permit better gas service to the citizens of the larger communities at a reduced cost.

The use of stokers for smokeless and economical burning of coal will naturally increase, where cities enforce smoke elimination. While a great variety of stokers are now available, we may presume that there will be improvements made in mechanical devices which will result in a decrease in the cost of such equipment. As far as economy is concerned, all larger buildings should be equipped with stokers; particularly where attendants are available to handle the operation. In the case of individual home owners, the capital required for such apparatus may well be beyond the means of the individual, and in a great many cases where houses are occupied by tenants, it seems quite unlikely that a stoker investment would be justified.

In order that the coal industry may more fully meet these requirements, it should be capable of furnishing a smokeless fuel to those who must have it at a reasonable price, and this, we believe, can be done if it processes the most unsalable portion of its production in a manner which will permit it to sell the smokeless product at about the same price it obtains for the better grades of domestic coal.

For many years, coal mining operations in parts of the Appalachian Field were carried on directly in conjunction with manufacturing beehive coke for the steel industry. This, a most inefficient coking operation, necessarily was replaced by systems which recovered by-products. The steel industry found that it was very often able to produce coke better suited to its particular needs by blending various coals, and therefore the growth of large by-product coking establishments has developed with the plants located at the point of coke consumption. As far as a domestic coke is concerned, there is no reason to believe that blending is either necessary or advisable. Therefore, by-product coking operations designed to manufacture domestic coke in connection with mining operations will be thoroughly practical provided the apparatus used does the work efficiently and cheaply, and is in keeping with requirements of the mining industry. In view of the demands now being made for smoke elimination, it would seem that the psychological time has arrived to proceed with the manufacture of a smokeless product for household use.

Recent research and developments in the hydrogenation of coal tar oils indicate their successful utilization in the manufacture of plastics. While it is quite impossible to visualize the extent to which this new development might stimulate manufacturing industries, it is believed that a new chemical industry of national scope and importance is in the process of development. Such a new outlet for tar would naturally either improve its market value or permit largerquantities to be disposed of at prevailing prices.

Coal mining communities of the State are afflicted with as great, or greater, unemployment problems as the larger industrial centers. There is little doubt but that Illinois can increase its production by a very substantial tonnage if it will process a portion of its coal to meet the smokeless requirements of the domestic consumers in its natural trade territory. By so doing, it may provide employment to many of the unemployed in the coal fields, and pay for their services from the savings to be had from the recovery of coal gas and tar oils from the coal processed.

ILLINOIS COAL AS A SOURCE OF GASEOUS AND LIQUID FUELS - LOOKING TO THE NOT-FAR-DISTANT FUTURE

From the Viewpoint of a Research Coal Chemist

see Circ. 10 for abstract

BY

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Gaseous and liquid fuels have come to be an indespensable part of our life. Fuel gas offers the great advantages of furnishing heat in an instantly available and accurately controllable form, in which respect it falls only slightly short of electricity. Much as we rely on gas, we could get along without it much more conveniently than we could without gasoline or liquid fuel substitutes for gasoline. The importance of gasoline in our life today is of particular interest when considered historically. Manufactured gas was introduced first in London in the year 1800. The natural gas industry dates from about 1850. Although the use of gas is widespread, there are many parts of this country, and the rest of the world, where gas is not available. In contrast, there is hardly a place on the globe where men live that gasoline has not been an influence. As a matter of fact, gasoline has been of the greatest relative influence in those isolated places to which gas will probably never come. The reason for gasoline's importance is, of course, the internal combustion engine, which dates from 1877 and which really only started to assume its present importance as a part of the automobile after 1900. ~~Figure I~~[1] ~~presents a chart of the production of petroleum in the United States~~. The rapid rise in the production of petroleum since 1900 ~~is quite evident, as is also~~ and the great decrease in price which has occurred since the early days of the industry are shown in Figure 1. The gasoline engine, especially as used in the automobile, is of course responsible for the demand which has led to this phenomenal growth in petroleum production. It also seems that we shall continue to need large quantities of gasoline with which to carry on, and at the same time ~~let us not forget that we shall also need~~ lubricating oils. Competing with gasoline as internal combustion engine fuel are diesel engine fuel oil and kerosene, both of growing importance because of economic factors and to be included in the same category of "indispensable materials" as gasoline.

The heavier oils are also widely used as fuels in boiler and industrial furnaces. In some cases where oil is cheap and coal or gas expensive, oil is used because of the savings involved. In most cases fuel oil is used because of convenience, controllability, cleanliness, and space economy. Especially is this true in the field of modern marine engineering. The design of the modern ocean liner or battleship is built around oil as the fuel. The dependence of the modern navy on oil fuel is, as you all know, responsible for such things as "oil imperialism" and the frantic effort of those countries without oil to produce liquid fuels somehow, regardless of expense.

This naturally leads us to ask, "why are gaseous and liquid fuels modern necessities?" Fuel gas, as ~~we previously~~ mentioned, need not be considered indispensable to our life, yet the many conveniences it offers and the fact that its use at present permits us to use more efficiently and profitably our energies in constructive endeavor, does make it essential to a high order of technically efficient civilization. Neglecting price, gas could be replaced by electricity in practically all its applications, or for domestic heat by centrally generated steam, with an increase in convenience. Not so with liquid fuels used in transportation. The automobile, which has so indispensably entered our lives and changed our mode of transportation, is dependent upon gasoline. ~~for its existence.~~ The nearest competition to the gasoline engine for automotive serivce is the diesel engine which also is dependent upon a liquid fuel. Solid fuels are at a great disadvantage because of their lack of convenience and flexibility, gaseous fuels because of their great volume per unit of energy. On shipboard, liquid fuels have the advantage over solid fuels of ease of storage and control, and the elimination of ashes. Sweating, heaving coal handlers are replaced by tiny steel tubes. All of the modern luxury liners and almost all the ships of the great navies of the world are dependent for their operation on liquid fuel. Electricity centrally generated in stationary power plants is of course unavailable for these motile uses until the problem of transmitting power without the intervening wire conductor is solved, a problem which many are inclined to view as insolvable.

Apparently then, unless drastic changes are to be made in the mechanical phases of our civilization, we must have a continuing supply of fuel oil and, let us not forget, a supply of lubricating oil. What are our present supplies and why do we need to feel that they will not continue to meet our needs?

Our present sources of gas~~, I need not tell you,~~ are from natural gas fields and from gas manufacturing plants. Natural gas is a wasting asset and will some day become only a memory in most parts of the United States. Manufactured gas, on the other hand, ~~I feel~~ will ~~have an~~ increas~~ing~~e in importance. There seems to be no critical condition with respect to gas. Developments in gas manufacture will come as a result of trends towards a more comfortable way of living.

Unlike gas, at present we have for all practical purposes only a natural source of liquid fuel, petroleum; and it, like natural gas, is also a wasting asset. From the daily news one gathers the impression that there is an oversupply of oil, but this, it turns out, is the result of uncontrolled production. The actual reserves of oil known to be in the ground are not any too plentiful, if one is to believe the conclusions of the men in the oil industry. News from within the industry reveals a story of a frantic search for oil by all of the major companies, using the most modern of scientific equipment. The situation also is summed up in Table 1, which was taken from the Oil and Gas Journal for May 2, 1935. 1/

1/ Pratt, W. E., Oil production - analysis of its development and stabilization; Oil & Gas Journal 33 (50), 17-18 (May 2, 1935).

TABLE 1.

ANALYSES OF PRODUCTION AND DISCOVERY EXPERIENCE OF THE AMERICAN OIL PRODUCING INDUSTRY BY PERIODS

PERIOD	Average Annual Production Millions of Bbls.	Average Annual Discoveries Millions of Bbls.	Ratio accumulated production to accum. discoveries	Ratio of av. annual prod. to av. annual discoveries	Ratio of average annual disc. to total discoveries
1859-1900	25	80	0.3	0.3	0.003
1901-1905	105	340	0.3	0.3	0.01
1906-1910	175	275	0.4	0.6	0.01
1911-1915	250	500	0.4	0.5	0.02
1916-1920	370	585	0.5	0.6	0.02
1921-1925	650	820	0.6	0.8	0.03
1926-1930	895	1990	0.5	0.4	0.07
1931-1934	870	580	0.6	1.5	0.02

Attention is called to the fact that in the four-year period, 1931-1934, there were produced and consumed approximately 35 times as much petroleum as during the forty year period 1859-1900. Also, that while ~~over~~ more than four times as much petroleum was produced in the five-year period, 1901-1905, this was less than one-eighth of the amount produced in the four years, 1931-1934.

Not only is new oil increasingly difficult to find, but it is more expensive to produce, due to deeper wells and more troublesome strata. Continued production from existing pools is also becoming more expensive because of increasing pumping costs and the costs of special production methods such as air drives and water flooding. The ultimate effect will, of course, be a rise in the price of those finished products which are in least competition, and a withdrawal of oil products from the more competitive markets. For example, we present the rapid growth of the importance of the cracking process for increasing the amount of gasoline obtainable from crude petroleum shown graphically in figure 2. This will be a temporary measure only. It is conceivable that we will have either to look for new sources of liquid fuels than natural petroleums, or to change our power units for our automotive vehicles. At the present, it seems easier to do the former.

Our other sources of liquid fuels can be the fossil solid fuels, i.e., coals of any or all ranks and types, oil shales, or agricultural products. It has been shown many times that agriculture cannot begin to furnish sufficient liquid fuel to meet our present demands. The production of oil from shale involves a high handling charge which makes that source unattractive when compared to coal, which is our other alternative. Our reserves of coal are enormous when compared to our reserves of oil and gas. The position of Illinois with respect to these reserves is indeed fortunate. Of the estimated three and one-half millions of millions of tons of reserves, Illinois is estimated to have two thousand millions of tons. Geographically, Illinois is one large coal reserve.

Table II

Proven Reserves of Mineral Fuels in United States*

	Coal (Million net tons)	Natural Gas (Trillion cu.ft.)	Petroleum (Barrels)
1934 production	390	1,633 a/	910,051,000
Total production to end of 1934	21,300 d/	30,310 b/	16,600,419,000
Proven reserves at end of 1934	3,414,550	40,000 c/	13,000,000,000

a/ Does not include some one-half trillion feet blown into the air and wasted in 1934.
b/ Does not include some 8 trillion feet blown into the air and wasted from beginning.
c/ Includes some 10 trillion feet that will be wasted if production methods continue as at present and if the "law of capture" is not superceded or intelligently modified.
d/ Does not include some 9 billion tons left in the mines or otherwise wasted.

* Garfias, V. R., Survey of Proven Reserves of Mineral Fuels in United States: Oil & Gas Journal 33 (43) 17 (3-14-35).

From the standpoint of technology and pure science there is no question that liquid fuels of suitable quality and in sufficient quantity, judged by present standards, can be made from coal. The question is, at present, one of economics to which in many European countries must be added that of a desire for an autonomous economy. As a matter of fact, in the period 1830 to 1859, oil from coal and shale largely replaced sperm and whale oil as illuminating oil. These oils were, in turn, replaced by petroleum oils made cheap by the introduction of the petroleum well by Drake in 1859.

Liquid fuels may be made from coal by three basic processes which are: (1) recovery and refinement of the products of either the so-called high or low temperature carbonization processes; (2) by destructive hydrogenation and refinement of the resulting products; and (3) by synthesis of hydrocarbon or alcohol mixtures from c arbon monoxide and hydrogen obtained in the complete or partial gasification of solid fuel. All three processes are in commercial or semi-commercial use at the present time. Because of our abundant supplies of petroleum, the economic urge to develop these processes in this country has been small. Conequently, we find that development has been carried furthest in those countries which have no national supply of petroleum, who have a highly developed industrial civilization and a highly nationalistic spirit, as Germany, England, France, Japan and Italy.

Oil from coal carbonization

Normally one may expect to recover 9 gallons of tar and 3 gallons of light oils per ton of coal carbonized in a standard by-product coke oven. (Figure 3). By certain oven constructions, the yield of light oils can be increased, at the expense of course of the gases and heavier tars. Low temperature coal carbonization, as is well known, results in a much higher yield of light oils and tar, say 3 and 25 gallons respectively, but the economic and mechanical difficulties ordinarily make low temperature carbonization of coal unprofitable. The liquid fuel which could be obtained from coal carbonized at the present time is only a small fraction of our total requirement. In 1933, for example, there were produced approximately 360 millon gallons of coke oven tar and approximately 100 million gallons of light oil, in contrast to a total motor fuel consumption in 1933 of almost 16,000 million gallons. According to Dr. A. C. Fieldner in the hearings during the recent Federal petroleum investigation, if all of the U. S. coal production were subjected to high temperature coking, the motor benzol produced would amount to only 12 per cent of the gasoline produced. Carbonization processes can supply only an insignificant part of our national liquid fuel needs since liquid fuels from these processes are only by- or minor-products. The major problem of the coke oven operator is the disposal of his coke. Figure 4 graphically shows certain trends in the coke market of which the steady growth of the domestic market for coke should be of especial interest to Illinois coal operators. Illinois coals cannot truthfully be said to be well suited for the production of metallurgical coke by present methods. An excellent domestic fuel coke can and is being made from southern Illinois coals.

Some interesting experiments on the coking of tar-coal and petroleum-coal mixtures in Knowles type ovens have recently been reported from England.* These ovens are the same type as those operated by the Radiant Fuel Corporation at West Frankfort, to coke Illinois slack coal. The Knowles type oven was originally designed to produce petroleum coke from petroleum refinery residues, for which purpose a large number of installations in this country and in foreign countries are in use. The plant at Corby England is of that type. Experiments at this plant have shown that mixtures of coal tar or coal tar pitch and either coking or non-coking coals yield excellent cokes when treated in these ovens. At the same time large yields of light oils are obtained as the result of cracking of the heavy oils during the coking. To produce good coke from petroleum residues and non-coking coal, the coal had to be quite finely ground and dispersed in the oil. ~~Figure 6 illustrates this process as a flow sheet.~~ The light oils in the gases from the oven are separated by means of a fractionating column, the heavy oils being recycled. Advantages claimed are an increased yield of the more valuable light oils, a decreased ash content in the coke due to the admixture of pitch coke to the coal coke and the possibility of using cheap non-coking slacks. In a complete installation only a few ovens would be required for treating the tar produced in the remaining ovens of the installation. This process is reported as still experimental.

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*Fisher, A., Processing of hydrocarbons with reference to developments at Corby: Colliery Guardian 150, 657-60, 706-8 (4-12,18-35).

The destructive hydrogenation of coal

Coal is composed largely of unsaturated aromatic compounds of great molecular weight and complexity. Under proper conditions, unsaturated organic compounds take up hydrogen to form saturated compounds of similar molecular structure in which behavior coal is no exception. Hydrogenated coal is, however, not much more valuable than is the raw coal. A large proportion, 50 per cent or more, is soluble in organic solvents and the material has great swelling and caking power. In the course of hydrogenation, some small amount of liquid material is formed, the amount being insignificant up to temperatures of 350° and increasing from there with increasing temperature of hydrogenation. This procedure for producing coking coal from a non-coking coal has been patented in Great Britain by the British Fuel Research Board as B.P. 301720 (12/28). If the temperature of hydrogenation is increased to about 450°C. and the pressure of hydrogen to 200 atmospheres, bituminous coals may yield 30 to 40 per cent of a tarry material. This, we must remember, is the result of treating coal alone with hydrogen. If, however, the coal is dispersed in a liquid and then treated with hydrogen at 450°C. and 200 atmospheres pressure, a conversion to liquid products of from 85 to 95 per cent may be obtained. This is the Bergius coal liquefaction or Berginization process on which Germany and Great Britain today base their hopes for oil independence.

The dispersing oil apparently dissolves the partially hydrogenated coal and permits further action of the hydrogen. The dispersing oil is itself acted upon during the process, furnishing an additional yield of light products. In commercial practice, therefore, heavy oil from the process is continuously recycled (Fig. 5). The oil also serves the mechanical purpose of facilitation, the introduction of the coal into the converters in the form of a paste. Figure 6 diagrammatically shows the complete, continuous process as commercially developed. The liquid products which first form may be distilled from the solid residue and refined, but since the purpose of the process is the production of a gasoline substitute, it is usual to treat the heavy oil fractions from the primary hydrogenation by a second destructive hydrogenation in the vapor phase. ~~Figure 8~~. Catalysts are used in both stages. In the first stage they are added in finely divided condition to the coal-oil paste; in the second stage the catalyst is supported in the reaction chamber on a suitable material. The nature of the catalyst ~~are~~ is an important part of the process and the subject of innumerable patents and much literature.

In the destructive hydrogenation process, two reactions are proceeding simultaneously, and ~~vying~~ compete for material. One reaction is pyrolitic decomposition, the other is hydrogenation. It is the function of the catalyst to increase the hydrogenation process at the expense of the decomposition process. These catalysts must be inert to the poisoning influence of the coal components, especially to that of sulfur. Iron oxide is added to the coal-oil base to absorb sulfur and to prevent its appearance in the finished gasoline, Naturally, increasing sulfur content of the coal increases the expense involved in its elimination.

The mechanical engineer will at once appreciate the difficulties involved in the construction of the equipment for this process. In addition to the high pressures and elevated temperatures involved, the steel is subjected to the action of both hydrogen and carbonaceous material, under which conditions the steel rapidly becomes brittle and loses its strength. A solution of this problem as incorporated in the new plant of the I.C.I. at Billingham, England, consists in constructing the converters with two walls--the inner one being an electrically heated, thin-walled tube in which the reaction is carried on; and an outer, thick-walled, pressure-resisting tube. The space between the two walls is filled with insulation so that the temperature of the outer tube does not exceed 150°C. The working pressure of hydrogen is maintained on both sides of the inner tube. Figures 9 and 10 show the large size of the units used and the elaborate precautions taken to guard the rest of the plant from the effects of failure of the reaction vessels. These views of the I.G. hydrogenation

These views of the I. G. Hydrogenation Plant in Germany, were furnished through the courtesy of Dr. A. W. Gauger of the Pennsylvania State College School of mineral industries who obtained them from the Standard Oil Development Company.

~~which is given in figure 11~~, is estimated to cost $11,000,000 and is designed to produce 37,000,000 gallons of gasoline annually from about 1100 tons of coal per day. About 440 tons of coal per day are hydrogenated, the remainder being used for power, steam, and hydrogen production. About 40-45 per cent of the heat put into the plant in the form of coal is recovered as liquid motor fuel. The cost at the plant of a gallon of motor fuel, made from coal at $3.10 per ton, is estimated at from 11 to 12 cents. The thermal efficiency of hydrogenation plants is about 45 per cent, that is, 45 per cent of the heat entering the plant in the form of coal is recovered as gasoline.

The plant can operate in competition to petroleum refineries, because of government guarantee of a preference tax which amounts to about 13 cents per gallon for the next 4 1/2 years; or, if the company wishes, to one-half this amount for the next nine years. The economic picture is not promising for the process in the United States at this time. What the future may bring--who knows? If we should have to turn to such a process, Illinois coals are suitable as a raw material for the process. (The high sulfur and ash content of Illinois coal will, as in most other applications of these coals, have to be taken into account in calculating costs.)

As mentioned above, the oil used to suspend the coal, and the heavy oils produced in the first stage, are hydrogenated by this process more easily than is the coal when proper catalysts are employed. As a result, the process has actually found a wider use in the production of gasoline from petroleum and coal tars than it has from coal itself. As crude oil and gasoline prices rise, we may expect to see a much wider application of hydrogenation to petroleum before it is applied to coal.

Synthesis from carbon monoxide and hydrogen

The third way in which liquid fuels may be obtained from solid fuels involves the formation of carbon monoxide and hydrogen and the reaction of these gases to form either mixtures of alcohols, mixtures of hydrocarbons, or both. Sabatier had shown as early as 1902 that methane could be formed by passing a mixture of carbon monoxide and three times as much hydrogen over a nickel catalyst at 300°C. Sabatier, it turns out, chose those conditions which favored the formation of methane. Further research, culminating in that of F. Fischer and H. Tropsch, showed that, by varying the temperature, gas, composition, pressure, and catalyst, mixtures of alcohols, aldehydes, and acids could be obtained from carbon monoxide and hydrogen.

The German I.G. in the meantime was working upon the synthesis of methanol from these gases. They found that by using zinc oxide as the catalyst and working at pressunes over 130 atmospheres and temperatures below 400°C. the reduction of carbon monoxide stops at the methyl alcohol stage. This process is now in large scale use all over the world. The mixture of oxygenated organic compounds was termed "synthol" by its inventors. Synthol was not a very satisfactory motor fuel, so researches were continued to attempt a complete reduction to the hydrocarbons. This was finally accomplished, the product being termed synthin, and later products "Kogasin." The synthesis may take place at low pressures or at high pressures, Dr. Fischer preferring to work at low pressures. The technical difficulties which had to be overcome were many. The catalysts were easily poisoned by sulfur compounds, which meant that the gases had to be thoroughly freed from sulfur--the reaction gives off much heat which had to be dissipated, which problem was solved in the design of the contact chamber. Figure 9 gives a diagrammatic scheme of a Kogasin synthesis unit. Water gas is produced, purified, and passed through the reaction chamber. The heat generated in the reaction chamber is removed by circulating oil passing through cooling coils embedded in the catalyst. The higher boiling products are condensed, the lower boiling ones removed by absorption. The process is remarkable for the variety of products which form and the dependence of the composition of the product upon catalyst and gas composition.

Table 3 shows the composition of a typical product, and Table 4 shows the variation in composition of the product upon catalyst and gas composition. This process is not yet in large scale commercial operation, but large scale experimental units have produced enough motor fuel for very extensive practical tests.

Table 3 *

Composition of primary product Kogasin

Product	Boiling range °F.	Amt. Present Wgt. %	Olefine content Volume %
Spirit	Under 86°	4	50
Gasoline	86° - 390°	62	30
Oil	Over 390°	23	10
Solid paraffin:	Melting point:		
From oil	120°	7	
From catalyst	160-180° and over	4	

* Koch, H., Die Benzinsynthese aus Kohlen oxyd und Wasserstaft bei gewöhnlichem Druck nach dem Verfahren von F. Fischer und Tropsch Glückauf 71: 85-90 (1-26-35).

Fischer, Franz, Die Synthese der Treibstoffe (Kogasin) und Schmieröle aus Kohlenoxyd und Wasserstoff bei gewöhnlichem Druck, Brennstoff Chemie 16: 1-11 (1-1-35).

Table 4

Dependence of olefine content on catalyst and gas composition

Catalyst base metal	Olefines in synthetic gasoline when using Water gas 100:1H_2 vol. %	Mixed gas 100:2H_2 vol. %	Cracked gas 100:3H_2 vol. %
Cobalt	55	35	12
Nickel	35	16	5

Mention was made that Dr. Fischer prefers to work at low pressures. This entails the handling of large volumes of gas, but the equipment required is light and relatively inexpensive. The I.G. in attacking this problem, favor high pressures, under which conditions the volumes of gas handled in the system are small, but the equipment, while smaller, must be constructed to withstand the high pressures. In the absence of actual operating figures, no choice can be made as to which is the most economical method of working.

Lubricants

In countries desiring complete freedom from dependence on outside sources for essential materials, the question of lubricants is just as important as the question of a liquid fuel supply. It has been shown to be technically possible to produce satisfactory lubricants from coal through hydrogenation of coal tar, or by synthesis from carbon monoxide and hydrogen. In this country it is probable that there always will be sufficient petroleum to meet the country's needs for lubricating oil. Even so, the importance of the type of petroleum from which lubricating oil is made is becoming less, as more highly developed methods of producing the lubricants are used. In modern oil refining processes using hydrogenation, aluminum chloride treatment, or differential solvent extraction, the character of the oil produced bears little resemblance to the raw stock.

Gas manufacture

So far, this discussion has been concerned with the future of liquid fuel production. It is the author's opinion that the possibilities of manufactured gas are enormous compared to present developments. Figure 10 shows the growing importance of gas supplied through mains, as compared with industrial uses. Several factors have worked against the further expansion of the gas industry. Gas was originally introduced as a means for furnishing light, and many of the statutory regulations set up for the regulation of gas supplies date from the days when light was produced by burning gas in bats wing burners or jets, which required a luminous flame. The introduction of the incandescent mantle obviated the necessity for the presence of illuminants in the gas. In the United States gas may be considered an obsolete source of light. Its present day importance is as a source of heat. What is wanted, therefore, is a gas which will deliver potential heat to our business at as low a cost as is possible by the medium employed. We can, therefore, ask the question, "Is the manufactured gas now supplied by public service gas companies the most desirable gas from the consumer's point of view?" The answer will not always be the same, since conditions vary. It is the author's opinion that heat can in many cases be delivered at a lower cost through the medium of a lower quality, but more cheaply prepared gas than is now the case. An important development in the manufactured gas industry has been the long distance, high pressure transportation by which the excess gas produced by coke ovens in industrial centers or at coal mines is made available in cities. The increasing importance to the coke oven operator of revenue from gas is shown in figure ~~14~~. 18 Fig 44 p 620 18

The expansion of the use of gas for domestic heating can well be to the advantage of the coal producer. A cheap producer gas would be just as valuable for this purpose as would a very high grade gas. The poor load factor at present associated with this type of service, due to seasonal demand, will, I feel, be ironed out through the increased use of air conditioning equipment in the summer.

An interesting side light on the problem of cheaply producing a fuel gas is the suggestion that coal be gasified in situ. In Italy and Russia this suggestion has been tried out on a moderate scale, not with any striking success however. Those of you who may have had to do with mine fires can appreciate the situation which is set up. The difficulties are not apparently so much in the regulation of the gasification as with roof falls, choking of gas passages through the swelling of the coal, and the formation of cracks in adjoining coal which cause dangerous leakages.

The expansion of the market for gas will always be affected by the competition of other "piped" fuels such as electricity and, in congested districts, steam. It should not matter to the coal industry which one dominates, since all have their ultimate source in coal. The coal producer should, however, be actively interested in the growth of the various industries, since the increased development of any or all of these utilities - gas, electricity, or public utility steam - will be to his advantage.

Cir 12

Friday, May 17

ROCK AND ROCK PRODUCTS

Elec. Eng. Auditorium

1. Rock and Rock Products - Technologic Trends in the Production and Utilization of Mineral Products.
   N. C. Rockwood, Pres., Rock Products, Chicago.

2. The Viewpoint of Science Regarding - Production and Utilization of the Non-Metallics.
   C. W. Parmelee, Head, Dept. of Cer. Eng., Univ. of Ill.
   J. E. Lamar, Head of the Non-Fuels Div., Ill. State Geol. Survey.

3. Blowing of Rock Wool from Illinois Rock.
   C. F. Fryling, Ill. State Geol. Survey. Missing from series.

4. The Building Stone Possibilities of Illinois Limestones. Filed in Ms. files.
   J. E. Lamar, Geol. and Head, Non-Fuels Div., Ill. State Geol. Survey.

5. Factors in the Development of a Rock Wool Industry.
   C. F. Fryling, Assoc, Chem., Ill. State Geol. Survey.
   Orval White, Pres., Mineral Insulation Co., Chicago Ridge.

6. Concentration of Non-metallics by Tabling of Agglomerated Materials.
   W. H. Coghill, Supervising Eng., Miss. Vall. Station, U.S.Bureau of Mines, Rolla, Mo. Missing from series.

7. The Significance of Accelerated Weathering Tests on Stone and Gravel.
   A. T. Goldbeck, Dir., National Crushed Stone Association, Wash., D.C.

8. Progress Report on the Study of the Utilization of Novaculite.
   C. W. Parmelee, Head, Dept. of Cer. Eng., Univ. of Ill.

9. Trends in the Utilization of Lime and Lime Products.
   Lee S. Trainor, Chief Eng., National Lime Assoc., Wash., D. C.

Comments on papers on "Rock and Rock Products"

General

It seems desirable to me that at the front of this report the following idea be expressed: -"Authors of the following papers are responsible for the statements and data contained therein."

Specific

Rock and Rock Product Trends - N. C. Rockwood

p. 6 - General trends in the aggregate markets. Some of the statements made are not complimentary to present public officials. May possibly require toning down.

✓ p. 9, line 10 - suggest change to "manufacture of many of the important....."

Significance of Accelerated Soundness Tests - A. T. Goldbeck

✓ p. 4, line 7 - suggest "secretions" be changed to "deposits."

✓ p. 5, line 3 - "autoclave" is one word.

✓ p. 14, part of the last paragraph needs editing badly. Suggest "On the other hand, one sample of argillaceous limestone whose failure in the sodium sulfate test was less marked than that of other samples does not give poor results in service."

Printed elsewhere — Papers missing on Flotation Processing of Limestone by B. L. Miller, and Concentration of Non-metallics by Tabling of Agglomerated Materials, by W. H. Coghill.

No illustrations or figures attached.

J.E.L.

~~Paper to be read at Third Annual Mineral Industries Conference of Illinois, May 17, 1935, Urbana, Illinois.~~

1

Rock and Rock Products Trends in

Production and Utilization

By Nathan C. Rockwood,
President-Editor, Rock Products, Chicago,

Since the surface of the earth is an uneven crust of rock, with the wrinkles filled here and there with shallow deposits of soil, or naturally disintegrated rock, all the output of the earth -- mineral, vegetable and animal -- might be termed "rock products". (R. W. Stone, of the Pennsylvania Geological Survey, once said that when we quarry limestone, which is the fossil remains of life, to put on the soil to feed plants, and the plants feed animals and ourselves, we are actually exploiting the bones of our ancestors.) However, the term rock products as used here is quite limited and refers (1) to the common rocks, rock fragments, or sediments, which find uses and markets in industry with no more than mechanical or physical processing; and (2) some of the common rock products manufactured by both mechanical and ~~somewhat crude~~ chemical processing.

In the first group are crushed stone, sand and gravel, silica sands, agricultural limestone, pulverized rock for various purposes, fluorspar, etc. In the second group are lime, cement, gypsum, rock wool, vermiculite, etc.

Winning the Raw Material

The first step in the process of producing and manufacturing all these products is their removal from their natural beds in the earth. Where the rock crust is intact, this means drilling, blasting, loading and hauling away. Most of these operations are conducted in open pits; but underground, or the room-and-pillar, method, of mining limestone and fluorspar is not unusual.

In ~~this primary~~ the operation of quarries the trend is, and has been for several years, toward more flexible equipment and safer high explosives. Many serious, unexplained accidents with nitroglycerine explosives have led the explosive manufacturers in a constant search for safer ones, and, while the search probably is not ended, much progress is being made. An indication of what is meant by more flexible equipment is the now universal use of full revolving power shovels of modest size, probably an average of about 2-cu. yd. dipper capacity, in place of the former cumbersome, railway-type shovel, and the use of motor trucks where feasible in place of industrial railways. Such equipment is not only more flexible in the quarry but more versatile, since it may be put to other use as well; consequently it has a greater salvage value.

A greater salvage value is desirable because a commercial quarry is no longer considered a fixture, as it was ~~once~~ in the days when its product was hauled to market exclusively by railroad at low freight rates. Markets now are more localized and more temporary, as ~~will be~~ is discussed farther on in this paper.

Where the earth's rock crust is already broken up, as in the case of sand and gravel, the methods of excavation and removal are more varied, including the use of power shovels and draglines, dredges of the suction pump, dipper, clamshell and ladder bucket types, scraper and cableway excavators. There is no particular trend or development in this part of sand and gravel production, except, of course, the constant perfection of the standard pieces of equipment.

The most pronounced trend in sand and gravel production in this section of the country, where deposits of good or fair material are relatively common, is toward smaller plants of a movable or portable character. Perfection of mechanical details in this type of equipment in recent years has made possible the preparation of satisfactory materials on a smaller scale than hitherto had been deemed feasible. Of recent years, too, the principal markets for sand and gravel have been highway construction jobs, where local materials, even if not so well prepared, were preferred to those brought from considerable distances, on which the freight charges far exceeded the price of the material itself. This trend will, of course, continue with still higher freight rates so long as the market is chiefly isolated highway construction. With a return of building construction in cities, the projected grade crossing elimination on trunk highways, widening and resurfacing of main highways, etc., it is probable that the so-called permanent plant will again find an increasing market for its product.

Preparation of Aggregates

The first step in the mechanical preparation of rock products is the crushing of large fragments to smaller ones of commercial sizes -- the "making of little ones out of big ones", according to the newspapers a popular pastime for jail birds. The larger fragments have a limited market for river and harbor revetments, sea walls, breakwaters, etc. The smaller fragments of rock or gravel have extensive markets for a great variety of purposes, the most common being railway track ballast, aggregates for cement concrete and bituminous concrete, highway surfacing, water purification and sewage filter beds, etc.; in the case of limestones for blast furnace and open hearth furnace flux.

For crushing the large fragments of rock or boulders to smaller sizes, a wide variety of crushers ~~types~~ is used. There have been many improvements in ~~these~~ crushers in recent years, particularly in those designed to make the smaller sizes of aggregate, or reduction crushers as they are called as distinct from primary crushers. Improvements in the design of the bell and concaves of the gyratory crusher result in larger crushing capacity and less grinding action. Roll type crushers are increasing in popularity for the production of small size aggregates extensively used for top dressing or surfacing of various types of highways. This market is expanding with the construction of secondary highways and the resurfacing of older paved highways. Crushed rock was formerly used exclusively for this purpose, but now crushed gravel is also used.

The next step in the preparation of aggregates after crushing is accurate sizing or screening. Originally all screening was done on flat gravity type screens or revolving cylindrical and conical screens. These types still are used extensively, especially for the coarser separations, but for the finer sizes the use of vibrating screens has now become the universal practice, except for such materials as require a thorough scrubbing as well as sizing. A plant serving a metropolitan building market is required to produce a surprising variety of sizes and mixtures of various sizes to meet specifications for many purposes, and to meet the individual whims of many engineers and architects. When a temporary or movable plant produces for a single highway, bridge or dam job, the engineers are often very lenient in the matter of specifications, much to the annoyance of ~~producers~~ owners of fixed plants, who take a just pride in the quality of their materials.

The third step in the preparation of rock for the aggregate market is the making of fine aggregate or sand. This is becoming a more and more involved and intricate process since it is being recognized that, next to the cement, the fine aggregate has the most important bearing on the quality of concrete. The first requisite is cleanliness, and the next a proper gradation of sizes to produce the densest mortar, and a workable mortar and concrete. A proper gradation requires a larger proportion of clean, fine particles -- minus 30-mesh -- than was the practice a few years ago, and to recover this material, many new types of hydraulic classifiers have been introduced in the last few years. In general these utilize principles long available in mining practice. Such devices include jigs and concentrating tables, which are the most recent additions to this industry.

Sand, or fine aggregate, is generally thought of as the natural product of rock disintegration -- usually largely composed of silica -- but in recent years the finer fragments from rock crushing operations, when thoroughly washed of all overburden and classified, are being more and more extensively used. Such crusher sand or stone sand may be limestone, dolomite or any other rock suitable for aggregate. Washing of coarse crushed stone aggregate is also being adopted to an increasing extent in order to compete the better with washed gravel and to eliminate the possibility of a contaminated material when operating a quarry in rainy weather.

A fourth and final step in the physical or mechanical processing of rock for commercial purposes is grinding it to powder. Pulverized rock is used for a great variety of purposes, such as a filler in bituminous pavements, a paint filler, for putty, etc., and, if a limestone, for inclusion in feed mixtures for cattle and hogs, and for any number of industrial uses. The largest tonnage of pulverized limestone is used for application to the soil as agricultural limestone. In Illinois this formerly was a by-product in the production of aggregates, being the material from ¼-inch to dust. However, when the specification required 3/16-inch dust, numerous plants specializing in this product were established, where pulverizing machinery is installed in addition to crushers. For very fine material, tube or ball mills are employed, and in at least one plant in this state the grinding is done wet and the fines are separated by hydraulic methods, and dried.

General Trends in the Aggregate Markets

We have already touched on market trends which affect the business of the aggregate producer. The most important of these have been induced by the attitude of government officials -- national, state, and local -- which has tended to overlook the great investment in commercial plants and the years of experience of commercial producers in perfecting their operations and their products and to turn to new local production of untried and unproved quality, using relief labor in most instances. It is true, of course, that in the evolution of the mineral aggregate industry looking toward greater mechanical perfection, fewer men are employed to produce the same tonnage as formerly. This is true of all industry. But it has made toward better and more economical materials, all things considered. To revert back to hand methods of production of doubtful materials for no reason other than that it gives employment with the least effort on the part of the government officials is not sound. The labor of these men could be better employed in making efficient and lasting use of tested and proved materials commercially produced. And this would prevent demoralization of one of the state's most important mineral industries.

The operation of the industry under its NRA code has tended to even out the costs of production between various plants, and this, in turn, has led to more uniform prices, but these prices have been uniformly low and barely enough for the strongest companies to survive, and the competition has been more keen under the code than ever before. Producers naturally insist, as a matter of equity and as employers and as taxpayers, that governmental authorities new

should not deprive them and their employes of their means of earning a livelihood and of paying their taxes.

Silica and Fluorspar

Three of the state's most important rock products, which, so far as the producer is concerned, require only mechanical preparation, are the silica of northern Illinois, the silica of southern Illinois, and fluorspar. In northern Illinois, silica is produced by pulverizing quartz sand from the St. Peter formation, with the industry centering chiefly in the vicinity of Ottawa. The St. Peter sandstone, which is quarried here at several places, requires very little or no crushing. It is washed, classified or screened, dried and pulverized for a variety of industrial purposes. The sand from the St. Peter formation is so uniform in grain characteristics that a certain carefully screened grade has long been used as a standard in testing cement.

This state produces large amounts of steel molding sand from the St. Peter formation in the Ottawa district. Natural bonded molding sand for iron foundries is also produced at numerous places. In the molding sand field there has been a trend toward a closer control of the nature of the sand used, looking to the selection of sands having an optimum life and suitability for their particular uses. Special attention is being given to molding sand bonds, their life or durability, bonding strength, etc. Such materials of superior quality are becoming increasingly important because of the trend toward the use of washed sand with an artificially added bond.

Another form of silica, known commercially as amorphous silica or tripoli, is mined in Union and Alexander counties of extreme southern Illinois.

7a is next

new

This material is either dry or wet ground and is produced in water or air floated grades of high purity.

The only outstanding trend in the production of silica products of which I am aware is the increasing attention being paid to the elimination of the hazards of silicosis, an industrial disease which has recently attracted national attention. Only very fine particles of silica constitute a hazard, and this may be largely eliminated by enclosing all crushing, grinding, screening and conveying equipment and removing the dust by suction fans through pipes or ducts to a dust collector. The use of respirators by the workmen is now required, as an additional safeguard. This industry is one of the most important mineral industries of the state; its products are shipped to all parts of the country, and it is highly desirable that its problems receive sympathetic understanding and treatment on the part of the public and of state officials.

The fluorspar industry is confined to the southern end of the state. This is a relatively rare rock product, which has many uses, chiefly as a fluxing agent in metallurgy, ceramics, etc. Its possible uses are probably many more. In this brief paper it can only be mentioned as one of the most valuable mineral resources of the state, which presents several special problems in recovery, processing, and utilization; problems that others here are much more familiar with than I am.

The Chemically Prepared Rock Products

~~The~~ A second group of rock products ~~referred to in the introduction~~ require chemical as well as physical processing. The simplest of these to manufacture is lime. Lime is limestone heated, or calcined, or "burned" to drive off the carbon dioxide, leaving calcium oxide instead of the original calcium carbonate. There are possibilities in the recovery and use of this carbon dioxide, now almost universally wasted. While the burning process is essentially simple and is so regarded by many lime manufacturers, it is not simple if the calcining is ~~so done so~~ controlled to produce desired qualities in the lime. Those qualities are to a certain extent inherent in the stone, but it makes a great deal of difference at what temperature the stone is burned, how long it is kept at burning temperatures, how cooled and how treated during the cooling process; also the kind and quality of the fuel used are important.

More and more attention is being paid to these details, and lime producers are constantly recognizing that quality is much more under their control than they used to believe.

Lime has innumerable uses in industry. At present its use in construction is secondary to its use in metallurgy, in chemical processes, for water softening and purification, for sewage treatment and for agriculture. The state has inexhaustible deposits of both high-calcium and dolomitic limestones, which undoubtedly will find more and more uses. ~~The metal magnesium~~ Magnesium, which occurs in dolomite, is already produced in metallic form from natural brines in other states on a fairly extensive scale. ~~from natural magnesium chlorides and from by-product chlorides.~~ It is ~~probable~~ possible that low-cost commercial processes will eventually be developed for recovering magnesium from carbonates or oxides. ~~more directly.~~ The possibilities of alloys containing the metal calcium (of which limestone, ~~of course,~~ is the carbonate) ~~as an alloy~~ have not been explored, but with the development of some cheap commercial method of winning ~~it~~ calcium from limestone or lime, it would doubtless ~~prove a valuable addition to~~ improve its economic standing among our industrial metals. In these cases, in the perhaps not too distant future, Illinois may become an important metal producing state as well as a nonmetallic mineral producer.

Lime is the starting point in the manufacture of ~~nearly all~~ many of the important cementing materials used in construction. For centuries probably lime and sand mixtures were the only mortar and concrete materials. The possibilities of making special lime cements by admixture of active silica and alumina ingredients have scarcely been explored, and in this field I believe there is a great future. The concrete of the Romans, which has resisted to this day sea water and other disintegrating forces of nature, was made of lime and a silica and alumina pozzolana. A pozzolana is a naturally active form of silica or alumina, but its action is too slow by modern standards. Research could well be directed, physically and chemically, toward processing silica and alumina to render them capable of rapid direct combination with lime and water to form hydraulic binders. In all these binders, when the solidifying reactions are over, apparently only simple calcium silicates and aluminates remain, which could very likely be arrived at by some simple and direct means.

Portland cement is pulverized limestone calcined in the presence of about 30 per cent ~~of~~ pulverized silica and alumina to "incipient fusion". A chemical combination or a solid solution of dicalcium and tricalcium silicates and aluminates results, which, after being

change to "possible" C.F.F.

See suggested revision starting p. 8 - last line (C.F.F.)

ground to powder and mixed with water, has an end reaction resulting in simple lime hydrate or calcium hydroxide and some simple calcium silicate and aluminate. Dicalcium and tricalcium silicates, the chief components of portland cement, do not exist in nature and probably do not exist for any length of time in concrete.

Trends in the manufacture of portland cement are distinctly toward truer chemical control. As in the case of lime manufacture, it was long contended that particular or peculiar properties in cements were inherent in the raw materials; that the combination of these raw materials within relatively broad limitations produced a "standard portland cement". It is now recognized that variation in the ratio of silica to alumina and iron has an important bearing on many of the qualities of portland cement. Too much alumina, for example, raises the heat of hydration, which in large mass concrete is important because it causes changes of volume during the hardening stages, and hence cracks in the masonry. Such knowledge has led to the U. S. Government requiring cement for large hydro-electric and irrigation dams to meet chemical specifications as well as fulfil the required physical tests.

The desire on the part of the cement manufacturer to use limestones which contained more than the allowable impurities led to experiments with oil flotation to concentrate the calcium carbonate content of these limestones, and these results, in turn, have shown how any of the important mineral components of a cement raw mixture may be concentrated or eliminated, by well-known metallurgical processes, as more accurate chemical formulas may require. This opens up a broad vista not merely of making special cements for special purposes but of making a really standard portland cement -- that is standard by chemical analysis as well as measuring up to certain standard requirements of physical strength, etc.

When limestones contain too much silica, alumina, and iron to make lime or portland cement, or, in other words, when they flux too easily, they may be just the thing to make rock wool. The process of manufacture is essentially the same except that in the heating or calcining of a rock wool mineral mixture the calcination is carried to the point of actually fluxing the material to a slag, which is blown into fibres by an air or steam jet as it is tapped from the furnace. Of course, artificial mixtures of limestone with the fluxing agents, silica, alumina and iron oxide, principally, may be made where the proportions of these minerals in the original limestone are not such as to make slagging or fluxing relatively easy.

The markets for rock wool are now chiefly confined to insulation of various kinds, and this market, when developed, is a huge one. Moreover, it would seem that many other uses are possible. I can see no reason why it should not be used for the many purposes of asbestos fibre. With lime or cement binder it could very likely be used for the manufacture of lightweight, thin but strong building units. The time is probably coming when fireproof durable building units will be made and handled and fashioned with the same facility that lumber is today -- which, incidentally, is the only virtue lumber has as a building material in comparison with these new ones.

* * * * * * *

This has been a very sketchy but, I trust, frank discussion of some of the trends and developments in the rock products industry. In view of the more detailed papers and discussions to follow, I can only hope it may prove provocative of thought and discussion rather than really informative to a group of experts, which you have done me the honor of inviting to address.

#

C.7.7.

✓ *N. C. Rockwood:*

✓ p1. *last line, 1st ¶.* delete "somewhat crude"

✓ p 8 – *9th line*. delete "so – as"

p 8 – *Last line* – gives impression that magnesium is extracted from dolomite.

? The phrase "The ~~metal~~ metal magnesium in dolomite" is also technically inaccurate.

✓ p 9. *line 2*. The sentence starting "It is probable that" appears to me to be the exact opposite of truth. I would be inclined to say "It is improbable that" This can be corrected by substituting "possible" for "probable". I believe that the author intended to say "possible".

✓ p9. *line 4 et seq.* The expression "the possibilities of the metal calcium as an alloy" is technically inaccurate. I also object to the statement that "have not been explored". Also there are commercial methods available, what is needed is cheaper methods.

C.7.7.

✓ p8. starting last line. Suggested revision.

Magnesium, which occurs in dolomite, is already produced in metallic form in other states on a fairly extensive scale from natural brines. It is possible that low-cost commercial processes will eventually be developed for recovering magnesium from carbonates or oxides. The possibilities of alloys containing the metal calcium (of which limestone is the carbonate) have not been completely ~~ex~~ explored. ~~but~~ With the development of some cheap commercial method of winning calcium from limestone or lime, it would doubtless improve its economic standing among our industrial metals.

The Viewpoint of Science Regarding the Production and Utilization of Nonmetallic Minerals

By

C. W. Parmelee

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and

J. E. Lamar

Head, Non-fuels Division, Illinois State Geological Survey

No. 6

~~The viewpoint of science regarding the production and utilization of nonmetallic minerals~~

~~By G. W. Parmelee and J. E. Lamar~~

In their beginning many uses of non-metallic minerals were probably fortuitous. It is doubtful if the discoverer of lime, whoever he was, definitely set out to produce calcium oxide from calcium carbonate. Rather it is probable that the discovery resulted from observations associated with the use of limestone in early out-door fireplaces and the effect of rain on the stone. Similarly the discovery of the fact that clay can be hardened by fire was probably accidental.

Up to the time when experimental science began, man added to his knowledge of the uses of non-metallics mostly by a more or less blind process of trial and error and by this method built up a considerable fund of useful information. With the advent of modern science, however, a very different procedure is possible. The development of new products or uses becomes a process directed towards specific ends.

With such a background the overall viewpoint of science regarding the production and utilization of non-metallic minerals may be concisely stated. There is no doubt that the future will witness the continuance of most of the existing uses for non-metallic minerals in their raw state and as manufactured products. There will be a continuous development of new products and uses, with increasing emphasis on the production of raw materials or products having definite physical, chemical, and mineralogical characteristics accompanied by a gradual tightening of specifications.

In the line of products for new uses, doubtless many will result from variations of existing routines in manufacture. For example, the crushed stone industry is interested in the production of stone sand as fine aggregate. This is a comparatively new use for crushed stone but the manufacture of this product is chiefly a matter of modification of existing stone crushing procedure. Similarly the production of clay building units in new shapes involves largely modification of existing methods of manufacture.

The tightening of specifications which non-metallic products must meet is already under way and results from the employment of scientific research by mineral consumers who in their improvements of their products find [desirable a closer control of] ~~closer~~ raw material. ~~control desirable.~~ As an example may be cited the now common requirement that stone for concrete roads pass an accelerated weathering test.

From the standpoint of major developments in the production and use of non-metallic minerals, science feels that progress will result primarily not from chance but rather from the coordinated efforts and knowledge of men trained in the various sciences ~~and~~ focused on specific problems. The specific assignment of science is to anticipate new needs or meet existing needs for non-metallic mineral products or processes on the basis of controlled and directed studies. ~~As~~ Tools for such work must [consist of] ~~be employed~~ the newest technique and apparatus including microscopes giving exceedingly high magnification, X-rays, new thermal, electrical, and mechanical devices, and improved methods of analysis and test.

Considering the nonmetallic mineral resources of Illinois, science finds that, excluding fuels and water, it deals basically with six major chemical compounds, silica, alumina, lime, magnesia, carbon dioxide, and calcium fluoride. In general it may be said that the six compounds listed are the basic building blocks of the nonmetallic industry of Illinois.

These six compounds may seem to be a small foundation for the extensive and varied non-metallic mineral industry of Illinois. However, when it is considered that these compounds in various combinations and in varying amounts offer an exceedingly great variety of combinations, the existing industry is understandable and its future evidently by no means limited. Alumina and silica in combination give rise to clay; lime and carbon dioxide to limestone; lime, magnesia and carbon dioxide to dolomite, and silica alone comprises the dominant part of many sands.

In the past, circumstances have been such that science has concerned itself primarily with the question of where materials of well recognized properties for known uses could be found in Illinois. So far as Illinois is concerned, this question can now be answered for a considerable portion of the State with reasonable detail. When, at present and in the future, science works with the natural materials of Illinois, it needs to have more than general information regarding the chemical character and physical properties of these materials. Consequently, not only is it necessary that collection of additional information go forward regarding the location and general character of the non-metallic mineral deposits of the State, but also that their chemical, physical, ceramic and mineralogical properties be known in detail.

It is clearly evident that in Illinois the future's challenge to science is a three-fold one involving:

(a) Continued accumulation of data regarding the location and physical aspects of the State's non-metallic resources to the end of charting supplies for existing uses and for other uses as they may appear.

(b) The securing of detailed chemical, physical, ceramic and mineralogical data regarding the State's nommetallic resources.

(c) The use of these data for the development by research of new mineral products from Illinois materials and the improvement of existing products.

Examples of the success of science in meeting its challenge by group research are numerous. Examples may be picked from researches carried out on the mineral deposits of Illinois; witness the recently completed studies on rock wool making material. Woolrock, that is the natural rock from which rock wool is made, was sometimes said to be a material peculiar to the State of Indiana. No specific, adequate chemical information regarding its composition and the permissible range in composition ~~permissible~~ were available. However, chemical research at the Survey was able to accurately delineate the composition of woolrocks and with this information as a basis for field studies, geological research was able to locate five major deposits of woolrock, well distributed within Illinois and capable of exploitation as a source of woolrock. In this connection it is of interest to note that the woolrocks discovered were all materials not in commercial use and had generally previously been considered of little value.

Other researches under way which illustrate the scientific viewpoint of the future of the non-metallic industries and the potential results of studies directed in accordance with this viewpoint, are the current petrographic, ceramic, and chemical investigations by the Survey and the Ceramics Department of the University of Illinois on the clays of Illinois. Until comparatively recently, our knowledge of the mineral composition of clays and shales was circumscribed by the serious experimental difficulties associated with the micro-analytical technique. New methods and extensive investigations of Illinois materials are resulting in a better understanding of the true nature of these materials. Naturally, there may be expected a correlation between the occurrence of certain mineral forms and the physical properties of the clays. Information of this nature points the way to an understanding of how Illinois clays and shales can be used to the best advantage for the manufacture of clay products and is basic to the improvement of existing products and the development of new ones.

In answering inquiries concerning sources of raw materials, the value of detailed data regarding the location of mineral deposits and their physical, chemical and mineralogical character, is coming to be increasingly evident. Inquirers are not usually satisfied by generalities but desire full information regarding the nature of deposits and of the materials available.

Examples could be multiplied. However, it seems clear that science foresees the future of the non-metallic industries as one dependent on the results of research and their practical application to meet the economic situation of the times and the industry.

SOME FACTORS IN THE DEVELOPMENT OF A MINERAL WOOL INDUSTRY *

* Published with the permission of the Chief, Illinois State Geological Survey, Urbana, Illinois. ~~Material~~ Presented at the Third Annual Mineral Industries Conference of Illinois, Urbana, May 18, 1935.

by

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and

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2/ President, Mineral Insulation Company, Chicago Ridge, Illinois.

Abstract

Factors which are responsible for the popularity of mineral wool for home insulation are enumerated. The beginnings of the rock wool industry in Indiana, together with present plant practices, are described. Suggestions based on similarities in the manufacture of rock wool and portland cement are advanced for overcoming production difficulties at present encountered. More semi-plant scale development work is advocated. Economic factors of importance are: (a) There are approximately thirty plants, eight in Indiana, the remainder scattered from Vermont to California; (b) freight rates are high, exceeding, in some cases, $50.00 per ton; (c) woolrock deposits are widespread; some have recently been found in Illinois, Ontario, and southern Indiana ~~[illegible]~~, ~~and Illinois~~; (d) patents on blowing insulation into dwellings are held jointly by six companies; (e) an estimated cost of a two-cupola plant, exclusive of land and quarry equipment, is $38,000; (f) it should be possible to produce rock wool at $20.00 or less per ton.

I. PROPERTIES AND USES OF MINERAL WOOL

Mineral wool is a light-weight material composed of thin, glassy fibers. The raw material from which it is produced consists either of sedimentary rocks, which appear to be mixtures of shale and limestone laid down simultaneously, or of various types of metallurgical slag. In order to secure a material which can be melted and blown into wool, it is necessary that its acidic and basic constituents be fairly evenly balanced.

Chemically, rock wool, which can be defined as mineral wool obtained from naturally occurring rocks, consists of silica, alumina, lime, and magnesia in combination. The composition limits have been determined experimentally.[1/] One

1/ Illinois State Geological Survey Bulletin No. 61, "Rock Wool from Illinois Mineral Resources," Urbana, Illinois, 1934.

important point revealed by this study is that the properties of rock wool are definitely determined by composition and blowing conditions. Therefore, provided the composition is correct, it is immaterial whether the wool is produced from a single rock, a mixture of rocks, or from some other material such as slag. Slag wool and rock wool of the same chemical composition, and blown under the same conditions, would be indistinguishable. However, it must be remembered that many slag wools are produced having compositions which are quite different from those yielded by rocks, and the differences in the products may be quite marked.

The most important use for mineral wool is as a heat insulating material. The tangled mass of fibers of which the material is composed serves to entrap a large number of small air pockets which, in turn, impart the property of low heat conductivity to the aggregate. Mineral wool has many advantages compared with other heat insulating materials. Among these may be mentioned:

(1) On the basis of its coefficient of heat transfer, mineral wool ranks among the best commonly available heat insulating materials.[2]

2/ Loc. cit. pp. 237-39.

(2) Deterioration is practically nil. It is quite usual to find it unimpaired after 25 years or more of service.

(3) In contrast with certain organic materials, it is inert toward moisture, and consequently its insulating properties show less tendency to fluctuate with changing weather conditions.

(4) It is thoroughly fire-proof and vermin-proof. This should be of importance from the standpoint of health and insurance rates.

(5) It can be fabricated in forms convenient for use in the building industry, such as ~~Some of these are:~~ loose fill, rigid board, and quilts.

(6) It is an excellent acoustical insulation material. In this connection, it is interesting to recall that it was used to insulate the broadcasting studios of Radio City.

(7) It is relatively inexpensive, and the indications are that it can be produced more cheaply than it is at present.

Although finding considerable use in industry, there is much to indicate that mineral wool will find its widest ~~use~~ application in the insulation of buildings. It can be expected to contribute towards better health by equalization of room temperatures, elimination of drafts, increased comfort in both summer and winter, and reduction of vermin and fire hazards. That it contributes materially towards the economical use of fuels is well known. A recent publication 3/ gives the calculated heat

3/ Sheet metal worker 26: 41-2, Jan., 1935.

losses through 1,000 square feet of wall. The wall consisted of clapboard on sheathing with building paper between, ~~2 by 4~~ 2x4 studs set at 16-inch intervals, and an inner wall of wire lathe and plaster. The calculation was made for a 15-mile per hour wind velocity, 200 days heating season, 30 degrees average temperature difference, and 24-hour load, with the following results:

	Heat Loss	Equivalent Tons Coal */
No insulation	38,000,000 B.t.u.	1.6
1 inch of rock wool,	18,700,000 "	0.8
3 5/8 inch " "	8,600,000 "	0.4

*/ The coal equivalence was calculated by us on the basis of 12,000 B.t.u. per lb. of coal.

II. MANUFACTURING PROCESS

The production of mineral wool from slag has been practiced for about 60 years. The most important improvements, however, were made about 35 years ago by C. C. Hall, who established a plant for the production of rock wool at Alexandria, Indiana. Incidentally, the rock wool industry was born during the depression of 1896. Mr. Hall, who had been operating a steel mill at Alexandria, tried local stone to find a more inexpensive fluxing agent. He found that the slag produced by the local stone readily blew into fibers when struck by the air blast of the smelter. He experimented further to satisfy his curiosity. After the steel mill had been closed, he investigated the possibility of using cheap natural gas, then available, to make fire-proof insulation out of the self-fluxing stone that he had discovered. He erected his first plant without further experimentation. The picture (Fig. 1) shows Mr. Hall, the first plant, the first car-load of mineral wool shipped from Alexandria, and the first men employed in the rock wool industry.

The first melting equipment is also visible. This was simply a brick puddling furnace employing natural gas fuel. It was constantly giving trouble because of refractory corrosion. Under these inauspicious conditions, the rock wool industry started. To Mr. Hall, the industry owes a tribute for thirty years of hard work put forth in its behalf.

Present-day practice follows very closely that finally established by Mr. Hall. Cupolas, about 5 feet in diameter and 8 feet high, are used. (Fig. 2.) A mixture of rock, or slag, and coke, is fed into the top of the cupola, and molten material flows out at the bottom in a steady stream. Combustion is supported by a blast of air fed into the bottom of the cupola

~~which in some respects resembles the type of equipment used for melting cast iron.~~ A temperature of about 1,500° ~~degrees~~ Centigrade is attained, and cooling is effected by a water jacket. A steam blast, issuing from a trough-shaped nozzle at a pressure of about 100 pounds per square inch, is directed at approximately a right angle to the stream of flowing material. This is broken up into innumerable small droplets which are propelled into a collecting chamber. During its flight through the air, each little droplet drags out a small thread of material which solidifies before falling.

Cupola capacity is rated at 1,000 pounds of wool per hour, but 500 pounds per hour has been considered satisfactory. The raw material must not be so fine that it blows out of the cupola or plugs it up. It is considered advisable to use an assortment of definitely sized materials in order to prevent excessive channeling within the cupola. The object of the melting operation is to secure a steady stream of molten material of homogeneous chemical composition at the proper blowing temperature.

The wool may be collected on an endless belt in a chamber about six feet wide and forty feet long. A small amount of oil is usually added to the steam used for blowing in order to reduce dust, to secure better cohesion, and to produce a more water-resistant product.

The crude wool can be fabricated into the various forms required by trade. It can be treated in special equipment in order to produce a refined product for blowing between walls; it can be loosely compressed into blankets, inserted into ready-built forms, sewed up between paper or wire netting to form quilts, or fabricated into plasters, bricks, and other forms. One difficulty encountered in fabricating mineral wool is slow drying, a consequence of its low heat conductivity. For this reason, it is essential to keep the wool fairly dry during the blowing process.

III. IMPROVEMENTS POSSIBLE IN ROCK WOOL PRODUCTION

(a) With present type of equipment:

It seems probable that most mineral wool plants now in operation are antiquated. Chief difficulties encountered are high and variable fuel consumption, wide variation in quality of product, and inability to maintain continuous operation.

These difficulties can be largely attributed to the empirical nature of the present manufacturing procedure. Little effort to establish control of the raw materials has been attempted. Rocks which are assumed to be of the proper composition are used, and temperature is controlled according to the whim of the operator. It is therefore ~~necessary~~ desirable to provide some degree of chemical control. Methods ~~analogous~~ similar to those used in the cement industry would be ideal, but the possibility of introducing such complete control at the present time appears to be too great an advance to bring about immediately. It is therefore suggested that a carbon dioxide determination might be used to advantage.[4] The weight of carbon dioxide in naturally occurring rocks is a fairly accurate measure of the basicity of the melt. The data would be used to proportion the charge so that its average carbon dioxide content would be some specified value, say, 28 per cent. It is evident that this method can only be applied as a control in the production of ~~rock~~ wool from rock,

4) Loc. cit. pp. 225-229.

and is not applicable in the case of ~~slag~~ wool from slag.

It is possible to suggest certain ways in which the efficiency of the present type of equipment might be improved; but before these are undertaken, an accurate heat balance for the process should be secured. Apparently, the cupolas have not been designed with an eye to heat economy, for the rock can be melted much faster than it can be blown. It would not seem impossible, however, to blow two or three streams simultaneously from the same cupola. At the same time, the possibility of reclaiming waste heat from the cupola and stack should not be overlooked. The U. G. I. producer gas generator, according to Haslam and Russell,[5] utilizes the water cooler for the generation

[5] Haslam and Russell, "Fuels and their combustion," McGraw-Hill Book Company, 1926, p. 587.

of steam. The possibility of effecting a similar economy should be investigated by a competent engineer.

A means of following the temperature of the slag stream should be provided. Adequate equipment should be provided to eliminate operating hazards.

(b) Possible improvements in the process:

It is quite evident that present methods are rather limited in regard to the range of compositions which can be employed, the type and size of raw material, and the extent to which mixtures of raw materials can be accommodated. A method allowing the use of mixtures, say of limestone and shale, would enjoy the following advantages:

(1) It would be possible to produce a product of predetermined composition.

(2) The location of the plant would be independent of the occurrence of woolrocks and could be decided entirely on economic considerations.

Some industrial attempts have been made to produce mineral wool by admixture of silica sandstone and limestone.[6] The

[6] Thoenen, J. R. - "Mineral Wool." Information Circular No. 6142, U. S. Dept. of Commerce, Bur. of Mines, June, 1929.

literature does not indicate what success has attended these efforts.

We wish to suggest pre-sintering of pulverized raw materials in a rotary kiln as a suitable method for production of clinker of controlled composition for subsequent melting in a cupola. Mineral wool could then be made from suitable mixtures of the following materials: homogeneous or non-homogeneous woolrocks, sandstone, shale, sub-woolrocks, slag, cinders, cement rock, clay, sand, gravel, loess, till, limestone, dolomite, oyster shells, etc.

On the basis of data presented before Congressional hearings on the tariff (Schedule 15, 1929) regarding the cost of portland cement production, ~~one of us~~ the senior author has estimated that the cost of grinding, mixing, and pre-sintering should be from $1.50 to $2.50 per ton of clinkered material. This added cost should be off-set, in part or in toto, by the following economies in cupola operation:

(1) Reduction of fluctuations in output of the cupolas.

(2) Reduction in fuel consumption for the cupola operation.

(3) The cheapest raw material available at any given time, from the list just presented, could be used.

(4) "Mineral wool cullet" could be used over by putting it through the sintering process. It would constitute the very cheapest form of raw material possible.*/

*/ In the production of granulated wool, and other finished products, there is a large loss due to sifting out of shot, large fibers, and other coarse material. At present, this loss may amount to 50 per cent by weight of the wool produced.

These possibilities for improvement in the production of rock wool indicate that the cost of production can be materially decreased.

Finally, unless one has had actual operating experience and is thoroughly familiar with the process, it would be rash to build a full sized plant. In the development of any industry from research, several steps are desirable before the process can begin profitably to produce for the market. A small scale plant should be built and operated successfully in order to obtain the engineering data necessary for the design of the full scale plant. The nucleus of a sales force must evaluate the product of the plant and determine in what manner it can best be marketed.

IV. ECONOMIC FACTORS

At the present time, there are approximately thirty producers of mineral wool. This includes the producers of both slag wool and rock wool, as well as at least one firm which produces a mineral wool using soda-lime glass as the raw material. It is apparent that the number of producers is increasing. There are three or four plants operating in the vicinity of Los Angeles, eight in Indiana, and plants are either in operation or are being established in Illinois, Texas, Ohio, New Jersey and Vermont, ~~and Illinois.~~

For many years the industry was largely centered around Alexandria, Indiana, but the general trend at present seems to be toward decentralization in order to supply local needs more economically. The factors which favor this decentralization, as well as those which are temporarily hindering it, are significant.

The large volume of ~~occupied by~~ a ton of mineral wool limits the amount of material that can be loaded into a box car. The bulk density of the material is about ten pounds per cubic foot, and only approximately 12 tons can be loaded per car. Therefore, the freight rate is high. The freight rate on rock wool from Alexandria to various points is as follows:

FREIGHT RATES PER TON ON ROCK WOOL
FROM ALEXANDRIA, INDIANA

Chicago	$ 4.80	Kansas City	$10.40
Cleveland	5.80	Minneapolis	11.20
St. Louis	6.00	Birmingham	15.00
Baltimore	9.00	New Orleans	19.40
Philadelphia	9.40	San Francisco	52.80
New York	10.00		

Another factor favoring decentralization of the industry has been the discovery of woolrocks in various places. Within the past four years, the discovery of woolrocks has been recorded in geological reports from ~~Ontario,~~ Illinois, southern Indiana, and ~~Illinois.~~ Ontario. Developments are now under way which indicate that premixture of limestone and shale is feasible. If successful, this will make the industry independent of the location of woolrock deposits and will accelerate the decentralization process.

There are several factors, however, which have retarded rapid decentralization of the rock wool industry. Among these has been the Rock and Slag Wool Code. ~~Under~~ While the code was in effect, a uniform retail price of about $50 per ton ~~has been~~ was maintained throughout the United States for mineral wool in bulk, and the price of the material refined for blowing into houses ~~has been~~ was approximately $70. This uniform price made it difficult to start up in a new locality and secure the bulk of the local market by cutting prices by an amount equal to the freight differential.

The patent situation is also a factor in delaying complete decentralization. Six of the larger producers are reported to control the patents for blowing refined rock wool into the walls of dwellings which have already been built. This makes it difficult for newcomers to break into what may be the most lucrative phase of the house insulation business. ~~However, it is possible that these patents will be broken when their validity is tested in court.~~ invalidated by court action.

Increased use of automobile trucking has helped the industry to overcome, to some extent, the unfavorable freight rates, thus delaying the necessity of decentralization. Since only one handling is involved, paper bags in place of burlap bags can be used. This difference in cost amounts to about $6.00 per ton.

The tardy recognition of the value of insulation in homes has been a serious drawback to the industry. It has taken the public some years to discover the merits of the various types of insulation available. Mineral wool has no structural properties; it is used solely for its heat retarding qualities. At the present time, mineral wool for house insulation meets practically no sales resistance, and it is possible to look forward with confidence to a widespread increase in its use.

Other important considerations for the prospective producer of mineral wool are the following: probable market, plant cost, production cost, and fuel cost. In the discussion of these, it should be realized that accurate figures can be obtained only from complete cost data. Furthermore, it must be remembered that such figures will vary from plant to plant, and from time to time. Nevertheless, with these limitations, we think that the estimates which we are able to present will be of value.

Probable Market

In 1931, the American Builder and Building Age published a series of articles attempting to evaluate the future market for insulating materials. The material for these articles was collected from the building industries by the publication. On the basis of the number of buildings which could be profitably modernized, and the probable new construction, it was estimated that there was an annual market for 11,700,000,000 square feet of insulating materials. At the time, it was thought ~~by one of us~~ that mineral wool could capture at least 50 per cent of this market, and it was estimated that the probable future market for mineral wool could be placed at $100,000,000.

Now that the economic trend seems to be upward, it is interesting to re-examine these figures. Apparently mineral wool has captured at least half, if not more, of the building insulation business. Subsequent to 1933, the mineral wool business has witnessed renewed activity, and has expanded beyond its pre-depression high. Three million dollars is believed to be a conservative estimate of the present annual business; and, considering the delayed housing construction, it does not seem unwarranted to expect the $100,000,000 per annum figure to be attained within a few years.

Cost of Plant

The following estimate is based on the use of new materials. The capacity of the plant is rated at 1,000 pounds of mineral wool per hour. Again, it should be remembered that local conditions may affect the cost one way or the other from the figures presented.

ESTIMATE OF COST OF A TWO-CUPOLA ROCK WOOL PLANT

Cupolas (2)	$ 1,500
Blowers	1,400
Steam boiler, pipes, valves, and stack	3,000
Collecting belts (2)	1,600
Shredding machinery	500
Dryer, wool compressor, etc,	5,000
Building materials,	10,000
Labor	8,000
Power and water	1,000
Miscellaneous	6,000
TOTAL	$38,000

An operating plant, with quarry and land, should therefore cost from $50,000 to $75,000. This makes no allowance for pilot-plant development, or the development of an adequate sales organization.

Fuel and Production Costs

The cost of fuel will vary with the location. It is reported that coke is obtainable in the Chicago area at from $4 to $5 per ton. Approximately one ton of coke is required per ton of wool produced. With the present type of equipment, it should be possible to produce wool at a figure under $20.00 per ton, figuring all costs.

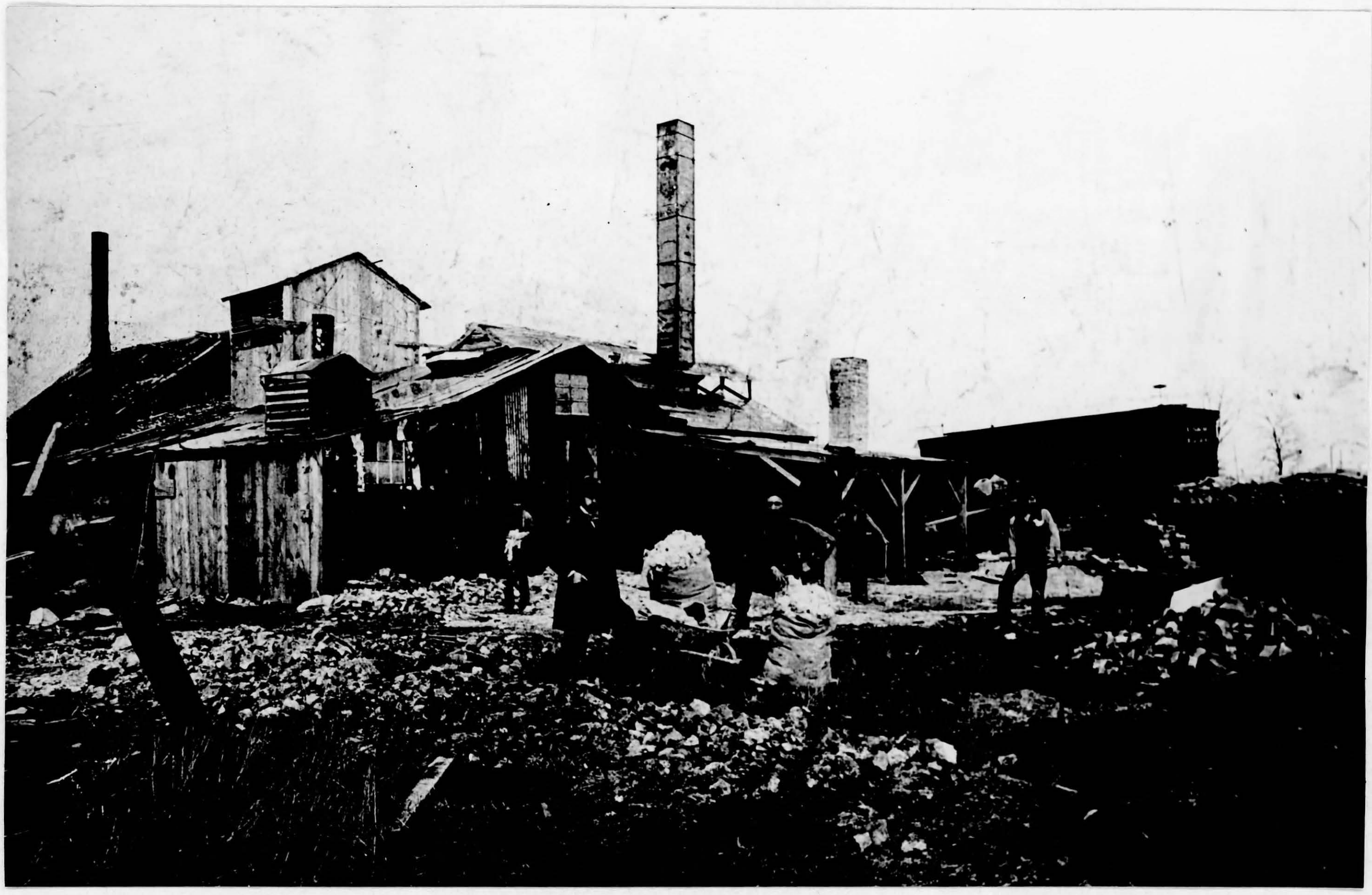

Figure 1.- First Rock Wool Plant. Courtesy - Mr. C. C. Hall.

Alexandria, Ind. 1897.

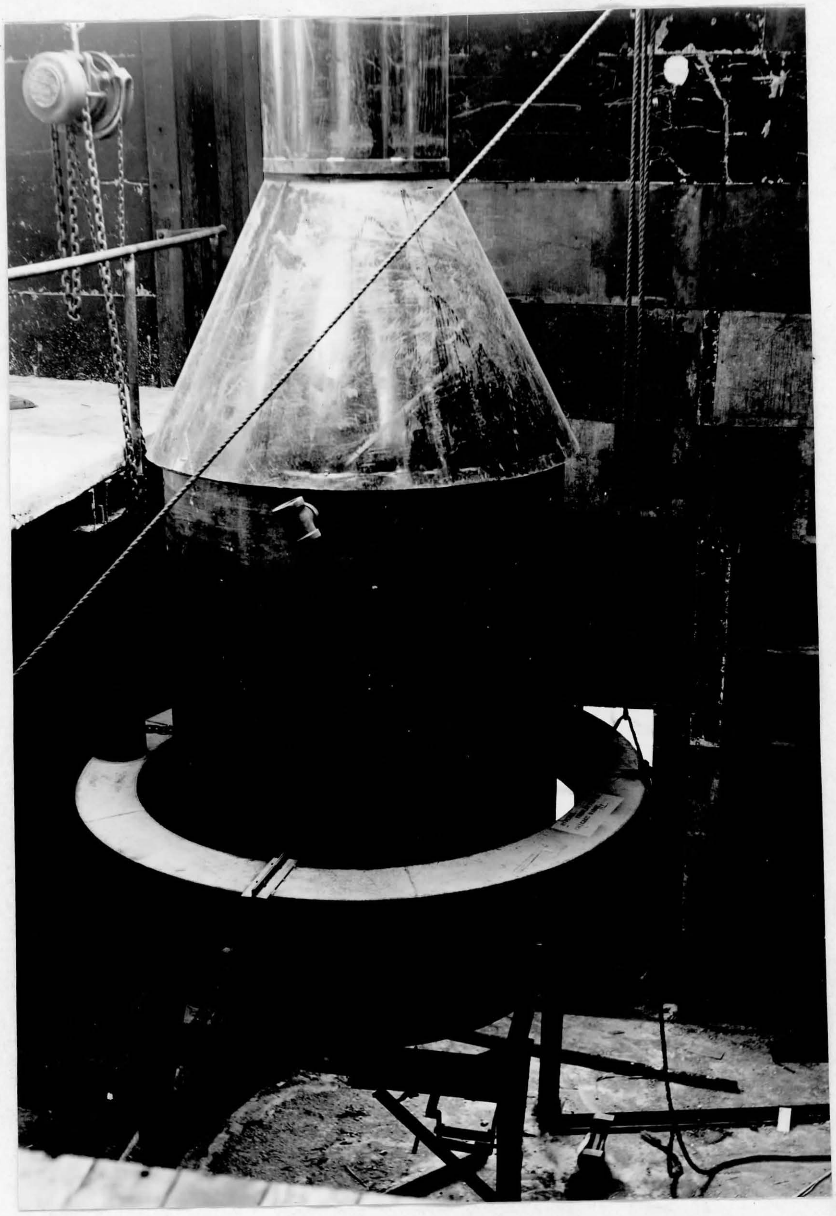

Figure 2. Rock Wool Cupola in course of construction.

Presented May 18, 1935, Urbana, Ill.
Mineral Industries Conference

#23

THE SIGNIFICANCE OF ACCELERATED SOUNDNESS TESTS ON STONE AND GRAVEL

by.

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All construction materials, when exposed to the elements, undergo change; this is a matter of common observation. Alteration in the original structure of the rock is brought about by physical or chemical effects or both. All of the well-known natural phenomena which are so effective in breaking down even the most durable of rocks as they occur in nature are equally effective in their action against these same rocks when they are used as structural materials.

Durability is a relative term. A comparatively non-durable material, considered from the standpoint of the geologist, may still be a useful and durable structural material for the particular kind of structure or the particular kind of exposure condition under consideration. Monumental structures are built with the hope they will last for centuries; office buildings with the practical certainty that obsolescence will govern their useful life; highways have an even shorter life, controlled to a varying degree by weathering effects and by the physical effects of traffic. The various structures in which stone and gravel are used are subjected to different degrees and kinds of exposure. Thus, an interior column may be continuously dry and not exposed to any great change in temperature. The footings of those same columns may have to combat the leaching action of continuous moisture. Outside exposure in a wet, cold climate will be far more severe than similar exposure in a dry, warm climate. Aggregates suitable for one condition may not be suitable for another.

In considering the materials for use in any structure, quite obviously the durability of those materials for the component parts of the structure with their different exposure conditions should be considered just as carefully as the stress-resisting properties of those materials. Sometimes mineral aggregates are used uncombined with cementing media, for illustration, as in sewage disposal trickling filters, but most commonly they are used in the form of concrete and when so used, it is pertinent to inquire regarding the exposure to which the concrete will be subjected, for the severity of the exposure condition influences the rapidity of disintegration.

Unsound aggregates have a different effect on the durability of concrete depending upon the kind of disintegration which takes place in the aggregate upon exposure to the weather and also upon the percentage of unsound aggregate present in the concrete. There are two general types of concrete failure due to unsound aggregates, namely, "pitting" and "spalling", but pitting of the concrete surface is much more common than spalling. Pitting is caused by the disintegration of weak, porous stone when subjected to the action of frost or water and such disintegration takes place with very little volume change of the aggregate. On the other hand, spalling of the concrete is produced when unsound aggregates of another class disintegrate under the action of freezing and thawing. Such aggregates are generally rather hard and strong initially, although they may be badly seamed. When they take up water and freeze, they expand with considerable force, thus producing either surface cracking in the concrete or ultimately they spall the concrete and form craters in the surface.

Typical of the first class of unsound aggregates are the argillaceous limestones and sandstones, shales, soft, friable, porous sandstone, etc. The failure of such aggregates is most likely to cause pits in the surface of the concrete which do not extend very deep and which lead to no particular harm. Naturally, if such fragments are present in high percentages, a general weakening of the concrete will occur, although there is evidence that coarse aggregates in concrete are protected to a considerable extent by their surrounding layer of mortar, assuming, of course, that the mortar is resistant to the weather.

Perhaps the principal offender in the second class of unsound materials which produces spalling of the concrete is chert, although not all cherts ~~do not~~ behave in the same manner, for some of them are entirely sound. Certain laminated rocks may cause spalling when sound material is interlaid with unsound material. For illustration, limestone may be laminated with layers of shale which upon taking up moisture and freezing, may cause expansion of the concrete and spalling. If this type of unsound material is present in the concrete in a high percentage, something more than mere surface spalling will take place. The concrete may suffer complete disintegration, particularly if it is subjected to severe exposure conditions and if the mortar is not highly resistant. Such aggregate is dangerous and capable of causing a great deal of trouble.

Certain improperly made blast furnace slags containing partially burned limestone, which in some way has gone through the blast furnace without complete combination with the silicious material in the iron ore, has been a source of spalled concrete. Such material is hard to detect by any form of accelerated soundness test, largely because of the difficulty of obtaining a sample containing the dangerous material.

The so-called "chocolate-bars" of Iowa and Minnesota which occur in some of the gravels in those States are also sources of spalling in concrete. These are ferruginous ~~secretions~~ deposits forming hard and firm fragments with a soft core which is said to be usually composed of clay. Chocolate-bars likewise have caused disruption of concrete. Certain isolated examples of unsound aggregates have been reported from time to time, one of them being composed of a feldspathic type of material which caused serious disintegration of the concrete.

Although unsound aggregates are known to be possible sources of trouble in concrete, it will be well to remember that the disintegration of concrete due to the presence of unsound aggregates is the exception rather than the rule. The durability of concrete, for the most part, is controlled by the durability of the mortar and, in general, most lack of durability can be traced to the presence of too much water in the concrete before it has hardened. This defect may be caused by either the use of too much mixing water or by so-called water-gain due to the heavier portions of the concrete displacing the excess water to the surface during the depositing operation.

Aggregates do at times cause trouble, however, and in recognition of this fact accelerated methods for detecting unsound aggregates have been devised. It is attempted by the use of accelerated tests to determine in a short time whether the aggregates will remain sound over a period of years. The tests most commonly employed are the Sodium Sulfate Soundness Test or the Magnesium Sulfate Test and in a number of laboratories freezing and thawing tests are also made. Experiments likewise have been conducted on the use of boiling and also with the use of an autoclave in which the aggregates are steamed under pressure and that pressure is suddenly released.

The sodium sulfate soundness test or the Test for Soundness of Coarse Aggregate by the Use of Sodium Sulfate, C89-32T, is now a tentative standard of the American Society for Testing Materials and it would seem fitting to discuss this test for the purpose of pointing out its seeming weaknesses and its applicability in the detection of unsound aggregates.

Briefly, the method consists first in the preparation of a saturated solution of sodium sulfate. This is done by dissolving either anhydrous sodium sulfate, Na_2SO_4, or crystalline sodium sulfate, $Na_2SO_4 \cdot 10H_2O$, in water at a temperature of 24° to 27°C. (75° to 80°F.), additional salt being used as may be necessary to insure saturation. The solution is allowed to cool to a temperature of 21°±1°C. (70°±2F.). Stated amounts of designated sizes of coarse aggregates comprise the sample which is immersed in the solution for a period of 18 hours during which time it is supposed to be kept at a temperature of 70°F. ±2°F. After 18 hours of immersion, the sample is removed from the solution and is put in a drying oven, previously brought to a temperature of 105° to 110°C. (221° to 230°F.), where it is dried to constant weight. Then it is allowed to cool to within the range of temperature specified for the solution, that is, to within 68° to 70°F. when it is again immersed. Unless otherwise specified, five cycles of this treatment constitutes a test. Finally, after the last cycle when the sample has cooled, it is washed free of sodium sulfate; the sample is dried to constant weight and screened over the same sieve on which it was retained before the test. The material passing this screen is considered as lost because of unsoundness of the stone or gravel. Crystallization of the sodium sulfate within the rock is intended to simulate the disrupting action of the frost.

There are several weak points in the test which is now a tentative test of the A. S. T. M. Solubility curves for sodium sulfate show that, at the temperature required by the test, the rate of solubility changes rapidly and if particular pains are not taken to see that the required range of temperature is not exceeded during the immersion of the specimen, crystallization of the salt may take place owing to a slight fall in temperature. It is highly important that the temperature be kept practically constant during the period of immersion. Another serious objection to the A. S. T. M. test is the manner of determining the percentage of loss of the individual fractions. It will be noted that the same sizes of sieves are used for determining the loss of each fraction as were employed in the preparation of that fraction of the sample. It may well happen that fragments which are just retained on that sieve in preparing the sample are slightly chipped as a result of the sodium sulfate test and in consequence thereof they pass through the sieve at the conclusion of the test and are thereby recorded as being unsound. Had these same fragments been just a little bit larger, they would have been retained on the sieve at the conclusion of the test and would, accordingly, be recorded as sound. It frequently happens that aggregates are so graded that one sample may have a high percentage of its fragments in a given fraction just above the minimum size sieve used in the preparation of that fraction. On the other hand, another sample may have the bulk of its fragments very much larger than the minimum size sieve used for preparing the fraction. The first sample would have a high percentage of loss and the second sample would have a low percentage of loss even though both samples were composed of identical materials. It is obvious that this is a serious defect in the method of making the test and the remedy would be to designate a smaller sieve for determining the percentage of loss than was used in the preparation of the sample. It would seem that the sodium sulfate test is not sufficiently definite to lend itself to quantitative determination of loss in the above manner. It may well be that some of the fragments, although badly cracked and split due to the action of the test, still are retained on the sieve. They obviously are unsound, but are not so recorded.

Other methods of making the sodium sulfate test, notably that of the American Society of Civil Engineers Committee on Filtering Materials employs a somewhat less definite method for determining the percentage of loss in a quantitative way. That method is attached hereto in appendix II.

The essential features of the A. S. C. E. method are as follows. The sample is composed of 10 to 20 fragments of stone, of about the same size. The sodium sulfate solution is prepared by the use of anhydrous sodium sulfate dissolved in water heated to 85°to 90°F. to make a saturated solution which is cooled before using. The sample is soaked in the sodium sulfate solution for 19 hours and the pieces removed one by one and carefully examined for any signs of failure. Then the entire sample is placed in shallow pans in a previously heated oven and maintained at 100° to 105°C. for four hours. The sample is then removed from the oven and allowed to cool for one hour after which it is re-immersed. When applied to material for use in trickling filters the test consists of 20 cycles. The rating of the specimen is computed as follows:

(a) Each of the fragments in the sample is allotted a percentage equal to its proportion of the total sample. For illustration, one piece would be 5 per cent of a 20-piece sample.

(b) An individual specimen breaking into 3 or more pieces, or which is so cracked that such breaking is obvious, is considered to have failed, provided each portion is more than 10 per cent of the original weight of the piece.

(c) The percentage by weight of chips, spalls, and flakes from the remaining pieces passing the 1/2 inch, No. 2 mesh sieve is used for determining the percentage of loss.

(d) The rating of the sample is 100 minus the percentage of lost material, including the pieces which have completely failed.

This method is at least free from the objection cited against the A.S.T.M. method, namely, the use of the same size sieve for determining loss as was used in the preparation of the sample. It has a further point in its favor, namely, the material which is considered as being lost is more definitely the material which has failed, although there is still some doubt whether a fragment of stone which merely splits into 3 pieces should arbitrarily be designated as an unsound fragment of stone. Perhaps this would be so for sewage disposal work, but there is considerable doubt as to whether such a fragment would cause any trouble whatsoever in concrete.

The sodium sulfate accelerated soundness test is an artificial way of simulating the expansion force due to the formation of ice within the pores of the aggregates and the question naturally arises, why a direct freezing and thawing test will not more nearly simulate the freezing action which takes place when stone is exposed to the weather. A number of laboratories have experimented with freezing and thawing tests, but thus far no standard method has been devised. In brief, there are three general methods employed for conducting freezing tests and many variations of these are possible. Method 1, The sample of stone is water-soaked and is then subjected to freezing in a freezing room. The sample may be totally immersed in water, partially immersed, or placed in the air during freezing. Method 2. The sample is placed in a freezing cabinet, such as an ice cream cabinet, in a can which is immersed in alcohol contained in the compartment of the freezing cabinet. The purpose of the alcohol is to convey heat away from the specimens rapidly and thus produce rapid freezing. In this case the specimens may be totally immersed, partially immersed, or merely placed in the air after having been water soaked. Still a third method calls for the immersion of a saturated sample in the calcium chloride brine solution. This brings about extremely rapid freezing.

The severity of these three tests seems to depend upon the rate which freezing takes place. Method No. 1 is the least severe; method No. 2 of intermediate severity, and Method No. 3 is extremely severe in its action. This was well demonstrated by a series of cooperative tests conducted several years ago between the (P. C. A.) Portland Cement Association, the University of Minnesota and the National Crushed Stone Association. Without going into the details of the test, it was noted that Method No. 1 seemed to be lacking in severity to such an extent that 500 cycles of freezing and thawing produced very little failure even on mortars containing shale as a fine aggregate. Method No. 3 produced practically complete disintegration with less than 1/10 the number of cycles, whereas Method No. 2, ~~while~~ although not as rapid as Method No. 3, ~~still,~~ gave results in a ~~reasonably short~~ period of time ~~which would~~ short enough to place the test in the class of accelerated methods. Method No. 2 is the method now used in the laboratory of the National Crushed Stone Association and except for the fact that we now use complete immersion, the method described in the July, 1929, Crushed Stone Journal is an accurate description.

Other methods of freezing and thawing have been used and dry ice lends itself to the performance of this type of test.

Thus far, the discussion on the two main accelerated soundness tests would seem to lead to conclusions as follows:

(1) That the results obtained in the sodium sulfate soundness test may vary:

(a) Because of the use of the same sieve for preparing the sample as for measuring the percentage of loss.

(b) Due to slight variations in temperature of the solution or to other unexplained variations in the method.

(2) The freezing and thawing accelerated soundness tests will give different percentages of loss for a given number of cycles, depending evidently upon the rate at which freezing takes place. It thus is insufficient to know that a sample has withstood a given number of cycles of freezing and thawing unless the exact procedure for making the test is known also.

An accelerated soundness test does not with certainty determine the soundness of an aggregate unless it is known that the results of that test agree with service behavior. The results obtained with the sodium sulfate test and the freezing and thawing test are only in fair agreement with one another, and there have been some notable examples of lack of agreement.

In the following table is shown the relation of freezing and thawing tests and sodium sulfate tests made on samples of stone, gravel and Portland cement mortar. It will be noted that in nine cases, freezing and thawing caused more disintegration than sodium sulfate and there are four cases in which the sodium sulfate test caused more loss than freezing and thawing.

Relation of Freezing and Thawing Test and
Sodium Sulfate Test

Sample No.	Per Cent Loss	
	Freezing 50 cycles	Sodium Sulfate 20 cycles
2	6	38
5	0	0
7	30	25
9	0	85
13	7	18
23	0	0
27	0	0
32	0	0
35	31	5
17	0	0
24	13	4
31	0	0
I	0	0
II	34	0
III	100	44
IV	71	40
V	6	0
VI	100	19
VII	27	2
51	0	.2

Note: Samples I to VII are Portland cement mortars and the remaining samples are stone and gravel.

The question may properly be asked, Does it necessarily follow, ~~that~~ if a specimen fails in an accelerated soundness test, that the concrete will also fail when subjected to the weather?

The answer to this question cannot be given with certainty. In the first place, the severity of exposure has much to do with the possible failure of the concrete. If the concrete remains dry and the temperature is above freezing, there seems little likelihood of failure even though the aggregate used is unsound as shown by accelerated soundness tests. On the other hand, it may well be that serious failure of the concrete will take place, even though sound aggregates are used as revealed, not only by accelerated tests, but by the behavior of the material in the ledge. As has been previously pointed out, failure of the aggregate is not the only kind of failure which takes place in concrete and failure of the mortar, due to excess mixing water, is a much more prolific source of failure than that due to the aggregate.

The above table which is discussed more fully in the July,1929, issue of the Crushed Stone Journal, is rather enlightening in showing the effect of excess moisture, particularly when viewed in the light of the information given in the table which follows:

Quantities of Materials Used in Mortar Tests

No.	Mix by Wt.	Cement lbs.	Sand lbs.	Water lbs.	Flow (1/2" drop)	Water-Cement	Combined Water, lbs. (estimated)	Free Water lbs. (estimated)
I	1:1	55.0	55.0	19.4	163	0.53	6.9	12.5
II	1:2	36.6	73.2	21.6	165	0.89	5.1	16.5
III	1:3	27.5	82.5	22.2	176	1.22	4.8	17.4
IV	1:4	22.0	88.0	22.9	164	1.57	4.2	17.7
V	1:2	36.6	73.2	19.2	169	0.79	5.1	14.1
VI	1:2	36.6	73.2	29.0	300+	1.19	5.1	23.9
VII	1:2	36.6	73.2	23.3	205	0.96	5.1	17.2

It will be noted in the above tables that the extent of failure of the different mortar specimens goes more or less hand in hand with the amount of free water present in the respective mixtures. The free or uncombined water, upon evaporation, leaves pore spaces which give access to the infiltration of water which may subsequently freeze and start disrupting action. It is interesting to note that the resistance to freezing and thawing of the mortar seems to bear more definite relation to the free water than to the water-cement ratio.

Tests show that sometimes stone which will fail in an accelerated soundness test will not fail when used in concrete, even after it has been exposed due to the failure of the mortar. A case in point might be of interest. Five different limestones were subjected to ten cycles of freezing and thawing in accordance with the National Crushed Stone Association methods. These various stones showed failure, varying from approximately 30 to 50 per cent of the total weight of the original sample. They were used in concrete of 1:2:3½ proportions and when the concrete specimens were subjected to 85 cycles of freezing and thawing the only effect was on the mortar which seemed to be softened and so disintegrated as to expose the coarse aggregate. This is a rather clear indication that it does not necessarily follow, because a coarse aggregate when subjected to a freezing and thawing test shows rather bad failure, that the concrete from which it is made will also show failure. A similar freezing test was made on four samples of concrete, three of them containing coarse aggregate which was open to some question when judged by the sodium sulfate test alone. The fourth sample of aggregate would be considered sound when judged by this test; yet these four samples of concrete when exposed to

75 alternations of the freezing and thawing test showed an external apperance about alike in all cases. In all of these samples the mortar had disappeared from the surface and had exposed the coarse aggregate. One of these aggregates was from Illinois and this particular sample gave rather poor results in the sodium sulfate test. The concrete was of 1:2:3½ proportions by loose volume, with water-cement ratios varying from 0.80 to 0.88.

At the Eleventh Annual Meeting of the Highway Research Board of the National Research Council held in Washington in December, 1931, a report was submitted by Mr. Verne McCown for the Mineral Aggregates Committee in which were summarized reports from various institutions bearing on the subject, "The Significance of the Sodium Sulfate and Freezing and Thawing Tests on Mineral Aggregates." It will be impossible in the present report to summarize the various conclusions drawn by the authorities quoted, but the following statements excerpted from the above report bear particularly on the significance of accelerated soundness tests as applied to aggregate.

In Illinois the samples which have given the most trouble are of argillaceous limestone or of chert. Apparently, certain of the argillaceous limestones which fail badly in both the sodium sulfate test and the freezing and thawing test, have given poor results in service. On the other hand, ~~another~~ one sample of argillaceous limestone ~~showing~~ whose failure in the ~~to~~ sodium sulfate tests ~~to not so~~ was less marked ~~an extent as the~~ than that of other samples does not give poor results in service. A sample of chert which is not much affected by the sodium sulfate test, but breaks down in a few cycles of the freezing and thawing test, has shown bad results in service.

The Iowa tests cite a sample of cherty limestone, not much affected by the sodium sulfate test, but showing extensive subdivision under the freezing and thawing test. This material contains from 0.5 to 10 per cent of chert and when used in pavement construction produces some surface spalling but no further disintegration. Apparently, in the Iowa laboratory, 16 cycles of freezing and thawing are considered equal to 5 cycles of the sodium sulfate test.

In the Tennessee report, it is stated that the presence of shale in coarse aggregate did not materially influence the transverse strength of concrete beams in amounts up to ten per cent of shale. There was some reduction, however, in compressive strength. Greater variation in strengths occurs among specimens of the same series caused by different methods of curing than was apparently due to the different percentages of shale used.

In Pennsylvania, 5 cycles of the sodium sulfate test are considered adequate for determining the soundness of coarse aggregate using the American Association of State Highway Officials method. One case is cited of a bad concrete failure, but in this case the aggregate would have failed within a few cycles of the sodium sulfate test.

In New York it is specified that in the sodium sulfate test, using 5 cycles, the stone shall lose not more than 15 per cent by weight.

One of the important conclusions from the National Crushed Stone Association tests is that coarse aggregate, even though in some cases [illegible], unsound, does not necessarily make for unsoundness in concrete. The unsound stone tested did not crack the concrete, nor did the stone leave the concrete or cause pitting. Only after the mortar had failed did the stone fail by continuous chipping.

The conclusions drawn from the Wisconsin tests are based on a sample from each of 21 quarries representing four types of Wisconsin limestones. Weathering tests consisting of 80 or more reversals of freezing and thawing of continuously immersed samples occasioned relative disintegration comparable with that which might have been expected from field inspection.

A part of the Minnesota conclusions reads, "A relationship exists between the durability of coarse aggregate and the durability of concrete made therefrom. A cement paste of concrete specimens used in freezing and thawing tests intended to reveal the durability of the aggregate should be of such quality at time of test that disintegration will depend more on aggregate quality than paste quality."

Kansas suggests that tests of aggregates should include tests in concrete before any source is condemned. Alternate freezing and thawing is a valuable method of studying the durability of concrete and concrete aggregates. The durability of concrete is greatly affected by the quality of the cement paste. A water-cement ratio of 0.8 or more is not likely to give concrete of adequate durability under severe exposure conditions. The use of unsound aggregate produces unsound concrete, the resistance of the mortar being only slightly effective in protecting the aggregate. Any aggregate containing absorptive chert should not be used until after careful investigation. The character of failure of aggregate is fully as important as the extent of the failure, - material which breaks into a few pieces with disruptive force, as chert, being much more detrimental than material which completely disintegrates, but not with such expansive force.

The Committee on Mineral Aggregates in commenting on the material from the various authorities quoted, points out the following indications:

(1) Certain argillaceous rocks and non-durable materials and some cherts cause failure of concrete in which they are used when exposed to freezing and thawing in the presence of moisture.

(2) The extent and rate of failure probably depend upon the amount of the unsound material in the concrete. This amount is still open to question.

(3) Failures of concrete when due to coarse aggregate, seem to be of two general types, - one where the aggregate disintegrates without much volume change and, the other, where the aggregate undergoes sufficient volume change to disrupt the concrete.

(4) Data on failure of concrete caused by unsound fine aggregates are somewhat conflicting and inconclusive.

(5) Extensive investigations indicate that an accelerated freezing and thawing test is valuable for the study of durability of concrete and aggregates.

(6) There is a conflict of opinion as to the value of the sodium sulfate soundness test.

(7) The use of present day soundness tests of aggregates as acceptance tests is questionable owing to lack of correlation with service conditions.

(8) All investigators agree, assuming the freezing and thawing test is a measure of durability, that the quality of the mortar or cement paste is probably the most important influence on the durability. High quality of mortar with low water-content makes concrete very resistant to freezing and thawing, even when aggregates considered unsound are used.

(9) Further investigations of soundness and durability are needed, both in the laboratory and in the field.

Certain well-known national specifications recognize the uncertainty of accelerated soundness tests and the greater certainty of service behavior as a criterion of soundness. For illustration, the

Federal Specifications Board specification which governs purchases by the Federal government reads as follows:

"E-2c. Soundness and resistance to abrasion.

"E-2c (1). Grade A crushed stone and gravel shall be considered to have met the requirements for soundness and resistance to abrasion provided evidence satisfactory to the Government can be furnished showing that the material has proved satisfactory as coarse aggregate in concrete which has been subjected for a period of at least 5 years to essentially the same conditions of service and exposure as the structure in which the material is to be used.

"E-2c (2). Grade A crushed stone failing to meet the requirement given in section E-2c (1) shall be subjected to the standard Deval abrasion test for stone and to the accelerated sodium sulphate soundness test and shall meet the following requirements:

	Per cent
Percentage of wear, not more than --------------	7
Loss in sodium sulphate test, not more than ---	15

"E-2c (3). Grade A gravel failing to meet the requirement given in section E-2c (1) shall be subjected to the modified Deval abrasion test for gravel and to the accelerated sodium sulphate soundness test and shall meet the following requirements:

	Per cent
Percentage of wear, not more than --------------	15
Loss in sodium sulphate test, not more than ----	15 "

In conclusion, I shall not attempt to improve on the comments made by the Mineral Aggregates Committee of the Highway Research Board. I think the question of the significance of accelerated soundness tests on aggregates can best be summed up by saying that when an aggregate fails in accelerated soundness tests, it should be looked upon with suspicion, but that before it is condemned the service record of that aggregate should be thoroughly investigated. Accelerated tests are not infallible and their relation to service behavior is not definitely established.

PRELIMINARY REPORT OF TESTS ON SMALL SPECIMENS OF SILICA REFRACTORIES FROM NOVACULITE

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Introduction

In the uplands of Alexander and Union counties of extreme southern Illinois are large, thick deposits of silica which assume several different forms. One of these, known commercially as novaculite, is found in solid beds, more or less white in color, and as a gravel of novaculite fragments and red clay. Much of the material from the former deposits is of high silica content as is also some of the gravel when washed free of clay. The novaculite gravel has been used in large amounts for road surfacing but neither it nor the novaculite from the solid beds have found their way extensively into channels of commerce for the manufacture of refractories. The Ceramics Department of the University of Illinois in cooperation with the Illinois State Geological Survey has undertaken the studies here described in order to broaden the uses for these materials and thereby to increase their consumption. This discussion is intended to present an outline of the problems encountered in the development of this material for silica refractories, a description of the methods used and the work done.

Previous Work on Silica Brick

A publication of the Geophysical Laboratory of the Carnegie Institution (Amer. Jour. Sci. 39, January, 1915) serves as an excellent summary of the work on the silica minerals to that date. McDowell[1] about

1. J. Spotts McDowell, A Study of the Silica Refractories, Amer. Inst. Min. Eng. Bull. 119.

three years later summarized the previously published data on manufactured silica brick. Numerous other investigators have contributed to our knowledge.

Taken as a whole, more accurate tests have been made and more is now known of the proper manufacture and application of silica refractories than any other common refractory.

The temporary and the permanent volume changes which silica undergoes upon heating are now well understood, largely through the work of Fenner.[2] Their significance to the manufacturer has been ade-

2. C. N. Fenner, Stability Relations of the Silica Minerals, Amer. Jour. Sci. 36:339.

quately explained by LeChatelier, McDowell, Ross, Sosman and others. On the other hand, the rates of these changes are not so well known. The rate of transformation of quartz to cristobalite and to tridymite are dependent upon the specific raw material, its grain size and the nature and the amount of impurities present.

In the choice of raw materials for silica refractories, the main points considered are chemical purity, size of grain obtainable, and the "magnitude of increase in volume upon heating".

The natural rock should contain at least 97 per cent of silica and not yield too fine a powder upon crushing. According to many writers the order of merit of the natural forms of silica is given as chalcedony, old quartzites and vein quartz. Quartz schists, sandstone and sand are considered unsuitable, the first two on account of their structure and the presence of many impurities in the form of inclusions; the latter two on account of their variability in composition and their excessive fineness after grinding.

The novaculite, under consideration here, is composed of that type of silica sometimes broadly classed as chalcedony which is known to invert more rapidly (at a given temperature) to cristobalite than the coarser grained varieties.

Resumé of Data Relating to Material, Manufacture and Uses

Nature of Silica Refractories.- Silica refractories act primarily as does silica. The stability relations, as determined by the Geophysical Laboratory may be briefly summarized as follows:

Inversion*	Temperature	Rate
Alpha-quartz to beta-quartz	573° ± 1°C	Rapid
Beta-quartz to tridymite	870° ± 10°C	Sluggish
Tridymite to cristobalite	1470° ± 10°C	Sluggish

* For complete discussion see Properties of Silica, by R. B. Sosman, Chem. Cat. Co., 1927.

In practice alpha-quartz always changes to beta-quartz sharply and quickly at 573°C. on heating and vice versa 572°C on cooling. But beta-quartz upon heating changes to beta-cristobalite instead of directly to tridymite. This change is possible as low as 870°C. The temperature at which this change takes place rapidly enough to be of commercial interest depends upon the nature of the silica, upon the impurities present, and upon the size of grain. In certain cases of fine powder, cristobalite has been produced in two or three days at 950°C. The cristobalite, after forming, then inverts to tridymite, more slowly than the inversion of quartz to cristobalite. Figure 1 shows how the density of the various silica minerals varies with temperature.

Thus the density of quartz at 573°C. changes from about 2.56 to 2.53, representing an increase in volume of about one per cent. Quartz at 1200°C. has a density of about 2.55, while cristobalite at the same temperature has a density of about 2.2. An inversion than at, say 1200°C, will cause an increase in volume of about 15.9 per cent and the change from cristobalite to tridymite is less than 1 per cent.

These are the volume changes that occur during heating. In cooling, if there is any untransformed quartz at 573°C., it will contract the same amount as it expanded. Over the range of about 200°C to 250°C cristobalite changes, in cooling, from a density of 2.225 to 2.29, a volume change of about 3 per cent. There are two inversion points in tridymite, at 117°C and at 163°C. The volume changes here are a fraction of a per cent.

Silica brick expands permanently during burning due to the change of quartz to cristobalite and tridymite. The volume change can amount to as much as 15 per cent, but rarely reaches that figure. As therefore would be expected, the specific gravities of silica brick are a good criterion by which to judge whether the brick has had proper heat treatment. The specific gravities of the three major modifications of silica are as follows: quartz 2.65; cristobalite 2.33; and tridymite 2.27. As only 70 to 80 per cent of the quartz is converted to cristobalite and 5 to 10 per cent to tridymite in a commercial burn, a brick with a specific gravity of less than 2.40 is considered satisfactory. Much of the ware on the market has a specific gravity of 2.30 and 2.35 and is decidedly superior to the ware of higher specific gravity.

Uses in Industries.— Silica refractories are useful mainly because of their rigidity at temperatures at which ordinary fire clay brick soften, also the silica brick expand slightly when heated instead of contracting.

Nature of Novaculite

Novaculite is a hard, white, compact rock of almost pure silica. It is cryptocrystalline, being composed of individual crystals of a mean diameter of about 0.05 micron to 0.10 micron. Probably a small amount of it is opaline. Quartz crystals are frequently found admixed with the finer novaculite grains.

In some deposits the novaculite occurs in fragments associated with red clay which may be easily removed by washing if necessary. Some deposits or parts of them are clay-free.

Less is known of these cryptocrystalline varieties of silica than of the other varieties. It is known, however, that they invert to cristobalite more rapidly, at a given temperature, than do the coarse grained varieties of quartz. Some observers have noted a lower density in the resulting cristobalite.

Ross (Op. Cit.) tested a material (Indiana chert) that would seem to be similar to the material under consideration, in that it was cryptocrystalline. He stated that this raw Indiana chert is of interest because its density is lower than that of quartz, being 2.585, and that the resultant brick had a density of 2.273, which seems to indicate a very high content of tridymite.

The density of Illinois novaculite is found to be as follows:

Tyler Mesh	Density
Through 8 on 10	2.54
" 10 " 14	2.54
" 14 " 28	2.63
" 28 " 48	2.63
" 48 " 100	2.64
" 100 " 200	2.64
" 200 ----------	2.64

These figures show clearly that the novaculite has a porosity of approximately 3 per cent. Ross reports the porosity of the Indiana chert as 1.83 per cent.

In every case where chert has been compared with quartz and given the same heat treatment, the chert has always inverted more rapidly. Mellor repeatedly heated chert and finally obtained a product which had a density of 2.22, a value even lower than that of vitreous silica. This material had a density of 2.61 before heating. This view regarding the rate of inversion of chert is also borne out by the work of Rieke and Endell.[3]

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3. Donald W. Ross, Silica Refractories, Tech. Papers of Bur. of Standards No. 116.

Nearly all the silica refractories manufactured in the United States are made of quartzite. Bricks have been manufactured from cryptocrystalline silica, for example bricks made from southern Illinois ganister, a material having roughly the texture of corn meal and comprised of chert fragments ~~not~~ and silica grains. It is reported that novaculite has also been used.

Work Done and Description of Methods

Packing of Particles.— Since the grain size distribution is of major importance in this type of refractory, the packing characteristics of the novaculite were determined. This was done by placing mixtures of different proportions of different sizes of the grains in a capsule and subjecting these mixtures to repeated impacts until the volume attained a minimum value. The results of mixtures of three sieved sizes are given in Figure 2.

The three grain sizes used are indicated on the figure and were:

Coarse - Through 8-mesh on 10-mesh
Medium - Through 28-mesh on 48-mesh
Fine - Through 200-mesh

The degree of packing has been shown on the figure as the ratio of the bulk packed volume to the true volume of the solids. In this way, unity becomes the maximum possible density of packing. Lines are drawn on this graph to show mixtures packing with equal voids. As another grain size is mixed with a uniform grain size, the volume of the mixture is decreased until a minimum is reached. Further additions increase the volume. The maximum density mix for the materials used here was 50 per cent coarse, 25 per cent medium, and 25 per cent fine.

More complex mixtures, novaculite mixed with varying proportions of southern Illinois tripoli, were studied by placing the mixtures of grains in a mold, applying pressure, and measuring the height of the piston at various pressures.

Figure 3 shows how the volumes of mixtures of grain sizes vary with pressure and grain size distribution. The screen analysis of the mixtures used varied as is shown in Table 1. In these mixes, tripoli finer than 200-mesh was added at the expense of the coarsest fractions. In each of these mixtures, the cumulative weight per cent of grains retained on any screen is a linear function of the logarithm of the width of the screen opening. The minimum points in Figure 3 show the proper amounts of finest and coarsest material which give the densest packing mixture of the group.

Table 1.- Screen Analysis of Novaculite Used in Packing Experiment (Fig.3)

Tyler Mesh	Weight Per Cent				
	No.1	No.2	No.3	No.4	No.5
Through 6 on 8	23	15	14	7	--
Through 8 on 10	7	7	7	7	7
Through 10 on 14	7	7	7	7	7
Through 14 on 20	6	6	6	6	6
Through 20 on 28	7	7	7	7	7
Through 28 on 48	13	13	13	13	13
Through 48 on 100	13	13	13	13	13
Through 100 on 200	14	14	14	14	14
Novaculite < 200	10	10	10	10	10
Tripoli < 200	--	8	9	16	23

Crushing Characteristics.— The material may be reduced in a jaw crusher to sizes about right to introduce in a wet pan for the completion of grinding. When reduced in this manner it takes about 15 minutes in a wet pan to obtain the correct particle size distribution. Screen analyses were made periodically during the grinding.

Rates of Inversion.— (a) Method of Determination. The study of inversion rates was made with a differential thermal expansion apparatus[4] (Fig. 4). The specimen S was inserted in the tube and rested on the shelf B. An alundum tube, P R, rests on top of the specimen and was used as a push rod to transmit volume changes to the gage G, which was sensitive to $\frac{1}{10,000}$ of an inch displacement. A molybdenum wire wound furnace was used for heating.

When making a test, the temperature was raised rapidly to some predetermined point and maintained there until the inversion was complete or until it was desired to terminate the test.

(b) Effect of grain size on the rate of inversion to cristobalite. Various grain size mixtures were studied. In figure 5, expansion has been plotted as a function of time. In these tests, the temperature rose at an approximately linear rate so that in 60 minutes the temperature was at 1400°C. The expansion that occurred after the first 60 minutes did so at a constant temperature (that is 1400°C). The initial expansion is due to the normal heating effect and the quartz inversion. The decrease which follows is soon changed to a rapid expansion due in part to the inversion to cristobalite, and upon completion of the change the curve flattens.

4. J. H. Chesters and C. W. Parmelee, The Measurement of Reaction Rates at High Temperatures, Jour. Amer. Cer. Soc. 17:50.

Aside from showing that the rate of inversion decreases with increasing grain size, these curves show that with rapid inversion there is considerable shattering of the grains. The sample composed of grains all finer than 200-mesh was almost completely inverted to cristobalite. Values higher than this show porosity increase which is due in part to shattering. This shattering becomes more pronounced as the grains become larger. Thus is developed one of the major problems, the determination of a rate of heating such that the rate of inversion will be accompanied by a minimum of shattering of the larger grains.

(c) Study of the effect of the composition of the bond on the rate of inversion to cristobalite. The study was carried out according to the method described above and the particle grading used was that of the three grain sizes giving maximum density. It was found that the composition of the bond greatly affects the temperature and the rate of inversion of quartz to cristobalite. Figure 6 serves to illustrate the type of data obtained.

As in Figure 5, expansions occurring after the first 60 minutes were measured at constant temperature. The first 60 minutes was the heating-up period, during which time the temperature was raised at a uniform rate to 1400°C.

The expansion was rapid until the alpha quartz had inverted to beta quartz, after which a shrinkage occurred. This shrinkage was thought to be an example of a solid state reaction, either with the bond or with the impurities present in the silica.

The curve labeled 1-5 in the figure represents material bonded with 2 per cent CaO. The porosity of the fired specimen was the same as the porosity of the same sample before firing. This is in contrast with Curve 1-A, which showed a large increase in porosity after firing. It is plain that one of the functions of CaO as a bond is to hold the grains of silica in place firmly during firing.

The sample containing the CaO had almost reached equilibrium in one hour at 1400°C, while the unbonded sample was still changing after 5 1/2 hours.

~~Other tests.~~ Tests to determine the effect of the temperature, time of burning, composition, and amount of bond upon the mechanical strength and degree of inversion of novaculite ~~These tests~~ are in progress. Until we have completed them and have made sure of their accuracy, it is felt that it would be best not to be too specific about the results.

The test pieces for compression have been made by the regular wet mold method with $Ca(OH)_2$ and some other materials for bonds. The specimens have been 1 1/4 inches by 1 1/4 inches by 2 1/2 inches. Some full sized bricks have also been made. The burns have been from 48 hours to 96 hours in duration and the finishing temperature cone 14 (1375°C) was recorded. The major part of the time of burning has been between 1100°C and 1260°C.

The small burned specimens are of good strength and some have the "ring" of commercial silica bricks when struck.

The problem seems to be to fire the material at a suitable temperature for a sufficiently long time to develop a sound product.

Summary

The Illinois deposits are large enough to supply all the raw material that would be needed for many years and are easily accessible.

This particular raw material has never been used extensively for the manufacture of refractories, insofar as we know. Chalcedonic silica has been successfully used, but may be a slightly different material.

Novaculite inverts to cristobalite more rapidly and at a much lower temperature than does quartzite, the inversion being more complete, under the same circumstances.

Novaculite must be inverted very slowly at a low temperature to prevent shattering of the grains. This material is very susceptible to the influence of various oxides as is manifest by marked changes in the rate of inversion to cristobalite. Lime made from southern Illinois limestone has been used successfully as a bond.

Other things being equal, the rate of inversion is a function of the temperature. The 200-mesh material, in the presence of 2 per cent CaO will invert to about 95 per cent cristobalite in one hour at 1400°C. This rate is, however, too fast to fire silica refractories, since the inversion must proceed very slowly. In the presence of certain fluxes, the inversion has been observed to proceed at a reasonable speed below 1000°C.

Proper grading of the grain sizes is of prime importance, both from the standpoint of manufacture and use. Novaculite will easily crush to the proper grade. The larger grains must be heated more slowly, otherwise the shattering becomes troublesome.

Trial specimens have been made which have the same compressive strength as commercial silica brick. These specimens were 1 1/4 x 1 1/4 x 2 1/2 inches. No full size brick have as yet been tested.

F. J.
25

MEMORANDUM: May 27, 1935

TO: Dr. M. M. Leighton and Dr. Frank H. Reed
FROM: Charles F. Fryling

RE: "Novaculite as a Source for Silica Refractories," by C. W. Parmelee.

Mr. J. E. Lamar asked for a review of the above paper, with the statement that it was at the request of Dr. Leighton.

The results are sufficiently promising to indicate that an important contribution is being made by Professor Parmelee. Such being the case, it is desirable that they be released in such a manner that the commercial development of our novaculite deposits is not impeded by any adverse criticism or inability on the part of the reader to understand the significance of the paper. From this viewpoint, I believe that the paper has certain defects which should be corrected before release.

In the first place, the title does not indicate the character of the paper. From the title, one might expect to learn whether novaculite can be used as a raw material for the manufacture of silica refractories, the exact conditions required in the manufacturing process, and the properties of the manufactured product. The investigation has not proceeded far enough to obtain these results. Therefore, it is suggested that this title be, "Preliminary Report of Tests on Small Specimens of Silica Refractories from Novaculite."

The grammatical construction is, in many places, loose and possibly misleading. Corrections (in red) have been suggested on the report.

The material in the report is poorly organized. The summary should be placed at the beginning for the convenience of readers. If possible, expressions such as "more rapidly," "at a much lower temperature," "very slowly," which occur in the summary, should be replaced by more definite descriptive phrases.

Pages 1 to 6 are largely descriptive of previous work. It is suggested that this material might be condensed, and, at the same time, clarified as regards expression.

The description of work done and the results attained is thought to be inadequate.

There is one apparent discrepancy which should be made clear. It is stated that "A faster inversion of the quartz to cristobalite would seem to be an advantage," while later it is stated, "Novaculite must be inverted very slowly at a low temperature to prevent shattering of the grains."

Novaculite ms

p.1, line 4, etc. Suggest change to "One of these, known commercially as novaculite, is found as fragmental material associated with red clay and also as solid beds more or less white in color. The latter deposits and the fragmental material when freed of clay are of high silica content."

References incomplete. Also give no date, or page numbers.

p.2, last paragraph. Suggest change to "The novaculite, under consideration here, is composed of that type of silica....." etc.

? It might be of value to briefly define chalcedony - also to define chert.

p.5, line 7. Suggest "of sedimentary origin and is known technically as chert" be deleted.

p.5, line 12, etc. Suggest change to "In some deposits the novaculite occurs in ~~rounded~~ fragments associated with red clay, etc."

p.6, line 23. Might a definition of ganister be of value?

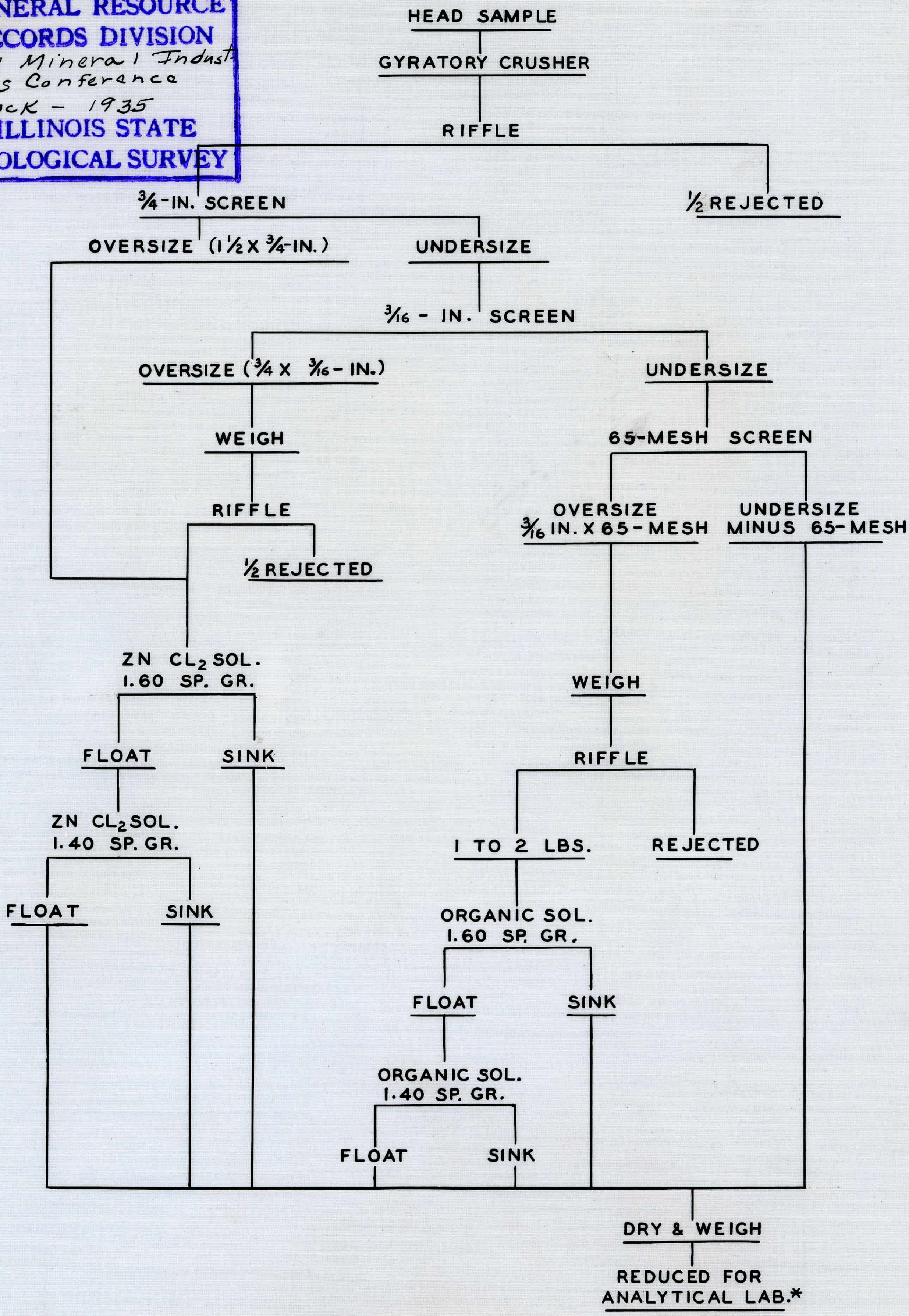
p.7a, line 19. What is the correct particle size distribution?

Ralph E. Grim

Reduce to 4 inches

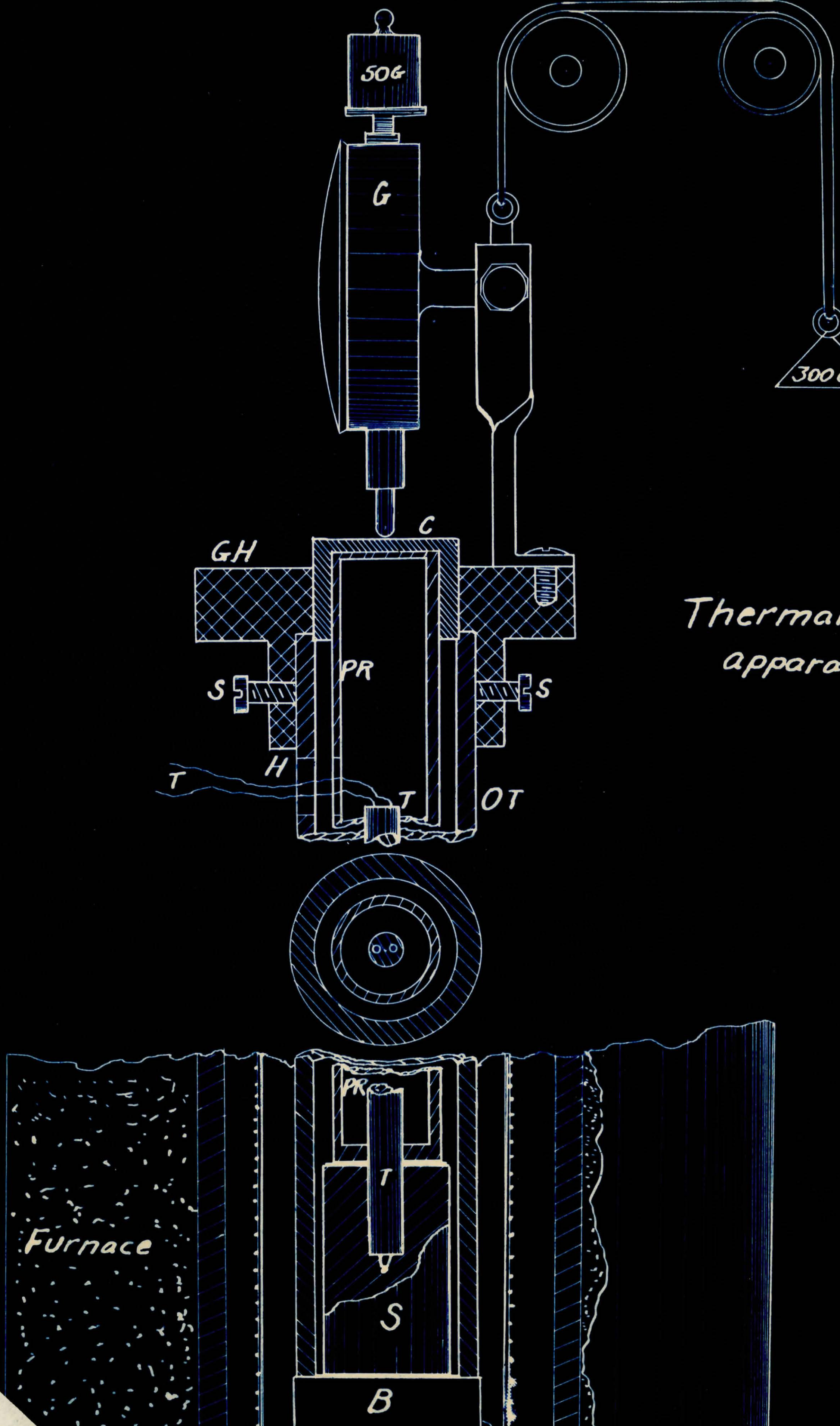
~~FLOW SHEET FOR TREATMENT OF PICKINGS~~ omit

Smith



*ASTM PROCEDURE FOLLOWED IN REDUCING PRODUCTS AND IN ANALYZING THEM FOR MOISTURE, ASH, AND SULFUR.

8pt (Fig. 1.— Flow sheet for treatment of pickings.



Thermal expansion apparatus

TRENDS IN THE UTILIZATION OF LIME AND LIME PRODUCTS

By Lee S. Trainor
Chief Engineer
National Lime Association, Washington, D.C.

PERHAPS A BETTER UNDERSTANDING OF THE SUBJECT WILL BE AFFORDED BY FIRST PRESENTING A SHORT DISCUSSION OF THE BROAD FIELD IN WHICH LIME IS USED. GENERALLY, LIME IS SOLD FOR A WIDE VARIETY OF USES IN THREE SEPARATE AND DISTINCT FIELDS; NAMELY,

(1) CHEMICAL AND INDUSTRIAL PROCESSES,
(2) CONSTRUCTION, and
(3) AGRICULTURE

A SIMPLE LIST OF THE CHEMICAL AND INDUSTRIAL PROCESSES EMPLOYING LIME WOULD READ LIKE A ROSTER OF THE NATION'S IMPORTANT INDUSTRIES INCLUDING,

(1) MANUFACTURE OF STEEL AND STEEL PRODUCTS
(2) PAPER, STRAWBOARD, AND ALLIED PRODUCTS
(3) GLASS
(4) LEATHER - DEHAIRING OF HIDES, ETC.
(5) TEXTILES
(6) REFINING OF OIL, LUBRICATING GREASES, ETC.
(7) PRODUCTION OF PAINTS, PIGMENTS, VARNISH, ETC.
(8) RUBBER
(9) SUGAR
(10) CALCIUM CARBIDE AND CYANAMIDE
(11) SODA, SODA-ASH, SODIUM BICARBONATE, AND OTHER STANDARD CHEMICALS
(12) DYESTUFFS AND INTERMEDIATES
(13) WATER TREATMENT
(14) SEWAGE DISPOSAL PROCESSES,

AND MANY OTHERS OF THE UTMOST IMPORTANCE IN OUR DAILY LIVES.

FEW PERSONS REALIZE THAT LIME IS AN ESSENTIAL ELEMENT IN THE HUMAN BODY, YET IT HAS BEEN ESTIMATED THAT THE BONES AND TEETH OF THE AVERAGE ADULT WOULD YIELD SUFFICIENT LIME TO WHITEWASH THE WALLS OF AN ORDINARY SIZED ROOM.

PROBABLY THE MOST IMPORTANT TREND IN THE CHEMICAL AND INDUSTRIAL USE OF LIME IS TO BE FOUND IN NEW AND IMPROVED METHODS OF TREATMENT FOR MUNICIPAL AND INDUSTRIAL WATER SUPPLIES AND IN THE TREATMENT AND PURIFICATION OF DOMESTIC AND INDUSTRIAL WASTES.

THE UNDERLYING PRINCIPLES INVOLVED IN THESE TWO IMPORTANT USES OF LIME ARE SOMEWHAT SIMILAR DEPENDING UPON THE ~~PROPERTY~~ ability OF LIME TO COMBINE WITH THE FREE AND HALF-BOUND CARBON DIXOIDE RESULTING IN THE PRECIPITATION OF CALCIUM CARBONATE AND MAGNESIUM HYDROXIDE. THESE PRECIPITATES UPON SETTLEMENT CARRY DOWN WITH THEM BACTERIA AND OTHER IMPURITIES. LIME IS FREQUENTLY USED IN COMBINATION WITH ALUM OR IRON SALTS TO PRODUCE OPTIMUM CONDITIONS OF COAGULATION FOR THESE MATERIALS.

A KNOWLEDGE OF THE IMPORTANCE AND VARIED USES OF LIME IN AGRICULTURE IS BY NO MEANS NEW OR CONFINED TO PRESENT-DAY FARM PRACTICE. EXAMINATION OF ANCIENT LITERATURE REVEALS THAT LIME WAS APPLIED AS A SOIL AMENDMENT LONG BEFORE THE CHRISTIAN ERA. THE SAME FACTORS (LEACHING AND CROPPING) WHICH CREATED LIME-POOR SOILS THEN ARE STILL AT WORK TODAY, AND UNLESS NATURE CHANGES RADICALLY, THE SOILS IN HUMID AREAS WILL ALWAYS BE AFFECTED BY THESE LIME-DEPLETING PROCESSES. SOME OF THE MORE IMPORTANT AGRICULTURAL USES OF LIME INCLUDE SOIL TREATMENT TO NEUTRALIZE ACIDITY AND PROMOTE THE GROWTH OF LEGUMES, GRAINS, GRASSES, TRUCK AND VEGETABLE CROPS; AS A FOUNDATION MATERIAL IN DUSTS AND SPRAYS USED TO COMBAT THE RAVAGES OF DISEASES AND INSECTS; AND/or AS A NECESSARY PART OF THE RATIONS OF FARM ANIMALS IN ORDER TO SUPPLY THE NEEDED CALCIUM FOR THE GROWTH AND DEVELOPMENT OF BONES AND TEETH.

FROM THE VIEWPOINT OF THE PRODUCER OF LIME PRODUCTS, THE FIELD OF SOIL CONDITIONING, OR ACID-NEUTRALIZATION, HAS BEEN, IS NOW, AND PROBABLY WILL CONTINUE

TO BE MOST IMPORTANT. THE VAST AMOUNT OF AGRICULTURAL RESEARCH THAT IS CONSTANTLY BEING CONDUCTED BY FEDERAL AND STATE INSTITUTIONS, ANNUALLY ADDS TO OUR KNOWLEDGE OF SOIL-CORRECTION PROBLEMS WITH THE RESULT THAT LIMING MATERIALS ARE BEING MORE INTELLIGENTLY USED.

ONE OF THE MOST NOTEWORTHY DEVELOPMENTS IN THIS FIELD WAS THE RECENT PERFECTION OF THE SO-CALLED HYDROGEN ION, OR pH METHOD OF DETERMINING THE DEGREE OF SOIL ACIDITY. BY EMPLOYING A COMPARATIVELY SIMPLE CHEMICAL OR ELECTRICAL TEST, IT IS NOW POSSIBLE TO QUICKLY AND ACCURATELY MEASURE JUST HOW ACID A SOIL IS. WITH THIS KNOWLEDGE IT IS POSSIBLE TO PRESCRIBE THE APPROXIMATE QUANTITY OF LIMING MATERIAL NEEDED TO CHANGE THE pH OF ANY GIVEN SOIL TO THE DESIRED REACTION.

RESEARCH ALONG A DIFFERENT LINE HAS ESTABLISHED THE DEGREE OF SOIL ACIDITY IN WHICH THE SEVERAL CROPS GROW BEST. ARMED WITH THIS SOIL AND CROP KNOWLEDGE THE COUNTY AGENT, OR OTHER AGRICULTURAL ADVISER IS IN A MUCH SOUNDER POSITION TO RECOMMEND THE PROPER PROCEDURE UNDER ANY GIVEN SET OF CONDITIONS.

IT SEEMS ONLY LOGICAL TO ASSUME THAT THE ENTIRE AGRICULTURAL INDUSTRY SHOULD PROFIT MUTUALLY WITH THE LIMING MATERIAL PRODUCER AS A RESULT OF THESE NEWER FINDINGS.

THE USE OF LIME FOR CONSTRUCTION PURPOSES DATES BACK TO THE EARLIEST RECORDS OF CIVILIZED MAN. IT IS PROBABLE THAT THE ART OF LIME-BURNING BEGAN WITH THE EARLIEST USE OF FIRE, SINCE A FIRE BUILT ON A LIMESTONE ENCLOSURE WOULD PRODUCE LIME. IT IS APPARENT THAT THE ANCIENT PEOPLE SOON DISCOVERED ITS VALUE AS A BINDING AGENT AND APPLIED THAT KNOWLEDGE IN THE CONSTRUCTION OF THEIR CRUDE SHELTER AS WELL AS THEIR MONUMENTS, MANY OF WHICH ENDURE TO THIS DAY.

THE USE OF LIME FOR BUILDING PURPOSES WAS DESCRIBED BY VITRUVIUS, PLINY, PALLADIUS, AND OTHERS, AND THE BOOK ON ARCHITECTURE WRITTEN BY VITRUVIUS REMAINED A STANDARD WORK DOWN TO THE 17TH AND 18TH CENTURIES.

THE ART OF PLASTERING WAS DEVELOPED TO A HIGH STATE OF PERFECTION BY THE ANCIENTS, AND GREEK HOUSES WERE ORNAMENTED WITH BOTH PLASTER AND STUCCO.

LIME CONTINUED TO BE USED AS THE PRINCIPAL BINDING AGENT IN MASONRY MORTAR THROUGHOUT THE AGES UNTIL QUITE RECENT YEARS, OR UNTIL THE GENERAL ADOPTION AND ACCEPTANCE OF PORTLAND CEMENT. THE WIDESPREAD USE OF CEMENT, IN MORTAR, WAS PREDICATED ON THE ASSUMPTION THAT INCREASED MORTAR STRENGTH GUARANTEED HIGHER STRENGTH IN MASONRY. AS A PEOPLE WE BECAME AFFLICTED WITH A STRANGE CASE OF STRENGTH COMPLEX.

THIS CHANGE IN WELL ESTABLISHED PROCEDURE WAS ACCOMPANIED BY WIDESPREAD DISSATISFACTION DUE TO AN EVER INCREASING NUMBER OF LEAKY MASONRY WALLS.

RECOGNIZING THE IMPORTANCE OF THIS SITUATION, INTENSIVE AND EXPENSIVE RESEARCH PROJECTS WERE INITIATED, AND THOSE IN CHARGE WERE INSTRUCTED TO INCLUDE A BROAD STUDY OF THE PROBLEM IN ORDER THAT ALL PERSONS INTERESTED might HAVE ACCESS TO KNOWLEDGE OF THE FACTORS that AFFECT THE SATISFACTORY PERFORMANCE OF UNIT MASONRY STRUCTURES. MUCH OF THIS RESEARCH WORK WAS BEGUN AT THE NATIONAL BUREAU OF STANDARDS IN WASHINGTON. OTHER PROJECTS WERE UNDERTAKEN AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY, MELLON INSTITUTE OF INDUSTRIAL RESEARCH AND MANY OTHER SIMILAR INSTITUTIONS. OTHER STUDIES ALONG MUCH THE SAME LINE ARE IN PROGRESS IN EUROPE, MORE ESPECIALLY IN GREAT BRITAIN. SOME OF THIS WORK HAS NOW BEEN IN PROGRESS FOR MORE THAN TEN YEARS AND A NUMBER OF TECHNICAL PUBLICATIONS HAVE BEEN ISSUED COVERING VARIOUS PHASES OF THE INVESTIGATIONS. THE WORK HAS NOT BEEN COMPLETED AND MANY AVENUES ARE YET OPEN FOR FUTURE EXPLORATION, HOWEVER, ENOUGH WORK HAS BEEN FINISHED TO JUSTIFY A FEW DEFINITE STATEMENTS. IT IS MY PURPOSE TO COVER A FEW OF THE HIGHLIGHTS OF THESE SEVERAL INVESTIGATIONS AND TO LEAVE WITH YOU ONE RECOMMENDATION DESIGNED TO ASSIST IN BUILDING BETTER MASONRY.

FIRST, LET ME SAY THAT THE DISTINGUISHED TECHNOLOGISTS AND AUTHORITIES IN CHARGE OF THESE SEVERAL INVESTIGATIONS ARE IN EXCELLENT AGREEMENT ON THE FUNDA- MENTAL PRINCIPLES INVOLVED AND I FEEL SURE THAT WHEN THE WORK AT HAND IS FINALLY COMPLETED THEIR FINDINGS WILL ALL BE IN GOOD AGREEMENT.

DURING THE EARLY STAGES OF THE STUDIES REFERRED TO, ATTENTION WAS FOCUSED UPON TESTS OF UNITS AND MORTAR SEPARATELY AND WHILE MANY VALUABLE DATA WERE ASSEMBLED AS A RESULT OF THE TESTS, THE REALLY IMPORTANT FACTORS DID NOT MAKE THEIR APPEARANCE UNTIL FIELD AND LABORATORY STUDIES WERE MADE OF MASONRY ASSEMBLAGES WHICH INCLUDES BOTH UNITS AND MORTAR. AS A RESULT OF THESE LATER TESTS IT WAS SHOWN THAT SATISFACTORY MASONRY DEPENDED LARGELY UPON THE SELECTION OF MUTUALLY ADAPTABLE MATERIALS. WHILE IT IS TRUE THAT CERTAIN VARIABLES ARE INTRO- DUCED OR INFLUENCED BY DESIGN AND QUALITY OF WORKMANSHIP EMPLOYED, IT IS FELT THAT THESE ITEMS HAVE FAR LESS IMPORTANCE THAN IS SOMETIMES ASSUMED AND THAT THE REALLY IMPORTANT FACTOR IS A WISE CHOICE OF MATERIALS.

IT IS HARDLY POSSIBLE AND CERTAINLY NOT PRACTICAL, IN AN ECONOMIC SENSE, TO CHANGE THE LONG ESTABLISHED PRACTICES OF MANUFACTURE OF BRICK AND OTHER UNITS TO PRODUCE ONLY ONE OR AT MOST AN EXTREMELY LIMITED TYPE OR VARIETY OF UNITS WHICH WOULD BE ADAPTABLE TO A GIVEN TYPE OF MORTAR. IT IS, HOWEVER, A PRACTICAL, ECONOMICAL AND STRAIGHTFORWARD PROCEDURE TO ADAPT MORTAR TO A WIDE RANGE OF UNITS. ADAPTATION IS EFFECTED THROUGH SELECTION, BASED ON KNOWN FACTS CONCERNING MORTAR PROPERTIES AS RELATED TO THE EXTENT AND INTENSITY OF ADHESION OF MORTARS TO DIFFERENT TYPES OF UNITS.

TO BOND UNIFORMLY, COMPLETELY, AND PERMANENTLY TO DIFFERENT TYPES OF BUILD- ING UNITS, IN DIFFERENT TYPES OF BUILDINGS CONSTRUCTED UNDER A DIVERSITY OF CONDITIONS, THE MORTAR SELECTED MUST FIRST, LAST, AND ALWAYS BE ADAPTABLE. AN ADAPTABLE MORTAR IS ONE THAT PRODUCES A GOOD EXTENT OF BOND WITH ALL TYPES OF BRICKS OR OTHER BUILDING UNITS WITHOUT INVOLVING THE NECESSITY OF WETTING THE UNITS BEFORE LAYING THEM. ADAPT- ABILITY IS THE RESULTANT EFFECT OF A COMBINATION OF SEVERAL VERY NECESSARY MORTAR PROPERTIES.

THESE PROPERTIES, LISTED IN ORDER OF THEIR IMPORTANCE ARE:

(1) WORKABILITY (THE CONTROLLING FACTOR BEING THE WATER RETAINING CAPACITY OF THE FRESHLY MIXED MORTAR)

(2) ADHESIVENESS OF BONDING POWER (A HIGH RATIO OF TENSILE BOND STRENGTH TO TENSILE MORTAR STRENGTH)

(3) LOW VOLUME CHANGES SUBSEQUENT TO HARDENING

(4) THE MAXIMUM AMOUNT OF STRENGTH OBTAINABLE WITHOUT MATERIAL SACRIFICE OF OTHER NECESSARY PROPERTIES.

(5) EXTENSIBILITY (DEFINED AS THE ABILITY TO UNDERGO A RELATIVELY HIGH DEGREE OF STRETCHING WITHOUT RUPTURE)

(6) FREEDOM FROM SOLUBLE MATTER THAT CONTRIBUTES TO EFFLORESCENCE, STAINING, ETC.

(7) A FAIR DEGREE OF POROSITY.

TIME WILL NOT PERMIT A FULL DISCUSSION OF ALL THE ELEMENTS ENTERING INTO THIS PICTURE. HOWEVER, IT IS IMPORTANT THAT WE HAVE SOME GENERAL CONCEPTION OF THE VARIOUS PROPERTIES AND THEIR INFLUENCE ON THE PRODUCTION OF SATISFACTORY MASONRY.

THE MOST IMPORTANT FACTOR INFLUENCING WORKABILITY OF MORTAR IS ITS WATER RETAINING CAPACITY, WHICH IS DEFINED AS THE PROPERTY OF RETAINING OR HOLDING THE MIXING WATER.

A FRESHLY MIXED MORTAR IS WORKABLE IF IT TENDS TO RESIST THE RAPID LOSS OF MIXING WATER WHEN IN CONTACT WITH ABSORBENT MATERIALS SUCH AS DRY POROUS BRICK, OR RESISTS SEGREGATION IN THE MORTAR WHEN IN CONTACT WITH NON-ABSORBENT MATERIALS.

MORTARS DEFICIENT IN WATER RETAINING CAPACITY STIFFEN QUICKLY WHEN BROUGHT INTO CONTACT WITH ABSORBENT UNITS DUE TO RAPID LOSS OF WATER UNDER SUCTION. SUCH MORTAR ALSO TENDS TO SEGREGATE AND BOND POORLY WHEN USED WITH NON-ABSORBENT UNITS, IT IS THEREFORE, POORLY ADAPTED FOR USE WITH A WIDE VARIETY OF BUILDING UNITS.

ON THE OTHER HAND A MORTAR OF HIGH WATER RETAINING CAPACITY REMAINS WORKABLE DURING THE BRICKLAYING OPERATIONS, WHICH ASSURES FULL AND COMPLETE BEDDING OF THE UNITS WITH INTIMATE CONTACT BETWEEN MORTAR AND UNITS OVER THE ENTIRE AREA. SUCH A MORTAR TENDS TOWARD MORE COMPLETE FILLING OF VERTICAL JOINTS SINCE IT REMAINS SUFFICIENTLY PLASTIC TO PERMIT THE MASON TO SHOVE THE UNIT INTO PLACE WITH THE HEADER JOINT FILLED.

BONDING POWER IS THAT COMPOSITE OF MORTAR PROPERTIES WHICH CAUSES IT TO BOND OR ADHERE UNIFORMLY AND COMPLETELY WITH A DIVERSITY OF UNITS AND UNDER WIDELY DIFFERENT CONDITIONS.

GOOD EXTENT AS WELL AS GOOD INTENSITY OF BOND OR ADHESION IS DEPENDENT TO A LARGE DEGREE UPON THE WATER RETAINING CAPACITY OR WORKABILITY OF THE MORTAR.

THE OPTIMUM CONDITION WOULD BE SECURED WHERE THE INTENSITY OF ADHESION OF THE MORTAR IS EQUAL TO OR GREATER THAN THE TENSILE STRENGTH OF THE MORTAR. AS A RESULT OF RESEARCH WORK NOW COMPLETED IT HAS BEEN DETERMINED THAT THE WATER RETAINING CAPACITY AND THE BONDING POWER OF MORTAR IS DIRECTLY PROPORTIONAL TO THE AMOUNT OF LIME IN THE MORTAR MIX. BOTH THE EXTENT AND INTENSITY OF BOND ARE IMPROVED AS THE PROPORTION OF LIME USED IS INCREASED.

MASONRY SPECIMENS BONDED WITH LIME OR HIGH LIME MORTARS WHEN TESTED FOR TENSILE BOND STRENGTH INVARIABLY FAILED IN THE MORTAR, WHEREAS SIMILAR SPECIMENS BONDED WITH PORTLAND CEMENT OR HIGH CEMENT MORTARS FAILED AT THE PLANE WHERE UNIT AND MORTAR MEET. UNDER THESE CONDITIONS IT IS IMPOSSIBLE TO EVEN ESTIMATE THE BOND STRENGTH OF LIME MORTARS.

IN CERTAIN MORTARS METALLIC STEARATES ARE ADDED. SUCH MATERIALS APPEAR TO IMPROVE THE PHYSICAL PROPERTIES OF THE MORTAR, BUT CERTAIN OTHER UNDESIRABLE CHARACTERISTICS ARE IMPARTED, THEREFORE, THEIR USE IS NOT GENERALLY RECOMMENDED. THE ADDITION OF STEARATE COMPOUNDS GENERALLY DO NOT IMPROVE THE WATER RETAINING

CAPACITY OF THE MORTAR EVEN THOUGH IT MAY APPEAR TO POSSESS HIGH WORKABILITY. A TOO GENEROUS AMOUNT OF STEARATE IMPAIRS FORMATION OF BOND BY INTERPOSING A THIN FILM OF INERT MATERIAL BETWEEN UNITS OF MORTAR.

THERE ARE THREE DISTINCT TYPES OF VOLUME CHANGE IN MORTARS, ALL DUE TO DIFFERENT CAUSES AND OCCURRING AT DIFFERENT PERIODS OF TIME IN THE LIFE OF THE MORTAR. THESE ARE:

(1) COMPACTING AND/OR SEGREGATION PRIOR TO CEMENTING ACTION.

(2) SHRINKAGE OCCURRING DURING HARDENING.

(3) VOLUME CHANGES OCCURRING SUBSEQUENT TO HARDENING DUE TO CHANGES IN MOISTURE CONTENT.

MEASUREMENTS REPORTED IN BUREAU OF STANDARDS RESEARCH PAPERS NOS. 321 AND 683 INDICATE THAT MINIMUM VOLUME CHANGES SUBSEQUENT TO HARDENING OCCUR IN MORTARS CONSISTING SOLELY OF LIME AND SAND. IN THE CASE OF MORTARS MADE FROM A MIXTURE OF LIME AND PORTLAND CEMENT SUCH VOLUME CHANGES WERE DECREASED AS THE PROPORTION OF LIME WAS INCREASED.

VOLUME CHANGES WHICH OCCUR SUBSEQUENT TO HARDENING OF THE MORTAR CONTINUE OVER MANY YEARS, AND WHERE THE EXTENT OF BOND INITIALLY OBTAINED IS POOR IT IS QUITE PROBABLE THAT SUCH BOND AS MAY EXIST WILL BE DESTROYED ENTIRELY AS A RESULT OF THE ALTERNATE EXPANSION AND SHRINKAGE OF THE HARDENED MORTAR.

IT SO HAPPENS THAT LOW WATER RETAINING CAPACITY AND HIGH VOLUME CHANGES SUBSEQUENT TO HARDENING ARE ASSOCIATED IN THE SAME MORTAR.

IN CONSIDERING STRENGTH IT IS NECESSARY TO CONSIDER STRENGTH OF MASONRY ASSEMBLAGES AND NOT THE STRENGTH OF THE INDIVIDUAL UNITS OR MORTAR SPECIMENS. IT IS NO PARADOX THAT MORTARS WHICH GAVE FAIRLY LOW VALUES IN COMPRESSIVE AND TENSILE STRENGTH WHEN TESTED SEPARATELY AND NOT IN CONTACT WITH MASONRY UNITS GAVE THE HIGHEST VALUES FOR FLEXURAL STRENGTH OF MASONRY BEAMS.

THE AVERAGE BONDING EFFICIENCY AS EVIDENCED IN TESTS OF BRICK BEAMS, BRICKS SET DRY, WAS HIGHER WITH MORTAR COMPOSED OF TWO VOLUMES OF LIME, ONE VOLUME OF CEMENT AND NINE VOLUMES OF SAND[9] THAN FOR ANY OTHER OF THE MORTARS STUDIED. FLEXURAL STRENGTH OF MASONRY IS OF PRIME IMPORTANCE IN AREAS SUBJECTED TO EARTHQUAKE SHOCK, HIGH WINDS OR OTHER CONDITIONS PRODUCING LATERAL STRESSES IN THE MASONRY. COMPRESSIVE STRENGTH OF MASONRY AS BUILT TODAY IS MANY TIMES THE ACTUAL REQUIREMENTS AND MAY BE DISMISSED WITH BUT SCANT ATTENTION.

EXTENSIBILITY OF MORTAR IS AN IMPORTANT ELEMENT IN MAINTAINING BOND ONCE IT IS FORMED.

THERE IS NO OUTSTANDING DIFFERENCE BETWEEN THE VALUES FOR VARIOUS MORTARS IN SO FAR AS EXTENSIBILITY IS CONCERNED, BUT ITS REAL SIGNIFICANCE IS IN CONNECTION WITH VOLUME CHANGE CHARACTERISTICS OF THE VARIOUS MORTARS.

EXTENSIBILITY MAY BE EXPRESSED NUMERICALLY AS THE RESULT OBTAINED BY DIVIDING THE MODULUS OF RUPTURE BY THE MODULUS OF ELASTICITY OF A HARDENED SPECIMEN AND IS EXPRESSED AS per cent. THE VALUE OBTAINED REPRESENTS THE ELONGATION THE MORTAR SPECIMEN HAS UNDERGONE AT THE INSTANT OF FRACTURE. WHEN THIS VALUE IS CONSIDERED IN CONNECTION WITH THE SHRINKAGE A HARDENED MORTAR UNDERGOES AS A RESULT OF DRYING, ITS TRUE VALUE BECOMES APPARENT. IN THE EVENT THE VALUE ESTABLISHED FOR EXTENSIBILITY IS IN EXCESS OF THAT ESTABLISHED FOR SHRINKAGE IN HARDENED MORTAR, THAT MORTAR WILL PROBABLY RETAIN ITS BOND THROUGHOUT THE LIFE HISTORY OF THE MASONRY. HOWEVER, IN THE EVENT THE MAGNITUDE OF SHRINKAGE IS THE GREATER VALUE, IT IS PROBABLE THAT SUCH BOND AS DOES EXIST WILL BE COMPLETELY DESTROYED AS A RESULT OF VOLUME CHANGES.

ALL STUDENTS OF THE PROBLEM RECOGNIZE THE DISFIGURING EFFLORESCENCE WHICH SOMETIMES APPEARS ON BUILDINGS AS A SYMPTOM ONLY, WHICH INDICATES THAT OPENINGS EXIST IN THE MASONRY THROUGH WHICH WATER ENTERS, WHEREUPON IT DISSOLVES THE SOLUBLE SALTS NATURALLY PRESENT IN ALL MASONRY MATERIALS, BOTH UNITS AND MORTAR, AND UPON EVAPORATION LEAVES THESE MATERIALS BEHIND TO MAR THE BEAUTY OF

THE WALL.

A REASONABLE POROSITY OF BOTH UNITS AND MORTAR IS ESSENTIAL TO SATISFACTORY MASONRY. THE OPTIMUM CONDITION WOULD BE TO SELECT UNITS OF UNIFORM RATE OF SUCTION WHICH WILL ABSORB FROM 20 to 40 GRAMS OF WATER IN ONE MINUTE WHEN ONE FACE OF THE BRICK IS IN CONTACT WITH WATER, AND SET THEM WITH A MORTAR POSSESSING IN HIGH DEGREE THE DESIRABLE PROPERTIES HERE DISCUSSED.

BEFORE CLOSING I WANT TO PRESENT THE ONE RECOMMENDATION PROMISED; FOR ALL NORMAL UNIT MASONRY ABOVE GRADE USE A MORTAR COMPOSED OF TWO VOLUMES OF LIME, ONE VOLUME OF PORTLAND CEMENT, AND APPROXIMATELY NINE VOLUMES OF SAND. A MORTAR OF THIS COMPOSITION HAS A HIGH RATING IN ALL THE ESSENTIAL PROPERTIES HEREIN DISCUSSED AND IS GENERALLY ADAPTABLE FOR USE WITH A WIDE VARIETY OF MASONRY UNITS.

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