BRAB conference report no. 6

Conference Proceedings

PORCELAIN ENAMEL IN THE BUILDING INDUSTRY

Conducted by the

BUILDING RESEARCH INSTITUTE

November 12 and 13, 1953

National Academy of Sciences—
National Research Council

...LDING RESEARCH INSTITUTE

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RESEARCH CONFERENCE REPORT NO. 6

PORCELAIN ENAMEL IN THE BUILDING INDUSTRY

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SPONSORED BY

THE BUILDING RESEARCH ADVISORY BOARD

AND

THE PORCELAIN ENAMEL INSTITUTE

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THE BUILDING RESEARCH INSTITUTE

DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH

NATIONAL ACADEMY OF SCIENCES • NATIONAL RESEARCH COUNCIL

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EDITOR, EDWARD H. F. DICKENS

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CHEMICAL PROPERTIES OF PORCELAIN ENAMEL COATINGS

By G. H. Spencer-Strong (Pemco Corporation)

The resistance of porcelain enamel coatings to chemical corrosion has long been recognized. This property, in fact, played a very considerable part in the choice and successful application of the material over the years.

The choice of the proper porcelain enamel to meet a given set of conditions should be based on the specific end use. Usually a considerable latitude of choice exists, making possible the selection of a material which will meet the end-use requirements efficiently and economically.

A very high percentage of the sheet steel enamels applied today are resistant to cold acids and usually to weak solutions of hot acids. Where the end-use is too rigorous for the normal acid-resistant enamel but does not require or is unsuited to the very highly acid resisting chemical ware enamels, a group of special purpose materials has been developed.

The development of porcelain enamels for the special purpose of resisting alkali attack is a rather recent achievement. Although silicates are not normally resistant to alkali solutions, especially at temperature, these materials have made a very good showing and have made possible the solution of some rather difficult problems.

Porcelain enamels are not attacked by organic solvents nor by neutral organic materials such as fats, oils, greases, and the like.

The use of porcelain enamels for protection against atmospheric corrosion combines some of the oldest and some of the newest uses for the material. The advantages of architectural porcelain enamels have long been known. More recent has been the use of porcelain enamel coatings, usually in somewhat modified form, for the protection of metals against corrosion at elevated temperatures. Such protection of metal against high-temperature corrosion covers a very wide field of end uses ranging from prevention of oxidation through protection against attack by heated atmospheres carrying acid gases to protection against some molten metals.

PHYSICAL CHARACTERISTICS OF PORCELAIN ENAMEL

By E. E. Howe (Chicago Vitreous Enamel Product Co.)

Porcelain enamel, which is usually considered as a finish, is in reality a composite material—glass and metal. The many useful physical properties that make porcelain enamel a desirable product for the building industry may not always depend upon the inseparable characteristics of the individual components, but must be considered on the basis of the combination. However, for the purposes of this discussion, the properties described will be that of the coating itself, just as if it were a separate entity. It is the purpose of this paper to describe the various physical characteristics that may be attributed to the glass-like layer of material which may be applied to the various metal structural shapes.

Of the many useful characteristics desired in a building material, porcelain enamel compares favorably with accepted quality products in common use and excels when compared to numerous others of both the common and uncommon class.

Its resistance to abrasion and its hardness affords long wearing quality under atmospheric and everyday usage conditions. Being of mineral or inorganic structure, the colors in porcelain enamel are unaffected by sun, heat, or cold. It is dimensionally stable with respect to moisture or dryness and is non-aging. The strength of porcelain enamel plus its thickness supplies strength or rigidity to the metal backing to which it is applied.

Thermally speaking, it will not support combustion or oxidize and has exceptional thermal shock resistance for a building material. Although it may not be considered a good thermal insulator for conducted heat, it reflects light and thermal radiation.

In a class by itself when it comes to color and textural variations in which it may be produced, the permanent eye-appeal of porcelain enamel is a distinctive physical characteristic which cannot be described, but must be seen to appreciate its uniqueness.

WEATHER RESISTANCE STUDY OF PORCELAIN ENAMEL STRUCTURAL UNITS

By Dwight G. Moore (National Bureau of Standards)

A study of the weather resistance of porcelain enamels has been in progress at the National Bureau of Standards since 1939. A total of 768 panels are being exposed at four locations selected to represent the following climates: (1) temperate residential, (2) temperate industrial, (3) temperate salt-air, and (4) semitropical residential.

The results so far obtained show that most enamels are highly resistant to deterioration under the conditions existing at the selected locations and further that those enamels that are not resistant can be rejected prior to installation by simple laboratory tests. Also, if proper care is taken to insure good coverage of all surfaces of the panel, the data indicate that even the poorest enamels will provide corrosion protection for an extended period of years.

The results obtained from an inspection made after seven years of exposure will be described in detail. The correlation obtained between weather resistance and various accelerated laboratory tests will be discussed.

RADIOCHEMICAL DECONTAMINATION CHARACTERISTICS OF PORCELAIN ENAMEL

By G. W. Parker and G. M. Herbert (Oak Ridge National Laboratory)

A limited number of porcelain enamels have been compared with conventional materials of construction generally rated superior in decontamination characteristics in a program intended to prove the suitability of porcelain enamel for the construction of radiochemical laboratory furniture.

The chemical properties of glass: versatile chemical resistance, low absorption and chemical exchange characteristics, and freedom from surface defects and porosity are found to a varying degree in all porcelain enamels. As expected, in contamination susceptibility and ease of decontamination, by conventional test, porcelain enamel was rated second only to plate glass and decidedly superior to stainless steel and preferred plastic materials.

In addition to its extra chemical resistance, porcelain enamel shows every indication of being a more desirable material for radiochemical fume hood superstructures than the materials of construction now available for this purpose. As a material for the construction of laboratory working surfaces, further investigation is indicated.

PORCELAIN ENAMEL MANUFACTURING PROCESSES

By G. H. McIntyre (Ferro Corporation)

Porcelain enamel is defined as a glassy composition which adheres to metal, and the various manufacturing steps from essential raw materials to the production of the finished product are discussed. Both dry process and wet process formulae are detailed. Methods of treating formed metal parts for the application and fusion of frit ground coats and cover coats are reviewed, with emphasis on the necessity for careful control procedures. The paper states that enamel frits are selected on the basis of workability, durability, resistance to chemical and weather corrosion, and general appearance with reference to color and gloss. Batch type and continuous type furnaces are described in which firings take place at temperatures of 1500 to 1600 degrees F for iron and below 1000 degrees F for aluminum. The paper concludes that the enamel industry has grown from a small "batch type" operation to a highly technical "continuous process" demanding the skill of well-trained engineers and scientists.

METHODS OF TESTING PORCELAIN ENAMELS

By W. N. Harrison (National Bureau of Standards)

What tests for porcelain enamels are needed by the architect to provide data for use in designing buildings? Are such tests available? Where? What is known about the strength of porcelain enamels, and how does their strength affect design?

Fortunately, no data on the structural strength of porcelain enamels as such is required for use in designing buildings and structures. Although published test results show that porcelain enameled specimens are somewhat stronger than similar specimens without the enamel, it would appear to be sound engineering practice to consider such increase in strength as an added safety factor. Hence appropriate strength data pertaining to the uncoated basis metal may be used when the strength of the coated metal must be taken into consideration. It is therefore the surface properties of porcelain enamels that interest the architect, and for which he needs test results on which to base specifications. For outer walls, high resistance to weathering is a paramount functional requirement. Extended exposure tests have shown a high correlation of weathering resistance with acid resistance, for which there is a simple test.

From the appearance standpoint, there are three principal factors: color, gloss and mechanical flatness. For some architectural applications, surface-abrasion resistance (or wear resistance) is also important. For all four of these properties, test methods are available. The sources from which all needed test methods can be obtained are given in this paper, together with an outline of the procedures.

THE DESIGN, MANUFACTURE, AND ERECTION OF ARCHITECTURAL PORCELAIN ENAMEL PARTS

By Benjamin B. Loring (Seaporcel Metals, Inc.)

Some of the history of porcelain enamel is reviewed, going back to the period when only "stock sheets" in white or black were available. Modern day accomplishments are discussed, citing numerous large buildings, including the Statler Hotel in Hartford and the new terminal building at the San Francisco Airport. The necessity for specifying proper sheet sizes and methods of attachment to avoid warping are considered. Care in installation, with reference to such matters as furring and caulking, is of prime importance in the author's opinion. Methods of attaching panels to cinder block, hollow tile, and concrete are also discussed. The paper concludes that architects and designers could benefit by incorporating the specifications issued by the Porcelain Enamel Institute in orders for the fabrication and enameling of porcelain enamel building materials.

PORCELAIN ENAMEL CURTAIN WALLS AND THEIR UTILIZATION IN THE BUILDING INDUSTRY

By E. X. Tuttle (Giffers & Vallet, Inc.)

In the author's opinion, porcelain enamel curtain walls will be the most important single factor in the development of building types during the next ten years. A prognosis is made on the conditions and trends which will influence the increasing acceptance of this material. Decentralization of industry coupled with the trend to one-story structures promises a widening market for porcelain enamel on steel and aluminum. The growing need for flexibility in commercial buildings, factories, schools, etc., favors the use of lightweight curtain walls, although it is suggested that the industry could bring about improvements in panels with reference to weathering and field erection. The author forwards the idea of a curtain wall "system" and describes its various components.

AN ARCHITECT'S VIEWPOINT OF PORCELAIN ENAMEL USED ALONE AND IN COMBINATION WITH OTHER MATERIALS

By William Lescaze (Architect, New York)

The philosophy of modern architecture is discussed, leading up to the present and future role of porcelain enamel. A variety of colors obtainable, ease of installation, and low maintenance are cited by the author as advantages of this type of construction. Reduction in weight and space-saving characteristics make porcelain enamel a logical choice for skyscraper and large scale construction. Various curtain wall developments are described, showing methods of joining and sealing. It is predicted that the curtain wall, windows, and sunshade units will be produced as an integrated whole. The ultimate goal in this prefabication technique would be to have the curtain wall contain heating and cooling systems, lighting and telephone conduits. The paper concludes that more research is necessary in order to take advantage of the full possibilities of this versatile and colorful material.

CREATIVE USES OF PORCELAIN ENAMEL

By Richard W. Hamilton (Albert Farwell Bemis Foundation)

As a result of the close cooperation between architects, artists, and manufacturers certain creative applications of porcelain enamel have been made and are described in this paper. Texture, multi-color finishes, and enamel used in combination with other materials are discussed, along with a review of the early experiments to integrate decorative elements with the functional parts of metal clad houses. Creative uses are described with reference to house exteriors and interiors, fireplaces, stores, banks, libraries, and signs.

ENGINEERING PROPERTIES OF PORCELAIN

By Forrest R. Nagley (Bureau of Ships, Navy Department)

Porcelain enamel, being a vitreous glass-like substance is notch-sensitive. As such it is not commonly regarded as a structural material or as contributing advantageously to the strength of the metal sheet, plate or shape to which it is applied as a coating. Although certain notch-sensitive metallic coatings cause permature brittle failure of the basis metal, none of the porcelain enamel coatings tested had any damaging effect; to the contrary all were beneficial.

During the past five years, suitable data have accrued which indicate that porcelain enamel coatings on steel and 61S aluminum alloy can be so formulated and applied as to be elastic within and slightly beyond the elastic limit, in outer fibre straining, of the basis metal to which they are applied. Further, there are indications that for special end uses, the enamel can be selected on the basis of its relative thermal coefficient of expansion so that the coating is under residual compressive stresses and can effectively withstand plastic deformation in tension. This plastic deformation was observed in porcelain enamel on bend-test specimens of 61S aluminum alloy rolled plate one-fourth inch thick.

Comparative data are presented on tensile strength and flexural strength of coated and uncoated metals. Other properties mentioned include: vibration damping, permanence of appearance characteristics, corrosion protection to basis metal, and flame-barrier attributes.

FLUES, FURNACES, AND EXHAUST SYSTEMS USING HIGH TEMPERATURE PORCELAIN ENAMELS AND CERAMIC COATINGS

By A. I. Andrews (University of Illinois)

This paper deals with the rapidly growing applications of porcelain enameled and ceramic coated metals to uses requiring service above normal temperatures. Although porcelain enamels have been used for kitchen utensils, room stoves, and kitchen ovens for many years, the emphasis of the paper is on the less-familiar and more-recent applications.

The elevated-temperature properties of porcelain enamels are excellent. Such properties as durability, resistance to flue gases, condensates and ash, thermal shock resistance, thermal conductivity, heat absorption and emission, and resistance to abrasion are discussed. Tables and curves illustrate the available data, but since many of the high-temperature uses are new, only a limited amount of precise data is available.

In the early part of World War II, research in this area was greatly accelerated because of the demand for better, longer-lasting, and more-available materials. Through the use of porcelain enamel and ceramic coatings and service life of stainless steels was lengthened, and other—cheaper—alloys and metals could be used to advantage. Following the successes achieved in airplane applications, many new uses were suggested in marine, industrial, and architectural areas. Large, factory smoke-stacks have been porcelain enameled and are being tried out with great promise. Heat interchangers are an important area of use because thin-walled porcelain enameled steel give good heat transfer, leading to high efficiency.

In the home, furnace flues and smokestacks have been on the market since before World War II, and they are giving excellent service. As with many new products, engineering and design are very important. The use of porcelain enamels for furnace combustion chambers, special heaters, and flues are illustrated in the paper.

Suggestions are made of other new uses for high-temperature porcelain enamels and ceramic coatings.

PORCELAIN ENAMEL COATINGS ON ALUMINUM

By B. C. Bricker (E. I. Dupont de Nemours & Co., Inc.)

Aluminum has long been recognized as an important tool in the building trades. The addition of a porcelain finish contributes color, surface hardness and chemical resistance to the desirable light weight and strength of aluminum, combining glass and aluminum into a single structural member of the versatility necessary in modern architecture.

Efficient utilization can be achieved only through intelligent correlation of the activities of the producers of porcelain enameled aluminum and the designers, engineers and architects who dictate its use.

THE USE OF PORCELAIN ENAMEL FOR HOSPITALS

By James J. Souder
(York & Sawyer, Kiff, Colean, Voss & Souder)

The story of building experience with porcelain enamels in hospitals is largely one of projection into the future. By examining what has been done, and why it has been done, we can bring the potential role of this material into focus.

First we must understand the rationale of the hospital problem. Today's hospital is a technical work center surrounded by living quarters for staff and for ordinary people who happen to be ill. It is built and maintained by the community at large. It's expected period of useful life is much longer than that demanded of most other buildings. This combination of factors requires structures which stretch the building dollar, minimize the operating dollar, provide aesthetic as well as practical cleanliness, assure fire safety, and offer the flexibility of arrangement required by constantly changing and improving techniques. Finally it must offer an environment which is inviting to both technician and layman.

Historically, porcelain enamel has played a minor part in meeting the hospital problem. With few exceptions it has been limited to movable or expendable equipment and many of these applications are currently supplanted by stainless alloys. Perhaps its most significant use, a side-product of wartime demand for speed, was the bulkheading of hospital ships, where lightness, cleanliness, fire safety, rapid installation and pleasant color were found in one material delivered complete rather than in the more usual combination of several materials laboriously put together at the worksite.

This shipboard application points the way to many similar ones on and within buildings, some of which are now being tried as our construction industry moves slowly away from the journeyman carpenter's piecework method toward the obvious goal of coordinated mass production. Exterior and interior walls, ceilings, work surfaces, equipment enclosures are among many foreseeable uses which will develop logically if the inherent capabilities, flexibilities and limitations of the material are respected.

THE USE OF PORCELAIN ENAMEL IN SALES STRUCTURES

By Paul R. Fritsch
(The Goodyear Tire & Rubber Company, Inc.)

A marketing revolution known as the shopping center has brought into very sharp focus the varied opinions and the many problems involved in exterior design of sales structures. The storefront, as the face of a sales structure, ought to be designed for a specific impression on customers.

In the so-called "downtown" sections, every store has been an individual project; but in the new convenient shopping centers all the stores are planned as a group. Designers and architects are in the frame of mind to eliminate from shopping centers all the disagreeable aspects of the old congested business sections. The arrangement of parking is usually such that customers have a panorama view of a large group of stores. Hence, a good group or collective appearance of the center is essential. Individual stores need a distinct identity. Chains or cooperative groups who have invested time and money developing a well known face must maintain their familiar appearance in shopping centers as well as in any other location.

The trick is to make the two objectives compatible. Good designers are doing it.

The exterior of a store ought to indicate the nature and the character of the business. Any shopping area is a modern bazaar, the market place where the buyer and seller meet. There is a serious, unfortunate tendency to make a shopping center a monotonous string of storefronts, all of the same color and same building materials. Frequently an attempt is made to keep all signs precisely uniform in size, shape, color, and type of lettering. This makes the over-all appearance of the shopping center about as exciting as the pigeon holes in a post office.

The over-all appearance of a group of stores should be interesting, stimulating and in good taste. Variety is an essential ingredient. The best foundation for variety is for each store face to be presented in a way that authentically portrays the nature and the character of the business. To fuse together a variety of stores, keeping the over-all effect pleasing and profitable as well as in good taste, requires a mixture of good design talent and a full appreciation of merchandising fundamentals.

THE USE OF PORCELAIN ENAMEL IN HOUSES

By Wentworth W. Lobdell
(Lobdell Realty Co.)

The use of porcelain for houses is still believed by most people to be impractical and too expensive. It is our opinion that the opposite is true. The Lustron home which gave us our introduction to a porcelain house resulted in our conclusions.

It was the first of more than twenty different prefab houses we had built or investigated that would undersell a conventional house of the same size. Cost of the conventionally built house was more than $1000 higher than the Lustron.

The maintenance cost was far below any other house we had built or heard about. The owners do most of their maintenance work themselves.

The sales resistance was as great or greater than any other house we had ever sold. However, we soon discovered that if our salesmen were properly educated and given the opportunity to answer all our prospects' questions, we could overcome practically all objections.

You can do almost anything with a porcelain house by way of design that you can do with any other material. After five years we have yet to find a family who has lived in a Lustron home who would not prefer a porcelain house to a conventional one.

Lustron proved that by combining the prefab method with the use of porcelain on steel, a better home of greater economy and livability would revolutionize the house-building industry.

PORCELAIN ENAMEL STEEL IN INDUSTRIAL BUILDING

By Milton Male and Carl F. Block
(United States Steel Corporation)

Porcelain enameled steel, both as corrugated or flat sheets and as built-up panels, provides the builder with an exterior material having exceptional properties for industrial buildings as well as office buildings. Panels cover a large area, are easier and faster to erect, and permit the application of a wide variety of recently developed insulation materials. In uninsulated buildings porcelain enameled panels need never be painted or replaced, a matter of importance these days when labor and material costs are mounting. Higher initial costs are recovered in six to nine years through reduced outlays for maintenance. Data are presented which compare initial costs and costs per year for porcelain enamel and other types of roofs. Factors which must be taken into account to obtain satisfactory erection experience are outlined. Illustrations are shown of buildings whose walls and roofs are porcelain enameled steel.

OPENING OF THE CONFERENCE

MR. GLENN A. HUTT: Gentlemen, let's come to order, please. We'll officially open this Conference on Porcelain Enamel in the Building Industry. First, Mr. Norman P. Mason, President of the BRAB Institute, has a few words of welcome for us. Mr. Mason.

MR. NORMAN P. MASON: Good morning, Mr. Moderator, and gentlemen of the porcelain enamel and building industries. It's a real privilege for me to have this opportunity to open this conference. As you probably know, this conference is a history-making one for our Building Research Institute because it is our first conference of this kind. We've had a long series of conferences that cut across the whole building economy and take in various phases of industry, but this is the first conference—and we hope it will be one of many—where a single product is explored. The Building Research Advisory Board is particularly interested in fostering research in the building construction industry, and is using every means it can to set your minds to thinking about the industry's problems and thereby stimulate you to arrive at conclusions. As you folks know, there are various approaches to research, and one of these is the conference where experts get together and exchange ideas and opinions.

I believe it is appropriate to point out here that the Building Research Advisory Board and the Building Research Institute are private industry organizations and that they do not get any money from the Government. They are supported by folks like you and me who believe in research. So when you go back to your companies, tell them what you think about the Building Research Advisory Board and the Building Research Institute and their work in behalf of the industry. If you are not already a member of the Building Research Institute, we certainly would be very happy to have your support. You have my best wishes, and those of BRAB, for a very, very successful conference. Thank you, Mr. Moderator.

MR. HUTT: Thank you, Mr. Mason. Next, we'll have the response by Mr. W. A. Barrows, President of the Porcelain Enamel Institute. Mr. Barrows.

MR. W. A. BARROWS: Mr. Moderator, Mr. Mason, members of BRAB, and guests. It is an honor for me to represent the porcelain enamel industry as its spokesman to accept the welcome of BRAB to this conference and to extend the welcome of the porcelain enamel industry to you. I had occasion to say a few words at the Porcelain Enamel Institute Forum, which was conducted recently in Columbus, Ohio, where we had a group of technical people interchanging information. I observed at that time that there's nothing new under the sun. That observation probably would apply here. Of course here in Washington we would probably have to say it as some politicians would: "It is reported that there is hardly anything new under the sun." So, we are here probably in the role of people interchanging information on subjects that are probably quite old to all of us. Shortly, Mr. Dana Chase will tell us how old the porcelain enamel industry is and that people in the building industry know their industry dates back probably to the time when man first got sense enough to come in out of the rain, but that its birthday has not yet been determined. There is a certain school of psychologists that would say the whole question is academic. But in any event, the beginning of the building industry goes back a long, long time—and so it does for the porcelain enamel industry.

Probably this conference will not disclose anything new or startling, but it might uncover some old information which might be very pertinent to both industries. We are going to have several experts here. They will have a lot of interesting facts and figures. To this information, we will have to add a little imagination, I believe, to bind them all together. We will be somewhat in the same position as the two little boys that were eating lollypops when a big fly buzzed around. One of them clutched his lollypop to his bosom and got himself all messed up. But the other fellow showed a little imagination: he took his lollypop and swatted the fly. So we'll see if we can't solve some of our problems with the facts plus a little imagination. This one-industry conference is a rather new trend, we understand, for BRAB, and we feel honored to be the first industry to participate in this new trend. We feel that what we have to offer will be of tremendous interest to the building industry, and we feel also that what the building industry might have to say about our material should be of very great interest to us. Let's get on with the program. Thank you.

Session 1

FUNDAMENTAL PROPERTIES OF PORCELAIN ENAMEL

PORCELAIN ENAMEL – FROM AN ANCIENT ART TO A MODERN INDUSTRIAL MATERIAL

By Dana Chase*
(Editor, Finish Magazine)

It was a pleasant surprise to learn of my selection as the kick-off speaker for this first BRAB-PEI Conference on Porcelain Enamel in the Building Industry. I assure you I consider it a distinct privilege to appear before this distinguished group.

Perhaps the reason for my selection was that anyone who has read the porcelain enameling publications over the period of the last quarter century would know that Dana Chase has editoralized for at least twenty-three years on the subject of porcelain enameled metal for architectural purposes—its possibilities and its future.

There are many leaders in the porcelain enameling industry who for twenty-five years or more have dreamed of the broad application of porcelain enameled metal in the building field. As an editor for most of this period, I have been in the fortunate position of having had a medium for carrying these thoughts to those who should be primarily interested in the fulfillment of these dreams.

My subject starts with PORCELAIN ENAMEL AS AN ANCIENT ART. I shall try to touch on just a few points pertaining to the interesting early history of enamels.

Enameling is so obscure in its origin as to be practically untraceable. We do know there are existing samples of porcelain enameling made several thousand years B.C.

The art of painting in enamel and fixing the colors by fire was practiced by the early Egyptians. Enameling was also practiced by the very ancient Chinese. There are also existing specimens of enamel work of early British, Saxon, and Norman manufacture.

There is a fine Celtic Shield of Enameled Bronze in the British Museum which should be of special interest to every enameler. It was found in the River Thames, and in spite of having been under the waters of that great river for possibly more than two thousand years, its decorations of small, rounded embosses of vermillion enamel are still perfect.

A study of the technical aspects of enameling as an ancient fine art, including Cloisonne, translucent enameling, surface painted enameling, etc., is a subject in itself—and one well worth your study.

A trip through the leading museums of the world would enable you to see many examples of exquisite enamel metal work dating from earliest history.

Unquestionably, the old enamelers were craftsmen of distinguished attainments. They were artists of the highest order. As one contemplates the various rare examples of their work, the conviction grows that the enamelers of antiquity were men having deep convictions in the beauty of enamel and willing to exert the greatest care in order to give it the utmost advantage in expressing its inherent beauty.

As we follow quickly from enamels as an ancient fine art to the point of our current interest, it may be said that the Germans and Austrians were probably the first people to adapt porcelain enamel to practical or industrial uses. They applied it to kitchen utensils in both cast iron and steel, when much of the earlier *art* enameling had been developed on the rarer metals.

Shortly after this, American industries took up the material and applied porcelain enamel to plumbing ware, kitchen-ware and a number of household items, both in cast iron and steel. It has grown in this country as a heat and corrosion resisting finish and as a finish for household products. Today porcelain enamel is used as a *permanent beauty treatment* for a wide variety of products in the home—particularly in the kitchen, in the laundry, and in the bathroom.

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* Mr. Chase is a graduate of Ohio University, and took graduate work in business administration at the University of Pennsylvania. He started his business career with a manufacturer of household appliances in 1926. For 28 years he has served with, sold to, and edited for the metal products manufacturers. As the first editor of a publication on porcelain enameling, dating from 1931, he was an early exponent of the use of porcelain enamel for architectural purposes, and has kept this subject before the fabricated metal products industry through the subsequent years. One of his positions in industry included management in a company devoted exclusively to the fabrication, finishing, and installation of architectural porcelain enamel.

Fig. 1.1—A portable altar made in Saxony, perhaps in Cologne in the 12th Century. The altar is enamel on metal in beautiful colors of cobalt, deep and pale greens, and sealing wax red (Courtesy, The Cleveland Museum of Art).

As a *heat-resisting* coating, it is used on everything from combustion chambers for home heating units to components for jet engines.

To resist *corrosion,* it has many uses, from the interior of pipe used for the transfer of chemicals, to the mufflers of our Navy's submarines.

One of the greatest attributes of porcelain enamel for many uses is *color*. A complete palette including practically every color, shade, and hue is available to the designer of metal products. Referring again to *art*, there are also many fine examples of *modern* art executed in porcelain enamel on copper, steel, and aluminum. There is a definite reason for mentioning modern art in enamels. This reason is its infinite possibilities for combining the abilities of the *artist* and the *architect* for the development of *buildings* of the *future*.

Let's come quickly now to the subject in which I am sure all of you have the greatest interest—porcelain enamel as a building material.

I would like to pause here to emphasize my next few comments, for within a very few minutes I will ask you to refer back to this point.

"Porcelain enamel is upon the threshold of great developments. Its future is to be glorious, magnificent—at least that is the belief of this speaker, and the opinion seems to be shared by others whose imaginative but practical foresight reveals a splendid future for this enduringly beautiful finishing material.

"During the last generation the skyscraper type of building has been developed amazingly. Now it has reached a phase where it has created a problem which must be met if future development is to be achieved. This problem is dead weight.

"Let's consider the Empire State Building in New York City. It stands upon a rectangular site approximately 198 feet by 425 feet in size, but only six stories cover the whole area, and since the tower proper, which rises some 1,300 feet above the street is set far back from the lot boundaries, practically all of the weight rests upon a comparatively small area in the center of the lot. The steel frame weighs 56,000 tons. Loads on individual columns are in excess of any in similarly constructed buildings. Some of the columns carry loads of over ten million pounds.

"It is this layman's belief that this sort of thing can *not* go on with economy, or even perhaps with safety. Relief from such column loads will be sought. Many believe it will be found in porcelain enameled metal. Thus, can much of the sheer weight of stone, tile and marble be disposed of by using applications of enameled metal for the exterior as well as for interior applications.

"The decorative possibilities for such treatment fire one's imagination. Towers that are soft in their pastel shades of enamel by day, and radiantly beautiful under artificial lighting by night, challenge the fancy of all who appreciate beauty."

I pause again, gentlemen, to call your attention to the fact that these last comments to which I called your specific attention were taken practically verbatim from an article entitled "Tinted Towers of Enameled Radiance," appearing in a publication serving the porcelain enameling industry, which it was my privilege to edit for 14 years. The point in calling this to your attention specifically is in the fact that this article appeared in a *January 1931 issue—almost 23 years ago*.

Now let's see what this same publication had to say in March 1931, in an article, "Porcelain Enamel Will Make the All-Steel House Practical." I will quote a few lines from this article:

"So definite is the surge toward a widespread use of steel for the carrying out of modern designs in architecture that it is only reasonable to suppose

Fig. 1.2—16th Century French enamel ewer stand, about 18 inches in diameter (Courtesy, The Cleveland Museum of Art).

that the time is not far off when houses will be built entirely or principally of steel. This means that not only frames and interior and exterior walls will be of steel, but that window sash and frames, doors and door frames, shelves, cabinets and other trim will also be of steel.

"The natural surface finish for much of the steel so used in porcelain enamel—indeed, the possibilities of applications of porcelain enamel for architectural steel utilizations are stupendous. The enameling industry should begin at once to develop them.

Remember, please, that these words were published *in 1931.*

As we all know, there has been a very definite awakening during recent years to the superiority of various materials formerly un-used in home construction. Outstanding among these in the early 30's was steel. Today, we find aluminum taking its place in the building picture.

Turning back to our enameling publication, I refer to an editorial, in the July 1931 issue, entitled "Is There a Place for Porcelain Enamel Steel in Modern Architecture?"

"There are those of us who believe there is a very definite place for porcelain enamel in the skyscraper and the residence of the future, and it is the hope that every possible opportunity will be taken by the enameling industry to point out these possibiilties Many feature articles on the subject have been published, with the thought in mind that some day in the not too distant future porcelain enamel will find its place in the building field, and that every constructive article printed may mean a step toward this goal.

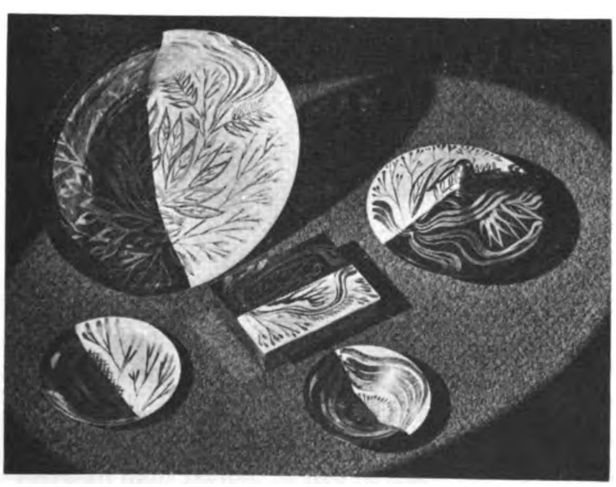

Fig. 1.3—Enameled art in the present mode is typified by this enamel on copper, with black, white, and gold decor, by H. Edward Winter, well-known Cleveland artist (Courtesy, Art Dept., University of Omaha).

Fig. 1.4—Built in 1926, the Security Building in Denver, Colorado was completely modernized 25 years later. Roland L. Linder and Associates, the architects, selected acid-resistant architectural porcelain for the exterior "face lifting." The project required the stripping back to the structural members of the 12-story building and the removal of approximately 900 tons of brick and terra cotta. The total weight of the "face lifting" architectural porcelain was only 30 tons. The pastel green, stipple finish was pleasantly contrasted by aluminum-colored caulking compound.

"The task of gaining the proper recognition for porcelain enamel in the building industry is certainly not a task for a single publication or a few individuals. It is a task that will require the interest and efforts of an entire industry."

Now I find in this same editorial the following specific suggestions: "Why not a porcelain enameled building for the Century of Progress? Certainly there would be details of construction to iron out, but no one can view the Century of Progress buildings that have already been constructed without realizing that there is ample originality on the staff of the Architectural Committee to handle any problem of design, and there is certainly ample talent among our steel companies, stamping companies, etc., to handle fabricating and construction details."

You know, in reviewing these old articles of 23 years ago I had practically forgotten this incident. At that time we carried through by writing to the Chairman of the Architectural Commission for the Century of Progress administration. To make this reference brief, I can say that leaders in the steel

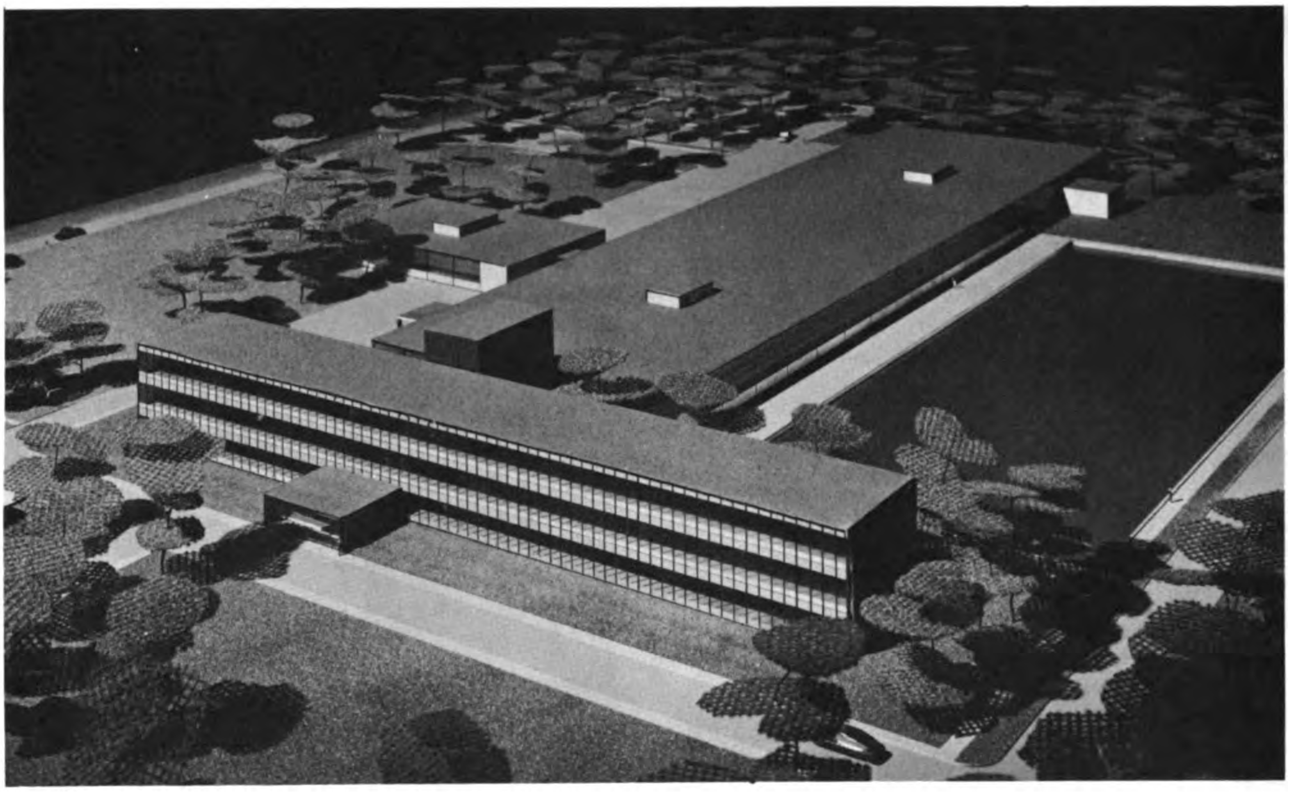

Fig. 1.5—Model of the General Motors Technical Center's engineering building group. Architects were Eero Saarinen & Associates; architect-engineers were from Smith, Hinchman & Grylls, Inc. (Courtesy, Architectural Forum).

Fig. 1.6—Glass and porcelain enamel panels in place in "curtain wall" of the administration building in the engineering group of the General Motors Technical Center, near Detroit, Michigan.

and porcelain enameling industries were giving serious thought to this problem. In fact, they did more than think—they acted—and as a result there were two porcelain enameled homes on display throughout the Century of Progress in Chicago (1932-1933).

What I wanted to stress to you here is the fact that the use of porcelain enamel as a building material is *not* new. It is true that as building materials are judged, it is in its early stages of development, subject to many refinements and improvements. There are literally thousands of installations of porcelain enameled structures throughout the country. Some of them represent excellent examples of the art of enameling combined with good architectural design. Many others, unfortunately, represent neither—and as a result, have done little to advance the use of a good material.

Before World War II, I had the privilege of managing a division of a company whose sole purpose was the fabrication, enameling and erection of architectural porcelain. An idea of the practical aspects of this material can be gained from its overwhelming choice by the large oil companies for their filling station properties. Here is one place where permanence and low upkeep are of prime

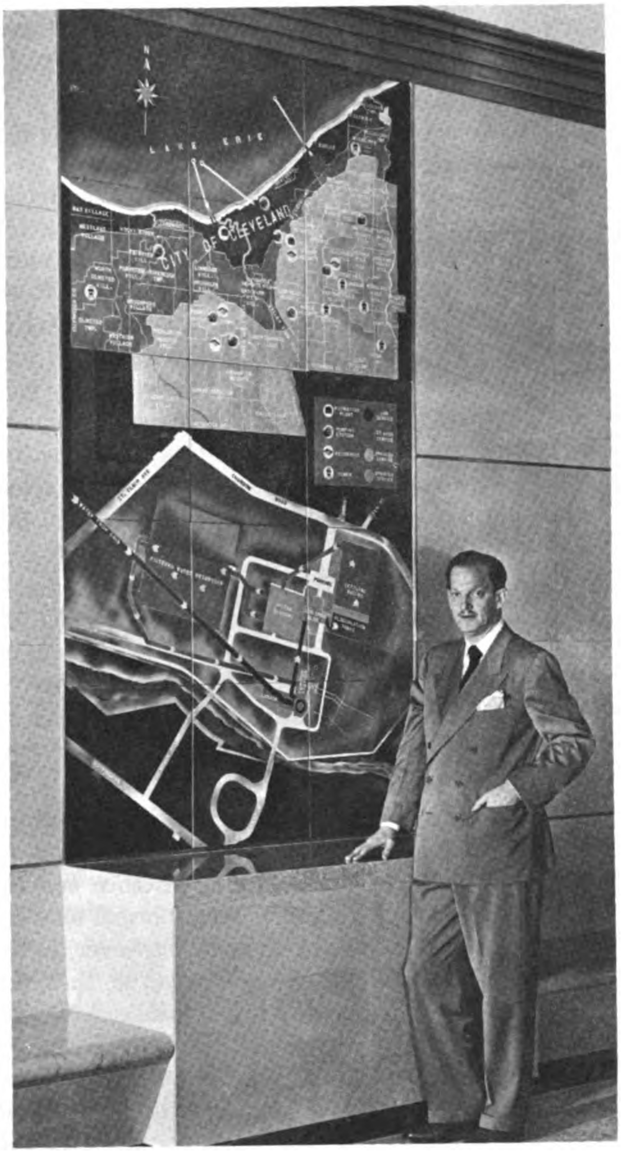

Fig. 1.7—One of the two 15-sectional porcelain enameled (16 gauge steel) murals in several colors, executed by H. Edward Winter, nationally known artist and designer, for the Nottingham Filtration Plant in Cleveland, Ohio. The mural includes a map of the city and a schematic plan of the water system facilities.

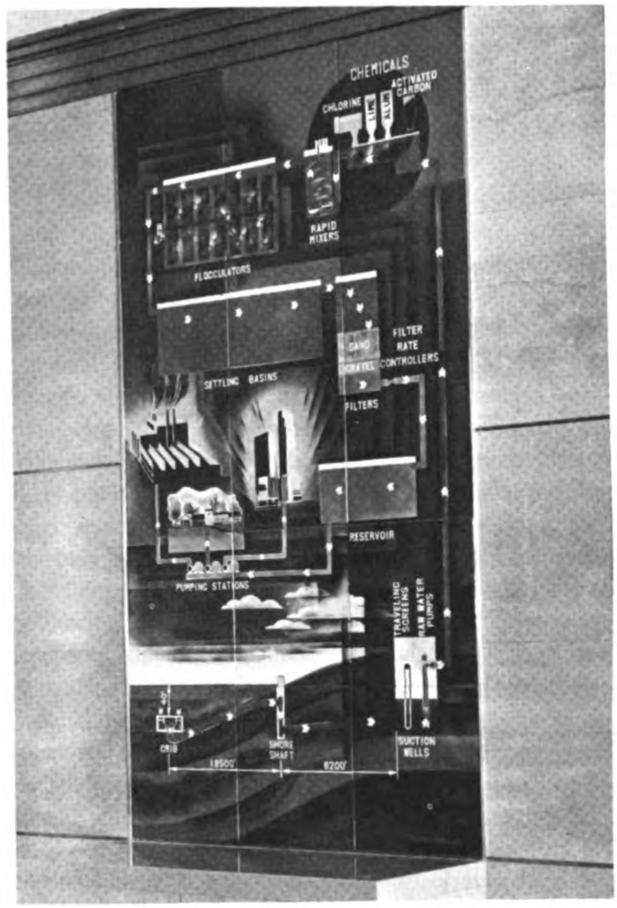

Fig. 1.8—The other mural—on the opposite wall—in the Nottingham Filtration Plant depicts diagrammatically the steps in the filtering process and distribution to consumers.

importance. Even before the Second World War shut off the steel supply, individual companies would take orders for three to four hundred filling stations at a time, from individual oil companies. As a result, there are thousands of such stations throughout the country, and where proper design has been combined with the right techniques of enameling and installation, the stations will stand for many, many years as a tribute to a permanent building material.

As will be evident, filling stations and small theatre and store fronts are not the type of structures that, regardless of their importance to the individual owners, serve to influence architects responsible for the design of today's skyscrapers. As a matter of fact, although it may be unfair to a fine building material, it appears that the use of porcelain enameled metal for the more common commercial structure may have *delayed* the day of its acceptance for the modern multi-storied buildings for the future.

Much has been done during the past few years by the porcelain enameling industry, and by individual interests who can see the advantages of general use of porcelain enameled metal as a comparatively light-weight, strong, durable, and beautiful building material.

With the leading steel companies and the producers of aluminum adding their research and market development facilities to those of the enamel manufacturers, it seems reasonable to believe that the dreams of 1931 may have gained a good start on their way to fulfillment during the early 1950's.

Certainly this BRAB-PEI Conference presents excellent evidence that the next few years may see a more complete fulfillment of these dreams of the last twenty.

CHEMICAL PROPERTIES OF PORCELAIN ENAMEL COATINGS

By G. H. Spencer-Strong
(Vice President and Director of Research, Pemco Corporation)

INTRODUCTION

The resistance of porcelain enamel coatings to chemical corrosion has been recognized and used to advantage by certain segments of industry for many years. The strategic mineral shortages current during World War II were responsible for the introduction of porcelain enamel to many new uses, resulting in a much wider appreciation of the properties of the coating and in the development of new types of porcelain enamel coatings for special end-uses, some of which were just as new as the coatings themselves. These experiences, together with the advances which the industry has made during the post-war years, have also demonstrated the flexibility of porcelain enamel coating compositions; that is, the ability of the industry to modify the coatings to meet a wide variety of new end-use requirements. As a result, there has been an increasing trend to consider porcelain enamels in their rightful category as materials of engineering rather than as simple coatings. This trend is reflected in the inclusion of symposiums on porcelain enamels and ceramic coatings in the programs of technical societies other than those directly connected with the ceramic industry, as, for example, the symposium, "Porcelain Enamels and Ceramic Coatings as Engineering Materials," held during the course of the 1953 Annual Meeting of the American Society for Testing Materials, and the present Forum.

Porcelain enamels are extremely versatile materials, the classification covering a very wide range of products with widely differing end-use characteristics. This fact is not usually appreciated by the casual observer and has given rise to many mistaken ideas about the product as, for example, the suggestion that porcelain enamel coatings would not be acceptable for application to general housing end-uses because the material is widely used on filling stations—and who wants to live in a filling station.

Porcelain enamels are glasses fused to metals. Their composition may be varied widely, making possible their application to an ever-increasing number of metals, ranging from porcelain enamels fused to aluminum at 980°F., copper, iron, and steel in the range 1350° to 1650°F., to stainless steel and high-nickel alloys at 1850°F. and higher. They may be produced in a wide range of physical and chemical properties and with combinations of properties which sometimes astonish persons who have spent most of their adult years in porcelain enamel development.

In the selection of porcelain enamel for almost any end-use the chemical properties exemplified by resistance to corrosion in service are major factors. Sanford and Britton[1], in outlining the six major reasons for the selection and use of the material in the chemical industry, give "resistance to acid corrosion" as their first criterion of selection.

Not too many years ago the major chemical properties of interest in considering the selection of porcelain enamels included acid resistance and resistance to atmospheric corrosion at normal temperatures. Modern porcelain enamels, however, cover a much broader field of end-usage, so that the chemical properties now being considered include such factors as acid resistance, alkali resistance, solubility in boiling water, and atmospheric corrosion not only at normal temperatures but also at elevated temperatures. Furthermore, many of the atmospheres considered at elevated temperatures are not normal atmospheres but rather gases resulting from industrial operations and chemical reactions which may contain acids and other corrosive agents.

For purposes of simplification, the chemical properties of porcelain enamels may be divided into four major categories: (1) Resistance to corrosion by acids. (2) Resistance to corrosion by water. (3) Resistance to atmospheric corrosion. (4) Resistance to corrosion by alkalies. Although the general chemical properties may thus be rather simply classified, the actual end-use requirements will normally not be so simple and will usually include combinations of specific chemical and physical properties.

RESISTANCE TO CORROSION BY ACIDS

The property of acid resistance in some form is of considerable importance to most users of porcelain enamel coatings. The early porcelain enamels ap-

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Fig. 1.9—Glass-lined storage tank being loaded onto flat car. Note the size of the tank. This tank must be enameled and fired in one piece.

plied to iron 100 years ago were undoubtedly used to protect the metal from rusting; and that some fairly early enamels were acid resisting as well was more so by accident than by design. As late as 1941, porcelain enamels designated as acid-resistant were considered as special coatings to be applied only to areas where this quality was deemed especially necessary.

Since there was no particular interest in special coatings for industrial uses and the like, acid-resistant materials for use at higher temperatures consisted of special-type porcelain enamels for use on cooking ware and the very resistant chemical ware enamels. The past decade has seen a very considerable change in porcelain enamels as regards this particular characteristic. The modern type of finish coat porcelain enamel is quite highly resistant to cold acids and in many cases shows excellent resistance to boiling acids of the organic type and to hot dilute solutions of the inorganic acids. This development has made possible the elimination of partial coatings of special types of enamel. Because the newer materials are extremely opaque, they may be applied in much lighter application weights than was normally possible, providing improvement not only in chemical resistance but also in physical characteristics. Thus, all modern porcelain enameled sanitary ware, including bathtubs and home appliances with white cover-coat porcelain enamels, are manufactured today with acid-resistant coatings usually in the AA and A acid resistance classifications. These same coatings are quite satisfactory for such end-uses as photographic trays, photographic tanks, and the like.

The development of a class of acid-resistant, porcelain enamel coatings lying between the so-called conventional coatings and the chemical ware enamels has opened a wide, new field for the industrial application of porcelain enamels. Included in this new field are many operations in the petroleum industry.

In the beverage and milk industries, the value of porcelain enamel tanks and equipment, with their resistance to corrosion and their ease of cleaning, has long been recognized. A whole new field for the application of acid-resistant, corrosion-resistant porcelain enamels is now developing in agriculture.

The selection of the proper porcelain enamels for use with hot or boiling solutions of acid chemicals presents a somewhat different problem than acid-resistant porcelain enamels for use at room temperature. All porcelain enamels should be selected on the basis of end-use requirements and this is particularly true of porcelain enamels for use with acid solutions at elevated temperatures and/or pressures. Thus, for example, many of the pre-war type, acid-resisting enamels are extremely resistant to cold acids but are not satisfactory for use with the same acids at boiling temperatures. Although many of the newer materials can be used for both types of service, differences in acid resistance between enamel compositions are much more pronounced at the higher temperatures.

There are two general methods for the determination of acid resistance, depending upon the end-use. For uses not involving contact with high-temperature solutions (such as architectural, uses

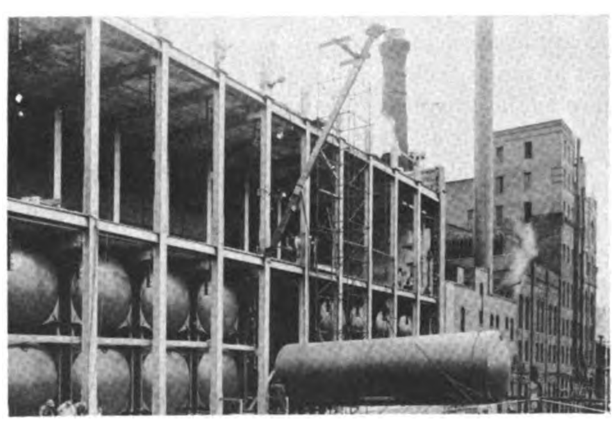

Fig. 1.10—Glass-lined tanks being installed in a stock house of the beverage industry.

including contact with acid industrial atmosphere at normal temperature, sanitary ware, home appliances, and most agricultural applications) a test method developed by the Porcelain Enamel Institute in 1938[2] is used. The method consists of the evaluation of surface attack induced by the application of a 10% citric acid solution. Results are classified in five categories ranging from AA (no visible attack) to D (complete destruction of glass in 15 minutes). Most modern, acid-resistant enamels lie in the upper half of the classification scale. It is generally conceded that such enamels will show equivalent resistance to any cold acid except hydrofluoric (which will dissolve any silicate glass).

Where the end-use involves contact with boiling acid solutions, a different type of test method[8] is required. Here the test specimen is sealed over the end of a pyrex glass tube and subjected to the boiling acid solution (usually under refluxing conditions) for a period of time ranging from 2½ hours for cooking utensil enamels to 30 days for chemical ware enamels. Enamel attack is determined by weight loss. It is interesting to note that, in the chemical ware industry, weight loss is converted into inches per year; and the enamels are classified on that basis, so that a Class A, or resistant, coating would lose less than 0.005" per year and have, therefore, an estimated life of more than seven years.

With porcelain enamels, as with other corrosion-resistant materials in contact with hot acid solutions, generalizations are extremely dangerous[1,4], since the rate of attack depends upon the composition of the enamel, the nature of the acid (its concentration, temperature, and pressure), and corollary conditions.

RESISTANCE TO CORROSION BY WATER

Porcelain enamels, being silicate glasses, are, in general, highly resistant to water solution, a fact which has long been recognized in their use. During the past 15 years there has been an interest in the application of porcelain enamels to such end-uses as range boilers, hot-water tanks, and the like. Here again, in spite of the fact that all normal porcelain enamels are quite resistant to water solution, it was desirable to secure an even greater coating resistance. This is particularly true in view of the widely variable composition of waters over the United States as well as the fact that in many cities varying chemical treatments are used, some of which considerably increase the corrosive properties of waters. Modern enamels designed for this type of end-use are actually fairly good chemical-ware enamels, since they are not only resistant to corrosion by boiling water but also show fairly good resistance to boiling alkalies and boiling acids. Although these materials have been developed for a specific end-use, they exemplify the sort of thing which can be done by the industry in meeting complicated problems.

ATMOSPHERIC CORROSION

End-uses taking advantage of the resistance of porcelain enamels to atmospheric corrosion at ambient temperatures constitute one of the oldest uses of the material; their use to protect metals from atmospheric corrosion at elevated temperatures is one of the newest. Porcelain enamels are unaffected by sunlight, high-humidity atmospheres, and salt spray. Since the weather resistance of porcelain enamels is the subject of another paper in this symposium, it will suffice to say that a moderate degree of acid resistance will provide an enamel which should give satisfactory service in almost any outside location. Poreclain enamels have rendered excellent service in resisting corrosion in industrial atmospheres.

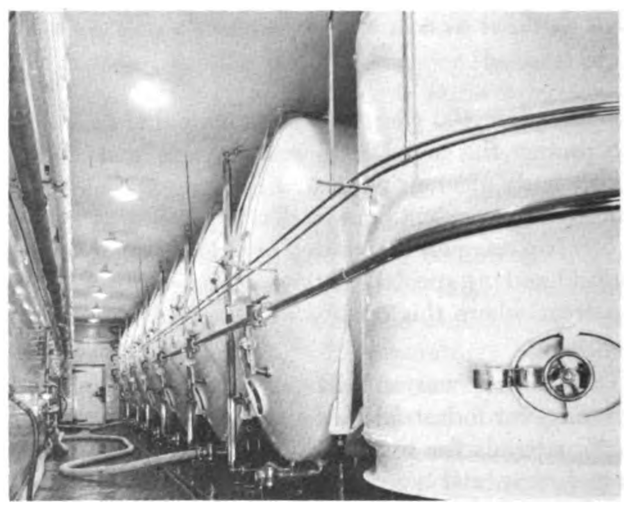

Fig. 1.11—Group of glass-lined storage tanks installed.

World War II was responsible for the rapid development and use of porcelain enamels in the protection of metals from high-temperature corrosion. Here end-uses included exhaust systems for internal-combustion engines, the coating of flues and stacks for housing, and the protection of heat-treating equipment. Porcelain enamels find many uses in the heating field, including such applications as oil burner parts and the protection of the combustion tubes on wall-type space heaters.

The application of porcelain enamel coatings to airplane exhaust systems during World War II gave rise to an entirely new field of endeavor and

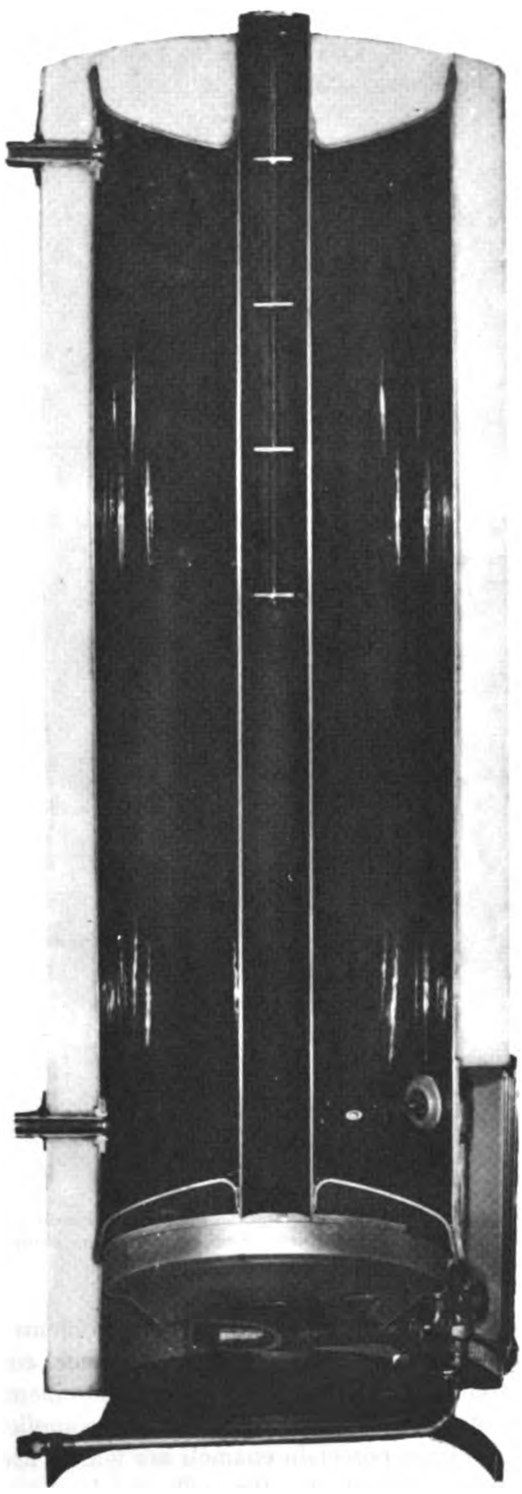

Fig. 1.12—Section through center flue-type porcelain enamel-lined hot water heater.

achievement, resulting in the development of a number of coating compositions for the protection of ferrous metals from oxidation and also from acid exhaust-gas components and other deleterious products of combustion at elevated temperatures. These coatings differ considerably in composition from normal porcelain enamels and are generally known to their users as ceramic coatings, since they are fundamentally non-glassy in nature.

Another interesting development resulting from these efforts has been the application of ceramic coatings to metals which are normally considered very resistant to high-temperature corrosion in themselves, such as various stainless steels and nickel compositions, such as monel metal. It has been found that the coatings considerably extend the life of the corrosion-resistant metals. At the same time there have been developed a series of modified porcelain enamel-type coatings for the protection of low carbon irons and steels at moderately elevated temperatures—that is, in the neighborhood of 1000° to 1200° F.

ALKALI RESISTANCE

Silicates, including glasses and porcelain enamels, are not normally considered to be particularly resistant to alkali solutions. In fact, strong solutions of boiling alkalies are often used for the purpose of removing porcelain enamel from metal. Possibly because of these considerations and also because the normal end-uses of porcelain enamel coatings did not involve alkalies, consideration of this particular physical characteristic has been quite recent. In the home appliance industry, for example, normal porcelain enamel coatings have withstood soaps and detergents satisfactorily for many years. During the past six to eight years, however, the introduction of automatic home appliances, including washing machines and dishwashers, have made possible the use of higher water temperatures and also the use of detergents which would not be satisfactory for normal hand dishwashing or hand laundering. At the same time, certain of these appliances have been used in semi-industrial applications where they are operated 8 to 12 hours a day, 6 days a week. Because of this situation, consideration of alkali resistance becomes mandatory; and, as a result, porcelain enamels which are quite resistant to alkali solutions equivalent to 5% caustic soda have been developed and put into use. It is interesting to note that some of these enamels not only show good resistance to alkali solutions but are also very acid resistant. In the chemical-ware enamel industry, alkali-resistant enamels have been developed and introduced during the past two years. As is the case with enamels used in contact with acid solutions at comparatively high temperatures, alkali-resistant enamels must also be chosen on the basis of specific end-use requirements, since their characteristics vary somewhat with different types of alkaline solutions.

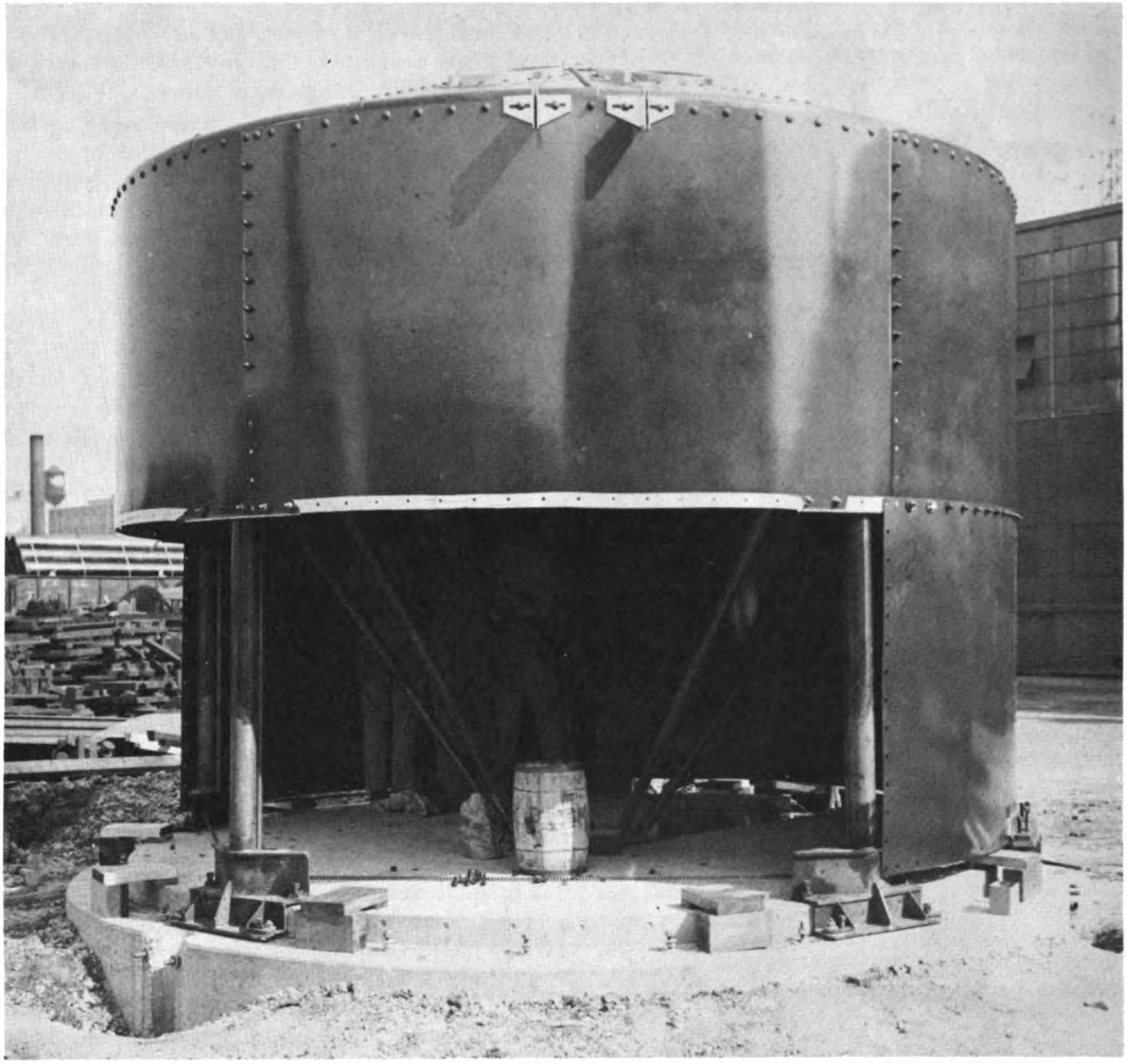

Fig. 1.13—First stages of the erection of porcelain-enameled silo, showing the top section complete and the panels of the second section in process of installation. As the sections of panels are completed the structure is raised on jacks, which may be seen in the photograph.

ORGANIC SOLVENTS, GREASES, AND OILS

Porcelain enamels are not affected by organic solvents such as the alcohols, naptha, gasoline, and the like. Neither are they attacked by oils or greases in either the cold or hot condition.

DISCUSSION

As was pointed out earlier in this paper, most practical applications of porcelain enamel coatings require a combination of chemical and physical properties in order to meet a specific end-use requirement. As the understanding of the possibilities of the material increases and its application to new end-uses expands, the requirements tend to be more complex. In some cases the actual problems incident to the selection of a porcelain enamel coating are comparatively simple, but the requirements for putting them to practical use may be complicated. For example, porcelain enamels are widely used as the lining of tanks for the milk and beverage industry, where acid resistance and cleanability are the prime end-use factors. Here the problem is often complicated by the great size of the units. Likewise in the application of porcelain enamel to the farm silo, weathering resistance and, particularly, acid resistance are the prime end-use factors. Here the complicating problems are those incident to the design and erection of the structure. In other cases the problem may lie in the development of a porcelain enamel coating to meet multiple end-use requirements simultaneously. Examples of porcelain enamel applications that have overcome problems of this type may be seen in some of the modern coatings used in the sanitary ware and home appliance fields, wherein resistance to cold acids, resistance to hot dilute alkalies, and resistance to boiling water had to be combined with a number of specified physical characteristics. In the problem of the protection of metals from internal-combustion engine exhaust gases at high temperatures, not only must the coatings resist corrosion and erosion from the hot exhaust gases moving at high velocity but they must also be applied to rather complex shapes.

The point of these remarks is not to magnify any of the difficulties involved in using the material but, quite the opposite, to point out that, once the end-use factors as regards chemical corrosion of a specific application are known and understood, porcelain enamel coatings either are available or can be developed to meet the requirements.

The foregoing discussion has been necessarily general in nature, its purpose having been to demonstrate the wide variety of chemical properties of porcelain enamel coatings that are available rather than to attempt to describe in detail the characteristics of a few specific materials.

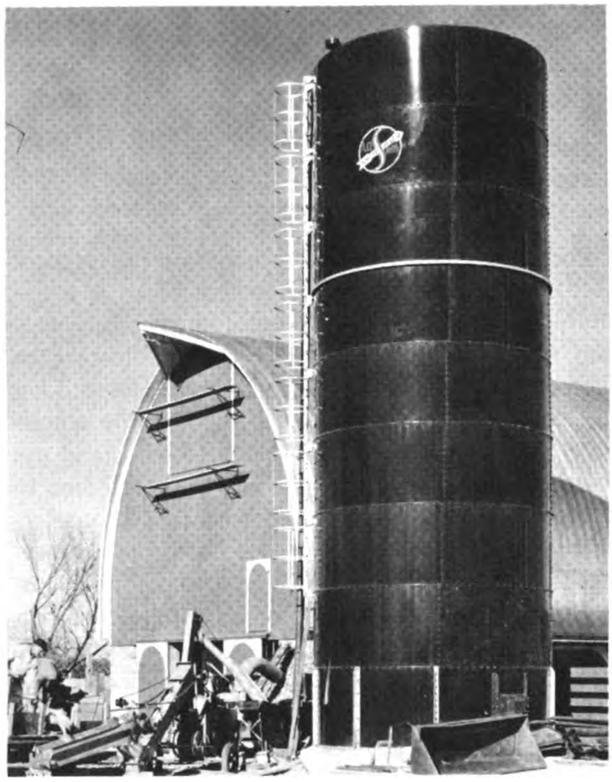

Fig. 1.14—Typical porcelain-enameled silo installation. The structure is porcelain enameled inside and out, thereby providing an acid-resistant, abrasion-resistant structure which will require a minimum of maintenance.

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PHYSICAL CHARATERISTICS OF PORCELAIN ENAMEL

By E. E. Howe*
(Director of Research, Chicago Vitreous Enamel Product Company)

Porcelain enamel embodies many useful physical and chemical characteristics which make it a desirable material for the building industry. In porcelain enamel is found the unique combination of permanent colors in numerous textural effects, long life, low maintenance and a truly versatile adaptable building material. The ability to withstand the wide variety of weather and service conditions to which a building is subjected may best be understood from a description of the numerous properties that porcelain enamels possess. Since the chemical properties have been presented elsewhere on this program, this discussion will confine itself only to the physical characteristics of porcelain enamel.

Porcelain enamel is usually considered to be a finish, but since it is so intimately and permanently bonded to the metal to which it is applied, it should be described as a composite material—glass and metal. The many useful physical characteristics that make it a desirable material may not always be assigned to the individual components acting independently, but must be delegated to the combination. However, it will be assumed for the purposes of this discussion that the glass layer is a separate entity and the following description of the physical properties refers only to the glass component of the glass-metal system.

THERMAL PROPERTIES

Fusibility and Fluidity

Enamel fuses at temperatures above low red heat. For coatings on aluminum, this may occur as low as 900° F. and for steel 1300° F., but in no sense can it be considered "baked." At fusing temperature, the fluidity or viscosity is in the magnitude of 10,000 poises. The fusibility occurs at such an elevated temperature and with such high viscosity that "cold flow" does not occur at atmospheric temperatures. Some coatings specifically developed for high temperature service withstand high velocity air movement at temperatures in excess of 1600° F.

Thermal Expansion

The thermal expansion and contraction of enamels should be comparable to the metal to which it is applied. For each specific metal the proper enamel is selected or compounded to "fit" the metal and this expansion or contraction of the enamel is isotropic or uniform in all directions. In calculating the expansion values of an enameled structure, the expansion of the metal itself is the controlling factor, and the enamel conforms to the metal.

Thermal Shock

Resistance to extreme changes in temperature is a property that varies with the different compositions, but in all instances enamels have an advantage in being able to withstand relatively high temperatures and repeated heating and cooling without deterioration. As an example, enamel on electric roaster pans are capable of withstanding innumerable heatings to 600° F. followed by a water quenching treatment. Extended heating at 600° F. and above of enamel in domestic range ovens is not an unusual service condition for this material.

Thermal Conductivity

The thermal conductivity of enamels has been established by actual test on enameled articles[1, 2] and by interpolation from the International Critical Tables[3]. In the strictest sense of the word, porcelain enamel should not be considered good insulating material, because it is applied as a thin coating. Of the non-metals it is equal in conductivity to most all of the materials currently used in building construction[4]. In the following table, the heat conductivity of various solids are shown to illustrate the relative merits of enamel with other materials:

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Approximate Heat Conductivity of Various Solids

	Calories per second per Sq. Cm. per °C.
Aluminum	0.60
Copper	1.00
Steel	0.11
Lead	0.08
Zinc	0.26
Asbestos	0.0002
Brick	0.0015
Enamel (Glass)	0.002
Gypsum	0.003
Marble	0.007
Rubber	0.0004

Specific Heat

It may be assumed that the specific heat of porcelain enamels, although based on limited data, is probably very similar to glass, which is listed in the International Critical Tables as ranging from 0.1881 to 0.2640 gm. cal. per °C.[5]

Emissivity

Excellent thermal emission characteristics of porcelain enamels make them suitable coatings for heat radiating surfaces. The Low Temperature Total Emissivity of enamel is reported[6] to be 0.95 which was the highest value obtained for any substance tested in a group of common materials. For comparison purposes, some of these materials are listed in the following table:

Low Temperature Total Emissivities

Zinc, highly polished	0.05
Aluminum, highly polished	0.08
Copper, polished	0.15
Cast Iron	0.25
Aluminum paint	0.55
Oxidized steel	0.70
White vitreous enamel	0.95
Lamp Black	0.95

Stability

Although thermal stability with regard to oxidation at elevated temperatures might be considered as a chemical characteristic, it is sufficiently important to require re-emphasis by listing in this presentation. Porcelain enamel is a glass resulting from fusion of mineral substances and is in the heat stable state, or fully oxidized. The reactions that result in glass formation, are not reversible with respect to heating or cooling such that reheating after final fusion produces no chemical change. This means that porcelain enamel is noncombustible, that it will not support combustion, and that it will not heat—oxidize, char, or change in composition or dimension as the result of heating.

APPEARANCE CHARACTERISTICS

Color

A highly desirable feature for a material that may be used in building construction is that it have a pleasing appearance. Since porcelain enamel is capable of being produced in practically any color desired, ranging from strong dark to light pastels and white, a wide latitude in color expression to suit individual taste is afforded. It is possible to obtain in the white or uncolored enamel glasses any degree of opaqueness ranging from a clear glass to an opaque glass with a diffuse reflectance of 90% relative to Magnesium Oxide as 100%. The widespread use of porcelain enamel as a coating for light reflectors attests to its light reflecting ability.

An essential feature of all of the colors in porcelain enamel is permanence. Since the pigments used as colorants and the material in which they are incorporated are not susceptable to change by light, heat, or atmospheric environment, the initial brilliance of the colors in porcelain enamel is retained throughout the entire life of a coated metal part.

Gloss

Because it is essentially a glass, it is usually observed as having high gloss. However, extensive installations in the architectural field make use of the so-called mat textures that have reduced gloss to varying degrees as desired. By special compounding, very low gloss enamels suitable for chalkboard use have been devised and are presently being exploited. It is not necessary, therefore, to always think of enamel as having high gloss, an impression which might be gained from observing the finishes used for household appliances. They can, however, be made quite glossy and with high brilliance. The brilliance being related to the index of refraction which is approximately 1.5 for most enamels.

Although certain small decorative bands or figures in gold, silver and platinum are produced on porcelain enamel, it is impractical to make porcelain enamel imitate metal or the metallic luster. Glass is distinctive in itself, and resists most efforts to make it appear like some other material.

Texture

Matness, or lack of gloss, has been mentioned as one possibility for obtaining variety in the textural effect of enamel and there are many other means of creating interest and adding to the appearance. Variegation in color by polychrome spraying, mixtures of two or more different colored frits, contrasting stipple and background, graining, and screening of different colors are also used. The so-called flat stipple or ripple finish used to break up surface high-lighting of single color coating is still another means of diversifying and creating interest used to good advantage in the architectural porcelain enameling field. Simulated wood finishes of different grains and colors have been popular for many years in the space heater industry where it is desired to have the end-use articles appear to be wood constructed furniture.

PHYSICAL AND MECHANICAL PROPERTIES

Adherence

The quality of the bond or adherence of glass to metal is excellent and far superior to any displayed by other coatings. This might not appear to be important, except when it is noted that porcelain enamel is not subject to "creep," a common complaint of other finishes on metal subjected to corrosive environment. No absolute values for adherence are available, due to a lack of a method to supply such information. However, it is interesting to note that because of the excellence of the bond of enamels to ferrous metal, all empirical testing currently in use involves deforming the metal.

Due to its tenacious adherence, the strengthening effect of enamel on metal is enhanced. It has been demonstrated that two boards, one on top of the other, when nailed together have greater strength when tested as a simple beam than the same two boards tested in a similar manner but not nailed together.

Hardness

One inherent quality of enamel that can contribute to long life for structural applications is its hardness. It has a "mineral" hardness rating of 5-6 (Apatite-Orthoclase) as based on the scratch hardness test using Moh's scale of minerals. The test is made by attempting to scratch the enamel surface with samples of minerals of varying degrees of hardness. The hardest mineral in the group is Diamond rated No. 10, and the softest is Talc rated No. 1.

Abrasion

Because of its hardness, its abrasion resistance (rubbing) is exceptionally good. The abrasion resistance of several different compositions as measured by a Taber Abraser has been reported by A. V. Sharon[7] and measured by other methods[8] by other investigators. Although there was some degree of difference between different compositions, it was apparent that all enamels displayed excellent resistance to rubbing abrasion. In some abrasion studies on several different materials in our laboratory using the Taber Abraser, the depth of penetration after 10,000 wear cycles using silicon carbide wheels showed the following results:

Depth of Abrasion After 10,000 Wear Cycles
Taber Abrasion Test

Material	Depth (cm.)
Hard Chromium Plate	.00019
Nickel Plate	.00048
Copper Plate	.00083
Porcelain Enamel	.00014

Some attempts have been made to measure the impact abrasion of enamels, but the tests have not been successful in producing consistent interpretable results. It is probable that this type of abrasion would deteriorate enamels much more rapidly than rubbing abrasion, but not as rapidly as plastic finishes or materials. Since there is insufficient laboratory evaluation of impact abrasion resistance, a comparison between the effect of a sandstorm on the organic finish of an automobile and the glass in the windows and windshield might be illustrative. Winds of high velocity carrying salt and sand picked up when blowing in from the ocean have been known to completely strip the finish from the metal, while at the same time the glass was virtually unaffected. Long service life of porcelain enameled signs in certain locations subject to high-velocity wind-transported solids is mute testimony of the good impact abrasion resistance of the material.

Elasticity

Although glass is usually considered an inelastic material, it does possess a certain amount of elasticity as described in the discussion of Engineering Properties. In a limited field of compositions[9], it has been determined that enamel glasses range in elasticity from 4950 to 5910 kg. per square millimeter. Since the specimens used by these investigators consisted of large bars, not representative of thin coatings with their known better elasticity, it might be deduced that enamel as a coating possesses much greater elasticity than the measurements indicate. This rather unusual characteristic of glass might be illustrated by comparing the effect of bending a rod of glass and a fiber or filament of the same material.

Compressive and Tensile Strength

The compressive strength of glass is considerably greater than its tensile strength as indicated by the work of Parmelee and Shaw[10] who reported values for compressive strength ranging from 77 to 81 kg. per sq. millimeter, as compared to a tensile strength of 3.28 to 8.09 kg. per sq. millimeter, reported by

Winkelmann and Schott[11] Tensile values as great as 491,000 lb. per sq. in. have been reported by Griffith[12] for glass fibers of 0.0013 inches in diameter, but it is doubtful that the full strength of the material can consistently be realized, due to its notch sensitivity. Notwithstanding the fact that the effective tensile strength of glass may be less than the metal to which applied, it is sufficient to impart a strengthening effect on metal.

Density

Although enamels are not completely dense coatings in the strictest sense of the word, and some special coatings have been prepared with a highly vesicular structure, the bulk density of most enamels very closely approximates the true density. An approximate average value for density that may be applied to most enamels is 2.5. The densities of some common metals shown in the following table will serve to indicate the relative density between enamel glass and the metal it might supplant if used as a coating for that metal:

Approximate Density of Certain Metals and Enamel

Aluminum	2.7
310 Stainless Steel	7.89
Nichrome	8.50
Copper	8.89
Iron	7.85
Titanium	4.5
Nickel	8.6
Brass	8.56
Monel	8.90
Enamel	2.5

Thickness

Conventional enameling practice involves the application of a base coat and one or more cover coats. Thickness of the base or ground coat will vary from 2 to 5 mils, and the thickness of the cover coats range from 3 mils up to as high as 20 mils, and possibly greater where textural effects such as stippling are employed.

The minimum thickness that has been commercially produced on porcelain enameled articles is in the neighborhood of 5 mils, however, in the so-called ceramic coating field, and particularly those for high temperature service, thicknesses of 1 or 2 mils are the rule, rather than the exception.

Electrical

Glass is a non-conductor, and thus porcelain enamel is also considered an electrical insulator. Actual measurements on various enamel compositions in our laboratory have produced values ranging from 100 to 300 volts per mil. Compositions can probably be developed to produce higher values of electrical resistivity, but increasing the total thickness will probably afford greater return, since the physical structure of the enamel layer is an influencing factor on total resistance. The true density of the glass influences the basic resistivity, but the bulk density (variable depending upon bubble structure) governs the practical limits of voltage breakdown. Thus at high voltages, the inherent restivity of the glass cannot be realized due to penetration or break-through at locations where relatively large bubbles occur.

Impact

The impact resistance of enamels is relatively poor, a common characteristic of all hard or brittle materials. Due to the difference in behavior between thick and thin coatings, impact values should probably state at what thickness of coating the determinations were made. There is, however, no satisfactory means of determining impact strength of enamels when measured independently of the metal base. For this reason, impact tests are performed on the glass-metal system and the strength, thickness and rigidity[13] of the metal have a strong influence on the apparent resistance of the enamel to impact. No usable values for impact strength can be reported due to numerous variables that affect the results; but practical experience can be relied upon to establish the proper metal and enamel thickness which has suitable impact strength for the particular service condition or arbitrary acceptance level.

In the brief time available to me, I have attempted to describe the physical properties of porcelain enamel. When these properties are combined with the chemical properties described by another speaker and subsequently translated into engineering applications, you have a permanent material with versatility from a standpoint of color, design, texture and durability that makes it most suitable for use in the building field. More and more architects have come to recognize these engineering properties in terms of consumer appeal and are using them as a sales tool.

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WEATHER RESISTANCE OF PORCELAIN ENAMELED STRUCTURAL UNITS

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INTRODUCTION

One of the fundamental properties of a porcelain enamel finish that is of interest to potential users is its resistance to weathering. Before selecting any given porcelain enamel for such structures as filling stations, stores, hospitals, office buildings or laboratories, an architect or engineer must first know what can be expected from the finish in the way of color stability, maintenance of initial gloss, and protection of the base metal from corrosion. There is therefore a definite need for adequate data on the weather resistance of various types of enamel and also for laboratory tests to indicate weather resistance.

An investigation designed to obtain such data was begun by the Enameled Metals Section of the National Bureau of Standards in 1939 and was planned with the assistance of an advisory committee from the industry. Through the cooperation of 16 manufacturers, 864 1-ft.-sq panels[1] and an equal number of 4x6 in. laboratory specimens were prepared. Most of the enamels furnished were regular commercial products; but they were not, in all cases, enamels that had been proved suitable for architectural purposes. On the contrary, some were not expected to have good resistance to weathering. The exposure sites selected were Washington, D. C., St. Louis, Mo., Lakeland, Fla., and Atlantic City, N. J.

The present paper describes the condition of the test panels after seven years of exposure and also describes the correlation obtained between weather resistance of the various enamels and their resistance to acid attack.[2]

DESCRIPTION OF SPECIMENS AND METHOD OF MOUNTING

Fourteen types of enamel were included in the investigation. These enamels were applied by cooperating manufacturers to 1-foot-square panels fabricated of 16-gage enameling iron with 1-inch flanged edges. An outward extension at the bottom and two tabs welded to the flange at the top permitted the panels to be rigidly fixed to the supporting racks. The crevices between specimens were not calked but were left open to facilitate removal of the panels during periods of inspection. Figure 1.15 shows a partial view of the installation at St. Louis, Mo.

WEATHER CONDITIONS PREVAILING AT EXPOSURE SITES

Table 1.1 lists the exposure locations, and Table 1.2 gives pertinent data on weather conditions during the 7-year period of exposure at each site. At all four locations the racks face south, the panels being exposed at 45° from the horizontal.

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[1] 768 of the panels were exposed, 192 at each of the four locations. The remaining 96 were placed in storage for later use as comparison standards.

[2] Earlier papers describing the investigation are listed as references 1, 2, and 3.

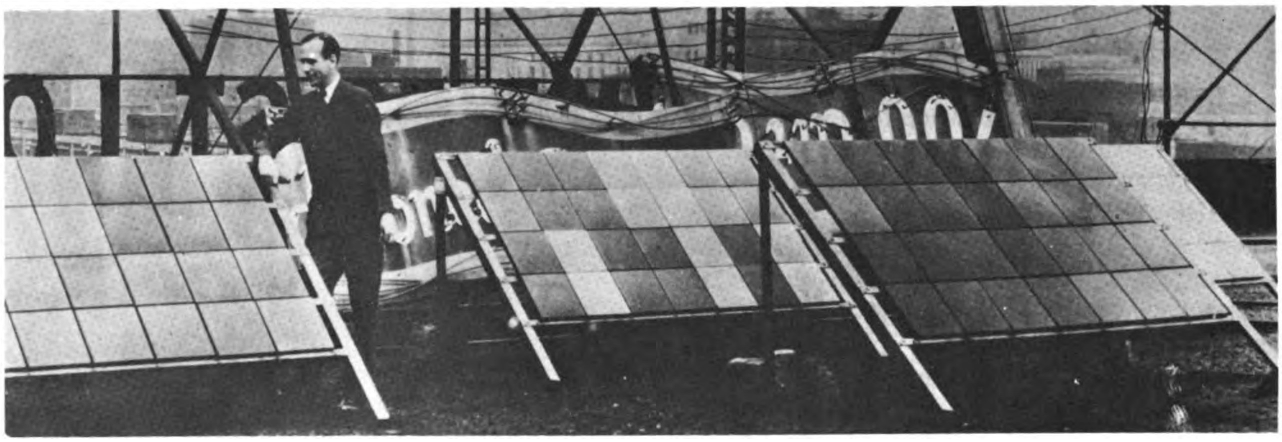

Fig. 1.15—Partial view of exposure test installation on the roof of a warehouse in St. Louis, Mo.

PHYSICAL CONDITION OF PANELS AFTER SEVEN YEARS OF WEATHERING

1. Protection of the steel against corrosion

No corrosion of the steel was noted on any specimens where the initial coverage was complete on all parts of the panel and where no mechanical damage had occurred during the exposure period. On one panel at the Washington, D. C. exposure site, the surface was accidentally fractured near the end of the first year of the testing period. This resulted in a local exposure of the metal. Over the next six years corrosion progressed into the metal to a depth of 0.003 in., but there was no appreciable penetration of the corrosion under the adjacent enamel such as sometimes occurs with organic finishes. In this case the size of the fracture had not increased from its original ⅛" diameter.

There was some corrosion damage to a few of the panels at the Atlantic City Site. At this location the racks are located on the grounds of the United States Coast Guard Station about a mile from the city proper. They are 30 yards from a protected cove and are in such a position as to be exposed to "salt air" without being subject to salt water spray. The galvanized steel on the supporting racks deteriorated rapidly under these conditions, many of the parts needing replacement after only seven years of exposure.

The severe corrosion resulting from the "salt air" at Atlantic City was responsible for a somewhat unexpected type of damage to the enamel surface resulting from poor enamel coverage of the backs of panels. On those panels that had been covered on the reverse side with only a ground coat and then

TABLE 1.1. EXPOSURE TEST LOCATIONS

City	Exposure site	Exposure conditions represented
Washington, D. C.	Roof, Industrial Building, National Bureau of Standards	Temperate, residential
St. Louis, Mo.	Roof, Union Electric Co. warehouse	Temperate, industrial
Lakeland, Fla.	Ground, Municipal Airport	Semitropical, residential
Atlantic City, N. J.	Ground, U. S. Coast Guard Station	Temperate, "salt air"

TABLE 1.2. GENERAL WEATHER DATA FOR THE FIRST 7 YEARS OF EXPOSURE (FROM U. S. WEATHER BUREAU RECORDS)

City	Exposure period	Annual rainfall[a] in.	Annual sunshine[a] hr.	Average temperature[a] °F.
Washington, D. C.	Dec. 1939 through Nov. 1946	39.8	2,597	57.0
St. Louis, Mo.	April 1940 through May, 1947	39.7	2,770	57.3
Lakeland, Fla.	July 1940 through March 1947	47.7	2,945[b]	72.3
Atlantic City, N. J.	August 1940 through April 1947	40.0	2,751	53.7

[a]Average computed from data for actual period of exposure.
[b]Taken from Tampa, Fla., records. Total sunshine for Lakeland not available.

fired in a box furnace while resting on alloy points, poor coverage of the steel occurred at the contact points. Corrosion had started at these areas and had, in some cases, progressed completely through the 16-gage steel to the under surface of the enamel on the face side. Fracture of the enamel on the face immediately above these areas occurred as the corrosion approached the enamel-metal interface. The resulting fractures resembled very large "fish scales" and are believed to have been caused by hydrogen generated during the corrosion process. The observation that hydrogen diffusing through steel may literally explode the enamel from the opposite surface had been reported previously by Zapffe and Sims[4].

The fact that a number of "fish-scale" type fractures were noted on the faces of panels over localized corrosion areas while some metal still remained beneath indicates that the fractures could not have been caused by the forcing off of the enamel by corrosion products, nor could they be caused by buckling of the enamel due to the release of compressive strains resulting from a small area of the underlying metal being removed by corrosion.

Figure 1.16 shows the face of a panel that was damaged by corrosion originating from firing marks on the reverse side. Several holes and also a number of the previously described fractures are apparent on this specimen. It should be pointed out, however, that these defects did not occur on the panels that had been given a thin second coat of enamel on the reverse side, nor had corrosion progressed to this stage at any location except Atlantic City.

2. Fading of colored enamels

Observation of color difference made on all panels during the seven year inspection indicated that:

(a) No colored enamel rated as Class AA or A by the Porcelain Enamel Institute acid-resistance test (see footnote 3) showed any noticeable change in color.

(b) No colored enamel of class B acid resistance showed any objectionable fading.

(c) Practically all deeply colored enamels of classes C and D acid resistance showed color change, and in most cases this fading was sufficiently pronounced to be considered objectionable.

(d) The colored full-mat enamels of the type included in the present investigation showed pronounced fading at all four locations.

(e) Fading of the colored enamels of poor acid resistance was almost equally pronounced at all four exposure areas.

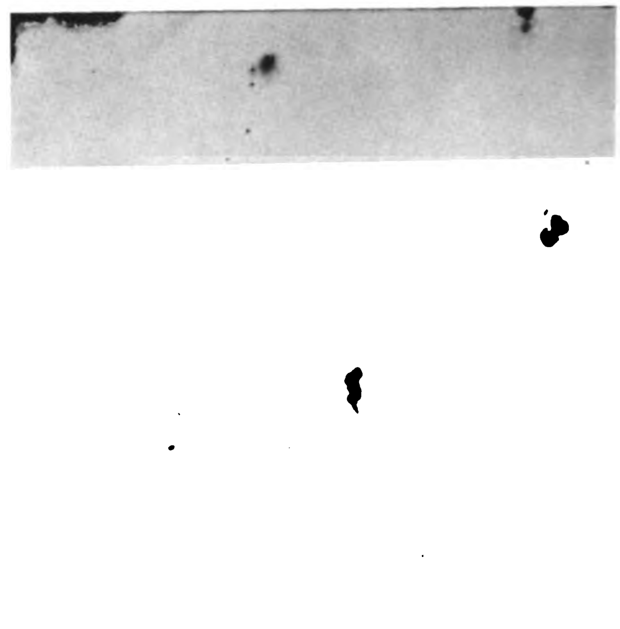

Fig. 1.16—White acid-resistant panel after 7 years of exposure in the "salt air" at Atlantic City, N.J. Surface defects, including the hole at right center, were caused by rusting through from areas of incomplete coverage on the back of the panel. Specimens with a thin second coat of enamel on the reverse side were not affected in this way.

3. Changes in specular gloss

Specular gloss measurements were made on each panel at the exposure site, by using the Hunter multipurpose Reflectometer[5] adjusted for a 45° angle of incidence. Measurements were made at two fixed locations near the center of the panel immediately after the cleaning operation, which consisted of: (a) washing with a warm 1-percent solution of trisodium phosphate, (b) thoroughly rinsing with tap water, and (c) drying in air. The initial gloss measurements were standardized against a liquid film[6]. The 7-year data were obtained with the same multipurpose reflectometer and with the same liquid-film standards.

[3] Test for Acid Resistance of Porcelain Enamels; Part I—Flatware. Issued by the Porcelain Enamel Institute, 1346 Connecticut Avenue, N. W., Washington, D. C. In the commercial test, which separates enamels according to classes, a small pool of 10-percent citric acid is placed on the specimen for 15 minutes at 80°F. The degree of attack is then evaluated by visual methods by using such characteristics as visual stain, blurring of image, and ease of removal of a pencil mark. Class AA shows no visible effect from the treatment and is the most resistant, with class A, class B, class C, and class D following in that order. Enamels falling in the last two classes are not considered as acid-resistant. A research test for acid resistance is included in the same pamphlet. The research test is quantitative in that the loss of 45° specular gloss is measured for each specimen after a 15-min. immersion in the 10-percent citric acid at 80°F.

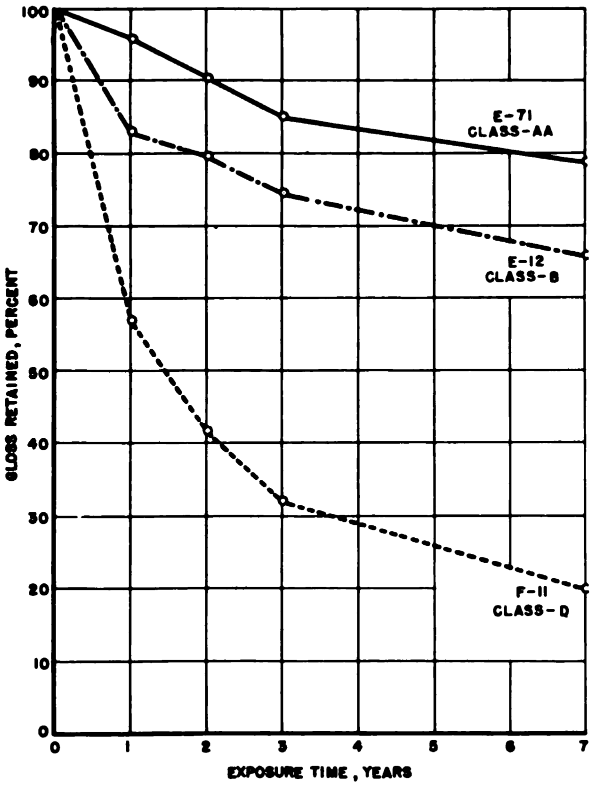

Fig. 1.17—Curves showing decrease in percentage of gloss retained with increasing exposure time for three typical panels exposed at Washington, D. C.

In general, it was noted that the 45° surface gloss changed at a faster rate in the earlier stages of exposure than later. Figure 1.17 illustrates this effect for three Washington panels that were chosen as being representative. In all three panels there was considerably more change during the first three years than during the next four, and in the case of panel F-11, there was more change during the first year than during the next six.

The average percent of initial specular gloss retained after seven years of weathering is given in Table 1.3. In this table the specimens are grouped according to their acid resistance. No values are listed for St. Louis. The St. Louis panels were found to have a dark gray deposit of fly ash and soot combined with a tarlike substance over the entire surface. The standardized cleaning procedure of washing with 1 percent trisodium phosphate solution did not remove this deposit, and vigorous scrubbing with a scouring powder was the only method found to give satisfactory cleaning. Unfortunately, this scrubbing had a polishing action that affected the gloss measurements and vitiated their reliability as a criterion of the degree of weathering.

Table 1.3 shows that there is good correlation between the class of acid resistance by the PEI commercial test (see footnote 3) and the average percentage of initial gloss retained. The data for the Lakeland panels showed this same good correlation, but at Washington and Atlantic City there was a reversal of two values, involving class B enamels in both instances. Only three class B enamels were included in the investigation. If more enamels of this class had been included a better average value would have been obtained and these reversals might not have occurred.

Table 1.3 shows only moderate differences in the percentage gloss retained at the three locations after seven years of exposure. The class AA and class A enamels were somewhat more affected by the conditions existing at Atlantic City than at Washington and Lakeland. On the other hand, the semitropical conditions at Lakeland appear to have produced more surface deterioration on class C and class D enamels.

ACCELERATED WEATHERING TESTS

In the early part of the investigation numerous possible accelerated tests for weathering resistance were investigated. Arc light radiation tests for as long as 500 hours failed to produce any appreciable gloss or color change in any of the enamels, indicating that solar radiation has little if any effect in the weathering mechanism of the enamel finish. Of the various tests tried only those involving acid attack tended to correlate with the field results. One test that showed early promise involved exposing specimens, while partially immersed in distilled water, to an atmosphere of carbon dioxide maintained at a pressure of 4 inches of mercury.

TABLE 1.3. SUMMARY OF GLOSS DATA SHOWING THE AVERAGE PERCENTAGE OF SPECULAR GLOSS RETAINED AFTER 7 YEARS OF WEATHERING FOR VARIOUS CLASSES OF ACID RESISTANCE.

No. of enamels averaged[b]	Acid resistance class[c]	Average percent of initial specular gloss retained[a] at— Washington	Lakeland	Atlantic City	Average at three locations
29	AA	73.3	81.6	69.6	74.8
15	A	69.7	70.0	62.3	67.3
3	B	70.7	64.2	50.2	61.7
24	C	54.9	43.1	52.8	50.3
16	D	44.4	36.0	46.3	42.2

[a] Percentage of gloss retained for St. Louis panels not included because tightly adhering surface deposits made gloss measurements unreliable.

[b] Each enamel represented by two panels at each location.

[c] From spot tests made on 12- by 12-in. storage panels, using the Porcelain Enamel Institute standard acid-resistance spot test for flatware.

The test was carried out at room temperature. The specimens were exposed for 17 hours with 45° specular gloss measured before and after test.

Figure 1.18 shows the correlation between average percentage of gloss retained after seven years of weathering and the results of both the CO_2 and the P E I Research Test for Acid Resistance (see footnote 3) on the same enamels. It will be noted from these curves that the seven year resistance to weathering has a considerably better correlation with the P E I Research Test for Acid Resistance than with the carbon dioxide test.

As pointed out earlier, the P E I spot test for acid resistance also correlates well with the average percentage of gloss retained after seven years of weathering and can undoubtedly function satisfactorily as an acceptance test until such time as more complete data are available.

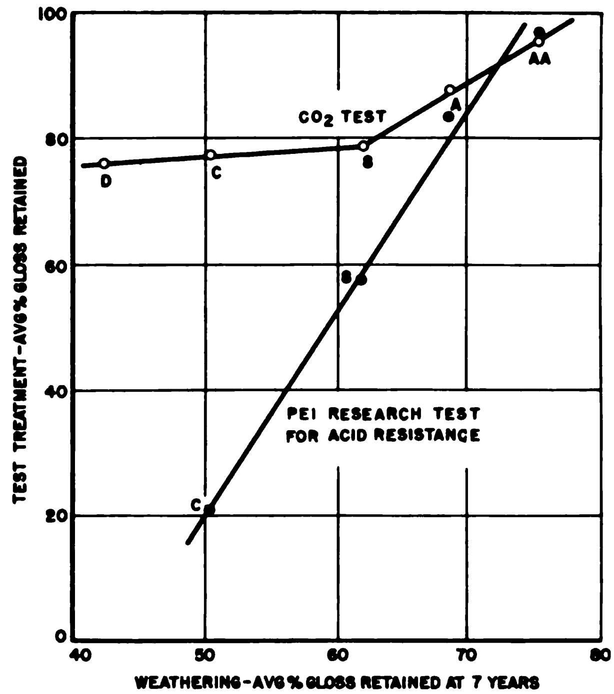

Fig. 1.18—Relation between the average percentage of gloss retained after weathering and the percentage of gloss retained after treatment of duplicate specimens by both the CO_2 and the PEI research test for acid resistance. Letters on curves show class of acid resistance by the PEI spot test. The gloss values for class D enamels were too low for measurement after the PEI research test treatment.

DISCUSSION

The cause of the gradual decrease in gloss of the enamel surfaces with weathering, as illustrated in Figure 1.17, is believed to be a slow leaching of slightly soluble constituents from the enamel surface, leaving a gel-like layer rich in silica. The rate at which this alteration occurs is a function of the composition of the enamel and the conditions to which the surface is exposed. After seven years the thickness of the altered layer may be comparatively heavy (up to 0.0012 in. thick) as was the case with one black enamel of very poor acid resistance, or it may be very thin on the enamels of high acid resistance.

This same type of surface deterioration also occurs with glass. According to Jones[7], when glasses containing less than 60 percent of silica are subjected to weathering, the cations from the glass surface go into solution and are replaced by hydrogen ions from weakly acid water, thus resulting in a hydrated-silica surface layer. That glasses of higher silica content also may show this same gel formation on longer exposure was shown by Laubengayer[8] in his study of a soda-lime-silica glass (66.5 percent of silicon dioxide) that was entombed in a burial vault in Cyprus for approximately 1,800 years. Laubengayer found that this glass was incrusted with a white flaky material that consisted mainly of hydrated silica. Also, other investigators[9] have found indications of the presence of a gel layer on old window glass and old glass tubing.

Fading of the colored enamels with poor acid resistance is also probably caused by the leaching and subsequent hydration of the surface layer. The resulting hydrated film on colored enamels usually assumes a lighter color than the original surface and gives a faded appearance to the panels. The degree of color change depends on the thickness and composition of the film and on the original color of the enamel. Unlike the panels studied by Sweo[10], the enamels in this investigation that had the deeper colors, rather than the pastel shades, showed the maximum color change. The etching at the bottom edges of the panels, as reported by Sweo, was noted on a few panels at Lakeland. The method of mounting the panels was such as to prevent water from collecting in pockets, but the heavy rainfall at Lakeland (see Table 1.2), together with the resulting high humidity, probably allowed water to remain along the bottom edge for prolonged periods during humid weather.

One of the more important observations made during the seven-year inspection was the great importance of good enamel coverage when panels are exposed to salt air. The salt air conditions at the Atlantic City exposure site are probably more severe than at most seacoast installations, and in commercial practice the reverse sides of the panels, where corrosion began, would not be exposed as they were in this investigation. It is the author's recommendation that on all seacoast installations, special care be taken to insure complete enamel coverage of the backs of panels and attachment lugs. The same precaution should probably also be followed on tropical or subtropical units, and as an engineering safety factor the practice could well be universal.

A discussion of the mechanism of weathering naturally results in bringing to the fore the enamels of relatively poor weather resistance. The important fact is, however, that enamels of good acid resistance, applied to obtain good coverage, were still in very good condition in all locations after seven years. Hudson and Banfield[11] working in England, also found acid-resistant enamels to be in excellent condition after five years in industrial or nonindustrial atmospheres, or after two years submerged in sea water.

On the basis of the seven-year data, the author feels that the following recommendations are valid:

1. Where appearance is an important factor, full-mat enamels of the type included in this investigation should not be used for outside installations, as they tend to accumulate and retain a dingy film and to fade.

2. Enamels of acid resistance less than class B (PEI test) should not be used in any architectural installation where general appearance and absence of fading are important. An acid resistance of class A or class AA is to be preferred.

SUMMARY

The various observations made during an inspection of 768 1-ft. square porcelain enameled panels of varying types exposed for seven years at Washington, D. C., St. Louis, Mo., Lakeland, Fla., and Atlantic City, N. J., may be summarized as follows:

1. Good correlation existed between acid resistance and the percentage of initial gloss retained, the enamels of best acid resistance retaining the highest percentage of their original gloss.

2. No noticeable fading of enamels of class AA or class A acid resistance occurred, nor was there objectionable fading of class B enamels. Practically all class C and class D colored enamels, however, showed very noticeable color change.

3. The seven-year data indicates that the conditions at Atlantic City were slightly more severe than elsewhere on the acid-resistant enamels, whereas Lakeland conditions were most severe on the non acid-resistant compositions.

4. The salt-air conditions at Atlantic City caused considerable corrosion of those parts of the panels that were incompletely covered by enamel. This corrosion caused failure of attachment lugs and in some cases failure of enamel on the face by rusting through to near the enamel-metal interface from areas of poor coverage on the back. Specimens with a thin second coat of enamel on the back were not affected in this way.

5. Where the initial coverage was complete on all parts of the panel and where no mechanical damage had occurred during exposure, protection of the metal against corrosion was unimpaired on all specimens after seven years of weathering.

Briefly stated, the results of the study show that most porcelain enamel finishes are highly resistant to deterioration under the conditions existing at the selected locations, and, further, that those enamels that are not resistant can be rejected prior to installation by simple laboratory tests. Also, if proper care is taken to insure good coverage of all surfaces of the panel, the data indicate that even the poorest enamels will provide corrosion protection for an extended period of years. If surface appearance is important, however, only those enamels of good acid resistance should be selected.

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RADIOCHEMICAL DECONTAMINATION CHARACTERISTICS OF PORCELAIN ENAMEL

By G. W. Parker and G. M. Herbert
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Our interest at Oak Ridge National Laboratory in porcelain enamel as a future material of construction, was stimulated by a visit from an executive in the porcelain enamel industry, in fact, the vice president of the Bettinger Enamel Corp., Mr. R. A. Weaver. It was through Mr. Weaver's friendly encouragement that the program of comparing the properties of porcelain, especially those related to radiochemistry, with the conventional materials was undertaken.

While a considerable amount of prejudice against porcelain enamel may exist in the average laboratory, it seems to have arisen from attempts to use the product under unfavorable conditions. Therefore, no matter how favorable porcelain may appear from a limited amount of investigation, caution should be exercised in making extrapolations to final applications.

Having found that in our combination of circumstances, that the better porcelains have just enough versatile chemical resistance besides the advantages of a low retention of radioactivity (contamination) and ease of cleaning (decontamination) to place them in a highly preferred class of materials, it is felt that an additional step such as the construction of prototype equipment is justified.

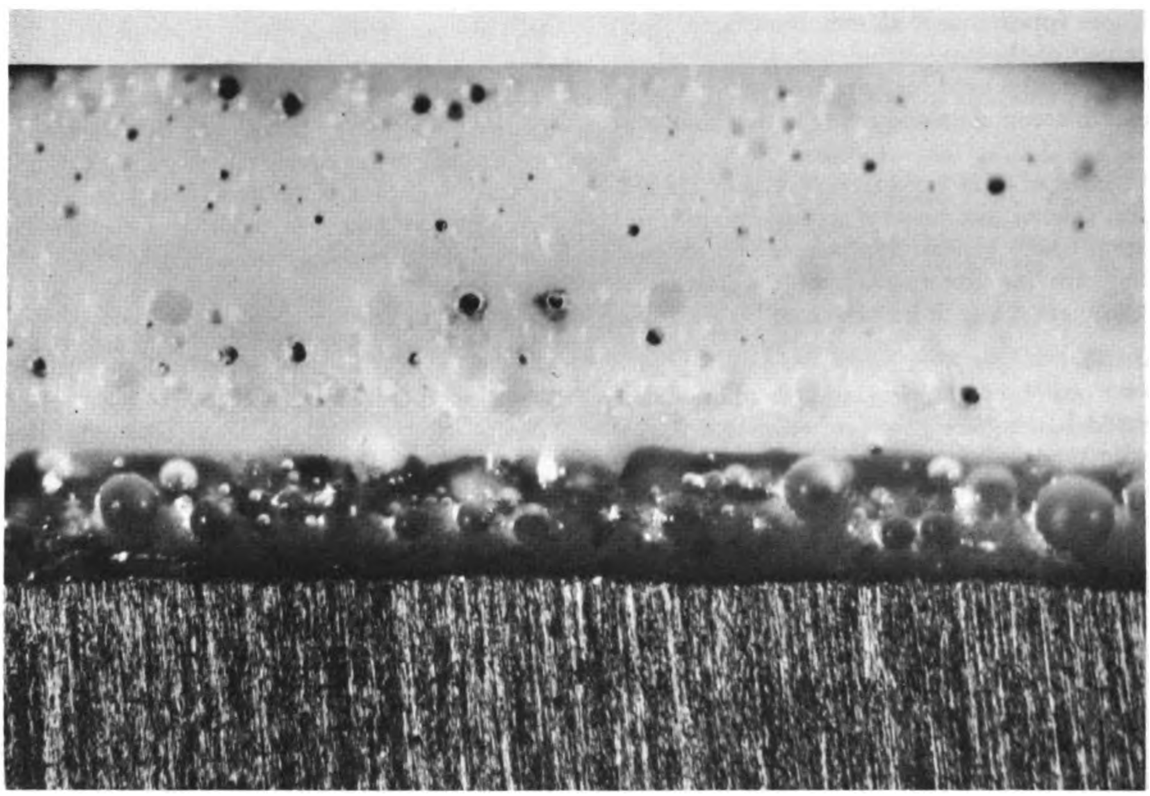

Fig. 1.19—A Photomicrograph (250X) of the Best Quality Porcelain Enamel (Ref. No. D-2).

Emphasis has been placed on adapting porcelain to fume hoods, ducts, dry boxes and similar specialized furniture construction where the limiting factors are acid, alkali and solvent resistance and mechanical resistance of the coating. On the other hand, an application of less stringent requirements which we believe deserves more attention is the adaptation of porcelain to building and partitioning panels particularly for laboratory buildings desiring something better than painted surfaces.

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* Dr. Parker has been affiliated with the Oak Ridge National Laboratory, Carbide and Carbon Chemical Corporation, since 1943. Previous to that time he was with the Manhattan Project at the University of Chicago Metallurgical Laboratories. His title now is Senior Chemist, his job is in the Radioisotope Research Laboratory, in charge of Chemical Division Hot Laboratory, Chemistry of Fission Product Elements and he has an honorary distinction of isolating the first visible amounts of two synthetic elements—atomic no. 43 and no. 61, Technetium and Promethium, respectively.

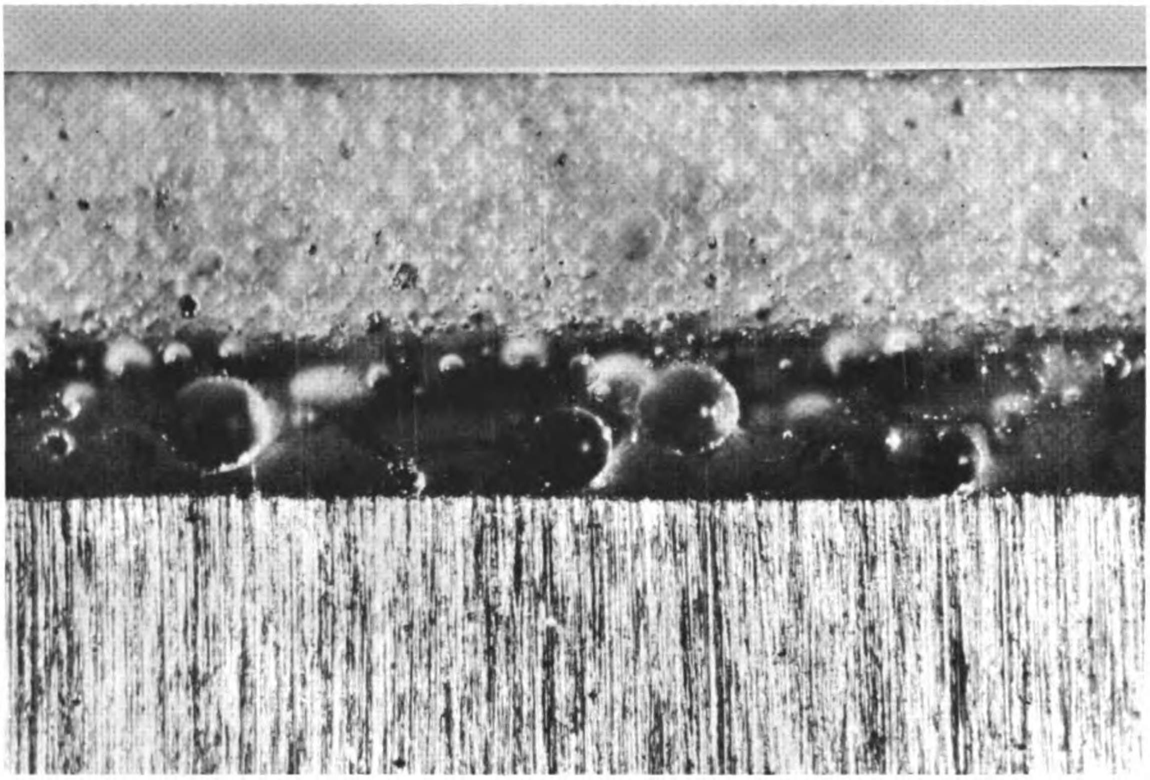

Fig. 1.20—A Photomicrograph (250X) of a Good Porcelain Enamel (Ref. No. D-1).

The comparisons made and suggested in this brief consideration of the suitability of porcelain enamel as a preferred surface for radiochemical laboratories are based on conventional, empirical tests of their behavior toward contaminating radioactivity. It should be pointed out that variations in the method of making the test can sometimes reverse the order of preference. For this reason perhaps, certain materials which have often been rated among the most desirable in other investigations have rated poorly in this instance.

Within the Atomic Energy Program a large amount of effort is continually devoted to the appraisal of materials and methods to control the biological and technical hazards of radiochemical contamination. The numerous problems related to the Design of Radiochemical Laboratories have been admirably presented in a Building Research Advisory Board Conference conducted by the National Research Council. The session on surfaces and finishes led by J. F. Terrill[1] reviewed the available test results and procedures including those developed by Tompkins and Bizzell[2] and Watson, Handley and West[3] for the evaluation of materials and the setting up of general criteria for selection. The requirements of a good material are summarized thus:

1. Smooth and nonporous surface (minimum of adsorption area and penetration).
2. Non-ionic (minimum exchange).
3. Resistant to corrosion by acids, alkalis, or organic solvents.
4. Resistant to heat.

Since none of the previous decontamination studies included porcelain enamel, it was decided to make contamination-decontamination tests on a limited number of commercial samples. These tests were intended to simulate those of Watson and coworkers[3] and to include some of the various reference materials used by them. For this reason it was felt that the results could be correlated with the previous work and with some specialized research conducted by the U.S. Army Corps of Engineers[4,5] and by the Naval Radiological Defense Laboratory[6].

MATERIALS USED

Porcelain Enameled Steel

The porcelain enamel coatings were of one principal type-commercial acid resisting porcelain, generally consisting of a blue-black, nickel-cobalt ground coat and an opacified enamel cover coat sometimes replaced or supplemented by a glaze.

In some instances only one side of the specimen had received the cover coat, in others both sides were assumed to be identical. The thickness of steel found was generally 20 gauge and the thickness of enamel about .005 inches of ground coat

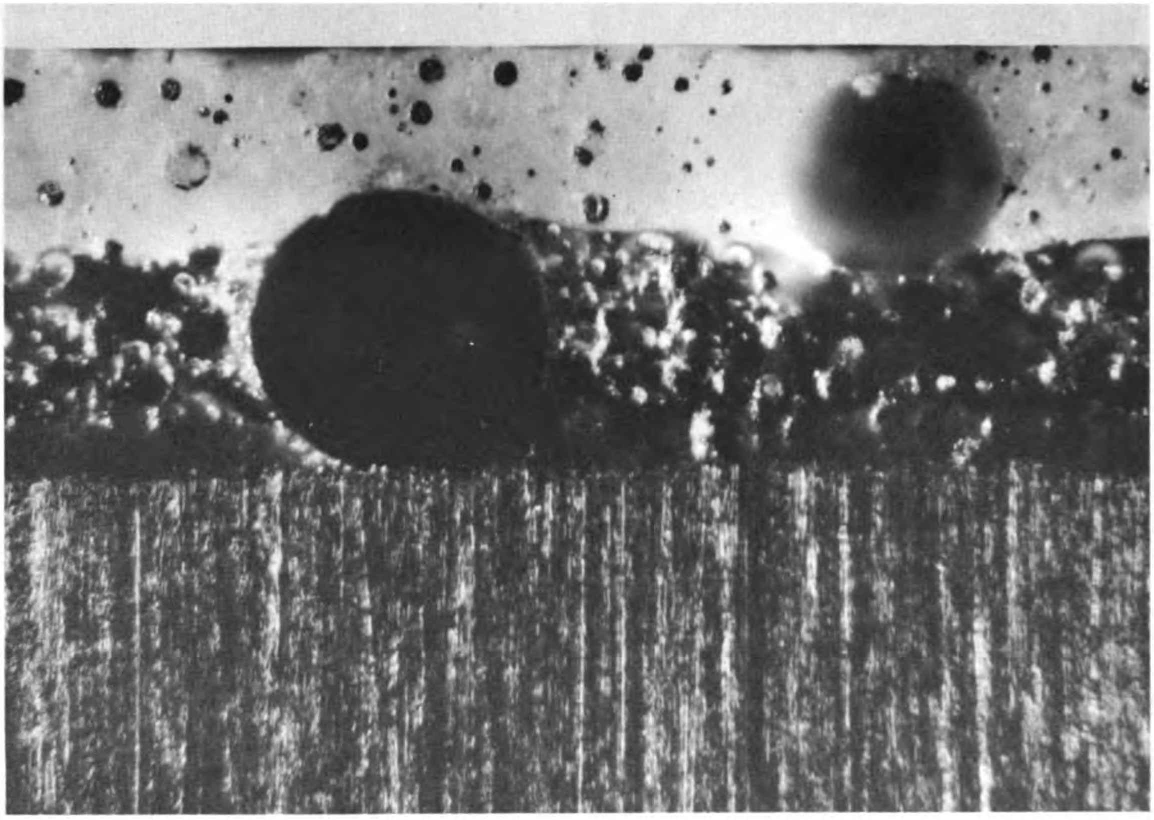

Fig. 1.21—A Photomicrograph (250X) of a Poor Quality Porcelain Enamel Showing Their Irregular Coating and Enlarged Gas Bubbles (Ref. No. B-3).

and about 0.15 inches of cover coat. (Fig. 1.19). In only one instance was an extra thickness of cover coat noted which was apparently a double coat and is indicated in the tables.

Visibly these enameled surfaces are quite different. The better enamels are highly reflecting and smooth and glossy in appearance. On examination with a 150 X microscope most white enamels seem to be transparent with small bubbles throughout their depth. The bubbles do not make surface pits, but are contained in the enamel. These result from the outgassing of hydrogen dissolved in the base metal. Uniformly small gas bubbles are characteristic of a good enamel (Figures 1.19 and 1.20). Figure 1.21 shows a poor enamel structure.

The white enamels are opacified by the addition of a few percent of an oxide of either antimony, titanium or zirconium, in preparation of the "frit," a modified low fusing glass containing some clay together with the usual glass formers[7]. Chemical resistance seems to be limited by the opacifier with the order of decreasing resistance being from antimony to zirconium.

Glass Coatings

The glass coatings (described as true boro-silicate glasses) differ from the enamels in that they are generally a single homogenous layer (without suspended particles) applied more heavily to a heavier gauge steel. Only one manufacturer (A. O. Smith Co.) supplied flat glass coated specimens. Because of the higher firing temperature required, the glass coatings are practically limited to massive curved structures.

Uncoated Reference Materials

1. Saran sheet 1/16 rolled.
2. Teflon ⅛" sheet.
3. Sheet glass—type B.
4. Polyethylene, ⅛" rolled sheet (smooth).
5. Plate glass, ¼" glazing quality.
6. Fluorothene—⅛" pressed sheet (smooth).
7. Stainless steel—2B mill finish (normal laboratory grade).
8. Stainless steel—#7 (mirror finish).

The samples of the above materials and of the enameled surfaces were not screened for flaws, but were taken as they came off of larger pieces. This fact may explain variations in duplicate or similar samples, but in spite of this the overall agreement between samples was good.

Acid Resistance

Since porcelain enamels vary considerably even within the acid-resisting grades to attack by strong chemical reagents, a limited exposure designed to represent a normal condition, within practiability, was arranged to assist in establishing relative acid resistance among the various commercial products solicited.

The test was carried out by the inverted watch-glass method[8], using a mixture of 10% each of hydrochloric and citric acids. A one-inch watch glass was half-filled (about ½ c.c.) with reagent and then covered with an enamel specimen before both are inverted. One hour was allowed as a sufficient time to etch or otherwise change the surface of an average specimen.

As a measure of degree of attack, the increase in surface roughness was gauged on a Surface Profilometer (Physics Research Corp.) and recorded in Table 1.4. The reading is given in micro-inches, root mean square. A change of 2 micro-inches was barely visible. The titanium and zirconium opacified enamels were consistently less resistant than those opacified with antimony.

TABLE 1.4

SURFACE CHANGES AS A MEASURE OF RELATIVE ACID RESISTANCE

Name or Code Letter of Porcelain Enamel or Glass	Color	Roughness (Microinches—R.M.S.) Average Profilometer Reading Before Acid Treatment	Average Change in Profilometer Reading After Treatment
Sheet Glass	Type "B"	1-2	0
A. O. Smith	Blue-Glass Coating	10-15	0
A. O. Smith	Black-Glass Coating	11-15	0
B-1	White (Double Tk.)	20-30	0
B-2	Black (Double Tk.)	10-20	0
I-1	White (TiO_2)	15-20	0
D-1	Gray	10-15	0
D-2	Sb. Op. White	8-12	0
Tile	Glazed-Sanitary	18-22	0
Tile	Glazed-Building	35-45	0
D-3	Black	12-15	+2
C-1	White	10-15	+2
G-1	White	20-25	+5
E-1	White (TiO_2)	20-25	+5
D-4	Ti. Op. White	9-15	+5
I-2	Black	20-25	+5
G-2	White	13-20	+6
D-5	Black (Pitted)	9-16	+7
E-2	Bl. Blk. Clear Glaze	15-25	+10
F-1	White	13-30	+18
F-2	Black	10-30	+20

Acid Treatment—10% Citric, 10% Hydrochloric for one hour @ R. T.

Contaminating Reagents

The contaminating activity applied to the samples was selected from two distinctly different radiochemical process wastes:

I. Mild Contaminant: A nitrate salt extraction column waste, slightly acid-deficient, and containing a high salt content (500 mgs./1 ml.). The salts present were partly the metal ions of stainless steel. This material, because of the effect of the massive salt content gave low retention of activity.

II. Severe Contaminant: A nitric acid extraction column waste of 3 year old fission products; 1.7N in free acid and containing less than 25 mgs of solids per milliliter. This salt was composed principally of sodium and iron. The effect of the strong acid and lower salt mass was to produce a much higher retention, or susceptibility, to contamination, roughly inversely proportional to the weight of inert salts. (Table 1.7).

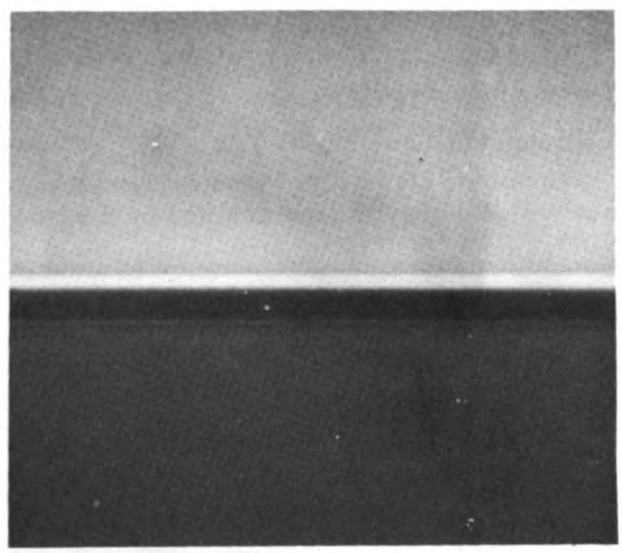

Fig. 1.22—An Enlarged Radioautograph of a Section of a Piece of Neutron Activated Porcelain. The White Bands Show the Active Sodium in the Cover Coat and Ground Coat.

The radiochemical analysis of these two differed slightly, but is not considered sufficient to alter the results materially. (Table 1.8).

Decontaminating Reagents

No significant portion of the investigation was devoted toward selection of an ideal reagent. With the exception of a brief study of the effect of pH on the most commonly used reagent: 5% citric acid, in which it was concluded that a mixture of 5% citric acid, 0.5N in HCl and containing 0.5% aerosol was more effective than a basic or neutral 5% sodium citrate solution.

The tendency to favor a reagent containing a low fluoride ion activity compatible with preservation of the original surface gloss of the porcelain is indicated in the Tables. The reagents used most commonly were as follows:

Reagent	Composition
1. Acidic Citrate Mixture	0.3M Citric Acid, 0.5M HCl, 0.5% Aerosol O.T.
2. Nitric Acid	5% HNO_3
3. Ammonium Silico-Fluoride	5% $(NH_4)_2\ SiF_6$
4. Ammonium Silico-Fluoride-Nitric Acid Mixture	(a) 2.5% $(NH_4)_2\ SiF_6$, 2.5% HNO_3 (b) 1.0% $NH_4\ SiF_6$, 5% HNO_3
5. Enamel Polish	One of several fine grain pumice - type commercial preparations.
6. Oxalic Acid	5% $H_2C_2O_4 \cdot 2\ H_2O$

METHOD OF TESTING

Contamination Susceptibility Test

The materials to be tested were cut into plaques about 2 x 2 inches and contaminated by pipetting onto each a 0.1 ml portion of the contaminant containing 10^8 Beta counts per minute at the counter geometry used. The contaminant was then allowed to dry without heating for approximately 6 hours in an open hood before proceeding with decontamination. The contaminating solution covered about 1 sq. cm. and presented a field of about 1 R/hr at 1 cm or about 50 milli R/hr. at 1 foot.

The samples were first flushed with water flowing at a rate of 2-3 gallons per minute for one minute. The water was flowed across the spot of maximum contamination rather than impinged upon it. Plaques were then air dried and counted on a mica end-window Geiger-Mueller counter at approximately 10% geometry or 18 mm. below the window. Little difficulty was experienced in counting samples exposed to the mild contaminant; however, when severely contaminated beyond the capacity of the G-M counter, an average equivalent counting rate was deduced from the counting rate through an aluminum absorber and a thin window sodium-iodide-crystal count rate meter.

The first count obtained, known as the susceptibility or "True Contamination" of the plaques is an

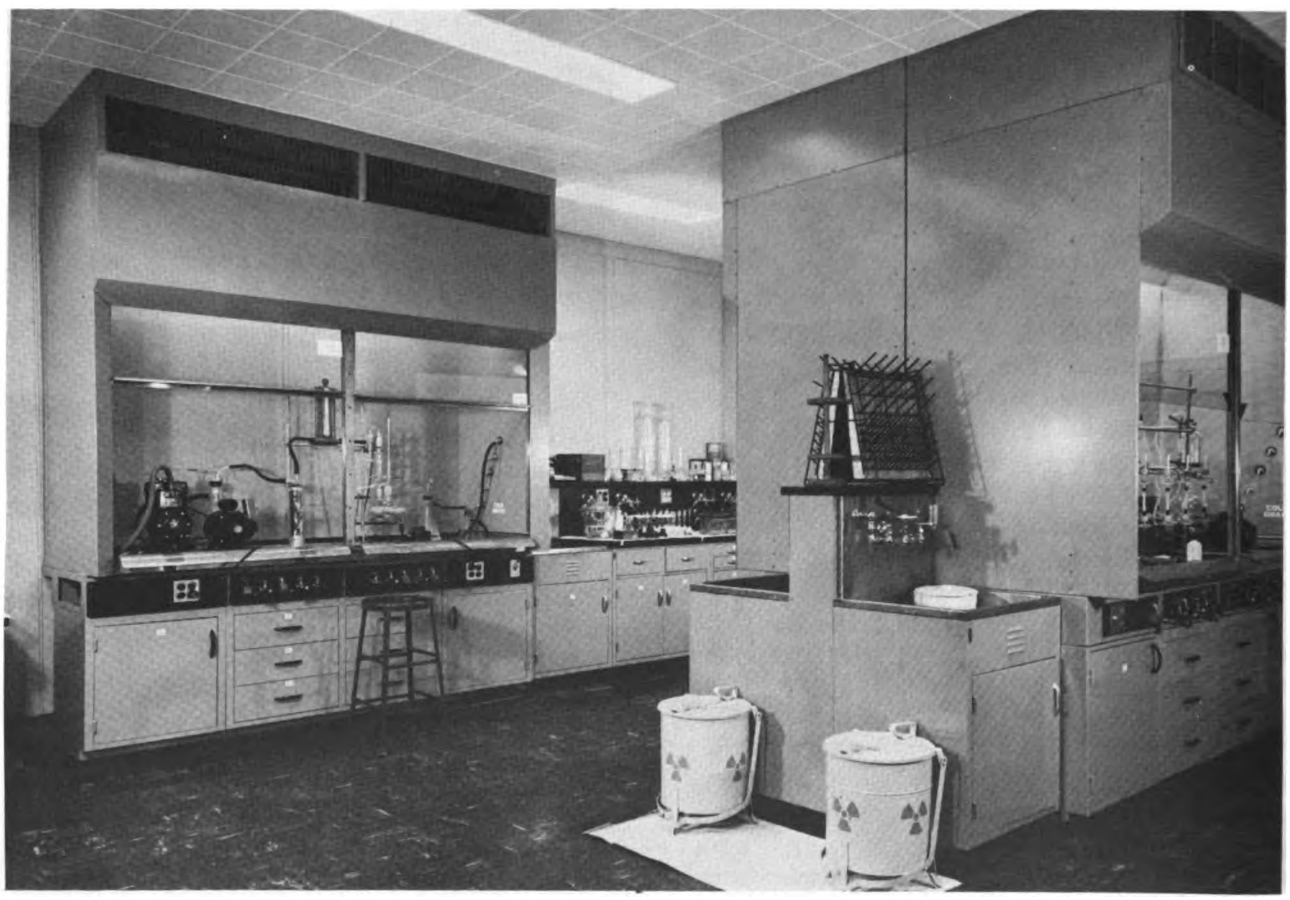

Fig. 1.23—Furniture Arrangement of a Typical Radiochemical Laboratory.

TABLE 1.5

EFFECT OF VARIOUS REAGENTS ON DECONTAMINATION OF PORCELAIN ENAMELS
(Mild Contaminant)

	Activity Remaining After Water Wash	Contaminability Relative to Sheet Glass	5% HNO_3	5% $(NH_4)_2SiF_6$	5% HNO_3	5% $(NH_4)_2SiF_6$	5% HNO_3	% Activity Rem. After 3rd Wash	5% HNO_3–5% $(NH_4)_2SiF_6$	% Activity Remaining (Final)
D-6 White*	20587	5.64	------	4500	----	2000	7	0.04	7	0.04
D-6 White	11113	3.04	113		19	15		0.09	2	0.01
D-2 Sb-Op-Wh.	5943	1.63	400		93	48		1.5	1	0.08
D-2 Sb-Op-Wh.	4009	1.10		183		65	9	0.28	3	0.09
D-2 Sb-Op-Wh.	3070	0.84	34		3	3		0.09	2	0.09
D-1 Gray	5386	1.5	117		49	18		0.33	2	0.04
D-3 Black	4714	1.3	85		53	58		1.2	10	0.21
D-4 Ti-Op-Wh.	5308	1.45	97		27	15		0.28	3	0.06
F-2 Black	14900	4.1	750		677	677		4.55	1	0.005
G-2 White	8747	2.4		26		26	12	0.13	6	0.06
F-1 White	9996	2.7	27		3	23		0.23	4	0.04
G-1 White	4419	1.21		89		28	13	0.28	6	0.14
G-1 White	3823	1.05	36		8	11		0.24	4	0.09
G-1 White	6996	1.92	352	95	51			1.12	7	0.15
Average		2.08						0.74		0.075

*Non Acid Resisting.

expression of the percent of the total activity remaining after hosing or flushing. This activity is assumed to be vaguely adsorbed on or combined with the surface. The following expression of susceptibility factor is only relative since it depends not so much upon the specimen as upon the mass/per unit area contaminated.

Counts remaining after flushing

$$\frac{\text{Counts remaining after flushing}}{\text{Original counts applied}} \times 100 = \text{S.F.}$$

Attempts to report absolute values on susceptibility factor are believed to be without basis; therefore for the purpose of this report they are given only as a ratio relative to sheet glass. These values are given as part of Table 1.5 and 1.6.

Reagent Decontamination Scrub

In a preliminary experiment, using the mild, low-acid contaminant, the plaques for decontamination, were first divided into three groups for conventional treatments with either acid-citrate, 5% HNO_3, or 5% ammonium silico-fluoride. Each plaque was scrubbed by hand using two paper tissue swabs for a period of one minute with the proper reagent and then rinsed with water for one minute. They were then air dried, mounted, and counted as before. The remaining activity was expressed as a ratio or Decontamination Factor (DF):

$$\frac{\text{Counts remaining from the susceptibility test}}{\text{Counts remaining after reagent scrubbing}} = \text{Reagent DF.}$$

An overall decontamination factor has been expressed as follows:

$$\frac{\text{Initial counts applied } (10^8)}{\text{Counts remaining after reagent scrubbing}} = \text{Overall DF.}$$

Obviously, this figure is dependent largely upon the amount of activity added and upon the mass of the activity and the area involved.

Second and Third Reagent Scrub

Two additional scrubbings with the acid reagent were made on the duplicate porcelain plaques only. Part of the group being treated with HNO_3 or Silicofluoride were exposed alternately to each reagent. (Table 1.6).

Ammonium Silico-Fluoride—HNO_3 Scrub

By this time the number of residual counts on most of the porcelain enameled plaques was quite

TABLE 1.6—CONTAMINABILITY—DECONTAMINABILITY OF PORCELAIN ENAMELS

MILD CONTAMINANT

	Contamination			Decontamination					
	Activity Not Removed By Water Wash: cts/min. (10^8 Counts Added)	Contaminability		0.5 M HC1 — 0.5 M Citric Acid					Percent of True Contamination Remaining
		Percent Retained	Relative to Glass	1st Wash Activity Remaining	2nd Wash Activity Remaining	3rd Wash Activity Remaining	4th Wash Activity Remaining: 5% SiF_6	4th Wash Activity Remaining: 5% SiF_6 5% HNO_3	
I. Glasses									
Sheet Glass	3650	0.00365	1	36	21	17	15		0.42
A.O. Smith-Blue*	3066	0.00306	0.8	218	129	89	71		2.3
A.O. Smith-Black	5066	0.00506	1.4	163	95	68	35		0.7
II. Acid Resisting Porcelains									
I—1 White	3775	0.00377	1.03	145	85	72	58		1.54
D—1 Gray	5386	0.00538	1.5	222	57	26		6	0.1
D—2 Sb. Op. Wh.	3892	0.00389	1.06	110	39	19		3	0.08
D—3 Black	4714	0.00471	1.3	1881	1462	1450		23	0.49
C—1 White	2384	0.00238	0.6	15	15	14	11		0.44
G—1 White	4560	0.00456	1.3	74	39	32	15		0.33
E—1 White	10920	0.01092	3.0	2458	1233	1027		92	0.09
D—4 Ti Op. Wh.	5308	0.0053	1.45	877	355	248		26	0.49
I—2 Black	4928	0.00492	1.4	85	51	41		9	0.2
G—2 White	8747	0.00874	2.4	332	171	141		12	0.1
D—5 Black	6660	0.00666	1.7	864	288	138		2	0.03
E—2 Clear Glaze Blue Black	11160	0.01116	3.2	1	898	643		62	0.5
F—1 White	9996	0.00999	2.7	1202	529	353		33	0.3
F—2 Black	14900	0.0149	4.1	4057	1749	1423		217	1.45
III. Non Acid Resisting Porcelain									
D—6	15850	0.0158	4.3	13600	—	—		37	0.2

* Only one side coated.

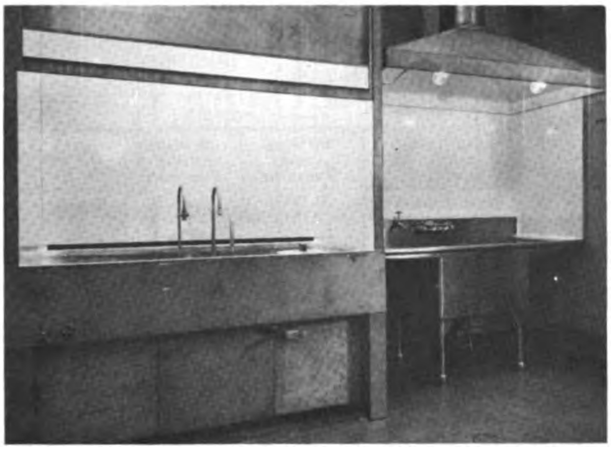

Fig. 1.24—Stainless Steel Laboratory Hoods Protected with a Vinyl Paint to Prevent Chloride Attack.

Fig. 1.25—Example of Failure of a Non-Acid Resisting Porcelain Under Improper Use.

low, but in spite of this, it was decided to see how effective a mixture of ammonium fluosilicate-nitric acid might be for removing the residual activity which had resisted the previous treatments. Some of them were then scrubbed with the 5% ammonium silico-fluoride—5% HNO_3 solution in the same manner as the previous scrubbings, rinsed, air dried, and counted. This final count was used to express the percent of activity remaining and may be used to calculate Reagent D.F.

Tri Sodium Phosphate

One group of reference materials were decontaminating so poorly, a 5% TSP solution was used as a final scrub. This was also ineffective. No further surface removing methods were employed although specific methods are available for decontaminating almost any material, sometimes mildly destructive in effect. This resort might be necessary when stainless steel becomes pitted by chloride attack.

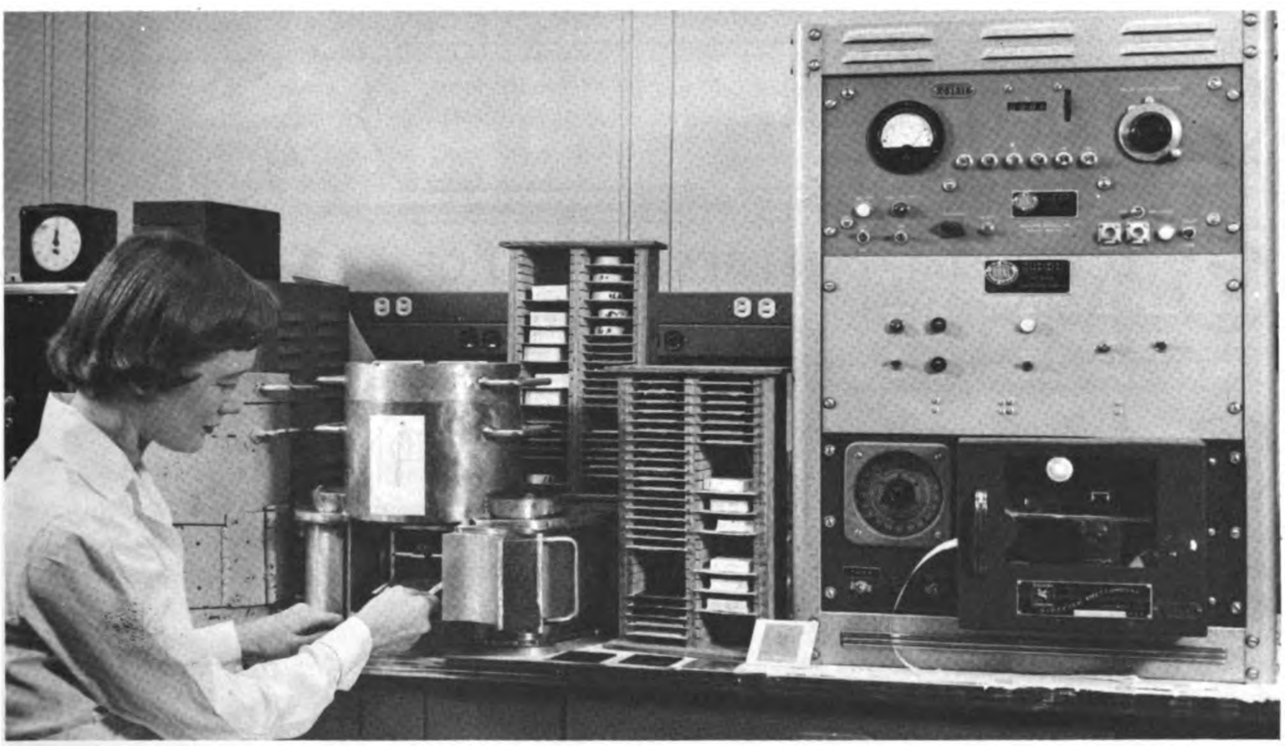

Fig. 1.26—Use of a G-M Counter For Measuring Radioactivity on Contaminated Porcelain Plates.

TABLE 1.7—CONTAMINABILITY—DECONTAMINABILITY OF PORCELAIN ENAMELS
SEVERE CONTAMINANT

	Contamination (10^6 Counts Added)			Decontamination							
	True Contamination (Act. not Removed by Water Wash) (x 10^6 counts per minute).	Contaminability		1st Wash Activity Remaining		2nd Wash Activity Remaining		3rd Wash Activity Remaining	4th Wash Activity Remaining	Percent of True Contamination Remaining
		Percent Retained	Relative to Sheet Glass	5% HNO_3	O.5N Citric	5% $H_2C_2O_4$	O.5N Citric	5% HNO 1%$(NH_4)_2SiF_6$	Enamel Polish	
I. Reference Materials										
A.O.S. Black										
—Glass Coating	4.2	0.42	2.4		5159	3117		216	126	0.03
Sheet Glass	1.73	0.173	1.		2516	1280		381	15	0.009
Plate Glass	2.3	0.23	1.33		3571	1622		457	0	0.0
Polythene	1.67	0.167	0.96		6580	3419		2140	195	0.1
No. 7 S. S.	1.44	0.144	0.83		1431	484		342	137	0.095
No. 2B S. S.	8.49	0.849	4.9		26676	17204		11798	4196	0.49
II. Porcelain Enamels										
D—2 Sb. Op. White	3.46	0.346	2.0		9994	5258		1763	88	0.025
D—1	3.32	0.332	1.92	4963			3755	472	244	0.073
I—1	3.46	0.346	2.0	18910			15872	7033	6223	1.8
G—1	6.78	0.678	3.92	52666			44752	15029	3004	0.44
C—1 (a)	4.06	0.406	2.34		56324	41762		20854	7050	1.7
C—1 (b)	6.78	0.678	3.92	163000			134000	14516	4449	0.65
B—1	2.3	0.23	1.33	10332			8192	320	192	0.08
B—3	31.7	3.17	18.32	970000			634000	388000	3200	0.10

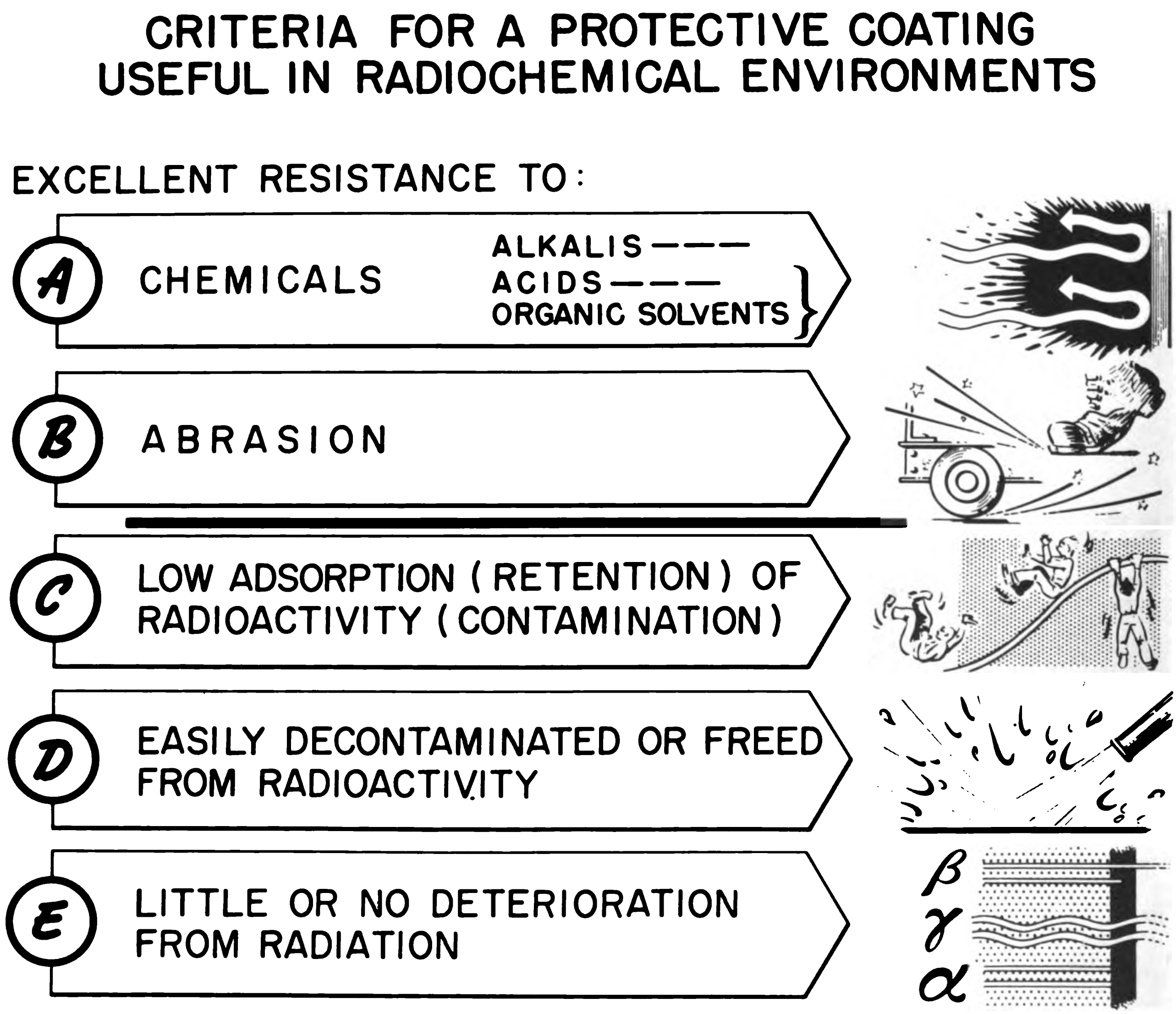

Fig. 1.27

DECONTAMINATION OF VARIOUS FINISHES OF STAINLESS STEEL

TYPE FINISH	ROUGHNESS VALUE microinches (RMS)	INITIAL ACT./in^2	cts/min/in^2 1 hr. contact	INITIAL ACT./in^2	cts/min/in^2 2 hrs. contact	INITIAL ACT./in^2	cts/min/in^2 3 hrs. contact	WT. LOSS %
		1 st		2 nd		3rd		
$\frac{1}{2}$ H.D.	8	25,275	2.75	19,875	62.4	22,305	5	4.65
# 1	60	38,170	13.8	20,481	39.75	26,800	9	2.49
2 B	15	25,166	3.87	19,762	39.8	24,600	5.5	2.12
2 D	30	42,179	9.7	15,780	87.3	25,050	4	2.70
# 4	10	23,944	6.88	14,045	31.3	23,300	5.5	2.90
# 6	8	24,775	9.12	15,287	33.15	18,530	7.5	2.70
# 7	4	18,453	7.75	13,950	32.6	17,675	8	2.96
100 GRIT	35	26,953	4.75	14,425	85.35	20,005	10	3.68

Fig. 1.28

EVALUATION OF RESULTS

Susceptibility to Contamination

The susceptibility to contamination of porcelain enameled steel was found to be of about the same order as that of reference materials. For both porcelain and reference materials a contamination susceptibility of from 0.8 to 15 times that of sheet glass was determined. The acid-resisting porcelain enamels were found to vary widely in this respect but this property in general was proportional to acid resistance and surface quality. The true glass coatings were equaled by the best porcelains and by mirror finish stainless steel. The vinyl paint and 2B stainless steel gave the highest susceptibilities in the mildly contaminated group. At the highest level of contamination the poorer enamels fail to compare favorably with standard reference materials (Table 1.6). Only the best porcelains and glass coatings are sufficiently resistant.

Decontamination

The reagent decontamination factors for enamels vary considerably between samples but somewhat less between reagents, with the true glass coatings being among the best and less acid resisting enamel coatings being among the poorer for every treatment. The mirror finish stainless steel compared favorably; however, the 2B mill-finish was decidedly inferior. Considering the relative standing of each surface for each reagent and averaging the standings, the descending order of decontaminibility would be as follows: glass plate, glass sheet, glass coating, acid resistant porcelain, #7 stainless steel (mirror finish), Fluorothene, Teflon, Polythene, Vinyl Paint, 2B stainless steel, non-acid resistant porcelain.

As was found in the previous experiments on decontamination, the effectiveness of successive scrubbings with the same reagent decreases rapidly; however, among the reagents used there was a surprising similarity in results. In some cases alternating reagents; i.e., HNO_3 and $(NH_4)_2 SiF_6$ was more effective than continuing with one.

The mixed nitric acid and silico-fluoride scrubbing was most effective as was expected. The best porcelains seem to withstand low fluoride concentrations without visible damage. However, the same net result may be had with other milder reagents in most cases. The residual activity varied from 0.001 to two percent for the different porcelains, with significant agreement between samples of the same material.

CONCLUSIONS

These experiments indicate that porcelain enameled steel should prove to be a very satisfactory material from the standpoint of decontaminability for use in those places where it is acceptable structurally, especially for vertical surfaces. There is a wide variation in the resistance of various enamel coatings, but if the best chemically resistant grade is used it is superior to any commonly used laboratory surface.

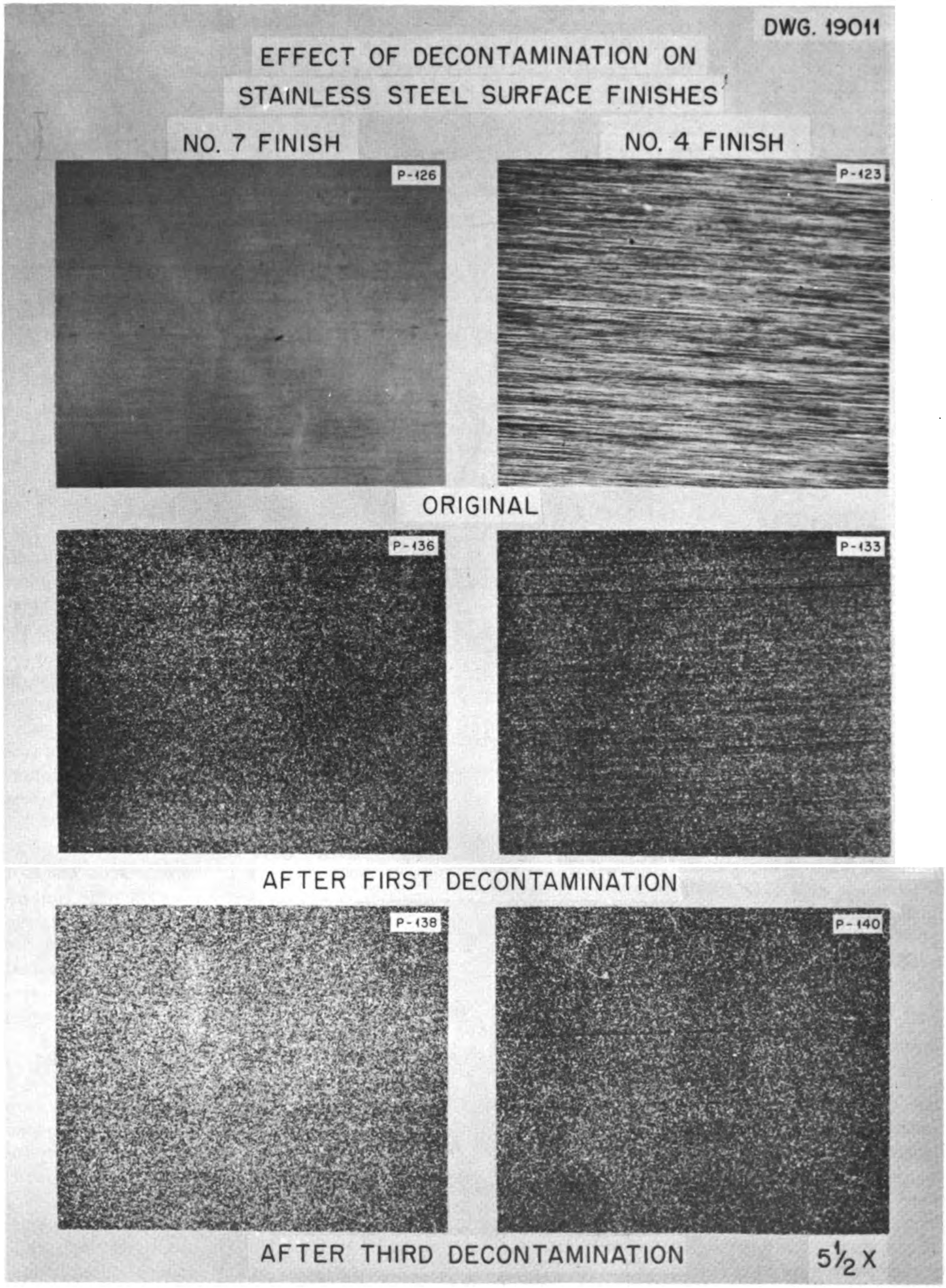
DWG. 19011
EFFECT OF DECONTAMINATION ON
STAINLESS STEEL SURFACE FINISHES
NO. 7 FINISH
NO. 4 FINISH
P-126
P-123
ORIGINAL
P-136
P-133
AFTER FIRST DECONTAMINATION
P-138
P-140
AFTER THIRD DECONTAMINATION
5½ X

Fig. 1.29

TABLE 1.8
RADIO-CHEMICAL ANALYSES

I. Mild Contaminant	*Counts/min/ml*
Gross Beta	1.83×10^8
Total Rare Earths	1.11×10^8
Strontium	2.91×10^7
Cerium	3.7×10^7
Ruthenium	8.5×10^8
Cesium	3.8×10^7
Zirconium Niobium	Negligible
II. Severe Contaminant	
Gross Beta	5.3×10^8
Total Rare Earths	3.7×10^7
Strontium	2.6×10^8
Cerium	3.8×10^7
Ruthenium	4.7×10^7
Cesium	4.6×10^7
Zirconium Niobium	Negligible

ACKNOWLEDGMENTS

The authors wish to acknowledge the generous cooperation of the porcelain enamel industry and the number of manufacturers whose products were submitted for testing. The list, by no means intended to be complete, included the following:

1. A. O. Smith .... Milwaukee, Wisconsin
2. Bettinger Enamel Corporation .... Waltham, Massachusetts
3. Barrows Porcelain Enamel .... Cincinnati, Ohio
4. Chicago Vitreous Enamel .... Chicago, Illinois
5. Ferro Corporation .... Cleveland, Ohio
6. Pfaudler Company .... Rochester, New York
7. Ingram-Richardson, Inc. .... Frankfort, Indiana
8. Pemco Corporation .... Baltimore, Maryland
9. National Bureau of Standards .... Washington, D. C.
10. Southwestern Porcelain Steel Corp. .... Sand Springs, Oklahoma
11. Lansdale Porcelain Enamel Corp. .... Lansdale, Pennsylvania
12. Porcelain Enamel Institute .... Washington, D. C.

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PORCELAIN ENAMEL MANUFACTURING PROCESSES

By G. H. McIntyre*
(Vice President and Technical Director, Ferro Corp.)

The purpose of this paper is to acquaint persons unfamiliar with porcelain enameling practices with the primary aspects of the manufacturing steps. The paper is not intended to be an operating manual. Detailed information can be obtained from literature[1] on the subject (also see other references at the end of this paper).

"Porcelain Enamel" is defined as a glassy composition which has been caused, or can be caused, to adhere to a metal or another enamel by proper application and fusion[2]. The key words are "glassy" and "fusion." All porcelain or vitreous enamels are true glasses bonded to metal by high temperature. These coating materials are strictly inorganic in structure.

Being true glasses, porcelain enamels have the same general properties as glass, but have the added advantage of being reinforced by the metal backing to which they are bonded. Porcelain enamels have excellent chemical, heat, and weather resisting properties and can be applied to ferrous and non-ferrous metals. A complete range of colors and color intensities is practicable.

RAW MATERIALS

The raw materials are essentially the same as those for any glass except a greater variety are included to provide a wide range of properties.

The raw materials are usually in powdered or granular form, purchased on rigid chemical and physical specifications. The smallest deviation in impurities can cause a wide difference in color or other physical properties of the enamel glass.

Enamel compositions are usually complex in formulation and composition. A common batch formula and the calculated yield of such a batch in the oxide form are shown in Table 1.10.

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TABLE 1.9

CLASSIFICATION OF ENAMEL MATERIALS[3]

Electrolytes	Colors
Borax	Cobalt oxide
Soda ash	Copper oxide
Magnesium carbonate	Iron oxide
Magnesium sulphate	Nickel oxide
Opacifiers	**Refractories**
Tin oxide	Quartz
Antimony oxide	Feldspar
Zirconium oxide	Clay
Sodium antimonate	Rutile
Fluxes	**Floating Agents**
Borax	Clay
Soda ash	Gum tragacanth
Soda nitre	Gum arabic
Fluorspar	Ammonium alginate
Cryolite	Bentonite
Whiting	
Barium carbonate	
Magnesium carbonate	
Litharge	
Red lead	
Zinc oxide	

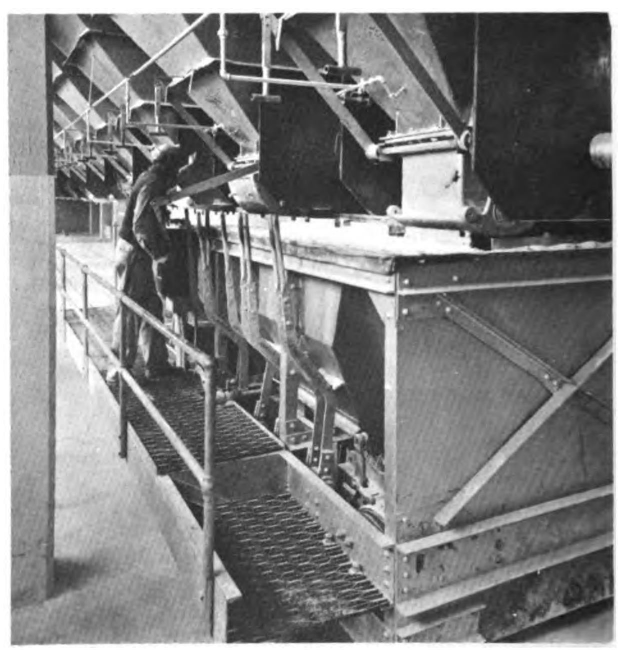

Fig. 1.30—Batch-gathering car gathering ingredients of raw material for a batch.

TABLE 1.10

COMMON BATCH FORMULA AND CALCULATED YIELD[4]

	Batch	Theoretical Melted Wt.	Oxide Yield				
Silica sand	204	204	SlO_2	204			
Anhydrous borax	293	293	Na_2O	90.2 B_2O_3	202.8		
Feldspar	293	293	Na_2O	8.8 K_2O	29.3 Al_2O_7	52.7	
			SlO_2	202.2			
Soda ash	88	51.5	Na_2O	51.5			
Soda nitrate	49	17.9	Na_2O	17.9			
Fluorspar	39	39	CaO	28.0 F_2	19.0 or		
			(CaF_2	39)			
Cryolite	20	20	Na_2O	8.9 Al_2O_3	4.9 F_2	10.9	
			or (NaF	12.0 AlF_3	8.0)		
Cobalt oxide	4	4	Co_3O_4	4			
Manganese oxide	6	6	MnO_2	6			
Nickel oxide	4	4	NiC	4			
TOTAL	1000	932.4					

Theoretical yield of glass: 932.4, or 93%. Theoretical volatile material: 67.6 or 7%.

The actual volatile loss will be greater than that indicated by the theoretical melted weight. The oxide yields in the table above may be totaled to give an oxide composition as follows:

SiO_2 (204 + 202.2)	406.2
B_2O_3	202.8
Al_2O_3 (52.7 + 4.9)	57.6
Na_2O (90.2 + 8.8 + 51.5 + 17.9 + 8.9)	177.3
CaO	28.0
K_2O	29.3
CO_3O_4	4.0
MnO_2	6.0
NiO	4.0
TOTAL	915.2
F_2 (19 + 10.9)	29.9

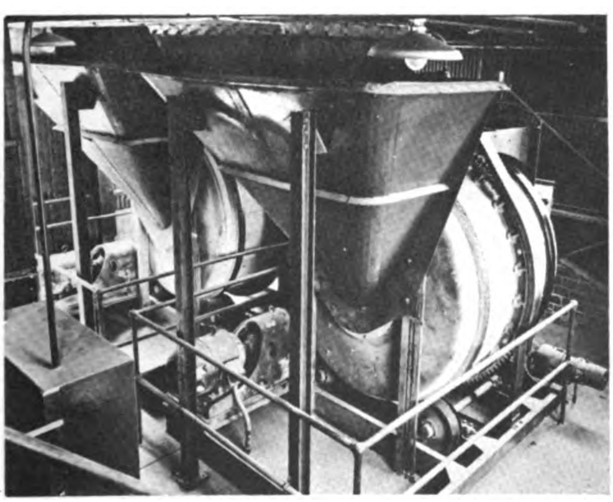

Fig. 1.31—Batch mixers.

Some idea of the enamel glass formulations may be obtained from the following examples of dry and wet process formulae for various uses:

DRY PROCESS CAST IRON PORCELAIN ENAMELS

Ground Coat

Silica	34.80
Feldspar	27.78
Borax	29.50
Soda nitrate	2.64
Red lead	5.28

Cover Coat

Feldspar	38.50
Borax (hydrated)	30.00
Sodium nitrate	3.50
Soda ash	3.00
Barium carbonate	4.50
Zinc oxide	8.00
Litharge	10.00
Fluorspar	10.00
Sodium antimonate	11.00

WET PROCESS CAST IRON PORCELAIN ENAMELS

Ground Coat

Silica	49.00
Feldspar	27.00
Borax	17.00
Fluorspar	7.00

White Cover Coat

Borax	28.70
Silica	24.80
Cryolite	20.30
Soda nitrate	2.30

Soda ash	4.10
Fluorspar	2.30
Litharge	11.30
Antimony oxide	6.30

Acid-Resisting White Cover Coat

Potash feldspar	8.70
Borax	11.60
Silica	25.80
Soda nitrate	5.10
Soda ash	14.30
Sodium antimonate	10.10
Sodium silico fluoride	1.70
Litharge	7.80
Zinc oxide	5.10
Whiting	3.00
Titanium oxide	6.80

SHEET IRON PORCELAIN ENAMELS

Ground Coat

Feldspar	29.30
Silica sand	20.50
Borax	29.30
Soda ash	8.80
Soda nitrate	4.90
Fluorspar	3.90
Cryolite	2.00
Manganese oxide	0.60
Cobalt oxide	0.40
Nickel	0.40

Cover Coat (Antimony White)

Nepheline syenite	18.30
Silica	25.70
Borax	23.07

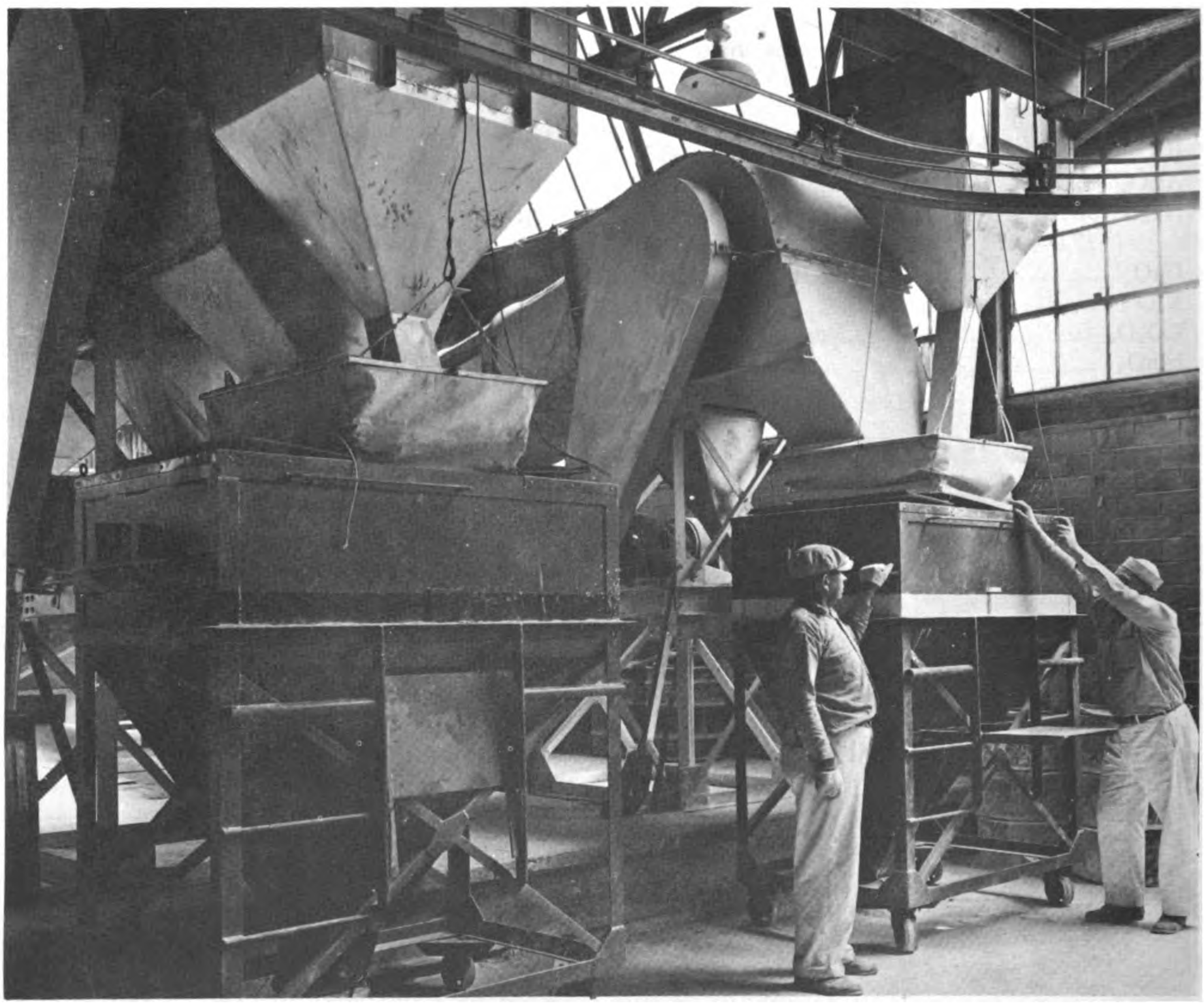

Fig. 1.32—Charging cars collecting the mixed batch, which is next hauled to and charged into the smelters.

Soda ash	6.34
Soda nitrate	2.96
Fluorspar	3.38
Cryolite	10.14
Zinc oxide	3.38
Sodium antimonate	6.76

COVER COAT (ZIRCON WHITE)

Dehydrated borax	23.40
Pyrophyllite	24.70
Silica	9.70
Na_2SiF_6	10.90
Fluorspar	6.00
Zinc oxide	3.20
$CaCO_3$	1.20
Milled Zircon	22.00
$NaNO_3$	1.50

COVER COAT (TITANIUM WHITE)

Feldspar	30.60
Cryolite	10.10
Zinc oxide	4.75
TiO_2	12.00
Quartz	30.80
Dehydrated borax	13.70
KNO_3	3.70
BaO_2	1.20

S. I. BLUE COVER COAT

Borax	27.80
Feldspar	25.80
Silica	22.30
Cryolite	4.30
Fluorspar	5.30
Soda ash	7.30
Soda nitrate	4.30
Manganese dioxide	1.00
Cobalt oxide	1.40
Iron oxide	0.50

MANUFACTURING PORCELAIN ENAMEL COATING MATERIALS

It is essential to compound the glass to obtain critical physical properties: the coefficient of expansion must be very nearly the same as that of the metal; the fusion range (the temperature at which the glass melts and bonds to the metal) must be within narrow limits; the degree of gloss, acid resistance, thermal shock resistance, opacity or reflectance, color, and ease of production must all be considered. After a particular formulation has been determined through research, development, and pilot-scale manufacturing—and full-scale production has been established—it is essential that all raw materials and the numerous manufacturing steps be carefully and accurately controlled.

The raw materials may be mixed in any standard

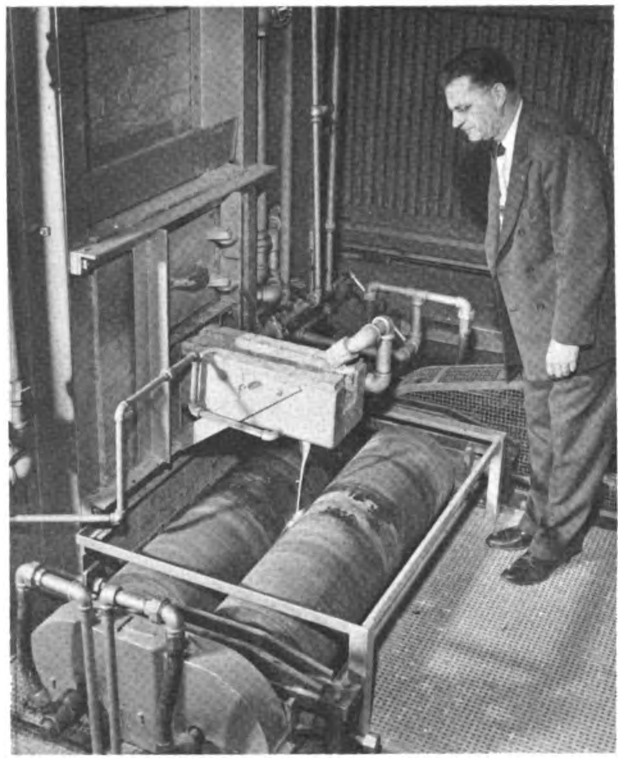

Fig. 1.33—Discharge end of a flake smelter, where the molten glass passes between water-cooled rolls.

Fig. 1.34—From the rolls above, the molten glass drops onto a vibrating conveyor at a lower level.

Fig. 1.35—The glass passes along on a conveyor, through a crusher (lower left corner), and then over two Syntron vibrating cooling conveyors.

type of dry mixer equipment. The mixer may resemble a cement-mixer or be any type of tumbling and stirring mechanism that will insure intimate and uniform mixing of the entire dry batch. Lumping and segregation of the raw materials must be avoided. As many as twelve to twenty different ingredients may go into a single glass mix.

The melting of these raw materials is accomplished in a batch or continuous type melting unit. The raw materials are heated in a refractory container similar to a glass-melting furnace, until the mass is completely molten and will empty from the furnace in a molten stream. During the smelting cycle chemical reactions take place to drive off volatile gases and form an alkaline or alkaline-earth boro-silicate, titanate, or zirconate glass of carefully predetermined physical properties. In a batch type smelter the cycle may be two to three hours at 2400° F. for 2500 pounds of glass. A continuous unit may deliver 700-1500 pounds per hour. Glasses of this type differ in the manufacturing procedures from window or bottle glass in their complexity and much less "fining" of the glass is required or even desirable.

The molten glass from the smelter must be chilled quickly to produce particles that are highly stressed, or friable, to insure ease of milling to a powder, which is the next major step in the preparation of the finished enamel. To accomplish this fritting, the molten glass may be discharged directly into a large volume of cool water or passed through massive, water-cooled, metal rolls. The first method forms small friable particles which must be dried; the latter, a continuous thin sheet which is deposited directly (no drying is required) onto a vibrating conveyor. Hammers and natural strains cause this sheet to fracture into flat flakes of uniform size 1/16"- 1½" in largest dimension. All "tramp" iron is removed, and the frit is usually packaged in 100-pound units for storage and shipment. Roll-quenching can be employed efficiently only with continuous smelting.

The batch type smelters are mostly of the open-hearth type. The batch is charged into the smelter from above and the heat applied after leveling off the batch. The fuel may be either natural gas or oil, but in general, a luminous type flame, with excess air to provide a good oxidizing condition, is desirable. Continuous smelters are usually constructed with a feeding mechanism at one end to force the raw mix into the smelter at a uniform rate and discharge the molten glass at the opposite end. There are several basic designs, but most are relatively shallow in depth. The molten glass remains in the smelter only long enough to complete the

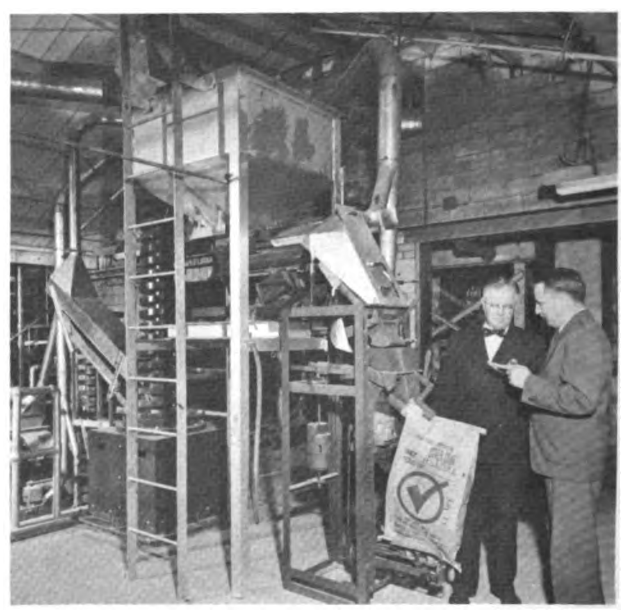

Fig. 1.36—The crushed glass, or flake, passes through magnetic separators, and then is discharged into bags.

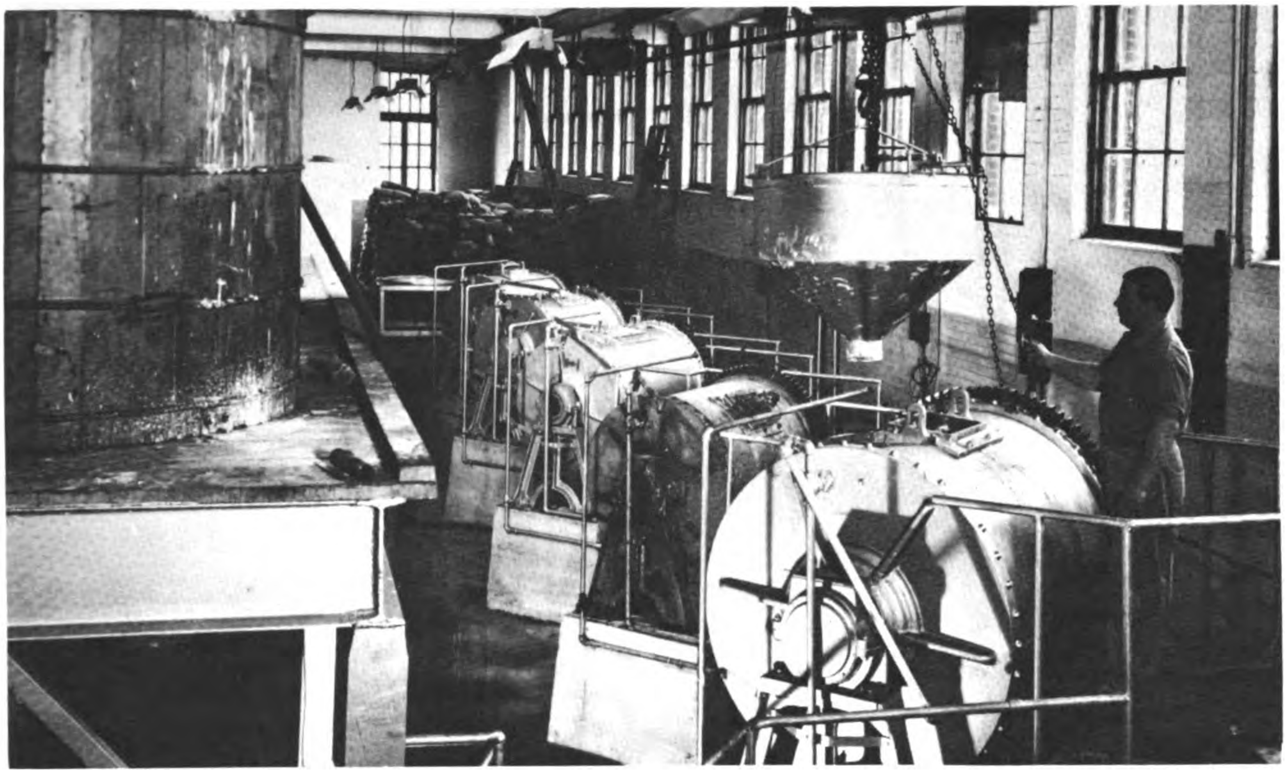

Fig. 1.37—The flake is milled with water electrolytes and coloring matter.

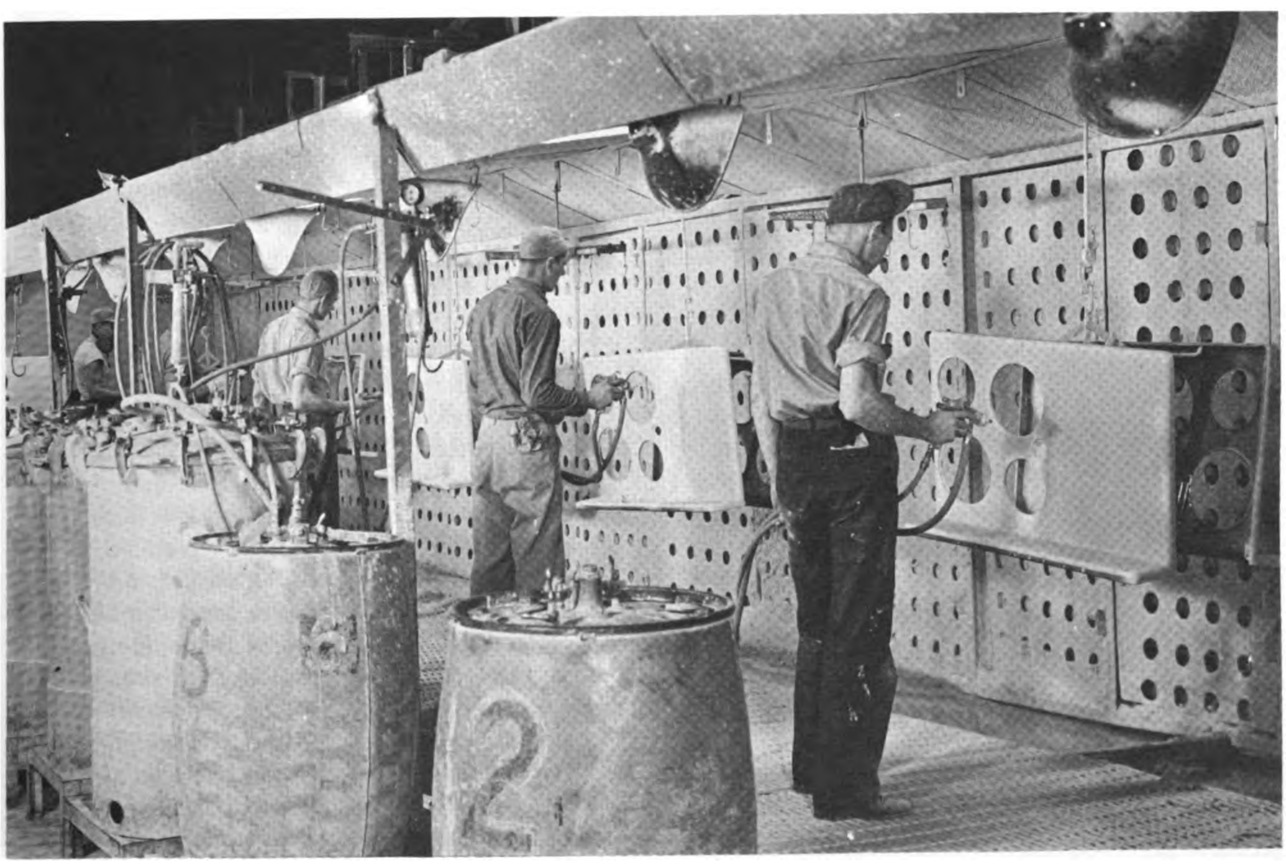

Fig. 1.38—Spraying white porcelain enamel cover coat on ground-coated range tops.

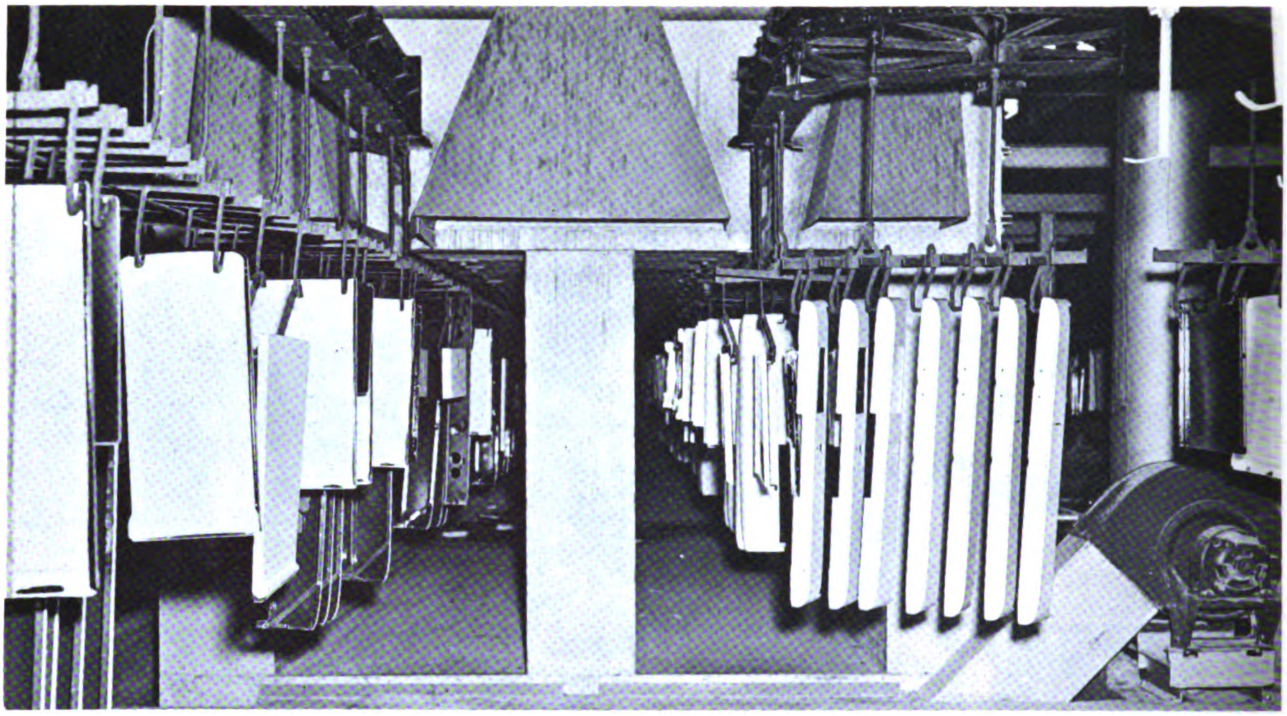

Fig. 1.39—Close-up of continuous furnace entrance.

chemical reactions, and a long firing time is not required. Fuel for the continuous smelters can be oil, gas, or electricity. Modern electric smelters, in which the electrical resistance of the molten mass acts as the heating element, are used in some plants. These smelters are efficient; but cost of installation is considerable, and their operation is economical only where cheap electrical power is available.

Quality control of the porcelain enamel frit manufacturing steps has been developed to a high degree. After the selection of standardized raw materials, all the manufacturing steps are carefully supervised and controlled by automatic equipment. This includes automatic control of the rate of fuel feed, raw material feed, draft and excess air conditions in the smelter, as well as the exact temperature cycles. The electric smelters are particularly adaptable to automatic cycle control of all phases. Usually there is a crew of technical personnel assigned to continuous testing of samples of all products. This group has full authority over acceptance of the finished product before shipment.

APPLICATION OF COATINGS TO METAL WARES

The application of the coatings to formed metal parts is a function of the organization manufacturing a completed product. It is customary for a manufacturer of porcelain enameled articles to purchase various types of coating materials from a few large manufacturers. The finish is applied to the specific article as a part of its manufacturing procedure.

The enameling processes can be divided into two major types; "wet" and "dry." The largest percentage of industrial enameling is carried on by the "wet" process. The enamel frit and related materials are selected for their specific properties of workability, durability, resistance to corrosion (by weather and chemicals), and general appeal as to appearance, including color and gloss. It is the usual practice to apply at least one ground coat and one cover coat of porcelain enamel on formed metal parts.

The ground-coat enamel contains adherence-promoting metallic oxides, such as cobalt and nickel. The cover coat is composed of a clear glass for dark colors and a highly opaque glass for white and pastel colors. If colors are desired, various ceramic coloring materials are added during the preparation of the enamel coating material.

In the "wet" process, the first step is to wet-mill the frit in a large, porcelain-lined batch mill in the form it is received from the frit manufacturer. In this step the mill is charged with frit, water, a clay to act as a suspending agent, various electrolytes to control the consistency of the enamel slip, and ceramic coloring materials, if color is desired. The milling is continued until the frit particles are reduced to a state of fine suspension in water—the average fineness being from 1% to 3% on a 200-mesh (U.S. Standard) sieve.

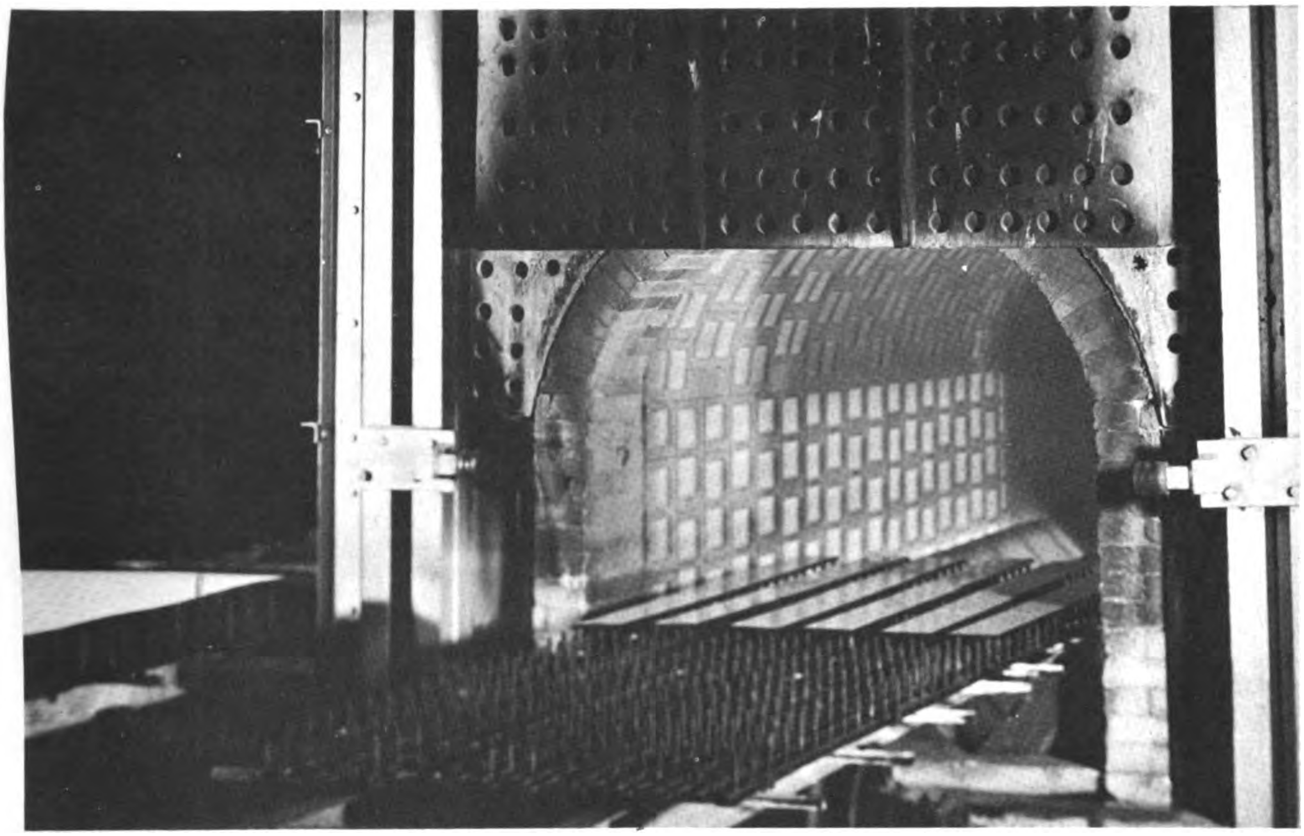

Fig. 1.40—View of a batch- or box-type furnace.

The ground coat is applied to the metal base by dipping, although it can be sprayed. The cover coat is applied to the fired ground coat by spraying or dipping. But before the ground coat is applied the metal base must be cleaned usually by chemical processes. The formed metal ware is submerged for an appreciable time in a hot alkali solution to remove grease, after which it is rinsed and then immersed in hot acid to provide an etched metal surface free of metallic oxide. These steps are followed by rinsing and neutralizing. Enamel is applied to the dry, clean, metal surface in a uniform thickness of about 1½ to 10 mils. After the wet enamel has been applied to the surface, the moisture is removed.

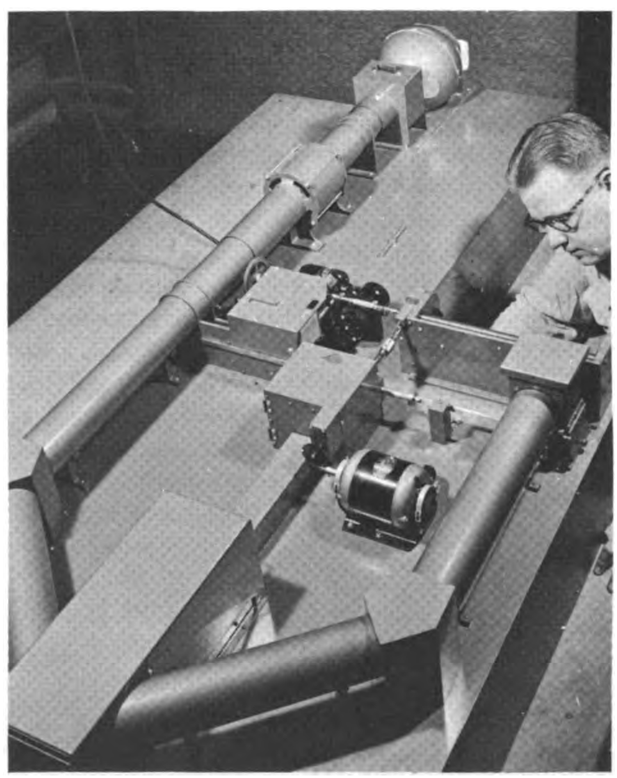

Fig. 1.41—A spectrophotometer checks for color matching.

In the next step the enamel powder is fused to the metal base. The fusion operation may be accomplished in box- or batch-type, muffled, fuel-fired furnaces or electrically heated furnaces. In the modern method the wares are placed on continuous conveyors which pass through a furnace of "U" or "straight-through" construction. In fuel-fired furnaces a muffle is present to prevent contact of the enamel with the waste gases of combustion during the fusion process. The formed metal

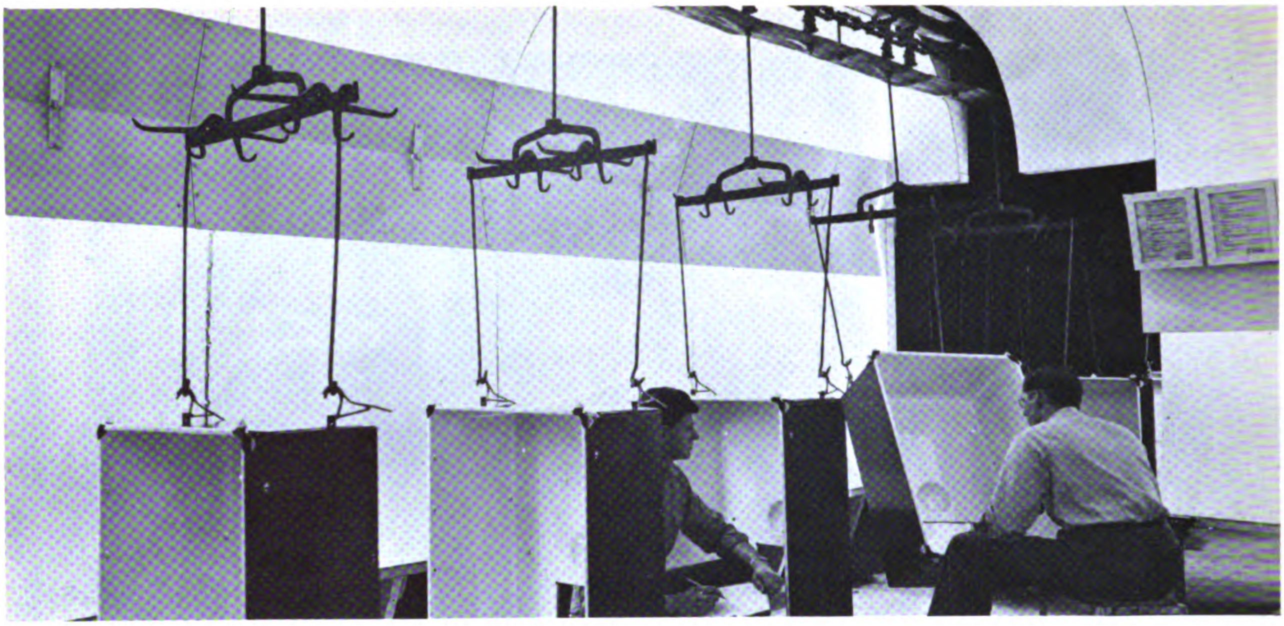

Fig. 1.42—Inspection booth.

ware with the raw enamel coating is heated until the enamel fuses and dissolves part of the oxide layer or part of the ground, or base coat, and becomes an integral part of the metal surface. The glass dissolves the fine particles of clay and coloring oxides; and as it cools after leaving the firing zone, the enamel forms a continuous glass layer thoroughly bonded to the metal base. The firing may take place at temperatures of 1500° to 1600° F. for iron and below 1000° F. for aluminum.

In "dry" process enameling the selection of the frit is specific for the particular qualities desired, but instead of wet-milling, the frit is dry-milled to a powder. This powder is dusted onto a previously cleaned metal base which has been coated with a refractory slush coating to form a ground coat, or bonding layer. The casting is heated to the fusion temperature of the enamel and quickly removed from the furnace, and the dry process powder is dusted onto the hot casting. The dusting is continued until the temperature of the casting drops below the softening point of the enamel. The work piece is again placed in the furnace and heated to the temperature at which the powdered frit will again melt as it is dusted onto the hot casting. This cycle is continued until the layer of enamel coating is built up to the desired thickness, which may be several times the thickness of enamel applied by the "wet" process.

QUALITY CONTROL

In each case much attention is paid to quality control, as there are many variables which effect the quality of the enamel coating. Quality control concerns itself with the following: proper strength of the cleaning solutions; fineness of milling; solubility of the enamel in milling liquor; proper rheotropic properties; type and quality of the metal base; thickness of coating; color and reflectivity; hardening time and temperature of firing; atmospheric conditions and cleanliness of the shop; and corrosion and mechanical shock resistance properties of the finished coating.

SUMMARY

The enameling process is exceedingly complex, but in its simplest form consists of applying glasses with selected properties and fusing at high temperatures to formed metal shapes. The process is one which requires considerable skill and technical control of operations. The industry has changed from an art involving a small batch or unit type of operation to a highly technical, continuous process, directed and controlled by highly trained engineers and scientists.

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METHODS OF TESTING ARCHITECTURAL PORCELAIN ENAMELS

By W. N. Harrison*

(Chief, Enameled Metals Section, National Bureau of Standards)

INTRODUCTION

What tests for poreclain enameled metals are needed by the architect to provide data for use in designing buildings? Are suitable test methods available? If so, where can descriptive literature be found? Do the required tests include measurements of the strength of porcelain enamel as a structural material These questions will logically occur to an architect who is considering the use of porcelain enameled metal in construction of a proposed new building, or in renovation of an existing one. The purpose of this discussion is to suggest useful answers to these inquiries.

Since the function of porcelain enamel in a building is to provide a protective and decorative finish for the basis metal, and it is not used as a structural material to support loads, no data on the structural strength of porcelain enamel as such, considered separately from the basis metal, is required for its selection. However, published test results do show that porcelain enameled metal specimens are somewhat stronger or stiffer than similar specimens without the enamel.[1]

Tests for the following properties of porcelain enameled metals are considered as having sufficient usefulness in the building industry to warrant their inclusion in this discussion: weather resistance, adherence, thickness, coverage, gloss, mechanical flatness of panels, color match, abrasion resistance, and (where high temperatures and large thermal gradients are involved as in space heaters and flues) resistance to heat and to thermal stresses. Tests for all of these properties are available; some have been adopted as standards by technical organizations and some have not. All are discussed briefly below.

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BRIEF DISCUSSION OF TEST METHODS

Weather Resistance

The evaluation of weather resistance represents one of those rare instances in which the results of a laboratory test have been checked against extensive, accurate observations of field performance and an excellent correlation established. The laboratory test is a simple one, namely the widely used spot test for acid resistance, which is a standard of the Porcelain Enamel Institute[2] and of the American Society for Testing Materials.[3] It consists of placing a small pool of 10% citric acid on the specimen for 15 minutes, washing it off, and classifying the effect, if any, by a specified procedure. This subject was treated in much greater detail in the paper on weather resistance given at this conference by D. G. Moore.

Adherence

It is important to know that the adherence of porcelain enamel to the basis metal, in panels to be incorporated into a building, is sufficiently strong to maintain the bond under reasonable conditions of flexure and impact. Even under severe abuse that causes a permanent distortion of the metal and fractures the enamel, the distorted area should tend to retain a protective residue of the enamel coating rather than being stripped bare. There is a standard test of the Porcelain Enamel Institute by means of which adherence can be evaluated quantitatively.[4] This test has also been adopted as a tentative of the ASTM.[5] The procedure involves first deforming an area on the porcelain enameled sheet metal about an inch in diameter, by using a hydraulic device to press a 1-inch steel ball on the face side of the specimen into a specified receptacle on the reverse side. This severe treatment normally causes the enamel to fracture and disrupt the surface continuity. The specimen is next tested to determine what percentage of the deformed area still retains adhering enamel. The test device permits lowering a head containing over 150 small probes, one-tenth inch apart and individually spring-mounted, onto the test area. These are rapidly scanned in sequence by an automatic device which records the number of probes that make electrical contact with the basis metal. A simple mathe-

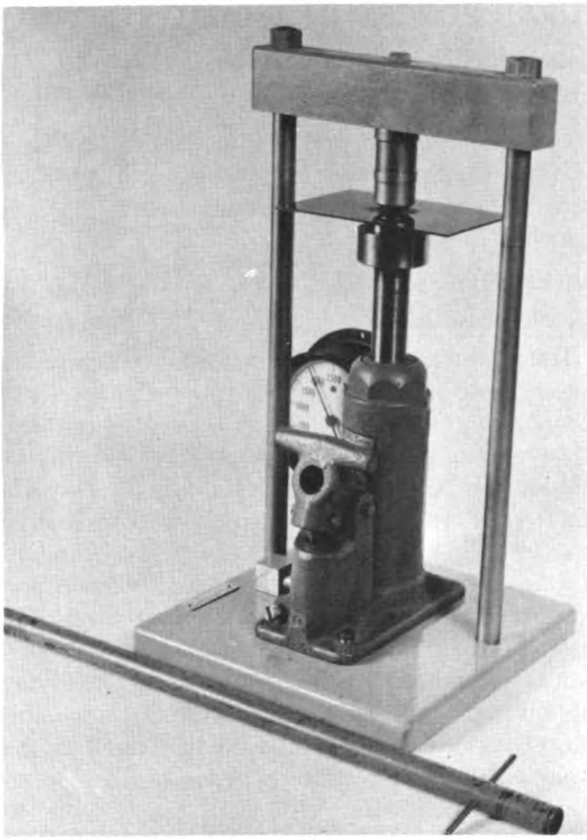

Fig. 1.43—Specimen-deforming apparatus for adherence test. An enameled sheet steel specimen, 4″ x 6″, is shown in position after being deformed by hydraulically pressing a 1″ steel ball on the face (upper) side into a receptacle of specified depth on the reverse side. The handle of the hydraulic jack is lying in the foreground, and the hydraulic pressure that was used is indicated on the pressure gage.

matical formula is used for converting this count into terms of the percentage of the deformed area on which sufficient coating was retained to prevent electrical contact of the probes with the basis metal. This value is known as the "adherence index" of the specimen.

Enamel Thickness

Considering the face side of an architectural panel, a measurement of enamel thickness is useful to insure that the enamel is not too thick. A satisfactory appearance gives assurance that the enamel is not too thin; too great a thickness, however, reduces the resistance to damage resulting from distortion.

For rapid inspection of large areas to determine nondestructively the thickness of porcelain enamel on a magnetic metal base, there are suitable instruments commercially available.[6] These operate by virtue of a magnetic circuit passing through a coil in a spool-shaped gage head and through the sheet of steel directly under the enamel where the gage head is placed. The reluctance of the magnetic circuit varies with the distance separating the gage head from other magnetic material such as the steel under the enamel. These instruments are calibrated to read directly in terms of enamel thickness, which is indicated on a dial. An entire panel may be scanned quickly by sliding the head across it in several directions while observing the dial readings.

If it should be considered necessary to determine the coating thickness over small radii, as at the flanged edges of panels having a magnetic metal base, this can be done by means of a different instrument that is also commercially available.[7] This apparatus measures the force necessary to pull a permanent magnet that is in contact with the enamel surface away from the specimen. Other things being equal, less force is required as the enamel thickness is increased, and by calibration the coating thickness is readily determined. Measurements are less conveniently and less rapidly made with this instrument, which is used chiefly for laboratory studies in which it is important to determine the enamel thickness over very small areas and on small radii.

When the basis metal is nonmagnetic the nondestructive measurement of thickness of the porcelain enamel coating involves the use of different principles. There is commercially available equipment that can be used for measuring enamel thick-

Fig. 1.44—PEI adherence meter. The electronic components are contained in the box at the right. A white 4″ x 6″ enameled metal specimen is in position for adherence evaluation following the deformation treatment. The deformed area of the specimen has been covered by lowering onto it the meter head containing over 150 probes, individually spring mounted. The test determines the percentage of the deformed area that retains sufficient enamel to prevent contact of the probes with the basis metal. At a "go" signal, the adherence meter automatically scans the probes and records the number of them that are in electrical contact with the metal. The results are converted into terms of "adherence index" by a simple mathematical formula.

Fig. 1.45—Coating-thickness gage. Used for measuring thickness of ceramic coating on non-magnetic metal. The instrument is described in reference 9. The specimen being tested is a turbine blade with a fir-tree type of root, that is visible at the right, below the upper knob. When the test head is in contact with the surface of the coating the instrument indicates the coating thickness, by virtue of variation in the inductance of a coil in the head with its distance from the metal in the specimen.

ness on nonmagnetic metals of exceptionally high electrical conductivity, such as aluminum and copper.[8] Comparable measurements are needed for specimens having basis metals of relatively low electrical conductivity, as exemplified by the 18-8 type of stainless steel. There is at present no instrument in regular production that will perform this function, but experimental ones have been made. The method of measurement is based on the change in inductance of a coil with the degree of proximity of a metal surface to which the coating being measured is affixed.

Coverage

Any structural panel of porcelain enameled metal that is visually acceptable will be sufficiently well covered on the face side. On the reverse side of a porcelain enameled steel panel, however, there should be inspection to determine that the metal is covered by the enamel. Poor coverage of localized areas due to partial "burn-off" of thin, irregular coatings, or scars made by the supporting tools during firing, may in time lead to corrosion of the metal induced by condensation of water on the reverse side of the panel or by water reaching that area through other means. At seashore locations this consideration is especially important.

The available instruments for measuring coverage (or lack of it) are probably unnecessarily sensitive, making it possible for a panel to appear poorly covered at spots while in fact these areas have a covering that consists of porcelain enamel which became heavily impregnated with iron oxide during the firing process. Such a covering might well prove adequate for the needs in many cases, but would be indicated as an area of defective coverage by the electrical resistance test described in the following paragraph. On the other hand, if there is sufficient coverage to avoid such indications on the reverse side of a panel one can be reasonably sure that the protection is adequate. Hence if considered as having a "built-in" engineering safety factor, the test may not be too severe, provided it is not applied to the edges of flanged panels.

The test referred to is known as the "swab test" (or "resistance test"), and consists of measuring the electrical resistance of the coating at selected areas by means of an ohmmeter with a self-contained source of constant voltage.[10] This known voltage is applied across the coating, between the outer and inner surfaces; one side of the circuit is grounded to the metal and the other side is connected to a wire which makes contact with a sponge or felt pad that is placed on the surface of the enamel and is saturated with an aqueous solution of an electrolyte, usually sodium chloride. As the swab is moved over the enamel surface, any discontinuity of the coating is indicated by a needle swing of the ohmmeter, showing lowered resistance. When this test is used, a logical course is to apply it only to areas indicated by visual inspection to be questionable.

Gloss

The appearance characteristics of a surface that contribute to what the eye sees as gloss, their measurement and relative importance, constitute a complex subject which is beyond the scope of this discussion, except to point out that some five or six separate factors are involved in making one surface appear more glossy than another. The term "specular gloss" refers only to the amount of incident light that is reflected as by a mirror. Several specimens placed in order of increasing gloss by eye might not be in just the same order when rated by instrumental measurement of specular gloss, but there would be a fairly good correlation between the two sets of ratings. Therefore the quantitative measurement of specular gloss is a reasonably good objective way of rating porcelain enameled metal panels according to visually observable gloss. A panel that could show a conspicuous highlight would have a higher specular gloss, generally speaking, than one that could not exhibit a conspicuous highlight. A test method for specular gloss has been adopted as standard by the Porcelain Enamel Institute, and is available from their headquarters.[11]

Mechanical Flatness

With a given source of illumination a badly

Fig. 1.46—One type of glossmeter. The white porcelain enameled steel panel being tested for specular gloss is at the lower right, and the gloss-head of the apparatus (which contains a light source) is being held in place by the operator. The fraction of incident light that is reflected, as by a mirror, is meaured with the aid of photoelectric cells.

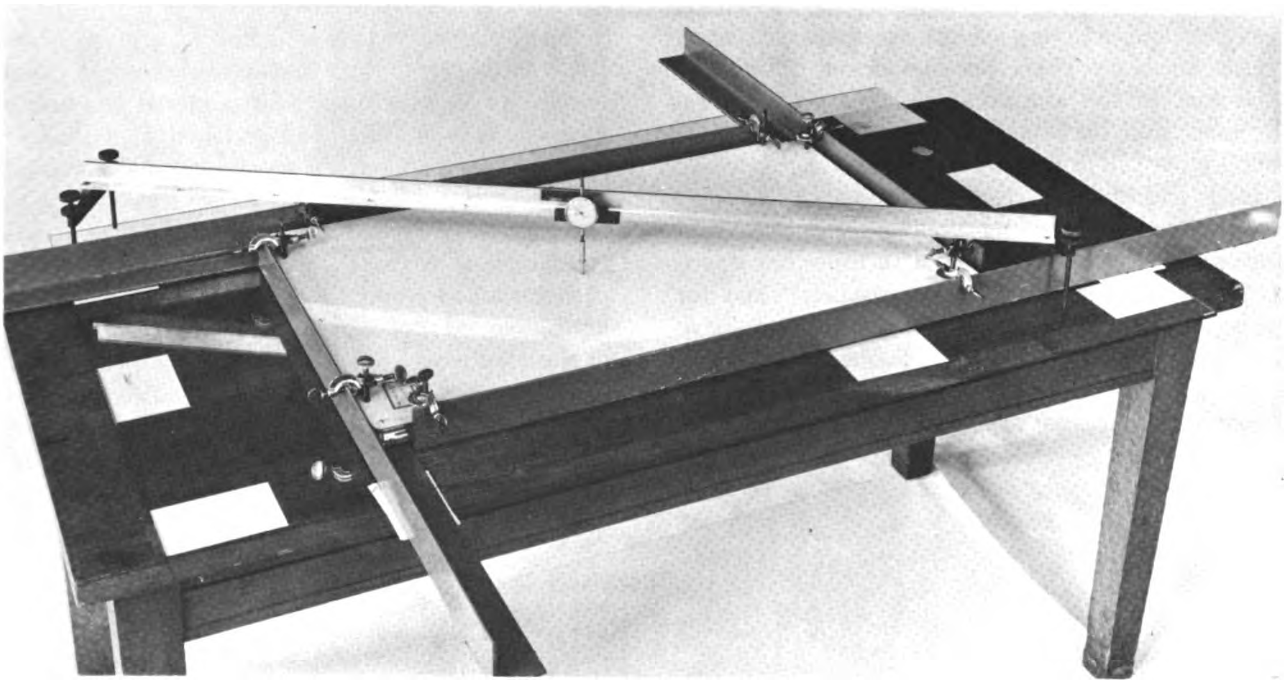

Fig. 1.47—Warpage test. A porcelain enameled steel panel is shown with its corners clamped in position on the flat surface of a six-foot table. The small white rectangles are shims for adjusting the position of the angle-iron frame members. The dial micrometer, as it is moved along the straight track, registers the waviness of the test panel, which is expressed numerically as a "waviness index" that is computed from data by a mathematical formula.

buckled panel of glossy material would exhibit highlights when viewed from a wide range of angles as compared to the more restricted range of angles from which highlights would be seen on a panel that was more nearly flat. Accurate meaningful measurements of deviations from flatness are not easily made, but there is a fairly simple method that will give useful results in many cases. This test method is a tentative standard of the Porcelain Enamel Institute,[12] and has also been adopted as a tentative of the ASTM.[13] The procedure provides for measuring the deviation of a panel from flatness in its free, unrestrained condition, and again when the corners of the panel are forced against a flat surface, in simulation of the installed position. It also provides for measurement after actual installation, if desired. In the first case two corners of the specimen, supported on a horizontal surface, are placed against a vertical flat surface, and the distance of the other two corners from the flat vertical surface are then measured with a rule. If the panel has a twist, at least one of the upper corners will not touch the vertical reference plane. In the second case the four corners of the panel to be measured are clamped against a horizontal flat surface, and the amount of buckling or warpage is measured with the aid of a dial micrometer. This micrometer travels on a straight track that is parallel to the reference surface; four traverses of the panel are made, two being diagonals between corners and two at right angles to each other across the center of the specimen, parallel to the sides and ends respectively. Mathematical formulas are provided for using the data to compute the twist in the free, unclamped specimen, and the "waviness index" of the clamped specimen.

Color Match

In some instances a quantitative evaluation of the color match between two panels is desirable. While no method for this measurement has been adopted as a standard for the porcelain enamel industry, there are devices for making color comparisons and expressing the results numerically.[14] The principles on which these instruments operate are somewhat too involved to justify their inclusion in this discussion. In most cases the best way to have such tests made is to arrange for their performance by a qualified commercial testing laboratory.

Abrasion Resistance

In many architectural uses for porcelain enamels the relative abrasion resistance of different enamels would probably not be highly important, since as a class they have good resistance to scratching, gouging and scraping effects as compared to organic finishes. There are significant differences, however, in the abrasion resistance of porcelain enamels, and for some uses abrasion resistance is important. An example is telephone booths, where pencils and other sharp tools are likely to be used in continual note-making, doodling and even vandalism. The Porcelain Enamel Institute has standard tests for surface abrasion resistance[15] and for resistance to gouging.[16] These test methods have been in effect for some years, and are now being studied with a view to revising them. The trend toward thinner coatings, for example, has been one of the changes making revision desirable, because the gouge-resistance test as originally designed works well for porcelain enamels that are in the vicinity of 15 mils thick, or more, but not as well on enamels that are in the 5 to 8 mil range, or thinner.

The test for resistance to surface abrasion consists of measuring the fraction of the initial gloss that is retained by the enamel when subjected to a specified abrasive treatment. This treatment involves placing a stated amount of a given abrasive on the specimen, together with a specified number of stainless steel balls of stated size and a given amount of water, all confined in a shallow cylinder clamped on the specimen with a rubber gasket at the contact area. The specimen with these articles attached is agitated rapidly in a horizontal plane with a specified mechanism until a predetermined amount of treatment has been administered. From initial and final determinations of the specular gloss of the specimen, the percentage of gloss retained is computed, and is taken as the "surface abrasion index."

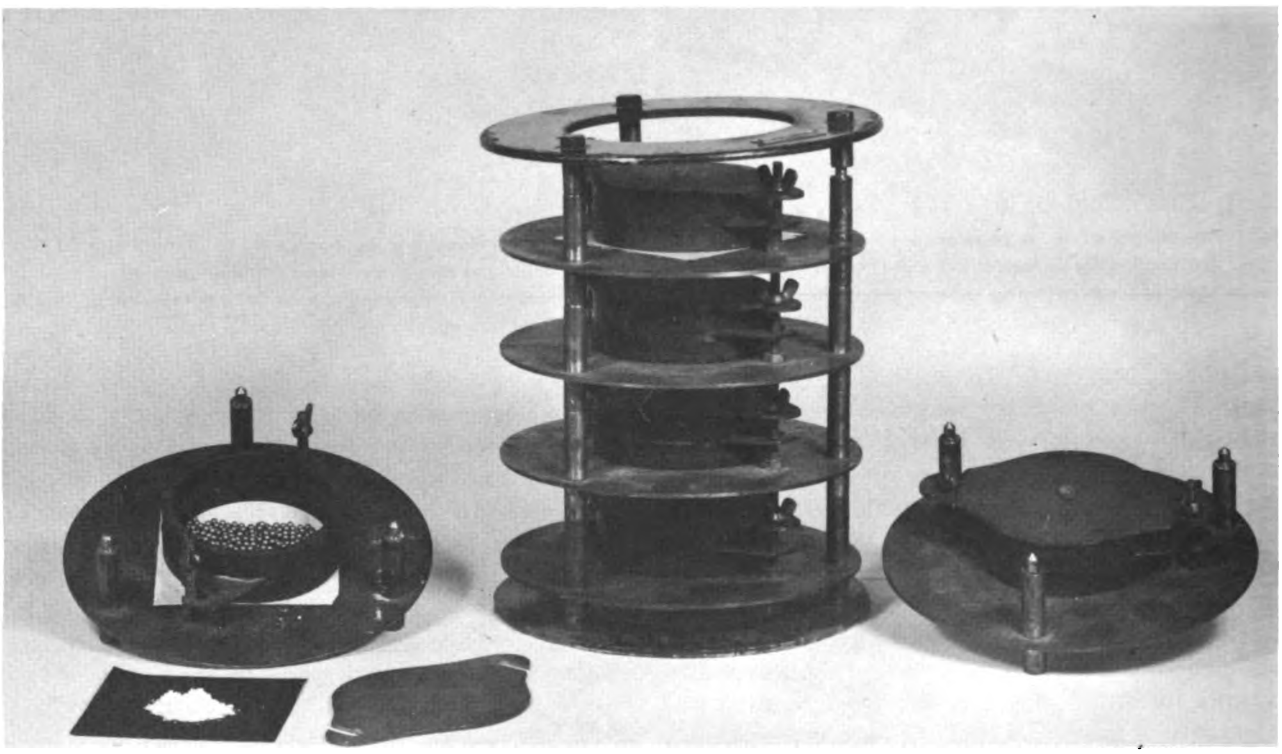

Fig. 1.48—Details of surface abrasion test. At left the porcelain enameled metal specimen (white square) is shown on circular brass base with superimposed, rubber-gasketed cylinder containing a charge of stainless steel balls. The charge of white abrasive powder is shown on a rectangle of black paper in the foreground, with the cover nearby. An assembly of similar units is at the extreme right; a hole at center of the cover, through which a charge of water was admitted, is closed with a cork. In the middle is a stack of units ready for simultaneous horizontal agitation.

The gouge-resistance test involves rolling a small steel ball on the surface of the specimen under various loads, and determining the load required to gouge into the enamel throughout 50% of the path of the ball. The PEI gouge-test equipment also includes facilities for substituting a phonograph needle for the rolling ball, and indications are that this device is better suited than the steel ball to use on thin porcelain enamel coatings.

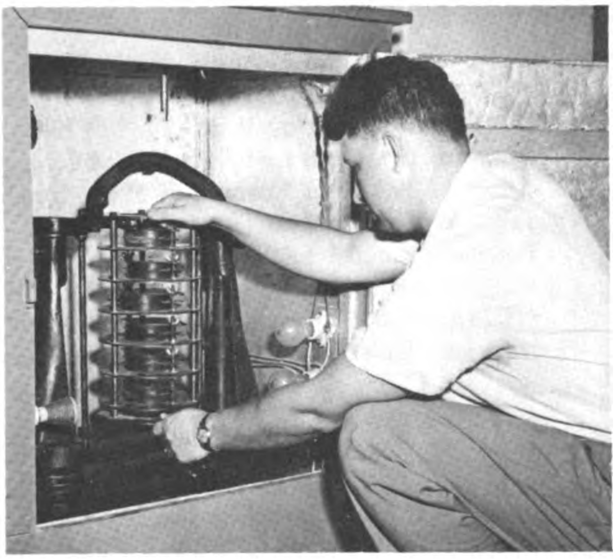

Fig. 1.49—Surface abrasion treatment assembly. Complete tier of six specimens mounted on circular brass plates, with the abrasive charge contained in rubber-gasketed brass cylinders that are clamped firmly to the surface of the specimens by bolts extending from base plates to covers. The tier of specimens is being mounted in an apparatus that will agitate the assembly horizontally in a fixed pattern at a specified frequency. Specular gloss determinations are made on the specimens before and after treatment, and the percentage of gloss retained is taken as the "abrasion index."

Other devices for testing abrasion resistance are available, but have not been adopted as standards by the industry.

RESISTANCE TO HEAT, TO HOT CORROSIVE GASES AND TO THERMAL STRAINS

The testing of porcelain enamels and ceramic coatings for resistance to high temperatures, and to corrosive action of hot combustion products or other gases at elevated temperatures, is an extensive subject in itself, which can only be touched upon here. It is most important, however, to distinguish between two classes of service which involve comparatively high temperatures.

The first of these classes of service is typified by flues for gas-fired furnaces. The efficiency of such furnaces is usually high, so that the temperature of the flue gases is moderate. The operation of these furnaces is normally intermittent and, when the heating flame is not burning, the chimney gases cool below the dew point and precipitate a liquid, acidic condensate on the walls of the flue. For this reason acid resistance and imperviousness are important requirements for the porcelain enamel coating on a steel flue liner. Porcelain enamel has been found to be sufficiently resistant to the maximum operating temperatures that are normally encountered in this service, and a high temperature ceramic coating is not required.

For service in which operating temperatures may reach the range of red heat, and in which acidic condensates are not a significant factor, high temperature ceramic coatings, rather than the conventional type of porcelain enamels, are indicated. An example of such service is that to which the inner jacket of a space heater is subjected.

No test methods specifically designed for use in connection with flues and furnaces have been adopted as standard. There are test methods described in the literature that may be used, however, provided they are carefully chosen. Thus in the case of porcelain enameled steel flue liners for use with gas furnaces, the acid resistance, enamel thickness and coverage tests that have been referred to above can be profitably used. The adherence test that was described cannot well be used without modification on curved specimens but qualitative versions of it are informative.

For high-temperature ceramic coatings to be used in the temperature zone that may be designated as "red hot," simulated service tests are probably next best to actual service tests. In the absence of acidic condensates, high acid resistance fortunately is not ordinarily required. Good adherence is important, and may be tested by a modification of the standard method 17 when the specimens are flat, otherwise in the same way as for gas-furnace flue linings. Resistance to high temperatures and thermal stresses, and to the corrosive action of high temperature gases, is best determined by subjecting specimens for extended periods to appropriate atmospheres and temperatures, with cyclic removal from the furnace and cooling to room temperature.

PROGRAM OF TEST DEVELOPMENT AND STANDARDIZATION

More than fifteen years ago a program of test development for porcelain enamels was established at the National Bureau of Standards in cooperation with the Porcelain Enamel Institute. During most of the ensuing time there has been a Research Associateship of the PEI working at the Bureau, in recent years with an assistant. The incumbent of this Research Associateship and members of the Enameled Metals Section of the National Bureau of Standards have worked with the appropriate committee of the Porcelain Enamel Institute (currently the Quality Development Committee) and with other representatives of industry in the

Fig. 1.50—Gouge-resistance test equipment. The load on the end of the lever is transmitted to the face of an enameled metal specimen (not visible) through a 3/32" steel ball under a hardened steel plate attached to the lower side of the lever. The specimen-support is moved slowly by a motor-driven worm gear, causing the loaded ball to roll on the specimen. The load required for the ball to gouge the enamel determines the "gouge resistance" of the specimen.

development of test methods which have been adopted over the years as standards. This work is still in progress, on a continuing basis. In order to keep the program in step with the changing needs of industrial progress, not only are new test methods developed, but existing ones are re-examined and revised as required.

In recent years the American Society for Testing Materials has taken cognizance of porcelain enamels and ceramic coatings as engineering materials. ASTM Committee C-22 on Porcelain Enamels and Ceramic Coatings was formed in 1949. This committee has been very active, and through its efforts a number of tests have already been adopted as tentative standards of the ASTM, and a variety of additional ones are being prepared for approval. The interest of the ASTM in porcelain enamels and ceramic coatings, and the effective activity of its committee C-22, are indicated by the symposium held in conjunction with the 1953 annual meeting of the ASTM [18]. The ASTM has had a substantial body of source material to draw on; namely, the standard test method of the Porcelain Enamel Institute and Enameled Utensils Manufacturers Council. It is a gratifying fact that a consistent body of standard tests for these materials is being formulated, many of which are already extant and others of which are in process of development. Fortunately most of the needs of the building industry for test methods can be met by test methods and equipment that are currently available. Architects and builders are urged to make use of them.

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1.1 GENERAL DISCUSSION

MR. W. N. HARRISON (National Bureau of Standards): Mr. Parker has shown by his slides that porcelain enamel is a very fine material from the standpoint of decontamination after exposure to radio activity. The question that I would like to ask is how does this fine property of porcelain enamel enter logically into the plans of architectural structures?

DR. PARKER: I would feel a little better if Mr. Ernest Dhein were to answer that question.

MR. ERNEST H. DHEIN (Office, Chief of Engineers, Dept. of the Army): The question raised by Mr. Harrison is a timely one but I would like to digress for a moment before attempting a direct reply. We are now on what appears to be the threshold of far-reaching changes in the basic concepts of design of architectural structures. While the role which porcelain enamel products will play in this drama cannot for obvious reasons be clearly delineated at this time, I venture the opinion that the potentialities are enormous. With resourceful leadership, aesthetic sensitivity, properly orientated research and the exercise of appropriate production controls, it is fully possible that porcelain enamel on metal and related media may one day be given preferential consideration in the basic design of important categories of structure. In fact, there appears to be no valid reason why this preference should not be extended to include the modernization of existing structures, notwithstanding the apparently considerable reorientation of constructional practices involved. In passing, may I say that my reference to important categories of structure was not intended to include gasoline filling stations, hamburger stands and the like, notwithstanding their undoubted usefulness to society.

While the considerations which might initially precipitate a porcelain enamel trend in structures are believed by some to be predominantly aesthetic in character, it appears fairly probable that engineering adaptability will be a factor of equal significance in the final evaluation. Mention of factors involved leads me to the deferred reply to Mr. Harrison's question, specifically as it relates to the problems of radiological contamination and decontamination so ably presented by Mr. Parker. As many of you no doubt are aware, some phases of this subject are in the sensitive category and cannot therefore be discussed at this time. However, there are a number of simple unclassified facts which I can tell you about which will make the contamination problem more understandable to those of you who have no background in this field. As differentiated from the concentrated, chemically active forms of radioactive isotope encountered in the laboratory, the radioactive residues produced by the detonation of an atomic bomb are widely dispersed and chemically inert. They usually associate themselves with dust particles or water droplets present in the atmosphere and in this form are superficially deposited on all forms of surface over a wide range of terrain; decreasing progressively in radioactivity with increasing distance from the point of detonation of the bomb. Their presence causes such areas to be radiologically contaminated. If people could be promptly evacuated from contaminated areas and would not be required to resume their operations in such areas for appreciable periods of time, the radiological hazard would be dissipated by normal processes of radioactive decay, and contaminant removal operations would not be required. However, where it is essential that people must remain in a contaminated area or must return at any early date to continue their jobs, the contaminant must be removed to the extent required to reduce the personnel hazard to acceptable tolerance levels. This process of removal is called decontamination. On some surfaces, decontamination is readily accomplished and is relatively thorough, whereas on others the contaminant clings tenaciously to the surface or migrates inward—as might be the case with highly absorbtive and porous materials—and removal is extremely difficult. In the latter case, gross surface removal techniques may be required in order to reduce the radiation level to acceptable limits.

The basic parameters which most strongly influence the contaminability-decontaminability characteristics of materials are relative smoothness, hardness, density, impermeability and continuity of surface. Since porcelain enamel possesses these properties to the optimum degree, it follows logically that it is the ideal material for use in exposed applications where radiological contamination and decontamination are potential problems. It might also be mentioned in passing that the parameters mentioned apply with equal force to biological contamination problems and, to a more limited degree, to chemical warfare. In the latter case, resistance to strong acids and alkalies is a factor of prime importance.

While architectural design problems are in the broad sense concerned primarily with the vertical surfaces of structures, the major radiological contamination-decontamination problems are associated with horizontal or near-horizontal surfaces such as roof decks, ledges, sills and the like. The roof problem is accentuated by the irregular geometry which characterizes the conventional and predominantly employed slag or gravel built-up roof surface. This type of surface not only acquires and retains more contamination than relatively smooth surfaces but is more difficult to decontaminate, especially if the contaminant particulates are associated with water droplets or a wet slurry.

Decontamination problems are further accentuated by the inadequate drainage conditions so often encountered on roofs. As a result of analyses of this nature, the question naturally arises, why not use porcelain enamel for roof surfaces? While it is recognized that the design and fabrication problems involved in such an undertaking would pose a very real challenge to the ingenuity of the industry, the effort conceivably might be justified. However, justification based on contamination problems alone would, under average conditions, be inadequate. Other and more substantial reasons for porcelain enamel roofs would normally be required; such as, for example, improved life expectancy, desirable light reflectance characteristics, improved appearance, cleanability and flexibility of design. A tentative summary of problems inherent in the use of porcelain enamel for the exposed surfaces of structures (interior as well as exterior) would not be complete—at least insofar as toxicological (biological, chemical and radiological) contamination is concerned—without mention of the item of jointing. The normally employed caulked joint contaminates readily and cannot be decontaminated short of physical removal. Even though the total area of joints would in most cases be relatively small, consideration of this phase of the jointing problem would be justified in any program of porcelain enamel exploitation. Mr. Harrison has conducted a fairly comprehensive investigation of the contaminability of jointing materials and may desire to comment at this time.

DR. HARRISON: Did you have in mind, Mr. Dhein, a discussion of the relative ease of decontamination of different types of joining materials? At this time, I am not prepared to go into that to any extent, except to report on the specimens that were prepared at the National Bureau of Standards. A number of different joining materials were used, and the results did show a significant difference in the different types of these materials. I believe that it would summarize the situation sufficiently well for the purposes of this discussion to say that joining materials which can be decontaminated are available and their identity can be determined. One source of identification is the Army Corps of Engineers. With reference to this investigation on joining materials, they do not by any means have the resistance of the porcelain enamel. But considering their relatively small area as compared to the large area of porcelain enamel, the total effect of contamination of the joining materials would not be significant when the best joining materials are used.

MR. J. SVEC (Ceramic Industry Magazine): I have two questions for Mr. Moore. I didn't quite understand what the effect is of the sun on the fading of the enamel. Or was there any effect?

MR. MOORE: No, there didn't seem to be any effect. We did several tests that are used in the paint industry for evaluation of paint coatings. In the so-called weather-o-meter, we have an arclight radiation plus sprayed water over the film. We couldn't see any visible effect at all from that treatment after 500 hours. On most paints, as I understand, the deterioration is quite pronounced after only 100 hours. We also tried the arclights without any water spray, and, in that case, after 500 hours we could see no effect. Perhaps there was a very slight change in color, but it was so slight, it could hardly be detected. That only occurred in some enamels.

MR. SVEC: My second question is this—I noticed your figures on loss of gloss were fairly relative. Were these losses in gloss perceptible to the naked eye?

MR. MOORE: Yes, they would be. The so-called glossmeter measures in a rough way what you see by eye. In some cases, the glossmeter will show you a greater loss in gloss than actually you think it should be when gauging by eye. But we think the meter might be more reliable than the human eye. But we have, say, 80% of the initial gloss retained. You start with a gloss maybe of

5.5% of the incident life that's reflected at 45°. After weathering, perhaps it's down to around 5%. Unless you have a storage panel to compare it with, you are not going to see, by eye, any change in gloss. In other words, this wouldn't be objectionable to the owner of the building.

MR. W. DERINGER (A. O. Smith Corporation): Mr. Chairman, with your permission, I'd like to make an observation, and then ask a question. The subject for discussion this morning was the Fundamental Properties of Porcelain Enamel. It seems to me that one of the fundamental properties of porcelain enamel has merely been overlooked. I think it is one of the very important ones. Dr. Parker in his discussion mentioned vinyl coatings and other plastic materials, and they showed up none too well compared to porcelain enamel when it came to decontamination. One of the properties in which porcelain enamel shines is the fact that it has zero water absorption. If you look up handbooks on plastic materials, they always list water absorption as one of its properties, because all plastics have some water absorption. Porcelain enamel has no water absorption, and for many applications where you are involved in trying to protect a metal surface from a solution of any kind, porcelain enamel does an outstanding job. The question I would like to ask is directed to Mr. Chase. He mentioned the fact that the first porcelain enamel homes were built some 25 years ago. I wondered if you or anyone else here knows how these houses look today. What is their present condition? And what about the maintenance that has been required during these years?

MR. DANA CHASE (Editor, Finish Magazine): I was afraid I might stick my neck out by not checking up on those homes before I mentioned them. Those aren't necessarily the first houses. The two houses I referred to were built in 1932 and 1933 for the World's Fair, and were, I think, good examples of architecture and very well received. I think one was moved to the north side of Chicago, and I will make it a point to check up on that on my return. I can't report on it now.

We were in conversation last night, and one chap reminded me of a house using porcelain enamel shingles in some nearby suburb of Cleveland. I saw it a number of years back. It has, I think, a complete porcelain enamel roof and porcelain enamel siding of a thin shingle material. I think it was considered at the time a very inexpensive type and probably a questionable type when compared with the more normal type of structure an architect would normally design. Nevertheless, this house is in very excellent shape today and hasn't required any upkeep. Now, I think there should be someone here who can confirm that. Mr. Hutt?

MR. HUTT: We built this house in 1932, and it's still in excellent condition. The only maintenance to the house has been on the glazed block of the chimneys, which had blown away. The porcelain is in excellent condition.

MR. CHASE: Now, we referred to thousands, literally thousands, of filling stations. As I mentioned, I don't believe that's pushed porcelain enamel forward in the architectural profession. But it certainly does give plenty of examples to check performances on ones that are properly designed and properly installed. I used to make a check on that personally through Standard Oil of Indiana and talked with the filling station owners and the ones who were responsible for maintenance. It was my observation over a period of several years that they had practically no maintenance except for one factor. That's been mentioned here and it is an extremely important one. It has undoubtedly improved under present conditions but it needs even more improvement. That is the matter of caulking. There are other answers to that now which I don't think we'll take time to go into here; but in the early days, the caulking was questionable. It wasn't studied for particular installations and the joints were wider than they are today, so that it became a common thing for the filling station operator to take a caulking gun and replace the caulking about every three or four years. To my knowledge, that is the only maintenance required for one of these filling stations. And of course it has reduced tremendously the amount of upkeep for painting, etc. Does that answer the question?

MR. N. CANNISTRARO (The Bettinger Corp.): My question is addressed to Dwight Moore. With a definite interest by architects for mat and semi-mat finishes for architectural applications, I would like to ask what is being done, or has been done, regarding tests to test mat and semi-mat finishes where gloss is not a definite requirement?

MR. DWIGHT MOORE: I mentioned in my talk that we do have some semi-mat and almost full mat enamels under investigation now. We have them exposed only in the Washington, D. C. location, because we found that the same pattern was followed by all four locations so that we could get our information, we thought, from just exposing them here in Washington. Those have been out now since 1946, and I looked at them last year and they are doing very well. They are much easier to clean them the old type of full-mat enamel. The ones that are colored don't seem to show any fading. We don't ourselves work on the development of enamels and development of mat enamels or anything like that. Probably some of the representatives from the various frit companies could talk with authority on what is being done in the development of mat and semi-mat enamels.

DR. SPENCER-STRONG: There appears to be a greater interest in lower mat enamels, and I presume that maybe it will reach a level and come back again. In most of these enamels, you can't test the acid resistance as readily. However, I can see no reason why, if necessary, we couldn't go to weight-loss methods or gloss-loss methods with an instrument to determine these factors. But there has been a great deal of improvement in so-called semi-mat enamels in the past three or four years.

DR. McINTYRE: Mr. Moore brought out the point that even low, D grade enamels that would end up as a full mat would definitely protect and give protection. Now I'd like to find out if possible, what would happen to the color. Would it really change so radically that it wouldn't be accepted?

DR. SPENCER-STRONG: I should think there would be some change in color. Even with a full-mat Class D Enamel. You'd have a build-up of a slight film of silica on the surface of the enamel and that would change your color. It would go grey.

MR. RUSSELL W. GREER (Pemco Corp.): I think Mr. Holcomb from Detroit can give us some information on porcelain enamel roofs that I know have been installed 25 to 28 years. It might be interesting to hear from him as to how they stood up on residential structures.

MR. J. W. HOLCOMB (Wolverine Porcelain Enamel Co.): You are right, Mr. Greer. We made our first installation in 1924. That was on a residence and was done in a maroon color and those shingles are just as good today as the day they were installed. Dr. Spencer-Strong said, I believe, this morning that we did things by accident and in that instance we came up with at least a Class C acid resisting enamel. Later, in 1925 we installed a pale blue roof in Detroit in another residence and that roof is still in excellent condition. Since that time we have made many, many thousands of shingles in various colors—blue, white, greens. Most of you have seen them on the service stations of Pure Oil Company and the Sun Oil Company. In the past 12 or 15 years, we have furnished shingles for many hundreds of Howard Johnson restaurants on the coast and in Florida, and all of those have stood up very, very well. I believe that demand for porcelain enamel shingles today is greater than ever before because of the excellent service they have rendered through the years.

MR. DAVID E. GAREN (Bureau of Ships, Navy Department): My question is addressed to Dr. Parker. Could you explain what would happen if a coated steel specimen was subjected to radioactivity and the coated area had a defect, such as a pin-hole, which revealed the base metal? Would the radioactivity be confined to that immediate area or would it spread throughout the metal, and how would this effect contamination?

DR. G. W. PARKER: I can only answer that generally. Corrosion provides the only way through which radioactivity can move, and my experience has been that in most cases even when there is a flaw in porcelain there is always enough of the enamelling left to give it semi-resistance. On the other hand, you are talking about a very small problem if you are talking about pin-holes. The contamination of course is proportionate to the area, and unless you are talking about degrees of contamination that are astronomical compared to things that I have experienced, a pin-hole doesn't mean anything. One sample we tested would be decontaminated to two or three counts a minute and its twin would show a hundred counts a minute. So it is necessary to regard average values. These are still, however, very minor problems.

DR. McINTYRE: I see that our allotted time for this period is now over. I'll now turn the meeting back to Mr. Hutt, the General Chairman.

Session 2

USES OF PORCELAIN ENAMEL IN BUILDING DESIGN

THE DESIGN, MANUFACTURE, AND ERECTION OF ARCHITECTURAL PORCELAIN METAL PARTS

By Benjamin B. Loring*
(Vice President, Seaporcel Metals, Inc.)

Not too many years ago most of us regarded the use of a porcelain enameled sheet as an inexpensive way of covering the back wall of a butcher shop or delicatessen store or the exterior of a hamburger stand. At that time many store fronts and delicatessen and refrigerator cases—the types used by butchers and delicatessens—were covered by what we in the industry called "stock sheets."

These sheets were of standard size, usually 24″ or 36″ wide by 5′, 6′, 7′, or 8′ long, obtainable in two basic colors; namely, white and black. They were sheared on the job to fit particular needs and attached to the wall with roofing nails. To dress this up, the nails were covered with batten strips fastened to the wall with nickel-headed screws.

In fact, I remember that one of our customers asked us to help him design something "different" for a large market, and one of our men came up with a scheme in red, white, and blue. It certainly did attract attention. But now, when I think of some of the monstrosities that were created, I really shudder.

As time went on, we realized what a wonderful material we had at our disposal, and as architects and engineers became aware of the merits of porcelain enamel, the industry engaged architects to help us design what we thought at that time would be the answer to the trade.

We then stopped manufacturing stock sheets and went in for 16-gauge enameling iron. These sheets, instead of being flat, were formed into panels, flutes, radius bends, compound curves, bull-nose shapes, mullions, fluted sections, and other special shapes. We developed a method of fastening that concealed the screw heads. Lugs or clips were spot-welded to the panels, and it was through the use of these clips that the panels were fastened to the background.

We also discovered that we had a wide range of colors, and as the frit manufacturers improved their product, we were able to obtain, in addition to the normal glossy finish, finishes that were matte and semi-matte in appearance. We were no longer restricted to a few colors and a single finish. We were proud of our ability to give architects and designers any colors they desired. These enamels were resistant to weather and withstood atmospheric conditions, consequently we feel today that we have an everlasting product.

We soon discovered that the fastening clips welded to the panels were damaged in the course of erection, and because of rusted attachments the panels would become loose and fall off the building. Today all manufacturers of architectural porcelain parts use stainless steel clips of good design.

However, even though we have a material which, from a usage point of view, we have merely scratched the surface, we know that there are limitations. Architects and designers must keep within the limitations, for otherwise—no matter how careful the manufacturer or the erector may be—a worth-while job cannot be done. Therefore, in addition to the attention that must be given to the over-all design of the building to be covered with porcelain enameled materials, particular attention must be given to the design of the individual pieces which makes up the whole unit. In addition to the shape, another matter of proper design is proper size. Some types of panels should not exceed 12 square feet; others, because of their shape, can be larger. The same is true with returns; they should be kept to such a size that they will not warp.

Most companies that specialize in architectural porcelain parts have drafting and engineering departments and will be glad to assist architects and designers in the preparation of their details.

Today porcelain enamel is being accepted not only for hamburger stands and the like, previously mentioned, but also for the fronts of buildings, spandrels, mullions, copings, etc. Some of these applications are in the form of a facing material; others are in the form of an actual curtain wall.

An example is the Standards Federal Savings and Loan Association Building in Los Angeles, California. This is a nine-story building with porcelain laminated to honeycomb aluminum. Another curtain wall job is the Orthopedic Hospital in Seattle, Washington.

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The Statler Corporation is putting up a new hotel in Hartford, Connecticut, using porcelain enamel materials. The San Francisco airport building, which will require an area of over 100,000 square feet, is also being done in porcelain enamel laminated sections, as are several other large projects. There is hardly a building that is being designed today that cannot use porcelain—and the advantages are numerous. The architect can allow his knowledge of art and color to be reflected in his designs, for he now has a material that has color and shape and is versatile in its application. The interest shown in porcelain enamel curtain walls is almost unbelievable. Inquiries are coming in from all over the world.

After the building project has been designed properly, the component parts must be carefully manufactured. Certain firms that are recognized as specialists in the field of manufacturing architectural porcelain enameled materials have acquired a certain "know-how" and technique which are of the utmost importance.

For porcelain enameling work a special type of steel is used; namely, enameling iron. Enameling iron is a low carbon steel that is processed with an additional heat treatment by the steel mills. The low carbon content and special treatment make the steel particularly adaptable to the enameling process. It has a high resistance to sagging, consequently there is a minimum of warping during the firing process that is necessary to fuse the glass.

After the sheet has been formed and all corners properly welded and ground smooth, the parts are ready for the metal preparation cycle. Here the parts are cleaned, pickled, and finally neutralized. This cycle removes whatever foreign matter might be on the metal, etches the metal, and provides a thin, inhibiting film that prevents rusting before the first enamel coating is applied. The part is now ready for the application of the first, or ground, coat.

In normal operations it is necessary to apply the ground coat on the steel prior to any decorative or finish coat. The ground coat has a predominately blue-black color. This color is due to the fact that the ground coat contains the oxides of cobalt, manganese, and nickel which are necessary to secure the unusual bond between the glass and the metal—a bond that is a fusion of the glass to the metal.

After the ground coat application, the part is fired at a temperature of approximately 1550° F. This fuses the glass and develops the adherence.

To this glass surface the cover or finish ooat is applied. This coat can be any one or more of a variety of colors and may be any degree of gloss that is desired. More than one color is obtained by the use of stencils. Decorations and designs are likewise obtainable through the use of stencils or by special art work. After spraying, the enamel is permitted to dry and that portion of the enamel not required is brushed off. Each color is a separate coat; and each coat is fired separately. Porcelain is also applied on the back of the parts, which serves as a protection against rust and helps to keep the parts flat.

Due to the tremendous amount of research made by the frit manufacturers, we now have porcelain enamel finishes which are resistant to cold acids and are also weather resistant even under the most severe atmospheric conditions. Changes in temperature will not affect this finish.

A visit to the color-matching departments of most porcelain enameling companies would give one the impression that they were in the novelty business, because of the various color samples that are in evidence—colors that have been submitted for matching. It is not unusual to see a color-matching man use a piece of a man's tie for a color; nor is it unusual for him to be called upon to match pieces of granite, marble, or other similar materials. These latter not only require color matching but also the production or submission of a composite color with a texture that approaches the original piece of granite, marble, or stone.

The quality of our porcelain enamel today is high and is so maintained because of the controls exercised at each stage of processing of the materials. This control starts in the mill room where the various types of frit or glass are ground and mineral oxides added for the desired color and extends through every operation—pickling, spraying, and fusing.

After the parts have been completely manufactured, they have to be installed or erected. The erection of these parts is just as much of an art as their design and manufacture. Unless the erector knows how to handle and how to install the pieces, all the designing and manufacturing care will be for naught.

It does not matter which trade handles the materials. What does matter is the knowledge that the mechanic possesses. I have seen good jobs erected by sheet metal workers, by carpenters, and by tile setters. I have also seen a well-manufactured article completely ruined by installers who lacked care or experience in the handling of the material.

Not too long ago it was the practice for general contractors to handle the installation of porcelain enamel building materials. However, today most architects insist that the firm that manufactures the material be required to erect the material, so as to have undivided responsibility.

In order to obtain a good installation job, the building must be furred out. In certain localities wolmanized or creosoted furring may be used. In other localities, due to certain code restrictions, metal furring must be used. Where metal furring is required, it should be fabricated from a material which will not rust easily. All attachments, such as screws and bolts, should also be non-corrosive.

The importance of proper furring cannot be overemphasized. Recently I inspected an installation that looked like waves on a rough sea, and found that the general contractor, instead of using 1" x 3" furring strips, used the lumber in which the parts were crated. Moreover, he used small nails to attach the panels to this crating lumber. Most of the panels were loose and could be removed easily by tugging lightly at them.

The furring strips should be attached to cinder-block buildings with case-hardened, steel-cut nails; galvanized toggle bolts, if the building is of hollow-tile construction; and drive-in expansion bolts (or a cartridge gun where union regulations permit), if the wall is concrete.

The job should be so designed as to permit a minimum of 1/8" space between the panels. This space is necessary in order to obtain a good caulking job.

There are many good caulking compounds on the market. However, they will not be effective if they are merely smeared over the joints. A good procedure is to "butter" the flange of the panel with the caulking compound and then, using a caulking-gun, insert the caulking compound for the full depth of the flange and to within 1/16" of the face of the panel. If a job is properly caulked, the caulking compound or mastic will last a long time and will be leak-proof. In addition to the mastic used for caulking, weather-proofing is also obtained by the use of extension sections of rubber or plastic.

Lately, we have been fortunate that there have not been too many disputes as to which union has the right to install porcelain enamel building materials. It has been agreed by the unions that prior usage will determine which union or craft has the right to handle the material.

After the porcelain has been completely erected and the joints caulked, the entire job should be wiped down so as to remove all traces of any marks left by the mechanics and also to remove any excess caulking which might have been permitted to accumulate on the face of the building.

Close coordination between the designer, manufacturer, and erector is necessary. A good policy to pursue is for architects and designers to incorporate in their specifications a provision to the effect that all porcelain shall be fabricated and enameled in accordance with the specification issued by the Porcelain Enamel Institute. All responsible architectural porcelain enamel manufacturers have subscribed to this set of specifications.

PORCELAIN ENAMEL CURTAIN WALLS AND THEIR UTILIZATION IN THE BUILDING INDUSTRY

By E. X. Tuttle*
(Vice President, Giffels & Vallet, Inc.)

"We anticipate that in the next generation steel building products will be to the steel industry what the railroads were to it before 1900 and what the automobile has been to it since 1900."

Ben Chapple, Assistant Executive Vice President for Marketing of the United States Steel Corporation made this statement to me recently, and David Austin, United States Steel's Executive Vice President, supports it.

Building products or materials for such products make up more than 20% of the production of both Aluminum Company of America and Reynolds Metals Company. Alcoa is highly enthusiastic regarding prospects for a substantial increase in the building products market in the next 5 or 6 years, and Reynolds expects its market to double in that period.

These manufacturers of raw materials believe that the use of metal wall panels, both exterior and interior, will be the principal reason for this startling market increase.

The only known satisfactory method of applying a permanent color other than grey to metals is that of porcelain enameling; and enamel, in the case of steel, is the most satisfactory corrosion preventive. Thus, porcelain enamel curtain walls, in my opinion, will be a major, if not the most important, factor in the development of building types during the next ten years.

Since the first skeletal structures were built late in the 19th Century, we have been screening them with curtain walls. But these walls, until recently, have been constructed of about the same kind of masonry used since Caesar's time—bricks and stone. A majority of buildings today depend upon a metal, concrete, or wood skeleton for stability entirely independent of walls and are made habitable by wrapping a skin around the framework.

The human effort involved in laying one heavy brick upon another, in multiple layers, to make a curtain is excessive. About the time the Carnegie building was completed in Pittsburgh in 1895 the need for a large, light building unit was definitely established. By far the most promising answer to this need is the factory-manufactured non-masonry panel.

It is conceivable that at some future date we may develop a means of wrapping a building in fabric and spraying it with a plastic material which will serve as satisfactory protection from the elements and which will remain substantially unchanged in certain desirable qualities throughout the life of the building. However, during what appears to be a long transitional period we must have, what I have called for about 20 years, a "big brick." This must be a unit which can be used for enclosing any size or shape of building.

We have had and are now using a number of different types of units and panels with varying degrees of success, and for general as well as special purposes—concrete blocks which were the first "big bricks"—we are using combinations of asbestos, metal, glass, wood, and concrete in both plain and sandwich forms. To date none of these units has had anything like the universal application to our skeletal structural era that the brick and the stone slab had to their preceding structural era. Of course, this is because our present method of building lends itself to a greater variety of surfacing.

Other reasons for what appears to some of us as the slow development of curtain wall units are: the necessity for conditioning the public to acceptance of non-masonry units; building code limitations; the reluctance of labor to accept new materials and techniques; labor's jurisdictional squabbles; and a lack of unprejudiced research and development.

The building industry does not have the homogeneity of aim and action of less-complicated industries and, as a result, comparatively little research has been accomplished that has not been slanted toward particular materials and processes. I feel that salutary results could be realized by the association, for unprejudiced research and development, of the aluminum, steel, enameling and other elements of the building industry interested in the promotion of light-weight curtain walls.

The importance of porcelain enamel in my discussion of the subject of curtain walls is out of all proportion to the number of words which I propose

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to devote to it. This is due to the fact that, though porcelain enamel can be used on a variety of metals in any shape, its use depends upon the development of architecturally desirable and workable curtain wall *systems,* upon which I will elaborate later.

It appears to me that the principal purpose of this paper in this series of discussions is one of pointing out conditions and trends which will influence the development and use of building curtain walls, and porcelain enamel-surfaced walls in particular—a market prognosis.

The application of, and the need for, lightweight curtain walls is not confined to any one category of buildings. In some form or other and with varying degrees of success they have been applied to factories, laboratories, schools, stores and other retail facilities, houses, and a variety of institutional buildings. They are probably as generally applicable to buildings as plumbing fixtures which, interestingly enough, are usually surfaced with porcelain enamel.

When I hung out my shingle and took my T-square in hand in 1930, I spent many hours at dinner parties, and occasionally on a platform, carrying the torch for non-traditional architecture. Though we see some rather sorry examples of a transitional architecture in traveling through the country, the Greeks and Gothicists have become history. It is a rare industrialist, indeed, who requires a Georgian front on the office end of his plant. School Boards are interested in plans and light and air. The architect specializing in house design is seldom asked to design a colonial cottage or (and I shudder at the thought) a 1920 English house. Though the public is basically conservative in its opinions and tastes it has accepted the idea that a new architecture is in the making. As a result, materials which can be fabricated with present-day manufacturing facilities are acceptable and, further, imitative materials are not mandatory or even desirable. Thus, a practical porcelain enamel curtain wall is not, or will not be, confronted with the hurdle of convention, as has been the case in the past.

The United States is building and rebuilding on a scale and at a rate probably never before experienced by any civilization or era. To me this is so important a factor in our consideration of porcelain enameling curtain walls that I want to devote some time to its consideration. Few people realize the strain that this rapid change may place upon some of our building product manufacturing facilities.

Until about the first of this century communities in this country, following the pattern of European communities and due to our being part of a predominantly agrarian society, had developed in knots at seaports and along rivers. Houses often served as offices and small shops. The first factories, like houses, were multi-storied. As the cities grew, they became vertical to take advantage of desirable, centrally located property.

The development of modern communication and transportation facilities, coupled with congestion resulting from the move from farms to cities, has made it both possible and desirable to decentralize. America is spreading out, and American society is tending to become nomadic. Factors influencing the decentralization trend are so numerous and strong that there is ample reason to suppose that it will continue. Need for security in time of war, for reduction in distribution costs, for proximity to raw materials, and for better living conditions for personnel are all important factors in this trend.

Perhaps as powerful a reason as any for the move to open spaces is the almost universal acceptance of the one-story plant (and let me say in passing, the one-story house and even the one-story school). A modern plant with its manufacturing area on one floor, having large open spaces, ample artificial light, accessible overhead services, movable or mobile material—handling equipment, and easy access to rail and truck docks, is so much more efficient than the multi-story mill building of the past that a manufacturer operating in the old structures finds it difficult to compete. Frequent changes in product and product design require a flexibility in plant layout and services that just cannot be obtained in most old buildings. Even the most modern and flexible structures are sometimes scrapped before they are 20 years old because their owners realize that new facilities will improve the quality of their product and make operation more profitable.

American industry is continuing to rebuild its plant and to increase its plant at the same time.

Increase in population, increase in use of appliances, change from specially built to factory-built units of numerous kinds, along with the decline of the crafts, are important elements in the expansion of our manufacturing facilities.

Changes in manufacturing centers are followed closely by changes in population centers, and requirements for schools, entertainment facilities, commercial and various institutional establishments change with them.

It is my opinion, based upon the conditions which I have outlined, that building and rebuilding will continue at a comparatively high level for some time to come.

Light-weight curtain walls are being used in important quantities; they are acceptable, but not for all purposes. The climate for their further development is highly favorable. It remains for the industry to devise panels which are more satisfactory than those manufactured at the present time.

Metal curtain walls are applicable to practically every type of building and suitable for all wall surfaces. There is a hesitancy on the part of owners and architects to use other than masonry apron walls; that is, walls below sash, in factories, but I am confident that objections to this use will be overcome by use of steel fenders, curbs, and plates.

Building codes and underwriter's regulations limit the application of metal panels, in some instances, to an importance little greater than that of paint over masonry. However, these limitations affect so small a proportion of the total market for curtain walls that the industry need not be worried seriously by them. Moreover, it appears that solutions permitting conformity with existing codes are in sight, and some modifications of codes can reasonably be anticipated.

Though various fibrous and plastic materials undoubtedly will continue to be used in curtain walls, metal may well be the predominant building wall surface in the fairly near future; and the materials will be, in all probability, steel and aluminum. To prevent corrosion, steel (except stainless) must be protected; and for color other than grey, both must be coated. No more permanent and satisfactory coating has been found to supply both protection and color than vitreous enamel. Because of the popular and highly desirable practice of introducing color into our building designs it appears that porcelain enamel is, and will continue to be for some time, a natural agent for the maintenance of a healthy competitive market for both aluminum and steel as curtain wall materials.

Because I am sure that my distinguished colleague, Bill Lescaze, who follows me on this program, will discuss the matter of color at some length, I do not propose to dwell upon the subject long. I do want to say, however, that the ability to employ permanent colors lavishly in our architectural designs opens up infinite possibilities for improving living and working conditions in our society.

Professor Wilby, one of the most thoughtful architects I have known, who was my senior design instructor at the University of Michigan, once said, "Because it makes of a house a prison, window sills over 30" from the floor are a chief cause of divorce in the United States . . ." A similar remark might well be made about the drab masonry walls constituting the principal views from so many millions of our windows. Color and variety of form can contribute immensely toward overcoming architectural monotony.

In spite of the enthusiasm evidenced by the building industry for light-weight curtain walls, we must remember that this method of enclosing buildings is considered new by the public.

To receive universal acceptance, innovations must not be just better but must be *substantially* better than the old. Brick walls can leak and for that be cursed, but a leaking metal curtain unit will be cursed and condemned.

There are a number of satisfactory curtain wall units on the market, but I doubt if any of their manufacturers would claim that any of them is the ultimate, even for the special purpose for which it was designed. Several of the curtain wall systems are admirably suited for plain surfaces with few openings, but introduction of windows and doors and other openings or breaks in the plane, presents weathering problems which have not been satisfactorily solved. The application of metal curtain wall units to the finished type of buildings requires as much, or more, of the skilled labor we try to supplant in factory and field, as is required in traditional building systems.

I believe that we are nibbling at the edges of curtain wall design, with only an occasional probe at its base. This is natural at this stage, but the need for a multi-purpose panel is so pressing that I am sure the industry will find the means to accelerate its development and then the means to manufacture it.

I do not propose to review in any detail the work accomplished to date upon curtain wall design, but there are several characteristics which will bear some consideration.

Design of metal wall panels is frequently treated as if lumber were the material used. We saw it up in suitable lengths and nail it to metal studs or girts. We hope we can make joints at openings tight by caulking and clamping. We use the panels as forms, for application of interior masonry which, basically, we are trying to eliminate. Often the panels are flat, imitative of stone, but warping and resultant highlights give an objectionable effect. There is a tendency to use attachment and closure methods and devices which are fairly precise but inconsistent with the tolerances required by the nature of field assembly of buildings.

Encouraging results can be seen in the development of the cross-section of the units themselves. There is no doubt that several satisfactory designs will appear very soon, but the problem of jointing has not been solved, or to my knowledge, is anywhere near to being solved appropriately. Perhaps Alcoa's pneumatic window seal foreshadows a solution to the whole matter of jointing.

Architects often contribute to the design of building products, and those fitted to do so are sometimes engaged to design and develop new products; but in the main they select available materials and products and use them as appropriately as possible in the buildings they design, though they also encourage the development of needed products. It is in an architects *customary* role that I want to close this paper.

I would like to describe to you the kind of curtain wall I would like to have. We may never get it, and if we do there may be reasons why we would want something else; but right now I would like to have a curtain wall *system*, not just a unit.

I would like to be able to extend fingers from a building skeleton to which fingers would be attached light, metal curtain units having their supporting grid system either between surfaces or exposed, all of which could be applied from inside the building. Joints between units and between units and sash and doors should not only be weather-tight but flexible enough to permit expansion and movement of both curtain and building. All should be capable of installation by semi-skilled labor.

The units themselves should be available in several sizes to permit adherence to scale of the structure. The outer surface should be broken in a pattern to eliminate "oil canning" and the inner structure should provide for a moisture barrier as well as for the application of various interior finishes. Further, I would like to have a fair range of colors from which to make selections.

This is quite an order, but I am confident that it will be filled. The market for such a system is not limited to the great office buildings in our large cities, but includes schools, houses, commercial buildings, factories, and institutions in every village, town, and city in the Nation.

AN ARCHITECT'S VIEWPOINT OF PORCELAIN ENAMEL USED ALONE AND IN COMBINATION WITH OTHER MATERIALS

By William Lescaze*
(Architect, New York, N. Y.)

We are here today to discuss a new kind of building material, one which an architect might use.

I would like to begin by stating what I believe architecture is, or what it should try to be—*not just* buildings, but real architecture created by architects. I have never had any doubt about what architecture is: architecture *is* and *must be* the living, tangible, visible image of the ideas and ideals of our fellowmen; the expression of the civilization which they have achieved at this time —*now*.

Although I don't agree with many of the statements attributed to the Great White Father of United States architecture, I should like to quote some of his recent remarks with which I am heartily in agreement: "What the American people have to learn is that architecture is the great *mother-art*, the art behind which all the others are definitely, distinctly, and inevitably related. Until the time comes when we *speak of Art* we immediately *think of buildings*, we will have no culture of our own."

And I believe that we have achieved a civilization which rates the qualification of *culture*.

I have often stated—and I state it again today—that modern architecture was not brought about by the advent of new materials. I am almost tempted to say this now even more forcefully: in its beginning, modern architecture had nothing to do with new materials. This may sound shocking to some of you. Let me explain.

Modern architecture came about because it was realized—first by a few of us, then by many more—that the copies or adaptations of other architectural styles were inept and had failed completely in their primary task of providing the *needs* and expressing the *ideals* of the 20th Century. Modern architecture came about—*regardless* of new construction methods and new building materials—simply as a long over-due attempt to create architecture *again* as the true expression of a civilization —created, mind you, and *not copied* from older civilizations.

I do not mean to minimize the contributions made by many technological developments. As one of the first users of some of them, I am in their debt and acknowledge it gladly. Nevertheless, technological developments as such had very little to do with the advent of modern architecture.

BRAB asked me to give you an "architect's appraisal of porcelain enamel", and BRAB further advised me "to pick up where Mr. Loring leaves off". This is not an easy task, but it is certainly a challenging one. And it is all the more challenging because BRAB and the BRAB Institute are dedicated to the stimulation of research and thereby to the advancement of technology—both of which organizations I respect, and to which I would like to make some contribution.

Let me make a personal confession; at this moment I happen to have the good fortune of being a balanced—that is, a happy—architect. An architect loves to be busy; and I find myself busy simultaneously in at least four of the major areas in which an architect wants to be of service to his fellowmen.

One of these areas is creation; that is, the design of one or two new buildings, and I am doing this at the present time for my beloved Manhattan.

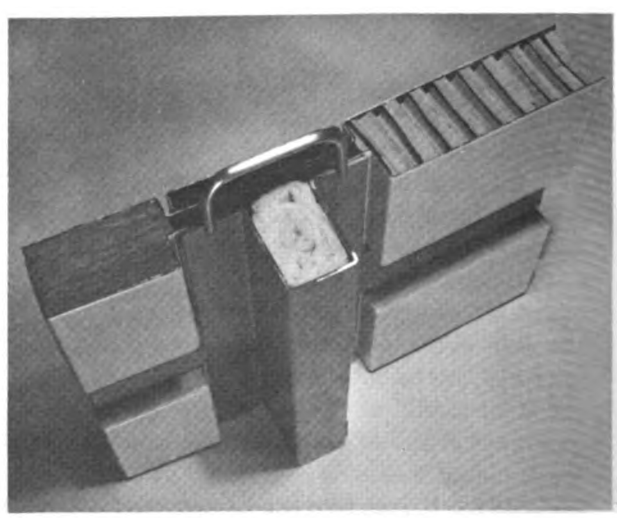


Fig. 2.1—Wall system developed for Porcelain Enamel Institute.

* Mr. Lescaze has been a leading figure in the field of modern architecture. He came to the United States in 1920. He established his own firm in 1923, and was in a partnership with offices both in New York and Philadelphia from 1929 to 1934. Since 1934 he has had his own architectural firm in New York City. In 1949, Governor Dewey appointed him Commissioner of the New York State Building Code Commission, which is preparing a new performance type building code for the entire State of New York. Mr. Lescaze is a Fellow of the American Institute of Architects. He has been retained by the Porcelain Enamel Institute to direct research on a porcelain enamel curtain wall.

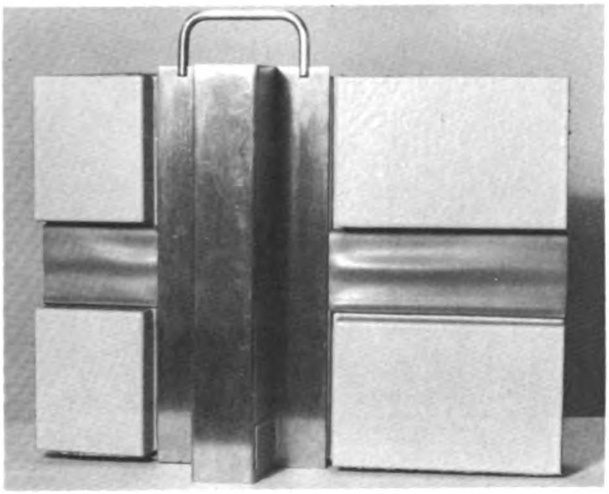


Fig. 2.2—Front view of pilot model.

Another area is exploration in the field of construction; and, as some of you know, I have recently directed a research project of the Porcelain Enamel Institute for the development of a curtain wall. I hope to carry the project still further, with the help of my friends in the Institute.

Still another area is formulation of the rules which regulate building construction. I need not tell you how progress of the art of building has been retarded by obsolete building regulations. As a member of the New York State Building Code Commission, I am helping to prepare an up-to-date *performance* type building code for the State of New York. Two portions of this code, both applicable to all residential buildings, have already been completed.

And finally there is the area of the correlation of the visual arts—sculpture, painting, mosaics, and landscaping—with architecture. I believe that if we value our civilization we must create or help to create a true and complete image of it. It takes more than just a single one of the arts to accomplish this. When all of the arts are brought together properly they harmonize as they otherwise never do. And when they harmonize, they express mankind and they do move people. I would urge, therefore, that all of us accept the thought—and carry it into reality—that at least 1 per cent of the cost of construction of all our important buildings, public and private, be earmarked and used (as a matter of good business) for participation of the Arts—sculpture, painting, stained glass, and mosaics —at the direction of the architect. But I must stress here that this should be done on the basis of one *very* important condition: that *Art* be *not* merely an afterthought—something irrelevant and pasted on later, as happens all too often—but that it be the active participant with architects in the development, design, and creation of the structure, and so create for us true and complete images representative of our civilization.

In addition to the areas of an architect's possible activity which I have just described—that is, design, building material development, building regulations, arts, and architecture—there are also those of city planning and industrial design, in which, I believe, an architect is prepared by training to be of service to his community.

There is no doubt in anyone's mind today that porcelain enamel is a good building material; that is, a good material for exterior walls. The big question, however, is: is the material ready?

Here is a building material that doesn't require costly maintenance and offers a choice of an infinite variety of colors that are permanent. Let's recognize the significance of this, because the use of color is becoming extensive—much more than it ever was.

In the course of the research for a porcelain enamel curtain wall, which we undertook for P.E.I., we received an amazingly large number of inquiries; that is, from architects who had definite projects on their drawing boards and who wanted advice regarding availability of the material, construction details, and estimate of costs. Let me emphasize here that architects are always eagerly searching for new and better building materials. These inquiries tend to bear this out.

You are all acquainted with the G. M. Technical Center near Detroit and its use of porcelain enamel wall panels, and you know many of the details.

You will be interested in Figs. 2.1, 2.2 and 2.3 which show the porcelain enamel curtain wall system which we developed for the Porcelain Enamel Institute.

You probably know that the United Mine Workers organization is about to build ten hospitals. I had the pleasure of discussing their problem with their architects, and I was told that they had decided on a wall unit consisting of a window and a porcelain enamel panel (Fig. 2.4), which was developed by Truscon Steel, a Division of the Republic Steel Corporation. Mr. Souder, who is presenting a paper at the 4th Session, will, I am sure, tell you more about this interesting development.

Let's go back to the uninhibited architect. What sort of a choice does he have today when he must decide on the type of exterior wall of the building he is designing? Because of codes, because of costs, because of a lot of other factors, his choice is still restricted mainly to brick, limestone, and

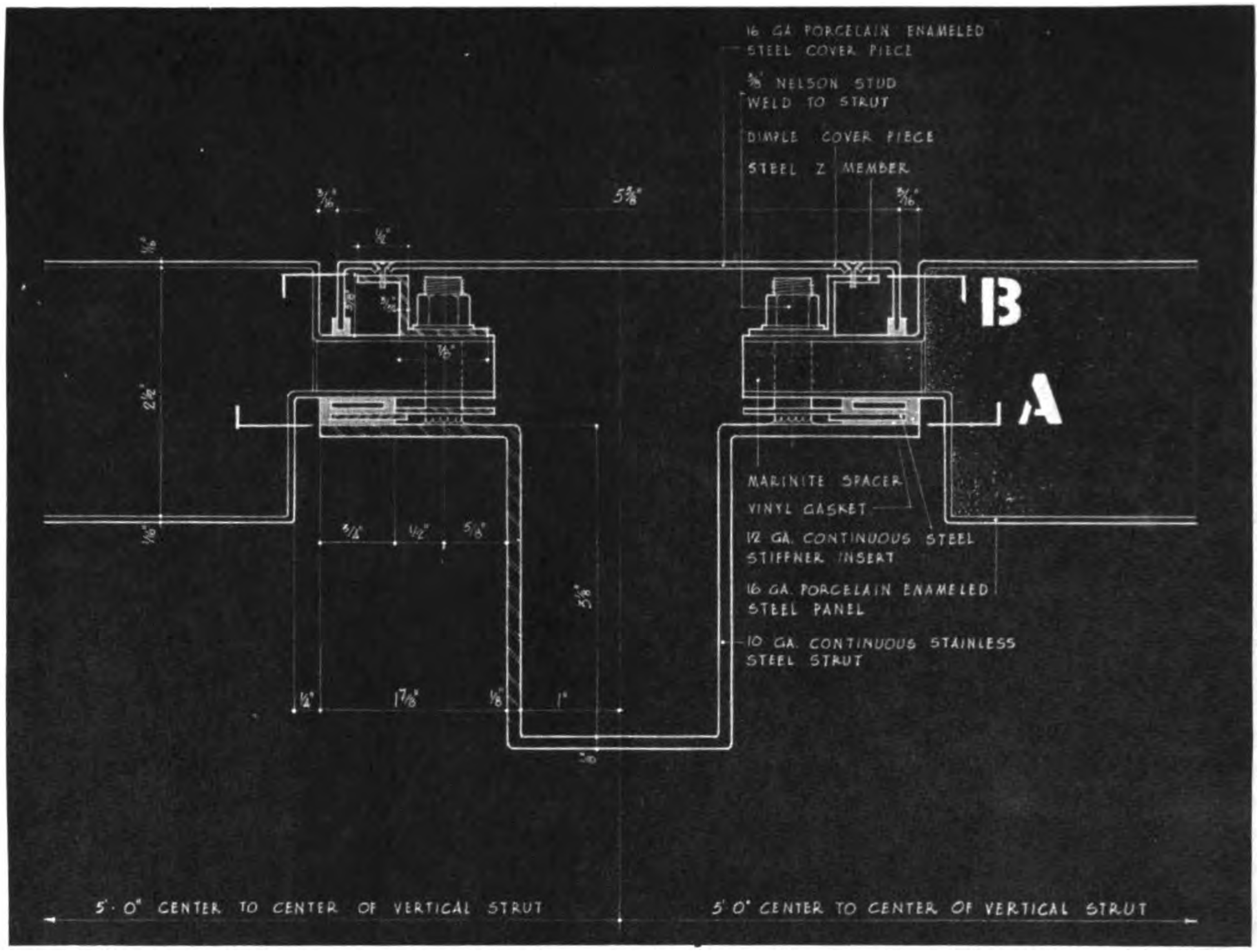


Fig. 2.3—Details of Porcelain Enamel Curtain Wall System.

marble for the lower stories, but certainly—inevitably—brick, brick elsewhere. The Assyrians, 2,000 or more years ago, had the same choice. However, we are not ancient Assyrians—and let us rejoice.

The unequal struggle between stone and the London climate has reduced Westminster Abbey to a state of dilapidation that, unless large-scale restoration is promptly undertaken, may make many parts of the building unusable.

This Westminster Abbey pinnacle (Fig. 2.5) is typical of stonework that is crumbling in face of the grime, soot, and chemical impurities in London's atmosphere. Near the top are two thin copper bands that temporarily prevent the pinnacle from collapsing.

In recent years several architectural firms have tried to develop new types of exterior walls. Such action signifies that they were no longer satisfied with the conventional types of wall they had inherited from their predecessors and that they had come to realize that masonry walls are anachronistic and ill-suited to skyscraper and large-scale construction (Fig. 2.6).

On the whole, most of these individual efforts were ill-fated. Why? Because the time to invent and to develop and test a building material is *not* when a building is on the drawing boards. Industry must be told the following again and again:

1. Wise, sound intelligent research must be done *before* any building project is on an architect's drawing board.

2. Industry must do the necessary experimenting —not the architect and not the architect's client (sponsor of the building).

3. Industry should know that only an architect or an engineer, thoroughly familiar with building *construction* and with all of its special problems, can guide industry through the necessary experimenting and lead it to the development of a satisfactory building construction material.

I am told that the Aluminum Company of America spent 2½ years in developing, in cooperation

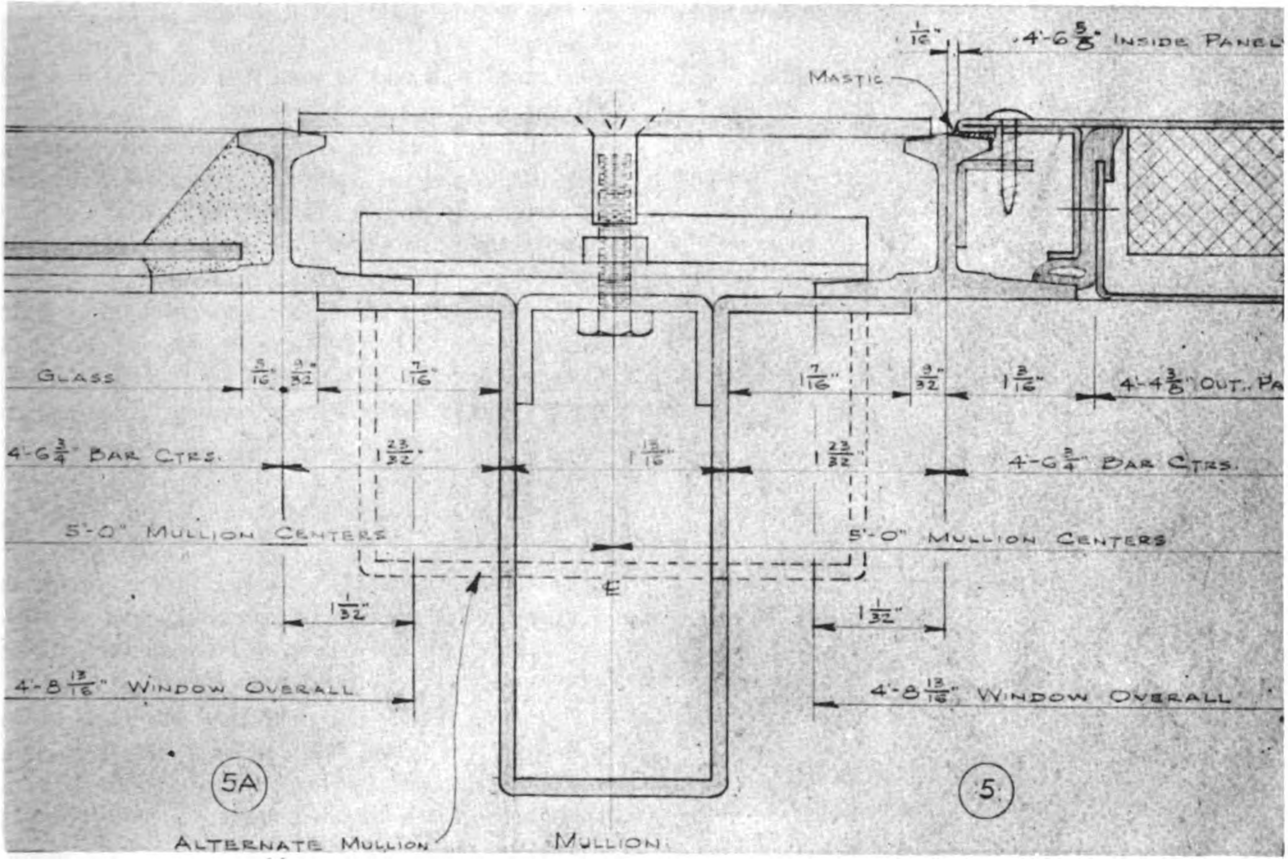
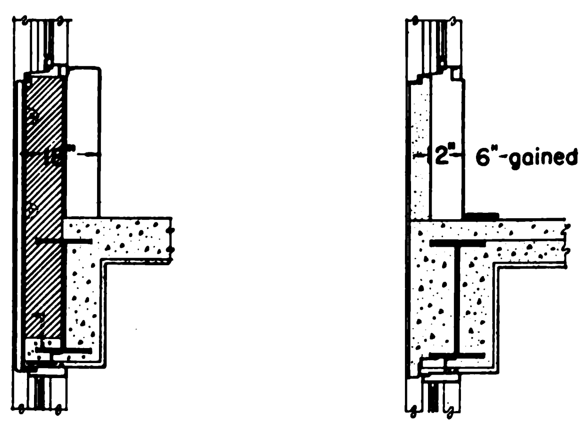


Fig. 2.4—Window and Wall Unit for Memorial Hospital Association of Kentucky, Inc.

Fig. 2.5—Crumbling pinnacle on Westminster Abbey (Photo Courtesy New York Times)



SPACE SAVING resulting from thin curtain wall construction as illustrated by a comparison between the typical wall section in Rockefeller Center, as actually built (left) and as it would work out with a thin curtain wall. Reduced thickness would add 2.62 per cent rentable area.

Fig. 2.6

with its architects, the panel used in its new home office building (Fig. 2.7).

No expensive scaffolding was required to install the Alcoa Building panels (Figs. 2.7); all installation was effected from within the building. Floors were completely and quickly enclosed without delays occasioned by bad weather.

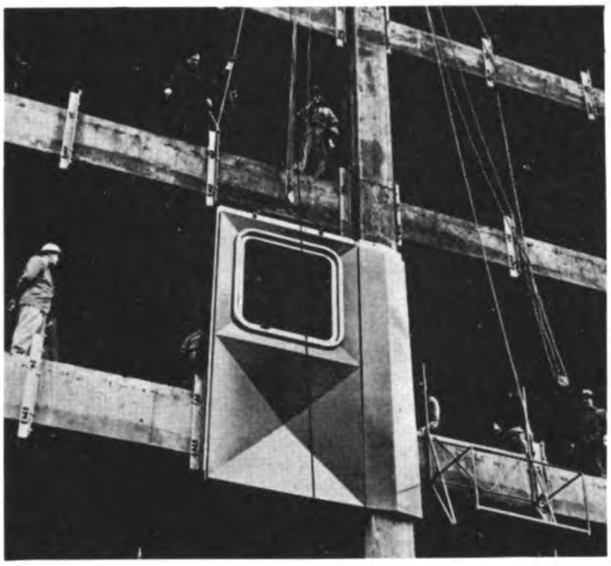


Fig. 2.7—Installation of Alcoa panels.

This is very good, but it doesn't go far enough. The wall of the Alcoa Building is a partly prefabricated wall and as such it is only one-half the answer to what we are seeking.

And now back to our exterior wall problem. For the Porcelain Enamel Institute we prepared the following studies (Figs. 2.8 and 2.9) to show some of the possibilities of variations of the outside surface.

The following statement appears in the 1953 report to the Governor from the New York State Commissioner of Housing: "We find that color, texture and the integration of contrasting materials . . . have become important in contemporary design."

In conclusion I would like to make the following observations:

1. Porcelain enamel has remarkable qualities as a facing material. It is permanent. It can provide beautiful colors. The material can be used as integral decoration.

2. Facing is not enough today. We have to go beyond the skin. We showed the Porcelain Enamel Institute what one complete system might be for non-coded areas. A study should now be made for coded areas.

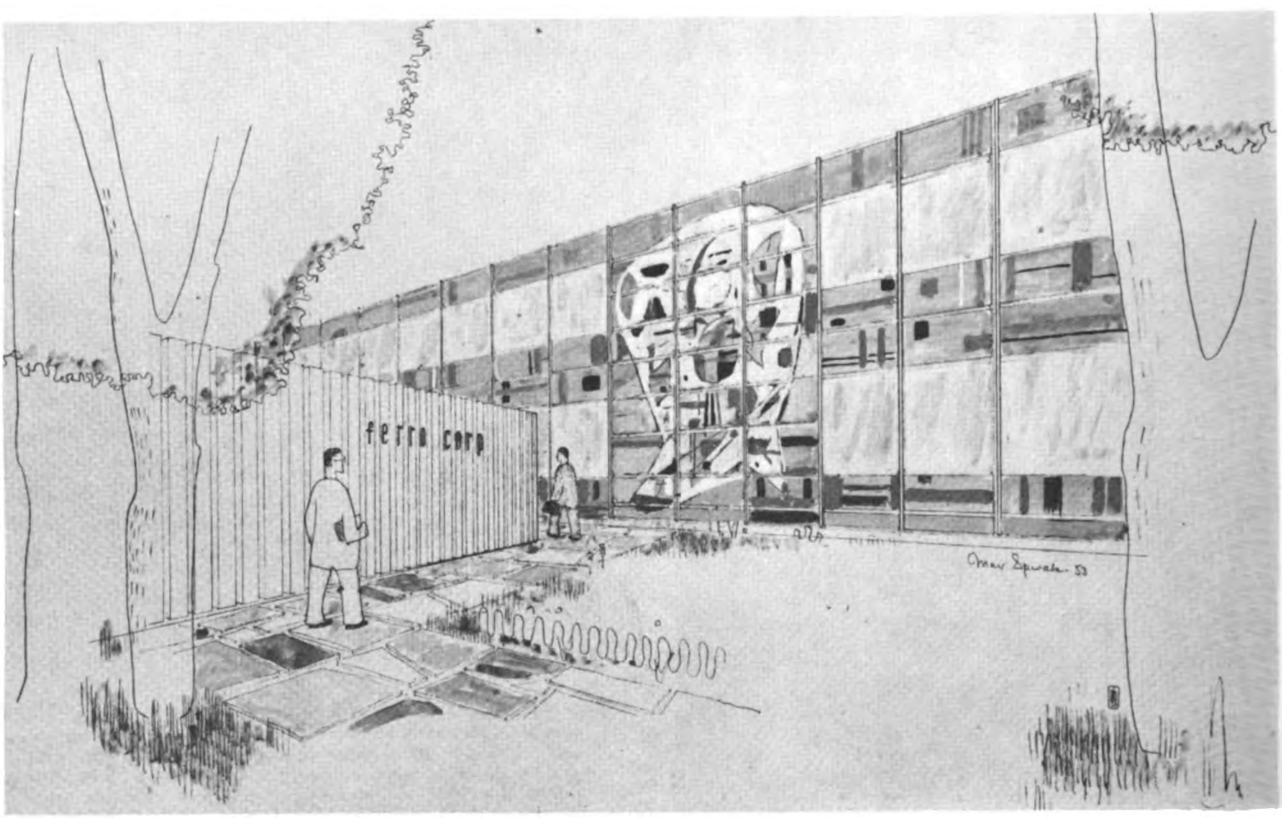


Fig. 2.8—Study in exterior curtain wall design.

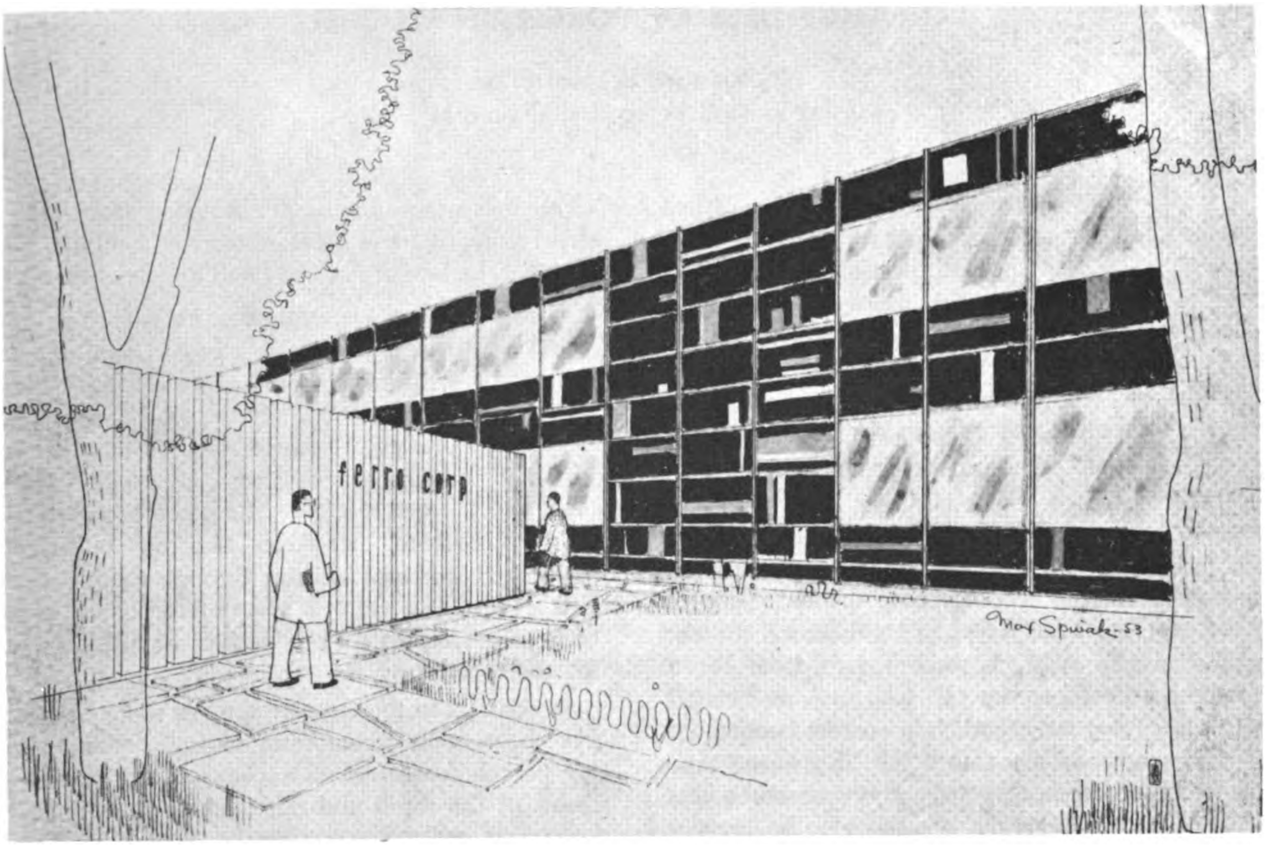


Fig. 2.9—Variation in curtain wall color and texture.

3. The goal is an exterior wall: not just the facing, but its backing, its insulation, its fire-resisting properties, its vertical and horizontal joints, and its necessary devices for attaching to the frame of the structure. The goal is a complete exterior wall system.
4. Progress is being made: the wall and the window are being considered together as a unit, as they should be.
5. Eventually, we may get a unit made of three elements; wall, window, and sunshade—all together. Since different sun exposures present different heat loads, we may envisage different types of units, distinct for each exposure.
6. An architect does not create *only* the skin of a building. He plans and organizes the inside, the guts, the things which make a building work properly. Since some of these things might well be located along the periphery (the exterior wall) of the building, we may think of a pre-fab curtain wall containing parts of the heating and cooling systems, containing perhaps also parts of the lighting and telephone systems.
7. And finally, what is needed is more and more research, in order for us to create better and better buildings.

CREATIVE USES OF PORCELAIN ENAMEL

By Richard W. Hamilton
(Albert Farwell Bemis Foundation, M.I.T.)

I am very pleased to follow such distinguished architects as Mr. Lescaze and Mr. Tuttle on this program, and I congratulate the Porcelain Enamel Institute for their judgment in engaging Mr. Lescaze to conduct their development work on curtain walls. As an architect myself, I wholeheartedly agree with what he has said about architecture and the advent of new materials.

As I listened to his remarks about the first uses of porcelain enamel in hamburger stands and gas stations, and the cheap and vulgar color schemes that characterized these installations, some very unpleasant memories were recalled to me. To earn living expenses when I was an architectural student in the middle west, I worked part time for a franchised dealer-contractor who was associated with one of the large porcelain enamel companies. My job was to take a transit and measuring tape out to a building and get accurate measurements of all parts of the building that were to be covered with architectural porcelain. Then I made separate drawings of every piece to be fabricated, showing curvatures, angles, returns, method of fastening to the existing walls, and so forth. Usually, we covered only the front of a building. We put fancy shirt-fronts on almost every kind of structure, both new and old. When it came to color selections, the owner usually decided what it was to be. Only rarely was an architect hired by the owners; the dealer-contractor had no design training, and although the parent company produced an excellent product from an engineering viewpoint, it offered no design assistance to the dealer. Needless to say, I was constantly arguing on the subject of color selection but rarely with success. Often a typical owner, perhaps of a bar, would want each of the horizontal rows of pans to be a different color; and occasionally we even got requests for different colored stripes running in both directions. I can't remember now whether I graduated from school first or one of these checkerboard or Zebra-striped bars got the best of me and I had to get another job.

I am sure I have dwelt on this story too long, but I do think it is important for the porcelain enamel industry to help make sure that we eliminate poor design in the future. I have recently seen new, horrible examples of poor design in the Boston area. I am sure the industry realizes that these poor installations are very bad from a public relations viewpoint. However, they can be largely eliminated if manufacturers, through their dealers, will set up some sort of a program with local architects to encourage owners to hire architects, even for the face-lifting store-front jobs.

In contrast to these past examples there certainly have been many outstanding examples of new uses for porcelain enamel in recent years. We have heard of the rapid and outstanding developments on curtain walls. I hope that this research will continue and develop load-bearing structural panels that can be used in light construction, and that it will inaugurate experiments with new finishes and textures.

Now I would like to describe a few examples of what I consider to be new, creative uses of porcelain enamel that have resulted from the close collaboration of architects, artists, and manufacturers.

I am sure most all of you remember the Lustron house. The porcelain enamel industry gained many technical advancements from the work done by Lustron. For example, under the direction of Mr. Eugene Howe, who spoke this morning, important work was done on color and finish control. Structural and heat-transfer engineers learned much about the problems of through wall metal contact and the structural complications involved in attempting to avoid it. I am sure all of this experience has been incorporated in the curtain-wall research and development.

The Lustron house was an all-porcelain-enamel house that used mostly solid colors and smooth surface finishes. In 1949, Carl Koch, an architect, was hired by Lustron to give "architectural treatment" to its 1950 house. Mr. Koch realized that many people felt that an all-porcelain-enamel house was cold and sterile, even when furnished. He went beyond the job for which he was hired: he explored

* Mr. Hamilton is an architect associated with the Bemis Foundation of the Massachusetts Institute of Technology. He is primarily engaged in the Bemis Foundation's long-standing research work on the industrialization of building processes in terms of sound, creative design. He holds degrees from the University of Michigan and Massachusetts Institute of Technology. He practices architecture mostly on a consulting basis. For the past three years he has taught a course in industrialized production of housing at M.I.T.

Fig. 2.10—Lustron House, 1949. Porcelain enameled panels used for roof, gable ends, and walls. Wall panels measure two feet square, roof "shingles," one by eight feet. Interior surfaces are also porcelain enameled steel. Purchasers were offered a wide range of integral pastel colors, inside and out.

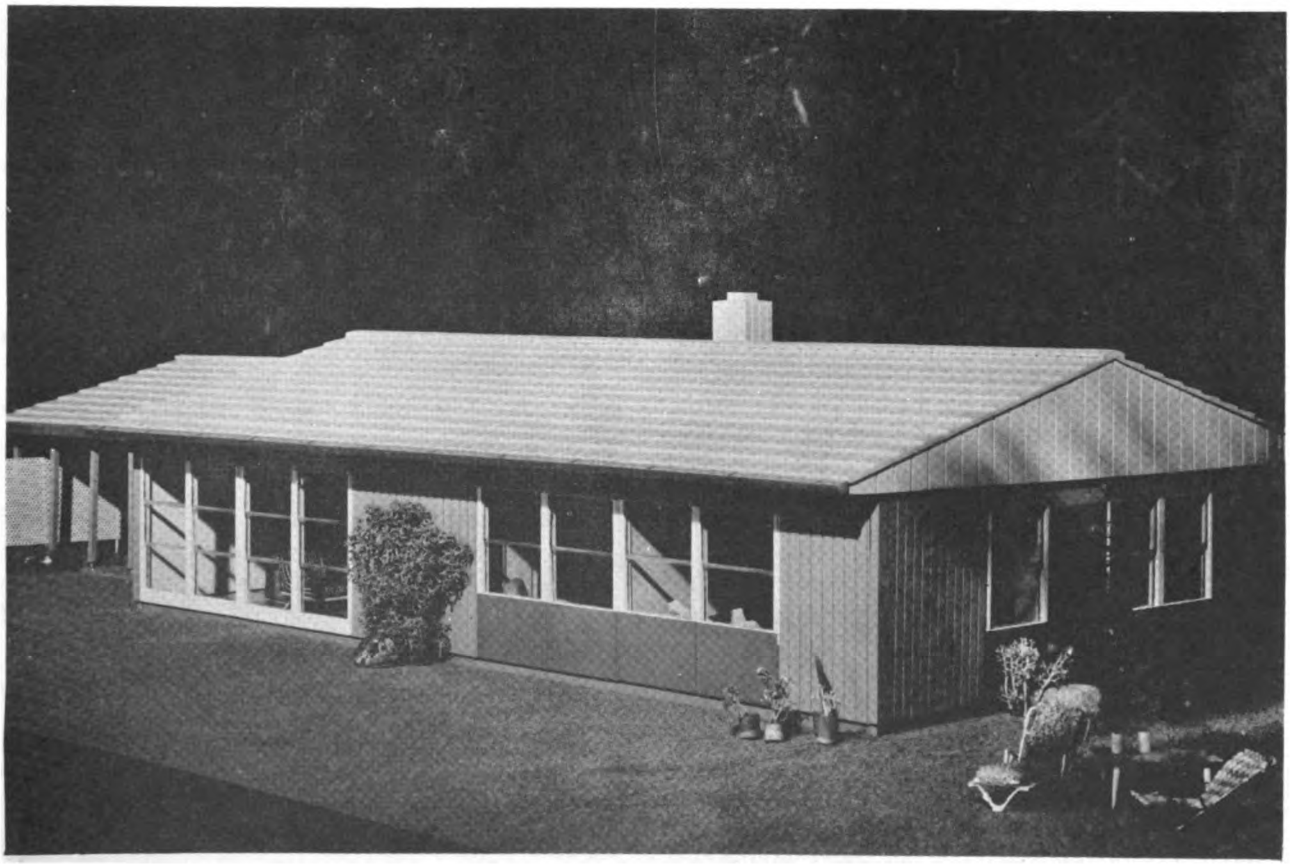


Fig. 2.11—Model of Architect Carl Koch's design for a 1950 three-bedroom Lustron House. New features include wall height panels, metal fences, improved color choices. Neutral brown and grey colors are used for the large wall surfaces; bright colors are used sparingly as accents in such a place as a door, or the bottom of window panels.

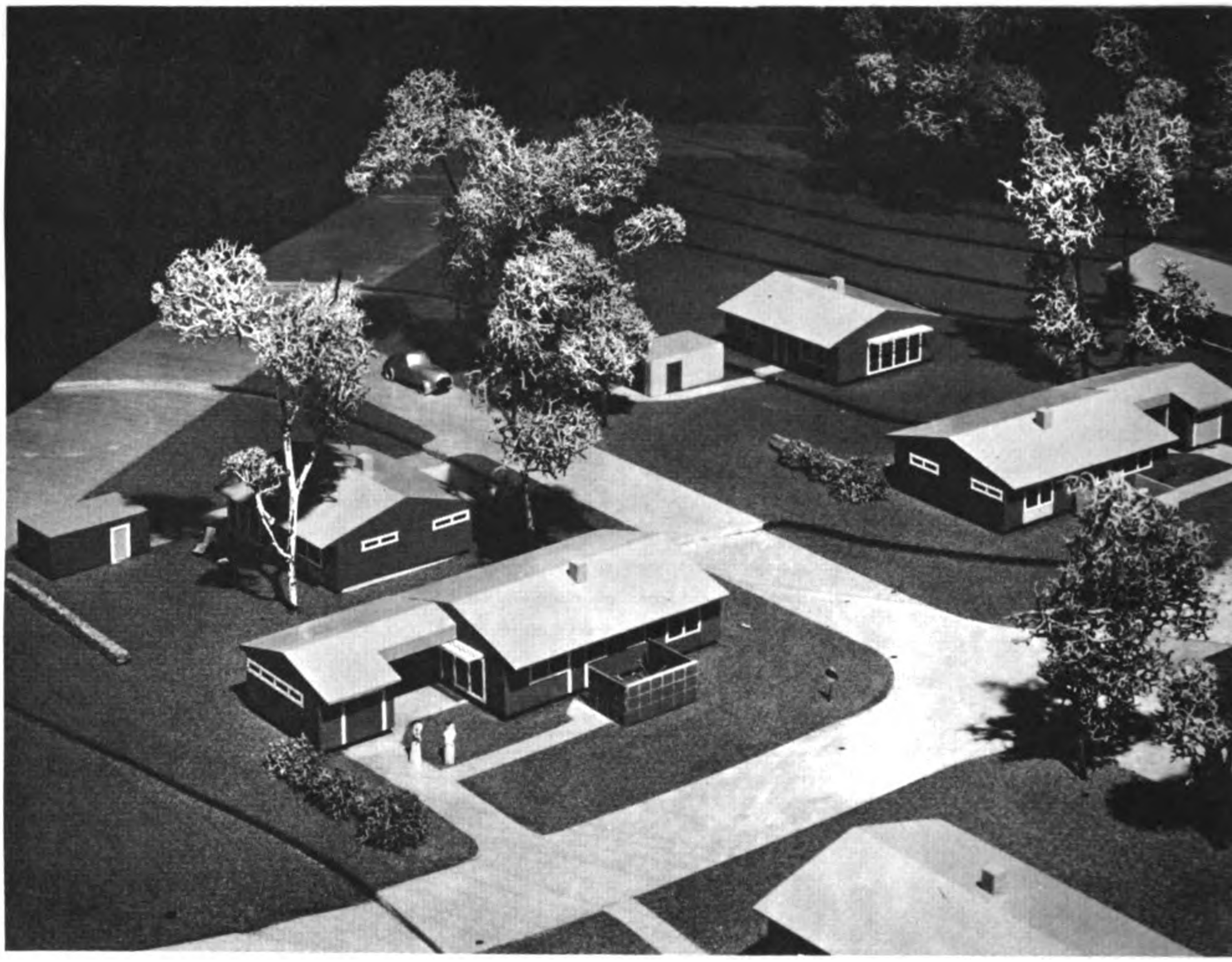


Fig. 2.12—Model of a possible neighborhood arrangement. With the color treatment previously described, it is possible to provide unity and at the same time avoid monotony in low cost housing.

the process for producing porcelain enamel and the method of fabricating the house. Then he got together with two of his colleagues at M. I. T., artist and designer, Gyorky Kepes, and prefabrication expert, Burnham Kelly. They realized that new creative uses of porcelain enamel offered a chance to give the small house rich and beautiful effects that could not be duplicated by the small custom-builder. They recommended the use of wall-height panels to improve design and eliminate the problem of sealing the 4-way exterior joints, which occurred with the use of the 2-foot by 2-foot panels.

Mr. Kepes experimented with perforations, corrugations, and rigidized metal to provide variations in texture, and he developed various multi-colored finishes. One of these was produced by spraying different colors from different directions onto a corrugated or rigidized surface. As an example of the resulting effect, an observer would see a red surface as he viewed a wall from one angle, a blue surface from another angle, and a violet surface when he was perpendicular to the wall.

Mr. Koch introduced wood and plastics into the interior, built-in features of the house to give it greater warmth and variation in texture.

I know that Washington is not the place to go into a lengthy discussion of the Lustron story, but before moving on I would like to describe quickly some of Mr. Koch's designs for Lustron's 1950 Model.

The living-room has a porcelain enamel fireplace and interior floor-to-ceiling panels.

Wood and plastic materials are used in the storage wall of the dining-room. These materials were used again for parts of the bedroom dressing table and closets.

New bathroom components which employ folding plastic doors for storage compartments are used.

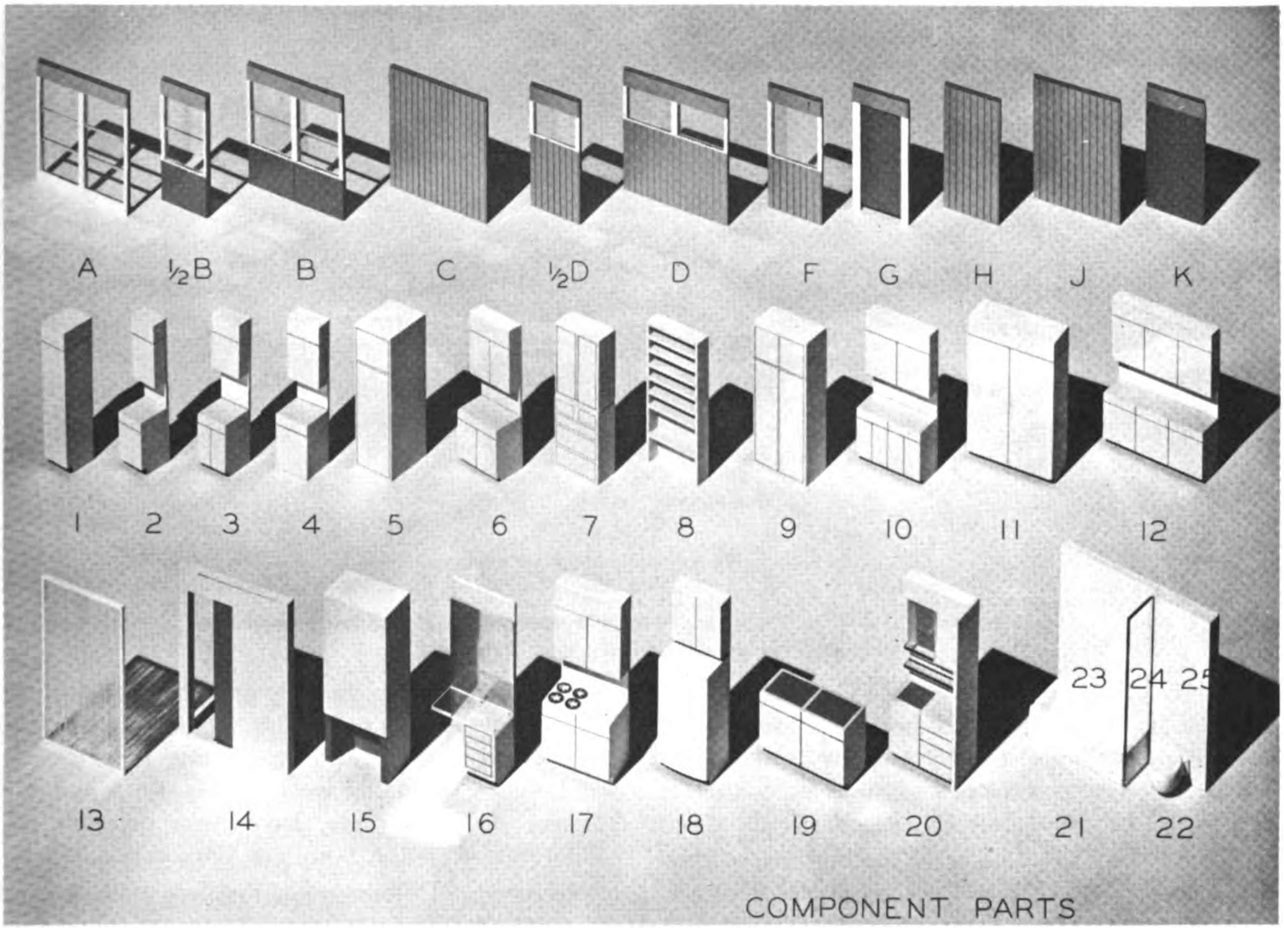


Fig. 2.13—Components of the proposed 1950 Lustron Houses. Woods and plastics are used in combination with porcelain enameled metal for the interior built-in features of the house to provide finishes with more variation in texture, and a feeling of greater warmth.

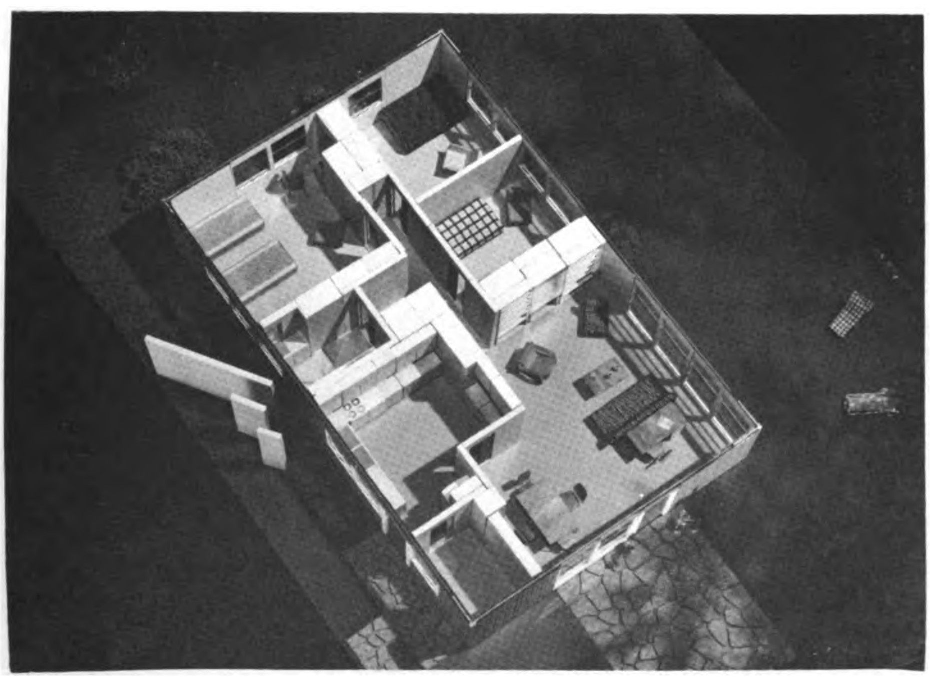


Fig. 2.14—Model of proposed 1950 three-bedroom Lustron House. Plan view showing use of various interior and exterior components.

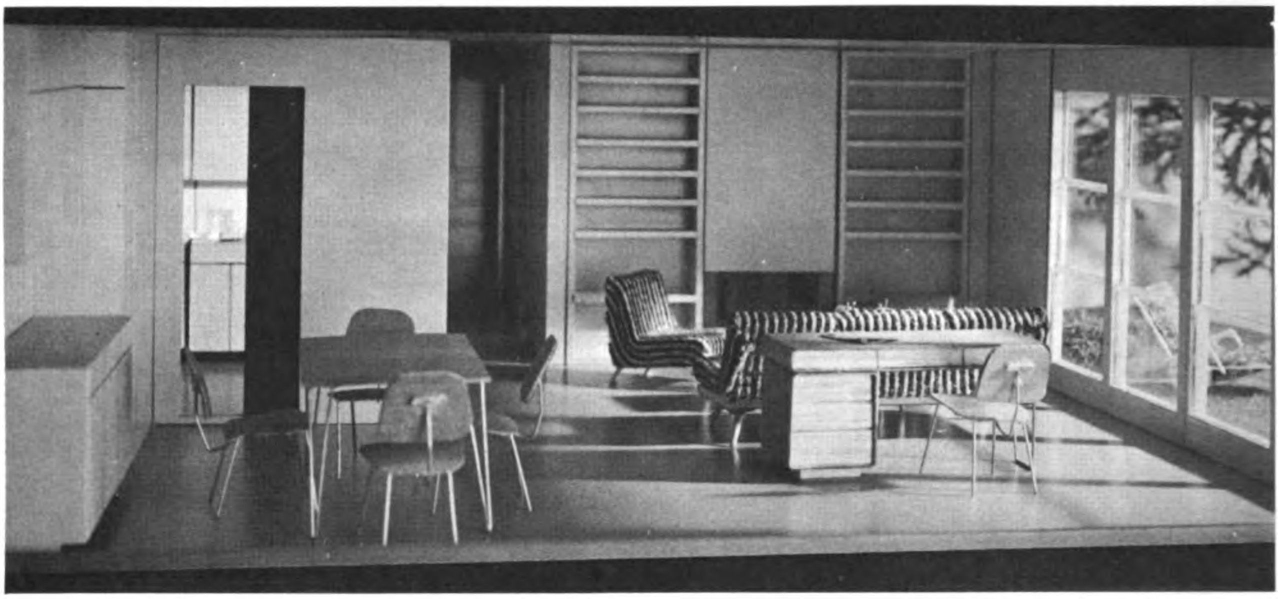


Fig. 2.15—Model of proposed 1950 three-bedroom Lustron House. View of living-dining area.

The color scheme of the exterior wall in the Lustron house has changed from the pastel used in the original house to neutral browns and greys used for the large expanses of surfaces, with the brighter colors used only for accent.

A small fireplace, similar to the one made from flat sheet metal, designed by Carl Koch for use in his own prefabricated Acorn house, was constructed with a different finish. An even, flat black coat of enamel was applied initially and then followed by an uneven coat of red. This produces a speckled effect and a slight texture. These fireplaces, in addition to all of the work by Mr. Koch and Mr. Kepes, described here, have been done in collaboration with the Bettinger Corporation.

In executing a living-room fireplace, with a mural by Gyorgy Kepes, in porcelain enamel the Kepes have used techniques that utilize the inherent drip-

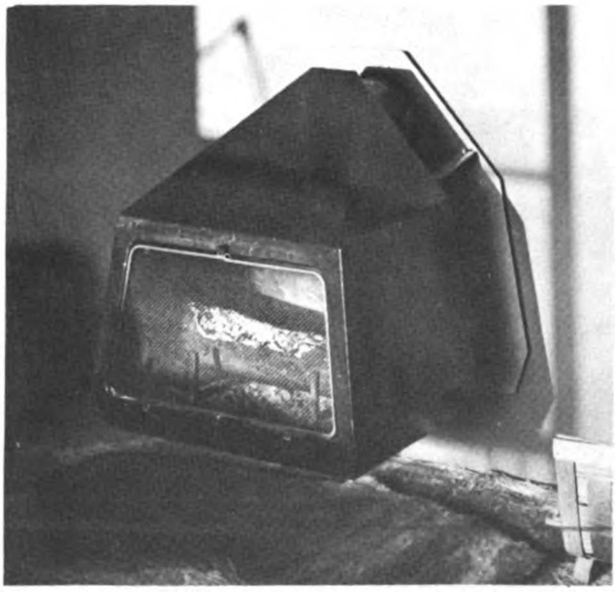


Fig. 2.16—The Acorn Fireplace, originally designed by Carl Koch for use in the prefabricated Acorn House. The fireplace is built of 16 gauge steel, and is of all-welded construction. Both solid color and speckled porcelain enamel finishes are now in quantity production by the Bettinger Enamel Corporation.

Fig. 2.17—Custom designed fireplace in Carl Koch's own house by Gyorgy Kepes. In executing this work Mr. Kepes has used a technique that utilizes the dripping quality of enamel, similar to the way in which ancient ceramic artists finished vases.

ping qualities of the enamel. These are the same techniques used by the ancient Chinese and Japanese ceramic artists in making their roses.

A store designed by Mr. Koch caters to amateur radio builders and high-fidelity radio fans. Most of the objects for sale are displayed in stockroom or hardware-store fashion and as a result the whole store became a display. The Architectural Forum says about this building that "on the exterior the display is pulled together and rapport between customers and merchandise further exploited by Kepes' diagrammatic radio-wave mural of wire and porcelain enamel on stamped steel. This mural should, and probably will, go into the textbooks. It is an example not just of art used with architecture but of art as an integral part of the architecture, something still rare in contemporary design. While decidedly a work of modern abstract feeling, it has a clear—even a literal—meaning for the shop's customers.

The Youth Library in Fitchburg, Mass., in my opinion, is the best example of the creative use of porcelain enamel in a modern building. The Kepes-Koch sculptor, William Talbot, and the Bettinger Corp. worked together to perform a true integra-

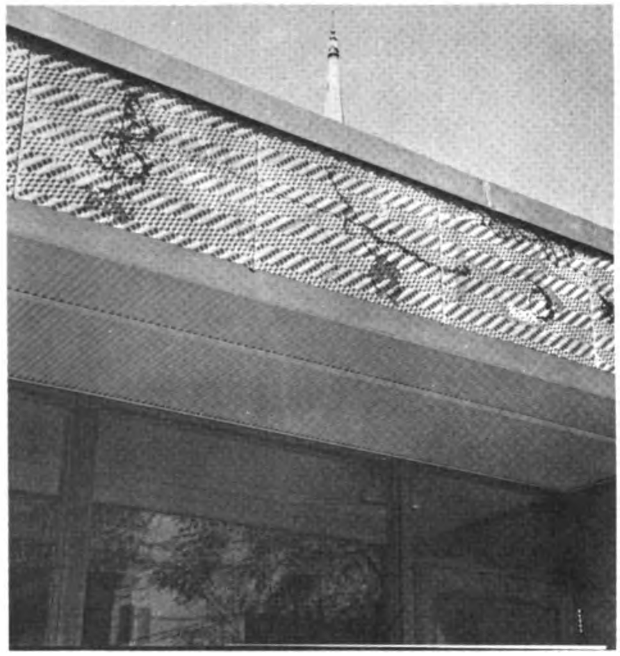


Fig. 2.18—Detail of the frieze, Youth Library, Fitchburg, Massachusetts. Porcelain enamel is shown in proximity to wood, glass, metal, and a luminous plastic soffit.

Fig. 2.19—Youth Library in Fitchburg, Massachusetts, designed by Carl Koch. Porcelain enamel frieze executed by Gyorgy Kepes.

Fig. 2.20—Detail of one of the owls, designed by Juliet Kepes, artist, and William Talbot, sculptor.

tion of art and architecture. Since the library is located in a busy downtown area, the architects designed for an enclosed court to be the major center of activity and interest.

In Fig. 2.19 we see appropriate symbolism in the wise owls that peer down from the gable ends of the saw-tooth skylights.

These wonderful creatures (Fig. 2.20) are the result of the combined efforts of the Kepes and sculptor, Talbot.

Although the manufacturers say rigidized material is hard to use, it does give a relief from the normally flat, monotonous surfaces. There is no doubt that architects welcome the development of more textured finishes.

Now in closing I would like to say that I hope that you do not feel that I have been trying to give you a lecture on modern art. Nothing could be farther from my mind. What I hope I have done is to stimulate manufacturers, architects, and artists to take new approaches to their design and research problems. I know this is what BRAB is trying to encourage in conferences like this. I hope that I have been able to make some contribution to their fine efforts.

Fig. 2.21—Porcelain enamel mural, "Cithara," by Doris Hall, Art Director of Bettinger Enamel Corporation. This mural illustrates use of a technique employed by ceramic artists that is more closely related to brush painting than is the work done by Mr. Kepes.

2.1 GENERAL DISCUSSION

MR. HUTT: Now, we come to the question and answer part of the program. Our Moderator will be J. G. Terry of Armco Steel Corporation. Mr. Terry graduated at Lehigh University. He is a professional engineer in the State of Ohio, a Development Engineer for Armco, where he has done extensive work on curtain walls. He is a member of the American Iron and Steel Institute and the P.E.I. Architectural Forum Committee. It gives me pleasure to introduce Mr. Terry, who will be joined by the speakers who participated in the program of this afternoon—Mr. Loring, Mr. Tuttle, Mr. Lescaze, and Mr. Hamilton.

MODERATOR TERRY: Now, are there any questions on this session this afternoon?

MR. ERIC PAWLEY (American Institute of Architects): My question is directed to Mr. Loring, but it requires a little background comment first. I was much interested in the papers this afternoon. Particularly those that indicated that at last we are beginning to have architecture with a little humor. Recently, on visits to such far-separated points as Seattle, Washington and Frankfurt, Germany, I found school buildings which used decorative elements with considerable humor. They were used functionally as well. A sign for a particular school in Seattle was composed of quite amusing caricatures of school-boys' faces made into letter-forms. It was in color and in metal. In Germany, I found a school of the pavilion type with wings connected by covered passages. Each wing was designated by a geometrical symbol, in this case cut out of metal forms. One wing was indicated by a rectangular design; and each classroom in that wing was indicated by a small figure based on a geometric form, such as a triangle. One classroom, for instance, had a chicken that was in triangular form. The idea was for identification of a particular classroom for young children, and a little senseless humor about it gave it quite a lift. During the 20's and 30's this country was considerably influenced by the schools of architecture in Europe, which were rather cold and aesthetic instead of warm and aesthetic. I think that the type of humor shown in Carl Koch's work is more indicative of an American approach, although that's a pretty big generalization. I think it's a valid one. The question is to Mr. Loring, and I'd like to follow it up with another comment afterwards, if I may. Is it economical to produce what might be called gadgets of this kind: "One-shot" porcelain enamel jobs on metal? A small volume in each piece, but perhaps the total would amount to quite a large business.

MR. B. B. LORING: When you say "one-shot", do you mean something in the art field or just a small piece that might be used repetitiously?

MR. PAWLEY: It is probably an individual piece.

MR. LORING: Well, I think it would be quite hard to answer that question, without knowing the piece you have in mind. Certain pieces which can be formed with the normal, shall we say, shears, brakes, and pressures. It might be economical to do so, but if a special dye had to be made, the dye itself might be so costly that it would make that piece uneconomical. I don't know whether I have answered the question.

MR. PAWLEY: Well, I think you have brought out the problems involved in this type of thing, which is what I was after. Now the other comment: there has been quite a bit of comment about the horrible period of gas stations and hamburger stands; and it struck me as quite amusing the other day to pass such a place here in Washington, for its exterior facing was made of porcelain enamel sheets in a very bright red brick-pattern. While I am horrified at attempts to make porcelain enamel imitate building materials, I would like to relate this particular finish to an aspectual humor in architecture. There is an architect in this country who is known for his insistence on precision in perhaps the most unprecise building material—that is, brick. He has been known to have a whole wall torn out because one joint was out of line. It seems to me that with the emphasis on bright colors, such as is evidenced by the paintings of Stuart Davis, let's say, who really goes in for bright ones (you can stand them in a house in an area where you don't pass every minute—like an entrance hall), it might be very charming to have a wall of porcelain enamel in a brick pattern which could be a heat radiator to counteract the front door as well as provide an over-all texture. In this case the design would be an abstract pattern, not an attempt to imitate brick. That's not a question; it's just a comment.

MR. J. G. HOLCOMB (Wolverine Porcelain Enameling Co.): The speakers this afternoon, as well as some of them this morning, seem to place the use of architectural porcelain enamel in the hamburger and the filling station industry almost exclusively. I want to take exception to that. My company has been in the porcelain enamel architectural materials business since 1924 and I don't think that more than 5 per cent of our volume is in that particular line. The Maul Macotta Corporation has been in business for about 20 years, and I don't think that I have ever seen them place their material on a service station or a hamburger stand, and I think the same holds true for the Macotta Company of Canada, Ltd.

I presume that we have some top-notch architects, engineers, and builders in this audience, and I'd like to clear up that false impression in their presence. I should also like to address a question to Mr. Tuttle of Giffels & Vallet, Inc., regarding curtain walls and systems and that article which appeared in the Wall Street Journal. Mr. Tuttle, don't you think it is a little early for anybody to try to compare costs of present-day curtain wall construction as we know it with the conventional type of masonry or stone and steel construction as we've known it? In other words, don't we have that inertia and these new materials and new methods to consider in trying to arrive at price? Now, I've asked that question daily. How does your curtain wall, for instance, compare with the conventional type of wall construction?

MR. TUTTLE: You are asking how does the curtain wall compare with the conventional type of construction?

MR. HOLCOMB: Yes. And don't you think it's a bit too early to try to compare costs?

MR. TUTTLE: It isn't too early to try; and the owners who are paying for these things are vitally interested in it. Most owners of buildings are not particularly interested in developing new materials; they are interested in what their buildings are going to cost and whether it is going to be satisfactory. Occasionally, a building like the Lever House is built, which is built for one purpose in mind—to serve as an advertisement. Well, a man doesn't build his plant for that reason. I can understand that, as you have indicated, at this particular stage of the development of the curtain walls new types might be more costly than the old types. But we don't want to continue that way. Does that give you an answer?

MR. HOLCOMB: Well, after a fashion; but don't you think that it is still a little early to try to compare the cost of one type of construction with the other?

MR. TUTTLE: Well, as I said, I don't think it is too early to try. I can understand why you can't meet it.

MR. HOLCOMB: I see. I have another question, Mr. Tuttle, if you don't mind. This has always been confusing—when you speak of curtain walls. We have a lot of requests from architects, and they frequently say they have a curtain wall job, but when we look at it we find that it isn't a curtain wall job—not in our book, at least; it is more or less a metal-clad building? Don't you think we need some revision on the nomenclature of this curtain wall, some description?

MR. TUTTLE: Well, I'd be glad to define a curtain wall in my terms. I don't know whether it will fit yours or not. To me a curtain wall is exactly what the two words imply: a curtain unsupported—I mean non-supporting; a non-supporting wall; purely a curtain hung upon a skeleton. And I don't consider the facing in the sense that we have used enamel sheets as well as other types of metal sheets to apply over bricks. Frequently walls of that nature are bearing walls. I'm talking about non-bearing walls when I say curtain walls. And they can be made of wood, brick, steel, aluminum, or enameled metal.

MR. N. CANNISTRARO (Bettinger Corporation): My question is addressed to Mr. Loring. I'd like to hear how you answer the question that is asked by the customer for a guarantee on curtain walls that are being put up today, and if there is a guarantee, on what basis. I know that is quite a question to ask but I'd like to hear the answer not only from you but also from the people in the audience.

MR. LORING: Frankly, we have made no guarantees and we refuse to make any guarantees because we do not know just what we could guarantee.

MR. CANNISTRARO: Well, my goodness, if you have a customer who is going to spend, in some instances, millions of dollars, you mean that has been enough of an answer? I know the question has been asked.

MR. LORING: Well, you know as well as I do that there have been some installations which have failed. And therefore we, not knowing enough about it, feel that we cannot give a guarantee; and those people who want a guarantee will use other materials for the time being, or until something is developed wherein we know what the results will be.

MR. CANNISTRARO: Then you feel that the panel has enough merit to overcome that obstacle. It might, if customers are buying it.

MR. LORING: Oh, some customers feel that they know more about it than we do; in certain instances we just follow specifications. However, we do make certain suggestions based upon the limited knowledge we have, but beyond that we refuse to, shall I say, stick our necks out.

MR. CANNISTRARO: May I ask Mr. Tuttle if he has had any experience with or would care to contribute anything on, that question.

MR. TUTTLE: Regarding a guarantee?

MR. CANNISTRARO: Regarding a guarantee, yes. I mean, how is the industry going to handle that? It's quite a problem.

MR. TUTTLE: I have never seen a brick manufacturer guarantee a brick wall. And with good reason.

MR. CANNISTRARO: Well, again that brings out a point that was brought up by one of the speakers: a brick wall can go ahead and leak and it may be damned, but a curtain wall that'll leak will be condemned.

MR. TUTTLE: I was the one that made that remark. I don't see how an architect or anyone can ask that a wall be guaranteed, when the manufacture of the material has little or nothing to do with its installation which is often the case. It is often the case the manufacturer of the material has little or nothing to do with the design of details I think probably you will be guaranteeing curtain wall construction just about the same way that the stone mason guarantees stone construction.

MR. CANNISTRARO: Thank you. I still didn't get an answer, gentlemen. I am wondering whether anybody in the audience could contribute anything?

MR. OSCAR S. SIGNER (Architectural Porcelain Fabricators): First I will say thanks to BRAB and to the PEI for arranging such a wonderful program. I want to say at the outset that I am an enthusiast about porcelain enamel exteriors. And perhaps because of my enthusiasm I wouldn't condemn gas stations and hamburger stands. It seems to me that if we hadn't had the gas stations and hamburger stands to experiment on we would not have arrived at this stage of development and so forth. (Applause) I am not disturbed or bothered about the horrible jobs that have been put up in the past, and because of my enthusiasm I have complete faith that we are going to solve the problems somehow, maybe the approach will be through the potentials of the market in the job ahead of us—the job of beautifying American architecture. I have faith that we will work these problems out if we approach them with an unselfish interest, not thinking of the dollar to grab but do a good job. And I think we can do that. This is where the question comes in. First to Mr. Loring, then to Mr. Lescaze: What are we going to do—how are we going to overcome the problem on these programs and plans which are on the board now? They will come as a deluge, I can tell you. We are a small organization, but we are already getting a lot of inquiries about wall-board panels and so forth. Once it catches on, the situation is as Mr. Loring placed it so aptly; you can do the best of jobs in the plant but when it comes to the installation you can do the best of jobs only with mechanics experienced in handling porcelain enamel. I am afraid there is a shortage of such mechanics. Can the PEI do anything about it with the unions? What do you people suggest to overcome this problem of getting sufficient mechanics? Institute a training program to assure us that when we do do a good job in the plant we will not have the good work cancelled out by improper, inadequate or indifferent installation work?

MR. LAWRENCE GICHNER (Gichner, Inc.): I would like to answer Mr. Signer's question. I'm here, because I am interested in the potentialities of keeping good mechanics busy, and I think I can help him if he has any installations pending. So that's one less worry, gentlemen. On the point of guarantee, I think we need to know what the customer wants guaranteed. And it might not be the things that we have in mind; it might be the things you already have the answers for. Will the colors hold up? And today we heard that colors have held up, that the colors definitely will stay. So let's ask the customer what it is that he wants guaranteed, and then come up with the answer as to whether it can be guaranteed or not. I am very much interested in the remark made by Mr. Holcomb that his firm does less than 5 per cent in gas stations and hamburger stands. I wonder if he wouldn't tell to us in what architectural field he does service.

MR. HOLCOMB: I believe I can answer that by telling you that we do work in just about every field. We have gone through certain cycles. For instance, we had our days when the theatre was very, very prominent, and in that field I think that we did a terrific volume. Of course, there have always been a lot of stores and projects of that nature. Now we are getting into bigger operations, involving entire blocks of stores in outlying communities. It is not unusual for us to do a complete block of stores, maybe including 16, 18, or 20 stores. In fact, last week I figured on a job with 26 different units. And I do know that the Maul Macotta Corporation has just signed a contract for a terrific operation which entails about 75,000 sq. ft. in an outstanding installation. So, I should say that we do all sorts of things. We can't favor one particular type of construction.

MR. TERRY: I'd like to ask Mr. Hamilton a question. You introduced a subject which I always thought was more or less on the forbidden list in curtain walls when you spoke of textures. I understood they wanted flat, stark surfaces which would be self-cleansing, rather than surfaces with valleys where you would have dirt-catching crevices and low-points. Has that been considered in your work?

MR. HAMILTON: I think you can tell from my examples that I wasn't stressing particularly applications on curtain wall material. But I think that there are textures and finishes that can be developed, which don't have these deep valleys; and certainly by the use of different color combinations you can avoid the creation of a flat-looking surface. But perhaps I'm out of place here in talking about uses of porcelain enamel other than specifically for curtain walls.

MR. TERRY: Are there any further questions from the floor?

MR. LORAN O'BANNON (Battelle Memorial Institute): One of the problems that is facing so many of our communities these days is the building of schools for our children. Within these communities new schools have been built, but since the war they have been found to be grossly inadequate. Specifically, in one community they built a new school for 600 students. Today they have about 1,500 in that school. In 7 years they are expecting about 2,400. The building of a school is a pretty serious business involving the spending of public funds and is rather time-consuming. I am wondering if anyone has given any thought to the construction of temporary buildings using curtain wall type of construction, a building which would be portable and could easily be moved about a city. In Columbus, Ohio, we have some wood structures at the present time. They are very unsightly; they are really monstrosities. With a porcelain enamel building which could be shifted about to meet the needs of shifting population, I think maybe we might be able to build an attractive building to which the youngsters would be glad to go. I wonder if anyone has given any thought to this subject.

MR. HUTT: Bill, will you answer that.

MR. LESCAZE: I think the problem has been found in other places besides the one the gentleman has referred to and that many efforts have been made, both in Europe and the United States for building temporary or demountable buildings. I don't happen to know of any system which is so good that I would be ready to say that is the answer to your problem. I just heard my colleague whisper to me that a company, Reynolds Metals, is developing a certain system. I'm sorry I can't say anymore than that, Jim.

MR. SCHEICK: I'd like to suggest to Mr. O'Bannon that he look into what is being done at the University of Michigan, under the Unistrut. They have carried pretty far, I think, the development of a portable frame for school buildings. As far as I know of this research work, there are many possibilities for the skin for those structures. It could be a case where steel people or Unistrut people and porcelain enamel people might get together. But it's a real thorough-going piece of research work that is being carried on there.

MR. J. E. BOURLAND (Texlite, Inc.): I have a question that I would like to raise. We have been talking about the permanence of porcelain enamel, and of course you know the trend of the new unitized wall. I am sure that they are also thinking about the internal finish of a building. We have been talking basically of putting porcelain in color on the exterior, but certainly color inside a building is a problem. My question is this; either Mr. Lescaze or Mr. Tuttle might answer it: What would be the public reaction to a finish that would stay the same for the duration of the life of the building—say also we finished it in one color and it could not be changed?

MR. LESCAZE: Both of us will answer that question, or we will try to. My quick reaction is that it would be a perfectly normal reaction. Don't exaggerate the importance of that wall you're describing. It's only the end-wall in a room. The inside of an exterior wall cannot be more than one wall of a room where there are three other walls which can have whatever color, whatever material, or whatever finish the customer may choose, so that if you hit on a fairly widely accepted range of color for that inside surface of your exterior wall, I can't see why it would not be welcome.

MR. TUTTLE: I'm glad you brought that up. I think that the concern over the permanency of the colors to be had with porcelain enamel in a home or any other building has been over emphasized. As Bill says, it will be welcomed to have colors on the inside in any kind of building. Women are always changing their wall-paper and re-decorating their houses, but they do so because they can usually do it easily. It doesn't occur to anyone to paint the tile floor or vestibule, nor does it ordinarily occur to anyone who has a pine-paneled room to paint it red. He's willing and satisfied to keep the pine paneling throughout his life; and I think that probably is true of some of the old, English oak woodwork in cathedrals and in the dining halls at Eton and that sort of thing. I believe the child brought up in our home that was always red and yellow would feel at home just as much as if the wall-paper were changed every year or two.

MR. BOURLAND: I'd like to make just one more comment—the reason why I raised that question. As you know, we have built some of the filling stations, but we have also done a lot of monumental work. We finished the eighteen-story Texas Company building in New Orleans, which has considerable porcelain on the outside and much more on the inside. Of course, they have carried out a rather modern scheme and we want to remain friendly with the Texas Company. That is why we are curious as to what your reaction would be to the problems that are going to face them for the next fifty years.

MR. S. EUGENE HUBBARD (Structural Clay Products Research Foundation): I'd like to make a remark on the question the chair asked a few minutes ago about texture, and also the question that was just brought up. It might be very desirable if we could, in fact, make our materials stand up and look the same at the end of twenty years as they did when they were put up. We also heard this morning from Mr. Moore that smooth surfaces, the so-called self-washing surfaces will accumulate a scum in bad atmospheres which is practically impossible to clean off. It might very well be that the provision of suitable textures would sort of mask that accumulation of dirt and help to preserve the appearance of the building. In other words, you wouldn't get the random effect on a smooth surface that you would expect.

MR. PAWLEY: I think it's important in this talk about textures and porcelain enamel that we don't suddenly get a rash of porcelain enamel panels which represent knotty pine. That's not the idea at all. You've got a wonderful material and you should exploit its intrinsic properties. The textures are fine but they shouldn't reproduce or attempt to reproduce the textures of older types of building materials. It is a question of abstract texture rather than representational texture.

MR. DWIGHT G. MOORE (National Bureau of Standards): I wanted to correct the impression that Mr. Hubbard had about the cleanability of the surface. I certainly didn't mean to say that these panels were difficult to clean, especially the glossy panels. They are practically self-cleaning except in atmospheres such as we have for example, around the railroad station out in St. Louis and even those, if they were cleaned regularly would be satisfactory. I understand that in St. Louis the people that service porcelain signs, and other signs too, do have the service wherein they go around cleaning the signs every six months. That way they are not difficult to clean. In other atmospheres, for example, around Washington, Atlantic City, and Lakeland, the panels are practically self-cleaning. The only ones that are difficult to clean are the ones that have what they call a poor mat surface, which have absolutely no gloss to them at all. As I understand it, no enamels of that type are being used today. The ones that are being used are more of a semi-mat finish, which has just a trace of gloss. They are not the full-mat enamels that we included in this study.

MR. SIGNER: I am interested in the question raised about changing the interior colors because of the monotony that has existed for five to ten years. I want to have someone answer this question. It's technical. Since we are using light enamel spray coats now, if the panels are installed in a manner so that they can be removed (if desired, in about five or ten years or so), could we not re-enamel them with a light application of a different color and change them on the safe side. The cost will certainly warrant it, because it costs less to re-enamel one wall in ten years than it does to paint the wall every three years or so. Will someone answer that?

MR. HUTT: Mr. Loring, will you answer that?

MR. LORING: In the first instance, I don't think it will be practical to remove a wall for the purpose of changing color. Secondly, I think that in a well-planned home the owner of that home will maintain the color the same as she would maintain periodic furniture. I think it's those people who rush into something and buy, shall we say, the dime variety of furniture who are interested in changing their colors from day to day, or as often as the landlords will do it for them at no charge. Whether or not the removing of a panel would be feasible would depend a good deal on the structure underneath. I do know that we have tried in the past to take a panel off and re-enamel it after it has been in service, say ten years, and we have not had good luck with it.

MR. W. N. HARRISON (National Bureau of Standards): I would like to revert back just for a moment again to the question about the cleanability of porcelain enamel panels. In Dwight Moore's talk this morning he did mention—but I think it would bear re-emphasizing at this moment—that these particular panels which were difficult to clean were placed immediately opposite the railroad terminal along about 1939, and the thousands of coal-burning locomotives that have come into that station since then would fully account for a peculiar situation that would not be significant as a general application.

MR. HUTT: Being in Washington, we'll have to get out of here by 4:30 to prevent our being investigated for working overtime. So I'm afraid we'll have to bring this portion of this session to a close.

Session 3

PORCELAIN ENAMEL AS AN ENGINEERING MATERIAL

ENGINEERING PROPERTIES OF PORCELAIN ENAMEL**

By Forrest R. Nagley*

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We realize that the metals which are employed in the construction of ships' hulls, equipment, and machinery have been selected and specified on the basis of engineering properties; and design requirements have been set accordingly. These attributes commonly referred to as "mechanical properties", such as tensile strength, yield point or yield strength, and per cent elongation or ductility, must be depended upon in order that the vessel in every detail can be adequately engineered from the moment of its conception.

In the design of each component of the hull, its fittings, and the propulsion machinery, advantages are gained because of particular properties of certain steels and other materials thereby providing: (1) desirable distribution of weight, (2) buoyancy, (3) ship stability, (4) resistance to collapse under hydrostatic pressure and underwater explosion, (5) freedom from susceptibility to brittle fracture when cooled to the temperature of arctic waters, and (6) sufficient elasticity to permit thermal stressing imposed by the radiant heat of a tropical sun on topside surfaces and the cooling effect of sea water below the water line.

Simultaneously with design concepts, other notions of engineering properties come to mind as we envision ship operation conditions imposed by the very fact that the structure and machinery must be seaworthy and have no escape from continuous imposition of stress loading and stress reversals. These occur at very low frequencies as the vessel ploughs through the crests of heavy swells and bridges their troughs, or at quite high frequencies as the vibrations from the propulsion machinery and from propeller blades in the wake of shaft struts are transmitted throughout every member of the hull and equipments attached to it.

Further, and perhaps the most important property of a satisfactory marine material, is its resistance to the incessant corrosive attack of salt water and air. All combinations of forces must be analyzed as these contribute to deterioration in diverse forms and intensities. Porcelain enamel has proved itself as a desirable coating on wet-type exhaust mufflers subject to the corrosive attack of sea water coupled with its added erosiveness when flowing at high velocities and also coupled with thermal stressing and the shock of sudden changes in temperature. From these and similar observations we conclude that shipboard service conditions are severe indeed.

Further analysis indicates that these service requirements can be evaluated quantitatively; and therefore it is quite logical that the respective attributes of porcelain enamel applied to steel and aluminum alloy suitable for such service can be defined in terms of their applicable engineering properties. It seems quite logical to surmise that the properties which certain porcelain enamels have been found to possess to make them adaptable for shipboard use might well make the same particular porcelain enamel coatings attractive to builders of houses, hospitals, office buildings, hotels, and like structures.

Porcelain enamel coated sheets used for joiner bulkheads aboard Naval vessels provide considerable technical interest to builders of land-foundation structures. To the eye of a non-engineering or unscientific observer, the joiner bulkhead panel could be a sheet of just any old metal, the cheapest money can buy, sheared to size, riveted or welded in place, and painted. However, the otherwise simple sheet of painted metal becomes quite a different item to the shipfitters when they attach the cable runs, furniture, and sanitary fixtures.

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**The opinions and assertions set forth in this article are the personal ones of the author and are in no way to be construed as an official report reflecting the views or decisions of the Bureau of Ships, Navy Department, or any other agency of the Department of Defense.

The bulkhead also becomes an item of engineering significance to the officers and crews of the ship when confronted with the strenuous operational requirements afloat. It becomes an item of manpower significance to the ships' forces and economic significance to the taxpayer when maintenance becomes a material and financial burden. More particularly, from the military viewpoint, the bulkhead is significant to the task force commander when the course, and possibly the outcome, of combat can be attributed to, or possibly even decided, by the containment of a flash fire within a given compartment, the check of a raging fire resulting from an enemy hit, or freedom from secondary radiation under atomic attack. Sanitation in the washroom, watercloset, commissary, and sick bay spaces, and a proficient crew not reduced to a low fatigue factor attributable to negative psycho-physiological environments are also important.

Even as porcelain enamel coated metal sheets can be represented to Naval architects and marine engineers as a joiner bulkhead material, so can it be represented to architects and engineers for land-foundation structures as a material possessed of: (1) flexural strength, weight and thickness in optimum balance; (2) resistance to sustained vibrations and stressed reversals; (3) a surface which can be readily cleaned with soapy water, very light scrubbing, and simple rinsing, thereby restoring the initial finish without recoating; (4) permanence ot protection against corrosion; (5) the necessary attributes of a flame barrier; (6) a desirable degree of radiological decontaminability; (7) adsorptivity for sterlizing and anti-biological warfare reagents; and (8) appearance characteristics resulting from specially selected and controlled color and gloss, which contribute positively to habitability.

It is immediately recognizable that all of the foregoing properties can be quantitatively evaluated, specified, and as such, be associated with certain structures, their geometry, their function, and their environment. Therefore, these attributes are rightly referred to as "Engineering Properties." Certain of them have been studied to a greater extent than others in both commercial and Government laboratories. The data which I am about to present have been extracted from various test reports accumulated in the Bureau of Ships and are typical of the technical information on which porcelain coatings have been selected, and on which data for some of the specification requirements have been based. Most of these data cover flexual strength tests of coated and uncoated sheets and plates. I shall also present data in support of certain technical explanations as to how flexual strength is influenced by the selection of coating formulation, with particular reference to relative thermal co-efficients of expansion. Also I expect to present data on heat transfer characteristics, and then conclude with remarks about a few of the practical aspects of handling, fabricating, and repairing porcelain enamel coated items.

Of the fundamental concepts which the design engineer must always keep foremost in mind is the property of elasticity in the material which is to be selected as a strength member. Of course, allowable stresses must be based on tensile strength, yield strength, elastic limit, or endurance limit where fatigue is the essential consideration, or possibly creep rates where the structural element is subject to elevated temperatures while under applied stresses. So it comes natural to the designer to require data on which to set allowable stresses, ever keeping in mind that the nature of the failure, if failure should occur, also defines in part, what materials are to be considered for construction.

At the outset when studying porcelain enamel, it most commonly being a glass-like substance, the engineer must be mindful that glass and other amorphous materials fail in brittle cleavage rather than failing by the shearing or space-lattice slipping of crystals as in ductile metals. At first glance, the engineer might be prone to consider all porcelain enamels brittle materials which would fail without the warning of elongation within some elastic limit. On second thought one realizes that we are dealing with coated metal, not with plates or sheets of glass even though the porcelain might have one or more crystalline phases present. Once we have ascertained that the enamel coating can be elastic within the effective elastic limit of the metal to which it is applied, then we as materials engineers and designers are satisfied that we have a practical engineering material suitable for selection.

Porcelain enamel coatings can be suitably formulated and applied so that they are elastic within the elastic limit in outer fiber straining of the basis metal to which they are applied. Some of the data reported to the Bureau of Ships have indicated that, with special selection of the enamel with respect to thermal coefficient of expansion, the coating when applied in sufficient thickness, possesses the net effect of being ductile and adherent while the basis metal undergoes considerable permanent deformation. I have selected data to show the net effects of the porcelain enamel coatings largely by comparison of coated and uncoated

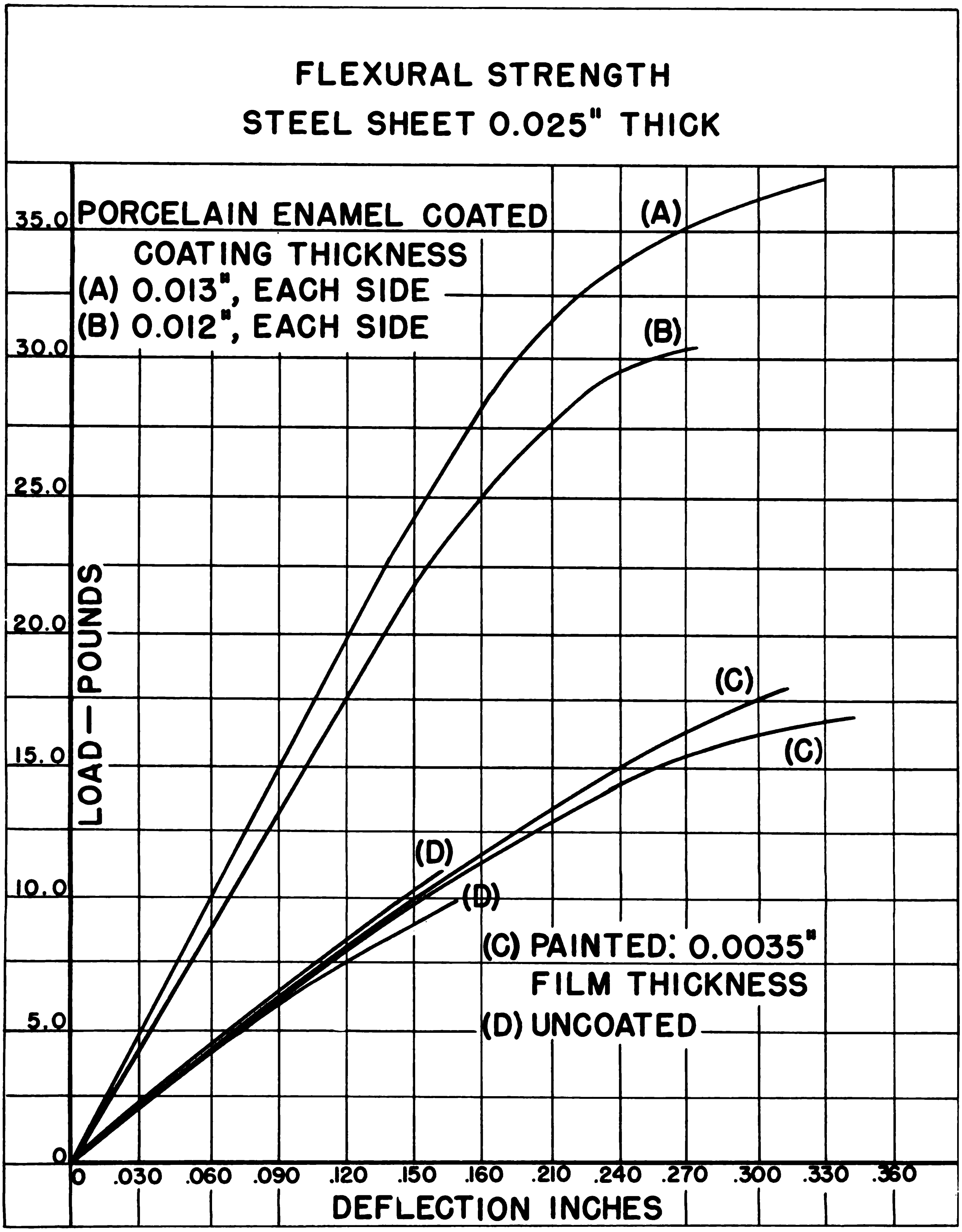

Fig. 3.1—Load-deflection curves for steel sheet—bare, painted, and porcelain enameled.

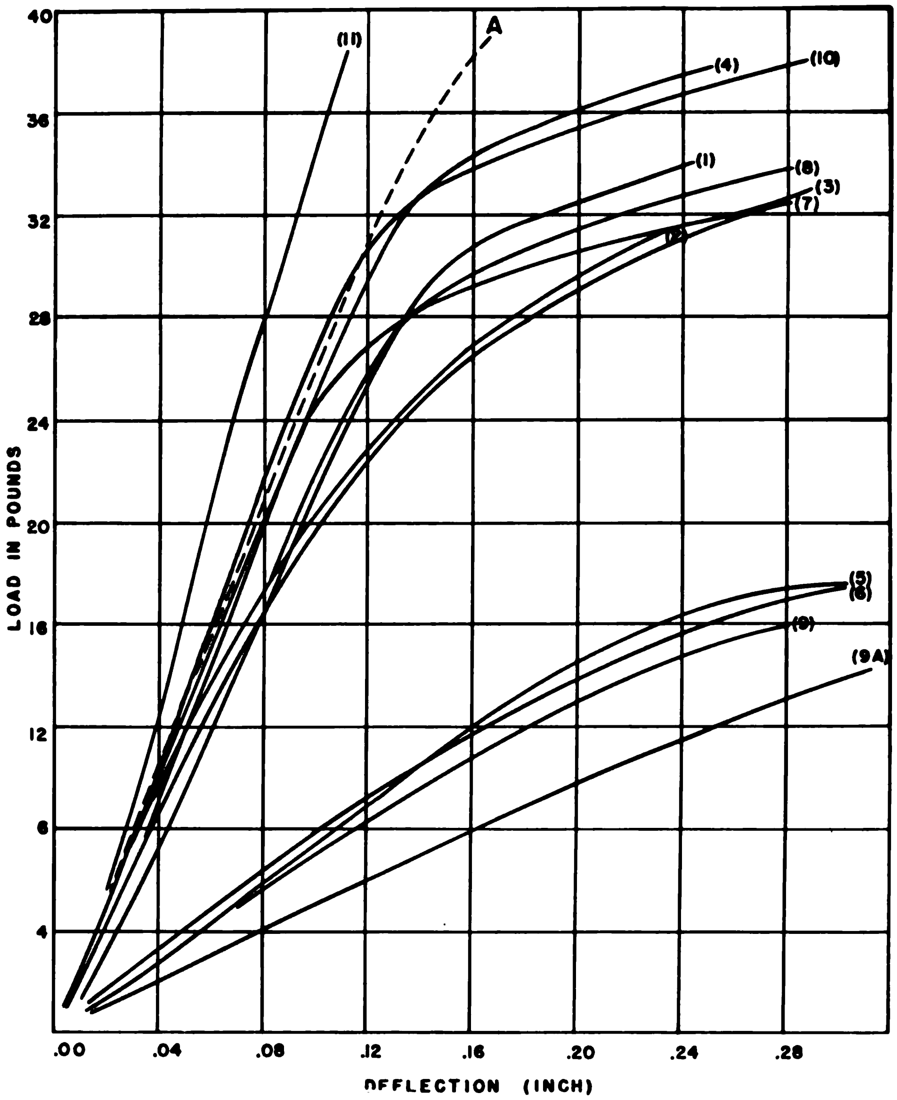

Fig. 3.2—Load-deflection curves, steel and 61S aluminum alloy sheets (see Table 3.1 for explanation).

metal specimens. A contribution made by the porcelain enamel to the flexural strength of a coated steel sheet is illustrated in Figures 3.1 and 3.2.

Throughout our work we have employed bend-test specimens 6″ x 2″ loaded as simple beams midway between supports 3½″ apart.

As indicated in Figure 3.1, the data do not indicate much difference in the flexural strengths of painted and bare steel. However, it can be readily noted that the addition of the porcelain coating contributed considerably to the stiffness of the panels as indicated by the slopes of the straight portions of the load-deflection curves. Also the flexural strengths have been significantly contributed to as indicated by the increase loads necessary to impart deformations at or near the yield strength areas of the curves.

Possibly of most significant interest is the matter of weight-saving which may be realized when thin-gage metal is used and added stiffness is achieved through the use of the porcelain. The average weight of the coated steel (basis metal thickness 0.024″) was 1.17 pounds per square foot. In order to obtain equivalent rigidity (in the flat) with bare steel, sheets weighing 1.30 pounds per square foot would be required. Hence, incidental to observing the elasticity, and possible ductility, of the particular ceramic coating tested, apparent advantages in weight savings at once become obvious.

Figure 3.2 is a composite graph (see Table 3.1 for explanation) showing the load deflection characteristics of various porcelain enamel coated sheets of steel and 61ST6 aluminum alloy.

Curves (1), (4), (8) and (10) represent 22 gage steel sheets with porcelain enamel coatings ranging in thickness from 0.008 to 0.014″ on each

TABLE 3.1

PORCELAIN ENAMEL COATED SHEET MATERIALS SHOWN IN FIGURE 3.2

Curve Number	Basis metal and its nominal thickness (inch)		Coating thickness on each side (inch)	Weight of coated sheet (lb./sq. ft.)
1	Steel	0.0299**	0.011	1.46
2 & 3	61S-clad aluminum alloy	0.070	0.003	1.02
				1.03
4	Steel	0.0299	0.0106	
			0.0114	1.52
5	61ST* aluminum alloy	0.032	0.002	0.531
6	61ST* aluminum alloy	0.032	0.002	0.53
7	Steel	0.034	0.015	1.81
8	Steel	0.0299	0.008	1.43
9 & 9a	Laminate: galvanized	0.010 (p)	0.005	1.77
	steel (g), between por-	0.019 (g)	outside	
	celain coated steel (p),	0.010 (p)	0.001	
	coated on both sides.		inside	
10	Steel	0.0299	0.014	1.50
11	61ST* aluminum alloy	0.051	0.006	0.92
"A"	61ST* aluminum alloy	0.051	0.003	——

*Note: Temper hardness in the coated condition not known. The basis metal before coating was of T6 temper.

**Note: The nominal thickness 0.0299 inch is that established by the American Iron and Steel Institute for Manufacturers' Standard 22 Gage.

side, and ranging in weight from 1.43 to 1.52 lbs. per square foot. Curve (7) represents steel of about 20 gage, 0.034" thickness, with a porcelain coating of about 15 mils thick on each side and weighing 1.81 lbs. per square foot. The curve designated as letter "A" represents 61S aluminum alloy conforming to the minimum requirements of Bureau of Ships Specification MIL-A-16994, which requires the basis metal to be 0.051" thick minimum.

Curve (11) is a porcelain coated aluminum alloy of basis metal thickness 0.051" with a coating of 6 mils on each side. It weighs only 0.92 lb. per square foot.

Curves (2) and (3) represent 61S clad aluminum alloy the basis metal thickness of which is 0.070" with a coating of 3 mils on each side. These coated sheets weigh 1.02 and 1.03 lbs. per square foot, respectively.

Curves (5) and (6) represent aluminum alloy sheet 0.032" thick, both coated to a thickness of 2 mils on each side. They weigh 0.53 lbs. per square foot.

Also of significant academic interest are curves (9) and (9a). They represent a laminated construction having a galvanized steel sheet 0.019" thick sandwiched between two porcelain coated steel sheets nominally 10 mils thick before coating, each having a coating thickness of 5 mils on the outside surface and 1 mil on the inside. These laminated sheets weighed 1.77 lbs. per square foot.

As a result of this comparative study it seems logical that either of two general types of porcelain coated sheet material is to be desired on the basis of what I choose to call a space-weight-strength factor. These two materials are as shown on curve (11) for the aluminum alloy and some other curve selected from (1), (4), (8) or (10) for steel.

Figure 3.3 is also a composite graph showing the load deflection characteristics of porcelain enamel coated 61S aluminum alloy in various thicknesses. In the uncoated condition, the aluminum alloy was of T6 temper. It is of significant interest to note that whatever loss in flexural strength is sustained because of the heat treatment of the basis metal, is more than made up for by the stiffness imparted by the coating.

Figure 3.4 shows the results of tensile tests of coated and uncoated 61ST6 aluminum alloy ⅛" thick. This study was conducted primarily to ascertain the effects of the coating on the tensile properties of the basis metal. It will be noted that the pre-fire treatment which has been found to be necessary for the application of porcelain enamels to aluminum-base alloys significantly reduces the

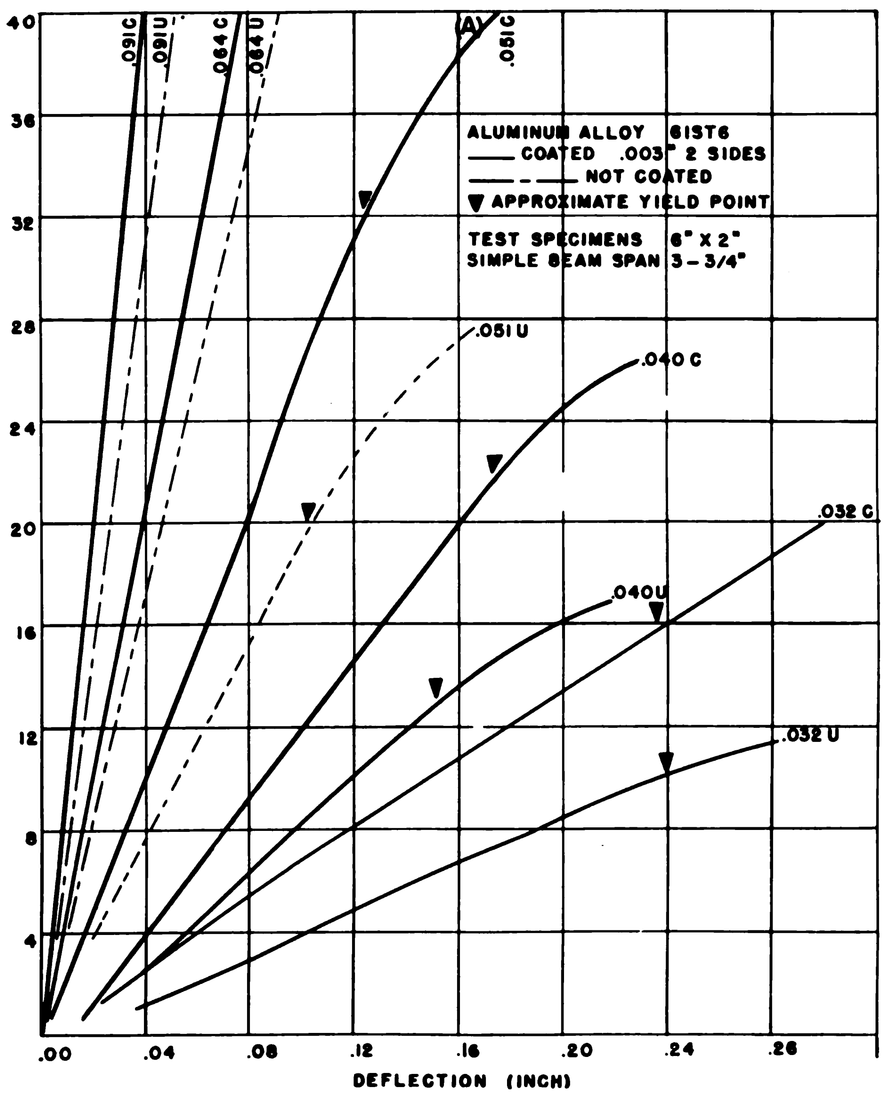

Fig. 3.3—Load-deflection curves, 61S aluminum alloy sheets, bare and coated, various basis metal thicknesses.

tensile strength of 61ST6. From this we can conclude that alloy of this same chemical composition not heat treated to impart high tensile strength can be satisfactorily employed for porcelain enamel coating.

However, it is also significant to note that in every instance after the plates have been pre-fired, the coating imparts from two to four per cent added strength to the coated alloy. Also of interest is the effect of water quenching after the application of two coats of porcelain. Thus, it would seem highly desirable to have a porcelain coating capable of withstanding thermal shock when quenched at a temperature slightly less than its maturing temperature.

Figure 3.5 shows the condition of the test bars after tensile testing. It will be noted that the porcelain coating of the test bars on the extreme right did not withstand thermal shock. However, subsequent to these tests, a particular porcelain coating has been found to withstand this degree of thermal shock but we have not had time to conduct tensile and flexural strength tests with it in the as-quenched condition.

Figure 3.6 is a composite graph showing thermal coefficient of expansion characteristics of three specially formulated frits for porcelain coating aluminum alloy. Of particular interest about these curves is the fact that the instantaneous thermal coefficient of expansion is not uniform over any particular temperature range and appears to be changing continuously. However, below a certain temperature referred to as a transition point, the instantaneous rate in change of coefficient is less than that above the transition point. This phenomenon was borne out by all three of the formulations tested in this series of experiments. The coefficient of expansion of 61S aluminum alloy: 14.1 x 10^{-6}/°F.)

TENSILE LOADING OF ENAMELED AND BARE 61ST6 ALUMINUM ALLOY 1/4 INCH THICK

PREFIRE °F - Min.	MATURING °F - Min.	MATURING °F - Min.	TENSILE STRENGTH p. s. i.	YIELD STRENGTH 0.2% set. psi	ELONGATION % in 2 In.
As received (Series A)			46,700	39,900	15.0
As received (Series B)			47,700	41,800	14.5
1000° - 10 Min. (bare)			23,450	12,300	18.0
1000° - 10 Min. (bare)			23,550	8,640	27.0
1000-10	1050-10 (one coat)		25,150	11,100	19.8
1000-10	1000-7 (one coat)		25,200	12,600	22.5
1000-10	1050-10	1000-10 (two coats)	25,050	11,250	20.3
1000-10	1000-7	1000-7 (two coats)	24,900	16,750	22.5
1000-10	1000-7 (bare)		22,150	8,835	23.3
1000-10	1000-7	1000-7 (bare)	21,025	7,945	28.0
1000-10	1050-10	1000-10 (two coats and	31,800	15,050	29.0
1000-10	1000-7	1000-7 water quench)	37,600	19,650	27.5
1000-10	1000-7	1000-7 (bare, quench)	25,525	10,765	30.0

NOTE: Water quenching applied only after second coat; otherwise all specimens cooled in air after prefiring and maturing cycles.

Fig. 3.4—Tensile test data.

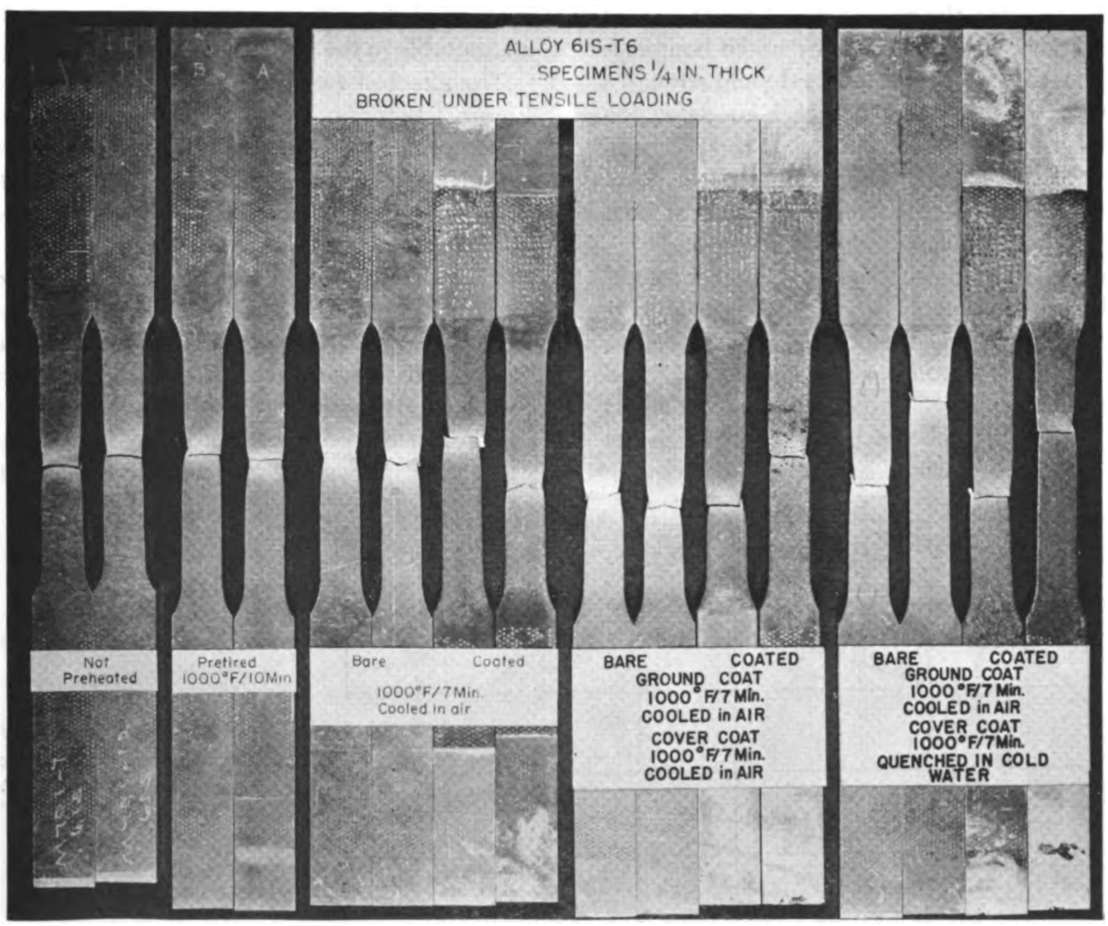

Fig. 3.5—Tensile test bars after testing.

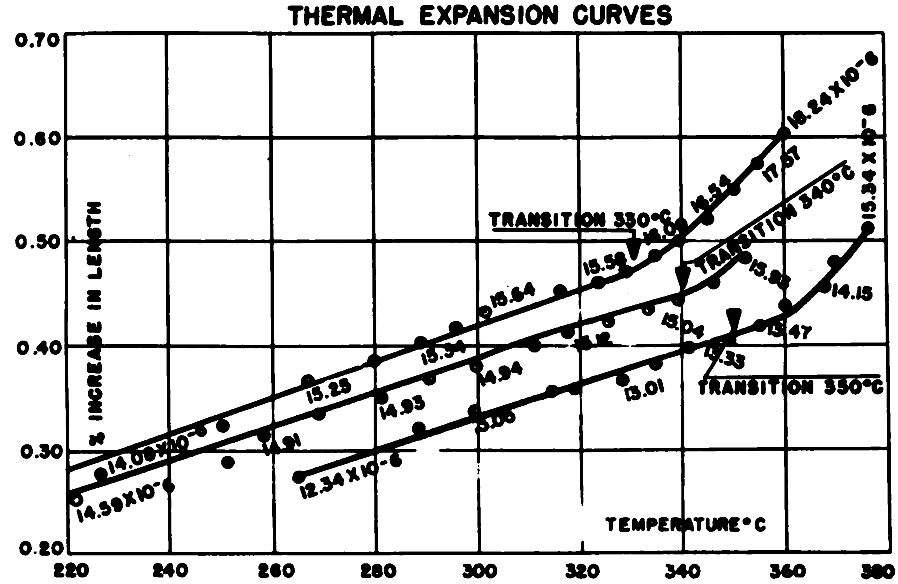

Fig. 3.6—Thermal coefficient of expansion of frits for coating aluminum alloy.

Each of these three frits was experimentally applied to flexural strength test bars and the load deflection characteristics studied.

Figure 3.7 shows the uncoated 61ST6 aluminum alloy in the as-received and pre-fired conditions. When tested under bending loads applied normal to and parallel with the rolling direction, the effect of the pre-fire heating on the alloy of T6 temper is obvious from the drastically reduced yield strengths as indicated by the two pairs of load deflection curves. Also of significant interest is the shape of the curves in the area of transition from elastic to plastic deformation——the straight sections of each curve representing elastic deformation and the curved and less sloping sections possibly representing plastic deformation. These are recognizable as analogous to the characteristic stress strain curves obtained by tensile testing of aluminum alloys and other metals which have no yield point, sometimes referred to as "drop of the beam", and observed when testing plain carbon steels.

Figure 3.8 represents load-deflection curves of the same alloy in the form of test bars coated with one coat of porcelain enamel. Except for the slightly irregular nature of curve (2), it is indicated that one coat only has but very little effect on the shape of the curve. However, curve (1) clearly indicates the added flexural strength and improved stiffness attributable to the presence of the porcelain coating.

The effect of two coats of enamel is indicated in Figure 3.9 to be quite pronounced. From these curves representing coated test bars, certain items of considerable significance become apparent at once. Beginning with curve (1), for example, one can trace a straight section at zero loading up to about 400 lbs., which would represent possibly the stiffness attributable to the basis metal and the coating on both sides of the test specimen. At about 400 lbs. it will be noted that the slope drastically changes, possibly because of stress rupture in the coating on the compression side of the bend test specimen. However, the coating on the tensile

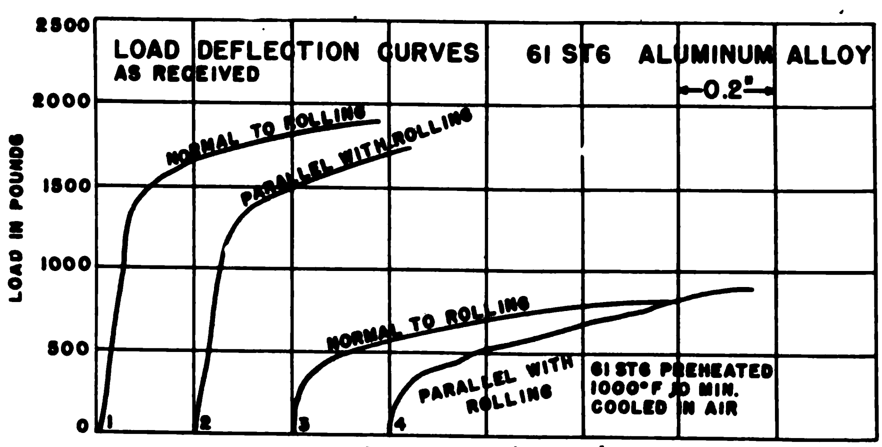

Fig. 3.7—Load-deflection curves for 61S aluminum alloy, ¼-inch thick, as received and after pre-fire heat treatment.

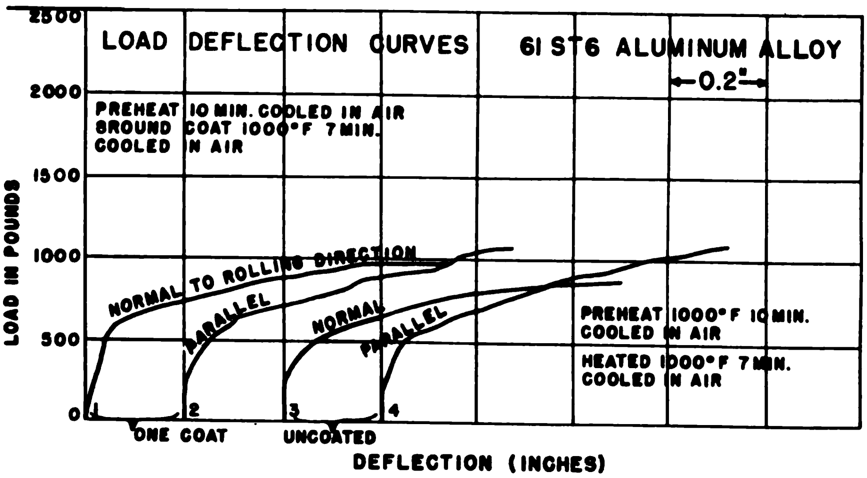

Fig. 3.8—Load-deflection curves for 61S aluminum alloy, one coat and bare ¼-inch plate with comparable heat treatment.

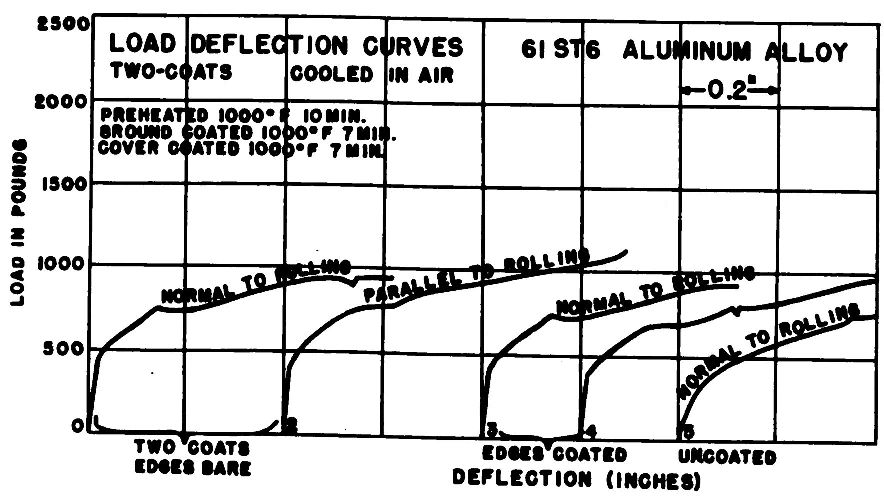

Fig. 3.9—Load-deflection curves for 61S aluminum alloy, two coats and bare ¼-inch plate with comparable heat treatment.

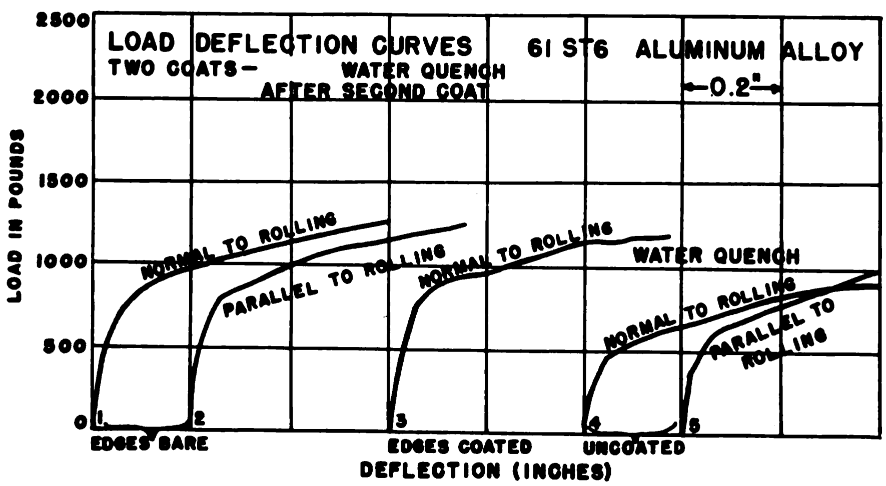

Fig. 3.10—Load-deflection curves for 61S aluminum alloy, two coats, water-quenched after second coat, and bare ¼-inch plate with comparable heat treatment.

TRANSVERSE LOADING ACROSS AND WITH ROLLING DIRECTION OF BARE AND ENAMELED PLATED 61ST6 ALUMINUM ALLOY 6" x 2" x 1/4"

All specimens prefired at 1000°F. for 10 minutes. All maturing cycles 1000°F. for 7 minutes followed by air cooling, except as noted. Yield loads estimated from load-deflection curves automatically plotted.

CONDITION OF BEND SPECIMEN	YIELD LOAD ACROSS GRAIN (pounds)	YIELD LOAD WITH GRAIN (pounds)
As received	1575	1400
Prefire only	413	358
One coat, edges bare	483	525
One coat, edges covered	475	---
Prefire plus one maturing cycle, bare	420	478
Two coats, edges bare	588	650
Two coats, edges covered	650	---
Prefire plus two maturing cycles, bare	550	425
Two coats, edges bare, water quenched	810	838
Two coats, edges covered, quenched	813	---
Prefire, two maturing cycles, bare, quenched	488	600

Fig. 3.11—Data on yield loads of bend test specimens.

side continues to contribute to the stiffness of the test bar. Then at about 600 lbs. a kind of yield point occurs. This yield point is shown on all four of the curves which represent coated test bars. Deflection thereafter continues without increased load until the basis metal becomes work hardened sufficiently to require increased loading, as would be expected according to the behavior of uncoated test bars.

Figure 3.10 represents water-quenched test bars and these curves are considered significant because there appears to be no perceptible break at or near the yield stress area of any of the curves. However, as in the case of tensile testing of water-quenched samples, the coating appears to contribute significantly to the stiffness and flexural strength.

The approximate loads where permanent deformation of the transverse bend specimens occurred are summarized in Figure 3.11. Here again, as in the case of the tensile stress data, it is indicated that the aluminum alloy to be porcelain enamel coated need not be of T6 temper because of the significant loss which occurs after the pre-fire heating. Also, as in the case of tensile testing, the effect of the coating in contributing to the yield strength is indicated.

Figure 3.12 shows photographically the effect of transverse bending on the coating in tension and compression. Stress rupture lines began forming in the compression side coating rather early (400 lb) in each of the tests. However, as indicated by the pair of bend test specimens in the upper left-hand corner, considerable bending occurred without the development of stress rupture lines in the coating under tensile straining.

Referring again to Figure 3.9, the possibility has been strongly indicated that porcelain enamel, prepared from frit selected on the basis of specific thermal coefficient of expansion, could be effective as an elastic material predominantly under tensile stress or compression stress. The next question that comes logically to the mind of the engineer is, "How much straining will the enamel withstand?"

We have found it convenient to determine some of the strain characteristics of a few porcelain enamels by applying them to the inside surfaces of copper nickel alloy rings as shown in Figure 3.13. Test rings used were 1" long cut from 8" nipples of 3½" iron pipe size tubing. Strain gages were attached as indicated at each side, top and bottom, thereby simultaneously providing two deformations in compression and two in tension.

Of particular interest to be noted in Figure 3.14 is the curve designated as "Gage 1 tension". It will be noted that at a deflection of 50 mils, the straining of the inside metal surface was estimated to be greater than 4000 micro inches per inch.

In Figure 3.15 it is to be noted that specimen BA, with a coating thickness of 7 mils, withstood deflection to a point of maximum stress in tension of 100 mils; thereby indicating that the amount of strain which this particular porcelain enamel withstood before rupture was well in excess of 4000 micro inches per inch and simultaneously indicated that the straining under compression of this same enamel was well in excess of 3500 micro inches per

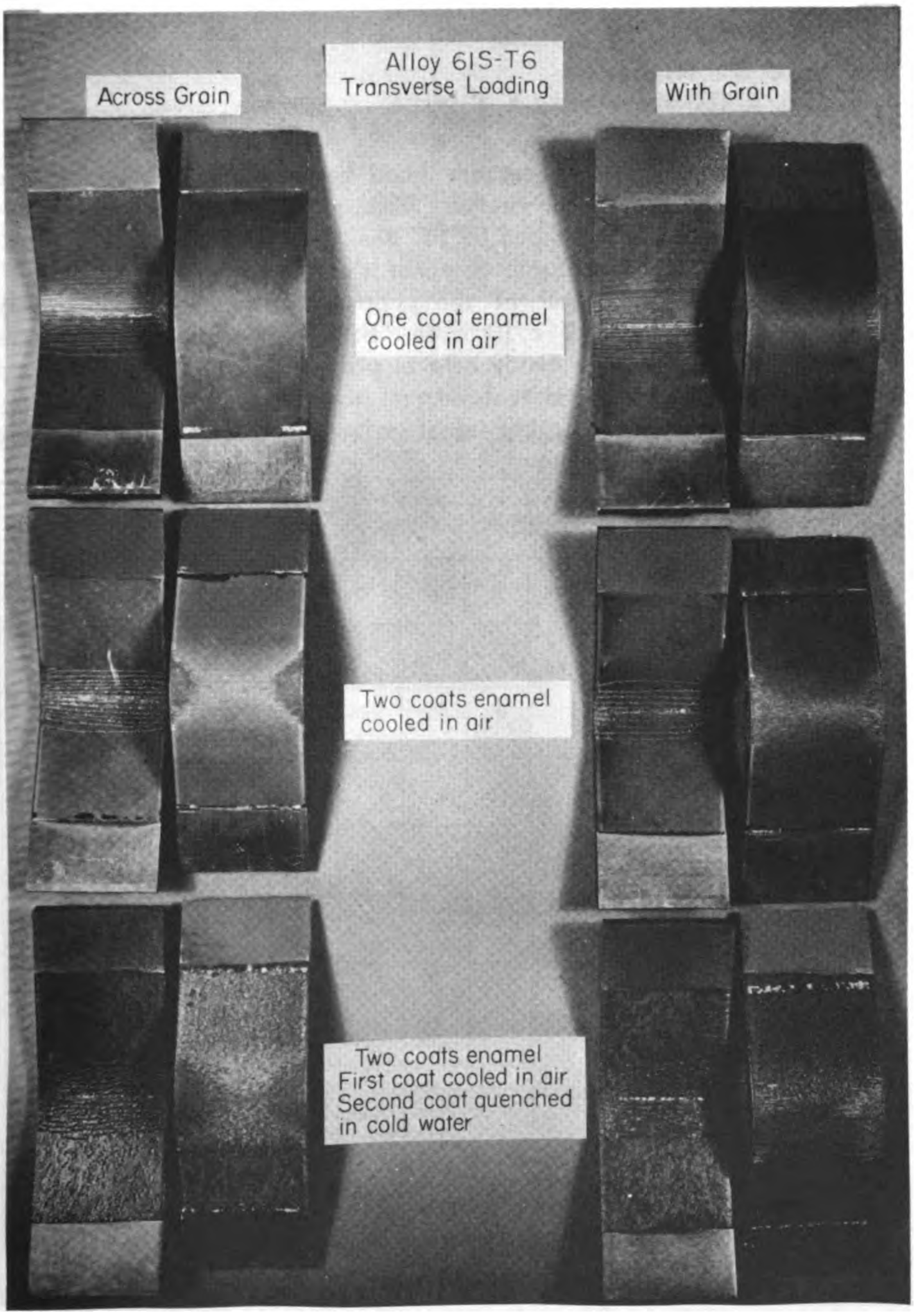

Fig. 3.12—Bend test specimens after bending, showing stress-rupture lines.

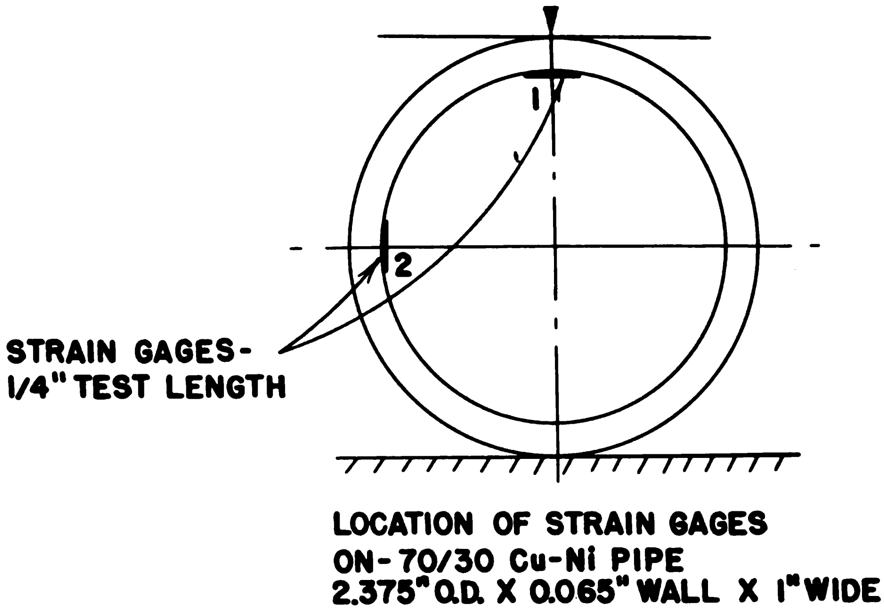

Fig. 3.13—Compression ring test specimen, showing strain gage location.

inch. Further, it was indicated that specimen BE which had a coating thickness of 13 mils, was probably the least elastic, in tension, of the enamels thus tested. It withstood straining of about 1750 micro inches per inch in tension, but better than 3500 micro inches per inch in compression.

Examination of the copper nickel alloy after the enamel coating had ruptured indicated bright metal surfaces. This was interpreted as absence of metallo-ceramic bond between the coating and the basic metal. The enamels used had been formulated to "fit" steel, the thermal coefficient of expansion of which is nominally 6.7 x 10^{-6}in./in./°F. That of the copper nickel alloy is nominally 8.7 x 10^{-6}in/in./°F. The porcelain enamel was probably held in place mechanically by the hoop stresses developed in the metal ring when cooling. Possibly the stress rupture failure of the coating

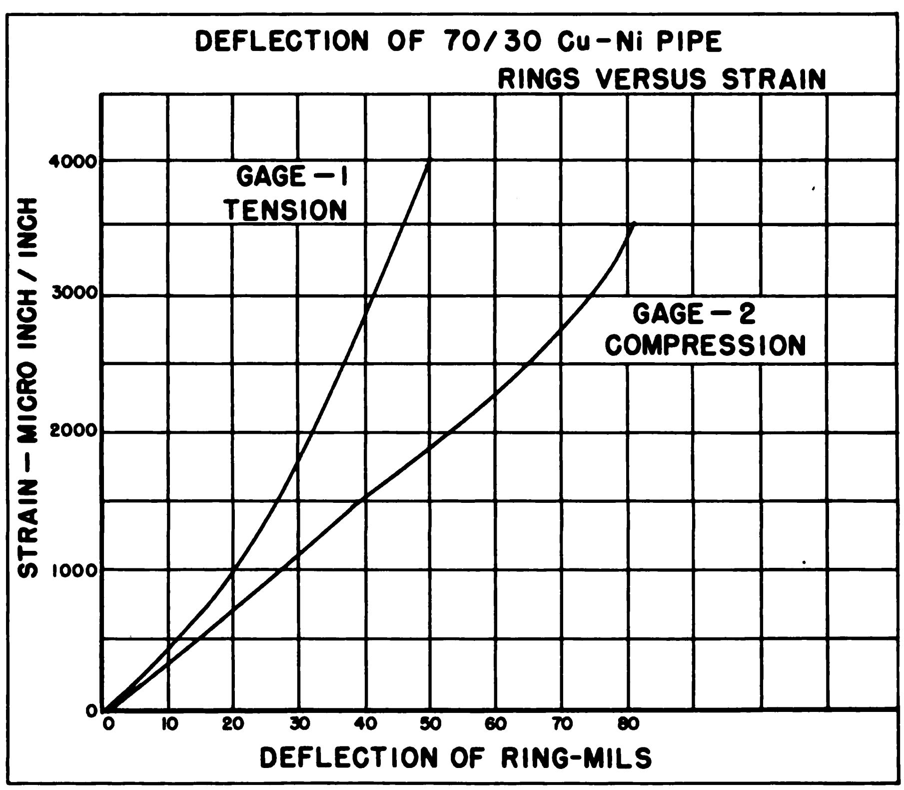

Fig. 3.14—Strain versus deflection of compression ring test specimen.

Flexural Test of Rings from Coated Pipe Samples			
Specimen Designation	Thickness of Coating Mils (a)	Number of Mils Rings were deflected before failure of coating.	
		Point of Maximum Stress in Tension	Point of Maximum Stress in Compression
AA	6	90	No failure at 100
AB	7	80	225
AC	6	45	No failure at 100
AD	7	70	No failure at 100
BA	7	100	120
BB	8	70	No failure at 100
BC	18	70	No failure at 100
BD	2	60	No failure at 100
BE	13	30	No failure at 100
BF	6	60-70	No failure at 100
CA	15-20	50	No failure at 100

(a) Thickness of coatings obtained by micrometer measurements.

Fig. 3.15—Compression ring test data.

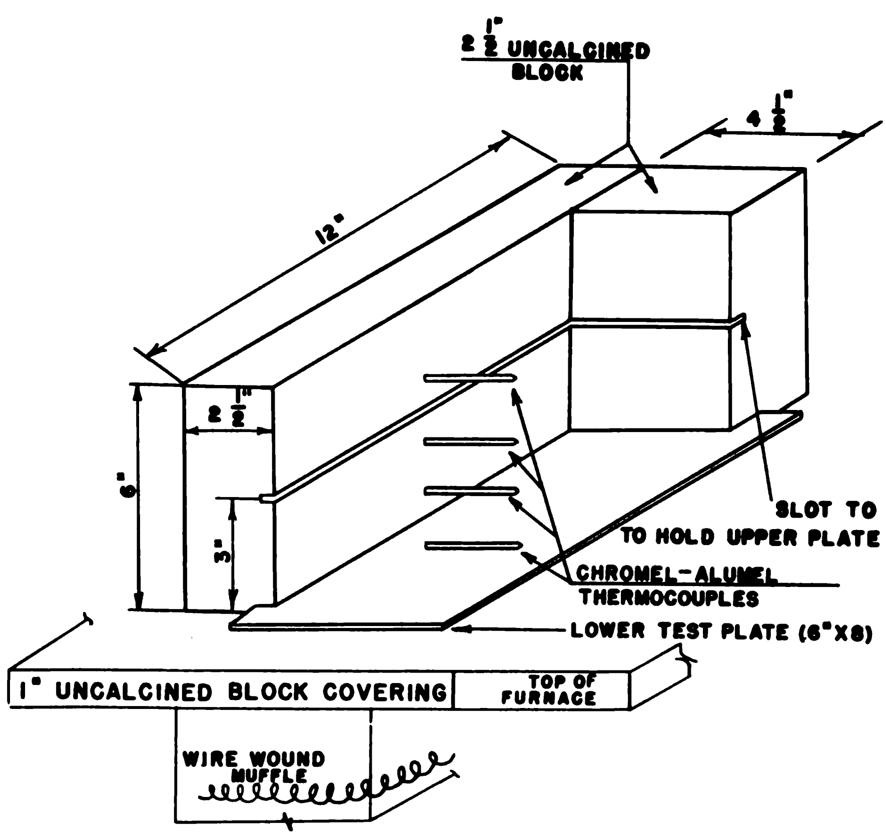

Fig. 3.16—Heat transfer test set-up.

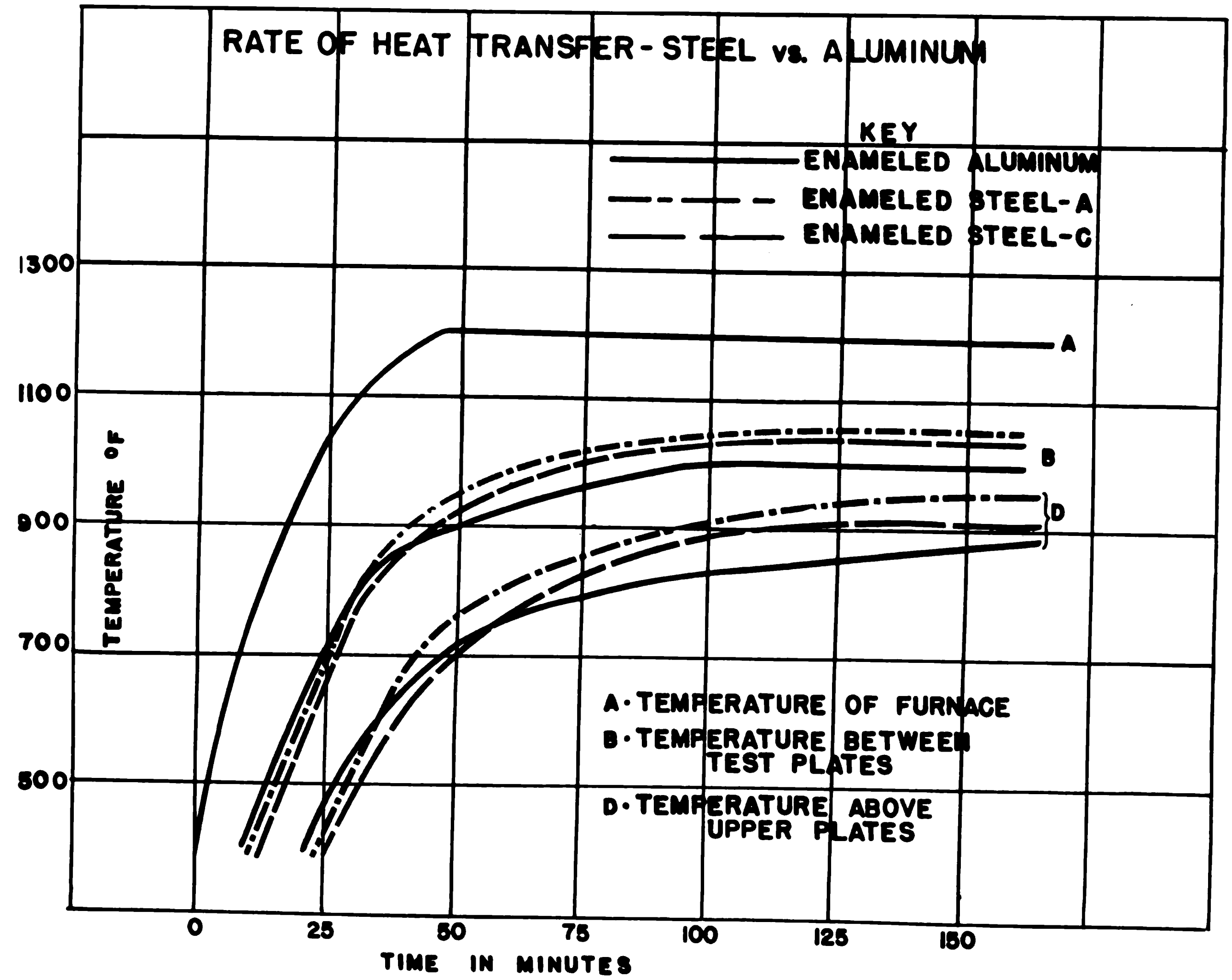

Fig. 3.17—Time-temperature curves, coated aluminum alloy versus coated steel at 1250° F.

was not influenced by any metallo-ceramic bond at the interface.

The copper nickel alloy tubing was relatively soft and its elastic limit was exceeded relatively early in each ring compression test. Hence, the ductility of the porcelain enamel (whether elastic or plastic or both) as indicated by this method of testing is a very close approximation of the porcelain enamel itself. However, as also indicated in Figure 3.5, when the coating may be under residual compression stress, the net effective strain limit may be greater than 4000 micro inches per inch. This observation is in support of the theory mentioned in connection with Figure 3.9 wherein a section of the load deflection curve also indicated that, when the porcelain enamel is under residual compressive stress, the net effective strain limit in tension might possibly exceed the elastic straining in outer fiber of aluminum bend test specimens.

Failure to apply correctly our knowledge of the elastic straining of porcelain enamel can be illustrated by the results of a test of porcelain enamel on an exhaust tube expansion joint. An experimental tube was constructed so as to have a bend and a bellows type expansion joint. The tube section was fabricated of ⅛″ thick medium steel rolled to an outside diameter of 16″ and seam welded. This particular expansion joint was intentionally constructed for test conditions under which deformation beyond the elastic limit would occur. This tube was blanked off at the bent end, fitted with a longitudinal gage bar, and mounted for external hydrostatic pressure testing.

External hydrostatic pressure loads were applied incrementally and load deformation curves plotted from the data recorded. Deformation of the tube walls under compression loading was determined by dial gages mounted on a spider rod. Failures of the porcelain enamel occurred only when the metal was permanently deformed, thereby demonstrating the appropriateness and advantages of using only those porcelain enamel coatings which have suitable elastic properties.

Reference has been made previously to the ability of the coating to withstand vibration. In our work we have not yet gone into this field of investigation as thoroughly as what we believe it should be. However, we do have some data on comparative vibration characteristics of a porcelain coated panel, a painted panel, and an uncoated panel of equal metal thickness. For our preliminary studies, several specimens 12" square were used. An area of approximately 1" in diameter was exposed at the center of one face of the coated panels. Each test plate was suspended from the ceiling of the sound room of the laboratory by means of cotton cord attached to two corners of the specimen. A microphone was placed near the center of the space opposite the exposed area of the steel and a soft rubber ball, suspended from another cotton cord, was used to strike the exposed area of the specimen. The microphone was connected to a sound frequency analyzer which in turn was connected to a sound level recorder which provided a graphic report of the change or degree of sound intensity given off by each plate being struck by the ball. The natural mode of vibration of the plate was found to be 105 cycles per second.

In the particular set of comparative data developed it was noted that the painted steel gave the best damping; namely, 18 decibels per second. Next was the uncoated steel plate of 5.5 decibels per second. The porcelain enamel coating of the type and method of application represented caused the least amount of damping but would thereby indicate that it was behaving as a material possessed of elastic properties remarkably comparable to those of the basis metal steel.

Mention has been made previously of desirable attributes of flame barrier materials. For the purpose of obtaining preliminary data on the heat

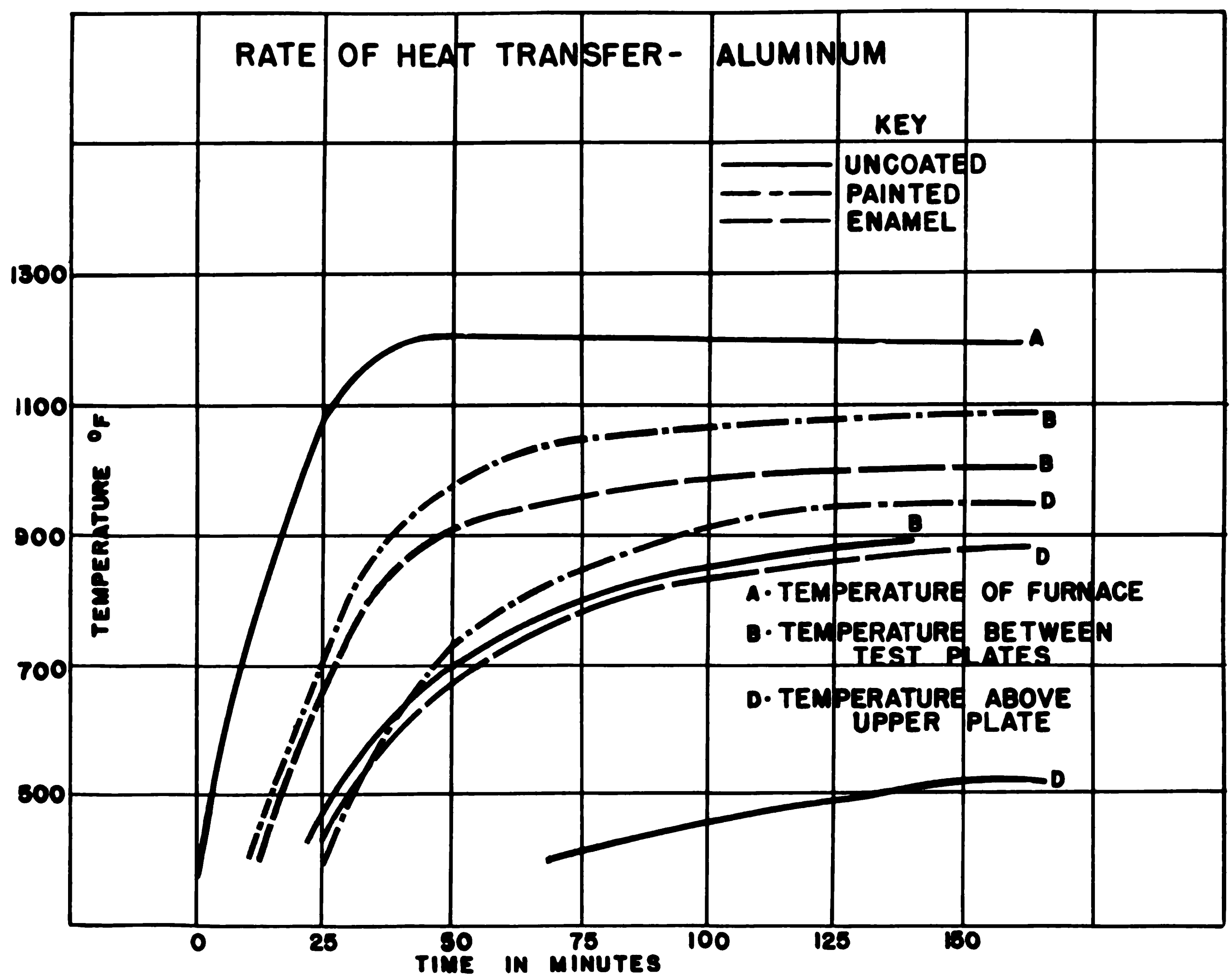

Fig. 3.18—Time-temperature curves, coated versus bare aluminum alloy at 1250° F.

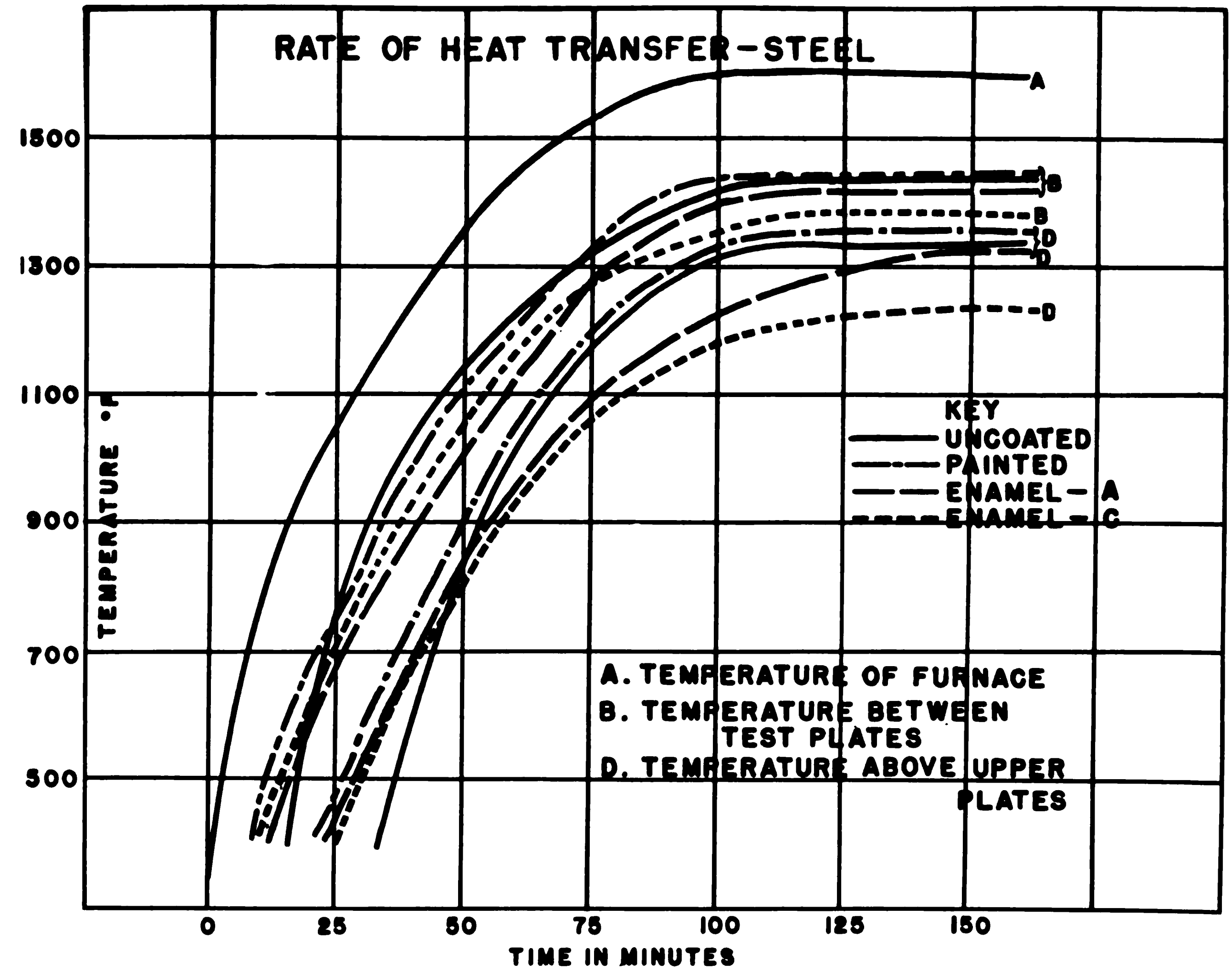

Fig. 3.19—Time-temperature curves, bare, painted, and porcelain enameled steel at 1750° F.

transfer characteristics of porcelain enamel coatings, some tests were made using a relatively simple test setup as shown in Figure 3.16. By this arrangement, two test plates are held flat and parallel, with a heating unit beneath, a dead air space between, and a topside surface partially shielded from convection currents. In this figure it will be seen that the effective heat transfer characteristics were made by a set of four thermocouples arranged so as to measure simultaneously the temperature on the side of an enamel plate exposed to the heat source, the temperature in the dead-air space, and the temperature immediately above the top panel. Rates of heating were plotted as shown in Figures 3.17, 3.18, 3.19 and 3.20.

A test for the purpose of making direct comparison between steel and aluminum yielded data as shown in Figure 3.17. The furnace or heat source temperature is shown by the upper solid line letter "A". In this particular test, which incidentally was limited to a heat source at 1,250° F., enameled aluminum appears to have been the most effective flame barrier, steel with enamel "C" next best, and steel with enamel "A" the least effective in retarding heat flow.

Figure 3.18 shows comparative data on the heat transfer characteristics of enameled, painted, and uncoated aluminum. At once it is noted that the uncoated aluminum is far superior to either the painted or enameled aluminum with respect to heat insulation.

Tests were conducted with porcelain enamel coated steel under conditions which permit the temperature of the heat source to reach 1750° F. which is well above that at which aluminum would have deteriorated. The results are shown in Figure 3.19 and it will be noted that a coating indicated as Enamel "C" provided the best resistance to heat transfer. Specific data on this particular coating are not available. However, it does appear worthy of note that the steel coated with Enamel "C" was affording significant resistance to heat transfer at a temperature above that at which aluminum would be expected to have melted.

From time to time the question arises as to the influence of color and other appearance properties on the effective heat transfer characteristic of a coating. Our data on this phenomenon are quite limited, but the information which we do have is shown in Figure 3.20. This figure shows the results of a very brief and incomplete preliminary study of the comparative effects of white, green and gray porcelain enamel on steel. In this case the white porcelain enamel appeared to offer the best resistance to heat transfer.

Now that we have given some careful detailed attention to a few but essential items of the technology of ceramic coatings on steel and aluminum alloy, it seems in order to have a look at a few of the very practical aspects of its use.

At first, serious concern was expressed as to whether or not extra care would be necessary in handling, erecting and installing porcelain enameled panels. However, in the case of porcelain coated metal panels we have made very careful observations as to whether or not their use would be limited because of special precautions in handling, sizing and erection. These materials may be sheared, drilled, and riveted substantially the same as uncoated steel and aluminum alloy sheets aboard a ship, and possibly in the construction of buildings. Shearing of porcelain coated panels may be done without any special precautions to avoid damage to the ceramic coating.

Figure 3.21 illustrates that the material can be drilled and riveted with conventional equipment without damage to the coating. Figure 3.22 illus-

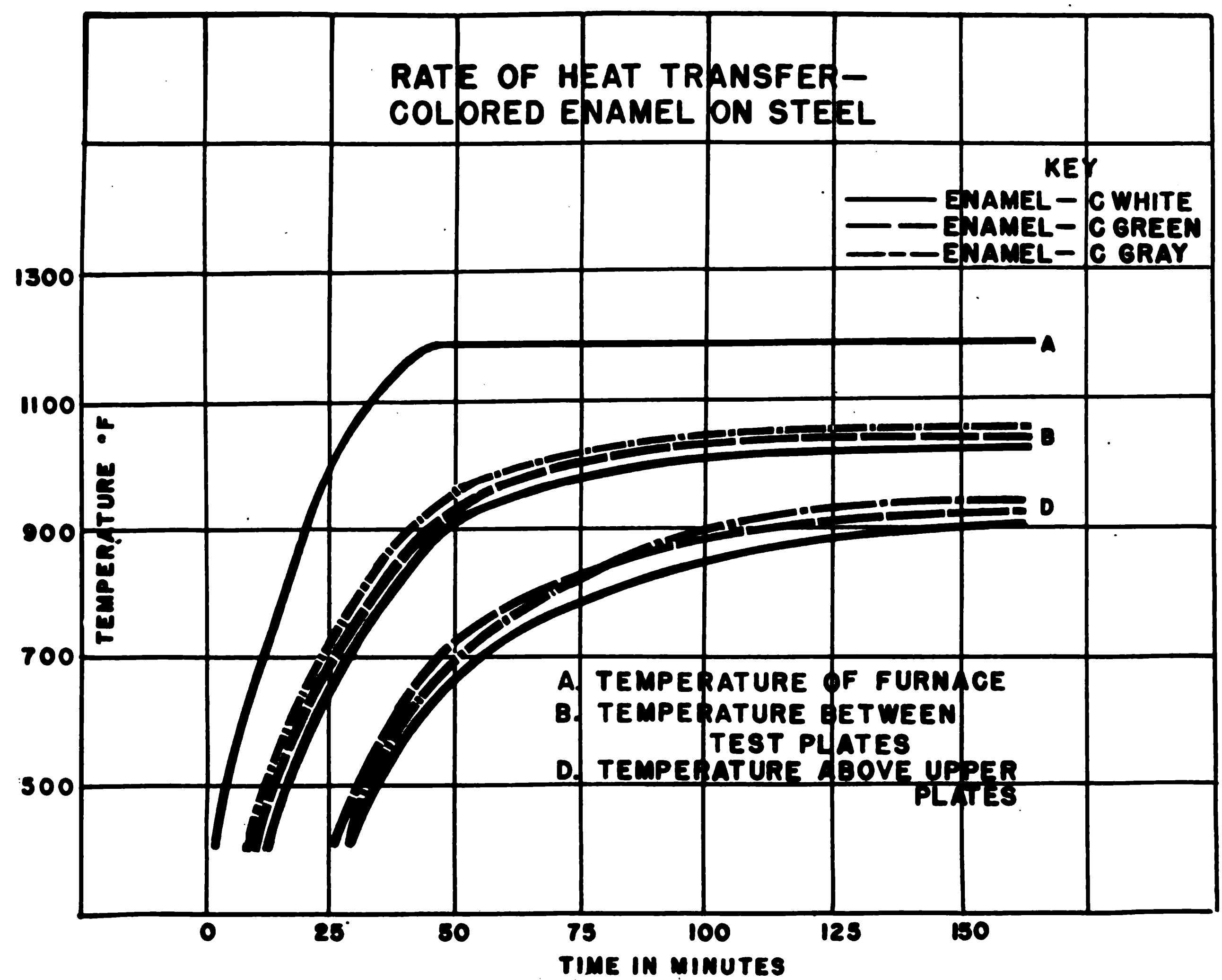

Fig. 3.20—Time-temperature curves, white, gray, and green porcelain on steel at 1250° F.

Fig. 3.21—Riveting porcelain enamel coated sheet.

trates the importance of flexural strength in the bulkhead material, by way of supporting sanitary fixtures. The principles illustrated by the attachment of sanitary fixtures also apply to cable runs and stateroom furniture secured to bulkhead panels.

The panels are suitable for securing the attachment screws by nuts and washers on the back side of the bulkhead. A coating of weld-spatter preventive compound is specified to be applied to the porcelain coated metal sheets prior to their delivery to the field activity. This weld-spatter preventive compound also functions as a separator material to prevent the enamel surfaces from being scratched during shipment thereby obviating the necessity of paper interleaving and later on providing a good surface for pencil layout marking. This preventive compound is readily washed off by warm water with the result that the finished work can be easily cleaned up to a surface of excellent appearance.

Referring to exhaust muffler service, it seems in order to illustrate that promise has been offered in the direction of repairing porcelain enamel coatings by means of flame spray method. Figure 3.23 shows the operation of repairing porcelain enamel which had been damaged on a wet type exhaust muffler. This method of coating repair is not in common practice. However, there are research projects under way for the further development of flame sprayable porcelain enamel, flame spray methods

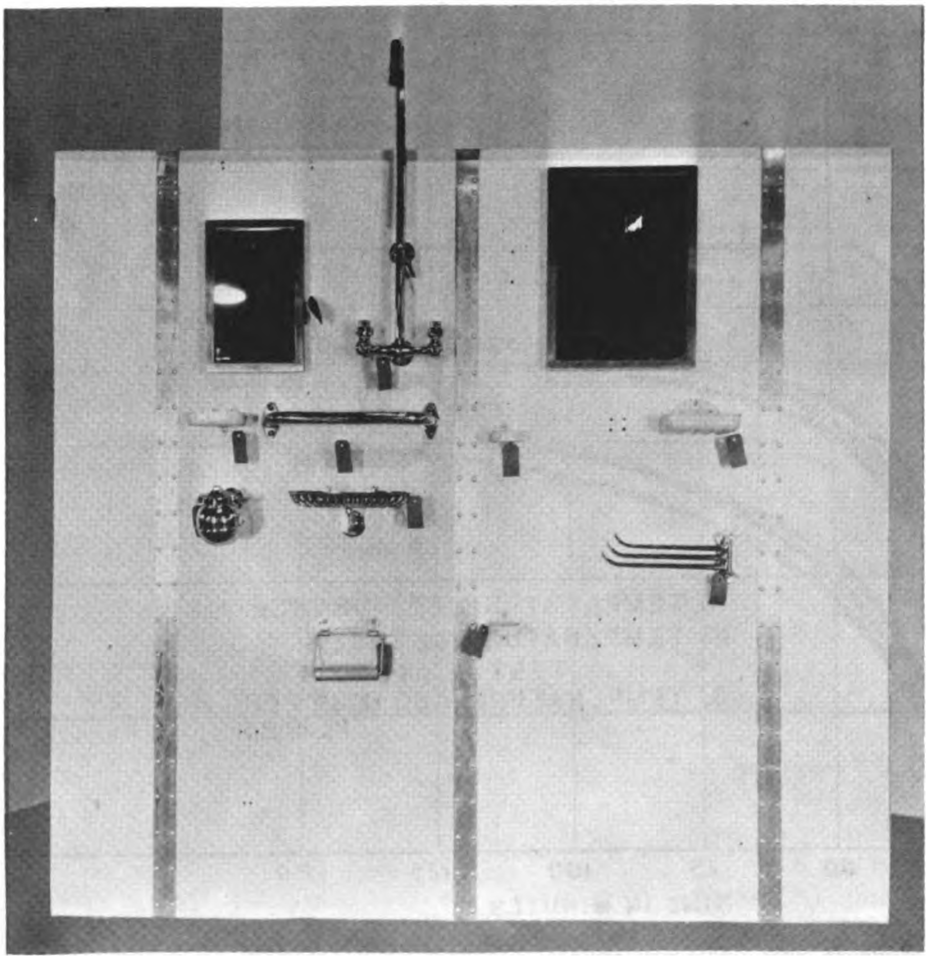

Fig. 3.22—Sanitary fixtures attached to enamel coated sheet, composite view.

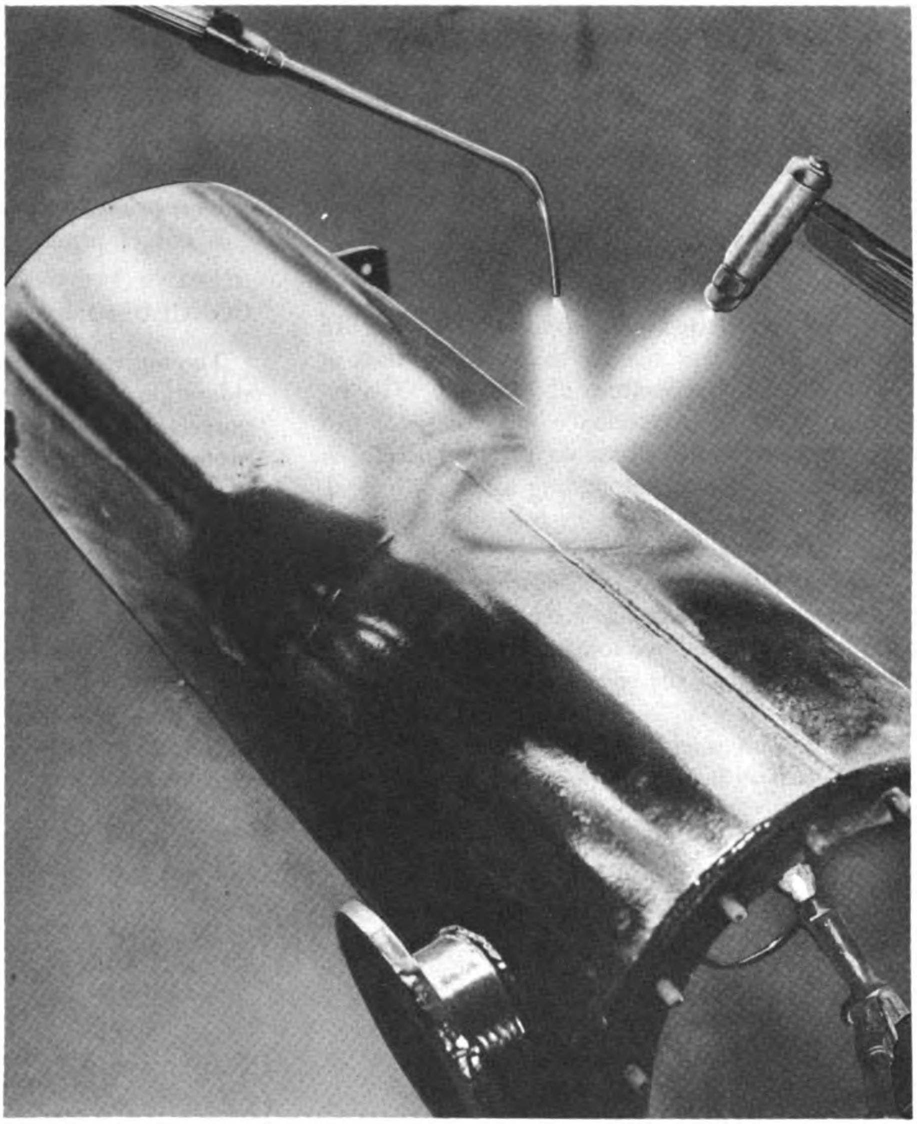

Fig. 3.23—Flame-spray enameling of exhaust muffler, for repair of coating.

and equipment for those applications where appearance of the surface is not one of the essential attributes of the coating.

In summarizing, it would seem that sufficient data have accrued to support technically the following:

a. Porcelain enamel coatings, when properly formulated and applied, can contribute significantly to the stiffness and flexural strength of metal sheets, plates, or shapes to which they are applied, without loss of resilience.

b. In the case of steel basis metal, each incremental improvement in stiffness and flexural strength obtains by using porcelain enamel with but one-third of what the weight increase would be if additional steel were used to obtain the same incremental increase.

c. In the case of 61S aluminum alloy, the porcelain enamel can be so formulated and applied that when elongated in tension, the coating can be made to perform as a ductile material significantly beyond the elastic limit of the basis metal in outer-fiber straining.

d. Theoretically, the effective strain limits of porcelain enamels which exhibit these unusual elastic properties, obtain from residual compressive stress in the coating. However, it seems reasonable to suspect that these particular enamels might also consist of one or more crystalline phases which cause the coating to behave under externally applied tensile loads in a manner characteristic of the basis metal. Future work with porcelain enamel in the field of X-ray diffraction studies is expected to throw considerable light on this theory. However, until these phenomena associated with the elastic property of enamel are clearly understood, care must be exercised in determining whether or not the surfaces to be porcelain coated are expected to be under compressive loading.

e. With respect to heat transfer properties, certain porcelain enamels can be so formulated and applied to steel that flame barrier properties are significantly improved, as indicated by tests at a heat-source temperature of 1750° F. Where improvement in thermal conductivity is desired, porcelain enamel coatings can also be suitably formulated and applied to either 61S aluminum alloy or steel as indicated by tests at a heat-source temperature of 1250° F. The increase in effective thermal conductivity of 61S aluminum alloy, attributable to the coating, is greater than the corresponding increase in steel. The data are insufficient to conclude with certainty the influence of color on flame barrier properties. However, assuming that the enamels represented in Figure 3.20 are alike in all respects except color, and have the same gloss, thickness, and texture, then the color, white, is to be given slight preference.

f. Sheets of steel and 61S aluminum alloy can be coated with certain porcelain enamels and by certain processes which produce panels suitable for practical handling, erection, and the attachment of fixtures in common use.

g. Porcelain enamel coatings on steel can be repaired by the flame spray process, but should be restricted to those end uses where appearance is not of primary importance.

CONCLUSION:

The author is of the opinion that favorable consideration should be given to the acceptance of porcelain enamel coatings for the adornment and protection of surfaces of 61S aluminum alloy and enameling-quality steel more especially where permanence of appearance properties is essential. Moreover, the author is also of the opinion that where mechanical destruction of the coating by impact is not expected, the added stiffness and flexural strength contributed by elastic porcelain enamel, might be safely used in stepping up the allowable design stresses, thereby achieving significant reductions in weight without sacrificing design load carrying capacity.

FLUES, FURNACES, AND EXHAUST SYSTEMS USING HIGH TEMPERATURE PORCELAIN ENAMELS AND CERAMIC COATINGS

By A. I. Andrews*

(Head of the Department of Ceramic Engineering, University of Illinois)

Since the term "high temperature" is a relative one and could be easily misunderstood, its meaning as used in this discussion must be explained. Although all temperatures above room temperature could be considered high temperatures, use of the term here will be confined principally to temperatures from 212° to 2000° F.

The terms "porcelain enamel" and "ceramic coating" also need some explanation. The term porcelain enamel covers a very wide variety of glasses applied to metal surfaces to form a relatively thin but continuous coating. Porcelain enamels vary greatly in their physical, chemical, thermal, and optical properties, with each variety finding its most important use. A porcelain enamel is, however, essentially a high-temperature material, for, in processing, it is fired at temperatures of 1400° F. and up. Enamels cannot be heated continuously at their firing temperatures without damage, but most of them will withstand long periods of service at temperatures 400 to 600 degrees lower than their firing temperatures. Although porcelain enamels always lengthen the useful life of the metal, at high temperatures the properties of the metal also play an important part in the useful life of the product.

In the development of porcelain enamels the property of appearance has always been a dominant factor. In high-temperature applications, however, appearance is not always a factor, and out of this difference in attitude the ceramic coating was developed. The ceramic coating differs from the porcelain enamel in that a much more refractory (higher melting temperature) glass is used. Further, the proportion of non-glassy refractory materials is greatly increased, sometimes to a point completely destroying the glossy appearance of the coating. These coatings, when applied to stable alloys such as stainless steel, protect the metal for long periods—almost indefinitely—at temperatures up to 1200° or 1300° F. At still higher temperatures—up to 1800° F.—they have useful lives measured in hundreds of hours. The principle of the protection of a metal by either a porcelain enamel or a ceramic coating is that the coating, applied as a thin film, must withstand heat at high temperatures and at the same time adhere to and insulate the metal from the surrounding atmosphere. In the selection and use of these coatings, many factors, such as heat transfer, mechanical strength, thermal shock resistance, and the metal base itself must be considered.

High-temperature applications of porcelain enamels are not new; and at the lower range of high temperatures, products utilizing these properties have been in mass production for a great many years. The porcelain enameled kitchen utensil and the granite pan which lay unharmed in the rubble after a house had burned to the ground are mute evidence of the resistance of porcelain enamel to heat. Although manufactured for use only in moderately elevated temperatures, it is resistant at temperatures far above those of its intended use. The porcelain enameled pan was certainly a forerunner of the use of porcelain enamel at high temperatures, which is only now being appreciated by designers, users, and manufacturers. With the discarding of the old, blackened range and the parlor stove, porcelain enamel found a greatly extended use as a high-temperature, non-corrosive material. Practically all ovens for stoves utilize porcelain enamel not only for its beauty, convenience and economy, but also because of its high-temperature resistance to corrosion and destruction. It is not at all necessary to discuss these applications further, for they are familiar to everyone.

Everyone, however, may not be familiar with some of the more recent applications of porcelain enamel in high-temperature service. In 1928, acid-resisting, porcelain enameled chimneys for the lining of old, brick "chimneys" were developed. These linings were used to protect such chimneys from deterioration caused by the condensation of water and acids from the flue gases when gas is used as fuel. Well over 110,000 of these chimneys have been produced. Your author installed one in his home in 1934; and with an oil-fired furnace, it is today unchanged. In 1943, a complete, independent, porcelain enameled flue was developed for government housing projects. This flue is shown in Figure 1. To this date 85,000 have been installed, and the current production is 15,000 to 20,000 per

* Prof. Andrews is past president of the American Ceramic Society and president of the National Institute of Ceramic Engineers. He is author of many technical papers and two books on porcelain enamel.

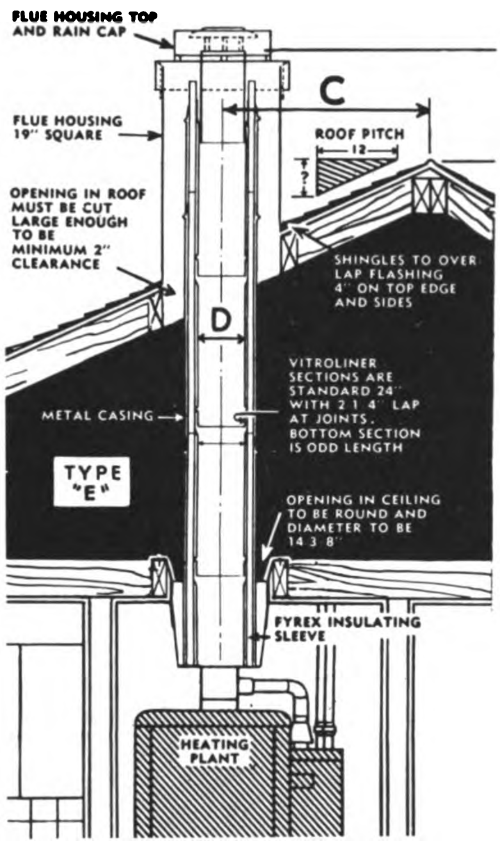

Fig. 3.24—Porcelain enameled flue (Illustration: courtesy of Condensation Engineering Corp., Chicago, Illinois).

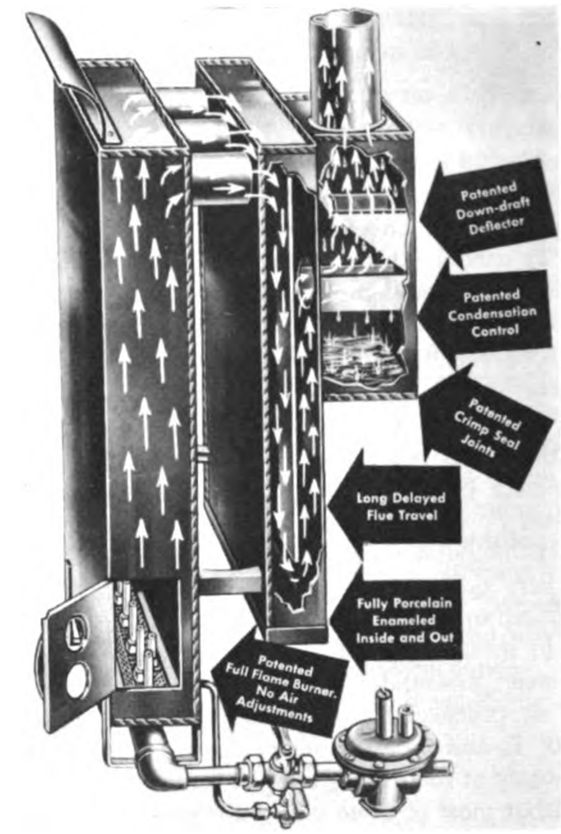

Fig. 3.25—Porcelain enameled space heater (Illustration: courtesy of Cole Hot Blast Manufacturing Co., Chicago, Illinois).

year. It has been accepted by the National Board of Underwriters for all fuels where flue gas temperatures do not exceed 1000° F. continuously or 1400° F. for infrequent brief intervals.

Figure 3.24 shows an installation diagram. The inner lining of the flue is made up of two-foot sections of acid-resisting porcelain enameled steel. Around this lining is a one-inch air space and an insulating sleeve covered with a steel jacket. The installation is comparatively light, and it is supported just below the basement ceiling by a metal flue-support. The flue does not contact combustible material at any point and is supported at the top by a metal flue housing.

In many furnace installations, the breech pipe between the furnace and the chimney is made of ordinary galvanized or black iron, which soon rusts or burns out. Porcelain enamel used on these parts does not deteriorate, thereby offering greater protection against flue gas escaping into the house.

The use of porcelain enamel in room heaters and floor furnaces has progressed very far. Figure 3.25 is a sectional diagram illustrating the flow of flue gases in such a porcelain enameled, gas space-

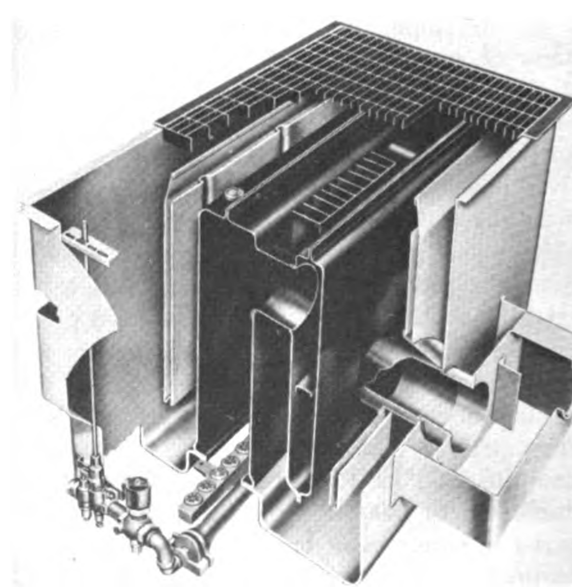

Fig. 3.26—Porcelain enameled floor furnace (Illustration: courtesy of Cole Hot Blast Mfg. Co., Chicago, Illinois.)

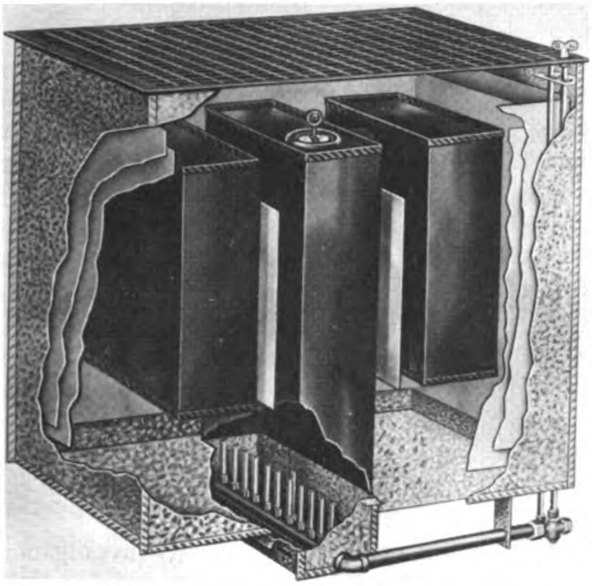

Fig. 3.27—Porcelain enameled floor furnace (Illustration: courtesy of Cole Hot Blast Mfg. Co., Chicago, Illinois).

heater. The flue gases and heat pass from the left chamber to the right, then around the baffle, and finally into the flue. The moisture in the gases is condensed and collected during the early stages of heating—before heat is developed sufficiently to take the moisture up the flue. On longer heating, the condensed water is re-evaporated and carried away with the flue gases. The porcelain enamel prevents rusting, and because of its resistance to high temperatures it gives the unit long life. Figure 3.26 shows a floor furnace with ceramic burner ports and forced-air, enameled combustion and heat transfer chambers. Figure 3.27 shows a floor furnace in which the gases flow to the right and left, giving excellent heat transfer. The light-appearing baffles prevent the heat from radiating from the center chamber to those on the outside. Figure 3.28 shows a wall-type gas heater. In some cases these heaters and furnaces depend upon the circulation of room air, while in other cases forced circulation is used. Many of these heaters installed in 1939 are said to be still in use. The use of one-

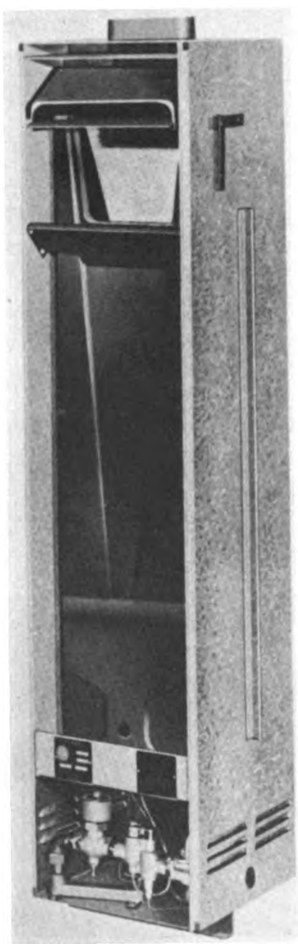

Fig. 3.28—Wall type porcelain enameled gas heater (Illustration: courtesy of Temco, Inc., Nashville, Tennessee).

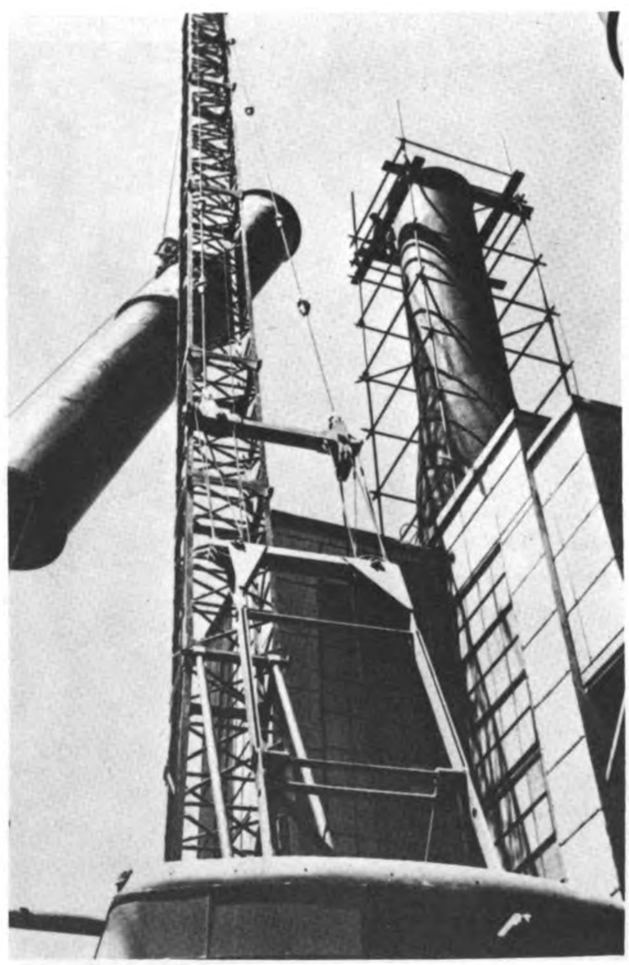

Fig. 3.29—Industrial smokestack, glass-lined inside and outside (Photo: courtesy of A. O. Smith Corp., Milwaukee, Wisconsin).

Fig. 3.30—Airplane exhaust system (Photo: courtesy of Ryan Aeronautical Co., San Diego, California).

coat porcelain enamel is extensive in this general area of manufacture.

Condensation in steel stacks offers a serious problem, as the acids from gases attack the steel and cause rapid deterioration, resulting in excessive maintenance and replacement costs. Although porcelain enameled smokestacks up to one foot in diameter have received some attention for industrial uses, the first large, factory stack to be porcelain enameled, "glass-lined", was installed in the spring of 1953. Figure 3.29 shows a 44-foot section of a six-foot diameter, porcelain enameled ("glass-lined") stack being installed as part of an 85-foot, powerhouse stack at the A. O. Smith Corporation plant in Milwaukee, Wisconsin. The glass lining, applied both on the inside and the outside of this stack, was fired at 1600° F.

Based on the results of preliminary investigations of test specimens, it is expected that this will be the beginning of a large industry, as it is estimated that 5,000 stacks are replaced each year in the United States

It is probable that porcelain enamel and ceramic

Fig. 3.31—Flame tubes for Jet Planes (Photo: courtesy of Ryan Aeronautical Co., San Diego, California).

coatings will find many new uses in space heaters, heat conduits, interchangers, boiler tubes, furnaces, and other high-temperature equipment in homes and in industrial and public buildings.

With shortages of high-temperature alloys and increased demands for higher-temperature materials, both brought on by World War II, the armed services turned to porcelain enamel for help to solve their problems. Extensive research was initiated in government bureaus, universities, industry, and the armed services laboratories. Prior to this time porcelain enamels had met the requirements of most uses to which they were put. But it was soon found that the requirements of airplane exhaust stacks, superchargers, nozzle boxes, tail pipes, marine exhaust systems, jet flame tubes, rockets, etc., were beyond the capacity of ordinary porcelain enamels. The result was a series of developments of very high temperature compositions, wherein refractory materials were bonded by high-temperature glasses to form coatings resistant to much higher temperatures. These became generally known as ceramic coatings. Even these coatings could not completely meet the more severe requirements of temperature and service desired.

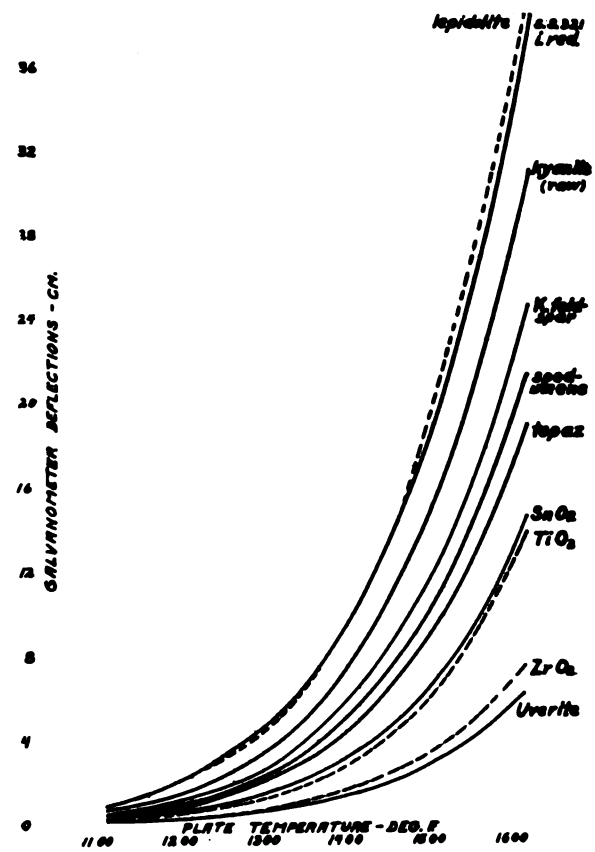

Fig. 3.33—Decrease of emissivity in the infra-red (0.7u-1.2u) for various coating materials—high temperature range—coatings 14 mils. thick (From: D. G. Bennett, J. A. Cer. Soc. XXX 297 (1947)).

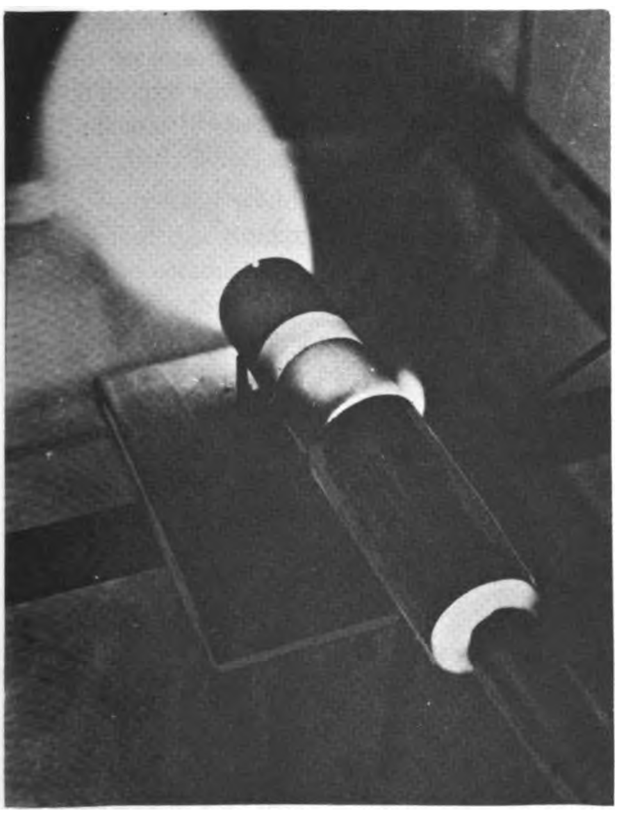

Fig. 3.32—Heat transmission of bare metal and coated steel. Detail view of specimen on gasoline torch burner stand showing band of glow where top coat was brushed away before the maturing fire. (From: D. G. Bennett, J. A. Cer. Soc. XXX 297 (1947).

But they have found important uses in extending the life of special alloys subjected to heat up to about 1800° F. and greatly extending the life of alloys and iron at lower temperatures. Figure 3.30 shows an exhaust system for an airplane. Figure 3.31 shows important parts for a jet engine. Experience has shown that ceramic coatings greatly extend the life of exhaust system components by protecting the metal from corrosion, oxidation, and carbon absorption. Such coatings are exceedingly thin (one or two one-thousandths of an inch) after firing, therefore they have practically no tendency to flake or crack off.

Another important property of ceramic coatings (also shared by porcelain enamel) is absorption and emission of heat. These coatings have been developed with a wide range of properties. The black and transparent coatings at high temperatures approach black-body absorption and emission. These properties closely approximate those of oxidized stainless steel. However, the specially developed coatings will absorb and emit only about

20% of this amount. Since these properties extend from the infra-red range into the visible range, a comparison of the heat emission of bare metal and ceramic-coated steel can be seen in Figure 3.32. Except for a band around the middle, the tube was coated with such a ceramic coating and heated by a blow torch. It is evident that the radiation from the bare-metal section is very strong and very low from where the tube was covered by the coating. Figure 3.33 shows the infra-red emission curves for a series of coatings and for uncoated No. 321 stainless steel (SS321). Many advantages can be taken of this range of emission of ceramic coatings. By using high absorption, high-emission coatings ware can be made to transfer heat; and by using low-absrоption, low emission coatings wares can be made to greatly reduce the transfer of heat. Since the absorption and emission percentages are alike, one supplements, rather than cancels, the other when passing heat through a panel, as in a space heater.

Another type of heat-suppressive coating which can be used is the ceramic paint CP44. This coating can be painted on, dried, and heated while the part is in service. It is not a long-life coating, but one that has good infra-red emission reduction and is convenient in special cases.

At high temperatures, ceramic coatings and porcelain enamels add strength, corrosion resistance, and control of heat flow to metal parts. When properly selected for the conditions of service, these properties can be used to advantage. Longer life of metal parts in many high-temperature uses in the home, in industry, and in war service equipment has been well demonstrated by many years of service.

PORCELAIN ENAMELED ALUMINUM

By B. C. Bricker*

(Electrochemicals Department, E. I. du Pont de Nemours & Co., Inc.)

Ceramics, which is recognized as one of the very earliest industries of man, has only in modern times become the subject of good, basic research. In years past, it was not uncommon for ceramic formulations to be considered a part of the family heritage, to be handed down from generation to generation. This procedure was designed to protect know-how. It served also to stifle an industry.

To name only a few of todays' types of ceramics developed through research, we have: high-temperature ceramic coatings for the protection of metals necessary in jet propulsion; superior porcelain enamels for steel, suitable for literally hundreds of applications; vitrifiable colors which are not affected by modern detergents; dielectric materials, the basis of the electronics industry, without which there would be no radar, no television; conductive coatings used for printed circuits and miniature electronic components; fiber glass, which can be combined with plastics to give an interesting structural material; and now, a vitreous enamel, designed for use on aluminum, which combines all the good properties, surface hardness, durability, and chemical-resistance of glass with the light weight, workability, and strength of aluminum.

The successful wedding of glass and aluminum has created new thinking in a product so new that we in the ceramic industry have barely scratched the surface in the development of its potential uses. Even in this early stage of development, however, background in research and field experience indicate clearly that one of the most important applications for porcelain enameled aluminum is in the building industry.

The first and perfectly reasonable question might be, "Why apply vitreous enamel on aluminum, which is itself a sound and acceptable structural product?" The answer is obvious: "To enhance the existing properties of the base metal and to add desirable new properties."

* Mr. Bricker received a B.S. degree in Ceramics at the University of Cincinnati in 1932. He had thirteen years of experience in ceramic research, development, and production prior to his association with du Pont de Nemours & Co., Inc. In addition to other assignments, he has had more than ten years of direct experience with porcelain enamel aluminum during its development.

PROPERTIES OF PORCELAIN ENAMELED ALUMINUM

Durability

The enamel contributes durability. The abrasion—resistant, long-wearing, hard, glassy structure provides a surface with long life at the very lowest maintenance cost.

Corrosion-Resistance

The enamel provides improved resistance to corrosion—resistance to alkalis and mild acids. The enamel is impervious to salt water, which broadens the use of aluminum in marine applications and adapts it for construction in previously questionable areas.

Flexural Strength

Porcelain enamel gives aluminum rigidity and resistance to flexing which are extremely important in any structural material. Glass under compression is strong. In designing for porcelain enameled aluminum, the strength of the glass under compression can be taken into consideration with the possibility of reducing the metal thickness to offset the additional weight of the enamel.

An average vitreous coating for aluminum weighs 10 grams per mil thickness per square foot. Hence, on a volume weight basis, the enamel is approximately 1.4 times the average weight of aluminum sheet stock.

As a typical example, if a 3-mil coating is added to the surface of .051″ sheet aluminum stock, the increase in total thickness is less than 6% and the increase in weight is less than 10%, but the gain in flexural strength and resistance to surface denting is more than 60%.

For many applications, an enamel coating on both faces of relatively light sheet stock imparts sufficient rigidity to allow a substantial savings in base metal cost.

Fire Resistance

We all recognize the hazards of fire, and there is nothing we can say to emphasize further the known and established fire barrier properties of glass as compared to any other finish. For certain applications, the excellent thermal conductivity of aluminum is highly desirable. However, for structural uses, the insulating value of glass contributes an important feature to aluminum as a base metal.

Color

Color is exciting and useful. To all the other desirable features of aluminum is now added a durable surface in full-color range. There is practically no limitation on the variations in color and surface textures which can be obtained.

ADVANTAGES OF PORCELAIN ENAMELED ALUMINUM IN CONSTRUCTION

Porcelain enameled aluminum fills a long-felt need in the building industry by combining the best features of many structural materials into a single product. The many possible applications for this new material become apparent upon examination of some of its unusual and outstanding properties.

Workability

Porcelain enameled aluminum has excellent workability. It can be sawed, cut, sheared, drilled, or punched with little or no exposure of the base metal. Raw edges show little corrosion with time and the enamel does not spall or erode back from a cut edge. Porcelain enameled aluminum is supplied in stock size panels which can be cut and fitted on the job. The workability saves cost by eliminating a great deal of prefabrication and permitting the use of less-expensive standard shapes and sizes.

There was recently installed in the Du Pont Building in Wilmington, Delaware, a test office partition composed of panels of impregnated paper core laminated with .051″ sheet aluminum, coated on the outside faces with 3 mils of porcelain enamel. The panels, which were purchased in a standard 2′ x 8′ size, were cut to fit as required on the job. The vitreous enameled aluminum molding and trim came in standard lengths. The installation was made by local workmen who had no previous experience in handling porcelain enameled metals. The only equipment required for installing the partition, other than that normally at hand, was a band saw blade with teeth designed for cutting aluminum.

Spall-Resistance

Porcelain enameled aluminum is resistant to spall or flaking off. If chipped or cracked, the damaged area will not enlarge and, since there is no disfiguring corrosion, repair is necessary only where the damage is extreme.

Thermal Shock-Resistance

Porcelain enameled aluminum may be plunged into cold water from elevated temperatures with no detrimental effects on the coating.

Flexural Strength

Although the enamel imparts sufficient additional flexural strength to the aluminum for most applications, if additional strength is required, the metal can be subjected to heat treatment after coating to develop the maximum strength of the base metal.

Welding

Porcelain enamel can be applied over welds. If carefully done it is possible to weld a reverse face after the enamel has been applied, without visual damage to the coating.

Long-Life

Although innumerable laboratory tests have been conducted and the importance of simulated life tests is recognized without reservation, the life expectancy of porcelain enamel coating has not been determined. Only time can positively establish if there is a life limitation. There are field installations of porcelain enameled aluminum which have now been in service for longer than 6 years. These installations have been satisfactory in every respect and show no signs of deterioration; after all, the finish is glass.

Low Shipping Costs

Low packaging and shipping costs are important. Enameled aluminum requires no heavy wood crating but is commonly packed in light-weight fiber cartons. Because of the light weight, there is a substantial saving in shipping costs which, on many items, represents a sizeable portion of the selling cost.

The weight factor is important not only in portable equipment but in any item or any material which must be transported to a specific location for installation or use.

Compared with common finishes, a vitreous surface has permanence, color stability, and chemical resistance, and affords maximum fire protection. It is easily cleaned and eliminates costly periodic refinishing. The importance of low maintenance costs cannot be over-emphasized when a structural finish is being selected.

Development of Uses

We cannot give too much emphasis to the importance of cooperation among the various branches of industry if we are to make full utilization of porcelain enameled aluminum in the architectural field and derive full benefit from its use.

In the ceramic industry, the producers of first and low-melting glasses, with their collective research facilities and production know-how, are charged with the responsibility of supplying a vitreous product which affords minimum application problems to the enameler and has the superior properties required in the end-use of the completed product. While this is a challenge, the frit manufacturers have demonstrated many times in recent years that they are capable of developing and producing the basic components needed for the new products which we have come to demand in our modern living.

The enamelers are charged with the responsibility of combining glass and aluminum in such a manner as to obtain the maximum utilization of the inherent good properties of both.

The aluminum producers are responsible for the base metal—the structural heart of the product. The progress which has been made during the past 20 years in improving the properties and the production of the metal assures us of an adequate supply of aluminum. Considering the wealth of data already accumulated, we need have no doubts of the future quality of the base metal.

It must be recognized that porcelain enameled aluminum is not a substitute material, but rather an entirely new product which combines into one package the very best features of all modern building materials. It demands progressive thinking in design and engineering.

Only you who use the product are in position to recognize and understand the full importance of this development; and only you are in a position to give intelligent direction to future research, production, and utilization of porcelain enameled aluminum in modern architecture.

Porcelain enameled aluminum is a product flexible to the architect and sound to the designer and engineer. It has displayed no basic weakness.

Its future in the building industry rests with you, the architects, designers, and engineers, who dictate its use.

3.1 GENERAL DISCUSSION

Now we come to the question and answer period. Our Moderator this morning, Robert C. Myers, Director of Market Development, U. S. Steel Corp. has been in the selling, advertising, merchandising and developing field since his graduation from the University of Pittsburgh in 1936. Mr. Myers is active in many trade associations, is currently a member of the Board of Directors of the Construction Industries Manufacturers Association and is a vice president of the National Industrial Advertisers Association. In addition, and of more importance to this group, Mr. Myers is also a current vice president of the Porcelain Enamel Institute.

MR. MYERS: Thank you, Glenn. We'd like to hear from as many persons as possible, either by questions or comment to members of the panel or the audience.

MR. S. EUGENE HUBBARD (Structural Clay Products Research Foundation): I have a question for Mr. Bricker. Mr. Bricker's demonstration showed the superiority of enamel in compression; but, on the other hand, Mr. Nagley showed this morning that in bending, the first rupture occurred on the compression side. Can these two viewpoints be reconciled. If so, just how can that be done?

MR. MYERS: Here's Mr. Nagley offering an answer to your question.

MR. FORREST R. NAGLEY (Bureau of Ships, Navy Dept.): Yes, those can be reconciled, depending on how you select the enamel and the ply; that is, whether or not you want to have residual stress and tension or residual stress and compression, so that when bent you get the effect of relieving the residual stress in the coating. Does that answer your question?

MR. HUBBARD: I believe that does answer the question, thank you.

MR. NAGLEY: Mr. Bricker, do you want to say something?

MR. B. C. BRICKER (E. I. du Pont de Nemours & Co., Inc.): No; I think that covers pretty much what had been discussed by Forrest and I before, in case that question did come up.

MR. WILLIAM H. LOWRY (Vitreous Steel Products Co.): With respect to the porcelain enamel non-structural bulkhead materials, are there official recommended practices set up covering the fabrication; that is, shearing, sewing, punching, and drilling, and direction of the material at the shipyard?

MR. NAGLEY: There has been no official recommended practice set up ready for promulgation. We're collecting data and would appreciate, as we have in the past, any suggestion you have to make.

At this time I'd like to give credit where credit belongs for having submitted the suggestion as to what the punch should be like. Thank you for telling us about how to punch the stuff. May I ask if my colleague, Mr. Woodland, over at the Bureau of Ships wants to say anything along that line? Do you Woody?

MR. E. C. WOODLAND (Bureau of Ships, Navy Dept.): In response to the question asked about the accumulation of data for erection purposes, there is nothing official that has been put out by the Bureau of Ships, although some of our naval shipyards and some of the private shipyards have compiled instructions which they are using locally and which can be made available to anyone upon request. I think that about covers that question.

MR. WILLIAM J. CONKLIN (Mayer & Whittlesey, Architects in New York City): I should like to ask a question of Mr. Nagley and Dr. Andrews. Material has been presented this morning showing that certain ceramic coatings can produce remarkable heat-resistant properties in steel and also that enamel surfaces add structurally to the base metal. Can you perceive the day when structural steel for building purposes could receive a firing of a ceramic coating at the factory and then arrive on the building site already fire-proofed, eliminating completely the need for all forms of masonry or concrete fire-proofing?

PROF. ELMER R. QUEER (Pennsylvania State College): I don't fully understand the question. From what I do understand of it, what you would like to know is whether a completely fabricated piece could be made and shipped to the building and then installed as such. I don't see any reason why that can't be done; that is, a complete wall make up of these wall sections. The greatest difficulty would probably be the sealing between the different sections. So far as the piece is concerned, it certainly could be done.

UNIDENTIFIED PERSON: Mr. Moderator, I should like to add a point there. I believe what Mr. Conklin has in mind is whether you can provide adequate heat capacity to take care of the fire-proofing. I doubt very much whether you can do that with merely a coating of enamel, because the fire requirements are based on heat capacity that's usually provided through masonry around the structural members.

UNIDENTIFIED PERSON: Mr. Moderator, I should like to point out one thing that Mr. Nagley had shown on one of his slides, the effect of color on the emmissivity of surfaces. This slide ran down only to a temperature of, as I recall, about 200° F. If you go below 200° F. and reach normal temperatures that we encounter, except for solar radiation, the color has no affect. In other words, a white and a black, and any other color surface, have about the same emmissivity so far as enamel is concerned. When I speak of normal temperatures I mean from zero to 100 degrees F., wherein sunlight is not involved.

MR. JAMES T. BALDWIN (Armstrong Cork Co.): This is an architect's question. We are frequently rather stupid on technical matters. As I understand from a lot of the discussion yesterday, one of the high points of enameling steel was that it provided a marvelous method of reducing moisture corrosion attacks. The blue base coat was mentioned as being very important. In its application you coated both sides and all edges of the entire piece. There was discussion this morning on enameling of aluminum. No mention was made of that kind of coating. Is that another advantage in the use of aluminum as your base metal?

MR. BRICKER: So far, on the coating aluminum, most of that has been on one side. Of course, we have done both; some of the Navy work was coated on both sides. But when we come to a cut edge we make no attempt to protect that edge after it has been cut or sawed. And on any cut which has been run, we have yet to encounter—when the enamel was properly applied—any corrosion or severe cutback from a raw edge.

MR. W. A. BARROWS (Barrows Porcelain Enamel Co.): It occurred to me yesterday when Jim Holcomb was talking about this tile that we had been questioned by architects as to what effect the edge coverage has on the ultimate life of the panel. Jim Holcomb might have some comment regarding edge coverage as it pertained to the tile that he had cited as being in use for some thirty years, and is still serviceable today. I wonder if Jim Holcomb is in the audience? Jim, maybe I can save you a little time by asking a direct question. Was any particular attempt made to cover edges, other than normal practice, in the running of your tile that has been in service so long?

MR. J. A. HOLCOMB (Wolverine Porcelain Enameling Co.): In the normal course of operations, although possibly no particular effort is made to cover edges, you do get a certain degree of coverage on those edges.

MR. BARROWS: I would gather from our experience in sign work and architectural work and from Jim's experience on those tiles or shingles that this coverage is almost automatic; in fact you could hardly prevent these edges from getting some degree of coverage, although that coverage is not, you might say, in a full glassy coating form as you would have on the face of the piece. There is a sufficient coverage there, however, to give very adequate weather protection.

MR. HERBERT R. SPENCER (Erie Enameling Co.): Somewhat in answer to the last question: Last week I inspected three buildings which were made of flat sheets of porcelain enamel on steel. The edges of the sheets have been exposed to the weather ever since the buildings were built. I found that the edges had been slightly covered in the enameling process; and there was no failure in any spot on all three buildings. We erected them, as I recall, about 1930—which shows a reasonable life expectancy. I have a question for Mr. Bricker, the answer to which really ought to be of interest to this audience. I believe many people did not fully understand Mr. Bricker's talking of aluminum sheets which were coated with porcelain enamel while yesterday we were talking of steel sheets which are also coated with porcelain enamel. If both coatings are porcelain enamel, what are the advantages of using an aluminum sheet as opposed to a less-expensive steel sheet?

MR. BRICKER: I think we'll find them if we go back to some of the statements I made in my talk. First of all, you have the possibility of doing a certain amount of fabrication on the job; by that I mean when we talk about cut edges—cutting pieces on the job in the field. Now it is true that if you install a panel, a sheet, or an extrusion without doing any work on the piece at the scene of the job some enamel is going to be over the edge. But most of what has been installed so far has been cut, in other words, a raw edge. So you do have this possibility of workability on your job. Weight is another important factor. I think those two are the main things that have created the most interest in this program so far. I think, too, that there are many applications for which both porcelained steel and porcelained aluminum will be used on the same job. I know of one case where they were thinking of building in terms of using porcelained steel on the first two floors and going the rest of the way with aluminum, and they requested bids on that basis. In that particular instance, they felt steel had some advantage in strength. Even that, so far as we are concerned, is a debatable question. Nevertheless, in going higher up on the building they were thinking strictly in terms of weight. And I think in a situation of that kind we are taking advantage of the good properties or the best properties of the two materials side by side.

MR. J. G. TERRY (Armco Steel Corp.): If I recall correctly, Mr. Moore said yesterday that there was no evidence, even in intentionally damaged panels, of undercutting of the enamel where raw steel was exposed. Therefore I fail to see the advantage of aluminum used in the cut panel.

MR. MYERS: I don't know to whom you were directing that question. Would you care to comment on that Mr. Bricker?

MR. BRICKER: You're throwing a curve at me there on the steel question, and I'm not qualified to answer it. However, I do know that in the case of the type of damage you're speaking of, nothing would happen to an aluminum panel. Now, whether or not steel will equal that, I can't answer. I know there are many of you here who probably can.

MR. MYERS: There again, I think that time will answer some of those questions. I'm not in a very good position to moderate a discussion of this kind. In your behalf, Mr. Bricker, unless someone has some other comments, we would like to have further comments on the same subject before we ask for another question?

UNIDENTIFIED VOICE: Mr. Moderator, I'd like to make some remarks about this question. I think there are two factors that might be in favor of aluminum. One is that aluminum is as strong as iron, and when we bend a sample, or distort it, there is much better chance that the aluminum will flow by plastic deformation, and thereby assist in keeping the enamel from actually cracking. I think that if the metal is not strong we have a better chance to stand the bending test, such as Mr. Nagley showed you this morning, than we would have with the steel. Another fact that I think might be considered in favor of aluminum is that iron, when it does rust, leaves a colored oxide. Aluminum rust is white; and if we have a damaged area on the panel of the aluminum, it probably would not be nearly as conspicuous as one made of iron.

MR. J. VESUGAR (Vesugar Associates): I have a private business of my own but I am also representing the Bettinger Corp. here. One of my questions has been brought to life and answered by previous speakers. This question was related to the statement made yesterday that where porcelain enamel steel was damaged, that damage did not spread beyond the exposed portion. The other question I want to ask is: What is the advantage of aluminum over steel, taken weight-wise as well as cost-wise? In most building constructions the small weight difference between the two does not appear to me to be worth the consideration that the high cost of aluminum demands. Steel for the same purpose can be thinner than an aluminum sheet, giving almost the same strength weight-wise. Costwise, it would be very much cheaper.

MR. MYERS: Is there someone in the audience who would care to make a comment before we call on someone from the panel. Do you have any comments, Mr. Andrews?

MR. H. J. ANDREWS (Aluminum Company of America): In the strength tests which have been run so far—and there have been quite a few of them—we came up with, if I recall correctly, that the thickness of aluminum usually runs about 1.5 times the thickness of steel. Aluminum ends up with approximately 50% of the weight in all the tests comparing porcelain enamel on aluminum with porcelain enamel on steel. We get, in other words, a comparable strength factor with a 50% greater thickness and a 50% saving in weight.

MR. R. L. HILDEBRAN (United States Plywood Corporation): I came to this meeting firmly resolved that I was going to keep my mouth shut and my ears open, but at this point I do feel I have a comment that might be of interest. We've made very limited use of porcelain enamel in our particular company, but in the last two or three years we've seen one very serious flaw in porcelain on steel; namely, the susceptibility of the enamel to fracture. Now whether it ultimately would lead to damage of the steel on exposure, I'm in no position to comment. But from the architect's viewpoint, to see a lovely building where great attention has been devoted to choice of colors and degrees of gloss, have areas that were fractured either during transportation to the job site or which were fractured during installation, is disturbing and is something that, in our estimation, has proven to be a very serious drawback to porcelain on steel. For that reason we are quite interested in the possibilities of vitreous enamel on aluminum, primarily because it seems to offer a possibility of minimizing this damage incident to handling.

MR. WALTER A. TAYLOR (American Institute of Architects): It's very good to have Prof. Queer here to tell us of the often-neglected problems of condensation in walls. I'd like to have Prof. Queer re-emphasize that when he speaks of ventilation he means the ventilation of the wall area, I believe; and he's not generally concerned with the ventilation of the interior spaces of the building. The question I want to ask—I missed it if he did say something about it—assuming that your porcelain coated metal was not protected in any way on the inside, does Dr. Queer think that this metal should be coated on both sides because of the prevalence of moisture due to condensation or even to wind-blown moisture?

PROF. QUEER: I don't think you could have metal coated only on one side if it's susceptible to corrosion. There should be a coating on both sides because the interior surface of the metal is subjected to perhaps more-severe climatic conditions, superimposed upon which are the building conditions and what the exterior surface may be. Corrosion would be a very serious problem if it were not for the fact that the material either has a protective corroded surface on it or the surface has an enameling or an undercoating, so to speak. I'm glad you emphasized the other point, that the ventilation which I speak of is wall ventilation and not the ventilation of the building itself.

MR. BARROWS: Mr. Hildebran made a statement—he didn't ask a question—but I believe that there should be some comments regarding that statement, or possibly we should ask him a question. He mentioned the matter of delivering material to the job site in undamaged condition. I think that's a sort of a relative thing, and I wonder if Mr. Hildebran would say what item of building equipment can be delivered to the site without damage.

MR. HILDEBRAN: I know now that I should have kept my big mouth shut. Plywood generally gets there in pretty good shape but that's hardly pertinent here. We're just barely dipping our toes into the field of building panels, and the comments that I made were made in all sincerity, simply expressing an observation that we have had in our very limited experience in this field of endeavor which is new to us. I don't have an answer for you, Mr. Barrows, except that I know it's a common problem with a lot of materials; but as I said, it's been our feeling that possibly through the use of enameled aluminum we might have something less susceptible to the damage that we have noticed.

MR. LEONARD R. NACHMAN (Seaporcel Metals, Inc.): This is merely a comment on Mr. Hildebran's remarks. The inference I draw is that there is some doubt about the ability of porcelain enamel to withstand some usage. I would like to call his attention to the fact that porcelain enamel on a tremendous amount of Navy equipment withstood the rigors of a long war, with certainly much more severe handling of the equipment than would prevail at a building site. It has demonstrated its ability to carry such a burden.

MR. OSCAR S. SIGNER (Architectural Porcelain Fabricators): The saying is that fools rush in where angels dare not tread. I hope I'm not considered that fool when I make the following remark. I have been coming to conferences for about six or eight years. I remember, too—it must have been 1945—when someone would bring up a small sample of 2 x 2 aluminum when it was in the experimental stage and everybody would say, as a sneer was uttered, "It can't be done". The feeling never escapes me that it seems to be a fear of competition on the part of those of us who work with steel, a fear that aluminum was going to cut the ground from under our feet. Let us accept the fact that aluminum and porcelain is here to stay and that both steel and aluminum have their pros and cons. In certain instances you can use porcelain enameled aluminum, but where you cannot use porcelain and aluminum because of the nature of prefabrication, you will be able to use porcelain enameled steel. The sooner we adjust ourselves to the realization that porcelain enameled aluminum is here to stay and speak of the positive features of both as useful products in the great potential market we have the better it will be for all concerned—there is room for both. We must not approach the problem by putting our heads in the sand like the ostrich and say, "Oh, it can't be done —it won't be done", and then continue to knock each other's product. Rather, let us look at it positively, with market potentials in the architectural field for both products.

MR. WOODLAND: I'd like to make a few remarks that may help to answer some of the questions that have been asked. First of all, I would like to call your attention to the slides that were shown by Mr. Nagley covering the erection of porcelain enamel bulkheads. Those were porcelained enamel sheets and the stiffeners were 61ST extruded aluminum. The plates in the course of erection had to be sheared to the right sizes, which gives us the problem of two dissimilar metals coming in contact with each other. The material must be protected in order to overcome electrolytic action. This can be done in several ways. We can use either an insulating spar varnish or, as we have used, a liquid plastic with high dielectric properties. In these cases, as far as we have gone, we know of no trouble. In the case of damage to the sheets, and I don't know of any place where that material is any more subject to damage than it is in the course of erection in a ship. We have had it, yes; but so far we have been able to overcome such difficulties. One of the best ways that we have found in the case of porcelain enameled steel, where the fracture or the indentation was to such an extent that touching up would not give a level finish, was to use a leveling compound for metal. We have taken the same liquid plastic and pigmented it to the color of the material to which it was to be applied, and have thus obtained a very very satisfactory touched-up job.

MR. MYERS: I appreciate that very much. Also, I really wish we had time to hear from the gentleman from the Aluminum Company of America. I believe that the discussion has been good and the comments have been fine and spirited. I agree with the comment that somebody made that there certainly is room for many types of materials; and I repeat again, time will tell which way you want to use them.

Session 4

BUILDING EXPERIENCE WITH PORCELAIN ENAMEL

Problems, Solutions, Costs

THE USE OF PORCELAIN ENAMEL FOR HOSPITALS

By James J. Souder, A.I.A.*

(Office of York and Sawyer, Architects Kiff, Colean, Voss and Souder)

Hospitals have been with us in America ever since the Spanish colonists brought their armies to the West Indies and established permanent bases. Interestingly enough these hospitals came not as luxuries of the rich new world but as tools necessary for the conservation of military manpower. The conservation idea has gradually come to include the whole human resource, physical and mental, but the idea of the hospital as a permanent element of the community has been constant since the beginning.

Along with the idea of permanence several other ideas have been constantly present in the human mind whenever the word "hospital" is spoken. Cleanliness, spaciousness, comfort, quiet—all of these pleasant words and some less pleasant ones—like odor, fear, stark, expensive—suggest themselves. Apparently they always have. One of the earliest hospitals in the hemisphere—and it is still in use—has impervious ceramic floors, ceramic roof, window sills and ceramic aprons beneath the sills. Moreover, the ceramic material provides attractive color to counteract the strangeness and institutional spaciousness of the hospital, and it continues from the sick room out to the balconies and gardens in a way which we like to think of as modern.

We have been using tile in and on hospitals ever since and for some of the same reasons. Why have we not been using porcelain enamel?

For one thing the enameling industry has not been aggressive in selling its product or its potential product to the hospital designer and the hospital administrator. For another the hospital field has been slow in demanding better answers to its building problems. A mutual understanding of what industry can produce and what the hospital needs is obviously desirable.

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To understand the building needs of a modern hospital one must first get beyond the mystery of the white coated attendant and find out what makes a hospital different from other buildings with which we are more familiar. First and foremost, the hospital is a community enterprise. It is ordinarily built with taxpayers' dollars or contributors' dollars, and it is maintained with funds sought annually from the same source. It is expected to be durable enough to last several lifetimes and flexible enough to adjust to the changing techniques which come with each year of scientific investigation. It is both the doctor's workshop and the sick man's temporary home; therefore, it must offer convenience in operation, effectiveness in the use of important skills and, even more, it must offer living and working comfort to staff and patients. Finally it must eliminate every possible hazard to the life it tries to support.

Like any other building which houses people on a large scale, the hospital provides services on a mass basis. It takes delivery of everything from oxygen cylinders to orchids, then stores and distributes each needed item to the individual who needs it. Its elevators, dumb-waiters, pneumatic tubes, service trucks and its staff are on the move twenty four hours a day carrying goods and services to people who either cannot walk or have not the time to walk; yet a hospital dare not be noisy or dirty. Its work rooms and corridors must be kept quiet and immaculately clean. In fact we have built up in our minds such strong concepts in this regard that a hospital must not only *be* clean; it must *look* clean. Otherwise both patient, staff and public morale react adversely.

These concepts are widening every day as experience is beaten into us. A disastrous fire tells us that our use of decorative materials is limited to the incombustible. Management tells us that glare produces quick fatigue and higher personnel costs; contractors tell us that field fabrication may be a luxury instead of a necessity; an administrator warns us that the House of Science must also be a House of Mercy and that our buildings are becoming impersonal and forbidding.

The hospital then, is a building constantly abused by heavy traffic which must be built for little, operated on less, safe, peaceful, delightful to the eye and ear. Its space must expand or contract overnight and it must be as durable as the pyramids.

These are the things that determine the selection of materials which go into hospitals. They explain the widespread use of tile with its resistance to fire, water, abrasion, impact, acid, alkali and grease. They explain the growing use of stainless alloys and inorganic acoustical materials. They explain the openness and color of our newer hospitals.

Again, why have we not been using porcelain enamel? One might answer "why should we"? We have time proven materials resistive to abuse, which we can afford—that is we can afford them within limits. Moreover, all of us have seen tables and bedpans and cooking utensils replaced with stainless steel because their chipping made them both unsightly and unsanitary in fairly short order. This response of "why should we?" maintains the status quo and is fairly safe, but it is not entirely honest.

Our time proven materials do not have all the answers and their costs are increasing. If we are honest, we admit that masonry is not very flexible, that plaster frequently cracks or chips, that every joint is a potential problem. We also admit that our buildings are very much heavier than they need be and that putting them together piece by piece is a costly, long drawn out process.

Our answer, then, might better be "what can you offer?" That would be honest, because most of us not only don't know but haven't the dollar resources with which to find out. If industry knows that hospitals are built and maintained on restricted budgets, that interior partitions are subject to change, that the worker wielding a damp cloth is less costly than the painter; if industry knows that a light-weight exterior wall requires less steel and concrete to support it than do two feet of brick and block and plaster; if industry knows that shop assembly of a few parts is cheaper than field assembly of many parts; then industry should be pounding at our doors. I think that industry does know these things and many more which are less obvious. I think industry can tell us what special problems of physical and chemical resistance porcelain enamel can meet; it can tell us what first costs and what maintenance costs to expect; and it can tell us in broad terms what the possibilities and limitations of porcelain enamel are. Let me cite some examples:

Not too many years ago our Army was suddenly faced with the problem of transporting thousands of sick and wounded men across the ocean and sought to solve the problem by converting a series of ships into floating hospitals. In minimum time these ships had to be completely gutted of interior partitions, replanned and refitted in accordance with contemporary ideas of hospital convenience and cleanliness, and in accordance with shipbuilders' ideas of fire safety, weight and ability to endure movement. It was the porcelain enamel industry which came up with an effective answer and got the job. So far as I know this was the first and last time the industry has successfully invaded the hospital field. There were sales resistance and skepticism, to be sure, but the men who knew their product and worked with planners and designers in solving the problems of its application to the job at hand were convincing and were able to render a real service.

More recently our firm and two others undertook the design of a series of hospitals in a remote area where skilled labor is in short supply. In discussing ways of achieving a finished appearance at low first cost and low maintenance cost, we hit upon the idea of enclosing these buildings with a light-weight, skin wall made of insulated panels gasketed into standard metal window sections. We thought that perhaps such a wall, with porcelain enamel exterior treatment, could provide color and weather resistance, and by minimizing field fabrication and assembly labor, the wall could compete in price with conventional masonry walls. With modular design we thought we could make such a wall meet the future expansion and adjustment problems of rearrangement without having to tear the buildings apart. As a starter we went to see a series of window manufacturers and stated our problem. Only one expressed real interest. He began to work with our team and at the same time to call in enamelers, insulation manufacturers and gasket makers. Together we looked at similar building ventures and talked to the men who had designed them. Thus far none of us knew whether we could produce a satisfactory job or whether we could meet the cost objective. Several months and many dollars later we were able to let contracts for the manufacture and erection of exterior walls, complete with glazing, at an average square foot cost which is well under four dollars. The panel, limited to fifteen square feet of face area, has a porcelain enameled outer pan with an air space and weep holes immediately behind it to handle condensation. The insulating filler is fiberglass. The joints are sealed with specially extruded vinyl gaskets to meet requirements for waterproofing, expansion and vapor barriers. The inner pan is galvanized, bonderized, painted steel. The panels are removable for inspection or replacement. The whole venture has been a stimulating one for both the designers and the manufacturers.

These two examples of cooperative effort are cited because they offer a pattern of potential benefit to the community. Every dollar saved through the development of better, cheaper ways to do things is a dollar which can be put to another useful purpose. This is particularly true in the hospital field where the demand for facilities is continually stronger than the budget, and I hope that investigation in this field will be pushed.

Walls are only the beginning of the hospital applications one can foresee, and the fire resistive partition and curtain wall are only limited answers. In many building code jurisdictions, two or four hour fire rating requirements demand a more complete answer which may perhaps be found in lamination to heat resistive cores. Simple methods of reducing sound transmission, of fastening or refastening and of acceptable field jointing are needed. We need assurance that enameled panels can be field cut or punched without damage. This is because at the myriad penetrations of mechanical services which hospitals must have. The maintenance supervisor wants assurance that with the limited skills of his labor force he can perform field repairs to damaged surfaces.

Using the hindsight-foresight technique, we can uncover many more potential uses. Acoustic ceiling pans which won't rust or peel and which are easily cleaned are in great demand, particularly for grease or steam-laden atmospheres. Window stools and radiator enclosures which gather dust and dirt are an obvious possibility. Light, easily installed toilet and shower partitions with minimum joints and simply fastened accessories are still another. Certainly the whole question of work surfaces can stand critical review. But in noting porcelain enamel's good points, we must also note and overcome its past failures of chipping and staining. Current use of porcelain enamel chalkboards, elevator cab liners, and refrigerator liners will probably increase, particularly if costs are favorable. External use for copings, some roofings, sunshades, signs and applied lettering sounds probable. As air conditioning equipment becomes common, it may be found that replacement costs can be reduced by the application of enamel to parts exposed to weather or water action.

I understand that useful applications may be found in research laboratories where radioactive materials used are hotter than those employed in the average hospital. All of these are built-in uses where the special properties of porcelain enamels have value.

There are an equal number of movable equipment uses where porcelain enamel can capitalize on its resistance of heat, acids, alkalis and greases. Laundry and cooking equipment, sterilizers, pharmaceutical manufacturing vats are all instances where ceramic coatings should represent a saving over the white metals now in general use. However, caution must be exercised to be sure that only suitable uses are proposed; and it must be remembered that hospitals, unlike industry, are not receptive to the idea of frequent replacement, even at lower cost, because replacement too often means disruption of vital services which are in demand around the clock.

Apart from all of these matter-of-fact applications there is another, little explored, potential for porcelain enamel in hospitals. This may not mean much in production volume but which could mean a great deal in morale for patients and staff. The whole field of integral and applied decoration has been too long neglected in the buildings we call institutions. Color has been used, to be sure, but three dimensional decoration has been avoided indoors and out as an extravagance which hospitals can ill afford. I hope the day is not far away when we can convince ourselves that art and decoration are current expressions to be enjoyed in our everyday lives and not rare items from the past to be looked at on an annual trip to the museum. I hope, too, that we are receptive to the idea that our art objects do not of necessity have to be fashioned of Italian marble. Porcelain enamels have long been recognized among the useful and decorative materials available to craftsmen. They are not necessarily the enamels we have today and it may well be that our newer enamels in the right hands offer the designer more creative flexibility than he knows.

All of these potential applications require thought, salesmanship and willingness on the part of industry to join the architect or designer in the research and development which can assure successful results. Neither a hospital nor its architect is likely to take a flyer on the use of untried materials and methods. Not only are they conservative people by nature, they are also spending public or semi-public funds for whose effective use they feel responsible. Nevertheless, they are alert to new possibilities and ready to do their part in evaluating them. The general requirement for impervious surfaces, able to withstand impact and abrasion, and offering color and texture choices is so widespread in hospitals that the field of application is subject only to cost limitations and those of installation detail. Both are capable of practical solution.

As these solutions develop it is to be hoped that porcelain enamel will be respected for its own inherent characteristics and not misused in imitation of other materials simply to catch the public eye. I cannot resist mentioning that just this week I saw side by side two newly developed ideas for porcelain enamel. One was a handsome mural in which the artist took full advantage of line and glaze and firing to produce a highly individualized and imaginative decorative panel. The other was an exact reproduction in porcelain on steel of the old Spanish titles which were used in the first hospital in the Americas. The tiles were just as pleasing in color and texture as the mural, but they do nothing that cannot be done within the old limitations of clay. This I think is a mistaken sense of direction which time will overcome, just as it finally overcame the socket for the horsewhip on early automobiles.

Progress in design and application is equally as important as industrial progress. Only as these two phases of development mature, and only as they mature together, will the public imagination be captured. Fortunately the applications of porcelain enamel to hospital buildings have so far been approached with the objective of overcoming restrictions imposed by traditionally used materials; and while total experience today is limited, the idea has been planted in many minds. If history is a safe criterion, there will be attempts to better the experience and to expand it until the ingenuities of maker and user finally establish the measure of practical application.

THE USE OF PORCELAIN ENAMEL IN SALES STRUCTURES

By Paul R. Fritsch*
(The Goodyear Tire & Rubber Company)

The marketing revolution known as the shopping center has brought into very sharp focus the exterior design of sales structures. The storefront, as the face of a sales structure, ought to be designed to create a specific impression on customers. There are varied opinions on how it should be done.

NATURE AND CHARACTER OF BUSINESS

A long time ago I came to the conclusion that the exterior of a store ought to reflect the nature and character of the business. My browsing through over 300 varied types of shopping centers from coast-to-coast during the last three years has sharpened this conviction. The nature of the business is the type of product or service offered, as is represented, for example, by the clothier, the baker, the hardware merchant, the jeweler, the supermarket, etc. Obviously, a jewelry store and a hardware store should have different appearances. The character of the business is equally important. Is this a "Tiffany" jeweler or a "dollar down and a dollar a week" credit jeweler?

COLLECTIVE APPEARANCE

In the so-called downtown sections, every store has been planned as an individual project; but stores in the new, convenient shopping centers are planned as a group. Designers and architects are in the frame of mind to eliminate from shopping centers all the disagreeable aspects of the old, congested business sections. Parking that is plentiful, convenient, and free is a top requisite. The arrangement of parking is usually such that customers have a panoramic view of a large group of stores. Hence, a good group or collective appearance of the shopping center is essential. Yet, individual stores need a distinct identity. Chains or cooperative groups that have invested time and money in developing a well-known face must maintain a familiar appearance in shopping centers as well as in other locations. The trick is to make the two objectives compatible; and good designers are doing it. Any shopping area is a modern bazaar, the market place where buyers and sellers meet. The merchants use many devices for arousing interest and stimulating buying, one of which is

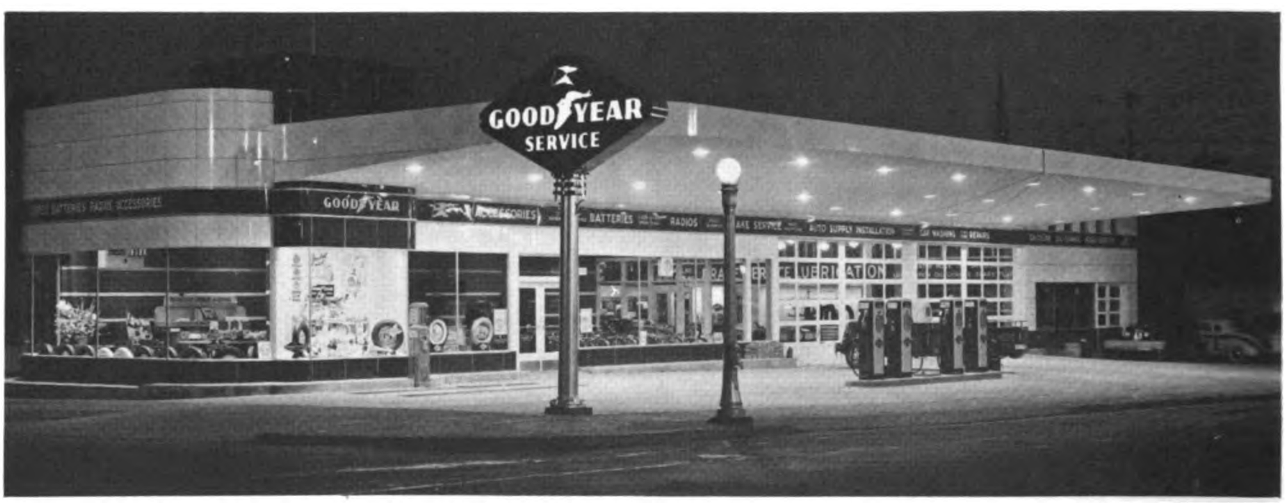

Fig. 4.1—Goodyear porcelain enameled gas station in Fort Wayne, Indiana.

distinct exterior store identity.

Unfortunately, there is a serious tendency to make shopping centers a monotonous string of uniform storefronts that have the same color scheme and the same design of signs, or they have little or no provision for quick identity. This uniformity makes a shopping center just about as exciting as the pigeon-holes in a post office. The collective ap-

* Mr. Fritsch has engineered and conceived many of the programs and techniques of his company, and has helped his company maintain prestige among its dealers. He has written for trade journals in the advertising field. He has also done considerable research on sign history, and has written papers on this subject. On subjects of dealer and store identity, he has addressed many groups, such as the Porcelain Enamel Institute, advertising clubs, and trade associations.

Fig. 4.2—Porcelain enamel sign at a Village Market.

Fig. 4.3—Porcelain enamel shopping center entrance sign.

pearance of a group of stores should be interesting, stimulating, and in good taste. Variety is essential, with each store front suggesting the nature and character of the business. A standard storefront design widely used by a chain group may have to be "dressed up" to fit into a good design scheme, but experience shows that it can be done without losing its essential family resemblance. To fuse together a variety of stores, keeping the over-all effect pleasing and profitable as well as in good taste, requires a mixture of good design talent and *full appreciation of merchandising* fundamentals.

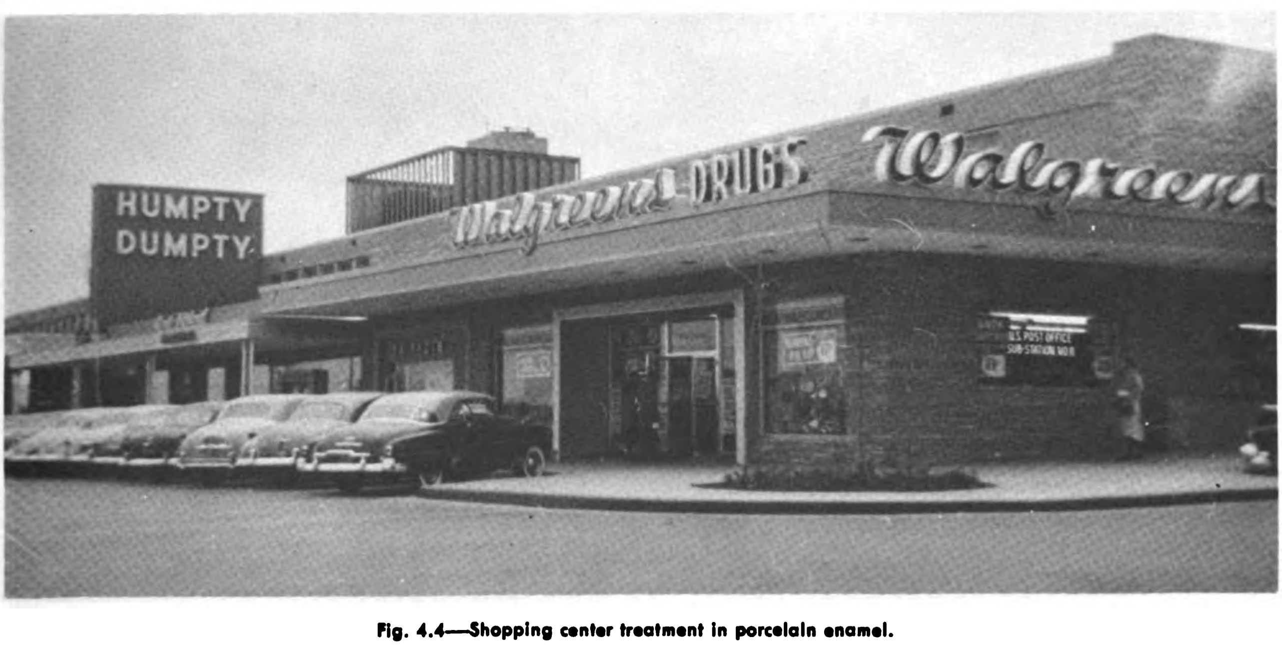

Fig. 4.4—Shopping center treatment in porcelain enamel.

Fig. 4.5—Porcelain enamel treatment on a store.

There always has been polite conflict among designers, architects, building owners, and the sign industry on the exterior treatment of sales structures. The sign industry is not articulate because it is not a cohesive industry. It is a sprawling, heterogeneous group of individuals who strive to serve all types of sign needs. However, through the efforts of the National Electric Sign Association

Fig. 4.6—Super-market in porcelain enamel.

Fig. 4.7—Cook Bros. Goodyear Dealer and service station in Akron, Ohio in process of construction with porcelain enamel finish.

and the Porcelain Enamel Institute some semblance of group activity and continuity in the industry is beginning to take form.

DESIGN DETAILS

The sign industry is capable of providing professional counsel in the essentials of good exterior identification of sales structures. Lettering design for outdoor use is quite different from lettering on a blueprint or in an advertisement. We have seen storefront lettering so thin that we looked through instead of at it; spacing so cramped that the lettering looked as if it had been squeezed through a cider press; or lettering so widely spaced that our eyes were incapable of fitting the letters together to make words or names. We cannot sacrifice legi-

Fig. 4.8—The completed Cook Bros. structure.

bility or assume that everyone has perfect vision. Even for elite stores there must be a certain amount of boldness in the copy so that the name or the nature of the business can be discerned quickly and clearly. For outdoor use, a trade-mark or any type of lettering must be designed in full scale for distance viewing; if designed on a small scale for close viewing and then photographically enlarged for reproduction on a storefront, the results may not be satisfactory for actual outdoor distance viewing.

In most of our everyday reading we are accustomed to good, clean, legible type and perfectly legible trade-marks. Hence, we have difficulty in interpreting lettering that is badly designed, badly spaced, or otherwise faulty for outdoor distance reading.

Pictorial designs are excellent aids for portraying the nature and character of stores, and besides making individual stores attractive, pictorials add interest to store groups in shopping centers.

IDENTITY AND FAMILY RESEMBLANCE

I have been privileged to observe the various viewpoints on identity and family resemblance of storefronts from a vantage point which enables me to have a sympathetic understanding of the interest of all the parties—the owner, the lessee who has to pay the rent, the designer, and the sign industry. The individual store-owner wants his name and the nature of his business to show up big and bold.

Chain groups, to work in concert, must maintain a family resemblance. New or remodeled, ***the building has become the sign.*** Building color and physical characteristics are a part of identity (like the orange roof on Howard Johnson restaurants), to cite an example. The point I want to make here is that when a distinct identity has been established it becomes valuable in the development of store traffic, and no merchant is wise in giving it up. The designer must take into account the realities of a retail business. If he does not, they creep in later with disastrous results; and the architectural profession often holds up such a design as a horrible example.

I have some slides here which show how our company progressed in store identity over a half-century and how deeply rooted is the desire for distinct and personal identity, based on the hard realization that the continuation of this identity has a direct bearing on dollar sales.

SUMMARY

Porcelain enamel has been the backbone of this program. We have used individual porcelain enamel signs, porcelain letters, and architectural porcelain. We have used these individually and collectively to provide uniform identity and distinct family resemblance among thousands of dealer and Goodyear stores, regardless of building characteristics and geographical location. Durability, color, and texture ranges make porcelain a versatile material for storefront faces.

THE USE OF PORCELAIN ENAMEL FOR HOUSES

By Wentworth W. Lobdell*
(Lobdell Realty Co.)

The use of Porcelain Enamel for wall construction in houses is believed by most people to be impractical and too expensive. One of the largest manufacturers of prefab housing in the country and one who believes in the future of steel houses told me that he believed this to be true. However, it is my opinion that porcelain is economical, practical and desirable for wall construction in homes and elsewhere.

It was the Lustron home that gave my company is first experience with porcelain as a building material. We were at first dubious of its qualities, but excited about the possibilities. Two years of hard work with a modest profit gave us the conviction that Lustron was a real honest-to-goodness answer to our archaic methods of building houses.

Contrary to public belief, the Lustron Corporation was very close to successful operation, and it is the opinion of many who were associated with Lustron that if it had been in operation for another six months, the plant would be in successful production today, the Government would have a sound investment, and the public would be getting the same advantages in housing that they are receiving from the mass production of automobiles.

Our company has been building houses since 1907. We built our first prefabricated house in 1937, and after investigating and building almost every other pre-fab house on the market since that time, our experience showed that we could build with conventional materials and methods at lower costs and have less sales resistance. The only exception was Lustron.

There are five main reasons why I believe an all-porcelain house is the answer to the mass-produced housing market. These are: Lower original cost, lowest maintenance cost, salability, flexibility and livibility.

Lower original cost was true with the Lustron home, though this may not have been entirely due to the use of porcelain. However, porcelain enamel metal was the most important overall factor, so it must be assumed that though we know porcelain is not the cheapest building material, it was the most important contributing factor in bringing about the lowest cost house on the market. Actual tests were made in Lima, Ohio, building an exact duplicate of the Lustron home using conventional materials and methods. The results showed an increase of nearly 15 per cent over the Lustron cost.

At this point, it is probable that many might wish to interject the statement that the actual cost to Lustron of their house was many times the price received from the dealer. It's easy to show that the final cost to the Government, due to its loss, was approximately $18,000 per house. But keep in mind that most of the money went to development, machinery, engineering, and promotional cost. The final production cost based upon the capacity output of the Lustron plant showed that the break-even point was only 20% of its capacity output at the market price Lustron was selling its homes.

My second statement, referring to lowest maintenance cost, brings out a startling comparison with other types of construction, because there is practically no maintenance on an all-porcelain building. That which is required is usually done by the owner and can best be described by a comment made by one of our Lustron owners when he said, "If one is willing to spend a dollar for enamel and an hour's time a year, a Lustron home can be kept in perfect condition."

Many people worried about damage that might occur, the cost of repairing or replacing, and the possibility that replacement parts might not be available. We overcame these doubts by having a local enamelling shop re-enamel part of a damaged panel to show how perfectly the repair and matching color could be accomplished. A reasonable facsimile of any Lustron part can be made by a competent sheet metal dealer and enamelled without excessive expense. Damage that we have repaired has been negligible, and the cost far less than what it would be for similar damage to a conventional wall. For example, a panel can be replaced in any wall of the house in a few hours at far less cost than repairing the same damage to a wood or plastered wall. The latter may require the whole exterior or an entire room to be redecorated after the damage is repaired.

A survey has recently been completed by Batten,

* Mr. Lobdell is a graduate of the University of Iowa, 1932. He built more Lustron homes than any other builder in the country. He was chairman of the Lustron Dealers' Association. More recently he has been engaged in promoting the use of the Lustron porcelain enamel panel for modified home use and for commercial buildings.

Fig. 4.9—A Lustron home.

Barton, Durstine & Osborn of New York for the United States Steel Corporation, who is in the process of manufacturing an all-steel house. Their survey shows that 96.6% of the Lustron home owners in their study preferred the Lustron to their previous homes, and the largest percentage attributed this to low maintenance cost and ease of cleaning.

My third and fourth points were concerned with sales resistance and flexibility. This sales resistance is the only negative I am using, but with proper study and training this can easily be a positive. In my opinion Lustron made two mistakes. They believed anyone could sell Lustron homes and that most everyone would buy them. In all our sales experience we have never encountered the need for such an extensive "educational sales talk" to sell a house. However, I believe this is true of any new or revolutionary product that has ever come on the market.

For example, we had to overcome arguments about color scheme changes. We did this by telling our prospects they could paint and decorate whenever they desired, and showed them panels sprayed with paint of all different colors. As you know, the porcelain surface is perfect for painting. However, I have yet to see paint on a Lustron wall.

Many wanted basements. We gave them basements, fireplaces, extra rooms, breezeways, garages and most anything they wished. Fortunately we didn't get a request for a 2-story house or an indoor swimming pool, though I suppose we would have tried to provide them.

Fig. 4.10—A Lustron home, with recessed porch, breezeway, sun-shades, and garage.

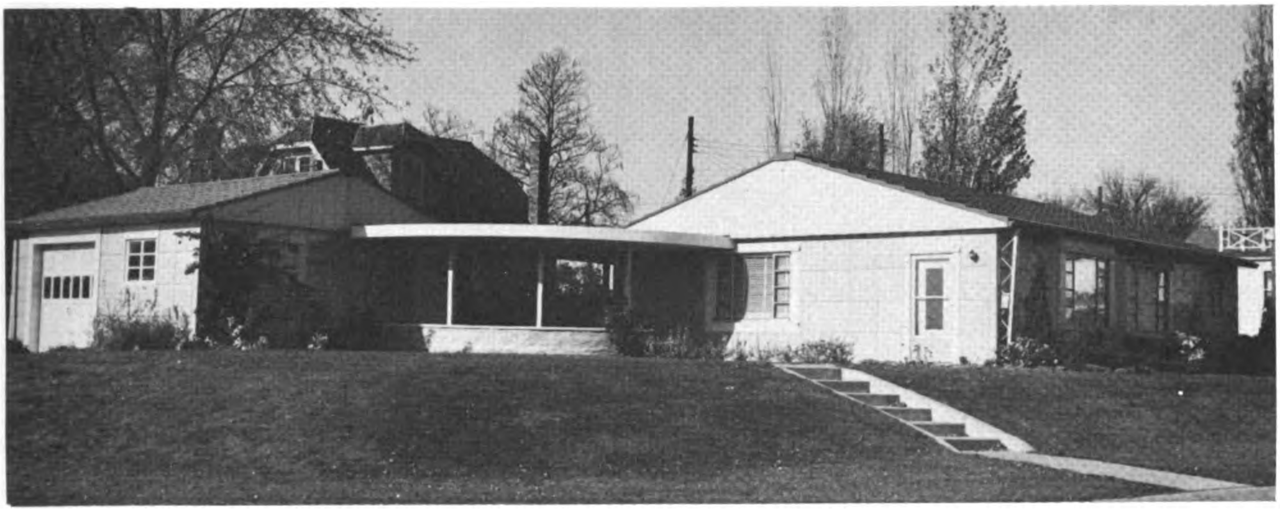

Fig. 4.11—A Lustron home with added features.

It was, among other things, the belief that the house had no flexibility that made it most difficult to sell. But we showed our prospective customers several identical homes that had different breezeways, garages and entirely opposite decorating schemes. When these houses were furnished by the different owners, they acquired an individuality that was most striking. We believe that we overcame this objection so completely that today very few owners have sold their homes for lack of flexibility. Rooms have been added for family increases; we see built-in bars, porches, new rooms finished in knotty pine, both real and artificial fireplaces, and so forth.

My last point was livibility. This, too, was hard to sell at the beginning, because no one had lived in an all-porcelain house long enough to be positive that it had desirable livibility. But now we know that it has it, and again the above mentioned survey results prove our earlier assumption:

97.5% of those contacted have no objection to porcelain interior
98% no objection to porcelain exterior
96.6% had a preference for the Lustron home over their previous homes
Only 14.5% preferred a surface which could be painted, but only
2% had altered the interior surface by painting or papering
94% of the respondents reported that they would buy another steel home.

Once again I would like to mention the two main factors for the preference for an all-porcelain house—low up-keep and ease of cleaning.

SUMMARY:

In summary, I say, and I hope you now agree with me, the all-porcelain house was not a fantastic dream. Lustron advertised "The Home of Tomorrow—Today." I can only reiterate that the all-porcelain house is the "Home of Tomorrow." Unfortunately, it is not available today, nor will it be until some far-sighted individuals have the courage of Carl Strandlund, and have or can make available the millions of dollars necessary to build the proper plant and equip it for the methods necessary for low-cost mass-production.

My hope is that here in this meeting are the individuals who have the courage and ability to recreate the "Home of Tomorrow" today.

PORCELAIN ENAMEL STEEL IN INDUSTRIAL BUILDINGS

By Milton Male and Carl F. Block*

(Market Development Division, United States Steel Corporation)

Porcelain enameled steel, both as corrugated or flat sheets and as built-up insulated panels, provides the builder with an exterior material having exceptional properties for industrial buildings as well as office buildings.

The esthetic appeal of porcelain enameled panels lies in the great variety of color and finish textures available for exterior roof and wall panels. The trend today is away from heavy, thick walls which employ wet construction. Thinner dry-wall panels covering a large area are easier and faster to erect, save valuable floor space, and permit the application of a wide variety of insulation materials which have been perfected in recent years.

In uninsulated buildings these porcelain enameled panels provide an ideal surface both for walls and roofs. A porcelain enameled sheet, being completely protected on both sides, needs never be painted. The one place where most industrial roof construction fails is on the under side, especially over purlins, where it is difficult or even impossible to satisfactorily protect the material with paint. After four or five years of exposure a repaint job is required in the usual type of industrial building construction. If the inside atmosphere of the building is hot, steamy or even mildly corrosive, the problem is greatly aggravated. Porcelain enamel, however, being glass fused on steel, is completely protected. The coating used may even be of an acid resisting type for difficult applications.

Porcelain enameled corrugated roofing and siding are manufactured by using a standard corrugated black steel base and applying a ground coat and a finish color coat, each coat being individually fused at 1550° F. The resulting corrugated sheet or flat panel, when properly installed, will provide protection against fire, moisture, smoke, steam, corrosive gases, and all common atmospheric conditions. This roof will never need painting for either protection or color. The protection is permanent, the color is permanent. Modern porcelain enamel colors, being inorganic, will not fade.

In conventionally constructed industrial buildings, normal maintenance has always been a major problem. And in recent years, of course, these costs have been steadily increasing due to the mounting cost of labor and material.

The practically complete elimination of maintenance where porcelain enameled steel exteriors and roofs are used, makes this type of application exceptionally economical. Any extra cost involved in the initial installation is usually recovered in from six to nine years through reduced outlays for maintenance. And incidentally, in those cases where cleanliness is required for sales and appearance advantages, the porcelain enameled surface, being smooth as well as hard, can be kept continually attractive in appearance for many years at a very low cost by occasional washing with soap or a detergent and water.

When porcelain enamel is erected, it is recommended that, when sheet metal screws are to be used at the sides and ends of the sheets, the sheets be pre-punched at one edge before enameling to minimize field drilling requirements. On large projects it may even be possible to pre-punch all the attachment holes, although in the average roof construction the exact location of the purlins and girts may be difficult to predict.

Where field drilling is necessary it can be done with a high speed drill. Self tapping stainless steel screws, equipped with stainless steel washers and neoprene or lead protective washers, are recommended for this use in order to permit the application to proceed from the outside of the building.

* Mr. Male graduated at M.I.T. in 1929. He was engaged in committee work for several years with the American Welding Society just after his graduation. In 1931 he joined the U. S. Steel Corporation, in the Research and Technology Department as Research Engineer and Director of Housing Research. This year he became manager of the Building and Construction Industry Section of its Market Development Division.

* Mr. Carl F. Block was born in Chicago, Illinois. He served in the U. S. Navy, 1917-1919, as a Navigation Officer. He attended University of Chicago in 1921 where he studied geology and chemistry and the University of Illinois in 1923 where he studied metallurgy. He started with Carnegie Illinois Steel Corporation (a subsidiary of U. S. Steel Corporation) in 1925 and has been with the Corporation since that date. He has worked in Sales, Sales Promotion, Market Development of all products of the Corporation. He is a member of the Engineering Society of Western Pennsylvania, the Pennsylvania Society of Professional Engineers, the Society of Military Engineers and the Highway Research Board. He is also associated with Building Officials Conference of America, Porcelain Enamel Institute, National Warm Air Heating and Air Conditioning, and American Iron and Steel Institute.

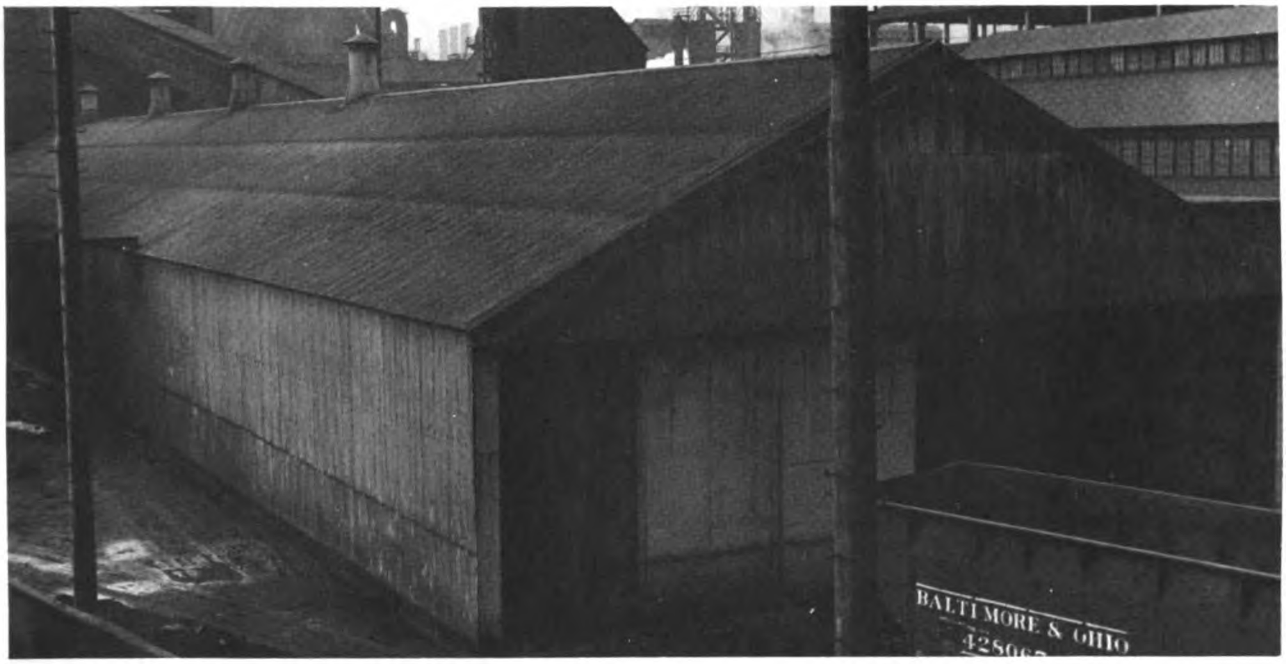

Fig. 4.12—Ore-thawing building covered with porcelain enamel corrugated steel at the National Works of National Tube. In this building cars of iron ore are thawed out in the winter by the use of live steam.

Fig. 4.13—Both the interior and the exterior of the ore-thawing building receive as severe abuse as any building, being continually wet and exposed to considerable dirt. No visitor to the building can resist rubbing a small area of the porcelain enamel siding—witness the several rubbed areas on the bottom panels, exposing bright, clean, unaffected enamel.

Fig. 4.14—One recent insulated structure (the general stores building at the U. S. Steel's new Fairless Works) is a good example of color at work. Emphasized here are the porcelain enamel sign and entrance trim.

This would eliminate the need for scaffolds and extra men required for a bolting operation.

The drills used should be sharp and dressed to an angle of 60° or 30° each side of the center line. Drilling through porcelain enameled sheets is not difficult, but it must be done with care. Two drilling operations are usually required to do the best type of job. First a #1 drill (.228″ Dia.) is used

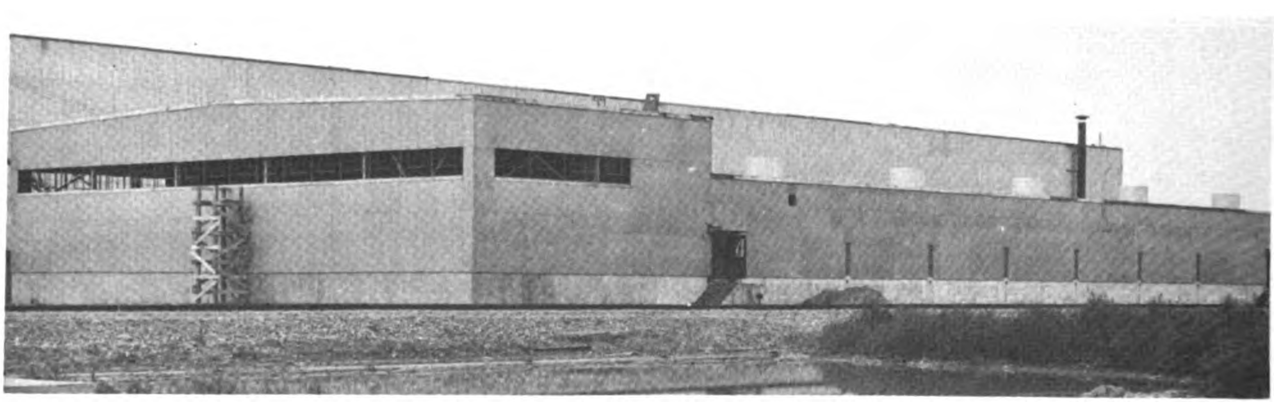

Fig. 4.15—This general stores building is 120 ft. x 600 ft., and contains 28,500 sq. ft. of insulated siding. The exterior is 16 gage corrugated porcelain enamel panels over 1½″ of Fiberglas insulation, backed by an interior wall of 22 gage corrugated galvanized steel. All attachments are stainless steel screws with neoprene washers. The exterior is greyish-blue, giving a very pleasing appearance.

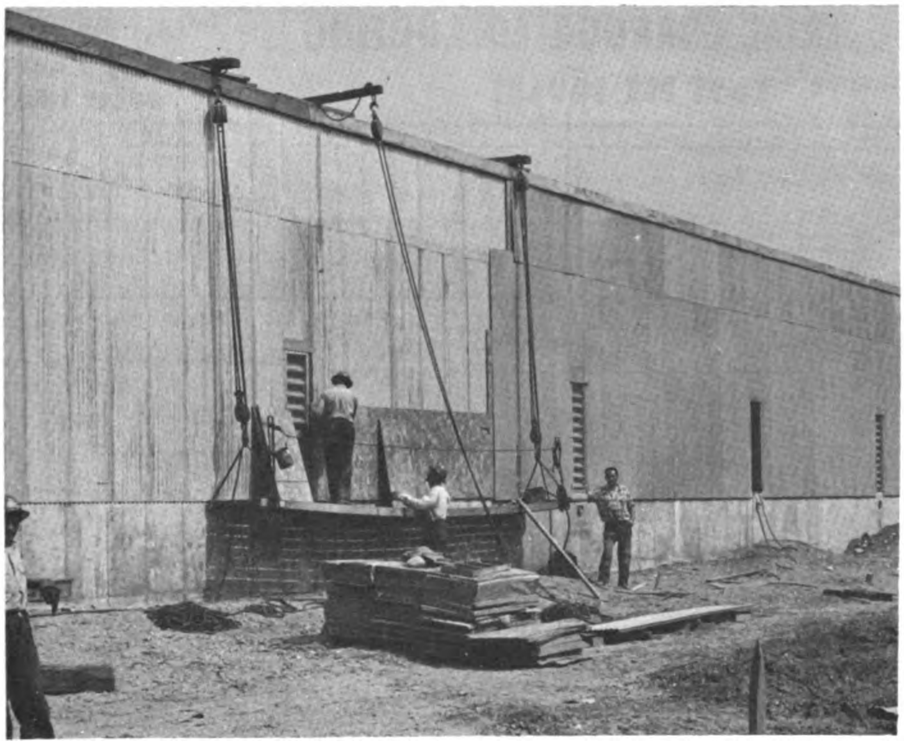

Fig. 4.16—Assembly of wall panels on the general stores building.

to drill through the sheet and into the structural member. This is followed up by a 17/64" Dia. drill to enlarge the hole through the sheet only, so that a #14 stainless steel self-tapping sheet-metal screw will clear the holes in the sheets and grip the hole in the structural member. Driving the screws with a mechanical or impact wrench insures a uniform tight seal.

Usual side and end laps are specified for the use of porcelain enameled roofing and siding sheets. Two and a half-inch corrugations are standard with the industry, with 27½" width for roofing and 26" for siding. Gages #18 through #24 are the common gages enameled. However, for certain uses other gages may be required. Lengths to 12′ are available, depending on the size of the manufacturer's firing furnaces.

There have been a number of industrial buildings constructed over the last twenty years using either side walls or roofs of porcelain enameled steel. A re-examination of many of these buildings recently has shown that, although they have had no maintenance, they are all today in excellent condition.

It is interesting to note that one of these examples erected in 1940 was finished with a green outside

Fig. 4.17—Cornice flashing of stainless steel is used with porcelain enamel on the general stores building.

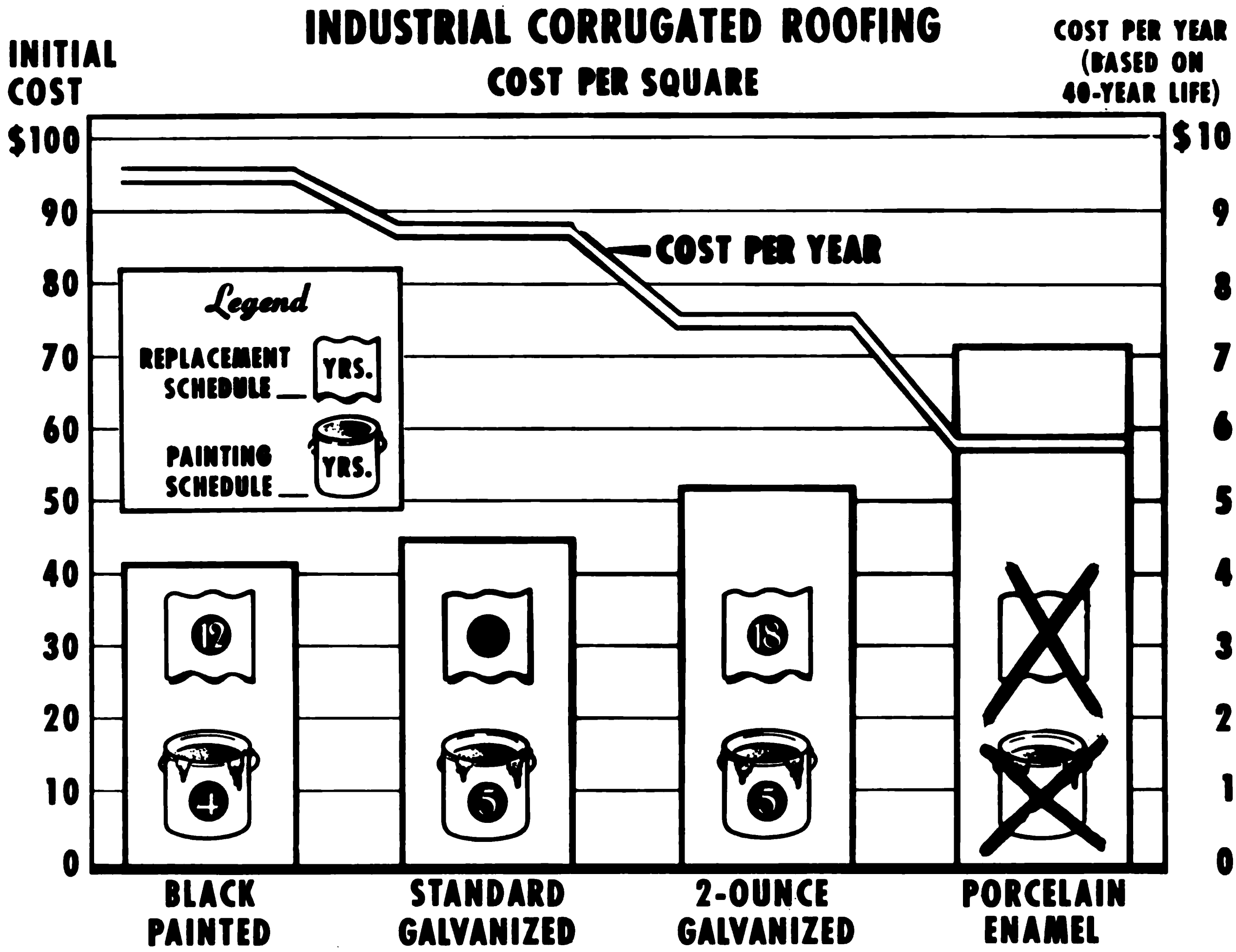

Fig. 4.18—Cost comparisons.

color and a white inside color for interior light reflection. Today, both surfaces are in excellent condition. Because of the glass-like surface very little dust adhered to the inside surface, so that continued good light reflection has prevailed during this period with no maintenance whatever.

One recent insulated structure (the General Stores Building of U. S. Steel's new Fairless Works) was covered with blue grey, 16 gage corrugated porcelain enameled panels. The insulation is 1¼" of Fiberglas with an interior wall of 22 gage corrugated galvanized steel. The entire wall was attached with stainless steel and neoprene washer screw assemblies. The cornice flashing was type 430 stainless steel.

These insulated panels were assembled in the field. The cost of this type of panel today is about $125.00 per square against $100.00 per square for the same panel with a 20 gage corrugated galvanized outer sheet with the same insulation and inner sheet.

The Central Maintenance Shop Building next to the Stores Building was planned with a large decorative exterior panel of flat porcelain enameled steel sheets in contrasting colors (in the case, fire-engine red). This same idea could be carried out for an entire building whenever such extra decoration would be desirable to set out the building or identify it for easy recognition.

Plant Office buildings, either as separate structures or as buildings attached to the plant structure itself, have utilized flat panels of varying sizes. These have been entirely of steel curtain wall construction or have been combined with masonry construction with appropriate details of fastenings worked out for both types of buildings.

Late last year a study was made of the cost of various steel roofing materials. The elements entering into the total cost included:

- Base cost of sheets
- Appropriate extras for length, width and corrugating
- A uniform item for freight and allowance for laps

Erection cost
Fastenings cost
Profit.

Costs were calculated for porcelain enameled sheets, two-ounce galvanized sheets, standard galvanized sheets and black painted roof sheets.

Maintenance, such as painting and replacement, where required, were added to determine total cost over a period of forty years. To this cost was added an interest charge of 3% so that a realistic comparison could be made of the different types of construction.

Figure 4.18 shows the result of this comparison. The bars show the initial, installed cost per square. You will note that enamel costs more, initially, than the other materials. However, the red line shows the average cost per square of roof per year, based on a 40-year life of the buildings. This indicates clearly that porcelain enamel provides the lowest cost per year for the entire group.

The future for the use of porcelain enameled panels is in our opinion a very bright one. Larger panels will be used for easier and faster erection, and color will play an increasingly important role in relieving the monotones of today's industrial building construction.

4.1 GENERAL DISCUSSION

MR. HUTT: We're now ready for the questions.

HERBERT J. SPENCER (Erie Enameling Co.): Mr. Moderator, I have one very brief question. Perhaps Mr. Souder would give the answer. For two days we have had quite a shot of the use of porcelain enamel, in particular, architectural porcelain enamel. Now I submit that very few of the architects in this country, aside from those who are in this room, know anything about the manufacture of porcelain enamel. I also submit that we manufacturers of porcelain enamel know very little about architecture and design. How can we get these two groups to cooperate to the end that architectural porcelain enamel will be accepted as a new medium of building?

JAMES J. SOUDER (York & Sawyer, Kiff, Colean, Voss and Souder): The whole process of mutual education is a difficult one because we are not very close together. I think the pattern so far is that the architects take the initiative generally, except that they receive advertising literature or see it in the standard publications, such as Sweet's catalogue for example. When we want to know something about a new material we have to scan the field and see what we can find. We often find it by devious means. We may attack the purveyor of one product to find out something about one of his component materials. Generally, I think you should tell us what we can do and come to us to find out what we are trying to do. You're always welcome in our offices, whether we happen to be working at the moment on your material or not. Beyond that, I think that the kind of meeting we are having here, where ideas from all users and manufacturers and research men, and where all views are exchanged and published and reported, is extremely valuable. In our own profession the architectural generals do a pretty good job covering this kind of meeting. I think it's a long-haul proposition. We've got to know each other better through meetings and through very frank discussions and mutual criticism. That's a sorry answer to your question, I'm afraid, but I can't give you a concrete one.

MR. HUTT: Are there any other comments on that one phase? Would anyone else like to comment from the floor?

MR. WALTER A. TAYLOR (American Institute of Architects): We have a device which has been used in connection with a number of materials. Most of these have been worked through the Producers' Council. We have what is called a package program in which there is an edited presentation that may or may not include live demonstration in its briefest form, all of which is presented in about one hour. Often-times two or three related products are covered. We prefer to have the presentation made by a technical man from the trade association concerned or the manufacturers' headquarters. If one is not available, the script is presented by local representatives. There are 108 chapters of the Institute which are looking for program material. If you could develop this type of package program, we'd be glad to announce its availability. Of course, you could go into the subject more thoroughly in a regional meeting, perhaps a technical seminar which would be possibly about one-fourth as long as this conference.

MR. R. W. HAMILTON (Bemis Foundation, Massachusetts Institute of Technology): I suggested yesterday, on the problem of the small buildings that normally are not touched by architects, that perhaps the porcelain enamel industry should take the lead in making some sort of arrangement with local architectural organizations to encourage, through mutual effort, the employment of architects perhaps only on an hourly basis for these small jobs. I think you all have had enough comments about poorly designed installations, but I think these comments largely resulted from the fact that architects were not involved at all. I don't know of any better way to develop the interest of the owners in better design than a cooperative effort between architects and porcelain manufacturers.

MR. PAUL R. FRITSCH (Goodyear Tire and Rubber Co.): I think, in direct answer to Spike's question, because there is recognition of that gap between the porcelain enamel industry and the architectural profession we are one step towards correcting it. On several occasions where we've had jobs—we don't own our stores, we lease them: we have local architects and local contractors design and build them for us according to our specifications—where the architects simply wern't familiar enough with porcelain to discuss it intelligently; and the result was that they just backed away from it. Sometimes they even tried to discredit the material, perhaps not because they really believed what they said, but because they were caught in an off-guard position. How it can be corrected is quite a long story, but I think the first step forward has been made in the recognition that there is that gap in between that has to be covered.

MR. HUTT: Milton Male, do you have anything to say on that? You've had quite a bit of experience.

MR. MILTON MALE (United States Steel Corp): In our contacts with architects in promoting the use of any material in building construction we find that they want to know the answers to a lot of very pertinent questions. They want to know the range of sizes that can be made available to them; they would like to have some fairly clear ideas of costs, methods of attachment, etc. A good many of the problems for which they are looking for answers have been touched on very briefly here in the course of this conference, but I still think that there is a wide gap in information that can be filled by the porcelain enamel industry and made available to architects who are looking for answers to specific questions. To find out what architects want to know involves making calls on them; you've got to put yourself in close contact with architects and be in a position to provide the answers to their questions.

MR. CARL F. BLOCK (United States Steel Corp.): I'd like to ask a question of Mr. Souder. In our company we attempt to contact architects several different ways, of course by advertising in the trade journals and things of that type. We also distribute those advertisements by direct mail to the architects. We cover probably 13,000 architects in the United States. The question I would like to ask is this: When an architect receives a direct mail letter with a pamphlet or information on a particular building product, how much attention does he pay to that? In your opinion do you think that is a good way to get the picture across to architects?

MR. SOUDER: You asked me a question that we have been going after for some time. Mr. Taylor indicated that the American Institute of Architects and the Producer's Council attack some of these problems jointly. That's one of them. I think the material is read directly in ratio to its appeal. If it has information, clearly presented information, it's likely to be read. If the information is specific, as Mr. Male suggested it should be, very often the material is filed permanently for reference. Many manufacturers use the AIA file clerk or a draftsman in the office to put the material where it can be found easily and used when needed. From my experience I would say it is seen; and if its got appealing factual information, it's usually read.

MR. J. E. BOURLAND (Texlite, Inc.): I am Chairman of the Architectural Division of the Porcelain Enamel Institute and I would like to speak in that capacity at this time. I'm afraid that the architectural division of porcelain enamel is in some respects like other industries which for various reasons are possibly "an hour late and a dollar short"; but instead of being an hour late and a dollar short, we are years late and many dollars short. I'll tell you why. It's because we have not furnished explanatory material, unfortunately because of the rapid development of this fine material which we have talked about these last two days. We have not put out adequate material; we have done a poor job of selling our material. We have not given you people whose responsibility it is to select materials the real information that you need. This year, as a project of the Architectural Division, we are putting first on our agenda, the development of a manual for the use of architectural porcelain in the building industry. Hearing this series of discussions you begin to appreciate the diversification of this material in the many ways it can be used. To condense all the available information and put it in black and white, gentleman, is a real job. I say that because it is going to take time. We hope that before the year is out we will have something that you people can use, so that you can specify our fine material and feel assured that you can use it to its best advantage.

MR. J. F. INGRAM (Ingram-Richardson Manufacturing Co.): I want to ask Mr. Souder a question. I was interested in his remarks about the use of porcelain enameled spangles on that hospital job having a cost of less than $4.00 per square foot. Would you care to comment on how that compares with masonry materials used in the same type of application?

MR. SOUDER: I don't have the cost figures with me, but our objective in approaching that was to see whether we could lick the cost of masonry materials. We designed typical wall sections complete; and they were not just a wall section, but a wall section and a bay or portion of a building. I might say here that we had a cost-plus contractor employed in order that we might use his know-how and his estimating facilities through the design period. We had the contractor estimate the same buildings, or the same building sections, using several different wall sections, various types of masonry applications, and the skin wall. The cost figure, I can't recall the exact figure, but I would guess that there's a differential of about 10 per cent in favor of the enamel.

MR. DAVID T. JAMES (Camp Detrick, Frederick, Md.): Mr. Souder, I hope there's a publication somewhere on these hospitals.

MR. SOUDER: They are being published currently in both architectural magazines and in Modern Hospital, one of the hospital journals.

VOICE (unidentified): There is quite an extensive article in one of the recent issues of either the "Architectural Forum" or the "Architectural Record"—I can't recall which. In the article the method or procedure used in the development of the whole program was outlined in considerable detail.

MR. SOUDER: "Architectural Forum" for August, September and November, I believe.

MR. MARK VAN DER KLOET (Erveen Corporation): I want to ask Mr. Lobdell if it would be economically possible to construct prefabricated houses on a much more modest scale than Lustron undertook

MR. LOBDELL: I believe that's possible. For example, I think you could build a prefab house using porcelain enamel on both the inside and outside and using wooden stairs. I think it would be a lot cheaper and a lot quicker. I believe that there will be a number of attempts made in the near future to prefabricate a house with porcelain enamel at least on the exterior and in some cases on the interior, too.

MR. E. C. WOODLAND (Bureau of Ships, Navy Department): I'd like to add a comment to the remarks that Mr. Souder made relative to porcelain enamel bulkheads being installed in hospital ships. They were installed, as he said, some ten years ago. On an inspection recently it was found that those bulkheads are still in the same perfect state of preservation as they were on the day they were put in and have required no maintenance whatsoever. In further comment, the Bureau of Medicine and Surgery of the Navy Department has requested the Bureau of Ships that on all new constructions their hospital spaces shall be fitted with porcelain enamel bulkheads.

MR. TAYLOR: I'd like to underscore what Mr. Male and Mr. Souder said about product literature. Some of you may have heard me preach this little sermon at a meeting of the Producer's Council. The difficulty is with the advertising expert whose desk is right up next to the boss'; he knows everything and insists on treating architects and the engineers like readers of the Saturday Evening Post. Well now, most of them are readers of the Saturday Evening Post, and they get that dose; but if you don't want your product literature thrown into the waste-basket then make it look like a textbook and forget what the advertising manager says about a beautiful naked woman stepping out of a shower stall. Give us some facts. As a matter of fact we get so excited about some of this so-called art-work that we forget whose product it is we're looking at. And for heaven sakes, don't print black, letter-pressed printing over some nice swabs of dark blue on a lot of silly nonsense that goes for art-work. Let's make and send out something that is technical and useful and can be understood by everybody on the drafting board.

MR. JOHN K. BOWERSOX (Associated General Contractors of America): I'd like to talk in line with what Mr. Taylor just brought out about joint ventures with the Producer's Council, which we also have. We have just recently worked out an educational, or what you might call instructional, program for the members of the AGC. We disseminate information in a bulletin form to our chapters, 122 of them, giving them a list of presentations that are available for chapter use. Portland Cement has done quite a bit of work in the gypsum association. All these presentations which are in the form of motion picture films, film strips, or slides are reviewed before they are sent out. Now much has been said about the architect but I think it was brought out yesterday and again today that the porcelain enamel job is only as good as it is installed; and that is an important fact. Since there are quite a few tricks of the trade connected with these porcelain enamel panels, I think it would be important that some type of presentation be worked up by the manufacturers which we could funnel out to the general contractors across the nation.

MR. HUTT: Any more comments? Questions, while the panel is still here? Thank you very much, members of the panel. I've enjoyed working with you. Now the final item on the program is the conference summary by William H. Scheick, Executive Director of BRAB, who made it possible for us to have this meeting. Mr. Scheick.

CONFERENCE SUMMARY

By William H. Scheick
(Executive Director, BRAB)

I'm not going to indulge in a blow by blow description of this conference in this summary, but I am going to try to make an appraisal of the program as a whole. I have a good feeling about it. The meeting had a very high technical caliber and, thanks to the excellent chairmaning by Glenn Hutt and the cheerful cooperation of the speakers, we had one that went like clockwork. Believe me, after working for a long time to arrange one of these conferences, that means a lot to us.

From BRAB's point of view, we always hope that our conferences will accomplish three things: We want them to summarize the field of knowledge under discussion; we want them to pick out some problems that lie in that field; and we like them to single out some problems where research should be done. Previous BRAB conferences have been on rather broad subjects where what was said was essentially of value to the whole building industry. Here's one where we were dealing for the first time with a specific product.

We hope this conference has values for the porcelain enamel industry and others closely related to it as well as for the building industry as a whole.

What we have been hearing has amounted to a case study of a material in the building industry. In spite of the fact that Mr. Chase and Mr. Bricker both referred to porcelain enamel as an ancient material and its use as an ancient art, we have been talking about it as a relatively very new building material.

I think that we would be quite remiss if we didn't say that this conference is about metals, too; we have been talking about porcelain enamel and certain metals combined, and we note that our architect speakers have gone on to include the entire structural unit with insulation and such components as windows and sunshades. So our "one-product conference" turns out to be very broad after all.

I note also that we have been talking about a man-made building material, not one that comes from nature with very little processing and goes directly into the building. From what we were told by our speakers in Sections 1 and 3, a lot of research and development has been done on this man-made material. That's quite similar to the research going on in industries other than the building industry today. The new industries—the chemicals, the electronics, and their technologies—have literally made themselves and created their own market.

With these "new" building materials (which are composites of the old in new form), research is performing that same creative function in the building industry.

Now, taking this case study of porcelain enamel and metals, it seems that a new building material must travel this road: first it must have suitable physical qualities; then there must be uses for it and acceptance of it for those uses; new possibilities and new problems must be determined as it is used, and constant, on-its-toes research must keep it economically competitive.

Our speakers in Sections 1 and 3, demonstrating broad technical knowledge and experience as chemists and ceramicists, gave us extensive proof that this material has many fine qualities suitable for building purposes.

We found challenge for the industry in Sessions 2 and 4. Mr. Tuttle and Mr. Lescaze, Mr. Souder, and Dick Hamilton dealt with the uses and acceptance of the material, and they also began to identify things they would like to see done in research. Their ideas are certainly valuable for the porcelain enamel industry. In various ways, these speakers touched on similar points. They described factors hindering the development of porcelain enamel: slow acceptance by the public, by codes, and by labor, some jurisdictional disputes, and the lack of unbiased research. Some others referred to early uses of the material, where signs and "utility buildings" created a bad taste for the public in a way that hindered further use of the material.

I'm going to be one guy on this program who doesn't see anything so bad about a filling station or a sign, like those Mr. Fritsch showed us in the last session, which were so excellently designed.

We always get back to the point that Hamilton and Souder and Lescaze were hammering at—that a new material must have the benefit of good design right from the start. Its early applications by people without taste and with no appreciation for the right use of the material are bound to be harmful to its acceptance by the public. We heard some criticism of attempts to imitate older materials, and this is a common fault afflicting the use of new materials as they come into the building field. The first users of a new material seem afraid to let it stand on its own, and afraid to see just what it has that is honest and good and can be truthfully applied in design. Our architecture has stopped copying from the past, and our modern architects are much better prepared to go along with our material researchers in eliminating these early mistakes in design in the uses of a new material.

We had some interesting proposals on the research problem. Mr. Tuttle and Mr. Lescaze got right down to brass tacks and called for very much the same things. Mr. Tuttle talked about "a big brick," meaning a big unit of wall surface. Then he said, "I don't mean units, either, I mean systems—wall systems." And Mr. Lescaze, after showing his picture of the Alcoa Building with that big panel going into place with a crane, called for studies to produce the wall, the window, and the necessary solar control. Mr. Tuttle pointed out that some of the faults of the present panels are that they imitate the structural methods of other materials, and that they have problems in fabrication and trouble with joints and openings. He feels that so far they've only nibbled at the big problem of panel construction. So he names some things he would like to have in a wall system.

I thought that Mr. Hamilton made a very excellent point that is so often overlooked in a technical meeting when he showed you that genuine art is possible with this material—art forms with newness and freshness, and possibilities that exist in no other materials.

It seemed to me that there was very little concern with codes in these talks. Codes used to be quite a bug-a-boo—sort of an idea that we scare the baby with, one which says we can't have a new material because of codes. We get the idea that we can take care of codes when we have a big movement ahead in education.

Finally—and not much was said about this except in scattered comment throughout—is the economics of today's building. Mr. Lescaze said that modern architecture isn't made by materials. He said that it was made by having to meet the requirements of the civilization and having to express and fulfill its ideals. He said when the architects go in this direction, new materials find their use, and I think that's quite logical.

I don't think that he stressed hard enough how much economics plays its part in today's design. Economics affects the way we design, the way we build, the way we plan, the way we must get at the efficiency of space, the way we must go after that lowest square foot cost of wall. We heard that in Mr. Souder's talk; we heard it in Milton Male's talk, and we know that the man with a factory, the man with a house, the man with a church, has to think about it with his building. I've observed that in our financing and operation of buildings we're after lowest annual cost over some assumed economic life. So our new materials certainly must show long-term economy.

From the general character of porcelain enamel and the reports we've heard today, I might suggest that one of their mottoes ought to be "maintenance zero." That is an objective for a designer in these days when our buildings become more and more highly mechanized and maintenance must be minimized in our structures.

It's interesting to me that BRAB was rather concerned about undertaking this kind of conference. Some of our thoughts were, "it might be too commercial," "we should keep on the broad general subjects." Now, I think this kind of conference is right down the alley for the building industry because it gets down to brass tacks on industry problems. I think that we ought to have a series of them, that we ought to continually turn over the whole field of major building materials in a series of conferences for a period of years.

I enjoyed this conference and found that I learned a lot sitting out there listening. Obviously, this kind of conference brings out competition within our industry. There are people here from other parts of this building industry who came, no doubt, to see what these porcelain enamel fellows were going to say about themselves. We have turned up problems that not only pertain to porcelain enamel, steel, and aluminum, but to other parts of the industry. And when one or the other solves one of these problems, then I believe some other part of the industry will follow and solve some problem of its own that gets at the same principle.

Thus we maintain the traditional competition for the building dollar between ourselves, and that's healthy. But I think we must have a broader view with conferences of this kind. We must regard them as an opportunity for the design professions, the different manufacturers—the competitors if you please—the builders, and everybody in this building industry to work together to put the industry as a whole in a better position to compete for consumer dollars with other industries.

Incidentally, I think you might like to know a little bit about the attendance here. There were 223 people registered. There were 35 from government; 24 from professional organizations, including the design professions, research institutions, etc.; 5 from academic institutions; 14 from building publications; 137 from industry organizations; and 8 from BRAB and the PEI staff, making 223.

We've got a lot of building ahead in the United States, and I am one who believes that the "golden age" of building in the United States is ahead in the very near future. I believe it is high time that, instead of a collection of building technologies, we have a *building science*. That's what BRAB is working for here and that is why it pleases us so much when people come here to conferences like this to work with us toward that end.

I want to extend the sincere thanks of BRAB and the Building Research Institute to the speakers who have done so much to make this a success. Our thanks to you, Mr. Hutt, for your wonderful handling of this meeting, and our thanks to the Porcelain Enamel Institute and its officers and members, and to the members of this Conference who made it a success by coming. I want to repeat Norm Mason's invitation to any of these organizations who like the BRAB idea and want to go along with BRAB by becoming members of the Institute.

MR. HUTT: Thank you, Mr. Scheick. Before we ring down the curtain, a couple of remarks. As a member of the Porcelain Enamel Institute and on behalf of the Porcelain Enamel Institute, I want to thank BRAB and the Building Research Institute for permitting us to hold this conference here. There's been a lot of work put into this conference. This conference was conceived last February by Harold Sylvester, who at that time was Director of Field Service for BRAB. There was a lot of work in planning for this conference; and in this planning and work, Bill Scheick and Ed Dickens of BRAB, as well as Ed Mackasek and John Oliver and Bill Brinker of the PEI, did a swell job in throwing everything together neatly and making this a success. You have been a wonderful audience, ladies and gentlemen; I've enjoyed working for you and with you, and with that I will call this Conference on Porcelain Enamel in the Building Industry at an end.

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