and fix it lastingly, for the good of mankind, we can still so arrange things that the tools are here for the good of others, so the way shall be open, all the material provided, building and instructors ready, the opportunity shall be afforded those coming after us to use facilities we did not have and, lacking these, we came to know their value.

There is a wide field of experimentation that really cannot be done elsewhere than in a school such as this. Individuals have not the time to devote to it. It is broadly in the line of the advancement of the science, requires much time and careful attention, and would never be worked out except in such a school and by students who were building themselves up in the working out of just such problems. Instance of this is the formula for crystalline glaze given the American Ceramic Society and the eighteen hundred experiments made in this school with it in which very much of interest was added that never would have been worked out except under these conditions.

The manufacturers of Germany demonstrated their belief as to the value of such research and, utilizing it in every available form, they went conquering the world. They were indeed far on their way in such conquest up to the time that the war lords fell out and so stopped their work and dragged them back to the old, old aboriginal manifestation of brute force and the lust for blood. Had they but kept to their work, utilizing scientific research in their manufacture as they had been doing, their conquest of the world would seem to have been assured, but the war lords decided otherwise and chose the way of blood.

This gathering here to-day is not just an accident, not something that happened without cause or reason. This gathering itself is a complete demonstration of the pressing importance and insistence of the subject of which I am speaking. You are gathered here to-day because of the persistent demand of the manufacturers for more ceramic research. They have not only clamored for it, they have worked for it, earnestly and self-denyingly. They have labored personally and collectively. This department of ceramic engineering came into being because of their demands and their effort. They labored with the University authorities; they worked with every succeeding Legislative Assembly; they begged appropriations, and then, rallying the clay workers throughout the State, demanded appropriations, and they got appropriations. All this labor and effort has crystallized and materialized in tangible form in this building we here dedicate to-day to the furtherance of our Art, for the good of those who are to come after us and who will, we know, surpass us. We dedicate that they may not lack the facilities that we lacked, that they may grow to do the things that we could not do. We dedicate in reverence and hope as our best contribution to the progress and good of the work we love.

I have treated my subject in a wandering fashion, possibly in a wondering fashion, for the reason that the need of the manufacturers for ceramic research is, and always has been, so great, so well known, so constant and insistent as to be self-evident and needing no demonstration. This dependence has existed from the earliest times, the want has always been felt. What was needed was a proper opportunity for research. A place was needed and tools and then education in using the tools. Men must be educated to becoming skilled in knowing how to use material and tool. Must be so trained that when reactions occur they must know why they occur and work intelligently to the desired end, and not blindly, as in the past. The quest has been much of the time blindly, gropingly, in the dark, but now is coming to be openly, understandingly, and in broad daylight. State universities like this, and buildings and appliances like these, are the tools which shall furnish the opportunities and appliances, for the training of the brains to mix with the clays that will then place our Art where it belongs, and our pioneer work shall not have been in vain.

I may only add that the men on this board who have really

done the most in the pioneer labor to bring this work to fruition are so modest and diffident and fearful of receiving the praise they so well merit for their efforts that they are sitting very tight, keeping very quiet and, following usage from time immemorial, are now putting forward that member of the board who probably did the very least in the real past work to now do the talking.

CHICAGO, ILLINOIS

DISCUSSION

By L. E. BARRINGER

President American Ceramic Society

Engineer of Insulations, General Electric Company

I prefer not to launch into the troubles of the electrical engineer, as I am afraid that would take a great deal of time because it is true that a large part of the electrical engineer's troubles to-day may be attributed to insulation and frequently to ceramic insulation. There are many forms of electrical insulation but true ceramic insulation forms a large part of the material used. I should like to tell you something about these electrical insulation problems but would prefer at this time to discuss the general aspects of ceramic research work as covered by the paper which has just been read.

In the first place, there is one point in Mr. Gates' paper to which I wish to take exception, and that is his last statement that the man who had done the least had now been put forward to do the talking. Mr. Purdy and I did not know whether he referred to us or to himself, but assuming that Mr. Gates referred to himself, in his modest way, I want to say that eighteen years ago, in his factory at Terra Cotta, Illinois, I was given the privilege of going into that factory and working during my summer vacation. I was then in the first engineering class in ceramics in Ohio State University and was given the opportunity of working in that factory, from the plaster shop to the decorating room, and of learning all that I could pick up in this way. While there I found that Mr. Gates had employed one of the first short-course students from Ohio State University and that he had set this young man experimenting upon all sorts of problems in colors and shapes of pottery, new kinds, unknown kinds, trying to develop something new and more beautiful, so I wish to say that in my opinion Mr. W. D. Gates is one of the pioneers in present day ceramic research. He had one of the very first laboratories, if I am not mistaken, and while Mr. Gates' motives may have been partly philanthropic (as he was always ready to encourage ceramic education and ceramic research), I suspect he had placed some dependence upon ceramic research for something that he really desired to obtain and that, therefore, he is a good example to put before you of the manufacturer's dependence upon ceramic research. Mr. Gates wanted something and he tried to get it by putting a technically trained man at work upon the necessary research.

Ceramic research is not different, or at least fundamentally different, from any other research. There is nothing to differentiate it in a general way. It requires the same sort of preparation and endeavor and the same attitude of mind but it is different in this respect—that it has taken longer to assume its proper place in the world's work. Personally, I think that this is largely because we have been handicapped by tradition. Ceramic industry is as old as the hills and from the ages past, we have record of the Chinese and Japanese potters producing most beautiful ceramic objects that are very rarely equalled, or excelled, to-day. We know that these old Chinese and Japanese potters worked by passing the secrets along from father to son. It was their greatest pride to discover something new and beautiful and then to have that live in the family as an heirloom, to be passed down to coming generations. That was the standard practice in China and Japan. Unfortunately the Germans, when they learned the secret of making pottery, particularly

porcelain, in imitation of the wares from the Orient, followed the same course and produced the wares in secret, nay, even with royal approval and protection in maintaining such secrecy.

I think that ceramic research has been largely handicapped by this tradition, a tradition which is now fast being broken down and dispersed. Other industries have, I might say, been born in a new era, as the electrical industry, and have not been subject to this old traditional habit of passing these discoveries on from father to son.

I was looking around the other day for a definition of research and I ran across this statement in the Encyclopedia Britannica: "Without research no authoritative works have been written, no scientific discoveries made, no theory of any value propounded." That is a very broad statement, but I think, after due consideration, it will be admitted that it is generally correct. When I read that, I tried to think of discoveries which might be termed "accidental." We hear of "accidental discoveries" but in nearly every case I could think of I knew that the discovery had been made simply as a side issue or as a by-product of research in some other line, but that it was almost invariably the result of something some man had found or observed in the course of research work started for some particular purpose. As a matter of fact, the most skilled research men closely watch every development, not only to attain what they seek as the ultimate result, but to avoid missing anything by the way, something perhaps that may be useful, or new or valuable.

In this connection I recall Mr. E. G. Acheson having told me of his discovery of carborundum. While he was experimenting in electric furnace work in the Edison laboratories he observed in his arc furnace a few tiny iridescent crystals, crystals so small and so few in number that I dare say they would undoubtedly have escaped the attention of most investigators. He immediately focused his attention upon this tiny crystal and separated it from the other material, and in his interest tested the hardness by scratching a diamond in his ring and thus the discovery of carborundum, a hard abrasive of which he realized the value immediately. That might be termed accidental "discovery," but yet it was made by a research man endeavoring to find something, but with his eyes wide open so as to make sure of missing nothing while trying to find something, and to my mind such discoveries are legitimately the product of research.

The country was never in greater need of research than at the present time, and particularly "organized research" where groups of investigators are working shoulder to shoulder to advance some particular field of knowledge. The great industries have recognized the value of research and particularly the value of organized research, as is evidenced by the research activities of the General Electric Company, the Westinghouse Company, the National Carbon Company, the Pittsburgh Plate Glass Company, the Norton Company and others I might mention. Then there are the groups in the colleges and the United States Government service. As an example of organized research I would say that I represent a company that employs over a hundred men engaged in research work, a company which has invested heavily and has invested because it pays and not only pays but the progress of the electrical industry is absolutely dependent upon systematic research and effort to advance. One of the best examples is electric lighting which has progressed tremendously in the last ten years. The old carbon filament was quite generally used ten years ago. Since then it has rapidly gone through the stages of metallized filaments, pressed tungsten filaments, drawn tungsten filaments and "gas-filled" lamps (nitrogen, etc.); all this has resulted from the determined efforts of the General Electric Co. and its research men to advance that particular field, which they have accomplished in a tremendously successful way. We have lighting to-day at a cost of one-third as much

as a few years ago, giving three times as much light at the same cost as in those days.

I do not believe, then, that there need be any very strenuous argument as to the value of research to the manufacturer.

As another example I would say that Mr. M. T. Herrick, in addressing the American Ceramic Society at its annual meeting last February, spoke of early research work by the National Carbon Co., with which he is closely identified, and stated that when that company was first formed it had great difficulty in producing electrode brushes and other forms of molded carbon to compete in quality and in price with the European articles. There was no high protective tariff available and it became necessary that his company either compete successfully or go to the wall. Representatives were sent to Europe to study methods. They traveled from factory to factory but very rarely were given the real secrets of the success of these European factories, and the representatives of the National Carbon Company came back empty-handed with this exception—that they had observed that there was one thing that every European factory had in common and that was a laboratory. Quite blindly, Mr. Herrick stated, the National Carbon Company put up a laboratory. Then they hired a man from the Massachusetts Institute of Technology and within a year he had introduced two or three valuable features. This is another example of the absolute dependence of the manufacturer upon research, and not only in this country but the world over. The Germans have been pioneers in the line of industrial research.

A few years ago we were called upon to develop porcelain bushings for high-voltage transformers. As you all know, very much greater voltages are being transmitted to-day over high-tension lines than a few years ago. Transformers had to be built for these higher voltage and where five or six years ago a transformer of 60,000 volts was considered large, the development rapidly made necessary transformers to be tested at 300,000 volts or more, and insulation had to be devised accordingly. We had been building comparatively small porcelain bushings to stand 50,000 to 70,000 volts and when it became necessary to go 300,000 we naturally thought the porcelain ought to be larger and thicker, so that we were soon making porcelain bushings five or six feet high. These large pieces proved very difficult to manufacture successfully and even when constructed did not entirely give the desired results. The interested electrical engineers studied the problem and after several months investigation found that the trouble was not in the porcelain but in the distribution of potential over the bushings and, as it were, the potential had piled up at certain points to such a degree as to be able to break through porcelain of almost any size or thickness. By devising the proper design and proper voltage distribution appliances the voltage was so distributed that instead of making bushings five or six feet high and correspondingly thick, we were actually able to reduce the size very considerably.

Now in this same development our next problem was to dry the bushings more quickly. I want to say in connection with this particular research in drying that although it was initiated by the ceramic engineer it was not solved by the ceramic engineer alone. I saw at the start that it had more to do with automatic temperature control and with accurate methods of measuring humidity and temperature than with the purely ceramic field, so a committee was organized with three mechanical engineers and one ceramic engineer and that problem was solved when the mechanical engineers provided the proper control apparatus. That was a mechanical engineer's problem, but the research men had to say that it was entirely a question of proper mechanical equipment.

I have pointed out these few things to show that while the manufacturer's progress must be dependent upon research,

upon the other side of the balance he is entitled to a just return for his investment and to insure that just return the research engineer or the research chemist must be broad enough and big enough to recognize all phases of the subject and to carry along his work accordingly.

I think one of our commonest perils in research work is to get too close to the problem. It is a good thing, I think, to get away from one's work occasionally, to back off from the picture as the artist does, in order to acquire a perspective, to see it differently and then return better equipped and with a better understanding of the work as a whole.

It is this kind of research that the manufacturer expects. I hope then that the research work which this new Ceramic department undertakes will be of such a character as will have a vision of the whole field, and that in teaching ceramics to the undergraduates the point will be emphasized as to the value of organized research, group research, and of the great value of coöperative effort and of always maintaining proper vision and perspective. When it is shown that the manufacturer is dependent upon research, this places a responsibility upon the research engineers which they must prepare to meet successfully.

SCHENECTADY, NEW YORK

DISCUSSION

By C. H. KERR

Director Research Laboratory, Pittsburgh Plate Glass Company

That the practical status of any industry cannot proceed in development without the growth of the fundamental scientific facts upon which that industry is based must be evident to any well-informed man, be he scientist or layman. Or as Dr. Clarke, of the United States Geological Survey, has aptly stated it, "There can be no applied science until there is a science to apply."

To the glass and enamel divisions of the ceramic industry this thought is especially applicable—in fact, it should be written in italics and kept constantly before the minds of those men who in their respective positions are instrumental in regulating the course of new developments in the industry.

An extended discussion of the problem of surface tension as it relates to glasses took place in one of our courts not long ago and the nature of that discussion illustrates as well as anything could illustrate it, the great lack of scientific knowledge and to an even greater extent the real need of such knowledge in the industry.

Let us acknowledge at once that in the field of glasses, enamels and other similar fused silicates the present state of development of chemical and physical science does not permit us to presuppose an ability to arrive at a completely satisfactory scientific solution of most of our problems. The extent of our knowledge concerning the laws governing systems with as many components as usually are present in the silicates with which we are concerned, is decidedly limited and developing but slowly. But, let us at the same time emphasize very strongly these two things: (1) that there are many incidental problems in connection with each branch of the industry that are capable of easy and complete solution and these problems can be taken care of while the main work is in progress and in all cases it is safe to assume that the solution of these problems alone will more than repay the employer for all laboratory expenditures; (2) that in studying the main problems of reactions in the silicate melts of many components it will always be found to be true that while answers which are complete from a scientific point of view are rarely possible, still as the study progresses there are constantly occurring ideas based on reasoning along lines of analogy which are susceptible of adaptation to practice. In the actual operation of the laboratory it will always be found that where

a worker would (or certainly should!) hesitate to offer a complete solution to any certain problem he will have ideas based on essentially sound data that extend beyond the range of present-day experimentation possibilities, but which nevertheless offer the best and safest foundations upon which to proceed with practical development work.

To name some of the unsolved problems in the glass industry is to show in the most conclusive possible manner the necessity of much greater development in the fund of scientific data and the manufacturers' dependence upon research. To name approximately all of the problems which present themselves to-day in an important bearing would exhaust the time of this meeting to the exclusion of everything else, but to name a few such problems will illustrate the present state of comparative ignorance in which the industry is struggling. Much work has been done within the past decade but it represents a mere beginning which is not more than an introduction to the real work which must inevitably follow.

What is seed or bubble in glass? This defect in glass is one that is common to all kinds of ware and one that causes enormous losses either directly in the manufacturing losses, or indirectly in the loss of business because of superior quality met with in competition. The defect is known under a variety of names, seed, blister, boil, bubble, etc., but practically nothing is known about it except its existence. Many assumptions as to the nature of this defect have been made, most of them based upon reasoning that proceeds from a highly questionable chemical reaction which looks well when written on paper, but nothing is known about the origin of the bubble, the nature of the material, if any, filling the void in the glass, or the conditions necessary to prevent its formation or accelerate its liberation.

Concerning the color of glass (meaning the great mass of commercial glasses which are supposed to be substantially colorless) there has been considerable investigation but the subject is still in a very unsatisfactory state. *What is the real nature of the coloring effect or iron impurities and how can it be controlled? When once standardized in control how can variations in purity of the raw materials be properly provided for? If neutralizing or decolorizing agents are required what is the best theory of overcoming the residual color effect of the original glass and how can this be applied?*

One great source of industrial loss is breakage traceable directly or indirectly to the annealing process. *What are the relations existing between the composition of the glass and its required annealing treatment? And the converse of the problem may be equally important—what is the correct annealing treatment as applied to the particular glass composition concerned?* Another question along the same line is of perhaps greater immediate importance—*what are the relations between certain common impurities in the glass and the necessary corresponding changes in annealing treatment?*

Another very large problem or field of problems lies in the relation existing between the glass and the containing pot or tank. *What defects are introduced from this source and how may the composition of the glass or of the containing vessel be altered to produce beneficial effects, or how may the process of manufacture be changed to avoid the resulting troubles?*

This list of problems might be added to indefinitely but it must be evident from even this small list that the fundamental problems of the glass and allied industries are far from a basis of satisfactory solution. Mechanically the glass industry has developed wonderfully, even magically, within the past quarter century and especially within the past decade. Chemically, the glass industry has stood still. There must be an awakening and a real development and the dedication of this building today is a very significant fact in this awakening. An industrial awakening is always of necessity a slow and tortuous process,