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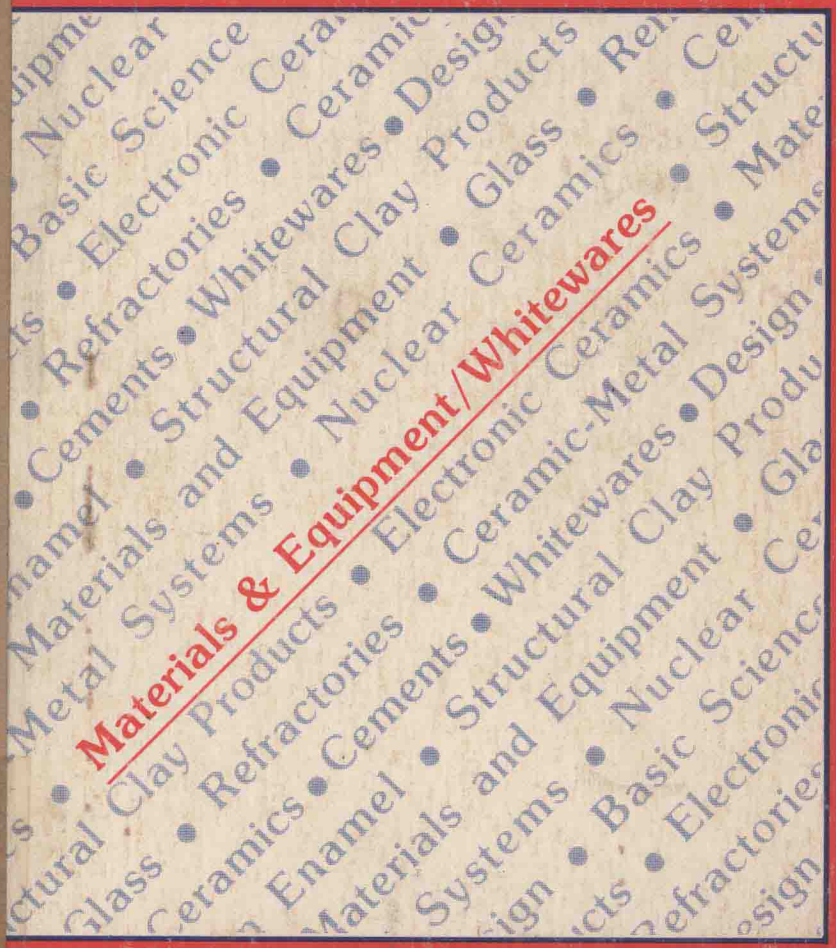

Materials & Equipment/Whitewares

A Collection of Papers Presented at the 86th and 87th Annual Meetings and the 1984 and 1985 Fall Meetings of the Materials & Equipment and Whitewares and Structural Clay Products Divisions

Cullen L. Hackler and John C. Meiman
Proceedings Committee

William C. Mohr
Chairman, Technical Services Advisory Committee

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Preface

Included in this sixth volume of *Ceramic Engineering and Science Proceedings* are papers from the 1985 Annual Meeting in Cincinnati and the 1985 Joint Fall Meeting in French Lick. The percentage of papers presented at the meeting, relative to the number published, is improving as many authors are understanding how rapidly these papers are published. It is our sincere hope that many more of our members will present and publish papers so that the exchange of information can be used to benefit our industry as a whole.

Direct contact with the individual authors is encouraged in case of any doubts, misunderstandings, or questions, as there may be some inadvertent inaccuracies or misprints due to our efforts to get this published quickly.

The Proceedings Committee for the Whitewares and Materials & Equipment Divisions wish to thank the authors, program chairmen, session chairmen, and others who helped in this publication.

Cullen L. Hackler
John C. Meiman
Proceedings Committee
Whitewares and Materials & Equipment Divisions

The programs of the Structural Clay Products Division contain many informative and valuable papers. Few of these papers are published in the *Journal* or the *Bulletin*, because the authors are generally plant operators, overwhelmed with the task of keeping their facility running. They do not have the time available to prepare a formal manuscript and then effect further modifications through the required review procedure. Publishing these papers in *Ceramic Engineering and Science Proceedings* is a highly desirable method of preserving the information and making it available to many interested people. The Technical Services Advisory Committee has taken the lead in assembling the Structural Clay papers which are printed herein. The Committee thanks the authors and all others who have cooperated to make this publication possible. It is hoped that the Structural Clay Division will follow up on this initial effort by devising a suitable method whereby Structural Clay papers may continue to be published in the *Proceedings* on a regular basis.

It should be appreciated that the papers herein have not been through the ACerS review process, and, therefore, some inadvertent inaccuracies may be found therein. Where questions arise, it is suggested that the author be contacted for clarification.

William C. Mohr, Chairman
Technical Services Advisory Committee
The American Ceramic Society

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Process Management—More Profit From the Process

C. L. Bennett

Corning Glass Works
Corning, NY 14831

Corning Glass Works initiated a program 10 yr ago to raise the productivity and predictability of its manufacturing processes. The Process Management System consists of documenting the process to establish the standard correct way to perform the operation, training the people to all do it that one best way, auditing the process daily by an independent observer to assure it is "on standard", and changing the process only when data is available from designed experiments.

I would like to start off with some basic elements I think we will all agree on. The first one is that *consistency* reduces the incidence of new manufacturing problems. That's easy to accept if one considers the opposite—*variability* certainly increases the risk of new problems. The second is consistency makes fixing problems easier. It's a lot easier to troubleshoot a process against a stable background, a relatively low noise level. That is, the elapsed time to problem solution is shorter in that kind of environment. Third, the more complex the process, the more steps, the more interactions involved, the more difficult it is to run successfully unless consistency is a cornerstone of the operation. That is, there comes a time when the whole process just goes out of control, you lose it entirely if you can't achieve and sustain consistency.

Now nothing I've said so far is controversial. Since we all believe consistency is good, why don't we always run consistent processes? What obstacles exist? Where does all the variability creep in? In the mid-1970s we analyzed a diverse range of processes at Corning to determine the sources of process variability. We identified the primary sources as: (1) inconsistencies in materials and services, (2) differences among equipment and instrumentation, (3) environmental and/or time factors, and (4) people who operate or interact with the process. The first three items are sometimes outside our control—power surges or brownouts, machine wear, variation in raw materials, etc. Surprisingly, it was item 4, variability associated with people, which was determined to be responsible for more than half of the total process variability.

By designing and implementing a system to bring consistency to its process operations, Corning has demonstrated that a majority of the variability associated with people can be eliminated. This system which we designated the Process Management System (PMS) requires no techological breakthrough, only minor capital investment, and generally shows significant results within a matter of several months. It is based on the application of deceptively simple principles:

USE WHAT WE KNOW. Convert the total process knowledge of operators, supervisors, engineers, and technical experts into uniform practice to which everyone adheres until better information is known.

PRESERVE WHAT WE LEARN. Systematically incorporate newly gained process knowledge into uniform practice.

USE SCIENTIFIC METHOD TO CHANGE THE PROCESS. Require that process changes be supported by valid experimental data which demonstrate that the change has the desired effect and that there are no adverse side effects.

Although the principles are simple, developing a formal system to ensure their consistent application in the day-to-day manufacturing environment was difficult. Previous attempts to standardize procedures, organize training, and control change had not succeeded. A careful study of these earlier efforts helped pinpoint the causes of failure.

There were cases where documentation existed, but the information was buried in lengthy narrative or the writer had assumed the user was already knowledgeable in process fundamentals. No mechanism existed to keep information up to date, and its usefulness deteriorated over time as the process underwent change. Often, documentation was mixed with new technology and reflected how the writer expected the process to behave rather than how it actually behaved. Training programs required extensive lead time to gather the necessary process information and reach consensus on its accuracy. No central agency existed to coordinate changes made in one department which might influence another either upstream or downstream in the process, or to keep permanent records. Systems were hastily built around short-term needs to respond to a crisis, rather than long-term objectives to eliminate sources of chronic problems. Each system was closely identified with the idiosyncracies of its originator, so it seldom survived the originator's tenure. The "everyone for himself" concept led to establishment of competing systems, waste, redundancy, and confusion, making it easy to justify circumvention.

The lessons we learned provided the structure for the Process Management System. We developed a closed-loop system, comprising five integral elements, under one agency which we call PMS:

DOCUMENTATION. Establish one agreed-upon best known way to setup, operate, maintain, and troubleshoot the process.

TRAINING. Train operators, supervisors, engineers to run the process as it is documented. (For us, this meant a massive retraining effort since incumbents had to be introduced to this new concept of uniform operation.)

AUDITS. Independently check the process daily. Check setups, critical conditions, techniques. Make sure we're operating the best way we know how. Note any discrepancies. Institute corrective action to eliminate off-standard situations when they are found.

CHANGE CONTROL. Formally manage process change. Require approvals based on justification by valid experimental or historical data. Use this control to keep documents accurate and current.

EXPERIMENT PLANNING. Require that experimentation with the process by planned and approved, that results be formally reported, and that historical records be kept in a central, accessible file.

Each of these elements has a defined set of standards, which I will briefly describe here:

Documentation, for example, consists of five categories: Process flow charts/flow sheets which trace the process from the introduction of raw materials through to the shipment of finished product. Material specifications, which outline authorized suppliers, acceptance criteria, process usage, safety data, and other specialized information. Machine specifications, which include all important information about equipment used in the process. Standard

operating procedures, which are the basic manufacturing procedures. Inspection procedures, which cover all inspections throughout the process whether incoming, in-process, final, or special tests. Each type of document is assigned a specific format to ensure consistent, comprehensive presentation of information. Standard operating procedures, for example, contain 12 standard sections, including setup, operation, shutdown, troubleshooting, and maintenance.

Emphasis is on documenting the best known way of operating the process. "Best known" means today's method which produces the most product consistently. In some cases, where process definition is incomplete, the "best known" way includes control strategy. This encompasses documenting a known set of parameters to use in starting up the process, then specifying the way to choose the direction and magnitude of changes which must be made. What is documented, then, is a way to uniformly run the process, even though the parameters themselves cannot be fixed.

Once a document is written (the author might be an operator, an engineer, a technician, or even the plant manager), it passes through an interdepartmental review and approval before it is accepted as *the* standard for operating the process.

The consistent documentation standard is in itself an advantage: Access to process information is simple after a brief introduction to PMS. That means an engineer transferred from our Harrodsburg, KY plant (which manufactures photochromic lens blanks to our Erwin, NY plant (which produces ceramic substrates for automotive pollution control) knows how to obtain accurate process information in an otherwise unfamiliar environment. We conservatively estimate it now takes a process engineer or production supervisor only one-third the former time required to become trained in the new operation.

With PMS, both new employees and incumbents are trained in this system as a formal manufacturing system to ensure process consistency. The objectives of the program are outlined, and the use of the system is explained. Specific job training then uses the document itself as a lesson plan. Everyone who interacts with the process is instructed in the one standard procedure.

How do we verify that we are operating to standard on the production floor? We use a two-level audit program. Not to be confused with quality control audits of the product, PMS audits check the entire process daily to see if it is running to standard. A typical daily audit might check as many as 200 critical variables for a single process. The results are compared against the documented standard; deviations are noted and reported as discrepancies; and corrective aciton is initiated. Most plants use the "daily audit exception report" as the agenda for the morning production meeting and plan correction action as a team. Typically these audits are conducted by an independent technician who does not report to production.

Since the daily audits concentrate only on critical variables, a twice-yearly audit is performed on each document in its entirety, even checking storeroom inventories to assure spare parts are maintained as documented. The job of conducting these audits is generally widely-shared throughout the plant and is considered a valuable training tool for new engineers or production supervisors since it creates a thorough familiarity with the process standards.

Without the ability to remain as dynamic as the process. PMS would not long survive in our rapidly changing manufacturing environments. Although PMS does tend to reduce the overall number of process changes made, it is

the hasty, poorly planned changes which are screened out. The result is fewer but better quality changes and a concomitant reduction in process upsets. Process changes can be proposed by anyone from the operator to the plant manager, but all are submitted for approval before the change is introduced. The exact nature of the change, its timing, and supporting justification are required, and change requests are often denied. Emergency changes—actions taken to resolve a process problem when time does not permit prior written approval—are allowed. They are, however, reviewed within a designated period (usually 36 h, which is sufficient to cover off-shifts and weekends when management may not be readily available) and the process is either restored to standard or a change request is formally processed. Approved change control forms are posted at workstations to communicate process change. If the change is complex, employees are trained in the new procedure.

The documentation specifies one way of operating the process. Under PMS, any temporary trial of a different-than-standard process which is used to justify process change or discover new information is considered an experiment. Like change control, these trials are planned in advance and submitted for approval.

A standard form is used to ensure that adequate provision has been made for statistical significance, randomization of variables not specifically being tested, calibration of instruments and gages, supervision to preserve identity and flow of experimental ware, and paired controls. All experiment plans are tracked to assure that results are documented, and any recommended process changes are followed up under the change control system.

The five elements work together to provide a framework for managing the wide variety of processes we operate at Corning. We stress that making this system work is everybody's job. PMS is presented as an effective tool for assisting with problem solving, providing a basis for good training, and bringing discipline to the process. It is closely linked with Corning's Total Quality program, which stresses participative management.

Before we established PMS at Corning, our typical production graph (Fig. 1) was disappointing. This composite of many processes shows only a slight positive slope, a mediocre yield, and a wide gap between the best demonstrated performance and the lowest point on the graph. The effects of PMS are apparent (Fig. 2): fewer, shallower upsets, reduced short-term variability, and a steeper learnign curve. Fewer backslides mean higher average yield and fewer service and quality problems in the field. Less variability results in a more consistent, predictable process which greatly improves the ability to plan. A steeper learning curve translates into higher yields as the operation matures.

We have used PMS as a successful strategy in a wide variety of manufacturing situations: in new plant start-ups, both domestic and overseas; in established businesses; in bringing in new processes, new products, including advanced technologies such as optical waveguide fibers and ceramic extrusion. We have invariably found that it contributes improvement in every kind of operation from intermittent processes operated only a few weeks or months each year to difficult processes with extremely tight specifications. We use it for all major process transfers, for turnkey projects, for joint ventures, for forming, finishing, and assembly operations.

This program is now operating in all of Corning's wholly-owned manufacturing facilities, both here and abroad. It has increased yields and reduced costs in every case where we have implemented it. It has earned literally millions

of dollars in excess of the costs required to maintain it. It is Corning's way of managing the process for improved profits.

Fig. 1. Typical production graph when using traditional process.

Fig. 2. Production graph when using process management.

Synergistic Process Control

PHILIP A. PARTINGTON

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A process control program that works is something many businesses can't afford to do without, yet do not have. A well-planned process control program reduces rejects, improves productivity and raises quality levels. Planning and implementing process control programs is a complex, time consuming and highly specialized task. Consistent quality success is not achieved by statistical process control, analytic trouble shooting teams, quality circles nor other participative management* alone. *Consistent quality success is only achieved when these concepts are linked to the value of the individual worker.

Introduction

Changing the culture in your manufacturing company from a permissive undisciplined atmosphere in which quality is managed by *inspection*, to a disciplined standards driven atmosphere in which quality is managed by *prevention*, is not an easy task.

It is a task which is all too often ignored in a quest for the quick fix to produce at more consistent quality levels to satisfy customer demands and keep operations cost competitive.

Practical, documented, useable process standards, when combined with the feedback mechanism of statistical monitoring and analysis techniques, are powerful tools which can and are being successfully used to meet these objectives. They are not a quick fix, however, and can only be successfully utilized in companies with a strong management commitment to change the culture and really recognize the value of the individual worker.

The much-touted Japanese success story must not be taken lightly, but by the same token cannot be directly imposed on most American manufacturing firms. We can, however, learn from the Japanese successes and apply certain key methodologies to our operations. The methodology of seeking to better understand processes combined with utilizing the assistance of the entire workforce to develop standards and then using sound statistical techniques to monitor processes, improves our capability to solve problems in a systematic manner and to then eliminate or reduce variables.

It is this constant reduction of variables which ultimately leads to higher quality at lower cost. This approach we call Synergistic Process Control:

Synergistic—Because this word means working together—management, hourly worker, technical engineer.

Process —Because it is the process which produces the variables which must be controlled.

Control —Meaning to *dominate* and *direct* rather than *react* and *reject* through inspection.

Synergistic Process Control had its beginnings with Shewart and Deming

with Juran and Crosby. More recently, it was Roger Slater of LTV Steel who pulled it all together for that company in a program called "The Integrated Quality Control System". Synergistic Process Control is a direct outgrowth of that approach. The six key steps are diagrammed in Fig. 1.

Six Steps Required for Implementation

Step I—Identify Key Variables

The important word here is key. Most manufacturing operations contain numerous variables. Some number in the hundreds. Many number in the thousands. It is necessary first to look in some detail at all of the variables which can be identified by your most experienced hourly and management people. Then through a process of questioning and sorting and sifting to get this monumental list down to a number which best represents the most important or *key variables* effecting your ability to produce products at a consistent quality level. This exercise is called process mapping. The Pareto principle of variable ranking and the well known "80/20 Rule" are techniques much in evidence in this effort. The result is a process map, an example of which is shown courtesy of the New Castle Refractories Company (Fig. 2).

The SPC team has mapped the key variables in this process by using a technique of methodically analyzing the process and then sorting it into: key control areas, key control points, and key control elements.

The key control elements contain the variables for which standards will be developed and statistical control charts may be used to monitor compliance.

It is important to note, incidentally, that right from the first step, communication to the users of this system is begun. It is also important to note that communication *from* the users must also begin.

An arrow designating user input is not shown in an attempt to avoid a confusion of arrows. However, the absence of these graphics, depicting communication from users, should not be mistaken as a lack of recognition of its importance. You will note that these communication feedback loops are evident in all steps of the process. Without total user involvement in the development, as well as the implementation and ultimate use of this system, it will not be effective.

Step II—Develop/Improve Standards

Once key variables have been identified and documented by the process map, we are ready to develop standards. This is accomplished by employing a rather simple but complete form which asks a number of who, what, where, when and how questions regarding each process element (Fig. 3).

Step III—Communicate to Users

All of the work which has gone into Steps I and II would be for naught unless we can effectively communicate the standards, methods and instructions developed to the ultimate users—the supervisory and hourly employees who do the job every day on the shop floor. This is the point where we in management often fail and fail miserably. We all too often have good information but keep it hidden in standard operating procedure manuals which no one looks at, much less communicates, to the hourly worker.

An effective way to avoid the pitfall of hiding valuable information away is to instead publish it in an easy to use and carry booklet form which is then

always accessible to each and every employee to use as a day-to-day guide and reminder of standards of performance and other management expectancies.

Step IV—Train in Statistical Methods

Somewhere between the very start of the program and the issuance of standards booklets, it is appropriate and necessary to train the users of this system in statistical methods. It is, after all, the use of statistical methods that enables us to monitor the process and bring it under better control. The users must have at least a basic understanding of statistical methods. Some may require more indepth knowledge.

Step V—Statistically Monitor the Process

Having accomplished Steps I-IV, we are now ready to implement the system and begin to statistically monitor the process. Statistical control charts take many forms. One example is given (Fig. 4). Note again at this point that the statistical control chart's primary function is to feedback information to the users on how well the process is performing to standard.

Statistical control charts are not designed to provide decoration for the walls of the QC manager's office never to be seen by the hourly operator. The chart should be located in such a manner as to provide information feedback to those who can take immediate action to correct out-of-compliance conditions or trends.

Over time, this feedback of information will provide data which can be diagnosed and used for problem solving.

Step VI—Diagnosis and Problem Solving

Diagnosis of statistical data and utilization of proven problem solving techniques provides the beginning of permanent corrections of undesirable conditions and reduction of process variables.

Note again the feedback loop of utilizing these corrections to re-define key variables and improve standards (Fig. 1).

Through this process,—*well-managed*—tighter and tighter control and consistent quality improvement is achieved.

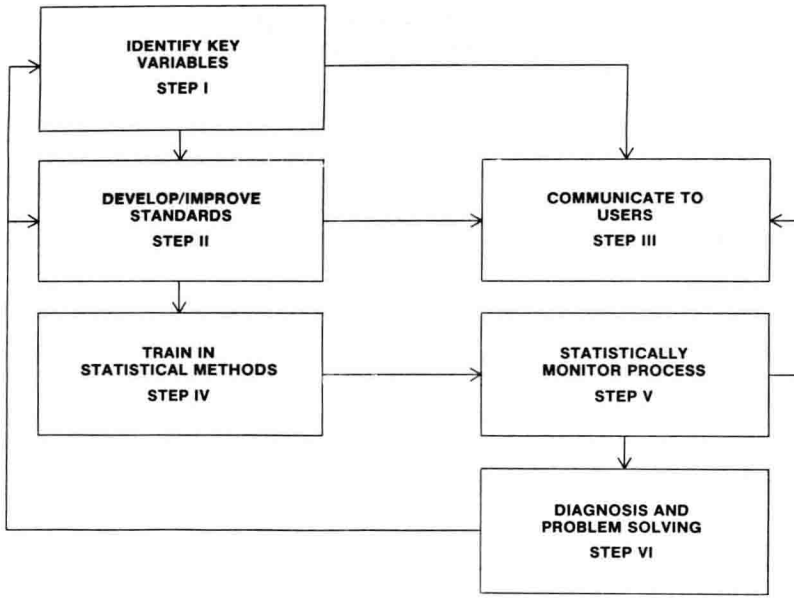

Fig. 1. Synergistic process control.

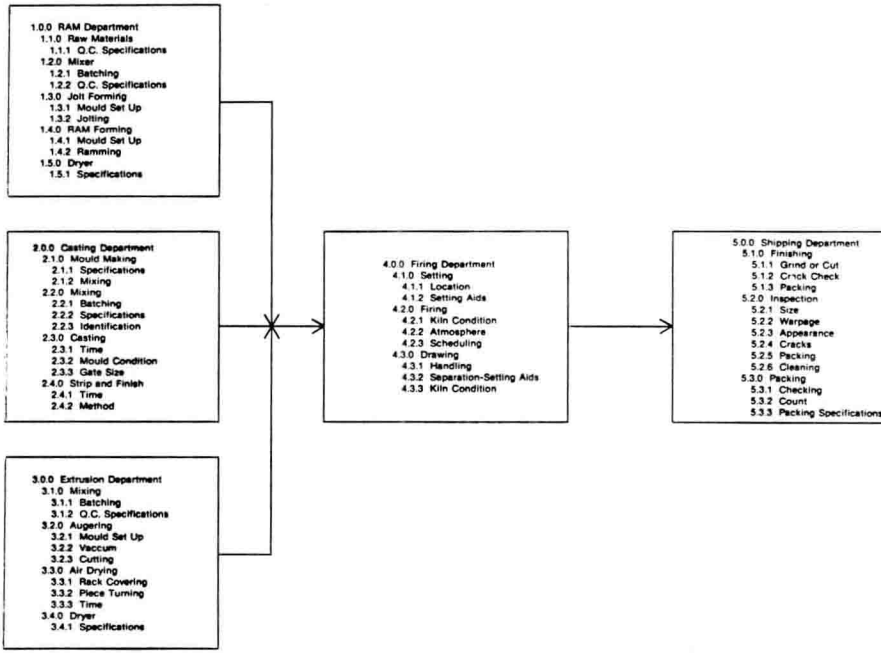

Fig. 2. New Castle Refractories Co. process map.

SYNERGISTIC PROCESS CONTROL

Standard Procedures
Process Control

Plant _____
Dept _____

File No _____
Date Orig Issue _____
Revision No _____
Date Revised _____

Control Area	Control Point	Control Element	No

Control Task | **Responsible for Control**

Process Standard

Reason for Control

Measurement	**Routine Reporting of Data**	**Control Chart**	Yes	No
Tools-Equipment -	Form/Form No. -			
Frequency -		Type -		
By -	By -	By -		

Operating Procedure

Corrective Action

Disposition of Non-Compliant Product

Review Procedure

Developed By:

_____ _____
SPC Coordinator

Approved:

_____ _____ _____
Department Superintendent/Manager | Manager - Quality Control | General Superintendent Plant Manager

Fig. 3. Form for process control.