

**CONTINUOUS IMPROVEMENTS IN ATOMIZED POWDERS
THROUGH TEAM-ORIENTED PROBLEM SOLVING**

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Abstract

A "Total Quality System" approach at Hoeganaes allows all employees to participate in achieving the organization's quality goals. The various phases of the quality system from product control, SPC, process documentation, team development, and team-oriented process development are reviewed.

One example of team-oriented process improvement will be demonstrated using the improvements achieved in the microcleanliness of atomized products.

Introduction

A Total Quality System is the basis for an organization-wide strategy for continuous improvement. All of the organization's resources are effectively used to achieve the objectives necessary for customer satisfaction. Methods for enhancing team building techniques to achieve continuous quality improvement of systems and processes are integrated into all operations. Statistical methods are used throughout to understand variability and process capability. A quality improvement timeline is shown in Figure 1.

As can be seen from the timeline, early quality systems were inspection-oriented. The basic premise was that a group of people were responsible to measure attributes, compare these attributes with specifications, decide whether the values were within specification and, if not, then sort the product. The primary flaw in the inspection oriented system was the issue of timely information feedback from the inspection department to the manufacturing department. This information loop resulted in excessive time lag, and the data provided did not assist the manufacturing group in improving the process. It was not easy for the manufacturing group to use the data in preventing recurrence

(1).

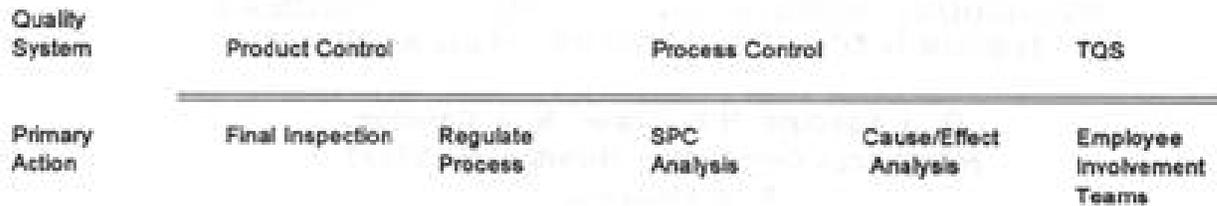


Figure 1: Quality Improvement Timeline

The inspection oriented system eventually evolved into process control. In a process control system, if the manufacturing operator responsible for a particular product is given the task of self-inspection, feedback is instantaneous and action can be taken immediately.

With process control firmly in place, process improvement is the next step. Specific improvement goals or targets are determined. A successful way to reach these improvement objectives is to form teams (2). At Hoeganaes, this improvement has been accomplished through Employee Involvement Teams (E.I.T.). The commitment to implementing teams came from executive management. E.I. Teams are therefore as much a part of management philosophy as a problem solving technique. A solid understanding of the principles of quality improvement by senior management laid the groundwork for a company-wide program. E.I. Teams are based on the concept that people take more interest and pride in their jobs when they are allowed to influence decisions made about their work. Increased interest and pride directly result in improved quality, which in turn makes the organization more effective. Another major tenet of E.I. Teams is the concept that employees are best equipped to recognize problems in their work areas, and to suggest the most appropriate avenues for improvement (3).

Employee Training

As with all new programs, the first step is training the employees. When a corporate-wide program is instituted, each employee must be trained. One problem with mass training programs is the lack of an opportunity for everyone to participate in a project to utilize the training immediately. An extended period of time may pass after the training is completed before an employee is involved in a quality improvement project. However, in the Hoeganaes program, E.I. Teams select a project during team training and as a result, momentum for the program continues after the training has been completed.

E.I. Teams use participative problem solving in all their

activities. This approach utilizes the collective knowledge of the group, rather than relying on one or two individuals to identify problems and find solutions. The knowledge of the group, combined with E.I. Team problem-solving methods and statistical techniques, leads to the most effective solutions possible. Six to twelve people are on each team. Each team goes through a 10 session training program as a team. The training is broken down into three basic parts:

- Problem solving methods.
- Quality control techniques.
- Group participation.

The training is designed to improve quality as well as to develop individual skills in communication, leadership, technical competence, and team spirit.

The first training session is in brainstorming. Brainstorming is a widely recognized technique used to encourage creative thinking. Teams can take advantage of brainstorming to generate a large number of new and creative ideas. Listed are the guidelines for brainstorming.

1. Generate a large number of ideas.
2. Free-wheeling is encouraged.
3. Don't criticize.
4. Encourage everyone to participate.
5. Record all the ideas.
6. Let ideas incubate.
7. Select an appropriate meeting place.

After the brainstorming session, the team is ready to go into problem-solving, which is broken into six steps:

1. Identify the problem - brainstorming
2. Define the problem
3. Investigate the problem
4. Analyze the problem
5. Solve the problem
6. Confirm the results

The next series of training sessions are devoted to cause and effect diagrams, which aid in defining the problem. Cause and effect diagrams help organize causes of problems so that the team can systematically investigate them. A cause and effect diagram, or fishbone diagram, helps categorize the major causes of the problems. One of the more common methods uses the "4 M's": Methods, Materials, Machines, and Manpower. Other categories can be added to these. The important thing is to determine what major

causes truly relate to the "effect" you are working on. A basic cause and effect diagram is shown in Figure 2.

As each possible cause of the effect is suggested, it is added to the cause-and-effect diagram as a minor branch. This is done to show the relationship between causes. The process continues until all possible causes are included and all inter-relationships are shown. Figure 3 displays a more detailed fishbone with "large" and "small" bones.

It is important to obtain as much information as possible and to continue to challenge the team for all possible causes. One way of doing this is to have the leader of the team use the five Ws and one H in trying to think of ideas. Asking who, what, when, where, why and how really helps bring out ideas. Subsequent phases of problem solving include investigating and analyzing the problem. Investigating the problem, the team will collect data and facts. Analyzing the problem involves finding all the possible causes and deciding which are the major ones.

Checksheets are tools for organizing and collecting facts and data. They assist in collecting data to help answer:

- What kind of problem?
- How many?
- How often?
- Where did the problem occur?
- Who is affected?

There are three main types of checksheets:

- Recording - used to collect measured or counted data.
- Checklist - used to make sure that a series of tasks is completed.
- Location - problem location checksheet.

Preparing the checksheet is essential for the next step: construction of a graph.

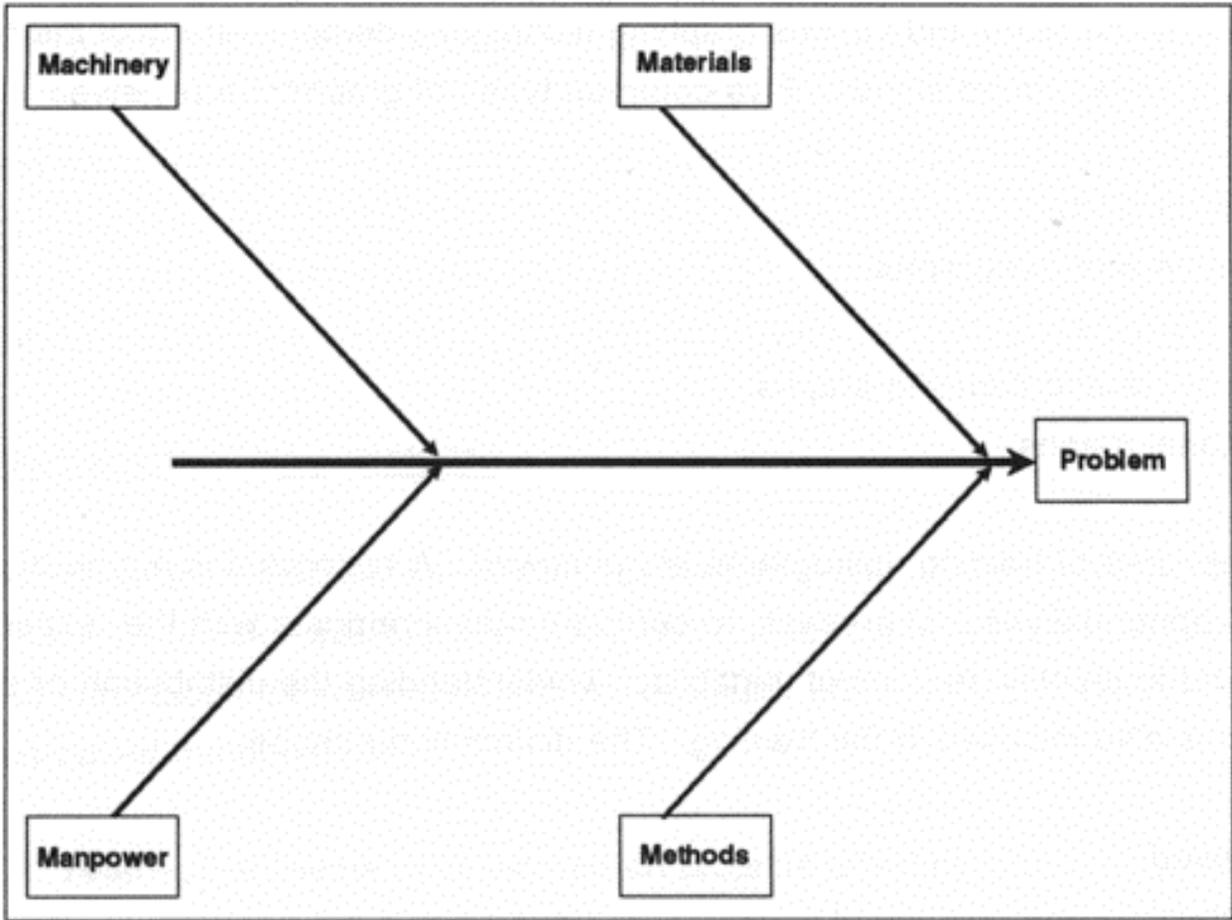


Figure 2: Cause and Effect Diagram

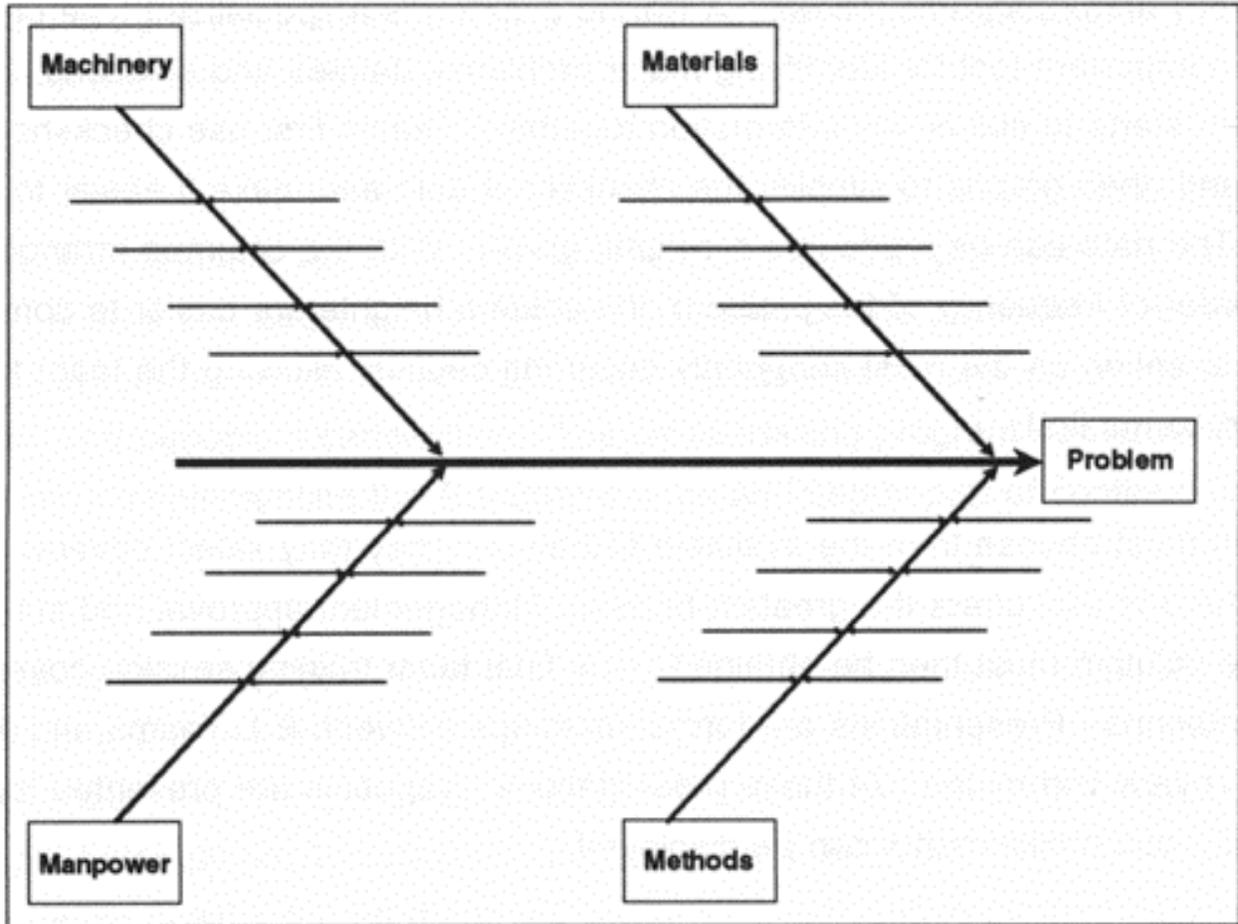


Figure 3: Cause and Effect Diagram with Minor Branches

Graphs and histograms assist in analyzing the problem and deciding which causes are major. Teams are trained in construction of graphs and histograms. Large amounts of data have been collected by the team and various graphing techniques demonstrate how the relationship between sets of data can be shown. Five common types of graphs are reviewed.

- Line graphs
- Column and bar graphs
- Area graphs
- Milestone and planning graphs
- Pictorial graphs

During the next step of training, histograms are reviewed. A histogram is a type of column graph to spot abnormalities in a process, to compare measurements with the "expected" distribution, and to identify sources of variability. Understanding the distribution or shape of the histogram is also included in the training. The distribution may be:

- Skewed
- Bimodal
- Bell-shaped
- Flat, dispersed

A discussion of Pareto diagrams follows. A Pareto diagram is a specialized type of column graph. It is an important tool for identifying major problems, causes and solutions. The Pareto diagram starts to pull all the information together. Teams first use checksheets to collect data, and then graphs to simplify the checksheet data and make it easier to understand. The data can be made into a column graph. With the columns arranged in descending order of frequency of the problem, the column heights are easier to compare. This focuses attention on the most commonly occurring causes, allowing the team to tackle the biggest problems first.

The team then must choose from the available solutions. They may select several, and recommend the one that offers the greatest benefit. Management approval and support to implement the solution must then be obtained. The final team training session covers making project presentations. Presentations are formal meetings between E.I. Teams and the management review committee. At these presentations, proposals are presented for approval and the Team's accomplishments can be displayed.

All the tools from the previous training sessions are commonly used in the formal presentation, including cause and effect and pareto diagrams, graphs, charts, and checksheets. Team members explain exactly how these tools helped in solving the problem.

The team summarizes their recommended solution, the cost of the proposed solution and the expected benefits. Confirmation of the results shows how data is being collected or will be collected to ensure the problem stays fixed.

The team training discussed here has been in place since 1988, and the program has expanded to 25 active teams throughout all facilities. Teams span the entire organization, with members coming from Manufacturing, Maintenance, Quality Control, Research and Development, Engineering, Purchasing, Finance, Sales and Marketing.

Team Development and Implementation

At the conclusion of team training the employees formed teams that in general, organized by work areas. The balance of this paper will describe the variety of ways these teams have contributed to continuous improvement, and the resultant effect on the microcleanliness of atomized iron-based metal powders.

Of the 25 E.I. Teams, five teams have worked on projects affecting atomized powder production. The team members include first-line operators, area supervisors, maintenance and clerical staff, as well as laboratory and office personnel. The involvement of team members whose primary responsibility lies outside the particular work area has lent depth and creativity to project selection and suggested solutions and recommendations. To date, 15 projects have been completed that have in one way or another contributed to quality improvement in the steel atomization area.

As processes were improved, the documentation was revised to include the changes. Areas ranging from raw materials selection, melt practice, and annealing procedures have been updated. To ensure that all personnel are well educated on the process improvements, a cross-training program was instituted, with specific guidelines for procedure review, operator qualifications, and periodic recertification. The cross-training program now extends throughout the corporation, complementing the E.I. program, as an integral part of continuous improvement.

The individual contributions of each of the 15 projects have culminated in significant benefits. One of the best examples of this is the improvement in microcleanliness of atomized powder forging grade materials. The progress made in microcleanliness since the inception of the team concept at Hoeganaes is detailed in the following discussion. The mechanical properties of near fully dense powder forged materials are strongly influenced by the composition, size distribution, and location of nonmetallic inclusions.

Microcleanliness Evaluation

Samples of powders intended for forging applications are blended with graphite and lubricant and repress powder forged under closely controlled laboratory conditions. After forging, the slugs are austenitized and quenched to ensure a hard, deformation resistant material for metallographic preparation.

The 25 mm diameter cylindrical forging slugs are sectioned longitudinally and mounted for metallographic sample preparation. All metallographic preparation is done using a Struers Abrapol automated grinder/polisher. Automated polishing is essential to provide the high quality scratch-free and stain-free surface required for automated inclusion assessment. Two cylindrical forging slugs are prepared from each powder sample, and three longitudinal sections are prepared for metallographic examination. An area of at least 120 mm² is examined on each section using an automated image analysis system giving a total

area covered of greater than 360 mm². Inclusions are sized according to their maximum Feret's diameter with the near neighbor concept applied. The results are presented in terms of three parameters, F₁, F₄ and F₆, which are defined as follows:

F₁ = the number of inclusions >30 μm per 100 mm²

F₄ = the number of inclusions ~> 100 μm per 100 mm²

F₆ = the number of inclusions ~> 150 μm per 100 mm².

A record is also kept of any inclusion greater than 75 μm . A Leitz TAS Plus image analyzer equipped with an automated scanning stage and auto-focus is used. The image analyzer consists of a high quality metallurgical microscope fitted with a video camera which displays the live images on a CRT screen. The video image is assessed in terms of its gray level characteristics, black and white being extremes on the available scale. An image modification technique is used to define the inclusions on the basis of the spacing of individually detected features. Using this technique, fragmented or diffuse inclusions are measured as individual particles without distorting the other particles within the field of view. This is made possible by feature-specific operations carried out under microprocessor control. This technique to evaluate microcleanliness has been used since 1985. It has been incorporated in ASTM standard test method B796 for nonmetallic inclusion level of powder forged (P/F) steel parts since 1988 (4).

Microcleanliness Improvement Results

The improvements in microcleanliness are illustrated for both a low alloy steel powder, ANCORSTEEL 4600V, and Ancorsteel 1000 P/F, a carbon steel powder.

Figures 4 to 6 display time periods plotted against inclusion levels for ANCORSTEEL 4600V. The bar graphs illustrate the +/- 3 sigma values for each time period. Period #1 is concurrent with inception of the E.I. program. Each period covers an equivalent amount of time or number of production lots. The data illustrates the improvement in cleanliness achieved across the time periods, and includes all inclusion types found in these materials. Figures 7 to 9 display F₁ F₄ and F₆ charts respectively for Ancorsteel 1000 P/F.

In both grades of powder, the cleanliness improvement shown is dramatic. The mean value as well as the variability has been reduced at least fourfold.

Summary

Successful quality programs recognize that all employees affected by a problem should be included in the decision making regarding the resolution. For training to be effectively implemented, a company must undergo a philosophy change to empower each employee. The success of a program is judged on how the employees are empowered to make change, and their ownership of the program. Finally, management must delegate responsibility for identification and resolution of problems to teams.

Acknowledgment

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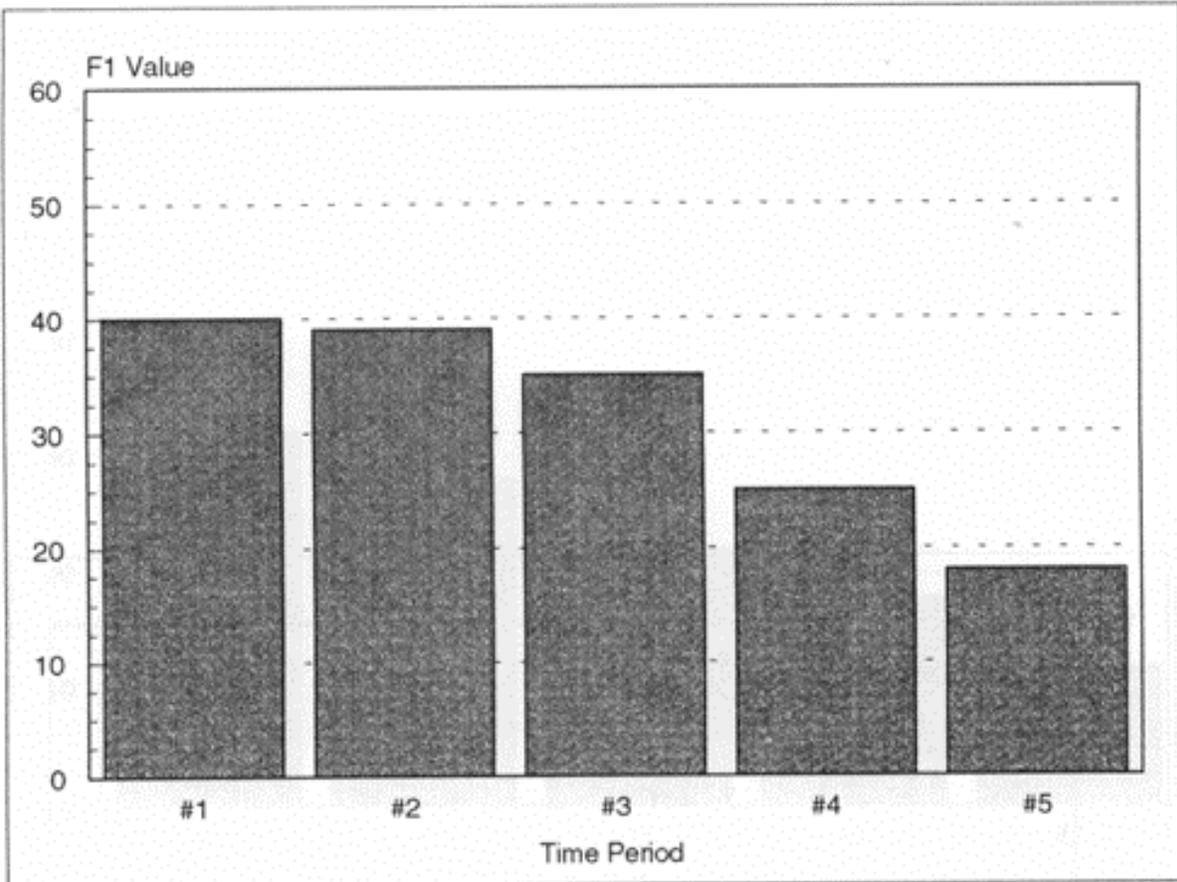


Figure 4: Reduction in Ancorsteel 4600V F_1 Inclusion Parameter with time

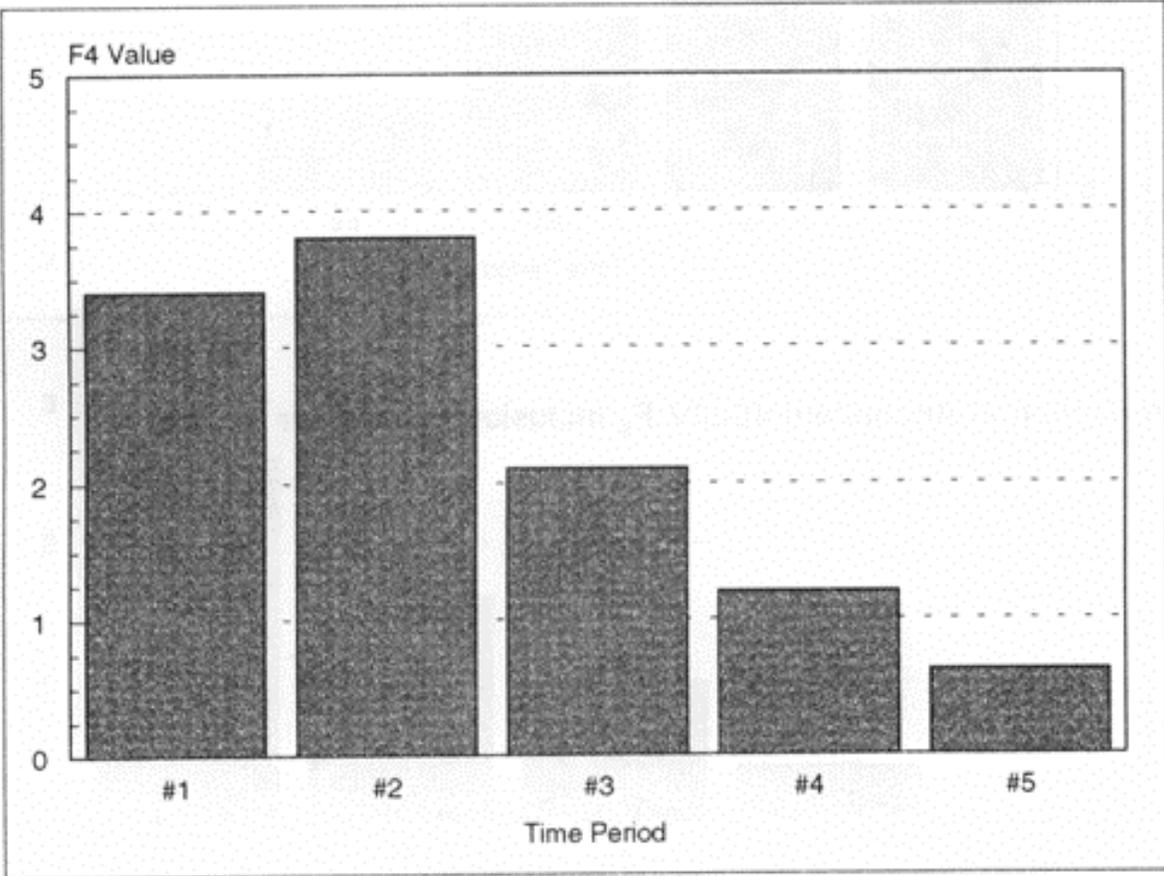


Figure 5: Reduction in Ancorsteel 4600V F_4 Inclusion Parameter with time

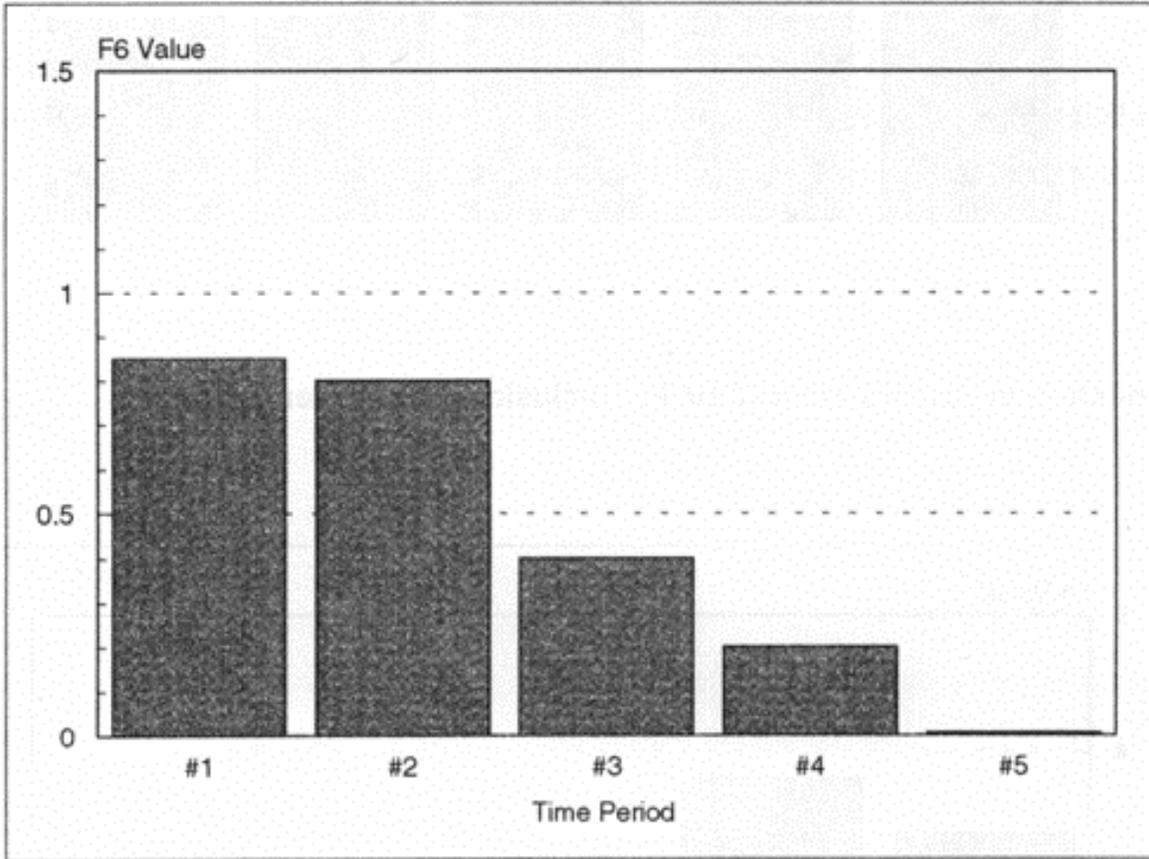


Figure 6: Reduction in Ancorsteel 4600V F_6 Inclusion Parameter with time

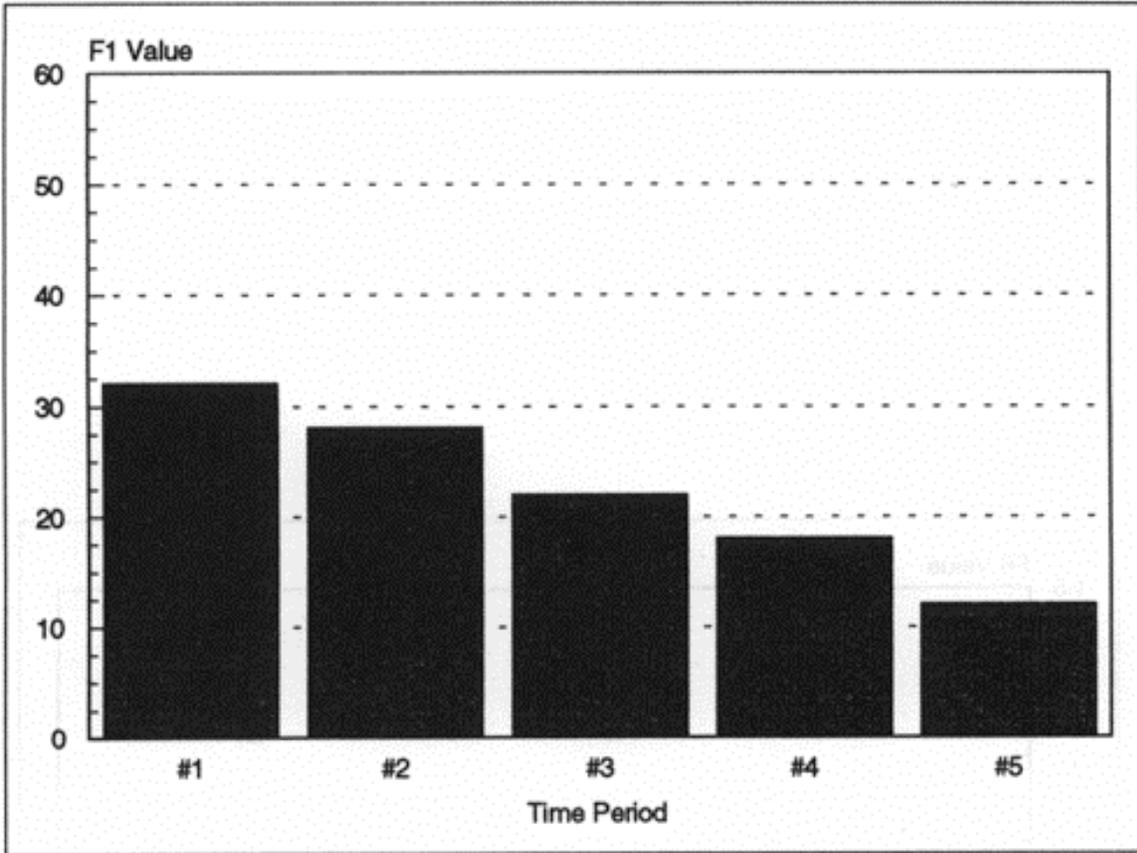


Figure 7: Reduction in Ancorsteel 1000 P/F F_1 Inclusion Parameter with time

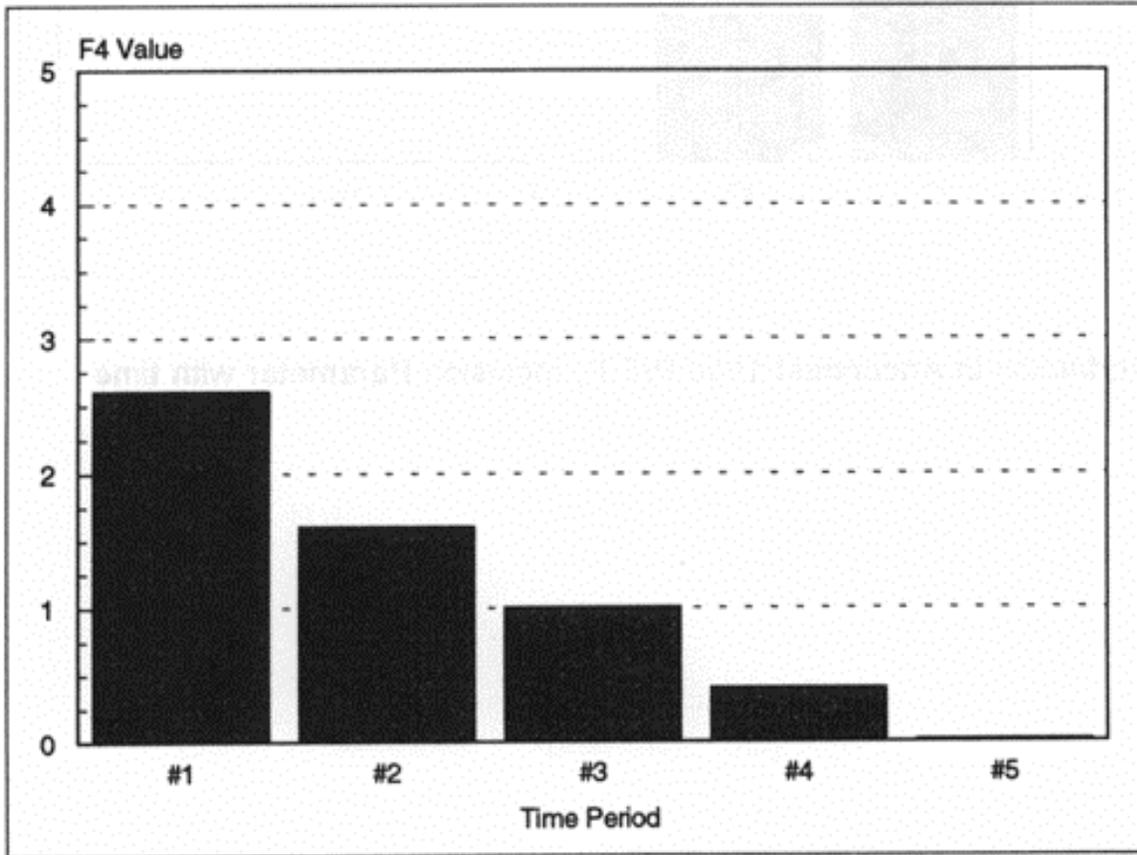


Figure 8: Reduction in Ancorsteel 1000 P/F F_4 Inclusion Parameter with time

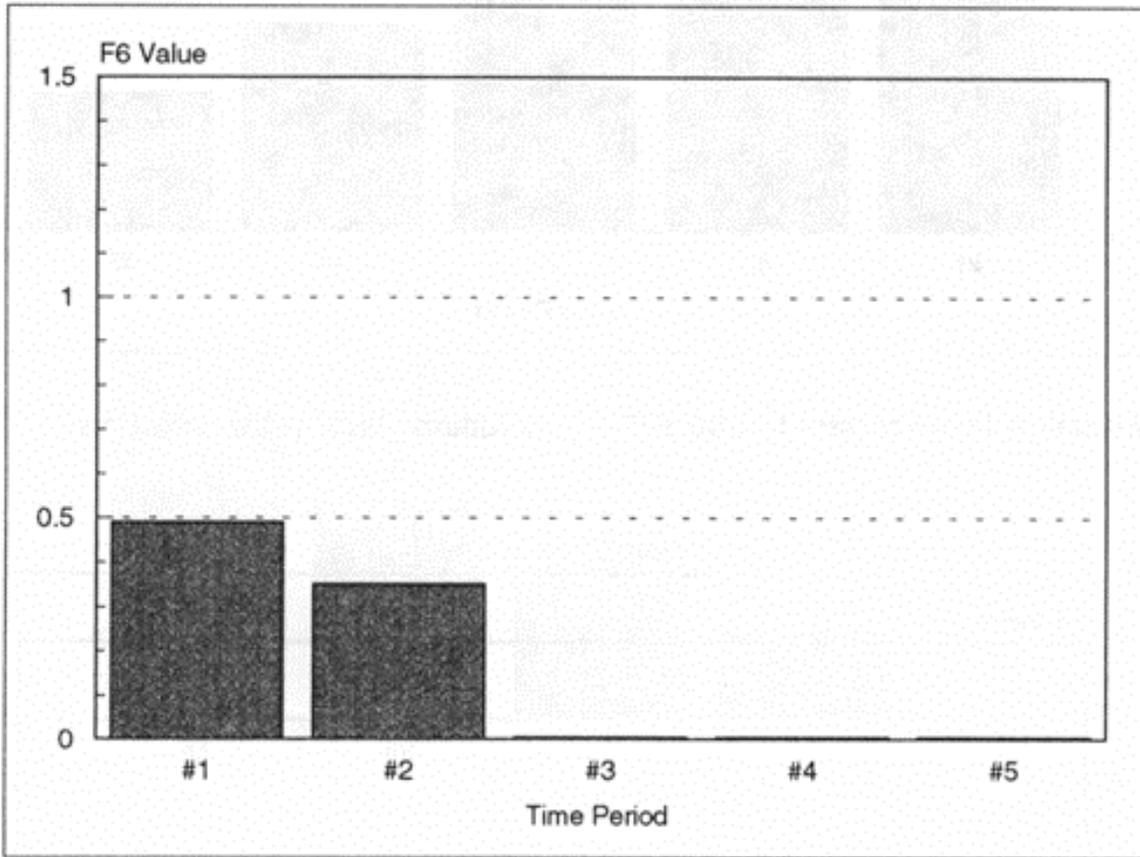


Figure 9: Reduction in Ancorsteel 1000 P/F F_6 Inclusion Parameter with time