STATISTICAL PROCESS CONTROL - A TOOL FOR PROFIT

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INTRODUCTION

SKW Trostberg is a producer of ferroalloys and additives for the steel, foundry, aluminum and chemical industries, with producing plants world-wide. This paper is intended to share the experience of SKW Alloys, Inc., a wholly owned United States subsidiary of SKW Trostberg, on the implementation of a Statistical Process Control System (SPC) and will describe the benefits realized at the two producing plants in the U.S. - Calvert City, Kentucky and Niagara Falls, New York. The program was formalized and began in January 1985 and the resulting improvement in 1985 will be compared to the year 1984 and earlier.

SKW Alloys made a commitment prior to 1985 to incorporate SPC as part of the overall quality control program. It became evident that American industry had fervently embraced the SPC concept, realizing that the strong competitive inroads achieved by the Japanese Auto industry were, among other things, clearly attributable to the successful use of SPC. Many suppliers to the American auto makers first adopted SPC out of necessity to remain qualified suppliers. After successful operational and financial performances became evident, many accepted SPC as a tool for profit. SKW senior management and quality/operations personnel had attended seminars and evaluated input from SPC consultants during 1983 and 1984. After careful consideration, SKW decided that the Ford Motor Co. had the most comprehensive Quality Systems Standards in SPC that best suited SKW and, therefore, modeled its program after the Ford program. After conforming with Ford's Q-1 and Q-101 requirements, it was felt that the program could readily be adapted to the other customer's requirements for vendor qualification. An SPC/QC Committee was formed with representation from key levels of management - Senior Executives, Purchasing, Sales/Marketing, Plant Operations, Customer Service and Quality Managers. This committee designed the program, set goals and would meet regularly to monitor progress and overcome obstacles. SPC had top management priority and commitment. The sequence of implementation is shown in Figure 1.

DESIGNING THE SPC SYSTEM

The system was designed to achieve the following fundamental goals of SPC that would relate to ferroalloy production:

1. Choose suppliers of raw materials that can show evidence of quality in their processes and products. The same quality surveys imposed on SKW as a supplier would in turn be applied to SKW's suppliers. The long-term goal on raw material purchasing was to lower the number of suppliers, lower inventories and reduce the necessity of testing the incoming products prior to production.

2. Monitor variables within the ferroalloy production process that can affect quality and efficiency. Analyze the process capability on final products and then embark upon a program of constant improvement. Build in "avoidance" of out of specification alloy as opposed to "detection". The committee felt that it was less costly to produce "on-grade" alloy than to cull-out marginal material for reprocessing.

3. Install the necessary charting and records that would provide statistical evidence of finished product quality in chemistry and sizing. This evidence could be verified by written detailed procedures and documentation/records retention.

The manufacturing process was defined in a step-by-step basis to provide the framework for the selection of key characteristics to chart, inspect, test, and audit for compliance. This was accomplished by a survey to all process supervisors and employees at both plants. The survey asked each employee to state, in their opinion, all process realities that affected quality. (Figure 2). The survey first revealed that the total ferroalloy production process consisted of six steps. Also, the survey was summarized into a process flow sheet. (Figure 3).

It became necessary to revise the SKW Quality Control Manual to incorporate SPC principles, formalize procedures and instructions in detail, and prepare a Standard Operating Practices (S.O.P.) Manual. Certain aspects of SPC, such as calibration records, more detailed procedures, and test variations necessitated the revision of the SKW Laboratory Manual. The three manuals were written with linking references for successful usage.

TRAINING IN THE USE OF SPC PROCEDURES

Training would be the key element to the success of the program. Top management needed to know the potential advantages and objectives of SPC. This was accomplished by a seminar that presented the concepts of SPC after historical outlines on the successes and failures rates when implementation programs of other industries were presented. Process control possibilities were demonstrated, utilizing statistical concepts. Management needed to commit to initial costs and the time demands of staff during implementation and program maintenance. They accepted that quality could be improved through consistency and the removal of process variables within the process by the use of statistics.

SPC Managers used consulting services and were trained at seminars in the most comprehensive manner. They would then monitor the entire system and provide "in-house" seminars for supervisors and employees. SPC Managers would interpret control chart results.

Operation Managers were trained at local universities on a less technical basis - the concepts of SPC where necessary as well as the working knowledge of control charts in order to maintain them and make sure of the control possibilities of the charts. Every department manager would write the procedures and action plans for out-of-control situations in their work areas for the production workers.

Section supervisors were trained "in-house" at seminars in three steps:

1. The Need for Statistical Process Control.
2. The Use of Control Charts, $\overline{X}$ & R on Key Characteristics.
3. Process Improvements.

Production workers received training by department head and SPC Managers. Meetings were held with Union leaders to gain their support and to point out the mutual benefits of a successful SPC program.

ESTABLISH FURNACE PERFORMANCE VARIATIONS

Historical chemistry variations on samples taken at the furnaces on the alloy products were evaluated to provide a starting point for improvement. The aim was to reduce variation by charting and procedural changes with regard to adjustment on mix batches. Any improvement on consistency would have a very beneficial effect on the end product quality. This is the very essence of SPC: Avoidance of off-grade rather than detection on finished product. Prior to implementing SPC, adjustments were made when it was realized that chemistry drift had occurred. Supervisors arriving for work could now look at a control chart and see graphically any drift in analyses quickly and rely less on verbal assessments from the departing supervisor. With control charts, corrections to the mix were delayed to at least three to five results before a mix change would be made. This in itself removed variation as the process for change was formalized and did not occur by intuition or "gut-feeling" that varied from operator to operator. Variation on the following examples relate to % of specification. Example: 50% FeSi - Silicon would have a specification range of 4% and variation would be expressed as 100% if that variation were 4% at the furnace. An example is shown for an alloy at each plant over a three year period.

Plant	Alloy	Element	1983	1984	1985
Niagara	75% FeSi	Si	148%	125%	93%
Niagara	75% FeSi	Al	120%	105%	88%
Niagara	75% FeSi	Ca	60%	50%	43%
Niagara	75% FeSi	Cr	150%	120%	66%
Calvert	50% FeSi	Si	125%	110%	90%
Calvert	50% FeSi	Al	50%	45%	40%
Calvert	50% FeSi	Ca	7%	5%	4%
Calvert	50% FeSi	Cr	45%	40%	38%

The improvements demonstrated in 1985 is evidence of the removal of some special causes, or by minimizing the effect of the causes.

PROCEDURES, INSTRUCTIONS AND ACTION PLANS

All tasks and service functions of the process were written by each department head. Those functions that had an effect on quality were separated and listed in such a manner as to determine what could possibly go wrong, what appropriate action to take in that case, and the supervisor to contact for corrective action, if necessary. After this study was completed, the Quality Managers wrote detailed procedures to complete the Standard Operating Practices (S.O.P.) Manual. Each department has a code and a cross-reference. All forms used in this manual are numbered and have procedures for completion. An audit system was designed to ensure compliance with those procedures in the S.O.P. Manual. The main purpose of this S.O.P. Manual is to provide the necessary elements of the complete process to allow for lot traceability, create quality awareness among employees, and to provide the basis for overall process improvement.

A continuing review of the process could now be made by a process improvement committee. The objective is to remove variation in the process now that the process overall was clearly defined and ready for continued improvement. A sense of common purpose was achieved that would reduce "finger-pointing" when out-of-control conditions occurred. Process capability studies could be made, evaluated by facts and numbers and then be improved by a team approach.

ADVANCED QUALITY-NEW PRODUCT PLANNING

The SKW system of SPC was designed to provide preventive measures as opposed to detection of "out-of-control" situations and off-grade materials. Training, data accumulation/analysis, and statistics would provide a more disciplined approach to such situations. This system could be demonstrated to the customer and would hopefully satisfy their quality expectations. It is recognized that management is accountable for most causes of variability. These causes have to be identified and addressed in all management areas: purchasing, raw material management, quality personnel, production (furnacing), processing, metallurgical engineering and sales/marketing departments.

Advanced Quality Planning in ferroalloy production could be used on developing new products desired by the customer, new products for competitive reasons, or improvement of existing products by new production techniques. To utilize the principles of "prevention ", the procedure for new product planning sued could be an adaptation of Ford's process FMEA (Failure Mode and Effects Analysis). The FMEA process is an analytical technique which identifies product related failure modes, assesses the potential customer effects of the failures, identifies the potential manufacturing process causes and identifies significant process variables to focus controls for prevention of the failure condition. The end result of this exercise is to develop a Risk Priority Number (RPN) to establish a priority for corrective action procedures. The main elements of a new process are listed and summarized on the basis of what can possibly go wrong in the judgment and experience of the staff involved in planning the production of the new product. Occurrence, detection and severity numbers are assigned on the basis of likelihood of failure with a ranking system; remote, low, moderate, high and very high likelihood. The RPN is calculated by multiplying the numbers assigned to occurrence, detection and severity. The production planning staff members establish the numbers by concensus. An example is shown on potential failure modes as follows:

PROCESS FUNCTION	OCCURRENCE	DETECTION	SEVERITY	RPN (Risk Priority No.)
A	3	5	10	150
B	5	2	3	30
C	3	3	3	27
D	1	1	8	8
E	3	2	4	24
F	8	7	8	448*
G	4	5	4	80

The planning staff would apply special attention and corrective action to reduce ranking by beginning with F, then A, G and so on. Other considerations in this analysis would be current controls that are in effect. Once a RPN number is established, consideration is given to recommended actions and status, actions taken, and assigning the responsible activity personnel. At this point, a new calculation would be made using the original criteria on process Function F, reducing the RPN to 96* by: occurrence as 4, detection as 3,and severity as 8.

APPLICATION

In 1985, SKW Alloys, Inc. acquired the Foote Mineral Co. proprietary nodulizers and inoculant alloys product lines. Plans to produce these new alloys at the Calvert City, Kentucky plant gave SKW a great opportunity to use the process FMEA approach months before the actual production of the new alloys. Process FMEAs were prepared for the production of each alloy. The Foundry Group personnel also prepared FMEAs for the performance trials of the new alloys at the customer foundry. Early in 1986, the Calvert City plant has started to produce the new alloys in trials of only a few of the total line. An example of a process FMEA for the production of Inoculoy 63 is shown in Figure 4, a foundry application FMEA is shown in Figure 5, and a foundry application test form is shown in Figure 6.

OPERATIONAL PERFORMANCE IN 1985 AS COMPARED TO 1984

In spite of 4% inflation in 1985 plus a wage increase for salaried personnel, an improvement in production efficiencies in 1985 actually lowered the cost of production on most alloys. An example is shown for two alloys: 50% FeSi and MgFeSi. For purposes of this analysis, production costs on each alloy in 1984 are expressed as 100.

ALLOY	1984	1985
50% Ferrosilicon	100	95.7
Mg Ferrosilicon	100	95.8

The improvement of production costs shown occurred during the first year of using Statistical Process Control. Granted, there are many factors that enter into the equation of product costs; increased production, operation time of the furnaces, and so on. Many can question if the improved performance relates to the use of S.P.C. alone. However, employee awareness, attention to detail, and improved training all all outcroppings of S.P.C. When one looks at capability improvement, purpose, and effort, facts such as those stated above cannot be argued.

CONCLUSION

Placed in proper perspective, S.P.C. can be a very useful tool to improve quality and productivity. As stated earlier, the Japanese had in thirty years implemented, refined and proved that S.P.C. can achieve those ends. American industry does not have the time to "catch-up" if it is to survive in world competition. It is safe to assume that the wheel has been invented and our industry is at a distinct advantage with a logical and workable program of proven S.P.C. principles. Total commitment and consistency of purpose must be accepted by all employees if S.P.C. in a quality control system will work. Process Control and Quality Control overlap and are interchangeable. The common denominator on each is the use of statistics and detailed procedures. Training will provide the direction to know where we are going, and how to get there. Teamwork and cooperation are essential for common purpose. In a world of increased competitive pressures in producing a product there is one reality -- make it "better" the first time and make it at a lower cost.

We must use Statistical Process Control - a tool for profit!

FIGURE 1

SPC IMPLEMENTATION MODEL

PERSONNEL/DEPARTMENT	FUNCTION	PROJECTED COMPLETION DATE
Senior Management	Attend SPC Seminar	1984
SPC Managers	Attend Seminars - become qualified on all aspects of SPC to be used "in-house". 1. Revised the Q.C. Manual 2. Revise the Laboratory Manual 3. Prepare a Standard Operating Manual	December 1984
Plant Operating Department Heads	Attend SPC Seminars - gain a working knowledge of Statistical Control Charts.	December 1984
Operating Foremen	Learn SPC Concepts and Awareness Use and maintain Control Charts.	December 1984
Production Personnel	Use and maintain Control Charts. Follow written procedures.	June 1985
Sales/Marketing	Apply for "Qualified Vendor Status"	1985 and beyond
SPC Managers	Compile and submit SPC data to Customers. Monitor progress on process capability/ performance.	February 1985
Purchasing	Survey Raw Materials Suppliers (Figure 4) Select control characteristics with SPC Managers.	"On-going"
SPC/QC Committee	Monitor progress on all of the above.	"On-going"

FIGURE 2

SURVEY OF THE FERRO ALLOY PRODUCTION PROCESS

PROCESS STEP	CHARACTERISTICS AFFECTING QUALITY	
1 RAW MATERIALS	Chemistry - Adherence to specifications - consistency Sizing - Correct size, elimination of excessive fines Moisture Content Contamination - Supplier, cross-contamination storage	
2 FEED-MIX SYSTEM (Batch preparation)	Bin stocking Weights - Accuracy Segregation Mix Calculation Accuracy Mechanical Failure	Cross-contamination on Common Bins Spillage Proper Training - procedures
3 FURNACING	Operator Error Electrode Positioning Slipping rates on electrodes Stoking for furnace Load balance (electrical)	Use of remelt material Material adjustment-top of furnace Ladle additions Stirring practice Tapping procedure
4 CASTINGS	Cast Thickness Bed Castings/Fines Casting Temperature Slag Formation/Separation Contamination	Segregation of casts Pouring practice Re-ladling
5 CRUSHING-SIZING	Cast Thickness Condition of Equipment (e.g. screens) Proper Equipment Contamination/Cleanliness Bin Maintenance (Proper separation - dry)	
6 STORAGE PACKAGING SHIPMENT	Dry Storage Accurate Weights Proper Labeling Contamination Transportation	Container dimensions Appearance Handling - degradation Chemistry Inspection Size Inspection

SKW Alloys Process Control

Figure 3

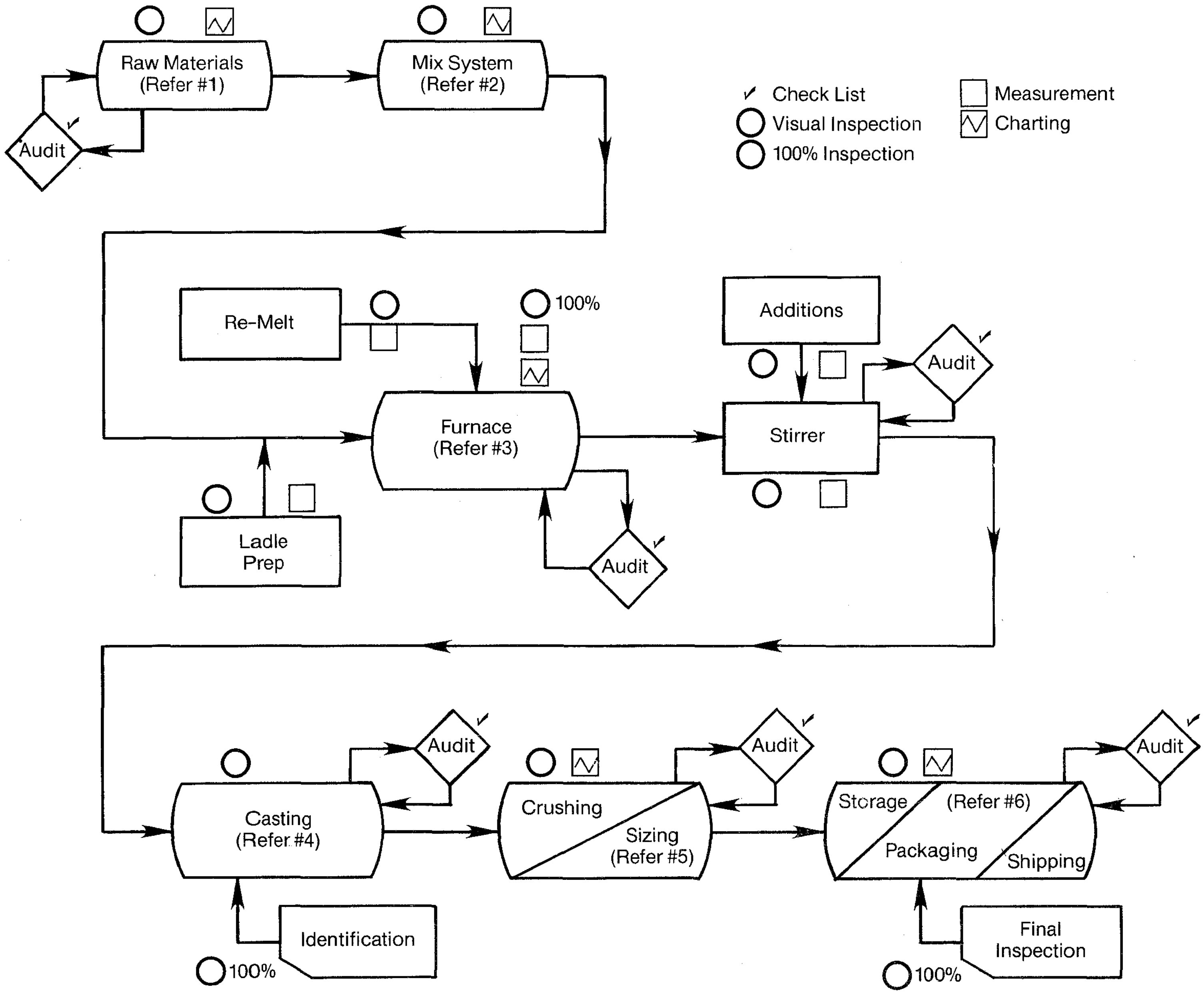

FIGURE 4

THE INTERNATIONAL METALLURGICAL GROUP OF SKW:

SKW TROSTBERG SKW ALLOYS SKW CANADA MUREX LIMITED ANGLO BLACKWELLS FLG

PROCESS FMEA

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PROCESS RESPONSIBILITY Calvert City, Ky.

PROCESS Production of Inoculoy 63

SCHEDULED PRODUCTION RELEASE March 1986

PROJECT PERSONNEL A.Harrington, K.Palmer, J.Jones, J. Wade

PROJECT LEADER A.Harrington

FMEA DATE 2/6/86

REV

					EXISTING CONDITIONS						RESULTING					
PRODUCT/ PROCESS	PROCESS FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL EFFECTS OF FAILURE	POTENTIAL CAUSE(S) OF FAILURE	CURRENT CONTROLS	OCCURENCE	SEVERITY	DETECTION	(RPN)	RECOMMENDED ACTION(S)	ACTIONS TAKEN	OCCURRENCE	SEVERITY	DETECTION	(RPN)	RESPONSIBILITY
Furnace Charge	Align Constitutents of final product	Incorrect Blend														
Furnacing	Conversion of raw materials to base chemistry	Incorrect final chemistry														
Tapping	Transfer of metal for processing	Contamination Chilled Metal														
Stirring Station	Adjustments to final chemistry	Incorrect Chemistry Segregation														
Casting	Form final product to cast	Incorrect size Contamination														
Crushing-Sizing	Size final product	Incorrect size														
Packaging-Shipment	Final preparation for Customer Shipment	Incorrect Packaging Incorrect Sizing Incorrect Product														

THE INTERNATIONAL METALLURGICAL GROUP OF SKW:

SKW TROSTBERG · SKW ALLOYS · SKW CANADA · MUREX LIMITED · ANGLO BLACKWELLS · FLG

FIGURE 5

PROCESS FMEA

PROCESS RESPONSIBILITY Foundry Engineer PROCESS Inoculoy 63 PROJECT PERSONNEL J.Schultz

SCHEDULED PROD.RELEASE PROJECT LEADER J.Schultz FMEA DATE 12/85 REV

PRODUCT/ PROCESS	PROCESS FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL EFFECTS OF FAILURE	POTENTIAL CAUSES OF FAILURE	EXISTING CONDITIONS					RECOMMENDED ACTIONS	RESULTING					RESPONSIBILITY
					CURRENT CONTROLS	occurrence	severity	detection	(RPN)			occurrence	severity	detection	(RPN)	
Inoculoy 63 Foundry Trial	Proprietary Inoculant Used in Gray and Ductile Iron	Incorrect Chemistry														
		Incorrect Size														
		Wet Alloy														
		Contaminated Material														
		Incorrect Addition														
		Incorrect Application														
		Incorrect Base Iron Chemistry														
		Inoculant Fade														

SKW

FOUNDRY QUALIFICATION
TEST FORM

Date: Page___of___
Prepared by:

SCOPE: To provide test information/evaluation of performance in foundries on new alloys or qualification of existing alloys.

ALLOY TESTED: SIZE:

ALLOY ANALYSIS:

Si	Mg	Al	Ca	Ce	Ba	Sr	La	Nd	Ti	Cr	B	Mn	P	S	C

FOUNDRY (Location): ____________________

FOUNDRY PERSONNEL PRESENT: ____________________

TEST RESULTS / FINAL CHEMISTRY

HEAT No.	Pouring Temp.	Metal Wt.	Lbs. Alloy Added	Nodul-arity	Chill at 1/32"	% C	% Si	% S	% Mg	% Mg Recy.

COMMENTS/OBSERVATIONS:

____

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____

____

REVISION NO: ________
REVISION DATE: ________
FORM NO.: SOP-14

COPIES TO: ________