THE PRACTICAL USE OF STATISTICAL PROCESS CONTROL AND COMPUTER MONITORED EQUIPMENT IN THE SHOT PEENING PROCESS.

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ABSTRACT

This paper describes the application of Statistical Process Control (SPC) and Computer Controlled / Monitored Equipment to the Shot Peening Process. By using SPC to prove the capability and control of the shot peening equipment, as well as the individual process set-ups, combined with a PC to monitor all of the Key Process Parameters, the need for regular Almen strip runs during production can be eliminated. With this process, Almen intensity test runs to verify the equipment itself are performed based on accumulated machine hours and not part lot sizes. This newly approved method has opened new doors in the shot peening industry making it possible to increase productivity and reduce costs.

KEYWORDS

Shot Peening, Computer Controlled Shot Peening, Statistical Process Control (SPC), Machine Verification, Key Process Parameters, Key Characteristics, Method 3 Shot Peening

INTRODUCTION

The Aerospace Industry has been cursed for decades with short production runs of components to be shot peened, couple this to the current trend of Just In Time production (JIT) and we have an environment of Almen strip set-up after set-up to meet the requirements of most aerospace shot peening specifications. The need for a more efficient method of processing parts is required to meet the increasing demands of this industry. Reduced costs and cycle times combined with improved quality and customer satisfaction are a must to compete in today's world market. A new approach must be taken to meet these needs where quality must be built in, and the process controlled, thus eliminating costly inspection and lengthy prove-out steps.

Key Characteristics

The first step in controlling the shot peen process is defining what the Key Characteristics are and what parameters have the greatest impact on these Key Characteristics. Key Characteristics are the purpose and or end results of the process. Different shot peening applications and equipment may have different Key Characteristics and Key Process Parameters (KPP's). In the manufacturing of Aircraft Landing Gear the main purpose of shot peening is to improve the resistance to fatigue and stress corrosion cracking. The two characteristics used to measure the effect of shot peening are Intensity and Coverage. These are defined as Key Characteristics in the Menasco Aerospace Shot Peen Specification MMC-137.

Identification Of Key Process Parameters

When the Key Characteristics have been defined, the process parameters that have a significant impact on Intensity and Coverage must be determined. The identification of these parameters can be obtained from various sources, for example; certain shot peen specifications (AMS 2432) cover this issue; controlled experiments can be conducted; and the in-house knowledge and experience of the shot peen process and applicable equipment. These sources are used together to identify the general and specific KPP's for the process. The following six (6) general KPP's have been identified and documented in Menasco Aerospace Specification MMC-137. 1) Shot Hardness and Size, 2) Shot Velocity, 3) Shot Flow, 4) Exposure Time, 5) Part Position(s), 6) Machine Set-Up (Blast Pattern) Verification.

Controlling Key Process Parameters

The specific KPP's are the parameters that control the general KPP's and are based on the above list, but can change depending on the shot peen equipment used. For example, the outside diameter peening machine, which is a Computer Controlled Wheelabrator, 6 wheel spinner hanger design, uses centrifugal bladed wheels to propel the shot peen media. See Wheelabrator General Arrangement. The Shot Velocity is controlled by the specific KPP Wheel Speed. Exposure time is controlled by the specific KPP's Travel Speed, Rotation Speed and the computer clock. Part Position is controlled by the computer program and designated tooling.

For inside diameter peening a Wheelabrator, horizontal lance nozzle system with a pressure pot has the specific KPP Air Pressure to control the Shot Velocity. Lance Travel Speed, Lance Rotation and the computer clock controls the Exposure Time and Part Position is controlled by designated tooling. Shot Flow is controlled by an electro-magnetic valve for both types of equipment All of the above mentioned specific KPP's except designated tooling are closed loop controlled by the computer and constantly corrected to maintain the mid-point of the control limits. All control limits are determined by AMS-2432 Specification or tighter. Designated tooling is used to ensure the part is positioned in the tooling in precisely the same position each time. The automated peening equipment then locks the tooling in the machine accurately. This provides accurate control over the part positioning from set-up to set-up.

Shot Size is controlled by a vibrating sieve located on the equipment with samples taken to verify this by off-line sieve tests and a visual analysis of the shot. Control limits for these KPP's have been established using standard SPC rules. A minimum of 20 points of data is collected and the control limits are established from this data defining the natural or normal variation of the process. Similar SPC techniques are used for the shot hardness as a sample is hardness tested for each new lot of shot received.

Machine Verification Procedure

To control the Machine Set-Up an approved document called the Machine Verification Procedure (MVP) is used. Each different model or type of shot peen equipment requires a separate MVP. The MVP contains the steps for determining if something in the machine has changed outside of it's normal or natural operating variation, ie: such as blade or nozzle wear. The actual steps involved in developing this procedure are outlined in figure (1), a flow chart extracted from the shot peen specification.

A Machine Verification Tool (MVT) or Almen strip holder is designed for the MVP and assigned a tooling number. Each nozzle or wheel shall have the MVT Almen Block (s) locations assigned to it for intensity determinations and later verification runs. A standard Technique Card with saturation curves, peening parameters etc. is developed for each wheel or nozzle where the target intensity for the procedure is based on normal production ranges. Control Charts and Capability Studies are then established for each wheel / nozzle technique card and data collection begins. See Figures (1, 4, 5).

A minimum of 20 data points using subgroups of 3, therefore 60 Almen test runs in total must be plotted and control limits established. These test runs at Menasco Aerospace must be conducted over a minimum of 2 months to capture the natural variation of the equipment. When the control limits have been established for each wheel / nozzle they define the normal intensity variation on the specified wheel / nozzle.

The MVP also contains the Control Charts for the media size using the sieve test, defective shapes using visual check and shot hardness. The sieve test and defective shot controls are specific to each shot peen machine (i.e. each MVP) where the shot hardness represents media received common to any machine. As described above, each of these have control limits calculated from 20 points of data collected over a minimum of two months to define what is the natural variation of this process. All of these tests are standard inspection requirements, but by using SPC we can determine what is natural to the process and when a special or unnatural event occurs in this particular parameter The control limits are required to be tighter than the actual specification limits.

Currently the machine hour interval used to verify the equipment is performed every 12 machine peening hours and is also performed after any routine machine maintenance. This machine verification is performed according to each wheels / nozzles individual technique card using a single speed, pressure and flow etc. using the MVT. The intensities achieved during the verification are then plotted onto the applicable control charts to determine if anything has changed outside of it's natural variation, see figure (5). During these verification runs all KPP's are monitored and controlled by the computer. The 12 hour interval was based on the confidence level in the process and on other specifications maximum Almen strip re-verification run. This time interval is translated into a 10 work day interval due to the large amount of part masking required with the authors aerospace components.

As the confidence level and understanding of our processes increases over time, it is anticipated that the original 12 hour interval will also be increased.

Shot size is checked and verified every 5 machine peening hours and is based on standard shot peening specifications. After the test has been performed the operator plots the value on the applicable control chart to determine if anything has changed outside of its natural variation.

The MVP also contains a flow chart illustrating the steps required to complete the verification. Included in this flow chart are the machine set-up steps, filling out control charts, verification time intervals and the required steps in a control limit violation. Each technique card requires separate approval and includes a set-up diagram, Almen block (MVT) location sheet, saturation curves and control charts.

If a control limit violation occurs on any Key Process Parameter the following steps are required. First, identification of the problem must be established, then a corrective action must be assigned and implemented and then controls or action plans to prevent reoccurrence of similar problems must be established. Each of these steps must be documented in the MVP and completed accordingly, see figure (3). Procedures for practicing Continuous Quality Improvement such as SPC have been developed and implemented by the C.Q.I. team.

After completion of the MVP and all Key Process Parameters are proven to be in control, the shot peen equipment therefore has demonstrated that it is capable of reproducing the same normal or natural results it was capable of when the MVP was first established.

Shot Peen Technique Approval

The standard aerospace part shot peen technique procedure requires a uniform intensity and coverage on the specified surface areas. Almen blocks are located on a test part to simulate the surfaces to be peened and measure the intensity. The Key Process Parameters are varied until the best intensity and coverage results are obtained. This set-up is documented on a technique card and approved. Each time a shot peen technician is required to peen a particular part, the technique card is pulled and the machine is set-up according to the parameters documented on the card. The test part is then run with all the Almen Blocks on it and if the Almen Intensities are within the specified range the operator continues to run the production lots. This shot peening procedure is called Method 1. See Figure (2).

Often peening shops will identify the highest and lowest intensity Almen block locations and only monitor these areas when completing the tests per Method 1. When peening the test part, the highest and lowest intensities achieved can be plotted onto a SPC run chart. After a minimum of 20 points or 20 test runs are completed the control and capability of the individual component can be determined. A technique card or setup that meets the minimum capability requirement and is in statistical control is then approved to a different level or method. If a technique set-up does not meet the requirements then a new set-up and procedure can be developed.

Method 3 Shot Peening

The above mentioned approval standard is called Method 3 and is being used for the peening of *BOEING* parts. This Method is comprised of two main systems. The MVP is the Method 2 standard which is the approval for a specific machine. When the technique card or set-up meets the control and minimum capability requirements mentioned above, and is developed in a machine that has an approved MVP, the technique is approved to Method 3. See Figure (1) for Method 2, See Figure (3) for Method 3.

Under Method 3 peening the control and capability of both the machine and the peening procedure for an individual part has been established. The natural variation of the process has been established and is verified on the previously mentioned time intervals. Any deviation form the natural variation will be detected by the control limits on the KPP's and therefore allows a high confidence level in the repeatability of the process. If a violation of the control limits occur, the technician may revert back to Method 1 peening for the particular component and rerun the test part.

A flow chart for processing components using these methods has been included in the Menasco Aerospace shot peen specification using a Wheelabrator Computer Controlled system. The flow walks the technician through a checklist including; verification that the KPP's are up to date for the MVP; preparation of the part and downloading the computer file; processing the part; violation of machine KPP's, and required inspection reports. The computer plays a critical role in this method where all part and MVP technique files containing all the processing parameters are stored in the computer and are called up when required. The files or techniques are protected by a password to ensure no parameters have been changed. When files are called up all parameter settings are immediately set-up in the computer. All applicable control limits are automatically applied to the KPP's. If a violation occurs during a production run the machine automatically shuts down and an alarm report is printed. The shot peen technician can then begin troubleshooting. When the cause is identified a corrective action must be implemented. If the corrective action can be taken in a reasonable amount of time the process can be held up until the action is complete and then peening may continue. If the corrective action requires an unacceptable time frame then the process can revert back to Method 1 and the original components test part can be run. If it passes specification requirement peening may resume under Method 1. Method 3 peening may not begin until corrective action is complete and controls or actions plans have been established to prevent reoccurrence. After peening the component a computer printout of the parameters and any alarm violations is printed and forwarded to inspection with the component.

CONCLUSION

By determining the natural variation of our KPP's and controlling them by computer alarms or control charts, in conjunction with providing capability and control of each set-up, any abnormal conditions or changes can be detected. This in turn has provided the customer with the confidence, that if no control limit violations occur, we have established the reliability and repeatability we require to process (shot peen) components when eliminating production Almen Strip test runs.

A pilot project for this method was set-up with metrics including cost, processing time, quality, and customer satisfaction. Three major components had been monitored under this program to determine the effectiveness of the new method. Both cost and processing time were cut in half or more and customer satisfaction and quality increased 40 percent. Overall this system is expected to increase shot peening productivity by a factor of 2 or possibly 3. Smaller production runs no longer pose a problem, part cycles are reduced (inventory turns increased) therefore reducing shot peening cost further. The continued use of the Wheelabrator Computer Controlled Shot Peening System and implementation of SPC has proven to be a reliable and efficient manufacturing tool.

Glossary of Terms

Cp: Capability ratio of tolerance width to capability
Cpk: Capability ratio of tolerance width to capability with centering data relative to the target value
UCL: Upper Control Limit of process
LCL: Lower Control Limit of process
CL: A solid line on the control chart indicating the average of the items plotted
X Bar: A variable control chart to track the process average
Histogram: Bar chart representing a frequency distribution
MR: Moving Range, control chart to track process variability
ID: Inside Diameter
OD: Outside Diameter

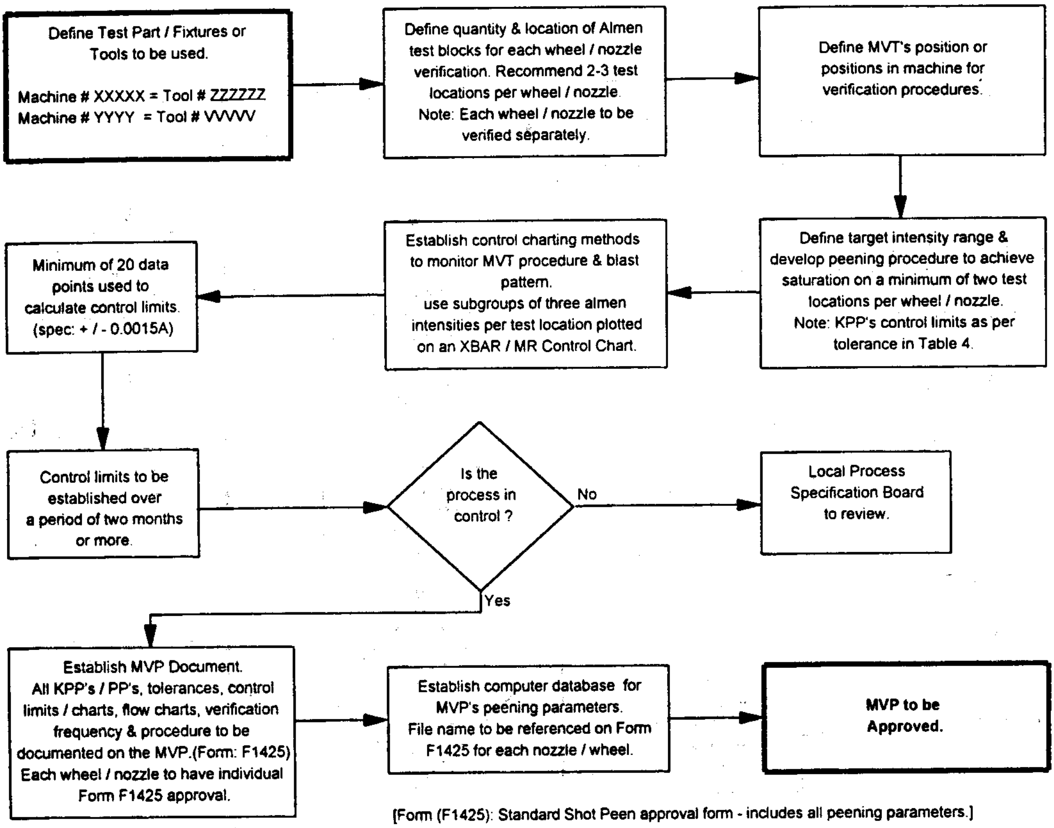


Fig. 1: Development of Machine Verification Procedure. (Method 2)

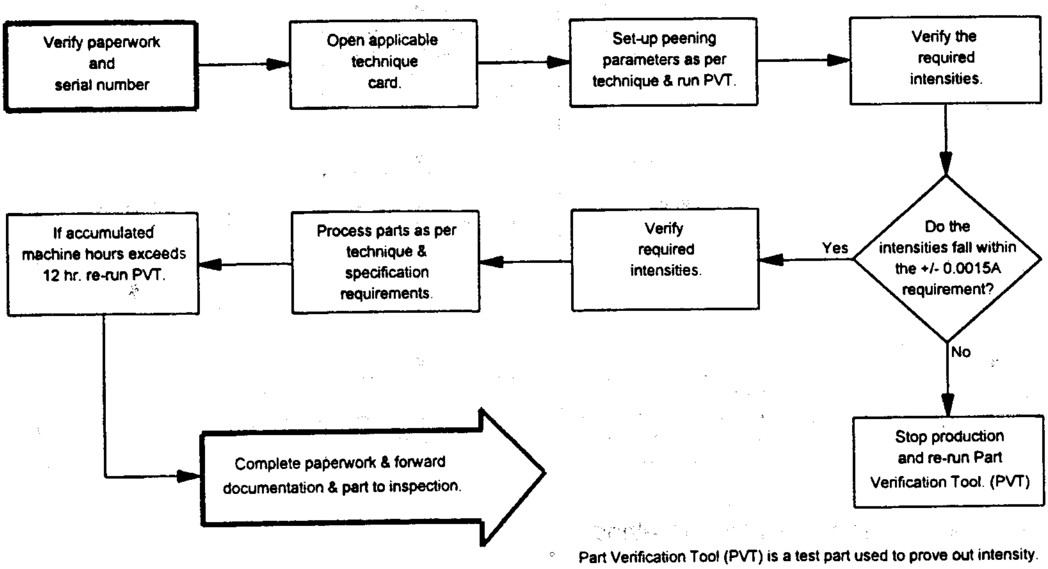


Fig. 2: Shot Peen Process Flow. (Method 1)

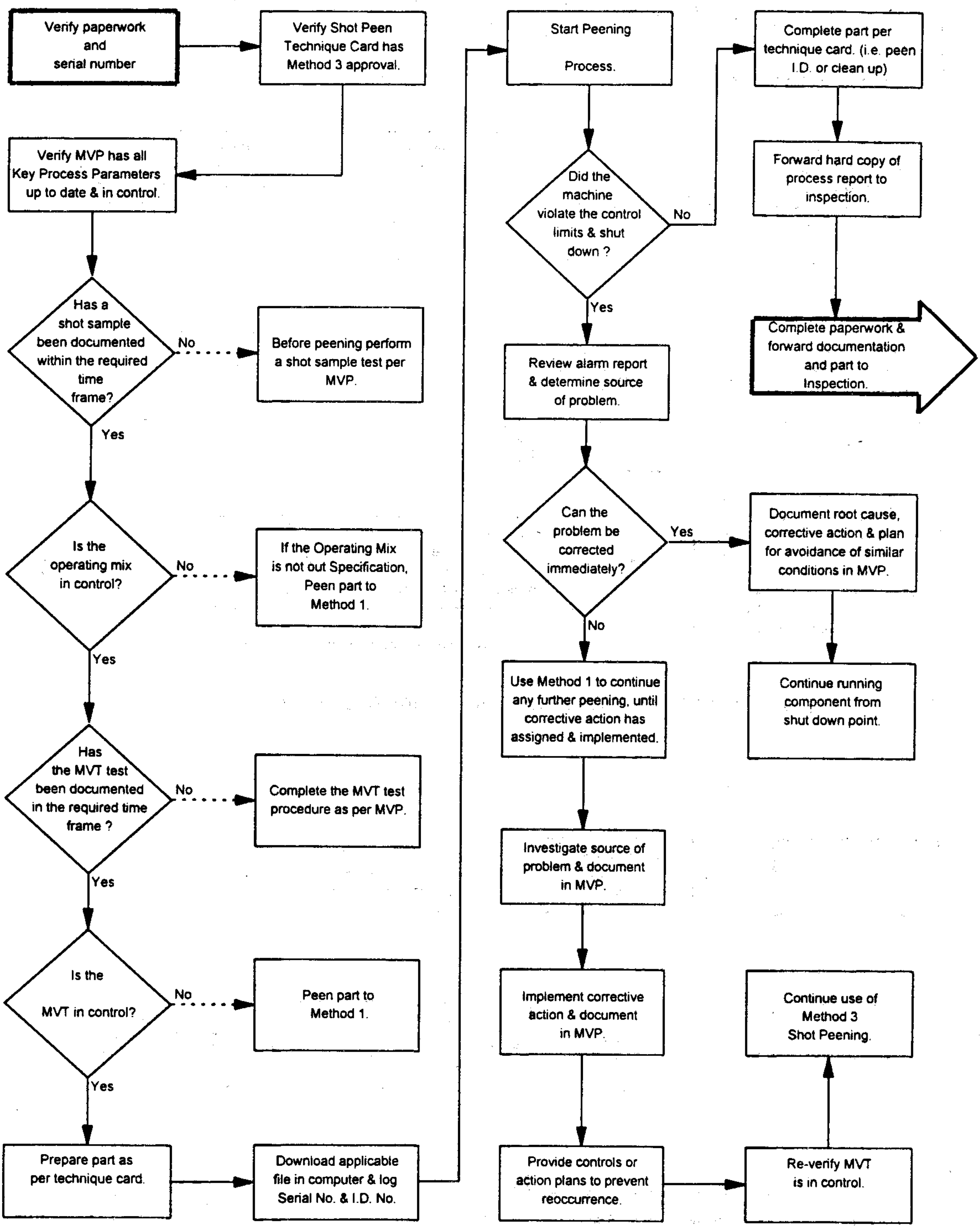


Fig. 3: Shot Peen Process Flow. (Method 3)

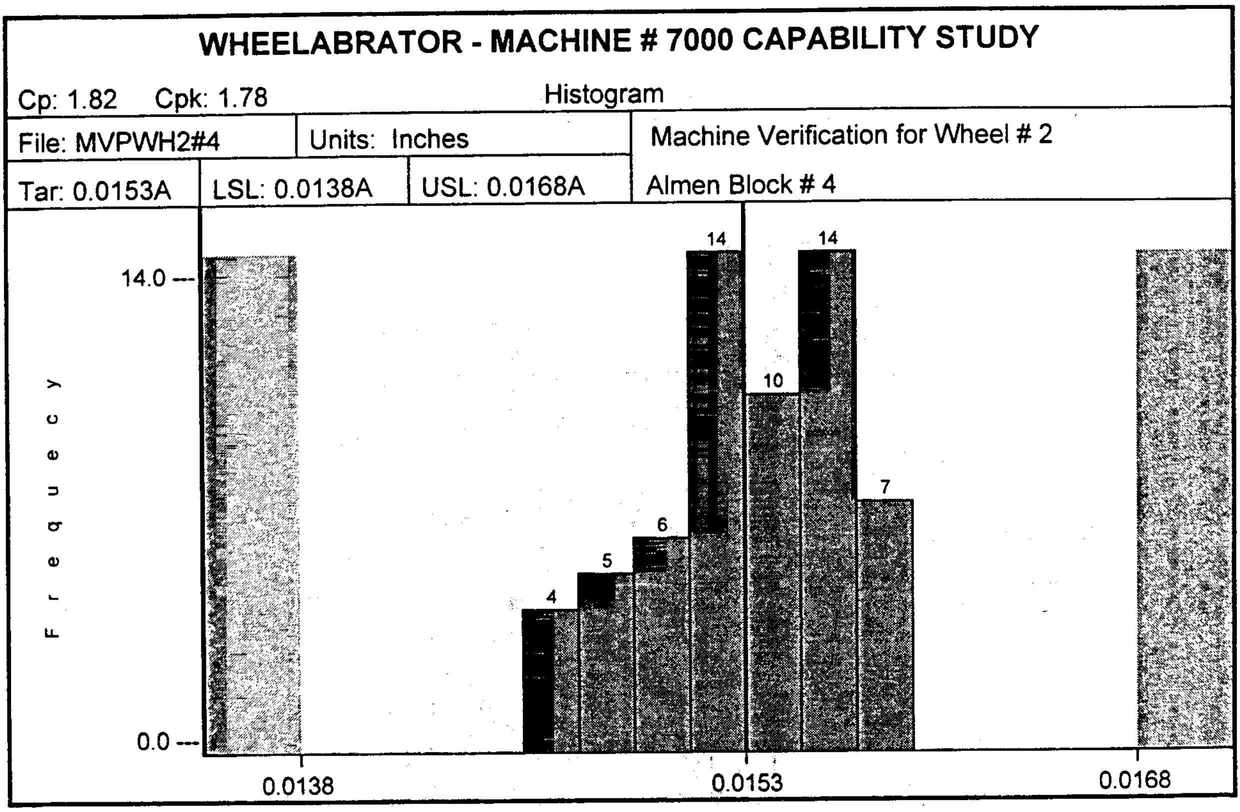


Fig. 4: Histogram illustrating Machine Capability.

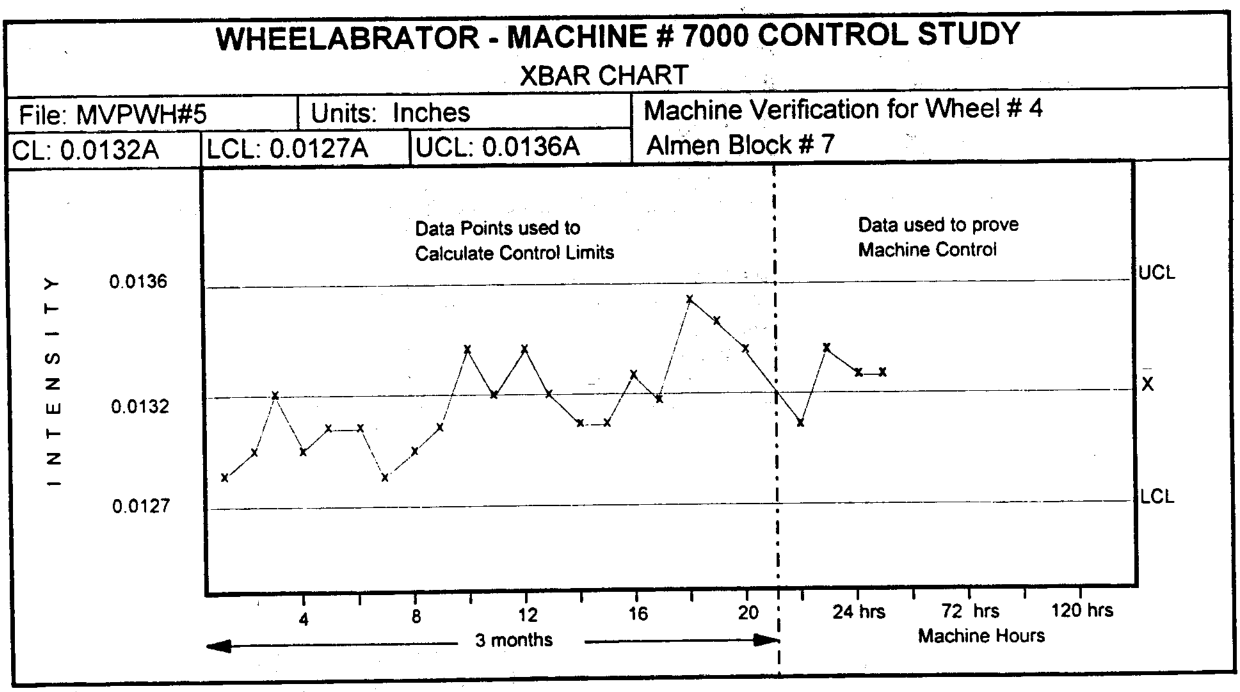
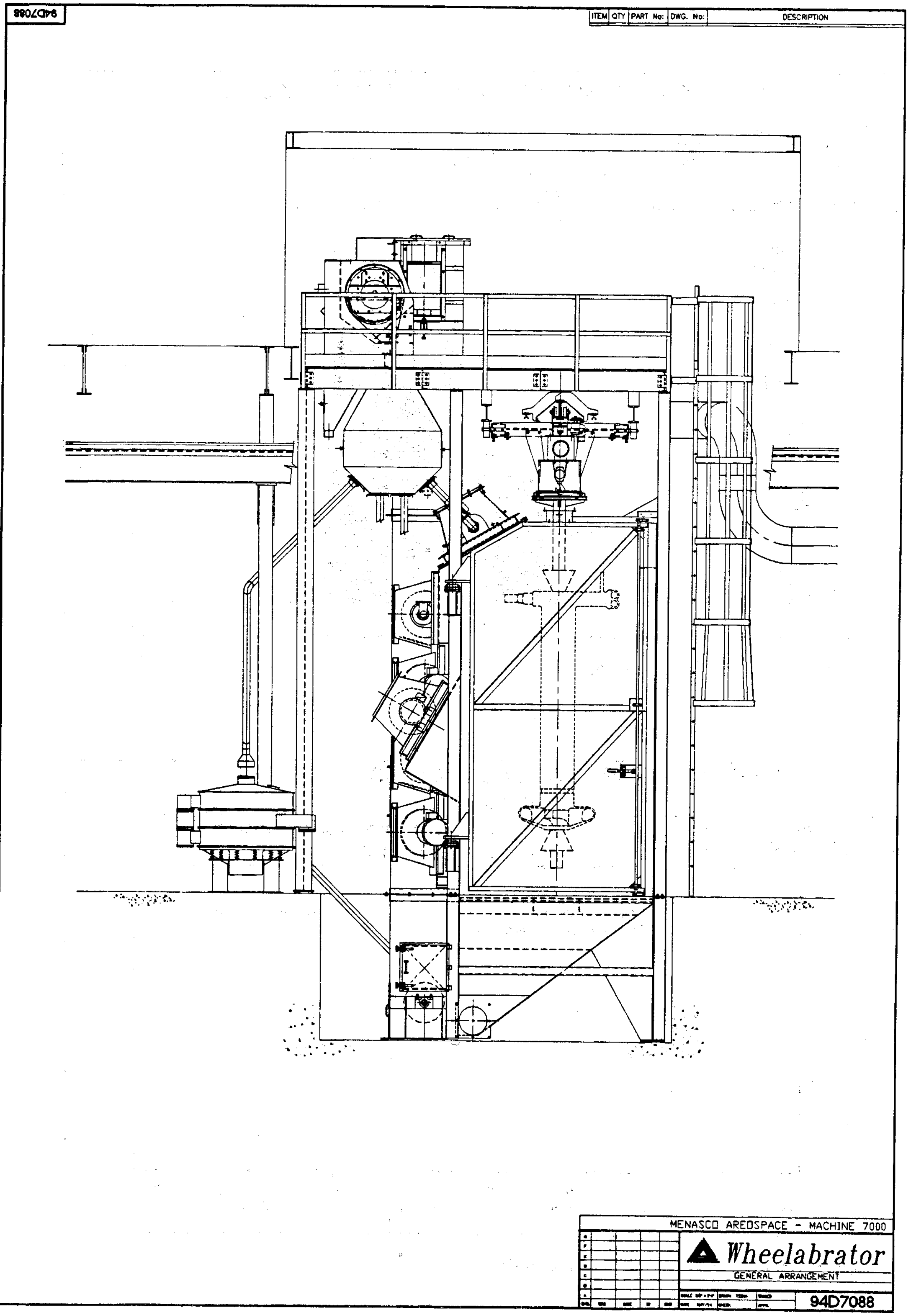


Fig. 5: Control Chart used to verify Machine is in Control.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ITEM QTY PART No: DWG. No: DESCRIPTION
MENASCO AREOSPACE - MACHINE 7000
Wheelabrator
GENERAL ARRANGEMENT
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