Installation and Implementation of an In-Process Coordinate Measuring Machine (CMM)

Federal Manufacturing & Technologies

Derek Johnston

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Final Report

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Abstract

This report documents the work accomplished during the installation and implementation of the in-process Coordinate Measuring Machine (CMM) in Department A. A wealth of knowledge has been gained in solving the many technical issues that delayed the partial implementation of this CMM. The work completed thus far lead to the successfully calibrated in-process CMM workstation. A great deal of current and future work has been outlined in the following pages that shall be used as a guide for the full implementation of this CMM with machining processes in Department A.

Summary

This project builds upon the previous work completed in Department B. In that department, engineers had already established an in-process verification tool by utilizing the Image 555 and Image 777 CMM workstations.

In order to reduce costs and increase the utilization of the existing two CMM workstations, the Image 555 was relocated from Department B to Department A. The relocation was relatively simple and straight forward. However, the implementation was a tremendous challenge that consumed more time than expected and yielded fewer results than anticipated. The first technical challenge was isolating the vibrations in the floor generated from adjacent machines. In Department B, the CMM was located on a separate concrete pad that isolated vibrations created by adjacent machines. In Department A, the CMM was placed on the same concrete floor as that of the adjacent turning machines in Department A. In order to isolate the vibrations from the machines a set of isolation dampener pads were utilized. Several different types of dampener pads had to be experimented with in order to reduce the vibrations without jeopardizing the stability of the CMM. The final solution to the vibrations and stability control resulted in a mid-range dampener pad that was used with a slower traverse speed set for on the CMM.

In order to make this CMM more user-friendly for both the operator and the engineer, a different type of CMM software system was chosen, Metrolog XG. Metrolog XG, in combination with Silma XG, provides the user with a visual-based programming tool that is easier to understand than typical DMIS coding, as was used in Department B. The Metrolog and Silma software allows the engineers to program off-line in a virtual simulation to test CMM programs before running the real part on the actual CMM.

Several CMM programs were created for calibration purposes using the new software and CMM. Two products were evaluated and used as an example throughout this report, illustrating how the in-process CMM works with the user-friendly software.

Discussion

Scope and Purpose

The intent of this project was to install and implement an operator friendly CMM workstation for in-process verification of products in Department A. The justification for this project was based upon several machined products in the department that require the use of expensive gages, first piece CMM inspection through Precision Measurement, and/or difficult to use comparator charts for work piece verification. The sought after benefits of an in-process CMM were immediate and accurate inspection results that could be utilized by virtually any machinist in the department once a CMM program/process was developed. Figure 1 illustrates the Image 555 CMM installed in Department A.

Figure 1: Image 555 CMM Workstation

Prior Work

This Image 555 CMM was already installed and implemented in Department B, by two engineers. These engineers have successfully developed in-process CMM programs for operators to use on products. Work in Department B continues with the use of a similar CMM workstation called the Image 777.

Activity

Installation

Due to the lack of extra floor space in Department A, an existing OGP comparator had to be excessed in order to make room for the new Image 555 CMM.

An Industrial Hygienist coordinated the beryllium surface contamination sampling for the Department A's optical comparator. The results indicated no measureable amounts of contamination near or around the proposed CMM work cell prior to installation.

Utility costs, hookup, and transportation were expensed by facilities, as the current comparator was slated for excess and the new CMM was simply being relocated inside KCP. No additional charges to the project were accrued for the entire installation, saving the project roughly \$20K. Figure 2 shows the final installation of the CMM in Department A.

Figure 2: CMM Utility Hookup Department A

Calibration Procedures

A new calibration procedure was developed through a combined effort by a Numerical Control Analyst, an Electrical Technician, and Metrology Senior Engineer. The previous calibration procedure used for this CMM in Department B could not be used because of the new CMM software, Metrolog XG. The following list discusses the personnel involved in the development of the CMM calibration procedures and the type of work that each contributed.

Numerical Control Analyst

Developed CMM software programs to check the accuracy and repeatability of the CMM according to the calibration procedure. The analyst developed CMM coding for the probe tip calibration, ball plates, and Z-plates. Figure 3 illustrates an example of the calibration command prompt as seen in the program by the technicians.

Electrical Technician

The technician was the primary contact for machine maintenance, setting up calibration data storage links, troubleshooting, and aided in developing the proper documentation for the calibration procedures.

Metrology Engineer

The engineer generated the calibration procedure document. This document is used to call out all of the necessary programs, steps, and equipment required by Metrology to verify the accuracy and repeatability of the CMM throughout the entire useful range of operation.

Figure 3: Calibration Program Prompt

Software Programs

Department B currently uses a software program called PCDMIS which is based primarily on DMIS logic. Engineers write CMM programs for various products that are manufactured in Department B. Once the program is written, the operator is able to run the program in 'operator-only' mode which safeguards some of the functions of the CMM and the program. The operator-only mode is intended to be a more straightforward and simple approach to using the CMM software.

In Department A, a different type of CMM software, Metrolog, was chosen based on an early review of the user-friendly programming architecture. Metrologic Group Inc. has been, and still is, successfully used throughout KCP by several engineers and operators. However, at any one time there are approximately a dozen different CMM program types being used to check a product. Typically, the type of software used, is based on what the CMM machine is capable of running, what the operator knows how to use, or what software was provided with the different CMM machine upon original purchase. Metrologic was chosen because of the visual off-line programming feature as described in the following sections.

On-Line Software

Metrolog XG is considered the 'on-line' or 'at the CMM' programming tool that engineers and operators can use to write programs and verify parts. The software allows the user to visually see on the computer simulation exactly what the adjacent CMM is performing. This software system also is used during the calibration and verification routines by maintenance and metrology. The Metrolog XG software works with the Brown & Sharp controller to drive the Global Image 555 CMM to different points based upon operator input or program logic. Figure 4 shows the complete CMM setup in Department A with the PC and controller.

Figure 4: CMM Workstation in Department A

Off-Line Software

The off-line software is what makes this particular software package unique and more cost effective for the engineer. The Silma XG software is essentially the virtual duplication of the actual CMM machine in Department A. This software tool allows engineers or programmers to build CMM programs and test their work in virtual reality before running on the actual machine using Metrolog XG. By programming from solid models generated in CAD systems such as SolidWorks or Pro-E, engineers are able to test an inspection process before a final definition has been established, saving designers and manufacturing time and money.

In order to reduce operating costs, a floating license was setup for multiple engineers. The convenience of the Silma software allows engineers to work at their desk in order to quickly pull up additional programs or converse with other engineers in their department. Figure 5 shows the Silma XG software with a modeled representation of the true CMM.

Figure 5: Silma XG Software

CMM Fixture

Many traditional fixtures such as V-blocks, standoffs, and Kurt vises are inadequate for smaller parts with multiple features. Therefore, due to the relatively large range of parts and part sizes in Department A, custom fixtures were necessary as shown in Figure 6. The new fixture was designed to allow the CMM to probe all of the necessary features without contacting the fixture or repositioning the part. With a slight modification, the fixture below was adapted for two parts that are part of active programs at KCP and will benefit from the use of an in-process CMM.

Plunger Valve
Piston 2Z Valve

Figure 6: CMM Dual Use Fixture

In-Process Implementation

The immediate need and further justification for this CMM stems from small parts such as the Plunger Valve and the 2Z Valve as previously discussed. The complexity of these parts along with the tight tolerance on several of the features requires a highly accurate turning center or lathe such as the Star machine as shown in Figure 7.

Figure 7: Department A Star Lathe

The tight tolerance of the many features and the relationship between each feature is what can make manufacturing difficult and expensive. In order to hold the tolerance and relationships between multiple features, several turning and live tools must be accurately synchronized with one another within a few tenths of an inch or less (0.0002"). This is achieved on the 11-axis Star Lathe (as shown in Figure 7), which is comprised of two turning centers and several live tool centers that can be positioned to machine much like a mill. Typically, the only way to verify that the different tools are properly setup and synchronized to another is to cut a part and measure the features with respect to one another. This process is time consuming and the tools can be difficult to adjust based purely on inspection results. Traditionally, a practice part made out of brass or some other softer scrap material is machined and then verified 100% through Precision Measurement, comparator, gages, and/or hand micrometers. But once the practice part or production part is removed, it is virtually impossible to return the finished part to the same location and orientation in order to continue machining. Therefore, the operator only has one chance to cut a part correctly before the part is inspected. Figure 8 shows the multiple tool holder positions and turrets that are required for such a part.

Figure 8: Department A Star Tool Holders and Live Tooling

The in-process CMM has the capability of providing the operator with accurate and instantaneous feedback based on the previously cut part. Thus, once the operator has properly set up the machine and is capable of running, only minor offset changes should be needed to compensate for tool wear and inexact setups. The quick turn around time associated with the in-process CMM eliminates the need for expensive gages or downtime waiting on first piece inspection from Precision Measurement. Figure 9 shows the features of the Plunger Valve that are critically orientated to one another as manufactured on the Star Lathe with live tooling as shown in Figure 8.

Figure 9: Solid Model of Plunger Valve

The fixture and part were first modeled in SolidWorks and functionally proven using the off-line CMM programming software, Silma XG, for clearance and positioning. Based on the successful simulation in Silma, the actual fixture was fabricated to match the model size, shape, and function.

Figure 10 illustrates an example of the contact points where the probe touches the part in order to record values in the Silma software. The placement and orientation of these touch points coincides with the proper dimensioning of the part, known as Geometrical Dimensioning and Tolerancing (GD&T).

Figure 10: Silma XG Simulated Probe Touch Points

Running CMM Programs

The sole purpose of this ADAPT project was to implement a user-friendly CMM for operators to use on a regular basis. Typically engineers and machinists do not possess the in-depth training or technical know-how required to run a CMM, therefore clear and precise instructions are necessary. The procedures or instructions can be documented directly in the MES work instructions following a machining process, or as an attached word document such as a Special Work Instruction. Typically, an attached word document allows the engineer to go into further detail and to organize instructions with illustrations in order to connect with the operator. Upon opening an attached word document from MES, the operator can print off the instructions required to utilize the CMM. As an example, the following instructions shall cover the following procedures that are required to inspect products on the CMM. Future work will involve the standardization of special work instructions for all engineers to follow.

Rough Outline:

- 1) Power up the CMM
- 2) Turn on the computer and log in
- 3) Load the required CMM program
- 4) Setup the fixture correctly
- 5) Calibrate the appropriate probe(s)
- 6) Run the CMM program
- 7) Interpret the results

Example Program

Once the procedures listed above are followed and the CMM program is opened, the program will prompt the operator to position the probe according to the illustration. Figure 11 is an example of a CMM prompt embedded in the program.

Figure 11: Silma XG Setup Prompt

Once the operator presses the continue button, another message will pop up on the computer monitor with an illustration to direct the operator to position the probe above an illustrated feature. The instructions and illustration are intended to ensure that the fixture is located in an approximate location that enables the program to find the exact location via an automated probing routine. Figure 12 shows an example of the positioning prompt popup illustration.

Figure 12: Silma XG Positioning Prompt Illustration

If the probe is in the correct position when the program starts the automated probing cycles, the CMM will perform a series of moves and probe touches that will locate the exact position of the fixture and part. At this point, the operator will not be required to perform any additional tasks until the CMM program is complete and all of the part features have been verified. For example, when the program begins the probing routines the CMM will move about the table in different directions and probing orientations in order to touch the various features. As a cautionary note, the operators are first instructed to run the program at a slower speed until they are familiar with the program.

Several probing touches are required in order to locate the part exactly. Once the fixture and part have been successfully located within the tolerance of the rough probing parameters, the part is then measured with many more points in multiple orientations to ensure that the true dimensions are captured.

Figure 13 illustrates some of the probing points taken to locate and orientate the part coordinate system so that all proceeding points are based upon the actual position and orientation of the part. This ensures that all measurements are related to the same point on the part as shown on the drawing. This automated probing also ensures that multiple operators can place each part in roughly the same location knowing that the CMM will properly locate and orientate the part coordinate system for inspection.

Figure 13: Silma XG Orientation Probing

Generating Reports

An inspection report is available for each successful CMM program run in order for the operator to review the results. The optional Print Editor feature in Silma XG allows the engineer to customize the report in order to focus attention on certain features, illustrate problem areas, or make quick comparisons to Precision Measurement as shown below.

Figure 14 shows an example of the final report based upon the CMM inspection in the Silma software. Note, the values all show nominal dimensions based on the virtual size of the part as generated in SolidWorks. In contrast, when the same CMM program is run in Metrolog with a production part, the inspection results reflect the actual dimensions and deviations from nominal. The format and look of the report is standard on both Metrolog and Silma.

Metrolog Group - M8.1250XG 9

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Figure 14: Silma XG CMM Report

Technical Challenges

Over the course of this project (FY08), there have been a series of stability problems and repeatability issues that have limited the implementation of this CMM in Department A. However, KCP maintenance and engineering personnel have learned a great deal about the design and operation of the Image 555 CMM by troubleshooting and repairing the ongoing problems throughout the project.

This CMM was originally setup in Department B for operators to use as an in-process verification tool. The initial setup in Department B was performed by trained technicians from Image Inc., maker of the Image 555. The relocation and setup in Department A was performed by KCP's maintenance and equipment personnel who have a broad range of experience in working on CMMs of all sizes and makes. Therefore, KCP's equipment personnel do not possess the same level of understanding and technical know-how for installing and setting up this particular type of CMM as do that of the Image Inc. technical representatives. In retrospect it would have been helpful to employ the trained technicians from Image Inc. However, the troubles encountered thus far have provided KCP's maintenance personnel with a much better understanding of how this CMM works and what things can go wrong.

In Department B, the CMM was located on a dedicated concrete pad that isolated vibrations from adjacent machining equipment such as lathes, mills, and grinders. However, there were still repeatability problems as a result of vibrations through the airline that was hooked up to the CMM via copper piping. This problem was fixed by using a flexible hose that eliminated the vibrations from the copper pipe to the CMM. The installation in Department A is somewhat different in that the CMM is sitting on the same floor as a series of turning machines. Therefore, vibrations generated from the turning equipment are transmitted through the floor to the CMM, effecting the repeatability and accuracy. With the help of an equipment engineer, Department A was able to economically isolate the machining vibrations with a set of rubber/foam pads placed under the four legs of the CMM. The first attempt in using cushioned pads or vibration dampeners failed because they were too soft and caused the CMM to sway in all directions depending upon probe head movement. As a result, a firmer set of pads were installed which reduced the top-heavy swaying motion but absorbed less of the machining vibrations. The remedial fix was to slow the machine traverse speeds down in order to reduce the top-heavy sway motion and to use a mildly firm set of pads in order to isolate as much vibration as possible. At this point, the machine was initially calibrated and released for engineering use.

After six months of light developmental use, the standard machine calibration control date had expired on the Image 555 which prompted a second calibration procedure. During the second calibration procedure, the repeatability failed, which prompted maintenance personnel to test the Renishaw probe head for damage. The probe head was sent off to Renishaw for inspection and repaired. In the mean time, a backup probe head was ordered in the event that this particular situation arose in the future where product

was dependent upon an in-process verification tool. Therefore, two working probe heads are now available for this CMM.

Despite having a new probe head, the repeatability continued to fail which prompted additional help from maintenance and engineering personnel. In order to isolate the problem to one particular moving component a new set of calibration programs were developed by a NC Analyst. The analyst was able to write a program for the CMM to perform a series of linear tests in each of the X, Y, and Z planes which helped identify the source of the problem. Because the machine moves on linear slides in the X, Y, and Z direction the additional programs helped to identify and calibrate each of the three axis after adjustment where made. These troubleshooting programs are now embedded in the main calibration program for maintenance personnel to use when necessary.

The source of the problem was identified by using the troubleshooting programs for the X, Y, and Z planes. It was determined that the repeatability in the XZ plane was out of tolerance because one of the air bearings was too tight, causing excessive drag and inconsistent movement across the horizontal linear slide. There are a total of five air bearings along the horizontal linear slide, each of which can be adjusted to affect the X, Y, and Z planes. With all five air bearings rechecked and adjusted, the repeatability problem was fixed and the machine was again calibrated and released for use.

There were many lessons learned throughout the repair process for the engineers and maintenance personnel involved. Upon release, the CMM repeatability and accuracy showed significant signs of improvement as a result of a better understanding for how the CMM properly functions. The calibration procedures as well as this technical document capture some of the many challenges and fixes that took place and that ultimately lead to the repair of the machine.

Summary of Accomplishments

The goal of this project was to implement a user-friendly CMM into Department A for operators to check their machining work on a routine basis. Due to time constraints and unforeseen technical difficulties with the equipment a complete implementation and testing period with an operator was not possible. However, a great deal of work has been accomplished and documented for future development.

The following accomplishments coincide with the attached information in the appendices A and B. All of the programming, part files, and project details have been included as a reference for the following accomplishments. This document shall serve as a reference for future development and implementation work. The accomplishments and lessons learned have prepared KCP's engineers and maintenance personnel for future work.

Installation

The installation was a success in that the machine has been completely relocated from Department B to Department A. This involved several equipment and facilities engineers as well as maintenance technicians.

Metrolog and Silma CMM Software Training

Several engineers and operators were exposed to a five day training course that outlined the basics of CMM programming using both Metrolog and Silma XG. This training was taught by a professional from Metrologic Group Inc.

Calibration Procedures

The CMM calibration procedures were setup with the help of programming; an electronic technician; and metrology. A metrology engineer is the owner of the calibration procedure which documents and controls the appropriate programs, calibration blocks, and procedures required to calibrate a CMM. The metrology department is in charge of establishing calibration procedure standards used throughout the plant for various CMMs such as the Image 555 in Department A.

Fixture Design and Fabrication

An immediate need for a specific fixture required the design and fabrication of a dual use or dual purpose fixture. The fixture design has been illustrated in previous sections for the Plunger Valve and the 2Z Piston Valve. The custom design of the fixture allows several features to be inspected during one setup. This reduces the complexity of the process and the inspection time between parts. The cost of the custom designed fixture was reasonable ~ \$1,500 and the fabrication took place at KCP in a relatively short time frame.

Troubleshooting and Technical Know-How

Throughout the installation and implementation several unforeseen technical challenges have popped up requiring additional technical support. The engineers and maintenance personnel involved in solving the various repeatability problems have learned a great deal about the design and function of this particular CMM. Through trial/error and with the help of additional programming, the maintenance personnel were able to make proper adjustments to compensate for vibrations and unbalanced air bearings.

Software License Updates and Upgrades

The CMM software packages Metrolog XG and Silma XG both have received updates from the vendor for the latest release as part of the software maintenance support paid for by this project and KCP's IT department. The Metrolog XG license was purchased for FY08 in which this project was activated. The Silma XG license was purchased by the IT department for the same period of time. Upgrades to the software include new releases for the following versions of software.

	<u>Version</u>	<u>Date</u>
Metrolog and Silma XG	V7.01	10/07
	V8.01	2/08
	V9.01	7/08
Opt. Silma XG Print Editor	V9.01	7/08

Future Work

The full implementation of this CMM requires continual engineering support and operator usage in order to make this a valuable tool for Department A. There are several active programs that have products in Department A that use gages and precision measurement that could some day benefit from an in-process inspection tool such as this CMM.

Re-processing old products and new product development work requires a lot of inspection support via gages or precision measurement CMMs. Thus, with the implementation of this new equipment in Department A, engineers will be able to test new machining processes and reduce costs on gage designs.

Future Training

In order to continue to implement this CMM in Department A. more engineers and operators will need to be trained on how to program and operate the CMM. Additional training can be attained from Metrologic Group Inc., but a great deal of training and information sharing can be derived from the personnel involved.

The benefit of the off-line Silma programming software can be very helpful to engineers from one department to another through the use of the floating license. The immediate plan will be to promote this new technology to new hires that are lightly loaded and looking for new projects to generate a cost savings by reducing cycle times and improving yields for products.

Program Control and Documentation

In the same way that the CNC programs are stored on the network for operators to download when needed, a similar system will need to be setup for the in-process CMM programs. The storage and control of the latest CMM program issues will most likely be controlled and monitored with the help of the NC Analysts group under a technical manager. Ideally, CMM programs will be accessible by the operator through a controlled system such as the DNC software. The crucial features of a controlling system will ensure that the operator is using the most current program and that key programming functions cannot be manipulated to alter results.

Manufacturing Buy-off

In the future, manufacturing may be able to inspect and perform the final buy-off for products inspected on the Image 555 CMM in Department A. The key challenges will be the calibration and program documentation procedures, adequate operator training, and a revision to some of KCPs business practices. Typically, most products are inspected and accepted by precision measurement, which is an unbiased third party group of CMM operators that have years of programming experience and a greater understanding of GD&T. In order for an operator to buy off products using a manufacturing CMM, a considerable amount of control and documentation will be required to ensure that defective parts are not accepted.

Classified Network

Previously in Department B, this CMM was utilized for both unclassified and classified inspection. In Department A, the CMM is located in an unclassified area which prevents the CMM from being used to inspect classified products. Typically products that have contours, splines, and difficult to machine features are classified. Thus, these complex features make the in-process CMM a valuable tool for inspecting features that require either expensive and complex gages or precision measurement support.

Appendix A – Programming and Product Definitions

Silma/Metrolog CMM Program

Plunger Valve

00001	DMISMN/BASE
00002	DMESW/COMAND, 'NEWWORKSESSION'
00003	DECP/L/DIST, 5, DEV, 4, TEMP, 1, ANGLE, 3
00004	III UNITS/mm, ANGDEC, TEMPC
00005	III SNSET/APPRCH, 0.25
00006	III SNSET/SEARCH, 0.05
00007	III SNSET/RETRACT, 0.250
00008	\$\$ Delete PROG from line below when on CMM
00009	T(TOL1) = TOL/CORTOL, XAXIS, -0.00790, 0.00790
00010	T(TOL2) = TOL/CORTOL, YAXIS, -0.00790, 0.00790
00011	MODE/prog, MAN
00012	G(CAD)=GEOM/MODEL, 'A='\\vad\userfiles\w60911\public\Metrolog \$
00013	XG\ID93\237988\237988asm.su3'
00014	DID(_PLP)=DEVICE/STOR, 'C:\Program Files\Metrologic Group\Metrolog \$
00015	XG\Probes\slot3.plp'
00016	OPEN/DID(_PLP), SNS
00017	SNSLCT/SA(3_A0.0_B0.0)
00018	D(CAD_PART)=TRANS/XORIG, 270.9355, YORIG, -403.1556, ZORIG, -447.1318
00019	TEXT/OPER, 'POSITION PROBE ACCORDING TO ILLUSTRATION'
00020	CALL/EXTERN, SYS, 'C:\Program Files\Internet Explorer\iexplore.exe', wait, \$
00021	'\\vad\userfiles\w60911\public\Metrolog XG\ID93\237988\setup.jpg'
00022	TEXT/OPER, 'BEGIN AUTO PROBING'
00023	F(PNT1)=FEAT/POINT, CART, 5.1740, 6.6080, 4.9850, 0.000000, 0.000000, 1.000000
00024	GOTO/5.1740, 6.6080, 4.9850
00025	MEAS/POINT, F(PNT1), 0
00026	GOTO/5.1740, 6.6080, 4.9850
00027	ENDMES
00028	DATDEF/FA(PNT1), DAT(A)
00029	D(CAD_PART2)=DATSET/DAT(A), XORIG, YORIG, ZORIG
00030	MODE/PROG, MAN
00031	F(PNT2)=FEAT/POINT, CART, 0.0000, 0.0000, -0.8575, 0.000000, 0.000000, 1.000000
00032	MEAS/POINT, F(PNT2), 1
00033	GOTO/0.0000, 0.0000, 2.0435
00034	PTMEAS/CART, 0.0000, 0.0000, -0.8575, 0.000000, 0.000000, 1.000000
00035	GOTO/0.0000, 0.0000, 2.0435
00036	ENDMES
00037	WKPLAN/YZPLAN

```

00038  D(PCS1)=TRANS/ZORIG,FA(PNT2)
00039  GOTO/0.0000,0.0000,0.3441
00040  F(PNT3)=FEAT/POINT,CART,-5.1740,-5.9724,0.1110,-1.000000,0.000000,0.000000
00041  MEAS/POINT,F(PNT3),1
00042  GOTO/-8.0751,0.0000,0.3441
00043  GOTO/-8.0751,-5.9724,0.1110
00044  PTMEAS/CART,-5.1740,-5.9724,0.1110,-1.000000,0.000000,0.000000
00045  GOTO/-8.0751,-5.9724,0.1110
00046  ENDMES
00047  D(PCS3)=TRANS/XORIG,FA(PNT3)
00048  GOTO/-0.6863,-1.2323,0.1110
00049  F(CIR1)=FEAT/CIRCLE,OUTER,CART,0.0000,-6.6080,-4.1275,1.000000,0.000000,$
00050  0.000000,9.8600
00051  MEAS/CIRCLE,F(CIR1),5
00052  GOTO/0.8000,-1.2323,-4.1275
00053  PTMEAS/CART,0.8000,-1.6780,-4.1275,0.000000,1.000000,0.000000
00054  GOTO/0.8000,-1.2780,-1.1753
00055  GOTO/0.8000,-2.8391,-0.3587
00056  PTMEAS/CART,0.8000,-3.1220,-0.6415,0.000000,0.707107,0.707107
00057  GOTO/0.8000,-3.3714,0.2383
00058  GOTO/0.8000,-4.5282,0.8935
00059  GOTO/0.8000,-5.8095,1.2482
00060  PTMEAS/CART,0.8000,-6.6080,0.8025,0.000000,0.000000,1.000000
00061  GOTO/0.8000,-7.4065,1.2482
00062  GOTO/0.8000,-8.6878,0.8935
00063  GOTO/0.8000,-9.8446,0.2383
00064  PTMEAS/CART,0.8000,-10.0940,-0.6415,0.000000,-0.707107,0.707107
00065  GOTO/0.8000,-12.1379,-1.8476
00066  PTMEAS/CART,0.8000,-11.5380,-4.1275,0.000000,-1.000000,0.000000
00067  ENDMES
00068  D(PCS4)=TRANS/YORIG,FA(CIR1),ZORIG,FA(CIR1)
00069  GOTO/-16.0000,-6.3300,3.7000
00070  GOTO/-16.0000,-6.3300,50.0000
00071  SNSLCT/SA(3_A90.0_B90.0)
00072  GOTO/-8.9000,-4.0000,25.0000
00073  F(PLN1)=FEAT/PLANE,CART,0.0000,0.0000,-1.0400,-1.000000,0.000000,0.000000
00074  MEAS/PLANE,F(PLN1),5
00075  GOTO/-0.6500,-2.6865,3.2258

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00076 PTMEAS/CART,0.0000,-2.6865,3.2258,-1.000000,0.000000,0.000000
00077 PTMEAS/CART,0.0000,2.6932,3.0790,-1.000000,0.000000,0.000000
00078 PTMEAS/CART,0.0000,3.2745,-2.0091,-1.000000,0.000000,0.000000
00079 PTMEAS/CART,0.0000,0.2942,-3.6220,-1.000000,0.000000,0.000000
00080 PTMEAS/CART,0.0000,-2.8684,-1.8957,-1.000000,0.000000,0.000000
00081 GOTO/-0.6500,-2.8684,-1.8957
00082 ENDMES
00083 DATDEF/FA(PLN1),DAT(A)
00084 D(PCS5)=DATSET/DAT(A),-XDIR,XORIG
00085 F(LIN1)=FEAT/LINE,BND,CART,0.0000,-4.8190,-1.0400,0.0000,4.8191,-1.0400,$
00086 1.000000,0.000000,0.000000
00087 MEAS/LINE,F(LIN1),3
00088 GOTO/-0.6500,-2.8684,-0.4851
00089 GOTO/0.2413,-4.6691,-0.6401
00090 PTMEAS/CART,0.2413,-4.6691,-1.0400,0.000000,0.000000,1.000000
00091 PTMEAS/CART,0.2413,0.0000,-1.0400,0.000000,0.000000,1.000000
00092 PTMEAS/CART,0.2413,4.6691,-1.0400,0.000000,0.000000,1.000000
00093 GOTO/0.2413,4.6691,-0.6401
00094 ENDMES
00095 D(PCS1)=ROTATE/XAXIS,FA(LIN1),YDIR
00096 GOTO/-3.0000,-5.0000,-2.0000
00097 F(CIR2)=FEAT/CIRCLE,OUTER,CART,0.5300,0.0000,-0.0000,1.000000,0.000000,$
00098 -0.000000,9.8600
00099 MEAS/CIRCLE,F(CIR2),7
00100 GOTO/1.2800,-4.9488,-1.9795
00101 PTMEAS/CART,1.5300,-4.5774,-1.8310,0.000000,-0.928479,-0.371384
00102 GOTO/1.5300,-4.5980,-2.8974
00103 GOTO/1.5300,-3.6706,-4.0079
00104 GOTO/1.5300,-2.4830,-4.8344
00105 PTMEAS/CART,1.5300,-1.4225,-4.7204,-0.000000,-0.288539,-0.957468
00106 GOTO/1.5300,-0.6016,-5.4014
00107 GOTO/1.5300,0.8449,-5.3687
00108 GOTO/1.5300,2.2315,-4.9555
00109 PTMEAS/CART,1.5300,2.8036,-4.0553,-0.000000,0.568677,-0.822561
00110 GOTO/1.5300,3.8479,-3.8381
00111 GOTO/1.5300,4.7242,-2.6868
00112 GOTO/1.5300,5.2657,-1.3451
00113 PTMEAS/CART,1.5300,4.9185,-0.3365,-0.000000,0.997668,-0.068250

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00114  → GOTO/1.5300,5.3998,0.6154
00115  → GOTO/1.5300,5.0461,2.0183
00116  → GOTO/1.5300,4.3347,3.2782
00117  PTMEAS/CART,1.5300,3.3297,3.6366,0.000000,0.675397,0.737454
00118  → GOTO/1.5300,2.8856,4.6054
00119  → GOTO/1.5300,1.5682,5.2036
00120  → GOTO/1.5300,0.1396,5.4329
00121  PTMEAS/CART,1.5300,-0.7664,4.8700,0.000000,-0.155460,0.987842
00122  → GOTO/1.5300,-1.8015,5.1274
00123  → GOTO/1.5300,-3.0906,4.4704
00124  → GOTO/1.5300,-4.1606,3.4965
00125  PTMEAS/CART,1.5300,-4.2854,2.4372,0.000000,-0.869253,0.494367
00126  → GOTO/1.2800,-4.6331,2.6349
00127  L  ENDMES
00128  T(CIR2_DIAM)=TOL/DIAM,-0.0300,0.0000
00129  OUTPUT/FA(CIR2),TA(CIR2_DIAM)
00130
00131  → GOTO/-3.0000,-5.0000,-2.0000
00132  $$
00133  D(PC57)=TRANS/YORIG,FA(CIR2),ZORIG,FA(CIR2)
00134  → GOTO/-2.0000,3.1905,0.0000
00135  → GOTO/-1.3930,0.0000,0.0000
00136  $$TEXT/OUTFIL,'=====
00137  TEXT/OUTFIL,'Key #2 Datum A diameter (9.86-9.83)'
00138  T(CIR2_D)=TOL/DIAM,-0.03,0
00139  OUTPUT/FA(CIR2),TA(CIR2_D)
00140  F(CYL1)=FEAT/CYLNR,INNER,CART,0.5300,0.0000,0.0000,1.000000,0.000000,0.000000,$
00141  1.5750,1.0253
00142  MEAS/CYLNR,F(CYL1),8
00143  → GOTO/0.6800,0.3864,0.0289
00144  PTMEAS/CART,0.6800,0.7853,0.0589,0.000000,-0.997197,-0.074822
00145  PTMEAS/CART,0.6800,-0.0589,0.7852,-0.000000,0.074822,-0.997197
00146  PTMEAS/CART,0.6800,-0.7853,-0.0590,-0.000000,0.997197,0.074822
00147  PTMEAS/CART,0.6800,0.0589,-0.7853,0.000000,-0.074822,0.997197
00148  PTMEAS/CART,1.4053,0.7853,0.0589,0.000000,-0.997197,-0.074822
00149  PTMEAS/CART,1.4053,-0.0589,0.7852,-0.000000,0.074822,-0.997197
00150  PTMEAS/CART,1.4053,-0.7853,-0.0590,-0.000000,0.997197,0.074822
00151  PTMEAS/CART,1.4053,0.0589,-0.7853,0.000000,-0.074822,0.997197

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00152  GOTO/0.6800,0.0290,-0.3865
00153  L
00154  ENDMES
00154  $$$TEXT/OUTFIL,' Key #4 Center hole diameter 1.575mm(1.555-1.655) or 0.0620"(0.0613 - 0.0651)'
00155  TEXT/OUTFIL,'
00156  T(TOL4) = TOL/DIAM,-0.02,0.08
00157  OUTPUT/FA(CYL1),TA(TOL4)
00158  GOTO/-0.8550,0.0000,-0.3860
00159  GOTO/-4.5000,0.0000,72.0000
00160  SNSLCT/SA(3_A0_0_B0.0)
00161  GOTO/-0.5000,0.0000,8.0000
00162  $$ Start profile of groove
00163  F(PNT4)=FEAT/POINT,CART,1.4259,0.0000,-4.9289,-0.000000,0.000000,1.000000
00164  MEAS/POINT,F(PNT4),1
00165  GOTO/1.1865,0.0000,7.8215
00166  PTMEAS/CART,1.1865,0.0000,4.9204,0.000000,0.000000,1.000000
00167  GOTO/1.1865,0.0000,7.8215
00168  L
00168  ENDMES
00169  F(PNT5)=FEAT/POINT,CART,3.7891,0.0000,4.9273,0.000000,0.000000,1.000000
00170  MEAS/POINT,F(PNT5),1
00171  GOTO/3.7891,0.0000,7.8284
00172  PTMEAS/CART,3.7891,0.0000,4.9273,0.000000,0.000000,1.000000
00173  GOTO/3.7891,0.0000,7.8284
00174  L
00174  ENDMES
00175  F(LIN2)=FEAT/LINE,BND,CART,1.1865,0.0000,4.9204,3.7891,0.0000,4.9273,0.000000,$
00176  1.000000,0.000000
00177  CONST/LINE,F(LIN2),BF,FA(PNT4),FA(PNT5)
00178  F(PNT6)=FEAT/POINT,CART,5.12767,0.00000,4.84482,0.707107,0.000000,0.707107
00179  MEAS/POINT,F(PNT6),1
00180  GOTO/5.6147,0.0000,5.2844
00181  PTMEAS/CART,5.12767,0.00000,4.84482,0.707107,0.000000,0.707107
00182  GOTO/5.6147,0.0000,5.2844
00183  L
00183  ENDMES
00184  F(PNT7)=FEAT/POINT,CART,5.44586,0.00000,4.52663,0.707107,0.000000,0.707107
00185  MEAS/POINT,F(PNT7),1
00186  GOTO/6.0927,0.0000,5.1615
00187  PTMEAS/CART,5.44586,0.00000,4.52663,0.707107,0.000000,0.707107
00188  GOTO/6.0927,0.0000,5.1615
00189  L
00189  ENDMES

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00190 F(LIN3)=FEAT/LINE,BND,CART,5.12767,0.00000,4.84482,5.44686,0.00000,4.52663,$
00191 0.00000,1.000000,0.000000
00192 CONST/LINE,F(LIN3),BF,FA(PNT6),FA(PNT7)
00193 F(PNT9)=FEAT/POINT,CART,5.78160,0.00000,4.41000,0.000000,0.000000,1.000000
00194 MEAS/POINT,F(PNT9),1
00195 GOTO/5.7816,0.0000,5.0563
00196 PTMEAS/CART,5.78160,0.00000,4.41000,0.000000,0.000000,1.000000
00197 GOTO/5.7816,0.0000,5.0563
00198 ENDMES
00199 F(PNT10)=FEAT/POINT,CART,6.70530,0.00000,4.41000,0.000000,0.000000,1.000000
00200 MEAS/POINT,F(PNT10),1
00201 GOTO/6.7053,0.0000,5.0598
00202 PTMEAS/CART,6.70530,0.00000,4.41000,0.000000,0.000000,1.000000
00203 GOTO/6.7053,0.0000,5.0598
00204 ENDMES
00205 F(PNT11)=FEAT/POINT,CART,7.03038,0.00000,4.46288,-0.707107,0.000000,0.707107
00206 MEAS/POINT,F(PNT11),1
00207 GOTO/6.6370,0.0000,4.9946
00208 PTMEAS/CART,7.03038,0.00000,4.46288,-0.707107,0.000000,0.707107
00209 GOTO/6.6370,0.0000,4.9946
00210 ENDMES
00211 F(PNT12)=FEAT/POINT,CART,7.34858,0.00000,4.78108,-0.707107,0.000000,0.707107
00212 MEAS/POINT,F(PNT12),1
00213 GOTO/6.8987,0.0000,5.2576
00214 PTMEAS/CART,7.34858,0.00000,4.78108,-0.707107,0.000000,0.707107
00215 GOTO/6.8987,0.0000,5.2576
00216 ENDMES
00217 F(PNT13)=FEAT/POINT,CART,7.7481,0.0000,4.9272,0.000000,0.000000,1.000000
00218 MEAS/POINT,F(PNT13),1
00219 GOTO/7.7481,0.0000,5.5772
00220 PTMEAS/CART,7.7481,0.0000,4.9272,0.000000,0.000000,1.000000
00221 GOTO/7.7481,0.0000,5.5772
00222 ENDMES
00223 F(PNT14)=FEAT/POINT,CART,8.7717,0.0000,4.9274,0.000000,0.000000,1.000000
00224 MEAS/POINT,F(PNT14),1
00225 GOTO/8.7717,0.0000,5.5774
00226 PTMEAS/CART,8.7717,0.0000,4.9274,0.000000,0.000000,1.000000
00227 GOTO/8.7717,0.0000,5.5774

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00228 L   ENDMES
00229 F(LIN4)=FEAT/LINE,BND,CART,5.7816,0.0000,4.4053,6.7053,0.0000,4.4098,0.000000,$
00230 1.000000,0.000000
00231 CONST/LINE,F(LIN4),BF,FA(PNT9),FA(PNT10)
00232 F(LIN5)=FEAT/LINE,BND,CART,7.03038,0.00000,4.46288,7.34858,0.00000,4.78108,$
00233 0.000000,1.000000,0.000000
00234 CONST/LINE,F(LIN5),BF,FA(PNT11),FA(PNT12)
00235 F(LIN6)=FEAT/LINE,BND,CART,7.7481,0.0000,4.9272,8.7717,0.0000,4.9274,0.000000,$
00236 1.000000,0.000000
00237 CONST/LINE,F(LIN6),BF,FA(PNT13),FA(PNT14)
00238 F(PNT15)=FEAT/POINT,CART,5.05000,0.00000,4.92250,0.000000,-1.000000,0.000000
00239 CONST/POINT,F(PNT15),INTOF,FA(LIN2),FA(LIN3)
00240 F(PNT16)=FEAT/POINT,CART,7.49000,0.00000,4.92250,0.000000,1.000000,0.000000
00241 CONST/POINT,F(PNT16),INTOF,FA(LIN6),FA(LIN5)
00242 $$ End top profile of groove
00243 $$ Start radial profile of groove
00244 D(PCS10)=ROTATE/XAXIS,7.000
00245 GOTO/4.3000,0.0000,6.3900
00246 F(PNT17)=FEAT/POINT,CART,4.42880,0.00000,4.92250,0.000000,0.000000,1.000000
00247 MEAS/POINT,F(PNT17),1
00248 GOTO/4.4288,0.0000,5.5728
00249 PTMEAS/CART,4.42880,0.00000,4.92250,0.000000,0.000000,1.000000
00250 GOTO/4.4288,0.0000,5.5728
00251 L   ENDMES
00252 F(PNT18)=FEAT/POINT,CART,6.2383,0.0000,4.4100,-0.000000,0.000000,1.000000
00253 MEAS/POINT,F(PNT18),1
00254 GOTO/6.2383,0.0000,5.0599
00255 PTMEAS/CART,6.2383,-0.0000,4.4100,-0.000000,0.000000,1.000000
00256 GOTO/6.2383,0.0000,5.0599
00257 L   ENDMES
00258 F(PNT19)=FEAT/POINT,CART,6.27000,-0.79574,4.49824,0.000000,0.707107,0.707107
00259 MEAS/POINT,F(PNT19),1
00260 GOTO/6.27000,-0.31860,4.95060
00261 PTMEAS/CART,6.27000,-0.79574,4.49824,0.000000,0.707107,0.707107
00262 GOTO/6.27000,-0.31860,4.95060
00263 L   ENDMES
00264 F(PNT20)=FEAT/POINT,CART,6.27000,-1.00787,4.71037,0.000000,0.707107,0.707107
00265 MEAS/POINT,F(PNT20),1

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00266  GOTO/6.27000,-0.54110,5.17360
00267  PTMEAS/CART,6.27000,-1.00787,4.71037,0.000000,0.707107,0.707107
00268  GOTO/6.27000,-0.54110,5.17360
00269  ENDMES
00270  F(LIN7)=FEAT/LINE,BND,CART,6.27000,-0.79574,4.49824,6.27000,-1.00787,4.71037,$
00271  1.000000,0.000000,0.000000
00272  CONST/LINE,F(LIN7),BF,FA(PNT19),FA(PNT20)
00273  F(PLN2)=FEAT/PLANE,CART,4.42880,0.00000,4.92250,0.000000,0.000000,1.000000
00274  CONST/PLANE,F(PLN2),PARTO,FA(XY-PLANE),THRU,FA(PNT17)
00275  F(PNT21)=FEAT/POINT,CART,6.27000,-1.22000,4.92250,0.000000,0.000000,1.000000
00276  CONST/POINT,F(PNT21),INTOF,FA(LIN7),FA(PLN2)
00277  $$$TEXT/OUTFIL,'=====
00278  TEXT/OUTFIL,'Key #436001-04 Radial location of 7degree (1.1mm, 0.4mm profile) '
00279  T(DIST1_Y)=TOL/DISTB,NOMINL,1.22000,-0.2000,0.2000,YAXIS
00280  OUTPUT/FA(ZX-PLANE),FA(PNT21),TA(DIST1_Y)
00281  $$
00282  D(PCS11)=ROTATE/XAXIS,-38.00
00283  GOTO/4.2000,0.0000,6.0000
00284  F(PNT22)=FEAT/POINT,CART,4.19830,0.00000,4.92250,0.000000,0.000000,1.000000
00285  MEAS/POINT,F(PNT22),1
00286  GOTO/4.1983,0.0000,5.5145
00287  PTMEAS/CART,4.19830,0.00000,4.92250,0.000000,0.000000,1.000000
00288  GOTO/4.1983,0.0000,5.5145
00289  ENDMES
00290  F(PNT23)=FEAT/POINT,CART,6.2086,0.0000,4.4100,0.000000,0.000000,1.000000
00291  MEAS/POINT,F(PNT23),1
00292  GOTO/6.2086,0.0000,5.0599
00293  PTMEAS/CART,6.2086,0.0000,4.4100,0.000000,-0.000000,1.000000
00294  GOTO/6.2086,0.0000,5.0599
00295  ENDMES
00296  F(PNT24)=FEAT/POINT,CART,6.27000,0.79574,4.49824,0.000000,-0.707107,0.707107
00297  MEAS/POINT,F(PNT24),1
00298  GOTO/6.27000,0.33500,4.96640
00299  PTMEAS/CART,6.27000,0.79536,4.49824,0.000000,-0.707107,0.707107
00300  GOTO/6.27000,0.33500,4.96640
00301  ENDMES
00302  F(PNT25)=FEAT/POINT,CART,6.27000,1.00787,4.71037,0.000000,-0.707107,0.707107
00303  MEAS/POINT,F(PNT25),1

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00304 GOTO/6.27000,0.50410,5.13830
00305 PTMEAS/CART,6.27000,1.00787,4.71037,0.000000,-0.707107,0.707107
00306 GOTO/6.27000,0.50410,5.13830
00307 ENDMES
00308 F(PLN3)=FEAT/PLANE,CART,4.19830,0.00000,4.92250,0.000000,0.000000,1.000000
00309 CONST/PLANE,F(PLN3),PARTO,FA(XY-PLANE),THRU,FA(PNT22)
00310 F(LIN10)=FEAT/LINE,BND,CART,6.27000,0.79574,4.49824,6.27000,1.00787,4.71037,$
00311 1.000000,0.000000,0.000000
00312 CONST/LINE,F(LIN10),BF,FA(PNT24),FA(PNT25)
00313 F(PNT26)=FEAT/POINT,CART,6.27000,1.22000,4.92250,0.000000,0.000000,1.000000
00314 CONST/POINT,F(PNT26),INTOF,FA(LIN10),FA(PLN3)
00315 $$TEXT/OUTFIL,'=====
00316 TEXT/OUTFIL,'Key #436001-03 Radial location of 31 degree (1.1mm, 0.4mm profile) '
00317 T(DIST1_Y2_Y)=TOL/DISTB,NOMINL,1.22000,-0.2000,0.2000,YAXIS
00318 OUTPUT/FA(PNT26),FA(ZX-PLANE),TA(DIST1_Y2_Y)
00319 D(PCS12)=ROTATE/XAXIS,31.000
00320 $$ End radial profile of groove
00321 $$TEXT/OUTFIL,'=====
00322 TEXT/OUTFIL,'Key #5 Groove center to datum -C- (6.27mm, 0.4mm profile) '
00323 TEXT/OUTFIL,' ***** Engineering Info Only *****
00324 F(PNT27)=FEAT/POINT,CART,6.27000,0.00000,3.70249,0.000000,1.000000,0.000000
00325 CONST/POINT,F(PNT27),INTOF,FA(LIN3),FA(LIN5)
00326 T(DIST7_X1_X)=TOL/DISTB,NOMINL,6.27000,-0.2000,0.2000,XAXIS
00327 OUTPUT/FA(PNT27),FA(ORIGIN),TA(DIST7_X1_X)
00328 $$TEXT/OUTFIL,'=====
00329 TEXT/OUTFIL,' Key #436002 Radial depth of groove (4.36 - 4.46)mm '
00330 T(DIST3_Z)=TOL/DISTB,NOMINL,4.41000,-0.05000,0.05000,ZAXIS
00331 OUTPUT/FA(PNT10),FA(ORIGIN),TA(DIST3_Z)
00332 $$TEXT/OUTFIL,'=====
00333 TEXT/OUTFIL,' Key #3 Distance from -A- center to datum -B- (1.02 - 1.07)mm '
00334 T(DIST4_Z)=TOL/DISTB,NOMINL,1.0400,-0.0200,0.0300,ZAXIS
00335 OUTPUT/FA(ORIGIN),FA(LIN1),TA(DIST4_Z)
00336 $$TEXT/OUTFIL,'=====
00337 TEXT/OUTFIL,' Key #436001-01 Groove location furthest from datum -C- (1.22mm, 0.4mm profile) '
00338 T(DIST6_X)=TOL/DISTB,NOMINL,7.49000,-0.2000,0.2000,XAXIS
00339 OUTPUT/FA(PNT16),FA(ORIGIN),TA(DIST6_X)
00340 $$TEXT/OUTFIL,'=====
00341 TEXT/OUTFIL,' Key #436001-02 Groove location closest to datum -C- (1.22mm, 0.4mm profile) '
00342 T(DIST7_X)=TOL/DISTB,NOMINL,5.0500,-0.2000,0.2000,XAXIS
00343 OUTPUT/FA(PNT15),FA(ORIGIN),TA(DIST7_X)
00344 TEXT/OPER,'REPOSITION PROBE FOR NEXT PART'
00346 GOTO/4.8000,6.5000,5.6000
00346 ENDFIL
00347 ----- End DMIS Code -----

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Piston, 2Z Valve

Plunger Valve Part Drawing

Fixture Design

Appendix B – Additional Project Information

Software and Hardware Info

Silma XG V9.01 Shared license, 2 unclassified, 1 classified.

Metrolog XG V9.01 Dongle 7115 – D93
 Dongle 7212 – Precision Measurement

CMM: Image 555,
Controller: Brown & Sharp

Software Quality Assurance Documentation

SOFTWARE QUALITY ASSURANCE PLAN FOR IN-PROCESS CMM

1. Background

This plan has been written to comply with the (SQA) requirements of Software Quality Assurance in Command Media. Software for this equipment meets the criteria found in Determine Software SQA category per Command Media (for Category 2 software). This SQA plan addresses the configuration management, verification, and validation of program files created by KCP personnel for the In-Process verification of production parts. The In-Process verification is operated via Metrolog XG software, programs stored on hard-drives, and manufacturing personnel manual inputs.

2. Definitions

System Software: The operating software which integrates the PC and CMM controller. This CE# system is Window base systems.

Executive software: The CMM software which supplies the specific information required to verify in-process machined dimensions by controlling a motorized 3D touch trigger probe head to verify product. This program is created by KCP personnel. The file name (program name) of the appropriate software will be based on part number and operation ID of the production traveler.

Secondary software: DataPage is secondary software included in Software Maintenance Agreement (SMA) to be used to analyze CMM data.

Machine Type	Operating System	Executive System
Global Activ 555	Windows XP Pro.	Metrolog XG

Full Control Mode: Full access mode in which programmers use Metrolog XG to write, edit, and maintain programs

Operator Mode: Limited access mode in which machinists can operate the CMM system & Metrolog XG to verify dimensions. Programs can not be altered or edited.

3. Organization, Tasks, and Responsibilities

The Process Engineer is responsible for writing the program that is used to verify in-process product in Department A. Manufacturing personnel use the Metrolog XG software to verify their work in the Operator Mode. If a program has not been written, manufacturing personnel may request responsible personnel to provide a CMM program based on information supplied in the production traveler or specified drawing to run the job.

4. Configuration Management

The master copy of updated software is stored in the cabinet adjacent to the CMM. A ghost of the hard drive is located under the Test Equipment CMM Projects folder. Manufacturer provides software in CD.

The Process Engineer will ascertain the correct issue and incorporate it into the assigned folder to be used in Operator Mode.

A folder may have more than one working program in it, **but must not contain two issues of the same program**. The old program can be kept in separated folder from the master in the disk directory. CMM programs will be backed up on a defined period (once a month) into d93cmm directory.

5. Software Verification and Validation

Process Engineer may select the most stable version of Executive software to operate the CMM.

- a. The Process Engineer will create or revise programs according to product requirements.
- b. The CMM program will be validated by the Process Engineer that it marks the correct information.
- c. Once validation is complete, the Process Engineer shall remove the old version from the working folder.
- d. Management and validation of the system software is the responsibility of Equipment Maintenance Engineering department.

6. Software Documentation

SMA is the system software documentation between the equipment manufacturer and the Kansas City Plant.

7. Software Backups

Program Backups, either on floppy disc or paper printout, shall exist for every current program on disk in excess of one Data Block or of suitable complexity to be saved. Backups shall be kept by the Engineering section responsible for writing the program. If backup copies of past issues or archived files are maintained, keep them labeled as “Outdated” or “History” and keep them unavailable to Manufacturing.

The system disk backup can be a physical backup or in the event of a manufacturer’s copy protection, can consist of a printed computer code. System backups are stored by Equipment Maintenance Engineering or the Maintenance Crib responsible for the equipment.