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SPC Techniques for the M-48 Coordinate Measurement Machine Applied to Uncertainty Analysis and Monitoring

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INTRODUCTION

The Moore M-48 Coordinate Measuring Machine (CMM) is used to calibrate step gages, ball bars and hole plates. The expanded uncertainty (2 sigma) of the M-48 CMM was determined to be $\pm 0.3 + 0.4$ L microns (L is length in meters), using the decomposition method[1]. The problem statement becomes, how do we monitor and control the calibration process to ensure that we maintain this level of reliability? Traditional methods of statistical process control, such as X-bar and R charts assume large lot production and are designed to detect changes in the process being monitored. Since calibrations are performed one at a time, with sometimes years between calibrations, standard control charting methodology falls a bit short of what is needed to maintain process capability.

DISCUSSION

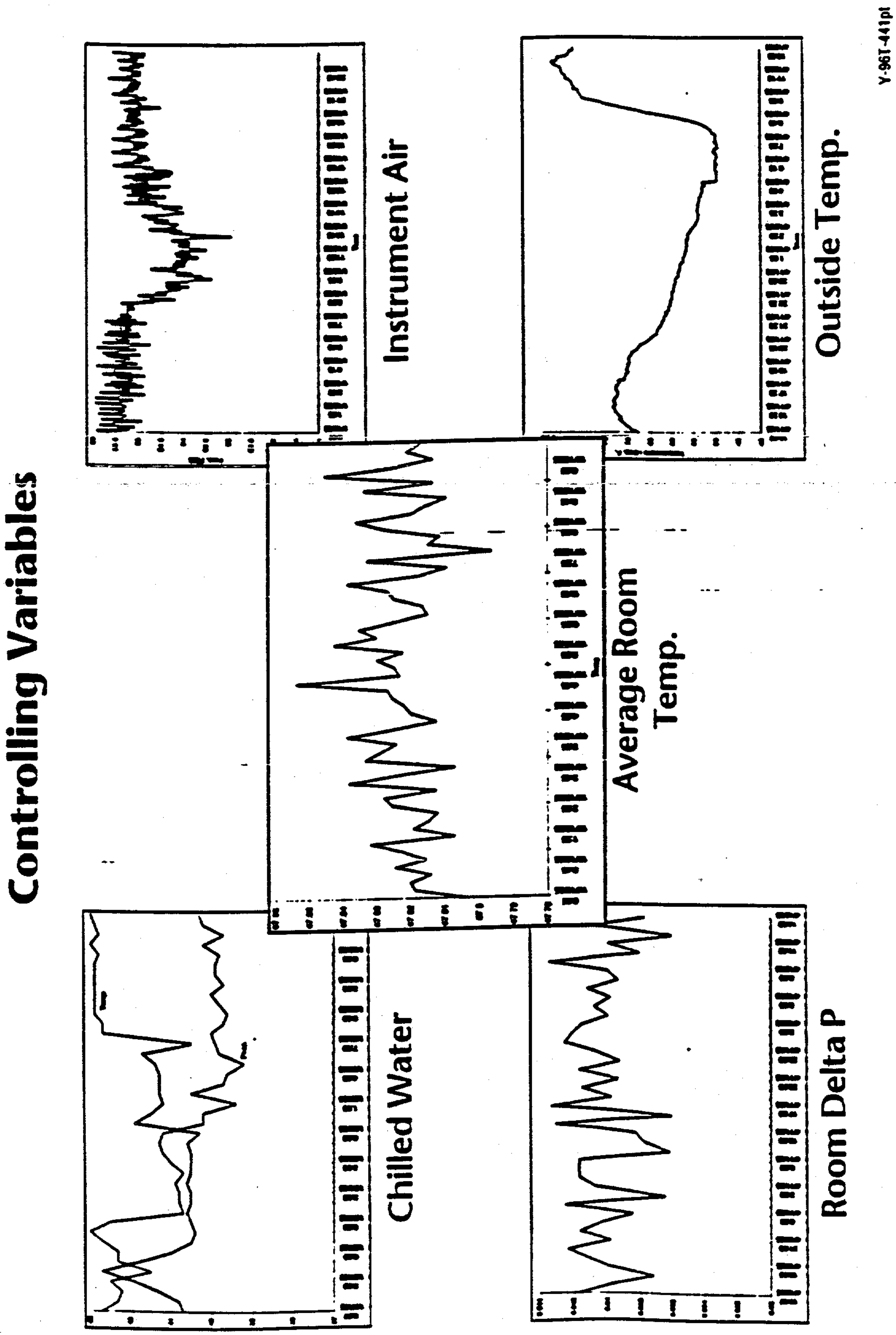
A link to the uncertainty analysis must be made to determine how to monitor the results of each calibration. Upon examination of the process uncertainty for the M-48 CMM we find the following parameters play an important roll in process capability. Since the M-48 uses laser scales, the Edlén equation is used to convert pressure, temperature and humidity to wavelength correction. The largest source of uncertainty comes from temperature effects based on gradients, accuracy of the thermistors and the actual coefficient of thermal expansion of the artifact. The probe calibration, which is performed for each calibration, is another important variable. Since the M-48 CMM's movement is very slow, drift is also an important parameter to monitor.

APPLICATION

The selection of check standards and measurement protocol is made based on the discussion above. Since temperature, pressure and humidity play an important role in the M-48's uncertainty the room's environment is closely controlled and monitored. The check standards used to monitor and track process capability are chosen in part to detect changes in environmental parameters. This serves to provide a backup to our environmental monitoring system. By using a Zerodur Cylinder with a zero coefficient of thermal expansion and two steel check standards of varying length we can detect environmental changes which affect the calibration. The Zerodur Cylinder takes temperature out of the picture. This allows us to detect errors, or drift in the thermistors used to monitor room, machine and artifact temperature. If all of the check standards are out of control, then we know that temperature was not the culprit but humidity, pressure, and probe calibration are key suspects.

X-bar, R and moving R charts are used to monitor process capability and repeatability of the check standards. The moving range chart estimates process variability. A spike in the moving range chart could detect an environmental change that affects all the check standards equally. When we have historical date on the artifact under calibration we also compare the standard deviations and repeatability between calibrations.

Using these techniques we've been able to detect small changes in room environment, small movements of the probe calibration gage block and small bends in artifacts which occurred between calibrations. These charts indicate the environmental parameters which we keep a close eye on.



EXAMPLES

In 1996 we ran an experiment to determine the effects of having a person in the M-48 CMM room on artifact temperature. Figure 1 illustrates the location of the person for the experiment and the setup used on the M-48 CMM.

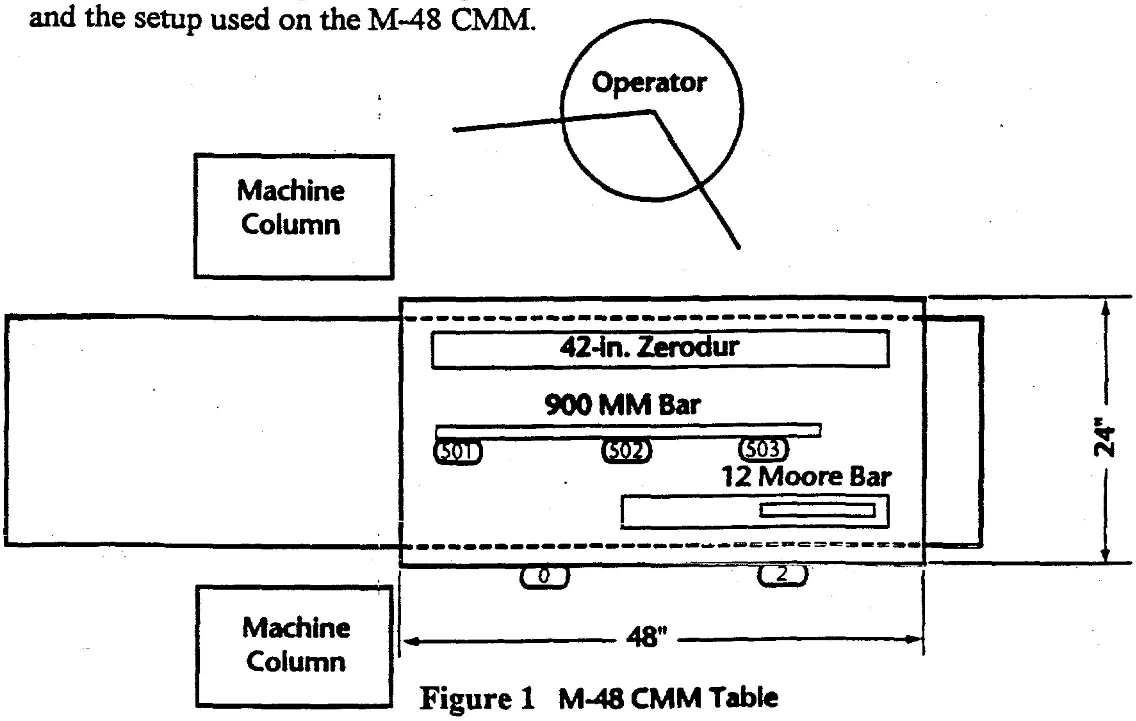


Figure 1 M-48 CMM Table

Figure 2 shows the effect that the heat load of one person in the M-48 measurement room has after five minutes. It takes 1 hr. and 45 minutes for the temperature of the 900-mm rectangular block to stabilize.

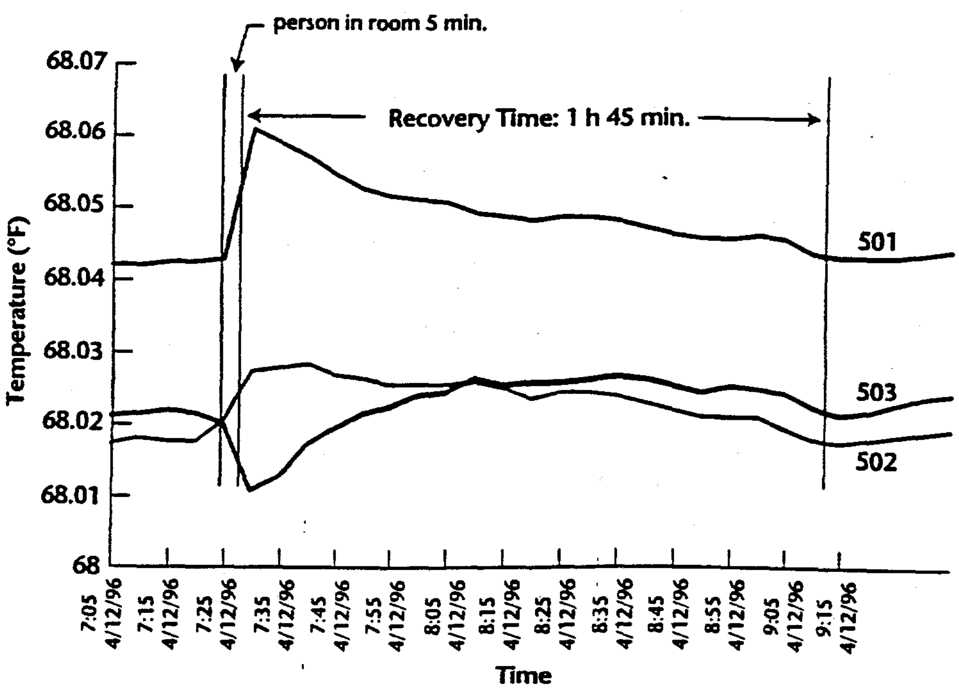


Figure 2

On November 11 the Moore bar check standard was replaced with two gage blocks. This allowed us to modify our calibration routine to reduce the calibration time, thereby reducing drift error. Gage blocks have a lower uncertainty than a Moore bar, which also gives us the ability to detect finer process changes. The new configuration is illustrated by Figure 3.

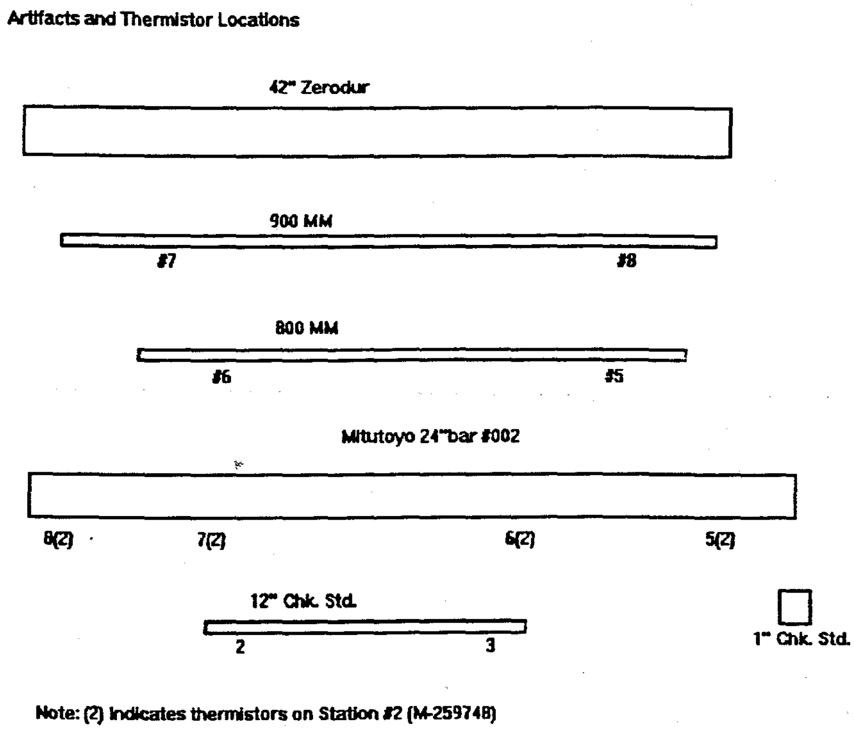


Figure 3 M-48 CMM Typical Artifact Setup

After making this configuration change and changed the calibration routine, we saw a step change in our temperature control. You can see this in the series of temperature control charts (Figures 4, 5 & 6) for the 900-mm rectangular block. The average temperature became more stable and moved closer to 20°C. This demonstrates how you can use statistical information to guide you in making minor process changes that can have a significant impact on repeatability.

Figure 4, illustrated on the following page, specifically shows the affect on the control chart and how the process moved in an incremental manner. Figure 5 shows the process control chart prior to changing the calibration routine. Figure 6 shows the new control parameters and improved process repeatability.

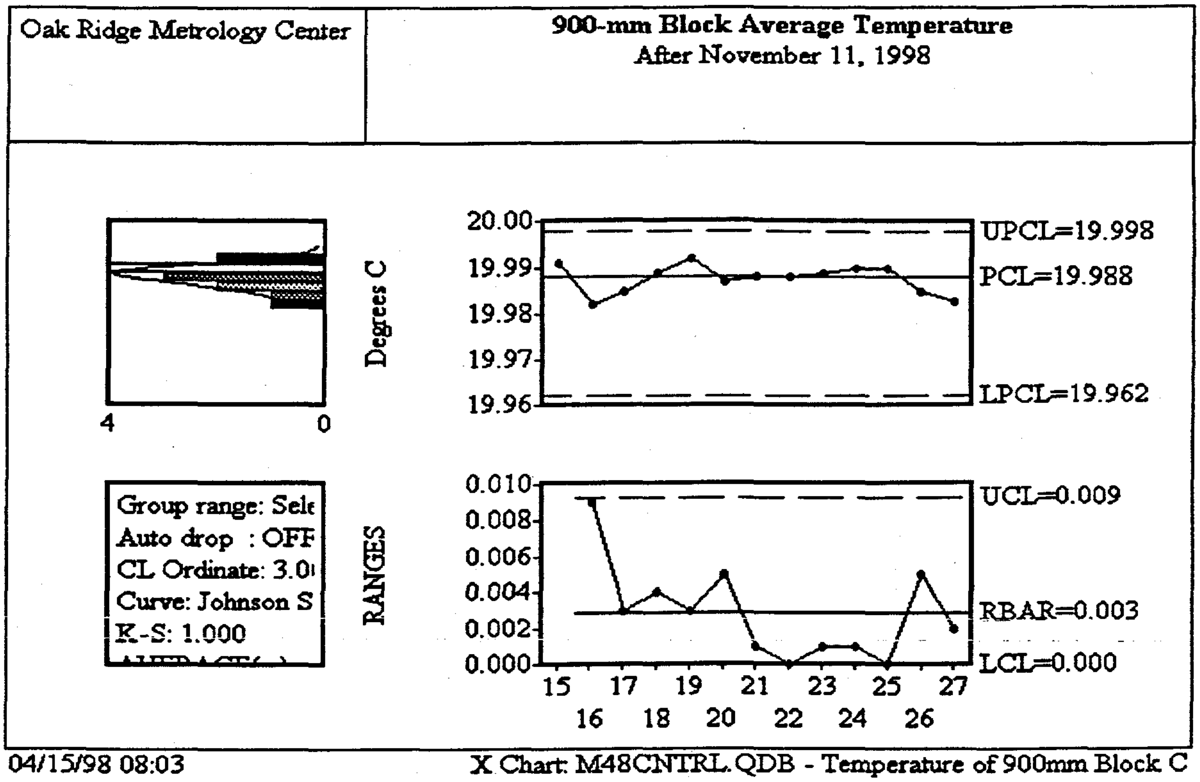


Figure 6 After Calibration Routine Change

CONCLUSION

Through the use of control standards and statistical methods we can monitor and improve the calibration process. Statistical methods can be used to validate designed experiments and subsequently monitor and maintain process capability and reliability.

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[1] B. Rasnick, B. Cox, M. Sherrill, *Determination Measurement Uncertainty on Coordinate Measurement Machines by Measurement Decomposition and Utilization of Reference Artifacts*