APPENDIX F

CONTROL CHARTS

Accuracy control (A/C) is based on the variation of products manufactured in the same manner. Even for controlled processes, i.e., where work circumstances do not change, some chance or random variation is normal. As variation is expected, A/C is also concerned with detecting when a process is deviating from its controlled condition. In other words, A/C/ engineers must be alert for variations which are not due to chance as they are indicators that something or someone is changing how work is being performed.

A/C engineers employ two kinds of charts for control purposes. One is for measurements such as the lengths of flat bars and the other addresses frequencies or counted data, e.g., the number in a sample of 100 that require rework. Both charts employ central lines indicating the average performance expected of a process and upper and lower control-limit lines. The limits are chosen so that values between them represent only normal, random variation. Values beyond the upper and lower control limits indicate that a work process is out of control. By plotting values of samples taken periodically, A/C engineers can also detect a drift toward loss of control.

Control of a work process is facilitated by maintaining plots of mean value ($\bar{x}$) and range (R) or standard deviation (σ). As the population mean and standard deviation are generally unknown, they are estimated by first obtaining a number of samples (k), each of the same size(n). The mean ($\bar{x}$) of the sample mean (x_i) is calculated as:

$$\bar{\bar{x}} = \frac{1}{k} \sum_{i=1}^{k} \bar{x}_i$$

and then assumed to be the estimated population mean.

In order to estimate the standard deviation of the population it is necessary to calculate the standard deviation for each sample. Because it is easier to obtain, range (R) is a preferred indicator. The range of variation of each sample (R_i) is used to calculate the mean range:

$$\bar{R} = \frac{1}{k} \sum_{i=1}^{k} R_i$$

The cental line for the mean or $\bar{x}$ chart is $\bar{\bar{x}}$, since it is an unbiased estimate of the population mean ($\bar{x}^1$). The mean range, $\bar{R}$, is not an unbiased estimate of the population standard deviation. But, if a normal distribution of the population is assumed, $\bar{R}$ can be used to get an unbiased estimate of the upper control limit (UCL) and the lower control limit (LCL).

A common approach employs the "three sigma limits", i.e.,

$$\bar{x}^1 \pm \frac{3\sigma}{\sqrt{n}}$$

Then, $A_2\bar{R}$ is substituted as an unbiased estimate of $3\sigma/\sqrt{n}$ and the Constant A_2 for a given sample size is obtained from a Table of Control Chart Constants (see ASTM Manual on Quality Control of Materials, American Society for Testing and Materials, Philadelphia, Pa., 1951). Thus for the mean or $\bar{x}$ chart:

$$\text{central line} = \bar{\bar{x}}$$
$$\text{UCL} = \bar{\bar{X}} + A_2R$$
$$\text{LCL} = \bar{\bar{X}} - A_2R$$

A similar approach is used for the range or R chart for which:

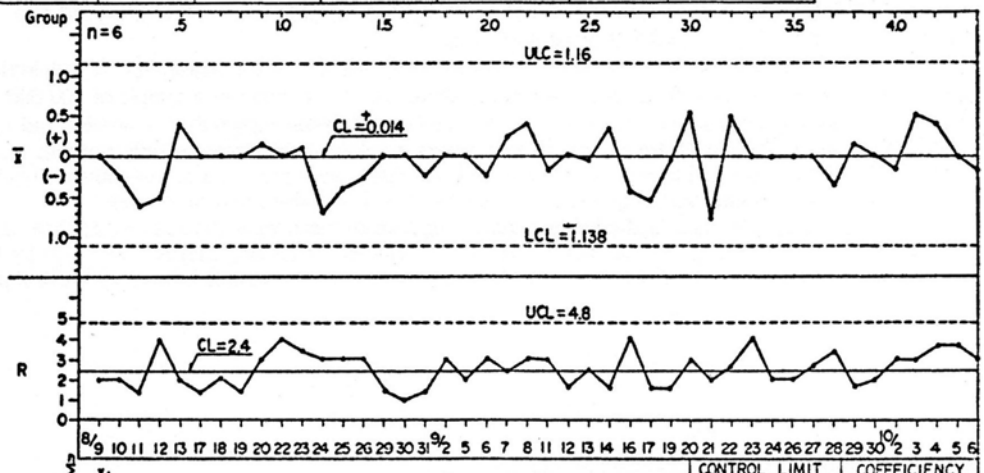
$$\text{cental line} = \bar{R}$$
$$\text{UCL} = D_4\bar{R}$$
$$\text{LCL} = D_3\bar{R}$$

where D_4 and D_3 are contants obtained from the same Table of Control Chart Constants.

Examples of control charts follow:

ACCURACY CONTROL GRAPH FOR SUMMARY OF GAS CUTTING BY FABRICATION SHOP, HULL CONSTRUCTION WORK SHOP

QUALITY PROPERTY	CUTTING ACCURCY	MEASURED POSITION	ENDS OF PARTS	FINAL CHECKER	ENGINEER IN CHARGE	SAMPLING	FREQ.	6/DAY
MEASURED PLACE	EVERYWHERE	MEASURING PERSON	WORKER	GRAPH MAKER	STAFF OF ACCURACY CONT.		METHOD	RANDOM
MEASURING INSTRUM'T	PRESCRIBED	ALLOWANCE LIMIT	BY ACCURACY STANDARD	INSTRUCTORS	ACCURACY CONTROLLER	JUDGEMENT	BY JUDGEMENT STANDARD	
MEASURING UNIT	0.5mm	FIRST CHECKER	ACCURACY CONTROLLER		ENGINEER IN CHARGE	CORRECTION	BY ACCURACY STANDARD	



$$\bar{\bar{X}} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (n=6) \qquad R = a - b \quad (a\text{---Largest error in same day},\ b\text{---Smallest error in same day})$$

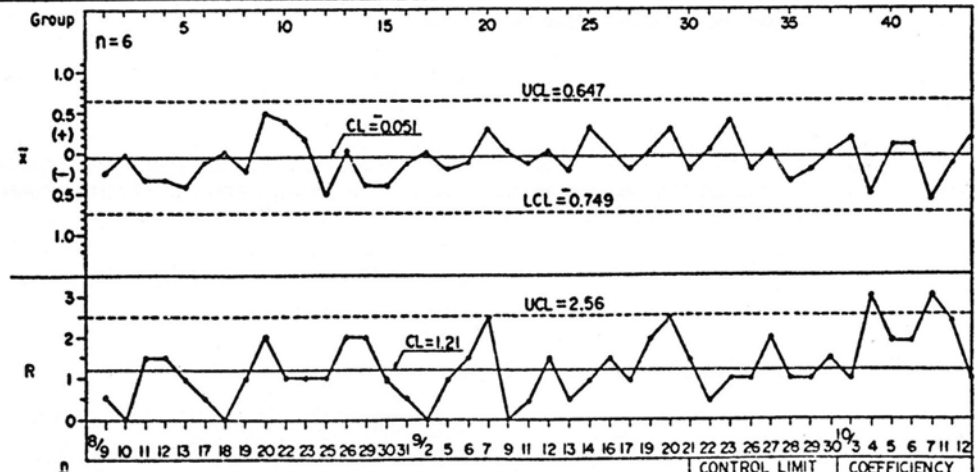
$$\bar{\bar{\bar{X}}} = \frac{\sum_{j=1}^{m} \bar{x}_j}{m} \quad (m=44) \qquad \bar{R} = \frac{\sum_{j=1}^{m} R_j}{m} \quad (m=44)$$

UCL --- Upper control limit, CL --- Center line, LCL --- Lower control limit

CONTROL LIMIT		n	A_2	D_4
$\bar{\bar{X}}$	$UCL = \bar{\bar{X}} + A_2\bar{R}$	2	1.880	3.27
	$CL = \bar{\bar{X}}$			
	$LCL = \bar{\bar{X}} - A_2\bar{R}$	3	1.023	2.58
R	$UCL = D_4\bar{R}$	4	0.729	2.28
	$CL = \bar{R}$	5	0.577	2.18
	~~$LCL = D_3\bar{R}$~~	6	0.480	2.00

ACCURACY CONTROL GRAPH FOR GAS CUTTING OF INTERNAL STRUCTURE BY FABRICATION SHOP, HULL CONSTRUCTION WORK SHOP

QUALITY PROPERTY	INTERNAL STRUCTURE SIZES (WxL)	MEASURING POSITIONS	ENDS OF PARTS	FINAL CHECKER	FOREMAN	SAMPLING	FREQ.	6/DAY
MEASURING PLACE	5K	MEASURING PERSON	WORKER	GRAPH MAKER	STAFF OF ACCURACY CONT.		METHOD	RANDOM
MEASURING INSTRUM'T	TAPE MEASURE	ALLOWANCE LIMIT	± 1mm	INSTRACTORS	ACCURACY CONTROLLER			
MEASURING UNIT	0.5mm	FIRST CHECKER	ASS. FOREMAN		ENGINEER IN CHARGE			



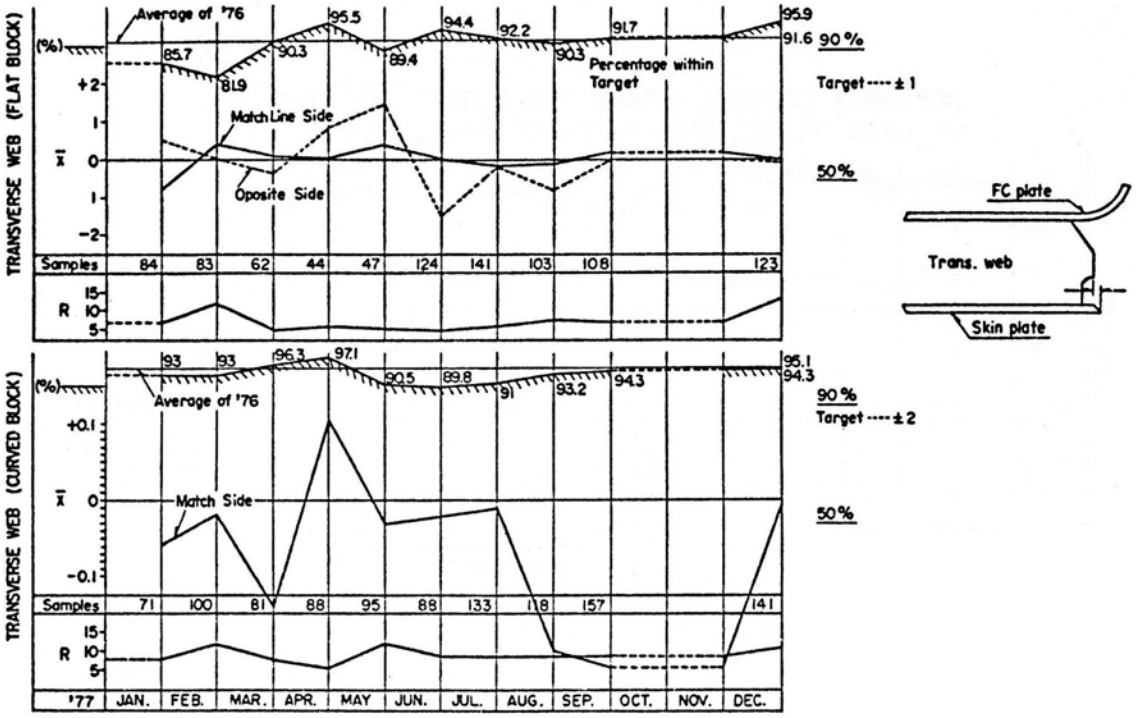
$$\bar{\bar{X}} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (n=6) \qquad R = a - b \quad (a\text{---Largest error in same day},\ b\text{---Smallest error in same day})$$

$$\bar{\bar{\bar{X}}} = \frac{\sum_{j=1}^{m} \bar{x}_j}{m} \quad (m=44) \qquad \bar{R} = \frac{\sum_{j=1}^{m} R_j}{m} \quad (m=44)$$

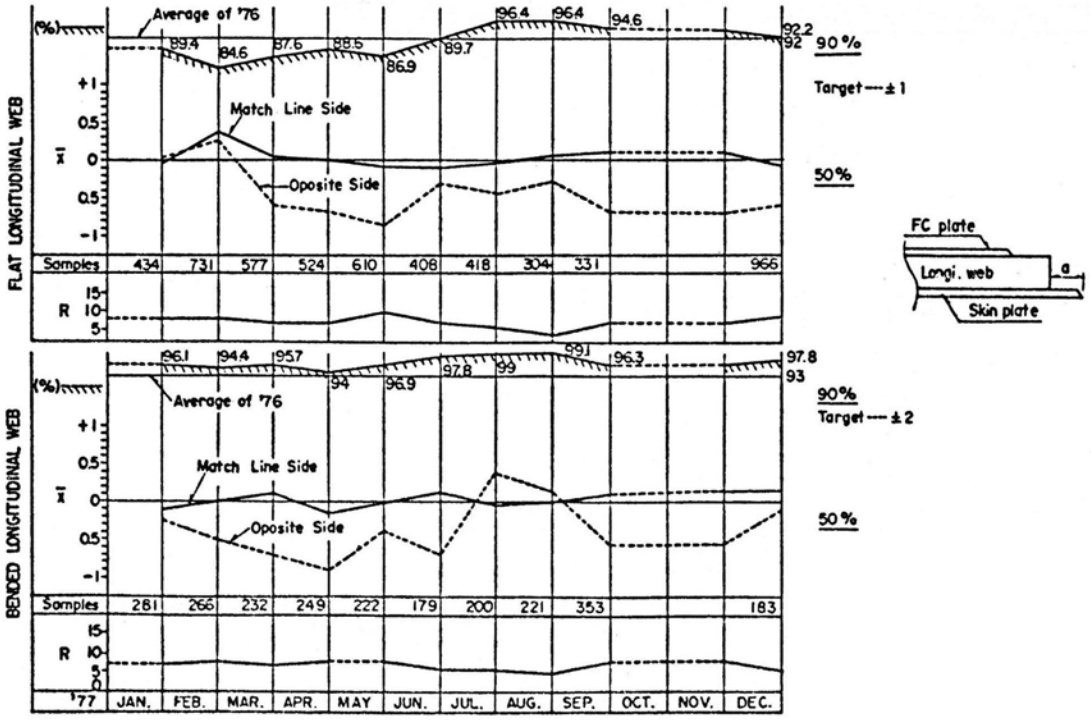
UCL --- Upper control limit, CL --- Center line, LCL --- Lower control limit

CONTROL LIMIT		n	A_2	D_4
$\bar{\bar{X}}$	$UCL = \bar{\bar{X}} + A_2\bar{R}$	2	1.880	3.27
	$CL = \bar{\bar{X}}$			
	$LCL = \bar{\bar{X}} - A_2\bar{R}$	3	1.023	2.58
R	$UCL = D_4\bar{R}$	4	0.729	2.28
	$CL = \bar{R}$	5	0.577	2.18
	~~$LCL = D_3\bar{R}$~~	6	0.480	2.00

ACCURACY CONROL GRAPH FOR ENDS SETTING OF TRANSVERSE WEBS



ACCURACY CONTROL GRAPH FOR ENDS SETTING OF LONGITUDINAL WEB



ACCURACY CONTROL GRAPH FOR MATCH LINE SETTING OF FACE PLATE AND WIDTH OF PANEL PLATE