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Enhanced Software for the GT1022 Automated Gaging System

Kansas City Division

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GT1022 AUTOMATED GAGING SYSTEM

R. E. Hines

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Final Report
R. E. Hines, Project Leader

Technical Communications
Kansas City Division

MASTER

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Abstract

Several enhancements have been added to the gaging software of a microcomputer-controlled gaging system (GT1022) that is used to acquire and process dimensional product data from multiprobe rotary gages. Processing routines have been developed to inspect five additional feature types: dimension, least squares center, MMC position with datum diameter bonus, total indicator reading, and two-sided wall thickness. Mathematical alignment routines have been added that permit parts to be gaged in a misaligned condition and then have the measurements corrected relative to the part's datum axes.

Summary

Enhanced capability has been added to the existing gaging software for the GT1022 (and 1910161-GK380) automated gaging system. The system acquires and processes dimensional data from product that is inspected on multiprobe rotary contour gages. A previous report described the GT1022 hardware and software as they existed two years ago. All of the original software capability has been retained as these upgrades were added.

Three types of mathematical alignment routines have been incorporated: X-Y translation (centering), centering plus tilt correction, and vertical (Z-axis) translation. This capability permits a product to be gaged in a slightly misaligned condition and then have its data mathematically aligned to its datum axes before calculating the final results for product acceptance. This generally allows the gage fixture to be simpler and cheaper.

Five new feature analysis routines have

been added to the four already existing: (1) dimension, (2) least squares center, (3) MMC position with datum diameter bonus, (4) total indicator reading, and (5) two-sided wall thickness.

A mastering routine was developed that uses two readings 180 degrees apart on the master rather than a single reading. This cancels some of the variability caused by set-up of the master on the gage.

The software now allows several versions of the same part with slightly different nominals and tolerances to be gaged with the same gage fixture. This is accomplished by assigning a "substation number" to the second version.

The contour of a surface that has several missing readings because of surface pockets can now be gaged. The "neglected zone" routine allows the software to be preprogrammed to neglect these zones.

Discussion

Scope and Purpose

AlliedSignal Inc., Kansas City Division (KCD), has been using the GT1022 Gaging System for about four years to efficiently gage the dimensional features of metal or plastic parts. The 1910161-GK380 Gaging System is equivalent to the GT1022. Both systems contain small computers to collect, analyze, and report measurement data for product acceptance. A previous report described the system operation and the gaging software that was developed.

The purpose of this report is to describe subsequent enhancements to the gaging software that are required. These added capabilities include the following:

- Mathematical alignment of the measured data to product datums,
- Additional feature analysis routines,
- Omitting measurements in neglected zones,
- Two-point mastering, and
- Substation operation.

Activity

Mathematical Alignment to Product Datums

Mathematical alignment of the data provides a useful capability on some product. Normally, it is required that the gage stage the part so that the product's datum planes and axes are perfectly aligned with those of the gage. Software routines have been developed for the

GT1022 that allow the product to be gaged in a slightly misaligned condition and then have its data mathematically aligned before calculating the results. This sometimes permits a simpler and cheaper gage to be used or permits a part to be gaged that would be very difficult to gage otherwise. Three types of mathematical alignment have been developed:

- XY translation (centering),
- Centering plus tilt correction, and
- Vertical (Z-axis) translation.

All of these alignment corrections require that a Data Adjustment File (see Appendix A) be created and that the PAL keyword be set to YES and the ADF keyword be set to the filename in the Initialization File. The mathematics and algorithms are derived from an Oak Ridge Y-12 Plant technical report.¹

X-Y translation (centering) alignment adjusts the dimensional readings to be relative to the product centerline based on a single datum diameter instead of the rotary table centerline. This is done by first finding the least squares center location (X_o , Y_o) of the datum diameter and then mathematically adjusting all readings to simulate an X-Y translation that brings the product centerline to the gage centerline. To implement this mode, set the Data Adjustment File line for adjustment type to #CENTER, N where N is the datum diameter probe number.

Centering plus tilt correction adjusts the dimensional readings to be relative to the product centerline formed by an upper and lower datum diameter. Conceptually, this

is done by finding the tilt angle of the product centerline and erecting it mathematically and then translating the bottom datum diameter to the gage centerline. To implement this mode, set the adjustment type line to #C-TILT, Nb, Nt where Nb is the bottom datum probe and Nt is the top datum probe.

Vertical (Z-axis) translation alignment shifts the dimensional readings along the Z-axis to bring a product feature (in this case, an average of the two highest points on a datum plane) in line with the gage datum plane. To implement this mode, set the adjustment type line to #Z-HIGH, N where N is the datum plane probe number.

Feature Analysis Routines

After the dimensional data have been collected from the probes, the feature analysis routines are used to analyze the data for the characteristics and tolerances defined on the product drawing. The gage engineer uses the Limit File (see Appendix A) to specify which routines are to be applied to each probe's data and in what sequence. The test limits also are specified in this file.

Currently, there are nine types of feature analysis routines available. Four of them were described in a previous report:

- Contour,
- Diameter,
- MMC position, and
- One-sided wall thickness.

Five more types have been added and are described in Appendix B, Feature Analysis Description:

- Dimension,

- Least squares center,
- MMC position with datum diameter bonus,
- Total indicator reading, and
- Two-sided wall thickness.

Neglected Zones

Previously, the gaging software could only be applied to parts that were complete surfaces of revolution about the axis of the rotary table. The Aft Case has a pocket covering about 20 percent of its revolution, but the contour must still be measured over the remaining surface. Because several readings would fall into the negative material zone, these must be recognized and omitted from the calculations. These regions are called "neglected zones."

A method was developed to permit the gage engineer to designate which probe numbers and reading numbers around the part should be neglected from the final calculations. To implement this mode, initiate mathematical adjustment as described previously and set the Data Adjustment File line for adjustment type to #N-ZONE, PROBE#, N1, N2, N3, N4, N5, N6 where the Nx values are the position numbers of up to six neglected points for the selected probe number. The software then changes the probe readings collected in the neglected zones to a large artificial value (88) that is never encountered in a real application. This large unique value then serves three purposes: (1) the calculation routines know to neglect this value, (2) it can be easily recognized in "data dumps" when doing engineering diagnostic studies, and (3) it would be immediately evident if it were accidentally included in the reported contour calculation.

A practical consideration when using this capability is to make sure the physical

probe tip can climb back out of the negative material region without damage to either the probe or product.

Two-Point Mastering

A master is used with a gage to establish where the nominal (zero) product dimension is located in space. Although a chuck is normally used to center the master on the gage's rotary table, there can still be some variability in its location from day to day. This can usually be neglected on contour measurements, but it can be significant on diameter measurements because the radial error is doubled when only a single probe is used.

A mastering method was developed to diminish the master locating problem for probes that will be gaging the diameters. This requires a master that can be chucked and then rotated 180 degrees to a second certified location. This method is performed by first collecting master readings at the zero degree position, then rotating the master 180 degrees and collecting master readings at that position. These two readings (material conditions) are averaged and the corresponding average master offset is subtracted to get the "correction constant" value that is stored in the Correction Constant File (see Appendix A).

The steps to implement this mode are (1) set the MST keyword to AUTO__2 in the Initialization File and (2) place a negative sign before the probe numbers and use the average offset material condition in the Master Deviation File for all probes that get the two-point mastering.

Substation Operation

Most of the dimensional gaging of the Aft Case occurs before a thin coating is applied. However, a few probes are also gaged after coating, and different test limits

apply. Because the coating thickness is well within the travel range of the probes, it would be cost effective to use the same gage base and master for both inspections and modify the gaging software to accommodate this.

This capability has been added to the software by assigning the basic "station number" to the primary full inspection. Because the secondary inspection uses most, but not all, of the support files used by the primary inspection, it is assigned a "substation number." The substation number is formed by adding 10, 20, 30, 40, or 50 to the primary station number. For example, a station number of "2" could have substation numbers of "12," "22," etc. The gaging software then knows to use the primary station number support files for functions that are common to both inspections and to use the exact station number for part specific functions (eg., limit files). See description of Initialization File in Appendix A.

The station number (or substation number) is input by the inspector through the keyboard to initialize the system. The Gage Operating Procedure prepared by the gage engineer specifies which number to use.

Accomplishments

The capability of the GT1022 computerized gaging system has been improved by adding enhancements to the gaging software. Three types of mathematical alignment were developed that allow measurement data from a product that is not aligned with the gage datums to be corrected relative to the product datum axes. Five additional feature analysis routines were added to the software. A two-point mastering capability was developed to reduce the master setup variability. Routines were added that allow the contour readings that occur over

surface pocket regions to be neglected but still gage the remainder of the surface.

Future Work

There is no definite future work planned for this project; however, the following areas have been considered.

- Motorize the rotary table movement and have the software control both the table movement and the collection of probe readings.
- Develop additional statistical quality control capability for the GT1022.
- Evaluate the use of the personal computer in computerized gaging applications.

Reference

¹ T. W. Bookhart, R. J. Easterday, and W. Q. Walter, *Correction of Inspection Data for Part Misalignment Utilizing a Small Computer*. Union Carbide Corporation, Oak Ridge Y-12 Plant: Document Y-1755, April 1971.

Appendix A

Support Files Description

This Appendix updates the original information and uses the same file types (1 through 9). File type 10 is new. Only enhancements to the original file structure are described here except where repetition is useful for clarity.

The GT1022 uses several types of files to direct gage operation. In addition, it also generates its own files for data storage. File types 1, 2, 3, 4, 5, and 10 are created by the gage engineer using the HP-BASIC text editor. File types 6, 7, 8, and 9 are self-generated by the program software.

Comment (documentation) lines may be included in any file of type 1-5 and 10 by placing a semicolon as the first character of a line following the line number and the exclamation mark (which are necessary to keep the HP computer from trying to interpret the line as an executable statement). This line will be disregarded at execution time.

Besides the semicolon mentioned above, various other "line decode symbols" are used to inform the gaging program how to process the line of information:

Symbol	Meaning
;	Comment (documentation) line.
*	Line to be processed; commas separate entries.
%	Limit file: identification number.
#.	Limit file: Probe numbers and test limits.
&	Limit file: last test for that feature type.
@	Limit file: end of the limit file.
*	Adjustment file: spatial location values.
#	Adjustment file: adjustment-type line.
@	Adjustment file: end of the file.

1. INITIALIZATION FILE (INCLUDES ENHANCEMENTS)

NAME FORMAT: INIT_STAX where X = Station number (1-4)
or Substation# = Station# MOD 10

FILE TYPE: ASCII
FILE SIZE: N/A

FUNCTION: This file is read by the "Init" subroutine of
the main program to initialize various
non-limit testing system parameters.

FILE SYNTAX: *ITEM, VALUE

ITEM	DESCRIPTION	VARIABLE TYPE
PNO	Part Number	Part_no\$(12)
PNM	Part Name	Part_name\$(16)
GNO	Gage Number	Gage\$(16)
UNT	Measure units	US\$(1) E = English, M = Metric
DMP	Data dump	Dump\$(3) ALL/REJ/NO(DEF)
RTY	Rotary mode	Rty\$(3) NO/YES(DEF)
SPR	Special mode	Spr\$(12)
MST	Master type	Mst\$(6) MANUAL/AUTO/ AUTO_2/AUTO_A
STO	Store data	Store\$(3) YES(DEF)/NO
CLP	Loop closure	Clp(real) .0001(DEF)
RNO	Total readings	Rno(real)
SBL	Volt stability	Stabil(real) .01(DEF)
PPS	Product passes	Ppasstot(real)
MPS	Master passes	Mpasstot(real)
PAL	Product adjust	Padj\$(3) YES/NO(DEF)
MAL	Master adjust	Madj\$(6) CENTER/C-TILT/NO
MRN	Master samples	Mrn(real)
MDB	M_datum bottom	Mdb(real)
MDT	M_datum top	Mdt(real)
----- FILE NAMES -----		
PLF	Product limits	Plim_file\$(12)
RLF	Monitor limits	Rlim_file\$(12)
PCF	Product comment	Pcmt_file\$(12)
RCF	Monitor comment	Rcmt_file\$(12)
MDF	Master offsets	Mdev_file\$(12)
CCF	Correction file	Ccon_file\$(12)
ADF	Adjustment file	Adj_file\$(12)

NOTES: 1. If Clp > 95 then 'Rused' equals 'Rno'.
If Clp < 95 then 'Rused' equals 'Rno - 1'.

2. Additional part numbers (PN2, PN3, PN4) and
part names (PM2, PM3, PM4) may be assigned
provided they all use the same limit file.

EXAMPLE: 10 ! ; -- INITIALIZATION FILE EXAMPLE --
20 ! *RNO, 9
30 ! *UNT, M
40 ! *PPS, 1

50 | *MPS, 1
60 | *DMP, REJ
70 | *CLP, .05
80 | *SBL, .02
90 | *GNO, 1452888-G2
100 | *PNO, 1466444
110 | *PNM, MIDDLE__CASE
120 | *RTY, YES
130 | *STO, YES
140 | *SPR, SPEC__1
141 | ;
142 | *PAL, YES
143 | *MAL, C-TILT
144 | *MRN, 8
145 | *MDB, 2
146 | *MDT, 5
150 | ;
160 | *MDF, MDF1466444
170 | *CCF, CCF1466444
180 | *PLF, PLF1466444
190 | *PCF, PCF1466444
200 | *RLF, RLF1466444
210 | *RCF, RCF1466444
215 | *ADF, ADF1466444
220 | ; END-OF-FILE

2. MASTER DEVIATION FILE (INCLUDES ENHANCEMENTS)

NAME FORMAT: MDFXXXXXX where XXXXXX = part number (opt.)

FILE TYPE: ASCII

FILE SIZE: N/A

FUNCTION: This file is used by the main gaging program and contains the certified deviation from nominal dimension at each probe location for the master. These values, combined with the probe readings taken at master time, generate a set of correction constants that represent readings that would be obtained from a perfect part. The computer then stores these values in a 'correction constant' file (see file 6 below) to be used later to determine the plus or minus material condition on the product relative to nominal.

FILE SYNTAX: *PROBE#, MPASS#, OFFSET__VALUE

where PROBE# > 0 == > Master at one point only and offset value is the material condition at that one point.

PROBE# < 0 == > Master at two points 180 degrees apart and the offset value is the average material condition of those two points.

EXAMPLE: 10 ! ;

20 ! ;PROBE, MPASS, OFFSET (MATL COND)

30 ! * +1, 1, +.003

40 ! * +2, 1, +.007

50 ! * -3, 1, -.004

60 ! * -4, 1, +.010

70 ! ; END-OF-FILE

3. PROBE DEFINITION FILE (NO CHANGES)
NAME FORMAT: CHAN_DEF
4. LIMIT FILE (NO CHANGES)
NAME FORMAT: PLFXXXXXX (Product limit file)
 RLFXXXXXX (Monitor unit limit file)
5. COMMENT FILE (NO CHANGES)
NAME FORMAT: PCFXXXXXX (Product comment file)
 RCFXXXXXX (Monitor unit comment file)
6. CORRECTION CONSTANT FILE (NO CHANGES)
NAME FORMAT: CCFXXXXXX
7. CALIBRATION-GENERATED FILE (NO CHANGES)
NAME FORMAT: CALFILE
8. DIRECTORY FILES (NO CHANGES)
NAME FORMAT: GDIR (Product directory)
 MDIR (Monitor unit directory)
9. STORED DATA FILES (NO CHANGES)
NAME FORMAT: GSNNNN (Product condensed data)
 MGSXXX (Monitor unit condensed data)
 RWNNNN (Product raw data)
 where NNNN = 1000 + data number
 XXX = 100 + data number

10. DATA ADJUSTMENT FILE (NEW)

NAME FORMAT: ADFXXXXXX where XXXXXX = part number (opt.)

FILE TYPE: ASCII

FILE SIZE: N/A

FUNCTION: This file provides the gaging software with factors to use when it is desired to mathematically align or adjust the measured readings from the product. These adjustments are generally done when the product's datums do not coincide with the gage datums.

FILE SYNTAX: *ALNDAT, APROBE, AR, AZ, ATHETA, AGAMMA
#ADJ__TYPE. PARAMETER__LIST
@

where APROBE = Probe number to be adjusted.
 AR = Radial distance to surface point.
 AZ = Height distance to surface point.
 ATHETA = Azimuthal offset angle to point.
 AGAMMA = Normal angle at point to X-Y plane.
 @ = End of file symbol.

<u>ADJ__TYPE</u>	<u>PARAMETER__LIST</u>
CENTER	PDB Product datum probe.
C-TILT	PDB, PDT Product bottom datum and top datum probes.
Z-HIGH	PDB Product datum probe.
N-ZONE	PRB#, Probe number and N1,N2,N3, reading locations to N4,N5,N6 be neglected (pad with Nx = 99 when <6 req'd).

NOTE: All *ALNDAT lines must appear before any
#ADJ__TYPE lines.

EXAMPLE: 10 ! ;
 20 ! *ALNDAT, 1, 6.455, 0.300, 0., 0.
 30 ! *ALNDAT, 2, 6.538, 4.560, 10., 0.
 40 ! *ALNDAT, 3, 7.280, 4.264, 0., 90.
 50 ! *ALNDAT, 4, 4.348, 3.340, 0., 270.
 60 ! *ALNDAT, 5, 4.348, 9.340, 0., 0.
 70 ! ;
 80 ! #C-TILT, 1, 5
 90 ! #N-ZONE, 3, 11, 12, 13, 14, 99, 99
 100 ! @

Appendix B

Feature Analysis Description

The GT1022 gaging software can apply various feature analysis routines to determine geometry, size, or position and then compare the results against tolerances. The five routines that have been added since the four original routines are described in this Appendix. The following symbols (in addition to those described in Appendix A) are used.

F: Total number of equally spaced readings taken in 360 degrees around the part (excluding the repeat of the first reading).

C_i: Contour value (material condition) at position "i" around the part.

P: Probe number.

P_A, P_B : Probe pair numbers.

(): Denotes that usage is optional (except in formulas).

D: Round to D decimal digits if D is positive. Truncate to D decimal digits if D is negative.

LABEL: Six (6) alphanumeric characters,
 where last character = A for average,
 = H for maximum,
 = L for minimum,
 = R for range,
 = X for N/A.

VALUE *: Calculated value is out-of-limit (O.O.L.)

COMMENT: Pre-programmed comment or remark.

MERIT: Measure of closeness of value to nominal:
 0.00 = = > At nominal
 +/-1.00 = = > At limit

IND: Visual indicator of merit (+ or - symbols):

Blank = = > Less than 75% of limit
 1 Symbol = = > Between 75% and 90%
 2 Symbols = = > Between 90% and 100%
 3 Symbols = = > On or outside of limits

--- CTR_LSQR ---

FUNCTION: Determines the position of a diameter (based on a least squares fit) relative to the axis of rotation and compares it against a tolerance for the specified probe. Results are stated as twice the radial off-centeredness. This function can be used for POSITION or CONCENTRICITY.

LIMIT FILE FORMAT: *CTR_LSQR, D, (COMMENT)
#LABEL, P, UP_LIMIT

CALCULATION:

$$\text{VALUE} = 2 \times \text{SQRT} (X^2 + Y^2)$$

$$\text{ANGLE} = \text{ARC TAN} (Y/X)$$

$$\text{where } X = (2/F) (\text{SUM } [C_i \cdot \cos \theta_i])$$

$$Y = (2/F) (\text{SUM } [C_i \cdot \sin \theta_i])$$

THETA = Azimuthal angle around part.

PRINTOUT FORMAT:

CENTER RESULTS: (COMMENT)

PRB#	LABEL	DESC	VALUE	U.LIMIT	L.LIMIT	OOL	MERIT	IND
1	VV101X		.033	.100	.000	0.000	.33	
6	VV106X		.160*	.100	.000	.060	1.60	+++

where VV = PS for POSITION

= CC for CONCENTRICITY

--- DIMENSION ---

FUNCTION: Determines the average, maximum, and minimum dimension relative to nominal and compares against tolerances for each specified probe. Results are in dimension (size) condition.

LIMIT FILE FORMAT: *DIMENSION, D, (COMMENT)
#LABEL, P, UP_LIMIT, LOW_LIMIT, SIGN

CALCULATION:

Avg. Dimension Material Condition (DIM) = (SUM C_i) / F

Avg. Dimension (size) = SIGN x DIM

Max. Dimension (size) = SIGN x MAX. C_i (if SIGN = +1.)
= SIGN x MIN. C_i (if SIGN = -1.)

Min. Dimension (size) = SIGN x MIN. C_i (if SIGN = +1.)
= SIGN x MAX. C_i (if SIGN = -1.)

NOTE: SIGN = +1. for an outside dimension.
= -1. for an inside dimension.

PRINTOUT FORMAT:

DIMENSION RESULTS: (COMMENT)

PRB #	LABEL	DESC	VALUE	U.LIMIT	L.LIMIT	OOL	MERIT	IND
3	DM103A	AVG	.033	.065	-.065	0.000	.51	
3	DM103H	MAX	.112*	.100	-.100	.012	1.12	+ + +
3	DM103L	MIN	-.025	.100	-.100	0.000	-.25	
7	DM107A	AVG	-.060	.065	-.065	0.000	-.92	--
7	DM107H	MAX	.022	.100	-.100	0.000	.22	
7	DM107L	MIN	-.125*	.100	-.100	-.025	-1.25	---

--- MMCPOS2D ---

FUNCTION: Determines the position of a diameter (based on a least squares circle fit) and compares it against a calculated tolerance based on the MMC tolerance bonus of the measured diameter plus the MMC bonus of the datum diameter. Position is stated as twice the radial off-centeredness.

LIMIT FILE FORMAT: *MMCPOS2D, D, (COMMENT)
#LABEL, PROBE_T, MMCTOL, RELVAL, MAXTOL,
PROBE_D, RELVAL_D

CALCULATION:

VALUE = POSITION = 2 x SQRT (X*X + Y*Y)

See "CTR_LSQR" Keyword for X, Y definition.

DIA = 2 x (SUM C_i) / F (Mat'l condition)

U.LIMIT = CALC_TOLERANCE = MMCTOL + (RELVAL - DIA_{meas})
+ (RELVAL_D - DIA_{datum})
= MAXTOL (if CALC_TOL > MAXTOL)
= MMCTOL (if CALC_TOL < MMCTOL)

where RELVAL = ABS (NOMINAL DIA - MMCDIA)_{meas dia}
RELVAL_D = ABS (NOMINAL DIA - MMCDIA)_{datum dia}
MAXTOL = user defined maximum tolerance.
PROBE_T = probe number on measured diameter.
PROBE_D = probe number on datum diameter.

PRINTOUT FORMAT:

POSITION OF DIA (MMC) RESULTS: (COMMENT)

PRB #	LABEL	DESC	VALUE	U.LIMIT	MMCTOL	OOL	MERIT	IND
2	2M102X		.033	.198	.100	0.000	.17	
5	2M105X		.180*	.120	.100	.060	1.67	+ + +

--- TOTAL_IR ---

FUNCTION: Determines the total-indicator-reading (TIR) of a surface relative to product datums and compares against the tolerance for the specified probe. This function can be used for RUNOUT, POSITION, PARALLELISM, or PERPENDICULARITY.

LIMIT FILE FORMAT: *TOTAL_IR, D, (COMMENT)
#LABEL, P, UP_LIMIT

CALCULATION:

$$\text{VALUE} = \text{MAX. } C_i - \text{MIN. } C_i$$

PRINTOUT FORMAT:

TOTAL_IR RESULTS: (COMMENT)

PRB#	LABEL	DESC	VALUE	U.LIMIT	L.LIMIT	OOL	MERIT	IND
2	VV102X		.033	100	.000	0.000	.33	
9	VV109X		.160*	100	.000	.060	1.60	+ + +

where VV = RN for RUNOUT
 = PS for POSITION
 = PL for PARALLELISM
 = PP for PERPENDICULARITY

--- WALTHICK ---

FUNCTION: Determines the maximum and minimum wall thickness deviation from nominal and compares against tolerances for each specified probe pair. Results are in material condition.

LIMIT FILE FORMAT: *WALTHICK, D, (COMMENT)
#LABEL, PA, PB, UP_LIMIT, LOW_LIMIT

CALCULATION:

Wall Thickness (W_i) = $(C_i)_A + (C_i)_B$

Avg. Wall Thickness = $(\text{SUM } W_i) / F$

Max. Wall Thickness = MAX. W_i

Min. Wall Thickness = MIN. W_i

NOTE: Probes A and B are assumed to be located opposite each other on the inside and outside contours.

PRINTOUT FORMAT

WALL THICKNESS RESULTS: (COMMENT)

PRB	LABEL	DESC	VALUE	U. LIMIT	L. LIMIT	OOL	MERIT	IND
1/5	WT101A	AVG	.024	.100	-.100	0.000	.24	
1/5	WT101H	MAX	.112*	.100	-.100	.012	1.12	
1/5	WT101L	MIN	-.025	.100	-.100	0.000	-.25	+ + +
3/8	WT103A	AVG	-.024	.100	-.100	0.000	-.24	
3/8	WT103H	MAX	.022	.100	-.100	0.000	.22	
3/8	WT103L	MIN	-.125*	.100	-.100	-.025	-1.25	---

END

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