Section 5 - Metrology System Operation

Executing Intrafield Jobs with DFAS or Micro DFAS (Without Using INSITU)

NOTE: To execute an intrafield test using INSITU, refer to the INSITU Operation procedure.

Version 7.1 of the metrology software has made the task of evaluating intrafield errors easier. Using the Edit Intrafield Layout option (Figure 5-1), a user can select the type of intrafield reticle, cell size, and number of columns and rows. The metrology software displays a list of options when the user selects Platen, Lens, or Wand. The lens type and wand position automatically select only those points that are valid for a particular field size. The configuration is saved as a template. Then using simple cursor commands, the user can delete or add points to that field. These points are sorted to minimize stage motions for maximum throughput and precision. The user can create and save templates for special configurations and then load the template into the Create/Edit Intrafield Layout menu by selecting the template name.

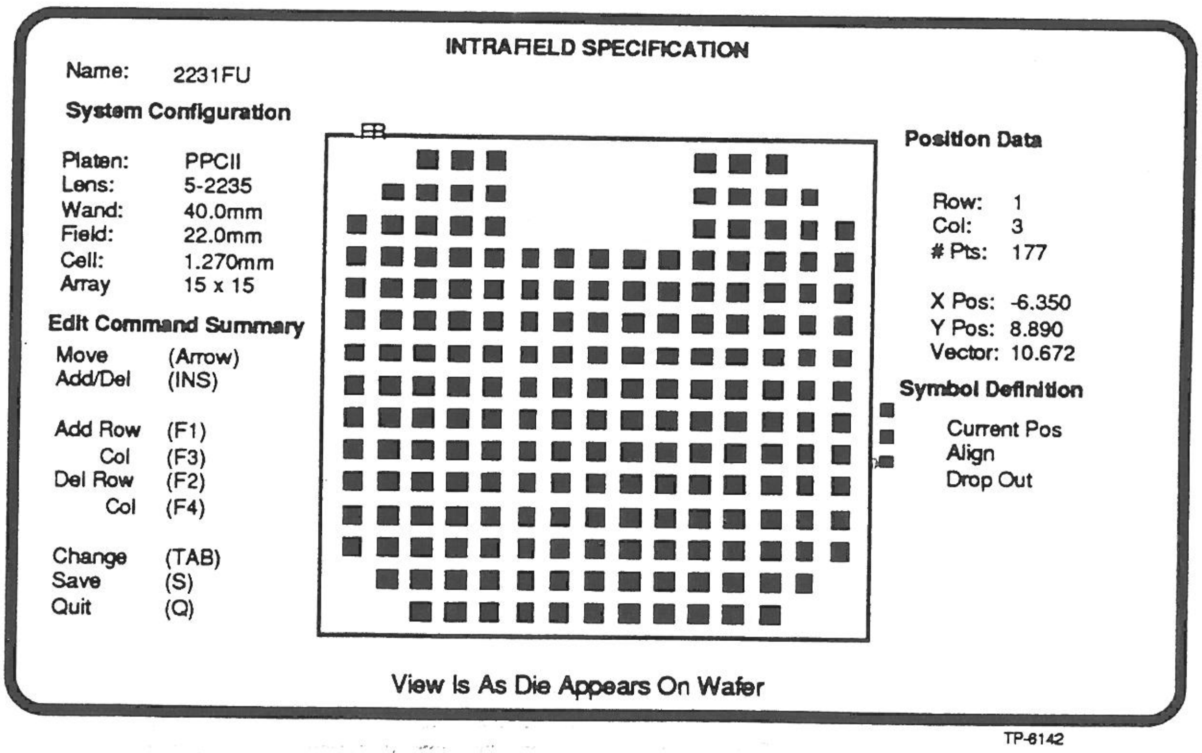


Figure 5-1
Intrafield Specification Display

User-Selectable Items from the Intrafield Specification Display:

Platen: Press TAB, to put the cursor at the PLATEN position at the top of the display. Press TAB again to display a submenu of the platen configuration options in the center of the screen. Enter the number of the platen the system is equipped with and press RETURN. Press RETURN again to move to the LENS position.

Lens: Press TAB to view the submenu of the available lens configuration options. Enter the number of the lens the system is equipped with and press RETURN. Press RETURN again to move to the WAND position.

Wand: Press TAB to view the submenu of the available wand configuration options. Enter the number of the wand configuration the system is equipped with and press RETURN. Press RETURN again to move to the FIELD position.

Field: Enter the desired field size to be measured. Press RETURN to move to the CELL position.

Cell: Enter the spacing between the alignment sites. Press RETURN to move to the ARRAY position. The maximum cell size is 10mm.

Array: Enter the size of the array to be read. If the array is going to be a 15x15 array, enter 15 and press RETURN. The array would then be automatically calculated as a 15x15 array. The array must be ≥3 and ≤19 and an odd number.

Platen Configuration	Lens Configuration		Wand Configuration
1. WDG	1. 10-77-58	11. 5-1635	1. 40.0
2. WSH	2. 10-77-61	12. 5-2035	2. 41.2
3. MMP	3. 10-78-06	13. 2142-g	3. 42.0
4. PPCI	4. 10-78-34	14. 2145-i	4. 44.0
5. PPCII	5. 10-78-37	15. 5-2232	5. 48.0
6. RPC	6. 10-78-45	16. 5-2235	6. 59.2
7. LLC	7. 10-78-46	17. 5-2529-g	7. 90.0
	8. 10-78-47	18. 5-2923	
	9. 10-78-48	19. 5-2040	
	10. 10-78-52	20. 2035-Krf	
		21. 2135-Krf	
		22. Orion	

Figure 5-2
Platen, Lens, and Wand Configuration Option Menus

When the metrology system receives a pass name that starts with "INT", it assumes that the user would like intrafield analysis to commence. The metrology system then takes control and steps the array, storing the alignment corrections in a history file INTRA##.FIL. If multiple dies are selected, the data at each field position is averaged such that one data file contains the average intrafield data for N number of sites.

Reading Intrafield Wafers with DFAS

Specify a standard grid alignment pass with the following:

1. Select Die-by-Die.
2. Any step size can be used so long as the fields do not overprint each other.
3. Set the DXD DETECTOR BASELINE CORRECTION so it aligns the center cell of the intrafield reticle (Table 5-1). For example:

   Assume:
   Wand location is 48mm
   5X Reduction Lens
   Intrafield reticle 4800-045 Rev. 2

   Enter the following in the job:

   DIE ALIGNMENT (FZT) OFFSET:
   X: 0
   Y: 0

   Enter the following in MODE:

   DXD DETECTOR BASELINE CORRECTION (mm):
   X: 0
   Y: 9.60 (48.0/5.0)

   This is the reference position for DFAS. The alignment offsets are based on this initial location.

Table 5-1
Y DXD Baseline Correction in MODE

DFAS Wand Location (mm)	5X Reduction	10X Reduction
40	8.00	4.00
41.2	8.24	4.12
44	8.80	4.40
48	9.60	4.80
59.2	11.84	5.92

4. The user can select a plug or array pass and then choose N number of dies. The resulting analysis is the average of all dies aligned.

If the alignment on the center cell is successful, the system then steps the user-selected intrafield layout and stores the information. At the end of the pass, the system displays the platen corrections necessary to drive the intrafield errors to zero (Figure 5-3).

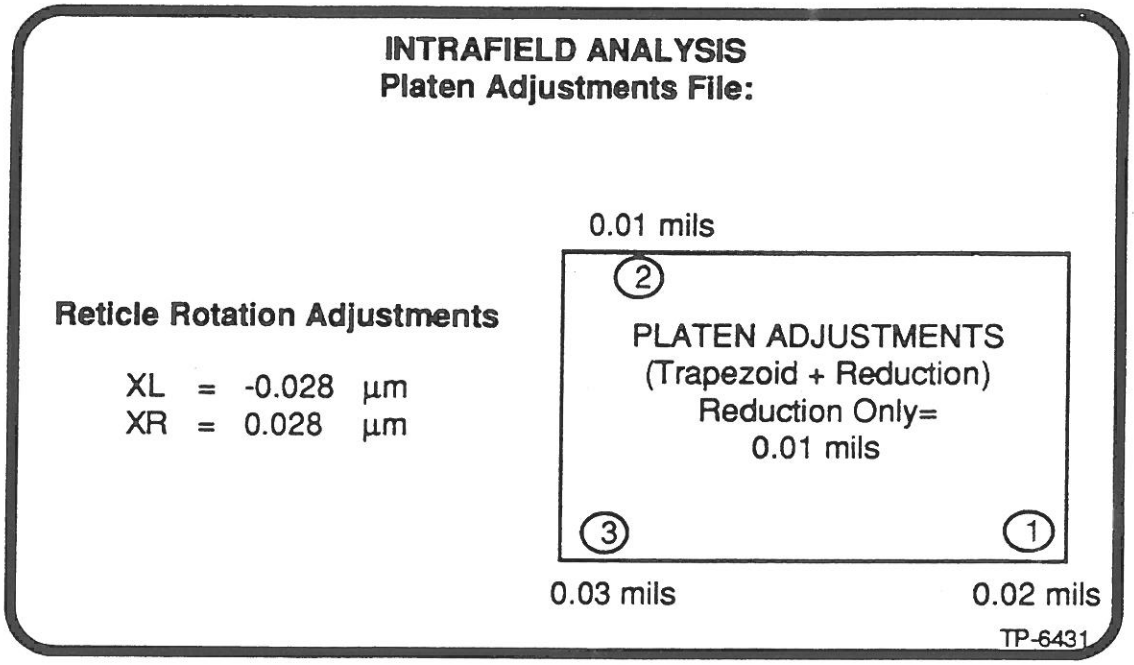


Figure 5-3
Intrafield Analysis Display

To use a latent pass to execute an intrafield job, create a two-pass job. Pass 1 would expose the fields to be aligned. Pass INT##### would then read the intrafield and suggest corrections. Thus **EXEC jobname\EXPOSURE PASS, INT PASS** from the MOP could automatically expose and average several dies to obtain and display platen corrections.

The data files for intrafield are now stored in the directory C:\DFAS\DFHIST\INTRA##.FIL, where ## can be a number from 1 to 99 similar to standard history files. The user can create a SMARTSET-compatible file as before by selecting Create SMARTSET Files from the main menu, then Intrafield as the type of file.

NOTE: The metrology system expects this new method of operation for creating intrafield analysis files and previous jobs will not work unless modified.

Reading Intrafield Wafers with Micro DFAS

Specify a standard grid alignment pass with the following job information.

1. Answer Y to USE LOCAL ALIGNMENT.
2. Answer Y to USE MICRO DFAS.
3. Any step size can be used so long as the fields do not overprint each other.
4. Set the DIE ALIGNMENT (FZT) OFFSET to 0 so that the Micro DFAS will align to the center cell of the intrafield reticle.

DIE ALIGNMENT (FZT) OFFSET:

X:	0
Y:	0

This is the reference position for Micro DFAS. The intrafield offsets are based on this initial location.

5. Answer Y to IS DIE-BY-DIE (DXD) TO BE USED, in MODE.
6. Select a plug or array pass and then choose "N" number of dies. The resulting analysis is the average of all dies aligned.

   If the alignment on the center cell is successful, Micro DFAS then steps the user-selected intrafield layout and stores the information.

At the end of the pass, Micro DFAS displays the platen corrections necessary to drive the intrafield errors to zero (Figure 5-3). The analysis uses the Lens Type and Platen Type selected in the intrafield template layout, so these should be selected correctly for proper operation.

To use a latent pass to execute an intrafield job, create a two-pass job. Thus the command **EXEC INTRAF\1,INTXX** would expose a wafer and then read the intrafield data.

The data files for intrafield are automatically stored in the directory C:\DFAS\DFHIST\INTRA##.FIL, where ## is a user-selectable number similar to standard DFAS history files. The user can create a SMARTSET-compatible file as before by selecting Create SMARTSET Files from the main menu, then Intrafield as the type of file.

NOTE: The metrology software expects this new method of operation for creating intrafield analysis files (using the letters INT for the beginning of the pass name), and previous jobs will not work unless modified.

Multiple Alignments Within a Die

By plugging the same die twice or more during mapping, with an offset associated with the distance to another alignment mark within the die, multiple alignments of each die take place.

The resultant alignment position for each die is the average of the multiple alignments. In this way by proper placement of alignment marks, one can force reticle rotation and magnification to be symmetric about the center of each die, reducing the error of these components by a factor of two.

Wafer Summary Screen (DFAS and Micro DFAS)

Wafer Summary - The screen format at the end of a map or align pass will appear as in Figure 5-4. The total time for step, align, and expose does not include AWA alignment, leveling, and wafer transfer time. This screen can be printed by pressing SHIFT+PRTSC on the metrology keyboard or if the autoprint option is ON the screen prints out automatically at the end of each wafer aligned. If the graphics option on the Defaults menu is OFF, the wafer summary screen remains on the screen during exposure of the wafer.

If not enough data points are aligned, the system only displays global baseline corrections based on the average of the dies aligned.

DFAS WAFER SUMMARY (DXD)

Job Name: MDFAS Pass Name: 3

Global Corrections (Add To Current)			
Global Baseline	mm	X	0.00022
		Y	0.00016
Wafer Scale	ppm	X	1
		Y	1
Orthogonality	ppm		1
Rotation	µm		0.1
	µrad		0.6

Statistics		
DFAS Residuals nm	X	67
±3 Sigma	Y	73
Number of Alignments		100
Failures		0
Exposures		100
Average DXD Time		0.76
Step+DXD+Expose Time		167.04

TP-6465

Figure 5-4
Wafer Summary Screen for Grid or Mapping Data

Executing Focus Jobs

Systems Equipped with FOCUS Command (6.04.3 or Later MOPs)

If the system is equipped with INSITU, it is easier to use the INSITU for testing the system focus, intrafield, and the Micro DFAS baseline. For operation of the INSITU commands refer to the INSITU Operation procedure.

System Focus

This is the absolute system focus. The zero or reference point of the system focus is now 0. All focus changes or offsets are applied to this value. All compensation values for pressure or temperature are applied to system focus so as to be transparent to the user.

Since the job focus offset is directly referenced to the system focus in MODE, the operator should have to set the job focus for each process level only once. When all job focuses are properly set, the system focus in MODE should be the only necessary focus change (unless the process has been changed). Any atmospheric changes affect the wafer stepper as a whole (all jobs) and therefore the system focus in MODE sets all the jobs back to the best focus position.

All versions of software prior to 6.04.3 used the POC mid-travel position (251) or the ACS (with the RS-232 cable) mid-travel position (1000) as the zero point; however, it was not the reference point.

FOCUS Command

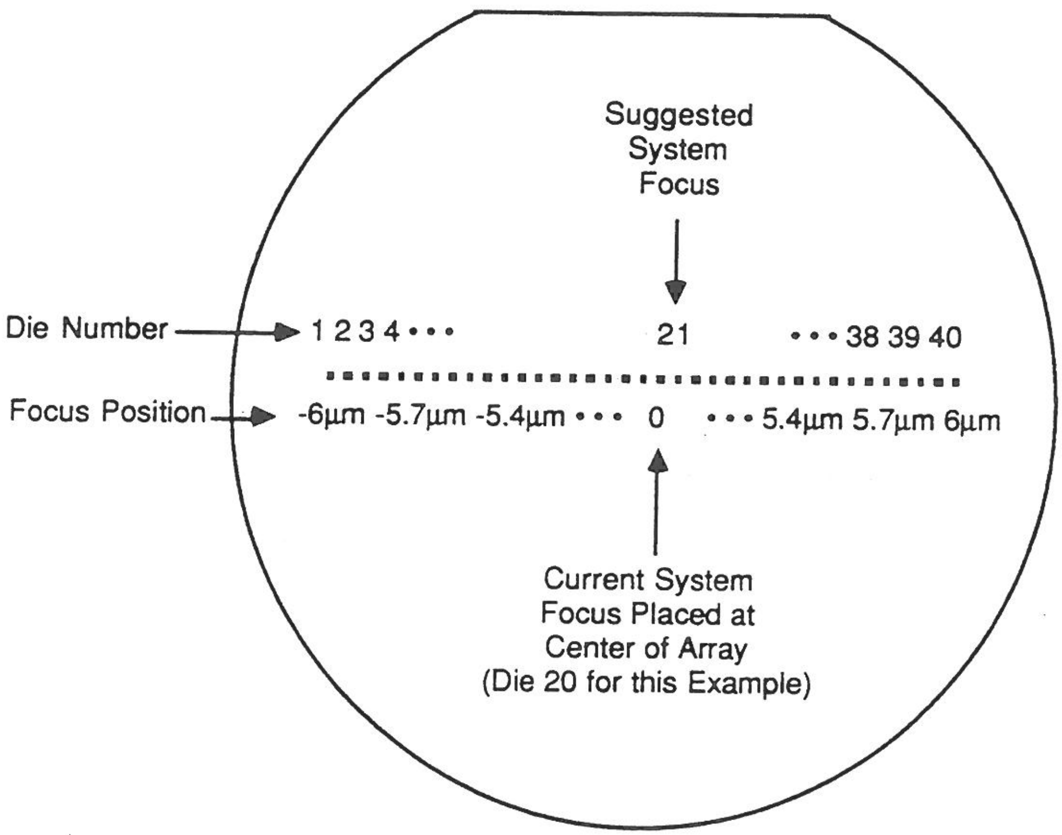
When the operator enters the command FOCUS, the system prompts for a jobname, pass, and exposure time, but not for focus information.

NOTE: Do NOT use 1st level when starting the AWH. Start the FOCUS command by pressing **RESET** then **S/C**.

The wafer is automatically stepped with focus increments being controlled by the FOCUS command software to produce approximately ±6μm change in focus. The array is automatically centered around the current system focus (see Figure 5-5 for an example).

After the wafer is exposed, it is read by the metrology system. The results are then displayed on the monitor. The user is then prompted with the new suggested system focus and asked whether to update the system focus in MODE. A **YES** response updates the system focus setting in MODE with the new focus value. If a **NO** response is entered, the system does not update the system focus value, however; the system prompts the user with the suggested job focus offset. This job focus offset should be entered into the specific job and will only affect that job.

Focus Array Example



For Example

Current System Focus: (Die 20 for this Example)	5	(0.5µm)
Focus Offset Increment: (Calculated for ±6µm)	3	(0.3µm)
Suggested System Focus: (Die 21 for this Example)	8	(0.8µm)

TP-6135

Figure 5-5
Example of FOCUS Command Operation

FOCUS Command Operation Overview

Figure 5-6 is a flowchart of the FOCUS command operation.

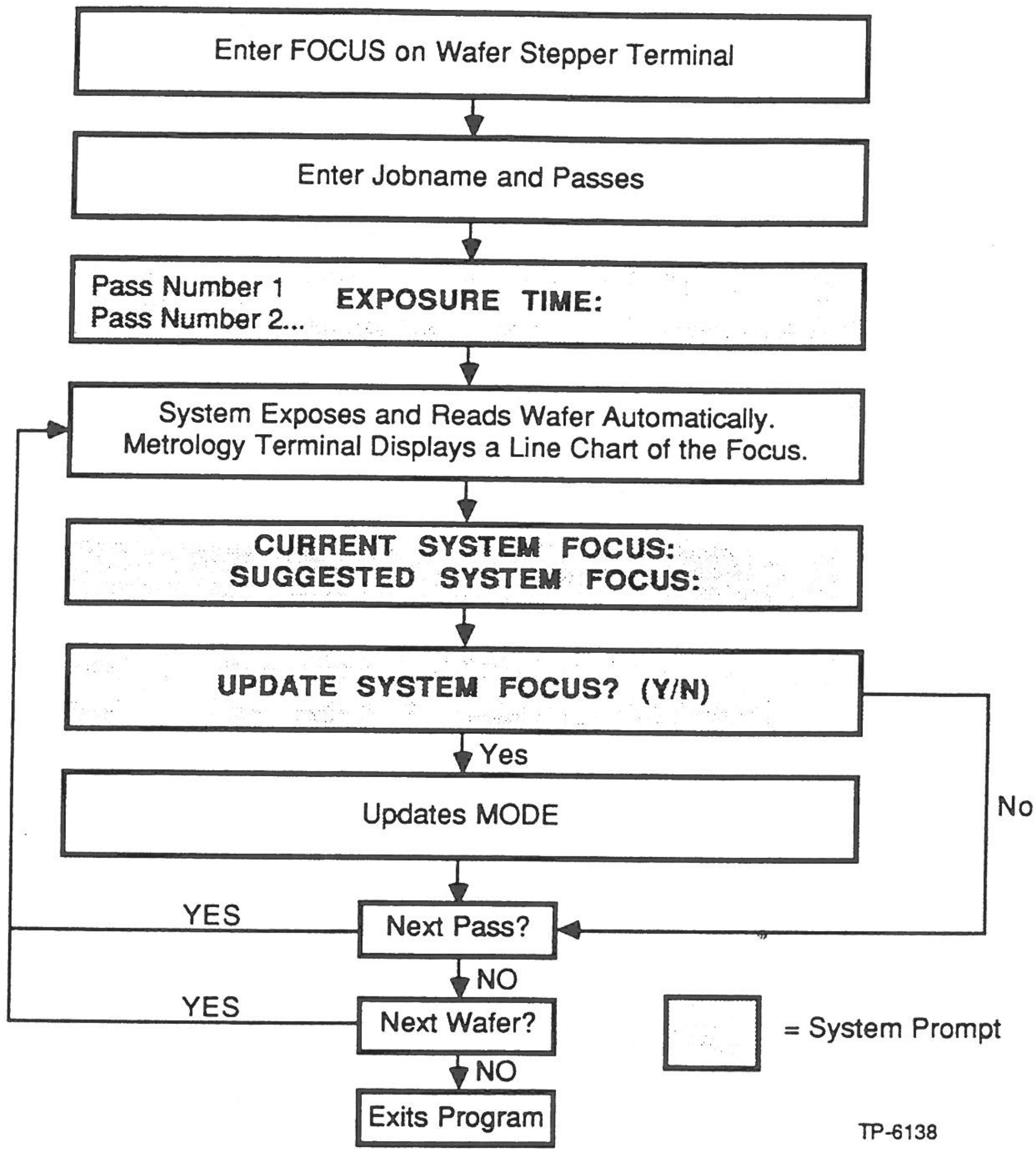


Figure 5-6
FOCUS Command Operation Flowchart

FOCUS Command Job Specification

NOTE 1: The following is the recommended job specification. Use the 4800-045 Rev. 2 intrafield reticle. The die alignment offsets shown are for the 4800-045 Rev. 2 reticle.

NOTE 2: The user can enter multiple passes to expose several rows of focus dies without changing the wafer. It is recommended, however, to have 40 dies in each row for minimum Y stepping and to obtain the best throughput.

NOTE 3: When using the 4800-045 Rev. 2 reticle, it is necessary to use a paper aperture (made from clean-room paper) in order to mask off the center of the reticle. If the paper aperture is not used, the dies may overlie each other, causing alignment problems.

Enter the following on the wafer stepper system to be tested.

Enter the following in MODE:

DXD DETECTOR BASELINE CORRECTION (mm):
X: 0
Y: 9.60250 (48.0/5.0)

This is the reference position for DFAS. The alignment offsets are based on this initial location.

Table 5-2
Y DXD Baseline Correction in MODE

DFAS Wand Location (mm)	5X Reduction	10X Reduction
40	8.00	4.00
41.2	8.24	4.12
44	8.80	4.40
48	9.60	4.80
59.2	11.84	5.92

Enter the following in the job specification:

NOTE 4: Refer to Appendix A for restricted pass names.

SPEC SYSFOC

COMMENT: Specify these array parameters on 125mm systems with 101.6mm objective spacing. Use for the FOCUS command.

WAFER SIZE: 125mm

STEP SIZE IN X: 1.27

***C-OUNT, S-PAN, OR A-LL:** C

HOW MANY COLUMNS? 40

STEP SIZE IN Y: 1.27

***C-OUNT, S-PAN, OR A-LL:** C

HOW MANY ROWS? 1

Alignment Parameters:

STANDARD KEYS? Y

RIGHT KEY OFFSET
IN X:
IN Y:

PASS: FOC

PASS COMMENT: Exposes and reads wafer automatically

EXPOSURE TIME: (Use best exposure for g-line systems and 1.5 x normal exposure for i-line systems)

FOCUS OFFSET [-50 -> +50]:

USE LOCAL ALIGNMENT: Y

MAXIMUM PERMISSIBLE DIE ALIGNER MOTION: 500

REVERT TO P-REVIOUS ALIGNMENT OR G-LOBAL: P

NUMBER OF SITES PER DXD ALIGNMENT: 1

DIE ALIGNMENT (FZT) OFFSET:
X: 0
Y: 0

PASS SHIFT:
X:
Y:

RETICLE BAR CODE: 4800-045 (Rev. 2)

MASKING APERTURE SETTING:
XL: 45
XR: 45
YF: 45
YR: 45

MASKING APERTURE OFFSET:
XL: 0
XR: 0
YF: 0
YR: 0

RETICLE ALIGNMENT OFFSET:
XL: 0
XR: 0
Y: 0

RETICLE ALIGNMENT MARK PHASE (P, *N, X): N

A-RRAY, P-LUG, L-ABEL: A

DROPOUTS:
R:

Job/Aperture Verification Test

(Required for initial use of the FOCUS command)

1. **EXEC** a wafer using the SYSFOC job at best exposure and focus.
2. Develop the wafer.
3. Using a microscope, check the following:

   a. There should not be more than 1 image printed in the center of each die.
   b. There should be no aperture clipping of the DFAS targets.
   c. The dies should NOT overlie each other.

NOTE: When using the 4800-045 Rev. 2 reticle, it is necessary to use a paper aperture (made from clean-room paper) in order to mask off the center of the reticle. It is important that only the center cell be exposed.

4. If any of the problems in step 3 are present, correct the job or calibrate the apertures (or create a more accurate paper aperture), whichever is applicable, before operating the FOCUS command.

Detailed FOCUS Command Operation Procedure

NOTE: Make sure that the AGC option for the metrology system is turned ON before operating the FOCUS command.

1. From the system prompt, enter the command **FOCUS jobname\pass,** where **jobname** is the job containing the array to be tested, and **pass** is the pass name used from within the job. The FOCUS command controls the focus increments automatically to create a focus change of approximately ±6µm centered around the current system focus.

   When this command is entered, the system displays the following prompt:

   EXPOSURE TIME:

2. Enter the best known exposure for the process being used.
3. Load a standard test wafer into the send cassette and perform the following:

NOTE: Make sure that the metrology system is at the **Waiting For MOP Command** prompt before continuing.

NOTE: Do NOT use 1st Level S/C with the FOCUS command.

4. Press **HLT**, **RESET**, and **S/C** then the **EXP** button when the wafer is at the align position (make sure that the AWA AUTO/MAN switch is set to MAN).

   When the exposures are completed, the metrology system automatically reads the latent dies and displays a line graph of the system focus (Figure 5-7).

NOTE: The operator does NOT need to enter the metrology menus to set any parameters. The FOCUS command performs all the functions automatically.

The following is displayed when the pass is completed:

CURRENT SYSTEM FOCUS:

This is the current system focus setting in MODE.

SUGGESTED SYSTEM FOCUS:

This is the value the system has calculated for the best system focus.

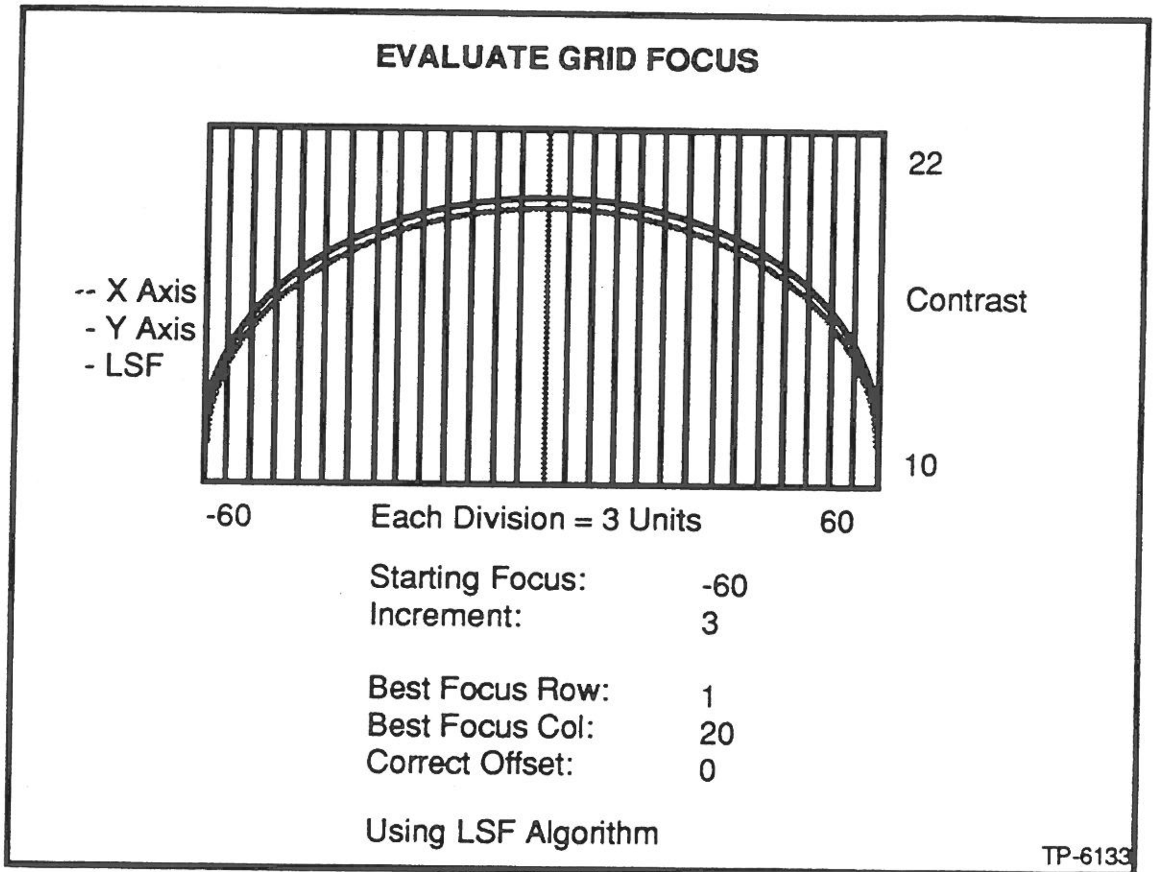
5. The user is then prompted with the following question:

UPDATE SYSTEM FOCUS? (Y/N)

If the user enters Y (yes) the new system focus is automatically entered into MODE and saved to the hard disk.

If the user enters N (no) the program is exited unless another pass was specified or another wafer is ready to be loaded onto the wafer chuck.

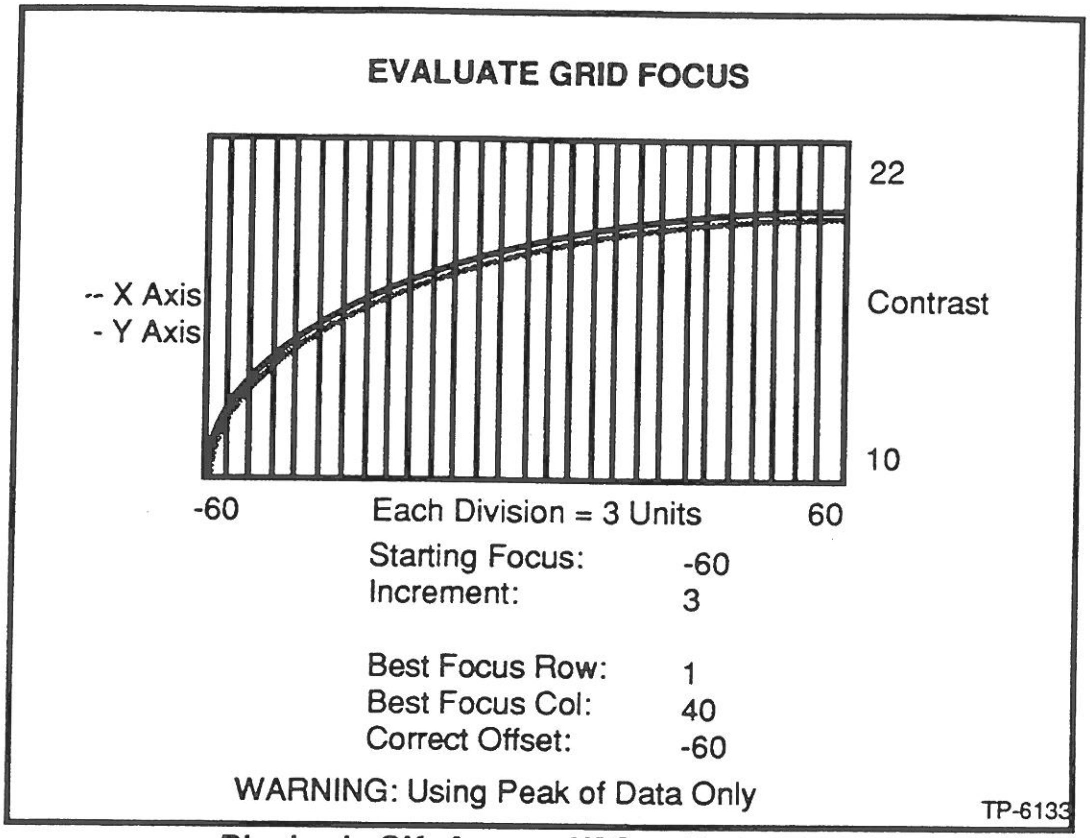
Figure 5-7 is what the optimum Evaluate Grid Focus display should resemble.



Good Display, Answer YES to Update MODE.

Figure 5-7
Optimum Evaluate Grid Focus Display

Figure 5-8 is an example of an Evaluate Grid Focus display where the focus array is off center. The system focus that the DFAS suggests should be entered into MODE and the job exposed again. The focus array should then be centered in the display and it should say "Using LSF Function" (Figure 5-7).

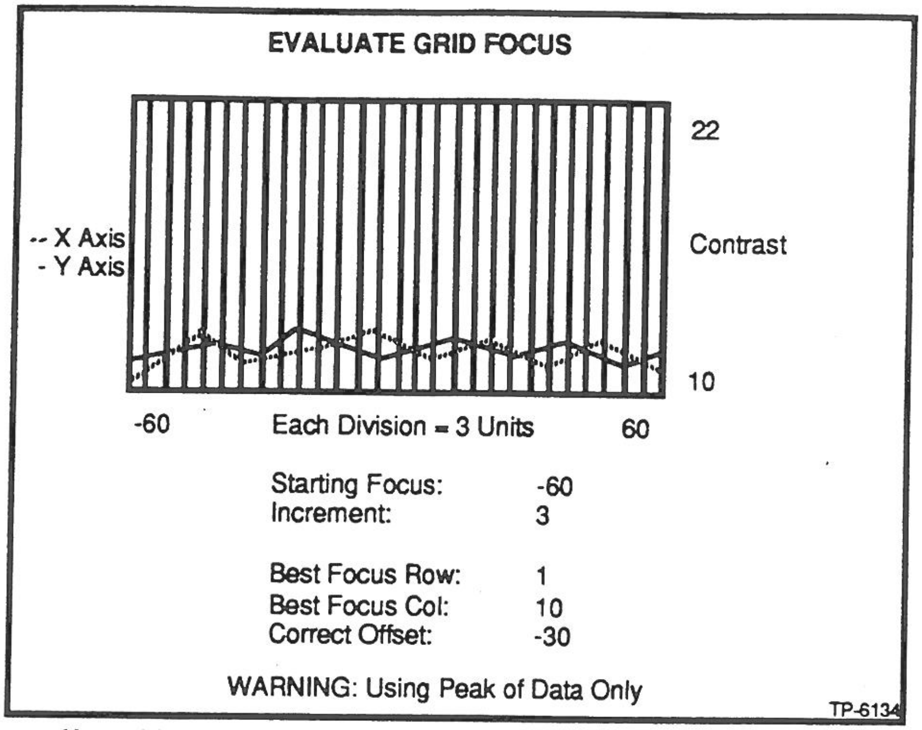


Display is OK; Answer YES to Update MODE and Repeat FOCUS Test to Center Array

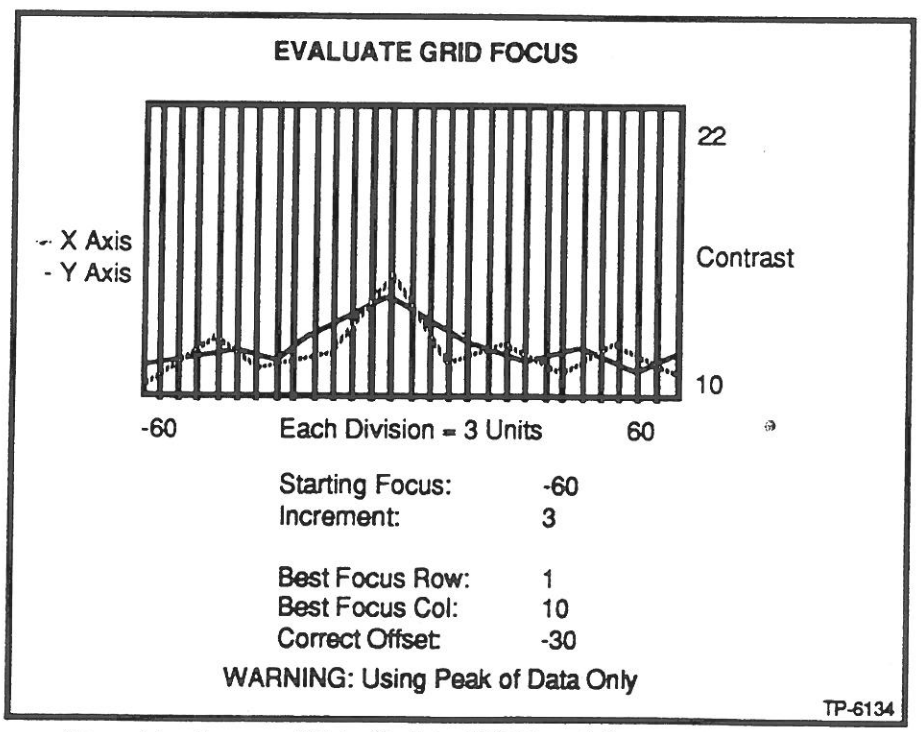
Figure 5-8
Improperly Centered Evaluate Grid Focus Display

Figure 5-9 is an example of an Evaluate Grid Focus display where the system read very bad alignment data. The system will display whatever data it reads, good or bad. It is possible that the system will choose a focus setting based on this data; do NOT update MODE or the job when the display resembles Figure 5-9. The problem is most likely one of the following:

a. Incorrect job specification.
b. Stepper focus beyond 12µm; EXPO a normal focus/exposure array to determine what the focus setting should be and then try the FOCUS command again.
c. The metrology system is not operating correctly (contact GCA field service).
d. Double images on wafer; check job specification and apertures.
e. Inadequate exposure time.



Unusable; Answer NO to Update MODE and Correct the Problem



Unusable; Answer NO to Update MODE and Correct the Problem

Figure 5-9
Unusable Evaluate Grid Focus Displays

Focus Test without the FOCUS Command

In order to use the EXPO command with this feature fully, one should become familiar with the wafer stepper AEXPO and DEXPO commands in the wafer stepper software manual. The command AEXPO allows the user to execute a fixed type of EXPO command to minimize operator errors with a fixed starting and ending focus.

The basic concept for using the metrology system to find system focus is based on the fact that the metrology system gives maximum signal on a latent image when the system is at best focus.

Latent Focus Test

To execute a latent focus job, perform the following:

1. Load a reticle with DXD alignment targets onto the system.
2. EXPO an array. (The FOCUS option should be chosen from within the EXPO command.)

NOTE: Due to some minor limitation, the starting row should always be an odd value (Row,1,3,5,7 etc.). The starting and ending columns should be specified left to right (1-5). If not, the data will be interpreted incorrectly.

3. The exposure time should be set to about twice the nominal exposure.
4. After the EXPO command exposes the focus array, abort the job. Do NOT remove the wafer from the wafer chuck.
5. **EXEC** a DXD reading pass (a five-by-five array is recommended at 0.25µm increments) using the DFAS or Micro DFAS to align the array. Do NOT remove the wafer from the wafer chuck as the first pass exposes a latent image, no global alignment is necessary. Similar to executing intrafield analysis, the pass name should start with FOC. When the metrology system encounters this keyword it automatically sets the starting focus and focus increment.
6. After the wafer is brought to the AWA align position, press **EXP** on the button box. On completion of the pass, it displays the focus data as in Figure 5-7. The suggested focus setting is also displayed. The user can save the display by pressing **D** on the metrology keyboard.
7. The system displays the focus alignment data graphically as in Figure 5-7. The suggested focus is displayed.
8. Enter the suggested system focus in the wafer stepper MODE or in the job focus offset in the particular job.

A possible set of MOP commands may look like

EXPO FOCTEST\FOC (Expose focus matrix)
CTRL C ABORT (Abort EXPO job)
EXEC FOCTEST\FOC (Read focus data and perform analysis)

NOTE: The AEXPO command can be used in place of the EXPO command if the user specifies DEXPO files.

INSITU Operation

INSITU has 2 commands in the wafer stepper MOP. They operate as follows:

- **SETUP** - This automatically reads focus, intrafield, and Micro DFAS baseline. MODE is updated with the new corrections automatically (Figure 5-10).
- **INSITU** - This command displays the INSITU utility options list (Figure 5-11).

SETUP Command

NOTE: Select intrafield templates before using INSITU.

When the command SETUP is entered on the wafer stepper keyboard, the following is executed automatically. If the wafer stepper system is equipped with PPC, RMS and AWAD, the focus, intrafield, and the baseline tests are performed automatically without user intervention (Figure 5-10).

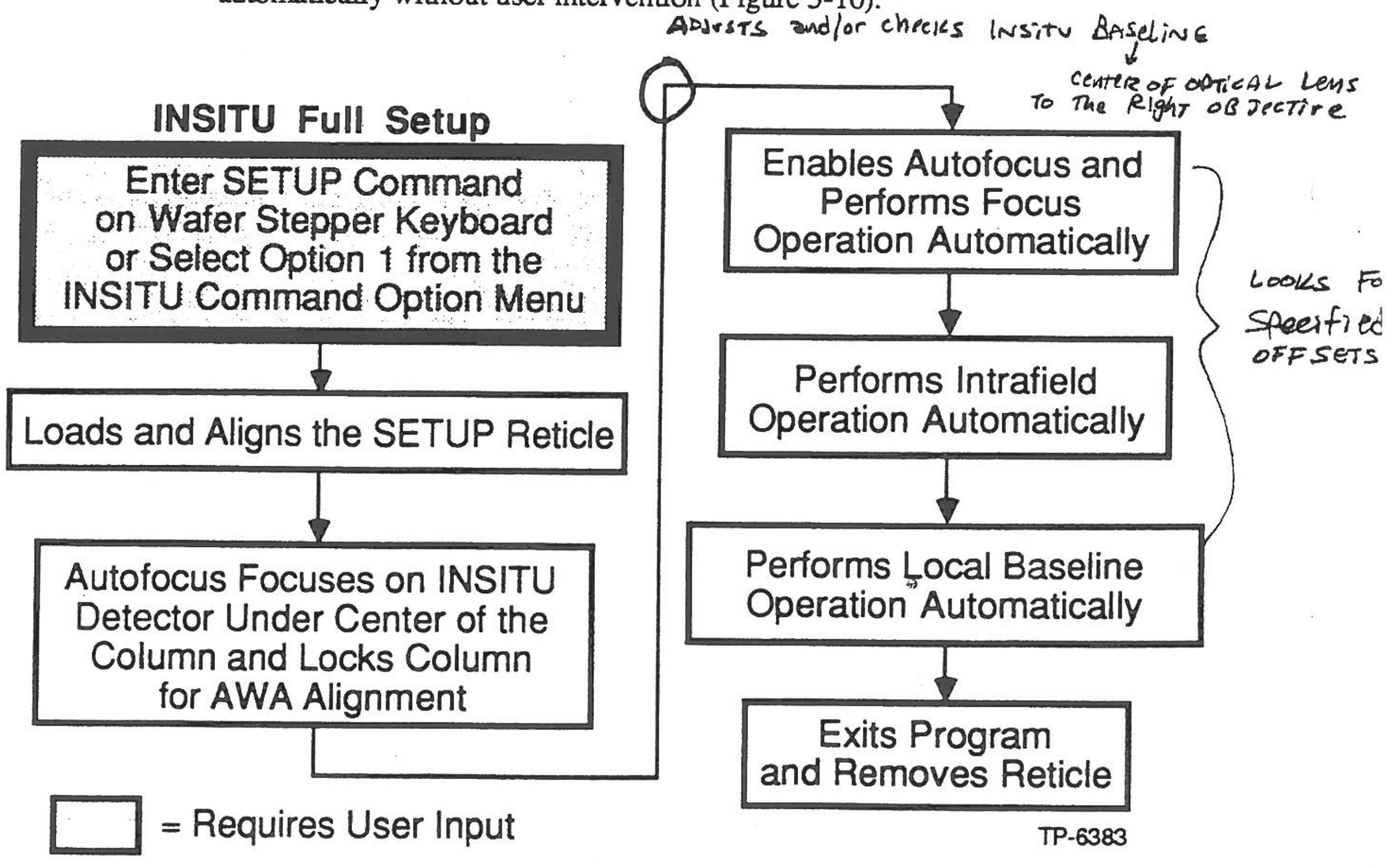


Figure 5-10
SETUP Command Operation Flowchart

The INSITU Utility Options Menu

The INSITU Utility Options Menu, as shown in Figure 5-11, permits the user to perform various system tasks using INSITU as a measuring device. Each option within the menu is described in the following paragraphs.

INSITU UTILITY OPTIONS

1. Full Set-Up
2. Determine Focus Using INSITU
3. Intrafield Analysis Using INSITU
4. Determine Micro DFAS Baseline Using INSITU
5. Determine Dose Control Parameters
6. Exit

Enter Number Of Desired Option:

TP-7686

Figure 5-11
INSITU Utility Options Menu

Full Set-Up

The full set up all command automatically adjusts system focus, intrafield and local aligner baseline, then automatically updates the mode file with the new corrections. The find focus test is performed first, the set mag/trap test is performed second and the set Micro DFAS baseline test is performed last.

The full set up all command adjusts system parameters to a reference or zero value without the use of send-ahead wafers. The operator must make sure that the Setup-01 reticle is present in the RMS library to run the full set up command function.

Determine Focus Using INSITU

The determine focus using INSITU software is a metrology tool which analyzes the best focus offset for the INSITU detector. The focus offset used to expose wafers is a fixed offset from the INSITU focus offset.

Since the job program focus offset is directly referenced to the system focus in mode file, the operator should have to set the job program focus for each process level only once.

When all job program focus settings are properly set, the system focus in mode file should be the only necessary focus change (unless the process has been changed). Any atmospheric changes affect the AUTOSTEP system as a whole (all jobs) and therefore, the system focus in the mode file sets all the jobs to the best focus position.

The software relies on INSITU alignment techniques and the Setup-01 reticle to determine system focus. The INSITU detector is commanded to be placed directly under the lens and to perform a series of alignment scans on the center cell of the reticle. The autofocus system moves the optical column ±12 microns from the current focus position. A focus cycle which performs 41 focus samples is performed until the fixed lens assembly is 12 microns below the current focus setting. The increment between focus samples is equal to 0.6 microns. The software then plots a curve of the relative contrast values at the different 41 focus sample positions on the automatic focus calibration plot and then performs a least-squares-fit analysis to determine the nominal focus position as it relates to the peak contrast level. The new focus value, as displayed by the red vertical bar on the automatic focus calibration plot, is determined and automatically entered into MODE.

Intrafield Analysis Using INSITU

The intrafield analysis using INSITU software is a metrology tool which determines lens magnification, X-axis trapezoid, Y-axis trapezoid, and reticle rotation errors which are all measured and corrected by using INSITU and the Setup-01 reticle. This reticle contains an array of quad-style Micro DFAS alignment targets spaced on 1.0mm steps. The lens magnification errors are measured by stepping the INSITU detector to each user-selected target and performing a local alignment to determine the positional X and Y-axis displacement.

After the alignment data has been collected, the intrafield error coefficients are calculated and displayed. The X and Y-axis trapezoid and mag errors are automatically sent to the reticle stage where the platen is calibrated to the new calculated position. The reticle rotation errors are sent to the RMS aligner controller and the reticle is realigned to the new calculated position.

Determine Micro DFAS Baseline Using INSITU

The determine Micro DFAS baseline using INSITU software is a metrology tool which determines the nominal distance between the local alignment system (Micro DFAS) and the center of the reticle. INSITU aligns to four marks at the edges of the exposure location and calculates the exact center of the reticle. The INSITU artifact is positioned under the Micro DFAS where it performs an alignment to the INSITU artifact. The software calculates the X-axis and Y-axis local baseline corrections and automatically applies the corrections in the MODE file.

Determine Dose Control Parameters

The determine dose control parameters ensure that all GCA AUTOSTEP 200 systems deliver the same amount of energy to the wafer surface for the same number of units in the job description file during exposure. The dose control parameters assumes that every MAXIMUS 2000 can deliver 500mW/cm^2. In reality, no MAXIMUS 2000 light source delivers the same amount of energy, therefore, we adjust the shutter opening time by the following linear equation:

New Time (sec) = Scale * Job Time(sec) + Offset(sec)

The scale and offset values are contained in the MODE file. Use the following procedure to calculate the scale factor and offset values.

1. Enter the **INSITU** command at the system keyboard.
2. Select menu option **5** - Determine Dose Control Parameters from the INSITU utility options menu. The following sequence of events occur automatically:

   a. The reticle is removed from the platen.
   b. The aperture blades are set to 5mm (at the wafer) in the X and Y-axis.
   c. The IQ probe is placed under the center of the lens.
   d. The shutter opens and closes from 0 to 800msec to sample light intensity and the data is collected and presented on the metrology screen as shown in Figure 5-12.
   e. The new scale and offset values are calibrated. The absolute dose error, which is displayed in the **Error %** column of Figure 5-12 and plotted on the graph, should be within ±2% or the test is automatically repeated.

Once the dose error is within specification, the new scale and offsets values are automatically loaded into the MODE file.

Dose Control System

Expected mJ	Real mJ	E-R mJ	Error %	Time Sec
30.00	30.12	-0.12	-0.4	0.177
50.00	50.20	-.20	-0.4	0.290
100.00	100.24	-.24	-0.2	0.573
150.00	150.01	-.01	0	0.850
200.00	200.02	-.02	0	1.139
250.00	249.99	.01	0	1.422
300.00	300.34	-.34	-0.1	1.708
350.00	350.68	-.68	-0.2	1.992
400.00	400.52	-.52	-0.1	2.274

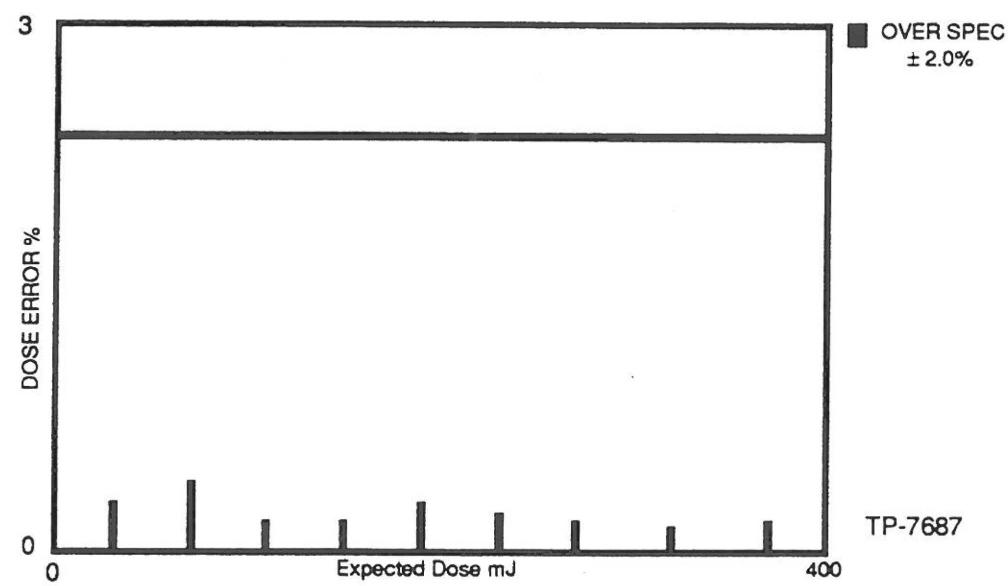


Figure 5-12
Dose Control System Display Example

Exit

The Exit menu selection removes the user from the INSITU Utility Options menu and returns to the system prompt.

Section 6 - SMARTSET Operation

Overview of Using SMARTSET

Intrafield Analysis

Intrafield analysis characterizes both the optical column setup and the intrinsic lens properties which determine image placement within a field.

Intrafield analysis evaluates the optical quality of a wafer stepper system independently from the mechanical quality. This two-step process separates mechanically correctable errors (such as reduction, rotation, and trapezoid) from total image placement errors, to optimize the system's optical column.

SMARTSET measures image placement errors, displays vector maps of modeled components, and recommends corrections required for column setup.

Correctable intrafield errors are:

Error	Cause
Die Rotation and Translation	Improper Reticle Placement
Reduction	Barometric Pressure and Temperature Changes
Trapezoid	Improper Platen Position

After mechanical corrections have been made, the remaining image placement errors (such as distortion and anamorphism) are intrinsic to the lens. The remaining errors unaccounted for in the model (such as alignment errors, stage precision and local lens distortions) are referred to as *residuals*.

Mechanically Correctable Errors from Intrafield Analysis

Die Rotation and Translation Errors

Rotation errors are caused by improper reticle placement. Corrections for these are obtained using the Platen Corrections option (Figure 6-1) from the Intrafield Analysis menu. Adjustments are made by entering the correction into the RMS reticle rotation prompt in MODE or by manually adjusting the manipulator for non-RMS systems.

Translation errors can be *viewed* in intrafield analysis, but are *analyzed* only in grid analysis. Refer to *Grid Analysis* for a description of translation errors.

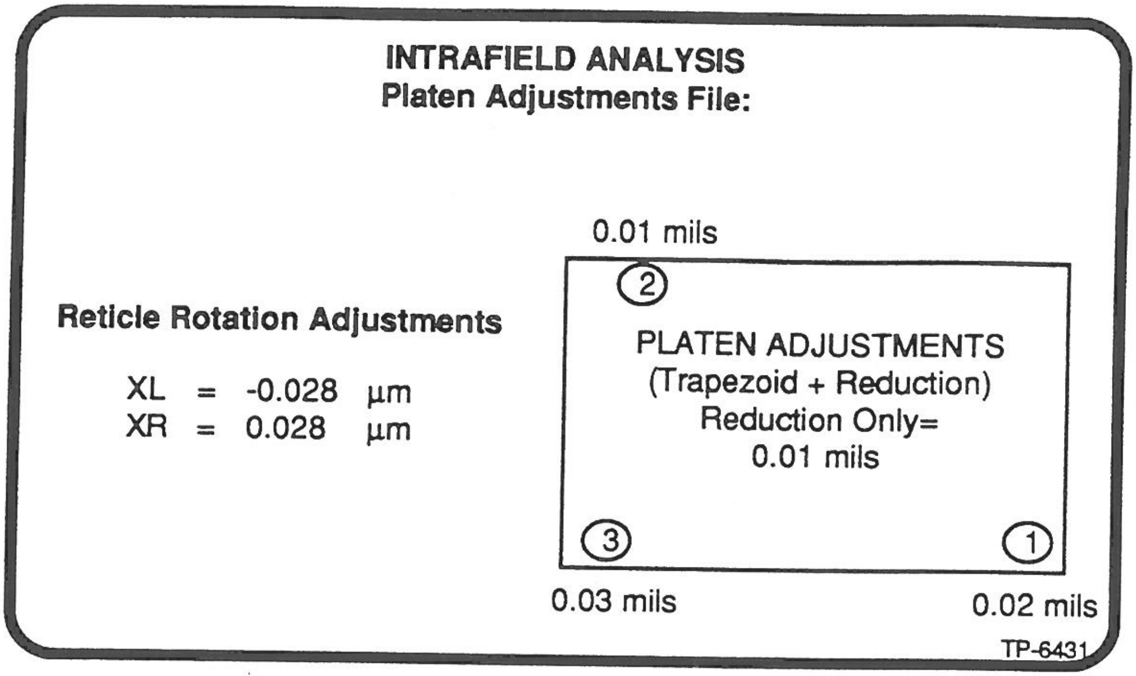


Figure 6-1
Typical Platen Corrections Display

Reduction and Trapezoid Errors

Reduction and trapezoid are correctable intrafield errors caused by improper platen position and/or variations in temperature and barometric pressure. Correction factors are obtained using the Platen Adjustments option from the Intrafield Analysis menu.

SMARTSET vector maps show the image placement errors at each measurement point. Software tabulates and displays minimum, maximum, mean, and standard deviation data for each plot.

Uncorrectable Errors from Intrafield Analysis

Distortion Errors

Distortion is a variation of magnification and reduction, proportional to a power of the distance from the reduction lens center. The result is the transformation of a square into a pincushion or barrel image (Figure 6-2). Distortion is an intrinsic lens error and cannot be corrected.

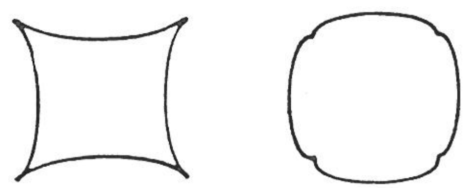


Figure 6-2
Examples of Pincushion and Barrel Images

Anamorphism Errors

Anamorphism is the difference in magnification along two orthogonal axes. A square is distorted into a rectangle or rhombus. Anamorphism is an intrinsic lens error, and therefore cannot be corrected.

Grid Analysis

Grid analysis optimizes the stepping characteristics of a wafer stepper system by comparing the *actual* array placement on the wafer in relation to the *expected* placement. The location of each field within the stepped array, specified by coordinates X and Y, is analyzed to determine any deviation.

The following lists grid placement errors and their causes.

Error	Cause
Translation	Improper Baseline
Scale	Improper Stage Setup
Orthogonality	Improper Stage Setup
Rotation	Microscope Rotation

SMARTSET measures and displays vector maps of grid placement components and recommends corrections, which must be entered into the MODE file on the wafer stepper system. These corrections include baseline, scale, orthogonality, and microscope rotation.

Grid analysis can be used for setup of a single system, or for matching multiple systems to one reference system. When matching is performed, the reference system must be set up first.

Translation Errors

Translation errors occur when the actual array placement is different from the expected placement. The expected placement is determined by the global baseline, which is the distance between the right-hand microscope objective and the optical center of the reduction lens (see Figure 6-3).

A deviation, in any direction, in array placement from the baseline value is interpreted as a baseline error that can be corrected using software.

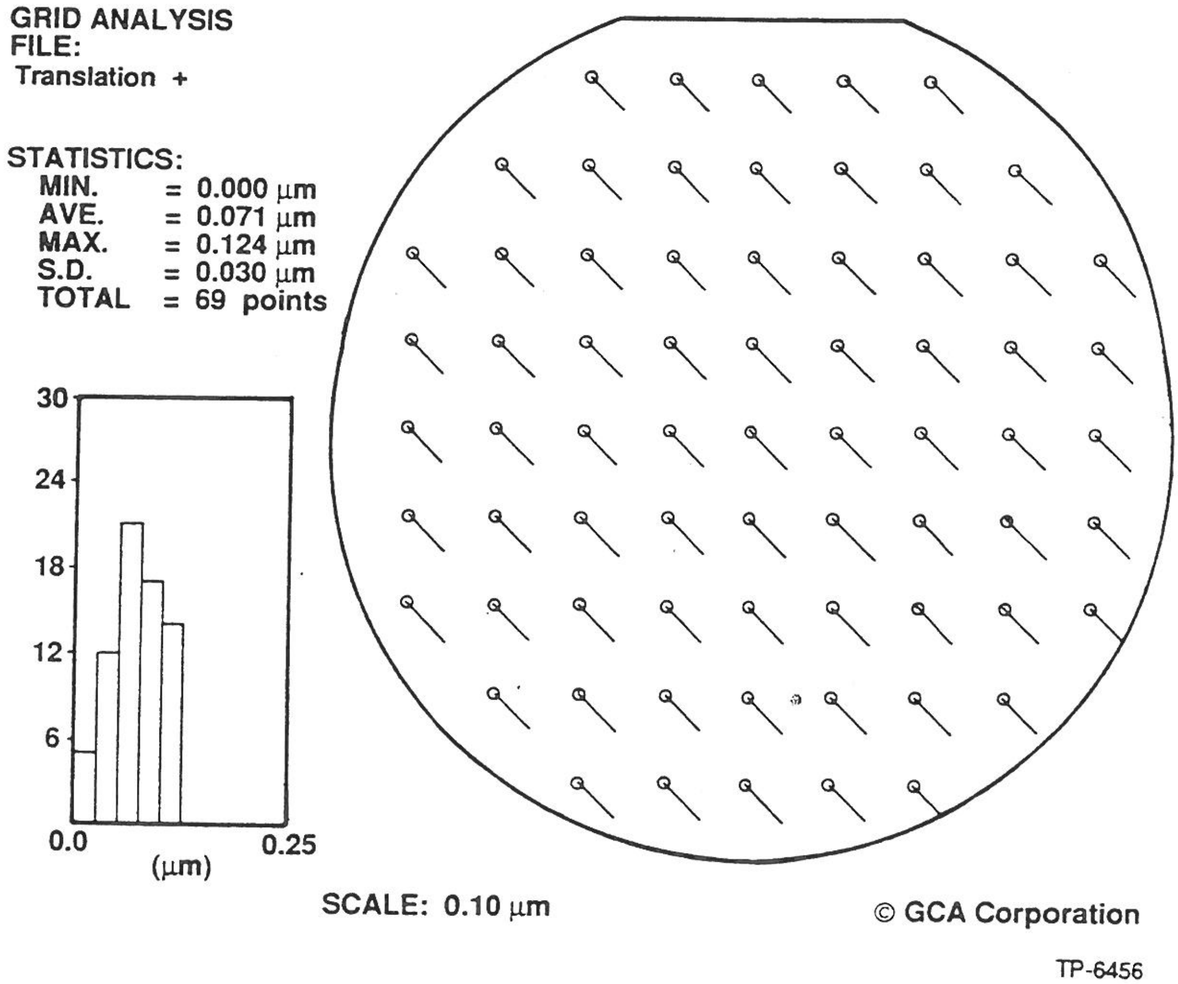


Figure 6-3
Example of Translation (Global Baseline) Error

Scale Errors

The stepping distances of the stages are established by both stage mirror flatness and laser metrology. Scale is the ratio of *specified* movement to *actual* movement (Figure 6-4).

To match X and Y stepping on a single system, a pattern array is stepped in one orientation and measured after rotating the wafer 90° to provide the necessary corrections.

When matching the stepping characteristics of several wafer stepper systems, an artifact wafer from the reference system is used to enable scale equalization among the group.

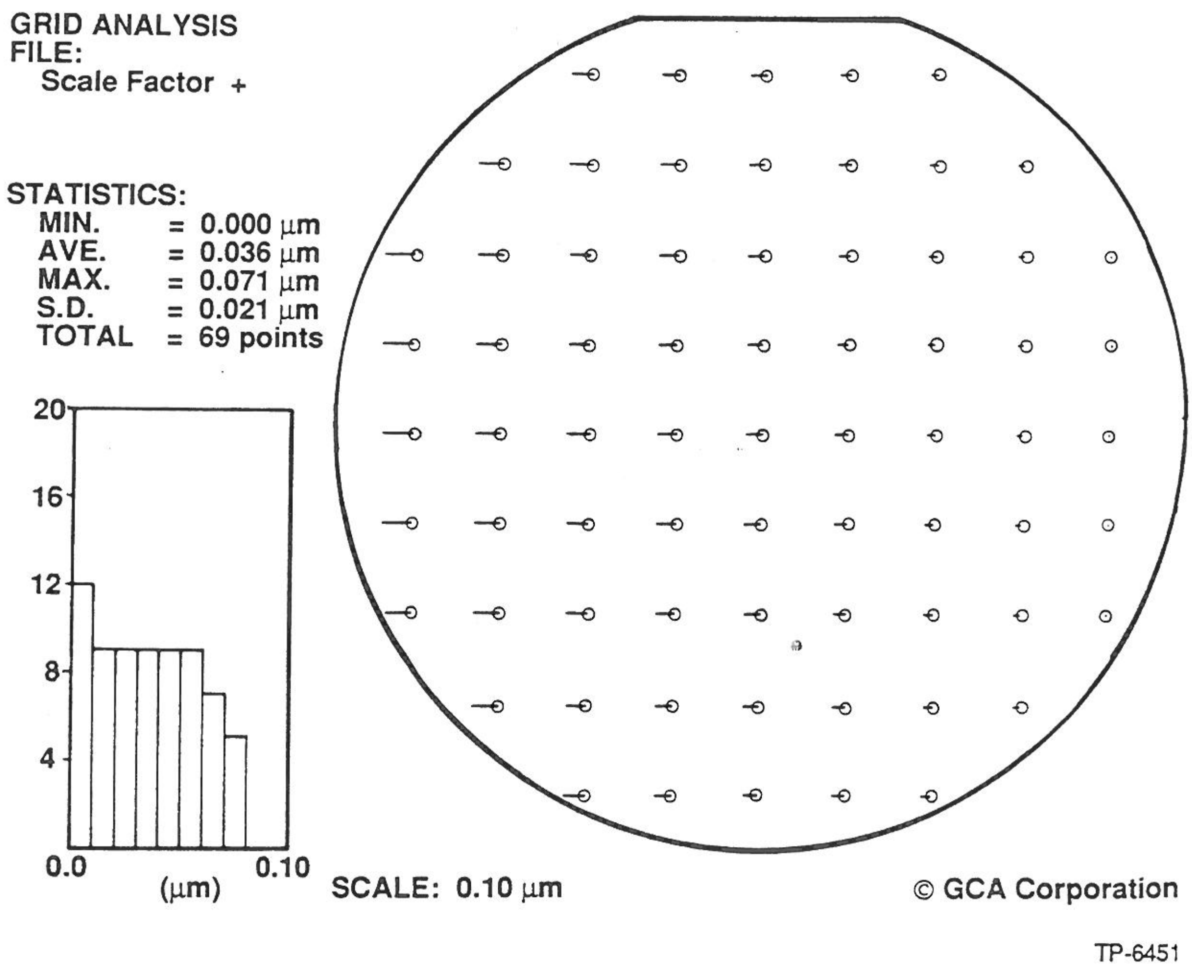


Figure 6-4
Example of Scale Error

Orthogonality Errors

Orthogonality is the ability of the X motion to step perpendicularly to the Y motion. Orthogonality errors are rows that are not perpendicular to columns. The orthogonality of X and Y stepping is determined by the angle between the stage mirrors (Figure 6-5).

Like scale corrections, orthogonality corrections can be calculated by measuring an array at a 90° rotation with respect to the orientation at which it was exposed. In the case of matching, equalization of orthogonality among the systems being matched is more important than absolute orthogonality. Orthogonality matching among systems can be achieved by measuring the reference system artifact wafer on each system.

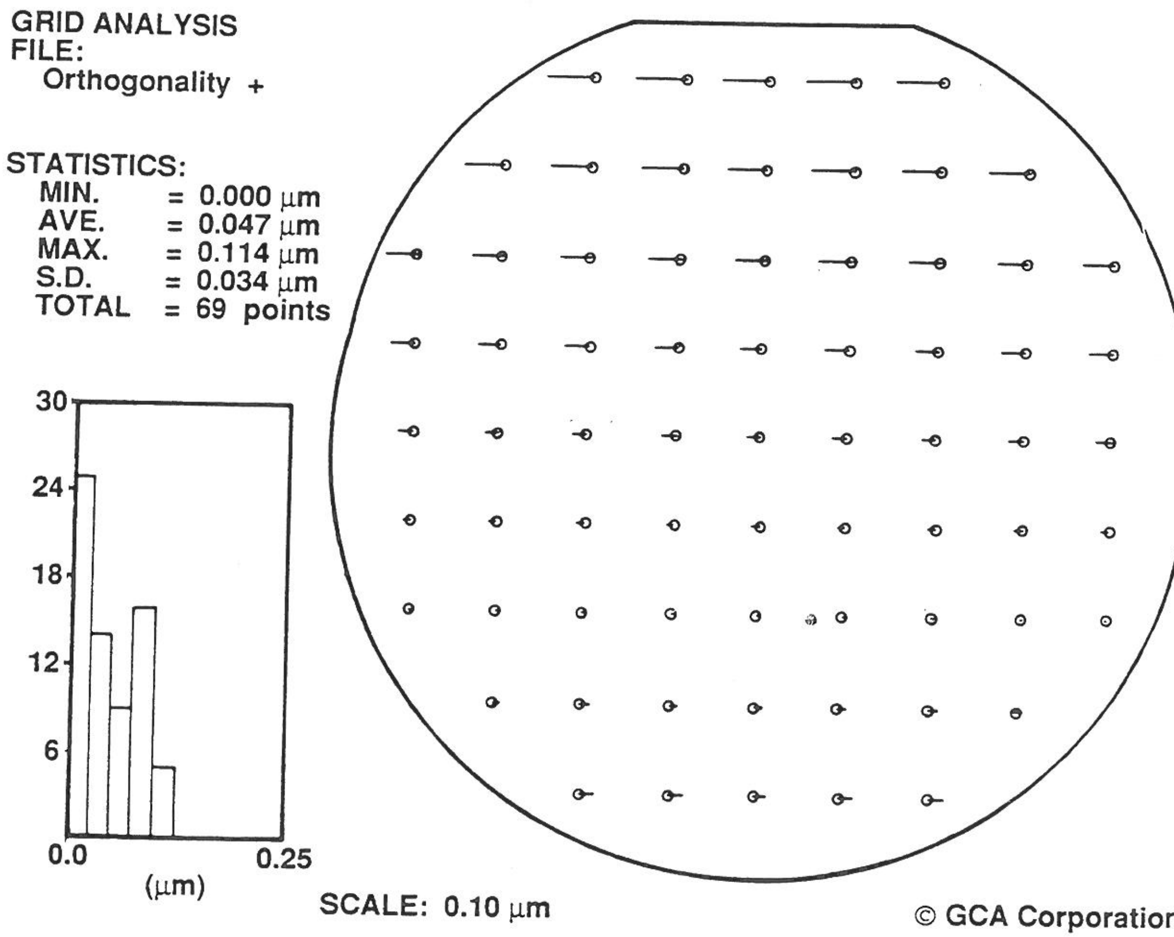


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Figure 6-5
Example of Orthogonality Error

Rotation Errors

Microscope rotation is the angle (theta) formed by the X-axis and a line drawn through the microscope objectives (using the right-hand objective as the pivot point): see Figure 6-6.

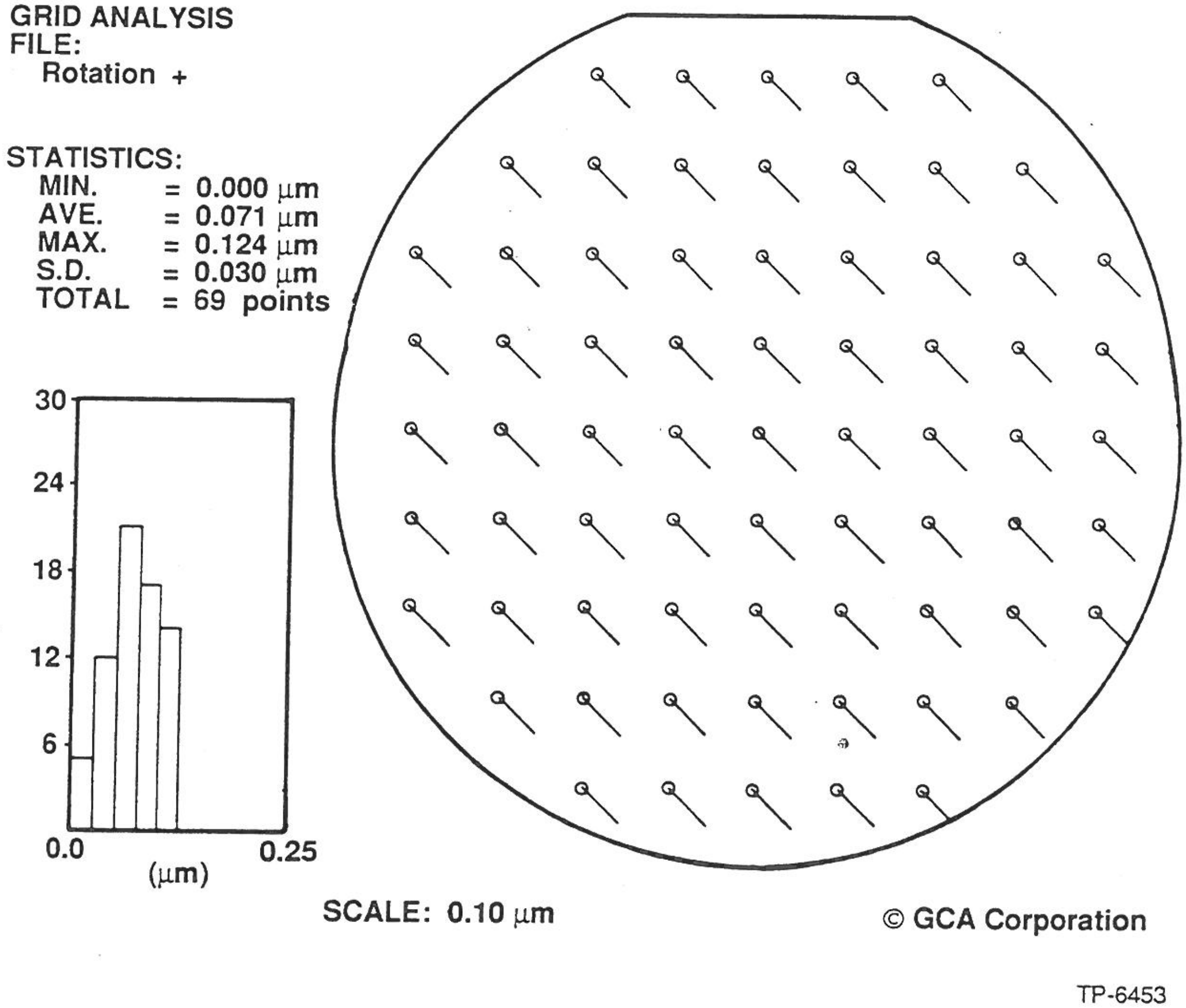


Figure 6-6
Example of Microscope Rotation

Setting Up SMARTSET

When SMARTSET is used for the first time, do the following:

1. Set up directories for each wafer stepper system being characterized.
2. Make sure that the metrology system job specifications, as required, are properly set up.

Creating SMARTSET Files from Metrology Data

The metrology system, as one of its functions, creates data files known as history files. These files have the information to create files compatible with SMARTSET. The history files are stored in a LIFO method, last in first out. This means that the first history file, example HIST01.FIL, would have been created by the last wafer run. The number of files stored is user-selectable (1-50) in the Edit Defaults menu. The type of SMARTSET files that can be created are:

- Grid Analysis Files
- Intrafield Analysis Files
- IQ Uniformity Files

There are several reasons to create these files.

- To make a permanent copy of wafer data
- To graphically view specific component errors
- To edit data files to remove selected points
- To print data in a graphics format
- To improve wafer stepper performance

Creating SMARTSET Grid Files

Every time a wafer is aligned in either DXD or mapping mode, a data file is created in the directory C:\DFAS\DFHIST entitled HIST01.FIL. To convert and transfer this information for SMARTSET analysis, choose the Create SMARTSET File (Figure 6-7) from the System Program menu. If no SMARTSET output directory has been selected, the user is prompted with a list of SMARTSET directories to choose from. If no directories have been created by SMARTSET, an error message is displayed. The user must create these directories with SMARTSET, as this establishes certain operational characteristics associated with the directory. See the SMARTSET manual for more details. The user can run SMARTSET using the SMARTSET option from the System Program menu.

To create a SMARTSET file, perform the following:

1. Select the stepper directory. The Create SMARTSET File menu appears:

CREATE SMARTSET FILE
Version 7.1

Type of Data File

1. Grid
2. Intrafield
3. Uniformity
4. Previous Menu

Figure 6-7
Create SMARTSET File Menu

2. Select option 1, GRID. A list of history files HIST01 -- HISTNN is displayed. Select the files to be used. Remember, the first file is the last wafer run.
3. Enter a filename. This name can be any legal DOS format filename with no extension. For example: WAF#1234. If the filename is chosen correctly, the metrology system creates and installs this file in the proper SMARTSET stepper directory.

   The user can manipulate this file now or later using the SMARTSET analysis package. In order to minimize errors, this version updates the DEFAULT.GPD file to contain the proper AWA offsets, AWA row and column, etc. Choose the Default option in the SMARTSET Source Of Mode Data menu to maintain constant analysis.

Creating SMARTSET Intrafield Files

Every time a wafer is executed with the "INT" option described in the Executing Intrafield Jobs procedure, a data file is created in the directory C:\DFAS\DFHIST called INTRA01.FIL. This file contains the necessary information to create and transfer an intrafield type SMARTSET file. The same procedure as used in the Creating SMARTSET Grid Files procedure can be followed, except option 2 should be selected in the Create SMARTSET File menu.

Creating SMARTSET Uniformity Files

When IQ is executed from the MOP if the proper hardware is installed, the metrology system generates data files in the directory C:\DFAS\DFHIST called UNIF01.UNF. A SMARTSET file can be created as above except by selecting option 3, Uniformity, in the Create SMARTSET File menu.

Performing SMARTSET Analysis

Using SMARTSET to perform grid and intrafield analysis involves the following:

- Data Collection, which uses the local alignment system to gather alignment data. The arrays read can be any logical stepping pattern with enough dies to have accurate data.
- Data Averaging, which is used to gain statistical confidence in the data. If more than 1 wafer is read and averaged, the vector plots are more accurate.
- Data Viewing, which displays the data and the suggested corrections.

Once this is accomplished, manually enter the corrections recommended by SMARTSET into the wafer stepper system.

Most tasks performed during SMARTSET operation are invoked using menus. The structure of these menus is shown in Figure 6-8.

To move through the SMARTSET menus, use the following guidelines:

- To return to the previous menu, press the space bar.
- To select an option, enter the option number and press RETURN.

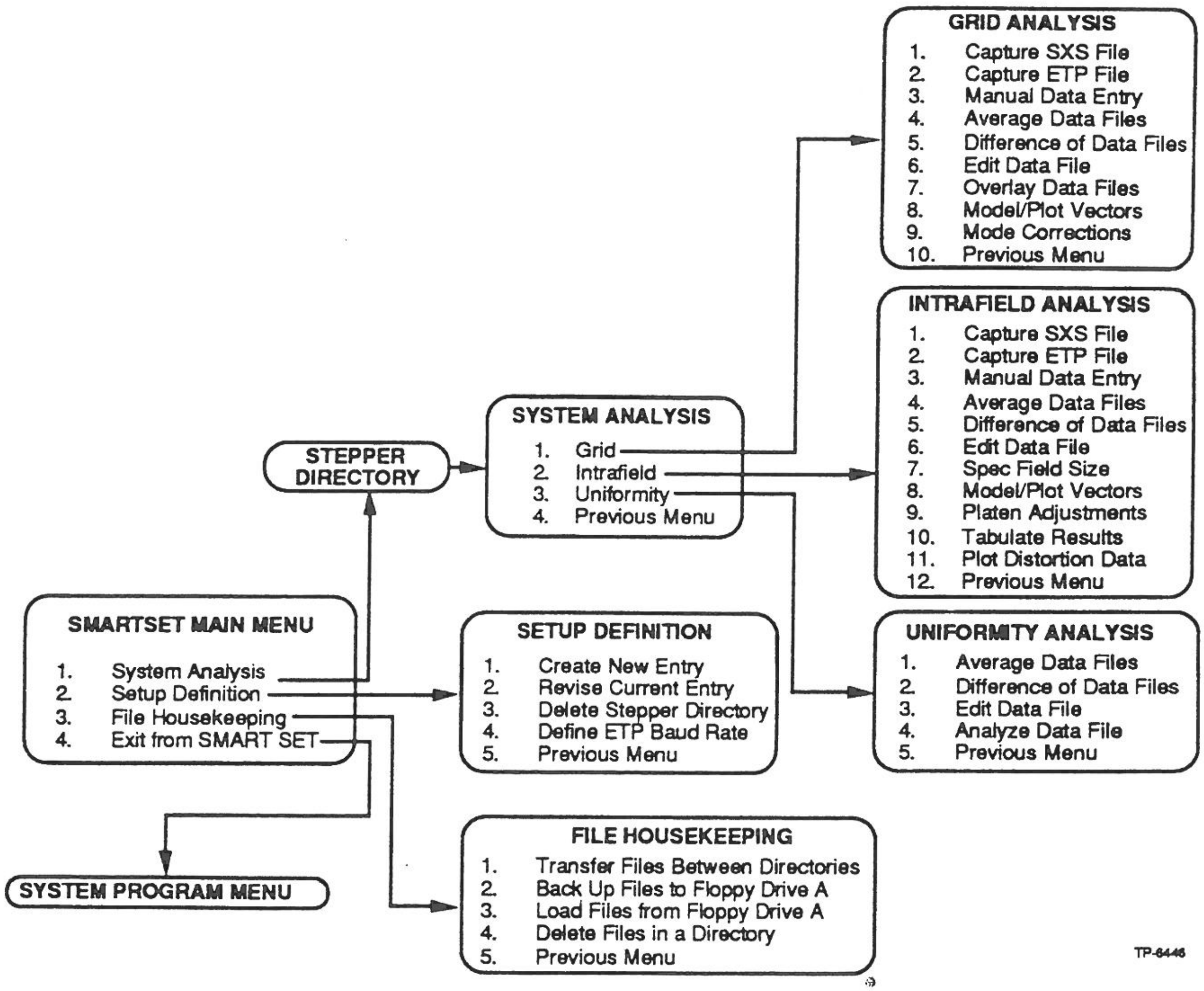


Figure 6-8
SMARTSET Menus Block Diagram

NOTE: See Figure 4-1 for a complete SMARTSET flowchart.

Manually Entering Data into SMARTSET

SMARTSET software enables files to be created to hold the locations and magnitudes of desired data by using the Manual Data Input option from either the Grid Analysis or Intrafield Analysis menus. Values can be manually entered for any measurement technique, if a local alignment system is not available for automatic collection of this data. These values are entered as number pairs and represent X- and Y-axis placement errors. A blank wafer (grid Figure 6-9) or die (intrafield Figure 6-10) is displayed, on which user-specified data is entered.

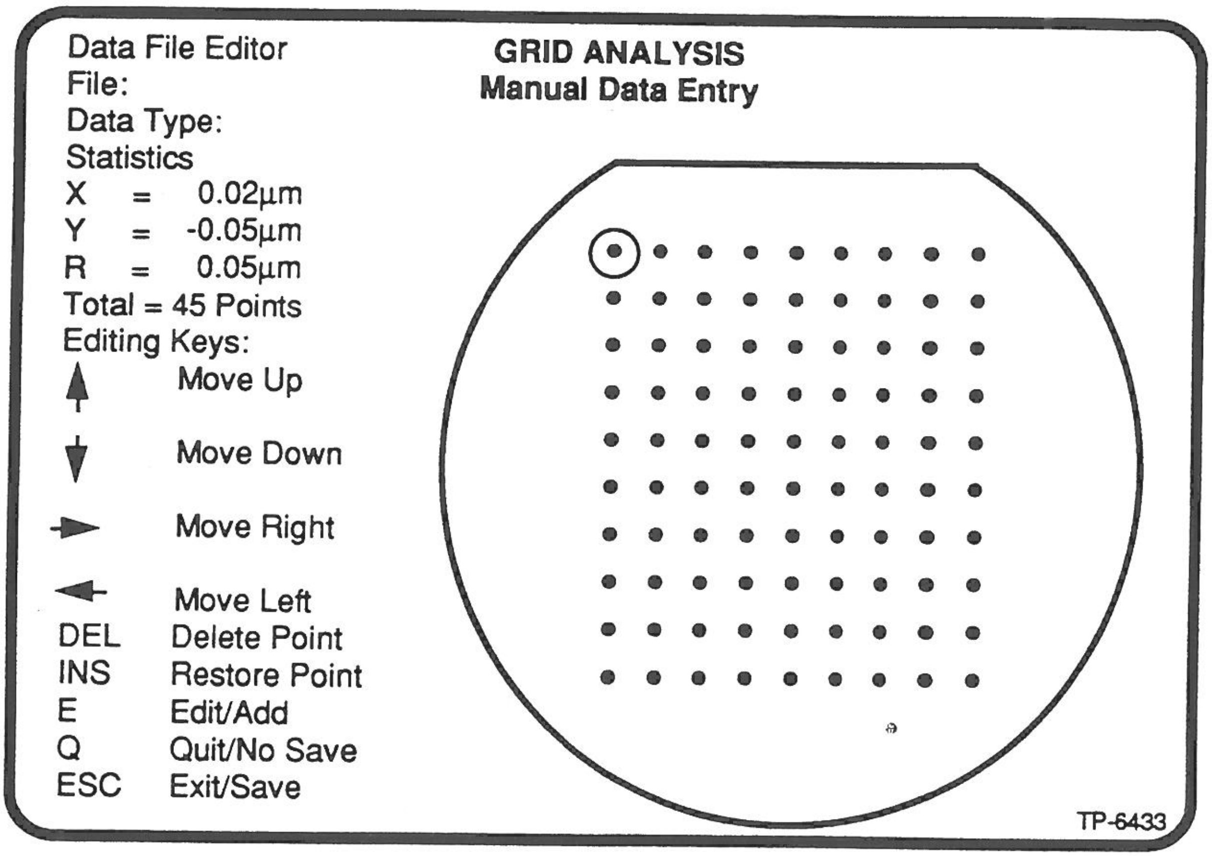


Figure 6-9
Manual Grid Data Entry Display

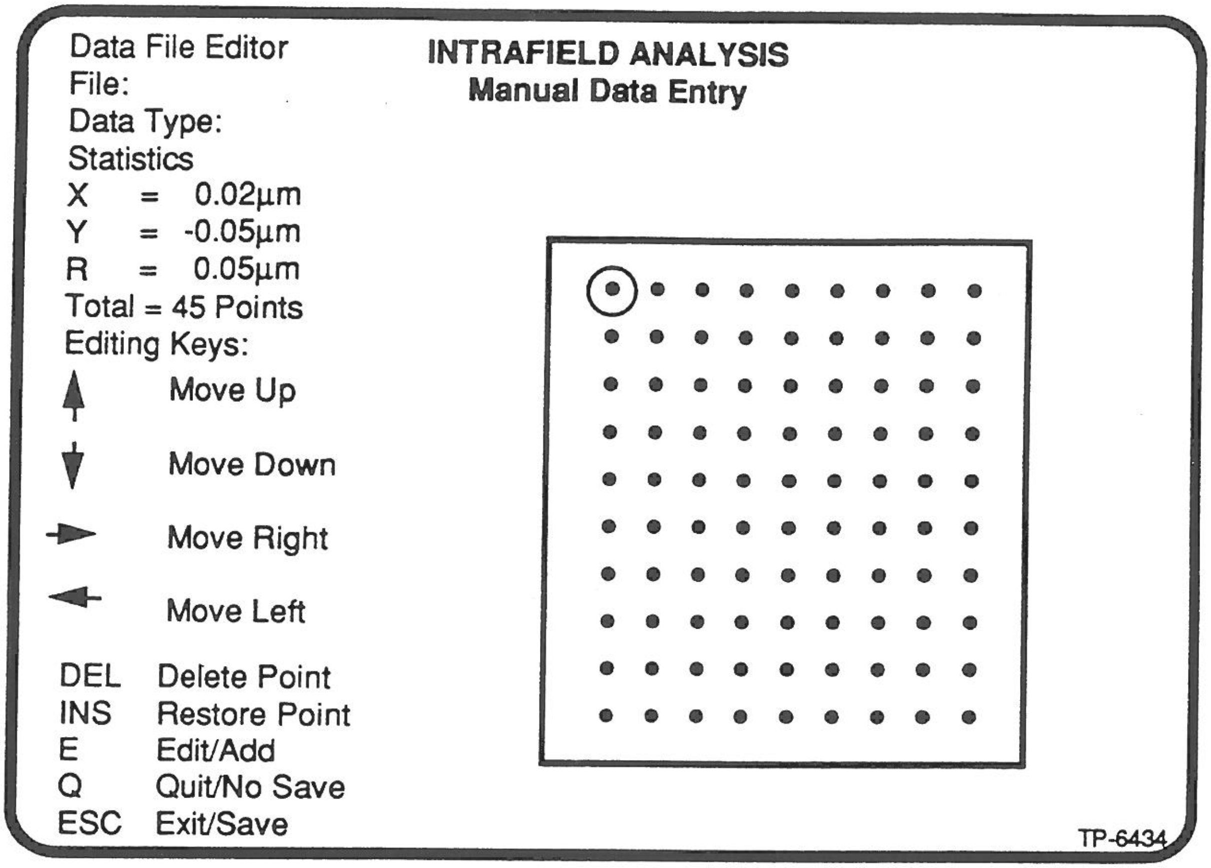


Figure 6-10
Manual Intrafield Data Entry Display

Averaging SMARTSET Data Files

Averaging the results of several wafers provides statistical confidence to the data analysis. To average the data, perform the following procedure.

1. From the SMARTSET menus, select option 4 from the Grid Analysis menu (Average Data Files): this displays a directory of existing grid files.
2. Select the files to be averaged, following each entry by pressing the RETURN key.
3. When the list is complete, press the ESC key.
4. Name the file.

Performing Grid Analysis

SMARTSET uses the laser metering system of the stages to determine the position of the field alignment targets on the test wafer to acquire the alignment data.

Before data acquisition is performed, make sure that the wafer stepper's local alignment system is properly set up, with the stages correctly integrated. It is not necessary to read SMARTSET wafers on the same system at which they were generated. A reference system can be set up to read wafers from the remaining systems.

Grid analysis can be performed using a single system, or using several systems; this is called *grid matching*.

Perform the following:

1. Identify the reference system.
2. Set up the reference system by collecting the data, averaging the data, and making any recommended corrections to the reference system. (See following procedure.)
3. Match the other systems to the reference system. (See following procedure.)

Setting Up the Reference System

Use the following procedure to optimize the stepping performance of a single system, or setting up the stages of a reference system for grid matching. This procedure uses the intrafield reticle (P/N 4800-045 for 5X systems).

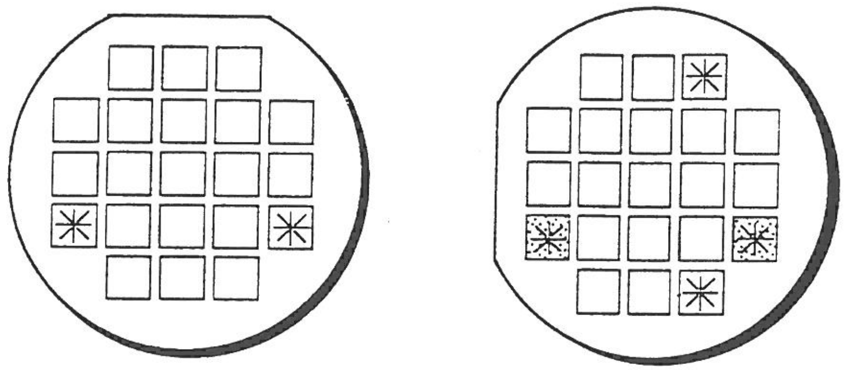
1. Expose the first pass of a job that places DXD targets onto the wafer. The job must be specified so that the wafer can be rotated 90°, aligned, and read by the metrology system (Figure 6-11).
2. Execute the second pass of the job that reads the data points at a 90° rotation. Read enough data points to have statistical confidence.
3. Create the SMARTSET Grid files for the wafers read.
4. If several wafers are read, average the results using the Average Data Files option from the Grid Analysis menu.
5. Use the Model/Plot Vectors option from the Grid Analysis menu and view the averaged data.
6. Make sure that no edge data points are throwing the SMARTSET data out of specification. Edit the data file and delete any edge data points that are out of specification.
7. Use the Mode Corrections option from the Grid Analysis menu (Figure 6-12). Select the System Setup (90° Rotation) option to view the orthogonality and Y scale corrections:

   Scale: When correcting for scale, enter only the Y scale value suggested by SMARTSET using the MODE command from the wafer stepper system. This matches the Y stepping with the X stepping. If there is a Y scale value already in MODE, add the new value to it.

Orthogonality: Enter the orthogonality correction suggested by SMARTSET into the wafer stepper system MODE. If there is an orthogonality value already in MODE, add the new value to it.

NOTE: Orthogonality and scale corrections can be set with an accuracy of ±1ppm.

8. Repeat steps 1 through 7 and make sure that the mode corrections are close to 0. If the mode corrections are worse, check the signs of the errors.



After Wafer is Exposed and Developed,
Rotate 90° and Note New Alignment Marks

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Figure 6-11
Wafer Rotation for Orthogonality Setup

GRID ANALYSIS
Mode Corrections

Baseline Correction
X: 0.00016mm
Y: 0.00025mm
Microscope Rotation
Ø: 0.05µm/mm
Scale Factor
Y: 1.0ppm
Orthogonality
-0.8ppm

Figure 6-12
Grid Mode Corrections Menu (System Setup Option)

Matching Other Systems to the Reference System

To perform grid matching for several systems, perform the following procedure for each system being matched. This procedure uses the intrafield reticle (P/N 4800-045 for 5X systems).

1. On the reference system, expose the first pass of a job that places DXD targets onto the wafer.
2. On the system to be matched, execute the second pass of the job that reads the data points. Read enough data points to have statistical confidence.
3. Create the SMARTSET Grid files for the wafers read.
4. If several wafers are read, average the results using the Average Data Files option from the Grid Analysis menu.
5. Use the Model/Plot Vectors option from the Grid Analysis menu and view the averaged data.
6. Make sure that no edge data points are throwing the SMARTSET data out of specification. Edit the data file and delete any edge data points that are out of specification.
7. Use the Mode Corrections option from the Grid Analysis menu. Select the System-to-System option to view the MODE corrections (Figure 6-13):

   Global baseline: Corrects the global baseline using the recommended baseline tests. (The baseline numbers given by SMARTSET enable tracking of the combined baseline error.)

   Microscope rotation: Use the micrometer on the left side of the alignment microscope to correct for the rotation error determined by SMARTSET, or use the Microscope Correction option in MODE. The relationship between the microscope micrometer adjustment and the SMARTSET value must be determined for each wafer stepper system. Perform this calibration only once per system. If there is a microscope rotation value already in MODE, add the new value to it.

   Scale: When correcting for scale, enter both the X and Y scale values suggested by SMARTSET by entering the corrections into the wafer stepper MODE. If there is a scale value already in MODE, add the new value to it.

   Orthogonality: Enter the orthogonality correction suggested by SMARTSET into the wafer stepper MODE. If there is an orthogonality value already in MODE, add the new value to it.

NOTE: Orthogonality and scale corrections can be set with an accuracy of ±1ppm.

8. Repeat steps 1 through 7 and make sure that the mode corrections are close to 0. If the mode corrections are worse, check the signs of the errors.

GRID ANALYSIS
Mode Corrections

Baseline Correction
X: 0.00016mm
Y: 0.00025mm
Microscope Rotation
Ø: 0.05µm/mm
Scale Factor
X: 1.0ppm
Y: 1.0ppm
Orthogonality
-0.8ppm

Figure 6-13
Grid Mode Corrections (System-to-System Option)

Performing Intrafield Analysis

Setting Up the Reference System (Using Latent Imaging)

Perform the following procedure to expose a wafer and collect data for SMARTSET intrafield analysis. Before acquiring intrafield data, perform grid analysis to check stage performance, since stage orthogonality errors and scaling factors affect intrafield analysis results.

1. Expose a job on the reference system that exposes an intrafield die and then reads the intrafield data without removing the wafer from the system.
2. Create SMARTSET intrafield files for the dies read.
3. If several dies were read, average the files by selecting the Average Data Files from the Intrafield Analysis menu.
4. Model and plot the data using the the Model/Plot Vectors option from the Intrafield Analysis menu.
5. Make sure that the maximum vectors for trapezoid, reduction and rotation (*individually* and not *combined*) do not exceed 0.05µm (Figure 6-14). If any of these vectors exceed 0.05µm, adjust the platen as follows:

   a. From the Intrafield Analysis menu, select Platen Adjustments (Figure 6-15): this displays a screen listing adjustments to be made to the reticle platen, which will minimize reduction, rotation, and trapezoid.
   b. Enter the value for rotation into MODE on the reference system.
   c. Correct for reduction and trapezoid using either PPC or MMP.
   d. Remove the reticle, and repeat steps 1 through 5, until none of the vectors listed in step 5 exceed 0.05µm.

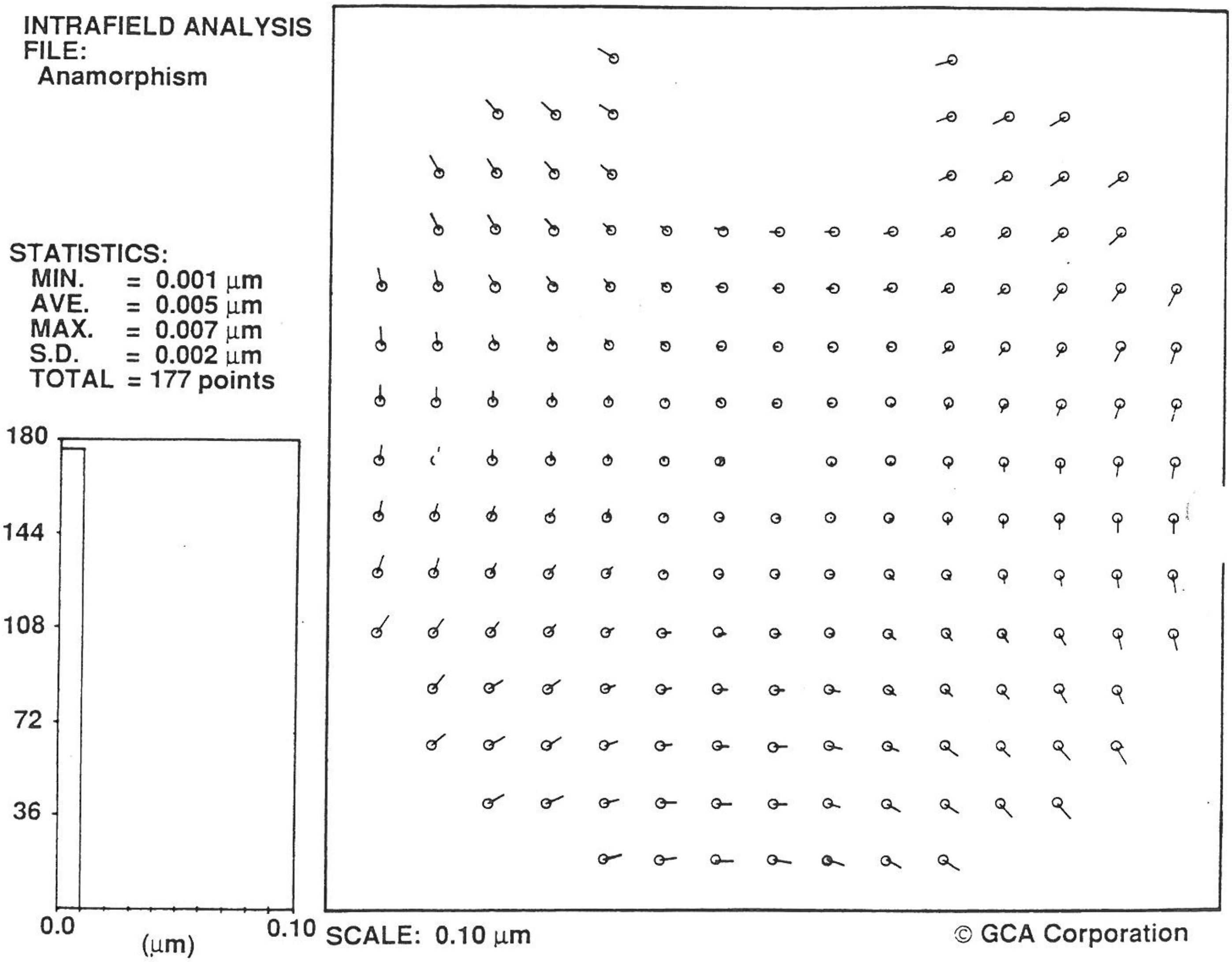

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Figure 6-14
Typical Intrafield Analysis Display

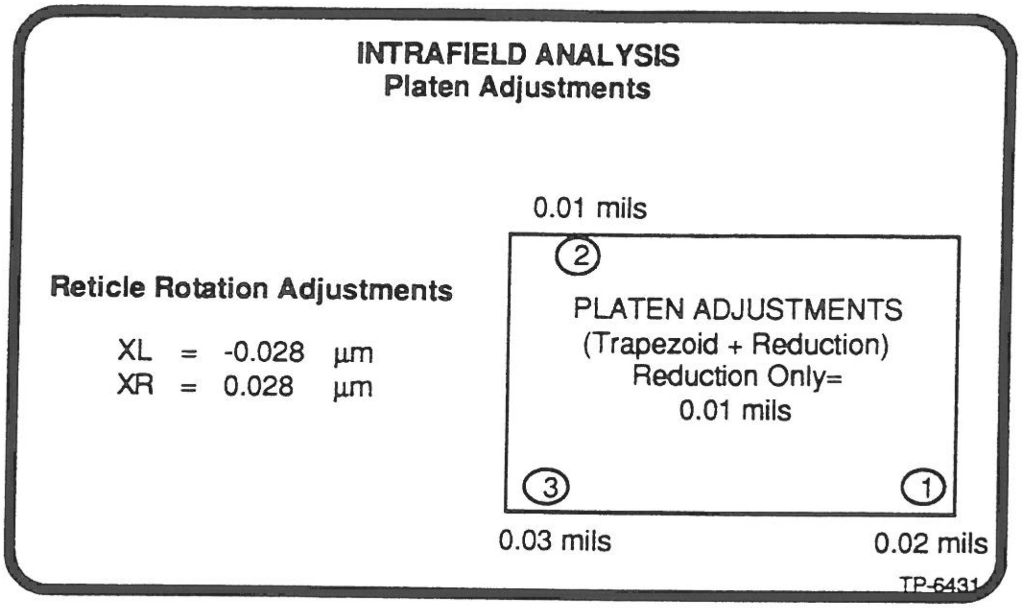

Figure 6-15
Typical Platen Corrections Display

Matching Other Systems to the Reference System

Perform this procedure for each system to be matched.

1. Expose a job on the system to be matched that exposes an intrafield die.
2. Read the intrafield die on the reference system.
3. Create SMARTSET intrafield files for any dies read.
4. If several dies were read, average the files by selecting the Average Data Files from the Intrafield Analysis menu.
5. From the Intrafield Analysis menu, select the Difference of Data Files option to subtract the reference system file from the system to be matched file. Name the file.
6. Model and plot the difference file.
7. The intrafields are matched when:

   Measured - Translation - Residuals $\leq$ 0.2µm (Figure 6-16).

   If the intrafields are not matched, perform the following on the system to be matched:

   a. From the Intrafield Analysis menu, select Platen Adjustments: this displays a screen listing adjustments to be made to the reticle platen, which will minimize reduction, rotation and trapezoid.
   b. Enter the value for rotation into the reference system using the command MODE.
   c. Correct for reduction and trapezoid using either PPC or MMP.
   d. Remove the reticle, and repeat steps 1 through 7, until the intrafields match.

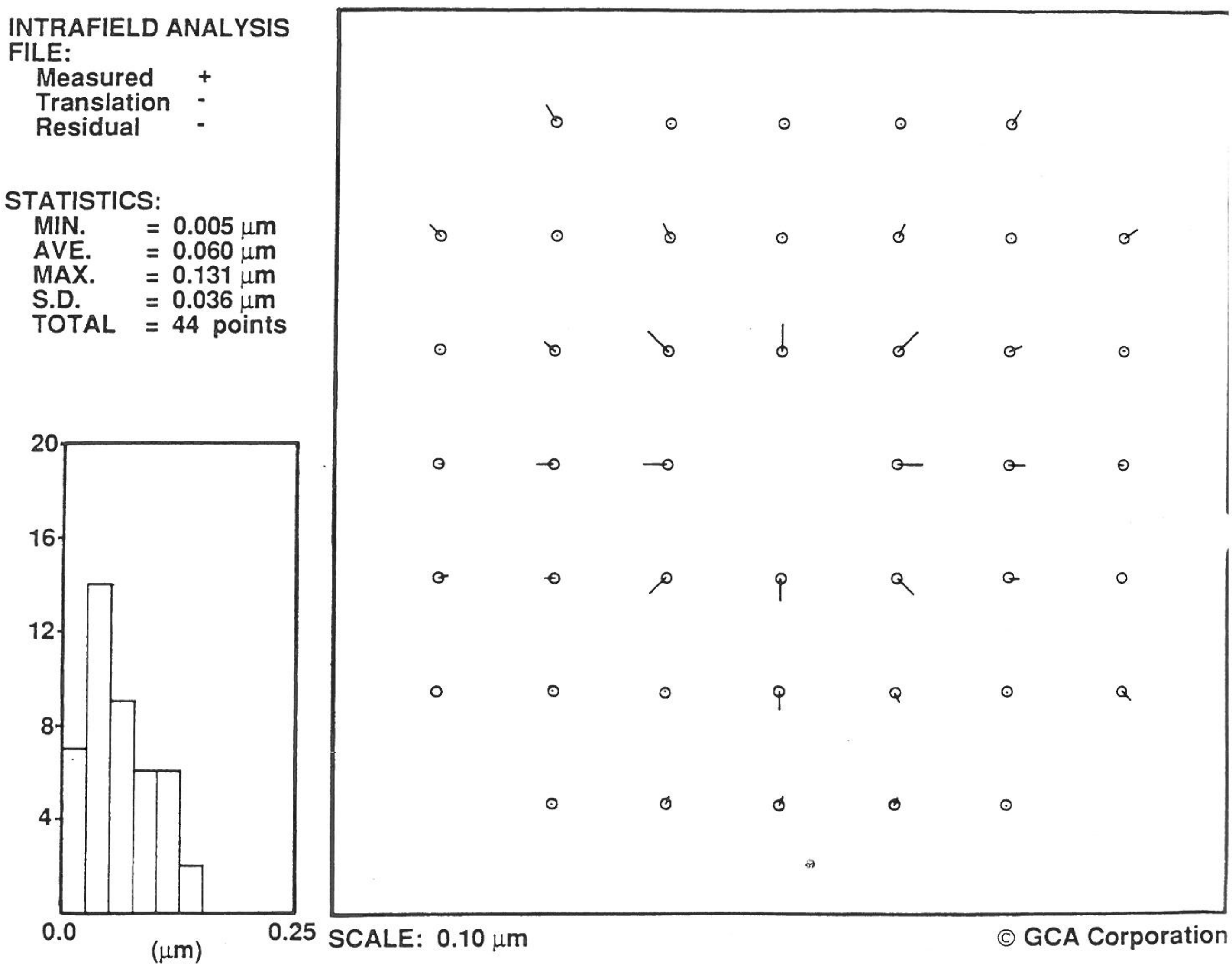

Figure 6-16
Measured-Translation-Residual Display

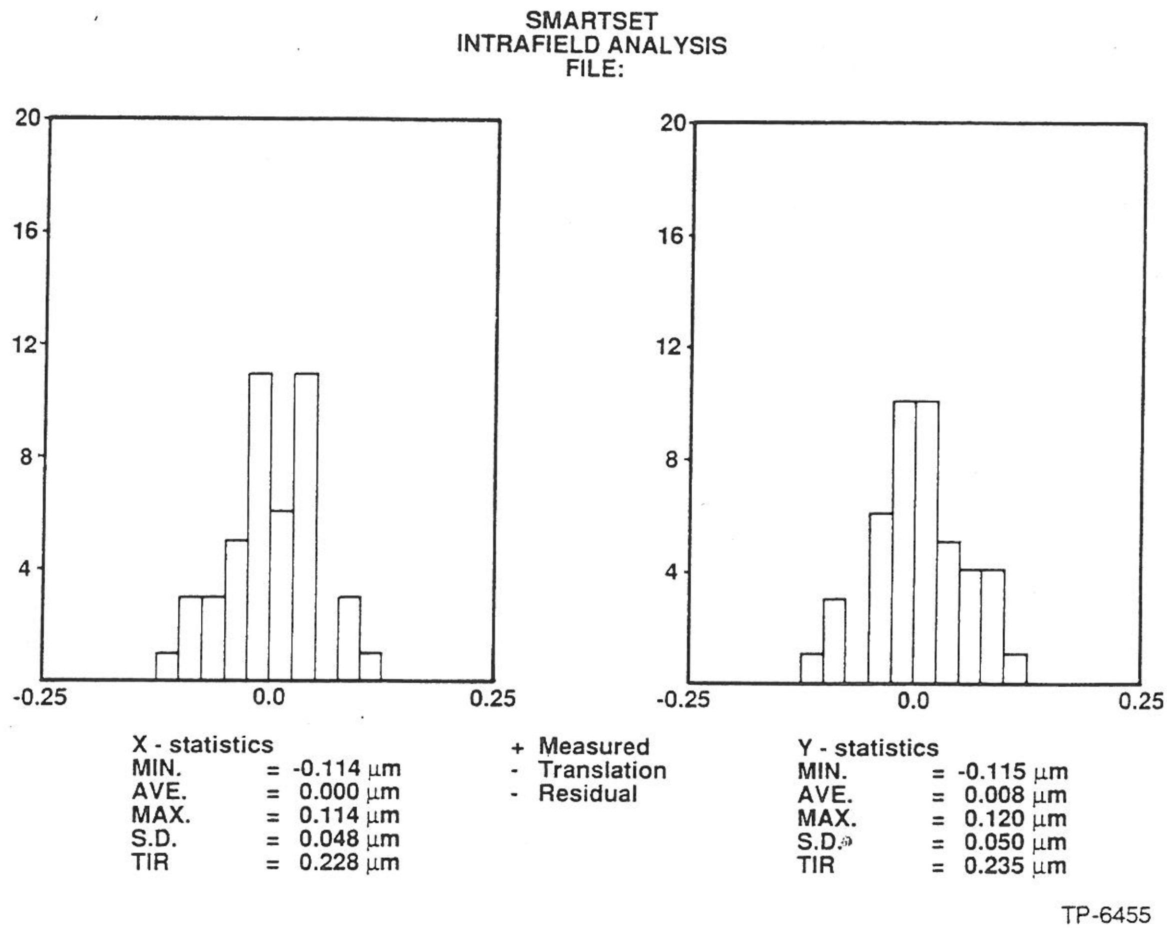

Figure 6-17
Measured-Translation-Residual Bar Chart Display

Uniformity Analysis

This procedure allows the user to analyze the wafer stepper MAXIMUS uniformity through SMARTSET. Refer to the 7.1 AUTOSTEP 200 System Operation Manual (P/N 069424) for additional IQ information.

1. Enter the command **UNIF** on the wafer stepper keyboard.
2. Select option 1 (Calculate and Display Uniformity) from the IQ menu.
3. Follow the screen prompts until the command is completed.
4. Create a SMARTSET Uniformity file (the procedure to create a uniformity file is in Section 6).
5. Analyze the SMARTSET uniformity file by selecting option 4 (Analyze Data File) from the Uniformity Analysis menu (Figure 6-18).
6. View the display. If there are cold areas being displayed outside the usable field, remove those data points by performing the following:

   a. Select option 3 (Edit Data File) from the Uniformity Analysis menu.
   b. Select the file to edit.
   c. Using the cursor keys, move the cursor over the data points to delete and press the DEL key. If a mistake is made, press the INS key to reinsert the data point.
   d. Press ESC to exit and save the file.
   e. Repeat steps 5 and 6 to analyze the data file.

GCA Intensity Analysis
Data File Name: 10-10-89.unf

Array size = 21 x 21
Field Size in X = 14.1 mm
Field Size in Y = 14.1 mm

Intensity within Field

Maximum	=	308.011 mW/cm^2
Warm	>	313.622 mW/cm^2
Average	=	305.973 mW/cm^2
Cool	<	298.323 mW/cm^2
Minimum	=	277.595 mW/cm^2

Uniformity within Field

$$\frac{\text{Max - Min}}{\text{Max + Min}} * 100.0 = 5.19\%$$

[F1] Enter title
[F3] Change array size
[F4] Smooth plots
[F9] Print screen
[F10] Select cutoff

Legend
Red = Hot
Green = Midpoint + -2%
Blue = Cold

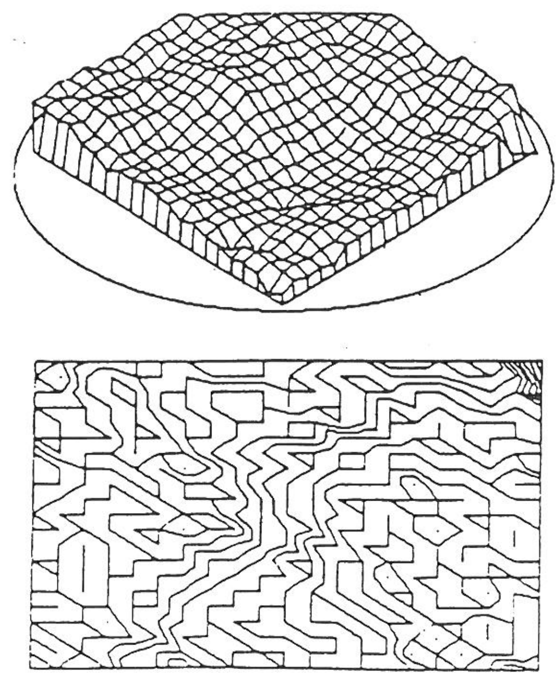

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Figure 6-18
Uniformity Analysis Plot Display

Function Keys from within the Uniformity Analysis Menu

The following function keys can be used while displaying uniformity plots

F1	Allows the user to enter a title name for the uniformity analysis display.
F3	Allows the user to enter the number of rows and columns to display.
F4	Smooths the display plot.
F9	Prints the uniformity analysis display.
F10	Allows the user to enter a cutoff point for the data being displayed.

Appendix A - Restricted Pass Names

NOTE: The following pass names (used as the first pass name letters) should only be used when the specific special function is to be used.

DFAS and Micro DFAS Systems

INT Causes automatic INTRAFIELD analysis to be performed.
FOC Causes automatic FOCUS analysis to be performed.