GSI Lumonics

9-POINT GRID CALIBRATION

Instruction Manual

60 Fordham Road

Wilmington, MA 01887

GMAX™ SYSTEMS

MULTI-AXIS BEAM HANDLING

P/N 176-25009

Rev. B

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1. Using 9-Point Grid Calibration

1.1 Introduction

The Grid Generation and Grid Calibration Program was created by GSI Lumonics for use with its two and three axis scanning systems. Although originally written for grid generation and calibration of post-objective scanning systems (like the HPLK), the 9-point grid calibration function can also be used with the pre-objective HPM scanning systems. The key to successful adaptation of this program to the scanning system depends on careful mapping of the field to the program, measurement of the errors in the field, and selection of the sign (+ or -) of the correction to achieve the desired effect.

The Grid Program used to have three modules:

1. Theoretical Grid Generator
2. 9-Point Grid Corrector
3. 2-Point Grid Corrector

NOTE

The "Theoretical Grid Generator" works only for post-objevtive scanning systems and has been replaced by the "PostGrid" program. Only the "9-Point Grid Corrector" module has been retained but was renamed to "9-Point Grid Calibration".

1.2 Warranty

GSI Lumonics (GSLI) warrants this product to be free from defects in workmanship for 12 months from the date of shipment. GSLI will, replace the software if it is defective within the warranty period and returned, freight pre-paid, to a service center designated by GSLI.

GSI Lumonics requests that customers obtain a Return Authorization Number prior to returning the software, and that they carefully pack it in the original packing or equivalent.

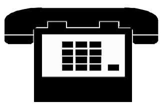
1.3 Customer Support

GSI Lumonics has support services available to you concerning problems with the software or manual you are using.

Before calling for assistance, please make sure you refer to any appropriate sections in the manual that may answer your questions.

If you need further assistance:

The customer service personnel will be able to give you direct assistance and answers to your questions.



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In the U. S.: (978) 661-4300

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... ask for the GMAX Customer Service Department

GSI Lumonics also asks that you take a moment to complete the Customer Reply Card at the end of the manual. The information from this card will help us to serve you better.

1.4 Software Provided

The program disk or directory contains four files needed to run the grid program:

9p-grid.exe

fe.uif

tgrid.uif

gc.uif

The three files with the extension **uif** pass data to the executable code in **9p-grid.exe**. These files are grouped in a subdirectory \mark\cal**9p-grid**.

Also included are files to measure the scanning system's accuracy. These are the grid and box image files:

$calgr1.job and **$calgr2.job**

$17grid.mcl

These files are grouped into two subdirectories:

\mark\mcl

\mark\job

respectively.

1.5 Background

The 9-Point Grid Calibration can be used in two ways:

1. It can reduce errors in the positioning of the laser beam.
2. It can reduce errors in the positioning of the visible pointer beam, if used, relative to the laser beam.

These improvements in system accuracy result from measuring the actual deviation of a particular laser beam from its ideal performance and using this error information to modify the theoretical correction model.

When the user creates an object, a series of ideal vectors are generated which represent that object in perfect Cartesian space. When the user issues the **mark** command, these vectors are processed into X and Y scanner angles (mirror rotations). For various geometrical reasons, there is a non-linear mapping of the positions of the user's object to the scanner angles required to reproduce that object on the substrate. A real-time correction scheme is used to generate these scanner angles while the object is being scanned.

The preset factory corrections are based on an ideal Laser Scanning System. Any deviations in the assembly, alignment or manufacture of the components will produce a slightly distorted image (maybe too large or too small at the extremes of the field.) This includes the manufacturing discrepancies of the **f-ø** (f-theta) pre-objective scanning lens. By using the 9-Point Grid Calibration, the precision of each individual imprint can be enhanced by minimizing its unique deviations.

In maintaining an unambiguous and repeatable method of applying the correction algorithm to the laser beam, it is important that the user carefully follow the conventions outlined in this document. Seemingly small changes in system setup or numbering can lead to erroneous results, repetition without minimization or errors, and frustration.

1.6 Correcting the Laser Cutting Beam

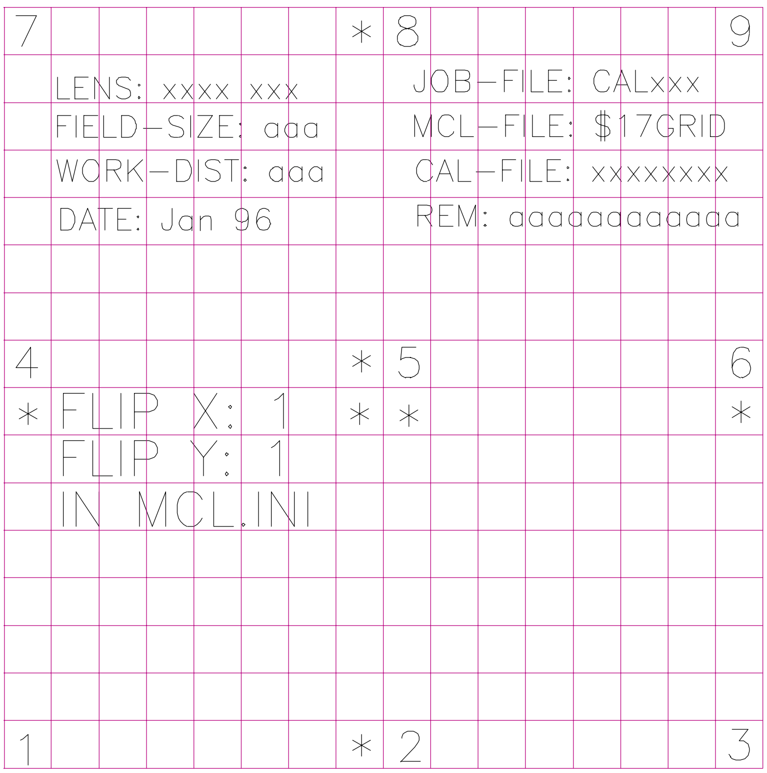
After starting up the computer and the Laser System, call up the **JOBEDITOR** program.

If you do not have the **JOBEDITOR** program you will have to perform the described steps with your own application program. Of course you can use the MARK.exe utility supplied with PC-MARK to execute the required PC-MARK commnads.

Using the Configuration Menu, load the calibration file **for your system**. This establishes a known starting reference for all measurements and corrections. Load the job **$calgr1.job**.

Refer to the following figure for the **$calgr1.job** pattern. The asterisks "*" are used to mark the other side of the major axis lines. The "extra" lines are included to illustrate the overall rectilinearity of the pattern.

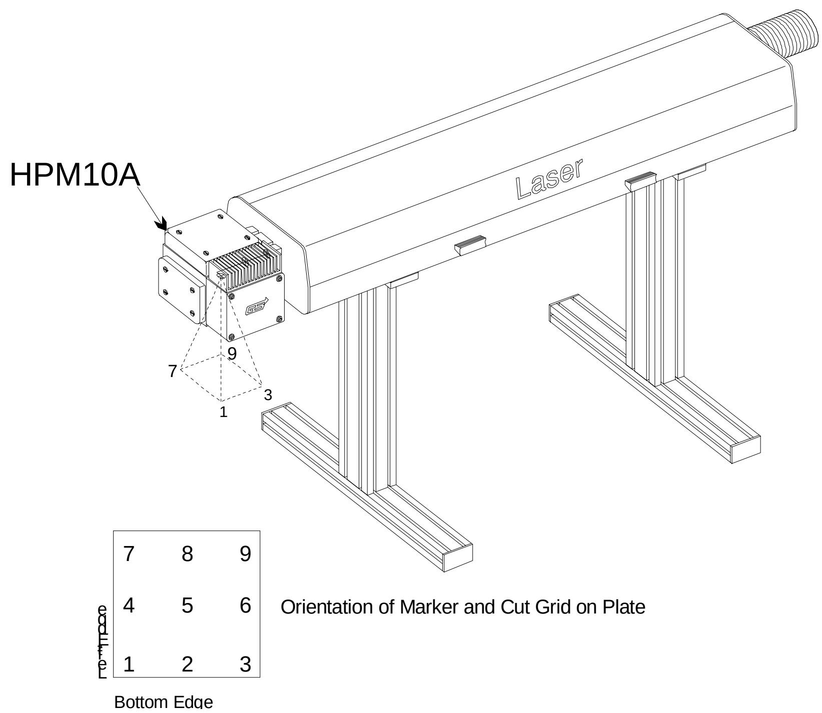
Grid Pattern Template for Laser Beam Calibration



This pattern assumes that you have the FLIP X and FLIP Y option in the mcl.ini file set to 1. See next paragraph for details.

1.7 Orientation of Test Pattern

The plate should be drawn in the orientation of the following figure. If the orientation of the cut pattern is different, or the numbers are not written normally you may have to alter the orientation of the scanning system axes. An initialization file (**mcl.ini**) is used when you start your system to achieve the correct orientation. You may want to consult your manual before altering this file.
If you have the the flip x and flip y settings enabled for your system: use **clagr1.job**.
If you have the the flip x and flip y settings disabled for your system: use **clagr2.job**.
This manual assumes you are using the **calgr1.job**.



Orientation of Marker and Cut Grid on Plate

Use the following checklist as a guide to setup the scanning system calibration:

1. Add text to the grid pattern to identify the calibration file used, the specific imprint (if you have more than one) and the date to keep track of the plate and its parameters.
2. Select a plate to cut the grid pattern on. A substrate which is thick and rigid enough to remain flat should be used. Otherwise the plate should be held flat on a supporting block.
3. Check the height of the substrate to the imprint. Even if the plate is not at the ideal focal length, the value should be recorded for future use. (This can be added to identification text string.)
4. Check the laser "scribe" parameters to ensure that a quality, high-contrast cut is made. Your past experience with this substrate should guide these choices.
5. Mark the plate with the grid pattern.

1.8 Measuring the Grid Pattern

In this example we will assume that your system is configured for a 4.0 inch x 4.0 inch field!

It is important that the cuts on the plate be measured as accurately as possible. Measurement errors will directly affect the performance of the grid calibration software. Several methods are possible. The following paragraph is intended to suggest possible techniques, what equipment is available will dictate the method chosen.

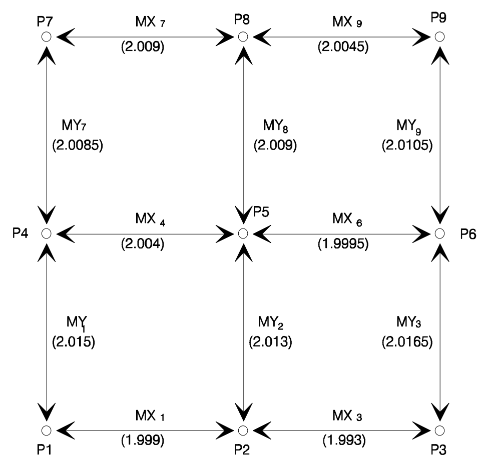
Equipment commonly found in a well-supplied machine shop can be used, including:

Optical comparators (fairly easy to setup)

Precision calipers (which require greater care)

More esoteric methods include using digitizers to record the point-to-point spacing. If such devices are used, they must be calibrated to ensure accurate measurement.

The following figure shows an example of a measured plate. The measured dimensions appear in Parentheses ( ). These values will be used in the following calculations.



The error evaluation method which is recommended includes a few simple steps:

1. It is assumed that the center of the field is correctly aligned.
2. The initial measurements are made from the center point (P5), to the on-axis points P2, P4, P6 and P8.
3. Once these referents have been recorded, the four corner points are measured relative to the appropriate adjacent points in each axis.
4. After the actual cuts have been measured, the scanning system's errors can be computed. For each dimension, Measured Distance minus Theoretical Distance equals Error [M - T = E]. Be careful to preserve the sign of the error, since this has a significant impact on the correction results.

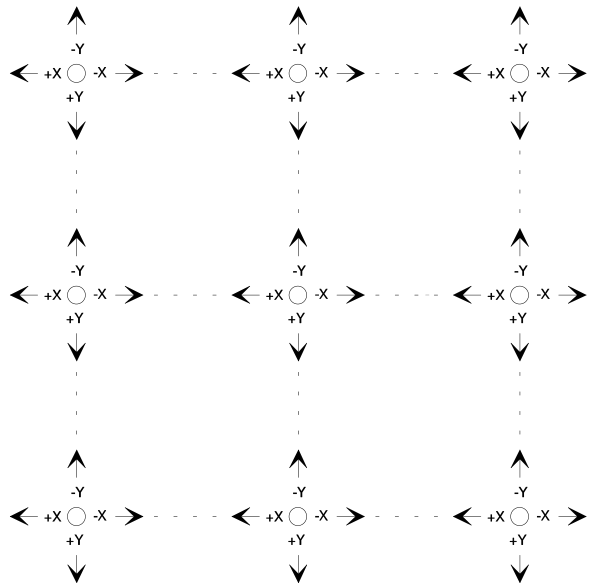
After all the points have been measured and the errors calculated, you should have a table like the following:

Measured Grid Point Placement Errors

Grid Point	MX	MY	EX	EY
P1	1.999	2.015	–0.001	0.0150
P1		2.0130		0.0130
P3	1.993	2.0165	–0.007	0.0165
P4	2.004		0.004	
P5				
P6	1.9995		–0.0005	
P7	2.009	2.0085	0.009	0.0085
P8		2.009		0.009
P9	2.0045	2.0105	0.0045	0.0105

1.9 Calculating the Grid Corrections

From the error data, the corrections can be calculated. See the following figure of how each point moves when a correction of X or Y is applied to it. It is readily apparent that to move any point (Pn) to the left, always enter a positive X correction. Likewise to move a point down to the bottom of the plate, always apply a positive Y correction.



When viewing the points on the plate, we are tempted to think in terms of moving points either towards or away from the center point (P5). It is this perspective of trying to expand or shrink the grid which may create confusion about the appropriate sign for the correction. This flipping of the sign is an illusion, as the previous figure demonstrates.

Refer to the figure when reviewing the measured plate errors to aid in visualizing the proper sign for each point.

For our example, we would add the corrections to the previous table to produce the following table:

Grid Point Placement Errors and Corrections

Grid Point	MX	MY	EX	EY	CX	CY
P1	1.999	2.015	–0.001	0.0150	0.001	–0.015
P1		2.0130		0.0130		–0.0130
P3	1.993	2.0165	–0.007	0.0165	–0.007	–0.0165
P4	2.004		0.004		–0.004	
P5						
P6	1.9995		–0.0005		–0.0005	
P7	2.009	2.0085	0.009	0.0085	–0.009	0.0085
P8		2.009		0.009		0.009
P9	2.0045	2.0105	0.0045	0.0105	0.0045	0.0105

The correction values of the previous table, CX and CY would then be entered into the 9-Point Grid Calibration Program's entry form. The activation of this program is covered in the next section.

1.10 Generating a Corrected Grid

After cutting the plate and computing the errors, we are ready to generate the corrected grid. First, we want to copy the standard correction grid files into the grid Calibration's subdirectory. On most scanning system PC's, the grid files are located in the subdirectory **C:\MARK\CAL**. The following example assumes that the calibration software is located in the **C:\MARK\CAL\9P-GRID** directory.

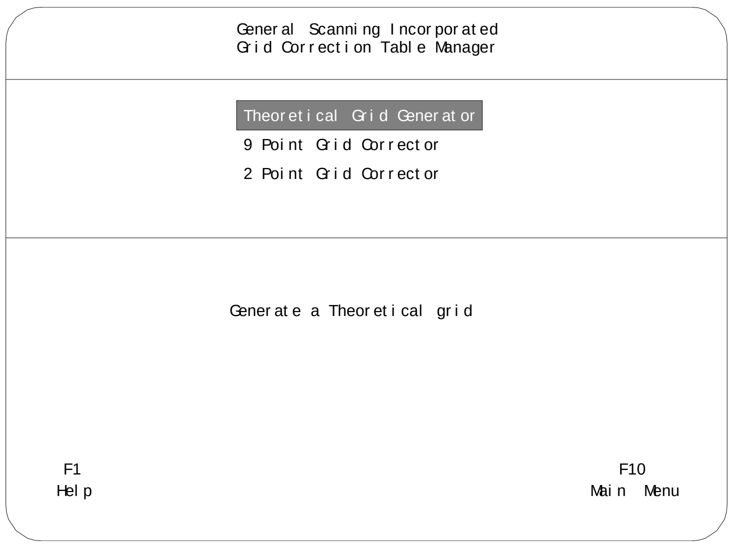
C:\>copy \mark\cal\ft163.* \9p-grid*.* [enter]

C:\>9p-grid [enter]

After the grid program boots, you will be presented with the main screen.

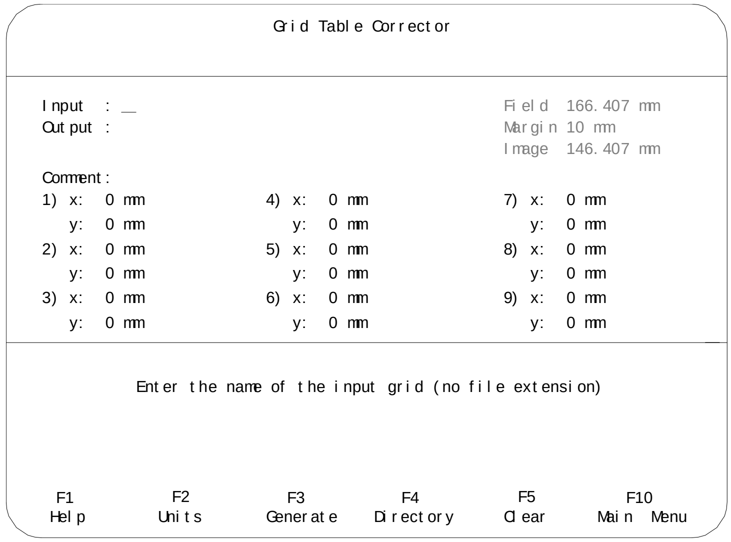
As stated earlier, previous additional modules have been disabled. Use the arrow keys to select the 9 Point Grid Calibration and press ENTER.

Grid Correction Main Menu (previous version)



The following screen will appear.

9 Point Grid Calibration Screen

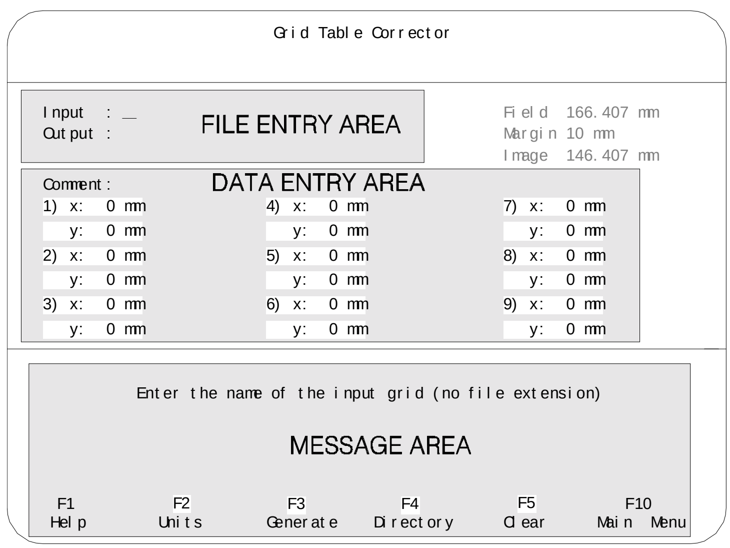


The Grid program is a forms oriented system.

The form has three regions:

- File entry
- Data Entry
- Messages

Forms Regions



The **file entry** region lets the user specify a source grid file (input) and a to-be-created grid file (output).

The **data entry** region allows the user to enter X and Y corrections for each of the nine points mapped on the sample plate.

The **message area** displays messages to the user as well as showing what functions are performed by keys to

1.10.1 9-Point Grid Calibration Menu Field Descriptions

Referring to the previous figure, the following is a description of the menu items.

Input This is the name of the grid file that will be read in. This is an optional field. The name must be a valid MS-DOS file name. Since an extension will be provided automatically you must not provide one. The basename of the file name must not be any longer than eight characters.

Output This is the name of the grid file that will be generated. The name must be a valid MS-DOS file name. Since an extension will be provided automatically you must not provide one. The basename of the file name must not be any longer than eight characters.

When you save a correction table, **9p-Grid** creates two files that contain data for the table. One file contains the actual correction values. The other contains information about the grid table.

Both files are given the name that you had entered in the **Output** field of the menu form. The grid table has an extension of **.asc** and the information file has an extension of **.inf**. For example, if you entered the name **grid1** for the file when you saved the grid table, the program would write the table to the file **grid1.asc** and write the associated information to the file **grid1.inf**.

The format of an **.inf** file is described here. It is provided for reference purposes only. It is not expected (although it is allowed) that this file will be edited by hand or created by some other mechanism.

This is an example of an **.inf** file:

```
// General Scanning GmbH Pre-Objectiv Calibration-File
//# File [FTGENER] generated 11-11-1994 by "PRECAF" Ver. 1.4
// Theoretical 114.9 mm field with 163 mm F-Theta lens (0 mm margin)
// REMARKS: ! File identical to old DEFAULT and FT163 files !
// If you need to adjust the size of objects in your application program
// (e.g. TRUVIEW, Job Editor) to their real size in the field, you can
// calculate a new "d" parameter as follows:   [REM: d(old) = .1561898]
// d = d(old) * (size in the field) / (size on the screen)
// Enter the new "d" between the quotation marks below:
d ".1561898"
// !!!!!!!!!!! Do not change any of the parameters below this line !!!!!!!!!!!
magic "ed"
version "1"
comment "163 mm Generic F-Theta lens"
angle "20.20023"
e ".01299"
m "0"
z "0"
//# focallength ".163"
//# fieldsize ".1149347"
// **************************** End of file ****************************
```

Maximum Field (F) This is the maximum possible X or Y dimension of the field. This value is calculated based upon the scanner angle and the distance from the Y mirror to the target. You cannot alter this field.

Margin (M) This is the margin within the field that is to be used as a guardband for corrections to beam position. This guardband allows compensation values to exceed the theoretical values obtained for the specified field size without exceeding the range of DAC values. You cannot alter this field.

Active Field (I) This is the actual drawing size of the image. It is derived from the field size (F) and the margin (M). You cannot alter this field.

Comments The comment allows you to add notes to the grid that will be generated. When the grid is viewed in other functions, (such as the 9-Point Grid Calibration) the comment that you entered here will be displayed.

1(x,y) through 9(x,y) These values are a measured delta correction at this point in the calibration target. The delta correction must be smaller than the margin. These corrections must be measured with respect to a fixed reference point in the calibration target. See Section 1.10.1 for an example of how to determine these values.

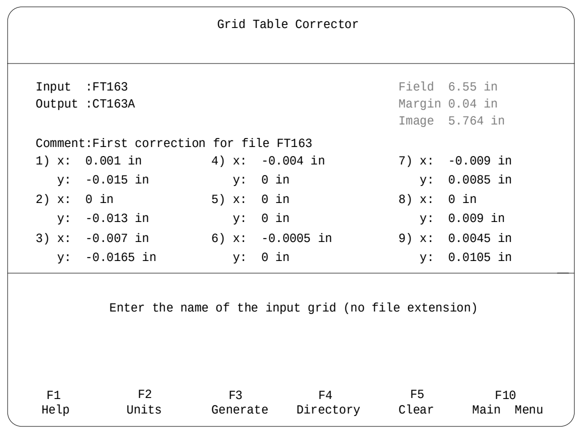
1.10.2 Entering Changes to the 9-Point Grid Calibration Menu

Following our sample plate, enter **FT163** for the **input** file. Press enter or arrow down to the next line. For **output**, use the file name **CT163** or **CT163A**. The **C** stands for **Corrected** and the trailing **1** or **A** allows us to serialize the new files and keep track of what file is created from what error information. (The **T163** part ties us back to the original file **FT163**, of course.)

Arrow down to the data region. Press to clear any correction values and use to roll through the dimension units (in, mm, cm, m, ft, in ...). The arrow keys allow you to move around the screen to enter the correction data. Use the minus sign character "**-**" to prefix negative values. Using the data from the last table, we would have a data entry sequence like:

1)	x:	0.001	[enter]
	y:	–0.015	[enter]
2)	x:	[arrow down]	
	y:	–0.013	[enter]
3)	x:	–0.007	[enter]
	y:	–0.0165	[enter]
4)	x:	–0.004	[enter]
	y:	[arrow down]	
5)	x:	[arrow down]	
	y:	[arrow down]	
6)	x:	–0.0005	[enter]
	y:	[arrow down]	
7)	x:	–0.009	[enter]
	y:	0.0085	[enter]
8)	x:	[arrow down]	
	y:	0.009	[enter]
9)	x:	0.0045	[enter]
	y:	0.0105	[enter]

The 9 Point Grid Calibration menu will look like the following:



Check the values on the screen. If the corrections have been entered correctly, press to generate the new correction grid. As the program runs, it displays messages informing the user as to its status:

loading data from the source file

calculating new points

storing the new file data.

Once the new file has been completely saved, the message **Done** is displayed. Use

to return to the main menu and then

to quit the **9p-Grid** program.

Now the new grid files need to be copied into the scanning system calibration subdirectory. Assuming the new files were created with the **CT163A**, you would type:

C:\mark\cal\9p-corr>copy ct163a.* \mark\cal*.* [enter]

The next step is to verify the correction process. To do so we cut a new plate using the new correction files to measure the improvement and residual errors.

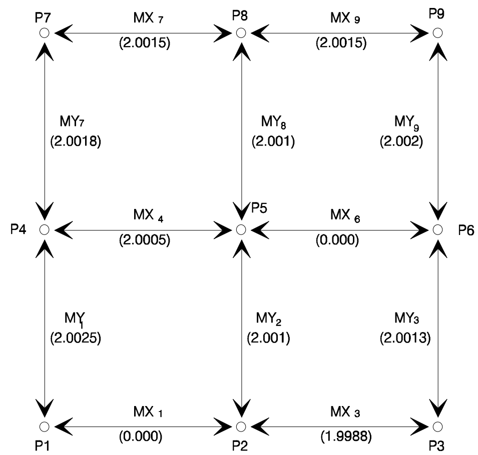
1.11 Quantifying the Effect of the Grid Calibration

Restart the scanning system device driver by typing **pcmark** at the DOS prompt. After the driver has been reloaded into memory, restart the **JOBEDITOR**. Before loading a job, use the configuration-calibration menu to load the **CT163A.INF** file. This will automatically load the new correction data file into the scanning system device driver. Now, load the calibration grid file **$calgr1.job** into **JOBEDITOR**. Ensure that the grid is correctly sized (4.00 in) and centered in the field.

Run through the plate setup checklist before cutting the plate. Again, it is recommended that a text string be added to identify the source file **CT163A**, the scanning system, the date etc.

Mark the new plate and proceed to measure its dimensions as previously described. Continuing our example, the second plate was measured as shown in the following figure:

Dimensions of Corrected Grid Pattern Plate



Calculating the errors from the corrected grid plate, we obtain the following table:

Measured Residual Grid Point Placement Errors

Grid Point	MX	MY	EX	EY
P1	0.000	2.0025	0.000	0.0025
P1		2.001		0.001
P3	1.9988	2.0013	–0.0012	0.0013
P4	2.0005		0.0005	
P5				
P6	0.000		0.000	
P7	2.0015	2.0018	0.0015	0.0018
P8		2.001		0.001
P9	2.0015	2.002	0.0015	0.002

If we compare these results with the results from the first corrected grid plate, we find that the largest errors are 0.0165 and 0.0025, respectively. In terms of relative accuracy, the original plate was off by 0.825% at the maximum measured error. The corrected grid plate was off by 0.125% at the maximum measured error. This is more than a six-fold improvement (6.6 times) in the positioning accuracy of the laser cutting beam.

NOTE

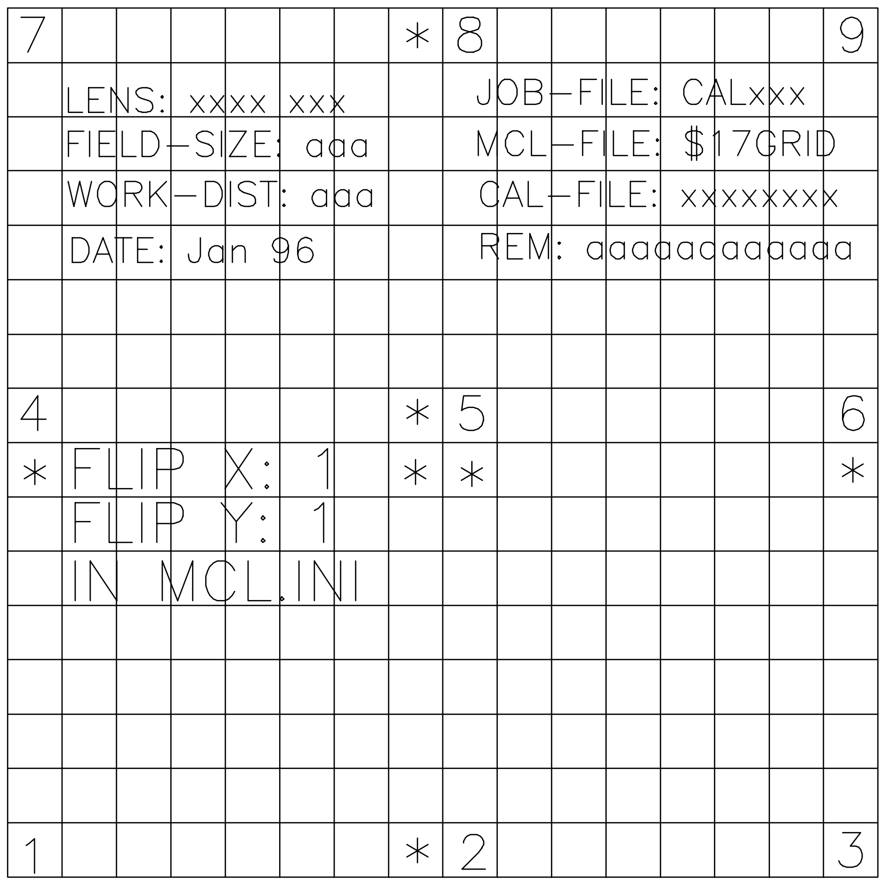
All of these dimensions and results are from a real laser scanning system; these are not fictitious numbers.

It should also be noted that the original performance of the example laser scanning system was quite good (approximately 2.5 times the specified system accuracy.) How much improvement this technique can achieve on a specific unit will vary. If the corrected plate errors remain larger than desired, it is advised that the correction be performed again.

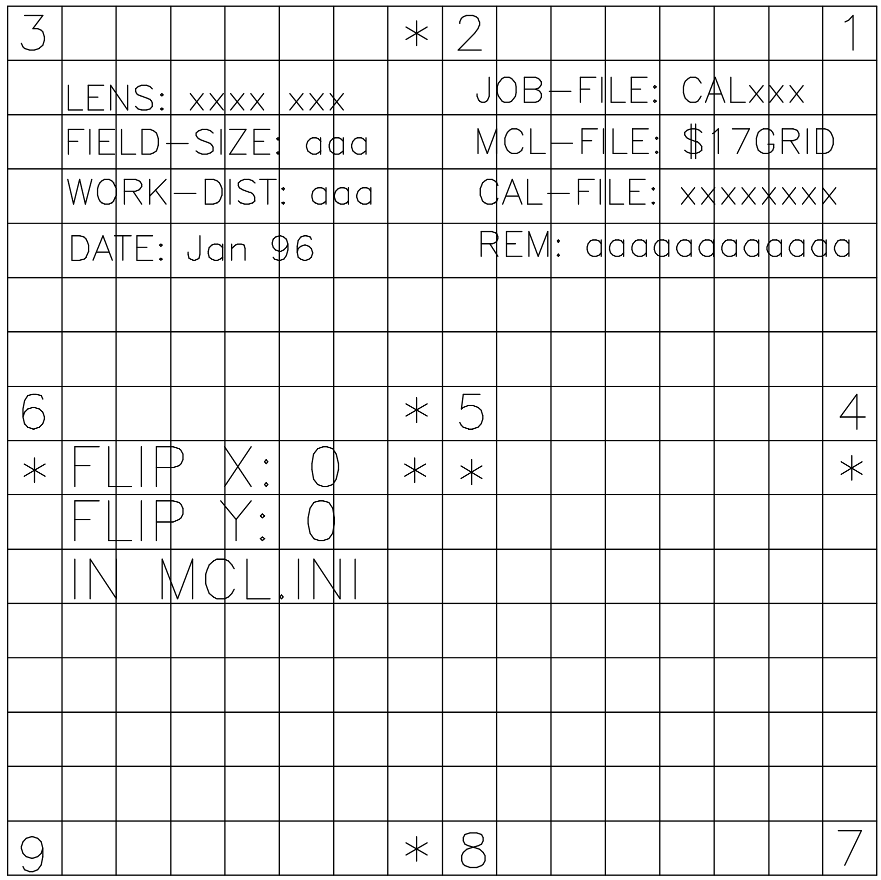
The entire correction process is iterative. After calculating the residual errors, new corrections can be derived and applied to the correction data file. When running the grid correction program, the input file is **CT163A**, not **FT163**. The corrections are **incremental** and must be added to the previous "set" of corrections. It should not be necessary to re-apply the method more than two or three times even for the most demanding applications.

2. Appendix B

2.1 Grid Pattern Template for Scanning Systems with Flip X and Flip Y enabled



2.2 Grid Pattern Template for Scanning Systems with Flip X and Flip Y disabled



2.3 Quick Reference for 9p-Grid Program

Motion Keys	**Arrow Keys**		Move cursor or menu lightbar in the appropriate direction.
	Page Up		Move to first item on screen.
	Page Down		Move to last item on screen.
	Home		Move to first item on screen.
	End		Move to last item on screen.
Editing Keys	**Escape**		Abort edit in process.
	Backspace		Delete last character entered.
	Enter		Accept entry.
Function Keys	**F1**	**Help**	Give help about current data item or menu selection.
	F2	**Units**	Change the units of the data item that the cursor is on.
	F3	**Generate**	Generate the grid.
	F4	**Directory**	Show grids in the current directory.
	F5	**Clear**	Clear the grid corrections to 0.
	F10	**Quit**	Go to previous Screen / Abort calculations in process.

2.3.1 Relationship of 9 Calibration Points in the Field