Laser Doppler Displacement Meter™
Laser Measurement System

Title:

Incoming inspection procedure

Document identification: MCV 500 incoming

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1 Scope

The scope of this document is to define the procedure and methods for the inspection and acceptation of the product.
The system come with a performance certificate, so it is not necessary to test the performances but only the integrity after transportation.

1.1 Product Description

The Laser Doppler Displacement Meter, referred to herein as LDDM™, is an instrument system which measures displacement to an accuracy of one part in one million (1 ppm). A laser is positioned on the axis along which the target moves. The laser beam is returned by a reflector mounted on the axis along which the target moves. The reflected beam is detected near the laser source: the original and reflected beams run parallel, adjacent paths. After detection the displacement information is calculated and sent to a digital display for read-out .

The LDDM™ instrument system consists of four components; a Laser Head Module, Retroreflector, Processor Module and a Display Module or Notebook computer as shown in Fig. 2-1

7.0 Displacement Measurement

7.1 Introduction

The LDDM™ CNC Calibration Package is designed to calibrate CNC machine tools, CMMs (Coordinate Measuring Machines), and other precision measurement machines and stages.

Based on the LDDM™, Optodyne's innovative Dopplometry technology has broken through the technological barrier of bulky, cumbersome laser heads, time consuming set-up and alignments, and costly measurement methods. Optodyne's CNC Calibration Package allows for a large misalignment tolerance making it possible to setup the package and have it operational in a matter of minutes.

7.2 Hardware Required

The basic hardware and software required for linear calibration are listed below:

    a. Single Aperture Laser Head   L-109
    b. Processor Module with RS-232 Interface   P-108D
    c. Automatic temperature compensation Probes   IATCP
    d. Ø05" Retroreflector   R-102
    e. Metrology/Analysis Program   W-500
    f. 90° beam Bender (Ø0.5")   LD-37
    g. Magnetic Base   LD-03
    h. Adapter Platform   LD-14A
    i. 12 ft Cable Set   LD-21L
    j. Carying Case   LD-20A
    h. Notebook PC   Not supplied

Some of the hardware is shown in Fig. 7-1.

FIG.7-1 CALIBRATION HARDWARE

7.5 Installation and Alignment

7.5.1 Important Considerations

1. Check that all cables are firmly connected before connecting the power cable and switching the power switch to the on position.

2. Always mount the laser head on a stationary part and the retroreflector on a moving part. Never use a tripod to mount the laser head. The tripod may introduce an error. For example, on most CNC machine tools, the spindle is moving in the Z-direction and the bed is moving in X-and Y-direction. Hence, when calibrating the X- and Y-direction, mount the laser head on the spindle (or near the spindle by a magnetic hold) and the retroreflector on the bed. Then to calibrate the Z-direction, mount the laser head on the bed and the retroreflector on the spindle. However, for most CMM machines, the bed is fixed and the spindle is moving in X-, Y-, and Z- directions. Therefore, always mount the laser head on the bed and mount the retroreflector on the spindle or the moving carriage.

    CAUTION! Never turn on the spindle of the CNC while either the laser or retroreflector are mounted there. This could cause injury to the operator and/or damage to the equipment.

3. When installing the laser head, make sure that the laser beam coming out from the 90° beam bender will travel in the direction of the displacement measurement.

4. Vibration and loose connections must be minimized by proper mounting. Make sure that all supports and cables are completely stationary. A spindle, for example, must be secured by a brake so it will not rotate.

5. The output laser beam and the retroreflector must be aligned properly such that the beam intensity is above the minimum requirement along the entire measurement path.

7.5.2 Installation

7.5.2.1 Set up LDDM Program

To set up LDDM program from windows version 3.x

1. Insert Setup Disk in a floppy drive.
2. In File Manager or Program Manager, click File, and then click Run.
3. Type A:\setup, then click OK.
4. Follow the instructions on your screen to continue through the Setup progress.
5. After the setup is done, an LDDM icon will show in the window. The LDDM program is ready.

To setup LDDM program from Windows 95

1. Insert Setup Disk in a floppy drive.
2. Click the Start button, and then click Run.
3. Type A:\setup, then click OK in the pop up windows.
4. When a screen message appears as follows, click OK to continue.
5. After the setup is done, an LDDM icon will show in the window. The LDDM program is ready.

```
┌──────────────────────────────────────────────────────────────┐
│ SETUP                                                          │
├──────────────────────────────────────────────────────────────┤
│                                                                │
│      /!\      Warning – Can not copy file A:\DDEML.DL_ Since the│
│     /___\     Destination file is already in use               │
│                                                                │
│                  ┌──────────────────┐                          │
│                  │       OK         │                          │
│                  └──────────────────┘                          │
│                                                                │
└──────────────────────────────────────────────────────────────┘
```
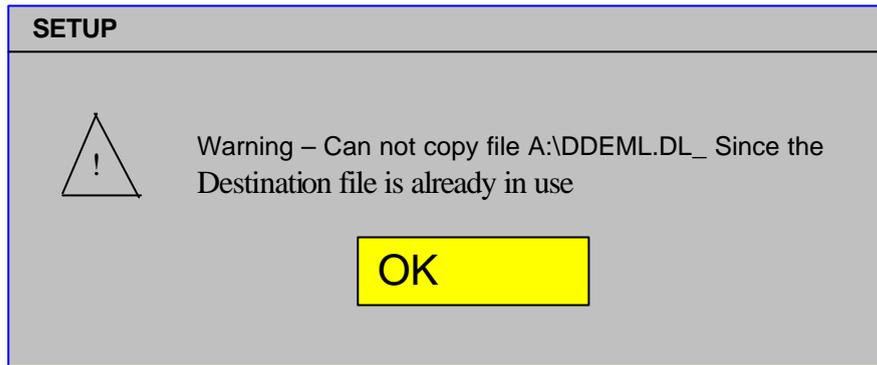
7.5.2.2   Starting LDDM Program

To start LDDM from windows, run Windows and double clicking on the LDDM icon. The main menu of LDDM program will appear on your screen (see figure 7-10). Click on Linear for linear measurement. The measurement program will appear on your screen (see figure 7-11).

7.5.2.3 Setup Laser Head and Retroreflector

Attach the 90° beam bender (Fig. 7-2) to the front of the laser head. Make sure both exit beam and return laser beam are covered by the steering mirror on the 90° beam bender. To mount the laser head to the spindle, you may use the spindle mount adapter (Fig. 7-3) or the magnetic base (Fig. 7-4). The retroreflector and post (Fig. 7-5) can be mounted on the bed or on a magnetic base (Fig. 7-6). Make sure all screws are tight and the surface of the magnetic base is free of grease. Various other mounting techniques are shown in Fig. 7-7, Fig. 7-8, and Fig. 7-9.
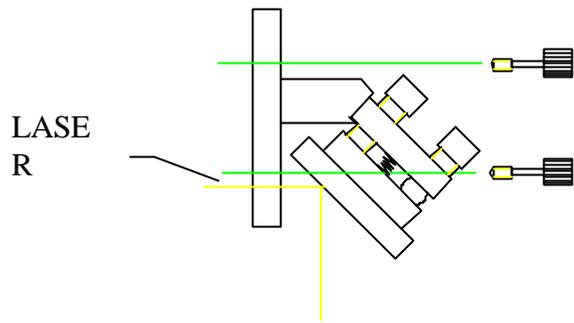
LASE
R

FIG. 7-2 90° BEAM BENDER
(LD-37)

POST

ADAPTER
(LD-14A)
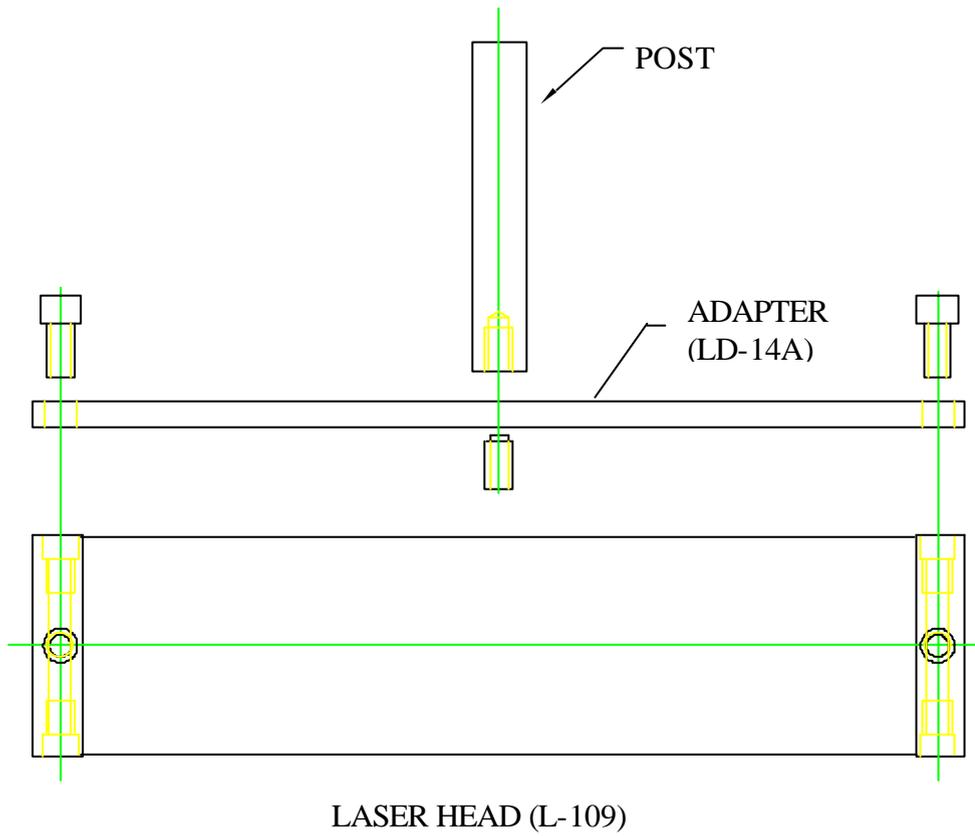
LASER HEAD (L-109)

FIG. 7-3 SPINDLE MOUNT ADAPTOR

RETROREFLECTO
R
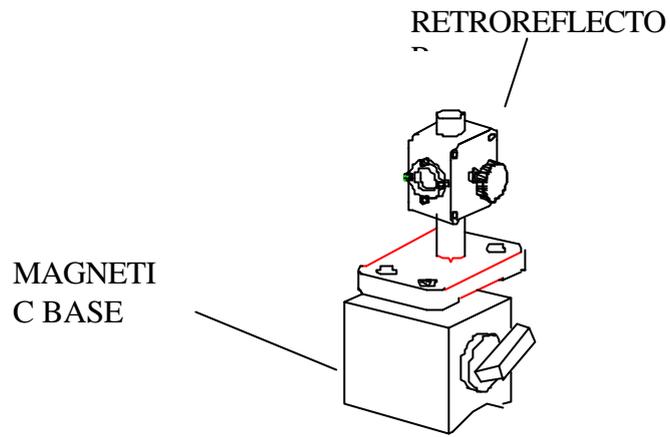
MAGNETI
C BASE

FIG. 7-4 RETROREFLECTOR MOUNTED
ON MAGNETIC BASE

SPINDL
E

RETROREFLECT
OR
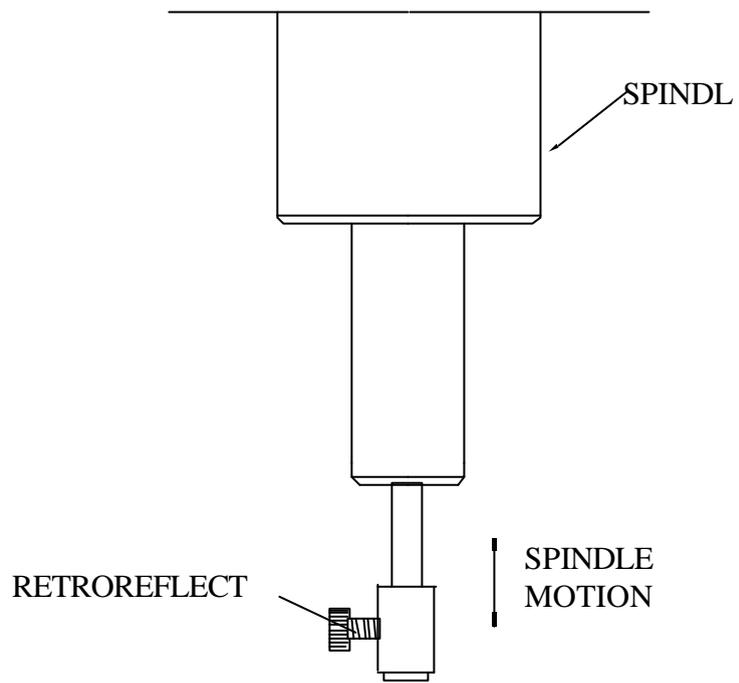
SPINDLE
MOTION

FIG. 7-5 RETROREFLECTOR MOUNTED
ON A SPINDLE
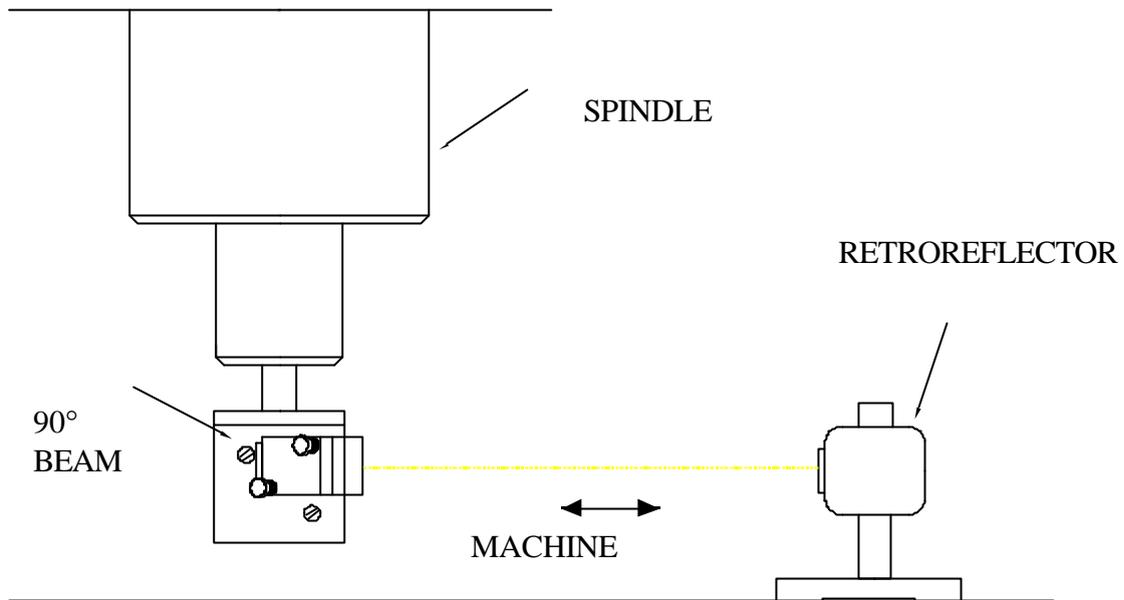
FIG. 7-6 LASER HEAD MOUNTED
ON A SPINDLE

7.5.3 Description

1. Decide which axis of travel you want to measure, which part is moving and which part is stationary for this axis of motion. It is noted that the movable part of the machine may depend on the axis you are measuring. That is, the X-axis movable part may not necessarily also be the Y-axis or Z-axis movable part. (See Fig. 7-7, 7-8).

    Mount the laser head on the stationary part, and the retroreflector on the moving part. Move the movable part of the machine to the starting point or the end point, then mount the retroreflector as close to the laser head as possible.

2. Setup the notebook PC and the Windows software to display the LDDM readings (see section 7.5.2.1 and 7.5.2.2).

3. Adjust the laser head or the 90° beam bender such that the output beam is parallel to the direction of travel. (See Section 7.5.4 Alignment Procedure).

4. Move the retroreflector perpendicular to the laser beam direction such that the return beam enters the receiving aperture of the laser head.

5. Move the movable part from the starting point to the end and make sure that the beam intensity is above the minimum requirement along the entire measurement path.

6. Now the laser is aligned and ready to do the measurement.

7. If you are using automatic temperature and pressure compensation, place the air temperature and pressure sensor near the laser beam path and the material temperature sensor near the lead screw or the machine bed.

7.5.4 Alignment Procedure

1. Make sure the Laser beam is parallel to the stage travel by using a magnetic cross or masking tape as a target.

    A) When the target is near the laser head, move the cross to the center of the beam.
    B) When the target is away from the laser head, move the laser beam to the center of cross, by steering the beam.
    C) Repeat A and B until the laser beam is parallel to the stage travel.

2. Move the retroreflector, not the laser beam, to be certain that the return laser beam is centered in the receiving aperture and the intensity reading is maximun.

3. Move the stage in and out and make sure the intensity reading remains maximum. Otherwise, repeat steps 1 and 2. Sometimes the intensity readings are maximum at two ends, but lower in the middle. Move the retroreflector to the location where the intensity reading is at the minimum, then move the retroreflector laterally (do not steer the laser beam) until the intensity is at the maximum at that location.

7.6 Software Description

The Metrology program is used to determine the positioning discrepancy of machine tools, coordinate measuring machines, XY-stages, or any other linear measuring device. The calibration system utilizes an extremely sensitive LDDM™ to detect any measurement discrepancy. After the LDDM™ is attached to the device to be calibrated, the device is operated to exercise a typical calibration procedure, and the LDDM™ senses any discrepancies from a theoretically perfect measurement. The discrepancies are recorded for later analyses and data reduction to produce correction factors for the device to be calibrated. The LDDM™ is supported by an IBM PC with special Windows software to direct the operator through the setup and execution of measurement procedures. The software includes several default and operator selectable measurement parameters that are used by calibration equations. Interim or final reports can be created to show the results of any calibration procedure.

7.6.1   LDDM for Windows

Here you will find descriptions about each choice and action on every screen in the software. You will also find instructions on how to take a measurement run for each type of measurement.

Bolded characters

In this manual, you will find **bolded** characters. When prompted, these bolded characters should be typed where specified.

Using the Mouse

In the **LDDM for Windows** package, only the left mouse button is used. In the program, a single click on the left button is usually sufficient to carry out an action, with a few exceptions. When prompted to click on a button, please move the mouse marker to that particular button, and simply click the left mouse button on it.

Text Boxes:

Instead of clicking on buttons, there are some boxes in the software where you must type in text. Move the mouse to the open box and look for the mouse marker symbol to change into a vertical line which looks similar to an I. There are then two ways to enter text. You may click the left mouse button at the beginning or end of the text, use the **Backspace** key to delete the previous text, and then enter your new text. You may also "Block" the text to be deleted by first moving the I (mouse text marker) to the beginning of the text, holding down the left mouse button, and then moving the mouse to the end of the text. You may then replace the whole text you have "blocked" by typing in your new text.

FIG.7-9 CMM CALIBRATION

7.6.2.1 Set up LDDM Program

To set up LDDM program from windows version 3.x

1. Insert Setup Disk in a floppy drive.
2. In File Manager or Program Manager, click File, and then click Run.
3. Type A:\setup, then click OK.
4. Follow the instructions on your screen to continue through the Setup progress..
6. After the setup is done, an LDDM icon will show in the window. The LDDM program is ready.

To setup LDDM program from Windows 95

1. Insert Setup Disk in a floppy drive.
2. Click the Start button, and then click Run.
3. Type A:\setup, then click OK in the pop up windows.
4. When a screen message appears as follows, click OK to continue.
5. After the setup is done, an LDDM icon will show in the window. The LDDM program is ready.

SETUP

⚠ !   Warning – Can not copy file A:\DDEML.DL_ Since the Destination file is already in use

OK
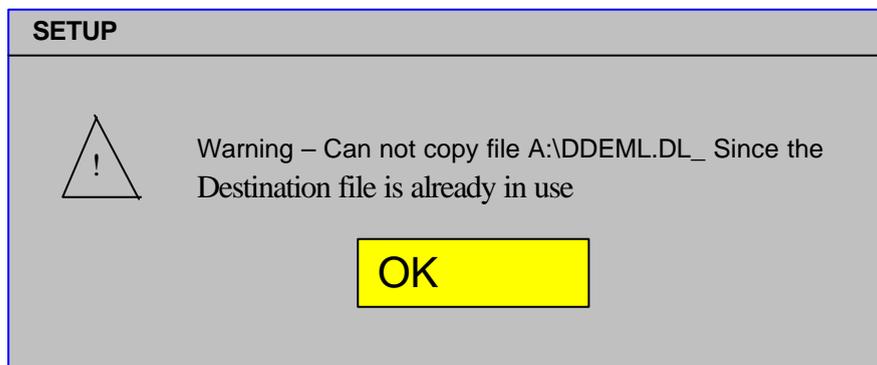
7.6.2.2 Starting LDDM Program

To start LDDM from windows, run Windows and double clicking on the LDDM icon. The main menu of LDDM program will appear on your screen (see figure 7-10). Click on Linear for linear measurement. The measurement program will appear on your screen (see figure 7-11).

7.6.3 Main Menu
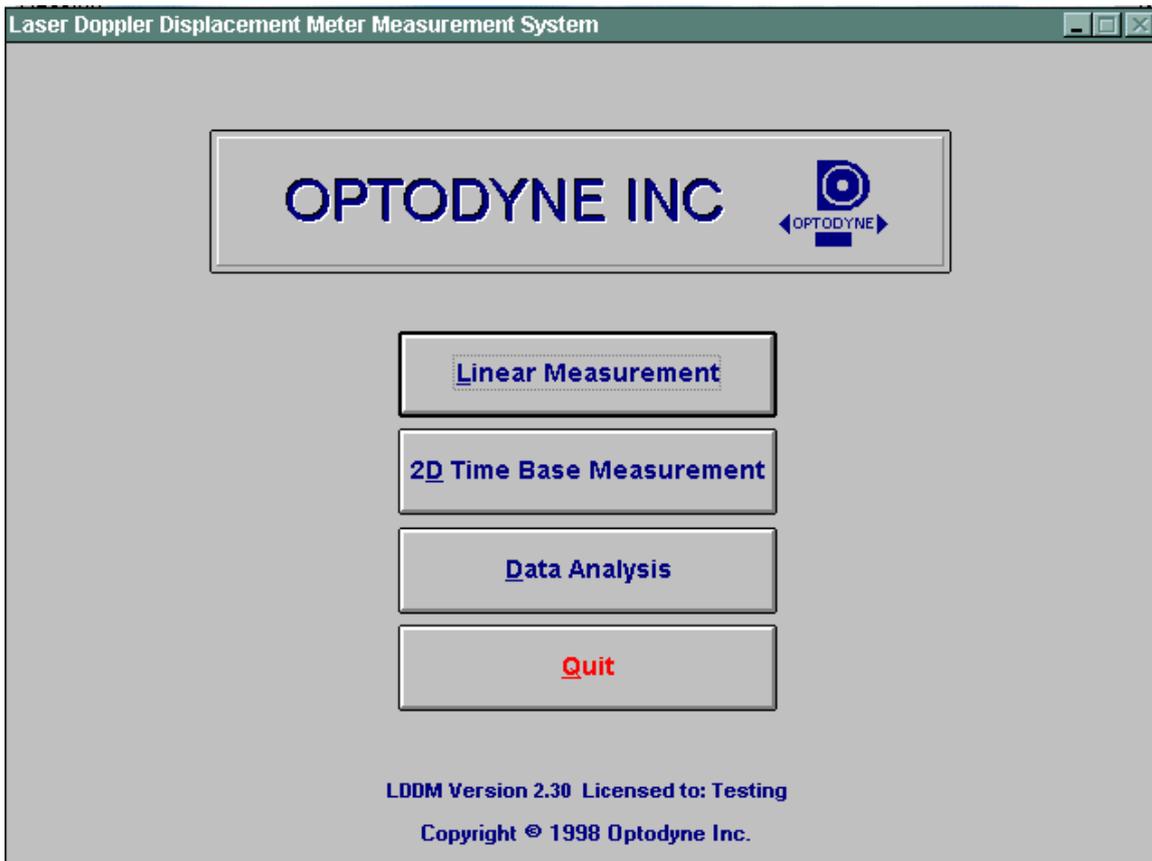
FIG.7-10 MAIN MENU

Click on **Linear** if you would like to take a linear measurement.
Click on **2D Time Base Measurement** for circular test or dynamic
measurement
Click on **Quit** if you would like to exit the program.

7.6.4 Linear Measurement

After clicking the **Linear Measurement Box** on the Main Menu, you will be greeted by the Linear Measurement Data Screen (Fig. 7-11). If the LDDM is not connected properly, an error message box will appear indicating that the LDDM interface not found, either turn off or not connected. Please check your connections and the LDDM reading on the display should appear. If the dashed lines should persist, press the **In/mm** button.

A. Linear Measurement Main Display
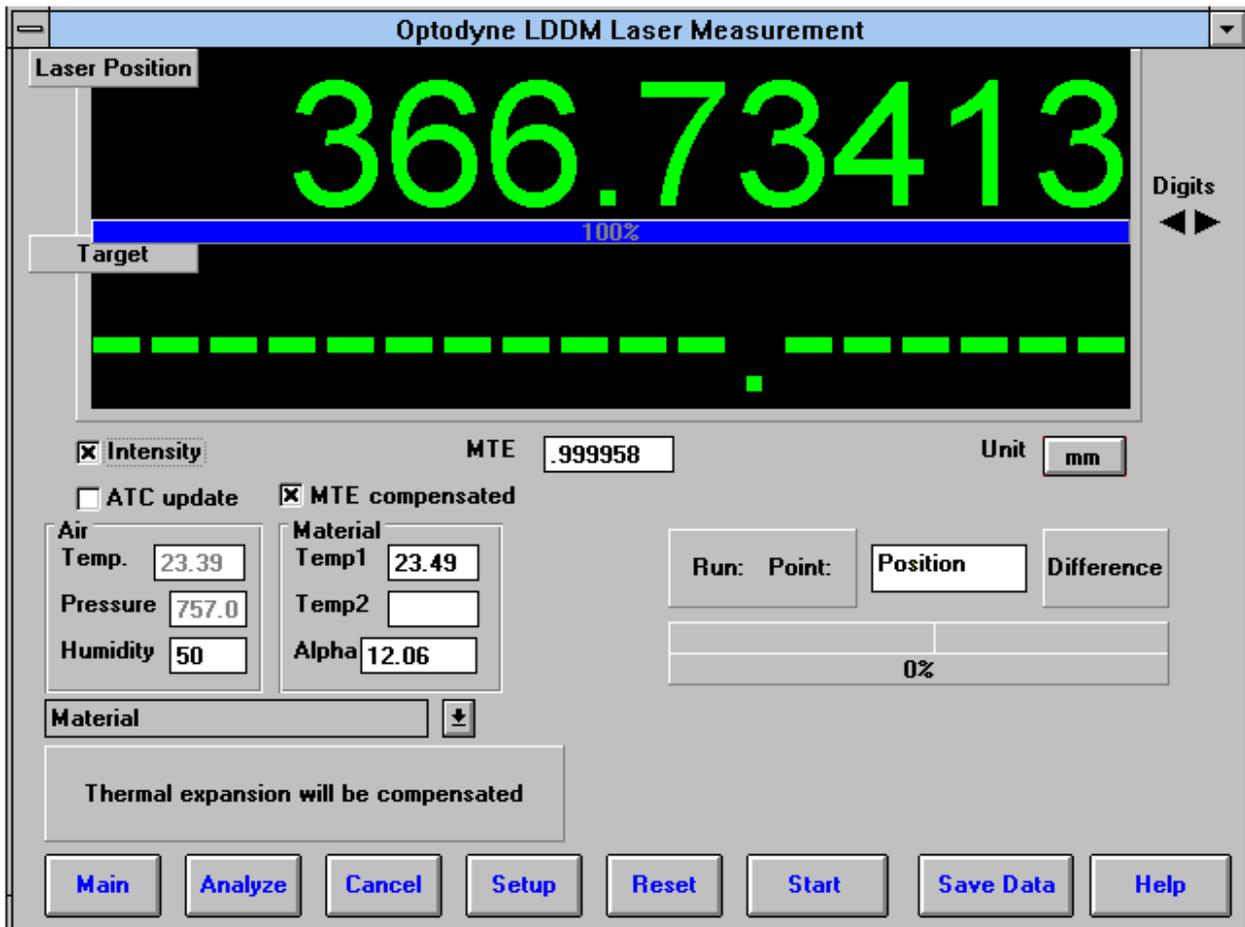
FIG.7-11 LINEAR MEASUREMENT MAIN DISPLAY

Choices on the Main Display are as follows:

Intensity: Align your system visually, then check your alignment by clicking on this box. A blue bar will appear in-between the Laser Position window and the Target window. This blue bar will range from between 0 and 100%. Please make sure that the intensity is at least 80% over your whole run. Press the intensity box again to return the system to its original state.

The two boxes next to the Intensity box show the Pressure and Temperature that the Processor Box is reading. If you have an ATC probe, these numbers will be continually changing. If you do not have an ATC probe, the values will be 68 degrees and 29.9 inHg. When the Intensity Box is clicked on, these values will disappear.

ATC update: The ATC update updates the air pressure, air temperature and material temperature readings from the processor box. The MTE value will be calculated from these updated values and Alpha material coefficient. A X mark will appear when the ATC value has been updated correctly for the next measurement.

MTE compensated: To show compensation for Material Thermal Expansion, please click the box to show the X mark. If the X mark does not appear on the screen, the displacement value will show only environmentally compensated values.

MTE: The MTE value can be manually changed in this box.

Unit: This box, when clicked on, will allow the user to change between the inch and metric systems.

Digits: Clicking the left arrow will decrease the amount of digits shown (data will still be taken to 6 digits). Clicking the right arrow will increase the amount of digits shown (max 6). To decrease the amount of digits shown, click the right arrow once, and then the left arrow.

Air/Material Environmental, Alpha Boxes: Values may be entered in the Air Temperature and Pressure boxes for those people who do not have an ATC probe. Humidity should be entered for all users of the LDDM system. The Material Temperatures are averaged together to get the MTE coefficient value. The material alpha can also be manually changed if the material list does not include the material of the machine being calibrated.

Run: Point:, Position, Difference: The values in these boxes are the respective values during a measurement. They show the Run number that you are taking (up to 7), the point number, the target position, and the difference between the LDDM reading and the target position.

The percentage bar shows how much of the current measurement is done.

For automatic measurements, a stoplight will appear. The green light indicates that the program is ready for the system to go to the next data point. The yellow light indicates that the retroreflector has dropped below the velocity threshold and is waiting for the set delay to complete. The red light indicates that the system is taking the data point.

Material Box: The material list and their corresponding alpha values are listed here. Click the mouse on the down arrow and a list of materials are shown. Please choose from the material list or enter your own value to the alpha box above.

The dialog box is just underneath the material box. This box displays messages and describes the actions you are taking.

Buttons at the bottom of the screen:

Main: exits the linear measurement package and loads the main menu.

Analyze: exits the linear measurement package and enters the analyze data package.

Cancel: By pressing this button, the popup screen allows you to cancel the last data point taken during a run, or the second popup screen allows you to cancel the whole measurement.

Setup: Opens the setup window, where measurement specifications may be edited or viewed.

Reset: Using this key allows for the reset of the LDDM.

Start Measurement: This button starts the measurement defined in the setup window.

Save Data: This button will allow for the data storage of the last measurement taken.

The Laser Position window shows the current position of the retroreflector. This value always shows a value compensated for air temperature, pressure and relative humidity, but may or may not be compensated for MTE (if MTE compensated box is clicked on or off).

The Target window will show a value during a measurement. This value is the next point where data collection will take place.

B. Linear Measurement Setup Screen (Fig. 7-12)

To input information: Please move the mouse pointer over the box on which you wish to change the information. The mouse pointer will turn in to a vertical bar. Two things may be done:

1) Block the text. Hold the mouse button down and move over the text completely. The text being blocked will become inverted in color (white on black). Type in the information to be entered. The original text will be replaced by the new information.

2) Click the mouse button while the vertical bar is over the box. Use the arrow keys and the delete key to erase the previous information. Then input the new information.
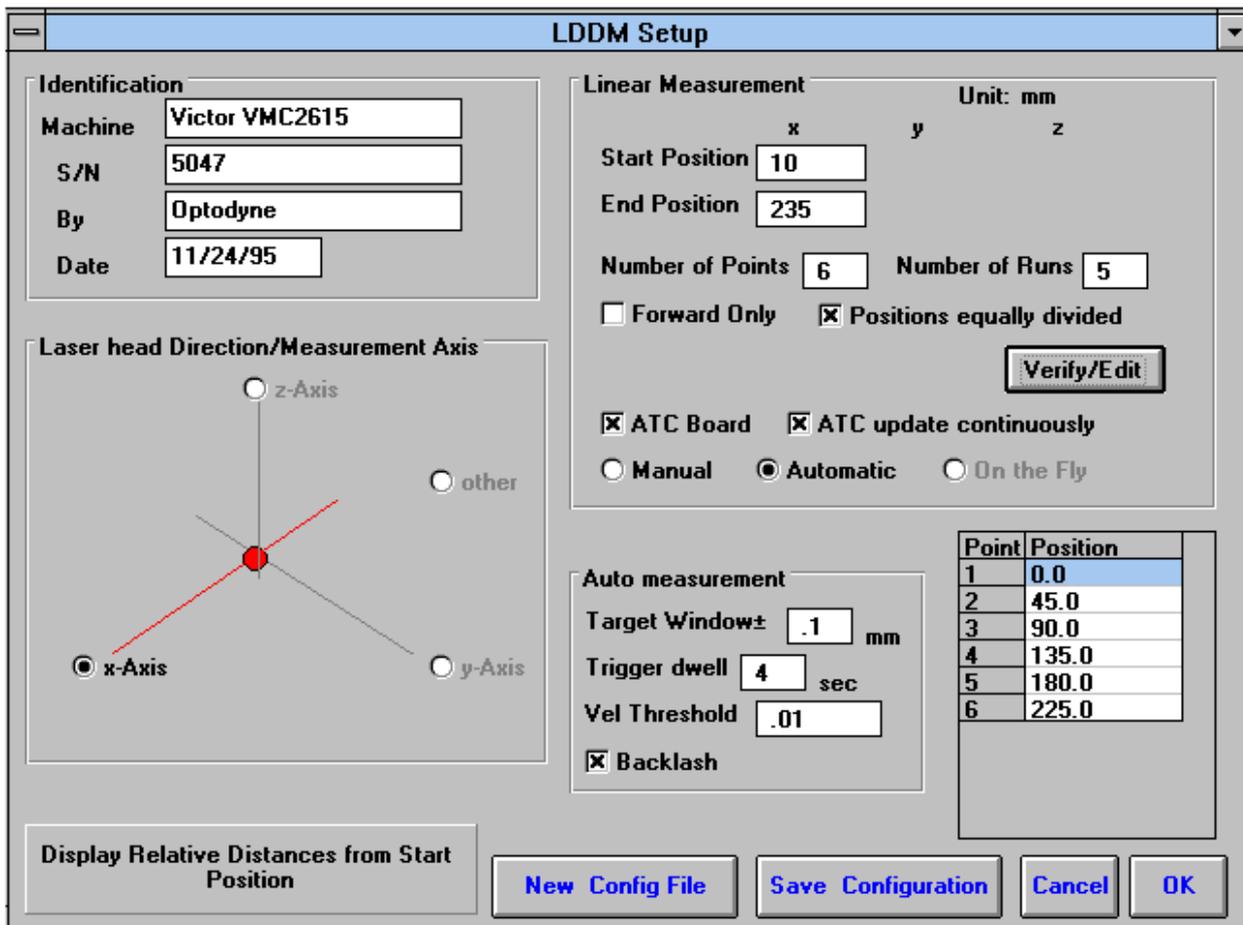
FIG.7-12 LINEAR MEASUREMENT SETUP SCREEN

Identification Box:

The identification of the machine, i.e. the machine type, serial number, the person doing the calibration, and the date, is entered here and is saved in the data file. The date is automatically entered using the computer system date.

Laser head direction/Measurement Axis Box:

You may choose either the x-axis, y-axis, or z-axis for on-axis measurements, or if you have the diagonal measurement kit, you may choose other for a volumetric measurement. Click on the circle closest to the type of measurement you would like to take.

Linear Measurement:

Start Position: Enter the coordinate of the machine position that you are going to be starting at (for that given axis).

End Position: Enter the final coordinate of the machine position that you will be ending at (for that given axis). Please make sure that the end position is always large than the start position.

Number of points: Counting the zero point as the first point, please enter the number of points for the run.

Number of Runs: Choose the number of runs for this measurement, 1 through 7.

Verify/Edit: Click on this button to see the data acquisition setup. Make sure that your increments are correct. If there are increments to be changed to an irregular interval, you may edit the box.

Forward Only: Click the box to an X mark if the measurement is to be forward only. Leave the box blank if it is to be a bi-directional measurement.

ATC Board: If you have an ATC board, please click the mouse here and make an X mark. If you do not have an ATC board, please make sure that there is no X mark there.

ATC Continuous Update: If you have the ATC board option marked with an X, you can choose ATC Continuous Update to monitor your material temperature for changes during the measurement. This is only necessary for larger machines, or measurements that take many hours to complete (otherwise the material temperature change should be negligible for most machines). This option will cause the MTE value in the Analysis program to be 1.000000.

Please choose the type of measurement you wish to take:

Manual: The Start Measurement button will turn into a "TAKE" button after the measurement begins. At every collection point, this button will have to be pushed.

Automatic: The software will collect data every time the retroreflector comes within a "Target Window", drops under a certain velocity and sits still for a designated dwell time.

On-The-Fly: There is no On-The-Fly capability for the Linear Measurement.

Auto Measurement Box:

Target Window (automatic and on-the-fly): For automatic and on-the-fly measurements, being within this value of the target position allows the software to take data.

Trigger dwell (automatic only): For automatic measurements, the settling time of the machine (typically 3-5 seconds) is entered here. Choose a value of at least 2 seconds less than the programmed machine dwell time. This allows the computer to finish the data collection before the machine start to move again.

Vel Threshold (automatic only): This is the threshold that the velocity of the retroreflector must drop underneath so that a data point can be taken.

Backlash (automatic only): If the box has an X, backlash at the end and beginning of each run (other than the first point) will be taken. The distance necessary to remove the backlash and allow the software to re-trigger is twice the target window.

New Configuration: You may load a previous configuration file if you have one for this particular machine.

Save Configuration: This updates the LDDM.CFG file so that the data seen on the screen will appear each time LDDM for Windows is run.

Cancel: Cancel the above changes and revert to the previous values.

Ok: Settings are ok for this measurement. If you saved this setup as the default, it will come up first every time, otherwise the previous setup will re-appear next time the program is run.

C. Example of a Linear Measurement

Linear Measurement Main Display (See Fig. 7-11):

1) Check your units in middle right hand side. If it is not the correct type, click on the **inch/mm** icon.

2) Align the laser head visually according to the user's guide. Click the **intensity** button on the middle left hand side and check to see if the laser is aligned over the whole travel. After alignment, click off the **intensity**.

3) Click once on the **setup** icon on the bottom row of Icons.

Linear Measurement Setup Screen (See Fig. 7-12):

4) Setup your system information on the upper right hand side of the machine. Input the **identification** of the machine you are calibrating. To type the text, please move the arrow of the mouse pointer until it turns into a text cursor (an up and down line). Or please hit the tab key until one of the text boxes is highlighted. Type your machine data in.

5) Enter the axis of measurement (or the diagonal) by clicking the appropriate box on the bottom left graph (**X**, **Y**, **Z** or **OTHER** for diagonal)

6) Enter the **machine coordinates** that you wish to calibrate in the upper right corner.

7) Enter the **number of points**, including zero, that you wish to calibrate. E.g.   For a ten inch run, with 2 inch increments, enter 6.

8) Enter the **number of runs** (typically 7 for NMTBA, or 5 or VDI, ISO and at least 3 for B5)

9) Press the **Verify/Edit** button to see the increments. You may manually change these increments if you would like to.

10) If you are manually changing the values, make sure that the **Positions Equally Divided box** is clicked off to show: **Positions As Shown Below**.

11) Change the # of points as necessary to achieve the correct increment that
 You desire (Press **Verify/Edit** to check again).

12) Choose **Forward Only** or **Bi-Directional** runs.

13) Click on the **ATC board** if you have one.

14) Click on **ATC Continuous Update** if you want continuously update the ATC value during the measurement .

15) Choose your type of measurement:

Manual

> you may: 1) Hit the **enter key** at each point, or
> 2) Click the **mouse** on Take at each point

Automatic

To take data automatically, you will have to program the machine controller to do 2 or 3 things: to move in a certain increment with a delay time in-between movements (3-5 seconds recommended), and add a backlash movement that is greater than double the target window at each end (backlash is optional).

The following information will be necessary for Automatic measurements:

Target Window: This tells the computer a distance window around the target position where the computer is allowed to take data.   This value is related to the backlash needed (see below).   A typical value is .001 inch or .02 mm, depending how tight your machine is.   The backlash movement of the machine must be at least double this value.

Trigger Dwell: Set this value for two seconds less than the machine delay time for each point.

Velocity Threshold: This value keeps the risk of false triggering down.   A good value to use is 0.01 for inches, 0.1 for metric.

Backlash: Check here if you want to account for backlash.   The backlash at the beginning and end of each forward/backward run has to be at least TWICE the target window value.

16) Saving the Configuration File:

Save this configuration file by clicking the **Save Config File** Icon.   Type the name of the file which you would like the setup saved to (usually the name of the machine).   Press **Enter** or **OK** after typing it in.

The program will ask you if you would like to save the file, press **Yes**.

The program will then ask if you want to use this file as your default.   If **Yes** is clicked, this setup will be loaded every time that the Linear Measurement Module is loaded.
To load a configuration file next time, click on **New Config File**.   You may either:

> 1) Click on the file name and press **OK**
>
> 2) Double click on the file name
>
> 3) Type the name of the file name, example: **LDDM.1CF** and hit enter.
>   The extension .1CF indicates a configuration file.

17) Press **OK** to get back to the main screen.

Taking Data Points for a Linear Measurement (Fig. 7-13)

18) Press **ATC update** (X) to update the values.

19) Input the **Humidity Value**.

20) Choose your material from the list given. Press the **Down arrow key** and you will get a list, press the **down arrow key** or **PgDn key** from there to scroll down.

21) Choose the number of digits on the upper right hand side of the screen you wish the screen to display. Click the **right arrow button** to increase the amount (up to six), or click the **left arrow button** to decrease the amount.

22) Move your retroreflector to the beginning of your run. Click on **Start**.

Manual: If you are manually operating the laser/machine, press the designated key to take data as shown (after you move the machine). Also, if you would like to change the target position, you may do so in the value box located in-between the run information.

Automatic: If you are running the automatic program, you will see a stoplight appear. The red means that the conditions for a measurement have been met (inside the target window, and the velocity is lower than the given one), yellow means that the delay is being counted and the green means that the data has been collected and the program is waiting for you to move to the next point (Fig. 7-13).
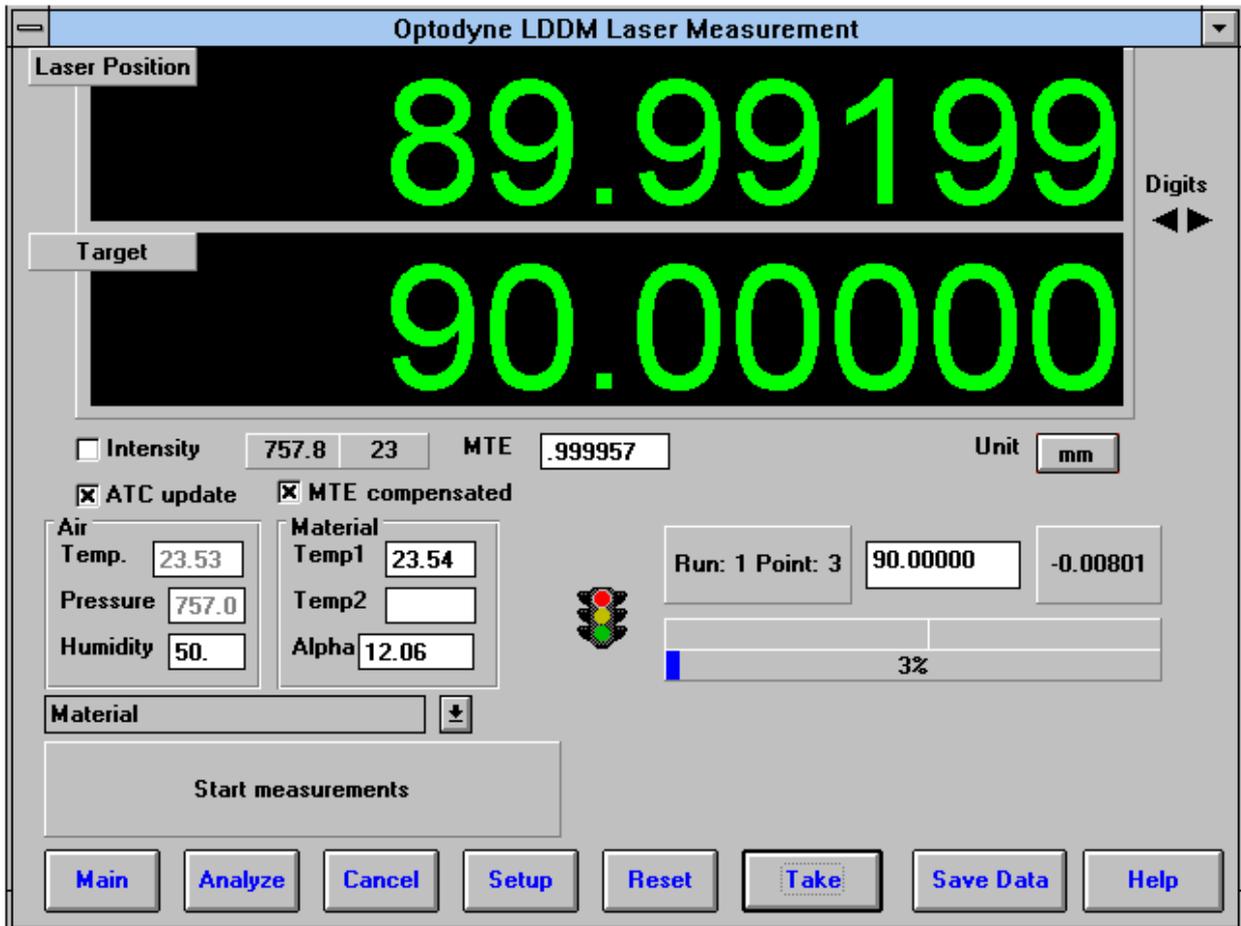
FIG.7-13 AUTOMATIC LINEAR DATA COLLECTION

23) After all the data is taken, press **OK** to save the data, or **cancel** to not save the data.

24) To save data, type in the **filename** to save and hit **<Enter>** (the extension is automatically saved as .LIN). You may also save collected data by pressing the **save data button**, and follow the procedure above.

25) To analyze the data click on the **Analyze button**. When it prompts you, unload the module.

D. Linear Data Analysis Menu (Fig. 7-14)


```
┌─────────────────────────────────────────────────────────────────────────┐
│ □  ▪              Analysis - [Analysis]                        ▼  ▲      │
│ ▪  File   Data Selection   Analysis   Help                              ▲ │
├─────────────────────────────────────────────────────────────────────────┤
│ [📂] [💾] [📊] [🖨]                              [⬆] [⬇] [Exit]          │
├─────────────────────────────────────────────────────────────────────────┤
│   Position Measurement, Error Analysis (mm)   File=C:\LDDM\VICTORX2.LIN   Date :02/24/95
│   Machine :Victor VMC2615   S/N :5047   By :Rick
│   Start Position: ( 10, 0, 0)   End Position:  ( 235, 0, 0)
│   Total Travel = 225   Points = 6   No of Runs= 5
│   Pressure: 764.12   Humidity: 0.00   Air Temp: 20.41   Material Temp: 18.31
│   Max Error:  0.00104        Min Error: -0.00351        Mean: -0.00117
```

Position,mm	Run #1	Run #2	Run #3	Run #4	Run #5
10.0	0.00040	-0.00036	-0.00111	-0.00145	-0.00272
55.0	0.00022	0.00021	-0.00115	-0.00176	-0.00265
100.0	0.00023	0.00015	-0.00078	-0.00151	-0.00198
145.0	-0.00073	-0.00058	-0.00177	-0.00255	-0.00288
190.0	0.00024	-0.00005	-0.00056	-0.00085	-0.00178
235.0	-0.00085	-0.00181	-0.00111	-0.00223	-0.00244
235.0	-0.00092	-0.00127	-0.00203	-0.00213	-0.00306
190.0	0.00086	0.00043	-0.00002	-0.00114	-0.00112
145.0	-0.00053	-0.00153	-0.00225	-0.00268	-0.00351
100.0	0.00047	-0.00057	-0.00102	-0.00226	-0.00222
55.0	0.00104	-0.00052	-0.00094	-0.00160	-0.00243
10.0	0.00074	-0.00041	-0.00141	-0.00159	-0.00230

FIG.7-14 LINEAR MEASUREMENT DATA ANALYSIS TABLE

Under the **File Menu**, you can open a **new** data file, **save** a data file, set your **printer type**, set your **printer style**, or return to the **main menu**. When loading a file, choose the files with the extension of .LIN for linear. You can only **print data** tables using the print function under this heading.

Under the **Data Selection** heading, you can only choose **Displacement** when looking at a linear (.LIN) file.

Under **Analysis**, you can choose **Error**, **NMTBA**, **NMTBA with Zero Shift**, **VDI 3441**, **ISO**, or **B5** for different types of data manipulation. After choosing **Error**, you will be given a choice on what you wish to see, **Runs #1-7**, and **forward** or **backward**. Click with the mouse button on which runs you wish to see.

The following icons have the following function in Analysis:

[📂] Open a new data file.

[💾] Save a data file.

[📊] Graph a data file (After graphing, you may also change the scaling of the graph by checking X on adjust grid).

 Print a data graph (for printing data tables, use the Print option under the "File" heading)

 Moves to the previous screen.

 Moves to the next screen.

 Exits the program.
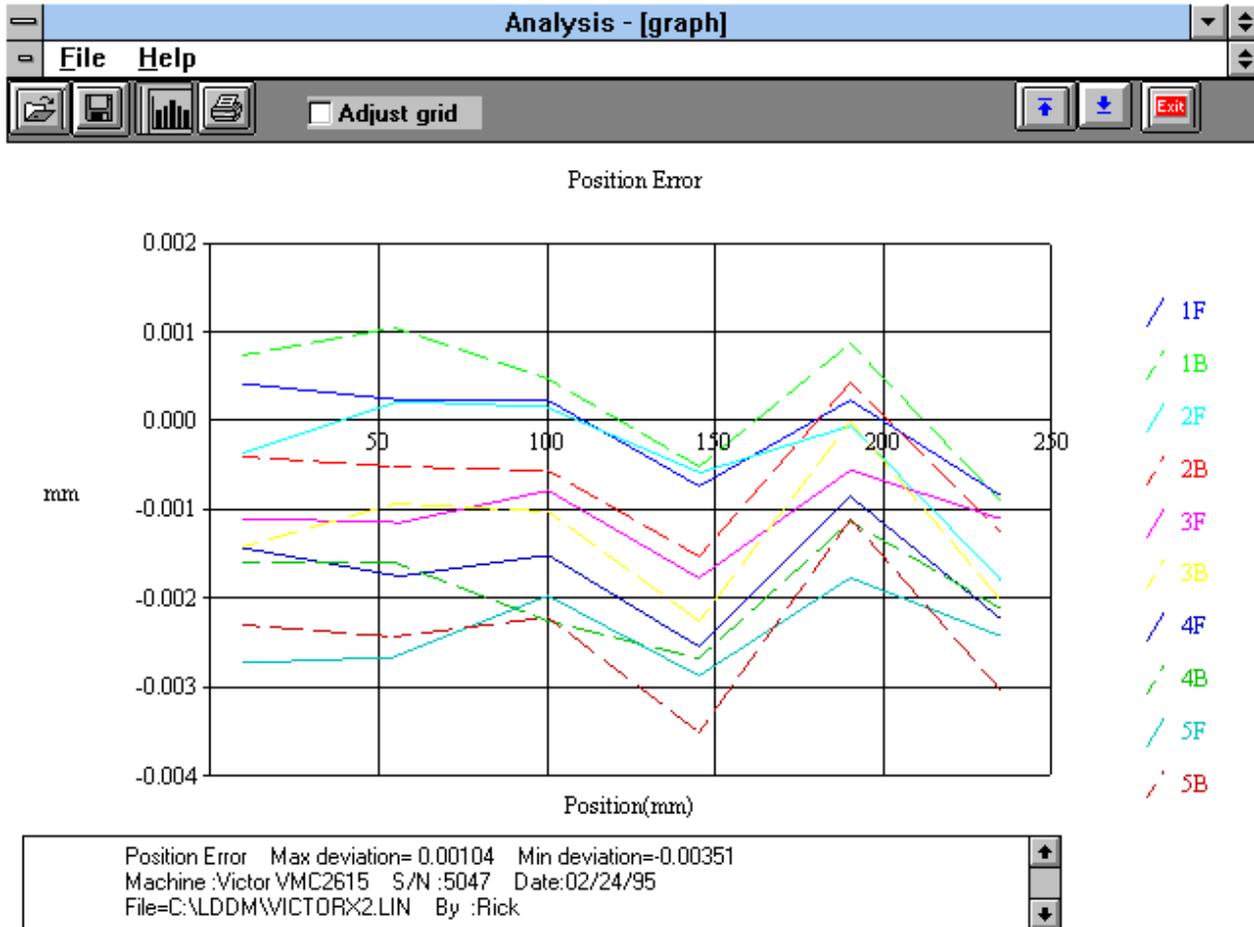
FIG.7-15 LINEAR MEASUREMENT DATA PLOT
(INDIVIDUAL PLOTS TOGETHER)

7.7 Accuracy and Error Sources

Displacement measurements are accurate within the following tolerances depending on the speed of light compensation and operating temperature. Assume at a standard condition, i.e. 68°F, 29.9 inHg, and 40% relative humidity, the accuracy is ±1 ppm. For example, the error is ±12 μin for a total travel of 12 inches. The LDDM™'s displacement accuracy depends on a correct system setup and operation combined with accurate utilization of atmospheric pressure, air temperature, humidity and material temperature data.

The following are some potential measurement errors, and how they affect displacement measurements. The LDDM™ has a stability of 0.1 ppm. All of the following measurement errors add to this value. The sources of error in displacement measurement are:

1. Measurement of atmosphere pressure, air temperature and humidity to determine the speed of light.

2. Material temperature measurement, the material temperature may be higher or lower than the air temperature. The difference may be as large as the actual variation in room temperature.

3. Mis-alignment between machine travel and laser measurement axis. This is the cosine error, which is equal to (1-cos x) where x is the mis-alignment angle.

4. Mechanical vibration and stress of the retroreflector and the laser head.

These errors are common to all laser interferometers.

The sum total of all the errors listed above determines the overall accuracy of the laser measurement system in your application. (More details in Appendix J).

7.8 Taking a Measurement

1. Decide which axis you are going to measure, from which starting point to which end point, and the increment per stop. Key in all the variables and pertinent information into the computer.

2. For automatic data collection, program your machine controller with the specific increment per stop, total number of stops (or total travel), and the speed. The dwelling time at each stop should be longer than (6) seconds.

3. Set up the LDDM™ by following the instructions in Section 7.5.

4. Set up computer and load the appropriate software by following the instructions in Section 7.6 or the software manual.

5. Set up the desired configuration or load an existing configuration.

6. Move the machine to the starting point.

7. Reset the LDDM™ reading, click the start button. Then move the machine to the first stop.

8. For automatic data collection the computer will wait (5) seconds after the machine is stopped and then automatically record the LDDM™ reading. For manual data collection, after the machine is stopped, wait (5) seconds then click the taken button to record the LDDM™ readings.

9. Continue to move the machine to the next stop and repeat step 8.

10. Repeat step 9 until the 'end' point. This is done for single-direction measurement.

11. For bi-directional measurement, move the machine about 0.5 inch (at least 2 x target window) further, stop, wait (6) seconds, then return to the 'end' point, stop, wait (6) seconds and repeat step 8 for the return travel.

12. After all data has been collected, you need to save the data. You may click the analysis button to analyze the data now or save the data now and to analyze the data later.

8.0 Circular Test (Laser/Ballbar)

8.1 Introduction

The circular test accessories (LB-500) are designed for circular test with an MCV-500 laser system. The single aperture MCV-500 laser system is based on laser dopplermetry. Hence, a flat-mirror can be used as a target. Pointing the laser beam in the X-direction and mounting the flat-mirror target on the spindle, the X-coordinate of the spindle motion can be measured even with a large Y-direction movement. By repeating the measurement in the Y-direction, the Y-coordinate of the spindle motion can be measured. The data on X-coordinate and the data on Y-coordinate can be combined to generate the measured circular spindle path. Hence the MCV-500 can be used as both a laser for positioning measurements and a ballbar for circular tests. As compared with a telescopic ballbar, the major features of the circular test using the MCV-500 are the following.

1. The measurement is non-contact, no cables to worry about, no friction or bearings.
2. The circular path radius can be varied continuously from 0.01 inches to 6 inches.
3. The data rate is up to 1000 data/sec.
4. The measuring speed is up to 4m/sec.
5. Large alignment tolerance is achieved by using an optical adapter.
6. Linear accuracy is traceable to N.I.S.T.
7. The tangential velocity and acceleration can be measured and displayed.
8. A compact notebook computer can be used with user friendly Windows™ software for data collection and analysis.

8.2 Hardware Required

The basic hardware and software required for the circular test are listed below:
    a. Single Aperture Laser Head   L-109
    b. Processor Module with RS-232 Interface   P-108D
    c. 6" Flat-mirror w/steering   LD-71

d. Metrology/Analysis Program with Circular Path   W-500/w-500lb
e. Optical Adapter   LD-69
f. Magnetic Base   LD-03
g. Adapter Platform   LD-14A
h. 12 ft Cable Set   LD-21L
i. PC Card and Cable   IPC5-1000
j. Notebook PC   Not supplied

FIG. 8-1 HARDWARE FOR LASER/BALLBAR

FIG. 8-2 LASER/BALLAR CIRCULAR TEST SETUP

8.5 Installation and Alignment

8.5.1 Important Considerations

1. Check that all cables are firmly connected before connecting the power cable and switching the power switch to the on position.

2. Always mount the laser head on a stationary part and the flat-mirror on a moving part. Never use a tripod to mount the laser head. The tripod may introduce an error. For example, on most CNC machine tools, the spindle is moving in the Z-direction and the bed is moving in X-and Y-direction. Hence, when measuring the X- and Y-direction, mount the laser head on the spindle (or near the spindle by a magnetic holder) and the flat-mirror on the bed. Then to measure the Z-direction, mount the laser head on the bed and the flat-mirror on the spindle. However, for most CMM machines, the bed is fixed and the spindle is moving in X-, Y-, and Z- directions. Therefore, always mount the laser head on the bed and mount the flat-mirror on the spindle or the moving carriage.

    CAUTION! Never turn on the spindle of the CNC while either the laser or flat-mirror are mounted there. This could cause injury to the operator and/or damage to the equipment.

3. When installing the laser head, make sure that the laser beam coming out will travel in the direction of the measurement, and is perpendicular to the flat-mirror.

4. Vibration and loose connections must be minimized by proper mounting. Make sure that all supports and cables are completely stationary. A spindle, for example, must be secured by a brake so it will not rotate.

5. The output laser beam and the flat-mirror must be aligned properly such that the beam intensity is above the minimum requirement along the entire circular path.

8.5.2 Installation

8.5.2.1 Set up LDDM Program

See Section 7.5.2.1.

8.5.2.2 Starting LDDM Program

See Section 7.5.2.2.

8.5.2.3 Install PCMCIA Card

Set the PC Notebook near the Processor module. Insert the interface PCMCIA Card (IPC5-1000) to the PC Notebook. Each card is for a single channel and up to 2 PCMCIA Cards or 2 channels for two laser systems (MCV-500). Make sure all the hardware is installed and aligned properly. Make sure the PCMCIA Card is plug-in firmly with good contact and proper communication established. For some PC, the PCMCIA Card has to be inserted before boot.

8.5.2.4 Setup Laser head and Flat-mirror target

Attach the optical adapter to the front of the laser head (Fig.8-3). Align the output beam by move the optical adapter up/down and left/right such that the output laser beam is pointing to the same position with and without the optical adapter. Tighten the two screws on the side. Mount the laser head with the optical adapter on the bed with a magnetic holder and the flat-mirror on the spindle directly or with a magnetic holder, as shown in Fig.8-4. For some machine, the bed is moving, then mount the laser head on the spindle and the flat-mirror on the bed. For XY-plan measurement, pointing the laser beam in the X-direction (or Y-direction) and the flat-mirror perpendicular to the laser beam. Move the laser head or the flat-mirror such that the laser beam is always reflected by the flat-mirror over the whole circular path. The standard flat-mirror is 6" long. It will cover a circular path of 6" diameter. For large diameter, a longer flat-mirror is available.

Finally, adjust the two screws on the mounting of the flat-mirror (Fig.8.5) such that the return laser beam enters the aperture of the optical adapter. The green light on the data collection screen should be on. Move the spindle along the circular path and make sure the green light is always on. Otherwise, fine adjust the flat-mirror again.

OPTICAL ADAPTER (LD-

LASER HEAD (L-109)
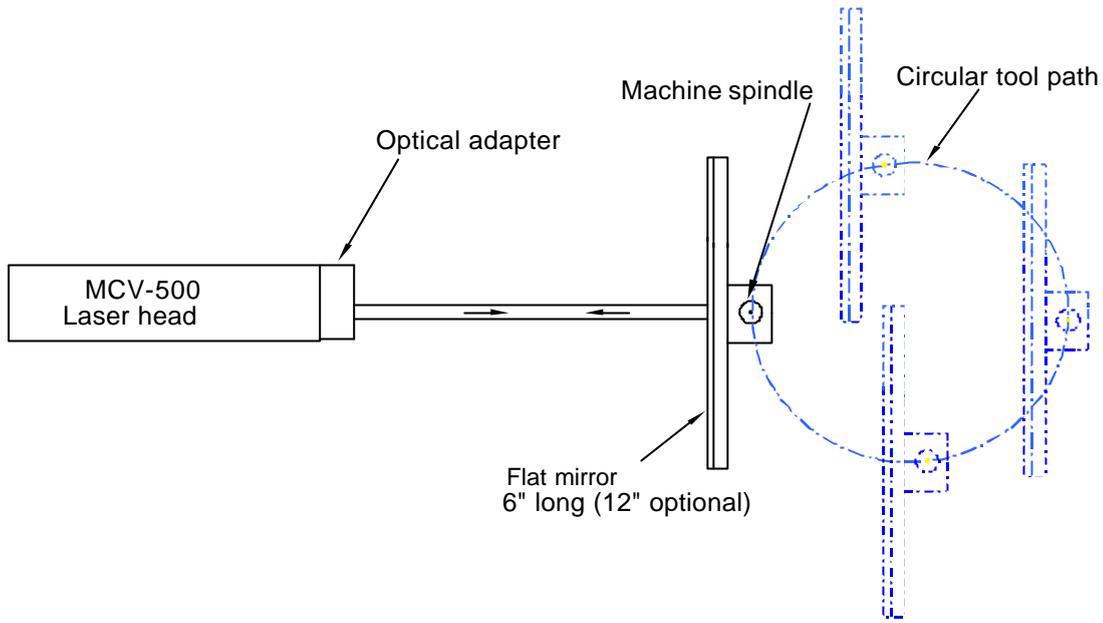
FIG. 8-4   SCHEMATIC OF LASER CIRCULAR TEST

ADJUSTABLE SCREW

MIRROR

MAGNETIC BASE
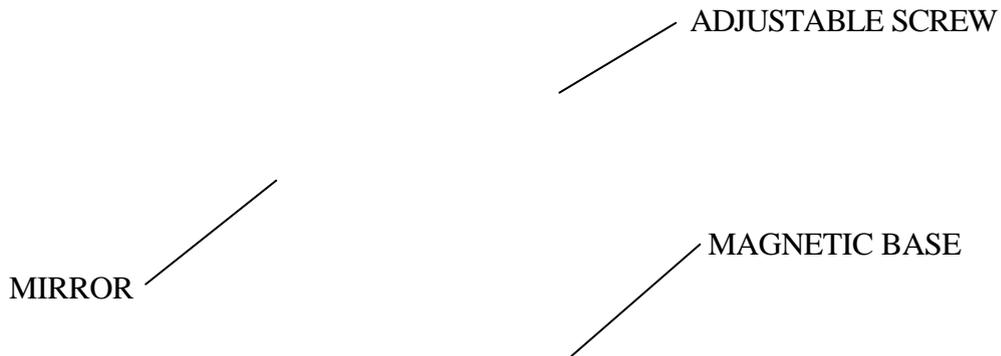
FIG. 8-5 FLAT-MIRROR TARGET WITH TWO ADJUSTABLE SCREWS

8.6 Software Description

8.6.1 General Description

For general description, windows, installation and starting LDDM program, see section 7.6.

8.6.2 2D Time Base Data Collection

The 2D time base collects data through a special PCMCIA card. The maximum data rate is 1000 data/sec. Click on the "2D time base" button in the main menu to get the data collection screen as shown in Fig.8-6.
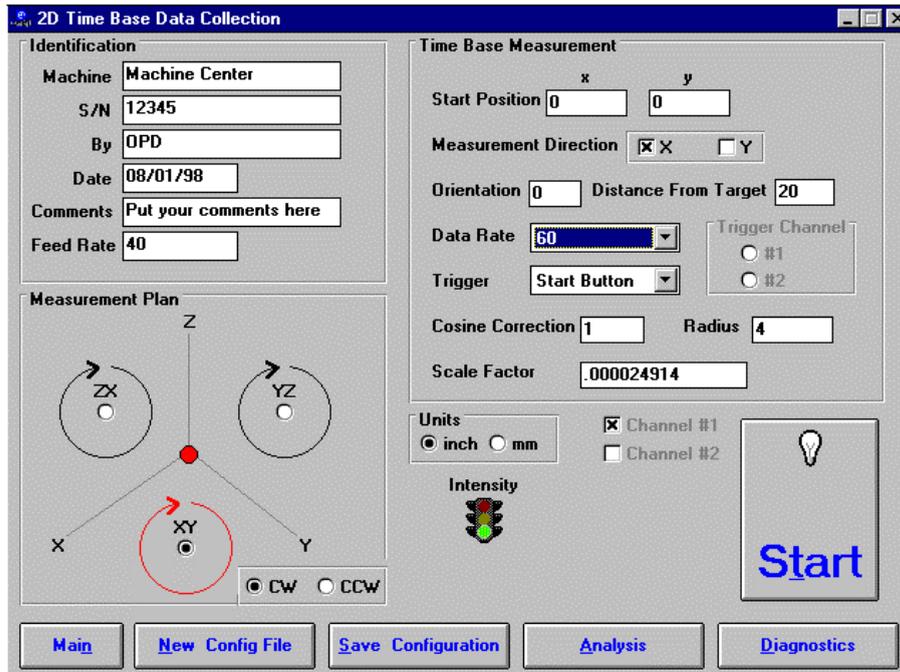
FIG. 8-6 2D TIME BASE DATA COLLECTION SCREEN

Choices on the data collection screen are as follows:

Identification: Input the machine type, serial number, operator, date, your comments or remarks and feed rate in/min or mm/min.

Measurement plan: Select the plan of measurement, xy, yz, or zx, and direction of the circular path, either cw or ccw.

Time base measurement: Enter start position, measurement direction, and distance from the target. The orientation is the angle between the measurement direction and the first-axis direction. The data rate is determined by the selected feed rate and radius (see section 8.5.3). Trigger mode is "start button" only. The displacement or velocity trigger will be added later. Cosine correction is 1 for normal operation. It is 2cos(angle) for double pass and the angle is the angle between outgoing and return eams. The radius is the radius of the programmed circular path. The scale factor is 0.000024914 in or 0.000632816 mm. Click "in" for inch unit and "mm" for metric unit. Click both channels for 2 channel data collection.

Intensity: The green light indicates the laser is aligned properly and the red light indicates the alignment is off. Block the laser beam to check whether the PCMCIA Card is installed properly.

Start/stop: Click "start" to start the data collection and "stop" to stop the data collection. After stop, enter the filename to save the data collected. The extension .2dr will be added automatically.

8.6.3 Data Analysis

To analyze data, go to the main menu first then click on the "analysis". Click on "file" to open a file with extension .2dr. The file usually is very large, please wait a while for the file to be ready. After the .2dr data shown on the screen, click on "data selection" and "displacement 1".

The displacement values will be calculated and displayed as shown in Fig 8-7.

Analysis - [2D Time Base]

File   Data Selection   Analysis   Help

Displacement 1
Velocity 1
Acceleration 1
Displacement 2
Velocity 2
Acceleration 2

=C:\T\TEST1CWX.2DR   Date :07/20/98
Machine   S/N :V1170   By :CPH
Measurement Direction = X
Start Position = 20 (in)
Feedrate = 40 in/minute   Sampling rate: 30/sec

Max: 3.5068697   Min: -4.4937880   Mean: -0.4897788

Data Point	Displacement 1
49	-0.2406692
50	-0.2184709
51	-0.1964469
52	-0.1743233
53	-0.1521249
54	-0.1299265
55	-0.1076783
56	-0.0855796
57	-0.0635058
58	-0.0414818
59	-0.0195326
60	0.0026160
61	0.0246150
62	0.0467138
63	0.0689121
64	0.0908364
65	0.1128355
66	0.1346602
67	0.1566343
68	0.1785088
69	0.2003584
70	0.2222827
71	0.2441572
72	0.2660815

FIG.8-7 THE ANALYSIS SCREEN WITH DISPLACEMENT DATA

After the displacement values are displayed, click on the "graph" to plot the displacement. A typical plot of the displacement is shown in Fig 8-8.

☒ Adjust grid   Exit

Displacement 1

Grid Adjustment

	X	Y
Max		
Min		
Ticks	2	2

Displacement 1   Max = 3.51   Min = -4.49   Mean = -0.49
Machine :Vertical Milling Machine   S/N :V1170   Date:07/20/98
File=C:\T\TEST1CWX.2DR   By :CPH
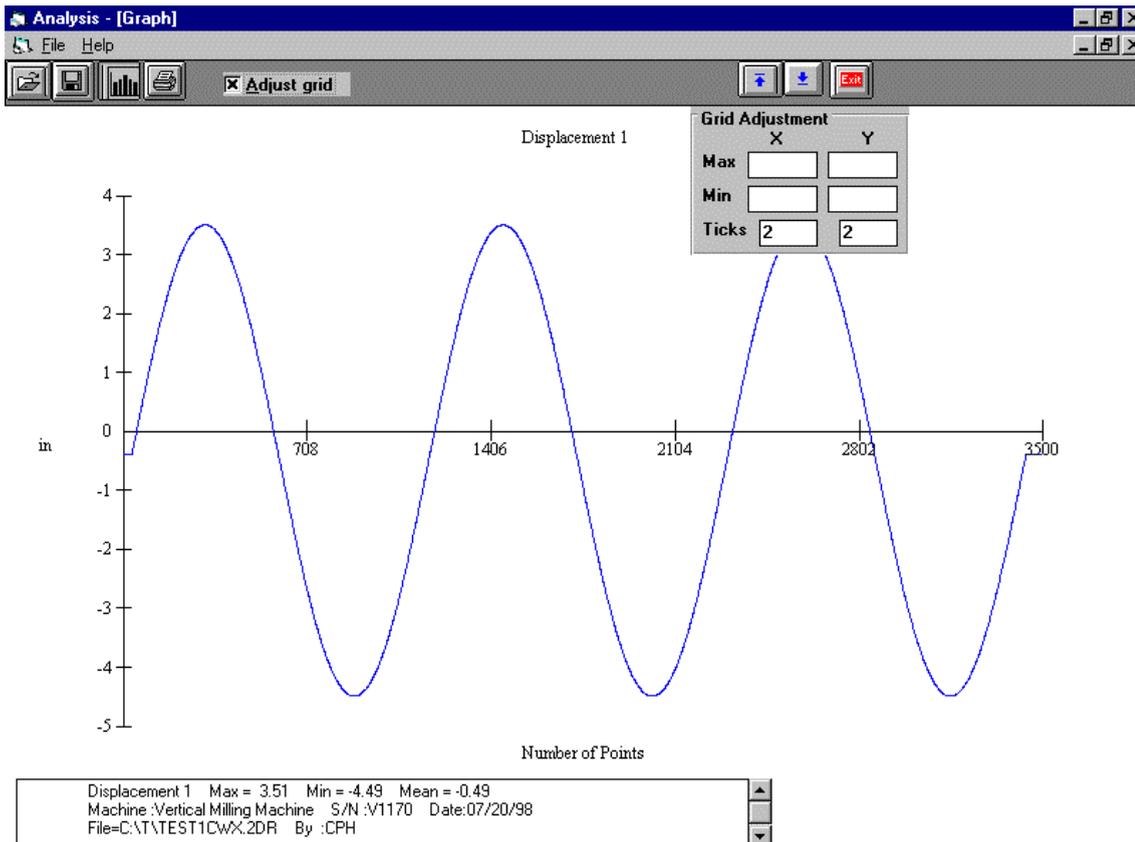
FIG. 8-8 A TYPICAL PLOT ON DISPLACEMENT DATA

8.6.7 Accuracy Velocity, acceleration and others

As shown in section 8.6.3, the displacement values can be displayed or plotted. Click on the "velocity 1", the velocity values are calculated and displayed. Click on the "graph" to plot the velocity profile. Similarly, the acceleration values can be calculated by click on the "Acceleration 1" button. To remove a spike or spikes, click on the "R-spike" button, and specify the starting point and the ending point, the spike or spikes between the starting and ending point, will be removed and the displacement values recalculated. Please note that, remove the spikes may distort the circular path.

9.0 Vector Measurement or Sequential Diagonal Measurement

Hardware Required

The basic hardware and software required for the vector measurement are listed below:

    a. Single Aperture Laser Head   L-109
    b. Processor Module with RS-232 Interface   P-108D
    c. Automatic Temperature Compensation Probes   IATCP

d. 3"x4" Flat-mirror w/steering   LD-71S
        e. MCV-500 Windows Program with Sequential
        Diagonal Data Collection and Processing   W-500/W-500SD
        f. Optical Adapter   LD-69
        g. Magnetic Base   LD-03
        h. Adapter Platform   LD-14A
        i. 12 ft Cable Set   LD-21L
        j. Cross Link   LD-44
        k. Diagonal Steering Mirror   LD-37S
        l. Notebook PC   Not supplied

   Some of the hardware is shown in Fig.9-1.

FIG. 9-1 VECTOR MEASUREMENT HARDWARE

9.5 Installation and Alignment

9.5.1 Important Considerations

1.   Check that all cables are firmly connected before connecting the power
      cable and switching the power switch to the on position.

2.   Always mount the laser head on the machine bed and the flat-mirror on
      the spindle. If the machine bed is too small, mount the laser head on an
      extension bar tight to the machine bed. Never use a tripod to mount the
      laser head. The tripod may introduce an error.
      CAUTION! Never turn on the spindle of the CNC while the flat-mirror is
      mounted there. This could cause injury to the operator and/or damage to
      the equipment.

3.   When installing the laser head, make sure that the laser beam coming
      out will travel in the direction of the measurement, and is perpendicular to
      the flat-mirror.

4.   Vibration and loose connections must be minimized by proper mounting.
      Make sure that all supports and cables are completely stationary. A
LD-21L spindle, for example, must be secured by a brake so it will not rotate.   LD-69
LEMO   Optical
                                                                                  Adapter

5.   The output laser beam and the flat-mirror must be aligned properly such that the beam intensity is above the minimum requirement along the entire diagonal path. It is a good practice to steer the flat-mirror back and forth and stopped at the middle of the peak intensity.

9.5.2 Installation

9.5.2.1   Set up LDDM Program

See Section 7.5.2.1.

9.5.2.2   Starting LDDM Program

See Section 7.5.2.2.

9.5.2.3   Setup Laser Head and Flat-mirror Target

OPTICAL ADAPTER (LD-

LASER HEAD (L-109)

MOUNTING SCREW
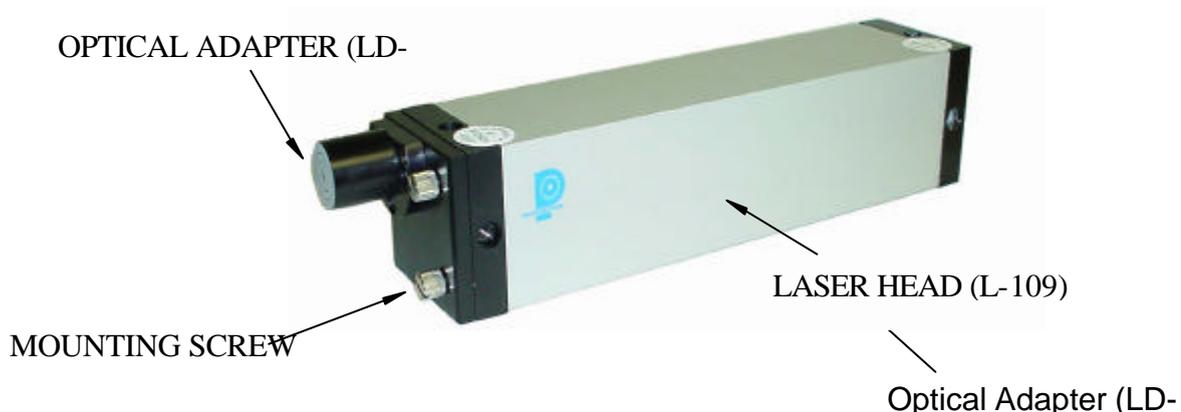
Optical Adapter (LD-

FIG. 9-2   LASER HEAD WITH OPTICAL ADAPTER

Attach the optical adapter to the front of the laser head (Fig.9-2). Align the output beam by moving the optical adapter up/down and left/right such that the output laser beam is pointing to the same position with and without the optical adapter. Tighten the two screws on the side. Mount the laser head with the optical adapter and the diagonal steering mirror on the bed with a magnetic holder and the flat-mirror on the spindle directly or with a magnetic holder, as shown in Fig.9-3. Point the laser beam in the first diagonal direction and the flat-mirror perpendicular to the laser beam. Move the laser head or the flat-mirror such that the laser beam is always reflected by the flat-mirror over the whole diagonal path. The standard flat-mirror is 3" x 4". It will cover a movement of less than 2". For large movement, a larger flat-mirror is available.

Finally, adjust the two screws on the mounting of the flat-mirror (Fig.9-4) such that the return laser beam enters the aperture of the optical adapter. The beam intensity should be above the minimum requirement along the entire diagonal path. Otherwise, fine adjust the flat-mirror again. For some machine a cross-link (LD-44) is needed to rotate the flat-mirror to be perpendicular to the laser beam.
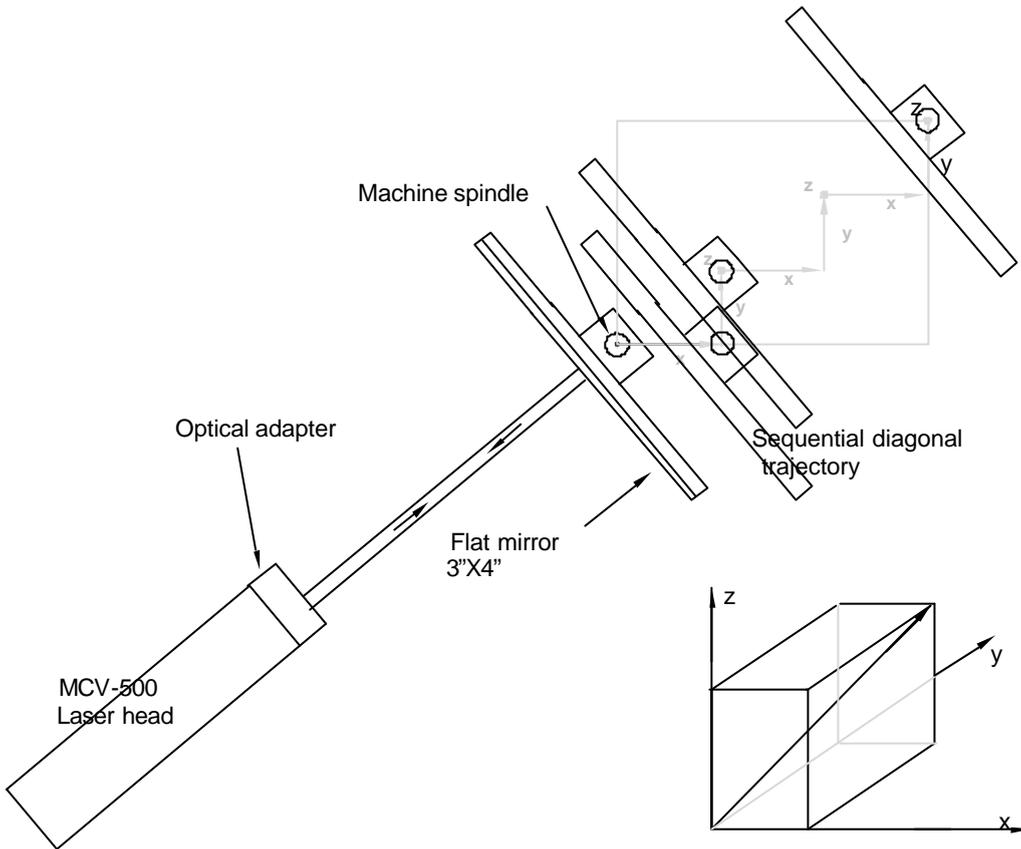
FIG. 9-3 SCHEMATICS OF SEQUENTIAL DIAGONAL MEASUREMENT
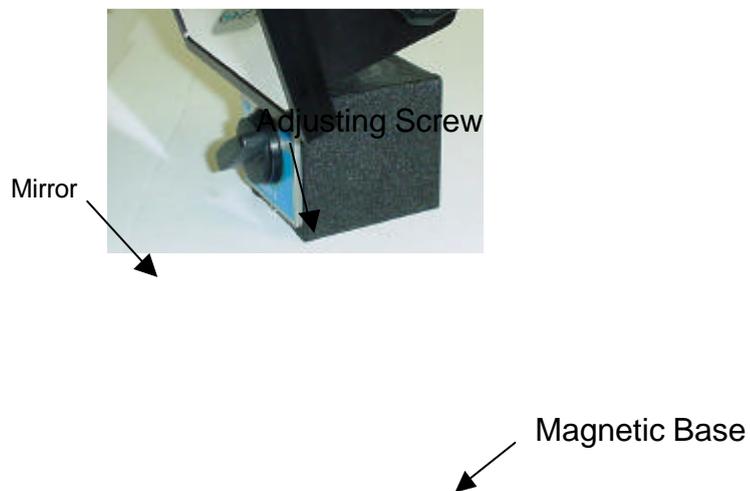
FIG. 9-4 FLAT-MIRROR TARGET WITH TWO
ADJUSTABLE SCREWS

9.6 Software Description

3) Click once on the **setup** icon on the bottom row of Icons.
Linear Measurement Setup Screen (See Fig. 7-12):

4) Setup your system information on the upper right hand side of the machine. Input the **identification** of the machine you are calibrating. To type the text, please move the arrow of the mouse pointer until it turns into a text cursor (an up and down line). Or please hit the tab key until one of the text boxes is highlighted. Type your machine data in.

5) Click the "other" and "sequential" button.

6) Enter the **machine coordinates** of the working volume that you wish to calibrate in the upper right corner.

7) Enter the **number of points**, including zero that you wish to calibrate. E.g. For a ten increments per axis, enter 31.

8) Enter the **number of runs**.

9) Press the **Verify/Edit** button to see the increments.

10) Choose **Forward Only** or **Bi-Directional** runs.

11) Click on the **ATC board** if you have one.

12) Choose your type of measurement:

Manual

you may: A) Hit the **enter key** at each point, or
               B) Click the **mouse** on Take at each point

Automatic

To take data automatically, you will have to program the machine controller to do 2 or 3 things: to move in a certain increment with a delay time in-between movements (3-5 seconds recommended), and add a backlash movement that is greater than double the target window at each end (backlash is optional).

The following information will be necessary for Automatic measurements:

FIG. 9-4 PLAT-MIRROR TARGET WITH TWO ADJUSTABLE SCREWS

Target Window: This tells the computer a distance window around the target position where the computer is allowed to take data. This value is related to the backlash needed (see below). A typical value is .001 inch or .02 mm, depending how tight your machine is. The backlash movement of the machine must be at least double this value.

Trigger Dwell: Set this value for two seconds less than the machine delay time for each point.

Velocity Threshold: This value keeps the risk of false triggering down. A good value to use is 0.01 for inches, 0.1 for metric.

Backlash: Check here if you want to account for backlash. The backlash at the beginning and end of each forward/backward run has to be at least TWICE the target window value.

13) Saving the Configuration File:

Save this configuration file by clicking the **Save Config File** Icon. Type the name of the file, which you would like the setup saved to (usually the name of the machine). Press **Enter** or **OK** after typing it in.

The program will ask you if you would like to save the file, press **Yes**.

The program will then ask if you want to use this file as your default. If **Yes** is clicked, this setup will be loaded every time that the Linear Measurement Module is loaded.

To load a configuration file next time, click on **New Config File**. You may either:

     A) Click on the file name and press **OK**

     B) Double click on the file name

     C) Type the name of the file name, example: **LDDM.1CF** and hit enter.
     The extension .1CF indicates a configuration file.

14) Press **OK** to get back to the main screen.

Taking Data Points for a Linear Measurement (Fig. 7-13)

15) Input the **Humidity Value**.

16) Choose your material from the list given. Press the **Down arrow key** and you will get a list, press the **down arrow key** or **PgDn key** from there to scroll down.

17) Choose the number of digits on the upper right hand side of the screen you wish the screen to display. Click the **right arrow button** to increase the amount (up to six), or click the **left arrow button** to decrease the amount.

18) Move your flat-mirror target to the beginning of your run. Click on **Start**.
Manual: If you are manually operating the laser/machine, press the designated key to take data as shown (after you move the machine).

Automatic: If you are running the automatic program, you will see a stoplight appear. The red means that the conditions for a measurement have been met (inside the target window, and the velocity is lower than the given one), yellow means that the delay is being counted and the green means that the data has been collected and the program is waiting for you to move to the next point.

19) After all the data is taken, press **OK** to save the data, or **cancel** to not save the data.

20) To save data, type in the **filename** to save and hit **<Enter>** (the extension is automatically saved as .LIN). You may also save collected data by pressing the **save data button**, and follow the procedure above.

21) To analyze the data click on the **Analyze button**. When it prompts you, unload the module.

4) Click on **Analysis** then **3 Squareness**, the screen will shown the 3 squareness errors in the XY-plan, YZ-plan and ZX-plan as shown in FIG. 9-8.

5) Click on **Analysis** then **X-axiz**, the screen will shown the linear position errors, vertical straightness and horizontal straightness in the X-axis as shown in FIG. 9-9.

6) Click on the **Modify Pitch, Yaw and Roll**, a popup screen will shown the values of some parameters as shown in FIG. 9-10. You may change these parameters or enter new ones. Click **OK**, the linear position errors, vertical straightness and horizontal straightness will be modified by the new parameter values. Click on **Graph**, a screen will popup for you to select the plots. A plot of linear position errors, vertical straightness and horizontal straightness is shown in FIG. 9-11. Click on   to get back to the analysis screen. To save the data file, click on **file** and **save**. The data will be saved under filename.SDX.

9.8 Taking a Measurement

1. Decide which diagonal you are going to measure, from which starting point to which end point, and the increment per stop. Key in all the variables and pertinent information into the computer.

2. For automatic data collection, program your machine controller with the specific increment per stop, total number of stops (or total travel), and the speed. The dwelling time at each stop should be longer than (6) seconds.

3. Set up the LDDM™ by following the instructions in Section 7.5.

4.	Set up computer and load the appropriate software by following the instructions in Section 7.6 or the software manual.

5.	Set up the desired configuration or load an existing configuration.

6.	Move the machine to the starting point.

7.	Reset the LDDM™ reading, click the start button. Then move the machine to the first stop.

8.	For automatic data collection the computer will wait (5) seconds after the machine is stopped and then automatically record the LDDM™ reading. For manual data collection, after the machine is stopped, wait (5) seconds then click the taken button to record the LDDM™ readings.

9.	Continue to move the machine to the next stop and repeat step 8.

10.	Repeat step 9 until the 'end' point. This is done for single-direction measurement.

11.	For bi-directional measurement, move the machine about 0.5 inch (at least 2 x target window) further, stop, wait (6) seconds, then return to the 'end' point, stop, wait (6) seconds and repeat step 8 for the return travel.

12.	After all data has been collected, you need to save the data. You may click the analysis button to analyze the data now or save the data now and to analyze the data later.

13.	Repeat the same for the second diagonal, the third diagonal and the forth diagonal.

11 System acceptation and Reporting

11.1	For each item will be reported if the system is working correctly or some defect is found.

11.2	The failure of a single components that is not affecting the total performance of the system will not affect the acceptation of the system.

11.3	The failure of the component will be reported in detail and the component will be rejected and repaired or substituted as for warranty rules.