References

Internet References

- UML & Design Patterns
  - http://atlas.kennesaw.edu/~dbraun/csis4650/A&D/UML_tutorial/class.htm
  - http://www.vtc.com/products/UML_tutorials.htm
- RS232 Communication and VB.Net Help
  - http://www.codeproject.com/
  - http://cboard.cprogramming.com/networking-device-communication/137503-rs232-serial-communication-help.html
  - http://www.boxesandarrows.com/view/six_tips_for_improving_your_design_documentation
  - http://extremeelectronics.co.in/avr-tutorials/rs232-communication-the-basics/
- Crystal Reports
  - https://www.blackbaud.com/files/support/guides/ crystal/crystal_tutorial.pdf
  - http://www.homeandlearn.co.uk

Appendix

1. Working Instruction – Production Process Automation System
2. System Design
3. Calculations and Algorithms

CHAPTER 9

9.1 Appendix 01

Working Instruction

Production Process Automation System

1. **Starting the Calibration Automation System.**

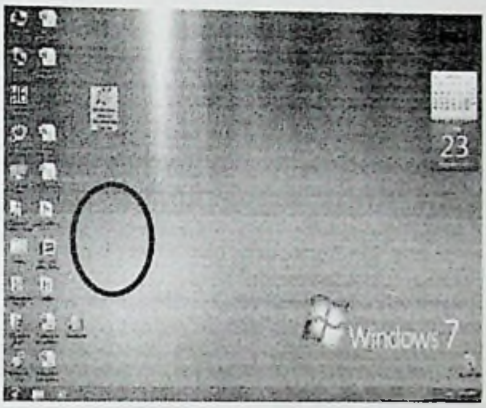
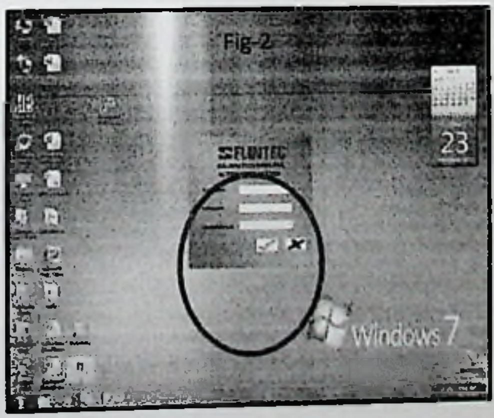
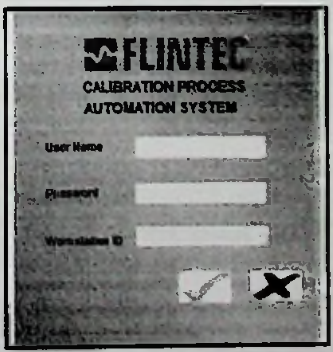


Fig-1

1.1) Double Click on the Production process automation System Icon. (Fig-1) Login screen will appear as follows (fig-2)





Note: If network connection is not available, User unable to get login window.in this case massage box will appear as follows (fig-2.1)

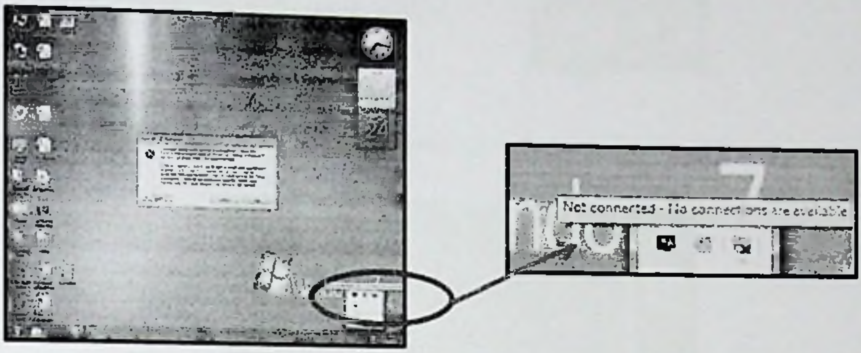


Fig2.1

1.2) User must enter own user name & password .Then press ENTER key on the key board. Workstation ID will enabled. (Fig-3)

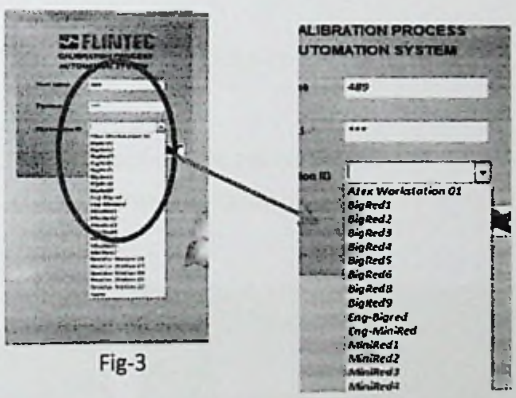


Fig-3

1.3) Select the correct Workstation ID from dropdown List.

1.3.1) How to select the correct work station

BIG RED - (5KN-50KN), (1Klb-5Klb) or (500Kg-2000Kg)

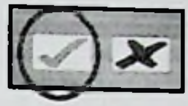
Ex: When we have a SLB-2.5Klb-BH Load cell, we can Test it with BIGRED Machine.

MINI RED – (1KN-5KN), (200lb – 1Klb) or (20Kg-500Kg)

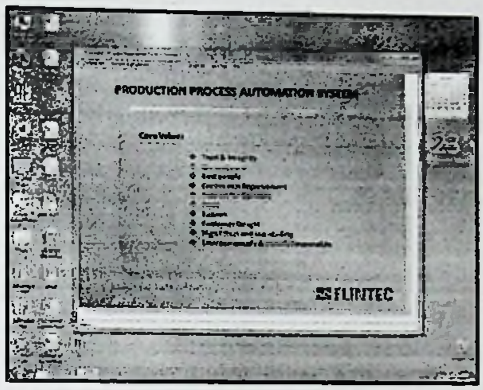
Ex: When we have a SB6-2Kn Load cell, we can Test it with MINIRED Machine.

MORE HOUSE – (7.5t – 300t) , (250Kn-900Kn)

1.4) Click on the right mark button.

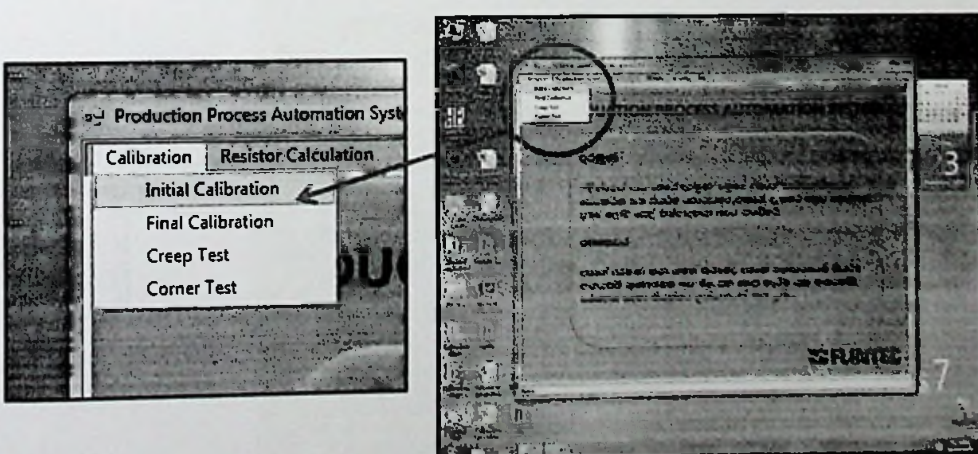


Production Process Automation System will appear as follows. (Fig-4)



(Fig-4)

1.5) Click Calibration menu on the menu bar.
1.6) Select required test from the menu. (Fig-5)



(Fig-5)

1.7) User must have other accessories for the test.
Ex: Proper Fixtures, Test Cable, Torque Drive, Load button etc..

1.7.1) Place the fixture on the work station.

1.7.2) Place the load cell at the correct position.

1.7.3) Insert correct bolts through the bolt holes.

1.7.4) Adjust the torque drive value as specified. (User can follow the TS (Technical Specifications) documents)

1.7.5) Torque the bolt one by one and torque again a firstly torqued bolt.

1.7.8) Connect test cable to the junction box.

Note: Test cable length & gage (A.W.G.) must same as customer requirement. Because the load cell readings will change in those criteria (OHMS law).

1.7.9) Connect Load cell to the test cable.

2. Initial Calibration.

2.1) Select Initial Calibration from the menu.

Initial Calibration Window will appear as follows (Fig-6) Work station & Operate name will fill automatically.

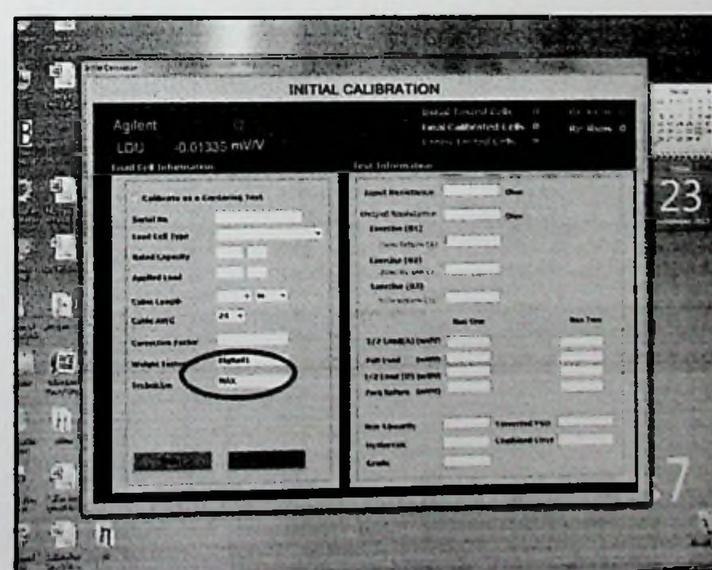


Fig-6

2.2) Enter Tested Cell serial number to the text box & press Enter Key on the key board.(Fig-7)

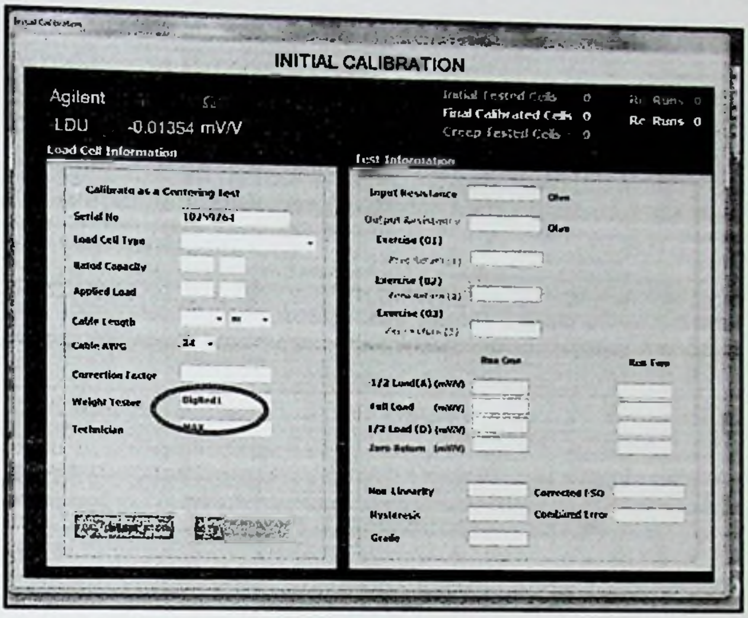


Fig-7

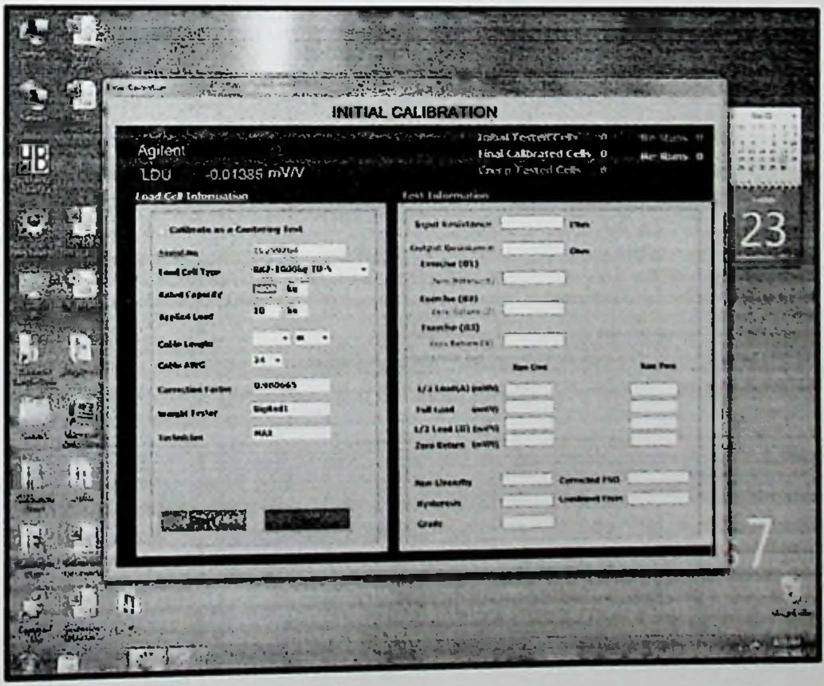


Fig-8

2.3) Then some load cell information will fill automatically.

2.3.1) **Load Cell Type** - It will get from the SQL Data base.

Ex: BK2-100Kg-TU

Load Cell Family Capacity Loading Introduction

2.3.2) **Rated Capacity** -It will get from the system. User can check it with load cell type.

Ex: When user have a SB14 - 5Klb-BH Load cell, It's Rated capacity is 5Klb.

2.3.3) **Applied Load** -It will get from the system. User can check it with the following Calculations.

1KN = 1000N:

1Kg = 9.80665N: 1lb = 4.44822166N

Ex: When user have a SLB-5Klb-BH Load cell

- Rated load = 5Klb
  5Klb Means 5000lb
- 1lb = 4.44822166 N
- 5000lb =4.442822166 x 5000
  = 22241.1083 N
- = 22241.1083 / 1000 (Convert to the KN)
- =22.241 KN

So user can test this cell with 20Kn weight stack.

2.3.4) **Cable Length**- User must select this value manually. And select the cable length measured unit "m" for Meter or "ft" for Feet. (This value is a test cable (see1.7.8) length.)

2.3.5) **Cable AWG** - User must select this value manually.

2.3.6) **Correction Factor** – It will calculate automatically.

Ex: as previous example (2.3.3)

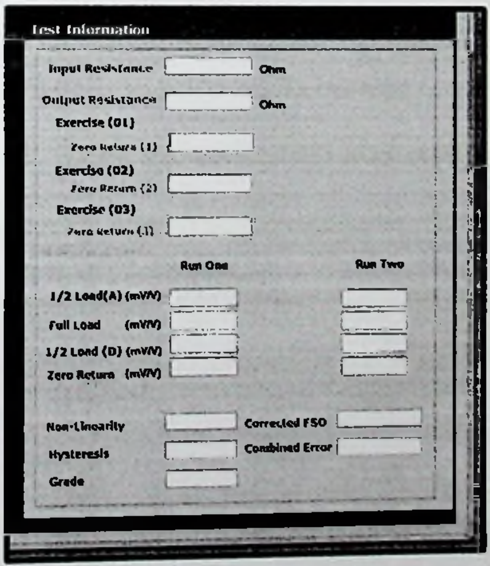
5Klb = 2241.1083 N but user have 20000 N weight stack.

- Rated Load = 5Klb
- 5Klb = 22241.1083N
- Applied Load=20000N
- Correction Factor = 22241.1083 / 20000 = **1.112055415**

2.3.7) **Weight Tester** -User selected work station ID at starting.

2.3.8) **Technician** - It will fill automatically as login user name & Password.

2.4) Click on the **"START"** button. Then program will go to automatically mode



2.4.1) **Input Resistance- Control** box will switch (via USB) the relays to the Load cell input lines and Agilent will ready to measure the resistance then measured readings will send to the PC from Agilent via RS 232.

Note: If input resistance is not in acceptable range message box will appear and break the program.

2.4.2) **Output Resistance** -Relays will connect the load cell Output lines and get readings as above method.

2.4.3) **Exercise (01) /(02)** - Wish to get the warm-up& check the zero returns before testing the load cell .

* LDU ready to measure mV/V readings.

* Send command to the power relays.(rated load will apply to the tested cell)

*Measured reading will display on the PC.

* After applying the full load send command to the relay for removing the load.

* When load is completely removed, the timer will start to 15 seconds wait period.

* After15 seconds system will get the Zero return reading.

* Then start another exercise as above method.

Note: If exercise02 zero return is out of spec system will check again the zero return as Exercise 03, at the third exercise zero _return is out of spec tested cell will reject as High Zero Return.

2.4.4) **Multi Point Test**-Wish to check the performance (Non Linearity / Hysteresis) of the load cell.

- Applying the half load of the applied load
- 15 Seconds waiting for stable the measured readings.
- Get the mV/V value as ascending reading.

*Applying the second half of the load (Full Load).

- 15 Seconds waiting for stable the measured readings.
- Get the mV/V value as Full Load Reading (Full Scale Output) (FSO).
- Removing the second half of the load.
- 15 Seconds waiting for stable the measured readings.
- Get the mV/V value as Descending reading.

*Removing the all applied load.

- 15 Seconds waiting for stable the measured readings.

*Get the zero Return reading as Multipoint Zero?

Note: If the Non Linearity, Hysteresis or Multi Point zero are not in the acceptable range system will start another multi_point test as Run Two.

2.4.5) **Non-Linearity**–The maximum deviation from a straight line (Ideal LC) drawn between the zero output and

The full scale output.

2.4.6) **Hysteresis** –The different between the readings of the increasing (Ascending) and decreasing (Descending) load at the same load.

2.4.7) **Grade**-Grade is selected according to the performance of the Load Cell.

Ex: If N/L & Hysteresis are below than ±0.040 & greater than ±0.020 Grade is "GP"

2.4.8) **Corrected FSO**- Full scale output at the actual load.

Raw F.S.O. XCorrection Factor

Ex: Full Load Reading - 2.75611

Correction Factor - 0.980665

2.75611 x 0.980665 = 2.70282

2.4.9) **Combined Error**- Themaximumerror from the straight line drawn between zero and full Scale from the increasing and decreasing loads.

*********** **After initial calibration test all tested data will save in the data base** ***************

3. Fixing Resistors.

3.1) Starting the resistor calculating program at resistor taking work station as following method.

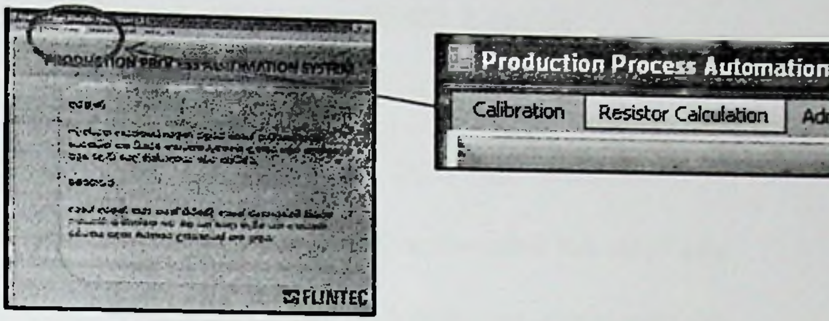


Fig-11

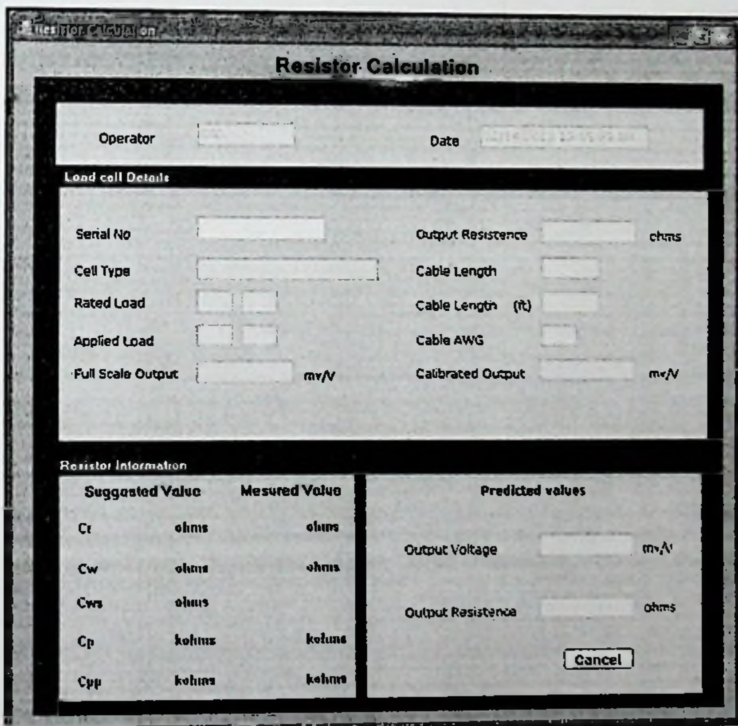


Fig-12

3.1.1) **Operator**- Operate name of the current login user.

3.1.2) **Date** – Current date and time.

3.1.3) **Serial Number** –Enter Serial number of the initial test completed load Cell.

3.1.4) **Cell Type** -It will get from the SQL Data base.

3.1.5) **Rated Load** - It will get from the system.

3.1.6) **Applied Load** - It will get from the system.

3.1.7) Full **Scale Output** – It will get from the initial test saved data.

3.1.8) **Output Resistance** - It will get from the initial test saved data.

3.1.9) **Cable length** –length of cable at initial calibration test (It will get from Initial test saved data)

3.1.10) **Cable length (ft)** – Cable length value will convert to the Feet Automatically.

3.1.11) **Cable AWG** - Value of the test cable AWG (It will get from Initial Test saved data)

3.1.12) **Calibrated Output** –The electrical signal produced when the full Load is applied to the cell.

3.2) then press Enter Key.

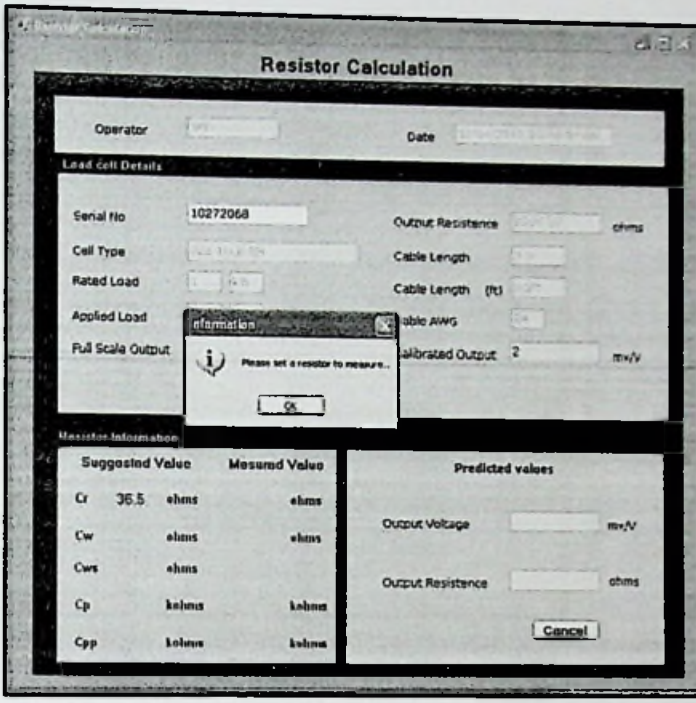


Fig-13

First resistor (CR) will suggest and "Please set a resistor to measure" message box will appear.

User must get the resistor from the bin ,connect to the Agilent test leads and press enter or click "OK" on the

Message box. Then measured resistor value will get and calculate another resistor as this method.

Note: Five resistors (CR, CW, CWS, CP , CPP) must get as above method

After getting the fifth resistor (CPP) system will calculate the "Output voltage" &"Output Resistance" as predicted value.

And "Record Saved Successfully" message box will appear as follows.

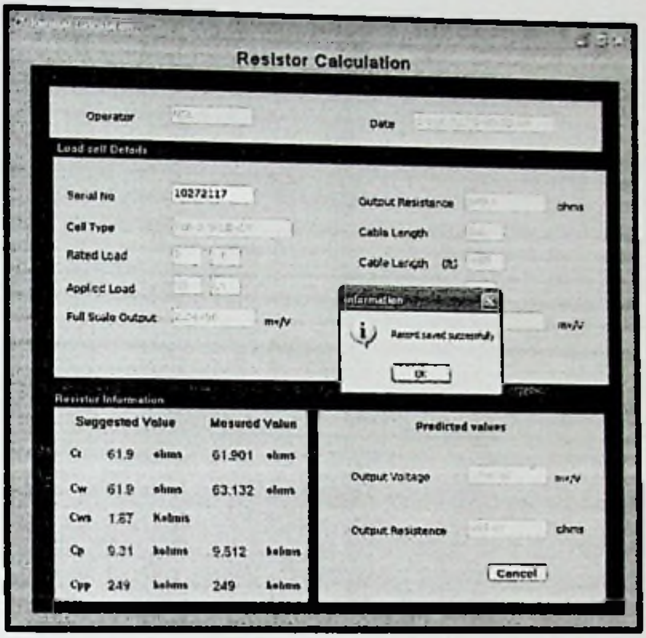


Fig-14

*********** User must mount these resistors at correct positions on the relevant load cell PCB (Printed Circuit Board)***********

4. Final Calibration.

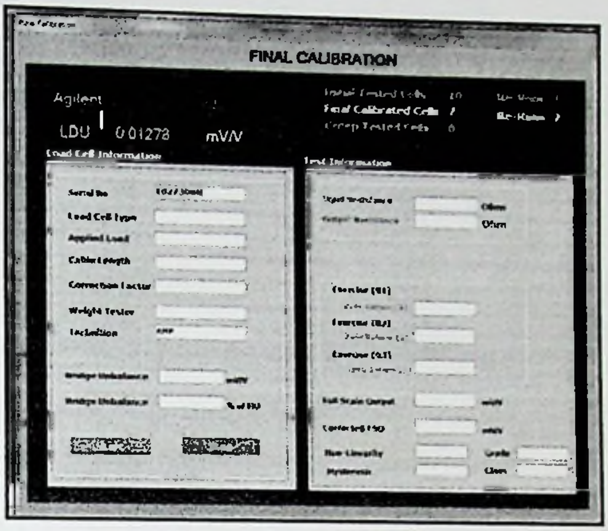


Fig-15

4.1) Click on the calibration in menu bar and select "Final Calibration" from the dropdown list.

4.1.1) **Serial Number** - Enter serial number of the resistor mounted load cell.

4.1.2) **Load Cell Type** - It will get from the data base (as initial calibration test).

4.1.3) **Applied Load** - See (2.3.3)

4.1.4) **Cable Length** - It will get from the initial calibration saved data.

4.1.5) **Correction Factor** - See (2.3.6)

4.1.6) **Weight Tester** - See (2.3.7)

4.1.7) **Technician** - See (2.3.8)

4.2) Click on the **"START"** button. Then program will go to automatically mode.

4.2.1) **Input Resistance** - System will get the input resistance (see 2.4.1)

4.2.2) **Output Resistance** – System will get the output resistance (see 2.4.2)

4.2.3) **Exercise (01) /(02)**- Wish to get the warm-up& check the zero returns again before testing The load cell

Note: If exercise02 zero return is out of spec system will check again the zero return as Exercise 03, at the third exercise zero return is out of spec tested cell will reject as High Zero Return. (See 2.4.3)

4.2.4) **Full Scale Output** – System will apply full load to the load cell and get the mV/V Readings at 15 seconds

4.2.5) **Corrected F.S.O - Full** scale output at the actual load.(see 2.4.8)

4.2.6) **Non-Linearity** – It will get from the saved initial test data (see 2.4.5)

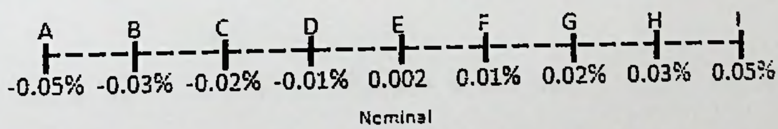
4.2.7) **Hysteresis** - It will get from the saved initial test data (see 2.4.6)

4.2.8) **Grade** - It will get from the saved initial test data (see 2.4.7)

4.2.9) **Class** – It will calculate with the Factored F.S.O and Output resistance as following Method.

Factored F.S.O / Output resistance

As the result system will generate the load cell class according to the following method.



4.2.9) **Bridge Unbalance** – The signal of the load cell with no load applied.

After the above process message box will appear "Remove the York to get to unbalance"

User must remove the York (Load Applying fixture to the load cell) form the testing load cell and click OK.

System will get the load cell unbalance in mV/V.

4.2.10) **Bridge Unbalance** – Calculated value of the percentage of the unbalance with F.S.O.

Bridge Unbalance (mV/V) / F.S.O. X 100

4.3) all readings are within in the acceptable ranges Message box will appear as "Test Completed Successfully"

4.4) then click "OK" Record will save in the data base.

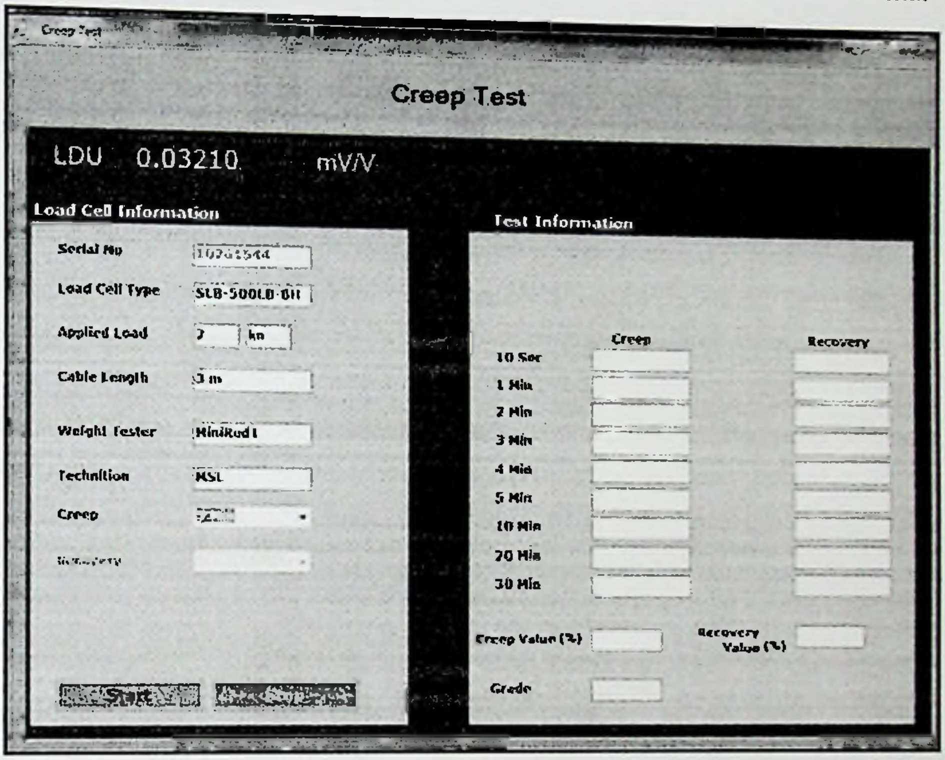
4.5) Message box will appear as "Do you Want to Creep test"

Note: if click "Yes" user can start the creep test continuation (When wants to check only creep test it can start from the Calibration menu)

If click "NO" calibration test will stop and save final calibration data in data base.

5. CREEP TEST

The change in output signal occurring while under load and all environmental



conditions are constant

Fig-16

5.0.1) **Serial Number** - Enter serial number of the testing load cell.

5.0.2) **Load Cell Type** – Load cell type will get automatically as data base.

5.0.3) **Applied Load** - Applied load will get automatically (See 2.3.3)

5.0.4) **Cable length** – Cable length will fill as final calibration saved data.

5.0.5) **Weight Tester** - See 2.3.7

5.0.6) **Technician** – See 2.3.8

5.0.7) **Creep** – User can select the creep time period as 5 min, 10 min, 20 min or 30 minutes.

Note: Creep time will decide as customer requirement.

5.0.8) **Creep Recovery** –User can select the recovery creep test after removing the load.

5.1) click **"Start"** button for start the creep test.

5.2) System will apply the load required load to the load cell.

5.3) after applying the full load timer will start to count from 0 second.

5.4.1) **10 sec** - Timer pass the 10 seconds, system get the mV/V value in to the 10 sec text box as first reading.

5.4.2) **1min/2min...5min** – System will get the mV/V readings as above method.

5.4.3) **10min/20min/30min**– if user select the creep time(see5.0.7) greater than 5 min system will go to these steps

5.4.4) **Creep value (%)**- Creep value will calculate as following method.

$$\frac{\text{5 min reading} - \text{10 second reading}}{\text{10 second reading}} \times 100$$

Ex: 10 sec - 2.00000 mV/V

1 min – 2.00001 mV/V

2 min – 2.00003 mV/V

3 min – 2.00006 mV/V

4 min – 2.00007 mV/V

5 min – 2.00007 mV/V

$\underline{2.00007 - 2.00000} \times 100$

2.00000

0.00007 x 100

2.00000

0.000035 x 100

0.004 %

5.4.5) **Creep recovery-** If user select the recovery test (see 5.0.8) system will start the recover test.

After finishing the time, system will remove the applied load and start the timer and get readings without load as creep test. Then calculate the creep recovery value.

5.4.6) **Grade** – See 2.4.7

Note: some load cell grades will depend with N: L: Hys:, and Creep value.

5.5) Message box will appear as "Test Completed Successfully".

5.6) Data will save to the data base.

6.) Calibration Report

6.1) Click report tab on the menu bar.

6.2) Select final data report from list

6.3) Enter serial in to the text box on top of window.

6.4) Click on the "View" button.

6.5) Data report will display as Fig-17

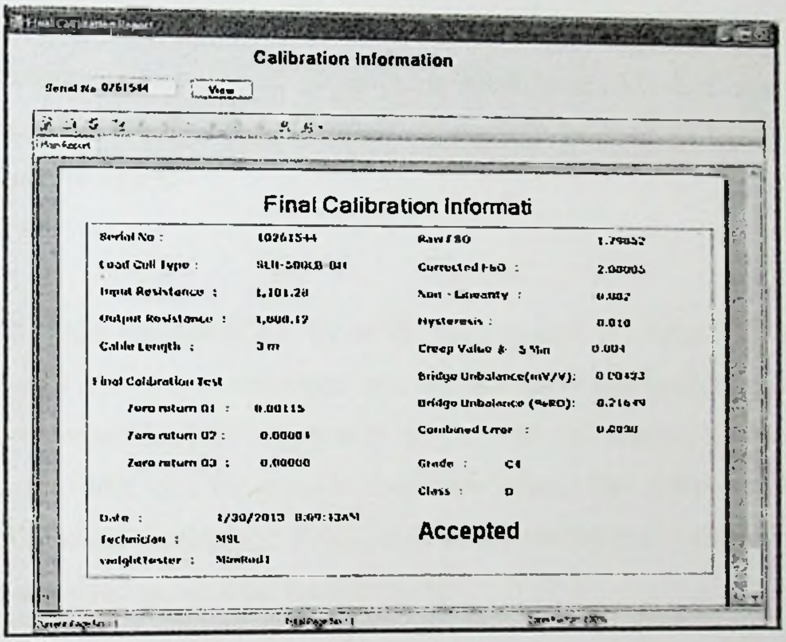


Fig-17

6.6) Click on the printer icon in window to print this report.

6.7) Erase the serial no using backspace key and enter another number in the text box wish you get the report and click "View" button again.

9.2 Appendix -02

System Design

<u>Overview Design of the System</u>

Big Red machine, Agilent, LDU, valves, Relays and PC are the main components in this system and all the commands are given by the PC.

Big Red Machine:

Big Red machine is basically works by using pneumatic and it controls using pneumatic valves. Valves release the pneumatic pressure, when the machine needs to apply a load and do the opposite when it needs to release the load. There are five valves are used in one Big Red machine and it controls sets of weights.

Agilent Multimeter:

Measuring the input and output resistances are one of the main process in load cell calibration. Each load cell contains its own Input resistance and as well as output resistance. Output resistance is the most important as it effects directly to the load cell classification. Agilent multimeter is the equipment that uses for measure resistance values. The Agilent multimeter controls through a RS232 communication port. RS232 com port is used to send commands to the Agilent and retrieve the measured values from the multimeter.

LDU:

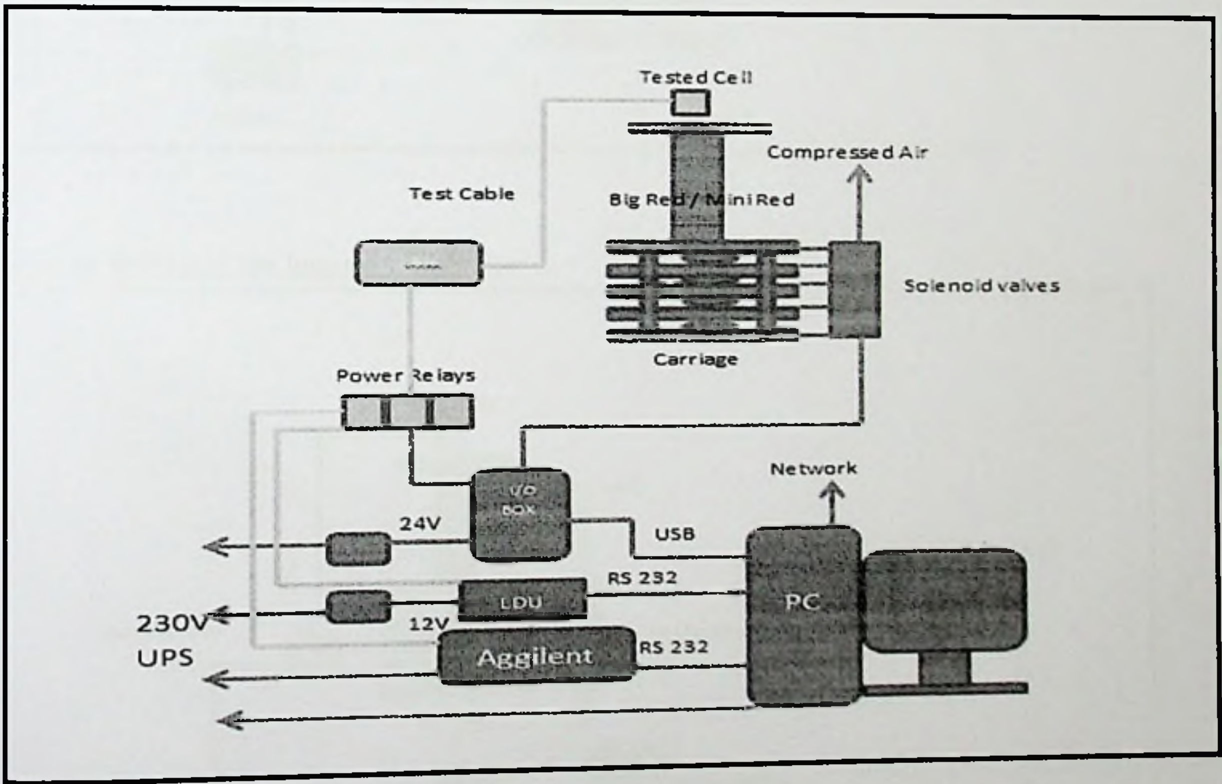
The variation of the Load cell with the weight is measured as a mV/v voltage and LDU use as the measuring equipment. LDU is one of the manufacturing products of Flintec and it generates digital outputs. RS232 communication port enables the communication between the PC and LDU and it carrying the inputs and outputs.

Control Box

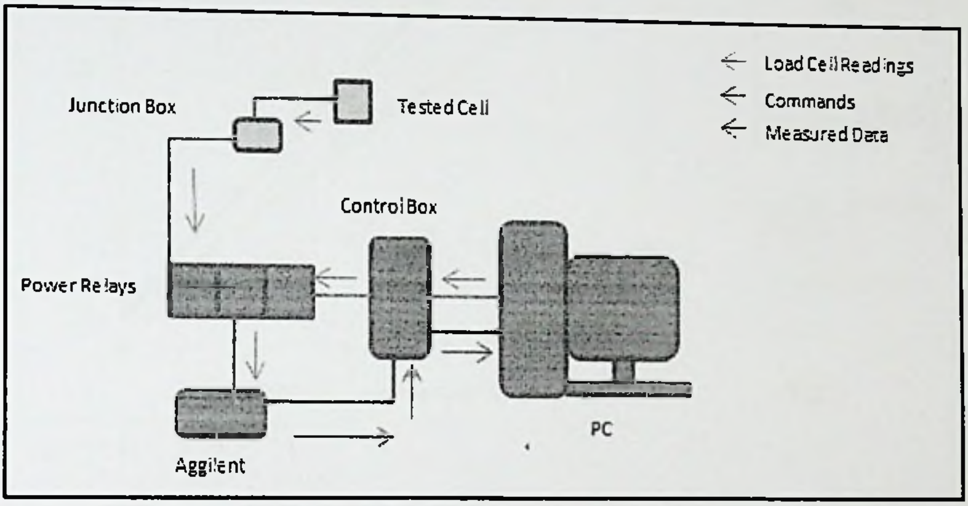
Control box controls the whole system including Agilent and valves. Control box is prepared using a designed PCB, relays and IC. The communication happens between the PC and control box through the Parallel communication port. The PC sends commands as ASCII values and IC switches the relays accordingly.

Main tasks done by the control box :

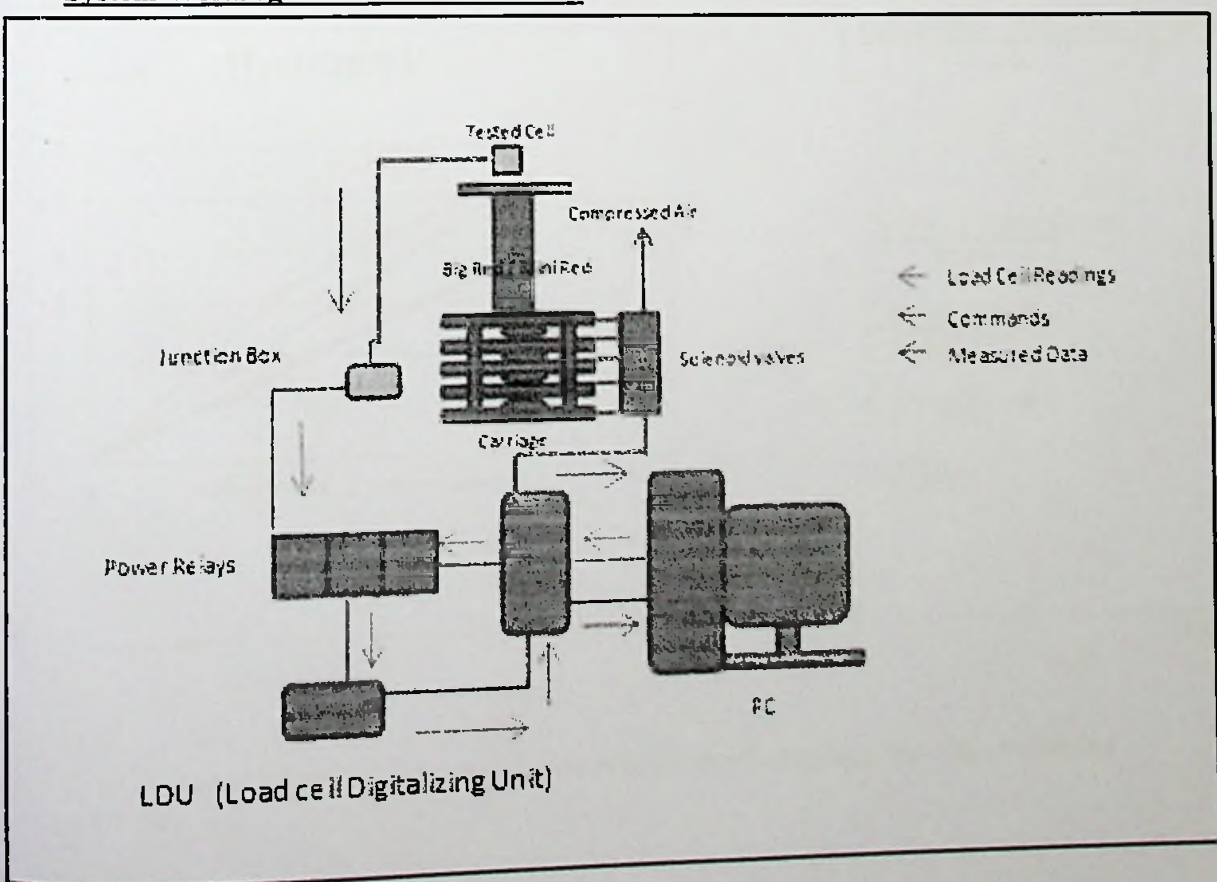
- Switches the relays for measure Input & Output resistance
- Switches the relays for control the valves



Input/ Output Resistance Measuring



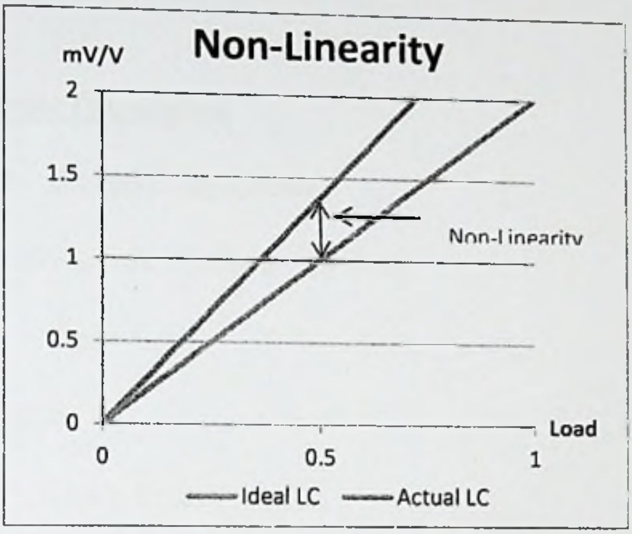
System Working Mechanism - Overview



9.3 APPENDIX – 03

Calculations and Algorithms

Non linearity of a load cell



$$\left[\frac{\frac{2.75611 - 1.37775}{2}}{2.75611}\right] \times 100 \times -1$$

$$\left[\frac{1.37805 - 1.37775}{2.75611}\right] \times 100 \times -1$$

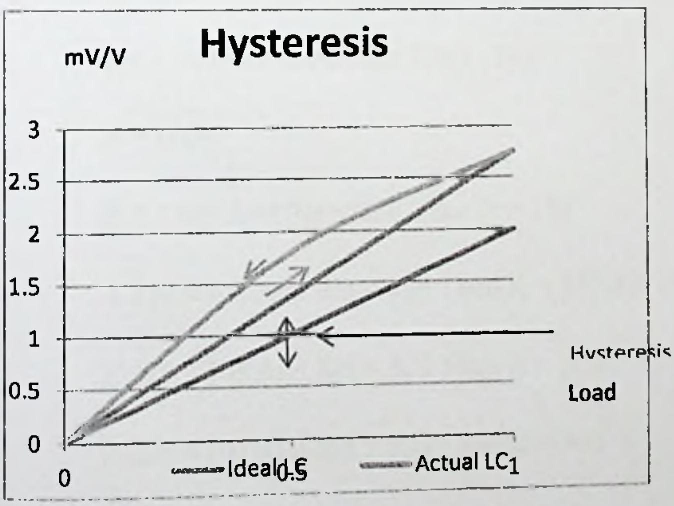
$$\left[\frac{0.0003}{2.75611}\right] \times 100 \times -1$$

$$0.000109 \times 100 \times -1$$

$$0.011 \times -1$$

$$\underline{\underline{-0.011}}$$

Hysteresis of a Load cell



$$\left[\frac{\text{Descending} - \text{Ascending}}{\text{F.S.O.}}\right] \times 100$$

$$\left[\frac{1.37818 - 1.37775}{2.75611}\right] \times 100$$

$$\left[\frac{0.00043}{1.75611}\right] \times 100$$

$$\left[0.00016\right] \times 100$$

$$\underline{\underline{0.016}}$$

Ex: ½ Load (Ascending) Reading - 1.37775 mV/V

Full Load (F.S.O) Reading – 2.75611 mV/V

½ Load (Descending) Reading - 1.37818 mV/V

Resistor Calculations

1. **Calculate Crs Resistor**

```
If Val(txtAWG.Text) = 24 Then
   Cres = 0.048
Else
   Cres = 0.0183
End If
RC = Val(txtCbLength.Text) * Cres    'RC-Cable resistance
RB = Val(txtOutPutRest.Text)
RB = Val(txtOutPutRest.Text) - RC
R = 1000
If 0 < RB And RB < 250 Then R = 175
If 250 < RB And RB < 425 Then R = 350.877193
If 425 < RB And RB < 625 Then R = 500
If 625 < RB And RB < 800 Then R = 700
Fo = Val(txtCaloutput.Text) / R
```

```
Ft = Val(txtCaloutput.Text) / (R - RC)

CRS = Val(txt_real_fso.Text) / Ft - RB
```

2. **Calculate Cr Resistor**

```
RS1 = RS / 2

Rs1k = Math.Abs(RS1 / 1000)

For j = 1 To 541

    Dic(j, 2) = Dic(j, 1) - Rs1k

Next

Call Search(2, Rs1k, Dic)
```

Cr = Nearest * 1000

3. **Calculate CW Resistor**

```
Rs1A = Format (Val (txtMCr.Text), "0.000")

Rs2 = Format (RS - Rs1A, "0.0000000000000")

Rs1Ak = Rs1A / 1000

Rs2k = Rs2 / 1000

For j = 1 To 515

Dic(j, 3) = Dic(j, 1) - Rs2k

Next

Call Search (3, Rs2k, Dic).
```

```
CW= Nearest * 1000
```

4. **Calculate CWS Resistor**

```
Rs2A = Val(txtMCw.Text)

Rs2Ak = Rs2A / 1000

Dim RS2K_temp = Format (Rs2k, "0.000000000000000")

Dim RS2AK_temp = Format (Rs2Ak, "0.0000000")

If Rs2Ak <> Rs2k Then

Rs2sk = RS2K_temp * RS2AK_temp / (RS2AK_temp - RS2K_temp)

For j = 1 To 515

Dic(j, 4) = Dic(j, 1) - Rs2sk

Next

Call Search (4, Rs2sk, Dic)

CWS = Nearest * 1000
```

5. **Calculate CP Resistor**

```
Rs2s1k = Rs2s1 / 1000

RScal = Rs1A + Rs2A * Rs2s1 / (Rs2A + Rs2s1)

Rp1 = Val(txtCaloutput.Text) * (RB + RScal) / (Val(txt_real_fso.Text) -
Val(txtCaloutput.Text))

'Rp1 = Val(txtCaloutput.Text) * (RB + RScal) / (2.08029321256042 -
Val(txtCaloutput.Text))
```

```
Rp1k = Rp1 / 1000

For j = 1 To 515

Dic(j, 5) = Dic(j, 1) - Rp1k

Next

Call Search (5, Rp1k, Dic)
```

CP= Nearest * 1000

6. **Calculate Cpp Resistor**

```
Rpf = Val(txtMCp.Text) * 1000

If Rpf = Rp1 Then Rpf = Rpf + 1.0E-21

PP1 = Rpf * Rp1 / (Rpf - Rp1)

PP1k = PP1 / 1000

For j = 1 To 515

Dic(j, 6) = Dic(j, 1) - PP1k

Next

Call Search (6, PP1k, Dic)

Rs31 = Nearest * 1000

If Rs31 > 1000 Then

Rs31 = Rs31 / 1000

End If

CPP = Rs31
```