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PTR-200-PRL

Automated Polyimide Recoater with Linear Proof Tester

Operator's Manual

Version 1.2

United States:
1400 Campus Drive West • Morganville, NJ 07751
+1 (732) 972-2880 • +1 (800) 421-8847 • Fax +1 (732) 972-6229

England:
8, Kew Court • Pynes Hill Office Campus • Exeter, EX2 5AZ
+44 (0) 1392 445777 • Fax +44 (0) 1392 445009

Web: http://www.vytran.com

VYTRAN

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Vytran LLC
1400 Campus Drive
Morganville, NJ 07751 USA

Phone: +1 (732)-972-2880
+1 (800)-421-8847
FAX: +1 (732)-972-6229

http://www.vytran.com

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1 Introduction

The PRL-200 is designed for recoating and proof testing polyimide coated fibers. It operates on a coat, cure and test recoat method, whereby a layer of polyimide is applied to the fiber through a die, followed by a filament heater to cure the polyimide and upon completing the recoat a linear proof test. When configured and operated properly, the PTR-200-PRL is capable of producing a high quality and a uniform polyimide recoat.

1.1 Parts Checklist

When unpacking the PTR-200-PRL for the first time, check to make sure that you have the following accessories:

- PTR-200-PRL Automated Polyimide Recoater with Linear Proof Tester
- 12.0V Power supply (PSU)
- AC power cord
- DC power cable
- RS-232 communication cable
- Fittings kit
- Tool kit containing:
  - 1 oz. bottle HD MicroSystems PI2525 Polyimide Recoat Material
  - 1 oz. spare bottle
  - Cotton swabs
  - 5/64” Allen key
  - 3/32” Allen key
  - 0.035” Allen key
- External vacuum pump with vacuum line
- PTR-200-CX-PRL Handset Controller

If you are missing any of the above or need replacements, please contact Vytran.

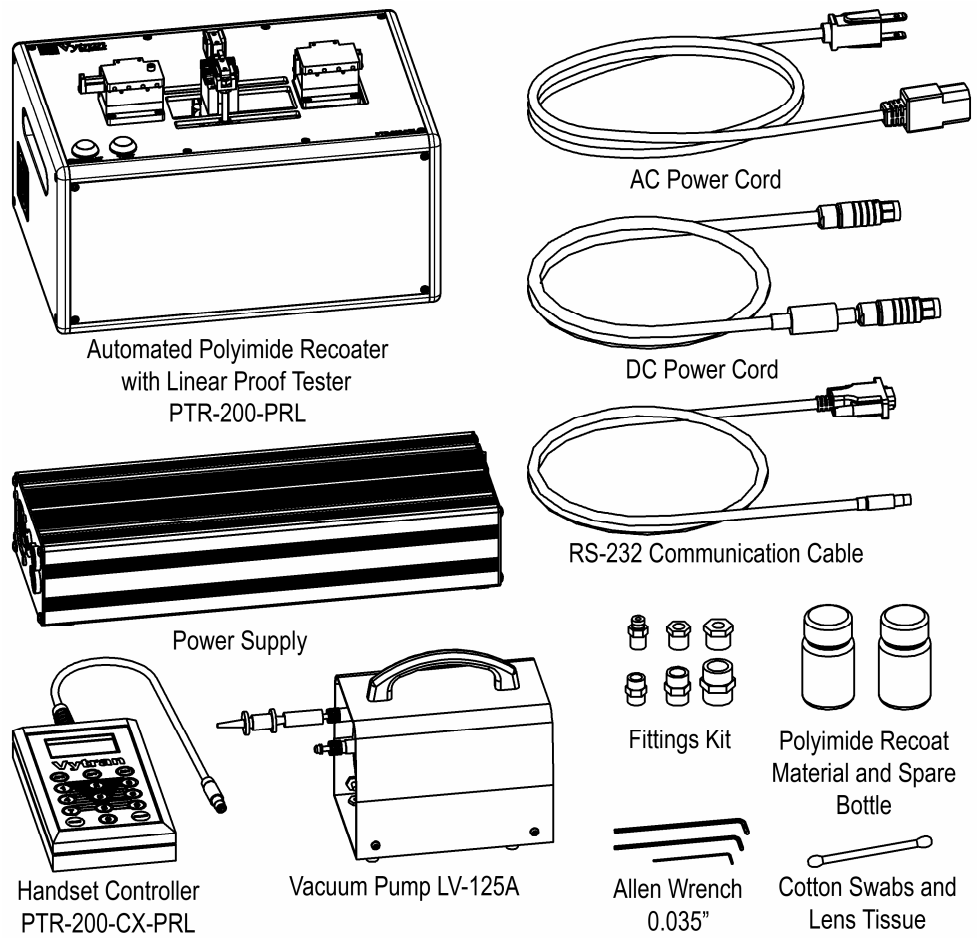


Figure 1: System Components

1.2 Powering Up

The PTR-200-PRL Power Supply Unit (PSU) accepts an AC input of 90-260 VAC; 47-63 Hz. Connect both the AC power cord and the DC power cable to the external Power Supply. Connect the Handset Controller and the DC power cable to the PTR-200-PRL.

Turn on the power supply and then turn on the PTR-200-PRL using the ON/OFF rocker switch located on the back of the recoater. The PTR-200-PRL will run an initialization process that includes homing the recoat die and tensioning motors and operating the recoat die (close/open). During the initialization process, the Handset Controller will display the status of the system. Once the homing process is completed, the Handset Controller displays the Main Menu screen and the PTR-200-PRL is ready for recoating.

1.3 Shutting Down

To shut down the PTR-200-PRL:

1. Turn off the PTR-200-PRL using the on/off rocker switch located on the back of the recoater.
2. Turn off the power supply.

2 Controlling the PTR-200-PRL

The PTR-200-PRL is configured and controlled from Vytran's PRL-200-CX-PRL Handset Controller, which also provides feedback and status of the unit. If the operator does not need to change parameter settings or receive status prompts, the Handset Controller can be removed and the unit operated simply by pressing the blue RECOAT and TEST buttons.

The Handset Controller allows the user to interface with the unit and modify the settings. The Handset Controller is based on a three (3) menus:

- Main Menu
- Configuration Menu
- Options Menu

Each menu and its contents are described below.

2.1 Main Menu

The Main Menu displays the unit status. From this menu, press the "CFG" button to enter the Configuration Menu or press the "OPT" button to enter the Options Menu.

2.2 Configuration Menus

There are three (3) levels to the Configuration Menu. At level one the user can select from five (5) topics - Inject, Undercoat, Overcoat, Recoat Length, or Proof Test. Within each of these topics are the parameters which can be viewed and/or copied. Below is a description of the five (5) topics and each topics parameters.

2.2.1 Inject

Inject Rate (µl/sec): This parameter is the polyimide injection rate, in microliters per second, into the die. The optimum Inject Rate will be dependant on the polyimide material being used.

Undercoat Qty. (µl): This parameter is the quantity of polyimide material, in microliters, injected into the die for the first loop of the head (the undercoat). The optimum Undercoat Qty will be primarily dependant on the bare fiber diameter, die size, and the length of the recoat.

Overcoat Qty. (µl): This parameter is the quantity of polyimide material injected into the die, in microliters, after the first loop of the head. The optimum Overcoat Qty will be primarily dependant on the die size, and the length of the recoat.

2.2.2 Undercoat

Head Sweep Vel. (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the bare fiber diameter, die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

2.2.3 Overcoat

Number of Overcoats: This parameter is the number of loops the head will make. The optimum Number of Overcoats will be dependant on the polyimide thickness layer desired (which will be dependant on the undercoat layer thickness and the parameter settings for the overcoat(s)).

Head Sweep Vel (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Overlap Delta (mm): This parameter is the additional distance, in millimeters, the head will travel on each pass. This will effectively taper the transition from original polyimide to recoated polyimide.

2.2.4 Recoat Length

Recoat Length (mm): This parameter is the desired bare fiber length, in millimeters, to be recoated. The actual recoat length will be approximately 8 millimeters longer on each end in order to compensate for the width of the head and the fiber load position.

2.2.5 Proof Test

Proof Test Units: This menu allows the user to select the desired units for displaying the Proof Test Level. Unit selections are: Newtons, kpsi, and grams.

Proof Test Level (units): This parameter is the Proof Test Level, in units user selected, to be applied after the recoat has been completed.

Proof Test Rate (mm/sec) This parameter is the rate, in millimeters per second, at which the Proof Test Level will be applied. The optimum rate is that which achieves the desired proof test level within 3 - 5 seconds of load applying time.

2.3 Options Menu

From the Options Menu, various system level configuration parameters and functions can be edited or executed.

Recoat Tension (Newtons): This parameter is the tension, in Newtons, applied to the fiber prior to initiating a recoat. The PTR-200-PRL also monitors the tension during the recoat and will automatically abort if the tension varies significantly from the Recoat Tension. The auto abort is intended to protect both the die and fiber.

Heater Settle Time (msec): This parameter is the amount of time, in milliseconds, allowed for the heater to stabilize when changing temperatures.

Die Close Time (msec): This parameter is the amount of time, in milliseconds, allowed for the die to close prior to execution of the subsequent process.

Fiber Unload Time (msec): This parameter is the amount of time, in milliseconds, allowed for the operator to unload the fiber prior to the PTR-200-PRL performing a system reset.

Inject to Die Qty (µL) This option is the quantity of polyimide material, in microliters, which will be injected into the die upon entering the quantity. This option is intended for use when changing materials or purging the system prior to storage.

Head to Home: This option performs a homing of the head and is useful as a diagnostic tool.

Tension Home: This option performs a homing of the proof test load cell and is useful as a diagnostic tool.

Move Head to Start: This option performs a movement of the head to the start position. The start position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Move Head to Stop: This option performs a movement of the head to the stop position. The stop position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Recoat Request State: This option enables or disables the request to input a recoat length each time the process is run. This option is primarily used when the length to be recoated varies significantly from recoat to recoat.

Set/Run Purge Cycles: This option is the number of recoat pump purge cycles that will be run upon entering the quantity.

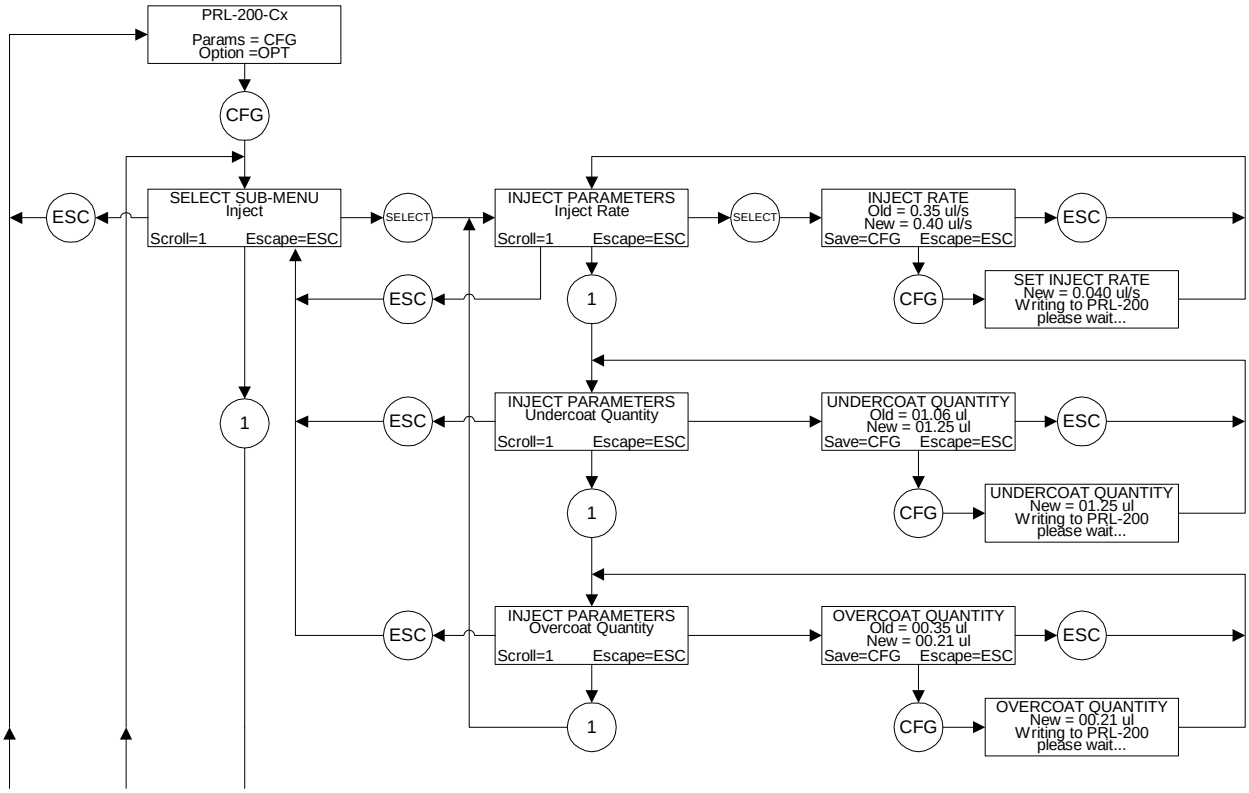
Recoat Tension This option is the amount of tension that will be applied to the fiber prior to the recoating.

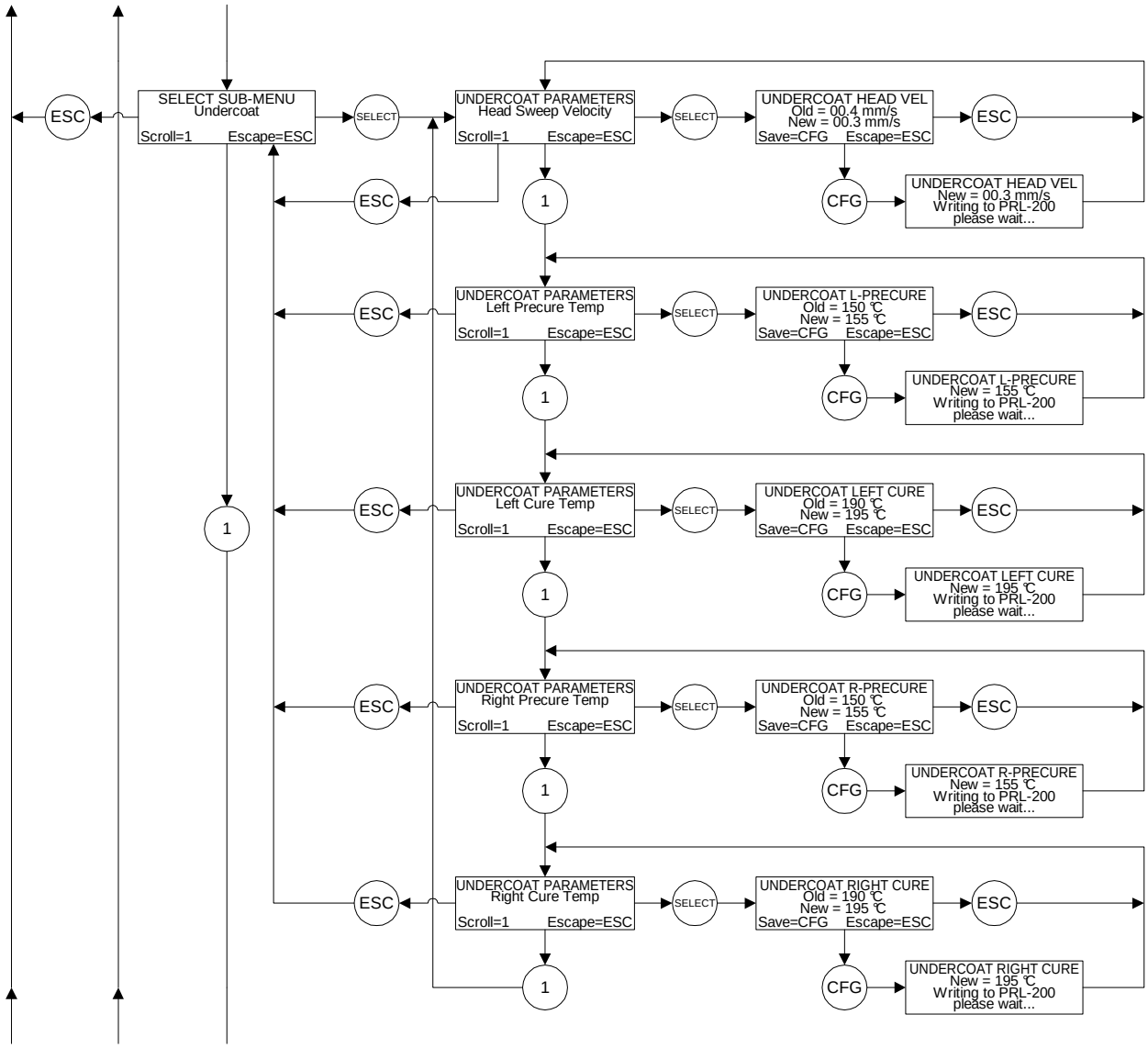
2.4 Parameter Limits

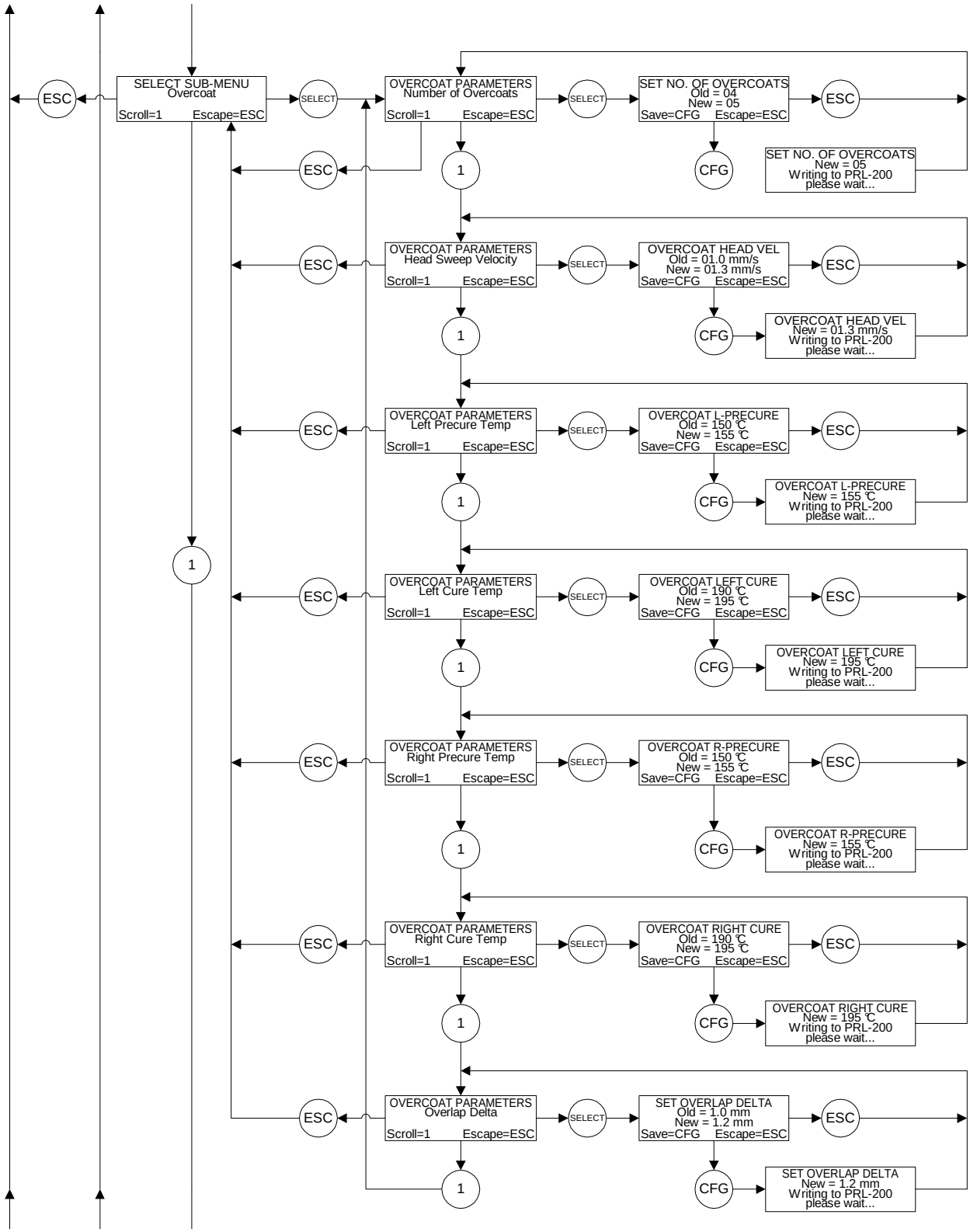
Parameter	Min	Max
Inject Rate (µL/sec)	0.01	2.00
Undercoat Qty (µL)	0.01	10.00
Overcoat Qty (µL)	0.01	10.00
Undercoat Head Sweep Vel (mm/sec)	0.01	20.00
Undercoat Left Precure Temp (℃)	100	200
Undercoat Left Cure Temp (℃)	100	300
Undercoat Right Precure Temp (℃)	100	200
Undercoat Right Cure Temp (℃)	100	300
Number of Overcoats	1	10
Overcoat Head Sweep Vel (mm/sec)	0.01	20.00
Overcoat Left Precure Temp (℃)	100	200
Overcoat Left Cure Temp (℃)	100	300
Overcoat Right Precure Temp (℃)	100	200
Overcoat Right Cure Temp (℃)	100	300
Overlap Delta (mm)	100	200
Recoat Length (mm)	0	2
Proof Test Level (Newtons)	0	20
Proof Test Rate (mm/sec)	0.1	5.0
Recoat Tension (Newtons)	2	10
Heater Stabilize Time (msec)	1	10000
Die Close Time (msec)	250	2500
Fiber Unload Time (msec)	5000	30000
Heater Stabilize Time (msec)	1	10000
Inject to Die Qty (µL)	1	100

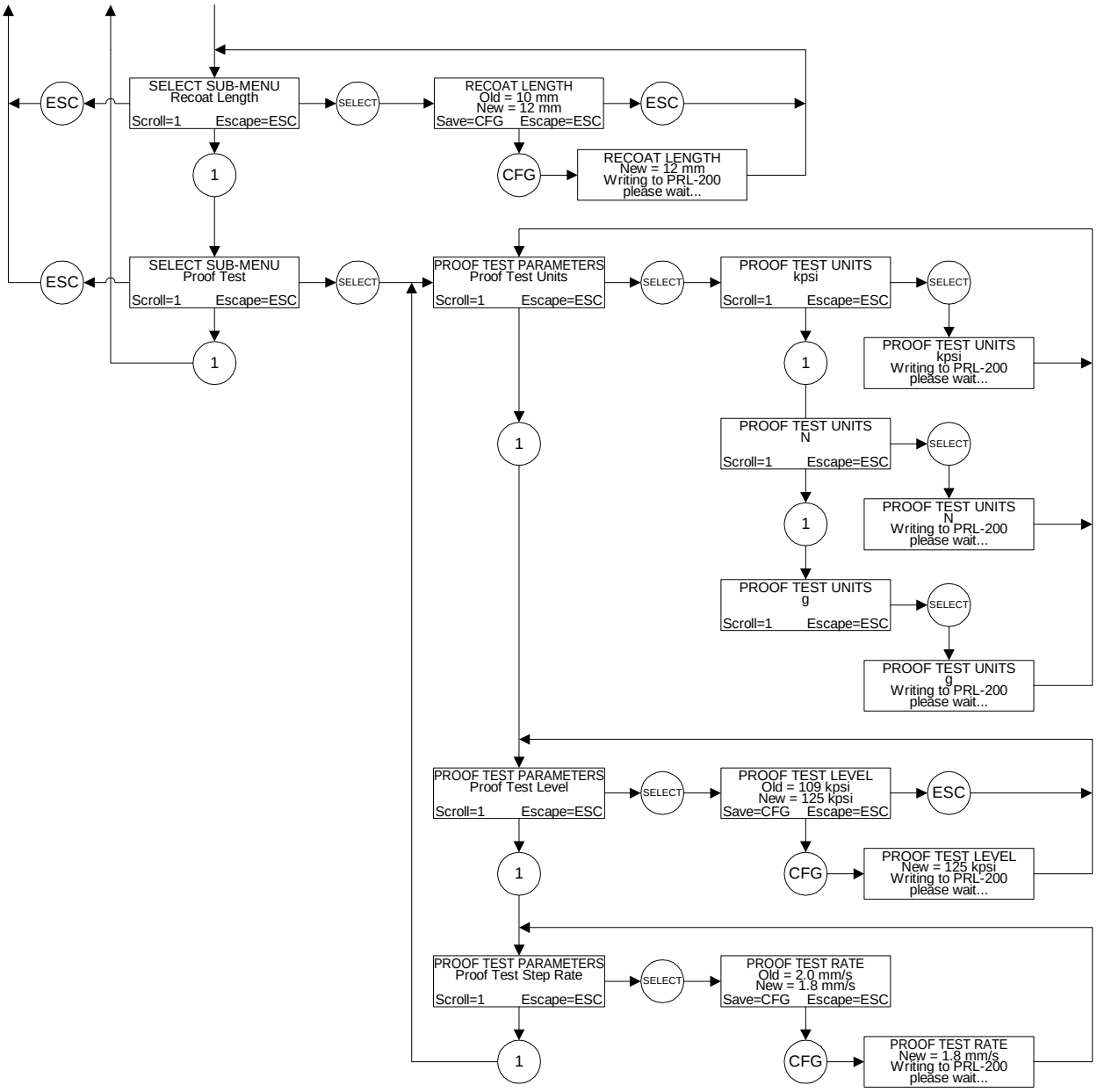
2.5 Configuration Menu Flow Chart

This flowchart is a guide for navigating through the Configuration Menu, and shows the display prompts and button key presses for viewing and editing the Configuration Parameters.



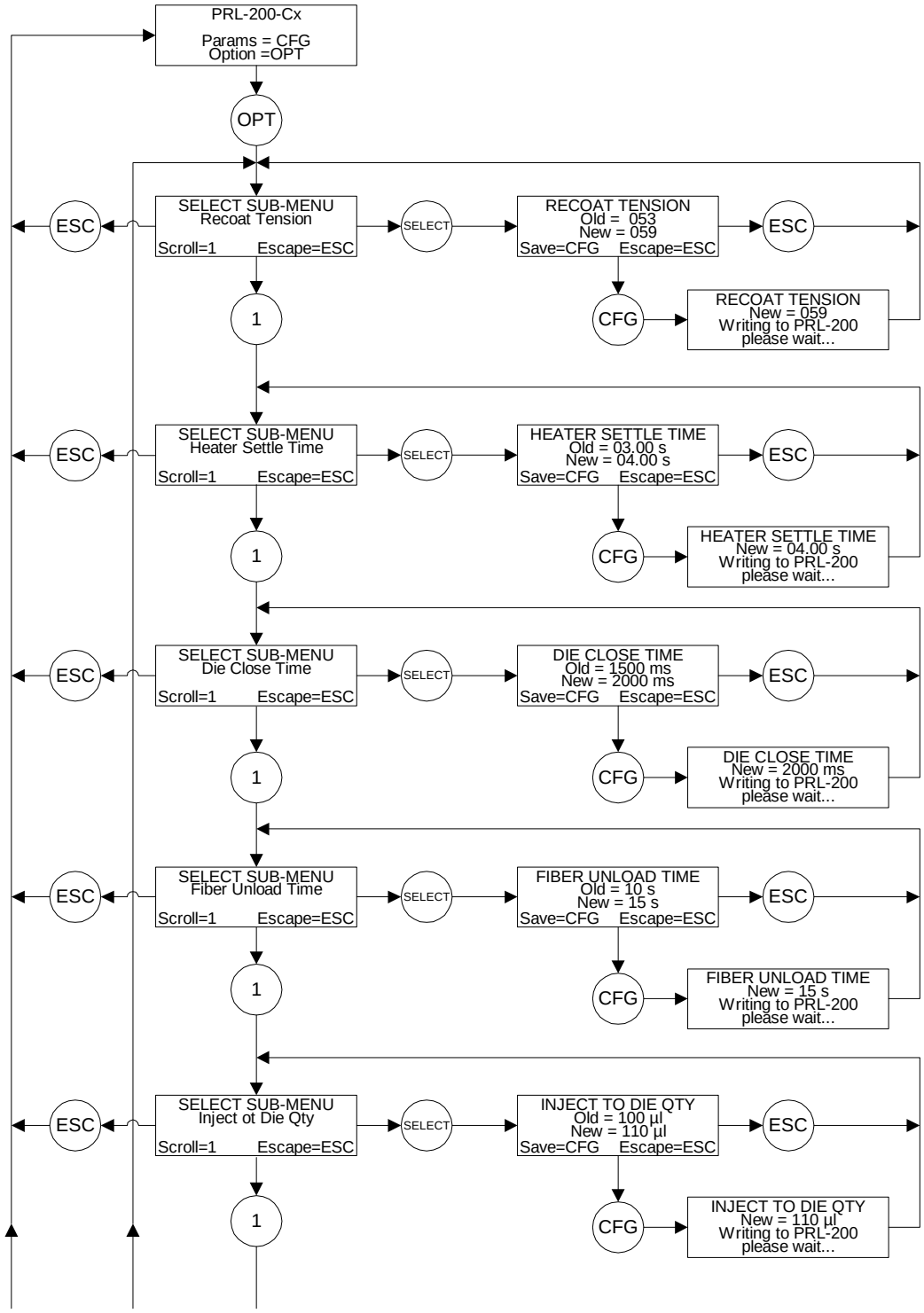

ESC
SELECT SUB-MENU
Undercoat
Scroll=1 Escape=ESC
SELECT
UNDERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
SELECT
UNDERCOAT HEAD VEL
Old = 00.4 mm/s
New = 00.3 mm/s
Save=CFG Escape=ESC
ESC
CFG
UNDERCOAT HEAD VEL
New = 00.3 mm/s
Writing to PRL-200
please wait...
1
UNDERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
SELECT
UNDERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
UNDERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...

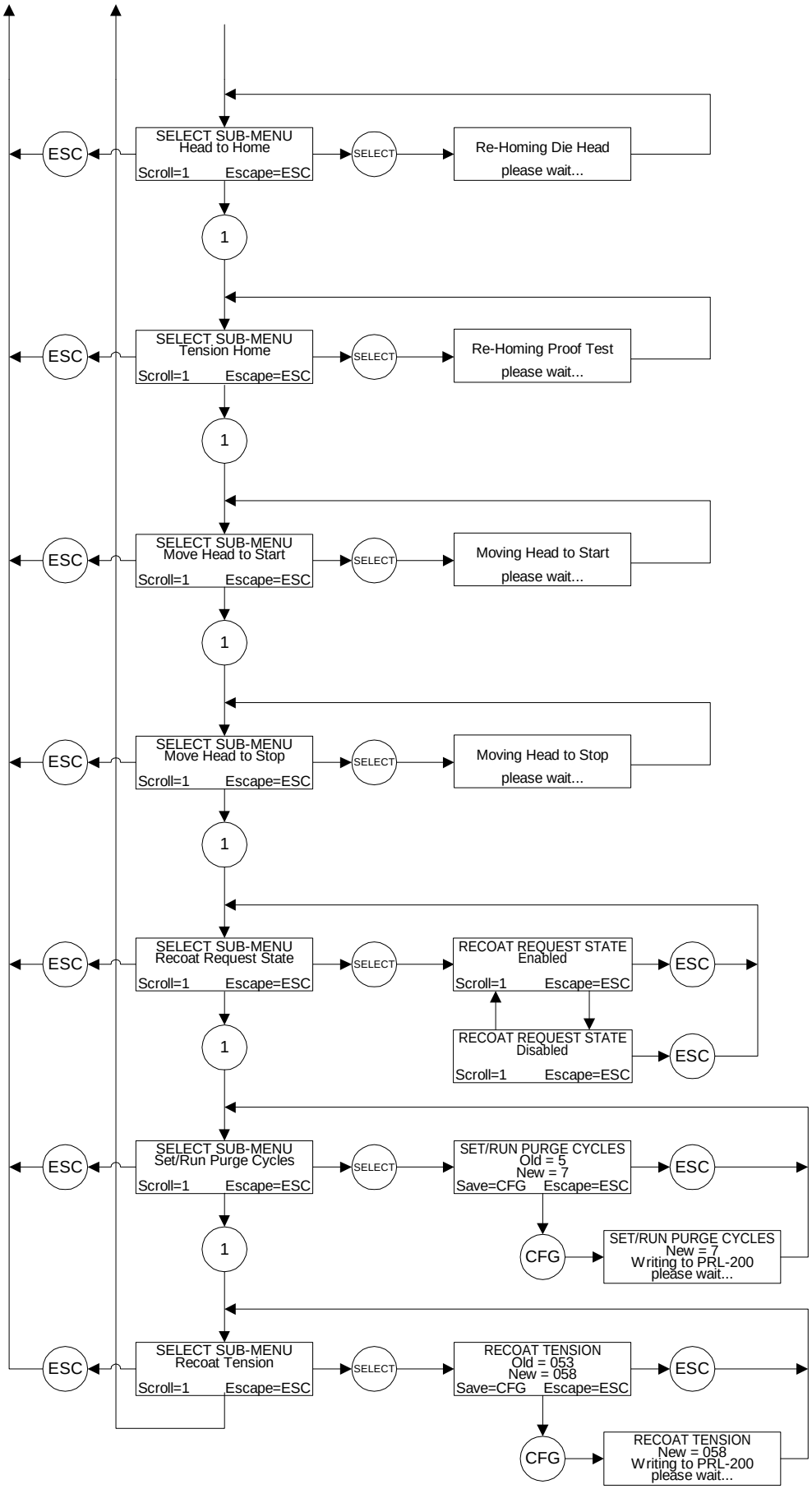

SELECT SUB-MENU
Overcoat
Scroll=1 Escape=ESC
ESC
SELECT
OVERCOAT PARAMETERS
Number of Overcoats
Scroll=1 Escape=ESC
SET NO. OF OVERCOATS
Old = 04
New = 05
Save=CFG Escape=ESC
CFG
SET NO. OF OVERCOATS
New = 05
Writing to PRL-200
please wait...
1
OVERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
OVERCOAT HEAD VEL
Old = 01.0 mm/s
New = 01.3 mm/s
Save=CFG Escape=ESC
OVERCOAT HEAD VEL
New = 01.3 mm/s
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
OVERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
OVERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
OVERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
OVERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Overlap Delta
Scroll=1 Escape=ESC
SET OVERLAP DELTA
Old = 1.0 mm
New = 1.2 mm
Save=CFG Escape=ESC
SET OVERLAP DELTA
New = 1.2 mm
Writing to PRL-200
please wait...


ESC
SELECT SUB-MENU
Recoat Length
Scroll=1 Escape=ESC
SELECT
RECOAT LENGTH
Old = 10 mm
New = 12 mm
Save=CFG Escape=ESC
ESC
1
CFG
RECOAT LENGTH
New = 12 mm
Writing to PRL-200
please wait...
ESC
SELECT SUB-MENU
Proof Test
Scroll=1 Escape=ESC
SELECT
PROOF TEST PARAMETERS
Proof Test Units
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
kpsi
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
kpsi
Writing to PRL-200
please wait...
1
PROOF TEST UNITS
N
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
N
Writing to PRL-200
please wait...
PROOF TEST UNITS
g
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
g
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Level
Scroll=1 Escape=ESC
SELECT
PROOF TEST LEVEL
Old = 109 kpsi
New = 125 kpsi
Save=CFG Escape=ESC
ESC
1
CFG
PROOF TEST LEVEL
New = 125 kpsi
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Step Rate
Scroll=1 Escape=ESC
SELECT
PROOF TEST RATE
Old = 2.0 mm/s
New = 1.8 mm/s
Save=CFG Escape=ESC
1
CFG
PROOF TEST RATE
New = 1.8 mm/s
Writing to PRL-200
please wait...

2.6 Options Menu Flowchart

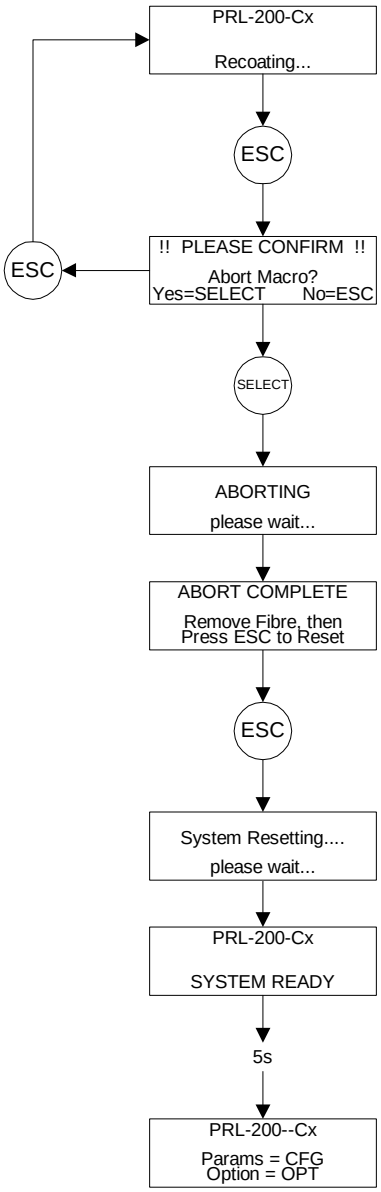
This flowchart is a guide for navigating through the Options Menu, and shows the display prompts and button key presses for editing parameters and executing system related functions.




SELECT SUB-MENU
Head to Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Die Head
please wait...
ESC
1
SELECT SUB-MENU
Tension Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Proof Test
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Start
Scroll=1 Escape=ESC
SELECT
Moving Head to Start
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Stop
Scroll=1 Escape=ESC
SELECT
Moving Head to Stop
please wait...
ESC
1
SELECT SUB-MENU
Recoat Request State
Scroll=1 Escape=ESC
SELECT
RECOAT REQUEST STATE
Enabled
Scroll=1 Escape=ESC
ESC
RECOAT REQUEST STATE
Disabled
Scroll=1 Escape=ESC
ESC
1
SELECT SUB-MENU
Set/Run Purge Cycles
Scroll=1 Escape=ESC
SELECT
SET/RUN PURGE CYCLES
Old = 5
New = 7
Save=CFG Escape=ESC
ESC
CFG
SET/RUN PURGE CYCLES
New = 7
Writing to PRL-200
please wait...
1
SELECT SUB-MENU
Recoat Tension
Scroll=1 Escape=ESC
SELECT
RECOAT TENSION
Old = 053
New = 058
Save=CFG Escape=ESC
ESC
CFG
RECOAT TENSION
New = 058
Writing to PRL-200
please wait...
ESC

2.7 Abort Flowchart

Even after the recoat process has been initiated it is possible to abort the process if required. The Abort Flowchart shows the display prompts and button key presses to abort a recoat process.



3 Recoat Injection System

The PTR-200-PRL has an automatic recoat injection pump fitted inside the unit. The pump is based on an automated syringe and distribution valve that can select one of three ports (Fill, Purge, or Inject) through which it can either draw or inject recoat material (see Figure 3). A bottle containing recoat material is installed directly on the pump, with the pump "Fill" tube inserted into the bottom of the bottle. A "Purge" tube runs from the pump to the top of the recoat bottle, and is used for cycling material back into the bottle. An "Inject" tube runs from the pump to the inject port of the die, which is located in the center of the lower right die. Once all air is purged from the injection system, the pump provides very accurate control of the volume and velocity of recoat material injection.

The recommended recoat material for use in the PTR-200-PRL is Pyralin PI2525, which is manufactured by HD MicroSystems. This is a fast imidizing at lower temperature coating. Do not attempt to use alternate recoat materials without first consulting Vytran on compatibility with the PRL.

Note: Pyralin PI2525 recoat material does have a limited shelf life of approximately 24 months from date of manufacture when stored at 0 to 18 degrees Centigrade. PI2525 is stable at room temperature (21 degrees Centigrade) for approximately 4 weeks with no significant change in properties. Using material that has passed its expiration date may cause both pump performance and recoat quality issues.

3.1 Priming the Injection System

It is very important to remove all air from the recoat injection system prior to performing a recoat. When operating the system for the first time, the pump must be filled with recoat material and cleared of all air in the pump and tubing. In order to clear the inject tube, recoat material must be injected out through the mold inject port and collected and disposed of. Make sure to have cotton swabs and NMP (1-Methyl-2-pyrrolidinone) available for this purpose prior to starting this procedure. NMP is the recommended solvent for cleaning uncured polyimide recoat material.

WARNING: Polyimide recoat materials can be hazardous to your health if not handled properly. Read the Material Safety Data Sheet provided in Appendix X, and make sure to follow all precautionary guidelines when working with this material.

To prime the recoat injection system:

1. Turn off power to the PTR-200-PRL.
2. Remove the front plate of the PTR-200-PRL by using the 3/32 Allen wrench provided in the tool kit to remove the four (4) black socket-head cap screws located at the corners of the plate.
3. The recoat pump is located on the left side of the PTR-200-PRL as shown in Figure 2. Unscrew the brown recoat bottle located at the front of the pump and remove by angling out through the front opening. The red Fill tube will flex to allow removal.
4. For new systems, replace the empty recoat bottle shipped with the unit with a new bottle of recoat material. For systems that have previously been run with recoat material, the recoat injection system should be flushed clean prior to adding new material (see 5.5).
5. Screw the new recoat bottle into place and replace the front panel and the four (4) socket head cap screws.

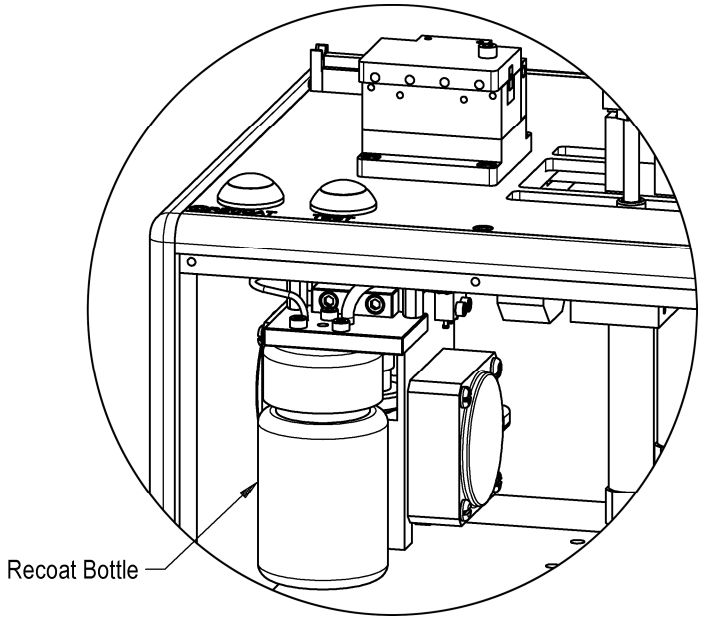


Figure 2: Recoat Bottle Access

6. Turn on power to the PRL-200 and wait for the system to initialize.
7. Execute five (5) Purge cycles (Options menu on Handset Controller). Each purge cycle will draw 100 microliters of recoat material from the bottom of the recoat bottle through the red Fill tube and inject material back into the top of the recoat bottle through the green Purge tube (see Figure 3). Five (5) Purge cycles are required to fill the pump with recoat material and force any air out of the pump system. This will take approximately 15 minutes to complete.
8. After the pump has completed its Purge cycles, the Inject tube that runs from the pump to the die must also be filled with recoat material and purged of air. Have cotton swabs and cleaning solution (NMP) available prior to proceeding.

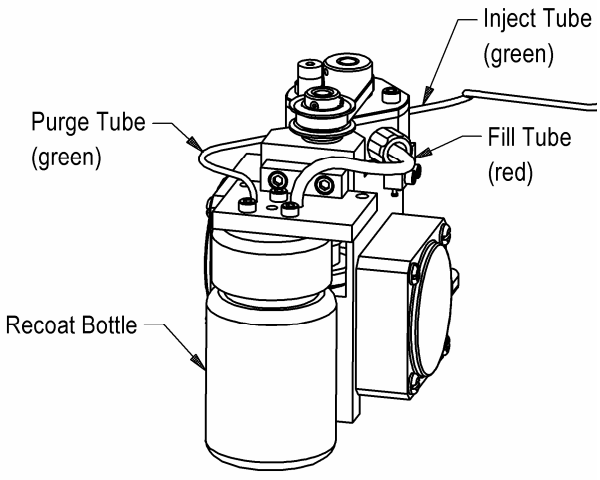


Figure 3: Recoat Material Flow

9. Set the Inject to Die Qty to 100µl (Options menu on Handset Controller).
10. Execute the inject command (press “Select” on the Handset Controller).
11. Watch for recoat material to emerge from the die inject port located at the center of the center of the bottom right die (see Figure 5). Make sure to collect the recoat material with a cotton swab as it comes out of the die injection port. Do not allow recoat material to run down between the die.
12. Execute three (3) additional “Inject 100” sequences to purge air completely from the inject tube. **Note:** Because the injection pump holds 100µl of recoat material, there will be a delay of approximately one minute between the second and third inject sequences while the pump refills.

13. After purging the inject tube, the recoat material should run freely from the die without bubbles. If bubbles are still present, run additional inject sequences.
14. Once the pump and the inject tube are purged, clean the die of all excess recoat material (see 3.2).

Note: Because the syringe in the recoat pump is mounted vertically, it is possible that an air bubble may still be trapped at the tip of the syringe after the above priming process. This air bubble will very slowly rise to the top of the syringe after which time it can be purged out. It is therefore recommended that at least one (1) additional Purge cycle is run the next day after the initial priming of the system.

3.2 Cleaning the Die

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP (1-Methyl-2-pyrrolidinone). NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

4 Recoat and Proof Test Process

4.1 The Polyimide Recoat Process

The PTR-200-PRL utilizes two Fiber Holding Blocks (FHB's) to securely clamp and position the fiber prior to recoating. The right-hand FHB has a linear drive mechanism for applying tension to the fiber. A load cell is incorporated into the linear drive mechanism for monitoring recoat tension. Once the fiber is positioned and securely clamped in the FHB's, pressing the recoat button will initiate an automated recoat process. The right-hand FHB will move to the right until the Recoat Tension is reached. With the fiber held under tension, the right die is closed and the Undercoat Quantity of material is injected into the die and the right heater is set to the Precure Temperature. The recoat head will move to the left depositing material while the right heater will precure the material. Upon reaching the appropriate length, the left die will close and additional recoat material will be injected into the die. The left heater is set to the Precure Temperature and the right heater to the Cure Temperature. The recoat head moves to the right depositing material while the right heater fully cures the previously precured material and the left heater precures the newly deposited material. Returning to the start position is defined as one loop or pass as the material initially deposited has been fully imidized.

This process is repeated until the desired recoat thickness has been achieved. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The recoated fiber is unloaded and the unit resets itself in preparation for the next recoat.

4.2 The Fiber Holding Blocks, V-Grooves, and Inserts

The FHBs are designed to accommodate a range of fiber buffer and cladding sizes through the use of changeable, bottom, FHB inserts. The top insert is spring loaded and does not require any change for 80 or 125 micron fibers. The bottom inserts are V-groove, and incorporate vacuum feed to assist in loading the fiber. The V-groove provides mechanical alignment to the recoat die. V-groove inserts are labeled according to clamping diameter in microns. Beyond the V-groove inserts are rubber inserts. The rubber inserts provide the clamping force and surface area required for tensioning and tension testing.

4.3 Stripped Fiber Requirements

The fiber to be recoated should be free of debris and have a smooth, continuous transition in the jacket strip region. The jacket interface should not extend beyond the original coating diameter.

4.4 Loading

To load the fiber for recoating:

1. If the Fiber Holding Block (FHB) tops are closed, open the FHB tops (see Figure 4). The head will move to the start position and the internal vacuum pump will turn on to aid in loading the fibers.

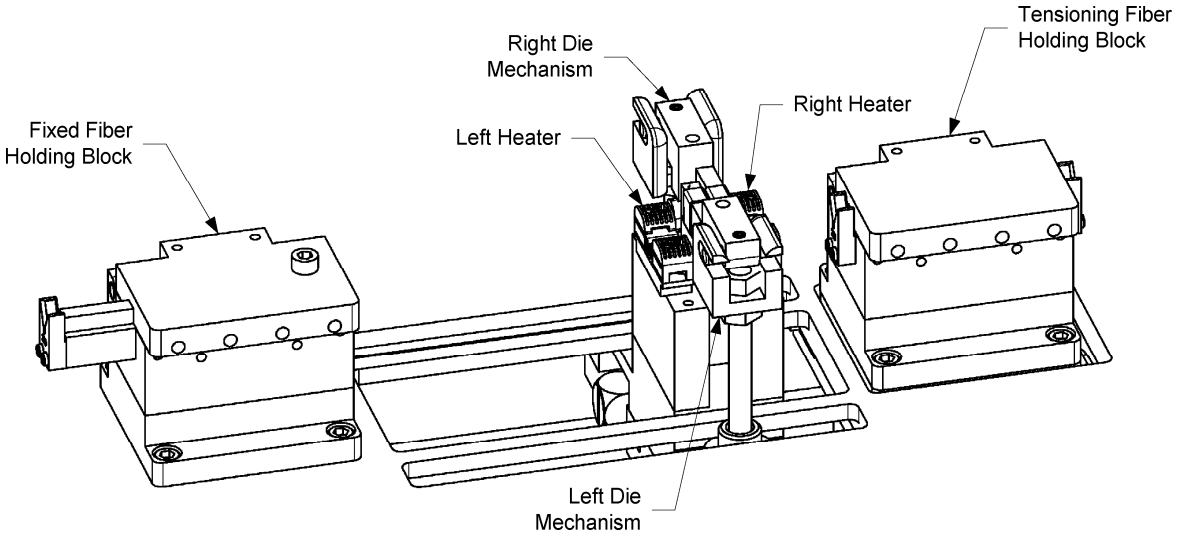


Figure 4: Recoat and Proof Test Components

2. If the FHB tops are open, the load fiber process can be initiated, by either pressing the blue RECOAT button or by closing and reopening both left and right FHB tops.
3. Check that the correct FHB inserts (top and bottom) are installed and that they are free from debris. Position the fiber in the left-hand FHB V-groove, with the stripped section to the left of the left heater. Lower the fiber into the right-hand FHB V-groove. The FHB vacuum should hold the fiber in place.
4. Manually position the fiber in the FHBs so that the right jacket interface is in line with the left edge of the recoat head (see Figure 5). Verify that the fiber is centered in the left and right die.
   Note: Damage to the die may occur if the fiber is not centered in the die when they close.

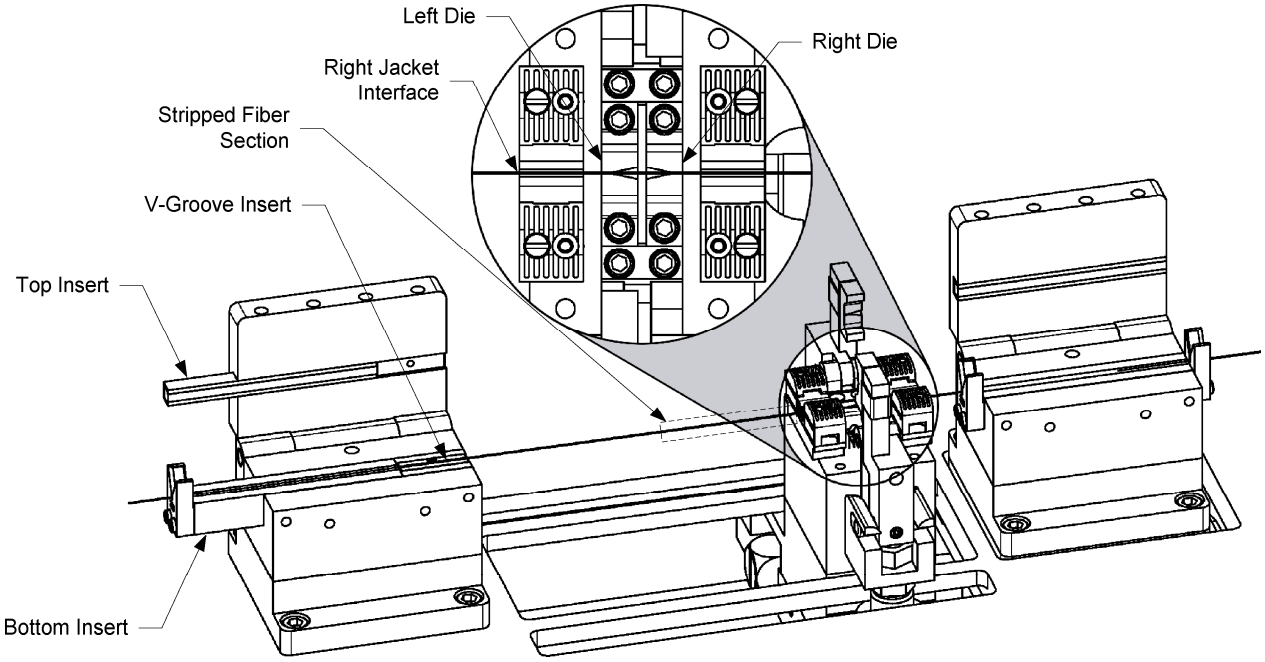


Figure 5: Fiber Position

5. Gently close the FHB lids. This will capture the fiber and turn off the external vacuum pump.
6. The fiber is now ready to be recoated.

4.5 Recoating

To recoat the fiber:

1. Visually confirm that the fiber is loaded properly, if not reload the fiber.
2. Initiate the recoat process by pressing the blue RECOAT button on the unit or the START button on the Handset Controller. The recoat process is fully automated as follows:
   a. The right-hand FHB will begin moving to the right, applying tension to the fiber.
   b. Once the Recoat Tension is reached, the right-hand block will stop moving.
   c. The handset controller will await input from the operator verifying the correct fiber position in the die. Upon confirming the correct fiber position to the handset the process will continue.
   d. The right die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Precure Temp and the head will pause for the Heater Stabilize Time.
   e. The head will move to the left at the Undercoat Head Sweep Vel depositing material while the right die evaporates the volatiles.
   f. Upon reaching the appropriate length, the left die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Cure Temp, the left heater will be set to the Left Precure Temp and the head will pause for the Heater Stabilize Time.
   g. The head will move to the right at the Undercoat Head Sweep Vel depositing material. The right heater will be imidizing the previously precured material while the left heater is evaporating the volatiles from the freshly deposited material. The head will complete at the initial start position plus the overlap delta. This is defined as one loop or pass as the material initially deposited has been fully cured.
   h. The process is repeated (using the Overcoat parameters) until the desired thickness has been achieved by the Number of Overcoats (loops or passes).
   i. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The tension is applied to the specified Level at the specified Rate and released.
3. Proceed to Unloading the Fiber.

4.6 Proof Testing

The Peak Tension should be set to ensure that the recoat meets the minimum strength requirement for its intended application. If using units of tension (kpsi), make sure to enter the correct fiber diameter (e.g. 125 microns) and not the coating diameter.

WARNING: Always wear safety glasses when proof testing fiber. The fiber under test can shatter and send glass particles flying.

To perform a Proof Test:

1. Load the fiber in the fiber holding blocks (see 4.4).
2. Check that the proof test parameters are set correctly.
3. Press the “TEST” button on the PTR-200-PRL.
4. Upon completion of the Proof Test, raise the fiber holding block tops and remove the proof tested fiber.

Note: It is not possible to abort a Proof Test once it has been started.

4.7 Unloading

To unload the fiber after recoating:

1. After the fiber is recoated, the external vacuum pump will turn on to assist in holding the fiber during the unloading process.
2. Hold the fiber securely and lift the left-hand FHB lid. The fiber will be free to move after lifting the lid, so it is important to keep the fiber secured (the V-groove extension is ideal for this).
3. Carefully lift while guiding the recoated fiber though the heaters.
   Note: Raising the FHB top will re-initiate the vacuum pump timer for an additional 15 seconds, after which time the unit will perform a homing routine. The recoated fiber should be removed within this 15 second window.
4. Raise the right-hand FHB top and remove the recoated fiber.
5. Check that no debris is left behind in the FHB V-grooves or on the top clamping surfaces.

Note: After a recoat has been removed (or even if there is a recoat failure), an automatic homing routine will be run 15 seconds after the left FHB top is raised. This homing routine will re-set the position of the right-hand FHB, and the head. The system waits for the FHB top to be opened to ensure that the fiber is being unloaded. If both FHB tops are closed prior to the 15-second time-out, the homing routine will be run immediately.

If the PTR-200-PRL homing process is interrupted or fails, all system functionality is disabled to prevent possible damage to the equipment. Remove any fiber from the FHB's and cycle the power OFF then ON. The PTR-200-PRL will initialize and attempt to run the homing process again. If any further difficulty is experienced, contact Vytran Technical Support for assistance.

5 Maintenance

5.1 Planned Maintenance

The PTR-200-PRL is designed for a production environment to give trouble-free operation provided normal planned maintenance is adhered to. Maintenance and repair procedures should be performed only by trained personnel. Improper service and/or repair could result in the safety features being disabled and can also lead to damage that will not be covered under warranty.

Planned Maintenance Schedule

	Every Shift	Daily	Monthly	12 Months
Inspect / Clean Fiber Holding Blocks[1]	√	√	√	√
Inspect / Clean die[2]	√	√	√	√
Flush recoat System[2] (as needed)			√	√
Purge Recoat System[2] (as needed)			√	√
Replace Recoat Material[2] (as needed)			√	√
Check Load Cell Calibration / Re-Cal[3]				√

[1] Maintenance operations can be performed by the operator.
[2] Maintenance operation can be performed by trained maintenance personnel.
[3] Vytran certified technician only.

5.2 Inspecting the Fiber Holding Blocks

The Fiber Holding Blocks (FHB's) should be inspected daily for debris and/or damage, which may prevent the tops from closing properly and the fiber from being clamped fully. It is particularly important to make sure that the bottom insert V-groove surfaces and the top insert clamping surfaces are free of debris and oils. This will help to ensure that the fiber will not break or slip during tensioning. Cleaning the metal insert surfaces is best accomplished using a cotton-tipped applicator wetted with acetone or alcohol. For embedded debris, a soft cleaning brush may be used. Cleaning the rubber insert surfaces is best accomplished using a cotton-tipped applicator wetted with alcohol. Do not use acetone as this will dry out the rubber causing it to become brittle and crack.

5.3 Inspecting and Cleaning the Die

The die of the recoat head should be inspected daily for debris and/or damage which may result in sub-optimum recoat performance.

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP. NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If

the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

5.4 Load Cell Calibration

The load cell calibration should be checked every twelve (12) months to ensure that accurate recoat and proof test tension is applied to the fiber. This task must be performed by a Vytran certified technician.

5.5 Flush Recoat System

The recoat injection system should be flushed clean every 1 month as part of the recoat material replacement procedure. Before flushing the system, make sure to have cotton tipped applicators and cleaning solution (NMP) available prior to proceeding. To flush the system:

1. Remove the internal recoat bottle and clean all exposed tubing and fittings with NMP.
2. Install a bottle filled 1/4 full with NMP on the pump.
3. Run 5 purge cycles.
4. Remove the bottle, dispose of contaminated NMP. Refill ¼ full with clean NMP and reinstall.
5. Run 5 more purge cycles.
6. Run several inject 100 sequences until NMP runs clear from the die inject port.
   Note: Make sure to collect material as it comes out of the die inject port. Do not allow material to run between the left and right die.
7. Remove the bottle of NMP from the pump.
8. Run several more inject 100 sequences until no more NMP exits the die injection port.
9. Run one purge cycle. Make sure to collect any NMP that comes out of the green purge tube at the top of the bottle fitting.
10. Clean all bottle tubing and fittings with NMP.
11. Install an empty bottle for storage, or a new bottle ¾ filled with fresh recoat material for use. If installing fresh material, proceed to 3.1 Priming the Injection System.

5.6 Purge Recoat System

The purge cycle is a process of emptying the recoat material of the Automatic Injector back into the recoat material bottle and refilling the pump with fresh recoat material drawn from the bottom of the bottle. Running 5 purge cycles is sufficient to entirely fill the pump with fresh recoat material.

If the system has not been used for an extended period (over 1 week), it is recommended that a single purge cycle be run to fill the pump with fresh material.

5.7 Replacing Recoat Material

Recoat material has a finite shelf life and should be replaced every 1 month. To replace the recoat material, first flush the system as outlined in Flush Recoat System (above). Once the system is flushed, fill a clean recoat bottle ¾ full with fresh recoat material and follow the procedures in Purge Recoat System (above).

Note: The one-ounce internal recoat bottle holds approximately 30,000 micro-liters when full. The number of recoats per fill and the approximate time before the material needs to be refilled can be determined based on the volume of material per recoat and the number of recoats per month. For most applications the material will need to be replaced before it runs out. Even if fresh material is added to the internal bottle prior to the Planed Maintenance schedule, the material should still be replaced since mixing of the old and new materials occurs.

5.8 Replacing a Heater

If a heater is sufficiently damaged such that a quality recoat cannot be performed, then replacement is required. The left and right heaters are identical and DO NOT need to be replaced as a pair. The heaters are comprised of a body which houses a graphite filament. When installed in the PTR-200-PRL, the heater is held in place by electrical contacts at the base of the heater body. This is a pin/socket contact compression fit.

To remove the heater:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die sets. This will allow additional access to the heaters.
3. Grab the body of the filament and using a front to back rocking motion, gently lift the filament body (pins) out of the contacts.

To install the heater:

1. Inspect the new heater for any deformation of the filament. If deformation is noted do not install nor use the heater.
2. Hold the filament body (not the graphite filament) and locate the pins into the electrical sockets.
3. To fully seat the heater, gently push down on the electrical contacts (located on the top of the heater).

5.9 Changing the Fiber Holding Block V-Grooves

To change a FHB V-groove insert:

1. Loosen the two (2) set screws accessible from the front of the FHB base using the 0.035” Allen key included in the LDC-200 tool kit. Do NOT remove the set screws completely; one full turn counter-clockwise should be sufficient to release the insert.
2. Remove the FHB V-groove and replace with the desired size. For dual sided inserts, the label for the desired size should face right side up and be readable. Make sure the vacuum feed ports are clear of debris by holding the insert up to a light and checking from behind to make sure light passes each of the ports. Clean if necessary.
3. Make sure the new insert is fully seated and flush with the inside face of the FHB.
   Note: The inside face of the FHB is the side closest to the head.
4. Re-tighten the set screws until they are snug. Do NOT over tighten.

5.10 Replacing the Die

If the die are sufficiently damage such that a quality recoat cannot be performed, then replacement is required. The top and bottom die are a matched set and are replaced as a pair. The top die are spring loaded which enables a slight pivoting during closure, while the bottom die are fixed mounted to the head.

To replace the top die:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. The top die pivots about a center pin which is pressure loaded with two (2) small springs. Remove and retain the top die retainer clip for reuse. This will expose the springs. Using the die, gently compress the springs. This will allow a rotation of the die by ~45 degrees and a removal of the die from the clamp. Remove and retain the springs for reuse.
3. Locate and clean the new top die to be installed.
4. Insert the two (2) springs into the clamp. With the die rotated ~45 degrees, gently collapse the springs with the die. Align the die pin with the clamp and rotate the die to 0 degrees to install.
5. Reinstall the die retainer clip.

To replace the bottom left die (no inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Remove the die from the head.
3. Locate and clean the new top die to be installed.
4. Seat the new die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

To replace the bottom right die (with inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Gently begin to remove the die from the head. An inject tube will be attached to the die. This tube will limit the distance the die can be removed from the head. Gently pull the die with the inject tube until resistance is felt
3. Locate and clean the new top die to be installed.
4. To release the old die from the inject tube, gently rotate the die while holding the inject tube. To install the new die onto the inject tube, gently rotate the die onto the inject tube while holding the inject tube. Slowly feed the inject tube into the head. Seat the die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

Appendix A: MSDS PI2525

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

MATERIAL SAFETY DATA SHEET

***** IDENTIFICATION *****

NAME: PI2525 SYNONYMS: POLYIMIDE COATING.
CHEM.FAMILY: Pyralin® Polyimide Coating. FORMULA: Proprietary.

MANUFACTURER:
HD MicroSystems™
Cheesequake Road
Parlin, NJ 08859

INFORMATION & EMERGENCY TELEPHONE NOS:
INFORMATION: Product: (800) 441-7515
EMERGENCIES: Medical: (800) 441-3637
Transport (CHEMTREC): (800) 424-9300

All Ingredients in This Product Are TSCA Listed/Reported.

***** PHYSICAL DATA *****

FORM: Viscous Liquid. ODOR: Aromatic.

APPEARANCE: Colorless to Amber. SOLUBILITY IN WATER: Slight.

***** COMPONENTS *****

Material(s):	CAS#	V.P. mm Hg @ 20C	Weight %
N-Methyl-2-Pyrollidone.	872-50-4	0.29	> 60%
Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer).	31942-21-9		10 - 30%

PI2525/AH1
05/19/98

***** HAZARDOUS REACTIVITY *****

INSTABILITY:
The product is normally stable.

INCOMPATIBILITY:
Avoid contact with:
Reducing agents; Oxidizing agents; Bases; Acids; Strong acids; Strong oxidizers.

DECOMPOSITION:

Decomposition products at high temperature may include:
Carbon monoxide (CO); Nitrogen oxides; Carbon monoxide, carbon dioxide, water.

POLYMERIZATION:
The product may polymerize endothermically if exposed to temperatures over 90 F, ultraviolet light or free radical initiators. This may increase viscosity.

***** FIRE & EXPLOSION DATA *****

FLASHPOINT: 194 F Seta CC

FIRE & EXPLOSION HAZARDS:
The product is not an unusual fire or explosion hazard.

EXTINGUISHING MEDIA:
Water spray, dry chemical or carbon dioxide.

SPECIAL FIREFIGHTING INFORMATION:
Toxic decomposition products may form under fire conditions. (See Decomposition Section.);
Wear full protective clothing and a full facepiece, positive pressure, self-contained breathing apparatus (SCBA);
Decontaminate contaminated clothing and equipment with soap and water. Dispose of residues per federal, state, and local regulation. (See Waste Disposal Section.).

OVERVIEW: The most likely routes of overexposure to this

PI2525/AH1 Page 2

***** HEALTH HAZARD INFORMATION *****

product are skin contact and inhalation. Skin irritation and/or other effects of skin contact are easily avoided by using proper gloves (see section titled GLOVES) and washing affected areas immediately if contact occurs. Volatile solvents will start evaporating during room temperature use of the product, such as thinning, pouring from jar to dispensing machine, and spin coating. Mist and solvent vapors will evolve if spray application is used. During wafer drying, 125 - 150 C, and final curing, 350 - 450 C, the remaining solvent(s) will evaporate. Potential overexposure to other chemicals used in the operation such as wafer etchants and cleaners should also be considered. Well designed area and personal air sampling and analysis can show if exposures are within established limits. Properly designed local ventilation and process enclosure are effective ways to limit employee exposure where needed.

In addition to meeting exposure limits, it is always prudent to use all practical means to minimize employee exposure to chemicals. A significant difference in overall exposure can be made with practical measures such as:

* Inhalation - minimizing by keeping jars of product covered
* Eye - avoiding contact by wearing chemical splash goggles where there is splash potential
* Ingestion - avoiding by washing hands before eating, drinking or smoking, and restricting these activities to outside the work area.

PRINCIPAL HEALTH EFFECTS:

>>>N-Methyl-2-Pyrollidone
****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Mild skin irritation; No skin sensitization; BY INHALATION: Respiratory effects. Toxic effects of repeated or prolonged animal exposures include: BY INHALATION: Respiratory effects; Bone marrow effects; Lymph system effects; Testicular effects; ****Additional animal tests have shown: No carcinogenic activity; No developmental toxicity; No genetic damage in bacterial or mammalian cell cultures; No reproductive toxicity. ****Human health effects of overexposure may include: By contact with liquid or vapor: Eye irritation with discomfort, tearing, or blurring of vision; BY SKIN OR EYE CONTACT: Eye irritation with discomfort, tearing, or blurring of vision; Skin irritation with itching, burning, redness, swelling or rash; BY INHALATION: Runny nose; Sore throat; Sneezing; Irritation of the nose and throat; Nonspecific discomfort, e.g., nausea, headache or weakness. ****Human effects of higher level

PI2525/AH1 Page 3

acute, repeated or chronic overexposure may include: BY SKIN OR EYE CONTACT: Skin reddening; Skin irritation with discomfort or rash; Dermatitis; Swelling; Burning. ***In addition: BY SKIN OR EYE CONTACT: There are inconclusive or unverified reports of human sensitization.

>>>Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer) ****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Skin irritation; Skin sensitization; Eye irritation.

ANIMAL DATA:

>>>N-Methyl-2-Pyrollidone
Inhalation 4 hour ALC: 1.7 mg/L in rats (Moderately toxic)
Skin absorption LD50: > 8,000 mg/kg in rabbits (Slightly toxic)
Oral LD50: 4,320 mg/kg (Slightly toxic).

CARCINOGENICITY LISTING:

No ingredients of this product are designated by IARC, NTP, OSHA, ACGIH or Dupont as potential carcinogens.

EXPOSURE LIMITS:
Workplace exposures should be kept below the following limits:

.	AIHA		ACGIH		OSHA	
Name/Units	8hr	15min	8hr	15min	8hr	15min
PARTICULATES (N.O.S.), respirable						
Units: mg/m3					5	
PARTICULATES (N.O.S.), total						
Units: mg/m3			10		15	
N-METHYL-2-PYRROLIDONE						
Units: ppm	10					

Also, DuPont has established and observes the following limits:

Name/Units	12 hr	8hr	15min	Ceiling
N-METHYL-2-PYRROLIDONE				
Units: ppm		25		

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NOTES ON EXPOSURE LIMITS:
PELs - OSHA Permissible Exposure Limits - 29 CFR 1910.1000, Subpart Z, or specific substance standards;
TLVs - ACGIH Threshold Limit Values - published by American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211;
WEELs- AIHA Workplace Environmental Exposure Limits - published by the American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031;
AELs - Dupont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits are lower than AEL in effect, government limits shall take precedence;
(C) = "ceiling", limit not to be exceeded for any time period;
(S) = "skin" , skin absorption may contribute significantly to the ingredient's internal toxicity.

***** FIRST AID INSTRUCTIONS *****

Skin Contact: For skin contact, immediately wash skin with soap and water. Wash contaminated clothing before reuse.
Eye Contact: For eye contact, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.
Ingestion: If swallowed, do not induce vomiting. Immediately give two glasses of water. Never give anything by mouth to an unconscious person. Call a physician.

***** PROTECTION INFORMATION *****

Adequate local ventilation should be used to keep exposures below applicable limits;
Other engineering controls such as totally enclosed handling systems are also preferred;
Respiratory protection will be needed if exposures can not be kept below applicable limits by other means.

Respiratory Protection:
A NIOSH/MSHA approved full-face mask equipped with chemical cartridges approved for methylamine may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, when exposure levels are not

PI2525/AH1 Page 5

known, or in any other circumstances where air purifying respirators may not provide adequate protection;
For most conditions, no respiratory protection should be needed; however, if handling at elevated temperatures without sufficient ventilation, use an approved air-purifying respirator. In dusty atmospheres, use an approved dust respirator;
Selection of a suitable respirator will depend on the properties of the contaminant(s) and their actual or expected air concentration(s) versus applicable limits. Consult ANSI Standard Z88.2 for decision logic to select appropriate NIOSH/MESA approved respirators;
A NIOSH/MSHA/OSHA approved air purifying respiratory with a dust/mist cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, exposure levels are not known or any other circumstances where air purifying respirators may not provide adequate protection;
Use a positive pressure air-supplied respirator if concentrations may exceed exposure limits. Air-purifying respirators are inadequate for this material;
If respirators are needed to meet applicable limits, a respiratory protection program up to the level of OSHA Standard 29 CFR 1910.134 is mandatory. This includes air monitoring, selection, medical approval, training, fit testing, inspection, maintenance, cleaning, storage, etc;
An OSHA/NIOSH respirator for protection against Nuisance Dust is recommended.

Gloves:

Gloves should be used when the possibility of skin contact exists;
The suitability of a particular glove and glove material should be determined as part of an overall glove program. Considerations may include chemical breakthrough time; permeation rate; abrasion, cut and puncture resistance; flexibility; duration of contact; etc.

Other Protection Practices:

Appropriate eye protection such as chemical splash goggles should be used if the possibility of eye contact exists;
Protective outer clothing should be used where the possibility of body contact exists. Contaminated work clothing should not be allowed out of the workplace;
Do not smoke, consume or store food or drinks in areas

PI2525/AH1 Page 6

where the product is handled or stored. After handling the product, wash hands thoroughly before leaving the work area;
Additional engineering controls, work practices and training may be required depending on exposure levels. These are discussed in the OSHA Respiratory Protection Standard (29 CFR 1910.134) and OSHA Hazard Communication Standard (29 CFR 1910.1200);
Do not breath dust. Avoid contact with eyes, skin, or clothing. Wash thoroughly after handling.

***** DISPOSAL INFORMATION *****

Spill, Leak or Release:
FOR SMALL SPILLS, absorb on rags, sand or other absorbent material;
FOR LARGE SPILLS, get workers out of affected area. If flammable liquids or vapors may be present, turn off electrical devices or other sources of sparks or flames. WEAR PROTECTIVE EQUIPMENT. Use supplied-air respiratory protection if vapor concentrations are not known;
Contain spill at source by diking or absorbing with sand. Do not allow spill to spread to or intentionally flush to sewer or ground. Wash area thoroughly. Adequately ventilate area;
Spill residue, cleaning rags and absorbent may be considered hazardous. (See Waste Disposal Section.).

Waste Disposal:
Components of this product may be considered hazardous;
Consult applicable Federal, State, and local regulations for allowable disposal methods.

***** PRODUCT INFORMATION *****

Contaminated Items:
Empty product containers, contaminated clothing and cleaning materials, etc. should be considered hazardous until decontaminated or properly disposed of. (See Waste Disposal Section.).

Storage:
Store product in a refrigerated location (0-4F), away from sunlight or ultraviolet light to ensure product viscosity stability.

PI2525/AH1 Page 7

***** ADDITIONAL INFORMATION *****

The following ingredients are subject to the reporting requirements of section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

INGREDIENT(S)	Weight %
N-Methyl-2-Pyrrolidone	> 60%

CALIFORNIA PROPOSITION 65: WARNING: This product does not contain chemical known to the state of California to cause cancer, birth defects, or other reproductive harm.

This product is a physical mixture. The health effects information about this product is based on the individual ingredients; The data in this Material Safety Data Sheet relates only to the specific product designated herein and does not relate to its use in combination with any other material or in any process.

Date of latest MSDS revision: 05/19/98

Person Responsible for MSDS:

Safety Coordinator - MSDS
DuPont P&EM / MCM
14 Alexander Drive
Research Triangle Park, NC 27709-4425
Telephone: (800) 284-3382
Outside U.S.: (919) 248-5775

PI2525/AH1 End of Material Safety Data Sheet Page 8

Appendix B: MSDS NMP

Material Safety Data Sheet

1-Methyl-2-pyrrolidinone

ACC# 08690

Section 1 - Chemical Product and Company Identification

MSDS Name: 1-Methyl-2-pyrrolidinone
Catalog Numbers: AC127630010, AC127630025, AC222080025, AC222085000, AC326930010, AC326931000, AC326932500, AC354890025, AC354900025, AC364380010, AC364380025, AC364381000, AC368450010, AC368450025, AC368451000, AC610411000, BP1172-4, BP11724LC, BP1172N119, BP2619-100, NC9749337, O3688-4
Synonyms: NMP; N-Methylpyrrolidone; N-Methylpyrrolidinone; N-Methyl-2-pyrrolidone; N-Methyl-2-pyrrolidinone; M-Pyrol; 1-Methyl-2-pyrrolidone; solvent in paint strippers.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
872-50-4	1-Methyl-2-pyrrolidinone	99	212-828-1

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: clear colorless liquid. Flash Point: 91 deg C.
Warning! Causes eye, skin, and respiratory tract irritation. May cause harm to the unborn child. **Combustible liquid and vapor.** May be harmful if swallowed, inhaled, or absorbed through the skin. Light sensitive. Hygroscopic (absorbs moisture from the air).
Target Organs: Respiratory system, eyes, skin.

Potential Health Effects

Eye: Causes eye irritation. May cause temporary corneal clouding.
Skin: Causes skin irritation. May be harmful if absorbed through the skin. Not expected to cause an allergic skin reaction. Because of the high permeability rate of N-methylpyrrolidone in human skin, prolonged exposures should be avoided.
Ingestion: May cause gastrointestinal irritation with nausea, vomiting and diarrhea.
Inhalation: Causes respiratory tract irritation. May cause headache. Material has a very low vapor pressure and inhalation exposures are not expected unless material is heated or misted.
Chronic: Prolonged or repeated skin contact may cause dermatitis. Adverse reproductive effects have been reported in animals. Testicular effects in rats were noted after repeated, high-dose oral and inhalation exposures.(BASF)Human occupational exposure has been associated with chronic eye irritation, headaches, and irritant contact dermatitis. Airborne concentrations of 49 to 83 ppm are intolerable.(REPROTEXT)

Section 4 - First Aid Measures

Eyes: In case of contact, immediately flush eyes with plenty of water for a t least 15 minutes. Get medical aid.
Skin: In case of contact, flush skin with plenty of water. Remove contaminated clothing and shoes. Get medical aid if irritation develops and persists. Wash clothing before reuse.
Ingestion: If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical aid.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Combustible liquid and vapor.
Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or appropriate foam.
Flash Point: 91 deg C (195.80 deg F)
Autoignition Temperature: 245 deg C (473.00 deg F)
Explosion Limits, Lower:1.3%
Upper: 9.5%
NFPA Rating: (estimated) Health: 2; Flammability: 2; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Remove all sources of ignition. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes, skin, and clothing. Keep away from heat and flame. Avoid breathing vapor or mist.
Storage: Keep away from sources of ignition. Store in a cool, dry place. Store in a tightly closed container. Keep under a nitrogen blanket.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
1-Methyl-2-pyrrolidinone	none listed	none listed	none listed

OSHA Vacated PELs: 1-Methyl-2-pyrrolidinone: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear chemical splash goggles.
Skin: Wear appropriate gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Liquid
Appearance: clear colorless
Odor: amine-like - mild odor
pH: 8.5-10.0 (100 g/l H2O)
Vapor Pressure: 0.342 mm Hg @ 25 deg C
Vapor Density: 3.4 (air=1)
Evaporation Rate: Not available.
Viscosity: 1.65 cps @ 25 deg C
Boiling Point: 202 deg C @ 760 mm Hg
Freezing/Melting Point:-24 deg C
Decomposition Temperature: Not available.
Solubility: Soluble.
Specific Gravity/Density:1.030
Molecular Formula:C5H9NO
Molecular Weight:99.13

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions.
Conditions to Avoid: Light, ignition sources, excess heat, exposure to moist air or water.
Incompatibilities with Other Materials: Strong oxidizing agents, strong acids.
Hazardous Decomposition Products: Nitrogen oxides, carbon monoxide, carbon dioxide.
Hazardous Polymerization: Will not occur.

Section 11 - Toxicological Information

RTECS#:
CAS# 872-50-4: UY5790000
LD50/LC50:
CAS# 872-50-4:
Draize test, rabbit, eye: 100 mg Moderate;
Oral, mouse: LD50 = 5130 mg/kg;
Oral, rat: LD50 = 3914 mg/kg;
Skin, rabbit: LD50 = 8 gm/kg;
.
Sensitization test (guinea pig): negative. test (humans): negative.(Merck)
Carcinogenicity:
CAS# 872-50-4: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No data available.
Teratogenicity: Proposition 65 maximum allowable dose level for developmental toxicity for N-methylpyrrolidone is 3200 ug/day for the inhalation route and 17,000 ug/day for the dermal route.

Reproductive Effects: See actual entry in RTECS for complete information.
Mutagenicity: See actual entry in RTECS for complete information.
Neurotoxicity: No data available.
Other Studies:

Section 12 - Ecological Information

Ecotoxicity: Daphnia: Daphnia: 4897 mg/l; 48 h; EC50Fish: Gold orfe: 4000 mg/l; 96 h; LC50Bacteria: >9000 mg/l; 48 h; EC50Algae: >500 mg/l; 72 h; IC50 log Pow = -0.46 (25°C)BOD5 = 1100 mg/l.COD = 1600 mg/l.
Environmental: No information available.
Physical: No information available.
Other: Biodegradable.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated	Not Regulated
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 872-50-4 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
CAS# 872-50-4: Test for Health Effects

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 872-50-4: immediate, delayed, fire.

Section 313

This material contains 1-Methyl-2-pyrrolidinone (CAS# 872-50-4, 99%),which is subject to the reporting requirements of Section 313 of SARA Title III and 40

Clean Air Act:

This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 872-50-4 can be found on the following state right to know lists: Pennsylvania, Minnesota, Massachusetts.

California Prop 65

WARNING: This product contains 1-Methyl-2-pyrrolidinone, a chemical known to the state of California to cause developmental reproductive toxicity.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

T

Risk Phrases:

R 36/37/38 Irritating to eyes, respiratory system and skin.
R 61 May cause harm to the unborn child.

Safety Phrases:

S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S 53 Avoid exposure - obtain special instructions before use.

WGK (Water Danger/Protection)

CAS# 872-50-4: 1

Canada - DSL/NDSL

CAS# 872-50-4 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of B3, D2A, D2B.
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

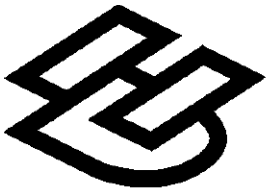
Canadian Ingredient Disclosure List

Section 16 - Additional Information

MSDS Creation Date: 6/10/2003
Revision #2 Date: 3/29/2005

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Appendix C: Pyralin Product Information



HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

Rev. Apr 01

PRODUCT INFORMATION
PYRALIN® PI2525, PI2555, PI-2575 & PI2556

PI2525, PI2555, PI-2575 and PI2556 polyimides [PI-2555 Series] are suitable for applications where the high cure temperatures typically used for polyimides (ca. 350°C) cause problems. Typical applications for these materials are as stress buffer or interlayer dielectric layers over low temperature substrates. These polyimides imidize faster and at lower temperatures than for standard polyimide precursors. The materials are supplied as solutions suitable for spin or roller coating application. A seperate adhesion promoter is recommended with PI-2525, PI-2555 and PI-2556 to improve adhesion to oxides and to metals. PI-2575 is self priming and does not require an adhesion promoter. Processing by wet or plasma etch is possible. Cured film thicknesses from 0.5 µm to 6 µm can be obtained.

Process Details

Coating

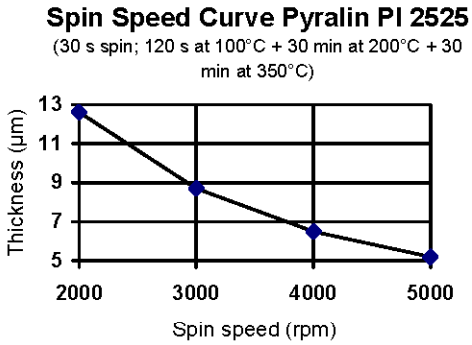
PI2555 Series products can be coated onto a variety of metals, alloys, semiconductor and ceramic substrates. HD MicroSystems adhesion promoters VM651 or VM-652 are recommended to provide good processability and adhesion with the PI-2525, PI-2555, PI-2556. Bonding of the polyimide to the substrate is achieved during the softbake cycle as the priming chemistry is activated by temperature.

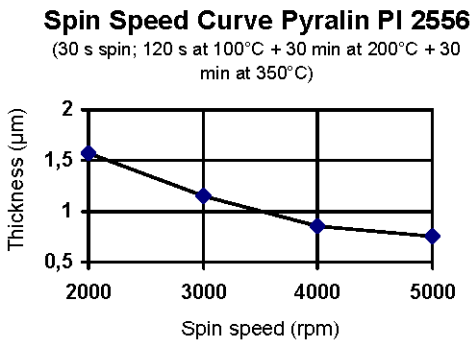
The polyimide solution is highly viscous. There are some guiding principles for dispensing materials of this type. Always coat substrates which are at room temperature. Never trap air into the solution. This can occur for example when the solution is moved during dispense. All bubbles take time to dissipate out of solution. If left in, coating "comets" will result. Dispensing should be in the centre and as close to the substrate as possible. A clean cut-off at dispense is neccessary before the spin process starts. It may be neccessary in the case of highly viscous solutions to have a short delay prior to spin to allow the polyimide to flow as far as possible and relax.

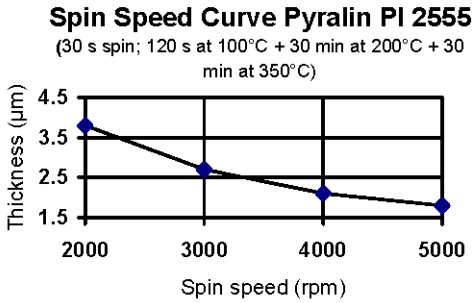
Both static and dynamic dispense may be used. Static dispense is the easiest, but requires more material to be dispensed for each substrate. Dynamic dispense uses less material, but requires greater control during dispense to ensure that the polyimide strikes the exact centre of the substrate. Any deviation will result in poor coating quality. The acceleration to final speed should be as low as possible to allow gradual flow of the polyimide across the substrate. Often one or more intermediate spin speeds are used to allow the polyimide to gradually cover more than 80% of the substrate before continuing on to the final speed. To reduce the backside contamination potential it is often beneficial to prolong the spread cycle until the bulk of the excess polyimide has been removed from the substrate. The final spin speed and time is determined by the film thickness required. Longer spin

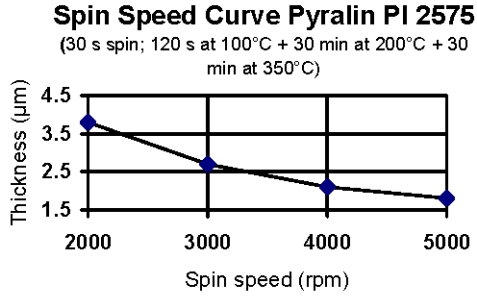
times will improve coating uniformity, but will also reduce the film thickness. In semiconductor applications, an Edge Bead Removal (EBR) and Backside Rinse process may be added to the coating cycle to remove polyimide from the edge and back of the wafer prior to baking. NMP (N-methyl-2-pyrrolidone) or NMP/IPA (isopropanol) can be used for this purpose.

Spin Speed Curves for cured Polyimide









Soft Bake

After application of the polyimide, a bake process is required. Both convection oven and hotplate bake methods may be used. The purpose of this stage, is to partially cure the polyimide prior to patterning. This bake stage leaves the polyimide coating dry, yet soluble in the etchant solution.

Choice of Photoresist

Polyimides of this type can be patterned using common photolithography techniques centered around positive photoresist. The underlying polyimide is an effective anti-reflective layer as there is significant absorption between 350 and 450 nm. This absorption can significantly reduce substrate reflection effects on the photoresist, usually seen as “notching“ after development.

The photoresist should be selected with the correct wavelength to suit the exposure tool in use. As a general guide, formulations with good adhesion in “wet etch“ semiconductor applications perform well. Other attributes include:

- Compatability to standard alkaline positive photoresist developers

- Low contrast performance so that a soft sidewall profile is always produced

- Capability to produce cleanly developed via holes in thick resist coatings

- Good development latitude, especially when over-developed

- The ease of producing a minimum dried 2,5 µm film thickness

The polyimide coating after softbake has minimum solubility in typical photoresist solvents. Photoresist can therefore be coated directly onto the polyimide coating without layer inter-mixing occuring.

Photoresist Application

Substrates should be coated directly with the resist selected. No dehydration bake should be given as this would make the polyimide totally insoluble in the developer. Instead an HMDS vapour prime is permissable if installed on-line but is not really neccessary for good resist adhesion to the polyimide.

Once coated, the resist should be given a softbake at 90°C either in a convection oven for 30 minutes or on a vacuum hotplate for 60 seconds. Once coated and baked, coatings may be held up to 24 hours before exposure.

Photoresist Exposure

Typical exposure: 50 mJ to 150 mJ

Once exposed, development should take place within 8 hours.

Photoresist Development / Polyimide Etch

A single step is used to develop the photoresist and etch the polyimide.

Most alkaline positive resist developers will dissolve both exposed photoresist and polyimide at varying rates. The choice of developer affects the quality of the polyimide image after development. Best results have been obtained using a NaOH based developer.

Thin polyimide layers up to around 5 µm can usually be developed quickly and cleanly with developer which is at ambient temperature. After development of the resist and then the polyimide using a spray puddle technique, a water rinse should be used to remove the developer. The substrate should subsequently be spun until dry.

When thicker polyimide layers need to be processed, it is often beneficial to heat the developer to between 23°C and 25°C. This accelerates the dissolution of the polyimide while having minimal effect on the solubility of the photoresist. In more extreme situations, this may be coupled to a double puddle process. The second puddle is used to develop only the polyimide layer.

Once developed, wafers may be held up to 8 hours before stripping the resist.

Resist Strip

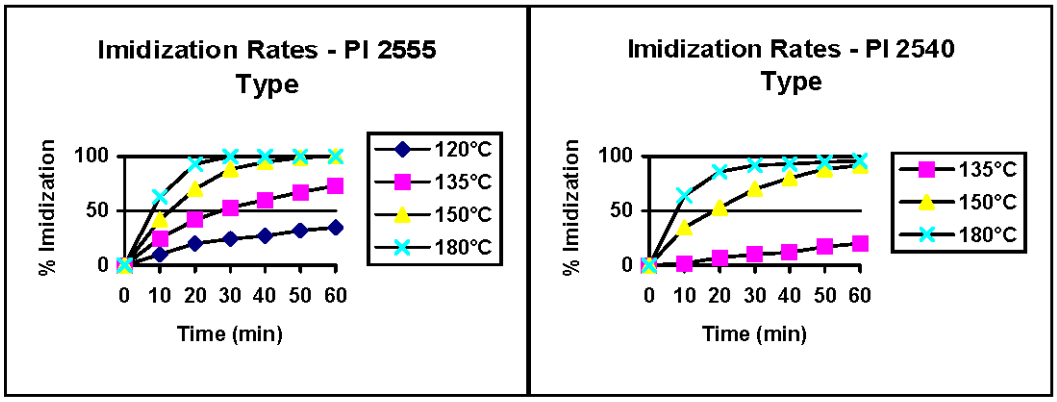
After developing, the photoresist needs to be stripped off the polyimide surface before curing. This step is usually carried out on automated track equipment to reduce surface contamination with resist residue which may result if clean solvents are not used. Resist solvent strippers are normally used.

Cure

The cure heating cycle converts the polyamic acid to the insoluble imide form and drives out remaining solvent. This process requires elevated temperatures and controlled environments to achieve the best results. There is sufficient energy at 180°C to complete the imidization of the polyimide, but higher temperatures are required to completely drive off solvents, thus achieving the ultimate electrical and mechanical properties. A programmable high temperature oven with typical nitrogen flow rate of 10 litres per minute is recommended for best results.

To activate the adhesion promoter, it is recommended that the cure be carried out up until 200°C in air (min 50% RH). Above this temperature, a nitrogen atmosphere should be used. The ramp rates (up and down) should be low to avoid high stress in the polyimide.

The maximum cure temperature may be higher than 300°C when the coating is to be subjected to a high temperature process after curing. In such cases, temperatures up to 400°C have been used to ensure that there is no outgassing during subsequent processes.



Processing Pyralin® PI2525, PI2555, PI-2575 & PI2556 products

(for ca. 7µm softbaked and 5µm cured film thickness)

Application of Adhesion Promoter*

- Dispense on static substrate, 3 seconds
- Hold for 20 seconds
- Spin dry for 30 seconds

Bake Adhesion Promoter

- On hotplate at 120°C for 60 seconds (optional)

*not required with PI-2575

Polyimide Coating

- Dispense on static substrate
- Rotate at 500 rpm for 5 seconds
- Rotate at final speed for 30 seconds (see spin speed curves)
- EBR/Backside rinse, 10 seconds
- Spin dry, 15 seconds

Soft Bake

- In convection oven at 120°C for 30 minutes

OR

- On hot plate at 120°C for 30 seconds followed by 150°C for 30 seconds

Coat Photoresist

- Dispense, 3 seconds
- Spread at 500 rpm for 5 seconds
- Spin at final speed for 30 seconds
- EBR / Backside rinse for 5 seconds
- Spin dry for 15 seconds

Softbake Photoresist

- On hotplate at 90°C for 60 seconds

Exposure

- 50 mJ to 150 mJ

Development

Developer:	NaOH, KOH or TMAH developer or DE 1000 at 21°C
Rinse:	DI water

Puddle Development process:

• Spray (100 rpm)	5 seconds
• Puddle	3 minutes
• Rinse (1000 rpm)	15 seconds
• Spin dry (5000 rpm)	15 seconds

Resist Strip

- Spray or spray/puddle acetone or standard resist stripper or N-Butlyacetate at ca. 2000 rpm
- Spin dry

Cure

Curing should be done in an oven using the following cure profile:

- Heating from room temperature to 200°C, ramp rate 4°C/minute in air
- Hold time at 200°C for 30 minutes in air
- Heating from 200°C to 300°C, ramp rate 2,5°C/minute in nitrogen
- Hold time at 300°C for 60 minutes in nitrogen
- Gradual cooling to room temperature

Solution Properties

	PI2525	**PI2555/PI-2575**	**PI2556**
Solids content (%)	25.0 +/-1.0	19.0 +/-1.0	15.0 +/-1.0
Viscosity (Poise)	60 +/- 10.0	14.0 +/-2.0	3.5 +/-1.0
Flash Point	93°C	60°C	54°C
Solvent (%)	N-Methyl-2-Pyrrolidone 100	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon 80/20 +/-5	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon Propylene Glycol Methyl Ether 70/14/15 +/-5
Ash content (%)	0.1 max.	0.1 max.	0.1 max.
Chloride content	5.0 ppp max.	5.0 ppp max.	5.0 pp max
Sodium content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Potassium content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Copper content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Iron content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Total metals	10.0 ppm max.	10.0 ppm max.	10.0 ppm max.

Cured Film Properties

Tensile strength (kg/mm²)	13.1
Elongation (%)	10
Modulus (kg/mm²)	245
Stress (dynes/cm^2)	3.6×10^8
Moisture uptake (%)	2 - 3
Dielectric constant (at 1 kHz, 50% RH)	3.3
Dissipation factor	0.002
Dielectric strength (volts/mil)	4000
Volume resistivity (ohm-cm)	10^{16}
Surface resistivity (ohm)	10^{15}
Coefficient of thermal expansion (ppm)	40
Coefficient of thermal conductivity (cal/(cm)(sec)(°C))	35×10^{-5}
Glass transition temperature	> 320°C

Decomposition temperature	560°C
Weight loss (% at 500°C, 120 min)	2.9
Specific heat (cal/g/°C)	0.26
Refractive index	1.70

Storage/Shelf Life

It is recommended that PI-2555 Series products be stored between 0°C to -18°C.

Pyralin® PI2525, PI2555, PI-2575 and PI2556 are stable at clean room temperatures (21°C) for ca. four weeks with no significant change in properties. When stored at -18°C, shelf-life is 2 years from date of manufacturing. Moisture contamination is detrimental to stability and must be avoided. Containers should be brought to room temperature before opening to avoid moisture condensation inside the botttle.

Safety and Handling

During all handling of Pyralin polyimide products, adequate ventilation must be provided. Skin and eye contact should be avoided. Exposed areas should be flushed with water immediately. For prolonged or repeated contact, milled butyl rubber or natural latex rubber gloves should be used. Disposable PVC gloves are not recommended.

United States

HD MicroSystems, LLC
P0 Box 80010
Wilmington, DE 19880
800-346-5656 (Phone)
302-892-0597 (Fax)

HD MicroSystems, LLC
1333 Lawrence Expressway
Suite 212
Santa Clara, CA 95051
408-260-0880 (Phone)
408-260-0885 (Fax)

Japan

HD MicroSystems, LLC
10-13, Shibuya 3-chome, Shibuya-ku,
Tokyo 150
Japan
81-3-3407-9003 (Phone)
81-3-3407-9037 (Fax)

Europe

HD MicroSystems Europe GmbH
DuPont Strasse 1
D-61343 Bad Homburg
Germany
49-6172-87-1822 (Phone)
49-6172-87-1824 (Fax)

Internet
www.hdmicrosystems.com

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Caution: Do not use in medical applications involving permanent implanation in the human body.

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

PTR-200-PRL

Automated Polyimide Recoater with Linear Proof Tester

Operator's Manual

Version 1.2

United States:
1400 Campus Drive West • Morganville, NJ 07751
+1 (732) 972-2880 • +1 (800) 421-8847 • Fax +1 (732) 972-6229

England:
8, Kew Court • Pynes Hill Office Campus • Exeter, EX2 5AZ
+44 (0) 1392 445777 • Fax +44 (0) 1392 445009

Web: http://www.vytran.com

VYTRAN

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Vytran LLC
1400 Campus Drive
Morganville, NJ 07751 USA

Phone: +1 (732)-972-2880
+1 (800)-421-8847
FAX: +1 (732)-972-6229

http://www.vytran.com

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1 Introduction

The PRL-200 is designed for recoating and proof testing polyimide coated fibers. It operates on a coat, cure and test recoat method, whereby a layer of polyimide is applied to the fiber through a die, followed by a filament heater to cure the polyimide and upon completing the recoat a linear proof test. When configured and operated properly, the PTR-200-PRL is capable of producing a high quality and a uniform polyimide recoat.

1.1 Parts Checklist

When unpacking the PTR-200-PRL for the first time, check to make sure that you have the following accessories:

- PTR-200-PRL Automated Polyimide Recoater with Linear Proof Tester
- 12.0V Power supply (PSU)
- AC power cord
- DC power cable
- RS-232 communication cable
- Fittings kit
- Tool kit containing:
  - 1 oz. bottle HD MicroSystems PI2525 Polyimide Recoat Material
  - 1 oz. spare bottle
  - Cotton swabs
  - 5/64” Allen key
  - 3/32” Allen key
  - 0.035” Allen key
- External vacuum pump with vacuum line
- PTR-200-CX-PRL Handset Controller

If you are missing any of the above or need replacements, please contact Vytran.

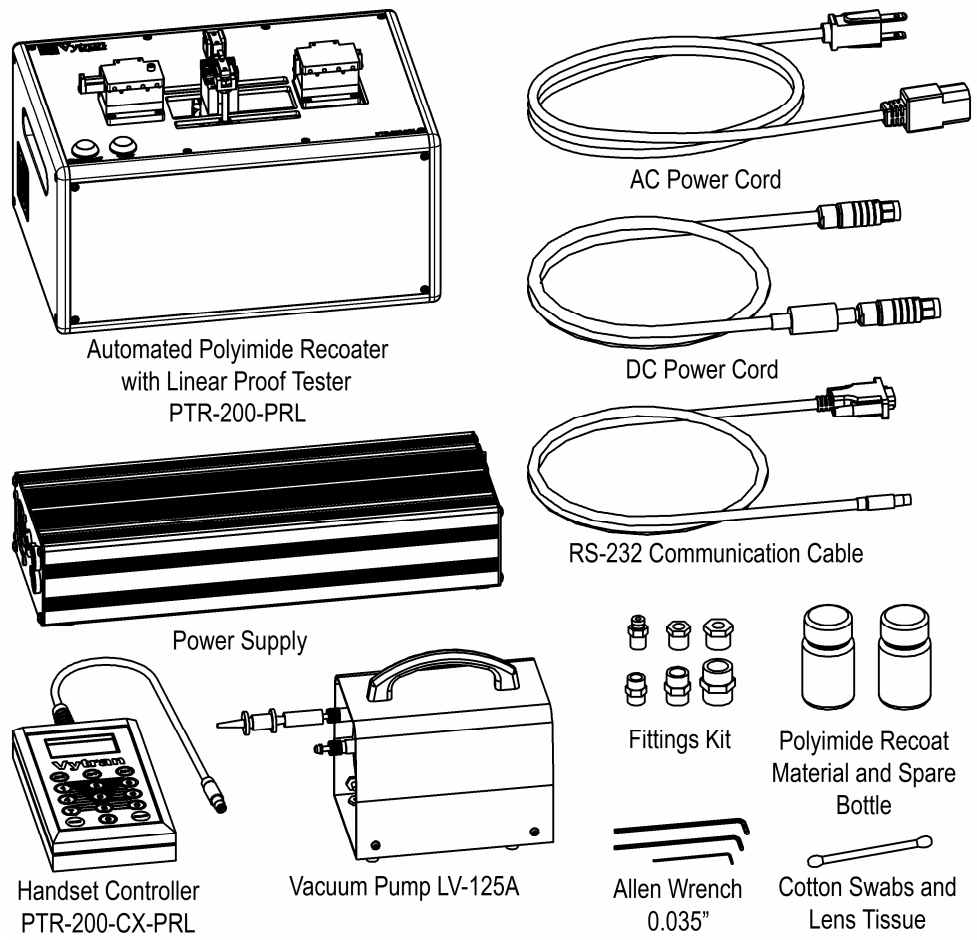


Figure 1: System Components

1.2 Powering Up

The PTR-200-PRL Power Supply Unit (PSU) accepts an AC input of 90-260 VAC; 47-63 Hz. Connect both the AC power cord and the DC power cable to the external Power Supply. Connect the Handset Controller and the DC power cable to the PTR-200-PRL.

Turn on the power supply and then turn on the PTR-200-PRL using the ON/OFF rocker switch located on the back of the recoater. The PTR-200-PRL will run an initialization process that includes homing the recoat die and tensioning motors and operating the recoat die (close/open). During the initialization process, the Handset Controller will display the status of the system. Once the homing process is completed, the Handset Controller displays the Main Menu screen and the PTR-200-PRL is ready for recoating.

1.3 Shutting Down

To shut down the PTR-200-PRL:

1. Turn off the PTR-200-PRL using the on/off rocker switch located on the back of the recoater.
2. Turn off the power supply.

2 Controlling the PTR-200-PRL

The PTR-200-PRL is configured and controlled from Vytran's PRL-200-CX-PRL Handset Controller, which also provides feedback and status of the unit. If the operator does not need to change parameter settings or receive status prompts, the Handset Controller can be removed and the unit operated simply by pressing the blue RECOAT and TEST buttons.

The Handset Controller allows the user to interface with the unit and modify the settings. The Handset Controller is based on a three (3) menus:

- Main Menu
- Configuration Menu
- Options Menu

Each menu and its contents are described below.

2.1 Main Menu

The Main Menu displays the unit status. From this menu, press the "CFG" button to enter the Configuration Menu or press the "OPT" button to enter the Options Menu.

2.2 Configuration Menus

There are three (3) levels to the Configuration Menu. At level one the user can select from five (5) topics - Inject, Undercoat, Overcoat, Recoat Length, or Proof Test. Within each of these topics are the parameters which can be viewed and/or copied. Below is a description of the five (5) topics and each topics parameters.

2.2.1 Inject

Inject Rate (µl/sec): This parameter is the polyimide injection rate, in microliters per second, into the die. The optimum Inject Rate will be dependant on the polyimide material being used.

Undercoat Qty. (µl): This parameter is the quantity of polyimide material, in microliters, injected into the die for the first loop of the head (the undercoat). The optimum Undercoat Qty will be primarily dependant on the bare fiber diameter, die size, and the length of the recoat.

Overcoat Qty. (µl): This parameter is the quantity of polyimide material injected into the die, in microliters, after the first loop of the head. The optimum Overcoat Qty will be primarily dependant on the die size, and the length of the recoat.

2.2.2 Undercoat

Head Sweep Vel. (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the bare fiber diameter, die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

2.2.3 Overcoat

Number of Overcoats: This parameter is the number of loops the head will make. The optimum Number of Overcoats will be dependant on the polyimide thickness layer desired (which will be dependant on the undercoat layer thickness and the parameter settings for the overcoat(s)).

Head Sweep Vel (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Overlap Delta (mm): This parameter is the additional distance, in millimeters, the head will travel on each pass. This will effectively taper the transition from original polyimide to recoated polyimide.

2.2.4 Recoat Length

Recoat Length (mm): This parameter is the desired bare fiber length, in millimeters, to be recoated. The actual recoat length will be approximately 8 millimeters longer on each end in order to compensate for the width of the head and the fiber load position.

2.2.5 Proof Test

Proof Test Units: This menu allows the user to select the desired units for displaying the Proof Test Level. Unit selections are: Newtons, kpsi, and grams.

Proof Test Level (units): This parameter is the Proof Test Level, in units user selected, to be applied after the recoat has been completed.

Proof Test Rate (mm/sec) This parameter is the rate, in millimeters per second, at which the Proof Test Level will be applied. The optimum rate is that which achieves the desired proof test level within 3 - 5 seconds of load applying time.

2.3 Options Menu

From the Options Menu, various system level configuration parameters and functions can be edited or executed.

Recoat Tension (Newtons): This parameter is the tension, in Newtons, applied to the fiber prior to initiating a recoat. The PTR-200-PRL also monitors the tension during the recoat and will automatically abort if the tension varies significantly from the Recoat Tension. The auto abort is intended to protect both the die and fiber.

Heater Settle Time (msec): This parameter is the amount of time, in milliseconds, allowed for the heater to stabilize when changing temperatures.

Die Close Time (msec): This parameter is the amount of time, in milliseconds, allowed for the die to close prior to execution of the subsequent process.

Fiber Unload Time (msec): This parameter is the amount of time, in milliseconds, allowed for the operator to unload the fiber prior to the PTR-200-PRL performing a system reset.

Inject to Die Qty (µL) This option is the quantity of polyimide material, in microliters, which will be injected into the die upon entering the quantity. This option is intended for use when changing materials or purging the system prior to storage.

Head to Home: This option performs a homing of the head and is useful as a diagnostic tool.

Tension Home: This option performs a homing of the proof test load cell and is useful as a diagnostic tool.

Move Head to Start: This option performs a movement of the head to the start position. The start position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Move Head to Stop: This option performs a movement of the head to the stop position. The stop position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Recoat Request State: This option enables or disables the request to input a recoat length each time the process is run. This option is primarily used when the length to be recoated varies significantly from recoat to recoat.

Set/Run Purge Cycles: This option is the number of recoat pump purge cycles that will be run upon entering the quantity.

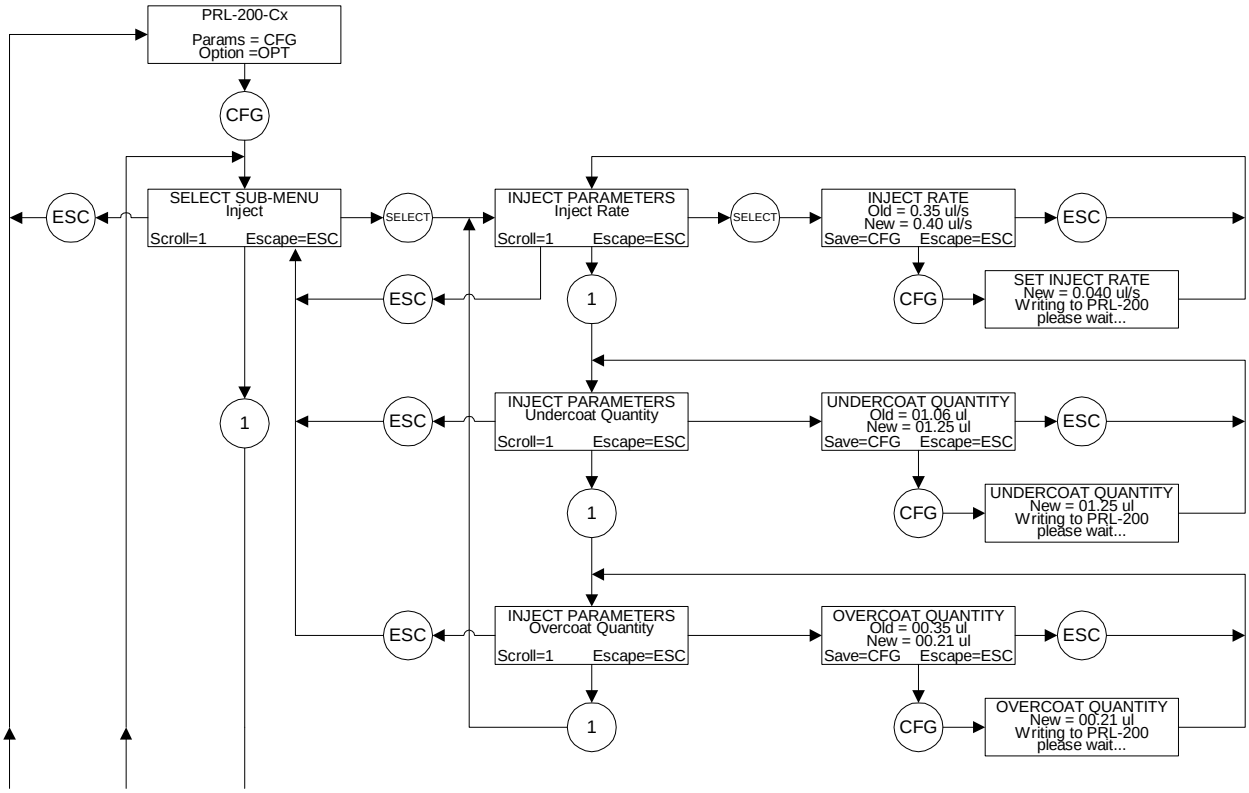
Recoat Tension This option is the amount of tension that will be applied to the fiber prior to the recoating.

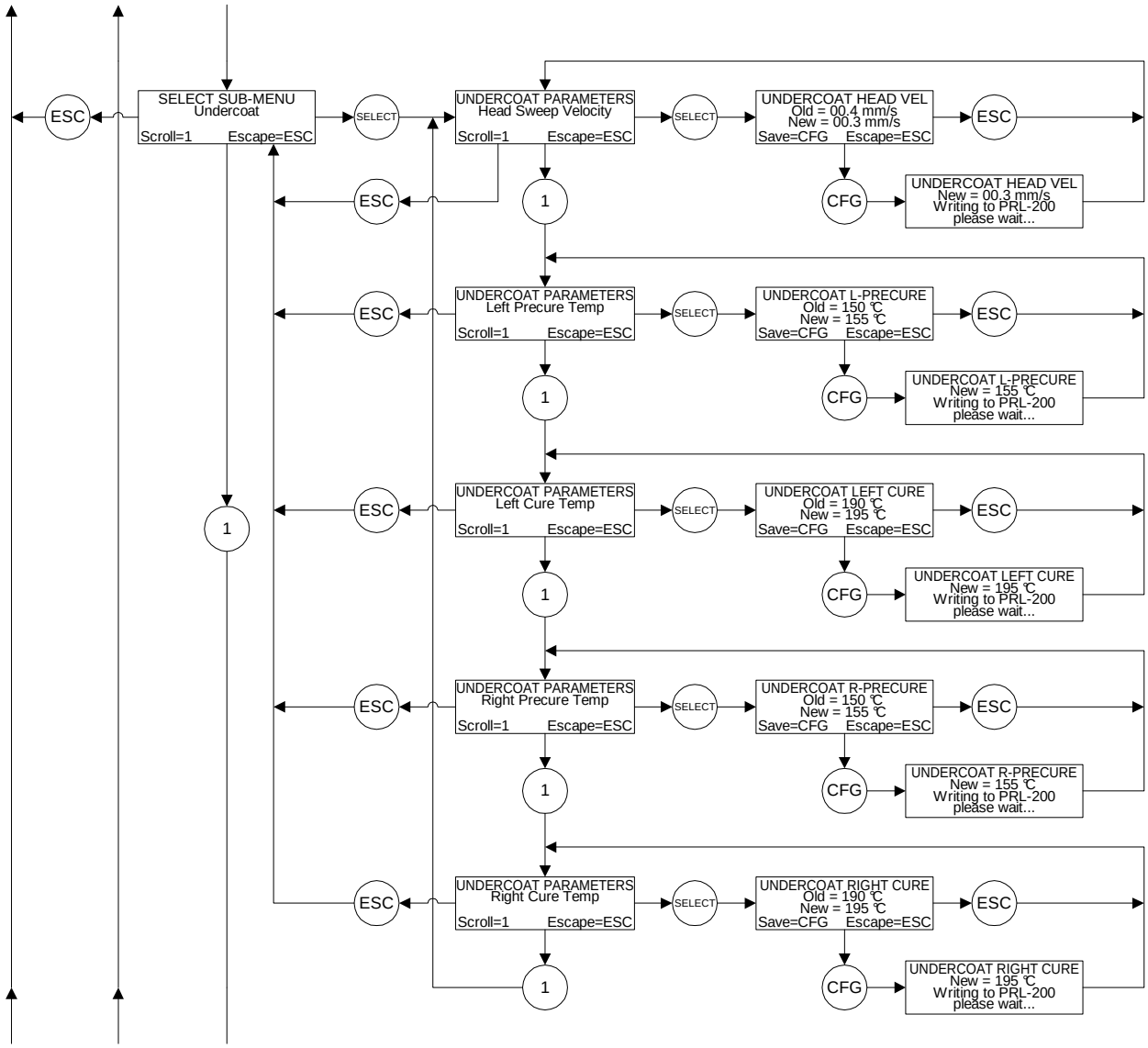
2.4 Parameter Limits

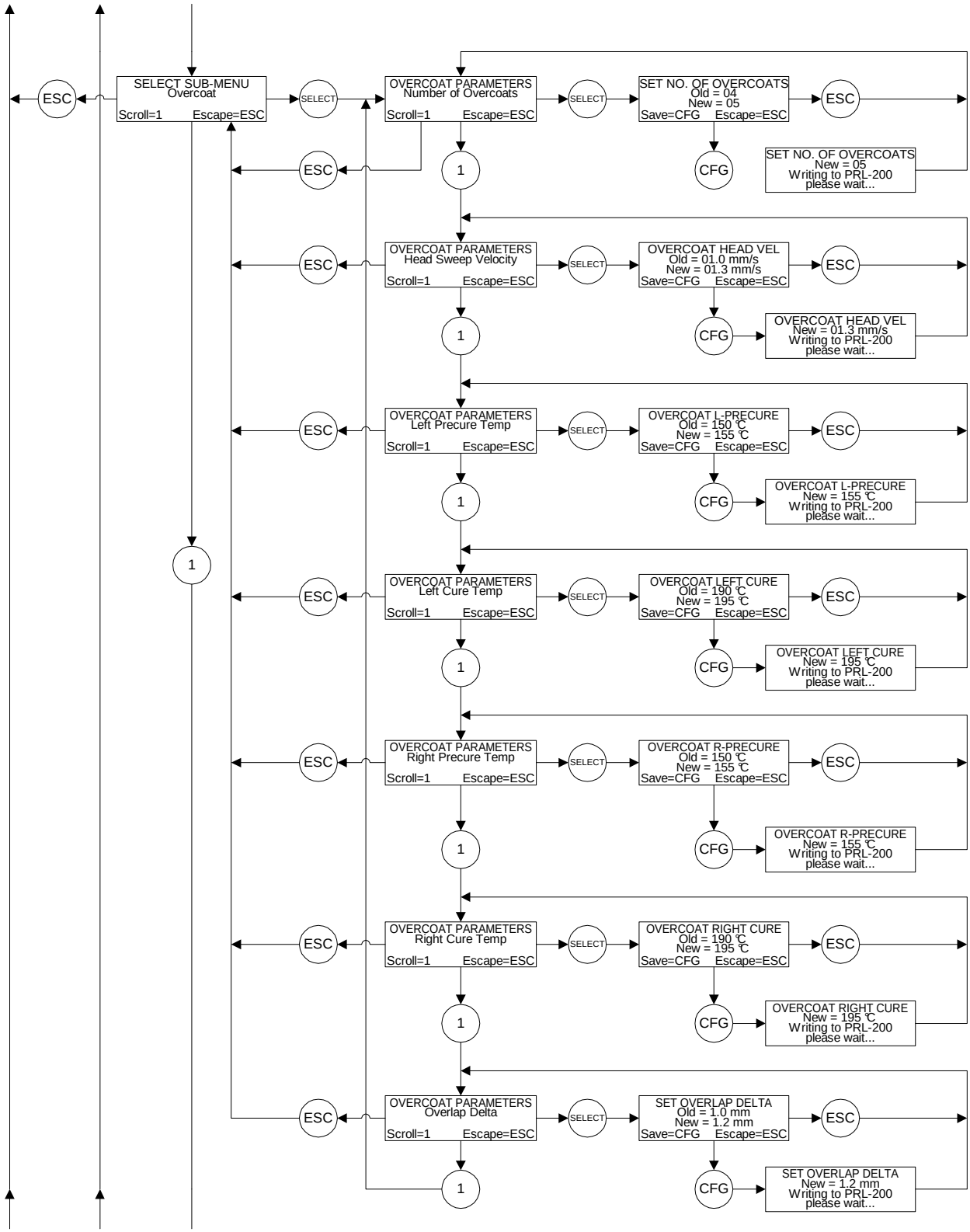
Parameter	Min	Max
Inject Rate (µL/sec)	0.01	2.00
Undercoat Qty (µL)	0.01	10.00
Overcoat Qty (µL)	0.01	10.00
Undercoat Head Sweep Vel (mm/sec)	0.01	20.00
Undercoat Left Precure Temp (℃)	100	200
Undercoat Left Cure Temp (℃)	100	300
Undercoat Right Precure Temp (℃)	100	200
Undercoat Right Cure Temp (℃)	100	300
Number of Overcoats	1	10
Overcoat Head Sweep Vel (mm/sec)	0.01	20.00
Overcoat Left Precure Temp (℃)	100	200
Overcoat Left Cure Temp (℃)	100	300
Overcoat Right Precure Temp (℃)	100	200
Overcoat Right Cure Temp (℃)	100	300
Overlap Delta (mm)	100	200
Recoat Length (mm)	0	2
Proof Test Level (Newtons)	0	20
Proof Test Rate (mm/sec)	0.1	5.0
Recoat Tension (Newtons)	2	10
Heater Stabilize Time (msec)	1	10000
Die Close Time (msec)	250	2500
Fiber Unload Time (msec)	5000	30000
Heater Stabilize Time (msec)	1	10000
Inject to Die Qty (µL)	1	100

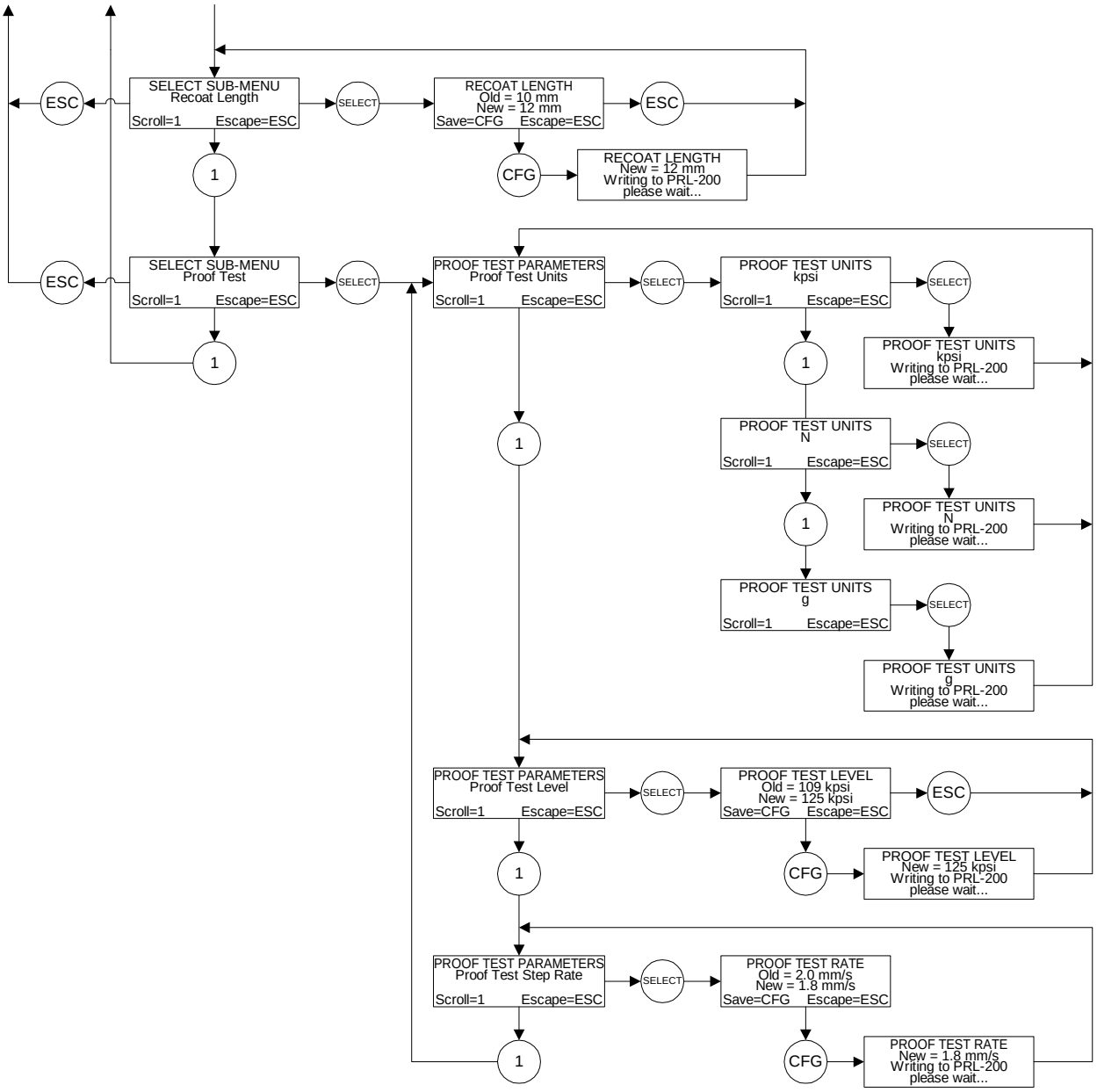
2.5 Configuration Menu Flow Chart

This flowchart is a guide for navigating through the Configuration Menu, and shows the display prompts and button key presses for viewing and editing the Configuration Parameters.



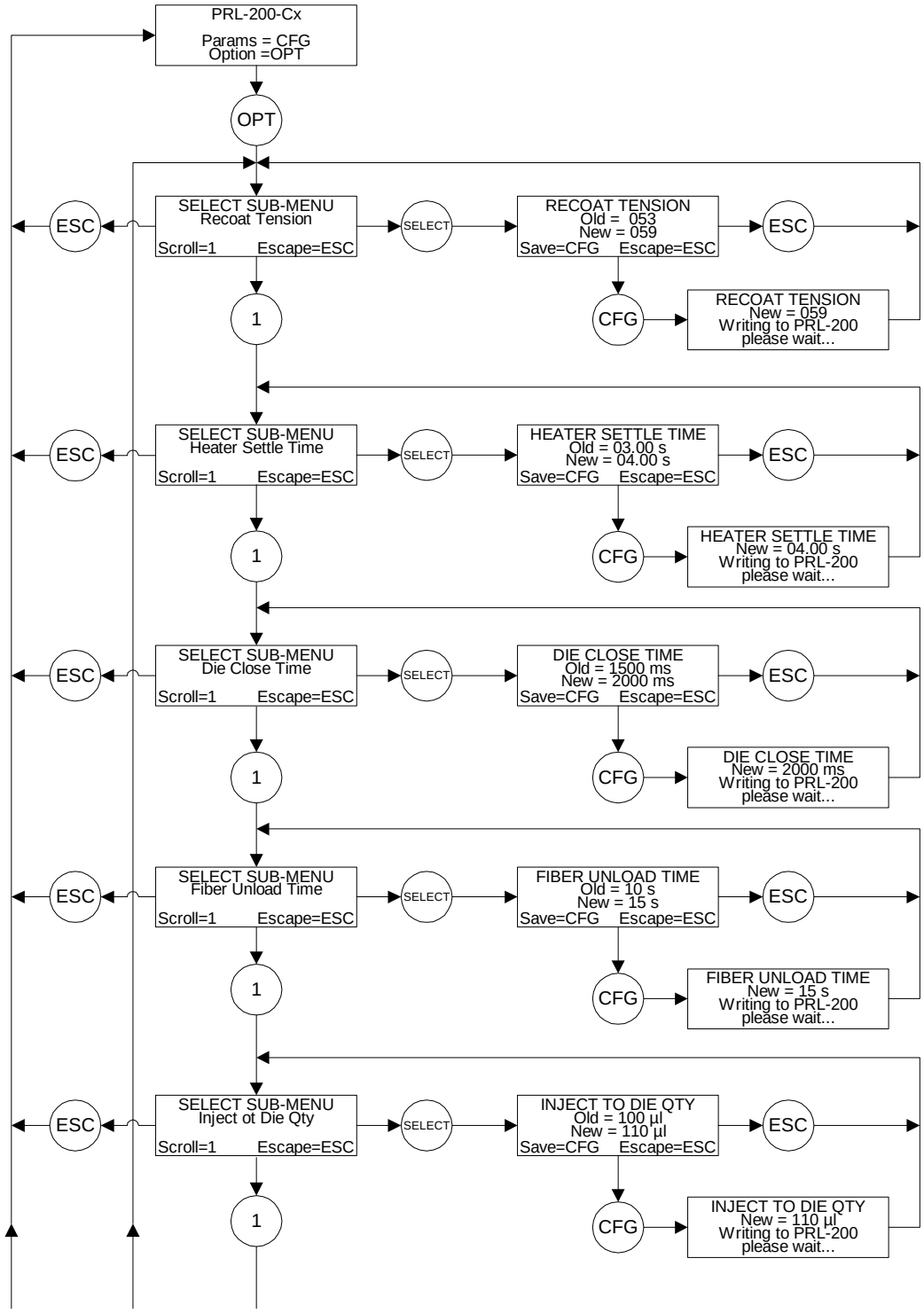

ESC
SELECT SUB-MENU
Undercoat
Scroll=1 Escape=ESC
SELECT
UNDERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
SELECT
UNDERCOAT HEAD VEL
Old = 00.4 mm/s
New = 00.3 mm/s
Save=CFG Escape=ESC
ESC
CFG
UNDERCOAT HEAD VEL
New = 00.3 mm/s
Writing to PRL-200
please wait...
1
UNDERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
SELECT
UNDERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
UNDERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...

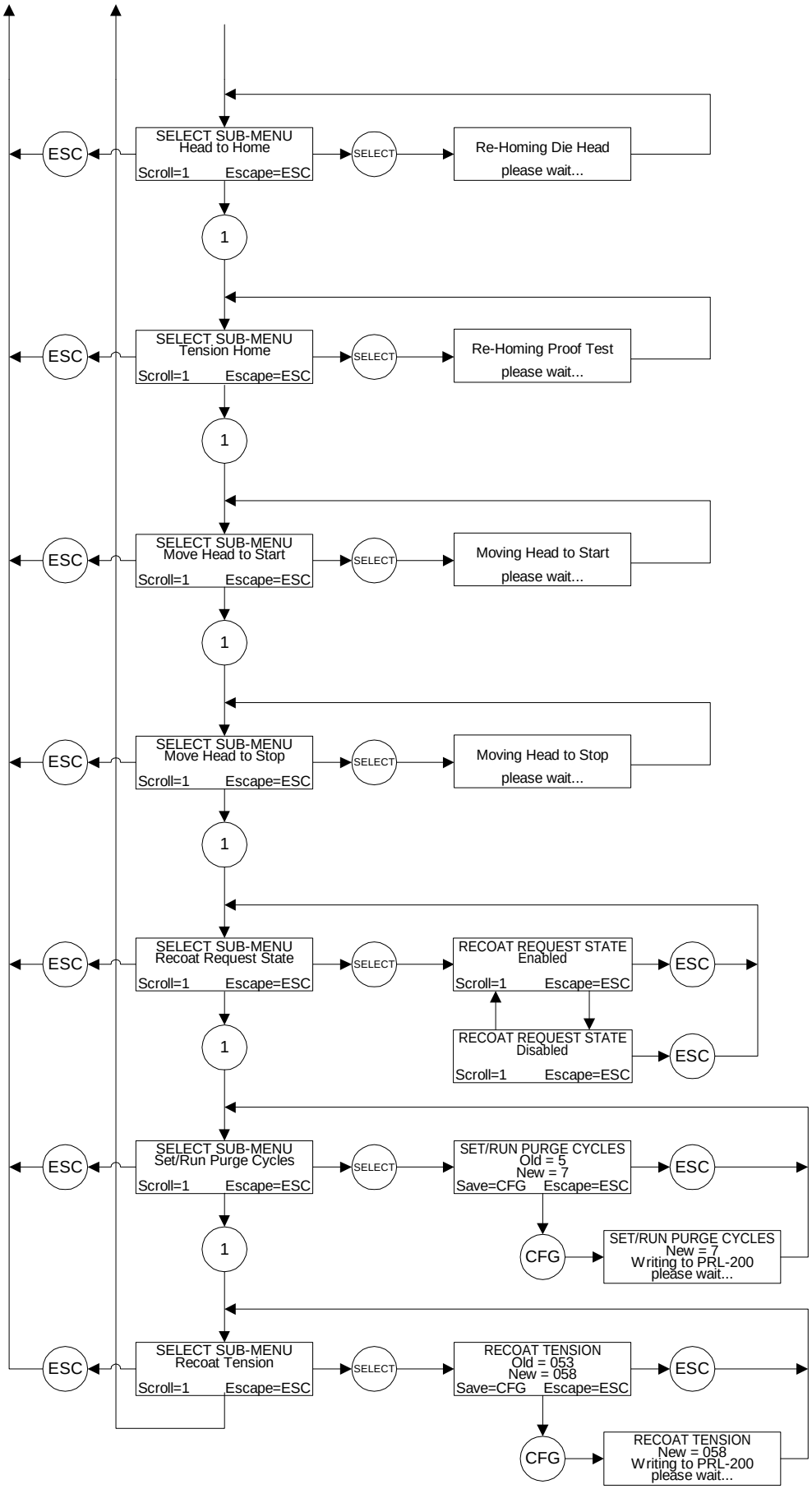

SELECT SUB-MENU
Overcoat
Scroll=1 Escape=ESC
ESC
SELECT
OVERCOAT PARAMETERS
Number of Overcoats
Scroll=1 Escape=ESC
SET NO. OF OVERCOATS
Old = 04
New = 05
Save=CFG Escape=ESC
CFG
SET NO. OF OVERCOATS
New = 05
Writing to PRL-200
please wait...
1
OVERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
OVERCOAT HEAD VEL
Old = 01.0 mm/s
New = 01.3 mm/s
Save=CFG Escape=ESC
OVERCOAT HEAD VEL
New = 01.3 mm/s
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
OVERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
OVERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
OVERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
OVERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Overlap Delta
Scroll=1 Escape=ESC
SET OVERLAP DELTA
Old = 1.0 mm
New = 1.2 mm
Save=CFG Escape=ESC
SET OVERLAP DELTA
New = 1.2 mm
Writing to PRL-200
please wait...


ESC
SELECT SUB-MENU
Recoat Length
Scroll=1 Escape=ESC
SELECT
RECOAT LENGTH
Old = 10 mm
New = 12 mm
Save=CFG Escape=ESC
ESC
1
CFG
RECOAT LENGTH
New = 12 mm
Writing to PRL-200
please wait...
ESC
SELECT SUB-MENU
Proof Test
Scroll=1 Escape=ESC
SELECT
PROOF TEST PARAMETERS
Proof Test Units
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
kpsi
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
kpsi
Writing to PRL-200
please wait...
1
PROOF TEST UNITS
N
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
N
Writing to PRL-200
please wait...
PROOF TEST UNITS
g
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
g
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Level
Scroll=1 Escape=ESC
SELECT
PROOF TEST LEVEL
Old = 109 kpsi
New = 125 kpsi
Save=CFG Escape=ESC
ESC
1
CFG
PROOF TEST LEVEL
New = 125 kpsi
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Step Rate
Scroll=1 Escape=ESC
SELECT
PROOF TEST RATE
Old = 2.0 mm/s
New = 1.8 mm/s
Save=CFG Escape=ESC
1
CFG
PROOF TEST RATE
New = 1.8 mm/s
Writing to PRL-200
please wait...

2.6 Options Menu Flowchart

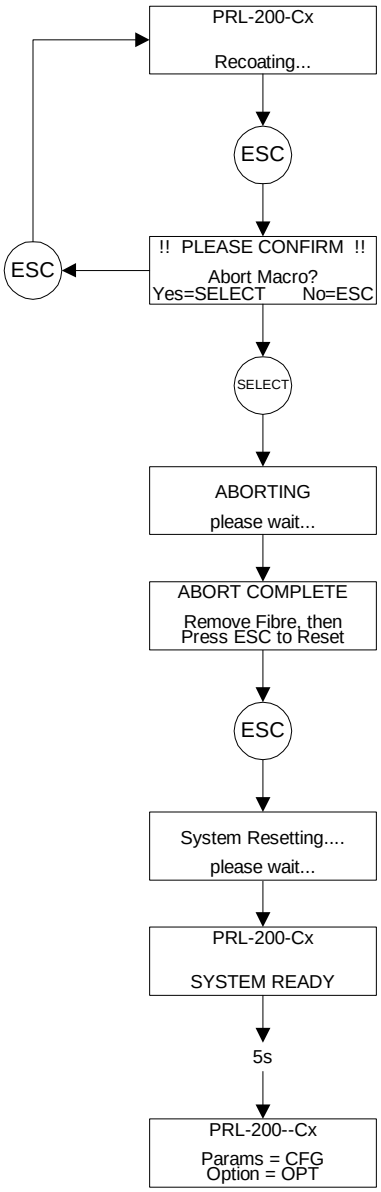
This flowchart is a guide for navigating through the Options Menu, and shows the display prompts and button key presses for editing parameters and executing system related functions.




SELECT SUB-MENU
Head to Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Die Head
please wait...
ESC
1
SELECT SUB-MENU
Tension Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Proof Test
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Start
Scroll=1 Escape=ESC
SELECT
Moving Head to Start
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Stop
Scroll=1 Escape=ESC
SELECT
Moving Head to Stop
please wait...
ESC
1
SELECT SUB-MENU
Recoat Request State
Scroll=1 Escape=ESC
SELECT
RECOAT REQUEST STATE
Enabled
Scroll=1 Escape=ESC
ESC
RECOAT REQUEST STATE
Disabled
Scroll=1 Escape=ESC
ESC
1
SELECT SUB-MENU
Set/Run Purge Cycles
Scroll=1 Escape=ESC
SELECT
SET/RUN PURGE CYCLES
Old = 5
New = 7
Save=CFG Escape=ESC
ESC
CFG
SET/RUN PURGE CYCLES
New = 7
Writing to PRL-200
please wait...
1
SELECT SUB-MENU
Recoat Tension
Scroll=1 Escape=ESC
SELECT
RECOAT TENSION
Old = 053
New = 058
Save=CFG Escape=ESC
ESC
CFG
RECOAT TENSION
New = 058
Writing to PRL-200
please wait...
ESC

2.7 Abort Flowchart

Even after the recoat process has been initiated it is possible to abort the process if required. The Abort Flowchart shows the display prompts and button key presses to abort a recoat process.



3 Recoat Injection System

The PTR-200-PRL has an automatic recoat injection pump fitted inside the unit. The pump is based on an automated syringe and distribution valve that can select one of three ports (Fill, Purge, or Inject) through which it can either draw or inject recoat material (see Figure 3). A bottle containing recoat material is installed directly on the pump, with the pump "Fill" tube inserted into the bottom of the bottle. A "Purge" tube runs from the pump to the top of the recoat bottle, and is used for cycling material back into the bottle. An "Inject" tube runs from the pump to the inject port of the die, which is located in the center of the lower right die. Once all air is purged from the injection system, the pump provides very accurate control of the volume and velocity of recoat material injection.

The recommended recoat material for use in the PTR-200-PRL is Pyralin PI2525, which is manufactured by HD MicroSystems. This is a fast imidizing at lower temperature coating. Do not attempt to use alternate recoat materials without first consulting Vytran on compatibility with the PRL.

Note: Pyralin PI2525 recoat material does have a limited shelf life of approximately 24 months from date of manufacture when stored at 0 to 18 degrees Centigrade. PI2525 is stable at room temperature (21 degrees Centigrade) for approximately 4 weeks with no significant change in properties. Using material that has passed its expiration date may cause both pump performance and recoat quality issues.

3.1 Priming the Injection System

It is very important to remove all air from the recoat injection system prior to performing a recoat. When operating the system for the first time, the pump must be filled with recoat material and cleared of all air in the pump and tubing. In order to clear the inject tube, recoat material must be injected out through the mold inject port and collected and disposed of. Make sure to have cotton swabs and NMP (1-Methyl-2-pyrrolidinone) available for this purpose prior to starting this procedure. NMP is the recommended solvent for cleaning uncured polyimide recoat material.

WARNING: Polyimide recoat materials can be hazardous to your health if not handled properly. Read the Material Safety Data Sheet provided in Appendix X, and make sure to follow all precautionary guidelines when working with this material.

To prime the recoat injection system:

1. Turn off power to the PTR-200-PRL.
2. Remove the front plate of the PTR-200-PRL by using the 3/32 Allen wrench provided in the tool kit to remove the four (4) black socket-head cap screws located at the corners of the plate.
3. The recoat pump is located on the left side of the PTR-200-PRL as shown in Figure 2. Unscrew the brown recoat bottle located at the front of the pump and remove by angling out through the front opening. The red Fill tube will flex to allow removal.
4. For new systems, replace the empty recoat bottle shipped with the unit with a new bottle of recoat material. For systems that have previously been run with recoat material, the recoat injection system should be flushed clean prior to adding new material (see 5.5).
5. Screw the new recoat bottle into place and replace the front panel and the four (4) socket head cap screws.

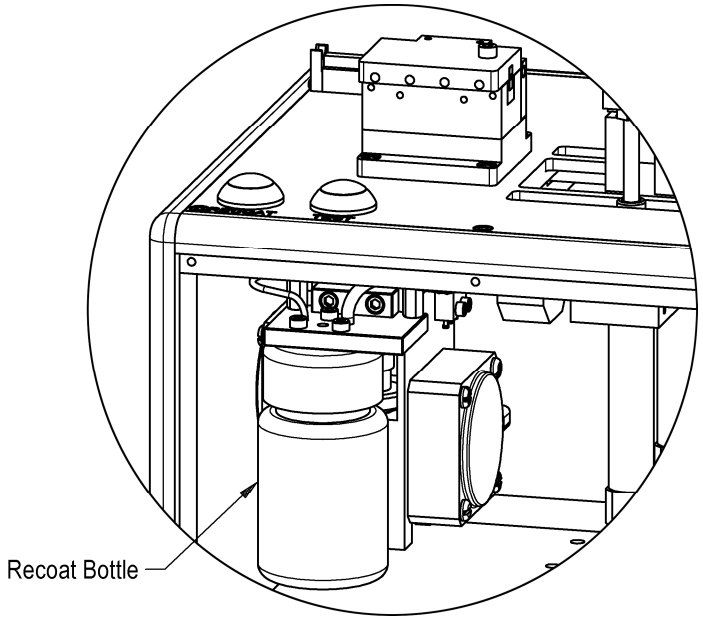


Figure 2: Recoat Bottle Access

6. Turn on power to the PRL-200 and wait for the system to initialize.
7. Execute five (5) Purge cycles (Options menu on Handset Controller). Each purge cycle will draw 100 microliters of recoat material from the bottom of the recoat bottle through the red Fill tube and inject material back into the top of the recoat bottle through the green Purge tube (see Figure 3). Five (5) Purge cycles are required to fill the pump with recoat material and force any air out of the pump system. This will take approximately 15 minutes to complete.
8. After the pump has completed its Purge cycles, the Inject tube that runs from the pump to the die must also be filled with recoat material and purged of air. Have cotton swabs and cleaning solution (NMP) available prior to proceeding.

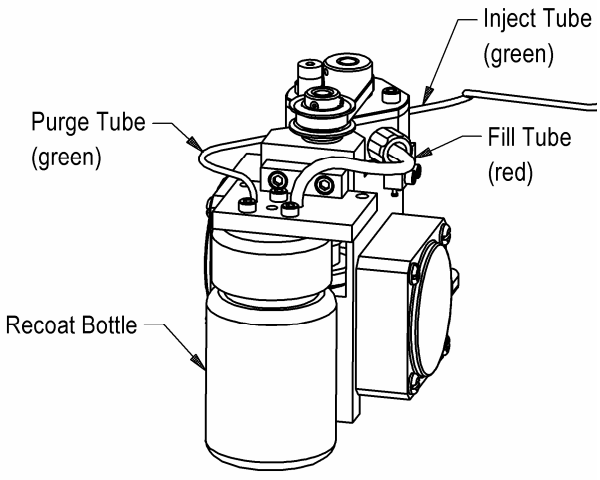


Figure 3: Recoat Material Flow

9. Set the Inject to Die Qty to 100µl (Options menu on Handset Controller).
10. Execute the inject command (press “Select” on the Handset Controller).
11. Watch for recoat material to emerge from the die inject port located at the center of the center of the bottom right die (see Figure 5). Make sure to collect the recoat material with a cotton swab as it comes out of the die injection port. Do not allow recoat material to run down between the die.
12. Execute three (3) additional “Inject 100” sequences to purge air completely from the inject tube. **Note:** Because the injection pump holds 100µl of recoat material, there will be a delay of approximately one minute between the second and third inject sequences while the pump refills.

13. After purging the inject tube, the recoat material should run freely from the die without bubbles. If bubbles are still present, run additional inject sequences.
14. Once the pump and the inject tube are purged, clean the die of all excess recoat material (see 3.2).

Note: Because the syringe in the recoat pump is mounted vertically, it is possible that an air bubble may still be trapped at the tip of the syringe after the above priming process. This air bubble will very slowly rise to the top of the syringe after which time it can be purged out. It is therefore recommended that at least one (1) additional Purge cycle is run the next day after the initial priming of the system.

3.2 Cleaning the Die

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP (1-Methyl-2-pyrrolidinone). NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

4 Recoat and Proof Test Process

4.1 The Polyimide Recoat Process

The PTR-200-PRL utilizes two Fiber Holding Blocks (FHB's) to securely clamp and position the fiber prior to recoating. The right-hand FHB has a linear drive mechanism for applying tension to the fiber. A load cell is incorporated into the linear drive mechanism for monitoring recoat tension. Once the fiber is positioned and securely clamped in the FHB's, pressing the recoat button will initiate an automated recoat process. The right-hand FHB will move to the right until the Recoat Tension is reached. With the fiber held under tension, the right die is closed and the Undercoat Quantity of material is injected into the die and the right heater is set to the Precure Temperature. The recoat head will move to the left depositing material while the right heater will precure the material. Upon reaching the appropriate length, the left die will close and additional recoat material will be injected into the die. The left heater is set to the Precure Temperature and the right heater to the Cure Temperature. The recoat head moves to the right depositing material while the right heater fully cures the previously precured material and the left heater precures the newly deposited material. Returning to the start position is defined as one loop or pass as the material initially deposited has been fully imidized.

This process is repeated until the desired recoat thickness has been achieved. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The recoated fiber is unloaded and the unit resets itself in preparation for the next recoat.

4.2 The Fiber Holding Blocks, V-Grooves, and Inserts

The FHBs are designed to accommodate a range of fiber buffer and cladding sizes through the use of changeable, bottom, FHB inserts. The top insert is spring loaded and does not require any change for 80 or 125 micron fibers. The bottom inserts are V-groove, and incorporate vacuum feed to assist in loading the fiber. The V-groove provides mechanical alignment to the recoat die. V-groove inserts are labeled according to clamping diameter in microns. Beyond the V-groove inserts are rubber inserts. The rubber inserts provide the clamping force and surface area required for tensioning and tension testing.

4.3 Stripped Fiber Requirements

The fiber to be recoated should be free of debris and have a smooth, continuous transition in the jacket strip region. The jacket interface should not extend beyond the original coating diameter.

4.4 Loading

To load the fiber for recoating:

1. If the Fiber Holding Block (FHB) tops are closed, open the FHB tops (see Figure 4). The head will move to the start position and the internal vacuum pump will turn on to aid in loading the fibers.

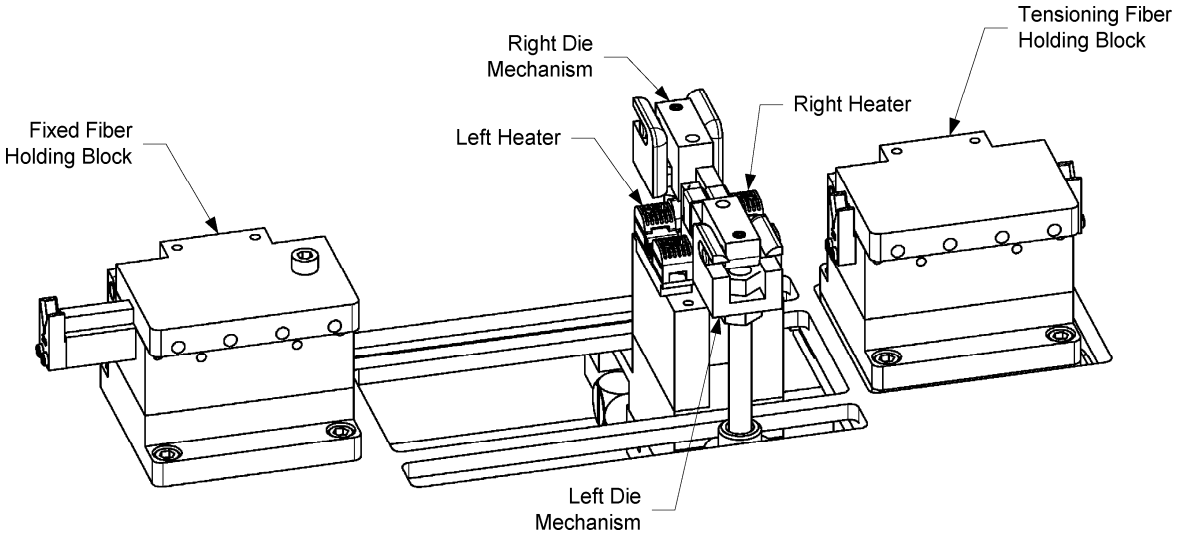


Figure 4: Recoat and Proof Test Components

2. If the FHB tops are open, the load fiber process can be initiated, by either pressing the blue RECOAT button or by closing and reopening both left and right FHB tops.
3. Check that the correct FHB inserts (top and bottom) are installed and that they are free from debris. Position the fiber in the left-hand FHB V-groove, with the stripped section to the left of the left heater. Lower the fiber into the right-hand FHB V-groove. The FHB vacuum should hold the fiber in place.
4. Manually position the fiber in the FHBs so that the right jacket interface is in line with the left edge of the recoat head (see Figure 5). Verify that the fiber is centered in the left and right die.
   Note: Damage to the die may occur if the fiber is not centered in the die when they close.

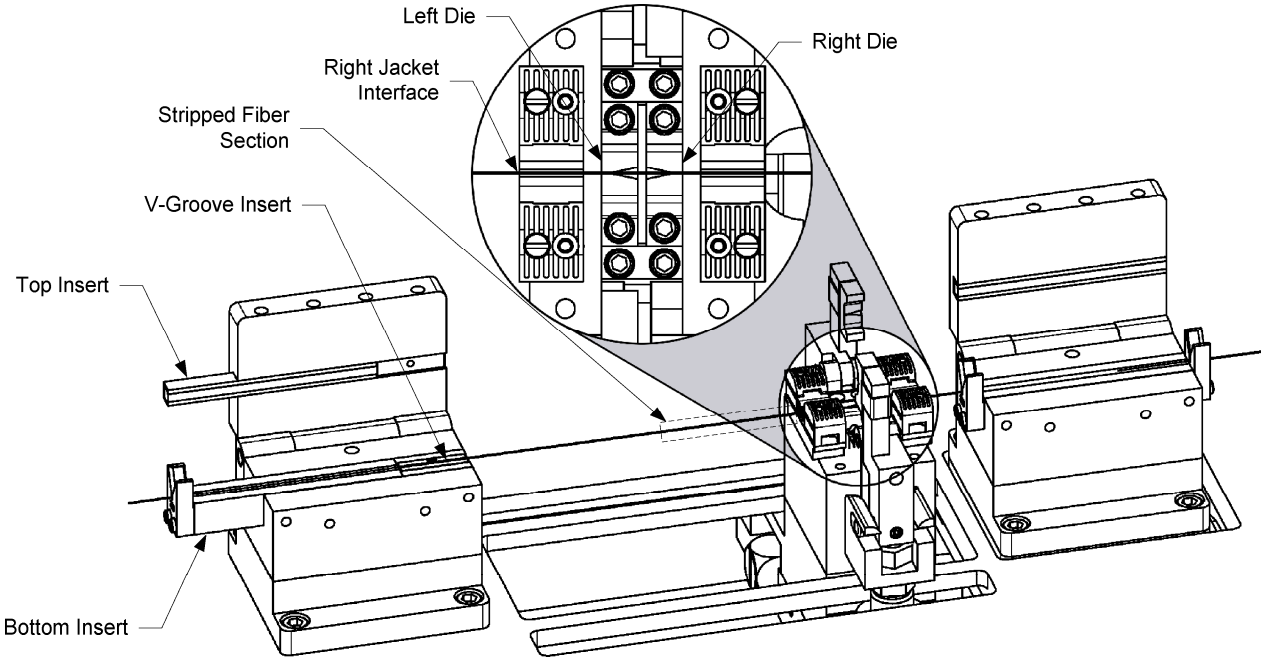


Figure 5: Fiber Position

5. Gently close the FHB lids. This will capture the fiber and turn off the external vacuum pump.
6. The fiber is now ready to be recoated.

4.5 Recoating

To recoat the fiber:

1. Visually confirm that the fiber is loaded properly, if not reload the fiber.
2. Initiate the recoat process by pressing the blue RECOAT button on the unit or the START button on the Handset Controller. The recoat process is fully automated as follows:
   a. The right-hand FHB will begin moving to the right, applying tension to the fiber.
   b. Once the Recoat Tension is reached, the right-hand block will stop moving.
   c. The handset controller will await input from the operator verifying the correct fiber position in the die. Upon confirming the correct fiber position to the handset the process will continue.
   d. The right die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Precure Temp and the head will pause for the Heater Stabilize Time.
   e. The head will move to the left at the Undercoat Head Sweep Vel depositing material while the right die evaporates the volatiles.
   f. Upon reaching the appropriate length, the left die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Cure Temp, the left heater will be set to the Left Precure Temp and the head will pause for the Heater Stabilize Time.
   g. The head will move to the right at the Undercoat Head Sweep Vel depositing material. The right heater will be imidizing the previously precured material while the left heater is evaporating the volatiles from the freshly deposited material. The head will complete at the initial start position plus the overlap delta. This is defined as one loop or pass as the material initially deposited has been fully cured.
   h. The process is repeated (using the Overcoat parameters) until the desired thickness has been achieved by the Number of Overcoats (loops or passes).
   i. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The tension is applied to the specified Level at the specified Rate and released.
3. Proceed to Unloading the Fiber.

4.6 Proof Testing

The Peak Tension should be set to ensure that the recoat meets the minimum strength requirement for its intended application. If using units of tension (kpsi), make sure to enter the correct fiber diameter (e.g. 125 microns) and not the coating diameter.

WARNING: Always wear safety glasses when proof testing fiber. The fiber under test can shatter and send glass particles flying.

To perform a Proof Test:

1. Load the fiber in the fiber holding blocks (see 4.4).
2. Check that the proof test parameters are set correctly.
3. Press the “TEST” button on the PTR-200-PRL.
4. Upon completion of the Proof Test, raise the fiber holding block tops and remove the proof tested fiber.

Note: It is not possible to abort a Proof Test once it has been started.

4.7 Unloading

To unload the fiber after recoating:

1. After the fiber is recoated, the external vacuum pump will turn on to assist in holding the fiber during the unloading process.
2. Hold the fiber securely and lift the left-hand FHB lid. The fiber will be free to move after lifting the lid, so it is important to keep the fiber secured (the V-groove extension is ideal for this).
3. Carefully lift while guiding the recoated fiber though the heaters.
   Note: Raising the FHB top will re-initiate the vacuum pump timer for an additional 15 seconds, after which time the unit will perform a homing routine. The recoated fiber should be removed within this 15 second window.
4. Raise the right-hand FHB top and remove the recoated fiber.
5. Check that no debris is left behind in the FHB V-grooves or on the top clamping surfaces.

Note: After a recoat has been removed (or even if there is a recoat failure), an automatic homing routine will be run 15 seconds after the left FHB top is raised. This homing routine will re-set the position of the right-hand FHB, and the head. The system waits for the FHB top to be opened to ensure that the fiber is being unloaded. If both FHB tops are closed prior to the 15-second time-out, the homing routine will be run immediately.

If the PTR-200-PRL homing process is interrupted or fails, all system functionality is disabled to prevent possible damage to the equipment. Remove any fiber from the FHB's and cycle the power OFF then ON. The PTR-200-PRL will initialize and attempt to run the homing process again. If any further difficulty is experienced, contact Vytran Technical Support for assistance.

5 Maintenance

5.1 Planned Maintenance

The PTR-200-PRL is designed for a production environment to give trouble-free operation provided normal planned maintenance is adhered to. Maintenance and repair procedures should be performed only by trained personnel. Improper service and/or repair could result in the safety features being disabled and can also lead to damage that will not be covered under warranty.

Planned Maintenance Schedule

	Every Shift	Daily	Monthly	12 Months
Inspect / Clean Fiber Holding Blocks[1]	√	√	√	√
Inspect / Clean die[2]	√	√	√	√
Flush recoat System[2] (as needed)			√	√
Purge Recoat System[2] (as needed)			√	√
Replace Recoat Material[2] (as needed)			√	√
Check Load Cell Calibration / Re-Cal[3]				√

[1] Maintenance operations can be performed by the operator.
[2] Maintenance operation can be performed by trained maintenance personnel.
[3] Vytran certified technician only.

5.2 Inspecting the Fiber Holding Blocks

The Fiber Holding Blocks (FHB's) should be inspected daily for debris and/or damage, which may prevent the tops from closing properly and the fiber from being clamped fully. It is particularly important to make sure that the bottom insert V-groove surfaces and the top insert clamping surfaces are free of debris and oils. This will help to ensure that the fiber will not break or slip during tensioning. Cleaning the metal insert surfaces is best accomplished using a cotton-tipped applicator wetted with acetone or alcohol. For embedded debris, a soft cleaning brush may be used. Cleaning the rubber insert surfaces is best accomplished using a cotton-tipped applicator wetted with alcohol. Do not use acetone as this will dry out the rubber causing it to become brittle and crack.

5.3 Inspecting and Cleaning the Die

The die of the recoat head should be inspected daily for debris and/or damage which may result in sub-optimum recoat performance.

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP. NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If

the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

5.4 Load Cell Calibration

The load cell calibration should be checked every twelve (12) months to ensure that accurate recoat and proof test tension is applied to the fiber. This task must be performed by a Vytran certified technician.

5.5 Flush Recoat System

The recoat injection system should be flushed clean every 1 month as part of the recoat material replacement procedure. Before flushing the system, make sure to have cotton tipped applicators and cleaning solution (NMP) available prior to proceeding. To flush the system:

1. Remove the internal recoat bottle and clean all exposed tubing and fittings with NMP.
2. Install a bottle filled 1/4 full with NMP on the pump.
3. Run 5 purge cycles.
4. Remove the bottle, dispose of contaminated NMP. Refill ¼ full with clean NMP and reinstall.
5. Run 5 more purge cycles.
6. Run several inject 100 sequences until NMP runs clear from the die inject port.
   Note: Make sure to collect material as it comes out of the die inject port. Do not allow material to run between the left and right die.
7. Remove the bottle of NMP from the pump.
8. Run several more inject 100 sequences until no more NMP exits the die injection port.
9. Run one purge cycle. Make sure to collect any NMP that comes out of the green purge tube at the top of the bottle fitting.
10. Clean all bottle tubing and fittings with NMP.
11. Install an empty bottle for storage, or a new bottle ¾ filled with fresh recoat material for use. If installing fresh material, proceed to 3.1 Priming the Injection System.

5.6 Purge Recoat System

The purge cycle is a process of emptying the recoat material of the Automatic Injector back into the recoat material bottle and refilling the pump with fresh recoat material drawn from the bottom of the bottle. Running 5 purge cycles is sufficient to entirely fill the pump with fresh recoat material.

If the system has not been used for an extended period (over 1 week), it is recommended that a single purge cycle be run to fill the pump with fresh material.

5.7 Replacing Recoat Material

Recoat material has a finite shelf life and should be replaced every 1 month. To replace the recoat material, first flush the system as outlined in Flush Recoat System (above). Once the system is flushed, fill a clean recoat bottle ¾ full with fresh recoat material and follow the procedures in Purge Recoat System (above).

Note: The one-ounce internal recoat bottle holds approximately 30,000 micro-liters when full. The number of recoats per fill and the approximate time before the material needs to be refilled can be determined based on the volume of material per recoat and the number of recoats per month. For most applications the material will need to be replaced before it runs out. Even if fresh material is added to the internal bottle prior to the Planed Maintenance schedule, the material should still be replaced since mixing of the old and new materials occurs.

5.8 Replacing a Heater

If a heater is sufficiently damaged such that a quality recoat cannot be performed, then replacement is required. The left and right heaters are identical and DO NOT need to be replaced as a pair. The heaters are comprised of a body which houses a graphite filament. When installed in the PTR-200-PRL, the heater is held in place by electrical contacts at the base of the heater body. This is a pin/socket contact compression fit.

To remove the heater:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die sets. This will allow additional access to the heaters.
3. Grab the body of the filament and using a front to back rocking motion, gently lift the filament body (pins) out of the contacts.

To install the heater:

1. Inspect the new heater for any deformation of the filament. If deformation is noted do not install nor use the heater.
2. Hold the filament body (not the graphite filament) and locate the pins into the electrical sockets.
3. To fully seat the heater, gently push down on the electrical contacts (located on the top of the heater).

5.9 Changing the Fiber Holding Block V-Grooves

To change a FHB V-groove insert:

1. Loosen the two (2) set screws accessible from the front of the FHB base using the 0.035” Allen key included in the LDC-200 tool kit. Do NOT remove the set screws completely; one full turn counter-clockwise should be sufficient to release the insert.
2. Remove the FHB V-groove and replace with the desired size. For dual sided inserts, the label for the desired size should face right side up and be readable. Make sure the vacuum feed ports are clear of debris by holding the insert up to a light and checking from behind to make sure light passes each of the ports. Clean if necessary.
3. Make sure the new insert is fully seated and flush with the inside face of the FHB.
   Note: The inside face of the FHB is the side closest to the head.
4. Re-tighten the set screws until they are snug. Do NOT over tighten.

5.10 Replacing the Die

If the die are sufficiently damage such that a quality recoat cannot be performed, then replacement is required. The top and bottom die are a matched set and are replaced as a pair. The top die are spring loaded which enables a slight pivoting during closure, while the bottom die are fixed mounted to the head.

To replace the top die:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. The top die pivots about a center pin which is pressure loaded with two (2) small springs. Remove and retain the top die retainer clip for reuse. This will expose the springs. Using the die, gently compress the springs. This will allow a rotation of the die by ~45 degrees and a removal of the die from the clamp. Remove and retain the springs for reuse.
3. Locate and clean the new top die to be installed.
4. Insert the two (2) springs into the clamp. With the die rotated ~45 degrees, gently collapse the springs with the die. Align the die pin with the clamp and rotate the die to 0 degrees to install.
5. Reinstall the die retainer clip.

To replace the bottom left die (no inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Remove the die from the head.
3. Locate and clean the new top die to be installed.
4. Seat the new die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

To replace the bottom right die (with inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Gently begin to remove the die from the head. An inject tube will be attached to the die. This tube will limit the distance the die can be removed from the head. Gently pull the die with the inject tube until resistance is felt
3. Locate and clean the new top die to be installed.
4. To release the old die from the inject tube, gently rotate the die while holding the inject tube. To install the new die onto the inject tube, gently rotate the die onto the inject tube while holding the inject tube. Slowly feed the inject tube into the head. Seat the die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

Appendix A: MSDS PI2525

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

MATERIAL SAFETY DATA SHEET

***** IDENTIFICATION *****

NAME: PI2525 SYNONYMS: POLYIMIDE COATING.
CHEM.FAMILY: Pyralin® Polyimide Coating. FORMULA: Proprietary.

MANUFACTURER:
HD MicroSystems™
Cheesequake Road
Parlin, NJ 08859

INFORMATION & EMERGENCY TELEPHONE NOS:
INFORMATION: Product: (800) 441-7515
EMERGENCIES: Medical: (800) 441-3637
Transport (CHEMTREC): (800) 424-9300

All Ingredients in This Product Are TSCA Listed/Reported.

***** PHYSICAL DATA *****

FORM: Viscous Liquid. ODOR: Aromatic.

APPEARANCE: Colorless to Amber. SOLUBILITY IN WATER: Slight.

***** COMPONENTS *****

Material(s):	CAS#	V.P. mm Hg @ 20C	Weight %
N-Methyl-2-Pyrollidone.	872-50-4	0.29	> 60%
Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer).	31942-21-9		10 - 30%

PI2525/AH1
05/19/98

***** HAZARDOUS REACTIVITY *****

INSTABILITY:
The product is normally stable.

INCOMPATIBILITY:
Avoid contact with:
Reducing agents; Oxidizing agents; Bases; Acids; Strong acids; Strong oxidizers.

DECOMPOSITION:

Decomposition products at high temperature may include:
Carbon monoxide (CO); Nitrogen oxides; Carbon monoxide, carbon dioxide, water.

POLYMERIZATION:
The product may polymerize endothermically if exposed to temperatures over 90 F, ultraviolet light or free radical initiators. This may increase viscosity.

***** FIRE & EXPLOSION DATA *****

FLASHPOINT: 194 F Seta CC

FIRE & EXPLOSION HAZARDS:
The product is not an unusual fire or explosion hazard.

EXTINGUISHING MEDIA:
Water spray, dry chemical or carbon dioxide.

SPECIAL FIREFIGHTING INFORMATION:
Toxic decomposition products may form under fire conditions. (See Decomposition Section.);
Wear full protective clothing and a full facepiece, positive pressure, self-contained breathing apparatus (SCBA);
Decontaminate contaminated clothing and equipment with soap and water. Dispose of residues per federal, state, and local regulation. (See Waste Disposal Section.).

OVERVIEW: The most likely routes of overexposure to this

PI2525/AH1 Page 2

***** HEALTH HAZARD INFORMATION *****

product are skin contact and inhalation. Skin irritation and/or other effects of skin contact are easily avoided by using proper gloves (see section titled GLOVES) and washing affected areas immediately if contact occurs. Volatile solvents will start evaporating during room temperature use of the product, such as thinning, pouring from jar to dispensing machine, and spin coating. Mist and solvent vapors will evolve if spray application is used. During wafer drying, 125 - 150 C, and final curing, 350 - 450 C, the remaining solvent(s) will evaporate. Potential overexposure to other chemicals used in the operation such as wafer etchants and cleaners should also be considered. Well designed area and personal air sampling and analysis can show if exposures are within established limits. Properly designed local ventilation and process enclosure are effective ways to limit employee exposure where needed.

In addition to meeting exposure limits, it is always prudent to use all practical means to minimize employee exposure to chemicals. A significant difference in overall exposure can be made with practical measures such as:

* Inhalation - minimizing by keeping jars of product covered
* Eye - avoiding contact by wearing chemical splash goggles where there is splash potential
* Ingestion - avoiding by washing hands before eating, drinking or smoking, and restricting these activities to outside the work area.

PRINCIPAL HEALTH EFFECTS:

>>>N-Methyl-2-Pyrollidone
****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Mild skin irritation; No skin sensitization; BY INHALATION: Respiratory effects. Toxic effects of repeated or prolonged animal exposures include: BY INHALATION: Respiratory effects; Bone marrow effects; Lymph system effects; Testicular effects; ****Additional animal tests have shown: No carcinogenic activity; No developmental toxicity; No genetic damage in bacterial or mammalian cell cultures; No reproductive toxicity. ****Human health effects of overexposure may include: By contact with liquid or vapor: Eye irritation with discomfort, tearing, or blurring of vision; BY SKIN OR EYE CONTACT: Eye irritation with discomfort, tearing, or blurring of vision; Skin irritation with itching, burning, redness, swelling or rash; BY INHALATION: Runny nose; Sore throat; Sneezing; Irritation of the nose and throat; Nonspecific discomfort, e.g., nausea, headache or weakness. ****Human effects of higher level

PI2525/AH1 Page 3

acute, repeated or chronic overexposure may include: BY SKIN OR EYE CONTACT: Skin reddening; Skin irritation with discomfort or rash; Dermatitis; Swelling; Burning. ***In addition: BY SKIN OR EYE CONTACT: There are inconclusive or unverified reports of human sensitization.

>>>Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer) ****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Skin irritation; Skin sensitization; Eye irritation.

ANIMAL DATA:

>>>N-Methyl-2-Pyrollidone
Inhalation 4 hour ALC: 1.7 mg/L in rats (Moderately toxic)
Skin absorption LD50: > 8,000 mg/kg in rabbits (Slightly toxic)
Oral LD50: 4,320 mg/kg (Slightly toxic).

CARCINOGENICITY LISTING:

No ingredients of this product are designated by IARC, NTP, OSHA, ACGIH or Dupont as potential carcinogens.

EXPOSURE LIMITS:
Workplace exposures should be kept below the following limits:

.	AIHA		ACGIH		OSHA	
Name/Units	8hr	15min	8hr	15min	8hr	15min
PARTICULATES (N.O.S.), respirable						
Units: mg/m3					5	
PARTICULATES (N.O.S.), total						
Units: mg/m3			10		15	
N-METHYL-2-PYRROLIDONE						
Units: ppm	10					

Also, DuPont has established and observes the following limits:

Name/Units	12 hr	8hr	15min	Ceiling
N-METHYL-2-PYRROLIDONE				
Units: ppm		25		

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NOTES ON EXPOSURE LIMITS:
PELs - OSHA Permissible Exposure Limits - 29 CFR 1910.1000, Subpart Z, or specific substance standards;
TLVs - ACGIH Threshold Limit Values - published by American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211;
WEELs- AIHA Workplace Environmental Exposure Limits - published by the American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031;
AELs - Dupont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits are lower than AEL in effect, government limits shall take precedence;
(C) = "ceiling", limit not to be exceeded for any time period;
(S) = "skin" , skin absorption may contribute significantly to the ingredient's internal toxicity.

***** FIRST AID INSTRUCTIONS *****

Skin Contact: For skin contact, immediately wash skin with soap and water. Wash contaminated clothing before reuse.
Eye Contact: For eye contact, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.
Ingestion: If swallowed, do not induce vomiting. Immediately give two glasses of water. Never give anything by mouth to an unconscious person. Call a physician.

***** PROTECTION INFORMATION *****

Adequate local ventilation should be used to keep exposures below applicable limits;
Other engineering controls such as totally enclosed handling systems are also preferred;
Respiratory protection will be needed if exposures can not be kept below applicable limits by other means.

Respiratory Protection:
A NIOSH/MSHA approved full-face mask equipped with chemical cartridges approved for methylamine may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, when exposure levels are not

PI2525/AH1 Page 5

known, or in any other circumstances where air purifying respirators may not provide adequate protection;
For most conditions, no respiratory protection should be needed; however, if handling at elevated temperatures without sufficient ventilation, use an approved air-purifying respirator. In dusty atmospheres, use an approved dust respirator;
Selection of a suitable respirator will depend on the properties of the contaminant(s) and their actual or expected air concentration(s) versus applicable limits. Consult ANSI Standard Z88.2 for decision logic to select appropriate NIOSH/MESA approved respirators;
A NIOSH/MSHA/OSHA approved air purifying respiratory with a dust/mist cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, exposure levels are not known or any other circumstances where air purifying respirators may not provide adequate protection;
Use a positive pressure air-supplied respirator if concentrations may exceed exposure limits. Air-purifying respirators are inadequate for this material;
If respirators are needed to meet applicable limits, a respiratory protection program up to the level of OSHA Standard 29 CFR 1910.134 is mandatory. This includes air monitoring, selection, medical approval, training, fit testing, inspection, maintenance, cleaning, storage, etc;
An OSHA/NIOSH respirator for protection against Nuisance Dust is recommended.

Gloves:

Gloves should be used when the possibility of skin contact exists;
The suitability of a particular glove and glove material should be determined as part of an overall glove program. Considerations may include chemical breakthrough time; permeation rate; abrasion, cut and puncture resistance; flexibility; duration of contact; etc.

Other Protection Practices:

Appropriate eye protection such as chemical splash goggles should be used if the possibility of eye contact exists;
Protective outer clothing should be used where the possibility of body contact exists. Contaminated work clothing should not be allowed out of the workplace;
Do not smoke, consume or store food or drinks in areas

PI2525/AH1 Page 6

where the product is handled or stored. After handling the product, wash hands thoroughly before leaving the work area;
Additional engineering controls, work practices and training may be required depending on exposure levels. These are discussed in the OSHA Respiratory Protection Standard (29 CFR 1910.134) and OSHA Hazard Communication Standard (29 CFR 1910.1200);
Do not breath dust. Avoid contact with eyes, skin, or clothing. Wash thoroughly after handling.

***** DISPOSAL INFORMATION *****

Spill, Leak or Release:
FOR SMALL SPILLS, absorb on rags, sand or other absorbent material;
FOR LARGE SPILLS, get workers out of affected area. If flammable liquids or vapors may be present, turn off electrical devices or other sources of sparks or flames. WEAR PROTECTIVE EQUIPMENT. Use supplied-air respiratory protection if vapor concentrations are not known;
Contain spill at source by diking or absorbing with sand. Do not allow spill to spread to or intentionally flush to sewer or ground. Wash area thoroughly. Adequately ventilate area;
Spill residue, cleaning rags and absorbent may be considered hazardous. (See Waste Disposal Section.).

Waste Disposal:
Components of this product may be considered hazardous;
Consult applicable Federal, State, and local regulations for allowable disposal methods.

***** PRODUCT INFORMATION *****

Contaminated Items:
Empty product containers, contaminated clothing and cleaning materials, etc. should be considered hazardous until decontaminated or properly disposed of. (See Waste Disposal Section.).

Storage:
Store product in a refrigerated location (0-4F), away from sunlight or ultraviolet light to ensure product viscosity stability.

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***** ADDITIONAL INFORMATION *****

The following ingredients are subject to the reporting requirements of section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

INGREDIENT(S)	Weight %
N-Methyl-2-Pyrrolidone	> 60%

CALIFORNIA PROPOSITION 65: WARNING: This product does not contain chemical known to the state of California to cause cancer, birth defects, or other reproductive harm.

This product is a physical mixture. The health effects information about this product is based on the individual ingredients; The data in this Material Safety Data Sheet relates only to the specific product designated herein and does not relate to its use in combination with any other material or in any process.

Date of latest MSDS revision: 05/19/98

Person Responsible for MSDS:

Safety Coordinator - MSDS
DuPont P&EM / MCM
14 Alexander Drive
Research Triangle Park, NC 27709-4425
Telephone: (800) 284-3382
Outside U.S.: (919) 248-5775

PI2525/AH1 End of Material Safety Data Sheet Page 8

Appendix B: MSDS NMP

Material Safety Data Sheet

1-Methyl-2-pyrrolidinone

ACC# 08690

Section 1 - Chemical Product and Company Identification

MSDS Name: 1-Methyl-2-pyrrolidinone
Catalog Numbers: AC127630010, AC127630025, AC222080025, AC222085000, AC326930010, AC326931000, AC326932500, AC354890025, AC354900025, AC364380010, AC364380025, AC364381000, AC368450010, AC368450025, AC368451000, AC610411000, BP1172-4, BP11724LC, BP1172N119, BP2619-100, NC9749337, O3688-4
Synonyms: NMP; N-Methylpyrrolidone; N-Methylpyrrolidinone; N-Methyl-2-pyrrolidone; N-Methyl-2-pyrrolidinone; M-Pyrol; 1-Methyl-2-pyrrolidone; solvent in paint strippers.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
872-50-4	1-Methyl-2-pyrrolidinone	99	212-828-1

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: clear colorless liquid. Flash Point: 91 deg C.
Warning! Causes eye, skin, and respiratory tract irritation. May cause harm to the unborn child. **Combustible liquid and vapor.** May be harmful if swallowed, inhaled, or absorbed through the skin. Light sensitive. Hygroscopic (absorbs moisture from the air).
Target Organs: Respiratory system, eyes, skin.

Potential Health Effects

Eye: Causes eye irritation. May cause temporary corneal clouding.
Skin: Causes skin irritation. May be harmful if absorbed through the skin. Not expected to cause an allergic skin reaction. Because of the high permeability rate of N-methylpyrrolidone in human skin, prolonged exposures should be avoided.
Ingestion: May cause gastrointestinal irritation with nausea, vomiting and diarrhea.
Inhalation: Causes respiratory tract irritation. May cause headache. Material has a very low vapor pressure and inhalation exposures are not expected unless material is heated or misted.
Chronic: Prolonged or repeated skin contact may cause dermatitis. Adverse reproductive effects have been reported in animals. Testicular effects in rats were noted after repeated, high-dose oral and inhalation exposures.(BASF)Human occupational exposure has been associated with chronic eye irritation, headaches, and irritant contact dermatitis. Airborne concentrations of 49 to 83 ppm are intolerable.(REPROTEXT)

Section 4 - First Aid Measures

Eyes: In case of contact, immediately flush eyes with plenty of water for a t least 15 minutes. Get medical aid.
Skin: In case of contact, flush skin with plenty of water. Remove contaminated clothing and shoes. Get medical aid if irritation develops and persists. Wash clothing before reuse.
Ingestion: If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical aid.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Combustible liquid and vapor.
Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or appropriate foam.
Flash Point: 91 deg C (195.80 deg F)
Autoignition Temperature: 245 deg C (473.00 deg F)
Explosion Limits, Lower:1.3%
Upper: 9.5%
NFPA Rating: (estimated) Health: 2; Flammability: 2; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Remove all sources of ignition. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes, skin, and clothing. Keep away from heat and flame. Avoid breathing vapor or mist.
Storage: Keep away from sources of ignition. Store in a cool, dry place. Store in a tightly closed container. Keep under a nitrogen blanket.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
1-Methyl-2-pyrrolidinone	none listed	none listed	none listed

OSHA Vacated PELs: 1-Methyl-2-pyrrolidinone: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear chemical splash goggles.
Skin: Wear appropriate gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Liquid
Appearance: clear colorless
Odor: amine-like - mild odor
pH: 8.5-10.0 (100 g/l H2O)
Vapor Pressure: 0.342 mm Hg @ 25 deg C
Vapor Density: 3.4 (air=1)
Evaporation Rate: Not available.
Viscosity: 1.65 cps @ 25 deg C
Boiling Point: 202 deg C @ 760 mm Hg
Freezing/Melting Point:-24 deg C
Decomposition Temperature: Not available.
Solubility: Soluble.
Specific Gravity/Density:1.030
Molecular Formula:C5H9NO
Molecular Weight:99.13

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions.
Conditions to Avoid: Light, ignition sources, excess heat, exposure to moist air or water.
Incompatibilities with Other Materials: Strong oxidizing agents, strong acids.
Hazardous Decomposition Products: Nitrogen oxides, carbon monoxide, carbon dioxide.
Hazardous Polymerization: Will not occur.

Section 11 - Toxicological Information

RTECS#:
CAS# 872-50-4: UY5790000
LD50/LC50:
CAS# 872-50-4:
Draize test, rabbit, eye: 100 mg Moderate;
Oral, mouse: LD50 = 5130 mg/kg;
Oral, rat: LD50 = 3914 mg/kg;
Skin, rabbit: LD50 = 8 gm/kg;
.
Sensitization test (guinea pig): negative. test (humans): negative.(Merck)
Carcinogenicity:
CAS# 872-50-4: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No data available.
Teratogenicity: Proposition 65 maximum allowable dose level for developmental toxicity for N-methylpyrrolidone is 3200 ug/day for the inhalation route and 17,000 ug/day for the dermal route.

Reproductive Effects: See actual entry in RTECS for complete information.
Mutagenicity: See actual entry in RTECS for complete information.
Neurotoxicity: No data available.
Other Studies:

Section 12 - Ecological Information

Ecotoxicity: Daphnia: Daphnia: 4897 mg/l; 48 h; EC50Fish: Gold orfe: 4000 mg/l; 96 h; LC50Bacteria: >9000 mg/l; 48 h; EC50Algae: >500 mg/l; 72 h; IC50 log Pow = -0.46 (25°C)BOD5 = 1100 mg/l.COD = 1600 mg/l.
Environmental: No information available.
Physical: No information available.
Other: Biodegradable.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated	Not Regulated
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 872-50-4 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
CAS# 872-50-4: Test for Health Effects

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 872-50-4: immediate, delayed, fire.

Section 313

This material contains 1-Methyl-2-pyrrolidinone (CAS# 872-50-4, 99%),which is subject to the reporting requirements of Section 313 of SARA Title III and 40

Clean Air Act:

This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 872-50-4 can be found on the following state right to know lists: Pennsylvania, Minnesota, Massachusetts.

California Prop 65

WARNING: This product contains 1-Methyl-2-pyrrolidinone, a chemical known to the state of California to cause developmental reproductive toxicity.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

T

Risk Phrases:

R 36/37/38 Irritating to eyes, respiratory system and skin.
R 61 May cause harm to the unborn child.

Safety Phrases:

S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S 53 Avoid exposure - obtain special instructions before use.

WGK (Water Danger/Protection)

CAS# 872-50-4: 1

Canada - DSL/NDSL

CAS# 872-50-4 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of B3, D2A, D2B.
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

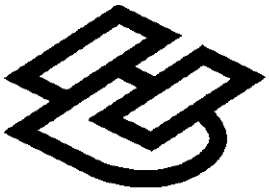
Canadian Ingredient Disclosure List

Section 16 - Additional Information

MSDS Creation Date: 6/10/2003
Revision #2 Date: 3/29/2005

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Appendix C: Pyralin Product Information



HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

Rev. Apr 01

PRODUCT INFORMATION
PYRALIN® PI2525, PI2555, PI-2575 & PI2556

PI2525, PI2555, PI-2575 and PI2556 polyimides [PI-2555 Series] are suitable for applications where the high cure temperatures typically used for polyimides (ca. 350°C) cause problems. Typical applications for these materials are as stress buffer or interlayer dielectric layers over low temperature substrates. These polyimides imidize faster and at lower temperatures than for standard polyimide precursors. The materials are supplied as solutions suitable for spin or roller coating application. A seperate adhesion promoter is recommended with PI-2525, PI-2555 and PI-2556 to improve adhesion to oxides and to metals. PI-2575 is self priming and does not require an adhesion promoter. Processing by wet or plasma etch is possible. Cured film thicknesses from 0.5 µm to 6 µm can be obtained.

Process Details

Coating

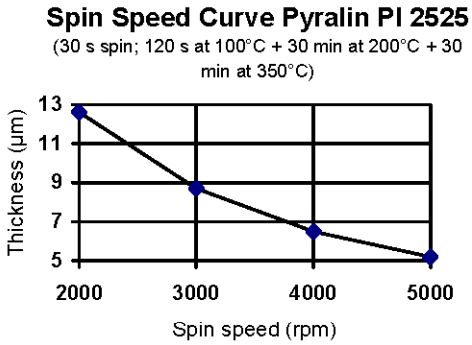
PI2555 Series products can be coated onto a variety of metals, alloys, semiconductor and ceramic substrates. HD MicroSystems adhesion promoters VM651 or VM-652 are recommended to provide good processability and adhesion with the PI-2525, PI-2555, PI-2556. Bonding of the polyimide to the substrate is achieved during the softbake cycle as the priming chemistry is activated by temperature.

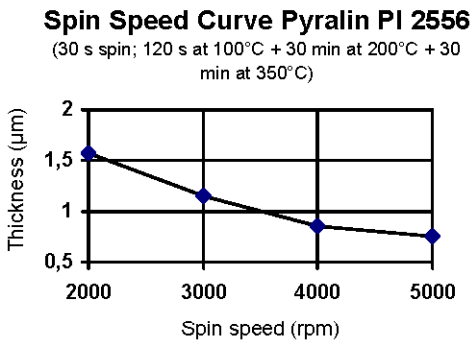
The polyimide solution is highly viscous. There are some guiding principles for dispensing materials of this type. Always coat substrates which are at room temperature. Never trap air into the solution. This can occur for example when the solution is moved during dispense. All bubbles take time to dissipate out of solution. If left in, coating "comets" will result. Dispensing should be in the centre and as close to the substrate as possible. A clean cut-off at dispense is neccessary before the spin process starts. It may be neccessary in the case of highly viscous solutions to have a short delay prior to spin to allow the polyimide to flow as far as possible and relax.

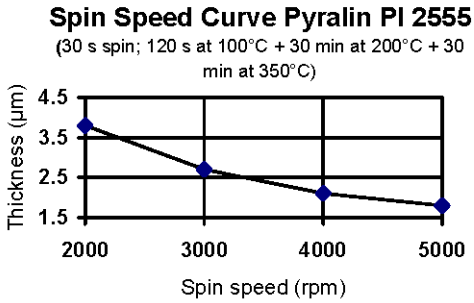
Both static and dynamic dispense may be used. Static dispense is the easiest, but requires more material to be dispensed for each substrate. Dynamic dispense uses less material, but requires greater control during dispense to ensure that the polyimide strikes the exact centre of the substrate. Any deviation will result in poor coating quality. The acceleration to final speed should be as low as possible to allow gradual flow of the polyimide across the substrate. Often one or more intermediate spin speeds are used to allow the polyimide to gradually cover more than 80% of the substrate before continuing on to the final speed. To reduce the backside contamination potential it is often beneficial to prolong the spread cycle until the bulk of the excess polyimide has been removed from the substrate. The final spin speed and time is determined by the film thickness required. Longer spin

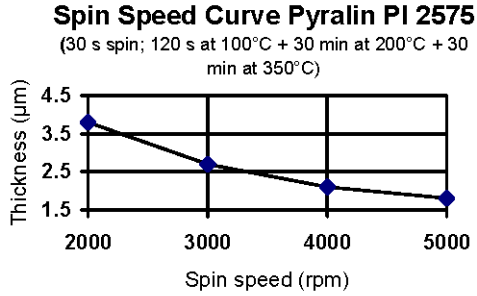
times will improve coating uniformity, but will also reduce the film thickness. In semiconductor applications, an Edge Bead Removal (EBR) and Backside Rinse process may be added to the coating cycle to remove polyimide from the edge and back of the wafer prior to baking. NMP (N-methyl-2-pyrrolidone) or NMP/IPA (isopropanol) can be used for this purpose.

Spin Speed Curves for cured Polyimide









Soft Bake

After application of the polyimide, a bake process is required. Both convection oven and hotplate bake methods may be used. The purpose of this stage, is to partially cure the polyimide prior to patterning. This bake stage leaves the polyimide coating dry, yet soluble in the etchant solution.

Choice of Photoresist

Polyimides of this type can be patterned using common photolithography techniques centered around positive photoresist. The underlying polyimide is an effective anti-reflective layer as there is significant absorption between 350 and 450 nm. This absorption can significantly reduce substrate reflection effects on the photoresist, usually seen as “notching“ after development.

The photoresist should be selected with the correct wavelength to suit the exposure tool in use. As a general guide, formulations with good adhesion in “wet etch“ semiconductor applications perform well. Other attributes include:

- Compatability to standard alkaline positive photoresist developers

- Low contrast performance so that a soft sidewall profile is always produced

- Capability to produce cleanly developed via holes in thick resist coatings

- Good development latitude, especially when over-developed

- The ease of producing a minimum dried 2,5 µm film thickness

The polyimide coating after softbake has minimum solubility in typical photoresist solvents. Photoresist can therefore be coated directly onto the polyimide coating without layer inter-mixing occuring.

Photoresist Application

Substrates should be coated directly with the resist selected. No dehydration bake should be given as this would make the polyimide totally insoluble in the developer. Instead an HMDS vapour prime is permissable if installed on-line but is not really neccessary for good resist adhesion to the polyimide.

Once coated, the resist should be given a softbake at 90°C either in a convection oven for 30 minutes or on a vacuum hotplate for 60 seconds. Once coated and baked, coatings may be held up to 24 hours before exposure.

Photoresist Exposure

Typical exposure: 50 mJ to 150 mJ

Once exposed, development should take place within 8 hours.

Photoresist Development / Polyimide Etch

A single step is used to develop the photoresist and etch the polyimide.

Most alkaline positive resist developers will dissolve both exposed photoresist and polyimide at varying rates. The choice of developer affects the quality of the polyimide image after development. Best results have been obtained using a NaOH based developer.

Thin polyimide layers up to around 5 µm can usually be developed quickly and cleanly with developer which is at ambient temperature. After development of the resist and then the polyimide using a spray puddle technique, a water rinse should be used to remove the developer. The substrate should subsequently be spun until dry.

When thicker polyimide layers need to be processed, it is often beneficial to heat the developer to between 23°C and 25°C. This accelerates the dissolution of the polyimide while having minimal effect on the solubility of the photoresist. In more extreme situations, this may be coupled to a double puddle process. The second puddle is used to develop only the polyimide layer.

Once developed, wafers may be held up to 8 hours before stripping the resist.

Resist Strip

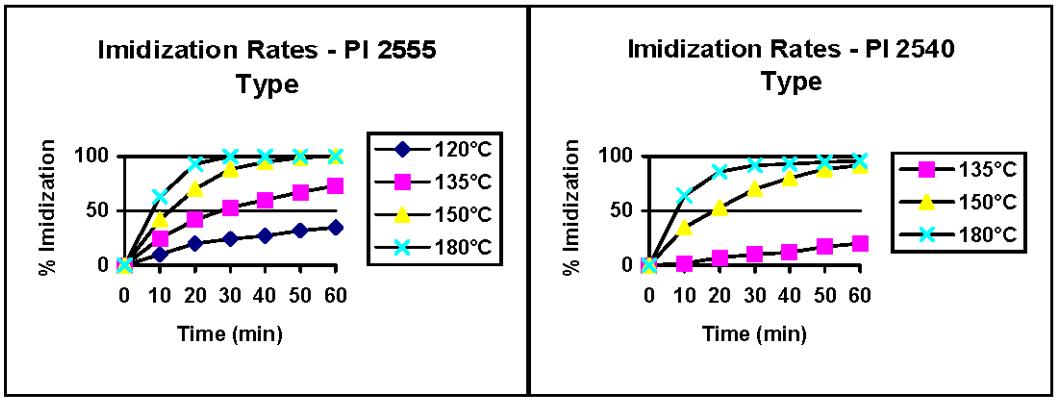
After developing, the photoresist needs to be stripped off the polyimide surface before curing. This step is usually carried out on automated track equipment to reduce surface contamination with resist residue which may result if clean solvents are not used. Resist solvent strippers are normally used.

Cure

The cure heating cycle converts the polyamic acid to the insoluble imide form and drives out remaining solvent. This process requires elevated temperatures and controlled environments to achieve the best results. There is sufficient energy at 180°C to complete the imidization of the polyimide, but higher temperatures are required to completely drive off solvents, thus achieving the ultimate electrical and mechanical properties. A programmable high temperature oven with typical nitrogen flow rate of 10 litres per minute is recommended for best results.

To activate the adhesion promoter, it is recommended that the cure be carried out up until 200°C in air (min 50% RH). Above this temperature, a nitrogen atmosphere should be used. The ramp rates (up and down) should be low to avoid high stress in the polyimide.

The maximum cure temperature may be higher than 300°C when the coating is to be subjected to a high temperature process after curing. In such cases, temperatures up to 400°C have been used to ensure that there is no outgassing during subsequent processes.



Processing Pyralin® PI2525, PI2555, PI-2575 & PI2556 products

(for ca. 7µm softbaked and 5µm cured film thickness)

Application of Adhesion Promoter*

- Dispense on static substrate, 3 seconds
- Hold for 20 seconds
- Spin dry for 30 seconds

Bake Adhesion Promoter

- On hotplate at 120°C for 60 seconds (optional)

*not required with PI-2575

Polyimide Coating

- Dispense on static substrate
- Rotate at 500 rpm for 5 seconds
- Rotate at final speed for 30 seconds (see spin speed curves)
- EBR/Backside rinse, 10 seconds
- Spin dry, 15 seconds

Soft Bake

- In convection oven at 120°C for 30 minutes

OR

- On hot plate at 120°C for 30 seconds followed by 150°C for 30 seconds

Coat Photoresist

- Dispense, 3 seconds
- Spread at 500 rpm for 5 seconds
- Spin at final speed for 30 seconds
- EBR / Backside rinse for 5 seconds
- Spin dry for 15 seconds

Softbake Photoresist

- On hotplate at 90°C for 60 seconds

Exposure

- 50 mJ to 150 mJ

Development

Developer:	NaOH, KOH or TMAH developer or DE 1000 at 21°C
Rinse:	DI water

Puddle Development process:

• Spray (100 rpm)	5 seconds
• Puddle	3 minutes
• Rinse (1000 rpm)	15 seconds
• Spin dry (5000 rpm)	15 seconds

Resist Strip

- Spray or spray/puddle acetone or standard resist stripper or N-Butlyacetate at ca. 2000 rpm
- Spin dry

Cure

Curing should be done in an oven using the following cure profile:

- Heating from room temperature to 200°C, ramp rate 4°C/minute in air
- Hold time at 200°C for 30 minutes in air
- Heating from 200°C to 300°C, ramp rate 2,5°C/minute in nitrogen
- Hold time at 300°C for 60 minutes in nitrogen
- Gradual cooling to room temperature

Solution Properties

	PI2525	**PI2555/PI-2575**	**PI2556**
Solids content (%)	25.0 +/-1.0	19.0 +/-1.0	15.0 +/-1.0
Viscosity (Poise)	60 +/- 10.0	14.0 +/-2.0	3.5 +/-1.0
Flash Point	93°C	60°C	54°C
Solvent (%)	N-Methyl-2-Pyrrolidone 100	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon 80/20 +/-5	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon Propylene Glycol Methyl Ether 70/14/15 +/-5
Ash content (%)	0.1 max.	0.1 max.	0.1 max.
Chloride content	5.0 ppp max.	5.0 ppp max.	5.0 pp max
Sodium content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Potassium content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Copper content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Iron content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Total metals	10.0 ppm max.	10.0 ppm max.	10.0 ppm max.

Cured Film Properties

Tensile strength (kg/mm²)	13.1
Elongation (%)	10
Modulus (kg/mm²)	245
Stress (dynes/cm^2)	3.6×10^8
Moisture uptake (%)	2 - 3
Dielectric constant (at 1 kHz, 50% RH)	3.3
Dissipation factor	0.002
Dielectric strength (volts/mil)	4000
Volume resistivity (ohm-cm)	10^{16}
Surface resistivity (ohm)	10^{15}
Coefficient of thermal expansion (ppm)	40
Coefficient of thermal conductivity (cal/(cm)(sec)(°C))	35×10^{-5}
Glass transition temperature	> 320°C

Decomposition temperature	560°C
Weight loss (% at 500°C, 120 min)	2.9
Specific heat (cal/g/°C)	0.26
Refractive index	1.70

Storage/Shelf Life

It is recommended that PI-2555 Series products be stored between 0°C to -18°C.

Pyralin® PI2525, PI2555, PI-2575 and PI2556 are stable at clean room temperatures (21°C) for ca. four weeks with no significant change in properties. When stored at -18°C, shelf-life is 2 years from date of manufacturing. Moisture contamination is detrimental to stability and must be avoided. Containers should be brought to room temperature before opening to avoid moisture condensation inside the botttle.

Safety and Handling

During all handling of Pyralin polyimide products, adequate ventilation must be provided. Skin and eye contact should be avoided. Exposed areas should be flushed with water immediately. For prolonged or repeated contact, milled butyl rubber or natural latex rubber gloves should be used. Disposable PVC gloves are not recommended.

United States

HD MicroSystems, LLC
P0 Box 80010
Wilmington, DE 19880
800-346-5656 (Phone)
302-892-0597 (Fax)

HD MicroSystems, LLC
1333 Lawrence Expressway
Suite 212
Santa Clara, CA 95051
408-260-0880 (Phone)
408-260-0885 (Fax)

Japan

HD MicroSystems, LLC
10-13, Shibuya 3-chome, Shibuya-ku,
Tokyo 150
Japan
81-3-3407-9003 (Phone)
81-3-3407-9037 (Fax)

Europe

HD MicroSystems Europe GmbH
DuPont Strasse 1
D-61343 Bad Homburg
Germany
49-6172-87-1822 (Phone)
49-6172-87-1824 (Fax)

Internet
www.hdmicrosystems.com

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Caution: Do not use in medical applications involving permanent implanation in the human body.

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

PTR-200-PRL

Automated Polyimide Recoater with Linear Proof Tester

Operator's Manual

Version 1.2

United States:
1400 Campus Drive West • Morganville, NJ 07751
+1 (732) 972-2880 • +1 (800) 421-8847 • Fax +1 (732) 972-6229

England:
8, Kew Court • Pynes Hill Office Campus • Exeter, EX2 5AZ
+44 (0) 1392 445777 • Fax +44 (0) 1392 445009

Web: http://www.vytran.com

VYTRAN

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Vytran LLC
1400 Campus Drive
Morganville, NJ 07751 USA

Phone: +1 (732)-972-2880
+1 (800)-421-8847
FAX: +1 (732)-972-6229

http://www.vytran.com

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1 Introduction

The PRL-200 is designed for recoating and proof testing polyimide coated fibers. It operates on a coat, cure and test recoat method, whereby a layer of polyimide is applied to the fiber through a die, followed by a filament heater to cure the polyimide and upon completing the recoat a linear proof test. When configured and operated properly, the PTR-200-PRL is capable of producing a high quality and a uniform polyimide recoat.

1.1 Parts Checklist

When unpacking the PTR-200-PRL for the first time, check to make sure that you have the following accessories:

- PTR-200-PRL Automated Polyimide Recoater with Linear Proof Tester
- 12.0V Power supply (PSU)
- AC power cord
- DC power cable
- RS-232 communication cable
- Fittings kit
- Tool kit containing:
  - 1 oz. bottle HD MicroSystems PI2525 Polyimide Recoat Material
  - 1 oz. spare bottle
  - Cotton swabs
  - 5/64” Allen key
  - 3/32” Allen key
  - 0.035” Allen key
- External vacuum pump with vacuum line
- PTR-200-CX-PRL Handset Controller

If you are missing any of the above or need replacements, please contact Vytran.

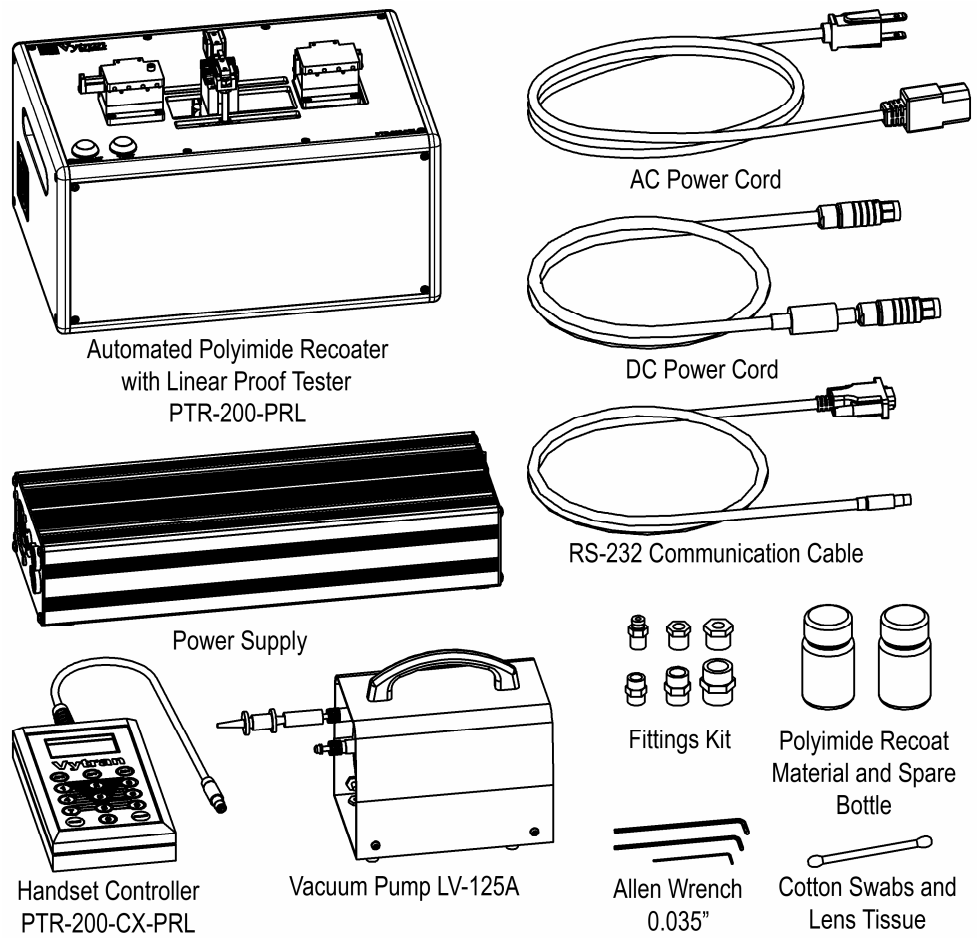


Figure 1: System Components

1.2 Powering Up

The PTR-200-PRL Power Supply Unit (PSU) accepts an AC input of 90-260 VAC; 47-63 Hz. Connect both the AC power cord and the DC power cable to the external Power Supply. Connect the Handset Controller and the DC power cable to the PTR-200-PRL.

Turn on the power supply and then turn on the PTR-200-PRL using the ON/OFF rocker switch located on the back of the recoater. The PTR-200-PRL will run an initialization process that includes homing the recoat die and tensioning motors and operating the recoat die (close/open). During the initialization process, the Handset Controller will display the status of the system. Once the homing process is completed, the Handset Controller displays the Main Menu screen and the PTR-200-PRL is ready for recoating.

1.3 Shutting Down

To shut down the PTR-200-PRL:

1. Turn off the PTR-200-PRL using the on/off rocker switch located on the back of the recoater.
2. Turn off the power supply.

2 Controlling the PTR-200-PRL

The PTR-200-PRL is configured and controlled from Vytran's PRL-200-CX-PRL Handset Controller, which also provides feedback and status of the unit. If the operator does not need to change parameter settings or receive status prompts, the Handset Controller can be removed and the unit operated simply by pressing the blue RECOAT and TEST buttons.

The Handset Controller allows the user to interface with the unit and modify the settings. The Handset Controller is based on a three (3) menus:

- Main Menu
- Configuration Menu
- Options Menu

Each menu and its contents are described below.

2.1 Main Menu

The Main Menu displays the unit status. From this menu, press the "CFG" button to enter the Configuration Menu or press the "OPT" button to enter the Options Menu.

2.2 Configuration Menus

There are three (3) levels to the Configuration Menu. At level one the user can select from five (5) topics - Inject, Undercoat, Overcoat, Recoat Length, or Proof Test. Within each of these topics are the parameters which can be viewed and/or copied. Below is a description of the five (5) topics and each topics parameters.

2.2.1 Inject

Inject Rate (µl/sec): This parameter is the polyimide injection rate, in microliters per second, into the die. The optimum Inject Rate will be dependant on the polyimide material being used.

Undercoat Qty. (µl): This parameter is the quantity of polyimide material, in microliters, injected into the die for the first loop of the head (the undercoat). The optimum Undercoat Qty will be primarily dependant on the bare fiber diameter, die size, and the length of the recoat.

Overcoat Qty. (µl): This parameter is the quantity of polyimide material injected into the die, in microliters, after the first loop of the head. The optimum Overcoat Qty will be primarily dependant on the die size, and the length of the recoat.

2.2.2 Undercoat

Head Sweep Vel. (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the bare fiber diameter, die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

2.2.3 Overcoat

Number of Overcoats: This parameter is the number of loops the head will make. The optimum Number of Overcoats will be dependant on the polyimide thickness layer desired (which will be dependant on the undercoat layer thickness and the parameter settings for the overcoat(s)).

Head Sweep Vel (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Overlap Delta (mm): This parameter is the additional distance, in millimeters, the head will travel on each pass. This will effectively taper the transition from original polyimide to recoated polyimide.

2.2.4 Recoat Length

Recoat Length (mm): This parameter is the desired bare fiber length, in millimeters, to be recoated. The actual recoat length will be approximately 8 millimeters longer on each end in order to compensate for the width of the head and the fiber load position.

2.2.5 Proof Test

Proof Test Units: This menu allows the user to select the desired units for displaying the Proof Test Level. Unit selections are: Newtons, kpsi, and grams.

Proof Test Level (units): This parameter is the Proof Test Level, in units user selected, to be applied after the recoat has been completed.

Proof Test Rate (mm/sec) This parameter is the rate, in millimeters per second, at which the Proof Test Level will be applied. The optimum rate is that which achieves the desired proof test level within 3 - 5 seconds of load applying time.

2.3 Options Menu

From the Options Menu, various system level configuration parameters and functions can be edited or executed.

Recoat Tension (Newtons): This parameter is the tension, in Newtons, applied to the fiber prior to initiating a recoat. The PTR-200-PRL also monitors the tension during the recoat and will automatically abort if the tension varies significantly from the Recoat Tension. The auto abort is intended to protect both the die and fiber.

Heater Settle Time (msec): This parameter is the amount of time, in milliseconds, allowed for the heater to stabilize when changing temperatures.

Die Close Time (msec): This parameter is the amount of time, in milliseconds, allowed for the die to close prior to execution of the subsequent process.

Fiber Unload Time (msec): This parameter is the amount of time, in milliseconds, allowed for the operator to unload the fiber prior to the PTR-200-PRL performing a system reset.

Inject to Die Qty (µL) This option is the quantity of polyimide material, in microliters, which will be injected into the die upon entering the quantity. This option is intended for use when changing materials or purging the system prior to storage.

Head to Home: This option performs a homing of the head and is useful as a diagnostic tool.

Tension Home: This option performs a homing of the proof test load cell and is useful as a diagnostic tool.

Move Head to Start: This option performs a movement of the head to the start position. The start position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Move Head to Stop: This option performs a movement of the head to the stop position. The stop position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Recoat Request State: This option enables or disables the request to input a recoat length each time the process is run. This option is primarily used when the length to be recoated varies significantly from recoat to recoat.

Set/Run Purge Cycles: This option is the number of recoat pump purge cycles that will be run upon entering the quantity.

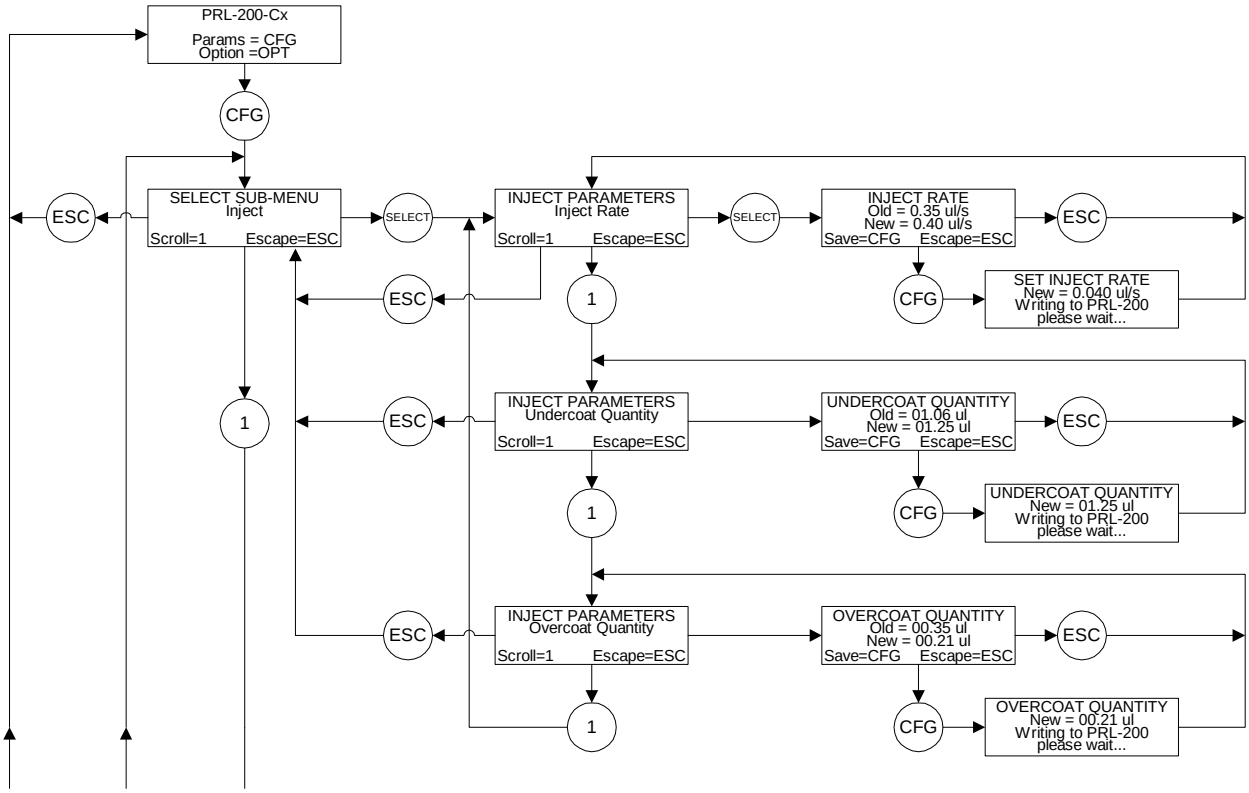
Recoat Tension This option is the amount of tension that will be applied to the fiber prior to the recoating.

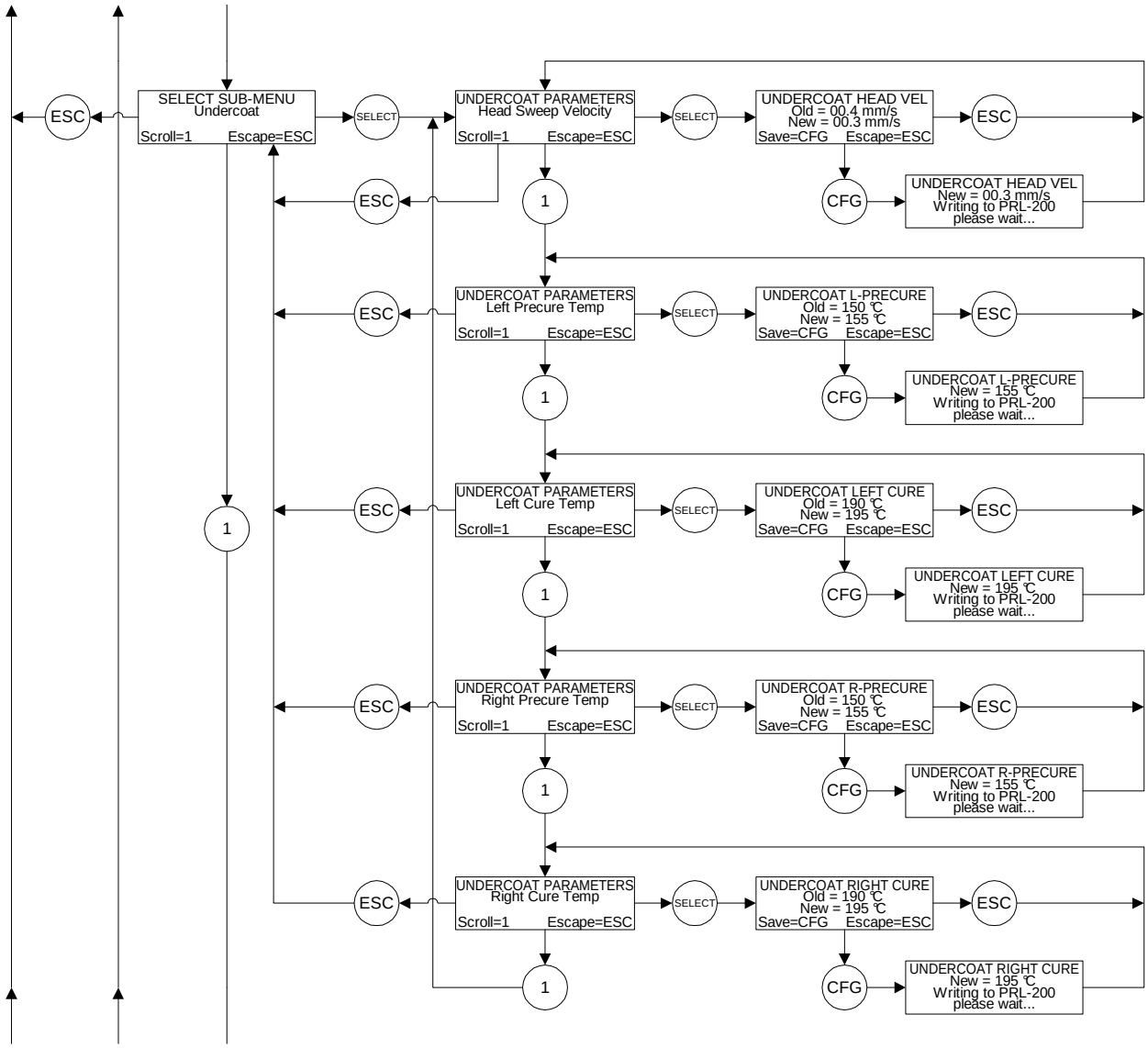
2.4 Parameter Limits

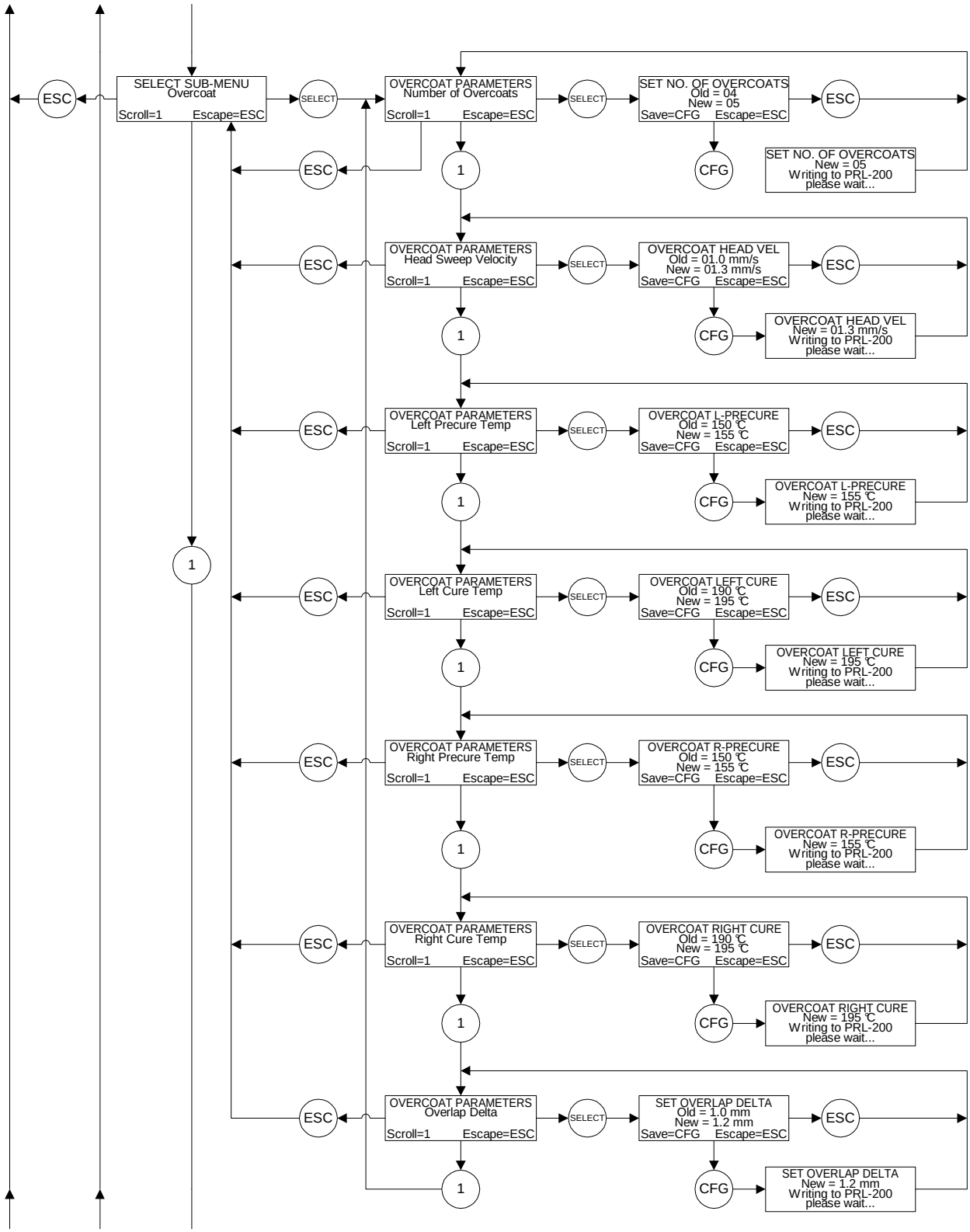
Parameter	Min	Max
Inject Rate (µL/sec)	0.01	2.00
Undercoat Qty (µL)	0.01	10.00
Overcoat Qty (µL)	0.01	10.00
Undercoat Head Sweep Vel (mm/sec)	0.01	20.00
Undercoat Left Precure Temp (℃)	100	200
Undercoat Left Cure Temp (℃)	100	300
Undercoat Right Precure Temp (℃)	100	200
Undercoat Right Cure Temp (℃)	100	300
Number of Overcoats	1	10
Overcoat Head Sweep Vel (mm/sec)	0.01	20.00
Overcoat Left Precure Temp (℃)	100	200
Overcoat Left Cure Temp (℃)	100	300
Overcoat Right Precure Temp (℃)	100	200
Overcoat Right Cure Temp (℃)	100	300
Overlap Delta (mm)	100	200
Recoat Length (mm)	0	2
Proof Test Level (Newtons)	0	20
Proof Test Rate (mm/sec)	0.1	5.0
Recoat Tension (Newtons)	2	10
Heater Stabilize Time (msec)	1	10000
Die Close Time (msec)	250	2500
Fiber Unload Time (msec)	5000	30000
Heater Stabilize Time (msec)	1	10000
Inject to Die Qty (µL)	1	100

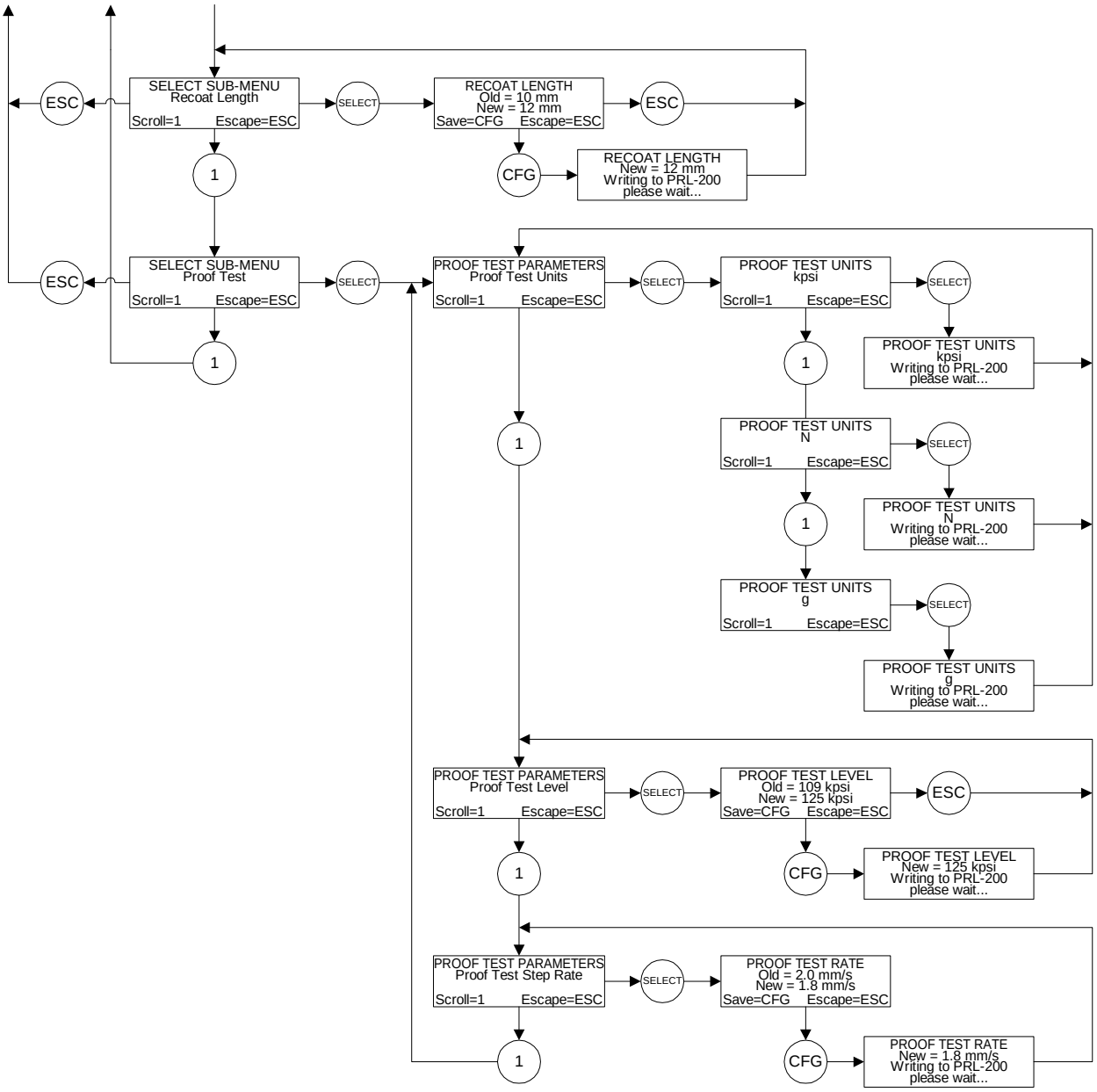
2.5 Configuration Menu Flow Chart

This flowchart is a guide for navigating through the Configuration Menu, and shows the display prompts and button key presses for viewing and editing the Configuration Parameters.



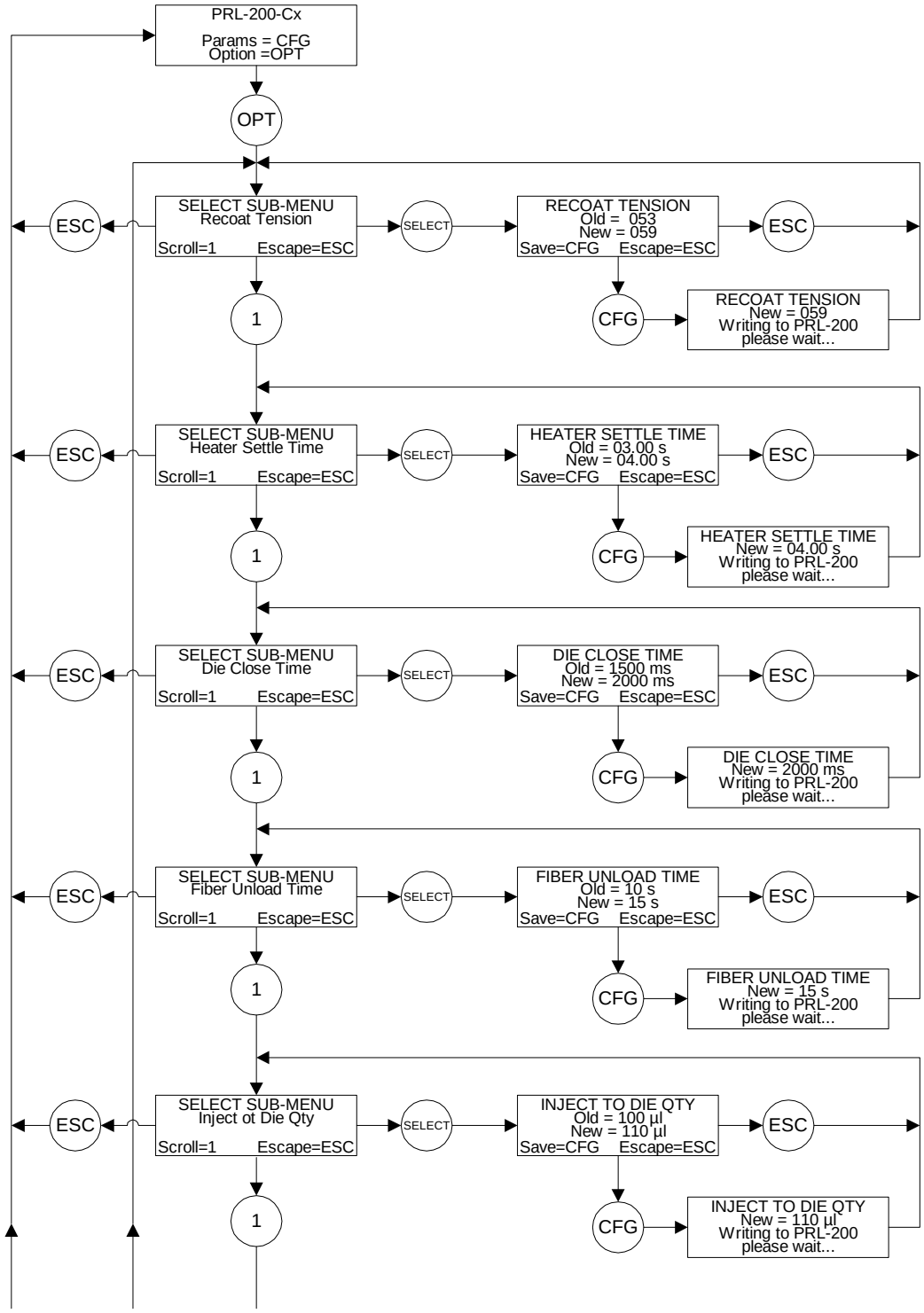

ESC
SELECT SUB-MENU
Undercoat
Scroll=1 Escape=ESC
SELECT
UNDERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
SELECT
UNDERCOAT HEAD VEL
Old = 00.4 mm/s
New = 00.3 mm/s
Save=CFG Escape=ESC
ESC
CFG
UNDERCOAT HEAD VEL
New = 00.3 mm/s
Writing to PRL-200
please wait...
1
UNDERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
SELECT
UNDERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
UNDERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...

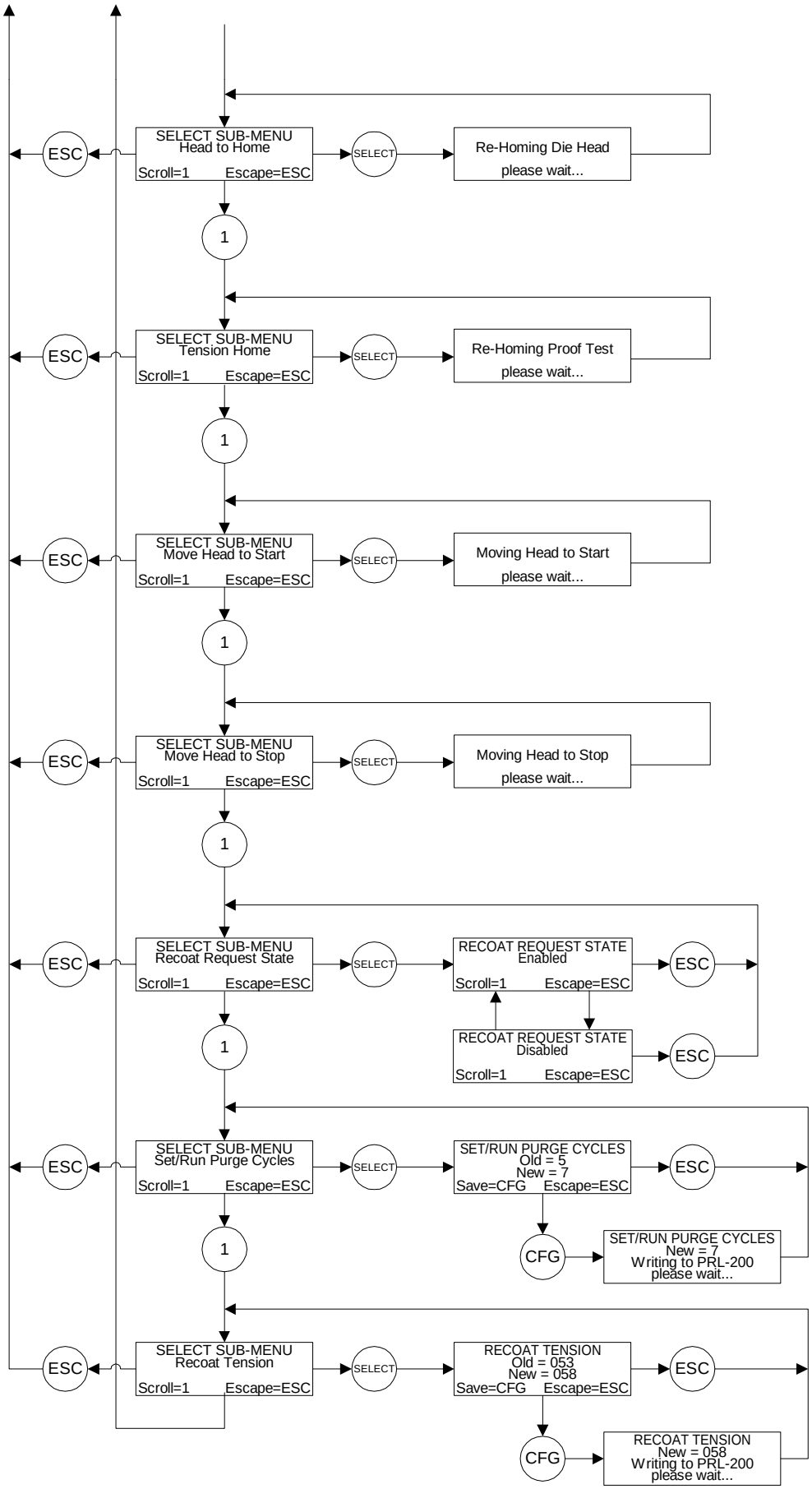

SELECT SUB-MENU
Overcoat
Scroll=1 Escape=ESC
ESC
SELECT
OVERCOAT PARAMETERS
Number of Overcoats
Scroll=1 Escape=ESC
SET NO. OF OVERCOATS
Old = 04
New = 05
Save=CFG Escape=ESC
CFG
SET NO. OF OVERCOATS
New = 05
Writing to PRL-200
please wait...
1
OVERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
OVERCOAT HEAD VEL
Old = 01.0 mm/s
New = 01.3 mm/s
Save=CFG Escape=ESC
OVERCOAT HEAD VEL
New = 01.3 mm/s
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
OVERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
OVERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
OVERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
OVERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Overlap Delta
Scroll=1 Escape=ESC
SET OVERLAP DELTA
Old = 1.0 mm
New = 1.2 mm
Save=CFG Escape=ESC
SET OVERLAP DELTA
New = 1.2 mm
Writing to PRL-200
please wait...


ESC
SELECT SUB-MENU
Recoat Length
Scroll=1 Escape=ESC
SELECT
RECOAT LENGTH
Old = 10 mm
New = 12 mm
Save=CFG Escape=ESC
ESC
1
CFG
RECOAT LENGTH
New = 12 mm
Writing to PRL-200
please wait...
ESC
SELECT SUB-MENU
Proof Test
Scroll=1 Escape=ESC
SELECT
PROOF TEST PARAMETERS
Proof Test Units
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
kpsi
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
kpsi
Writing to PRL-200
please wait...
1
PROOF TEST UNITS
N
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
N
Writing to PRL-200
please wait...
PROOF TEST UNITS
g
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
g
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Level
Scroll=1 Escape=ESC
SELECT
PROOF TEST LEVEL
Old = 109 kpsi
New = 125 kpsi
Save=CFG Escape=ESC
ESC
1
CFG
PROOF TEST LEVEL
New = 125 kpsi
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Step Rate
Scroll=1 Escape=ESC
SELECT
PROOF TEST RATE
Old = 2.0 mm/s
New = 1.8 mm/s
Save=CFG Escape=ESC
1
CFG
PROOF TEST RATE
New = 1.8 mm/s
Writing to PRL-200
please wait...

2.6 Options Menu Flowchart

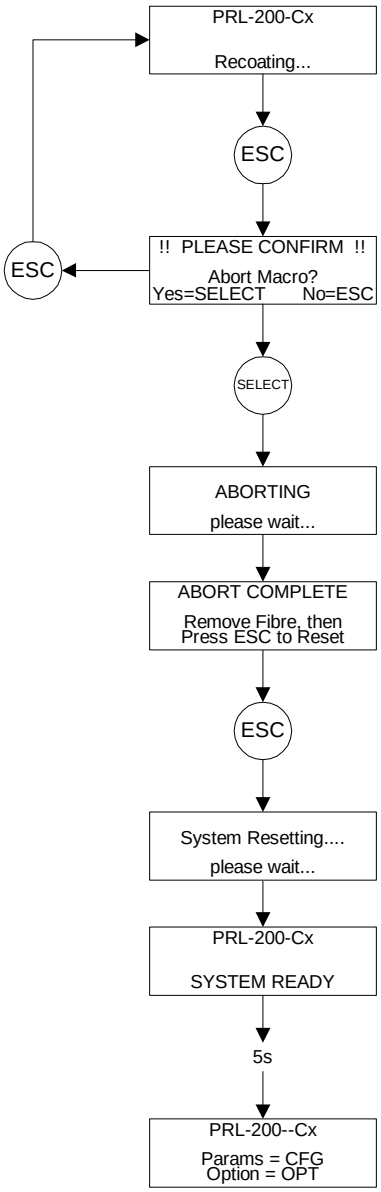
This flowchart is a guide for navigating through the Options Menu, and shows the display prompts and button key presses for editing parameters and executing system related functions.




SELECT SUB-MENU
Head to Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Die Head
please wait...
ESC
1
SELECT SUB-MENU
Tension Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Proof Test
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Start
Scroll=1 Escape=ESC
SELECT
Moving Head to Start
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Stop
Scroll=1 Escape=ESC
SELECT
Moving Head to Stop
please wait...
ESC
1
SELECT SUB-MENU
Recoat Request State
Scroll=1 Escape=ESC
SELECT
RECOAT REQUEST STATE
Enabled
Scroll=1 Escape=ESC
ESC
RECOAT REQUEST STATE
Disabled
Scroll=1 Escape=ESC
ESC
1
SELECT SUB-MENU
Set/Run Purge Cycles
Scroll=1 Escape=ESC
SELECT
SET/RUN PURGE CYCLES
Old = 5
New = 7
Save=CFG Escape=ESC
ESC
CFG
SET/RUN PURGE CYCLES
New = 7
Writing to PRL-200
please wait...
1
SELECT SUB-MENU
Recoat Tension
Scroll=1 Escape=ESC
SELECT
RECOAT TENSION
Old = 053
New = 058
Save=CFG Escape=ESC
ESC
CFG
RECOAT TENSION
New = 058
Writing to PRL-200
please wait...
ESC

2.7 Abort Flowchart

Even after the recoat process has been initiated it is possible to abort the process if required. The Abort Flowchart shows the display prompts and button key presses to abort a recoat process.



3 Recoat Injection System

The PTR-200-PRL has an automatic recoat injection pump fitted inside the unit. The pump is based on an automated syringe and distribution valve that can select one of three ports (Fill, Purge, or Inject) through which it can either draw or inject recoat material (see Figure 3). A bottle containing recoat material is installed directly on the pump, with the pump "Fill" tube inserted into the bottom of the bottle. A "Purge" tube runs from the pump to the top of the recoat bottle, and is used for cycling material back into the bottle. An "Inject" tube runs from the pump to the inject port of the die, which is located in the center of the lower right die. Once all air is purged from the injection system, the pump provides very accurate control of the volume and velocity of recoat material injection.

The recommended recoat material for use in the PTR-200-PRL is Pyralin PI2525, which is manufactured by HD MicroSystems. This is a fast imidizing at lower temperature coating. Do not attempt to use alternate recoat materials without first consulting Vytran on compatibility with the PRL.

Note: Pyralin PI2525 recoat material does have a limited shelf life of approximately 24 months from date of manufacture when stored at 0 to 18 degrees Centigrade. PI2525 is stable at room temperature (21 degrees Centigrade) for approximately 4 weeks with no significant change in properties. Using material that has passed its expiration date may cause both pump performance and recoat quality issues.

3.1 Priming the Injection System

It is very important to remove all air from the recoat injection system prior to performing a recoat. When operating the system for the first time, the pump must be filled with recoat material and cleared of all air in the pump and tubing. In order to clear the inject tube, recoat material must be injected out through the mold inject port and collected and disposed of. Make sure to have cotton swabs and NMP (1-Methyl-2-pyrrolidinone) available for this purpose prior to starting this procedure. NMP is the recommended solvent for cleaning uncured polyimide recoat material.

WARNING: Polyimide recoat materials can be hazardous to your health if not handled properly. Read the Material Safety Data Sheet provided in Appendix X, and make sure to follow all precautionary guidelines when working with this material.

To prime the recoat injection system:

1. Turn off power to the PTR-200-PRL.
2. Remove the front plate of the PTR-200-PRL by using the 3/32 Allen wrench provided in the tool kit to remove the four (4) black socket-head cap screws located at the corners of the plate.
3. The recoat pump is located on the left side of the PTR-200-PRL as shown in Figure 2. Unscrew the brown recoat bottle located at the front of the pump and remove by angling out through the front opening. The red Fill tube will flex to allow removal.
4. For new systems, replace the empty recoat bottle shipped with the unit with a new bottle of recoat material. For systems that have previously been run with recoat material, the recoat injection system should be flushed clean prior to adding new material (see 5.5).
5. Screw the new recoat bottle into place and replace the front panel and the four (4) socket head cap screws.

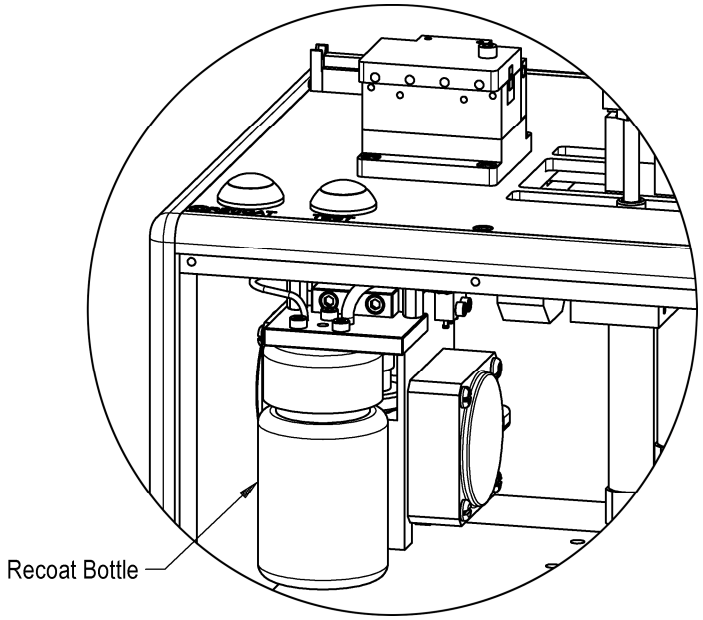


Figure 2: Recoat Bottle Access

6. Turn on power to the PRL-200 and wait for the system to initialize.
7. Execute five (5) Purge cycles (Options menu on Handset Controller). Each purge cycle will draw 100 microliters of recoat material from the bottom of the recoat bottle through the red Fill tube and inject material back into the top of the recoat bottle through the green Purge tube (see Figure 3). Five (5) Purge cycles are required to fill the pump with recoat material and force any air out of the pump system. This will take approximately 15 minutes to complete.
8. After the pump has completed its Purge cycles, the Inject tube that runs from the pump to the die must also be filled with recoat material and purged of air. Have cotton swabs and cleaning solution (NMP) available prior to proceeding.

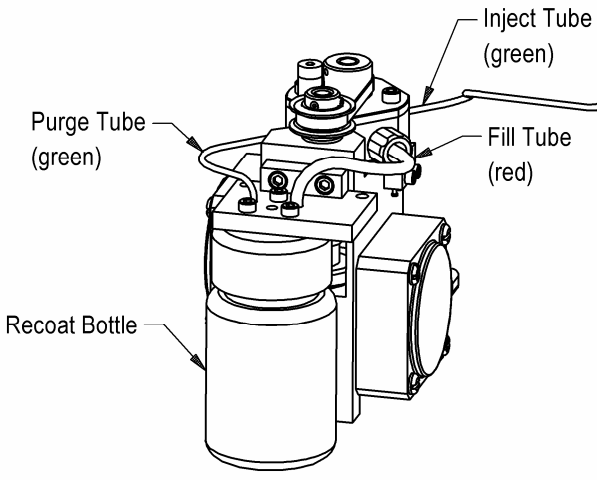


Figure 3: Recoat Material Flow

9. Set the Inject to Die Qty to 100µl (Options menu on Handset Controller).
10. Execute the inject command (press “Select” on the Handset Controller).
11. Watch for recoat material to emerge from the die inject port located at the center of the center of the bottom right die (see Figure 5). Make sure to collect the recoat material with a cotton swab as it comes out of the die injection port. Do not allow recoat material to run down between the die.
12. Execute three (3) additional “Inject 100” sequences to purge air completely from the inject tube. **Note:** Because the injection pump holds 100µl of recoat material, there will be a delay of approximately one minute between the second and third inject sequences while the pump refills.

13. After purging the inject tube, the recoat material should run freely from the die without bubbles. If bubbles are still present, run additional inject sequences.
14. Once the pump and the inject tube are purged, clean the die of all excess recoat material (see 3.2).

Note: Because the syringe in the recoat pump is mounted vertically, it is possible that an air bubble may still be trapped at the tip of the syringe after the above priming process. This air bubble will very slowly rise to the top of the syringe after which time it can be purged out. It is therefore recommended that at least one (1) additional Purge cycle is run the next day after the initial priming of the system.

3.2 Cleaning the Die

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP (1-Methyl-2-pyrrolidinone). NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

4 Recoat and Proof Test Process

4.1 The Polyimide Recoat Process

The PTR-200-PRL utilizes two Fiber Holding Blocks (FHB's) to securely clamp and position the fiber prior to recoating. The right-hand FHB has a linear drive mechanism for applying tension to the fiber. A load cell is incorporated into the linear drive mechanism for monitoring recoat tension. Once the fiber is positioned and securely clamped in the FHB's, pressing the recoat button will initiate an automated recoat process. The right-hand FHB will move to the right until the Recoat Tension is reached. With the fiber held under tension, the right die is closed and the Undercoat Quantity of material is injected into the die and the right heater is set to the Precure Temperature. The recoat head will move to the left depositing material while the right heater will precure the material. Upon reaching the appropriate length, the left die will close and additional recoat material will be injected into the die. The left heater is set to the Precure Temperature and the right heater to the Cure Temperature. The recoat head moves to the right depositing material while the right heater fully cures the previously precured material and the left heater precures the newly deposited material. Returning to the start position is defined as one loop or pass as the material initially deposited has been fully imidized.

This process is repeated until the desired recoat thickness has been achieved. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The recoated fiber is unloaded and the unit resets itself in preparation for the next recoat.

4.2 The Fiber Holding Blocks, V-Grooves, and Inserts

The FHBs are designed to accommodate a range of fiber buffer and cladding sizes through the use of changeable, bottom, FHB inserts. The top insert is spring loaded and does not require any change for 80 or 125 micron fibers. The bottom inserts are V-groove, and incorporate vacuum feed to assist in loading the fiber. The V-groove provides mechanical alignment to the recoat die. V-groove inserts are labeled according to clamping diameter in microns. Beyond the V-groove inserts are rubber inserts. The rubber inserts provide the clamping force and surface area required for tensioning and tension testing.

4.3 Stripped Fiber Requirements

The fiber to be recoated should be free of debris and have a smooth, continuous transition in the jacket strip region. The jacket interface should not extend beyond the original coating diameter.

4.4 Loading

To load the fiber for recoating:

1. If the Fiber Holding Block (FHB) tops are closed, open the FHB tops (see Figure 4). The head will move to the start position and the internal vacuum pump will turn on to aid in loading the fibers.

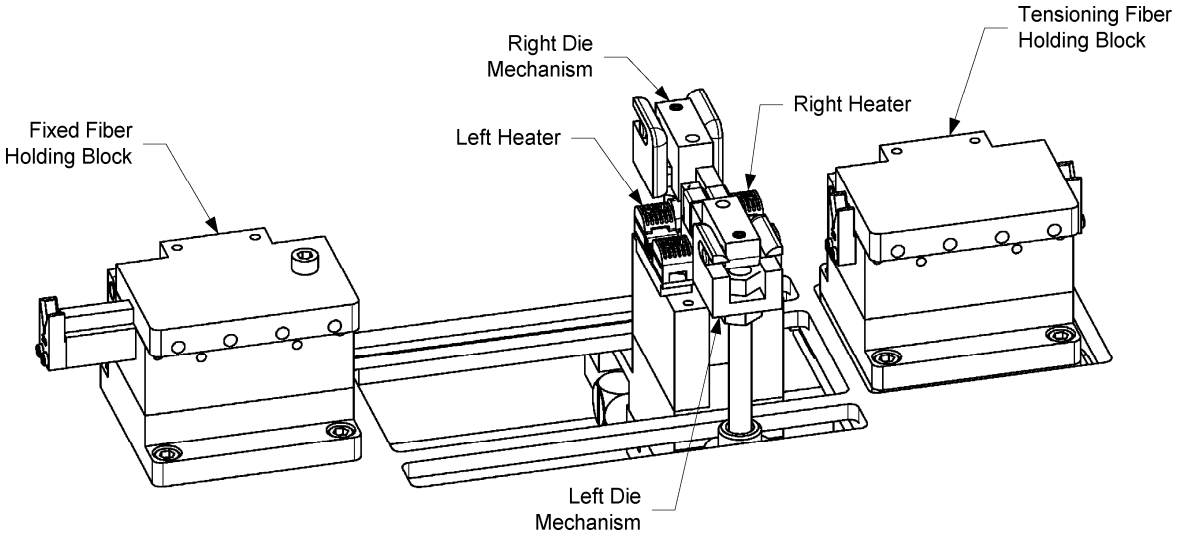


Figure 4: Recoat and Proof Test Components

2. If the FHB tops are open, the load fiber process can be initiated, by either pressing the blue RECOAT button or by closing and reopening both left and right FHB tops.
3. Check that the correct FHB inserts (top and bottom) are installed and that they are free from debris. Position the fiber in the left-hand FHB V-groove, with the stripped section to the left of the left heater. Lower the fiber into the right-hand FHB V-groove. The FHB vacuum should hold the fiber in place.
4. Manually position the fiber in the FHBs so that the right jacket interface is in line with the left edge of the recoat head (see Figure 5). Verify that the fiber is centered in the left and right die.
   Note: Damage to the die may occur if the fiber is not centered in the die when they close.

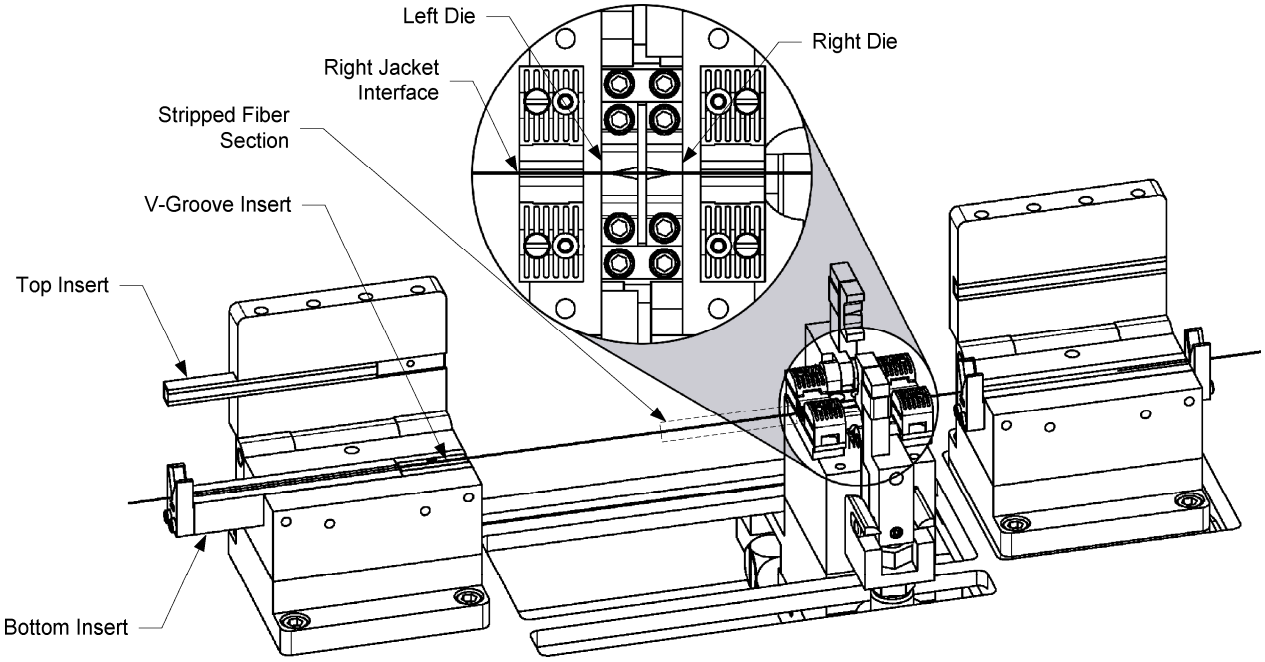


Figure 5: Fiber Position

5. Gently close the FHB lids. This will capture the fiber and turn off the external vacuum pump.
6. The fiber is now ready to be recoated.

4.5 Recoating

To recoat the fiber:

1. Visually confirm that the fiber is loaded properly, if not reload the fiber.
2. Initiate the recoat process by pressing the blue RECOAT button on the unit or the START button on the Handset Controller. The recoat process is fully automated as follows:
   a. The right-hand FHB will begin moving to the right, applying tension to the fiber.
   b. Once the Recoat Tension is reached, the right-hand block will stop moving.
   c. The handset controller will await input from the operator verifying the correct fiber position in the die. Upon confirming the correct fiber position to the handset the process will continue.
   d. The right die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Precure Temp and the head will pause for the Heater Stabilize Time.
   e. The head will move to the left at the Undercoat Head Sweep Vel depositing material while the right die evaporates the volatiles.
   f. Upon reaching the appropriate length, the left die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Cure Temp, the left heater will be set to the Left Precure Temp and the head will pause for the Heater Stabilize Time.
   g. The head will move to the right at the Undercoat Head Sweep Vel depositing material. The right heater will be imidizing the previously precured material while the left heater is evaporating the volatiles from the freshly deposited material. The head will complete at the initial start position plus the overlap delta. This is defined as one loop or pass as the material initially deposited has been fully cured.
   h. The process is repeated (using the Overcoat parameters) until the desired thickness has been achieved by the Number of Overcoats (loops or passes).
   i. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The tension is applied to the specified Level at the specified Rate and released.
3. Proceed to Unloading the Fiber.

4.6 Proof Testing

The Peak Tension should be set to ensure that the recoat meets the minimum strength requirement for its intended application. If using units of tension (kpsi), make sure to enter the correct fiber diameter (e.g. 125 microns) and not the coating diameter.

WARNING: Always wear safety glasses when proof testing fiber. The fiber under test can shatter and send glass particles flying.

To perform a Proof Test:

1. Load the fiber in the fiber holding blocks (see 4.4).
2. Check that the proof test parameters are set correctly.
3. Press the “TEST” button on the PTR-200-PRL.
4. Upon completion of the Proof Test, raise the fiber holding block tops and remove the proof tested fiber.

Note: It is not possible to abort a Proof Test once it has been started.

4.7 Unloading

To unload the fiber after recoating:

1. After the fiber is recoated, the external vacuum pump will turn on to assist in holding the fiber during the unloading process.
2. Hold the fiber securely and lift the left-hand FHB lid. The fiber will be free to move after lifting the lid, so it is important to keep the fiber secured (the V-groove extension is ideal for this).
3. Carefully lift while guiding the recoated fiber though the heaters.
   Note: Raising the FHB top will re-initiate the vacuum pump timer for an additional 15 seconds, after which time the unit will perform a homing routine. The recoated fiber should be removed within this 15 second window.
4. Raise the right-hand FHB top and remove the recoated fiber.
5. Check that no debris is left behind in the FHB V-grooves or on the top clamping surfaces.

Note: After a recoat has been removed (or even if there is a recoat failure), an automatic homing routine will be run 15 seconds after the left FHB top is raised. This homing routine will re-set the position of the right-hand FHB, and the head. The system waits for the FHB top to be opened to ensure that the fiber is being unloaded. If both FHB tops are closed prior to the 15-second time-out, the homing routine will be run immediately.

If the PTR-200-PRL homing process is interrupted or fails, all system functionality is disabled to prevent possible damage to the equipment. Remove any fiber from the FHB's and cycle the power OFF then ON. The PTR-200-PRL will initialize and attempt to run the homing process again. If any further difficulty is experienced, contact Vytran Technical Support for assistance.

5 Maintenance

5.1 Planned Maintenance

The PTR-200-PRL is designed for a production environment to give trouble-free operation provided normal planned maintenance is adhered to. Maintenance and repair procedures should be performed only by trained personnel. Improper service and/or repair could result in the safety features being disabled and can also lead to damage that will not be covered under warranty.

Planned Maintenance Schedule

	Every Shift	Daily	Monthly	12 Months
Inspect / Clean Fiber Holding Blocks[1]	√	√	√	√
Inspect / Clean die[2]	√	√	√	√
Flush recoat System[2] (as needed)			√	√
Purge Recoat System[2] (as needed)			√	√
Replace Recoat Material[2] (as needed)			√	√
Check Load Cell Calibration / Re-Cal[3]				√

[1] Maintenance operations can be performed by the operator.
[2] Maintenance operation can be performed by trained maintenance personnel.
[3] Vytran certified technician only.

5.2 Inspecting the Fiber Holding Blocks

The Fiber Holding Blocks (FHB's) should be inspected daily for debris and/or damage, which may prevent the tops from closing properly and the fiber from being clamped fully. It is particularly important to make sure that the bottom insert V-groove surfaces and the top insert clamping surfaces are free of debris and oils. This will help to ensure that the fiber will not break or slip during tensioning. Cleaning the metal insert surfaces is best accomplished using a cotton-tipped applicator wetted with acetone or alcohol. For embedded debris, a soft cleaning brush may be used. Cleaning the rubber insert surfaces is best accomplished using a cotton-tipped applicator wetted with alcohol. Do not use acetone as this will dry out the rubber causing it to become brittle and crack.

5.3 Inspecting and Cleaning the Die

The die of the recoat head should be inspected daily for debris and/or damage which may result in sub-optimum recoat performance.

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP. NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If

the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

5.4 Load Cell Calibration

The load cell calibration should be checked every twelve (12) months to ensure that accurate recoat and proof test tension is applied to the fiber. This task must be performed by a Vytran certified technician.

5.5 Flush Recoat System

The recoat injection system should be flushed clean every 1 month as part of the recoat material replacement procedure. Before flushing the system, make sure to have cotton tipped applicators and cleaning solution (NMP) available prior to proceeding. To flush the system:

1. Remove the internal recoat bottle and clean all exposed tubing and fittings with NMP.
2. Install a bottle filled 1/4 full with NMP on the pump.
3. Run 5 purge cycles.
4. Remove the bottle, dispose of contaminated NMP. Refill ¼ full with clean NMP and reinstall.
5. Run 5 more purge cycles.
6. Run several inject 100 sequences until NMP runs clear from the die inject port.
   Note: Make sure to collect material as it comes out of the die inject port. Do not allow material to run between the left and right die.
7. Remove the bottle of NMP from the pump.
8. Run several more inject 100 sequences until no more NMP exits the die injection port.
9. Run one purge cycle. Make sure to collect any NMP that comes out of the green purge tube at the top of the bottle fitting.
10. Clean all bottle tubing and fittings with NMP.
11. Install an empty bottle for storage, or a new bottle ¾ filled with fresh recoat material for use. If installing fresh material, proceed to 3.1 Priming the Injection System.

5.6 Purge Recoat System

The purge cycle is a process of emptying the recoat material of the Automatic Injector back into the recoat material bottle and refilling the pump with fresh recoat material drawn from the bottom of the bottle. Running 5 purge cycles is sufficient to entirely fill the pump with fresh recoat material.

If the system has not been used for an extended period (over 1 week), it is recommended that a single purge cycle be run to fill the pump with fresh material.

5.7 Replacing Recoat Material

Recoat material has a finite shelf life and should be replaced every 1 month. To replace the recoat material, first flush the system as outlined in Flush Recoat System (above). Once the system is flushed, fill a clean recoat bottle ¾ full with fresh recoat material and follow the procedures in Purge Recoat System (above).

Note: The one-ounce internal recoat bottle holds approximately 30,000 micro-liters when full. The number of recoats per fill and the approximate time before the material needs to be refilled can be determined based on the volume of material per recoat and the number of recoats per month. For most applications the material will need to be replaced before it runs out. Even if fresh material is added to the internal bottle prior to the Planed Maintenance schedule, the material should still be replaced since mixing of the old and new materials occurs.

5.8 Replacing a Heater

If a heater is sufficiently damaged such that a quality recoat cannot be performed, then replacement is required. The left and right heaters are identical and DO NOT need to be replaced as a pair. The heaters are comprised of a body which houses a graphite filament. When installed in the PTR-200-PRL, the heater is held in place by electrical contacts at the base of the heater body. This is a pin/socket contact compression fit.

To remove the heater:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die sets. This will allow additional access to the heaters.
3. Grab the body of the filament and using a front to back rocking motion, gently lift the filament body (pins) out of the contacts.

To install the heater:

1. Inspect the new heater for any deformation of the filament. If deformation is noted do not install nor use the heater.
2. Hold the filament body (not the graphite filament) and locate the pins into the electrical sockets.
3. To fully seat the heater, gently push down on the electrical contacts (located on the top of the heater).

5.9 Changing the Fiber Holding Block V-Grooves

To change a FHB V-groove insert:

1. Loosen the two (2) set screws accessible from the front of the FHB base using the 0.035” Allen key included in the LDC-200 tool kit. Do NOT remove the set screws completely; one full turn counter-clockwise should be sufficient to release the insert.
2. Remove the FHB V-groove and replace with the desired size. For dual sided inserts, the label for the desired size should face right side up and be readable. Make sure the vacuum feed ports are clear of debris by holding the insert up to a light and checking from behind to make sure light passes each of the ports. Clean if necessary.
3. Make sure the new insert is fully seated and flush with the inside face of the FHB.
   Note: The inside face of the FHB is the side closest to the head.
4. Re-tighten the set screws until they are snug. Do NOT over tighten.

5.10 Replacing the Die

If the die are sufficiently damage such that a quality recoat cannot be performed, then replacement is required. The top and bottom die are a matched set and are replaced as a pair. The top die are spring loaded which enables a slight pivoting during closure, while the bottom die are fixed mounted to the head.

To replace the top die:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. The top die pivots about a center pin which is pressure loaded with two (2) small springs. Remove and retain the top die retainer clip for reuse. This will expose the springs. Using the die, gently compress the springs. This will allow a rotation of the die by ~45 degrees and a removal of the die from the clamp. Remove and retain the springs for reuse.
3. Locate and clean the new top die to be installed.
4. Insert the two (2) springs into the clamp. With the die rotated ~45 degrees, gently collapse the springs with the die. Align the die pin with the clamp and rotate the die to 0 degrees to install.
5. Reinstall the die retainer clip.

To replace the bottom left die (no inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Remove the die from the head.
3. Locate and clean the new top die to be installed.
4. Seat the new die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

To replace the bottom right die (with inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Gently begin to remove the die from the head. An inject tube will be attached to the die. This tube will limit the distance the die can be removed from the head. Gently pull the die with the inject tube until resistance is felt
3. Locate and clean the new top die to be installed.
4. To release the old die from the inject tube, gently rotate the die while holding the inject tube. To install the new die onto the inject tube, gently rotate the die onto the inject tube while holding the inject tube. Slowly feed the inject tube into the head. Seat the die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

Appendix A: MSDS PI2525

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

MATERIAL SAFETY DATA SHEET

***** IDENTIFICATION *****

NAME: PI2525 SYNONYMS: POLYIMIDE COATING.
CHEM.FAMILY: Pyralin® Polyimide Coating. FORMULA: Proprietary.

MANUFACTURER:
HD MicroSystems™
Cheesequake Road
Parlin, NJ 08859

INFORMATION & EMERGENCY TELEPHONE NOS:
INFORMATION: Product: (800) 441-7515
EMERGENCIES: Medical: (800) 441-3637
Transport (CHEMTREC): (800) 424-9300

All Ingredients in This Product Are TSCA Listed/Reported.

***** PHYSICAL DATA *****

FORM: Viscous Liquid. ODOR: Aromatic.

APPEARANCE: Colorless to Amber. SOLUBILITY IN WATER: Slight.

***** COMPONENTS *****

Material(s):	CAS#	V.P. mm Hg @ 20C	Weight %
N-Methyl-2-Pyrollidone.	872-50-4	0.29	> 60%
Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer).	31942-21-9		10 - 30%

PI2525/AH1
05/19/98

***** HAZARDOUS REACTIVITY *****

INSTABILITY:
The product is normally stable.

INCOMPATIBILITY:
Avoid contact with:
Reducing agents; Oxidizing agents; Bases; Acids; Strong acids; Strong oxidizers.

DECOMPOSITION:

Decomposition products at high temperature may include:
Carbon monoxide (CO); Nitrogen oxides; Carbon monoxide, carbon dioxide, water.

POLYMERIZATION:
The product may polymerize endothermically if exposed to temperatures over 90 F, ultraviolet light or free radical initiators. This may increase viscosity.

***** FIRE & EXPLOSION DATA *****

FLASHPOINT: 194 F Seta CC

FIRE & EXPLOSION HAZARDS:
The product is not an unusual fire or explosion hazard.

EXTINGUISHING MEDIA:
Water spray, dry chemical or carbon dioxide.

SPECIAL FIREFIGHTING INFORMATION:
Toxic decomposition products may form under fire conditions. (See Decomposition Section.);
Wear full protective clothing and a full facepiece, positive pressure, self-contained breathing apparatus (SCBA);
Decontaminate contaminated clothing and equipment with soap and water. Dispose of residues per federal, state, and local regulation. (See Waste Disposal Section.).

OVERVIEW: The most likely routes of overexposure to this

PI2525/AH1 Page 2

***** HEALTH HAZARD INFORMATION *****

product are skin contact and inhalation. Skin irritation and/or other effects of skin contact are easily avoided by using proper gloves (see section titled GLOVES) and washing affected areas immediately if contact occurs. Volatile solvents will start evaporating during room temperature use of the product, such as thinning, pouring from jar to dispensing machine, and spin coating. Mist and solvent vapors will evolve if spray application is used. During wafer drying, 125 - 150 C, and final curing, 350 - 450 C, the remaining solvent(s) will evaporate. Potential overexposure to other chemicals used in the operation such as wafer etchants and cleaners should also be considered. Well designed area and personal air sampling and analysis can show if exposures are within established limits. Properly designed local ventilation and process enclosure are effective ways to limit employee exposure where needed.

In addition to meeting exposure limits, it is always prudent to use all practical means to minimize employee exposure to chemicals. A significant difference in overall exposure can be made with practical measures such as:

* Inhalation - minimizing by keeping jars of product covered
* Eye - avoiding contact by wearing chemical splash goggles where there is splash potential
* Ingestion - avoiding by washing hands before eating, drinking or smoking, and restricting these activities to outside the work area.

PRINCIPAL HEALTH EFFECTS:

>>>N-Methyl-2-Pyrollidone
****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Mild skin irritation; No skin sensitization; BY INHALATION: Respiratory effects. Toxic effects of repeated or prolonged animal exposures include: BY INHALATION: Respiratory effects; Bone marrow effects; Lymph system effects; Testicular effects; ****Additional animal tests have shown: No carcinogenic activity; No developmental toxicity; No genetic damage in bacterial or mammalian cell cultures; No reproductive toxicity. ****Human health effects of overexposure may include: By contact with liquid or vapor: Eye irritation with discomfort, tearing, or blurring of vision; BY SKIN OR EYE CONTACT: Eye irritation with discomfort, tearing, or blurring of vision; Skin irritation with itching, burning, redness, swelling or rash; BY INHALATION: Runny nose; Sore throat; Sneezing; Irritation of the nose and throat; Nonspecific discomfort, e.g., nausea, headache or weakness. ****Human effects of higher level

PI2525/AH1 Page 3

acute, repeated or chronic overexposure may include: BY SKIN OR EYE CONTACT: Skin reddening; Skin irritation with discomfort or rash; Dermatitis; Swelling; Burning. ***In addition: BY SKIN OR EYE CONTACT: There are inconclusive or unverified reports of human sensitization.

>>>Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer) ****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Skin irritation; Skin sensitization; Eye irritation.

ANIMAL DATA:

>>>N-Methyl-2-Pyrollidone
Inhalation 4 hour ALC: 1.7 mg/L in rats (Moderately toxic)
Skin absorption LD50: > 8,000 mg/kg in rabbits (Slightly toxic)
Oral LD50: 4,320 mg/kg (Slightly toxic).

CARCINOGENICITY LISTING:

No ingredients of this product are designated by IARC, NTP, OSHA, ACGIH or Dupont as potential carcinogens.

EXPOSURE LIMITS:
Workplace exposures should be kept below the following limits:

.	AIHA		ACGIH		OSHA	
Name/Units	8hr	15min	8hr	15min	8hr	15min
PARTICULATES (N.O.S.), respirable						
Units: mg/m3					5	
PARTICULATES (N.O.S.), total						
Units: mg/m3			10		15	
N-METHYL-2-PYRROLIDONE						
Units: ppm	10					

Also, DuPont has established and observes the following limits:

Name/Units	12 hr	8hr	15min	Ceiling
N-METHYL-2-PYRROLIDONE				
Units: ppm		25		

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NOTES ON EXPOSURE LIMITS:
PELs - OSHA Permissible Exposure Limits - 29 CFR 1910.1000, Subpart Z, or specific substance standards;
TLVs - ACGIH Threshold Limit Values - published by American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211;
WEELs- AIHA Workplace Environmental Exposure Limits - published by the American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031;
AELs - Dupont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits are lower than AEL in effect, government limits shall take precedence;
(C) = "ceiling", limit not to be exceeded for any time period;
(S) = "skin" , skin absorption may contribute significantly to the ingredient's internal toxicity.

***** FIRST AID INSTRUCTIONS *****

Skin Contact: For skin contact, immediately wash skin with soap and water. Wash contaminated clothing before reuse.
Eye Contact: For eye contact, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.
Ingestion: If swallowed, do not induce vomiting. Immediately give two glasses of water. Never give anything by mouth to an unconscious person. Call a physician.

***** PROTECTION INFORMATION *****

Adequate local ventilation should be used to keep exposures below applicable limits;
Other engineering controls such as totally enclosed handling systems are also preferred;
Respiratory protection will be needed if exposures can not be kept below applicable limits by other means.

Respiratory Protection:
A NIOSH/MSHA approved full-face mask equipped with chemical cartridges approved for methylamine may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, when exposure levels are not

PI2525/AH1 Page 5

known, or in any other circumstances where air purifying respirators may not provide adequate protection;
For most conditions, no respiratory protection should be needed; however, if handling at elevated temperatures without sufficient ventilation, use an approved air-purifying respirator. In dusty atmospheres, use an approved dust respirator;
Selection of a suitable respirator will depend on the properties of the contaminant(s) and their actual or expected air concentration(s) versus applicable limits. Consult ANSI Standard Z88.2 for decision logic to select appropriate NIOSH/MESA approved respirators;
A NIOSH/MSHA/OSHA approved air purifying respiratory with a dust/mist cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, exposure levels are not known or any other circumstances where air purifying respirators may not provide adequate protection;
Use a positive pressure air-supplied respirator if concentrations may exceed exposure limits. Air-purifying respirators are inadequate for this material;
If respirators are needed to meet applicable limits, a respiratory protection program up to the level of OSHA Standard 29 CFR 1910.134 is mandatory. This includes air monitoring, selection, medical approval, training, fit testing, inspection, maintenance, cleaning, storage, etc;
An OSHA/NIOSH respirator for protection against Nuisance Dust is recommended.

Gloves:

Gloves should be used when the possibility of skin contact exists;
The suitability of a particular glove and glove material should be determined as part of an overall glove program. Considerations may include chemical breakthrough time; permeation rate; abrasion, cut and puncture resistance; flexibility; duration of contact; etc.

Other Protection Practices:

Appropriate eye protection such as chemical splash goggles should be used if the possibility of eye contact exists;
Protective outer clothing should be used where the possibility of body contact exists. Contaminated work clothing should not be allowed out of the workplace;
Do not smoke, consume or store food or drinks in areas

PI2525/AH1 Page 6

where the product is handled or stored. After handling the product, wash hands thoroughly before leaving the work area;
Additional engineering controls, work practices and training may be required depending on exposure levels. These are discussed in the OSHA Respiratory Protection Standard (29 CFR 1910.134) and OSHA Hazard Communication Standard (29 CFR 1910.1200);
Do not breath dust. Avoid contact with eyes, skin, or clothing. Wash thoroughly after handling.

***** DISPOSAL INFORMATION *****

Spill, Leak or Release:
FOR SMALL SPILLS, absorb on rags, sand or other absorbent material;
FOR LARGE SPILLS, get workers out of affected area. If flammable liquids or vapors may be present, turn off electrical devices or other sources of sparks or flames. WEAR PROTECTIVE EQUIPMENT. Use supplied-air respiratory protection if vapor concentrations are not known;
Contain spill at source by diking or absorbing with sand. Do not allow spill to spread to or intentionally flush to sewer or ground. Wash area thoroughly. Adequately ventilate area;
Spill residue, cleaning rags and absorbent may be considered hazardous. (See Waste Disposal Section.).

Waste Disposal:
Components of this product may be considered hazardous;
Consult applicable Federal, State, and local regulations for allowable disposal methods.

***** PRODUCT INFORMATION *****

Contaminated Items:
Empty product containers, contaminated clothing and cleaning materials, etc. should be considered hazardous until decontaminated or properly disposed of. (See Waste Disposal Section.).

Storage:
Store product in a refrigerated location (0-4F), away from sunlight or ultraviolet light to ensure product viscosity stability.

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***** ADDITIONAL INFORMATION *****

The following ingredients are subject to the reporting requirements of section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

INGREDIENT(S)	Weight %
N-Methyl-2-Pyrrolidone	> 60%

CALIFORNIA PROPOSITION 65: WARNING: This product does not contain chemical known to the state of California to cause cancer, birth defects, or other reproductive harm.

This product is a physical mixture. The health effects information about this product is based on the individual ingredients; The data in this Material Safety Data Sheet relates only to the specific product designated herein and does not relate to its use in combination with any other material or in any process.

Date of latest MSDS revision: 05/19/98

Person Responsible for MSDS:

Safety Coordinator - MSDS
DuPont P&EM / MCM
14 Alexander Drive
Research Triangle Park, NC 27709-4425
Telephone: (800) 284-3382
Outside U.S.: (919) 248-5775

PI2525/AH1 End of Material Safety Data Sheet Page 8

Appendix B: MSDS NMP

Material Safety Data Sheet

1-Methyl-2-pyrrolidinone

ACC# 08690

Section 1 - Chemical Product and Company Identification

MSDS Name: 1-Methyl-2-pyrrolidinone
Catalog Numbers: AC127630010, AC127630025, AC222080025, AC222085000, AC326930010, AC326931000, AC326932500, AC354890025, AC354900025, AC364380010, AC364380025, AC364381000, AC368450010, AC368450025, AC368451000, AC610411000, BP1172-4, BP11724LC, BP1172N119, BP2619-100, NC9749337, O3688-4
Synonyms: NMP; N-Methylpyrrolidone; N-Methylpyrrolidinone; N-Methyl-2-pyrrolidone; N-Methyl-2-pyrrolidinone; M-Pyrol; 1-Methyl-2-pyrrolidone; solvent in paint strippers.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
872-50-4	1-Methyl-2-pyrrolidinone	99	212-828-1

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: clear colorless liquid. Flash Point: 91 deg C.
Warning! Causes eye, skin, and respiratory tract irritation. May cause harm to the unborn child. **Combustible liquid and vapor.** May be harmful if swallowed, inhaled, or absorbed through the skin. Light sensitive. Hygroscopic (absorbs moisture from the air).
Target Organs: Respiratory system, eyes, skin.

Potential Health Effects

Eye: Causes eye irritation. May cause temporary corneal clouding.
Skin: Causes skin irritation. May be harmful if absorbed through the skin. Not expected to cause an allergic skin reaction. Because of the high permeability rate of N-methylpyrrolidone in human skin, prolonged exposures should be avoided.
Ingestion: May cause gastrointestinal irritation with nausea, vomiting and diarrhea.
Inhalation: Causes respiratory tract irritation. May cause headache. Material has a very low vapor pressure and inhalation exposures are not expected unless material is heated or misted.
Chronic: Prolonged or repeated skin contact may cause dermatitis. Adverse reproductive effects have been reported in animals. Testicular effects in rats were noted after repeated, high-dose oral and inhalation exposures.(BASF)Human occupational exposure has been associated with chronic eye irritation, headaches, and irritant contact dermatitis. Airborne concentrations of 49 to 83 ppm are intolerable.(REPROTEXT)

Section 4 - First Aid Measures

Eyes: In case of contact, immediately flush eyes with plenty of water for a t least 15 minutes. Get medical aid.
Skin: In case of contact, flush skin with plenty of water. Remove contaminated clothing and shoes. Get medical aid if irritation develops and persists. Wash clothing before reuse.
Ingestion: If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical aid.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Combustible liquid and vapor.
Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or appropriate foam.
Flash Point: 91 deg C (195.80 deg F)
Autoignition Temperature: 245 deg C (473.00 deg F)
Explosion Limits, Lower:1.3%
Upper: 9.5%
NFPA Rating: (estimated) Health: 2; Flammability: 2; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Remove all sources of ignition. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes, skin, and clothing. Keep away from heat and flame. Avoid breathing vapor or mist.
Storage: Keep away from sources of ignition. Store in a cool, dry place. Store in a tightly closed container. Keep under a nitrogen blanket.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
1-Methyl-2-pyrrolidinone	none listed	none listed	none listed

OSHA Vacated PELs: 1-Methyl-2-pyrrolidinone: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear chemical splash goggles.
Skin: Wear appropriate gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Liquid
Appearance: clear colorless
Odor: amine-like - mild odor
pH: 8.5-10.0 (100 g/l H2O)
Vapor Pressure: 0.342 mm Hg @ 25 deg C
Vapor Density: 3.4 (air=1)
Evaporation Rate: Not available.
Viscosity: 1.65 cps @ 25 deg C
Boiling Point: 202 deg C @ 760 mm Hg
Freezing/Melting Point:-24 deg C
Decomposition Temperature: Not available.
Solubility: Soluble.
Specific Gravity/Density:1.030
Molecular Formula:C5H9NO
Molecular Weight:99.13

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions.
Conditions to Avoid: Light, ignition sources, excess heat, exposure to moist air or water.
Incompatibilities with Other Materials: Strong oxidizing agents, strong acids.
Hazardous Decomposition Products: Nitrogen oxides, carbon monoxide, carbon dioxide.
Hazardous Polymerization: Will not occur.

Section 11 - Toxicological Information

RTECS#:
CAS# 872-50-4: UY5790000
LD50/LC50:
CAS# 872-50-4:
Draize test, rabbit, eye: 100 mg Moderate;
Oral, mouse: LD50 = 5130 mg/kg;
Oral, rat: LD50 = 3914 mg/kg;
Skin, rabbit: LD50 = 8 gm/kg;
.
Sensitization test (guinea pig): negative. test (humans): negative.(Merck)
Carcinogenicity:
CAS# 872-50-4: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No data available.
Teratogenicity: Proposition 65 maximum allowable dose level for developmental toxicity for N-methylpyrrolidone is 3200 ug/day for the inhalation route and 17,000 ug/day for the dermal route.

Reproductive Effects: See actual entry in RTECS for complete information.
Mutagenicity: See actual entry in RTECS for complete information.
Neurotoxicity: No data available.
Other Studies:

Section 12 - Ecological Information

Ecotoxicity: Daphnia: Daphnia: 4897 mg/l; 48 h; EC50Fish: Gold orfe: 4000 mg/l; 96 h; LC50Bacteria: >9000 mg/l; 48 h; EC50Algae: >500 mg/l; 72 h; IC50 log Pow = -0.46 (25°C)BOD5 = 1100 mg/l.COD = 1600 mg/l.
Environmental: No information available.
Physical: No information available.
Other: Biodegradable.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated	Not Regulated
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 872-50-4 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
CAS# 872-50-4: Test for Health Effects

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 872-50-4: immediate, delayed, fire.

Section 313

This material contains 1-Methyl-2-pyrrolidinone (CAS# 872-50-4, 99%),which is subject to the reporting requirements of Section 313 of SARA Title III and 40

Clean Air Act:

This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 872-50-4 can be found on the following state right to know lists: Pennsylvania, Minnesota, Massachusetts.

California Prop 65

WARNING: This product contains 1-Methyl-2-pyrrolidinone, a chemical known to the state of California to cause developmental reproductive toxicity.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

T

Risk Phrases:

R 36/37/38 Irritating to eyes, respiratory system and skin.
R 61 May cause harm to the unborn child.

Safety Phrases:

S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S 53 Avoid exposure - obtain special instructions before use.

WGK (Water Danger/Protection)

CAS# 872-50-4: 1

Canada - DSL/NDSL

CAS# 872-50-4 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of B3, D2A, D2B.
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

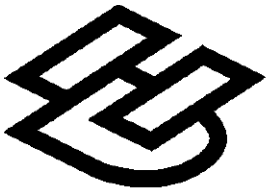
Canadian Ingredient Disclosure List

Section 16 - Additional Information

MSDS Creation Date: 6/10/2003
Revision #2 Date: 3/29/2005

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Appendix C: Pyralin Product Information



HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

Rev. Apr 01

PRODUCT INFORMATION
PYRALIN® PI2525, PI2555, PI-2575 & PI2556

PI2525, PI2555, PI-2575 and PI2556 polyimides [PI-2555 Series] are suitable for applications where the high cure temperatures typically used for polyimides (ca. 350°C) cause problems. Typical applications for these materials are as stress buffer or interlayer dielectric layers over low temperature substrates. These polyimides imidize faster and at lower temperatures than for standard polyimide precursors. The materials are supplied as solutions suitable for spin or roller coating application. A seperate adhesion promoter is recommended with PI-2525, PI-2555 and PI-2556 to improve adhesion to oxides and to metals. PI-2575 is self priming and does not require an adhesion promoter. Processing by wet or plasma etch is possible. Cured film thicknesses from 0.5 µm to 6 µm can be obtained.

Process Details

Coating

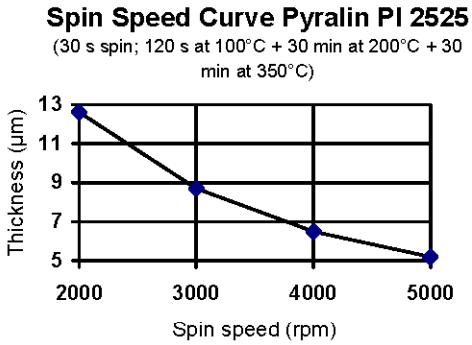
PI2555 Series products can be coated onto a variety of metals, alloys, semiconductor and ceramic substrates. HD MicroSystems adhesion promoters VM651 or VM-652 are recommended to provide good processability and adhesion with the PI-2525, PI-2555, PI-2556. Bonding of the polyimide to the substrate is achieved during the softbake cycle as the priming chemistry is activated by temperature.

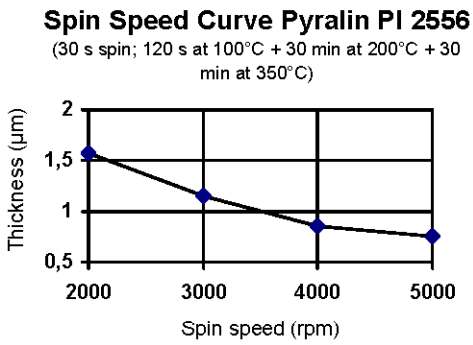
The polyimide solution is highly viscous. There are some guiding principles for dispensing materials of this type. Always coat substrates which are at room temperature. Never trap air into the solution. This can occur for example when the solution is moved during dispense. All bubbles take time to dissipate out of solution. If left in, coating "comets" will result. Dispensing should be in the centre and as close to the substrate as possible. A clean cut-off at dispense is neccessary before the spin process starts. It may be neccessary in the case of highly viscous solutions to have a short delay prior to spin to allow the polyimide to flow as far as possible and relax.

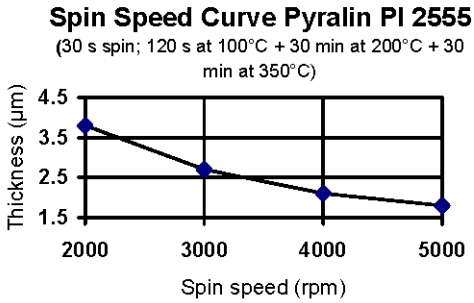
Both static and dynamic dispense may be used. Static dispense is the easiest, but requires more material to be dispensed for each substrate. Dynamic dispense uses less material, but requires greater control during dispense to ensure that the polyimide strikes the exact centre of the substrate. Any deviation will result in poor coating quality. The acceleration to final speed should be as low as possible to allow gradual flow of the polyimide across the substrate. Often one or more intermediate spin speeds are used to allow the polyimide to gradually cover more than 80% of the substrate before continuing on to the final speed. To reduce the backside contamination potential it is often beneficial to prolong the spread cycle until the bulk of the excess polyimide has been removed from the substrate. The final spin speed and time is determined by the film thickness required. Longer spin

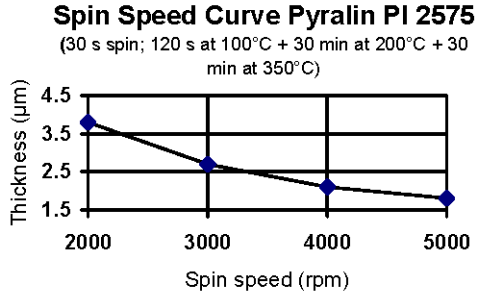
times will improve coating uniformity, but will also reduce the film thickness. In semiconductor applications, an Edge Bead Removal (EBR) and Backside Rinse process may be added to the coating cycle to remove polyimide from the edge and back of the wafer prior to baking. NMP (N-methyl-2-pyrrolidone) or NMP/IPA (isopropanol) can be used for this purpose.

Spin Speed Curves for cured Polyimide









Soft Bake

After application of the polyimide, a bake process is required. Both convection oven and hotplate bake methods may be used. The purpose of this stage, is to partially cure the polyimide prior to patterning. This bake stage leaves the polyimide coating dry, yet soluble in the etchant solution.

Choice of Photoresist

Polyimides of this type can be patterned using common photolithography techniques centered around positive photoresist. The underlying polyimide is an effective anti-reflective layer as there is significant absorption between 350 and 450 nm. This absorption can significantly reduce substrate reflection effects on the photoresist, usually seen as “notching“ after development.

The photoresist should be selected with the correct wavelength to suit the exposure tool in use. As a general guide, formulations with good adhesion in “wet etch“ semiconductor applications perform well. Other attributes include:

- Compatability to standard alkaline positive photoresist developers

- Low contrast performance so that a soft sidewall profile is always produced

- Capability to produce cleanly developed via holes in thick resist coatings

- Good development latitude, especially when over-developed

- The ease of producing a minimum dried 2,5 µm film thickness

The polyimide coating after softbake has minimum solubility in typical photoresist solvents. Photoresist can therefore be coated directly onto the polyimide coating without layer inter-mixing occuring.

Photoresist Application

Substrates should be coated directly with the resist selected. No dehydration bake should be given as this would make the polyimide totally insoluble in the developer. Instead an HMDS vapour prime is permissable if installed on-line but is not really neccessary for good resist adhesion to the polyimide.

Once coated, the resist should be given a softbake at 90°C either in a convection oven for 30 minutes or on a vacuum hotplate for 60 seconds. Once coated and baked, coatings may be held up to 24 hours before exposure.

Photoresist Exposure

Typical exposure: 50 mJ to 150 mJ

Once exposed, development should take place within 8 hours.

Photoresist Development / Polyimide Etch

A single step is used to develop the photoresist and etch the polyimide.

Most alkaline positive resist developers will dissolve both exposed photoresist and polyimide at varying rates. The choice of developer affects the quality of the polyimide image after development. Best results have been obtained using a NaOH based developer.

Thin polyimide layers up to around 5 µm can usually be developed quickly and cleanly with developer which is at ambient temperature. After development of the resist and then the polyimide using a spray puddle technique, a water rinse should be used to remove the developer. The substrate should subsequently be spun until dry.

When thicker polyimide layers need to be processed, it is often beneficial to heat the developer to between 23°C and 25°C. This accelerates the dissolution of the polyimide while having minimal effect on the solubility of the photoresist. In more extreme situations, this may be coupled to a double puddle process. The second puddle is used to develop only the polyimide layer.

Once developed, wafers may be held up to 8 hours before stripping the resist.

Resist Strip

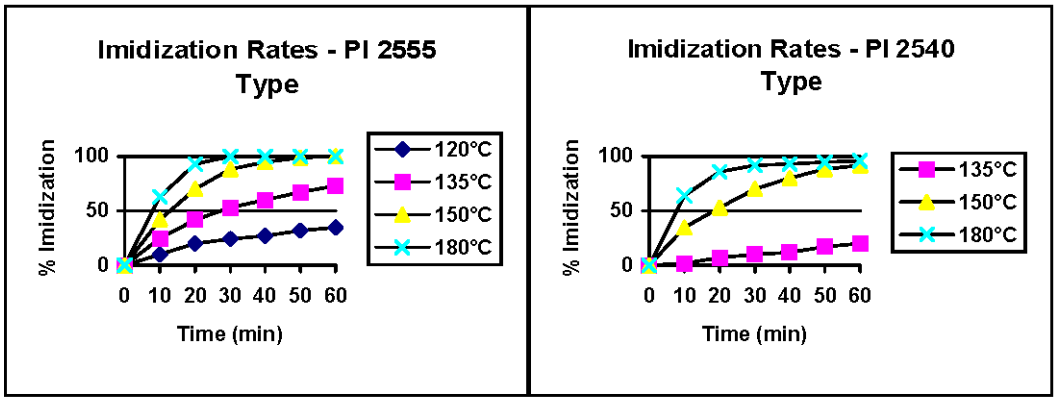
After developing, the photoresist needs to be stripped off the polyimide surface before curing. This step is usually carried out on automated track equipment to reduce surface contamination with resist residue which may result if clean solvents are not used. Resist solvent strippers are normally used.

Cure

The cure heating cycle converts the polyamic acid to the insoluble imide form and drives out remaining solvent. This process requires elevated temperatures and controlled environments to achieve the best results. There is sufficient energy at 180°C to complete the imidization of the polyimide, but higher temperatures are required to completely drive off solvents, thus achieving the ultimate electrical and mechanical properties. A programmable high temperature oven with typical nitrogen flow rate of 10 litres per minute is recommended for best results.

To activate the adhesion promoter, it is recommended that the cure be carried out up until 200°C in air (min 50% RH). Above this temperature, a nitrogen atmosphere should be used. The ramp rates (up and down) should be low to avoid high stress in the polyimide.

The maximum cure temperature may be higher than 300°C when the coating is to be subjected to a high temperature process after curing. In such cases, temperatures up to 400°C have been used to ensure that there is no outgassing during subsequent processes.



Processing Pyralin® PI2525, PI2555, PI-2575 & PI2556 products

(for ca. 7µm softbaked and 5µm cured film thickness)

Application of Adhesion Promoter*

- Dispense on static substrate, 3 seconds
- Hold for 20 seconds
- Spin dry for 30 seconds

Bake Adhesion Promoter

- On hotplate at 120°C for 60 seconds (optional)

*not required with PI-2575

Polyimide Coating

- Dispense on static substrate
- Rotate at 500 rpm for 5 seconds
- Rotate at final speed for 30 seconds (see spin speed curves)
- EBR/Backside rinse, 10 seconds
- Spin dry, 15 seconds

Soft Bake

- In convection oven at 120°C for 30 minutes

OR

- On hot plate at 120°C for 30 seconds followed by 150°C for 30 seconds

Coat Photoresist

- Dispense, 3 seconds
- Spread at 500 rpm for 5 seconds
- Spin at final speed for 30 seconds
- EBR / Backside rinse for 5 seconds
- Spin dry for 15 seconds

Softbake Photoresist

- On hotplate at 90°C for 60 seconds

Exposure

- 50 mJ to 150 mJ

Development

Developer:	NaOH, KOH or TMAH developer or DE 1000 at 21°C
Rinse:	DI water

Puddle Development process:

• Spray (100 rpm)	5 seconds
• Puddle	3 minutes
• Rinse (1000 rpm)	15 seconds
• Spin dry (5000 rpm)	15 seconds

Resist Strip

- Spray or spray/puddle acetone or standard resist stripper or N-Butlyacetate at ca. 2000 rpm
- Spin dry

Cure

Curing should be done in an oven using the following cure profile:

- Heating from room temperature to 200°C, ramp rate 4°C/minute in air
- Hold time at 200°C for 30 minutes in air
- Heating from 200°C to 300°C, ramp rate 2,5°C/minute in nitrogen
- Hold time at 300°C for 60 minutes in nitrogen
- Gradual cooling to room temperature

Solution Properties

	PI2525	**PI2555/PI-2575**	**PI2556**
Solids content (%)	25.0 +/-1.0	19.0 +/-1.0	15.0 +/-1.0
Viscosity (Poise)	60 +/- 10.0	14.0 +/-2.0	3.5 +/-1.0
Flash Point	93°C	60°C	54°C
Solvent (%)	N-Methyl-2-Pyrrolidone 100	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon 80/20 +/-5	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon Propylene Glycol Methyl Ether 70/14/15 +/-5
Ash content (%)	0.1 max.	0.1 max.	0.1 max.
Chloride content	5.0 ppp max.	5.0 ppp max.	5.0 pp max
Sodium content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Potassium content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Copper content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Iron content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Total metals	10.0 ppm max.	10.0 ppm max.	10.0 ppm max.

Cured Film Properties

Tensile strength (kg/mm²)	13.1
Elongation (%)	10
Modulus (kg/mm²)	245
Stress (dynes/cm^2)	3.6×10^8
Moisture uptake (%)	2 - 3
Dielectric constant (at 1 kHz, 50% RH)	3.3
Dissipation factor	0.002
Dielectric strength (volts/mil)	4000
Volume resistivity (ohm-cm)	10^{16}
Surface resistivity (ohm)	10^{15}
Coefficient of thermal expansion (ppm)	40
Coefficient of thermal conductivity (cal/(cm)(sec)(°C))	35×10^{-5}
Glass transition temperature	> 320°C

Decomposition temperature	560°C
Weight loss (% at 500°C, 120 min)	2.9
Specific heat (cal/g/°C)	0.26
Refractive index	1.70

Storage/Shelf Life

It is recommended that PI-2555 Series products be stored between 0°C to -18°C.

Pyralin® PI2525, PI2555, PI-2575 and PI2556 are stable at clean room temperatures (21°C) for ca. four weeks with no significant change in properties. When stored at -18°C, shelf-life is 2 years from date of manufacturing. Moisture contamination is detrimental to stability and must be avoided. Containers should be brought to room temperature before opening to avoid moisture condensation inside the botttle.

Safety and Handling

During all handling of Pyralin polyimide products, adequate ventilation must be provided. Skin and eye contact should be avoided. Exposed areas should be flushed with water immediately. For prolonged or repeated contact, milled butyl rubber or natural latex rubber gloves should be used. Disposable PVC gloves are not recommended.

United States

HD MicroSystems, LLC
P0 Box 80010
Wilmington, DE 19880
800-346-5656 (Phone)
302-892-0597 (Fax)

HD MicroSystems, LLC
1333 Lawrence Expressway
Suite 212
Santa Clara, CA 95051
408-260-0880 (Phone)
408-260-0885 (Fax)

Japan

HD MicroSystems, LLC
10-13, Shibuya 3-chome, Shibuya-ku,
Tokyo 150
Japan
81-3-3407-9003 (Phone)
81-3-3407-9037 (Fax)

Europe

HD MicroSystems Europe GmbH
DuPont Strasse 1
D-61343 Bad Homburg
Germany
49-6172-87-1822 (Phone)
49-6172-87-1824 (Fax)

Internet
www.hdmicrosystems.com

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Caution: Do not use in medical applications involving permanent implanation in the human body.

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

PTR-200-PRL

Automated Polyimide Recoater with Linear Proof Tester

Operator's Manual

Version 1.2

United States:
1400 Campus Drive West • Morganville, NJ 07751
+1 (732) 972-2880 • +1 (800) 421-8847 • Fax +1 (732) 972-6229

England:
8, Kew Court • Pynes Hill Office Campus • Exeter, EX2 5AZ
+44 (0) 1392 445777 • Fax +44 (0) 1392 445009

Web: http://www.vytran.com

VYTRAN

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Vytran LLC
1400 Campus Drive
Morganville, NJ 07751 USA

Phone: +1 (732)-972-2880
+1 (800)-421-8847
FAX: +1 (732)-972-6229

http://www.vytran.com

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1 Introduction

The PRL-200 is designed for recoating and proof testing polyimide coated fibers. It operates on a coat, cure and test recoat method, whereby a layer of polyimide is applied to the fiber through a die, followed by a filament heater to cure the polyimide and upon completing the recoat a linear proof test. When configured and operated properly, the PTR-200-PRL is capable of producing a high quality and a uniform polyimide recoat.

1.1 Parts Checklist

When unpacking the PTR-200-PRL for the first time, check to make sure that you have the following accessories:

- PTR-200-PRL Automated Polyimide Recoater with Linear Proof Tester
- 12.0V Power supply (PSU)
- AC power cord
- DC power cable
- RS-232 communication cable
- Fittings kit
- Tool kit containing:
  - 1 oz. bottle HD MicroSystems PI2525 Polyimide Recoat Material
  - 1 oz. spare bottle
  - Cotton swabs
  - 5/64” Allen key
  - 3/32” Allen key
  - 0.035” Allen key
- External vacuum pump with vacuum line
- PTR-200-CX-PRL Handset Controller

If you are missing any of the above or need replacements, please contact Vytran.

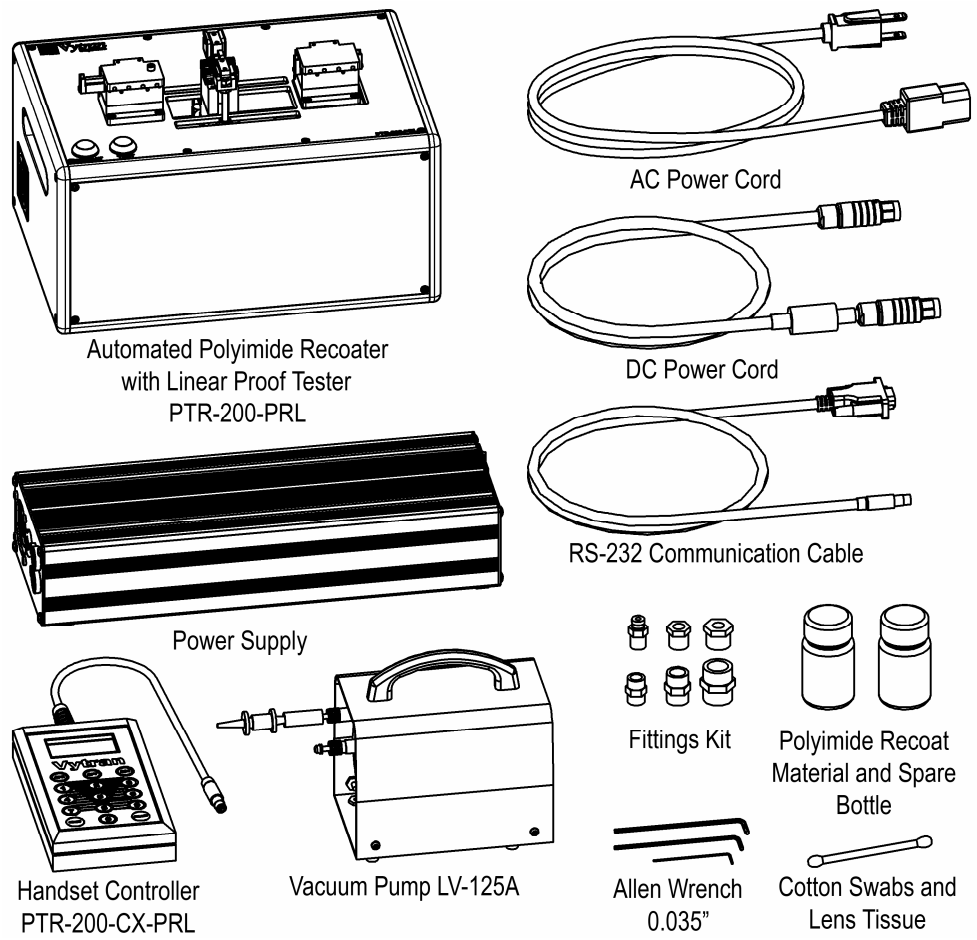


Figure 1: System Components

1.2 Powering Up

The PTR-200-PRL Power Supply Unit (PSU) accepts an AC input of 90-260 VAC; 47-63 Hz. Connect both the AC power cord and the DC power cable to the external Power Supply. Connect the Handset Controller and the DC power cable to the PTR-200-PRL.

Turn on the power supply and then turn on the PTR-200-PRL using the ON/OFF rocker switch located on the back of the recoater. The PTR-200-PRL will run an initialization process that includes homing the recoat die and tensioning motors and operating the recoat die (close/open). During the initialization process, the Handset Controller will display the status of the system. Once the homing process is completed, the Handset Controller displays the Main Menu screen and the PTR-200-PRL is ready for recoating.

1.3 Shutting Down

To shut down the PTR-200-PRL:

1. Turn off the PTR-200-PRL using the on/off rocker switch located on the back of the recoater.
2. Turn off the power supply.

2 Controlling the PTR-200-PRL

The PTR-200-PRL is configured and controlled from Vytran's PRL-200-CX-PRL Handset Controller, which also provides feedback and status of the unit. If the operator does not need to change parameter settings or receive status prompts, the Handset Controller can be removed and the unit operated simply by pressing the blue RECOAT and TEST buttons.

The Handset Controller allows the user to interface with the unit and modify the settings. The Handset Controller is based on a three (3) menus:

- Main Menu
- Configuration Menu
- Options Menu

Each menu and its contents are described below.

2.1 Main Menu

The Main Menu displays the unit status. From this menu, press the "CFG" button to enter the Configuration Menu or press the "OPT" button to enter the Options Menu.

2.2 Configuration Menus

There are three (3) levels to the Configuration Menu. At level one the user can select from five (5) topics - Inject, Undercoat, Overcoat, Recoat Length, or Proof Test. Within each of these topics are the parameters which can be viewed and/or copied. Below is a description of the five (5) topics and each topics parameters.

2.2.1 Inject

Inject Rate (µl/sec): This parameter is the polyimide injection rate, in microliters per second, into the die. The optimum Inject Rate will be dependant on the polyimide material being used.

Undercoat Qty. (µl): This parameter is the quantity of polyimide material, in microliters, injected into the die for the first loop of the head (the undercoat). The optimum Undercoat Qty will be primarily dependant on the bare fiber diameter, die size, and the length of the recoat.

Overcoat Qty. (µl): This parameter is the quantity of polyimide material injected into the die, in microliters, after the first loop of the head. The optimum Overcoat Qty will be primarily dependant on the die size, and the length of the recoat.

2.2.2 Undercoat

Head Sweep Vel. (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the bare fiber diameter, die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

2.2.3 Overcoat

Number of Overcoats: This parameter is the number of loops the head will make. The optimum Number of Overcoats will be dependant on the polyimide thickness layer desired (which will be dependant on the undercoat layer thickness and the parameter settings for the overcoat(s)).

Head Sweep Vel (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Overlap Delta (mm): This parameter is the additional distance, in millimeters, the head will travel on each pass. This will effectively taper the transition from original polyimide to recoated polyimide.

2.2.4 Recoat Length

Recoat Length (mm): This parameter is the desired bare fiber length, in millimeters, to be recoated. The actual recoat length will be approximately 8 millimeters longer on each end in order to compensate for the width of the head and the fiber load position.

2.2.5 Proof Test

Proof Test Units: This menu allows the user to select the desired units for displaying the Proof Test Level. Unit selections are: Newtons, kpsi, and grams.

Proof Test Level (units): This parameter is the Proof Test Level, in units user selected, to be applied after the recoat has been completed.

Proof Test Rate (mm/sec) This parameter is the rate, in millimeters per second, at which the Proof Test Level will be applied. The optimum rate is that which achieves the desired proof test level within 3 - 5 seconds of load applying time.

2.3 Options Menu

From the Options Menu, various system level configuration parameters and functions can be edited or executed.

Recoat Tension (Newtons): This parameter is the tension, in Newtons, applied to the fiber prior to initiating a recoat. The PTR-200-PRL also monitors the tension during the recoat and will automatically abort if the tension varies significantly from the Recoat Tension. The auto abort is intended to protect both the die and fiber.

Heater Settle Time (msec): This parameter is the amount of time, in milliseconds, allowed for the heater to stabilize when changing temperatures.

Die Close Time (msec): This parameter is the amount of time, in milliseconds, allowed for the die to close prior to execution of the subsequent process.

Fiber Unload Time (msec): This parameter is the amount of time, in milliseconds, allowed for the operator to unload the fiber prior to the PTR-200-PRL performing a system reset.

Inject to Die Qty (µL) This option is the quantity of polyimide material, in microliters, which will be injected into the die upon entering the quantity. This option is intended for use when changing materials or purging the system prior to storage.

Head to Home: This option performs a homing of the head and is useful as a diagnostic tool.

Tension Home: This option performs a homing of the proof test load cell and is useful as a diagnostic tool.

Move Head to Start: This option performs a movement of the head to the start position. The start position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Move Head to Stop: This option performs a movement of the head to the stop position. The stop position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Recoat Request State: This option enables or disables the request to input a recoat length each time the process is run. This option is primarily used when the length to be recoated varies significantly from recoat to recoat.

Set/Run Purge Cycles: This option is the number of recoat pump purge cycles that will be run upon entering the quantity.

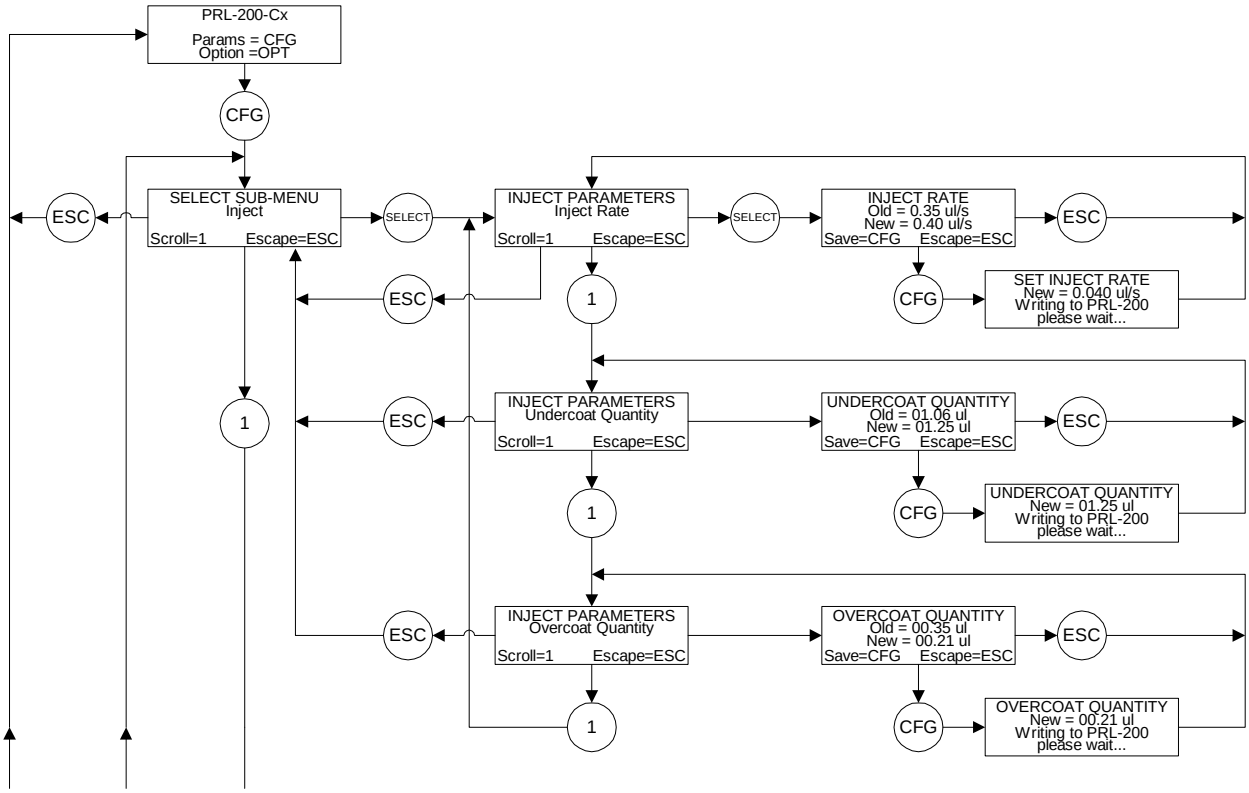
Recoat Tension This option is the amount of tension that will be applied to the fiber prior to the recoating.

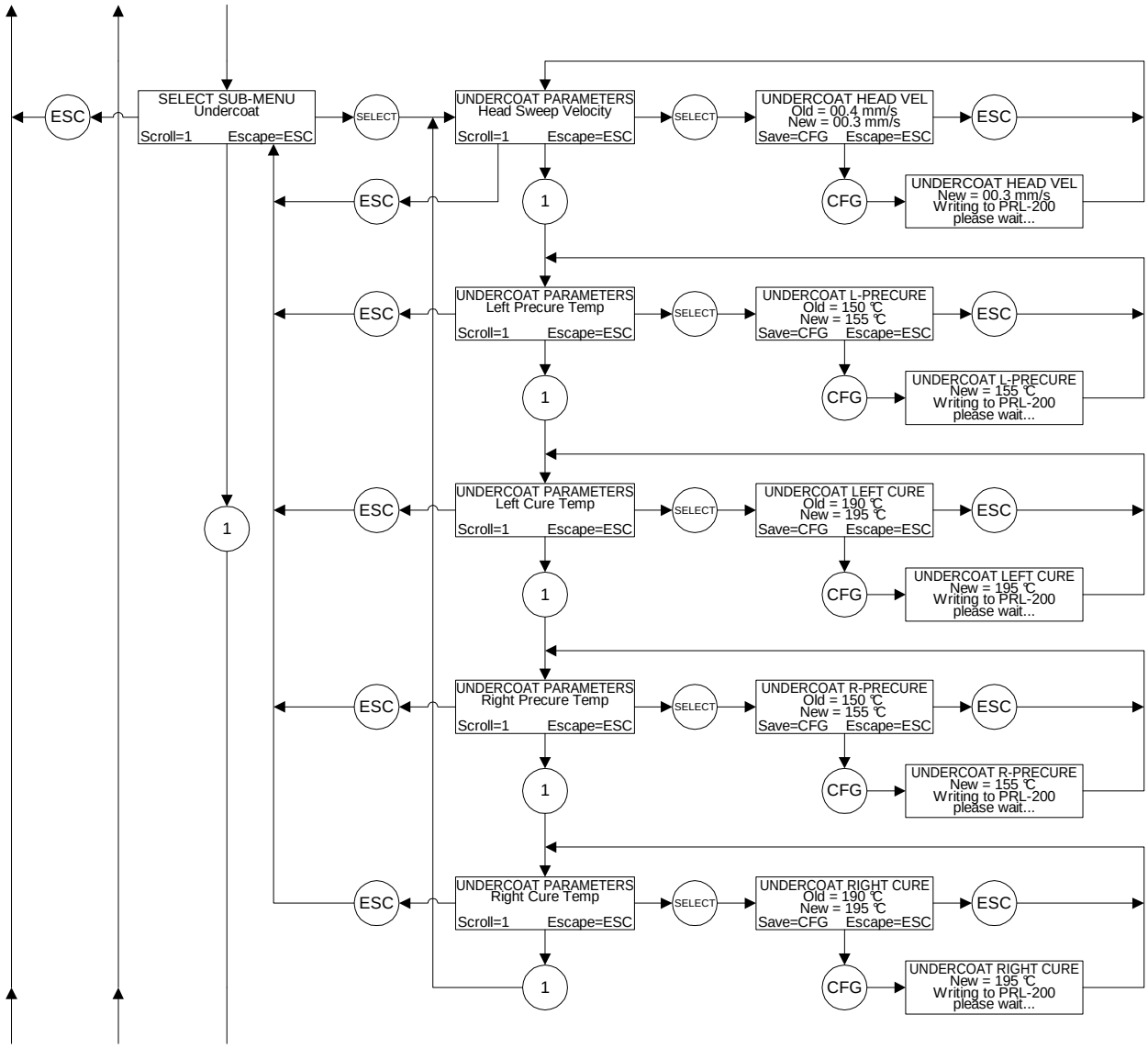
2.4 Parameter Limits

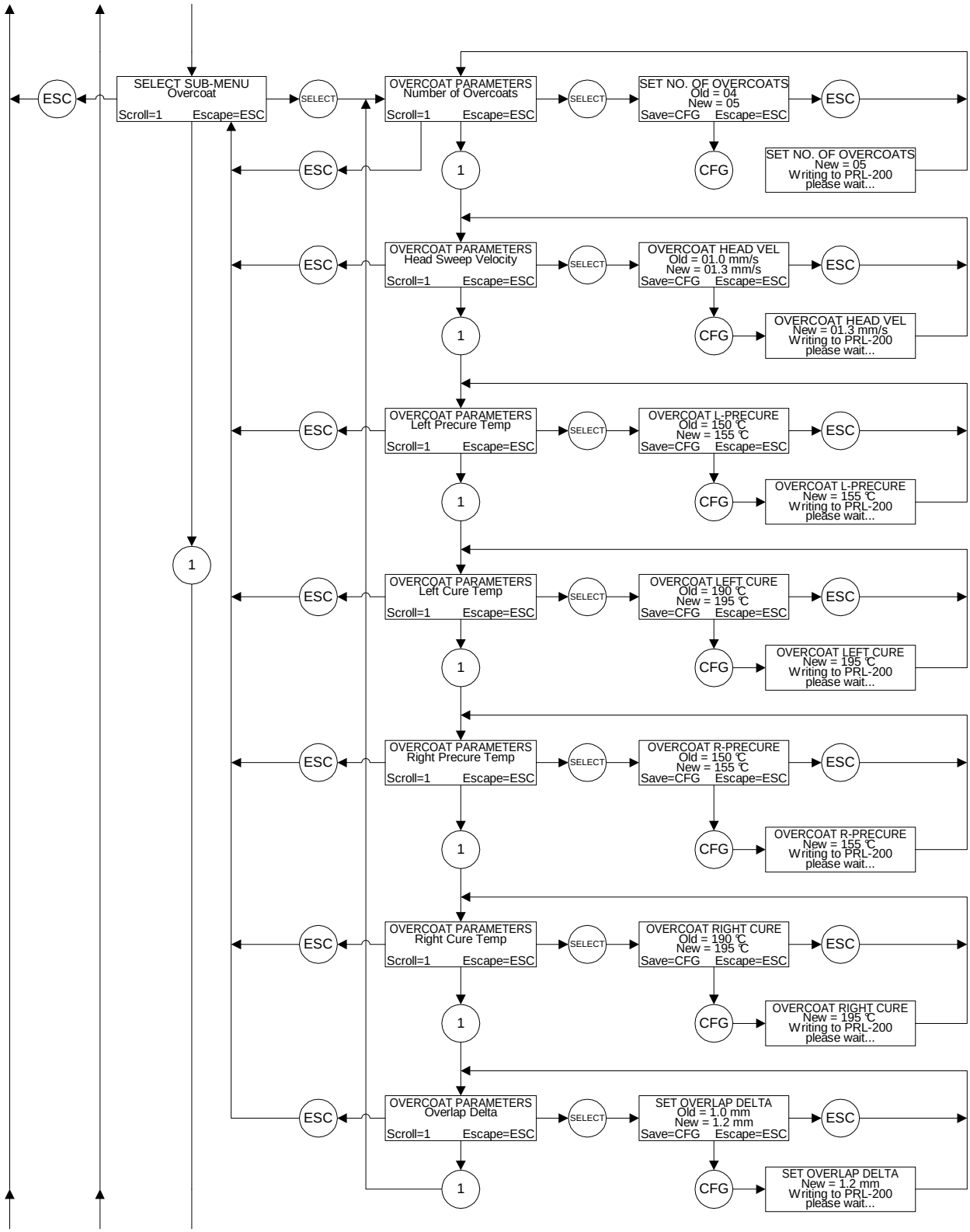
Parameter	Min	Max
Inject Rate (µL/sec)	0.01	2.00
Undercoat Qty (µL)	0.01	10.00
Overcoat Qty (µL)	0.01	10.00
Undercoat Head Sweep Vel (mm/sec)	0.01	20.00
Undercoat Left Precure Temp (℃)	100	200
Undercoat Left Cure Temp (℃)	100	300
Undercoat Right Precure Temp (℃)	100	200
Undercoat Right Cure Temp (℃)	100	300
Number of Overcoats	1	10
Overcoat Head Sweep Vel (mm/sec)	0.01	20.00
Overcoat Left Precure Temp (℃)	100	200
Overcoat Left Cure Temp (℃)	100	300
Overcoat Right Precure Temp (℃)	100	200
Overcoat Right Cure Temp (℃)	100	300
Overlap Delta (mm)	100	200
Recoat Length (mm)	0	2
Proof Test Level (Newtons)	0	20
Proof Test Rate (mm/sec)	0.1	5.0
Recoat Tension (Newtons)	2	10
Heater Stabilize Time (msec)	1	10000
Die Close Time (msec)	250	2500
Fiber Unload Time (msec)	5000	30000
Heater Stabilize Time (msec)	1	10000
Inject to Die Qty (µL)	1	100

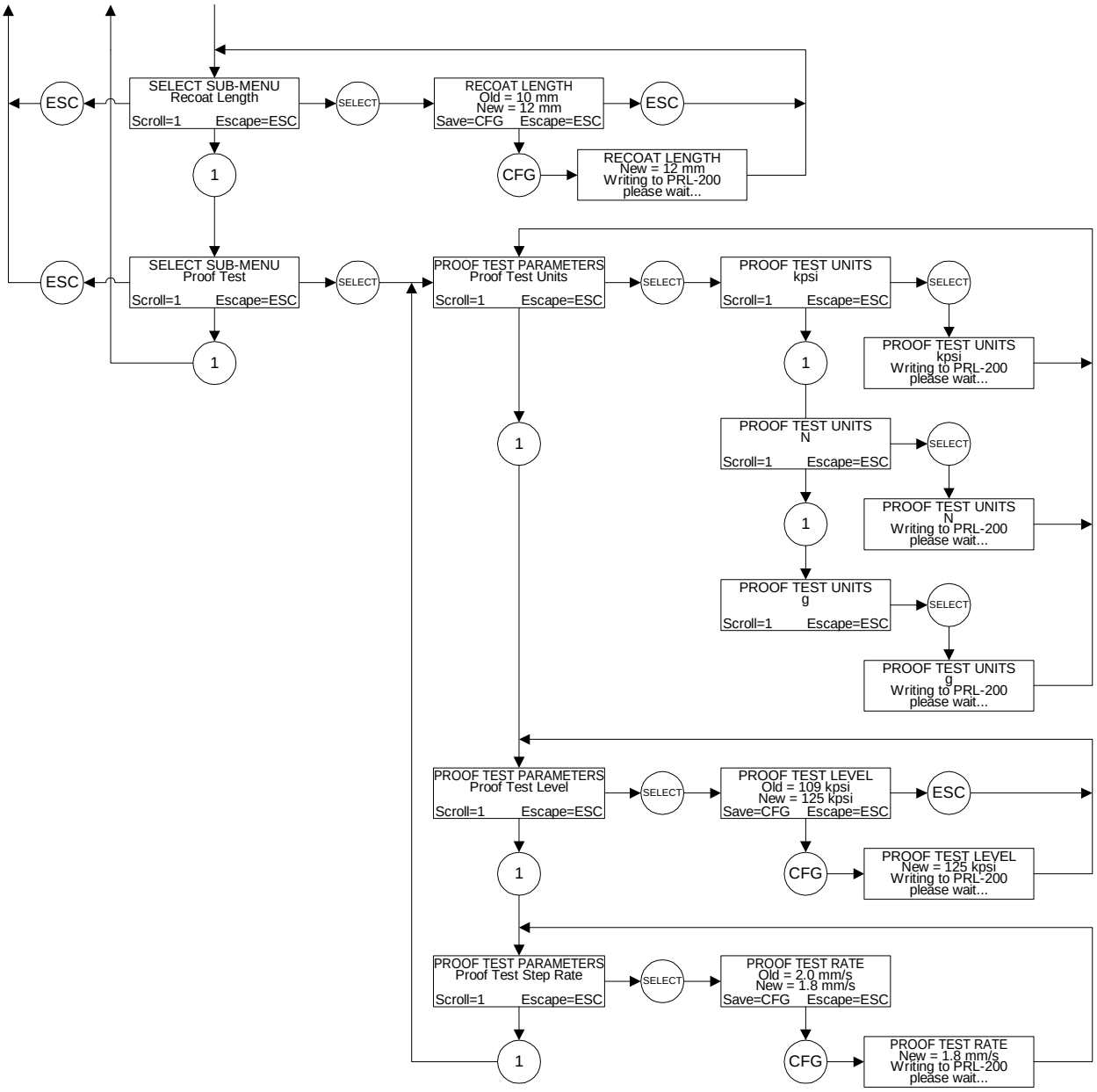
2.5 Configuration Menu Flow Chart

This flowchart is a guide for navigating through the Configuration Menu, and shows the display prompts and button key presses for viewing and editing the Configuration Parameters.



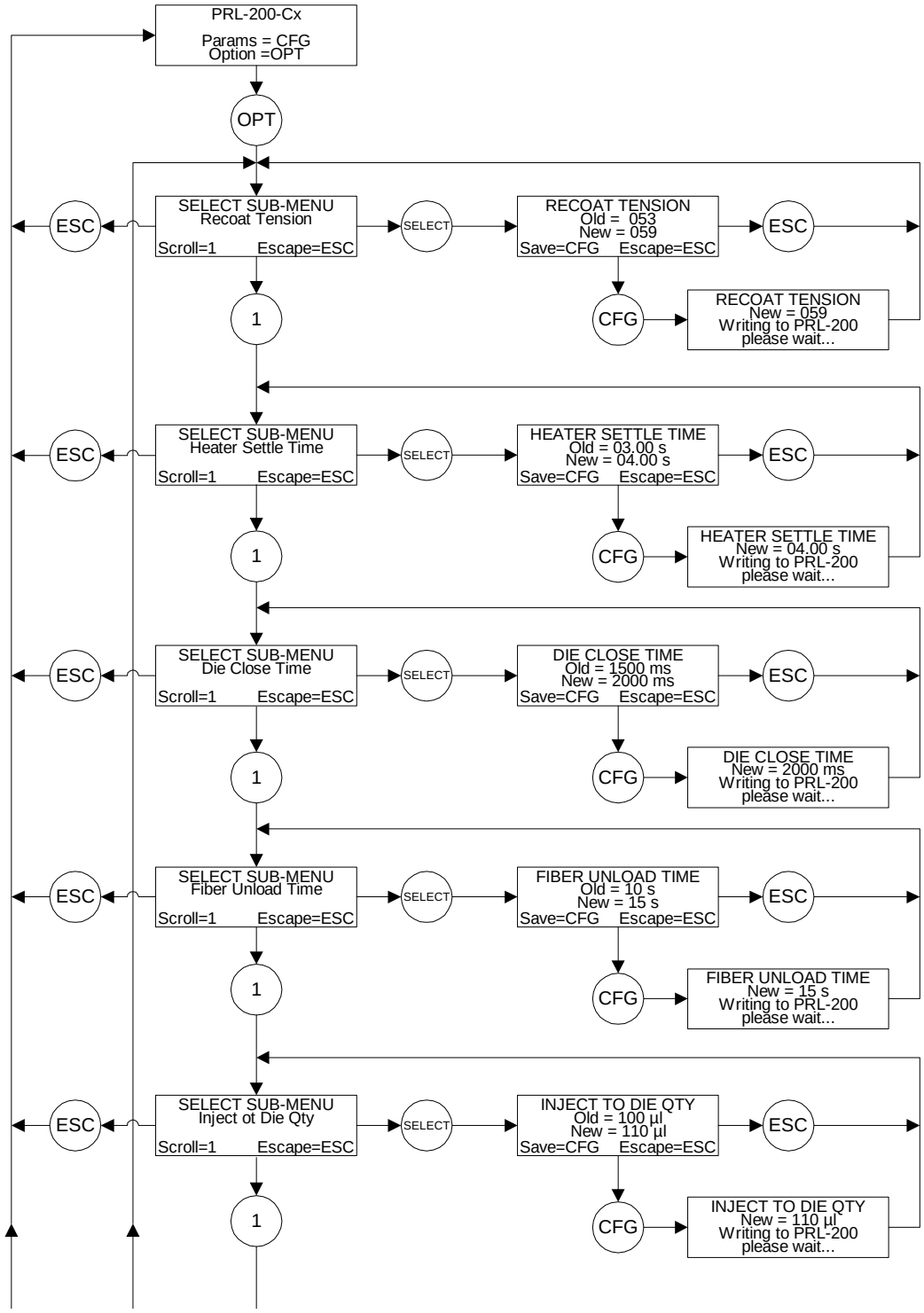

ESC
SELECT SUB-MENU
Undercoat
Scroll=1 Escape=ESC
SELECT
UNDERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
SELECT
UNDERCOAT HEAD VEL
Old = 00.4 mm/s
New = 00.3 mm/s
Save=CFG Escape=ESC
ESC
CFG
UNDERCOAT HEAD VEL
New = 00.3 mm/s
Writing to PRL-200
please wait...
1
UNDERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
SELECT
UNDERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
UNDERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...

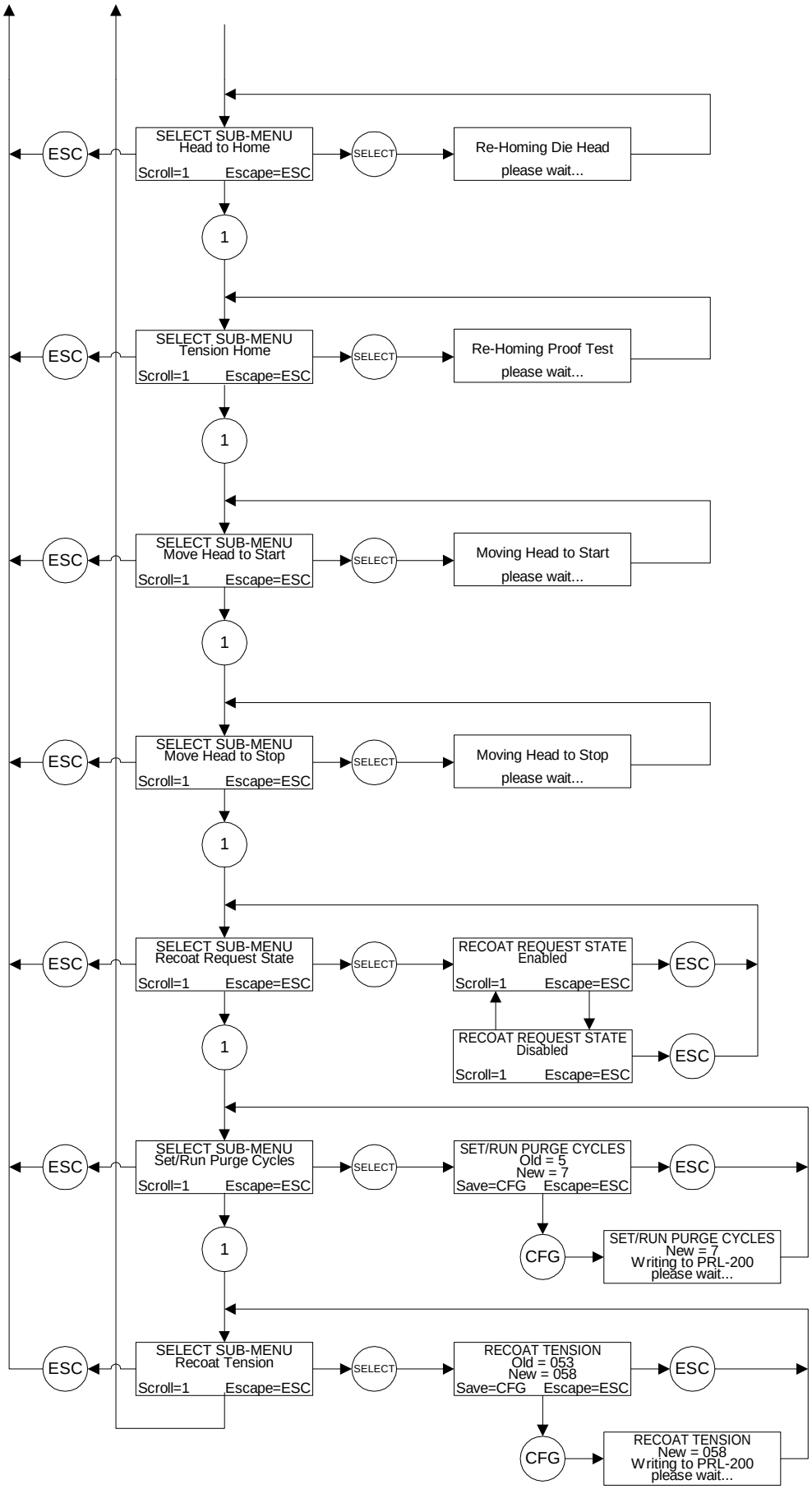

SELECT SUB-MENU
Overcoat
Scroll=1 Escape=ESC
ESC
SELECT
OVERCOAT PARAMETERS
Number of Overcoats
Scroll=1 Escape=ESC
SET NO. OF OVERCOATS
Old = 04
New = 05
Save=CFG Escape=ESC
CFG
SET NO. OF OVERCOATS
New = 05
Writing to PRL-200
please wait...
1
OVERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
OVERCOAT HEAD VEL
Old = 01.0 mm/s
New = 01.3 mm/s
Save=CFG Escape=ESC
OVERCOAT HEAD VEL
New = 01.3 mm/s
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
OVERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
OVERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
OVERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
OVERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Overlap Delta
Scroll=1 Escape=ESC
SET OVERLAP DELTA
Old = 1.0 mm
New = 1.2 mm
Save=CFG Escape=ESC
SET OVERLAP DELTA
New = 1.2 mm
Writing to PRL-200
please wait...


ESC
SELECT SUB-MENU
Recoat Length
Scroll=1 Escape=ESC
SELECT
RECOAT LENGTH
Old = 10 mm
New = 12 mm
Save=CFG Escape=ESC
ESC
1
CFG
RECOAT LENGTH
New = 12 mm
Writing to PRL-200
please wait...
ESC
SELECT SUB-MENU
Proof Test
Scroll=1 Escape=ESC
SELECT
PROOF TEST PARAMETERS
Proof Test Units
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
kpsi
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
kpsi
Writing to PRL-200
please wait...
1
PROOF TEST UNITS
N
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
N
Writing to PRL-200
please wait...
PROOF TEST UNITS
g
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
g
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Level
Scroll=1 Escape=ESC
SELECT
PROOF TEST LEVEL
Old = 109 kpsi
New = 125 kpsi
Save=CFG Escape=ESC
ESC
1
CFG
PROOF TEST LEVEL
New = 125 kpsi
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Step Rate
Scroll=1 Escape=ESC
SELECT
PROOF TEST RATE
Old = 2.0 mm/s
New = 1.8 mm/s
Save=CFG Escape=ESC
1
CFG
PROOF TEST RATE
New = 1.8 mm/s
Writing to PRL-200
please wait...

2.6 Options Menu Flowchart

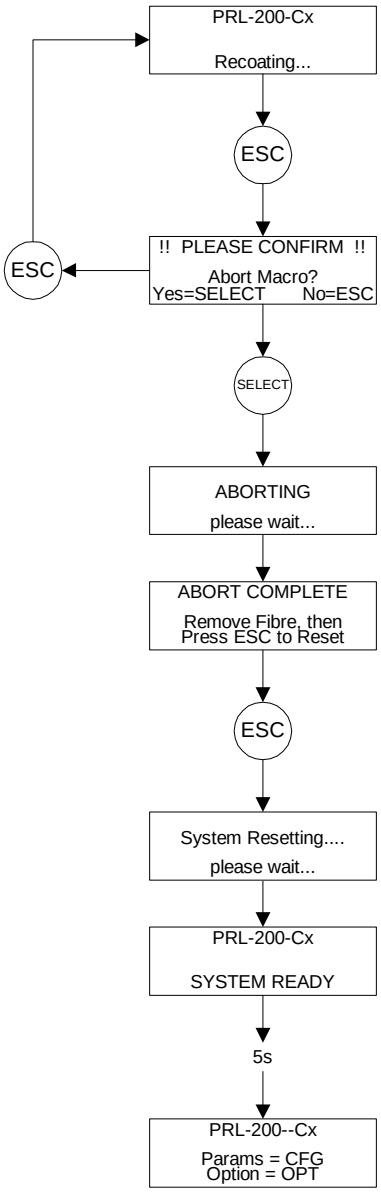
This flowchart is a guide for navigating through the Options Menu, and shows the display prompts and button key presses for editing parameters and executing system related functions.




SELECT SUB-MENU
Head to Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Die Head
please wait...
ESC
1
SELECT SUB-MENU
Tension Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Proof Test
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Start
Scroll=1 Escape=ESC
SELECT
Moving Head to Start
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Stop
Scroll=1 Escape=ESC
SELECT
Moving Head to Stop
please wait...
ESC
1
SELECT SUB-MENU
Recoat Request State
Scroll=1 Escape=ESC
SELECT
RECOAT REQUEST STATE
Enabled
Scroll=1 Escape=ESC
ESC
RECOAT REQUEST STATE
Disabled
Scroll=1 Escape=ESC
ESC
1
SELECT SUB-MENU
Set/Run Purge Cycles
Scroll=1 Escape=ESC
SELECT
SET/RUN PURGE CYCLES
Old = 5
New = 7
Save=CFG Escape=ESC
ESC
CFG
SET/RUN PURGE CYCLES
New = 7
Writing to PRL-200
please wait...
1
SELECT SUB-MENU
Recoat Tension
Scroll=1 Escape=ESC
SELECT
RECOAT TENSION
Old = 053
New = 058
Save=CFG Escape=ESC
ESC
CFG
RECOAT TENSION
New = 058
Writing to PRL-200
please wait...
ESC

2.7 Abort Flowchart

Even after the recoat process has been initiated it is possible to abort the process if required. The Abort Flowchart shows the display prompts and button key presses to abort a recoat process.



3 Recoat Injection System

The PTR-200-PRL has an automatic recoat injection pump fitted inside the unit. The pump is based on an automated syringe and distribution valve that can select one of three ports (Fill, Purge, or Inject) through which it can either draw or inject recoat material (see Figure 3). A bottle containing recoat material is installed directly on the pump, with the pump "Fill" tube inserted into the bottom of the bottle. A "Purge" tube runs from the pump to the top of the recoat bottle, and is used for cycling material back into the bottle. An "Inject" tube runs from the pump to the inject port of the die, which is located in the center of the lower right die. Once all air is purged from the injection system, the pump provides very accurate control of the volume and velocity of recoat material injection.

The recommended recoat material for use in the PTR-200-PRL is Pyralin PI2525, which is manufactured by HD MicroSystems. This is a fast imidizing at lower temperature coating. Do not attempt to use alternate recoat materials without first consulting Vytran on compatibility with the PRL.

Note: Pyralin PI2525 recoat material does have a limited shelf life of approximately 24 months from date of manufacture when stored at 0 to 18 degrees Centigrade. PI2525 is stable at room temperature (21 degrees Centigrade) for approximately 4 weeks with no significant change in properties. Using material that has passed its expiration date may cause both pump performance and recoat quality issues.

3.1 Priming the Injection System

It is very important to remove all air from the recoat injection system prior to performing a recoat. When operating the system for the first time, the pump must be filled with recoat material and cleared of all air in the pump and tubing. In order to clear the inject tube, recoat material must be injected out through the mold inject port and collected and disposed of. Make sure to have cotton swabs and NMP (1-Methyl-2-pyrrolidinone) available for this purpose prior to starting this procedure. NMP is the recommended solvent for cleaning uncured polyimide recoat material.

WARNING: Polyimide recoat materials can be hazardous to your health if not handled properly. Read the Material Safety Data Sheet provided in Appendix X, and make sure to follow all precautionary guidelines when working with this material.

To prime the recoat injection system:

1. Turn off power to the PTR-200-PRL.
2. Remove the front plate of the PTR-200-PRL by using the 3/32 Allen wrench provided in the tool kit to remove the four (4) black socket-head cap screws located at the corners of the plate.
3. The recoat pump is located on the left side of the PTR-200-PRL as shown in Figure 2. Unscrew the brown recoat bottle located at the front of the pump and remove by angling out through the front opening. The red Fill tube will flex to allow removal.
4. For new systems, replace the empty recoat bottle shipped with the unit with a new bottle of recoat material. For systems that have previously been run with recoat material, the recoat injection system should be flushed clean prior to adding new material (see 5.5).
5. Screw the new recoat bottle into place and replace the front panel and the four (4) socket head cap screws.

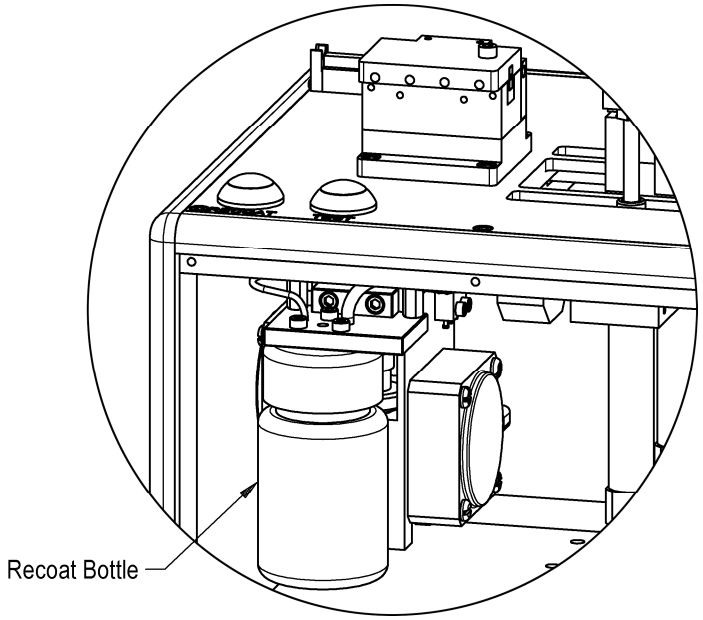


Figure 2: Recoat Bottle Access

6. Turn on power to the PRL-200 and wait for the system to initialize.
7. Execute five (5) Purge cycles (Options menu on Handset Controller). Each purge cycle will draw 100 microliters of recoat material from the bottom of the recoat bottle through the red Fill tube and inject material back into the top of the recoat bottle through the green Purge tube (see Figure 3). Five (5) Purge cycles are required to fill the pump with recoat material and force any air out of the pump system. This will take approximately 15 minutes to complete.
8. After the pump has completed its Purge cycles, the Inject tube that runs from the pump to the die must also be filled with recoat material and purged of air. Have cotton swabs and cleaning solution (NMP) available prior to proceeding.

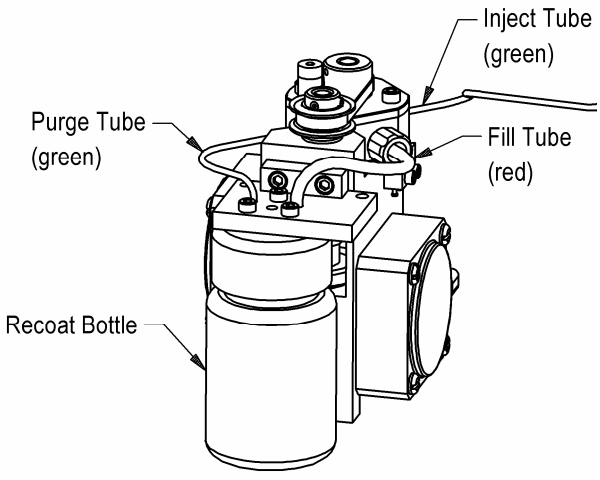


Figure 3: Recoat Material Flow

9. Set the Inject to Die Qty to 100µl (Options menu on Handset Controller).
10. Execute the inject command (press “Select” on the Handset Controller).
11. Watch for recoat material to emerge from the die inject port located at the center of the center of the bottom right die (see Figure 5). Make sure to collect the recoat material with a cotton swab as it comes out of the die injection port. Do not allow recoat material to run down between the die.
12. Execute three (3) additional “Inject 100” sequences to purge air completely from the inject tube. **Note:** Because the injection pump holds 100µl of recoat material, there will be a delay of approximately one minute between the second and third inject sequences while the pump refills.

13. After purging the inject tube, the recoat material should run freely from the die without bubbles. If bubbles are still present, run additional inject sequences.
14. Once the pump and the inject tube are purged, clean the die of all excess recoat material (see 3.2).

Note: Because the syringe in the recoat pump is mounted vertically, it is possible that an air bubble may still be trapped at the tip of the syringe after the above priming process. This air bubble will very slowly rise to the top of the syringe after which time it can be purged out. It is therefore recommended that at least one (1) additional Purge cycle is run the next day after the initial priming of the system.

3.2 Cleaning the Die

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP (1-Methyl-2-pyrrolidinone). NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

4 Recoat and Proof Test Process

4.1 The Polyimide Recoat Process

The PTR-200-PRL utilizes two Fiber Holding Blocks (FHB's) to securely clamp and position the fiber prior to recoating. The right-hand FHB has a linear drive mechanism for applying tension to the fiber. A load cell is incorporated into the linear drive mechanism for monitoring recoat tension. Once the fiber is positioned and securely clamped in the FHB's, pressing the recoat button will initiate an automated recoat process. The right-hand FHB will move to the right until the Recoat Tension is reached. With the fiber held under tension, the right die is closed and the Undercoat Quantity of material is injected into the die and the right heater is set to the Precure Temperature. The recoat head will move to the left depositing material while the right heater will precure the material. Upon reaching the appropriate length, the left die will close and additional recoat material will be injected into the die. The left heater is set to the Precure Temperature and the right heater to the Cure Temperature. The recoat head moves to the right depositing material while the right heater fully cures the previously precured material and the left heater precures the newly deposited material. Returning to the start position is defined as one loop or pass as the material initially deposited has been fully imidized.

This process is repeated until the desired recoat thickness has been achieved. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The recoated fiber is unloaded and the unit resets itself in preparation for the next recoat.

4.2 The Fiber Holding Blocks, V-Grooves, and Inserts

The FHBs are designed to accommodate a range of fiber buffer and cladding sizes through the use of changeable, bottom, FHB inserts. The top insert is spring loaded and does not require any change for 80 or 125 micron fibers. The bottom inserts are V-groove, and incorporate vacuum feed to assist in loading the fiber. The V-groove provides mechanical alignment to the recoat die. V-groove inserts are labeled according to clamping diameter in microns. Beyond the V-groove inserts are rubber inserts. The rubber inserts provide the clamping force and surface area required for tensioning and tension testing.

4.3 Stripped Fiber Requirements

The fiber to be recoated should be free of debris and have a smooth, continuous transition in the jacket strip region. The jacket interface should not extend beyond the original coating diameter.

4.4 Loading

To load the fiber for recoating:

1. If the Fiber Holding Block (FHB) tops are closed, open the FHB tops (see Figure 4). The head will move to the start position and the internal vacuum pump will turn on to aid in loading the fibers.

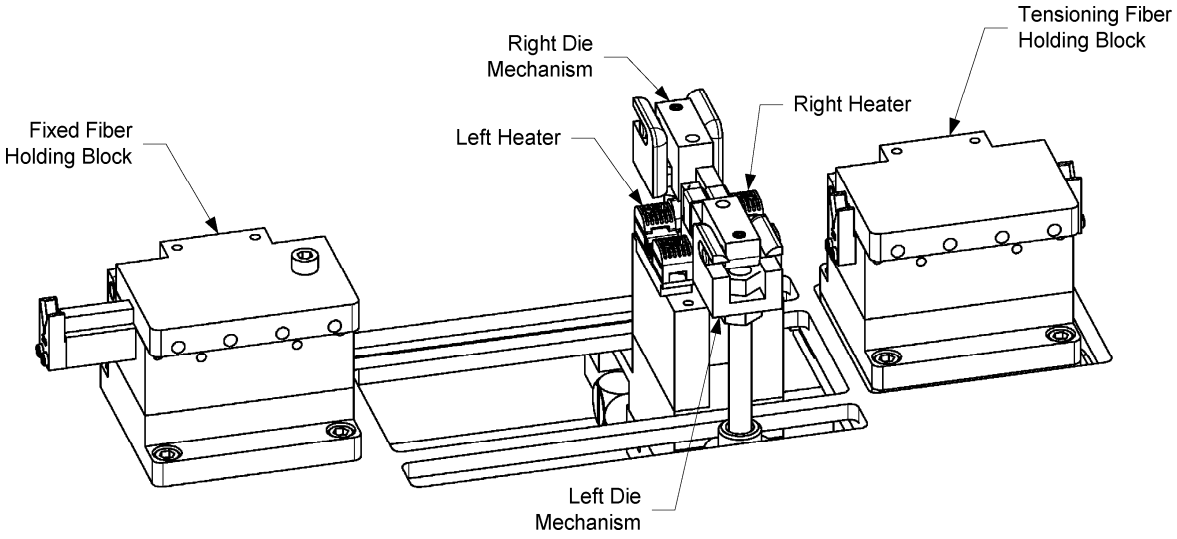


Figure 4: Recoat and Proof Test Components

2. If the FHB tops are open, the load fiber process can be initiated, by either pressing the blue RECOAT button or by closing and reopening both left and right FHB tops.
3. Check that the correct FHB inserts (top and bottom) are installed and that they are free from debris. Position the fiber in the left-hand FHB V-groove, with the stripped section to the left of the left heater. Lower the fiber into the right-hand FHB V-groove. The FHB vacuum should hold the fiber in place.
4. Manually position the fiber in the FHBs so that the right jacket interface is in line with the left edge of the recoat head (see Figure 5). Verify that the fiber is centered in the left and right die.
   Note: Damage to the die may occur if the fiber is not centered in the die when they close.

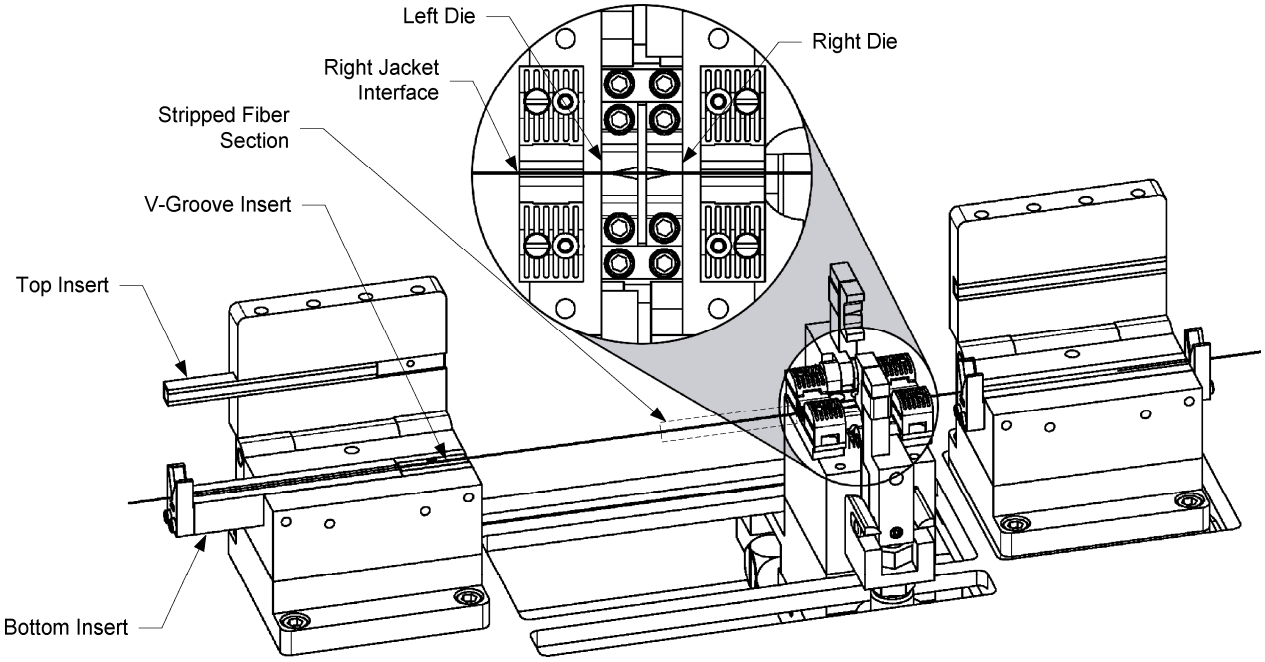


Figure 5: Fiber Position

5. Gently close the FHB lids. This will capture the fiber and turn off the external vacuum pump.
6. The fiber is now ready to be recoated.

4.5 Recoating

To recoat the fiber:

1. Visually confirm that the fiber is loaded properly, if not reload the fiber.
2. Initiate the recoat process by pressing the blue RECOAT button on the unit or the START button on the Handset Controller. The recoat process is fully automated as follows:
   a. The right-hand FHB will begin moving to the right, applying tension to the fiber.
   b. Once the Recoat Tension is reached, the right-hand block will stop moving.
   c. The handset controller will await input from the operator verifying the correct fiber position in the die. Upon confirming the correct fiber position to the handset the process will continue.
   d. The right die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Precure Temp and the head will pause for the Heater Stabilize Time.
   e. The head will move to the left at the Undercoat Head Sweep Vel depositing material while the right die evaporates the volatiles.
   f. Upon reaching the appropriate length, the left die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Cure Temp, the left heater will be set to the Left Precure Temp and the head will pause for the Heater Stabilize Time.
   g. The head will move to the right at the Undercoat Head Sweep Vel depositing material. The right heater will be imidizing the previously precured material while the left heater is evaporating the volatiles from the freshly deposited material. The head will complete at the initial start position plus the overlap delta. This is defined as one loop or pass as the material initially deposited has been fully cured.
   h. The process is repeated (using the Overcoat parameters) until the desired thickness has been achieved by the Number of Overcoats (loops or passes).
   i. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The tension is applied to the specified Level at the specified Rate and released.
3. Proceed to Unloading the Fiber.

4.6 Proof Testing

The Peak Tension should be set to ensure that the recoat meets the minimum strength requirement for its intended application. If using units of tension (kpsi), make sure to enter the correct fiber diameter (e.g. 125 microns) and not the coating diameter.

WARNING: Always wear safety glasses when proof testing fiber. The fiber under test can shatter and send glass particles flying.

To perform a Proof Test:

1. Load the fiber in the fiber holding blocks (see 4.4).
2. Check that the proof test parameters are set correctly.
3. Press the “TEST” button on the PTR-200-PRL.
4. Upon completion of the Proof Test, raise the fiber holding block tops and remove the proof tested fiber.

Note: It is not possible to abort a Proof Test once it has been started.

4.7 Unloading

To unload the fiber after recoating:

1. After the fiber is recoated, the external vacuum pump will turn on to assist in holding the fiber during the unloading process.
2. Hold the fiber securely and lift the left-hand FHB lid. The fiber will be free to move after lifting the lid, so it is important to keep the fiber secured (the V-groove extension is ideal for this).
3. Carefully lift while guiding the recoated fiber though the heaters.
   Note: Raising the FHB top will re-initiate the vacuum pump timer for an additional 15 seconds, after which time the unit will perform a homing routine. The recoated fiber should be removed within this 15 second window.
4. Raise the right-hand FHB top and remove the recoated fiber.
5. Check that no debris is left behind in the FHB V-grooves or on the top clamping surfaces.

Note: After a recoat has been removed (or even if there is a recoat failure), an automatic homing routine will be run 15 seconds after the left FHB top is raised. This homing routine will re-set the position of the right-hand FHB, and the head. The system waits for the FHB top to be opened to ensure that the fiber is being unloaded. If both FHB tops are closed prior to the 15-second time-out, the homing routine will be run immediately.

If the PTR-200-PRL homing process is interrupted or fails, all system functionality is disabled to prevent possible damage to the equipment. Remove any fiber from the FHB's and cycle the power OFF then ON. The PTR-200-PRL will initialize and attempt to run the homing process again. If any further difficulty is experienced, contact Vytran Technical Support for assistance.

5 Maintenance

5.1 Planned Maintenance

The PTR-200-PRL is designed for a production environment to give trouble-free operation provided normal planned maintenance is adhered to. Maintenance and repair procedures should be performed only by trained personnel. Improper service and/or repair could result in the safety features being disabled and can also lead to damage that will not be covered under warranty.

Planned Maintenance Schedule

	Every Shift	Daily	Monthly	12 Months
Inspect / Clean Fiber Holding Blocks[1]	√	√	√	√
Inspect / Clean die[2]	√	√	√	√
Flush recoat System[2] (as needed)			√	√
Purge Recoat System[2] (as needed)			√	√
Replace Recoat Material[2] (as needed)			√	√
Check Load Cell Calibration / Re-Cal[3]				√

[1] Maintenance operations can be performed by the operator.
[2] Maintenance operation can be performed by trained maintenance personnel.
[3] Vytran certified technician only.

5.2 Inspecting the Fiber Holding Blocks

The Fiber Holding Blocks (FHB's) should be inspected daily for debris and/or damage, which may prevent the tops from closing properly and the fiber from being clamped fully. It is particularly important to make sure that the bottom insert V-groove surfaces and the top insert clamping surfaces are free of debris and oils. This will help to ensure that the fiber will not break or slip during tensioning. Cleaning the metal insert surfaces is best accomplished using a cotton-tipped applicator wetted with acetone or alcohol. For embedded debris, a soft cleaning brush may be used. Cleaning the rubber insert surfaces is best accomplished using a cotton-tipped applicator wetted with alcohol. Do not use acetone as this will dry out the rubber causing it to become brittle and crack.

5.3 Inspecting and Cleaning the Die

The die of the recoat head should be inspected daily for debris and/or damage which may result in sub-optimum recoat performance.

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP. NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If

the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

5.4 Load Cell Calibration

The load cell calibration should be checked every twelve (12) months to ensure that accurate recoat and proof test tension is applied to the fiber. This task must be performed by a Vytran certified technician.

5.5 Flush Recoat System

The recoat injection system should be flushed clean every 1 month as part of the recoat material replacement procedure. Before flushing the system, make sure to have cotton tipped applicators and cleaning solution (NMP) available prior to proceeding. To flush the system:

1. Remove the internal recoat bottle and clean all exposed tubing and fittings with NMP.
2. Install a bottle filled 1/4 full with NMP on the pump.
3. Run 5 purge cycles.
4. Remove the bottle, dispose of contaminated NMP. Refill ¼ full with clean NMP and reinstall.
5. Run 5 more purge cycles.
6. Run several inject 100 sequences until NMP runs clear from the die inject port.
   Note: Make sure to collect material as it comes out of the die inject port. Do not allow material to run between the left and right die.
7. Remove the bottle of NMP from the pump.
8. Run several more inject 100 sequences until no more NMP exits the die injection port.
9. Run one purge cycle. Make sure to collect any NMP that comes out of the green purge tube at the top of the bottle fitting.
10. Clean all bottle tubing and fittings with NMP.
11. Install an empty bottle for storage, or a new bottle ¾ filled with fresh recoat material for use. If installing fresh material, proceed to 3.1 Priming the Injection System.

5.6 Purge Recoat System

The purge cycle is a process of emptying the recoat material of the Automatic Injector back into the recoat material bottle and refilling the pump with fresh recoat material drawn from the bottom of the bottle. Running 5 purge cycles is sufficient to entirely fill the pump with fresh recoat material.

If the system has not been used for an extended period (over 1 week), it is recommended that a single purge cycle be run to fill the pump with fresh material.

5.7 Replacing Recoat Material

Recoat material has a finite shelf life and should be replaced every 1 month. To replace the recoat material, first flush the system as outlined in Flush Recoat System (above). Once the system is flushed, fill a clean recoat bottle ¾ full with fresh recoat material and follow the procedures in Purge Recoat System (above).

Note: The one-ounce internal recoat bottle holds approximately 30,000 micro-liters when full. The number of recoats per fill and the approximate time before the material needs to be refilled can be determined based on the volume of material per recoat and the number of recoats per month. For most applications the material will need to be replaced before it runs out. Even if fresh material is added to the internal bottle prior to the Planed Maintenance schedule, the material should still be replaced since mixing of the old and new materials occurs.

5.8 Replacing a Heater

If a heater is sufficiently damaged such that a quality recoat cannot be performed, then replacement is required. The left and right heaters are identical and DO NOT need to be replaced as a pair. The heaters are comprised of a body which houses a graphite filament. When installed in the PTR-200-PRL, the heater is held in place by electrical contacts at the base of the heater body. This is a pin/socket contact compression fit.

To remove the heater:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die sets. This will allow additional access to the heaters.
3. Grab the body of the filament and using a front to back rocking motion, gently lift the filament body (pins) out of the contacts.

To install the heater:

1. Inspect the new heater for any deformation of the filament. If deformation is noted do not install nor use the heater.
2. Hold the filament body (not the graphite filament) and locate the pins into the electrical sockets.
3. To fully seat the heater, gently push down on the electrical contacts (located on the top of the heater).

5.9 Changing the Fiber Holding Block V-Grooves

To change a FHB V-groove insert:

1. Loosen the two (2) set screws accessible from the front of the FHB base using the 0.035” Allen key included in the LDC-200 tool kit. Do NOT remove the set screws completely; one full turn counter-clockwise should be sufficient to release the insert.
2. Remove the FHB V-groove and replace with the desired size. For dual sided inserts, the label for the desired size should face right side up and be readable. Make sure the vacuum feed ports are clear of debris by holding the insert up to a light and checking from behind to make sure light passes each of the ports. Clean if necessary.
3. Make sure the new insert is fully seated and flush with the inside face of the FHB.
   Note: The inside face of the FHB is the side closest to the head.
4. Re-tighten the set screws until they are snug. Do NOT over tighten.

5.10 Replacing the Die

If the die are sufficiently damage such that a quality recoat cannot be performed, then replacement is required. The top and bottom die are a matched set and are replaced as a pair. The top die are spring loaded which enables a slight pivoting during closure, while the bottom die are fixed mounted to the head.

To replace the top die:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. The top die pivots about a center pin which is pressure loaded with two (2) small springs. Remove and retain the top die retainer clip for reuse. This will expose the springs. Using the die, gently compress the springs. This will allow a rotation of the die by ~45 degrees and a removal of the die from the clamp. Remove and retain the springs for reuse.
3. Locate and clean the new top die to be installed.
4. Insert the two (2) springs into the clamp. With the die rotated ~45 degrees, gently collapse the springs with the die. Align the die pin with the clamp and rotate the die to 0 degrees to install.
5. Reinstall the die retainer clip.

To replace the bottom left die (no inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Remove the die from the head.
3. Locate and clean the new top die to be installed.
4. Seat the new die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

To replace the bottom right die (with inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Gently begin to remove the die from the head. An inject tube will be attached to the die. This tube will limit the distance the die can be removed from the head. Gently pull the die with the inject tube until resistance is felt
3. Locate and clean the new top die to be installed.
4. To release the old die from the inject tube, gently rotate the die while holding the inject tube. To install the new die onto the inject tube, gently rotate the die onto the inject tube while holding the inject tube. Slowly feed the inject tube into the head. Seat the die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

Appendix A: MSDS PI2525

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

MATERIAL SAFETY DATA SHEET

***** IDENTIFICATION *****

NAME: PI2525 SYNONYMS: POLYIMIDE COATING.
CHEM.FAMILY: Pyralin® Polyimide Coating. FORMULA: Proprietary.

MANUFACTURER:
HD MicroSystems™
Cheesequake Road
Parlin, NJ 08859

INFORMATION & EMERGENCY TELEPHONE NOS:
INFORMATION: Product: (800) 441-7515
EMERGENCIES: Medical: (800) 441-3637
Transport (CHEMTREC): (800) 424-9300

All Ingredients in This Product Are TSCA Listed/Reported.

***** PHYSICAL DATA *****

FORM: Viscous Liquid. ODOR: Aromatic.

APPEARANCE: Colorless to Amber. SOLUBILITY IN WATER: Slight.

***** COMPONENTS *****

Material(s):	CAS#	V.P. mm Hg @ 20C	Weight %
N-Methyl-2-Pyrollidone.	872-50-4	0.29	> 60%
Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer).	31942-21-9		10 - 30%

PI2525/AH1
05/19/98

***** HAZARDOUS REACTIVITY *****

INSTABILITY:
The product is normally stable.

INCOMPATIBILITY:
Avoid contact with:
Reducing agents; Oxidizing agents; Bases; Acids; Strong acids; Strong oxidizers.

DECOMPOSITION:

Decomposition products at high temperature may include:
Carbon monoxide (CO); Nitrogen oxides; Carbon monoxide, carbon dioxide, water.

POLYMERIZATION:
The product may polymerize endothermically if exposed to temperatures over 90 F, ultraviolet light or free radical initiators. This may increase viscosity.

***** FIRE & EXPLOSION DATA *****

FLASHPOINT: 194 F Seta CC

FIRE & EXPLOSION HAZARDS:
The product is not an unusual fire or explosion hazard.

EXTINGUISHING MEDIA:
Water spray, dry chemical or carbon dioxide.

SPECIAL FIREFIGHTING INFORMATION:
Toxic decomposition products may form under fire conditions. (See Decomposition Section.);
Wear full protective clothing and a full facepiece, positive pressure, self-contained breathing apparatus (SCBA);
Decontaminate contaminated clothing and equipment with soap and water. Dispose of residues per federal, state, and local regulation. (See Waste Disposal Section.).

OVERVIEW: The most likely routes of overexposure to this

PI2525/AH1 Page 2

***** HEALTH HAZARD INFORMATION *****

product are skin contact and inhalation. Skin irritation and/or other effects of skin contact are easily avoided by using proper gloves (see section titled GLOVES) and washing affected areas immediately if contact occurs. Volatile solvents will start evaporating during room temperature use of the product, such as thinning, pouring from jar to dispensing machine, and spin coating. Mist and solvent vapors will evolve if spray application is used. During wafer drying, 125 - 150 C, and final curing, 350 - 450 C, the remaining solvent(s) will evaporate. Potential overexposure to other chemicals used in the operation such as wafer etchants and cleaners should also be considered. Well designed area and personal air sampling and analysis can show if exposures are within established limits. Properly designed local ventilation and process enclosure are effective ways to limit employee exposure where needed.

In addition to meeting exposure limits, it is always prudent to use all practical means to minimize employee exposure to chemicals. A significant difference in overall exposure can be made with practical measures such as:

* Inhalation - minimizing by keeping jars of product covered
* Eye - avoiding contact by wearing chemical splash goggles where there is splash potential
* Ingestion - avoiding by washing hands before eating, drinking or smoking, and restricting these activities to outside the work area.

PRINCIPAL HEALTH EFFECTS:

>>>N-Methyl-2-Pyrollidone
****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Mild skin irritation; No skin sensitization; BY INHALATION: Respiratory effects. Toxic effects of repeated or prolonged animal exposures include: BY INHALATION: Respiratory effects; Bone marrow effects; Lymph system effects; Testicular effects; ****Additional animal tests have shown: No carcinogenic activity; No developmental toxicity; No genetic damage in bacterial or mammalian cell cultures; No reproductive toxicity. ****Human health effects of overexposure may include: By contact with liquid or vapor: Eye irritation with discomfort, tearing, or blurring of vision; BY SKIN OR EYE CONTACT: Eye irritation with discomfort, tearing, or blurring of vision; Skin irritation with itching, burning, redness, swelling or rash; BY INHALATION: Runny nose; Sore throat; Sneezing; Irritation of the nose and throat; Nonspecific discomfort, e.g., nausea, headache or weakness. ****Human effects of higher level

PI2525/AH1 Page 3

acute, repeated or chronic overexposure may include: BY SKIN OR EYE CONTACT: Skin reddening; Skin irritation with discomfort or rash; Dermatitis; Swelling; Burning. ***In addition: BY SKIN OR EYE CONTACT: There are inconclusive or unverified reports of human sensitization.

>>>Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer) ****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Skin irritation; Skin sensitization; Eye irritation.

ANIMAL DATA:

>>>N-Methyl-2-Pyrollidone
Inhalation 4 hour ALC: 1.7 mg/L in rats (Moderately toxic)
Skin absorption LD50: > 8,000 mg/kg in rabbits (Slightly toxic)
Oral LD50: 4,320 mg/kg (Slightly toxic).

CARCINOGENICITY LISTING:

No ingredients of this product are designated by IARC, NTP, OSHA, ACGIH or Dupont as potential carcinogens.

EXPOSURE LIMITS:
Workplace exposures should be kept below the following limits:

.	AIHA		ACGIH		OSHA	
Name/Units	8hr	15min	8hr	15min	8hr	15min
PARTICULATES (N.O.S.), respirable						
Units: mg/m3					5	
PARTICULATES (N.O.S.), total						
Units: mg/m3			10		15	
N-METHYL-2-PYRROLIDONE						
Units: ppm	10					

Also, DuPont has established and observes the following limits:

Name/Units	12 hr	8hr	15min	Ceiling
N-METHYL-2-PYRROLIDONE				
Units: ppm		25		

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NOTES ON EXPOSURE LIMITS:
PELs - OSHA Permissible Exposure Limits - 29 CFR 1910.1000, Subpart Z, or specific substance standards;
TLVs - ACGIH Threshold Limit Values - published by American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211;
WEELs- AIHA Workplace Environmental Exposure Limits - published by the American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031;
AELs - Dupont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits are lower than AEL in effect, government limits shall take precedence;
(C) = "ceiling", limit not to be exceeded for any time period;
(S) = "skin" , skin absorption may contribute significantly to the ingredient's internal toxicity.

***** FIRST AID INSTRUCTIONS *****

Skin Contact: For skin contact, immediately wash skin with soap and water. Wash contaminated clothing before reuse.
Eye Contact: For eye contact, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.
Ingestion: If swallowed, do not induce vomiting. Immediately give two glasses of water. Never give anything by mouth to an unconscious person. Call a physician.

***** PROTECTION INFORMATION *****

Adequate local ventilation should be used to keep exposures below applicable limits;
Other engineering controls such as totally enclosed handling systems are also preferred;
Respiratory protection will be needed if exposures can not be kept below applicable limits by other means.

Respiratory Protection:
A NIOSH/MSHA approved full-face mask equipped with chemical cartridges approved for methylamine may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, when exposure levels are not

PI2525/AH1 Page 5

known, or in any other circumstances where air purifying respirators may not provide adequate protection;
For most conditions, no respiratory protection should be needed; however, if handling at elevated temperatures without sufficient ventilation, use an approved air-purifying respirator. In dusty atmospheres, use an approved dust respirator;
Selection of a suitable respirator will depend on the properties of the contaminant(s) and their actual or expected air concentration(s) versus applicable limits. Consult ANSI Standard Z88.2 for decision logic to select appropriate NIOSH/MESA approved respirators;
A NIOSH/MSHA/OSHA approved air purifying respiratory with a dust/mist cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, exposure levels are not known or any other circumstances where air purifying respirators may not provide adequate protection;
Use a positive pressure air-supplied respirator if concentrations may exceed exposure limits. Air-purifying respirators are inadequate for this material;
If respirators are needed to meet applicable limits, a respiratory protection program up to the level of OSHA Standard 29 CFR 1910.134 is mandatory. This includes air monitoring, selection, medical approval, training, fit testing, inspection, maintenance, cleaning, storage, etc;
An OSHA/NIOSH respirator for protection against Nuisance Dust is recommended.

Gloves:

Gloves should be used when the possibility of skin contact exists;
The suitability of a particular glove and glove material should be determined as part of an overall glove program. Considerations may include chemical breakthrough time; permeation rate; abrasion, cut and puncture resistance; flexibility; duration of contact; etc.

Other Protection Practices:

Appropriate eye protection such as chemical splash goggles should be used if the possibility of eye contact exists;
Protective outer clothing should be used where the possibility of body contact exists. Contaminated work clothing should not be allowed out of the workplace;
Do not smoke, consume or store food or drinks in areas

PI2525/AH1 Page 6

where the product is handled or stored. After handling the product, wash hands thoroughly before leaving the work area;
Additional engineering controls, work practices and training may be required depending on exposure levels. These are discussed in the OSHA Respiratory Protection Standard (29 CFR 1910.134) and OSHA Hazard Communication Standard (29 CFR 1910.1200);
Do not breath dust. Avoid contact with eyes, skin, or clothing. Wash thoroughly after handling.

***** DISPOSAL INFORMATION *****

Spill, Leak or Release:
FOR SMALL SPILLS, absorb on rags, sand or other absorbent material;
FOR LARGE SPILLS, get workers out of affected area. If flammable liquids or vapors may be present, turn off electrical devices or other sources of sparks or flames. WEAR PROTECTIVE EQUIPMENT. Use supplied-air respiratory protection if vapor concentrations are not known;
Contain spill at source by diking or absorbing with sand. Do not allow spill to spread to or intentionally flush to sewer or ground. Wash area thoroughly. Adequately ventilate area;
Spill residue, cleaning rags and absorbent may be considered hazardous. (See Waste Disposal Section.).

Waste Disposal:
Components of this product may be considered hazardous;
Consult applicable Federal, State, and local regulations for allowable disposal methods.

***** PRODUCT INFORMATION *****

Contaminated Items:
Empty product containers, contaminated clothing and cleaning materials, etc. should be considered hazardous until decontaminated or properly disposed of. (See Waste Disposal Section.).

Storage:
Store product in a refrigerated location (0-4F), away from sunlight or ultraviolet light to ensure product viscosity stability.

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***** ADDITIONAL INFORMATION *****

The following ingredients are subject to the reporting requirements of section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

INGREDIENT(S)	Weight %
N-Methyl-2-Pyrrolidone	> 60%

CALIFORNIA PROPOSITION 65: WARNING: This product does not contain chemical known to the state of California to cause cancer, birth defects, or other reproductive harm.

This product is a physical mixture. The health effects information about this product is based on the individual ingredients; The data in this Material Safety Data Sheet relates only to the specific product designated herein and does not relate to its use in combination with any other material or in any process.

Date of latest MSDS revision: 05/19/98

Person Responsible for MSDS:

Safety Coordinator - MSDS
DuPont P&EM / MCM
14 Alexander Drive
Research Triangle Park, NC 27709-4425
Telephone: (800) 284-3382
Outside U.S.: (919) 248-5775

PI2525/AH1 End of Material Safety Data Sheet Page 8

Appendix B: MSDS NMP

Material Safety Data Sheet

1-Methyl-2-pyrrolidinone

ACC# 08690

Section 1 - Chemical Product and Company Identification

MSDS Name: 1-Methyl-2-pyrrolidinone
Catalog Numbers: AC127630010, AC127630025, AC222080025, AC222085000, AC326930010, AC326931000, AC326932500, AC354890025, AC354900025, AC364380010, AC364380025, AC364381000, AC368450010, AC368450025, AC368451000, AC610411000, BP1172-4, BP11724LC, BP1172N119, BP2619-100, NC9749337, O3688-4
Synonyms: NMP; N-Methylpyrrolidone; N-Methylpyrrolidinone; N-Methyl-2-pyrrolidone; N-Methyl-2-pyrrolidinone; M-Pyrol; 1-Methyl-2-pyrrolidone; solvent in paint strippers.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
872-50-4	1-Methyl-2-pyrrolidinone	99	212-828-1

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: clear colorless liquid. Flash Point: 91 deg C.
Warning! Causes eye, skin, and respiratory tract irritation. May cause harm to the unborn child. **Combustible liquid and vapor.** May be harmful if swallowed, inhaled, or absorbed through the skin. Light sensitive. Hygroscopic (absorbs moisture from the air).
Target Organs: Respiratory system, eyes, skin.

Potential Health Effects

Eye: Causes eye irritation. May cause temporary corneal clouding.
Skin: Causes skin irritation. May be harmful if absorbed through the skin. Not expected to cause an allergic skin reaction. Because of the high permeability rate of N-methylpyrrolidone in human skin, prolonged exposures should be avoided.
Ingestion: May cause gastrointestinal irritation with nausea, vomiting and diarrhea.
Inhalation: Causes respiratory tract irritation. May cause headache. Material has a very low vapor pressure and inhalation exposures are not expected unless material is heated or misted.
Chronic: Prolonged or repeated skin contact may cause dermatitis. Adverse reproductive effects have been reported in animals. Testicular effects in rats were noted after repeated, high-dose oral and inhalation exposures.(BASF)Human occupational exposure has been associated with chronic eye irritation, headaches, and irritant contact dermatitis. Airborne concentrations of 49 to 83 ppm are intolerable.(REPROTEXT)

Section 4 - First Aid Measures

Eyes: In case of contact, immediately flush eyes with plenty of water for a t least 15 minutes. Get medical aid.
Skin: In case of contact, flush skin with plenty of water. Remove contaminated clothing and shoes. Get medical aid if irritation develops and persists. Wash clothing before reuse.
Ingestion: If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical aid.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Combustible liquid and vapor.
Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or appropriate foam.
Flash Point: 91 deg C (195.80 deg F)
Autoignition Temperature: 245 deg C (473.00 deg F)
Explosion Limits, Lower:1.3%
Upper: 9.5%
NFPA Rating: (estimated) Health: 2; Flammability: 2; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Remove all sources of ignition. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes, skin, and clothing. Keep away from heat and flame. Avoid breathing vapor or mist.
Storage: Keep away from sources of ignition. Store in a cool, dry place. Store in a tightly closed container. Keep under a nitrogen blanket.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
1-Methyl-2-pyrrolidinone	none listed	none listed	none listed

OSHA Vacated PELs: 1-Methyl-2-pyrrolidinone: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear chemical splash goggles.
Skin: Wear appropriate gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Liquid
Appearance: clear colorless
Odor: amine-like - mild odor
pH: 8.5-10.0 (100 g/l H2O)
Vapor Pressure: 0.342 mm Hg @ 25 deg C
Vapor Density: 3.4 (air=1)
Evaporation Rate: Not available.
Viscosity: 1.65 cps @ 25 deg C
Boiling Point: 202 deg C @ 760 mm Hg
Freezing/Melting Point:-24 deg C
Decomposition Temperature: Not available.
Solubility: Soluble.
Specific Gravity/Density:1.030
Molecular Formula:C5H9NO
Molecular Weight:99.13

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions.
Conditions to Avoid: Light, ignition sources, excess heat, exposure to moist air or water.
Incompatibilities with Other Materials: Strong oxidizing agents, strong acids.
Hazardous Decomposition Products: Nitrogen oxides, carbon monoxide, carbon dioxide.
Hazardous Polymerization: Will not occur.

Section 11 - Toxicological Information

RTECS#:
CAS# 872-50-4: UY5790000
LD50/LC50:
CAS# 872-50-4:
Draize test, rabbit, eye: 100 mg Moderate;
Oral, mouse: LD50 = 5130 mg/kg;
Oral, rat: LD50 = 3914 mg/kg;
Skin, rabbit: LD50 = 8 gm/kg;
.
Sensitization test (guinea pig): negative. test (humans): negative.(Merck)
Carcinogenicity:
CAS# 872-50-4: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No data available.
Teratogenicity: Proposition 65 maximum allowable dose level for developmental toxicity for N-methylpyrrolidone is 3200 ug/day for the inhalation route and 17,000 ug/day for the dermal route.

Reproductive Effects: See actual entry in RTECS for complete information.
Mutagenicity: See actual entry in RTECS for complete information.
Neurotoxicity: No data available.
Other Studies:

Section 12 - Ecological Information

Ecotoxicity: Daphnia: Daphnia: 4897 mg/l; 48 h; EC50Fish: Gold orfe: 4000 mg/l; 96 h; LC50Bacteria: >9000 mg/l; 48 h; EC50Algae: >500 mg/l; 72 h; IC50 log Pow = -0.46 (25°C)BOD5 = 1100 mg/l.COD = 1600 mg/l.
Environmental: No information available.
Physical: No information available.
Other: Biodegradable.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated	Not Regulated
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 872-50-4 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
CAS# 872-50-4: Test for Health Effects

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 872-50-4: immediate, delayed, fire.

Section 313

This material contains 1-Methyl-2-pyrrolidinone (CAS# 872-50-4, 99%),which is subject to the reporting requirements of Section 313 of SARA Title III and 40

Clean Air Act:

This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 872-50-4 can be found on the following state right to know lists: Pennsylvania, Minnesota, Massachusetts.

California Prop 65

WARNING: This product contains 1-Methyl-2-pyrrolidinone, a chemical known to the state of California to cause developmental reproductive toxicity.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

T

Risk Phrases:

R 36/37/38 Irritating to eyes, respiratory system and skin.
R 61 May cause harm to the unborn child.

Safety Phrases:

S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S 53 Avoid exposure - obtain special instructions before use.

WGK (Water Danger/Protection)

CAS# 872-50-4: 1

Canada - DSL/NDSL

CAS# 872-50-4 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of B3, D2A, D2B.
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

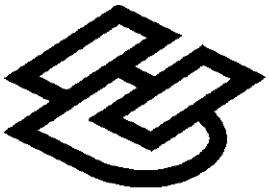
Canadian Ingredient Disclosure List

Section 16 - Additional Information

MSDS Creation Date: 6/10/2003
Revision #2 Date: 3/29/2005

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Appendix C: Pyralin Product Information



HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

Rev. Apr 01

PRODUCT INFORMATION
PYRALIN® PI2525, PI2555, PI-2575 & PI2556

PI2525, PI2555, PI-2575 and PI2556 polyimides [PI-2555 Series] are suitable for applications where the high cure temperatures typically used for polyimides (ca. 350°C) cause problems. Typical applications for these materials are as stress buffer or interlayer dielectric layers over low temperature substrates. These polyimides imidize faster and at lower temperatures than for standard polyimide precursors. The materials are supplied as solutions suitable for spin or roller coating application. A seperate adhesion promoter is recommended with PI-2525, PI-2555 and PI-2556 to improve adhesion to oxides and to metals. PI-2575 is self priming and does not require an adhesion promoter. Processing by wet or plasma etch is possible. Cured film thicknesses from 0.5 µm to 6 µm can be obtained.

Process Details

Coating

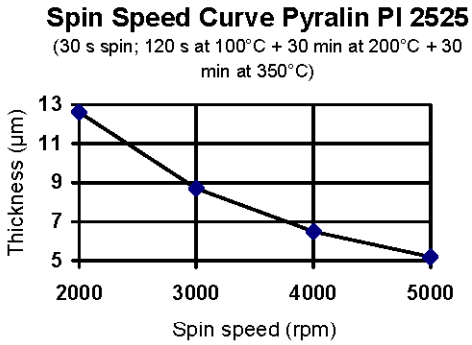
PI2555 Series products can be coated onto a variety of metals, alloys, semiconductor and ceramic substrates. HD MicroSystems adhesion promoters VM651 or VM-652 are recommended to provide good processability and adhesion with the PI-2525, PI-2555, PI-2556. Bonding of the polyimide to the substrate is achieved during the softbake cycle as the priming chemistry is activated by temperature.

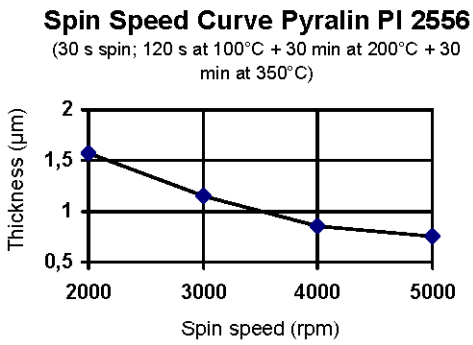
The polyimide solution is highly viscous. There are some guiding principles for dispensing materials of this type. Always coat substrates which are at room temperature. Never trap air into the solution. This can occur for example when the solution is moved during dispense. All bubbles take time to dissipate out of solution. If left in, coating "comets" will result. Dispensing should be in the centre and as close to the substrate as possible. A clean cut-off at dispense is neccessary before the spin process starts. It may be neccessary in the case of highly viscous solutions to have a short delay prior to spin to allow the polyimide to flow as far as possible and relax.

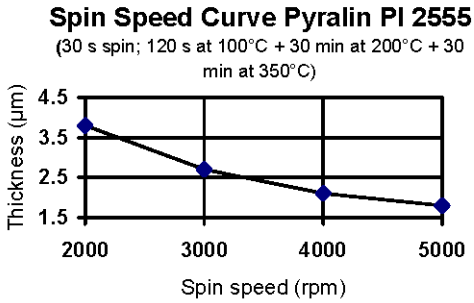
Both static and dynamic dispense may be used. Static dispense is the easiest, but requires more material to be dispensed for each substrate. Dynamic dispense uses less material, but requires greater control during dispense to ensure that the polyimide strikes the exact centre of the substrate. Any deviation will result in poor coating quality. The acceleration to final speed should be as low as possible to allow gradual flow of the polyimide across the substrate. Often one or more intermediate spin speeds are used to allow the polyimide to gradually cover more than 80% of the substrate before continuing on to the final speed. To reduce the backside contamination potential it is often beneficial to prolong the spread cycle until the bulk of the excess polyimide has been removed from the substrate. The final spin speed and time is determined by the film thickness required. Longer spin

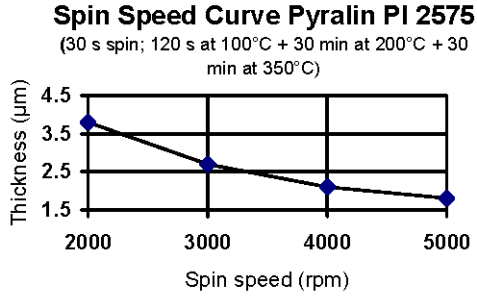
times will improve coating uniformity, but will also reduce the film thickness. In semiconductor applications, an Edge Bead Removal (EBR) and Backside Rinse process may be added to the coating cycle to remove polyimide from the edge and back of the wafer prior to baking. NMP (N-methyl-2-pyrrolidone) or NMP/IPA (isopropanol) can be used for this purpose.

Spin Speed Curves for cured Polyimide









Soft Bake

After application of the polyimide, a bake process is required. Both convection oven and hotplate bake methods may be used. The purpose of this stage, is to partially cure the polyimide prior to patterning. This bake stage leaves the polyimide coating dry, yet soluble in the etchant solution.

Choice of Photoresist

Polyimides of this type can be patterned using common photolithography techniques centered around positive photoresist. The underlying polyimide is an effective anti-reflective layer as there is significant absorption between 350 and 450 nm. This absorption can significantly reduce substrate reflection effects on the photoresist, usually seen as “notching“ after development.

The photoresist should be selected with the correct wavelength to suit the exposure tool in use. As a general guide, formulations with good adhesion in “wet etch“ semiconductor applications perform well. Other attributes include:

- Compatability to standard alkaline positive photoresist developers

- Low contrast performance so that a soft sidewall profile is always produced

- Capability to produce cleanly developed via holes in thick resist coatings

- Good development latitude, especially when over-developed

- The ease of producing a minimum dried 2,5 µm film thickness

The polyimide coating after softbake has minimum solubility in typical photoresist solvents. Photoresist can therefore be coated directly onto the polyimide coating without layer inter-mixing occuring.

Photoresist Application

Substrates should be coated directly with the resist selected. No dehydration bake should be given as this would make the polyimide totally insoluble in the developer. Instead an HMDS vapour prime is permissable if installed on-line but is not really neccessary for good resist adhesion to the polyimide.

Once coated, the resist should be given a softbake at 90°C either in a convection oven for 30 minutes or on a vacuum hotplate for 60 seconds. Once coated and baked, coatings may be held up to 24 hours before exposure.

Photoresist Exposure

Typical exposure: 50 mJ to 150 mJ

Once exposed, development should take place within 8 hours.

Photoresist Development / Polyimide Etch

A single step is used to develop the photoresist and etch the polyimide.

Most alkaline positive resist developers will dissolve both exposed photoresist and polyimide at varying rates. The choice of developer affects the quality of the polyimide image after development. Best results have been obtained using a NaOH based developer.

Thin polyimide layers up to around 5 µm can usually be developed quickly and cleanly with developer which is at ambient temperature. After development of the resist and then the polyimide using a spray puddle technique, a water rinse should be used to remove the developer. The substrate should subsequently be spun until dry.

When thicker polyimide layers need to be processed, it is often beneficial to heat the developer to between 23°C and 25°C. This accelerates the dissolution of the polyimide while having minimal effect on the solubility of the photoresist. In more extreme situations, this may be coupled to a double puddle process. The second puddle is used to develop only the polyimide layer.

Once developed, wafers may be held up to 8 hours before stripping the resist.

Resist Strip

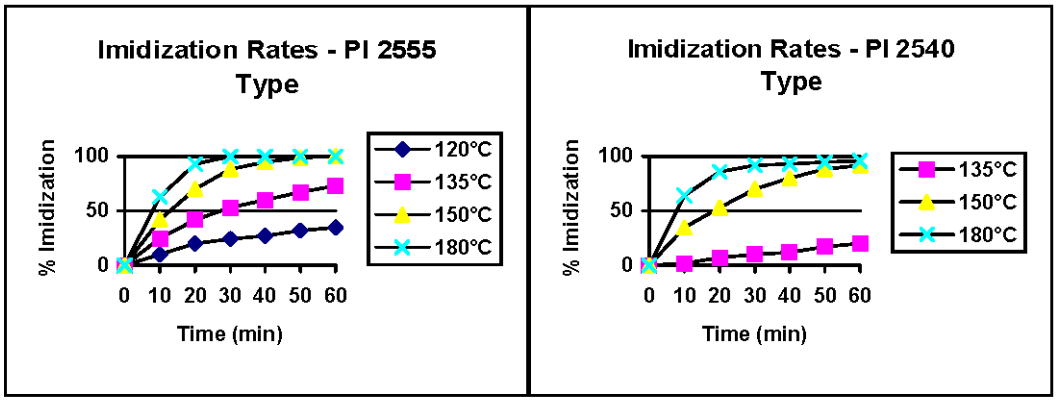
After developing, the photoresist needs to be stripped off the polyimide surface before curing. This step is usually carried out on automated track equipment to reduce surface contamination with resist residue which may result if clean solvents are not used. Resist solvent strippers are normally used.

Cure

The cure heating cycle converts the polyamic acid to the insoluble imide form and drives out remaining solvent. This process requires elevated temperatures and controlled environments to achieve the best results. There is sufficient energy at 180°C to complete the imidization of the polyimide, but higher temperatures are required to completely drive off solvents, thus achieving the ultimate electrical and mechanical properties. A programmable high temperature oven with typical nitrogen flow rate of 10 litres per minute is recommended for best results.

To activate the adhesion promoter, it is recommended that the cure be carried out up until 200°C in air (min 50% RH). Above this temperature, a nitrogen atmosphere should be used. The ramp rates (up and down) should be low to avoid high stress in the polyimide.

The maximum cure temperature may be higher than 300°C when the coating is to be subjected to a high temperature process after curing. In such cases, temperatures up to 400°C have been used to ensure that there is no outgassing during subsequent processes.



Processing Pyralin® PI2525, PI2555, PI-2575 & PI2556 products

(for ca. 7µm softbaked and 5µm cured film thickness)

Application of Adhesion Promoter*

- Dispense on static substrate, 3 seconds
- Hold for 20 seconds
- Spin dry for 30 seconds

Bake Adhesion Promoter

- On hotplate at 120°C for 60 seconds (optional)

*not required with PI-2575

Polyimide Coating

- Dispense on static substrate
- Rotate at 500 rpm for 5 seconds
- Rotate at final speed for 30 seconds (see spin speed curves)
- EBR/Backside rinse, 10 seconds
- Spin dry, 15 seconds

Soft Bake

- In convection oven at 120°C for 30 minutes

OR

- On hot plate at 120°C for 30 seconds followed by 150°C for 30 seconds

Coat Photoresist

- Dispense, 3 seconds
- Spread at 500 rpm for 5 seconds
- Spin at final speed for 30 seconds
- EBR / Backside rinse for 5 seconds
- Spin dry for 15 seconds

Softbake Photoresist

- On hotplate at 90°C for 60 seconds

Exposure

- 50 mJ to 150 mJ

Development

Developer:	NaOH, KOH or TMAH developer or DE 1000 at 21°C
Rinse:	DI water

Puddle Development process:

• Spray (100 rpm)	5 seconds
• Puddle	3 minutes
• Rinse (1000 rpm)	15 seconds
• Spin dry (5000 rpm)	15 seconds

Resist Strip

- Spray or spray/puddle acetone or standard resist stripper or N-Butlyacetate at ca. 2000 rpm
- Spin dry

Cure

Curing should be done in an oven using the following cure profile:

- Heating from room temperature to 200°C, ramp rate 4°C/minute in air
- Hold time at 200°C for 30 minutes in air
- Heating from 200°C to 300°C, ramp rate 2,5°C/minute in nitrogen
- Hold time at 300°C for 60 minutes in nitrogen
- Gradual cooling to room temperature

Solution Properties

	PI2525	**PI2555/PI-2575**	**PI2556**
Solids content (%)	25.0 +/-1.0	19.0 +/-1.0	15.0 +/-1.0
Viscosity (Poise)	60 +/- 10.0	14.0 +/-2.0	3.5 +/-1.0
Flash Point	93°C	60°C	54°C
Solvent (%)	N-Methyl-2-Pyrrolidone 100	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon 80/20 +/-5	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon Propylene Glycol Methyl Ether 70/14/15 +/-5
Ash content (%)	0.1 max.	0.1 max.	0.1 max.
Chloride content	5.0 ppp max.	5.0 ppp max.	5.0 pp max
Sodium content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Potassium content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Copper content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Iron content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Total metals	10.0 ppm max.	10.0 ppm max.	10.0 ppm max.

Cured Film Properties

Tensile strength (kg/mm²)	13.1
Elongation (%)	10
Modulus (kg/mm²)	245
Stress (dynes/cm^2)	3.6×10^8
Moisture uptake (%)	2 - 3
Dielectric constant (at 1 kHz, 50% RH)	3.3
Dissipation factor	0.002
Dielectric strength (volts/mil)	4000
Volume resistivity (ohm-cm)	10^{16}
Surface resistivity (ohm)	10^{15}
Coefficient of thermal expansion (ppm)	40
Coefficient of thermal conductivity (cal/(cm)(sec)(°C))	35×10^{-5}
Glass transition temperature	> 320°C

Decomposition temperature	560°C
Weight loss (% at 500°C, 120 min)	2.9
Specific heat (cal/g/°C)	0.26
Refractive index	1.70

Storage/Shelf Life

It is recommended that PI-2555 Series products be stored between 0°C to -18°C.

Pyralin® PI2525, PI2555, PI-2575 and PI2556 are stable at clean room temperatures (21°C) for ca. four weeks with no significant change in properties. When stored at -18°C, shelf-life is 2 years from date of manufacturing. Moisture contamination is detrimental to stability and must be avoided. Containers should be brought to room temperature before opening to avoid moisture condensation inside the botttle.

Safety and Handling

During all handling of Pyralin polyimide products, adequate ventilation must be provided. Skin and eye contact should be avoided. Exposed areas should be flushed with water immediately. For prolonged or repeated contact, milled butyl rubber or natural latex rubber gloves should be used. Disposable PVC gloves are not recommended.

United States

HD MicroSystems, LLC
P0 Box 80010
Wilmington, DE 19880
800-346-5656 (Phone)
302-892-0597 (Fax)

HD MicroSystems, LLC
1333 Lawrence Expressway
Suite 212
Santa Clara, CA 95051
408-260-0880 (Phone)
408-260-0885 (Fax)

Japan

HD MicroSystems, LLC
10-13, Shibuya 3-chome, Shibuya-ku,
Tokyo 150
Japan
81-3-3407-9003 (Phone)
81-3-3407-9037 (Fax)

Europe

HD MicroSystems Europe GmbH
DuPont Strasse 1
D-61343 Bad Homburg
Germany
49-6172-87-1822 (Phone)
49-6172-87-1824 (Fax)

Internet
www.hdmicrosystems.com

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Caution: Do not use in medical applications involving permanent implanation in the human body.

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

PTR-200-PRL

Automated Polyimide Recoater with Linear Proof Tester

Operator's Manual

Version 1.2

United States:
1400 Campus Drive West • Morganville, NJ 07751
+1 (732) 972-2880 • +1 (800) 421-8847 • Fax +1 (732) 972-6229

England:
8, Kew Court • Pynes Hill Office Campus • Exeter, EX2 5AZ
+44 (0) 1392 445777 • Fax +44 (0) 1392 445009

Web: http://www.vytran.com

VYTRAN

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Vytran LLC
1400 Campus Drive
Morganville, NJ 07751 USA

Phone: +1 (732)-972-2880
+1 (800)-421-8847
FAX: +1 (732)-972-6229

http://www.vytran.com

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1 Introduction

The PRL-200 is designed for recoating and proof testing polyimide coated fibers. It operates on a coat, cure and test recoat method, whereby a layer of polyimide is applied to the fiber through a die, followed by a filament heater to cure the polyimide and upon completing the recoat a linear proof test. When configured and operated properly, the PTR-200-PRL is capable of producing a high quality and a uniform polyimide recoat.

1.1 Parts Checklist

When unpacking the PTR-200-PRL for the first time, check to make sure that you have the following accessories:

- PTR-200-PRL Automated Polyimide Recoater with Linear Proof Tester
- 12.0V Power supply (PSU)
- AC power cord
- DC power cable
- RS-232 communication cable
- Fittings kit
- Tool kit containing:
  - 1 oz. bottle HD MicroSystems PI2525 Polyimide Recoat Material
  - 1 oz. spare bottle
  - Cotton swabs
  - 5/64” Allen key
  - 3/32” Allen key
  - 0.035” Allen key
- External vacuum pump with vacuum line
- PTR-200-CX-PRL Handset Controller

If you are missing any of the above or need replacements, please contact Vytran.

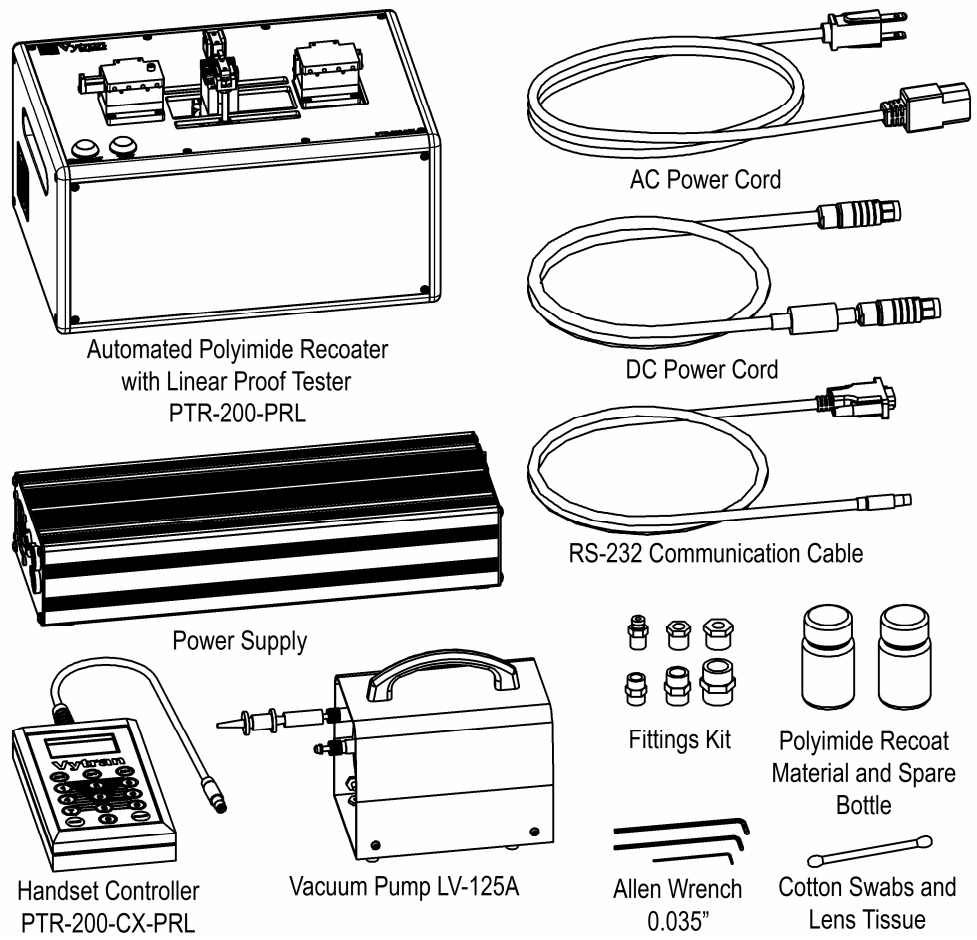


Figure 1: System Components

1.2 Powering Up

The PTR-200-PRL Power Supply Unit (PSU) accepts an AC input of 90-260 VAC; 47-63 Hz. Connect both the AC power cord and the DC power cable to the external Power Supply. Connect the Handset Controller and the DC power cable to the PTR-200-PRL.

Turn on the power supply and then turn on the PTR-200-PRL using the ON/OFF rocker switch located on the back of the recoater. The PTR-200-PRL will run an initialization process that includes homing the recoat die and tensioning motors and operating the recoat die (close/open). During the initialization process, the Handset Controller will display the status of the system. Once the homing process is completed, the Handset Controller displays the Main Menu screen and the PTR-200-PRL is ready for recoating.

1.3 Shutting Down

To shut down the PTR-200-PRL:

1. Turn off the PTR-200-PRL using the on/off rocker switch located on the back of the recoater.
2. Turn off the power supply.

2 Controlling the PTR-200-PRL

The PTR-200-PRL is configured and controlled from Vytran's PRL-200-CX-PRL Handset Controller, which also provides feedback and status of the unit. If the operator does not need to change parameter settings or receive status prompts, the Handset Controller can be removed and the unit operated simply by pressing the blue RECOAT and TEST buttons.

The Handset Controller allows the user to interface with the unit and modify the settings. The Handset Controller is based on a three (3) menus:

- Main Menu
- Configuration Menu
- Options Menu

Each menu and its contents are described below.

2.1 Main Menu

The Main Menu displays the unit status. From this menu, press the "CFG" button to enter the Configuration Menu or press the "OPT" button to enter the Options Menu.

2.2 Configuration Menus

There are three (3) levels to the Configuration Menu. At level one the user can select from five (5) topics - Inject, Undercoat, Overcoat, Recoat Length, or Proof Test. Within each of these topics are the parameters which can be viewed and/or copied. Below is a description of the five (5) topics and each topics parameters.

2.2.1 Inject

Inject Rate (µl/sec): This parameter is the polyimide injection rate, in microliters per second, into the die. The optimum Inject Rate will be dependant on the polyimide material being used.

Undercoat Qty. (µl): This parameter is the quantity of polyimide material, in microliters, injected into the die for the first loop of the head (the undercoat). The optimum Undercoat Qty will be primarily dependant on the bare fiber diameter, die size, and the length of the recoat.

Overcoat Qty. (µl): This parameter is the quantity of polyimide material injected into the die, in microliters, after the first loop of the head. The optimum Overcoat Qty will be primarily dependant on the die size, and the length of the recoat.

2.2.2 Undercoat

Head Sweep Vel. (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the bare fiber diameter, die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

2.2.3 Overcoat

Number of Overcoats: This parameter is the number of loops the head will make. The optimum Number of Overcoats will be dependant on the polyimide thickness layer desired (which will be dependant on the undercoat layer thickness and the parameter settings for the overcoat(s)).

Head Sweep Vel (steps/sec): This parameter is the velocity of the head, in steps/sec, for the first loop of depositing polyimide. The optimum Head Sweep Velocity will be dependant on the die size, and material being deposited.

Left Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during a polyimide deposition. The optimum Left Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Left Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Left Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the left heater during imidization (the pass after deposition). The optimum Left Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Left Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Right Precure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during a polyimide deposition. The optimum Right Precure Temp will be dependant on the Head Sweep Velocity, and material being deposited. The temperature is calibrated at the center of the heater while stationary. The Right Precure Temp is designed to evaporate the volatiles of the polyimide being deposited.

Right Cure Temp (degrees centigrade): This parameter is the approximate temperature, in degrees centigrade, applied to the right heater during imidization (the pass after deposition). The optimum Right Cure Temp will be dependant on the Head Sweep Velocity and the polyimide material. The temperature is calibrated at the center of the heater while stationary. The Right Cure Temp is designed to imidize the polyimide after the volatiles have been evaporated.

Overlap Delta (mm): This parameter is the additional distance, in millimeters, the head will travel on each pass. This will effectively taper the transition from original polyimide to recoated polyimide.

2.2.4 Recoat Length

Recoat Length (mm): This parameter is the desired bare fiber length, in millimeters, to be recoated. The actual recoat length will be approximately 8 millimeters longer on each end in order to compensate for the width of the head and the fiber load position.

2.2.5 Proof Test

Proof Test Units: This menu allows the user to select the desired units for displaying the Proof Test Level. Unit selections are: Newtons, kpsi, and grams.

Proof Test Level (units): This parameter is the Proof Test Level, in units user selected, to be applied after the recoat has been completed.

Proof Test Rate (mm/sec) This parameter is the rate, in millimeters per second, at which the Proof Test Level will be applied. The optimum rate is that which achieves the desired proof test level within 3 - 5 seconds of load applying time.

2.3 Options Menu

From the Options Menu, various system level configuration parameters and functions can be edited or executed.

Recoat Tension (Newtons): This parameter is the tension, in Newtons, applied to the fiber prior to initiating a recoat. The PTR-200-PRL also monitors the tension during the recoat and will automatically abort if the tension varies significantly from the Recoat Tension. The auto abort is intended to protect both the die and fiber.

Heater Settle Time (msec): This parameter is the amount of time, in milliseconds, allowed for the heater to stabilize when changing temperatures.

Die Close Time (msec): This parameter is the amount of time, in milliseconds, allowed for the die to close prior to execution of the subsequent process.

Fiber Unload Time (msec): This parameter is the amount of time, in milliseconds, allowed for the operator to unload the fiber prior to the PTR-200-PRL performing a system reset.

Inject to Die Qty (µL) This option is the quantity of polyimide material, in microliters, which will be injected into the die upon entering the quantity. This option is intended for use when changing materials or purging the system prior to storage.

Head to Home: This option performs a homing of the head and is useful as a diagnostic tool.

Tension Home: This option performs a homing of the proof test load cell and is useful as a diagnostic tool.

Move Head to Start: This option performs a movement of the head to the start position. The start position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Move Head to Stop: This option performs a movement of the head to the stop position. The stop position is calculated based upon the recoat length, overlap delta, and the number of overcoats. Use of the Head to Start and Head to Stop options enables the user to verify the correct recoat length has been entered.

Recoat Request State: This option enables or disables the request to input a recoat length each time the process is run. This option is primarily used when the length to be recoated varies significantly from recoat to recoat.

Set/Run Purge Cycles: This option is the number of recoat pump purge cycles that will be run upon entering the quantity.

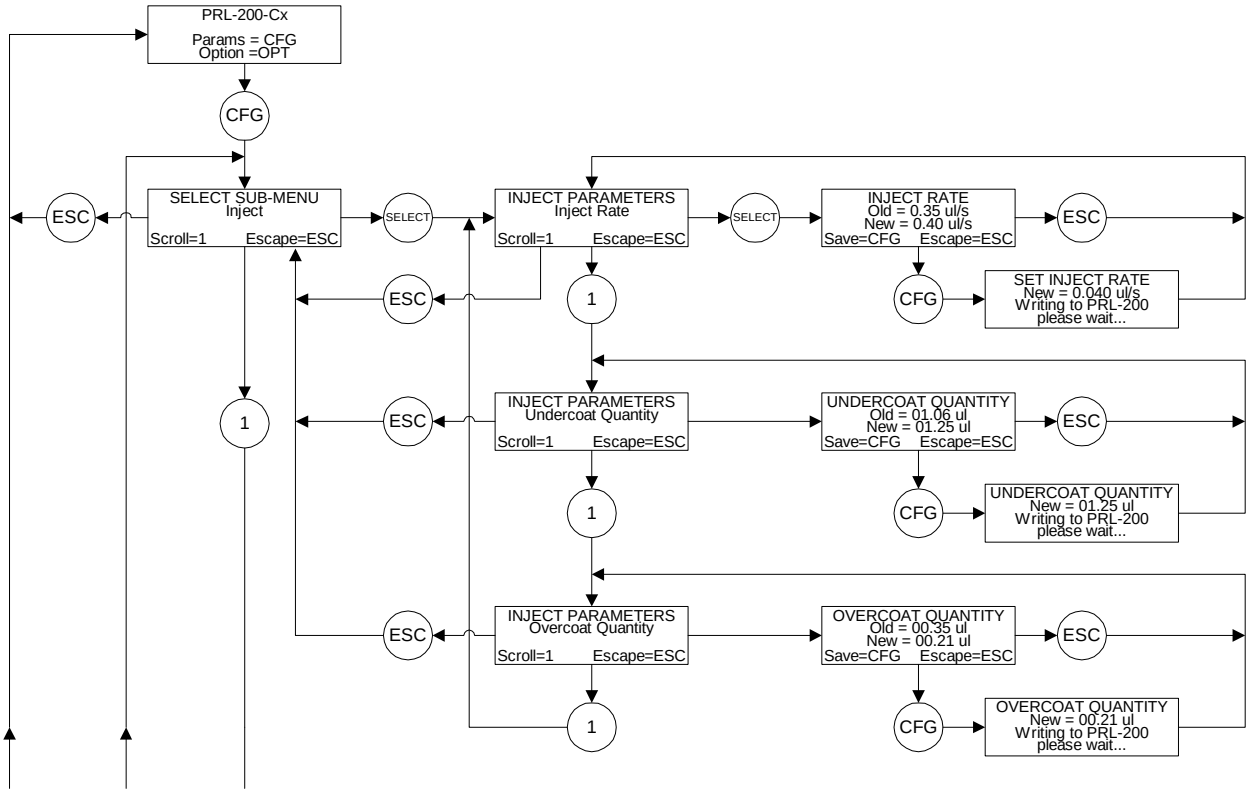
Recoat Tension This option is the amount of tension that will be applied to the fiber prior to the recoating.

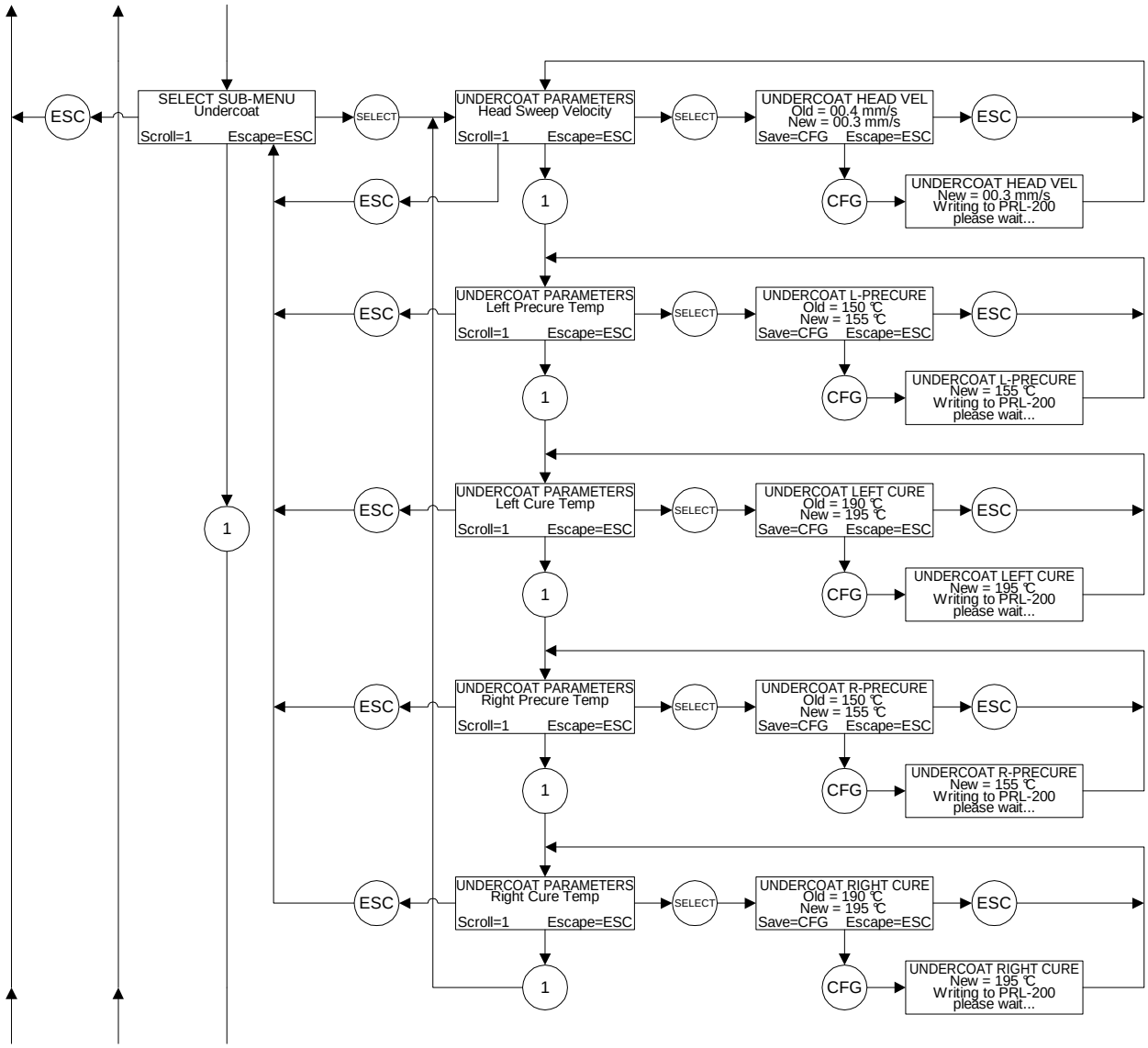
2.4 Parameter Limits

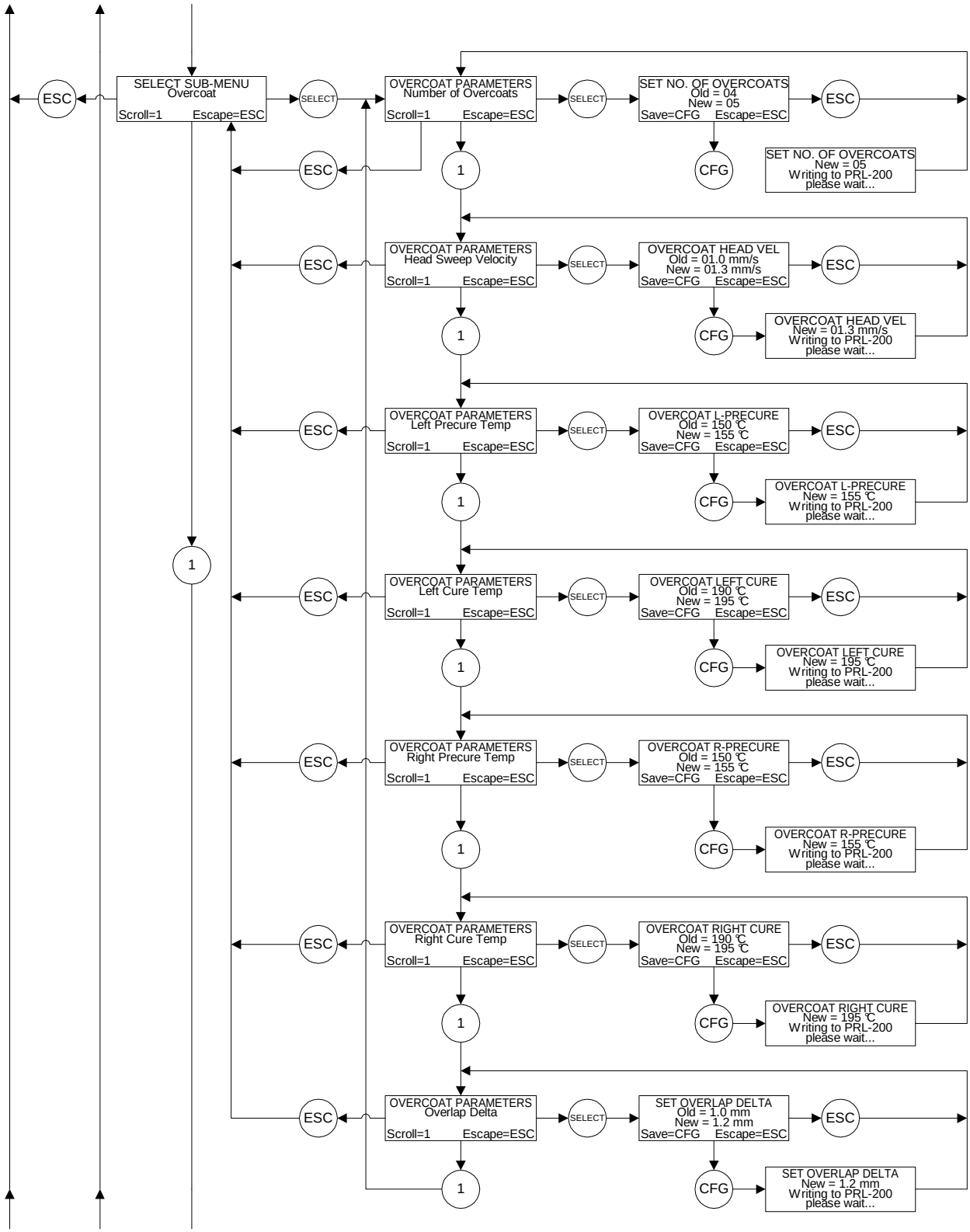
Parameter	Min	Max
Inject Rate (µL/sec)	0.01	2.00
Undercoat Qty (µL)	0.01	10.00
Overcoat Qty (µL)	0.01	10.00
Undercoat Head Sweep Vel (mm/sec)	0.01	20.00
Undercoat Left Precure Temp (℃)	100	200
Undercoat Left Cure Temp (℃)	100	300
Undercoat Right Precure Temp (℃)	100	200
Undercoat Right Cure Temp (℃)	100	300
Number of Overcoats	1	10
Overcoat Head Sweep Vel (mm/sec)	0.01	20.00
Overcoat Left Precure Temp (℃)	100	200
Overcoat Left Cure Temp (℃)	100	300
Overcoat Right Precure Temp (℃)	100	200
Overcoat Right Cure Temp (℃)	100	300
Overlap Delta (mm)	100	200
Recoat Length (mm)	0	2
Proof Test Level (Newtons)	0	20
Proof Test Rate (mm/sec)	0.1	5.0
Recoat Tension (Newtons)	2	10
Heater Stabilize Time (msec)	1	10000
Die Close Time (msec)	250	2500
Fiber Unload Time (msec)	5000	30000
Heater Stabilize Time (msec)	1	10000
Inject to Die Qty (µL)	1	100

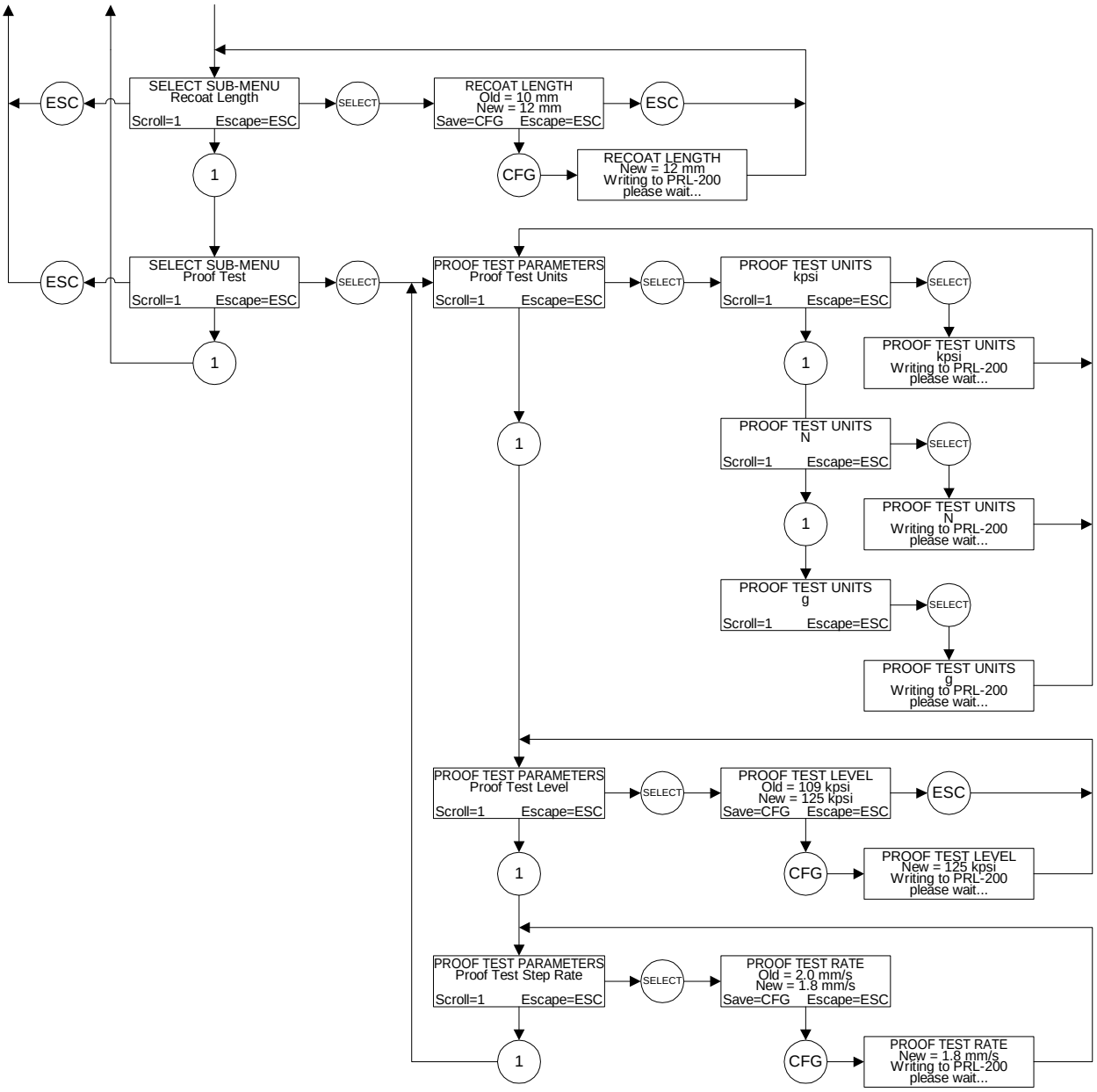
2.5 Configuration Menu Flow Chart

This flowchart is a guide for navigating through the Configuration Menu, and shows the display prompts and button key presses for viewing and editing the Configuration Parameters.



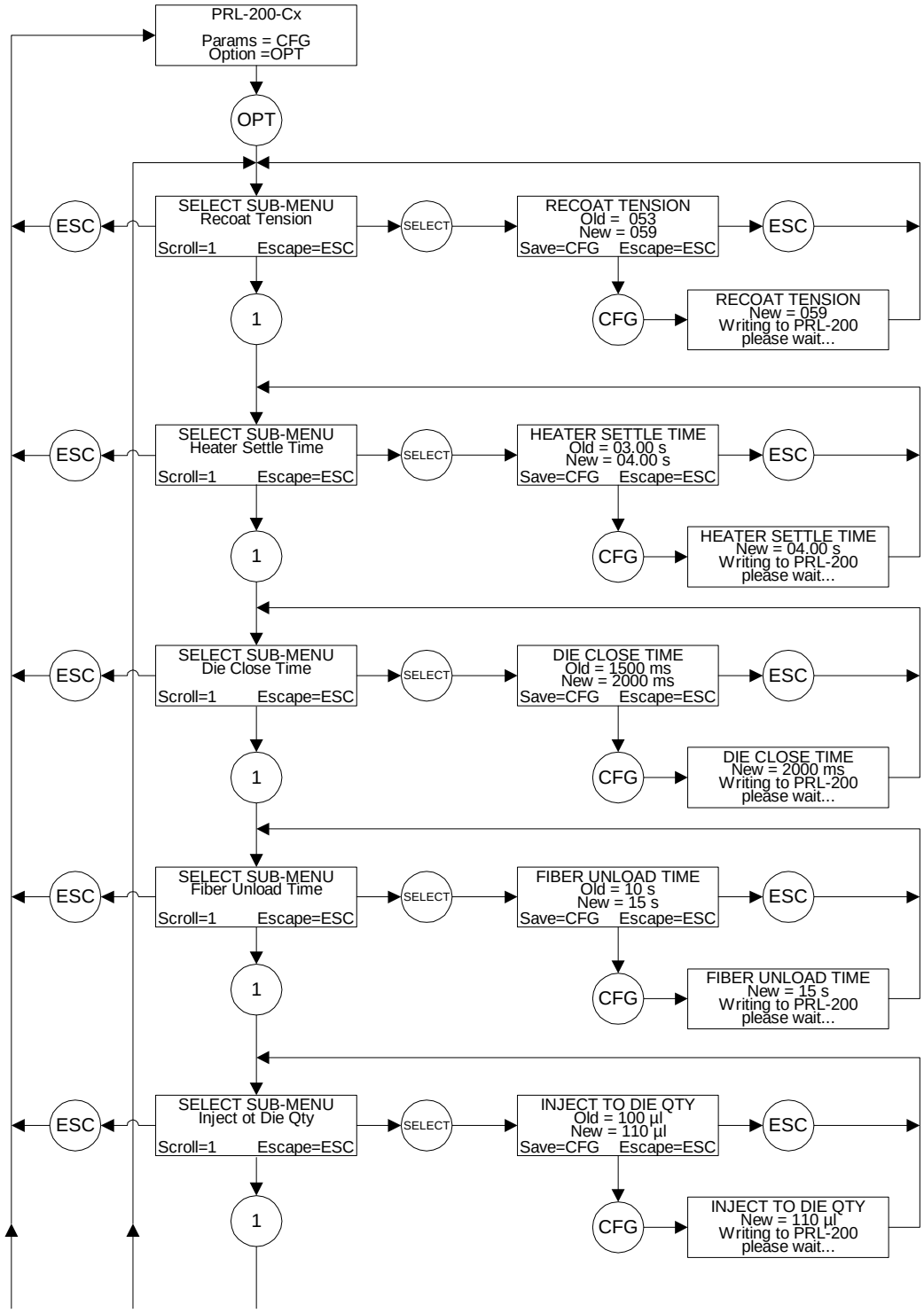

ESC
SELECT SUB-MENU
Undercoat
Scroll=1 Escape=ESC
SELECT
UNDERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
SELECT
UNDERCOAT HEAD VEL
Old = 00.4 mm/s
New = 00.3 mm/s
Save=CFG Escape=ESC
ESC
CFG
UNDERCOAT HEAD VEL
New = 00.3 mm/s
Writing to PRL-200
please wait...
1
UNDERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
SELECT
UNDERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
UNDERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
UNDERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
UNDERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
UNDERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
UNDERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...

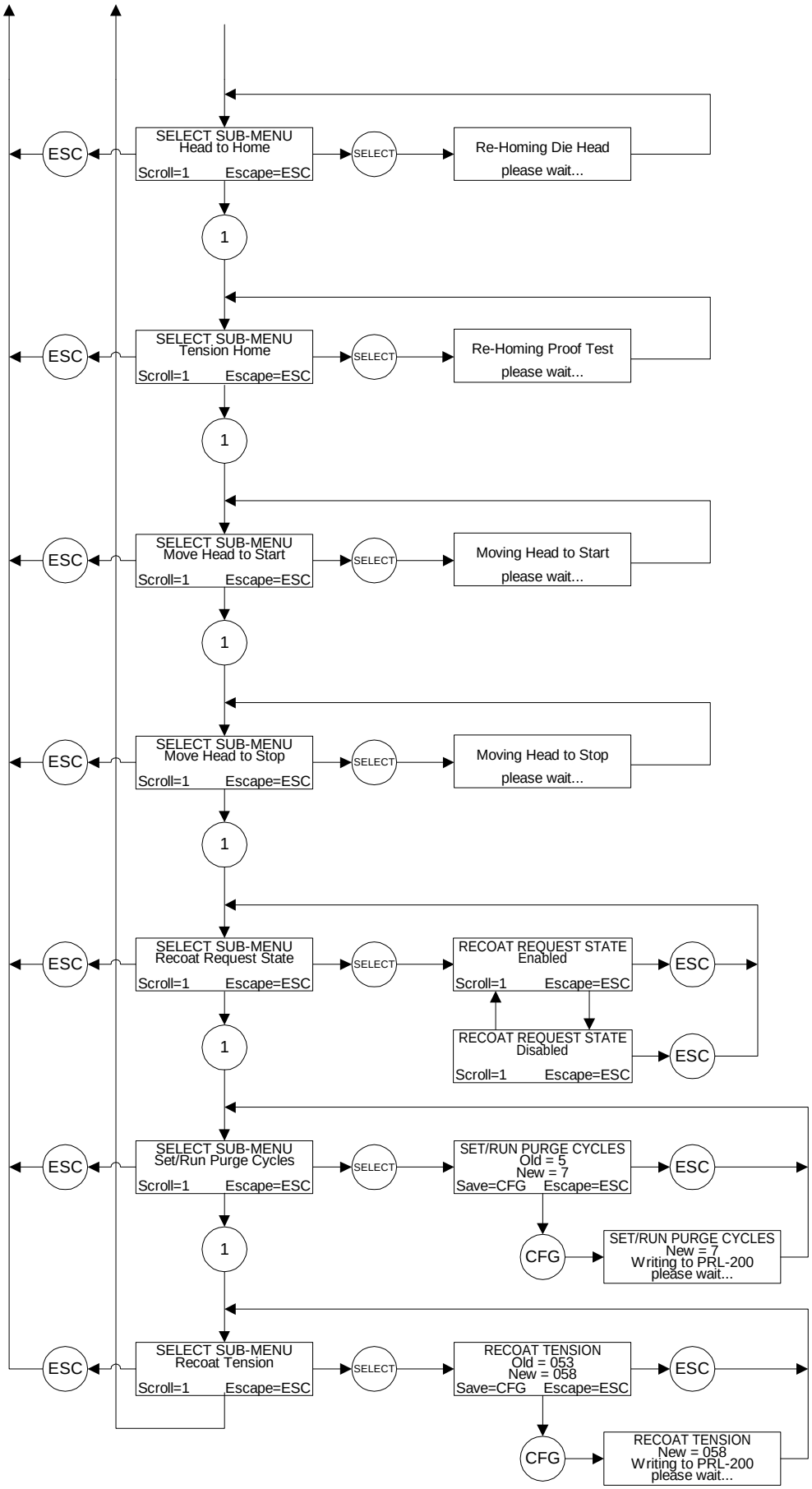

SELECT SUB-MENU
Overcoat
Scroll=1 Escape=ESC
ESC
SELECT
OVERCOAT PARAMETERS
Number of Overcoats
Scroll=1 Escape=ESC
SET NO. OF OVERCOATS
Old = 04
New = 05
Save=CFG Escape=ESC
CFG
SET NO. OF OVERCOATS
New = 05
Writing to PRL-200
please wait...
1
OVERCOAT PARAMETERS
Head Sweep Velocity
Scroll=1 Escape=ESC
OVERCOAT HEAD VEL
Old = 01.0 mm/s
New = 01.3 mm/s
Save=CFG Escape=ESC
OVERCOAT HEAD VEL
New = 01.3 mm/s
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Precure Temp
Scroll=1 Escape=ESC
OVERCOAT L-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT L-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Left Cure Temp
Scroll=1 Escape=ESC
OVERCOAT LEFT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT LEFT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Precure Temp
Scroll=1 Escape=ESC
OVERCOAT R-PRECURE
Old = 150 ℃
New = 155 ℃
Save=CFG Escape=ESC
OVERCOAT R-PRECURE
New = 155 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Right Cure Temp
Scroll=1 Escape=ESC
OVERCOAT RIGHT CURE
Old = 190 ℃
New = 195 ℃
Save=CFG Escape=ESC
OVERCOAT RIGHT CURE
New = 195 ℃
Writing to PRL-200
please wait...
OVERCOAT PARAMETERS
Overlap Delta
Scroll=1 Escape=ESC
SET OVERLAP DELTA
Old = 1.0 mm
New = 1.2 mm
Save=CFG Escape=ESC
SET OVERLAP DELTA
New = 1.2 mm
Writing to PRL-200
please wait...


ESC
SELECT SUB-MENU
Recoat Length
Scroll=1 Escape=ESC
SELECT
RECOAT LENGTH
Old = 10 mm
New = 12 mm
Save=CFG Escape=ESC
ESC
1
CFG
RECOAT LENGTH
New = 12 mm
Writing to PRL-200
please wait...
ESC
SELECT SUB-MENU
Proof Test
Scroll=1 Escape=ESC
SELECT
PROOF TEST PARAMETERS
Proof Test Units
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
kpsi
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
kpsi
Writing to PRL-200
please wait...
1
PROOF TEST UNITS
N
Scroll=1 Escape=ESC
SELECT
1
PROOF TEST UNITS
N
Writing to PRL-200
please wait...
PROOF TEST UNITS
g
Scroll=1 Escape=ESC
SELECT
PROOF TEST UNITS
g
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Level
Scroll=1 Escape=ESC
SELECT
PROOF TEST LEVEL
Old = 109 kpsi
New = 125 kpsi
Save=CFG Escape=ESC
ESC
1
CFG
PROOF TEST LEVEL
New = 125 kpsi
Writing to PRL-200
please wait...
PROOF TEST PARAMETERS
Proof Test Step Rate
Scroll=1 Escape=ESC
SELECT
PROOF TEST RATE
Old = 2.0 mm/s
New = 1.8 mm/s
Save=CFG Escape=ESC
1
CFG
PROOF TEST RATE
New = 1.8 mm/s
Writing to PRL-200
please wait...

2.6 Options Menu Flowchart

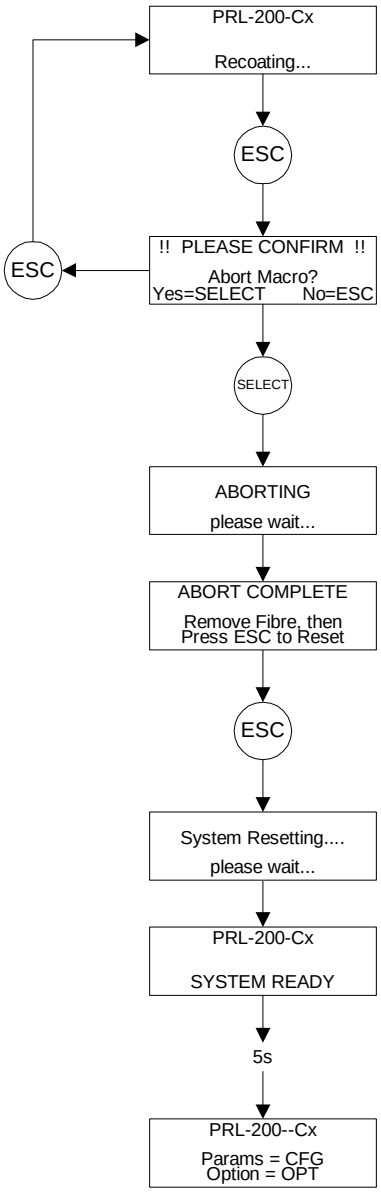
This flowchart is a guide for navigating through the Options Menu, and shows the display prompts and button key presses for editing parameters and executing system related functions.




SELECT SUB-MENU
Head to Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Die Head
please wait...
ESC
1
SELECT SUB-MENU
Tension Home
Scroll=1 Escape=ESC
SELECT
Re-Homing Proof Test
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Start
Scroll=1 Escape=ESC
SELECT
Moving Head to Start
please wait...
ESC
1
SELECT SUB-MENU
Move Head to Stop
Scroll=1 Escape=ESC
SELECT
Moving Head to Stop
please wait...
ESC
1
SELECT SUB-MENU
Recoat Request State
Scroll=1 Escape=ESC
SELECT
RECOAT REQUEST STATE
Enabled
Scroll=1 Escape=ESC
ESC
RECOAT REQUEST STATE
Disabled
Scroll=1 Escape=ESC
ESC
1
SELECT SUB-MENU
Set/Run Purge Cycles
Scroll=1 Escape=ESC
SELECT
SET/RUN PURGE CYCLES
Old = 5
New = 7
Save=CFG Escape=ESC
ESC
CFG
SET/RUN PURGE CYCLES
New = 7
Writing to PRL-200
please wait...
1
SELECT SUB-MENU
Recoat Tension
Scroll=1 Escape=ESC
SELECT
RECOAT TENSION
Old = 053
New = 058
Save=CFG Escape=ESC
ESC
CFG
RECOAT TENSION
New = 058
Writing to PRL-200
please wait...
ESC

2.7 Abort Flowchart

Even after the recoat process has been initiated it is possible to abort the process if required. The Abort Flowchart shows the display prompts and button key presses to abort a recoat process.



3 Recoat Injection System

The PTR-200-PRL has an automatic recoat injection pump fitted inside the unit. The pump is based on an automated syringe and distribution valve that can select one of three ports (Fill, Purge, or Inject) through which it can either draw or inject recoat material (see Figure 3). A bottle containing recoat material is installed directly on the pump, with the pump "Fill" tube inserted into the bottom of the bottle. A "Purge" tube runs from the pump to the top of the recoat bottle, and is used for cycling material back into the bottle. An "Inject" tube runs from the pump to the inject port of the die, which is located in the center of the lower right die. Once all air is purged from the injection system, the pump provides very accurate control of the volume and velocity of recoat material injection.

The recommended recoat material for use in the PTR-200-PRL is Pyralin PI2525, which is manufactured by HD MicroSystems. This is a fast imidizing at lower temperature coating. Do not attempt to use alternate recoat materials without first consulting Vytran on compatibility with the PRL.

Note: Pyralin PI2525 recoat material does have a limited shelf life of approximately 24 months from date of manufacture when stored at 0 to 18 degrees Centigrade. PI2525 is stable at room temperature (21 degrees Centigrade) for approximately 4 weeks with no significant change in properties. Using material that has passed its expiration date may cause both pump performance and recoat quality issues.

3.1 Priming the Injection System

It is very important to remove all air from the recoat injection system prior to performing a recoat. When operating the system for the first time, the pump must be filled with recoat material and cleared of all air in the pump and tubing. In order to clear the inject tube, recoat material must be injected out through the mold inject port and collected and disposed of. Make sure to have cotton swabs and NMP (1-Methyl-2-pyrrolidinone) available for this purpose prior to starting this procedure. NMP is the recommended solvent for cleaning uncured polyimide recoat material.

WARNING: Polyimide recoat materials can be hazardous to your health if not handled properly. Read the Material Safety Data Sheet provided in Appendix X, and make sure to follow all precautionary guidelines when working with this material.

To prime the recoat injection system:

1. Turn off power to the PTR-200-PRL.
2. Remove the front plate of the PTR-200-PRL by using the 3/32 Allen wrench provided in the tool kit to remove the four (4) black socket-head cap screws located at the corners of the plate.
3. The recoat pump is located on the left side of the PTR-200-PRL as shown in Figure 2. Unscrew the brown recoat bottle located at the front of the pump and remove by angling out through the front opening. The red Fill tube will flex to allow removal.
4. For new systems, replace the empty recoat bottle shipped with the unit with a new bottle of recoat material. For systems that have previously been run with recoat material, the recoat injection system should be flushed clean prior to adding new material (see 5.5).
5. Screw the new recoat bottle into place and replace the front panel and the four (4) socket head cap screws.

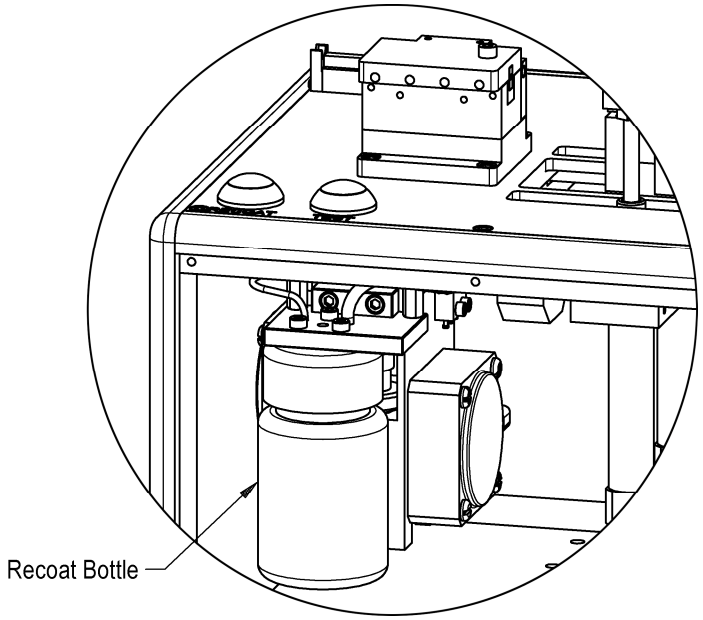


Figure 2: Recoat Bottle Access

6. Turn on power to the PRL-200 and wait for the system to initialize.
7. Execute five (5) Purge cycles (Options menu on Handset Controller). Each purge cycle will draw 100 microliters of recoat material from the bottom of the recoat bottle through the red Fill tube and inject material back into the top of the recoat bottle through the green Purge tube (see Figure 3). Five (5) Purge cycles are required to fill the pump with recoat material and force any air out of the pump system. This will take approximately 15 minutes to complete.
8. After the pump has completed its Purge cycles, the Inject tube that runs from the pump to the die must also be filled with recoat material and purged of air. Have cotton swabs and cleaning solution (NMP) available prior to proceeding.

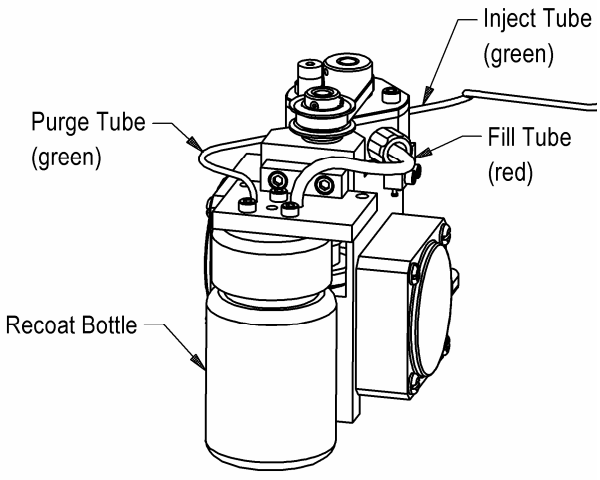


Figure 3: Recoat Material Flow

9. Set the Inject to Die Qty to 100µl (Options menu on Handset Controller).
10. Execute the inject command (press “Select” on the Handset Controller).
11. Watch for recoat material to emerge from the die inject port located at the center of the center of the bottom right die (see Figure 5). Make sure to collect the recoat material with a cotton swab as it comes out of the die injection port. Do not allow recoat material to run down between the die.
12. Execute three (3) additional “Inject 100” sequences to purge air completely from the inject tube. **Note:** Because the injection pump holds 100µl of recoat material, there will be a delay of approximately one minute between the second and third inject sequences while the pump refills.

13. After purging the inject tube, the recoat material should run freely from the die without bubbles. If bubbles are still present, run additional inject sequences.
14. Once the pump and the inject tube are purged, clean the die of all excess recoat material (see 3.2).

Note: Because the syringe in the recoat pump is mounted vertically, it is possible that an air bubble may still be trapped at the tip of the syringe after the above priming process. This air bubble will very slowly rise to the top of the syringe after which time it can be purged out. It is therefore recommended that at least one (1) additional Purge cycle is run the next day after the initial priming of the system.

3.2 Cleaning the Die

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP (1-Methyl-2-pyrrolidinone). NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

4 Recoat and Proof Test Process

4.1 The Polyimide Recoat Process

The PTR-200-PRL utilizes two Fiber Holding Blocks (FHB's) to securely clamp and position the fiber prior to recoating. The right-hand FHB has a linear drive mechanism for applying tension to the fiber. A load cell is incorporated into the linear drive mechanism for monitoring recoat tension. Once the fiber is positioned and securely clamped in the FHB's, pressing the recoat button will initiate an automated recoat process. The right-hand FHB will move to the right until the Recoat Tension is reached. With the fiber held under tension, the right die is closed and the Undercoat Quantity of material is injected into the die and the right heater is set to the Precure Temperature. The recoat head will move to the left depositing material while the right heater will precure the material. Upon reaching the appropriate length, the left die will close and additional recoat material will be injected into the die. The left heater is set to the Precure Temperature and the right heater to the Cure Temperature. The recoat head moves to the right depositing material while the right heater fully cures the previously precured material and the left heater precures the newly deposited material. Returning to the start position is defined as one loop or pass as the material initially deposited has been fully imidized.

This process is repeated until the desired recoat thickness has been achieved. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The recoated fiber is unloaded and the unit resets itself in preparation for the next recoat.

4.2 The Fiber Holding Blocks, V-Grooves, and Inserts

The FHBs are designed to accommodate a range of fiber buffer and cladding sizes through the use of changeable, bottom, FHB inserts. The top insert is spring loaded and does not require any change for 80 or 125 micron fibers. The bottom inserts are V-groove, and incorporate vacuum feed to assist in loading the fiber. The V-groove provides mechanical alignment to the recoat die. V-groove inserts are labeled according to clamping diameter in microns. Beyond the V-groove inserts are rubber inserts. The rubber inserts provide the clamping force and surface area required for tensioning and tension testing.

4.3 Stripped Fiber Requirements

The fiber to be recoated should be free of debris and have a smooth, continuous transition in the jacket strip region. The jacket interface should not extend beyond the original coating diameter.

4.4 Loading

To load the fiber for recoating:

1. If the Fiber Holding Block (FHB) tops are closed, open the FHB tops (see Figure 4). The head will move to the start position and the internal vacuum pump will turn on to aid in loading the fibers.

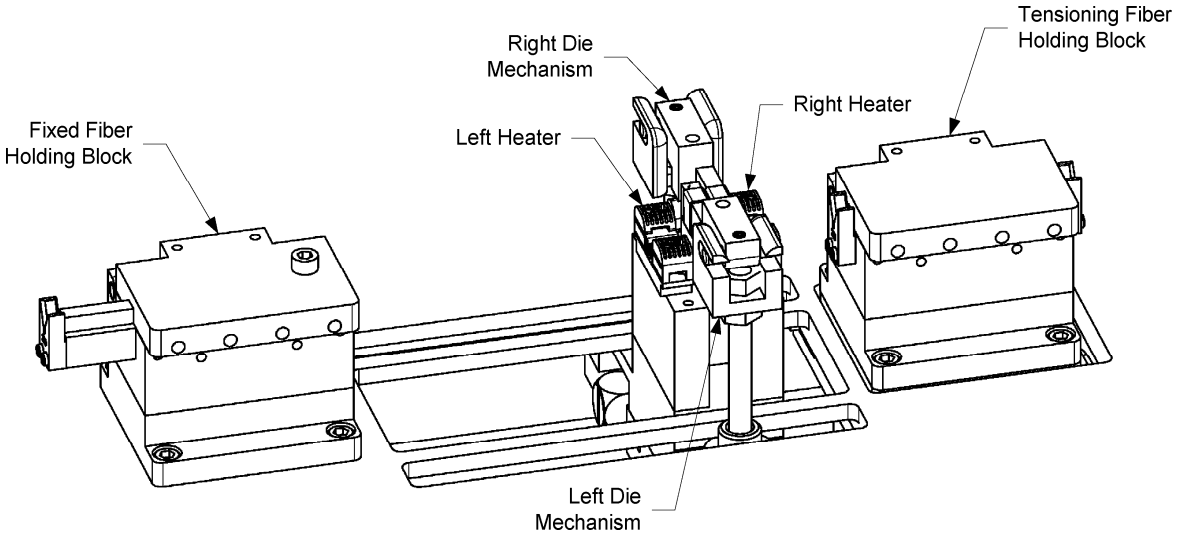


Figure 4: Recoat and Proof Test Components

2. If the FHB tops are open, the load fiber process can be initiated, by either pressing the blue RECOAT button or by closing and reopening both left and right FHB tops.
3. Check that the correct FHB inserts (top and bottom) are installed and that they are free from debris. Position the fiber in the left-hand FHB V-groove, with the stripped section to the left of the left heater. Lower the fiber into the right-hand FHB V-groove. The FHB vacuum should hold the fiber in place.
4. Manually position the fiber in the FHBs so that the right jacket interface is in line with the left edge of the recoat head (see Figure 5). Verify that the fiber is centered in the left and right die.
   Note: Damage to the die may occur if the fiber is not centered in the die when they close.

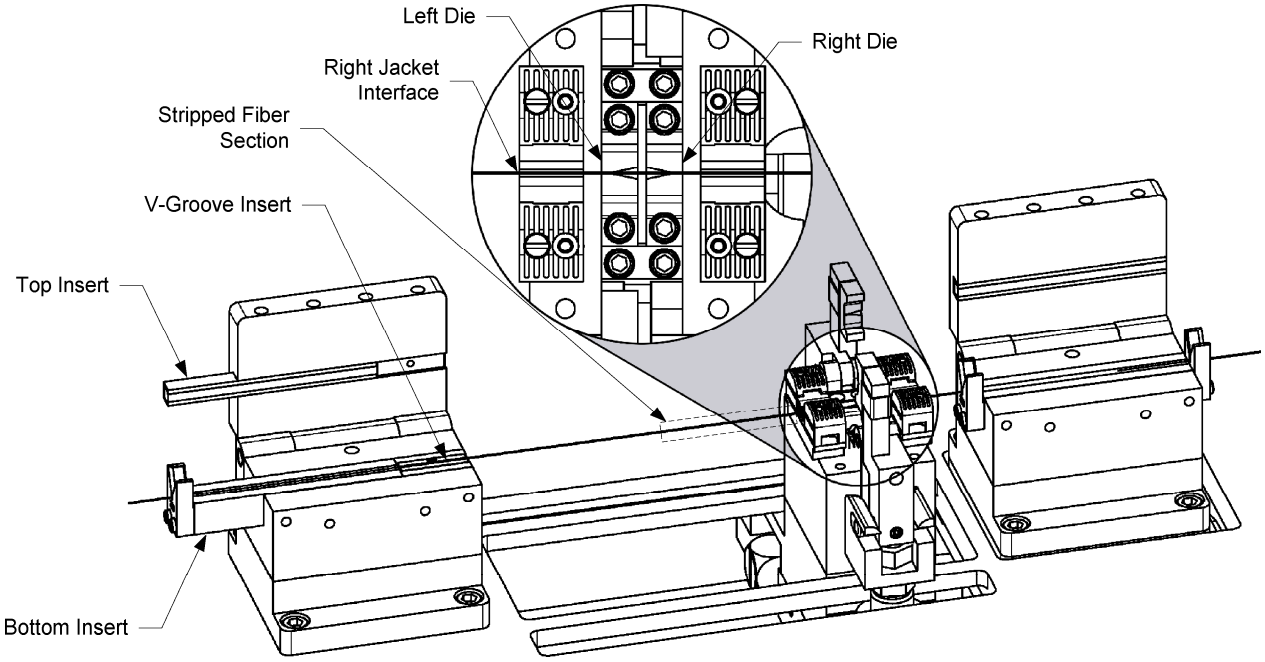


Figure 5: Fiber Position

5. Gently close the FHB lids. This will capture the fiber and turn off the external vacuum pump.
6. The fiber is now ready to be recoated.

4.5 Recoating

To recoat the fiber:

1. Visually confirm that the fiber is loaded properly, if not reload the fiber.
2. Initiate the recoat process by pressing the blue RECOAT button on the unit or the START button on the Handset Controller. The recoat process is fully automated as follows:
   a. The right-hand FHB will begin moving to the right, applying tension to the fiber.
   b. Once the Recoat Tension is reached, the right-hand block will stop moving.
   c. The handset controller will await input from the operator verifying the correct fiber position in the die. Upon confirming the correct fiber position to the handset the process will continue.
   d. The right die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Precure Temp and the head will pause for the Heater Stabilize Time.
   e. The head will move to the left at the Undercoat Head Sweep Vel depositing material while the right die evaporates the volatiles.
   f. Upon reaching the appropriate length, the left die will close and the Undercoat Qty will be injected at the Inject Rate into the die. The right heater will be set to the Right Cure Temp, the left heater will be set to the Left Precure Temp and the head will pause for the Heater Stabilize Time.
   g. The head will move to the right at the Undercoat Head Sweep Vel depositing material. The right heater will be imidizing the previously precured material while the left heater is evaporating the volatiles from the freshly deposited material. The head will complete at the initial start position plus the overlap delta. This is defined as one loop or pass as the material initially deposited has been fully cured.
   h. The process is repeated (using the Overcoat parameters) until the desired thickness has been achieved by the Number of Overcoats (loops or passes).
   i. A tension test is performed at the conclusion of the recoat process to verify fiber integrity. The tension is applied to the specified Level at the specified Rate and released.
3. Proceed to Unloading the Fiber.

4.6 Proof Testing

The Peak Tension should be set to ensure that the recoat meets the minimum strength requirement for its intended application. If using units of tension (kpsi), make sure to enter the correct fiber diameter (e.g. 125 microns) and not the coating diameter.

WARNING: Always wear safety glasses when proof testing fiber. The fiber under test can shatter and send glass particles flying.

To perform a Proof Test:

1. Load the fiber in the fiber holding blocks (see 4.4).
2. Check that the proof test parameters are set correctly.
3. Press the “TEST” button on the PTR-200-PRL.
4. Upon completion of the Proof Test, raise the fiber holding block tops and remove the proof tested fiber.

Note: It is not possible to abort a Proof Test once it has been started.

4.7 Unloading

To unload the fiber after recoating:

1. After the fiber is recoated, the external vacuum pump will turn on to assist in holding the fiber during the unloading process.
2. Hold the fiber securely and lift the left-hand FHB lid. The fiber will be free to move after lifting the lid, so it is important to keep the fiber secured (the V-groove extension is ideal for this).
3. Carefully lift while guiding the recoated fiber though the heaters.
   Note: Raising the FHB top will re-initiate the vacuum pump timer for an additional 15 seconds, after which time the unit will perform a homing routine. The recoated fiber should be removed within this 15 second window.
4. Raise the right-hand FHB top and remove the recoated fiber.
5. Check that no debris is left behind in the FHB V-grooves or on the top clamping surfaces.

Note: After a recoat has been removed (or even if there is a recoat failure), an automatic homing routine will be run 15 seconds after the left FHB top is raised. This homing routine will re-set the position of the right-hand FHB, and the head. The system waits for the FHB top to be opened to ensure that the fiber is being unloaded. If both FHB tops are closed prior to the 15-second time-out, the homing routine will be run immediately.

If the PTR-200-PRL homing process is interrupted or fails, all system functionality is disabled to prevent possible damage to the equipment. Remove any fiber from the FHB's and cycle the power OFF then ON. The PTR-200-PRL will initialize and attempt to run the homing process again. If any further difficulty is experienced, contact Vytran Technical Support for assistance.

5 Maintenance

5.1 Planned Maintenance

The PTR-200-PRL is designed for a production environment to give trouble-free operation provided normal planned maintenance is adhered to. Maintenance and repair procedures should be performed only by trained personnel. Improper service and/or repair could result in the safety features being disabled and can also lead to damage that will not be covered under warranty.

Planned Maintenance Schedule

	Every Shift	Daily	Monthly	12 Months
Inspect / Clean Fiber Holding Blocks[1]	√	√	√	√
Inspect / Clean die[2]	√	√	√	√
Flush recoat System[2] (as needed)			√	√
Purge Recoat System[2] (as needed)			√	√
Replace Recoat Material[2] (as needed)			√	√
Check Load Cell Calibration / Re-Cal[3]				√

[1] Maintenance operations can be performed by the operator.
[2] Maintenance operation can be performed by trained maintenance personnel.
[3] Vytran certified technician only.

5.2 Inspecting the Fiber Holding Blocks

The Fiber Holding Blocks (FHB's) should be inspected daily for debris and/or damage, which may prevent the tops from closing properly and the fiber from being clamped fully. It is particularly important to make sure that the bottom insert V-groove surfaces and the top insert clamping surfaces are free of debris and oils. This will help to ensure that the fiber will not break or slip during tensioning. Cleaning the metal insert surfaces is best accomplished using a cotton-tipped applicator wetted with acetone or alcohol. For embedded debris, a soft cleaning brush may be used. Cleaning the rubber insert surfaces is best accomplished using a cotton-tipped applicator wetted with alcohol. Do not use acetone as this will dry out the rubber causing it to become brittle and crack.

5.3 Inspecting and Cleaning the Die

The die of the recoat head should be inspected daily for debris and/or damage which may result in sub-optimum recoat performance.

The recoat head assembly contains two die sets (left and right), each with a semi-circular channel running longitudinally down the center of their mating surfaces. When closed, the die form a circular mold cavity around the section of fiber to be recoated. In order for the die to mate flush together, they must be free of all dirt and/or coating particles.

The die should be cleaned with a cotton tipped applicator wetted with NMP. NMP is the solvent for PI2525 and can be used to soften and lift away any residual recoat material. Wipe the top and both sides of the die using very light pressure only. Wipe both the left and right and top and bottom of the die set. If

the die does have an accumulation of recoat material stuck to it, allow the cleaning solution time (60-90 seconds) to soften and lift any material. After cleaning the die gently blow clean (canned) air across the die to thin out the NMP.

CAUTION: When cleaning the die be cautious not to contact or damage the heaters.

Note: The mating surfaces of the die are precision machined. Use only a soft cotton tipped applicator to clean the die. **Do not rub any hard objects across the surface of the die as this could scratch or chip the edges of the die channel and degrade the quality of the recoat.**

5.4 Load Cell Calibration

The load cell calibration should be checked every twelve (12) months to ensure that accurate recoat and proof test tension is applied to the fiber. This task must be performed by a Vytran certified technician.

5.5 Flush Recoat System

The recoat injection system should be flushed clean every 1 month as part of the recoat material replacement procedure. Before flushing the system, make sure to have cotton tipped applicators and cleaning solution (NMP) available prior to proceeding. To flush the system:

1. Remove the internal recoat bottle and clean all exposed tubing and fittings with NMP.
2. Install a bottle filled 1/4 full with NMP on the pump.
3. Run 5 purge cycles.
4. Remove the bottle, dispose of contaminated NMP. Refill ¼ full with clean NMP and reinstall.
5. Run 5 more purge cycles.
6. Run several inject 100 sequences until NMP runs clear from the die inject port.
   Note: Make sure to collect material as it comes out of the die inject port. Do not allow material to run between the left and right die.
7. Remove the bottle of NMP from the pump.
8. Run several more inject 100 sequences until no more NMP exits the die injection port.
9. Run one purge cycle. Make sure to collect any NMP that comes out of the green purge tube at the top of the bottle fitting.
10. Clean all bottle tubing and fittings with NMP.
11. Install an empty bottle for storage, or a new bottle ¾ filled with fresh recoat material for use. If installing fresh material, proceed to 3.1 Priming the Injection System.

5.6 Purge Recoat System

The purge cycle is a process of emptying the recoat material of the Automatic Injector back into the recoat material bottle and refilling the pump with fresh recoat material drawn from the bottom of the bottle. Running 5 purge cycles is sufficient to entirely fill the pump with fresh recoat material.

If the system has not been used for an extended period (over 1 week), it is recommended that a single purge cycle be run to fill the pump with fresh material.

5.7 Replacing Recoat Material

Recoat material has a finite shelf life and should be replaced every 1 month. To replace the recoat material, first flush the system as outlined in Flush Recoat System (above). Once the system is flushed, fill a clean recoat bottle ¾ full with fresh recoat material and follow the procedures in Purge Recoat System (above).

Note: The one-ounce internal recoat bottle holds approximately 30,000 micro-liters when full. The number of recoats per fill and the approximate time before the material needs to be refilled can be determined based on the volume of material per recoat and the number of recoats per month. For most applications the material will need to be replaced before it runs out. Even if fresh material is added to the internal bottle prior to the Planed Maintenance schedule, the material should still be replaced since mixing of the old and new materials occurs.

5.8 Replacing a Heater

If a heater is sufficiently damaged such that a quality recoat cannot be performed, then replacement is required. The left and right heaters are identical and DO NOT need to be replaced as a pair. The heaters are comprised of a body which houses a graphite filament. When installed in the PTR-200-PRL, the heater is held in place by electrical contacts at the base of the heater body. This is a pin/socket contact compression fit.

To remove the heater:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die sets. This will allow additional access to the heaters.
3. Grab the body of the filament and using a front to back rocking motion, gently lift the filament body (pins) out of the contacts.

To install the heater:

1. Inspect the new heater for any deformation of the filament. If deformation is noted do not install nor use the heater.
2. Hold the filament body (not the graphite filament) and locate the pins into the electrical sockets.
3. To fully seat the heater, gently push down on the electrical contacts (located on the top of the heater).

5.9 Changing the Fiber Holding Block V-Grooves

To change a FHB V-groove insert:

1. Loosen the two (2) set screws accessible from the front of the FHB base using the 0.035” Allen key included in the LDC-200 tool kit. Do NOT remove the set screws completely; one full turn counter-clockwise should be sufficient to release the insert.
2. Remove the FHB V-groove and replace with the desired size. For dual sided inserts, the label for the desired size should face right side up and be readable. Make sure the vacuum feed ports are clear of debris by holding the insert up to a light and checking from behind to make sure light passes each of the ports. Clean if necessary.
3. Make sure the new insert is fully seated and flush with the inside face of the FHB.
   Note: The inside face of the FHB is the side closest to the head.
4. Re-tighten the set screws until they are snug. Do NOT over tighten.

5.10 Replacing the Die

If the die are sufficiently damage such that a quality recoat cannot be performed, then replacement is required. The top and bottom die are a matched set and are replaced as a pair. The top die are spring loaded which enables a slight pivoting during closure, while the bottom die are fixed mounted to the head.

To replace the top die:

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. The top die pivots about a center pin which is pressure loaded with two (2) small springs. Remove and retain the top die retainer clip for reuse. This will expose the springs. Using the die, gently compress the springs. This will allow a rotation of the die by ~45 degrees and a removal of the die from the clamp. Remove and retain the springs for reuse.
3. Locate and clean the new top die to be installed.
4. Insert the two (2) springs into the clamp. With the die rotated ~45 degrees, gently collapse the springs with the die. Align the die pin with the clamp and rotate the die to 0 degrees to install.
5. Reinstall the die retainer clip.

To replace the bottom left die (no inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Remove the die from the head.
3. Locate and clean the new top die to be installed.
4. Seat the new die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

To replace the bottom right die (with inject port):

1. Remove any fiber from the unit, clean the die, and shut the unit down. This will relieve the air pressure to the die open/close cylinder.
2. Manually open the die set to be replaced. Remove and retain the two (2) 5/64” hex socket head cap screws that secure the die to the head. Gently begin to remove the die from the head. An inject tube will be attached to the die. This tube will limit the distance the die can be removed from the head. Gently pull the die with the inject tube until resistance is felt
3. Locate and clean the new top die to be installed.
4. To release the old die from the inject tube, gently rotate the die while holding the inject tube. To install the new die onto the inject tube, gently rotate the die onto the inject tube while holding the inject tube. Slowly feed the inject tube into the head. Seat the die into the head and insert the two (2) 5/64” hex socket head cap screws. Gently tighten the screws.

Appendix A: MSDS PI2525

HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

MATERIAL SAFETY DATA SHEET

***** IDENTIFICATION *****

NAME: PI2525 SYNONYMS: POLYIMIDE COATING.
CHEM.FAMILY: Pyralin® Polyimide Coating. FORMULA: Proprietary.

MANUFACTURER:
HD MicroSystems™
Cheesequake Road
Parlin, NJ 08859

INFORMATION & EMERGENCY TELEPHONE NOS:
INFORMATION: Product: (800) 441-7515
EMERGENCIES: Medical: (800) 441-3637
Transport (CHEMTREC): (800) 424-9300

All Ingredients in This Product Are TSCA Listed/Reported.

***** PHYSICAL DATA *****

FORM: Viscous Liquid. ODOR: Aromatic.

APPEARANCE: Colorless to Amber. SOLUBILITY IN WATER: Slight.

***** COMPONENTS *****

Material(s):	CAS#	V.P. mm Hg @ 20C	Weight %
N-Methyl-2-Pyrollidone.	872-50-4	0.29	> 60%
Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer).	31942-21-9		10 - 30%

PI2525/AH1
05/19/98

***** HAZARDOUS REACTIVITY *****

INSTABILITY:
The product is normally stable.

INCOMPATIBILITY:
Avoid contact with:
Reducing agents; Oxidizing agents; Bases; Acids; Strong acids; Strong oxidizers.

DECOMPOSITION:

Decomposition products at high temperature may include:
Carbon monoxide (CO); Nitrogen oxides; Carbon monoxide, carbon dioxide, water.

POLYMERIZATION:
The product may polymerize endothermically if exposed to temperatures over 90 F, ultraviolet light or free radical initiators. This may increase viscosity.

***** FIRE & EXPLOSION DATA *****

FLASHPOINT: 194 F Seta CC

FIRE & EXPLOSION HAZARDS:
The product is not an unusual fire or explosion hazard.

EXTINGUISHING MEDIA:
Water spray, dry chemical or carbon dioxide.

SPECIAL FIREFIGHTING INFORMATION:
Toxic decomposition products may form under fire conditions. (See Decomposition Section.);
Wear full protective clothing and a full facepiece, positive pressure, self-contained breathing apparatus (SCBA);
Decontaminate contaminated clothing and equipment with soap and water. Dispose of residues per federal, state, and local regulation. (See Waste Disposal Section.).

OVERVIEW: The most likely routes of overexposure to this

PI2525/AH1 Page 2

***** HEALTH HAZARD INFORMATION *****

product are skin contact and inhalation. Skin irritation and/or other effects of skin contact are easily avoided by using proper gloves (see section titled GLOVES) and washing affected areas immediately if contact occurs. Volatile solvents will start evaporating during room temperature use of the product, such as thinning, pouring from jar to dispensing machine, and spin coating. Mist and solvent vapors will evolve if spray application is used. During wafer drying, 125 - 150 C, and final curing, 350 - 450 C, the remaining solvent(s) will evaporate. Potential overexposure to other chemicals used in the operation such as wafer etchants and cleaners should also be considered. Well designed area and personal air sampling and analysis can show if exposures are within established limits. Properly designed local ventilation and process enclosure are effective ways to limit employee exposure where needed.

In addition to meeting exposure limits, it is always prudent to use all practical means to minimize employee exposure to chemicals. A significant difference in overall exposure can be made with practical measures such as:

* Inhalation - minimizing by keeping jars of product covered
* Eye - avoiding contact by wearing chemical splash goggles where there is splash potential
* Ingestion - avoiding by washing hands before eating, drinking or smoking, and restricting these activities to outside the work area.

PRINCIPAL HEALTH EFFECTS:

>>>N-Methyl-2-Pyrollidone
****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Mild skin irritation; No skin sensitization; BY INHALATION: Respiratory effects. Toxic effects of repeated or prolonged animal exposures include: BY INHALATION: Respiratory effects; Bone marrow effects; Lymph system effects; Testicular effects; ****Additional animal tests have shown: No carcinogenic activity; No developmental toxicity; No genetic damage in bacterial or mammalian cell cultures; No reproductive toxicity. ****Human health effects of overexposure may include: By contact with liquid or vapor: Eye irritation with discomfort, tearing, or blurring of vision; BY SKIN OR EYE CONTACT: Eye irritation with discomfort, tearing, or blurring of vision; Skin irritation with itching, burning, redness, swelling or rash; BY INHALATION: Runny nose; Sore throat; Sneezing; Irritation of the nose and throat; Nonspecific discomfort, e.g., nausea, headache or weakness. ****Human effects of higher level

PI2525/AH1 Page 3

acute, repeated or chronic overexposure may include: BY SKIN OR EYE CONTACT: Skin reddening; Skin irritation with discomfort or rash; Dermatitis; Swelling; Burning. ***In addition: BY SKIN OR EYE CONTACT: There are inconclusive or unverified reports of human sensitization.

>>>Polyamic acid of Benzophenone Tetracarboxylic Dianhydride/4,4-Oxydianiline/m-Phenylenediamine (Polymer) ****Toxic effects described in animals include: BY SKIN OR EYE CONTACT: Skin irritation; Skin sensitization; Eye irritation.

ANIMAL DATA:

>>>N-Methyl-2-Pyrollidone
Inhalation 4 hour ALC: 1.7 mg/L in rats (Moderately toxic)
Skin absorption LD50: > 8,000 mg/kg in rabbits (Slightly toxic)
Oral LD50: 4,320 mg/kg (Slightly toxic).

CARCINOGENICITY LISTING:

No ingredients of this product are designated by IARC, NTP, OSHA, ACGIH or Dupont as potential carcinogens.

EXPOSURE LIMITS:
Workplace exposures should be kept below the following limits:

.	AIHA		ACGIH		OSHA	
Name/Units	8hr	15min	8hr	15min	8hr	15min
PARTICULATES (N.O.S.), respirable						
Units: mg/m3					5	
PARTICULATES (N.O.S.), total						
Units: mg/m3			10		15	
N-METHYL-2-PYRROLIDONE						
Units: ppm	10					

Also, DuPont has established and observes the following limits:

Name/Units	12 hr	8hr	15min	Ceiling
N-METHYL-2-PYRROLIDONE				
Units: ppm		25		

PI2525/AH1 Page 4

NOTES ON EXPOSURE LIMITS:
PELs - OSHA Permissible Exposure Limits - 29 CFR 1910.1000, Subpart Z, or specific substance standards;
TLVs - ACGIH Threshold Limit Values - published by American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211;
WEELs- AIHA Workplace Environmental Exposure Limits - published by the American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031;
AELs - Dupont Acceptable Exposure Limit. Where governmentally imposed occupational exposure limits are lower than AEL in effect, government limits shall take precedence;
(C) = "ceiling", limit not to be exceeded for any time period;
(S) = "skin" , skin absorption may contribute significantly to the ingredient's internal toxicity.

***** FIRST AID INSTRUCTIONS *****

Skin Contact: For skin contact, immediately wash skin with soap and water. Wash contaminated clothing before reuse.
Eye Contact: For eye contact, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.
Ingestion: If swallowed, do not induce vomiting. Immediately give two glasses of water. Never give anything by mouth to an unconscious person. Call a physician.

***** PROTECTION INFORMATION *****

Adequate local ventilation should be used to keep exposures below applicable limits;
Other engineering controls such as totally enclosed handling systems are also preferred;
Respiratory protection will be needed if exposures can not be kept below applicable limits by other means.

Respiratory Protection:
A NIOSH/MSHA approved full-face mask equipped with chemical cartridges approved for methylamine may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, when exposure levels are not

PI2525/AH1 Page 5

known, or in any other circumstances where air purifying respirators may not provide adequate protection;
For most conditions, no respiratory protection should be needed; however, if handling at elevated temperatures without sufficient ventilation, use an approved air-purifying respirator. In dusty atmospheres, use an approved dust respirator;
Selection of a suitable respirator will depend on the properties of the contaminant(s) and their actual or expected air concentration(s) versus applicable limits. Consult ANSI Standard Z88.2 for decision logic to select appropriate NIOSH/MESA approved respirators;
A NIOSH/MSHA/OSHA approved air purifying respiratory with a dust/mist cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed limits. Protection provided by air purifying respirators is limited. Use a positive pressure air supplied respirator if there is any potential for an uncontrolled release, exposure levels are not known or any other circumstances where air purifying respirators may not provide adequate protection;
Use a positive pressure air-supplied respirator if concentrations may exceed exposure limits. Air-purifying respirators are inadequate for this material;
If respirators are needed to meet applicable limits, a respiratory protection program up to the level of OSHA Standard 29 CFR 1910.134 is mandatory. This includes air monitoring, selection, medical approval, training, fit testing, inspection, maintenance, cleaning, storage, etc;
An OSHA/NIOSH respirator for protection against Nuisance Dust is recommended.

Gloves:

Gloves should be used when the possibility of skin contact exists;
The suitability of a particular glove and glove material should be determined as part of an overall glove program. Considerations may include chemical breakthrough time; permeation rate; abrasion, cut and puncture resistance; flexibility; duration of contact; etc.

Other Protection Practices:

Appropriate eye protection such as chemical splash goggles should be used if the possibility of eye contact exists;
Protective outer clothing should be used where the possibility of body contact exists. Contaminated work clothing should not be allowed out of the workplace;
Do not smoke, consume or store food or drinks in areas

PI2525/AH1 Page 6

where the product is handled or stored. After handling the product, wash hands thoroughly before leaving the work area;
Additional engineering controls, work practices and training may be required depending on exposure levels. These are discussed in the OSHA Respiratory Protection Standard (29 CFR 1910.134) and OSHA Hazard Communication Standard (29 CFR 1910.1200);
Do not breath dust. Avoid contact with eyes, skin, or clothing. Wash thoroughly after handling.

***** DISPOSAL INFORMATION *****

Spill, Leak or Release:
FOR SMALL SPILLS, absorb on rags, sand or other absorbent material;
FOR LARGE SPILLS, get workers out of affected area. If flammable liquids or vapors may be present, turn off electrical devices or other sources of sparks or flames. WEAR PROTECTIVE EQUIPMENT. Use supplied-air respiratory protection if vapor concentrations are not known;
Contain spill at source by diking or absorbing with sand. Do not allow spill to spread to or intentionally flush to sewer or ground. Wash area thoroughly. Adequately ventilate area;
Spill residue, cleaning rags and absorbent may be considered hazardous. (See Waste Disposal Section.).

Waste Disposal:
Components of this product may be considered hazardous;
Consult applicable Federal, State, and local regulations for allowable disposal methods.

***** PRODUCT INFORMATION *****

Contaminated Items:
Empty product containers, contaminated clothing and cleaning materials, etc. should be considered hazardous until decontaminated or properly disposed of. (See Waste Disposal Section.).

Storage:
Store product in a refrigerated location (0-4F), away from sunlight or ultraviolet light to ensure product viscosity stability.

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***** ADDITIONAL INFORMATION *****

The following ingredients are subject to the reporting requirements of section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

INGREDIENT(S)	Weight %
N-Methyl-2-Pyrrolidone	> 60%

CALIFORNIA PROPOSITION 65: WARNING: This product does not contain chemical known to the state of California to cause cancer, birth defects, or other reproductive harm.

This product is a physical mixture. The health effects information about this product is based on the individual ingredients; The data in this Material Safety Data Sheet relates only to the specific product designated herein and does not relate to its use in combination with any other material or in any process.

Date of latest MSDS revision: 05/19/98

Person Responsible for MSDS:

Safety Coordinator - MSDS
DuPont P&EM / MCM
14 Alexander Drive
Research Triangle Park, NC 27709-4425
Telephone: (800) 284-3382
Outside U.S.: (919) 248-5775

PI2525/AH1 End of Material Safety Data Sheet Page 8

Appendix B: MSDS NMP

Material Safety Data Sheet

1-Methyl-2-pyrrolidinone

ACC# 08690

Section 1 - Chemical Product and Company Identification

MSDS Name: 1-Methyl-2-pyrrolidinone
Catalog Numbers: AC127630010, AC127630025, AC222080025, AC222085000, AC326930010, AC326931000, AC326932500, AC354890025, AC354900025, AC364380010, AC364380025, AC364381000, AC368450010, AC368450025, AC368451000, AC610411000, BP1172-4, BP11724LC, BP1172N119, BP2619-100, NC9749337, O3688-4
Synonyms: NMP; N-Methylpyrrolidone; N-Methylpyrrolidinone; N-Methyl-2-pyrrolidone; N-Methyl-2-pyrrolidinone; M-Pyrol; 1-Methyl-2-pyrrolidone; solvent in paint strippers.
Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100
Emergency Number: 201-796-7100
For CHEMTREC assistance, call: 800-424-9300
For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
872-50-4	1-Methyl-2-pyrrolidinone	99	212-828-1

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: clear colorless liquid. Flash Point: 91 deg C.
Warning! Causes eye, skin, and respiratory tract irritation. May cause harm to the unborn child. **Combustible liquid and vapor.** May be harmful if swallowed, inhaled, or absorbed through the skin. Light sensitive. Hygroscopic (absorbs moisture from the air).
Target Organs: Respiratory system, eyes, skin.

Potential Health Effects

Eye: Causes eye irritation. May cause temporary corneal clouding.
Skin: Causes skin irritation. May be harmful if absorbed through the skin. Not expected to cause an allergic skin reaction. Because of the high permeability rate of N-methylpyrrolidone in human skin, prolonged exposures should be avoided.
Ingestion: May cause gastrointestinal irritation with nausea, vomiting and diarrhea.
Inhalation: Causes respiratory tract irritation. May cause headache. Material has a very low vapor pressure and inhalation exposures are not expected unless material is heated or misted.
Chronic: Prolonged or repeated skin contact may cause dermatitis. Adverse reproductive effects have been reported in animals. Testicular effects in rats were noted after repeated, high-dose oral and inhalation exposures.(BASF)Human occupational exposure has been associated with chronic eye irritation, headaches, and irritant contact dermatitis. Airborne concentrations of 49 to 83 ppm are intolerable.(REPROTEXT)

Section 4 - First Aid Measures

Eyes: In case of contact, immediately flush eyes with plenty of water for a t least 15 minutes. Get medical aid.
Skin: In case of contact, flush skin with plenty of water. Remove contaminated clothing and shoes. Get medical aid if irritation develops and persists. Wash clothing before reuse.
Ingestion: If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical aid.
Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.
Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Combustible liquid and vapor.
Extinguishing Media: Use water spray, dry chemical, carbon dioxide, or appropriate foam.
Flash Point: 91 deg C (195.80 deg F)
Autoignition Temperature: 245 deg C (473.00 deg F)
Explosion Limits, Lower:1.3%
Upper: 9.5%
NFPA Rating: (estimated) Health: 2; Flammability: 2; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks: Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Remove all sources of ignition. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Avoid contact with eyes, skin, and clothing. Keep away from heat and flame. Avoid breathing vapor or mist.
Storage: Keep away from sources of ignition. Store in a cool, dry place. Store in a tightly closed container. Keep under a nitrogen blanket.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.
Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
1-Methyl-2-pyrrolidinone	none listed	none listed	none listed

OSHA Vacated PELs: 1-Methyl-2-pyrrolidinone: No OSHA Vacated PELs are listed for this chemical.
Personal Protective Equipment
Eyes: Wear chemical splash goggles.
Skin: Wear appropriate gloves to prevent skin exposure.
Clothing: Wear appropriate protective clothing to prevent skin exposure.
Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Liquid
Appearance: clear colorless
Odor: amine-like - mild odor
pH: 8.5-10.0 (100 g/l H2O)
Vapor Pressure: 0.342 mm Hg @ 25 deg C
Vapor Density: 3.4 (air=1)
Evaporation Rate: Not available.
Viscosity: 1.65 cps @ 25 deg C
Boiling Point: 202 deg C @ 760 mm Hg
Freezing/Melting Point:-24 deg C
Decomposition Temperature: Not available.
Solubility: Soluble.
Specific Gravity/Density:1.030
Molecular Formula:C5H9NO
Molecular Weight:99.13

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions.
Conditions to Avoid: Light, ignition sources, excess heat, exposure to moist air or water.
Incompatibilities with Other Materials: Strong oxidizing agents, strong acids.
Hazardous Decomposition Products: Nitrogen oxides, carbon monoxide, carbon dioxide.
Hazardous Polymerization: Will not occur.

Section 11 - Toxicological Information

RTECS#:
CAS# 872-50-4: UY5790000
LD50/LC50:
CAS# 872-50-4:
Draize test, rabbit, eye: 100 mg Moderate;
Oral, mouse: LD50 = 5130 mg/kg;
Oral, rat: LD50 = 3914 mg/kg;
Skin, rabbit: LD50 = 8 gm/kg;
.
Sensitization test (guinea pig): negative. test (humans): negative.(Merck)
Carcinogenicity:
CAS# 872-50-4: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No data available.
Teratogenicity: Proposition 65 maximum allowable dose level for developmental toxicity for N-methylpyrrolidone is 3200 ug/day for the inhalation route and 17,000 ug/day for the dermal route.

Reproductive Effects: See actual entry in RTECS for complete information.
Mutagenicity: See actual entry in RTECS for complete information.
Neurotoxicity: No data available.
Other Studies:

Section 12 - Ecological Information

Ecotoxicity: Daphnia: Daphnia: 4897 mg/l; 48 h; EC50Fish: Gold orfe: 4000 mg/l; 96 h; LC50Bacteria: >9000 mg/l; 48 h; EC50Algae: >500 mg/l; 72 h; IC50 log Pow = -0.46 (25°C)BOD5 = 1100 mg/l.COD = 1600 mg/l.
Environmental: No information available.
Physical: No information available.
Other: Biodegradable.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P-Series: None listed.
RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated	Not Regulated
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA
CAS# 872-50-4 is listed on the TSCA inventory.
Health & Safety Reporting List
None of the chemicals are on the Health & Safety Reporting List.
Chemical Test Rules
CAS# 872-50-4: Test for Health Effects

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 872-50-4: immediate, delayed, fire.

Section 313

This material contains 1-Methyl-2-pyrrolidinone (CAS# 872-50-4, 99%),which is subject to the reporting requirements of Section 313 of SARA Title III and 40

Clean Air Act:

This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 872-50-4 can be found on the following state right to know lists: Pennsylvania, Minnesota, Massachusetts.

California Prop 65

WARNING: This product contains 1-Methyl-2-pyrrolidinone, a chemical known to the state of California to cause developmental reproductive toxicity.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

T

Risk Phrases:

R 36/37/38 Irritating to eyes, respiratory system and skin.
R 61 May cause harm to the unborn child.

Safety Phrases:

S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S 53 Avoid exposure - obtain special instructions before use.

WGK (Water Danger/Protection)

CAS# 872-50-4: 1

Canada - DSL/NDSL

CAS# 872-50-4 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of B3, D2A, D2B.
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

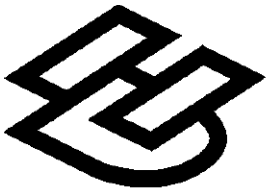
Canadian Ingredient Disclosure List

Section 16 - Additional Information

MSDS Creation Date: 6/10/2003
Revision #2 Date: 3/29/2005

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Fisher has been advised of the possibility of such damages.

Appendix C: Pyralin Product Information



HD MicroSystems™
An Enterprise of Hitachi Chemical and DuPont Electronics

Rev. Apr 01

PRODUCT INFORMATION
PYRALIN® PI2525, PI2555, PI-2575 & PI2556

PI2525, PI2555, PI-2575 and PI2556 polyimides [PI-2555 Series] are suitable for applications where the high cure temperatures typically used for polyimides (ca. 350°C) cause problems. Typical applications for these materials are as stress buffer or interlayer dielectric layers over low temperature substrates. These polyimides imidize faster and at lower temperatures than for standard polyimide precursors. The materials are supplied as solutions suitable for spin or roller coating application. A seperate adhesion promoter is recommended with PI-2525, PI-2555 and PI-2556 to improve adhesion to oxides and to metals. PI-2575 is self priming and does not require an adhesion promoter. Processing by wet or plasma etch is possible. Cured film thicknesses from 0.5 µm to 6 µm can be obtained.

Process Details

Coating

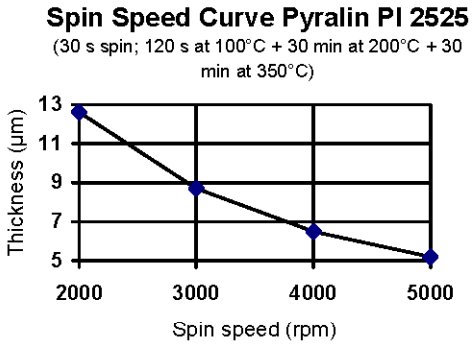
PI2555 Series products can be coated onto a variety of metals, alloys, semiconductor and ceramic substrates. HD MicroSystems adhesion promoters VM651 or VM-652 are recommended to provide good processability and adhesion with the PI-2525, PI-2555, PI-2556. Bonding of the polyimide to the substrate is achieved during the softbake cycle as the priming chemistry is activated by temperature.

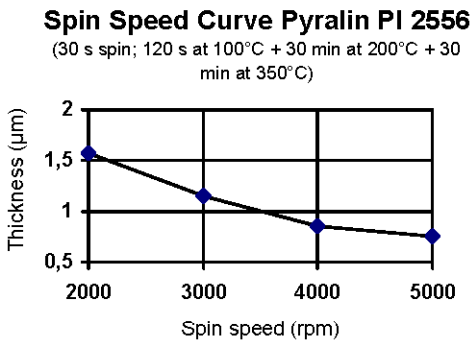
The polyimide solution is highly viscous. There are some guiding principles for dispensing materials of this type. Always coat substrates which are at room temperature. Never trap air into the solution. This can occur for example when the solution is moved during dispense. All bubbles take time to dissipate out of solution. If left in, coating "comets" will result. Dispensing should be in the centre and as close to the substrate as possible. A clean cut-off at dispense is neccessary before the spin process starts. It may be neccessary in the case of highly viscous solutions to have a short delay prior to spin to allow the polyimide to flow as far as possible and relax.

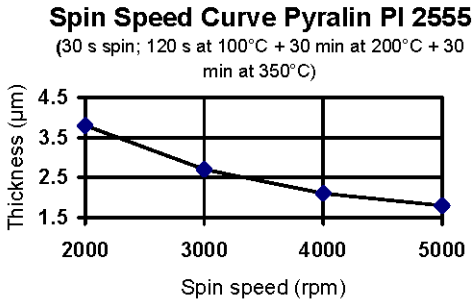
Both static and dynamic dispense may be used. Static dispense is the easiest, but requires more material to be dispensed for each substrate. Dynamic dispense uses less material, but requires greater control during dispense to ensure that the polyimide strikes the exact centre of the substrate. Any deviation will result in poor coating quality. The acceleration to final speed should be as low as possible to allow gradual flow of the polyimide across the substrate. Often one or more intermediate spin speeds are used to allow the polyimide to gradually cover more than 80% of the substrate before continuing on to the final speed. To reduce the backside contamination potential it is often beneficial to prolong the spread cycle until the bulk of the excess polyimide has been removed from the substrate. The final spin speed and time is determined by the film thickness required. Longer spin

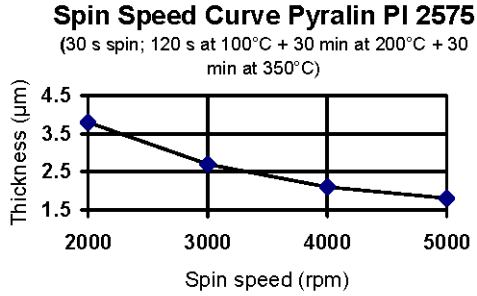
times will improve coating uniformity, but will also reduce the film thickness. In semiconductor applications, an Edge Bead Removal (EBR) and Backside Rinse process may be added to the coating cycle to remove polyimide from the edge and back of the wafer prior to baking. NMP (N-methyl-2-pyrrolidone) or NMP/IPA (isopropanol) can be used for this purpose.

Spin Speed Curves for cured Polyimide









Soft Bake

After application of the polyimide, a bake process is required. Both convection oven and hotplate bake methods may be used. The purpose of this stage, is to partially cure the polyimide prior to patterning. This bake stage leaves the polyimide coating dry, yet soluble in the etchant solution.

Choice of Photoresist

Polyimides of this type can be patterned using common photolithography techniques centered around positive photoresist. The underlying polyimide is an effective anti-reflective layer as there is significant absorption between 350 and 450 nm. This absorption can significantly reduce substrate reflection effects on the photoresist, usually seen as “notching“ after development.

The photoresist should be selected with the correct wavelength to suit the exposure tool in use. As a general guide, formulations with good adhesion in “wet etch“ semiconductor applications perform well. Other attributes include:

- Compatability to standard alkaline positive photoresist developers

- Low contrast performance so that a soft sidewall profile is always produced

- Capability to produce cleanly developed via holes in thick resist coatings

- Good development latitude, especially when over-developed

- The ease of producing a minimum dried 2,5 µm film thickness

The polyimide coating after softbake has minimum solubility in typical photoresist solvents. Photoresist can therefore be coated directly onto the polyimide coating without layer inter-mixing occuring.

Photoresist Application

Substrates should be coated directly with the resist selected. No dehydration bake should be given as this would make the polyimide totally insoluble in the developer. Instead an HMDS vapour prime is permissable if installed on-line but is not really neccessary for good resist adhesion to the polyimide.

Once coated, the resist should be given a softbake at 90°C either in a convection oven for 30 minutes or on a vacuum hotplate for 60 seconds. Once coated and baked, coatings may be held up to 24 hours before exposure.

Photoresist Exposure

Typical exposure: 50 mJ to 150 mJ

Once exposed, development should take place within 8 hours.

Photoresist Development / Polyimide Etch

A single step is used to develop the photoresist and etch the polyimide.

Most alkaline positive resist developers will dissolve both exposed photoresist and polyimide at varying rates. The choice of developer affects the quality of the polyimide image after development. Best results have been obtained using a NaOH based developer.

Thin polyimide layers up to around 5 µm can usually be developed quickly and cleanly with developer which is at ambient temperature. After development of the resist and then the polyimide using a spray puddle technique, a water rinse should be used to remove the developer. The substrate should subsequently be spun until dry.

When thicker polyimide layers need to be processed, it is often beneficial to heat the developer to between 23°C and 25°C. This accelerates the dissolution of the polyimide while having minimal effect on the solubility of the photoresist. In more extreme situations, this may be coupled to a double puddle process. The second puddle is used to develop only the polyimide layer.

Once developed, wafers may be held up to 8 hours before stripping the resist.

Resist Strip

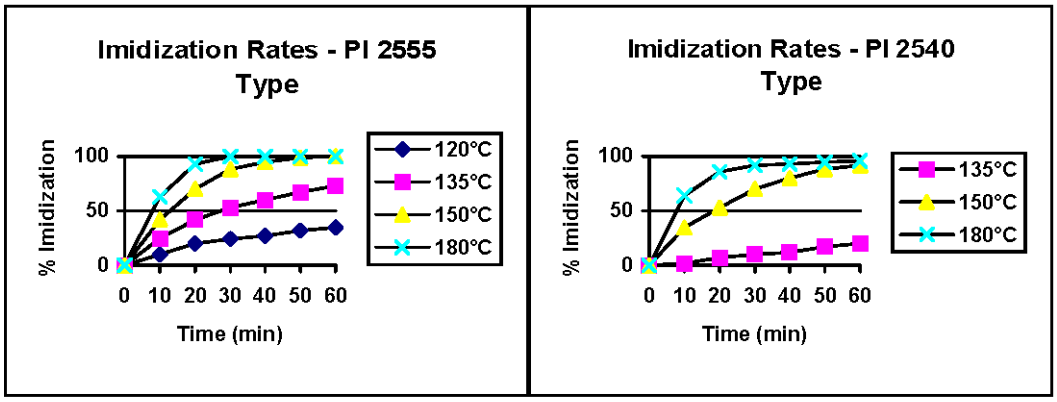
After developing, the photoresist needs to be stripped off the polyimide surface before curing. This step is usually carried out on automated track equipment to reduce surface contamination with resist residue which may result if clean solvents are not used. Resist solvent strippers are normally used.

Cure

The cure heating cycle converts the polyamic acid to the insoluble imide form and drives out remaining solvent. This process requires elevated temperatures and controlled environments to achieve the best results. There is sufficient energy at 180°C to complete the imidization of the polyimide, but higher temperatures are required to completely drive off solvents, thus achieving the ultimate electrical and mechanical properties. A programmable high temperature oven with typical nitrogen flow rate of 10 litres per minute is recommended for best results.

To activate the adhesion promoter, it is recommended that the cure be carried out up until 200°C in air (min 50% RH). Above this temperature, a nitrogen atmosphere should be used. The ramp rates (up and down) should be low to avoid high stress in the polyimide.

The maximum cure temperature may be higher than 300°C when the coating is to be subjected to a high temperature process after curing. In such cases, temperatures up to 400°C have been used to ensure that there is no outgassing during subsequent processes.



Processing Pyralin® PI2525, PI2555, PI-2575 & PI2556 products

(for ca. 7µm softbaked and 5µm cured film thickness)

Application of Adhesion Promoter*

- Dispense on static substrate, 3 seconds
- Hold for 20 seconds
- Spin dry for 30 seconds

Bake Adhesion Promoter

- On hotplate at 120°C for 60 seconds (optional)

*not required with PI-2575

Polyimide Coating

- Dispense on static substrate
- Rotate at 500 rpm for 5 seconds
- Rotate at final speed for 30 seconds (see spin speed curves)
- EBR/Backside rinse, 10 seconds
- Spin dry, 15 seconds

Soft Bake

- In convection oven at 120°C for 30 minutes

OR

- On hot plate at 120°C for 30 seconds followed by 150°C for 30 seconds

Coat Photoresist

- Dispense, 3 seconds
- Spread at 500 rpm for 5 seconds
- Spin at final speed for 30 seconds
- EBR / Backside rinse for 5 seconds
- Spin dry for 15 seconds

Softbake Photoresist

- On hotplate at 90°C for 60 seconds

Exposure

- 50 mJ to 150 mJ

Development

Developer:	NaOH, KOH or TMAH developer or DE 1000 at 21°C
Rinse:	DI water

Puddle Development process:

• Spray (100 rpm)	5 seconds
• Puddle	3 minutes
• Rinse (1000 rpm)	15 seconds
• Spin dry (5000 rpm)	15 seconds

Resist Strip

- Spray or spray/puddle acetone or standard resist stripper or N-Butlyacetate at ca. 2000 rpm
- Spin dry

Cure

Curing should be done in an oven using the following cure profile:

- Heating from room temperature to 200°C, ramp rate 4°C/minute in air
- Hold time at 200°C for 30 minutes in air
- Heating from 200°C to 300°C, ramp rate 2,5°C/minute in nitrogen
- Hold time at 300°C for 60 minutes in nitrogen
- Gradual cooling to room temperature

Solution Properties

	PI2525	**PI2555/PI-2575**	**PI2556**
Solids content (%)	25.0 +/-1.0	19.0 +/-1.0	15.0 +/-1.0
Viscosity (Poise)	60 +/- 10.0	14.0 +/-2.0	3.5 +/-1.0
Flash Point	93°C	60°C	54°C
Solvent (%)	N-Methyl-2-Pyrrolidone 100	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon 80/20 +/-5	N-Methyl-2-Pyrrolidone Aromatic Hydrocarbon Propylene Glycol Methyl Ether 70/14/15 +/-5
Ash content (%)	0.1 max.	0.1 max.	0.1 max.
Chloride content	5.0 ppp max.	5.0 ppp max.	5.0 pp max
Sodium content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Potassium content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Copper content	0.5 ppm max.	0.5 ppm max.	0.5 ppm max.
Iron content	1.0 ppm max.	1.0 ppm max.	1.0 ppm max.
Total metals	10.0 ppm max.	10.0 ppm max.	10.0 ppm max.

Cured Film Properties

Tensile strength (kg/mm²)	13.1
Elongation (%)	10
Modulus (kg/mm²)	245
Stress (dynes/cm^2)	3.6×10^8
Moisture uptake (%)	2 - 3
Dielectric constant (at 1 kHz, 50% RH)	3.3
Dissipation factor	0.002
Dielectric strength (volts/mil)	4000
Volume resistivity (ohm-cm)	10^{16}
Surface resistivity (ohm)	10^{15}
Coefficient of thermal expansion (ppm)	40
Coefficient of thermal conductivity (cal/(cm)(sec)(°C))	35×10^{-5}
Glass transition temperature	> 320°C

Decomposition temperature	560°C
Weight loss (% at 500°C, 120 min)	2.9
Specific heat (cal/g/°C)	0.26
Refractive index	1.70

Storage/Shelf Life

It is recommended that PI-2555 Series products be stored between 0°C to -18°C.

Pyralin® PI2525, PI2555, PI-2575 and PI2556 are stable at clean room temperatures (21°C) for ca. four weeks with no significant change in properties. When stored at -18°C, shelf-life is 2 years from date of manufacturing. Moisture contamination is detrimental to stability and must be avoided. Containers should be brought to room temperature before opening to avoid moisture condensation inside the botttle.

Safety and Handling

During all handling of Pyralin polyimide products, adequate ventilation must be provided. Skin and eye contact should be avoided. Exposed areas should be flushed with water immediately. For prolonged or repeated contact, milled butyl rubber or natural latex rubber gloves should be used. Disposable PVC gloves are not recommended.

United States

HD MicroSystems, LLC
P0 Box 80010
Wilmington, DE 19880
800-346-5656 (Phone)
302-892-0597 (Fax)

HD MicroSystems, LLC
1333 Lawrence Expressway
Suite 212
Santa Clara, CA 95051
408-260-0880 (Phone)
408-260-0885 (Fax)

Japan

HD MicroSystems, LLC
10-13, Shibuya 3-chome, Shibuya-ku,
Tokyo 150
Japan
81-3-3407-9003 (Phone)
81-3-3407-9037 (Fax)

Europe

HD MicroSystems Europe GmbH
DuPont Strasse 1
D-61343 Bad Homburg
Germany
49-6172-87-1822 (Phone)
49-6172-87-1824 (Fax)

Internet
www.hdmicrosystems.com

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