

**Modular Coil Fabrication- VPI/ Autoclave Activities
D-NCSX-MCF-003-00**

Princeton Plasma Physics Laboratory Procedure			
Procedure Title: Modular Coil Fabrication-VPI/ Autoclave Activities			
Number: D-NCSX-MCF-003	Revision: 00	Effective Date:	
		Expiration Date: <i>(2 yrs. unless otherwise stipulated)</i>	
Procedure Approvals			
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Responsible Division: NCSX Project			
Procedure Requirements Designated by RLM			
LABWIDE:			
X	Work Planning Form # WP-1188 & 1138 (ENG-032)		Lockout/Tagout (ESH-016)
	Confined Space Permit (5008,SEC.8 Chap 5)		Lift Procedure (ENG-021)
	Master Equip. List Mod (GEN-005)	X	ES&H Review (NEPA, IH, etc.) NEPA 1283
	RWP (HP-OP-20)		Independent Review
	ATI Walkdown	X	Pre-Job Brief
X	Post-job Brief *		
D-SITE SPECIFIC:			
X	D-Site Work Permit (OP-AD-09)		Door Permit (OP-G-93)
	Tritium Work Permit (OP-AD-49)		USQD (OP-AD-63)
X	Pre-Job Brief (OP-AD-79)		T-Mod (OP-AD-03)
	** DCA/DCN (OP-AD-104) # _____		

* Required for installations involving internal vacuum installations, critical lifts, and for the initial installation of repetitive work.

** OP-AD-104 was voided by procedure ENG-032. However, DCA's that were open at the time of adoption of ENG-032 are still considered valid for work approval purposes.

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Note: X indicates that comments were received and incorporated

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Technicians performing task		X	
Field Supervisors		X	
Quality Control Representative		X	
Training Rep.			
RLM Larry Dudek			

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RECORD OF CHANGE

Revision	Date	Description of Change
00	1/17/05	Initial release

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1 Scope

1.1 Introduction

The Modular Coil Manufacturing Facility is divided into 6 workstations. Each workstation has a specific set of tasks that will be performed as part of the overall fabrication process. This procedure addresses the manufacturing, inspection, test and QC inspection points for a specific workstation.

- Station No. 1... Winding Form Preparation & Post VPI Activities
- Station No. 2... Winding Station A/ Molding and VPI Preparation
- Station No. 3... Winding Station B/ Molding and VPI Preparation
- Station No. 4... Vacant
- **Station No. 5... VPI and Autoclave Activities**
- Station No. 1... Post VPI Activities
- Station No. 6... Coil Testing

1.2 Scope

This procedure is used to impregnate the modular and Twisted Racetrack coils with epoxy. The work is all performed at Station No.5. The activities include:

- Installing the Modular Coil into the autoclave
- Preparing the modular coil for VPI
- Preparing the epoxy resin
- Vacuum impregnating the Modular coil
- Preparing the VPI'd coil for removal
- Cleanup of the autoclave

1.3 Identification of Coil being manufactured:

Station Number: _____

Winding Form Type: _____ (A, B, C or Twisted)

MC Winding Form ID No: _____

Modular ID Coil Number: _____

2 Applicable Documents

2.1 NCSX-MIT/QA-142-01:

All applicable documents associated with this procedure, are identified in the MIT/QA Plan, document number **NCSX-MIT/QA-142-01**.

2.2 NCSX-PLAN-MCWFOP-00:

All Modular Coil work processes are governed by the “Modular Coil Manufacturing Facility Operations Plan”, document number **NCSX-PLAN-MCWFOP-00**.

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3 Safety Requirements:

All work will be performed in a safe manner in accordance with PPPL safety policies **ES&H 5008** and “Integrated Safety Management” (ISM) policy.

3.1 Job Hazard Analysis:

A JHA will be generated for the winding stations, identifying existing or potential workplace hazards and to evaluate the risk of worker injury or illness associated with job tasks. (Reference document **ESH004 “Job Hazard Analysis”**) The IH representative will review the JHA’s for accuracy as well as completeness. It will be reviewed with all activity participants at the Pre-Job briefings.

3.2 Autoclave Activities:

All entries into the autoclave regardless of whether or not the chamber lid is in place will require a CONFINED SPACE permit. Entry into the autoclave once the chamber has been heated shall only be permitted per written orders by the Industrial Hygienist.

4 Prerequisites & Conditions:

4.1 Pre-Job Briefing:

A pre-job briefing will be held, describing the processes and safety issues prior to starting any part of this procedure. Attendance shall be documented via training sign-in sheet.

Pre job Briefing complete: _____
MC Field Supervisor **Date**

4.2 Daily Operations Startup and Shutdown:

Each working day, it is required to complete and initial the daily operations startup log to ensure that the station is ready to commence work activities for the day. Date and initial the daily log book. See section 6.1 and 6.2 for details.

4.3 Torque Values:

The following torque values shall be used for securing hardware unless otherwise specified in the procedure. (Low carbon steel hardware)

3/8-16UNC	18 ft-lbs	3/8-24UNF	19 ft-lbs
½-13 UNC	38 ft-lbs	½ -20 UNF	40 ft-lbs
5/8-11 UNC.....	83 ft-lbs	5/8-18 UNF...	95 ft-lbs
¾-10 UNC.....	105 ft-lbs	¾-16 UNF	102 ft-lbs
1-8 UNC	236 ft-lbs	1-14 UNF	212 ft-lbs

5 Materials and Parts for this station

The following materials and/or equipment will be used with this procedure.

General Description	Material	Reference Document/Product No.
Solvent	Acetone	MSDS# 00561
Vacuum Pressure Impregnation Epoxy System	Resin/ Hardener/Accelerator	CTD-101K (Composite Tech Dev. Corp.) 3-part system [MSDS #04979]
Autoclave	Equipment	
Vacuum leak checking equipment	Equipment	

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Epoxy delivery system		
Viscometer	Equipment	
Hot Plate	Equipment	
Digital scale	Equipment	
Bench top oven	Equipment	
Nitrogen	Material	

6 Fabrication Process

This fabrication procedure is to be used as guide to complete the VPI activities. Deviation from this procedure can be made during the VPI process with the concurrence of the VPI Director or MC Field Supervisor. All deviations shall be documented in the procedure and initialed by the VPI Director or MC Field Supervisor.

6.1 Daily Startup Activities:

- 6.1.1 Check all daily supplies needed;
- 6.1.2 Verify operation of all equipment needed that day.
- 6.1.3 Check station for cleanliness
- 6.1.4 Check that the day’s travelers and procedures are in their document holder.
- 6.1.5 Date and initial the stations log book that these startup activities have been completed.

6.2 Daily Shutdown Activities:

- 6.2.1 Turn off power to equipment not in use.
- 6.2.2 Clean entire workstation area.
- 6.2.3 Verify that all Traveler and data sheet information is complete.
- 6.2.4 The Lead Technician shall verify that the Station’s Log Book has been completed and signed for the day.
- 6.2.5 Date and initial the stations log book that these startup activities have been completed.

6.3 Position the MCCW in the Autoclave

A confined space permit is required for performing any work in the autoclave.

- 6.3.1 Ensure that the autoclave is ready to receive a coil and winding form.

Verified by: _____ Date: _____ Lead Technician
--

- 6.3.2 Transport the MCWF to the autoclave and secure the MCWF to the support structure using Lift procedure **D-L-NCSX-984**. Remove the top lifting beam once the MCWF has been secured.

6.4 VPI Director

The VPI Director will be appointed by the Manufacturing Facility Manager, and is responsible for all activities associated with the epoxy filling of the modular coils. The VPI Director may not be the same for all modular coils.

VPI Director for this coil shall be: _____

Verified by: _____ Date: _____ Manufacturing Facility Manager

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6.5 AC Power Notification

Notify the AC power group 48 hours prior to the start of VPI operations to transfer the autoclave/VPI systems to the electrical backup circuit.

Notified: Verified by: _____ Date: _____ <p style="text-align: center;">VPI Director</p>

6.6 ESU Notification:

Notify the Emergency Services Unit (ESU) 24 hours prior to the start of VPI operations. Contact the ESU the morning of the VPI operation per the emergency response procedure **D-NCSX-OP-EO-41**. [A "RUN" copy of the emergency response procedure must be obtained for each VPI operation]

Notified: Verified by: _____ Date: _____ <p style="text-align: center;">VPI Director</p>

6.7 Industrial Hygiene Notification:

Notify the PPPL IH group 24 hours prior to the start of VPI operations.

Notified: Verified by: _____ Date: _____ <p style="text-align: center;">VPI Director</p>

6.8 Epoxy Delivery System Preparation

6.8.1 Using Diagram Figure 1- VPI Delivery System, connect the modular coil to the epoxy delivery system. The number of coil connections as well as the connection details will be at the discretion of the VPI Director. CLEARLY identify sprue numbers so that they are visible from the autoclave windows. Record sprue location on appropriate figure- Figure 8-Sprue Locations for Type C Casting, Figure 9- Sprue Locations for Type B Casting, Figure 10-Sprue Location for Type A Casting, Figure 11- Sprue Locations for Twisted Racetrack Coil.

6.8.2 Apply a vacuum to the entire delivery system [Do not include coil in test]. Pump down the system to 1 Torr maximum. No more

6.8.3 **Acceptance criteria:** The vacuum test level shall be maintained for one hour minimum with no greater than a 15 Torr rise. The start time begins from the time the system was isolated from the vacuum source.

Leak Test Results: Start Time: _____ Vacuum Reading: _____ Stop Time: _____ Vacuum Reading: _____
--

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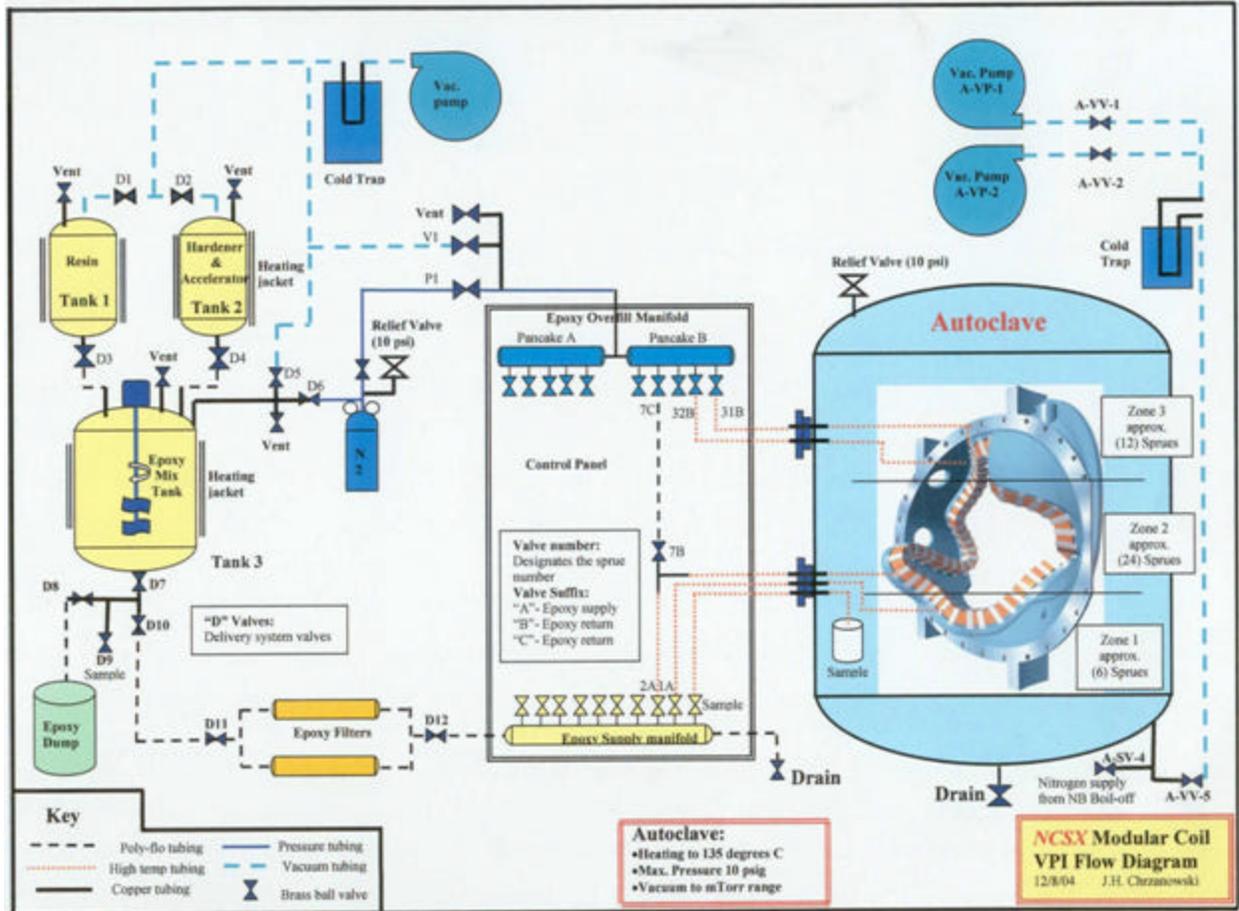


Figure 1- VPI Delivery System

Table 1- VPI Valve Identification Key

Valve ID	Valve Description	Valve ID	Valve Description
D1	Vacuum to Tank 1	7B thru 30B	Zone 1 Fill valves
D2	Vacuum to Tank 2	7C thru 30C	Zone 2 Fill & Vacuum/return valves
D3	Tank 1 to Tank 3	31B thru 42B	Zone 3 Vacuum/return valves
D4	Tank 2 to Tank 3	A-VV-5	Vacuum to Autoclave chamber
D5	Vacuum to Tank 3	A-SV-4	Pressure to Autoclave chamber
D6	Pressure to Tank 3	P1	Pressure to overfill manifold
D7	Shut off valve to Tank 3	V1	Vacuum to overfill manifold
D8	Valve to epoxy dump/waste	Sample	Fill valve for in vessel epoxy sample
D9	Sample valve from Tank 3	Sprue Number	Zone & Description
D10	Valve to fill manifold	1-6	Zone 1 Fill valves
D11	To Epoxy Filters	7-30	Zone 2 Fill & Vacuum/return valves
D12	From Epoxy Filters	31-42	Zone 3 Vacuum/return valves
1A- 30A	Fill valves to coil sprues		

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6.8.4 Install the thermocouples in the autoclave and on the coil being impregnated in the locations identified by the VPI Director. Using Table 2-Thermocouple Locations and Figure 2-Thermocouple Locations identify and show positions of each thermocouple.

Table 2-Thermocouple Locations

Thermocouple No.	Thermocouple Location	Thermocouple No.	Thermocouple Location
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	

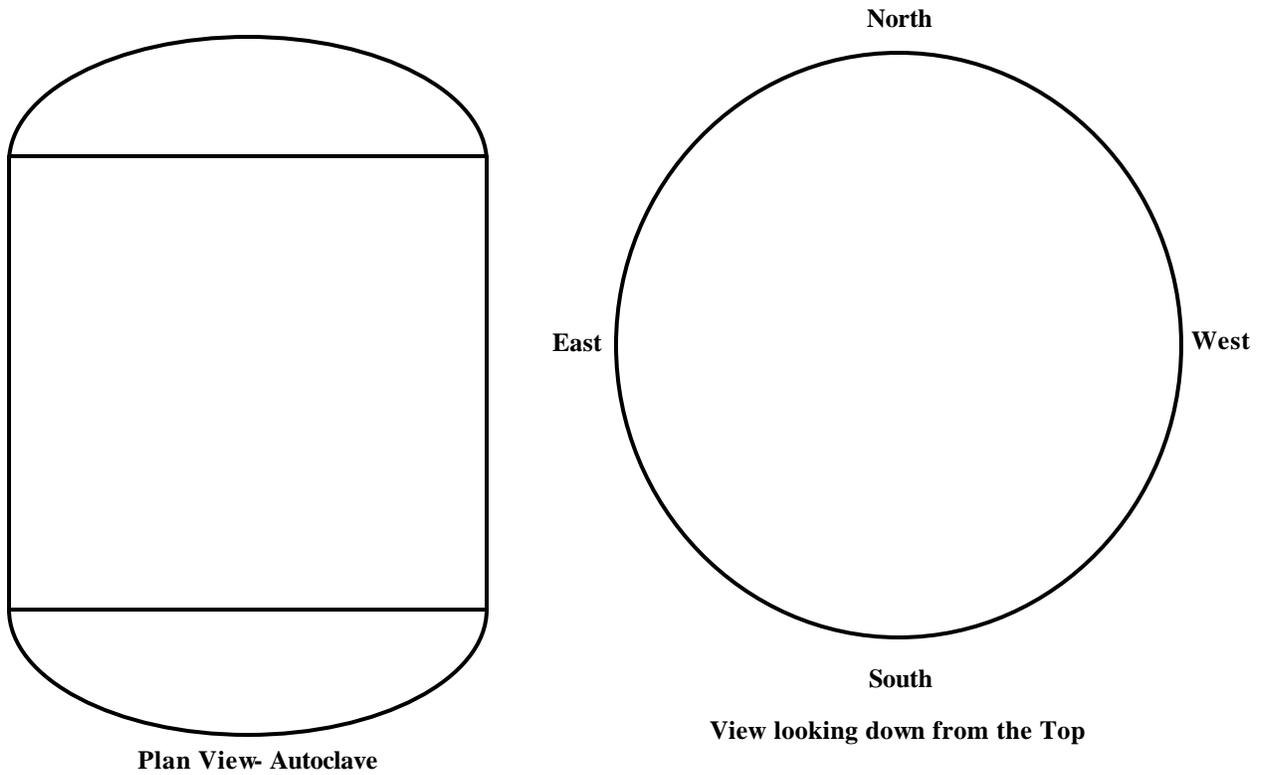


Figure 2-Thermocouple Locations

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6.8.5 Reinstall the autoclave lid and secure in place using the 3/4-10 UNC hardware and torque to appropriate value per section 4.3.

Verified by: _____ Date: _____ Lead Technician
--

6.8.6 A final inspection shall be made by the VPI Director and lead technician of the entire delivery system. This inspection will include as a minimum the following:

6.8.6.1 Verify that all epoxy connections are secure.

6.8.6.2 Verify that the labeling of sprues and valves is correct and that sprue numbers are visible from viewing ports.

6.8.6.3 Verify that the bag mold is adequately supported. [Primarily the lower section]

6.8.6.4 Verify that the epoxy sample container [In Autoclave] is in position.

6.8.6.5 Verify that all thermocouples are properly located and functioning.

Verified by: _____ Date: _____ Lead Technician
_____ Date: _____ VPI Director

6.8.7 Open epoxy filter valves D11 and D12.

6.8.8 Apply vacuum to the bag mold and manifold by turning on vacuum pump and opening valve V1.

6.8.9 Apply a vacuum to the autoclave chamber by turning on the autoclave vacuum pump and opening valve A-VV-5.

6.8.10 Allow the mold and autoclave vacuums to equalize.

Vacuum readings:

Mold:

Autoclave:

Notes:

Verified by: _____ Date: _____ Lead Technician
--

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6.9 Epoxy System:

6.9.1 Epoxy Description: MSDS of epoxy MUST be at Station #5.

- **CTD-101K:** a modified 3-part anhydride cured epoxy system with excellent performance at cryogenic temperatures.
- *Manufacturer:* Composite Technology Development Inc.
1505 Coal Creek Drive
Lafayette, Colorado 80026
Phone: (303) 664-0394

6.9.2 Epoxy Working and Cure Temperatures

- *Mixing Temperature:* 40-60 degrees C
- *Cure Cycle:* 5 hours @ 110 degrees C
- *Post Cure:* 16 hours @ 125 degrees C

6.9.3 Epoxy Mix Ratio: By weight/Gallon

Description	Ratio-Parts per weight	Calculated Weight/gallon pounds	Calculated Weight/gallon grams
Resin (part A)	100	5.0	2268
Hardener: (Part B)	90	4.5	2041.2
Accelerator: (Part C)	1.5	0.075	34.02
Total		9.575	4343.22

6.9.4 Epoxy Mixture per Coil:

Using a digital scale carefully weigh out the three components of the VPI epoxy system and place them in clean separate containers. [**Reference lbs x 453.6 = grams**]

6.9.4.1 Total mix for Twisted Racetrack coil (TRC) VPI Operation: 14-gallons

Description	Calculated Weight lbs	Calculated Weight grams
Resin (part A)	70	31,752
Hardener: (Part B)	63	28,577
Accelerator: (Part C)	1.05	476.3
Total	134.05	60,805.3

Epoxy breakdown for TRC: Approximate allocations

- 6 gallons for coil
- 4 gallons for fill lines
- 4 gallons extra (back fill and measurements)

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6.9.4.2 Total mix per Modular coil (Type A, B and C) VPI Operation: 24-gallons

Description	Calculated Weight lbs	Calculated Weight grams
Resin (part A)	120	54,432
Hardener: (Part B)	108	48,989
Accelerator: (Part C)	1.8	816.5
Total	229.8	104,237.5

Epoxy breakdown for Modular Coils: Approximate allocations

- 11.2 gallons for coil
- 6 gallons for fill lines
- 4 gallons extra (back fill and measurements)

6.10 Preparation of Epoxy Components
(Reference see figure 2)

6.10.1 Using a digital scale carefully weigh out the three components of the VPI epoxy system and place them in clean separate containers. Use the quantities as prescribed in sections in 6.9.4.1 and 6.9.4.2. Record the actual weights below.

Description	Measured Weight Grams	Measured Weight Pounds
Resin (part A)		
Hardener: (Part B)		
Accelerator: (Part C)		
Total		

Verified by: _____ <p align="center">Lead Technician</p> _____ <p align="center">VPI Director</p>	Date: _____ Date: _____
--	--

- 6.10.2 Pre-mix weighed components of Part B (hardener) and Part C (accelerator) together. Mix the epoxy system components in a clean container using either a paddle or air mixer.
- 6.10.3 Pour the pre-weighed component of Part A (resin) into Tank No. 1. See Figure 3- Epoxy Mixing System.
- 6.10.4 Close Tank No. 1 lid and secure.
- 6.10.5 Pour pre-mixed components of Part B (hardener) and Part C (accelerator) into Tank No. 2
- 6.10.6 Close Tank No. 2 lid and secure.

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- 6.10.7 Using heating jackets, heat and maintain the temperature of Tanks 1 and 2 at 50 degrees C (+/- 5)
- 6.10.8 Once at temperature, apply a vacuum to the both tanks and components. Maintain a 2-3 Torr vacuum on the components until the boiling (degassing) of the components has subsided (VPI Director's discretion)

Degassing Data:

Vacuum- Tank #1: _____ Vacuum- Tank #2: _____

Temperature - Tank #1: _____ Temperature- Tank #2: _____

Time Start degassing- Tank #1: _____ Time Start degassing- Tank #2: _____

Time Stop degassing - Tank #1: _____ Time Stop degassing- Tank #2: _____

Observations:

Verified by: _____ Date: _____

Lead Technician

_____ Date: _____

VPI Director

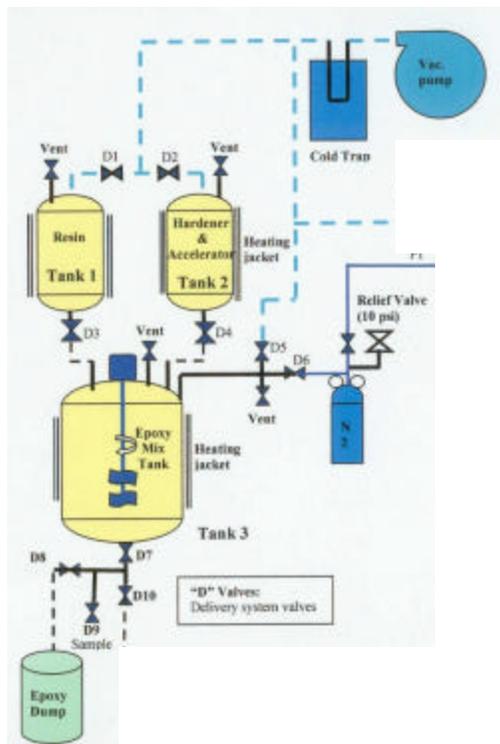


Figure 3- Epoxy Mixing System

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- 6.10.9 Components shall be maintained at the 50-degrees C temperature per VPI Director's direction.
- 6.10.10 Once the Modular Coil is within 4 hours of starting the VPI, the final mixing of the components will commence.

6.11 Mixing of Epoxy Components

- 6.11.1 The VPI Director shall verify that the VPI check list has been successfully completed and that the Modular Coil or TRC is ready for epoxy impregnation.

VPI PRE-REQUISITE CHECKLIST

• Mold and Delivery system ready:	<input style="width: 90%;" type="checkbox"/>
• Epoxy Components weighed out and degassed:	<input style="width: 90%;" type="checkbox"/>
• AC Power Notified:	<input style="width: 90%;" type="checkbox"/>
• ESU Notified:	<input style="width: 90%;" type="checkbox"/>
• Industrial Hygiene Notified:	<input style="width: 90%;" type="checkbox"/>
• Autoclave readiness checklist complete: Attach copy of completed Checklist to back of procedure	<input style="width: 90%;" type="checkbox"/>
• Obtain copy of Emergency Response Procedure:	<input style="width: 90%;" type="checkbox"/>

Verified by: _____ Date: _____ <p align="center">VPI Director</p>

- 6.11.2 Verify that valves D3 thru D10 are **closed**.
- 6.11.3 Vent Tanks No. 1, and 2 by **closing** valves D1 and D2, and **opening** the vent valves on Tanks 1 and 2.
- 6.11.4 **Open** valves D3 and D4 and allow the epoxy components to drain into Tank No. 3 (Mixing Tank).
- 6.11.5 Once all of the components have drained into Tank No. 3, start the mixing motor. The time/speed or revolutions for the mixer are: _____
- 6.11.6 **Open** valve D5 and begin pulling a vacuum on the epoxy components being mixed. Maintain a 2-3 Torr vacuum on the components until the boiling (degassing) of the mixture has subsided. (VPI Director's discretion)

Degassing Data: Vacuum- Tank #3: _____ Temperature- Tank #3: _____ Time Start degassing/mixing- Tank #3: _____
--

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Time Stop degassing - Tank #3: _____
Observations:

Verified by: _____ Date: _____
Lead Technician
_____ Date: _____
VPI Director

6.12 Gel Test Procedure (“Scrambled Egg Test”)

The “Scrambled Egg Test” will be performed just prior to every VPI injection. The purpose of the test is to verify the cure integrity of the epoxy mixture.

- 6.12.1 Draw approximately 1 pint of mixed epoxy from the 30-gallon mix tank by opening valve D7 and D9. This epoxy will be **discarded** and not used for viscosity or test samples.
- 6.12.2 Draw an additional 1.5 quarts of epoxy from the same valve D9. This epoxy will be used for all viscosity and gel tests related to the VPI.
- 6.12.3 Pour approximately 1 ounce of epoxy from the sample epoxy into a metal disk
- 6.12.4 Place the metal disk on a pre-heated hot plate set at 110 degrees C.
- 6.12.5 Periodically stir the mixture. The mixture should Gel in approximately 10- 20 minutes.

Start time for ‘Scrambled Egg’ test: _____
Time that epoxy gelled: _____
Observations:

Verified by: _____ Date: _____
Lead Technician
_____ Date: _____
VPI Director

- 6.12.6 The VPI director must decide whether the mixture will be used for the epoxy impregnation of the coil should the Gel Time (Cure) not be within the above limits, (The rejected epoxy shall be oven cured in 1 gallon batches to minimize any exothermic reaction of the epoxy)

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6.13 Viscosity Measurements

“Viscosity” measurements will be taken during the epoxy fill-cycle and continue until the epoxy mixture has begun to Gel or get thicker in consistency.

- 6.13.1 Pour approximately (1) pint of the epoxy mixture into a metal container and place onto a hot plate that will be maintained at the same temperature as the epoxy in the autoclave chamber.
- 6.13.2 Position the viscometer into the epoxy, and begin to record viscosity, time and temperature at the frequency as directed by the VPI Director. Record all data on “Viscosity Data Sheet” at back of procedure.

6.14 Emergency Dump:

- 6.14.1 If it becomes necessary to dump the epoxy from Tank 3 for any reason, open valves D7 and D8. This allows the epoxy to flow into a 55 gallon steel drum. This can also be used for cleaning the tanks after epoxy use. Caution should be used to minimize the amount of mixed waste that may be generated.

6.15 Coil Fill Procedure

All valving operations as noted below are to be used as a guide. Deviation from this procedure (Field Changes) can be made during the VPI process with the concurrence of the VPI Director. All field changes must be indicated in the Run Copy of this procedure and initialed by the VPI Director.

- 6.15.1 The VPI Director shall verify that all prerequisites have been completed and that the modular coil is ready to receive epoxy.
- 6.15.2 Record all data in the appropriate table, identified below.

Thermocouple Readings: **Table 4- Thermocouple Readings**
VPI Sprue Log: **Table 5- VPI Log**
Viscosity Readings **Table 3- Viscosity Measurements**

- 6.15.3 During the coil filling operation, the VPI Director may decide to modify the atmosphere in the autoclave to support the filling operations. He/she may also elect to apply a positive pressure (5 psig max) to the fill tank to enhance the filling operations. These decisions are the discretion of the VPI Director, but must be documented in the procedure.
- 6.15.4 **Close** vacuum valve D5 on the mixing tank, and open the vent valve to allow the mixing tank to return to atmospheric pressure.
- 6.15.5 **Close** all “A” valves; and “B” valves in zone 3 [valves 31 thru 42].
- 6.15.6 **Open** valve D10 and allow the epoxy to flow through the filters and fill the manifold.
- 6.15.7 **Open** all Zone 1 valves 1A thru 6A on the control panel to allow the epoxy to flow into the lower portion of the modular coil. Figure 5-Typical Zone 1 Valve Assembly
Record start time: _____
- 6.15.8 **Open** “SAMPLE” valve and fill the sample can in the autoclave with epoxy. Once the epoxy can has been filled, **close** the “SAMPLE” valve.

Epoxy Sample Obtained:

Verified by VPI Director: _____ **Date:** _____

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- 6.15.9 Record all times, as well as any VPI notes on the VPI Data sheet Table 5- VPI Log. Observe and record the time that epoxy exits each sprue on the coil.
- 6.15.10 Continue filling operations until the epoxy exits sprues 7 thru 30 [Zone 2] and approaches the tee connection. **Open** the corresponding “A” valve. Once the line from the manifold “A” valve to the tee connection is filled, **Close** the corresponding “B” valve. This allows that sprue to be used for filling the coil. Figure 4- Typical Zone 2 Valve Assembly
- (Note: The time allowed between opening the fill and closing the vent valves is at the discretion of the VPI Director.)*
- 6.15.11 The VPI Director, at his/her discretion will begin to **open** the “B” valves for Zone 3 [sprue 31-42] valves as the epoxy level rises in the coil.
- 6.15.12 Continue flowing epoxy into the coil via the Zone 1 and 2 valves until epoxy is observed exiting each of the Zone 3 (Vent) valves [31 thru 42]. Figure 6-Typical Zone 3 Valve Assembly. **Close** each Zone 3 vent valve once epoxy reaches the control panel.
- 6.15.13 The VPI Director will determine when the filling operation has been completed.
- 6.15.14 The autoclave must be at positive pressure at the conclusion of the filling operation. This pressure is used to reinforce the bag mold until Gel temperature has been reached.

Verified by: _____ Date: _____ VPI Director

- 6.15.15 If there is evidence of air bubbles in the vent lines, or if the VPI director judges the necessity, the “Milking” procedure may be applied to the VPI process. Go to section 6.16 **Milk Procedure (optional)**
- 6.15.16 If the VPI Director is satisfied with the epoxy fill of the coil. Go to section 6.17 Cure Cycle- (GEL)
- 6.15.17 The coil filling operation is complete and is ready for starting the cure cycle.

Verified by: _____ Date: _____ VPI Director

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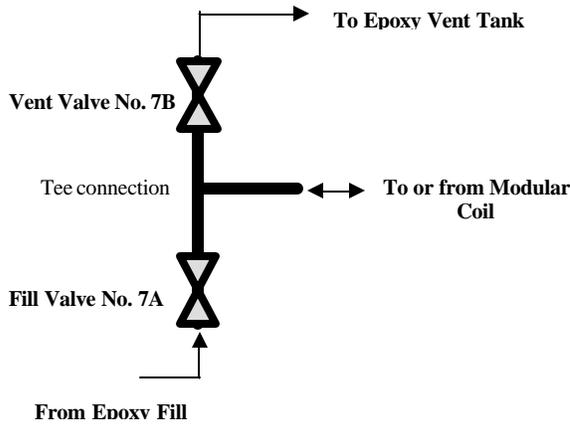


Figure 4- Typical Zone 2 Valve Assembly

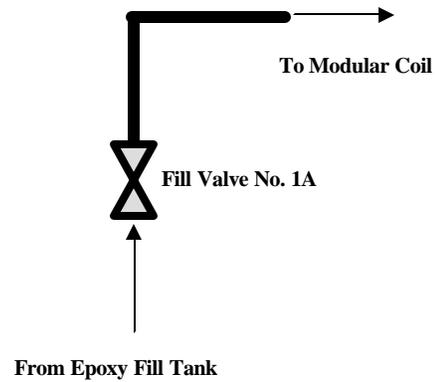


Figure 5- Typical Zone 1 Valve Assembly

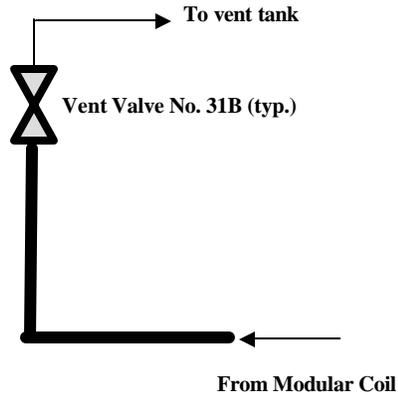


Figure 6- Typical Zone 3 Valve Assembly

6.16 Milk Procedure (optional)

Process used for removing trapped gas pockets by flowing epoxy back and forth through the coil once the coil has been filled.

- 6.16.1 **Close** all “A” and “B” valves.
- 6.16.2 Remove the nitrogen pressure from the mix tank and allow the tank to return to atmospheric pressure.
- 6.16.3 Remove the vacuum from the overflow manifold and raise the pressure to atmosphere.
- 6.16.4 **Open** all Zone 1 [1A thru 6A] and Zone 3 [31B thru 42B] valves as well as the Zone 2 overflow manifold valves [7B thru 30B].
- 6.16.5 Raise the pressure on the overflow manifold to 5 psig and move the epoxy to within 6 inches of the coil.
- 6.16.6 Remove the pressure on the overflow manifold and apply 500 to 1000 microns vacuum.

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- 6.16.7 Apply 5 psig of nitrogen pressure to the mix tank move epoxy approximately 18 to 24 inches in the vent lines.
- 6.16.8 Remove the pressure on the mix tank and vacuum on the overflow manifold.
- 6.16.9 Repeat entire milking process.
- 6.16.10 If no bubbles are seen, go to section 6.17 Cure Cycle- (GEL)
- 6.16.11 If bubbles are seen, repeat milking process.

Note: *During the cure cycle, the delivery system and tanks should be cleaned.*

6.17 Cure Cycle- (GEL)

During this phase the coil is slowly brought up to the cure [Gel] temperature of 110 degrees C and held for a period of 5 hours.

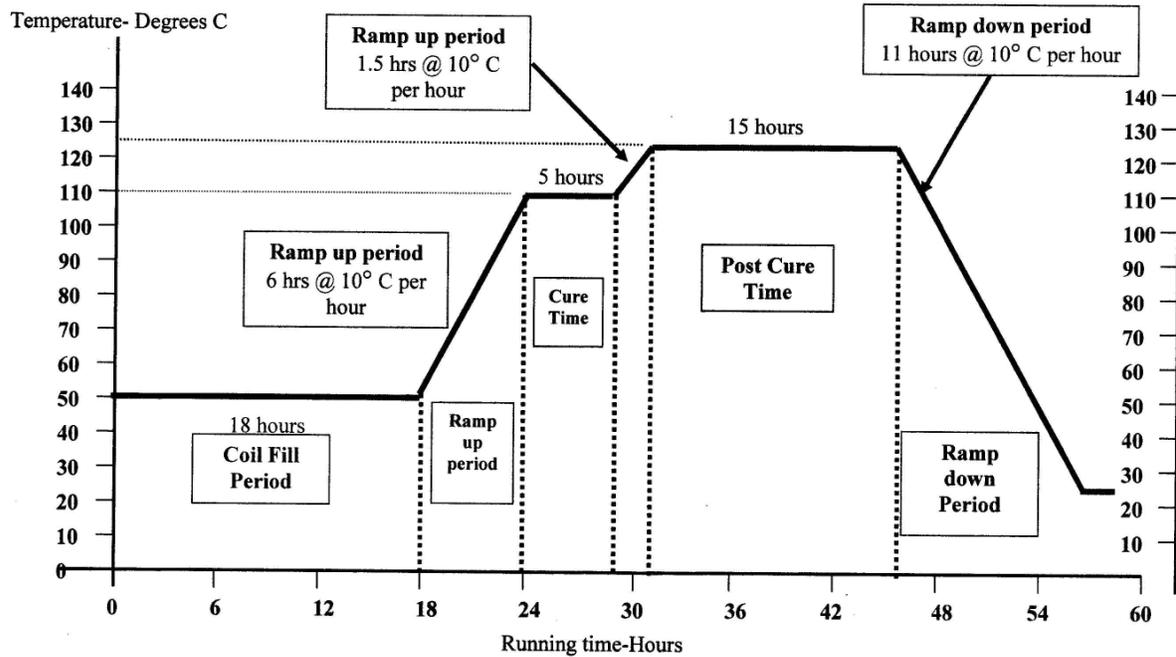


Figure 7- VPI Cure Cycle

- 6.17.1 Close all valves.
- 6.17.2 Maintain positive pressure in the autoclave . Autoclave pressure start of temperature ramp -up: _____
- 6.17.3 Begin the temperature ramp -up to 110 degrees C @ rate of 10 degrees per hour.

Time- Begin Ramp up: _____

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6.17.4 During the ramp up cycle, continue to monitor the viscosity readings while increasing the temperature at the same rate as the coil. Continue to record readings in viscosity table at the frequency identified by the VPI Director. Abort viscosity readings once sample mixture begins to Gel. Clean viscometer.

6.17.5 It will take approximately 6 hours to reach Gel temperature.

Time- Gel Temperature Reached: _____

6.17.6 Once at temperature, hold the coil at 110 degrees C for 5 hours.

6.18 Post Cure Cycle

Temperature at time which maximum mechanical and electrical properties are reached

6.18.1 After 5 hours at Cure [Gel] temperature begin ramp up to 125 degrees C @ a rate of 10 degrees per hour.

Time- Begin Ramp up: _____ Lead Tech. _____

6.18.2 Slowly vent the autoclave pressure until it reaches atmospheric pressure.

Verified by: _____ Date: _____ VPI Director or Lead Tech.

6.18.3 It will take approximately 1.5 hours to reach post cure temperature.

Time- Post Cure Temperature Reached: _____ Lead Tech. _____

6.18.4 Once at temperature, hold coil at 125 degrees C for 15 hours. During this operation, continue to monitor and record data at the frequency identified by the VPI Director.

6.19 Ramp-Down Period

This is the period that the coil temperature to slowly lowered to room temperature.

6.19.1 After 15 hours at temperature, begin the ramp -down phase of the cure cycle.

6.19.2 Shut down all heaters.

Start of Ramp-Down: _____ Lead Tech. _____
--

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- 6.19.3 Keep the autoclave chamber closed until the coil temperature reaches 45 degrees C.
- 6.19.4 The coil temperature shall ramp down at a rate of approximately 10 to 15 degrees C per hour.
- 6.19.5 Once the coil has reached a maximum temperature of 45 degrees C the autoclave door and lid may be opened.

The epoxy impregnation and curing operations have been satisfactorily completed.	
Lead Technician: _____	Date: _____
VPI Director: _____	Date: _____
QC shall verify completion of documentation:	
Quality Control Representative: _____	Date: _____

6.20 Post Autoclave Activities:

A confined space permit is required for performing any work in the autoclave.

- 6.20.1 Remove the autoclave lid and position it on the Winding Facility Floor.

Verified by: _____	Date: _____
Lead Technician	

- 6.20.2 Remove the epoxy sample from the autoclave and clearly label the can with the coil number and VPI date. Store the epoxy specimen in a safe dry area for future testing.
- 6.20.3 Carefully cut and remove all of the epoxy feed lines running between the coil and feed-thru port.
- 6.20.4 Disconnect all thermocouple lines from the coil.
- 6.20.5 Clean the autoclave and delivery system, prepare for the next coil.
- 6.20.6 Using the overhead crane, re-install and secure the top lifting beam to the coil support ring.
- 6.20.7 Verify that all hardware has been torqued and that casting is ready for transport from the autoclave to the Turning Fixture at station number 1.

Verified:	
Lead Technician: _____	Date: _____
Field Supervisor: _____	Date: _____

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7 Completion of Activities at VPI Station:

7.1 Document Verification:

Verify that all pertinent data in the procedure and data sheets have been completed.

7.2 Field Package:

Ensure that all data sheets, photographs, QC inspection sheets, etc are included in the “Coil Field Package”.

7.3 Approval:

Prior to releasing a modular coil to the Post VPI station, it is required that the all-responsible individuals sign the release indicating that all processes at the VPI/Autoclave station have been satisfactorily completed. The release will include signatures from the Station Lead Technician, VPI Director and the QC representative.

All epoxy impregnation/cure (VPI) activities have been satisfactorily completed.	
Lead Technician: _____	Date: _____
Field Supervisor: _____	Date: _____
QC shall verify completion of documentation:	
Quality Control Representative: _____	Date: _____

The epoxy filled coil is ready for transfer to the Post VPI station:

Comments:
--

8 Glossary of Terms:

•**Bag Molding-** A less expensive method of building a mold where high tolerance outside dimensions are not required and can accommodate more difficult configurations. Can be made using silicone sheet or tape with a rigid strong back for support

•**Cure temperature:** Temperature at which the epoxy begins to solidify (GEL) and to reach cured properties

•**Degass:** To remove trapped air in epoxy components via 1-2 Torr vacuum

•**Gel Point:** The time at which the viscosity of the epoxy mixture rises and the mixture begins to solidify

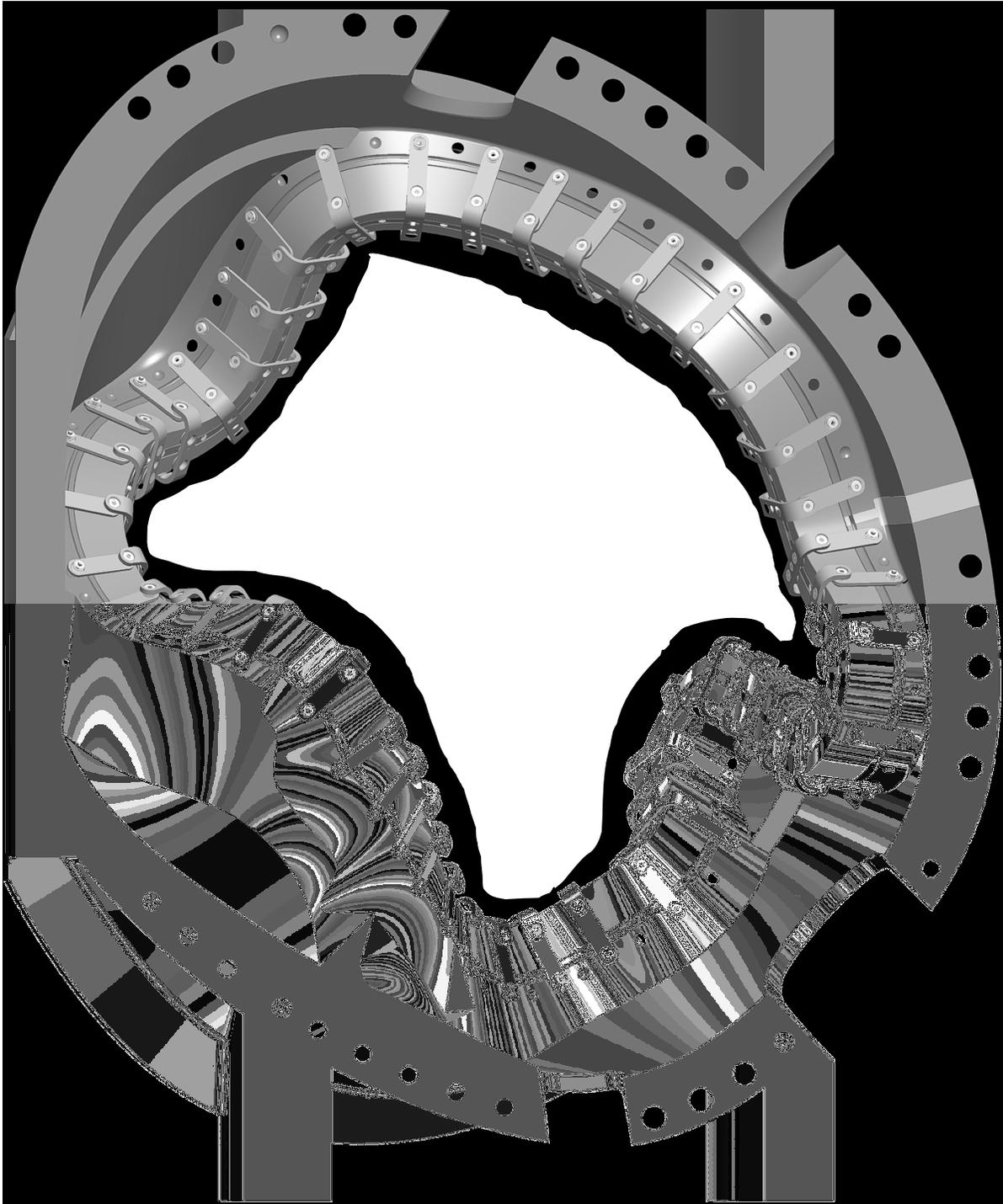
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- Milking**- Term used for back flowing epoxy through coil once coil has been filled to remove trapped gas pockets
- Post-Cure Temperature:** Temperature at time which maximum mechanical and electrical properties are reached
- Pot life (*working time*)**- The life of the epoxy from the time that it is mixed until it begins to gel
- Ramp up**- Process of raising the temperature to cure a coil during VPI
- “Scramble Egg Test”**- Test used to verify the correct mixture of components prior to introducing the epoxy to the coil. Test verifies that the epoxy mixture will Gel at the correct temperature.
- Soak Period:** Period of time following epoxy fill in which additional epoxy may be wicked into the coil insulation usually under slight positive pressure
- Sprues**- Fittings for epoxy entrance & exit from coil mold
- Viscometer:** operates on the principle of rotating a cylinder or disc immersed in the liquid under test and measuring the torque necessary to overcome the viscous resistance to rotation. (Digital readout) Equipment is used to measure the viscosity of the epoxy components.
- VPI [Vacuum Pressure Impregnation]:** The process of filling a coil with epoxy resin using both vacuum and pressure control.

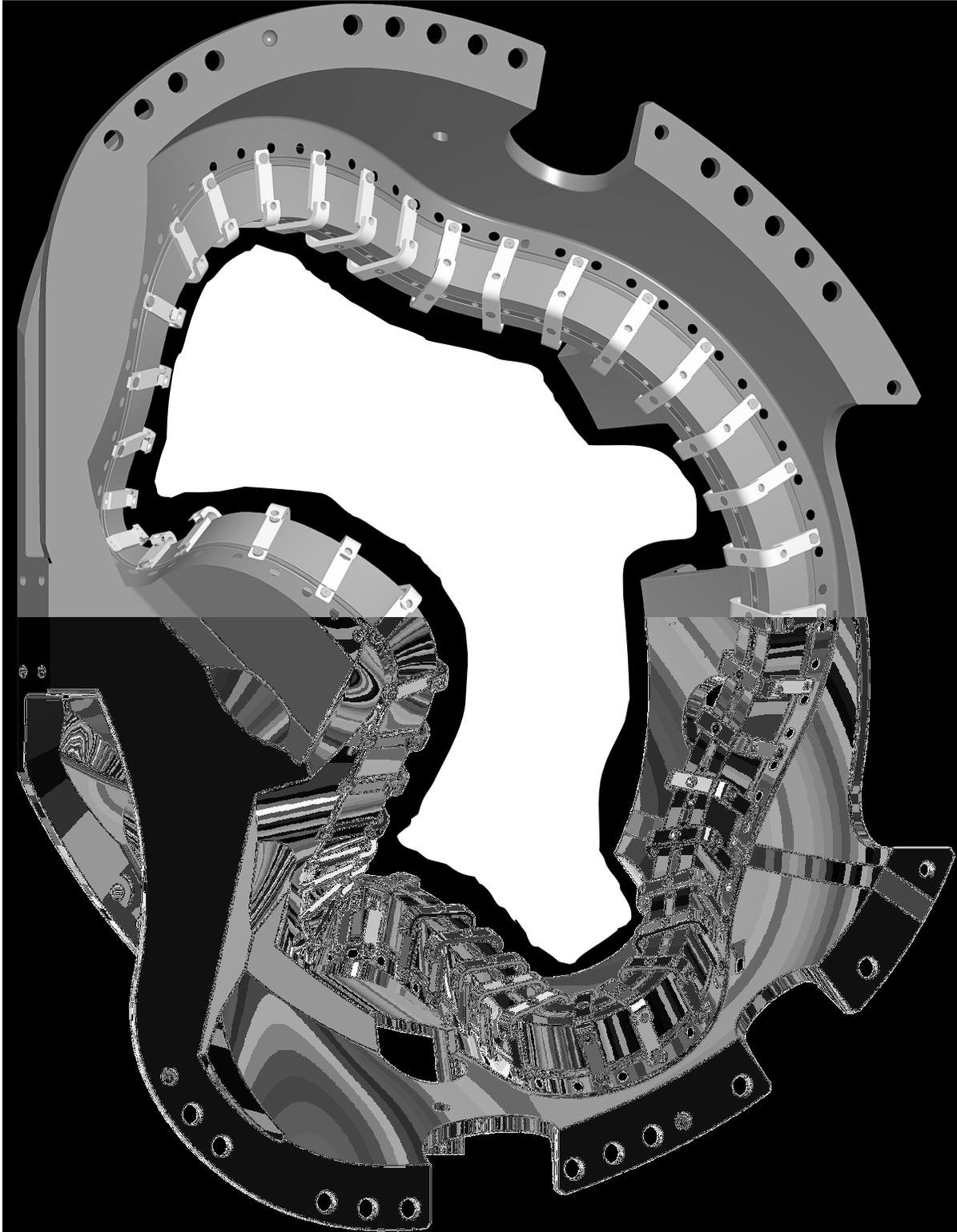
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Figure 8-Sprue Locations for Type C Casting



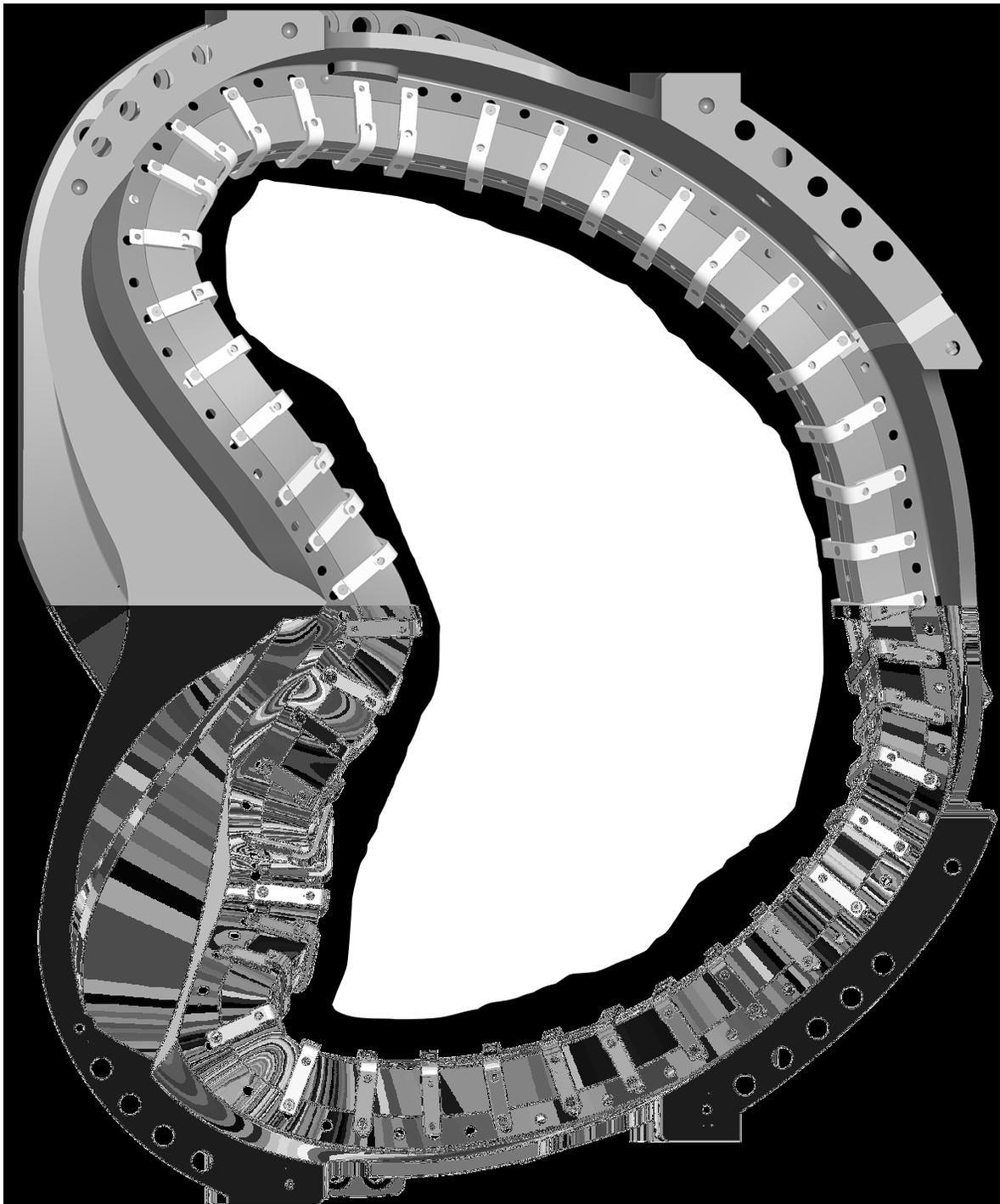
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Figure 9- Sprue Locations for Type B Casting



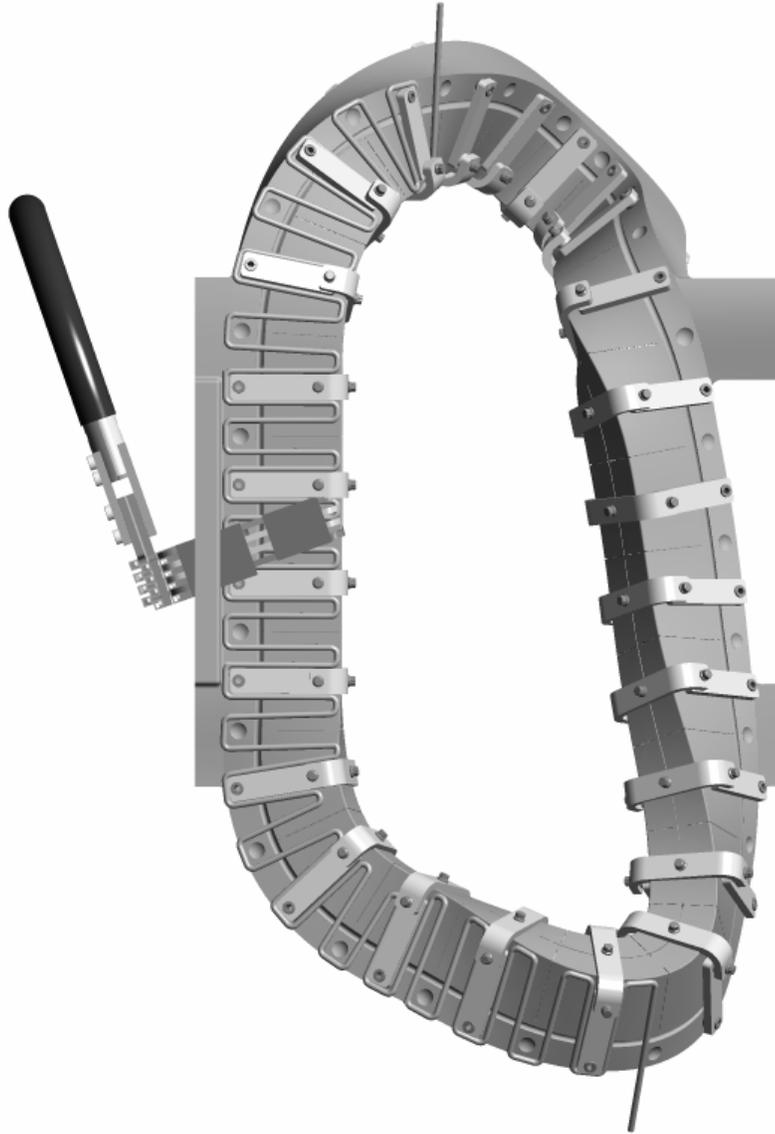
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Figure 10-Sprue Location for Type A Casting



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Figure 11- Sprue Locations for Twisted Racetrack Coil



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Table 4-Thermocouple Readings

Time									
Thermocouple No.									
#1									
#2									
#3									
#4									
#5									
#6									
#7									
#8									
#9									
#10									
#11									
#12									
#13									
#14									
#15									
#16									
#17									
#18									
#19									
#20									
#21									
#22									
#23									
#24									

Date: _____ **Sheet no.** _____

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Table 4 continued-Thermocouple Readings

Time									
Thermocouple No.									
#1									
#2									
#3									
#4									
#5									
#6									
#7									
#8									
#9									
#10									
#11									
#12									
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#14									
#15									
#16									
#17									
#18									
#19									
#20									
#21									
#22									
#23									
#24									

Date: _____ **Sheet no.** _____

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Table 4 continued-Thermocouple Readings

Time									
Thermocouple No.									
#1									
#2									
#3									
#4									
#5									
#6									
#7									
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Date: _____ Sheet no. _____

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GENERAL VPI NOTES