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NCAMP Process Specification
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Polymer Additive Manufacturing Materials, Machine, Processing and Quality Requirements Specification for Antero® 840CN03 and Stratasys Inc. Fortus 900™ Machine

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REVISIONS:

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N/C	Royal Lovingfoss	04/24/2024	Document Initial Release
A	Jonathan John	2/11/2025	Pg. 12, Table 2, The header on colum to was changed from “Revision description” to “Revision Date” Pg. 13, Moved figure 2 from section 5.4.8 to 5.4.2, as it is the more relevant section. Renamed to Figure 1.

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1. Scope

This process specification describes the methods of fabricating test coupons using a Free Form Fabrication (FFF) process (Fusion Deposition Modeling (FDM™)) using Stratasys Antero(R) 840CN03 thermoplastic resin on the Stratasys Fortus 900 printer. Specifically, this specification covers the constituent material, the configuration of the machine, operating software, machine calibration, and machine and build parameters and acceptance criteria. In addition to the instructions contained in this specification, users are advised to obtain hands-on guidance directly from the machine manufacturer for the setup of the machine, part design, establishing the build and slice files as well as determination of the correct build parameters.

This specification does not contain all the necessary information typically required for the fabrication of FDM parts, such as personnel qualification, facility requirements or any part acceptance criteria. Users should refer to their existing company process specification for such information.

1.1 Purpose

This specification establishes the requirements for the Fused Deposition Modeling (FDM™) process using Stratasys Antero(R) 840CN03 thermoplastic resin on the Stratasys Fortus 900 printer combination, herein referred to as “FDM System”. This specification requires qualified processors.

1.2 Classification

a) Raw Resin – Raw material purchased to Stratasys Specifications.

b) Filament – When the Raw Resin is processed and procured to NMS 840 and NMS 840/1, “Aerospace Filament Specification (Antero(R) 840CN03)”.

c) Fortus 900 – A machine supplied by Stratasys, identified by Serial number at a specific location where Type I material manufactured to this Process Specification, for Qualification and/or Equivalency.

An example may include a manufacturer having multiple *Stratasys Fortus printers.*

d) FDM System – Is representative of the combination of FDM equipment and software, configured, calibrated, and maintained outlined per this Process Specification.

1.3 Types

Type defines the material used in the FDM process.The type shall specify the predominant resin used in the feedstock. The resin type shall use ASTM D4000 abbreviations (aka, standard symbols); if the resin type is not listed in ASTM D4000, abbreviations known in the industry shall be used. If the base resin is mixed with an amount of another resin, the name shall include “blend” to indicate a mixture of the blended component.

Type 1 Material: Poly-ether-ketone-ketone (PEKK) Blend, carbon nanotube filled (2-3% by weight), with Stratasys trademarked name “Antero(R) 840CN03.”

If Type is not declared in subsequent sections, it is inferred then that Type 1 is being referenced.

1.4 Health and Safety

While the materials, methods, hardware, applications, and processes described or referenced in this specification may involve the use of hazardous materials and hazardous environments, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials or processes and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. Applicable Documents

The following specifications, drawings, and publications, of latest issue when not specified, form a part of this document to the extent specified herein.

2.1 Stratasys/NCAMP Documents:

Document No.	Document Title
SSYS 410495-0001	Antero 840CN03 Resin Specification
NMS 840	Antero 840CN03 Filament Specification
NMS 840/1	Antero 840CN03 Material Specification
SSYS 410518-0001	Filament Certificate of Compliance
SSYS 413054-0001	Resin Certificate of Compliance
SSYS 402737-0001	Fortus 900 3D Production System User Guide

2.2 Industry Standards:

Document No.	Document Title
ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D7078	Standard Test Method for Shear Properties of Composite Materials by V-Notched Rail Shear Method
ASTM D5766	Standard Test Method for Open Hole Tensile Strength of Polymer Matrix Composite Laminates
ASTM D6742	Standard Practice for Fille Hole Tension and Compression Testing of Polymer Matrix Composite Laminates
ASTM E466	Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials.

ASTM D5961 Procedure C	Standard Test Method for Bearing Response of Polymer Matrix Composite Laminates
ASTM D790	Standard Test Methods of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D3418	Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetery
ASTM D7191	Standard Test Method for Determination of Moisture in Plastics by Relative Humidity Sensor

2.3 US Government Publication:

Not Used

2.4 Abbreviations and Acronyms:

DSC	Differential Scanning Calorimetery
BOM	Bill of Material
°F	Degrees Fahrenheit
ESD	Elextrostatic Dissipative
FDM	Fused Deposition Modeling
inHg	In. of Mercury
Hz	Hertz
OEM	Original Equipment Manufacture
PEKK	Poly-ether-ketone-ketone (Thermoplastic)
PPE	Personal Protective Equipment
QA	Quality Assurance (Department)
QMS	Quality Management System
VAC_{RMS}	Volts Alternating Current (Root Mean Square)

2.5 Terms and Definitions:

- Addictive Manufacturing (AM) – Process of joining materials to make parts from 3D model data, usually layer upon layer.
- Batch – Defined quantity of feedstock with uniform properties and composition.
- Bead – A single line of extrudate material from an FDM liquefier tip.
- Bead Mode – Pre-programmed settings that can be used to replace default inputs within Insight™ to better tailor printing parameters to unique geometries or build styles.
- Breakaway – A type of Support Material (consumable) that represents the method of removal from the final part.
- Build – The physical activities the machine takes in producing a single or set of parts within a unique start and stop of the machine.
- Build Chamber – The “in-oven” portion of the FDM System hardware that includes the platen, tip wipe, tip calibration, and purge chute.

- Build Envelope – The three-dimensional space within the FDM System that can be utilized to produce a part or sets of parts.
- Build Style – Preset building parameters used to create parts within the pre-processing software.
- Canister – Packaging used to house filament to aid in maintaining moisture and eliminating contamination.
- Cognizant Engineering Authority – also referred to as: Responsible Process Engineer, or more generically materials and processes engineer – is intended to represent an individual or department that in compliance with their organization's policies have the ability to deviate from specifications as long as documentation and appropriate protocols defined by the organization are followed.
- Constituent Material – Raw components that will be compounded to produce the final filament feedstock. Each raw material should possess a unique lot or batch identifier as defined by the raw components' manufacturer.
- Control Center – A software module provided with Insight to pack several parts into a single build and allows for manipulation of location, orientation, and enable machine scheduling.
- Controller Software (SW) – Software that controls motion and extrusion during the FDM process workflow.
- Contour – The exterior bead, setting the perimeter of a given layer.
- Command Move Binary File (CMB) – Part specific toolpath file created by Insight that is sent to the printer for execution via Control Center. Contains machine and material type as well as XYZ coordinates and bead areas of all toolpaths.
- Part – Physical object produced by FDM System.
- Custom Groups – Insight's editable parameters used to modify toolpath settings
- Double Dense Fill – A type of Fill Pattern that has overlapping, 90° intersections of sparse layers.
- Feedstock – Bulk raw material supplied to the AM process.
- Fill Pattern – Preset methods of different ways or lattice structures used to complete the interior of a part.
- Filament – Feedstock of raw material in continuous rod form, used in FDM Systems
- Fortus F900 – A specific model of 3D printer, trademarked by Stratasys, denoting the build volume and grade of printer.
- Fused Deposition Modeling (FDM™) – A type of extrusion based additive manufacturing technology that enables the construction of three-dimensional objects, prototypes and products through a computer-aided process.
- Insight™ – Stratasys pre-processing software that converts .STL files into machine process-able file .CMB which generates and controls toolpaths.
- Lattice – Re-occurring pattern of geometries used to fill the interior of a part.
- Linked Contour – Two adjacent contours are joined as one continuous toolpath.
- Lot (Filament Lot) – The quantity of Stratasys consumables manufactured at one time to a single set of defined properties using a single raw resin lot or batch.
- Machine – The computer guided apparatus that is used to create the extruded 3D part.
- Machine Controlling Software – Software that controls motion and extrusion during the fabrication process workflow, manipulation of location, orientation, and enables

machine scheduling.

- Manufacturer – the organization who designed/built the system.
- Material – The initial filament that is fed into the machine to be extruded.
- Material Supplier – The organization that manufactures the filament material.
- Material Extrusion – An additive manufacturing process in which material is selectively dispensed through a nozzle or orifice. Common varieties include thermoplastic extrusion such as Fused Filament Fabrication.
- Model Material (also referred to as Direct Material) – Material which forms a portion of the finished part.
- Microstructure – the resulting structure observed under magnification as a function of the interaction of contour and raster beads combining to fill-in the boundary that represents the geometry being printed on a per layer basis.
- Part – A physical extruded 3D object created through fabrication including but not limited to production articles, coupons, and specimens.
- Qualification – Demonstrates that the implementation meets the requirements and is suitable for operation.
- Qualified Operator – The person(s) trained to set up, operate, and maintain a Fortus F900.
- Raster – The internal bead, used by the fill pattern between the perimeters created by a contour.
- Raw Resin Lot or Batch – Total quantity of a unique lot or batch identifier as defined by original resin manufacturer.
- Seam – The start and stop location of a contour for each perimeter for every part layers.
- Shall – Expresses a binding requirement.
- Should/May – Expresses a recommended or allowed action.
- Solid Fill/Mode – In Solid, Insight™ will fill a single contour bead around the outside with rasters in a repeating, alternating pattern to fill as much space as possible.
- Sparse Fill – Sparse fill is designed to expand the gap between rasters within the confines of the part to reduce the amount of material used. Raster width for sparse fill can be controlled exactly like in solid mode but the gap between rasters is controlled with the variable cell size.
- Style/Build Style – Preset building parameters used to customize toolpaths within Insight.
- Support – Structure separate from the part geometry that is created to provide a base and anchor for the part during the building process.
- Support Style – The fill pattern built underneath overhanging components are built in the exact manner as the toolpath sparse mode.
- System – Refers to the combination of equipment and software used to process FDM material.
- Toolpath – A plan of predetermined xy coordinates used to drive motion and material deposition control.
- User – The person or organization that is creating parts using the system.
- Validation – Identifies that the requirements for a product are sufficiently correct and complete.
- Verification – Identifies that the implementation has been evaluated to determine that

all design requirements have been met.
- Will – Expresses a declaration of intent.

3. Environmental Control

3.1 Fabrication Facility Conditions

The FDM System is for indoor use only
a) Operating temperature: 60°F (15.5°C) to 85°F (29°C)
b) Humidity: 0%RH to 80%RH non-condensing

3.2 Fabrication Facility Electrical Requirements

Facility power is required to meet the following power quality and nominal voltage requirements:

a)	Rating:	13.5KVA
b)	Voltage:	230VAC nominal 3-phase service with 5% regulation **Note**: 230VAC as measured phase-to-phase
c)	Frequency:	50 Hz or 60 Hz
d)	Current:	40 Amp circuit
e)	Full load current:	34 Amp full load current on all three phases
f)	Maximum inrush current	~570 Amps for 2ms
g)	Three wire plus ground electrical connection	

Operation of the FDM System outside this range is not recommended and degradation of the FDM System performance and shortened component life expectancy will be experienced. The FDM System is to be operated on a 3-phase service meeting the recommendations for power quality given in IEEE Standard 141-1976. Facilities who are unsure of their power quality should contact their service provider.

3.3 Compressed Air Requirements

The FDM System has an onboard pressure regulator, onboard particle filtration, water, and oil separation. Air-lines must be used in conjunction with the following:

a) Supply pressure at the FDM System:
    a. 90-120 PSI with a minimum flow of 20 SCFM
    b. Input Manifold Air Pressure setting 75 ± 5 PSI
    c. Non-lubricated
    d. Non-condensing
b) DIN ISO 8573-1 Quality Class 4 or better is recommended to improve onboard filter life
c) Connection: Dimensional standard A-A-59439

4. Equipment Control

a) The FDM System shall be installed in accordance with all Stratasys Inc. installation manuals and guidance, including installation of line power transformers as required and recommended by Stratasys (Section 3, Setup and Installation found in SSYS 402737-0001) to be performed by a qualified electrician.
b) T20F tips are required to process Type 1 Material.

4.1 Fused Deposition Modeling (FDM™) Equipment

a) FDM Systems must be identified by names or numbers for setup and traceability.
b) All FDM Systems must be calibrated in accordance with Section 5: Calibration of SSYS 402737-0001.
c) All FDM machines must have a maintenance plan based on the manufactures' recommended procedures.
d) Record of calibration and machine maintenance must be retained as QA records and must comply with Section 4.2.2.

4.2 Machine Maintenance and Control

Modifications or repairs to major sub-system equipment may demonstrate significant changes in build quality and are noted in Table 1. Any changes made and communicated by Stratasys or replacement of these components must be reviewed and dispositioned by designated cognitive engineering authority and may require requalification per Section 9, repeated Equivalency, or even full certification based on the change classification.

Table 1. Critical Sub-System Components

Sub-System	Description
Head	Critical sub-components within the head consist of drive motors, heater blocks, drive wheels, on-board electronics
Platen	Scratching of the build surface can result in lack of vacuum
X, Y, or Z Motor	Mechanism that drives belt or screw controlling gatry motion or platen location. Observed faults, shifts, and motion failures will result in replacing these motors and requiring requalification.
Gantry Rail	Structures holds the head and bridge and controlls and maintains rigity during x and y motions.
Master Computer	On-board computing system
Universal Power Supply	Critical component of the electrical system to regulate incoming power to all electronics on an FDM System

4.2.1 Preventative Maintenance

a) Preventive maintenance will be performed on each FDM System used to fabricate production parts. This maintenance will verify proper operation of the FDM System.

b) Preventive maintenance will be performed a minimum of every three months per Stratasys' recommend maintenance procedures per Section 6: System Maintenance – Quarterly Maintenance (SSYS 402737-0001).
c) All maintenance activities will be performed in accordance with the Stratasys standard procedure using Stratasys replacement parts as needed.
d) After maintenance has been performed on a FDM System, the FDM System shall be calibrated using the Stratasys calibration procedure outlined in Section 5, Calibration (SSYS 402737-0001).
e) Liquefier tips shall be replaced after 368 cubic inches of use.

4.2.2 Maintenance Record

A record of all machine maintenance activities, calibrations, and repairs will be maintained for each FDM System and stored per the user's applicable quality management system procedures.

5. Software Control

Software for additive manufacturing systems is an essential part of the process and must be defined and be under configuration control. Specific software versions utilized for the qualification of the material will be controlled for that material. Any changes to software used in this process shall be approved via ACN through NCAMP.

Type 1 material shall be built in accordance with the approved software version in Table 2.

Table 2: Software Revisions

Number	Revision Date
Pre-Processing Software: Insight Version 15.7 or higher (Build 3331)	Qualification-Initial Release
Controller Center 15.7 or higher (Build 3331)	Qualification-Initial Release
Controller Software Version: 4.12.4202.0 or higher	Qualification-Initial Release

Note: The software for the Fortus 900 machines are provided by Stratasys Inc.

5.1 Model Preparation

Model preparation is performed using industry standard CAD and .STL modification software. The required output of this process is a .STL file that can be imported into Stratasys' pre-processing software. The control and verification of these software packages is at the discretion of the user.

5.2 Pre-Processing

The Insight™ software, provided by Stratasys, has a release version designation that must be recorded and maintained for any certified production. Version installed on the machine must match version listed in Table 2 of Section 5.

5.3 .CMB and Job File Creation

Pre-loaded CMB's for all coupon geometries and orientations shall be used for Type 1 Qualification and Equivalency and should be downloaded from the NCAMP website. For a list of all Pack Files and CMBs for each test type and coupon contact NCAMP and the files will be provided.

5.4 Build Styles and System Mode

Insight™ has pre-programmed parameter sets that can be used when certain geometric features, functional results, or aesthetic effects are required. These build styles consist of Part Interior Style, Visible Surface Style, Support Styles, and System Mode.

5.4.1 Part Interior Style

Part interior styles consist of Solid (default), Sparse, and Double Dense Sparse.
Type 1 material shall be built using Solid Part Interior Style.
NOTE: Utilizing "Sparse Fill" or "Sparse Double Dense" will disallow the use of the reported test data from solid fill samples.

5.4.2 Solid

Type 1 material shall be built using a single outer contour and -45/+45 raster pattern.
NOTE: The rasters and contours are controlled by multiple variables, some of which can be changed to improve build and part quality through improved microstructure and decreased porosity of fill per Section 6. Example of how contour, raster, and build orientation interact is shown below in Figure 1.

Figure 1. The internal structure that is formed through raster to raster and raster to contour interactions as a function of cross section and build orientation.

5.4.3 Sparse

The default cell size for materials should not be expanded as the material will no longer stay in the x-y plane as it will still be molten while trying to bridge the expanded gap. The rasters alternate so as to create a lattice structure with gaps every other layer. This infill style provides adequate structural support to maintain final part geometry, but is not intended as a mechanically robust feature.

5.4.4 Sparse Double Dense

Sparse Double Dense mode contains a sparse pattern that no longer alternates every layer; both the original raster angle and its 90° variant are extruded on every single layer, this mode uses more material than standard sparse mode and has the potential for increased strength compared to standard sparse mode.

5.4.5 Visible Surface Style

Changing the contour and raster definitions only on the visible layers is an option to increase the aesthetic appearance of parts. These settings, please select Normal for coupon printing, should not be touched unless specific drawing callouts and expert Insight™ training has been approved as there is a high possibility of adversely affecting the mechanical properties.

5.4.6 Support Style

Type 1 material shall be built using Sparse Support and is default as Sparse per Section 5.4.3.

5.4.7 Stabilizer Walls

Stabilizer walls are a method of building tall, thin parts without the use of Support material but may still require anchoring to ensure successful build. For Type 1 Material that has an aspect ratio of greater than 3:1 the following settings will be used:

- Three points of contact, outer two points shall be close to the edges of the coupons, the inner point shall be within the gage section shall be used along.
- Stabilizer walls are placed on parts before including any processing supports when setting up inside INSIGHT.
- 0.5 inch separation. (applicable for all coupons with 0.5-0.75 inch tab width)
- Check flat back option on stabilizer wall settings.
- Wall penetration shall be -0.0050in
  NOTE: Non-contact gap can be increased on specimens printed in ZX-45 and do not have stabilizer walls contacting the base of the specimen at the start of the build layer

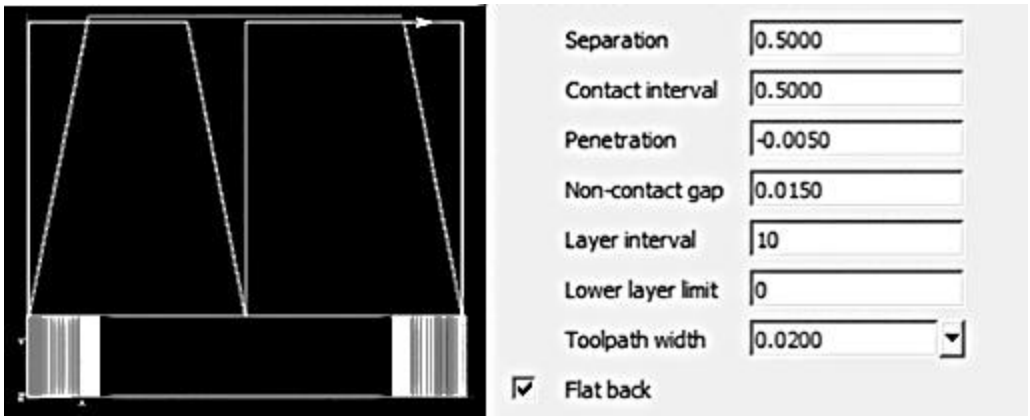


Figure 2 Example of stabilizer wall and settings used in Insight for Type 1 Material.

5.4.8 Controller Software Parameters

Controller Software has a release version designation that must be recorded and maintained in accordance with the user's designated Job Tracking system for Type 1 material. Version installed on the machine will match the version called on in Table 2 of Section 5. Change notification documents for updates to be provided and validated by Stratasys.

6. Materials Control

6.1 Deliverable Material

a) All parts using Type 1 material to be fabricated with Stratasys F900 Antero(R) 840CN03 material (Part Number 355-02510).
b) Filament must be converted in compliance with NMS Filament Specification (NMS

840 and NMS 840/1) from an approved source.

6.2 Consumable and Expendable Materials

Consumable and expendable materials are necessary for part production and shall not be part of bill of material (BOM) or will be used in the part assembly.

6.3 Support Material

a) Antero Support, SUP8000B – Part Number 355-03260 is the only approved support material to be used with Antero® 840CN03 and shall be removed per Section 7.4. The material shall use T20F tips.
b) The support material shall not permanently adhere to the final deliverable part. Moreover, it shall not adversely affect or contaminate the finished product. The removal should be secured by a visible inspection per Section 8.4

6.4 Miscellaneous Contact Materials

a) Build sheets – Only Stratasys part number 325-00475 or 325-00475-S, High Temp Build Sheets shall be used; Re-use of build sheets is not allowed for Type 1 Material.
b) Gloves and other PPE for handling parts, tools for support removal, shall be utilized as required when handling the build sheets.

6.5 Material Receiving Inspection

a) Stratasys shall provide a filament Certificate of Acceptance document (SSYS 410518-0001) for each Stratasys Filament Lot of material for pull force, moisture content, melt flow rate, average filament diameter, max filament ovality, surface resistivity, flaw diameter, and DSC.
b) Stratasys shall provide a resin Certificate of Acceptance (SSYS 413054-0001) for each Raw Resin Batch or Lot in conformance with SSYS 410495-0001.
c) Document Stratasys Filament Lot#, Raw Resin Batch#, and per user's designated Job Tracking system.
d) As printed specimen need to be performed as part of lot acceptance, recording thickness, and as printed Tension, Compression, and Flex in conformance with NMS 840 and NMS 840/1.

NOTE: Additional drying must be conducted prior to loading into the printer per Section 7.1

6.6 Material Storage Control

NOTE: All requirements in this section apply to both Type 1, Deliverable Material and Support Material.

Storage area conditions shall maintain a temperature between 13°C - 24°C (55°F - 75°F) and a relative humidity of 0% - 60%. If conditions exceed requirements, materials shall be tested for moisture content per ASTM D7191 and dried per Section 7.1 prior to use.

FDM Materials, including Type 1 and support material, shall be stored unopened in the

original canisters until ready for installation and use in the FDM System in accordance to Section 4. Operating the System > Material, Canisters, and Liquefier Tips (SSYS 402737-0001). Filament canisters shall be properly stored per manufacturer'-s recommendations at 13°C - 24°C (55°F - 75°F) and 60% maximum relative humidity.

a) First time used canisters do not need to be dried unless an issue was found. If issue was found with seal the material shall be dried per Section 7.1 drying time and conditions shall be recorded per user's designated Job Tracking system.

NOTE: NMS 840 adheres to a moisture content reading equal to or less than 0.04% as a specification limit for shipping material.

Table 3. In-Process Canister Requirements

Properties	Test Method	Unit	Requirements
Pull force	-	lbs	NMS 840/1
Moisture	ASTM D7191	%	NMS 840/1
Melt Flow	ASTM D1238	g/10 min	NMS 840/1

b) Opened, partially used canisters shall be sealed by retracting all filament material and returning the stopper to prevent moisture absorption and can be stored with unopened canisters.
c) Opened, partially used canisters can be stored for 36 months from date of manufacture after opening provided the factory seals and caps are returned to place after use.
d) Opened, partially used canisters that have been stored at ambient laboratory conditions for longer than 12 hours shall be tested for moisture content per Section 7.1d and 7.1e and dried per Section 7.1f if moisture exceeds the above specified moisture values.

7. Build Process

7.1 Start-up

a) Control Center: Parts must stay in the same location as set by control center, no part relocation is acceptable. If a part is moved by the operator the job must be restarted so that the part is re-centered to the original location.
NOTE: Machine User Interface part relocation may also be disabled per Section 4: Operating the System > Touchscreen Navigation > System Defaults (Figure 4-7 of SSYS 402737-0001).
b) Machine heat up time and stabilization must be at minimum the time prompted by the machine for each material set, these times are also listed in Table 2-6 of SSYS 402737-0001. If minimum heat up time is not met prior to starting the job, the job must be canceled, and the machine must be allowed to heat up to the minimum time for specified material combination.
c) The oven plane temperature shall be stabilized to a set point of 155°C (311°F) with

an acceptable range of 15°C (60°F) when measured at the back left and front right location.

d) Deliverable, Type 1 Material shall have a moisture content less than 0.04% when tested per ASTM D7191 prior to loading. If material moisture content does not meet this criterion the material will be re-dried per Section 7.1f and retested. If canister fails a second time, material shall be rejected and dispositioned by a cognizant engineering authority.
e) Support Material shall have a moisture content of less than 0.09% when tested per ASTM D7191 prior to loading. If material moisture content does not meet this criterion the material will be re-dried per Section 7.1f and retested. If canister fails a second time, material shall be rejected and dispositioned by a cognizant engineering authority.
f) Material preparation must be conducted within the following limits.
    a. Remove the top cap from the canister
    b. Vacuum oven temperature must be 70°C ± 7°C (154.4°F ± 18°F).
    c. Canister shall be positioned upright in vacuum oven once oven has reached set point temperature
    d. Material must be dried in oven for a minimum of 12hr.
g) Machine Readiness values fall within the following limits, as recorded in the user's preferred scheduled maintenance documentation within the past annual quarter, or since machine modification as described in section 4.2. If there is no record that meets these criteria, then Machine Readiness checks shall be performed prior to printing. ***NOTE:*** *This check is only to validate that a calibration, PM, or checklist has been completed within the last quarter and that the values below are within the specified limits.*
    a. A dryer check must have been performed after the most recent Quarterly PM and before fabrication and marked as completed per the user's preferred scheduled maintenance documentation.
        i. Record manometer PSI-G reading per user's designated Job Tracking system.
        ii. Dewpoint meter shall be less than or equal to -50°C (-58°F) using (Vaisala DM70 or equivalent) as measured at the head
        iii. Record value per user's designated Job Tracking system.
    b. A head motor test must have been performed after the most recent Stratasys Service performed PM, before fabrication and marked as completed per user's designated Job Tracking system.
        i. Torque values for the following error test results must be less than 5% of full torque (which reads as 0.5) with NO filament present.
        ii. Record value in torque values per user's designated Job Tracking.
    c. A tip ramp-up test must have been performed after the most recent Stratasys Service performed PM, before fabrication and marked as completed per user's designated Job Tracking system.
        i. Tip ramp-up results from 200°C (392°F) to 300°C (572°F) shall take less than 55 sec for Model tip.
        ii. Tip ramp-up results from 200°C (392°F) to 300°C (572°F) shall take less than 55 sec for Support tip
        iii. Record liquefier heat up time value per user's designated Job Tracking system.

d. Liquefier Heater Gradient Check
    i. Model liquefier temperature shall be 390°C - 425°C when stabilized at the 400°C setpoint as measured with calibrated Stratasys thermocouple (P/N 403610-0001 or P/N 410730-0001) installed as a tip.
    ii. Support liquefier temperature shall be 345°C - 385°C when stabilized at the 360°C setpoint as measured with calibrated Stratasys thermocouple (P/N 403610-0001 or P/N 410730-0001) installed as a tip.
e. Oven Temperature Check
    i. The oven temperature shall exceed 145°C as measured approximately one inch above the Back-Left corner of the platen while the platen is at Z=2 location.
    ii. The oven temperature shall vary by no more than 15°C between points located approximately 1 inch above the Back-Left corner, Center, and Front-Right corner of the platen while the platen is at the Z=2 location.
f. Density of 1 x 1 x 0.25 in Rectangular Prism
    i. Five solid-fill of 1 x 1 x 0.25 in Rectangular Prisms of 0.25 cubic inch in volume shall be printed and weighed. The average weight of the rectangular prisms shall be greater than 5.0g. This is to ensure that the volumetric flow rate of the machine, material, and tip is correct. This is to be done as part of the machine setup sequence and is not a part print or coupon print.

h) Material must be sufficient to complete the entire build without enabling the FDM System automated “material change-over” procedure to occur. If material quantity is insufficient, the canister must be replaced with a canister that can meet this criterion, that has been dried per Section 7.1.
i) Tip life must be sufficient to complete the build and stay under the maximum allowed tip material volume consumption of 368 in^3 (equivalent of 4 full canisters). If tip life is not sufficient, tip must be replaced with a tip per approved procedures (see Section 4: SSYS 402737-0001) as tips cannot be replaced during a part build.
j) Material loading must be conducted in accordance with the procedure outlined in the Changing Tips or material type per Section 4: Operating the System of SSYS 402737-0001. If material loading procedure is not followed material must be removed and reloaded in accordance with the procedure per Section 4: Operating the System > Unloading Material from the Liquefier Tips in SSYS 402737-0001.
k) Material build sheets described in Section 6.4a shall be placed on the platen to achieve vacuum.
l) The vacuum light must illuminate green to indicate acceptable vacuum before the job is started.
m) The purge bucket must be emptied prior to starting the build. Failure to empty the purge bucket shall not fail a build unless an overflow of the purge bucket occurs during the build.
n) The tip calibration procedure must be conducted per Section 5: Calibration > Adjusting XYZ Calibration Offsets for Controller Software version 3.31 and later per the requirements listed in SYSS 402737-0001.
    a. Tip offset values must be adjusted until the support toolpath is centered between all X and Y zero indicators. Failure to achieve this calibration shall result in replacement of tips. If second set of tips fails to meet this criterion, contact Stratasys Field Service representative.

b. Z box support layer thickness must measure within ±0.0005 in (0.01mm) of the slice height (0.0100 in). Failure to achieve this calibration shall result in replacement of tips. If second set of tips fails to meet this criterion, contact Stratasys Field Service representative.

o) The health monitoring light pole must be green prior to starting the build. If the light pole is not green, follow machine touchscreen prompts to address the issue. If issue is not resolved by touchscreen prompts, contact Stratasys Field Service representative.

7.2 Fabrication

a) Prior to build removal confirm the build is a 100% complete via touching the machine display screen. Builds removed prior 100% completion will be invalidated.
b) Builds will not contain any part failures regardless of location within the build. Builds with this incident shall result in disposition by user designated cognitive engineering authority.
c) Builds will not encounter a resume status at any point throughout the build. Builds with this incident shall result in disposition by user designated cognitive engineering authority.
d) Builds will not encounter any system errors at any point throughout the build. Builds with a system incident shall result in disposition by user designated cognitive engineering authority.

7.3 Part Removal

a) Vacuum must be shut off from the display screen prior to removing the part and build sheet from the machine. Failure to shut off Vacuum prior to part removal shall not fail build unless part is deformed or damaged during process.
b) Parts shall be removed at a minimum of 30 minutes after the platen has reached its end of the build position and can be left in the build chamber for up to 48hrs.
c) Parts shall be removed from build sheet prior to reaching room temperature.
d) Parts shall be removed manually from build sheet without the use of tools directly contacting the parts.

CAUTION: Care should be taken on fine feature geometries to not distort parts on removal.

NOTE: Wear heat resistant glove and proper PPE while removing parts and build sheet from platen and until parts have cooled to room temperature.

7.4 Support Removal

a) Remove build sheet with part attached from oven prior to separating part from build sheet. If part delaminates from build sheet during removal from oven the build shall not be rejected.
b) Support removal should be conducted while parts are between 32-71°C (90-160°F) and support can be easily removed without damaging the part.
c) In the case where support removal cannot be completed prior to part cool down,

reheat parts in an oven at 55-80°C (130-175°F) until they reach oven temperature and supports can again be easily removed.

a. Parts may not exceed a 2 hour out of oven limit while the support removal procedure is still being conducted. This is for coupon removal and no coupons should require more than the 2 hour limit.

NOTE: Wear heat resistant glove and eye protection while attempting to remove support from parts.

d) As necessary, use needle nose pliers, probes, knife, or a pick to remove the support material from the part.

CAUTION: care must be taken when removing support to prevent breaking of small features and gauging of part

NOTE: Use special care when removing support material from thin sections of the part, as to not puncture the part.

e) Remove support using a generally flat work surface.
f) **NOTE:** All rework shall be documented in the production routing prior to being started.

7.5 Fabricated Parts Identification & Storage

a) Completed parts are compatible with all major inks and markers and can be directly labeled once cooled.
b) Parts shall be stored immediately, after support material removal and inspection in a sealed bag, at temperatures between 60°F and 95°F.
c) Sealed bags should be properly labeled according to user's preferred part identification methods. Parts in bags with no label shall be dispositioned by user designated cognitive engineering authority.

8. Inspection Control

8.1 General

Quality Assurance must insure that the FDM System is adequately controlled to consistently produce quality parts that meet the requirements of this specification.

8.2 Quality Testing & Control

Type 1 material shall be inspected in accordance with this specification.

- All requirements of the applicable Engineering Drawing shall be met.
- All non-conforming conditions shall be submitted on the appropriate rejection documentation.
- All parts shall be individually weighed, and part weight should be recorded per user's designated Job Tracking system.

8.3 Dimensional Inspection

Dimensional requirements are specified on the engineering drawing. Parts produced by the FDM process in the as built condition, would be limited to the accuracy defined below. Accuracy greater than those specified below may require additional post processing to achieve. To remove any thermal effects, dimensional inspections should occur at room temperature after the part has been removed and any support material removed:

Highest Accuracy:	± 0.005 inch or ± 0.0015 inch / inch (Whichever is greater (reference only))
Minimum Wall Thickness:	0.020 inch (reference only)
Layer Thickness:	0.010 inch (nominal)
Profile Tolerance:	0.030 inch (reference only)
Geometric Tolerance:	ANSI Y14.5M.
Raster orientation:	Must be +/- 45° (for coupons)

8.4 Visual Inspection

8.4.1 Typical Acceptable Anomalies

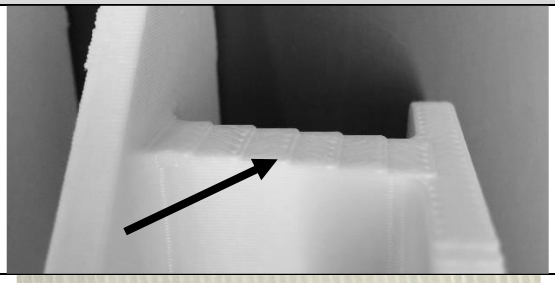
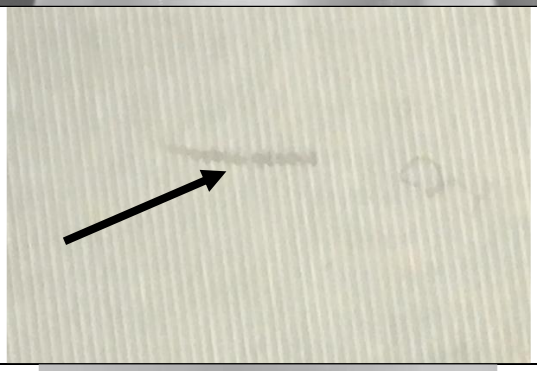
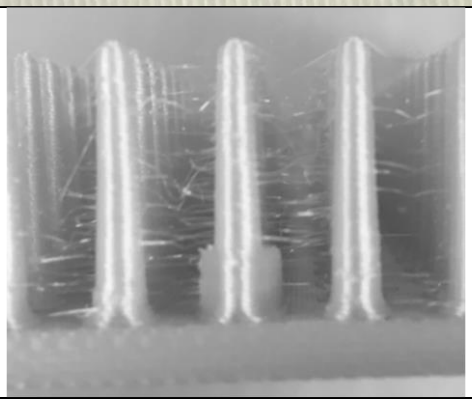
The following anomalies are inherent to the FDM process, are deemed aesthetic, and are acceptable to the extent specified herein.

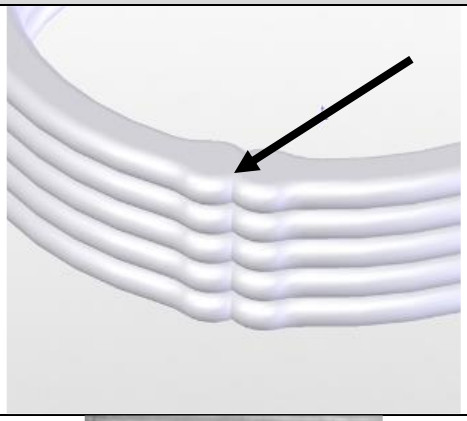
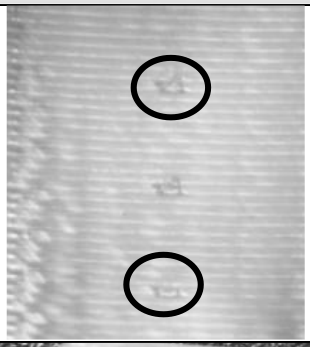
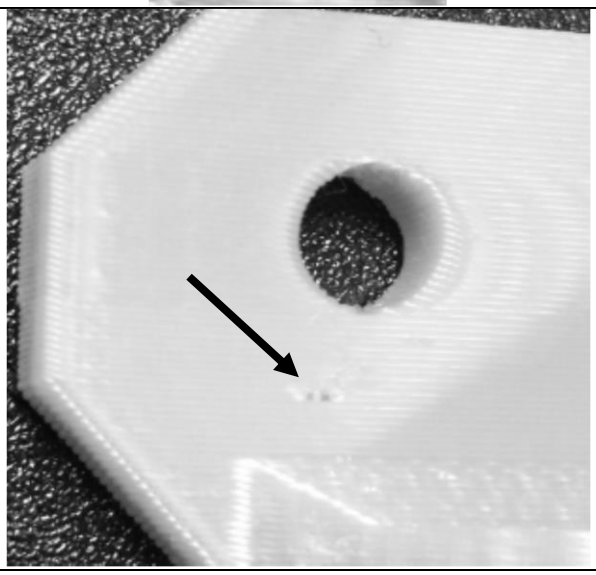
Table 4. Common Anomalies Inherent to FDM Process

Anomalies	Definition	Allowable Limit
Porosity	Incomplete part fill inherent to the process due to FDM bead microstructure gaps.	Acceptable levels are determined by the tuning process of the material, deviations from the tuning process are captured in other defect descriptions
Stairstepping	Visible, perceptible lines or ridges between successive build layers that are typical on highly curved surfaces.	Ridges should not be greater than the height of the deposition slice for the appropriate tip
Scratches	Shallow cut or scrape on the surface of a part occurring from routine handling, such as support removal.	Scratches shall not be greater than 2mm^2 in surface area or greater than one layer deep
Stringing	Short/thin lengths of filament that protrude from the part surface due to residual melted extrudate being drawn away from the part as if a string.	Hairs of 0.2mm that can be removed without damaging the surface of the part
Seams	The start/stop location of a build contour layer.	Seams are inherent to FDM builds and are acceptable, as long as the seam does not expose or extend 25% of the layer height.
Color Striation	Gradual change from dark to light color	Pigmentation is allowed as long as color does not display dark brown or black which is an indication of burnt material

Anomalies	Definition	Allowable Limit
Stabilizer wall indentions	Repeated pattern of pox marks on the outer 1/3rd of a contour that is in contact with a stabilizer wall	Stabilizer walls shall not penetrate through the exterior contour it is connected to at any point on the part.
Pin holes	Small divot in surface caused by removal of support structure, typically seen around vertical holes	Must be smaller than 2mm^2

Table 5. Representative Examples of Acceptable Anomalies

Anomalies	Picture / Figure
Stairstepping	
Scratches	
Stringing	

Anomalies	Picture / Figure
Seams	
Stabilizer wall indentions	
Pin holes	

8.4.2 Unacceptable Defects

Parts with the following part defects shall be rejected and dispositioned by user designated authority.

Table 6. List of Part Defects

Defect	Definition
Sink	Thin vertical wall pulls in just below horizontal stiffener, causing a deviation in dimensions greater than 1% for verticality
Start/Stop Error	Machine triggers an error that causes the build to pause or stop
Burn	Discoloration seen as dark brown or black color change to the material, can be in streaks or sections of beads that are greater than 0.08mm^2
Embedded Support	Excess support in model material leaving discoloration
Crack	Sharp break in a feature
Delamination	Separation from two model layers
Warpage	Deformation of features due thermal mass and residual stress build up causing failures in meeting tolerances required for the part
Curl	Deformation of features and surfaces due to excessive part shrinkage (can cause delamination from support interface, greater than 0.5 mm/250 mm
Overfill	Excessive material deposition causing bead structure disruption, visible globs of material and loss of definition to bead cross section circularity
Heavy Seams	Seams in excess of 3mm. greater than bead width
Vertical Surface Uniformity	Waviness of vertical wall over multiple layers, a function of gantry repeatability, oven temp and Z stage consistency, in which the stacking of layers are inconsistent and result in a toolpath greater than 1500 micro-in RA
Under-fill	Gaps between adjacent rasters particularly in the raster straightaways. This is a result of under-extrusion and would cause a decrease in part mass. This can be verified by printing density samples confirming mass output.
Purge Blobs	Extrusion from a purge gets redistributed and embedded into a part inclusion for the purge part

9. Retention of Qualification

The Qualification of Type 1 material was based on the system and processes outlined within this specification. Any changes to the material, machine, software including physical location is considered to be a change to the process. All changes to the system shall be submitted to the cognizant design authority for review and disposition via Advanced Change Notice (ACN).

It is up to the manufacturer to maintain the system to the requirements outlined in the Maintenance manual. Any deviation to the prescribed maintenance shall be considered as a non-conformance and shall be dispositioned by the cognizant design authority. Repair, as defined by any action not outlined in the maintenance manual for normal maintenance, shall be considered to be a change to the system and submitted to the cognizant design authority for review and disposition.

10. Quality Assurance

10.1 Process Control

In-process monitoring data should be in accordance with user's applicable company process specification or an approved shop practice. For material qualification and equivalency purposes, the in-process monitoring data should be provided to the appropriate organizations in accordance with the applicable test plan. Process control testing is not required for the fabrication of finished parts.

10.2 Visual Inspection

Verify that there are no obvious defects such as warpage, dry spots, etc. Finished products for material and additional machine qualification purposes must be labeled in accordance with the applicable test plan for identification purposes.

10.3 NDI Testing

An NDI procedure has yet to be developed for additively manufactured polymer materials that is both time and cost effective for the material qualification and part build level. At this time the industry standard is to use a rigorous visual and dimensional inspection process of the additively manufactured coupons or parts.

11. Shipping

For material qualification and equivalency purposes, it may be necessary to send the finished parts to a designated test lab as specified in the applicable test plan. The finished parts shipping instruction should also be included in the applicable test plan.