CMH-17
COMPOSITE MATERIALS HANDBOOK

# Feedstock Material Standardization

**Presented to:** America Makes and ANSI Additive Manufacturing Standardization Collaborative (AMSC) *Current and Future Landscape for Additive Manufacturing (AM) Feedstock/Precursor Materials Standardization*

Session 1: Presentations on Industry Standards and Guidance Documents

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On behalf of CMH-17

# Outline

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- FAA Requirements for Material Control
  - Importance of Stable Materials
  - Regulatory Framework
- CMH-17 Activities
- Composite Material Control Methods
- AM Material Control Methods

# FAA Requirements

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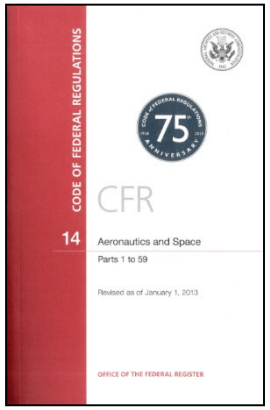
- Regardless of material or process, some fundamental regulations always apply to civil aviation products and articles

**§21.31 Type design.**

The type design consists of—

(a) The drawings and specifications, and a listing of those drawings and specifications, necessary to define the configuration and the design features of the product shown to comply with the requirements of that part of this subchapter applicable to the product;

(b) Information on dimensions, materials, and processes necessary to define the structural strength of the product;



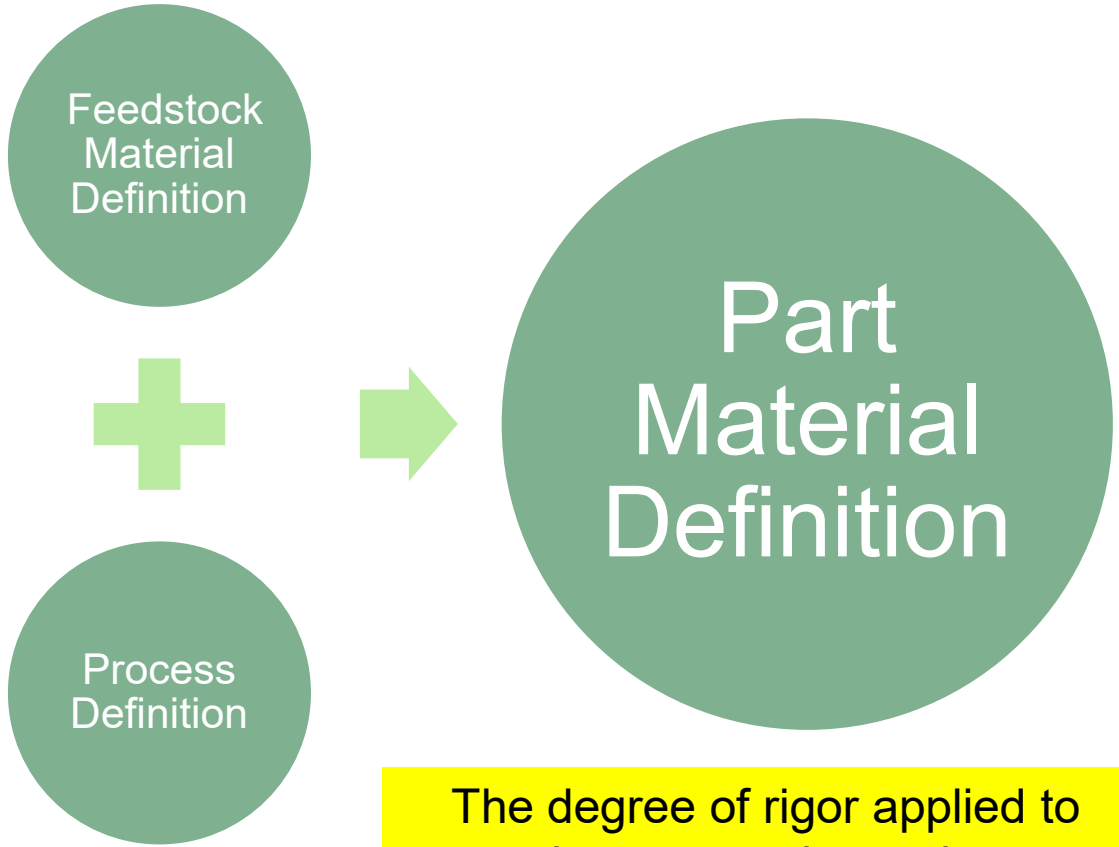

**§25.603 Materials.**
The suitability and durability of materials used for parts, the failure of which could adversely affect safety, must—
(a) Be established on the basis of experience or tests;
(b) Conform to approved specifications (such as industry or military specifications, or Technical Standard Orders) that ensure their having the strength and other properties assumed in the design data; and
(c) Take into account the effects of environmental conditions, such as temperature and humidity, expected in service.

- In short, material and process definition is part of the type design of an aircraft, engine, or propeller, and must be certified and approved the same as any other design feature
  - Could be in the form of a specification and/or process control document (PCD), instructions on a drawing, or other documentation, as long as all necessary information is documented

- In addition to the general requirement to adequately define the design to ensure it meets the airworthiness regulations (for strength, performance, etc.), there are specific rules for the various products that focus on material control, process control, and design values

# FAA Regulatory Requirements for M&P Control

- **Three items to define and control:**
  1. Feedstock material
     - For composites, this is more than just laminate materials – also core, adhesive, and non-fly away materials
     - For AM, this includes reuse methods, but may also include build plate and support materials
  2. Process to convert to a part
  3. Final part material
     - ***<u>This is what regulations control</u>***
     - Ensure required chemical, physical and mechanical properties are achieved




The degree of rigor applied to these controls can be commensurate with the criticality of the applications

# Importance of Stable Materials

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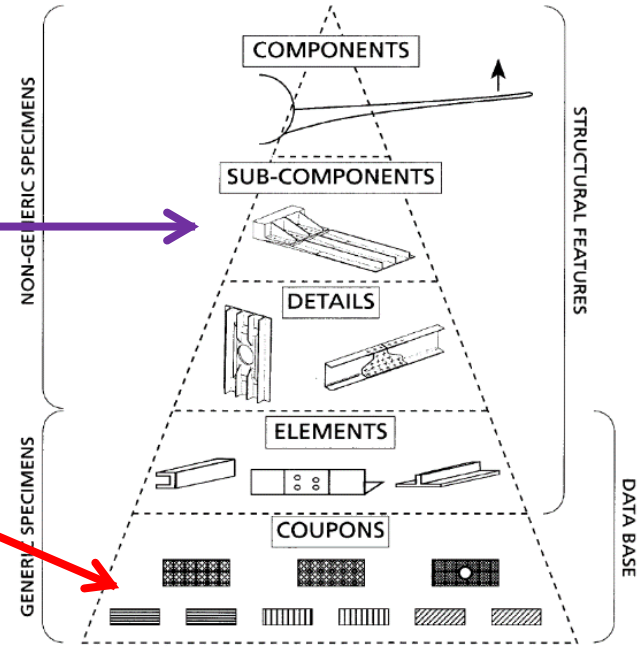
- **The importance of adequate M&P control cannot be overstated**
  - You cannot certify a product if the final product isn't stable
  - Always requires a stable uncured / feedstock material
- **Design Values**
  - Design values must be derived from stable materials and processes

Equivalency testing required to "buy into" a published composite material database – spec minimums are insufficient

**Stable Materials are the Foundation for successful advanced M&P applications**

Having a stable manufacturing process is required to make the more complex testing relevant to the final product.

For the building block approach to be viable the materials which form the base must be stable.




Information on the building block and equivalency testing can be found in CMH-17 Volume 3

# Material and Process Control

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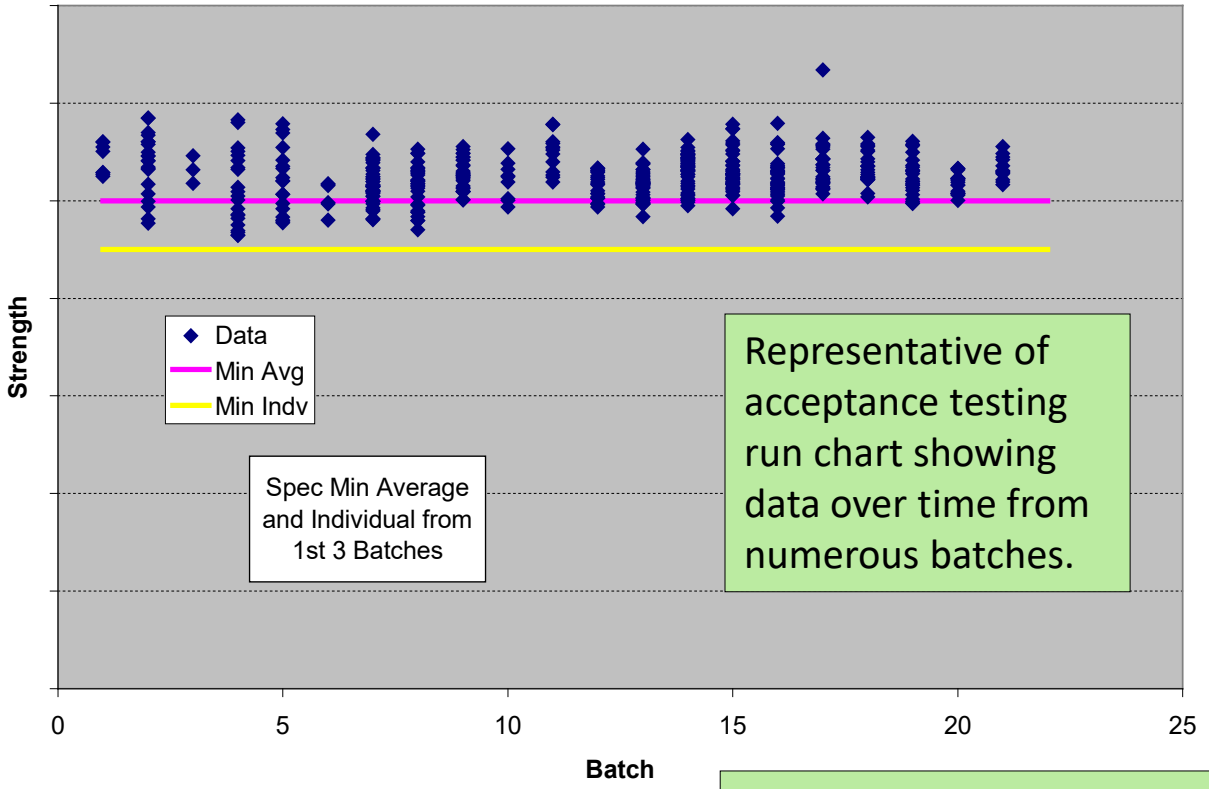
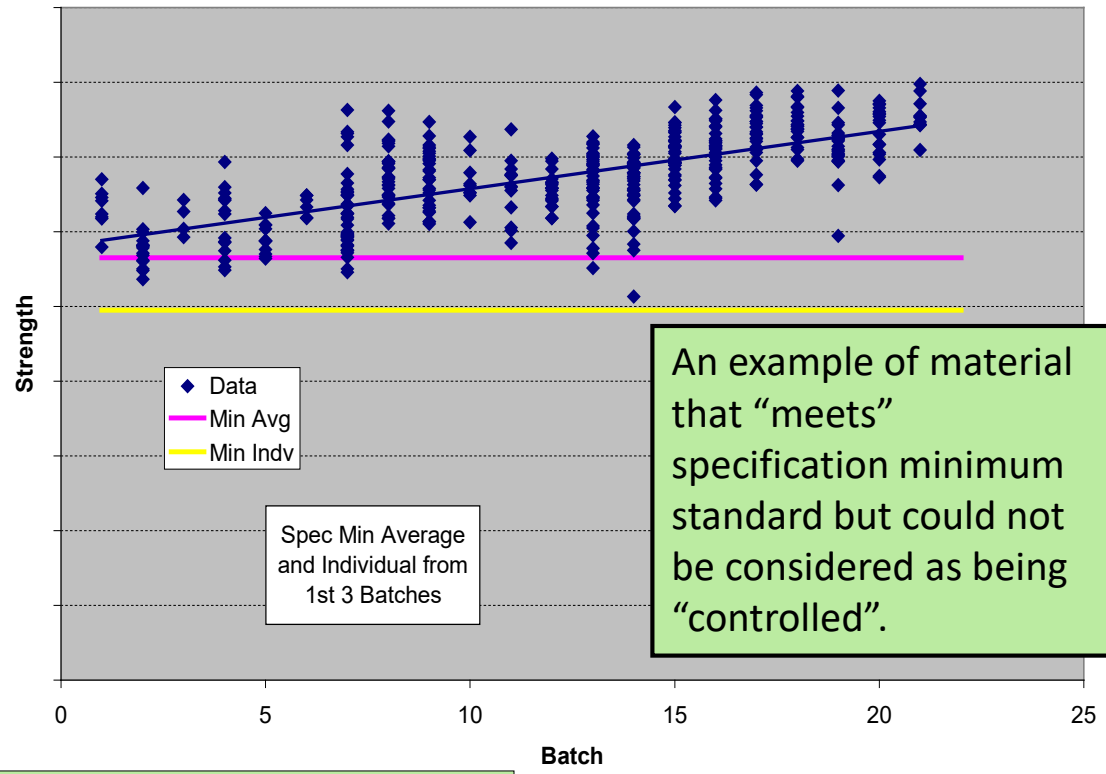
## Example of Controlled Materials




Representative of acceptance testing run chart showing data over time from numerous batches.

## Is this a stable material property?




An example of material that "meets" specification minimum standard but could not be considered as being "controlled".

When controlling composite materials, we typically have spec minimums for strength, and both lower and upper bounds on modulus

# Regulatory Framework

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- OMB Circular A-119 Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities
  - Establishes policy guidelines on implementation
    - *"all Federal agencies **must use voluntary consensus standards in lieu of government-unique standards in their procurement and regulatory activities**, except where inconsistent with law or otherwise impractical."*
    - Requires reporting to NIST/OMB *"where an agency elects to use or develop a government-unique standard in lieu of using a voluntary consensus standard"*
- From FAA Reauthorization Act of 2018
  - SEC. 329. PERFORMANCE-BASED STANDARDS. The Administrator shall, to the maximum extent possible and consistent with Federal law, and based on input by the public, ensure that regulations, guidance, and policies issued by the FAA on and after the date of enactment of this Act are issued in the form of performance-based standards, providing an equal or higher level of safety.

***Take-Away:***
*Minimal FAA Guidance Forthcoming – Need Industry Stds*

# CMH-17 Handbook

- Volume 1 Polymer Matrix Composites: *Guidelines for Characterization of Structural Materials*
- Volume 2 Polymer Matrix Composites: *Material Properties*
- Volume 3 Polymer Matrix Composites: *Materials Usage, Design and Analysis*
- Volume 4 Metal Matrix Composites
- Volume 5 Ceramic Matrix Composites
- Volume 6 Structural Sandwich Composites (Initial Release)
- Volume 7 Additive Manufacturing (Forthcoming)


**http://store.sae.org/cmh-17/**

# CMH-17 Goals

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- The handbook has three goals/purposes:
  1. Provide material data
     - Physical and mechanical properties
     - Tied to a single material specification AND a single process specification (published elsewhere, but publically available)
  2. Describe how to generate material data
     - Material and process control
     - Test matrices
     - Statistical methods
  3. Describe how to use material data
     - Design guide based on:
       - Proven methods / best practices
       - Includes information on manufacturing and maintenance

*The handbook itself does not publish specifications, but has guidelines on what information should be included in specifications, minimum requirements for material data submission, and best practices for use of composite and non-metallic AM materials*

# Composite Feedstock (Raw Material) Control



- Composite Material Specifications are typically set up so that a single document controls both the raw (uncured) / feedstock material *and* the processed material
  - Controls Chemical, Physical, and sometimes Mechanical Properties of the raw/feedstock material
  - Controls Chemical, Physical, and Mechanical Properties of the processed material
  - Tied to a set of process instructions
  - Same feedstock material could be cured different ways and have multiple sets of material data



Reference
DOT/FAA/AR-02/109

# Composite Feedstock (Raw Material) Control

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- Raw composite material forms are controlled at a combined level (e.g., prepreg), but they also must have control at the component level (e.g. fiber, fabric, and resin)
- Several fiber and fabric reinforcement standards exist and are referenced in composite material specifications
- Resin specifications are nearly non-existent, but may be part of a prepreg specification
  - Resin formulation is proprietary and generally governed by a PCD referenced in the composite specification
  - **Note Composite PCD use is different than AM PCD**

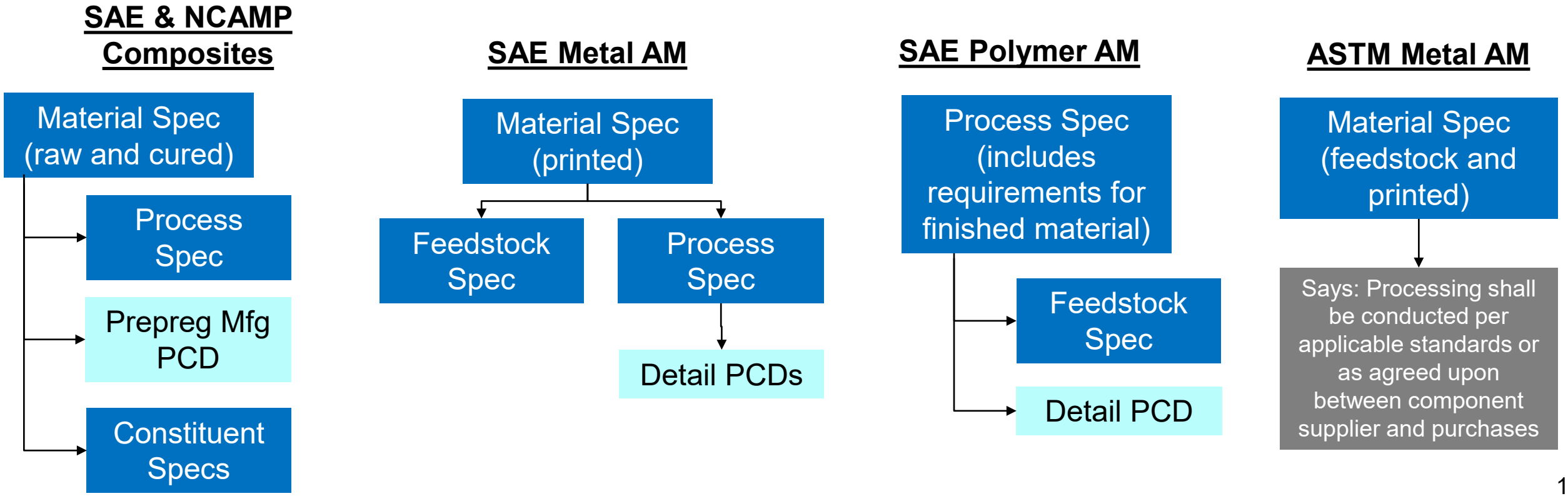
*6.2.2.1 Process control documents (PCD)*

A Process Control Document (PCD) is developed by the material supplier with the material user. The PCD is used to define and control the raw materials used to fabricate a composite material, the processes and equipment used to fabricate the material, and the test methods used to assure the material supplier and the customer that a given batch is comparable to the material originally qualified. The PCD is commonly held at the material supplier's facility but is approved by the material user. A separate PCD is typically used for each specification a given material is manufactured to. The PCD establishes the systems that will be used to control the material, and the approval process necessary if a change is necessary. Guideline for PCD creation for a prepreg material are contained in NCAMP Document No.: NRP 101, "Prepreg Process Control Document (PCD) Preparation Guide."

Reference CMH-17 Rev G Volume 3

# AM Feedstock Control

- AM Specifications are typically using different structures than composites where the feedstock is controlled in a different specification than finished/printed material
  - Published AM specifications found in SAE, ASTM and NCAMP



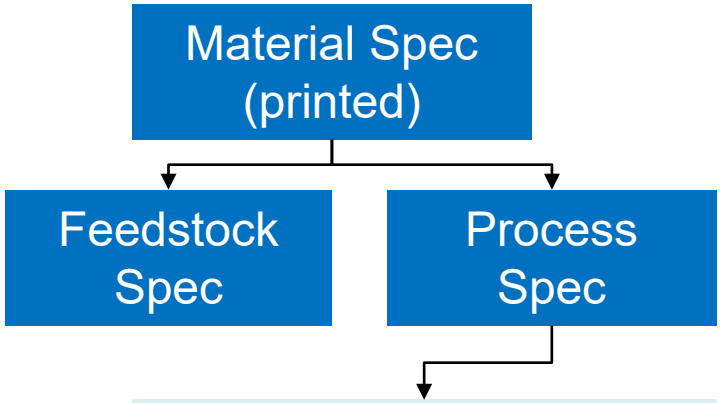
# AM Feedstock Control



- Regulatory speaking, any specification structure is acceptable as long as it controls the required information
- Advantage to controlling feedstock separately is the potential to make it a commodity, even if the printed material isn't one
- Methods of controlling **material reuse** (e.g., recycled powder) are **not yet standardized**
  - Can be controlled by number of reuses or qualify to powder specification/standard
  - Could be part of the feedstock specification, or a PCD under the process specification
  - Have to define if reused powder can only be mixed with powder from the same lot, or if lots can be mixed

# AM Powder Reuse

- One method – reuse within a single lot only




Reuse PCD

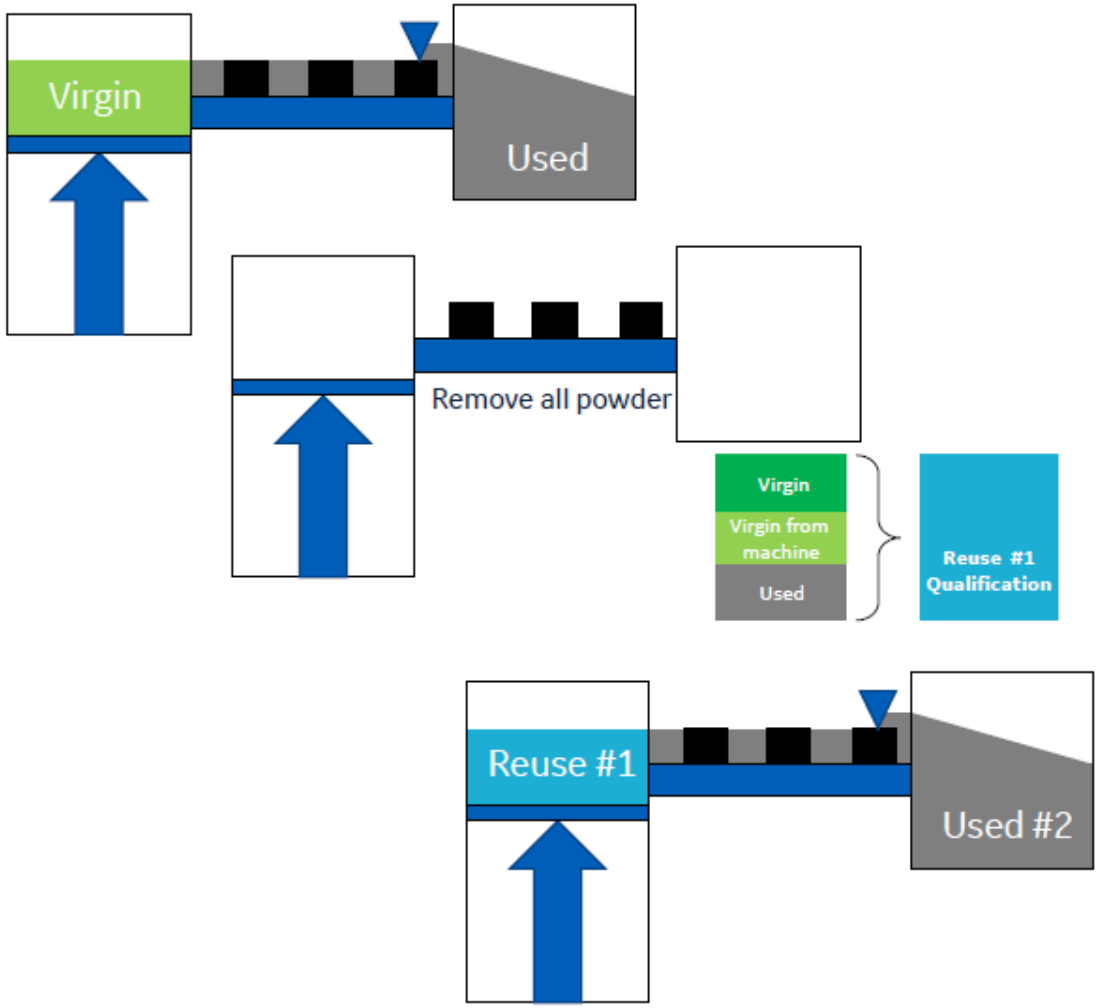
- Virgin Powder Spec
- Virgin Material Spec

PCD references

- Allowable & Design Value Equivalency

PCD sets standards

- Each reuse qualified → PCD defines process




| Powder Spec Comparison | SAE | ASTM | NCAMP |
|---|---|---|---|
| Chemistry | Yes | Yes | Yes |
| Manufacturing Method | Yes | | Yes |
| Particle Size Distribution | Yes | | Yes |

# Thoughts for the Future

- Feedstock materials are the easiest to make a commodity
  - Reuse has to be defined somewhere; ideally if the specification captures all key characteristics, reused powder could be evaluated against the same standard
  - Would be beneficial to standardize Heat and Lot traceability methods
  - Can we / Should we / How do we scale the degree of rigor for feedstock material control for low criticality applications?
- Industry Standards Organizations are encouraged to develop feedstock material standards that support end-state material controls
  - Standardization promotes safety
- CMH-17 is developing a new volume that will include best practice guidelines and data for controlled materials and processes
  - www.cmh17.org or email info@cmh17.org