

# MMPDS of Alloy into CADS

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Aluminum Casting Performance Initiative  
(ACPI)

AMC Technology Review

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# Overview

- **Needs and Benefits:** Develop Aluminum AMS 4215F C355-T6 data set including high temperature tensile and room temperature fracture toughness for submission into MMPDS and CADS tool, allowing DoW casting users to utilize this alloy in new parts or for optimization of existing parts.
- **Progress:** AFS Plate#1 Test casting rigging design and validation including pattern preparation; preliminary and production trials on-going at participating foundry; collected separately cast test bar data from the industry (eight foundries) and design allowable estimation per MMPDS method.
- **Transition:** Working with AFS ALM Technical committee oversight, technical publications and presentations at Technical Conferences, out-reach to member foundries by incorporating the data into MMPDS handbook and CADS tool accessible to AFS Members and DOW/DLA personnel with a link to the final report and supporting pedigree information.
- **Cost Share Proposed:** \$42,295 provided to date of \$ 300,000 proposed



# Needs

- Problem

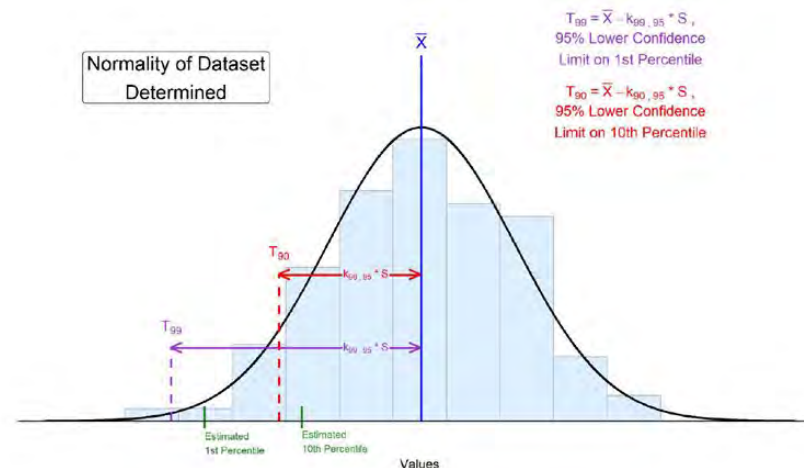
- To design, specify and utilize C355-T6 aluminum in fuel system and high temperature applications, statistical properties must be incorporated into the Metallic Materials Properties and Data Standardization Handbook (MMPDS); which is the only publicly available source in the U.S. for material allowable that the FAA generally accepts for compliance with Code of Federal Regulations (CFR) for material strength properties and design values for aircraft certification and continued airworthiness.

- Objective

- To gather separately cast data and generate room temperature properties including fracture toughness and high temperature tensile for ½” section thickness from test casting designated areas; derive statistically design allowable for incorporation into MMPDS and CADS with pedigree information such as SDAS.

- Technology

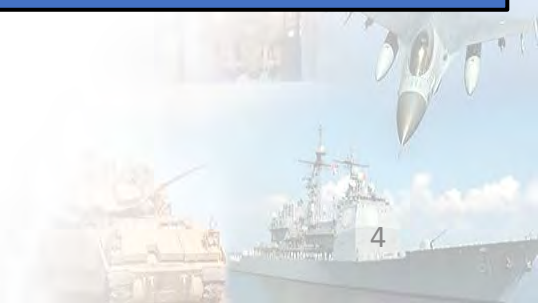
- This project will generate the properties using a third-party credited test laboratory from the test castings made by the participating AFS member foundries in multiple heats; analyze the data using MMPDS statistical method and incorporate into MMPDS Handbook and CADS (Casting Alloy Data Search) web tool.



# Benefits

- Allowing DOW/DLA/Aerospace casting users to utilize Aluminum C355-T6 aluminum alloy in new parts or for optimization of existing parts.
- Room temperature fracture toughness and elevated temperature tensile properties derived statistically using MMPDS method made available to the OEMs as well as aerospace aluminum foundries.
- Realistic optimum lightweight designs by eliminating ad-hoc casting knockdown factors; elimination of additional testing and part validations.

*“This effort which is providing statistically derived design allowable for C355-T6 aluminum sand cast alloy per AMS 4215F to OEM design engineers. This work is going to benefit the overall casting acquisition of complex fuel systems, small aircraft IC and jet engines, or other cast components requiring strength and higher temperature performance by aerospace and defense customers.”—Randy Oehrlein, VP of Technology, Carley Foundry and AFS ALM Member with multiple awards*



# Milestones/Tasks

- **Completed**

- Collection and statistical analysis of the separately cast test bar historical data from eight foundries with pedigree information.
- AFS Plate #1 Test Casting 8"x8"x0.5" Rigging design, simulation validation and pattern modifications for production trials.
- Test laboratory (Element Lab – Wixom, MI and Cincinnati, OH) work order released with test bar layout for excising from test plate..
- Finalization of elevated temperature tensile and room temperature fracture toughness testing methods with desired samples for MMPDS submission, under guidance from MMPDS Organization (managed by Battelle).

- **In Progress**

- Pre-trial at Carley Foundry, followed up with production runs.
- Testing Laboratory schedule.

- **Planned**

- Incorporate combined separately cast statistical properties into CADs with a report to individual foundries.
- Continue production trials at multiple participating foundries.
- Start testing at both the laboratory locations.
- Gather data for Meta modeling for separately cast test bar historical data and AFS Test Plate #1 casting generated data.

# Technical Progress

- Separately Cast Test Bar Historical data Collection and statistical analysis of over 6,500 heats/lots from the following foundries:
  - Carley Foundry
  - Ohio Aluminum
  - Eck Industries
  - Morris Bean & Co
  - Tampa Al and Brass Foundry
  - Boose Aluminum Foundry
  - Magellan
  - Mitchell Aerospace

**Summary of Total Eight Foundries Separately Cast Test Bar C355-T6 Properties Statistical Analysis using MMPDS Method (T99 - 1st percentile and T90 - 10th percentile)**

| Foundry           | Process  | Test Bar Gauge Dia | No. of Lots | TUS                      |      | ksi  |      | TYS |      | ksi |     | ELG  |      | %    |      | BHN  |      | Min  |      | TUS  |      |      |      | TYS  |      |      |      | % E  |      |     |     | BHN  |      |  |  |
|-------------------|--|--------------------|-------------|--------------------------|------|------|------|-----|------|-----|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|-----|------|------|--|--|
|                   |  |                    |             | T99                      | T90  | T99  | T90  | T99 | T90  | T99 | T90 | T99  | T90  | Min  | Max  | Mean | SDEV | Min  | Max  | Mean | SDEV | Min  | Max  | Mean | SDEV | Min  | Max  | Mean | SDEV | Min | Max | Mean | SDEV |  |  |
| Fdy A             | Dry Sand/NB (V)                                  | 0.5                | 1901(372)   | 38.9                     | 41.8 | 30.7 | 33   | 2.4 | 3.7  | 77  | 84  | 34.4 | 55.5 | 45.3 | 2.5  | 30.1 | 48.5 | 35.9 | 2.5  | 2    | 11.1 | 5.3  | 1.2  | 76.5 | 114  | 94   | 7.2  |      |      |     |     |      |      |  |  |
| Fdy B             | Dry Sand/NB (H)                                  | 0.5                | 2210 (2210) | 36.8                     | 37.5 | 29.6 | 30.6 | 0.5 | 1.3  | 86  | 89  | 37   | 56.5 | 40.8 | 2.73 | 30   | 47.4 | 33.3 | 2.1  | 1.1  | 5.1  | 2.3  | 0.8  | 82.6 | 109  | 93.7 | 3.2  |      |      |     |     |      |      |  |  |
| Fdy A             | Green Sand (H)                                   | 0.5                | 975 (389)   | 38                       | 41   | 29.5 | 32   | 2.4 | 3.4  | 78  | 84  | 34.2 | 53.5 | 44.6 | 2.5  | 28.7 | 48   | 35.3 | 2.4  | 2    | 7.7  | 4.9  | 1.1  | 78.7 | 104  | 92   | 5.3  |      |      |     |     |      |      |  |  |
| Fdy B             | Green Sand (H)                                   | 0.5                | 449(449)    | 35.5                     | 38.1 | 29.5 | 30.5 | 1.4 | 2.2  | 83  | 88  | 37   | 49   | 41.6 | 2.2  | 30   | 44.2 | 32.9 | 1.8  | 1.1  | 6.2  | 3    | 0.5  | 85.7 | 100  | 93.3 | 3.7  |      |      |     |     |      |      |  |  |
| Fdy A             | Sand Cast (Dry (NB) / Green Sand Combined)       | 0.5                | 2095 (672)  | 38.7                     | 41.7 | 30.3 | 32.7 | 2.5 | 3.6  | 77  | 84  | 34.2 | 55.5 | 45.1 | 2.5  | 28.7 | 48.5 | 35.7 | 2.5  | 2    | 11.1 | 5.2  | 1.2  | 76.5 | 114  | 92.8 | 6.3  |      |      |     |     |      |      |  |  |
| Fdy B             | Sand Cast (Dry (NB) / Green Sand Combined)       | 0.5                | 2661 (2661) | 36.8                     | 37.6 | 29.6 | 30.7 | 1.1 | 1.4  | 86  | 89  | 37   | 56.5 | 40.9 | 2.7  | 30   | 47.4 | 33.2 | 2.1  | 1.1  | 6.2  | 2.4  | 0.8  | 82.6 | 109  | 93.6 | 3.3  |      |      |     |     |      |      |  |  |
| Fdy A             | Permanent Mold (V)                               | 0.5                | 610 (608)   | 36.6                     | 40.3 | 31.9 | 35.2 | 1.5 | 2.9  | 72  | 77  | 36.6 | 49.7 | 44.4 | 2.6  | 29.1 | 47.8 | 38.5 | 2.2  | 2    | 7.9  | 4.6  | 1.3  | 69   | 98   | 83.8 | 4.2  |      |      |     |     |      |      |  |  |
| Fdy B             | Permanent Mold (V)                               | 0.5                | 451 (451)   | 36.4                     | 37.5 | 28.8 | 30.8 | 1   | 1.52 | 85  | 89  | 37   | 58.2 | 40.9 | 2.8  | 30.1 | 39.5 | 33.3 | 1.83 | 1.2  | 5.8  | 2.6  | 0.8  | 82.6 | 100  | 93.2 | 3.2  |      |      |     |     |      |      |  |  |
| Fdy C             | Dry Sand   | 0.5                | 604 (167)   | 44.5                     | 46.3 | 33.5 | 34.3 | 3.2 | 4.5  | 93  | 99  | 43   | 53.1 | 48.5 | 1.49 | 33.1 | 38.6 | 35.7 | 1.05 | 2.6  | 11   | 6.4  | 1.4  | 98.6 | 109  | 106  | 3.8  |      |      |     |     |      |      |  |  |
| Fdy D             | Dry Sand (Gravity) - sub-size test bar           | 0.25               | 32          | Insufficient sample size |      |      |      |     |      |     |     | 50.1 | 57.7 | 53.7 | 1.71 | 30.1 | 36.5 | 33.1 | 1.57 | 10   | 22.2 | 15.5 | 3.4  |      |      |      |      |      |      |     |     |      |      |  |  |
| Fdy D             | Dry Sand (LP)-sub-size test bar                  | 0.25               | 112 (112)   | 48                       | 51.2 | 28.6 | 31.1 | 5.5 | 10.5 |     |     | 49.3 | 58.6 | 54.3 | 1.91 | 30.1 | 38.2 | 33.7 | 1.68 | 8.1  | 20.7 | 15.1 | 2.76 |      |      |      |      |      |      |     |     |      |      |  |  |
| Fdy D             | Dry Sand (Gravity and LP Combined) - sub-size TB | 0.25               | 144(143)    | 48.4                     | 58.6 | 28.9 | 31   | 6.6 | 11   |     |     | 49.3 | 58.6 | 54.2 | 1.88 | 30.1 | 38.2 | 33.6 | 1.67 | 8.1  | 22.2 | 15.2 | 2.9  |      |      |      |      |      |      |     |     |      |      |  |  |
| Fdy E             | Dry Sand   | 0.5                | 203 (190)   | 36.6                     | 38.9 | 25.9 | 29.1 | 1.7 | 2.2  | 92  | 92  | 37.3 | 52.7 | 43.7 | 3.55 | 22.8 | 47   | 33.8 | 4.3  | 2    | 6.5  | 3.2  | 0.84 | 92.6 | 119  | 100  | 5.5  |      |      |     |     |      |      |  |  |
| Fdy F             | Dry Sand   | 0.5                | 43          | Insufficient sample size |      |      |      |     |      |     |     | 34.8 | 50.6 | 45.1 | 3.89 | 27.8 | 45.2 | 34.6 | 3.99 | 0.1  | 9.4  | 5.7  | 2    | 80   | 109  | 98.3 | 6.01 |      |      |     |     |      |      |  |  |
| Fdy G             | Dry Sand   | 0.5                | 6           | Insufficient sample size |      |      |      |     |      |     |     | 36.7 | 42.9 | 40.6 | 2.4  | 26.6 | 35.2 | 31.2 | 2.93 | 2    | 5.5  | 3.6  | 1.32 | 76   | 104  | 95   | 10.4 |      |      |     |     |      |      |  |  |
| Fdy H             | Dry Sand   | 0.5                | 19          | Insufficient sample size |      |      |      |     |      |     |     | 37.4 | 49.2 | 43.4 | 3.2  | 30   | 37.3 | 32.4 | 2.11 | 2.9  | 10.6 | 5.9  | 2.4  |      |      |      |      |      |      |     |     |      |      |  |  |
| Fdy A,B,C,E,F,G,H | Sand (Dry and green) Combined                    | 0.5                | 3905(2659)  | 35.1                     | 38.4 | 29.8 | 31.2 | 0.7 | 1.9  | 83  | 88  | 34.2 | 56.5 | 43.2 | 3.3  | 28.7 | 48.5 | 34.6 | 2.62 | 1.1  | 11.1 | 3.9  | 1.68 | 76.5 | 114  | 93.4 | 4.2  |      |      |     |     |      |      |  |  |
| Fdy A, B          | PM Combined                                      | 0.5                | 1028 (612)  | 36.1                     | 38.5 | 29.4 | 31.2 | 0.8 | 2    | 71  | 79  | 36.6 | 58.2 | 42.9 | 3.2  | 29.1 | 47.8 | 36.3 | 3.29 | 1.2  | 7.9  | 3.8  | 1.47 | 69.1 | 100  | 87.8 | 6    |      |      |     |     |      |      |  |  |

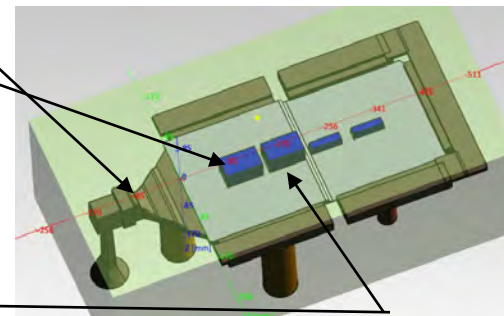
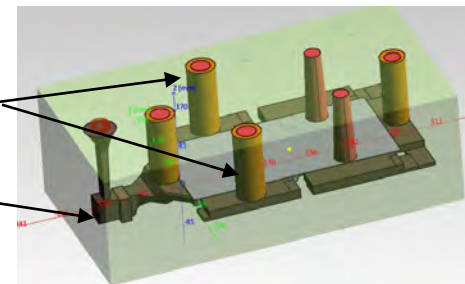
| Foundry  | Process   | Test Bar Gauge Dia | No. of Lots | TUS                      | ksi   | TYS     | ksi | ELG | %   | BHN | Min   | TUS |      |      |      | TYS  |      |      |      | % E  |     |      |      |      |
|--|---|--------------------|-------------|--------------------------|-------|---------|-----|-----|-----|-----|-------|-----|------|------|------|------|------|------|------|------|-----|------|------|------|
| <b>Summary of Cast Integral Test Bar C355-T6 Properties Statistical Analysis using MMPDS Method (T99 - 1st percentile and T90 - 10th percentile)</b> |   |                    |             |                          |       |         |     |     |     |     |       |     |      |      |      |      |      |      |      |      |     |      |      |      |
| Fdy D  | Dry Sand (Gravity) - sub-size 0.25" Cast Integral | 0.25               | 36          | Insufficient sample size |       |         |     |     |     |     |       |     | 52.2 | 56.6 | 55.2 | 1.09 | 42.5 | 46.1 | 44.6 | 0.93 | 4.1 | 9.9  | 7.3  | 1.59 |
| Fdy D  | Dry Sand (LP)-sub-size 0.25" Cast Integral        | 0.25               | 62          | Insufficient sample size |       |         |     |     |     |     |       |     | 47.6 | 57   | 54   | 1.89 | 34.1 | 38.9 | 35.6 | 1.15 | 5.2 | 19.8 | 13.4 | 3.68 |
| <b>Applicable Standards with Minimum Properties Required</b>   |   |                    |             |                          |       |         |     |     |     |     |       |     |      |      |      |      |      |      |      |      |     |      |      |      |
|  |   |                    |             | TUS, ksi                 |       | TYS ksi |     | E%  |     | BHN |       |     |      |      |      |      |      |      |      |      |     |      |      |      |
| ASTM B26 - Table 2 Properties min required in ksi or %   |   |                    |             |                          | 36.00 |         | 25  |     | 2.5 |     | NA    |     |      |      |      |      |      |      |      |      |     |      |      |      |
| AMS 4215F - Separately Cast Test Bar Properties, min in ksi or %   |   |                    |             |                          | 37.00 |         | 30  |     | 1   |     | NA    |     |      |      |      |      |      |      |      |      |     |      |      |      |
| AMS 4215F - From Casting / Cast Integral TB, min in ksi or %   |   |                    |             |                          | 35    |         | 28  |     | 2   |     | NA    |     |      |      |      |      |      |      |      |      |     |      |      |      |
| ASTM B108 - PM C355-T61 Properties - Separately Cast, min in ksi or %  |   |                    |             |                          | 40    |         | 30  |     | 3   |     | 85-90 |     |      |      |      |      |      |      |      |      |     |      |      |      |
| ASTM B108 - PM C355-T61 Properties - Casting Designated, min in ksi or %   |   |                    |             |                          | 40    |         | 30  |     | 3   |     |       |     |      |      |      |      |      |      |      |      |     |      |      |      |
| ASTM B108 - PM C355-T61 Properties - Casting Non-Designated, min in ksi or %   |   |                    |             |                          | 37    |         | 30  |     | 1   |     | 85    |     |      |      |      |      |      |      |      |      |     |      |      |      |

# • Example: Foundry A Data for Dry Sand C-355-T6

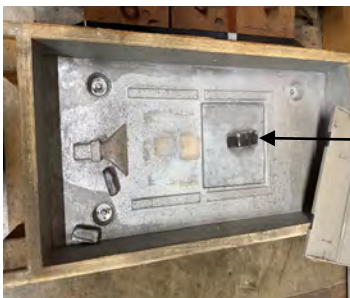
| Supplier: Alloy - Temper    | FdyB: C355 - T6   |          |                        | FdyB: C355 - T6   |          |                                   | FdyB: C355 - T6   |        |                        | FdyB: C355 - T6   |         |                        |
|-----------------------------|-------------------|----------|------------------------|-------------------|----------|-----------------------------------|-------------------|--------|------------------------|-------------------|---------|------------------------|
| Product Form                | separate TB in PM |          |                        | separate TB in PM |          |                                   | separate TB in PM |        |                        | separate TB in PM |         |                        |
| Property(Orientation)       | TUS               | (AA)     |                        | TYS               | (AA)     |                                   | ELG               | (AA)   |                        | BHN               | (AA)    |                        |
| Thickness Min / Max         | 0.5               | 0.5 in   |                        | 0.5               | 0.5 in   |                                   | 0.5               | 0.5 in |                        | 0.5               | 0.5 in  |                        |
| Sample Size                 | 451               |          |                        | 451               |          |                                   | 451               |        |                        | 451               |         |                        |
| Sample Mean                 | 40.944            | ksi      |                        | 33.305            | ksi      |                                   | 2.64              | %      |                        | 93.217            | BHN     |                        |
| Sample Std. Dev             | 2.775             | ksi      |                        | 1.83              | ksi      |                                   | 0.807             | %      |                        | 3.184             | BHN     |                        |
| Sample Skewness             | 1.407             | ksi      |                        | 0.512             | ksi      |                                   | 0.448             | %      |                        | -0.092            | BHN     |                        |
| COV                         | 6.777             | %        |                        | 5.494             | %        |                                   | 30.557            | %      |                        | 3.416             | %       |                        |
| Sample Min / Max            | 37                | 58.2 ksi |                        | 30.1              | 39.5 ksi |                                   | 1.2               | 5.8 %  |                        | 82.6              | 100 BHN |                        |
| Number of Heats / Lots      | 451               | 451      |                        | 451               | 451      |                                   | 451               | 451    |                        | 451               | 451     |                        |
| Number of Machines / Builds | 0                 | 0        | VOL 2 ONLY             | 0                 | 0        | VOL 2 ONLY                        | 0                 | 0      | VOL 2 ONLY             | 0                 | 0       | VOL 2 ONLY             |
| Method                      | T99               | T90      | Status                 | T99               | T90      | Status                            | T99               | T90    | Status                 | T99               | T90     | Status                 |
| Weibull                     | 36.4              | 37.5     | Lower 50% Subtra       | 29.35             | 30.7     | Lower 50% Subtracting 0.200 units |                   |        | Rejected               |                   |         | Rejected               |
| Pearson                     |                   |          | Skewness is outsi      | 29.25             | 30.72    | Accepted Subtracting 0.200 units  |                   |        | Rejected               |                   |         | Rejected               |
| NonParametric               | 37                | 37.5     |                        | 30.1              | 30.7     |                                   | 1.2               | 1.6    |                        | 82.6              | 89      |                        |
| Normal Method               | 34.05             | 37.08    | Not normal             | 28.76             | 30.76    | Not normal                        | 0.64              | 1.52   | Not normal             | 85.3              | 88.79   | Not normal             |
| 50 % Censored Normal        | 35.54             | 37.68    | R <sup>2</sup> = 0.929 | 29.05             | 30.83    | R <sup>2</sup> = 0.967            | 0.83              | 1.54   | R <sup>2</sup> = 0.908 | 84.04             | 88.04   | R <sup>2</sup> = 0.999 |
| Best Fit                    | Weibull           | Weibull  |                        | Pearson           | Pearson  |                                   | Normal            | Normal |                        | Normal            | Normal  |                        |
| Rounded                     | 36.4              | 37.5     |                        | 28.8              | 30.8     |                                   | 1                 | 1.52   |                        | 85                | 89      |                        |

# AFS Test Plate #1 (1/8"(F) and 1/2"(E) Thick) Final Rigging Design 3D Model with Tooling

1. Casting: 8.375"x8.375" with 1/2" and 1/8" thickness
2. Mold: No bake silica sand; approx. 2" sand all around
3. Risers: **two open**; each 1.5" dia x 4" ht
4. Riser Sleeve: 4 - Insulating TAMPGARD or equivalent (1.5" dia x 4" ht)
5. Inlet – 1" dia. 1.78x1.16 top and 1x0.32" at bottom sprue
6. Filter: 2" x 2" x 0.89" thick – Sivex or ceramic foam 20 ppi
7. Chill – Cast Iron (3x3x2" and 2.75x1.25x1" thick)
8. Tilting the mold by 5 degree.

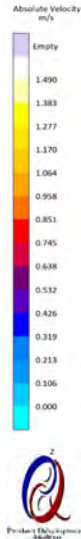
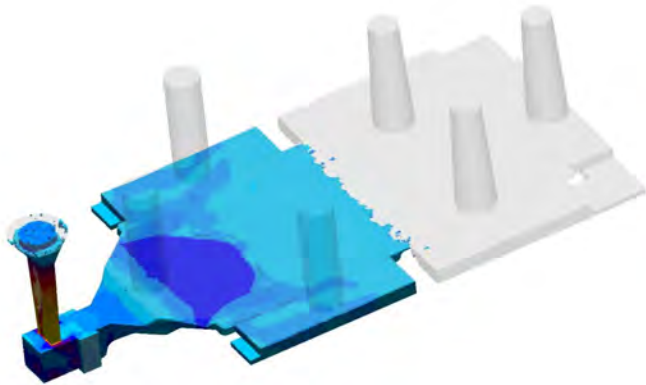


Moved these chills to edge

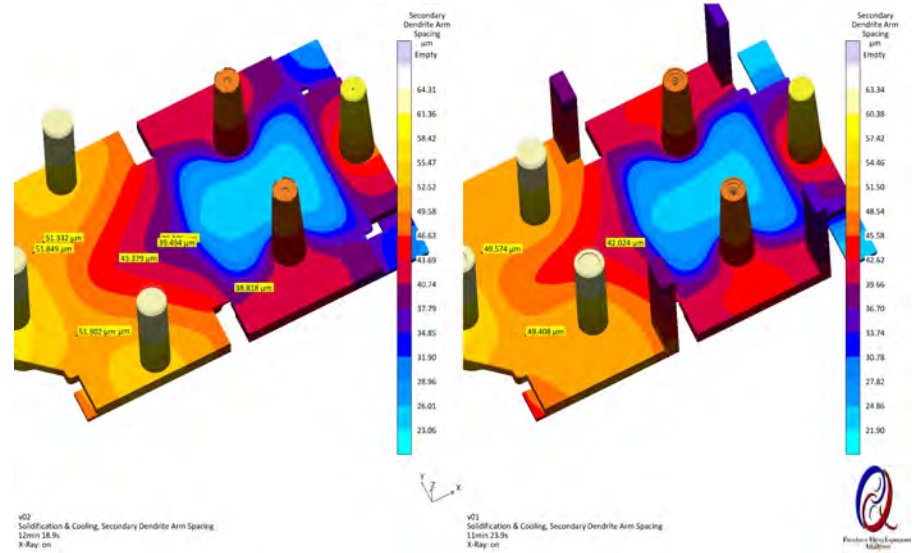
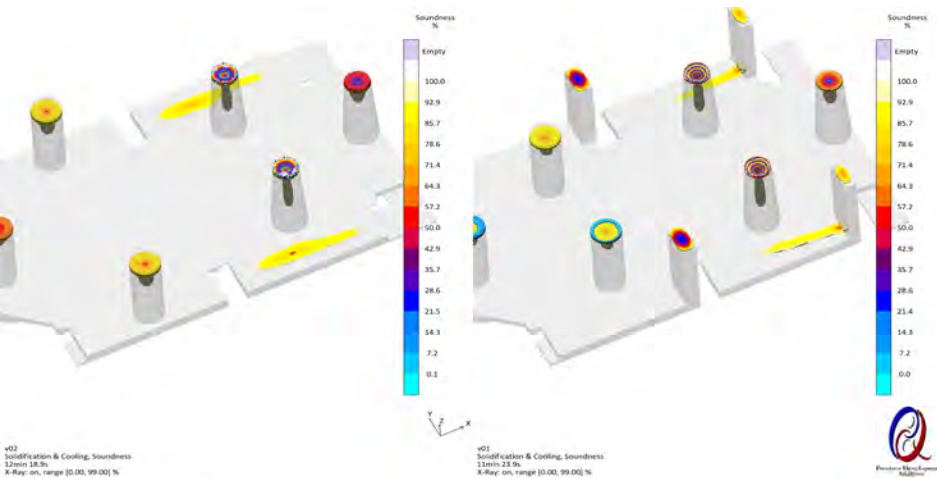


# Simulation Results

Temperature profile at 35% filled



Casting predicted sound, no primary shrinkage



Casting with predicted SDAS

# AFS Test Plate #1 Pre-Trial Results

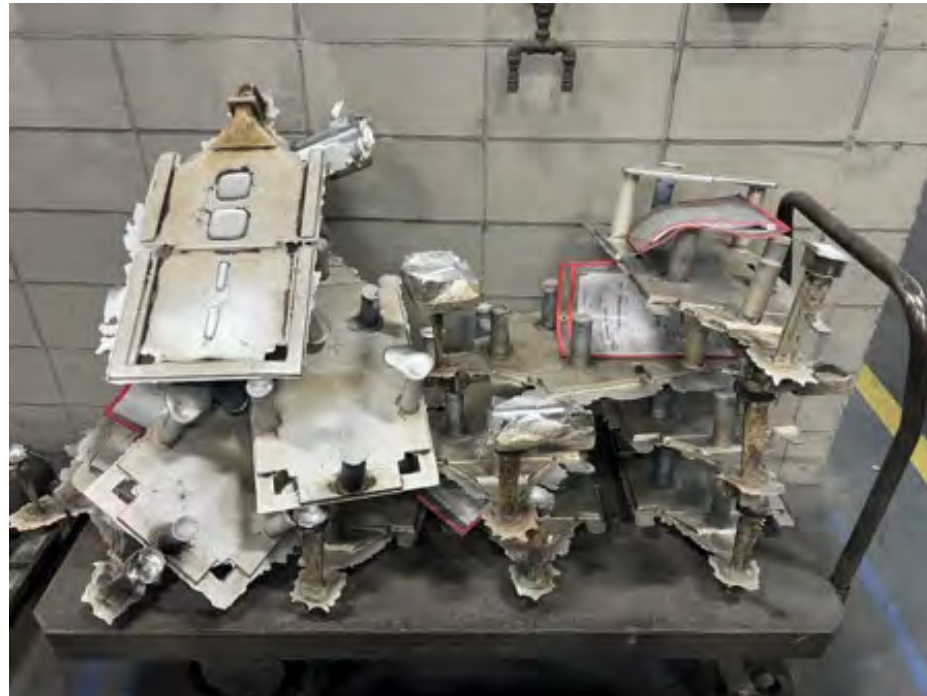


1/2" (right) and 1/8" thick 8"x8" Test Plates



1/2" thick 8"x8" Test Plate X-Ray  
confirming Grade B

# AFS Test Plate #1 Production Castings Poured at Carley Foundry



Total 18 castings poured and being processed

# Alloy Data Being Generated

- C-355-T6 (AMS 4215 Spec) - with static, fatigue and elevated temperature and fracture toughness data for inclusion in MMPDS for 1/2" section thickness (may be some 1/8" thickness subject to funding availability) from test bars excised from the AFS Test Plate #1 Sand Casting made using chills and heat treated.

| AFS - C-355 - T6 Test Plane - Casting Section Thickness 0.5"                           |             |                               |  |            |           |  |
|--|-------------|-------------------------------|--|------------|-----------|--|
| TEST Type  | ASTM Test   | Statistical Basis             | Min. Test Count                        | # of Heats | # of Lots | Target No. of Testing Samples                        |
| <b>Mandatory</b>   |             |                               |  |            |           |  |
| Tension  | E8 and B557 | A and B Basis                 | 100                                    | 10         | 10        | 125  |
| Tensile Elongation & Reduction in Area   | E8 and B558 | S Basis                       | 30 (Part pf the above)                 | 3          | 10        | 35   |
| Elastic Modulus - Tensile  | E111        | Typical                       | 9                                      | 3          | Multiple  | 11   |
| Compression  | E9          | S Basis                       | 20                                     | 3          | 10        | 23   |
| Elastic Modulus - Compression  | E111        | Typical                       | 9                                      | 3          | Multiple  | 11   |
| Shear Ultimate Strength (Direct)   | B769        | S-Basis                       | 30                                     | 3          | 10        | 34   |
| Density  |             | Typical                       | 2                                      |            | Multiple  | 3  |
| Poisson's Ratio  |             | Mandatory                     | 6                                      | 3          | 3         | 8  |
| Hardness in BHN (not recognized by MMPDS, however, we will submit)                     | E10         | A and B Basis                 | 30                                     | 3          | 10        | 35   |
| <b>Secondary</b>   |             |                               |  |            |           |  |
| Fatigue - Strain C   | E606        | Raw Data                      | 16 (10 at R= -1, and 6 other R ratios) |            |           | 18   |
| Fatigue - Load C E466 Raw Data   | E466        | Raw Data                      | 18 (6 tests at 3 R ratios)             |            |           | 20   |
| High Temperature Tensile<br>(RT, 250, 300, 325, 350, 425, 600 F)                       | E21         | Raw Data                      | 15                                     | 3          | 5         | 16   |
|  |             |                               | (90 at elevated temp)                  |            |           | (total 100, 16 at each elevated temp, RT from above) |
| Fracture Toughness - Plain Strain (initiation) - subsize specimen                      | E399/E645   | Min, max, avg, COV, S-Basis   | 30                                     | 3          | 3         | 35 at RT   |
| Fracture toughness - Plain Stress and Transitional Stress (tearing), sub-size specimen | E647        | Raw data with best-fit curves | 8                                      | 2          | 5         | 12 at RT   |

# Test Bar Traceability and Marking Plan

Traceability for the various Test Bars coming from test castings (Plate E) poured by participating foundries (6-7 foundries)

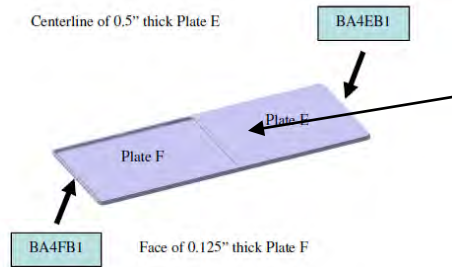


Figure C2. Location of ID Numbers on Casting Number1

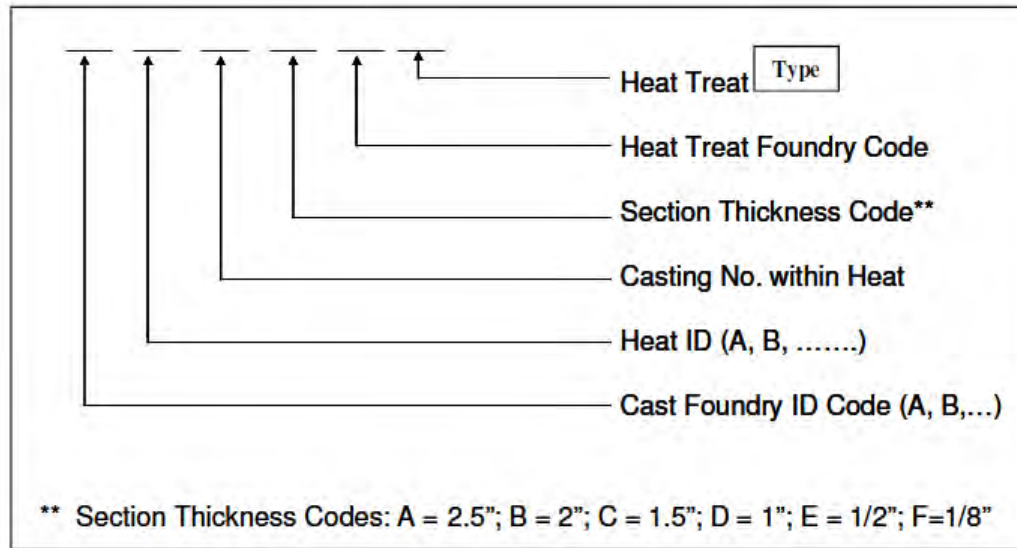
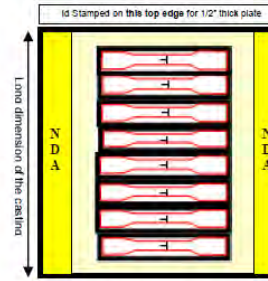


Figure C1. Format for casting identification numbers. Note; heat treat foundry code and lot number will be added by the heat treat facility.

# Test Specimens Cutting Plans

## Cutting Plan for Casting 1--Plate E (1/2" thick)

### Cutting Plan E1



#### Cutting Plan E1

T=tensile (8)  
sub-standard test bars-  
3/4" long x 0.5" diameter,  
3/4" wide blanks

Plate = 8" x 8",

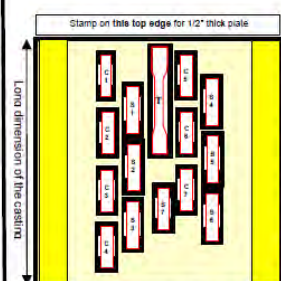
**YELLOW** = 1" wide  
edges on left and right  
are non-designated  
areas

Tensile blanks are 3/4" wide and 3 1/4" long,



Plate E (1/2")-Cut test  
bar blanks on casting  
center line

### Cutting Plan E2



#### Cutting Plan E2

T=tensile (1)  
3" long x 0.5" diameter.

C=compression (7)  
1.2" long x 0.375"  
diameter.

S=shear (7)  
1.5" long x 0.375"  
diameter.

Plate = 8" x 8",

**YELLOW** = 1" wide  
edges on left and right  
are non-designated  
areas

Tensile blanks are 3/4" wide and 3 1/4" long; Shear blanks are  
1/2" wide and 2" long; Compression blanks are 1/2" wide and  
1.3" long

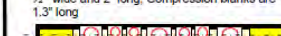
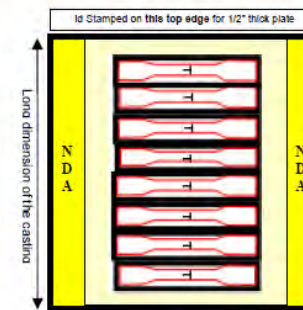


Plate E (1/2")-Cut test  
bar blanks on casting  
center line

### Cutting Plan E4



#### Cutting Plan E4

LCF= Load  
Controlled fatigue  
(4)

HCF= Load  
Controlled fatigue  
(4)

sub-standard test bars-  
5" long x 0.25" or 3/8"  
neck diameter finished

Plate = 8" x 8",

**YELLOW** = 1" wide

Fatigue blanks are 1/2" dia x 5" Long



Plate E (1/2")-Cut test  
bar blanks on casting  
center line

### Cutting Dimensions

|  | Thin Plate (0.5" thick)   |
|--|---|
| Tensile<br>(UTS, YS,<br>%PE,<br>Modulus) | <br>G = 1", A = 1 1/4", D = 0.25"<br>Overall Diameter = 0.50",<br>Total Length = 3" |
| Compression<br>(YS,<br>Modulus)          | <br>ASTM E8,<br>E557, and<br>E111<br>L = 1.2", d = 0.375"                           |
| Shear (US)<br>ASTM E769<br>and E831      | <br>L = 1.5", d = 0.375"  |
| Pin Bearing<br>(US and YS)<br>ASTM E238  | <br>L = 3.75", w = 1.5", t = 1/8"   |

Fracture Toughness Specimen Size: 1.25" x 1.85" x 0.45"

# CADS Data Incorporation – Web Tool

All the data generated will be entered into CADS after completion and validation

The image shows a screenshot of the American Foundry Society (AFS) website. A red vertical arrow points to the top navigation bar. A red horizontal arrow points to the 'Designers & Buyers' link in the navigation bar. A red arrow points to a dropdown menu that includes 'Alloy Database', 'Casting Source Directory', 'Design Tutorials', 'AFS Library', 'Cast In North America', and 'MCDP'. To the right of the screenshot, the text 'www.AFSINC.ORG' and 'www.AFSCADS.com' is displayed in red. Below the screenshot, there is a banner image showing industrial scenes.

A new user friendly and simpler version 3.0 has been live since 2023!

# Project Plans

- **Next 12 months:**

- Incorporate combined separately cast statistical properties into CADS with a report to individual foundries.
- Complete pre-trial with properties and start production test plates at multiple foundries.
- Start property testing at two locations of test laboratory.
- Gather data for Meta modeling for separately cast test bar historical data and AFS Test Plate #1 casting generated data.

- **Long Term:**

- Generate data with preliminary statistical analysis for submission to MMPDS with technical report.
- Develop meta model algorithm for predictive and prescriptive properties as a function of chemistry.
- Incorporation of MMPDS design allowable into CADS with a link to the final report.



# Transition Plan

- Project review at various AFS ALM Technical Committees' quarterly meetings.
- Technical Publications and presentations at various AFS Conferences.
- MMPDS Handbook inclusion into the new edition with these C355-T6 Sand Cast Aluminum properties data.
- Incorporation of separately cast and the MMPDS design allowable into the web-based search tool – CADS.
- Project progress announcements into Casting Source and Modern Casting magazines of AFS.
- Outreach to DLA/DOW Primes through participating leading foundries with the data for new products / redesign.
- Potential inclusion into the Aluminum Association data.



# Leveraging

- Lesson learned from CIR/CHAMPS – AFS led, AMC/DLA funded projects on E357, A206, 17-4/15-5 PH MMPDS inclusion.
- AMC/DLA funded; continuously upgraded and maintained CADS web-search tool by PDA/AFS.
- In-kind costs share through separately cast historical properties data; production and shipment of required test plate sand castings including x-ray, heat treatment of each.

# Project Metrics

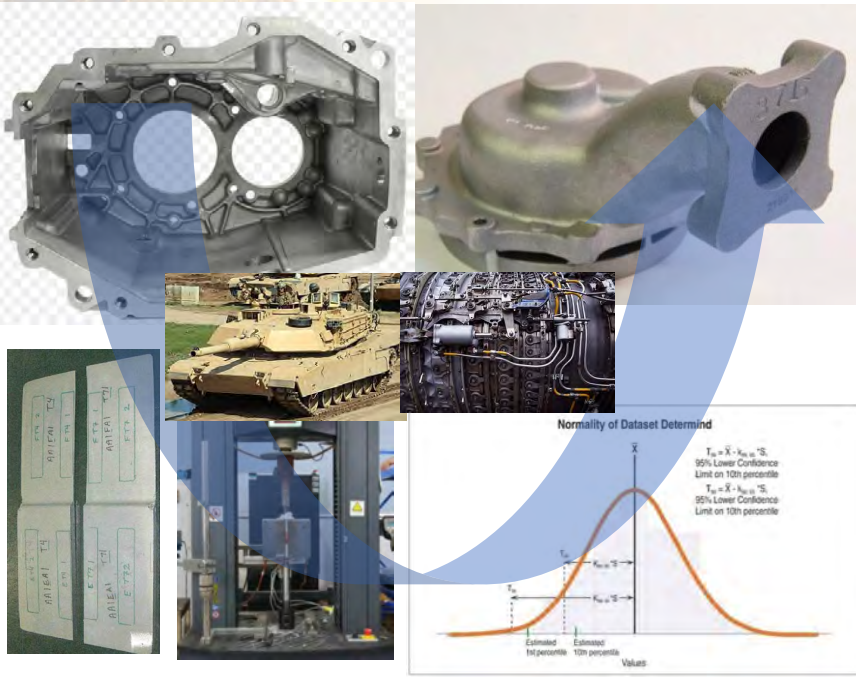
| Description   | Baseline                         | Threshold   | Objective   | How to Measure  | Target Date | Progress | How Demonstrated  |
|---|----------------------------------|---|---|---|-------------|----------|---|
| Statistically Validated Property Data for C355-T6 Sand Cast                                     | None available                   | AMS 4215F Designated properties:<br>35 ksi UTS<br>28 ksi YS<br>2% Elong               | AMS 4215F Designated properties:<br>36 ksi UTS<br>29 ksi YS<br>2% Elong | Mechanical Property testing per MMPDS protocol and ASTM testing standards                                   | Nov 27      | 0%       | Per CIR/CHAMPS protocol for E357, A206 test plates cast, to be tested at Element and data to be submitted and accepted by MMPDS |
| Separately Cast C355-T6 Sand Test Bars Historical Data Statistical Analysis                     | None available                   | AMS 4215F Separately Cast Test Bar<br>37 ksi UTS<br>30 ksi YS<br>1% Elong             | AMS 4236B Non-Designated<br>37 ksi UTS<br>30 ksi YS<br>1% Elong         | Mechanical Property testing per ASTM testing standards  | April 26    | 100%     | Per MMPDS methodology, analyzed over 6,500 heats/lots from eight foundries  |
| C355-T6 Data Incorporated into MMPDS  | Data not in MMPDS (only S basis) | A&B Allowable Data including elevated tensile and room temperature fracture toughness | A&B Allowable Data from designated area of Test Castings                | Mechanical Property testing per MMPDS protocol and ASTM testing standards                                   | Nov 27      | 0%       | Per CIR/CHAMPS protocol for E357, A206 test plates cast, to be tested at Element and data to be submitted and accepted by MMPDS |
| Separately Cast Combined and Test Casting Designated area design allowable MMPDS data into CADs | None available                   | Per ASTM B26, AMS 4215F designated properties   | Per ASTM B26, AMS 4215F designated properties                           | Historical Data from industry and Mechanical Property testing per MMPDS protocol and ASTM testing standards | Nov 27      | 0%       | Insertion into CADs with a link to the technical reports  |

# Acknowledgements

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# MMPDS of C355-T6 Alloy into CADS

DLA - POC: DLAR.DPR@dla.mil



## Problem

- Alloys not in MMPDS system are utilized much less due to knockdown factors applied.
- A lack of available MMPDS alloys causes non-optimization in design and sourcing.

## Objectives

- Develop pedigreed data for new a new alloy to be added to the MMPDS handbook, including chemistry, tensile properties, and processing parameters.

## Benefits to Warfighter

- Providing access to more alloys for DoW components and applications, will allow more manufacturers to produce the parts faster, and cheaper. It will also allow new parts to be designed with the new alloy in mind, creating opportunities for optimization.

## Description of Project

Develop C355-T6 data set for submission into MMPDS and CADS tool, allowing DoW casting users to utilize this alloy in new parts or for optimization of existing parts

**Team:** American Foundry Society, ATI, PDA

## Milestones / Deliverables

- Best Practice Test bar properties of C355-T6 with MMPDS driven allowables
- C355-T6 Test Plate Castings
- Testing of chemistry and properties by third-party lab
- Comprehensive data analysis and MMPDS submission
- Meta model development from historical and experimental data
- CADS Data Incorporation

