

# Cost-Effective Fast Response and Sustainability for Critical Castings

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## Emergent Metal Casting Technologies (EMCS)

AMC Technology Review

June 24-25, 2026



# Overview

- **Needs and Benefits:** The investment casting (IC) process has longer cycle time and is labor-intensive leading to long procurement lead times and considerable landfill waste. This project will:
  - Reduce production lead times (reduced shell drying time; faster burnout of wax patterns)
  - Decrease costs (reduced scrap)
  - Reduce wastes associated with used shell material (recycle and re-use)
  - Provide DoW/DLA more consistent quality of complex investment castings
- **Progress:** Accelerated shell drying and pattern burn out work completed with algorithms developed; the used shell custom ball mill for pulverizing, fluidized bed separator and sieve screener equipments installed with trial runs; and test plates casting trials continuing with simulation-based validations for feeding distance algorithm development.
- **Transition:** Working with AFS Technical committees, technical publications and presentations at Technical Conferences, out-reach to member foundries for production implementation of the algorithms for shell drying and pattern burn out; Excel embedded riser sizing and feeding distance calculator to AFS investment foundry members and DLA supply chain, industry participation.
- **Cost Share:** \$337,706 provided of \$ 597,720 proposed



# Needs

- Problem

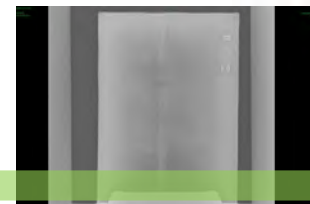
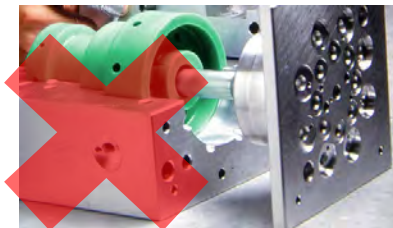
- Investment cast parts are used in critical DoW applications. DLA needs cost-effective investment cast parts produced rapidly, with agility and improved quality, in low volumes without the issues of wax tooling logistics, while seeking a reduction in used ceramic shell material disposal.

- Objective

- To reduce time to market for investment cast military-centric replacement components through reduced shell drying cycle time, enabling faster burnout of 3D printed wax-like patterns, recycle and reuse shell material, and develop best practice data driven tools for risering systems to improve DLA's casting procurement agility to support warfighter readiness.

- Technology

- This project will develop a process for recycling alumina based ceramic shells and reuse; intelligent sensor driven faster shell drying recipes and process; faster wax like 3D printed SLA patterns burn-outs used in the toolingless investment casting through a series of demonstrations working with the investment foundries. Project will develop an excel embedded risering calculator aid to reduce scrap, rework and improve yield.



# Benefits

- Shell recycling and reuse will lower the cost with reduced landfill for better sustainability.
- Toolingless approach of using efficient burn-out of wax like 3D printed patterns will eliminate traditional wax dies (and related logistics of storage, re-work) and shorten the lead time with agility (ability to make design changes for low volumes)
- Faster shell drying will reduce further the investment casting lead time and cost.
- Rising calculator will aid design and foundry process engineers with optimized yield with reduced rework and scrap, hence overall quality.

*“Advancing Investment casting through Innovation-enhancing efficiency, reducing lead times and ensuring quality for a more resilient and sustainable future for DOW” —Paul Leonard, Director of Engineering, Barron Industries and AFS Board Member*

# Milestones/Tasks

- **Completed**

- Task 1 (UNI) – Completed rapid shell drying and pattern burn out laboratory work and developed algorithms with user manuals.
- Task 2 (CPP) – Commissioned shell recycling equipments with initial trials.
- Task 3 (PDA/MetalTek) – Horizontal test plates poured with x-ray in 17-4/15-5 PH & 8620 Steels with preliminary simulation work and historical data collection on 12 investment cast parts.

- **In Progress**

- Task 1 (UNI) – Production trials planning with member foundries for both sensors.
- Task 2 (CPP) – Laboratory shell formation using recycled shell material.
- Task 3 (PDA/MetalTek) – Combination (horizontal and vertical) test plates being poured and characterize with x-ray; historical x-ray data collection and analysis.

- **Planned**

- Task 1 (UNI) – Further optimization of shell drying, foundry production trials using sensor kits and algorithms developed.
- Task 2 (CPP) – Characterization of reused shells, foundry production trials using recycled materials and evaluate performance against virgin shell materials.
- Task 3 (PDA/MetalTek) – Complete test casting campaigns with x-ray characterization; generate data by simulation using actual test conditions; historical data gathering and initial analysis.

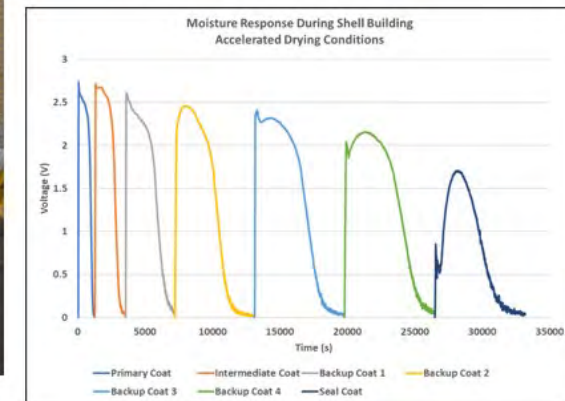
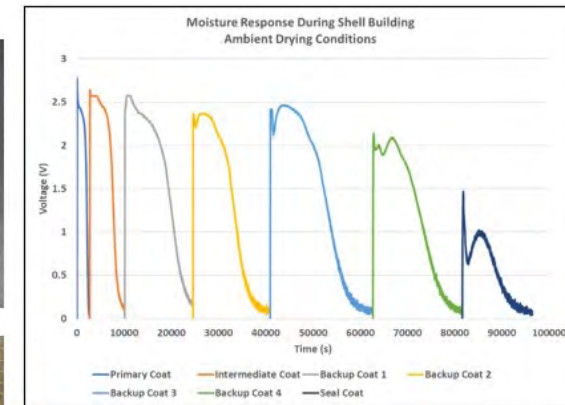
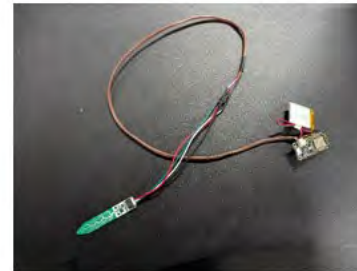
# Task 1: Shell Drying and Pattern Burnout - UNI Lead

## Work Accomplished (Next 3 slides)

- **Pattern Burnout algorithm** validated with user manual.
- Accelerated shell drying algorithm developed with user manual.
- A new **stand-alone moisture** sensor for shell drying developed and evaluated against I-Button sensors.
- Fast drying patented slurry trials and compared against accelerated shell drying.

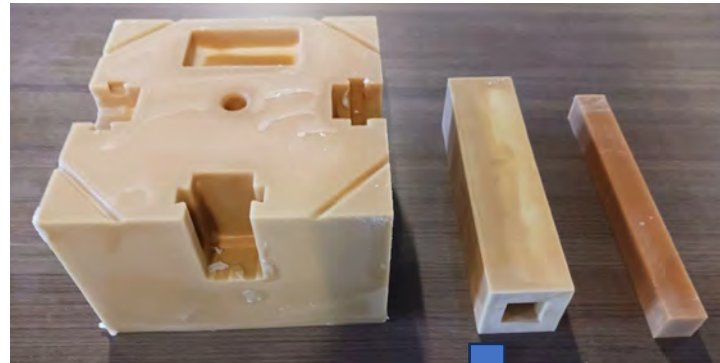


Dashboard for pattern burn out



# Pattern Burn Out Algorithm Evaluation

- 28 samples - Used 3 different patterns
  - 4.988 lb, 0.644 lb, 0.248 lb
- Programmed all of the methods into Node-RED
- **C5.0** the best method
  - Only 1 error
  - Several False positives on other models



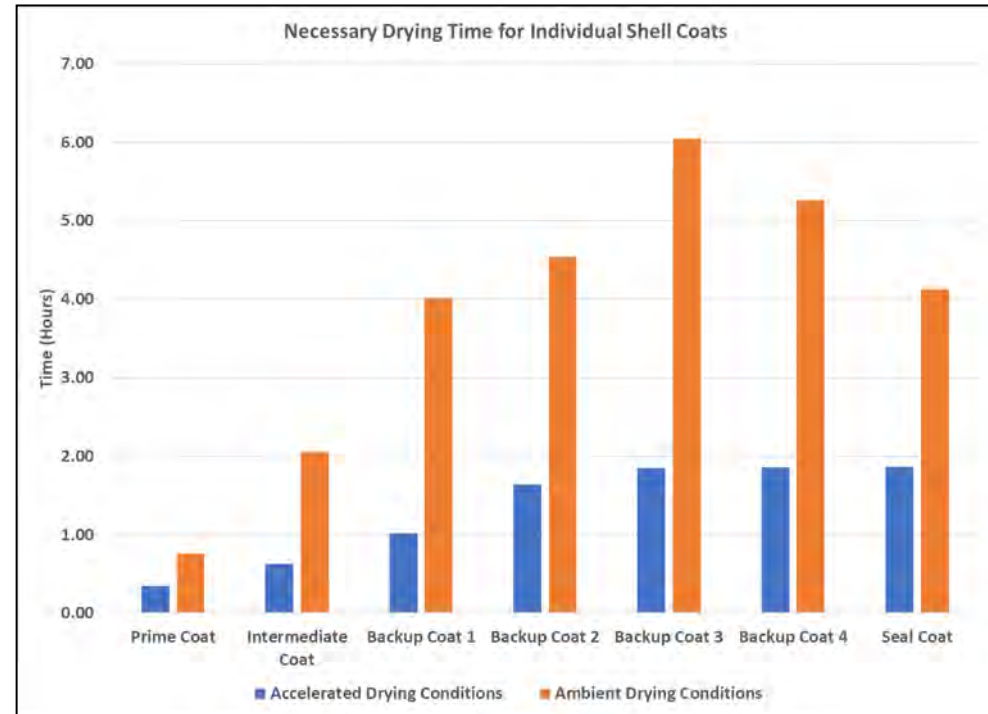
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	C5.0	CART 2	Initial CART	LR
Times Correct	27	12	8	4
Times Wrong	1	16	20	24
True Finish	24	11	6	0
True Non-Finish	3	1	2	4
False Finish	1	3	2	0
False Non-Finish	0	13	18	24
Accuracy %	96.43	42.86	28.57	14.29
Error %	3.57	57.14	71.43	85.71
Sensitivity %	100	45.83	25	0
Specificity %	75	25	50	100



# Shell Cycle Times – Typical Observed

Shell Building Step	Time to Dry (hr)	
	Accelerated	Ambient
Prime Coat	0.3	0.8
Intermediate Coat	0.6	2.1
Backup Coat 1	1.0	4.0
Backup Coat 2	1.6	4.5
Backup Coat 3	1.9	6.0
Backup Coat 4	1.9	5.3
Seal Coat	1.9	4.1
<b>Total</b>	<b>9.2</b>	<b>26.8</b>



Almost 1/3<sup>rd</sup> reduction!



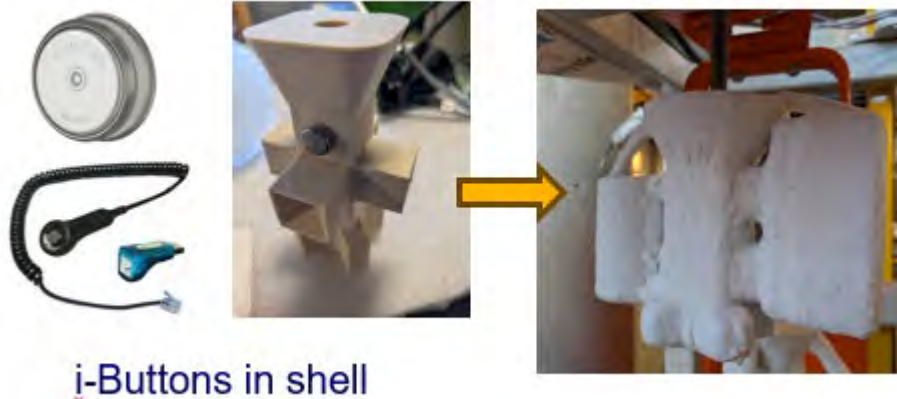
Shells from the Design of Experiments



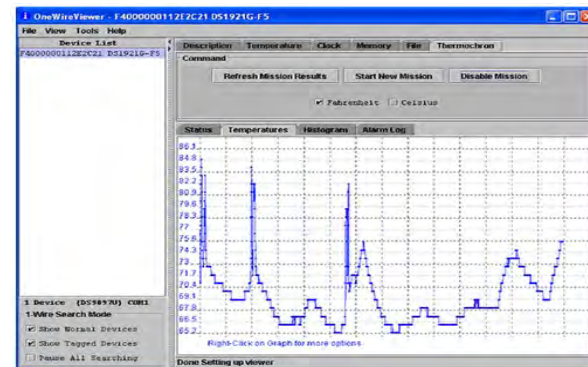
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# i-Button sensor evaluation



Experiment #	Temperature	Humidity	Pattern Size
1	70	20	Small Tree
2	70	30	Small Tree
3	70	40	Small Tree



## Design of Experiments for i-Button sensor evaluation

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# Project Plans

## Task 1: Shell Drying and Pattern Burnout - UNI Lead

- **Next 12 months:**
  - Further Optimization of shell drying – heating, air flow etc.
  - Industry trials at Yamaha Motor, Kovatch Castings and Fabri USA.
  - More out-reach to foundries and furnace companies for the use of both the algorithms.
  - Benchmark Toolingless process focus – additive examples.
- **Long Term:**
  - Reduce shell dry cycle time – materials, process, sensors.
  - Flash fire burnout of 3D AM Patterns.
  - Production Casting Trials.
  - Evaluate AI driven intelligent processing.



# Task 2: Shell Recycling and reuse – California State Polytechnic University – Pomona (CPP) Lead

## Work Accomplished (next 2 slides)

- Ball Mill, Fluidized Bed Separator and Screen Sieve Separator equipments installed and operating procedure developed.
- Used alumino-silicate based shells received from Barron-Industries and MetalTek.
- Ran multiple trials for recycling and re-use in the laboratory.



Pulverization Ball Mill



Fluidized Bed  
Vibratory Separator



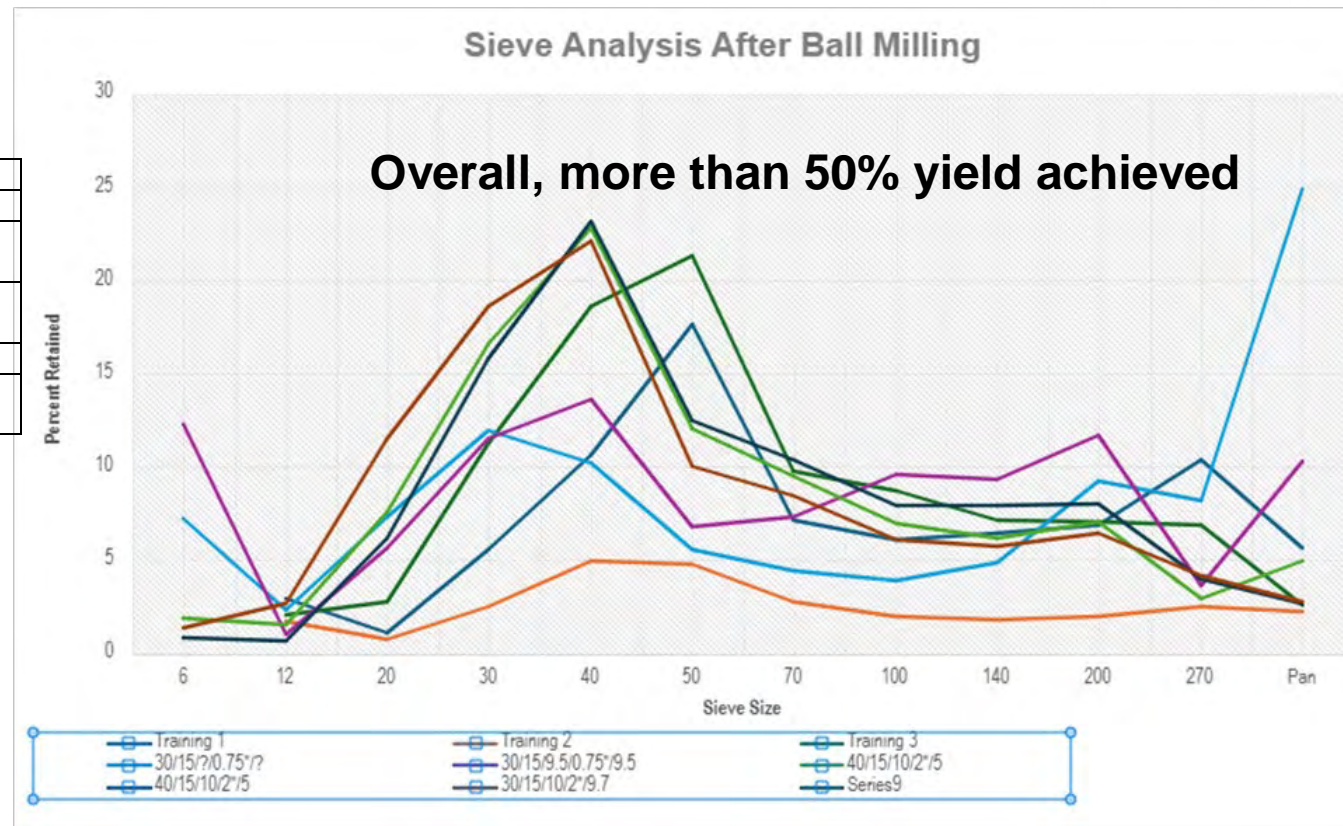
Sieve Separator



# Work Performed

Variable	Low	High
RPM	30	40
Milling time (min)	15	30
Media amount (Kg)	5	10
Media size (in)	0.75	2
Shell material amount	5	10

Experimental matrix for the shell recycling trials conducted



Nomenclature: First number=Mill RPM, Second=duration of milling cycle (min), Third=Media amount (Kg), Fourth=size of media balls (in), Fifth=Amount of material (Kg)

Results of ball milling trials to date. Note that there appears to be consistency on the size distribution even when parameters are modified.



# Work Performed

Testing of Reuse of reclaimed shell Vs Virgin Shell Material



Modulus of Rupture Test Bars



After 7 coats

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Permeability Test Bars



After final seal coat 13



# Project Plans

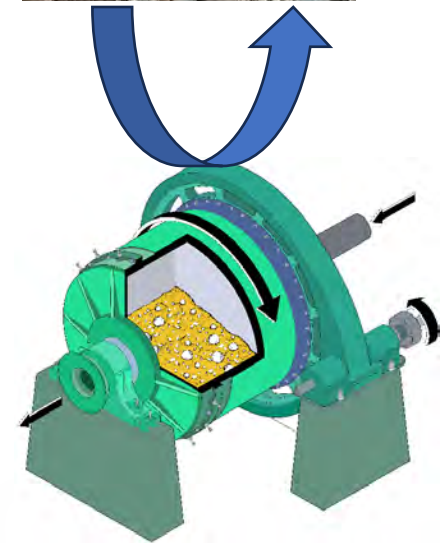
## Task 2: Shell Recycling and reuse – California State Polytechnic University – Pomona (CPP) Lead

- **Next 12 months**

- Reclaimed Vs Virgin shell performance evaluation including casting trials at participating foundries.
- Continue out-reach for used shell material with foundries.

- **Long Term**

- Shell recycling – Alumino silicate, zircon
- Shell reuse of recycled shell material
- Validation by Casting Trials (Industry Participation)



# Task 3: Rising Calculator Tool – Product Development Analysis (PDA) / MetalTek Lead

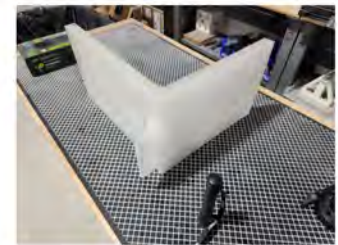
## Work Accomplished (next 3 slides)

- Test Plate Casting Campaign A and B finalized with design and simulation.
- Completed eight horizontal top riser test castings in both 17-4/15-5PH and 8620 steels with x-ray characterization.
- Campaign A combination (horizontal and vertical) test plate 3D printed patterns and shells prepared and poured in 17-4/15-5 PH Steel.
- Continue gathered proprietary rigging case studies of twelve industrial/military castings with historical data including x-rays.
- Continue outreach to industries for more such data.
- Continue generate more data through simulation using target and actual process conditions.

Test Plate 2-A



Plate 2B/2C and 6B/6C



**3 days Vs 6 weeks with traditional wax dies !**

# Campaign A and B Test Plates

DOE Matrix (Controlled Variables)														
Campaign	Alloys	Plate # for Traceability	Shape						Shell Thickness		External Shell Interface		Base Shell Materials	
			T=0.5", 1"	Section Thickness (T) inc	Riser Size	Side Riser (combined)			10 mm	14 mm	Canned (Natural Convection)	Un-canned	Fused Silica	Alumino Silicate
					Top Riser	Horizontal	Common Riser Size	Horizontal	Vertical					
A	17-4/15-5 PH Stainless Steel	1-A	Thin Plate (w/T=12)	0.5	2" dia/Sq x 6" ht	0.5" x 6" x 7.2"					x		x	x
		2-A	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	x
		3-A	Thick Plate (w/T=5.5)	1	4" dia/sq x 3.5" ht	1x5.5x9.4					x		x	x
		4-A	Bar (w/T=2)	0.5	1.5" dia./sq x 4"ht	0.5"x1x6.75					x		x	x
		1-B / 1-C	Thin Plate (w/T=12)	0.5			3" dia/Sq x 6" ht	0.5" x 6" x 7.2	0.5" x 6" x 9"		x		x	x
		2-B / 2-C	Thick Plate (w/T=8)	1			4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	x
		3-B / 3-C	Thick Plate (w/T=5.5)	1			4" dia/sq x 6" ht	1x5.5x9.4	1x5.5x 11		x		x	x
		4-B / 4-C	Bar (w/T=2)	0.5			2" dia./sq x 7"ht	0.5"x1x6.75	0.5"x1x9		x		x	x
	8620/4320 CLA Steel	5-A	Thin Plate (w/T=12)	0.5	2" dia/Sq x 6" ht	0.5" x 6" x 7.2"					x		x	x
		6-A	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	x
		7-A	Thick Plate (w/T=5.5)	1	4" dia/sq x 3.5" ht	1x5.5x9.4					x		x	x
		8-A	Bar (w/T=2)	0.5	1.5" dia./sq x 7"ht	0.5"x1x6.75					x		x	x
		5-B / 5-C	Thin Plate (w/T=12)	0.5			3" dia/Sq x 6" ht	0.5" x 6" x 7.2	0.5" x 6" x 9"		x		x	x
		6-B / 6-C	Thick Plate (w/T=8)	1			4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	x
		7-B / 7-C	Thick Plate (w/T=5.5)	1			4" dia/sq x 6" ht	1x5.5x9.4	1x5.5x 11		x		x	x
		8-B / 8-C	Bar (w/T=2)	0.5			2" dia./sq x 7"ht	0.5"x1x6.75	0.5"x1x9		x		x	x
B	17-4/15-5 PH Stainless Steel	2-D	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	
		2-E / 2-G					4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	
	8620/4320 CLA Steel	6-D	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	
		6-E / 6-G					4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	
	17-4/15-5 PH Stainless Steel	2-H	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	
		2-I / 2-K					4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	
	8620/4320 CLA Steel	6-H	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	
		6-I / 6-K					4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	
	17-4/15-5 PH Stainless Steel	2-L	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	
		2-M / 2-O					4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	
	8620/4320 CLA Steel	6-L	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	
		6-M / 6-O					4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	
	17-4/15-5 PH Stainless Steel	2-P	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	
		2-R / 2-S					4" dia/sq x 6" Ht	1"x8"x11"	1"x8"x13"		x		x	
	8620/4320 CLA Steel	6-P	Thick Plate (w/T=8)	1	4" dia/sq x 4.25" Ht	1"x8"x11"					x		x	

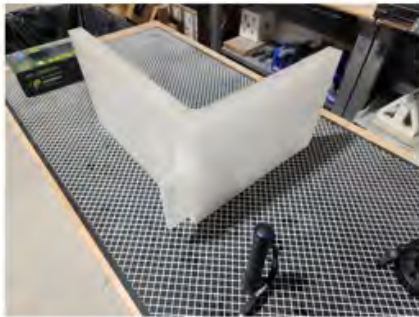
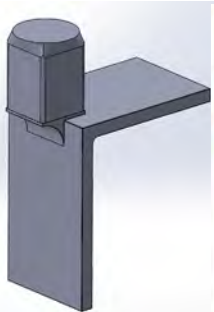
↓ 8 Test Plates Finished

↓ 4 Test Castings (8 Plates) Poured

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# Example - Plate 2-A

- Plate 1"x8"x11"
- Riser: 4" Sq x 4.25"Ht



## Combination Plate 2- B/C Design, 3D printed Waxlike Pattern and Castings (17-4 PH)



Plate 2-A Meets Grade A in X-Ray

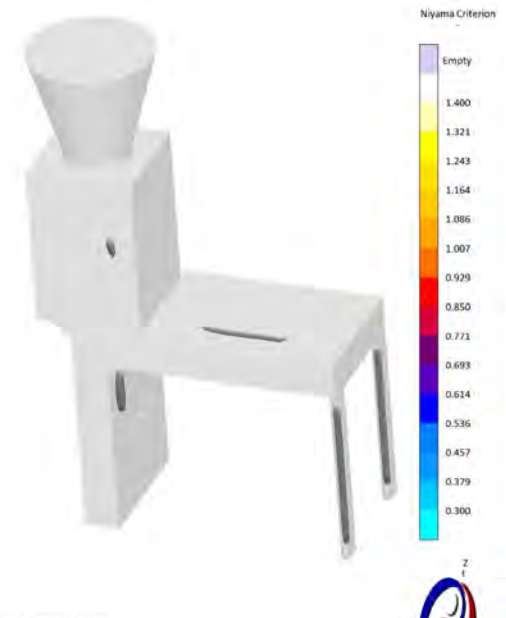
# 8620 Vs 17-4/15-5 PH Test Plate 1in thick

Objective: Generate meta data from simulation of various test castings being poured at foundry in Campaign A/B.

**8620 LA Steel**



**17-4/15-5 Stainless Steel**



**More shrinkage due to longer freezing range under same process conditions**



Product Development Analysis

# Project Plans

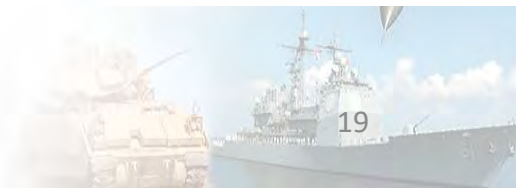
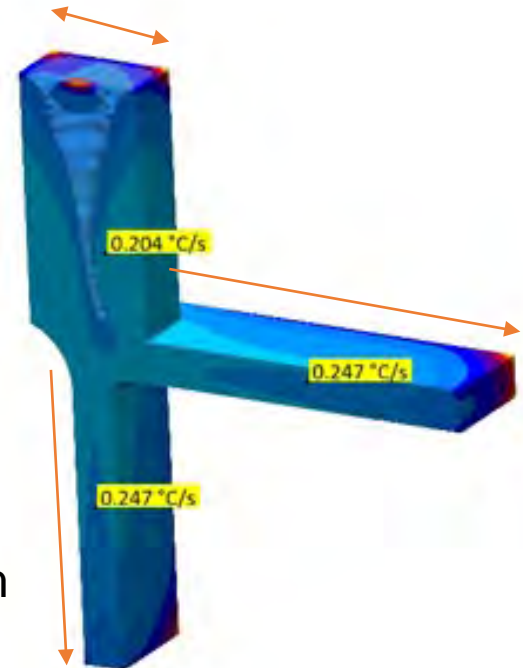
## Task 3: Riser Calculator Tool – Product Development Analysis (PDA) / MetalTek Lead

- **Next 12 Months**

- Complete Campaign A and B Test Castings with data analysis from x-rays.
- Continue proprietary rigging historical data collection and analysis for the algorithm.
- Generate mete data by simulating actual test casting conditions and correlate.

- **Long Term:**

- Evaluate current rigging / risering configurations (industry examples / participation by providing case studies with required data).
- Develop best practice rigging / risering design algorithm using historical data / simple test castings / examples / ICME / Simulation for Ferrous Alloys.
- Validation algorithm by Casting Trials (Industry Participation).



# Transition Plan

- Project review at various AFS Technical Committees' quarterly meetings.
- Technical Publications and presentations at various AFS Conferences annually, International Journal of Metalcasting (IJMC) and ICI.
- Provide the sensor kits with user manual to interested member foundries for both pattern burn out and accelerated shell drying (Task 1).
- Recommended parameters for shell recycling and guideline for reuse (Task 2).
- Provide the excel embedded risering calculator to AFS members and DLA / DOW Investment casting supply chain with manual at the end of the project (Task 3).
- Engage investment AFS and ICI member foundries and DLA supply chain for casting demonstrations on pattern burnout, recycled alumina shell, shell drying technologies developed in the Year 5.
- Interested investment foundries/engineering company– MetalTek, Barron Industries, O'Fallon, Eagle Precision Cast Parts, PDA



**Sensor kits  
distributed at  
2026 Casting  
Congress**



# Leveraging

- AFS funded research (14-15#04) to CPP on lab scale shell recycling study.
- DOW and DOE funded research at UNI on shell drying and pattern burn out.
- In-kind costs share through used shell material supply, casting trials and demonstrations for each task by the industry participation (almost 50% of the total in-kind provided)

# Project Metrics

Description	Baseline	Threshold	Goal	How Measured	Target Date	Progress	How Demonstrated
Reduction in investment shell production cycle time	72 hours	50 hrs. (30%)	36 hours (50%)	clocking time during demonstration	28-Mar	80%	building shells using SLA and real-time sensors
Reduction in the shell materials with the reuse of recycled shell	Industry survey / participating foundries	20%	30%	demonstration by casting trials	28-Mar	30%	casting trials at foundries and compare with current practice
Reduction in rework and/or scrap due to shrinkage using risering tool	Industry survey / participating foundries	15%	25%	demonstration by casting trials	28-Mar	30%	casting trials at foundries and compare with current practice
Improvement in casting mold yield by optimum risering using risering tool	Industry survey / participating foundries	5%	10%	demonstration by casting trials	28-Mar	30%	casting trials at foundries and compare with current practice
Reduction in lead time for new parts using toolingless approach	6 months (Industry survey / participating foundries)	4 months	3 months	demonstration by casting trials	28-Mar	20%	casting trials at foundries and compare with current practice

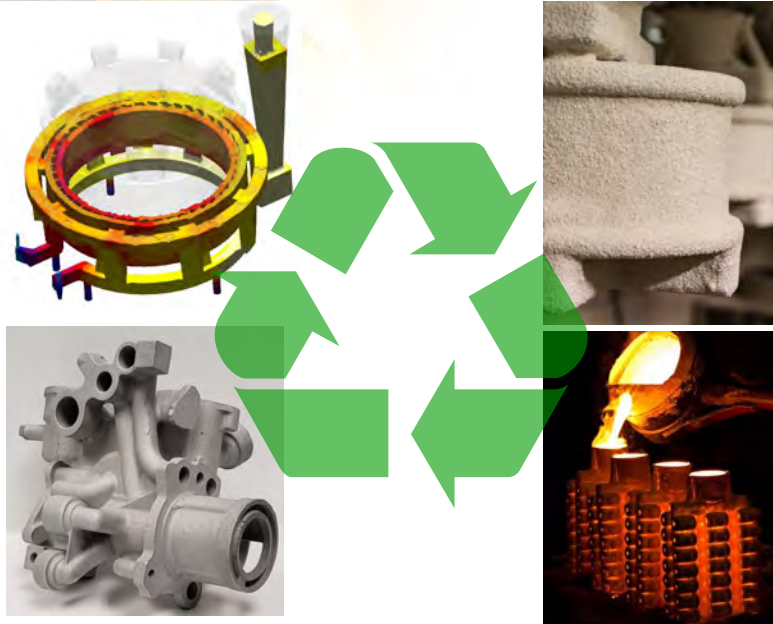
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# Acknowledgements

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# Cost-Effective Fast Response and Sustainability for Critical Castings

DLA - POC: DLAR.DPR@dla.mil



## Problem

- The investment casting process is relatively slow and labor-intensive, leading to long procurement times and considerable landfill waste

## Objectives

- Reduce investment shell production cycle time by 50%, reduce landfill volume and purchase of shell materials by 50% through recycling and reuse of shell material, reduce rework and scrap due to shrinkage by 25%, and improve casting mold yield by 10%

## Benefits to Warfighter

- Improved casting procurement agility for DLA by reducing lead-times, improving quality, reducing cost of cast parts, and reduction in waste

## Description of Project

This project will reduce production cycle times, decrease costs, and provide DoW/DLA more consistent quality of complex investment castings

**Team:** American Foundry Society, ATI, University of Northern Iowa, California State Polytechnic University, MetalTek International, Product Development and Analysis



## Milestones / Deliverables

- Validate use of recycled shell materials through lab analysis and test castings
- Develop fast dry shell materials and production techniques
- Validate new pattern burnout techniques
- Define best practice rigging techniques
- Validate use of recycled alumino-silica shell material
- Technology transfer of project results to metalcasting industry