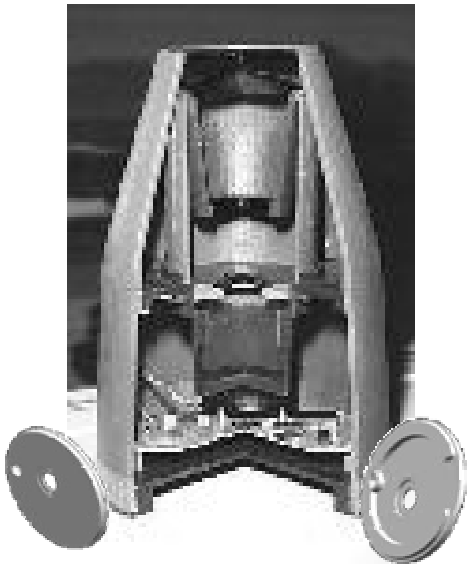
Rapid Tooling for Die, Squeeze and Permanent Mold Casting

Case Western Reserve University
John F. Wallace
David Schwam

Rapid Tooling for Metal Mold Processes



Status

Two rapid metal tooling methods are currently being evaluated:

- A ductile iron permanent mold cast at Saint Louis Precision Casting is used in production at Arrow Aluminum; the thermal fatigue resistance of this mold is being monitored.
- Two die casting rapid inserts have been machined of P20 at CAM Tool and are in production of military components at SciCast.

Objectives:

Develop rapid, cost effective methods for fabricating metal tooling for the diecast, squeeze-cast, and permanent mold processes. Make the advantages of metal mold processes more available to DLA's short leadtime and low volume casting needs.

Approach:

Evaluate and optimize die/mold material selection and fabrication method for prototype quantities of castings (500-50,000).

Deliverables

On-line database of guidelines for **selection of materials** and **fabrication methods** for rapid metal tooling that will promote:

- Shorter lead times; Lower cost
- Tighter tolerances
- More metal molded castings

for DLA low volume, high specification casting procurements

What is Rapid Tooling For Metal Mold Processes ?

Quick and cost-effective methods of fabricating permanent mold, die/squeeze casting inserts, and/or metal slides and cores

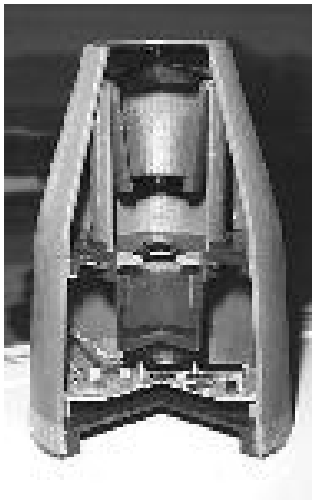
IN	WE DEAL WITH
PROTOTYPING	Making a small number of castings (singles or tens)
RAPID TOOLING	Making one tool (mold, inserts, slides, cores) used to cast short to medium production numbers of parts (hundreds to thousands) in a short period of time

Why Rapid Metal Mold Tooling?

- Current prototyping for short runs relies mostly on sand cast components. The performance and dimensional accuracy of metal mold castings provides an important option.
- The faster cooling rated attainable by permanent mold, die casting and squeeze casting provides higher integrity and better mechanical properties.
  - Commercial example: Safety critical control arms and steering knuckles on automotive front suspensions made as aluminum squeeze castings
  - Military example: Diecast chassis for an electronic system. More dimensional accuracy than sand casting, lower part cost than investment casting
  - Military example: Diecast fuse for a munitions system. More dimensional accuracy and lower cost than a fabrication
- The key is quicker, lower cost tooling

DLA Need For Metal Mold Processes

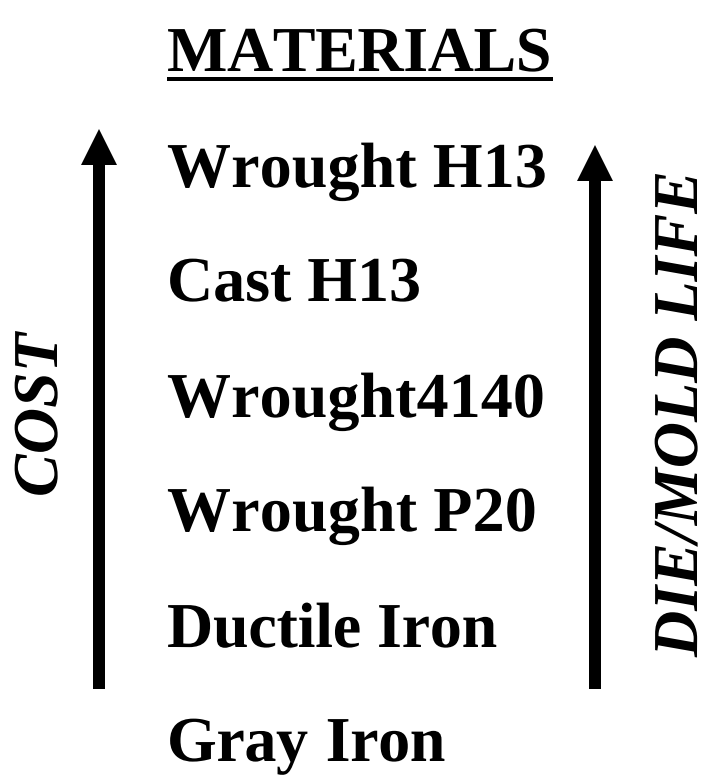
- Short notice replacement of worn out parts in weapon systems when no “spares”are available. Often, the old part was invest-ment cast and a metal mold process is a cost-effective option.
- New parts for systems under development for which metal mold processes would provide cost or functional advantages
- Will provide suppliers to DLA and weapon system OEM’s options which complement sand, plaster, ceramic, and invest-ment casting processes commonly used in military applications

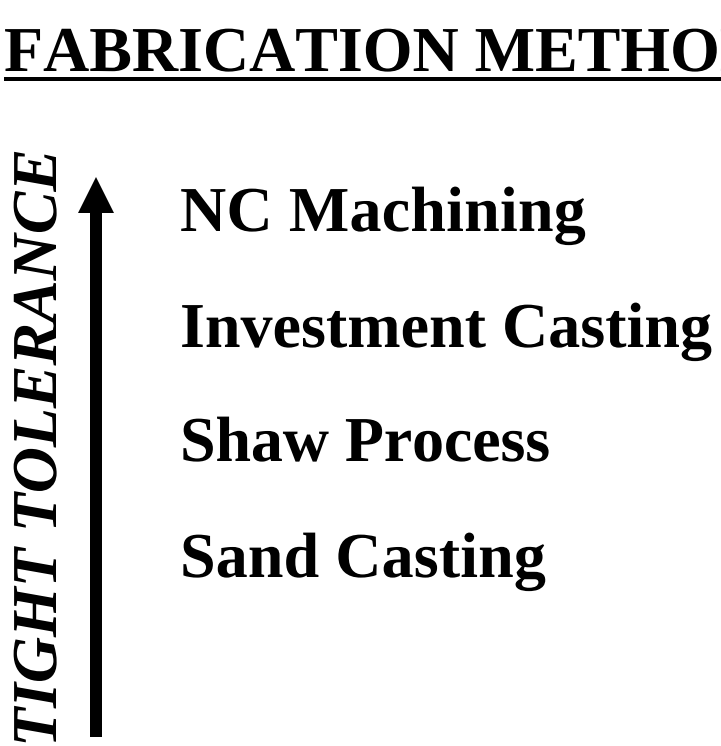


AGM-88 HARM

Rapid Tooling Approach

The focal point of this study is the <u>MATERIAL</u> and the <u>FABRICATION METHOD</u> of the rapid tooling:





Justification For DLA

Optimized selection of die/mold materials and fabrication methods will ensure the required number of production castings can be made, while targeting a 30% reduction in tooling cost.

About 7% of the US die casting $6 Billions is for the military, or $420 Million. Tooling cost can reach 20% or $84 Million/year. An estimated 20% of these or $17 Million are for short runs. At 25%-30% cost savings this translates into about $5 Million/year savings. The short term anticipated ROI is 15:1.

The benefits of the project extend into all the branches of the military and the US casting industry.

Rapid Tooling Industry Partners

The study involved industrial partners early on. Performance of rapid tooling fabricated during the study is monitored in production and compared to the results of the simulated testing.

FABRICATION METHOD	TOOL MAKER	FOUNDRY
No-bake sand	**St.Louis Precision**	**Arrow Aluminum**
Machining	**CAM Tool & Eng.**	**SciCast**
Investment casting	**Precision Metalsmith**	**TBD**
Metal Spraying	**RSP Tooling**	**TBD**

Rapid Tooling Materials Evaluation

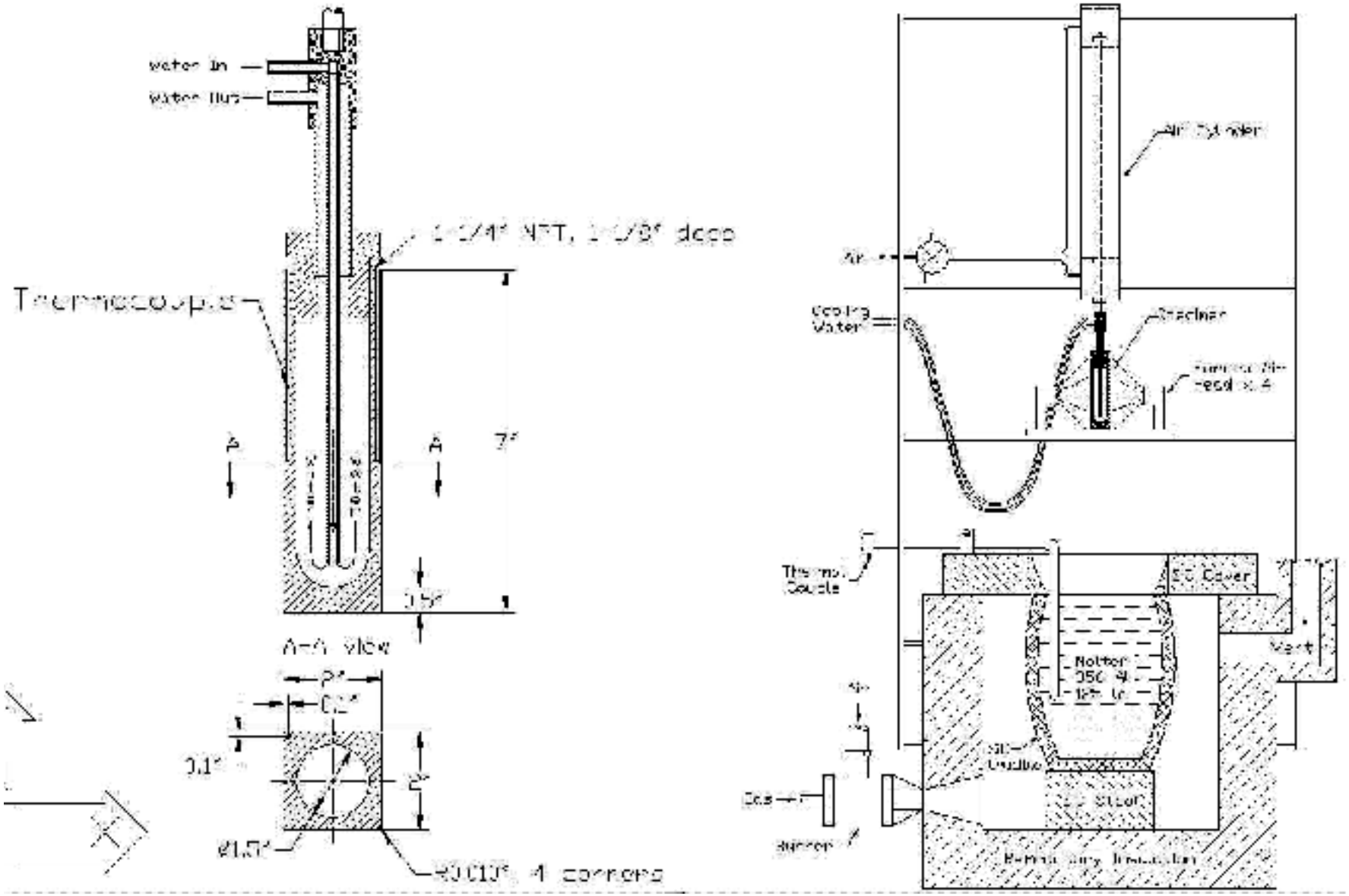
• A key issue in selecting the material for rapid tooling is to ensure it will last long enough to make the required number of parts yet last no longer than necessary

•The Thermal Fatigue Immersion test at CWRU can simulate the die casting or permanent mold casting environment, and is used to rate candidate materials for prototype dies and molds.

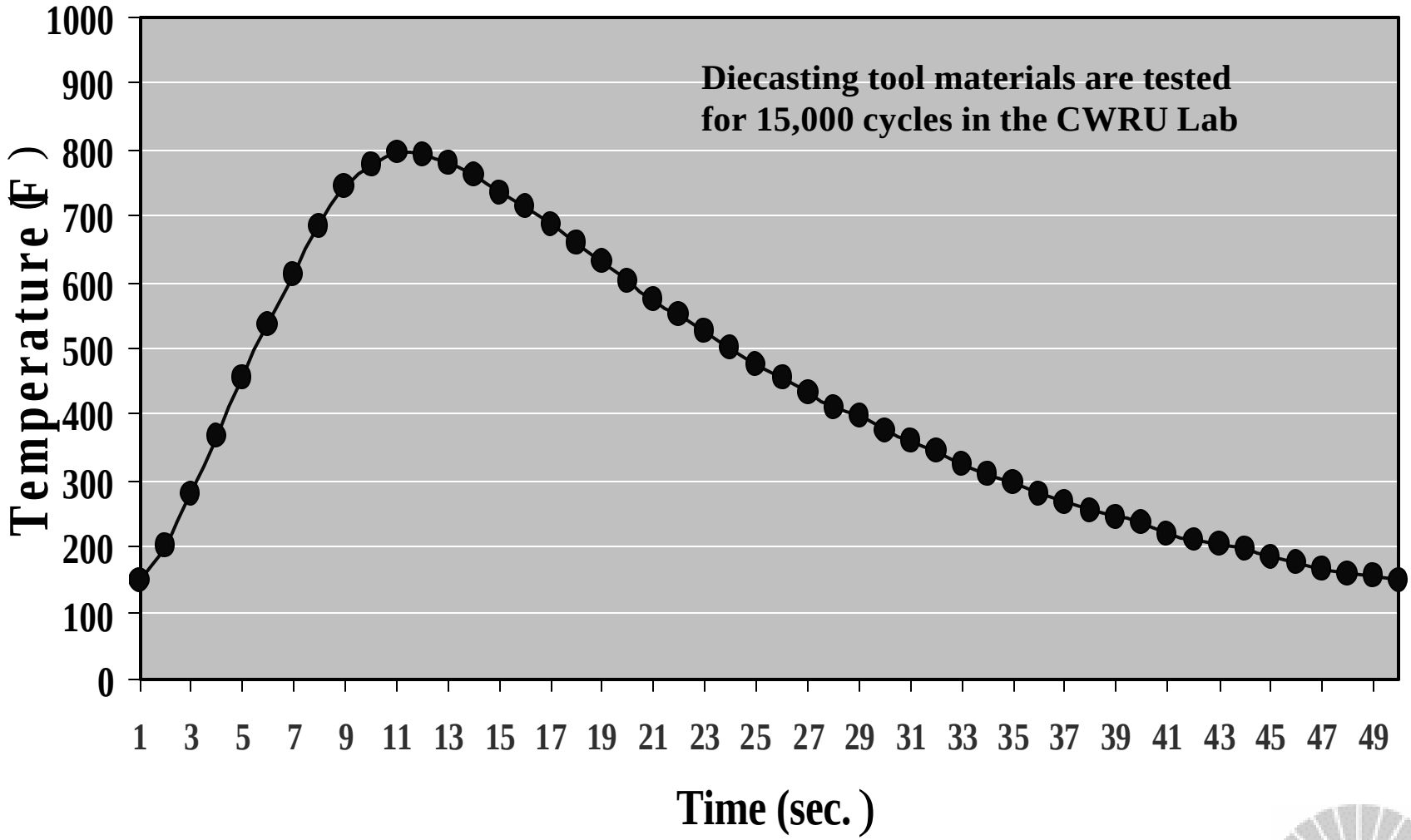
•This unique test has become the industry standard for evaluation of permanent mold and die materials.

•The mechanical properties of identical castings made with different rapid tools will be compared.

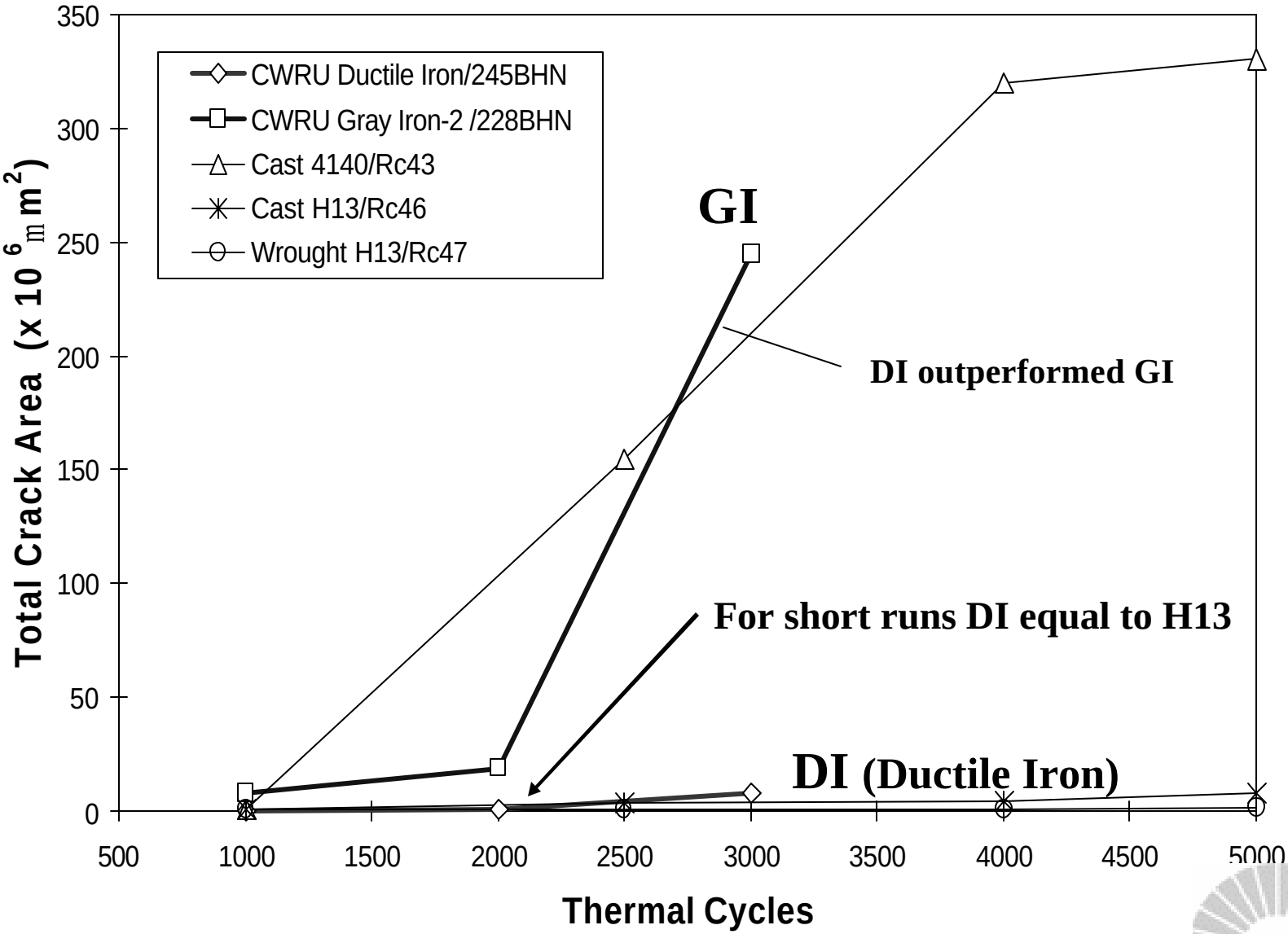
Thermal Fatigue Immersion Test and Equipment (Intermittent immersion and cooling every 36 seconds)



Typical Thermal Fatigue Cycle For The Evaluation of Permanent Mold Materials



Thermal Fatigue Performance of Selected Mold Materials Represents Resistance of Tools To Cracking



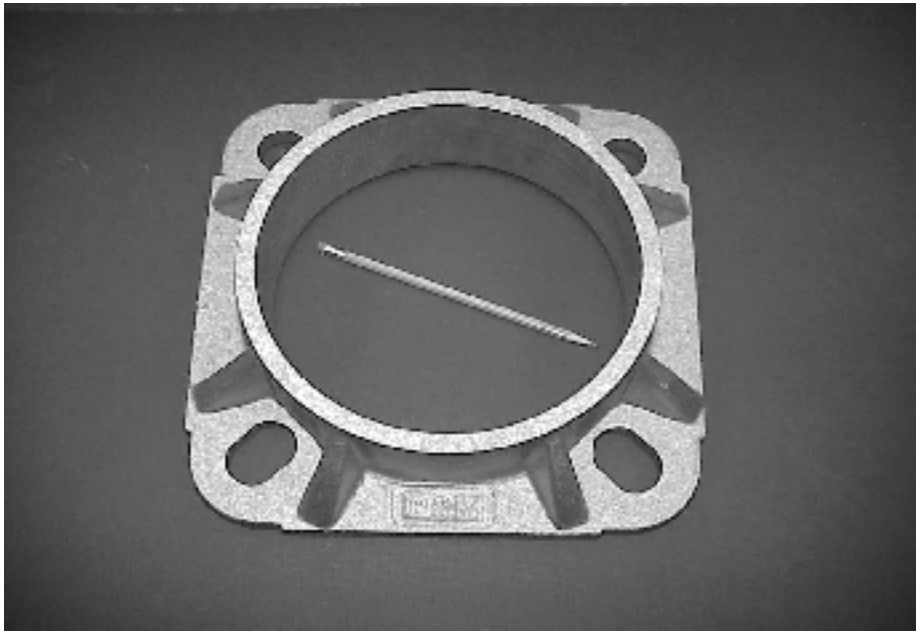
DOD Component

ABRAMS M1A1 Tank

PART: Steering handle
SUPPLIER: Arrow Aluminum
METAL: A356
PROCESS: Permanent Mold
ANNUAL USE: 500 units

PROBLEM ADDRESSED: Long lead time to production of prototypes.
SOLUTION: Metal mold was created as a casting using rapid prototyping technology

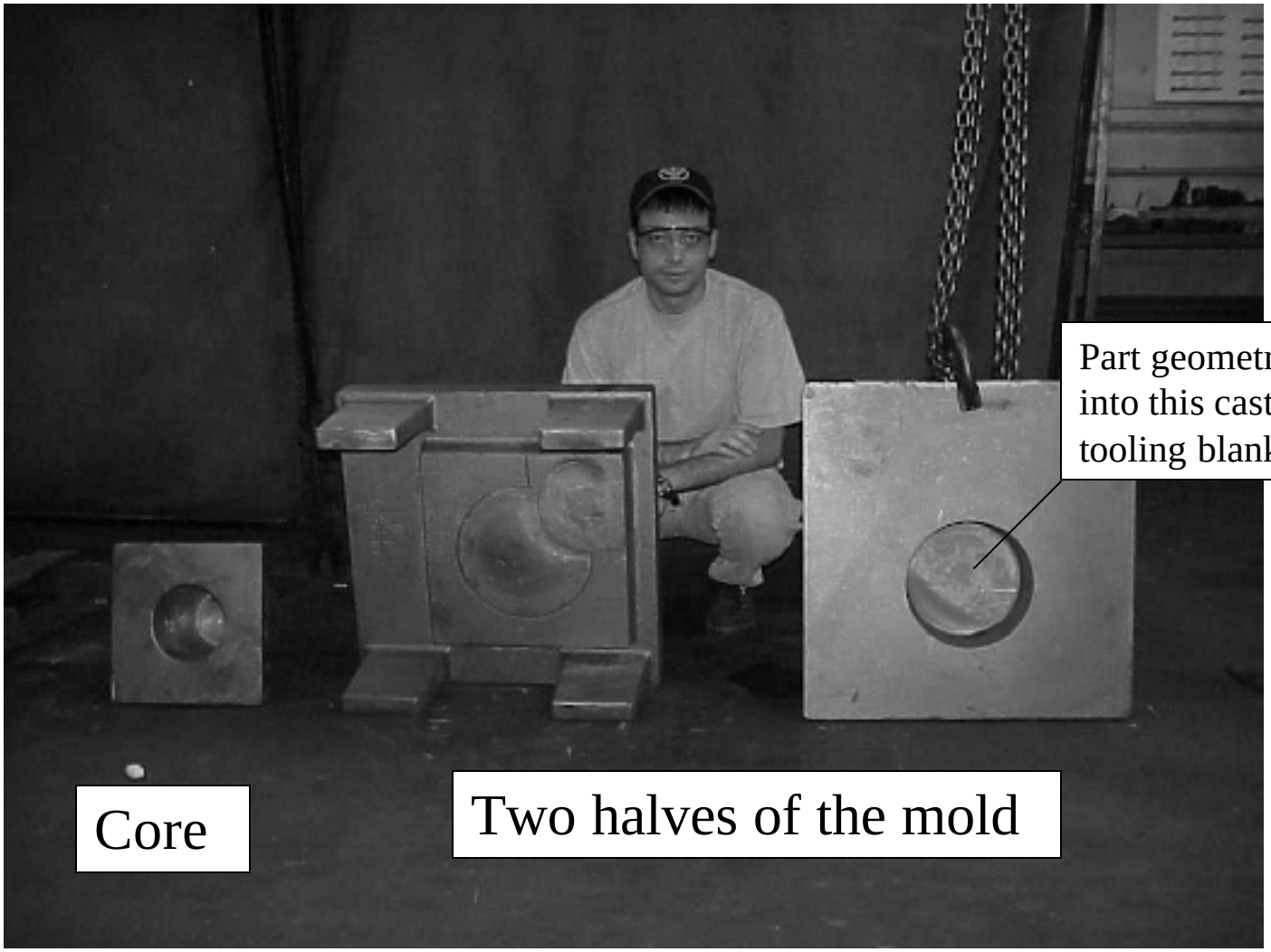
PART: Pole Base
SUPPLIER: Arrow Aluminum
METAL: A356
ANNUAL USE: 5,000 units
The sharp geometry changes make this part a good test.



PROBLEM ADDRESSED: Excessive thermal fatigue cracking of the permanent mold near the heavy sections of the casting.

SOLUTION: Metal mold made from cast ductile iron using a rapid prototyping technique. Ductile iron chosen as the tool material based on thermal fatigue data from the the CWRU immersion tests. So far 5,000 castings have been made with no tool cracking.

Ductile Iron Permanent Mold Inserts Cast at St. Louis Precision Casting were delivered to Arrow Aluminum

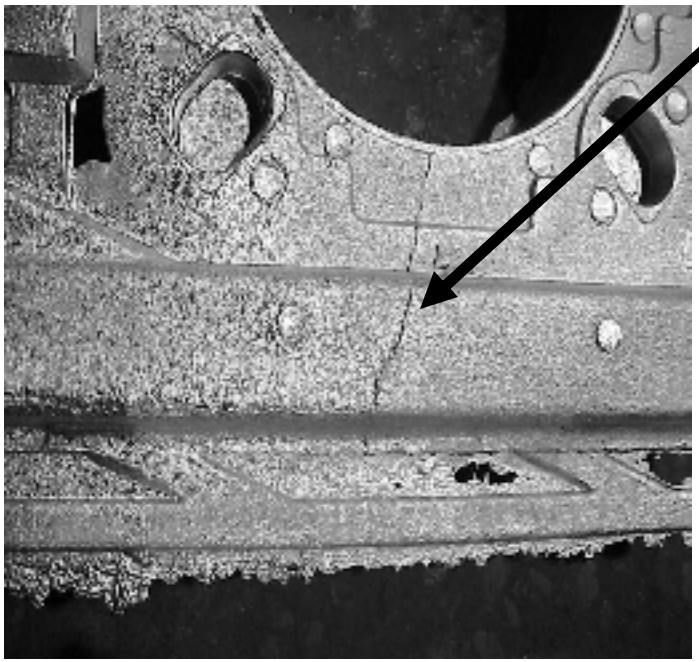


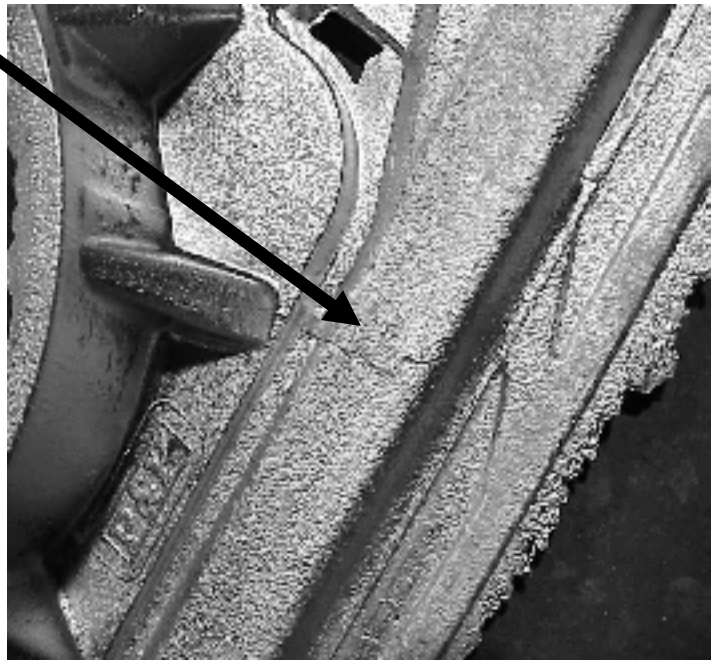
Cost effectiveness and short lead times were demonstrated

Technical Progress – Rapid Permanent Mold

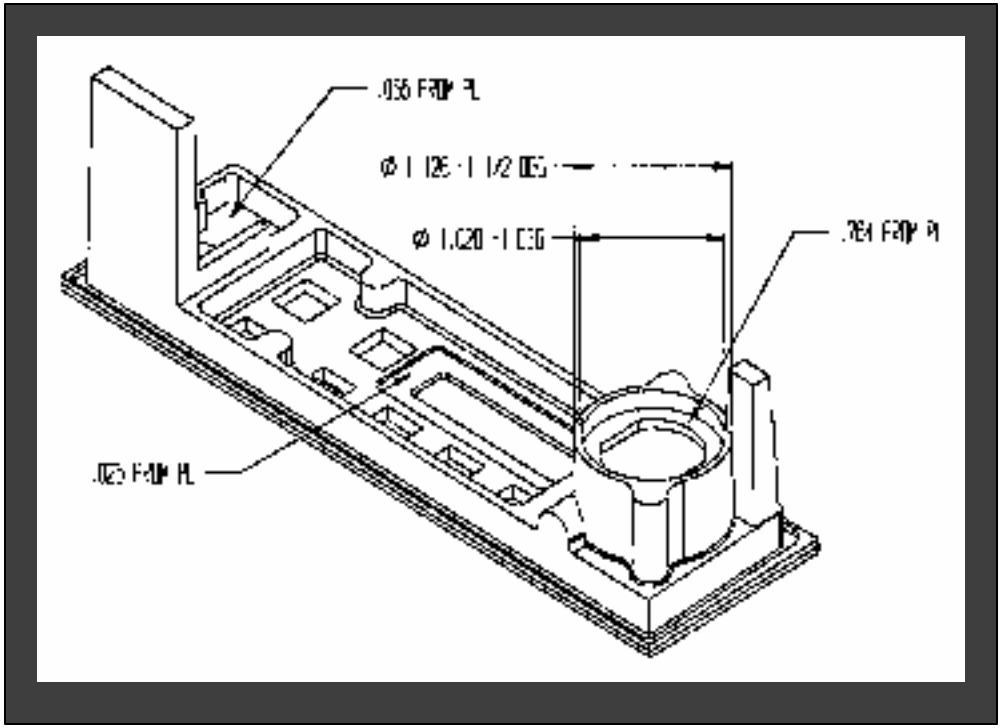
The new Ductile Iron permanent mold cast at St. Louis Precision Casting has replaced an old Gray Iron mold in production at Arrow Aluminum. The thermal fatigue resistance of the new mold is being monitored.

Fins caused by thermal fatigue cracking of the old, Gray Iron mold





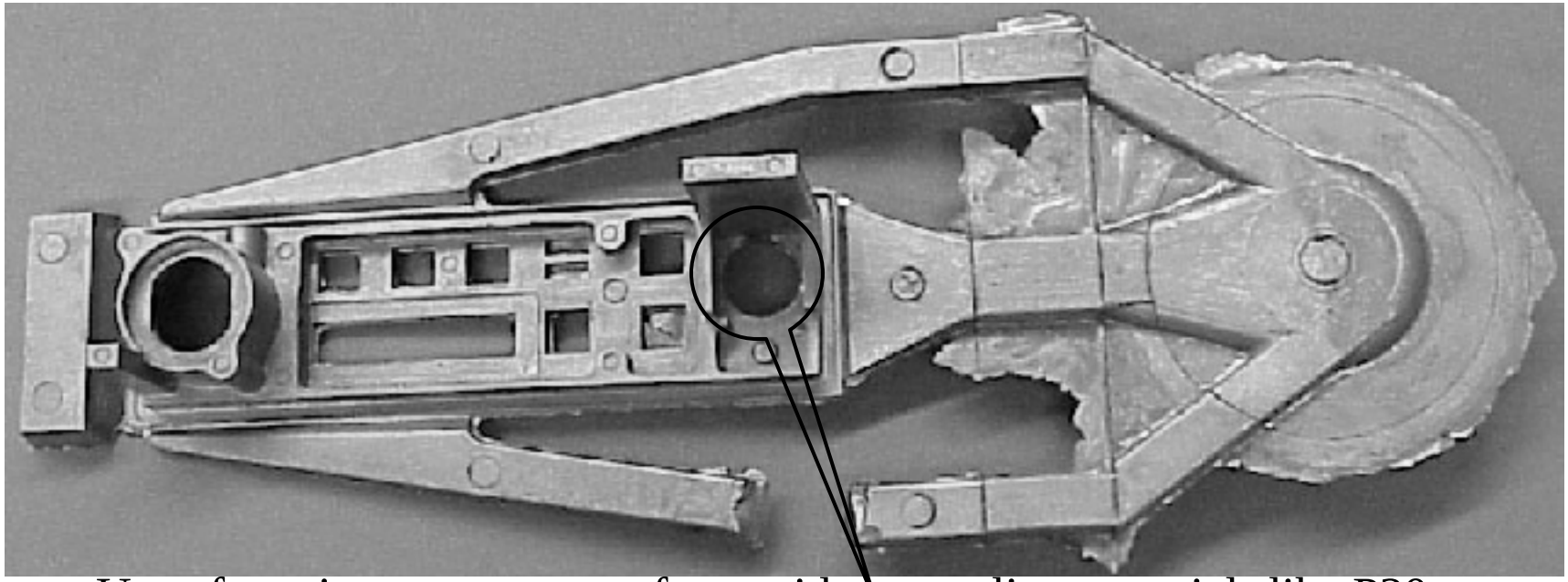
PART: Front Panel of Tactical Decryptor Ground Unit
SUPPLIER: SciCast
METAL: A380
ANNUAL USE: 20,000 units (considered medium volume in die casting)



PROBLEM ADDRESSED: Long delivery time for new models of The Tactical Decryptor Units (TDU). High dimensional accuracy requires Die Casting.

SOLUTION: Machine rapid tooling from P20 or soft H13 steel using a CAD generated pattern. This method can shorten lead times significantly from 24-36 weeks to 4-6 weeks.

Die Cast Front Panel of a MYK-7A Decryptor Unit
(including runners and biscuit)

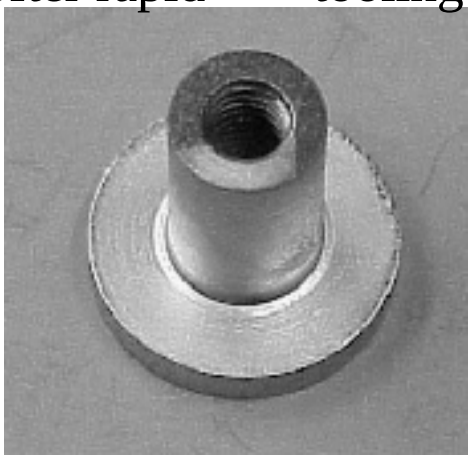


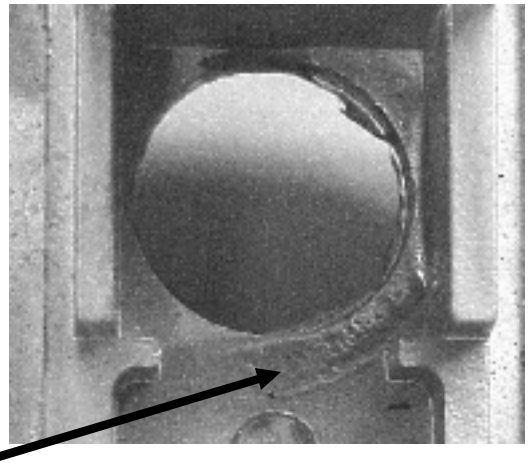
Use of coatings to protect softer rapid tooling materials like P20

<u>TiN coated core pin</u>

Creates round hole across gate. Would usually be damaged by impingement of Al jet from gate.

TiN provides local protection as learned in DOE projects



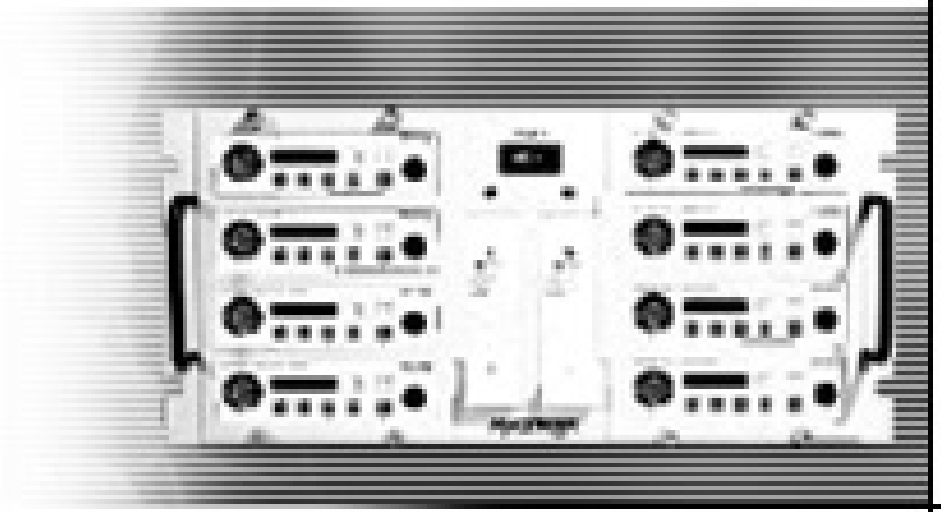


Washout damage

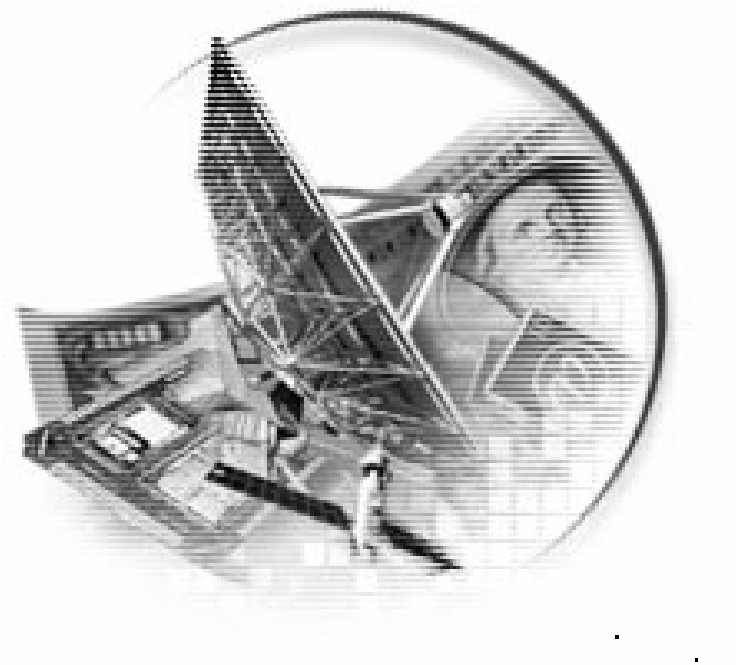
The Product

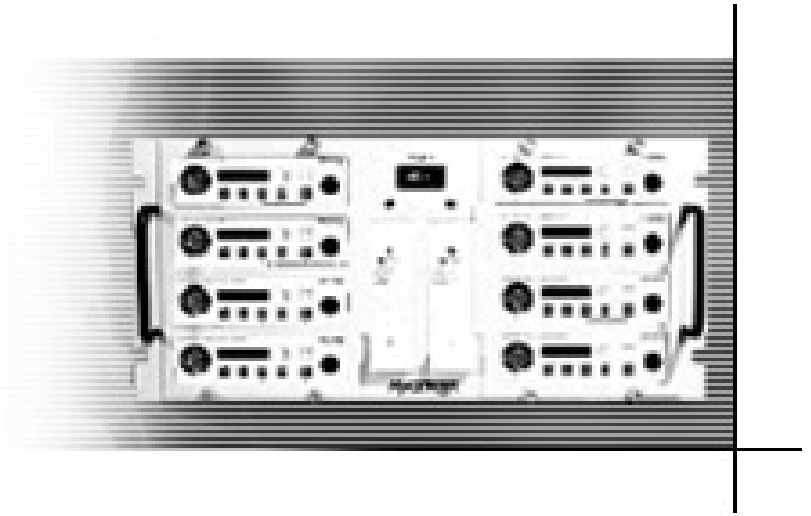
Front panel of MYK-7F6 unit. Die cast in aluminum 380.

Tactical encryption and decryption units (TDU) are used to secure electronic communication in the battlefield.



Tactical Ground Encrypted Communication Systems





***Rainbow Mykotronx* is a world-renowned designer and manufacturer of cryptographic solutions for technologies ranging from the high-traffic of electronic commerce to the isolation of space to the rigors of the battlefield. More Rainbow Mykotronx products have received National Security Agency certification than those of any other organization.**

Military End User

Cryptologic Systems Group (CPSG)

Lt. Col. Scott Lamont
Mr. Greg Fowler

Lackland Air Force Base

The Die Caster

SciCast International Incorporated

- SciCast International, Inc.
  650 Rt. 100 North
  Bechtelsville, PA 19505

- Phone: 610-369-3060
  Fax: 610-367-4759

Heat sink for electronic circuit of Joint Direct Attack Munition (JADAM)

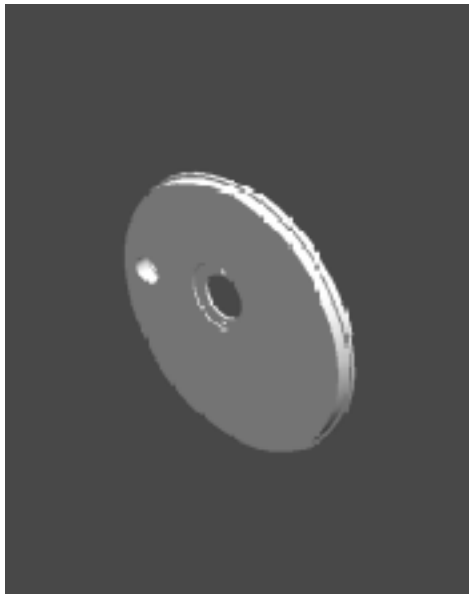
Customer: Textron (supplies Smart Bombs to Air Force)

Die Caster: SciCast

Tool Maker: Cam Tool and Engineering

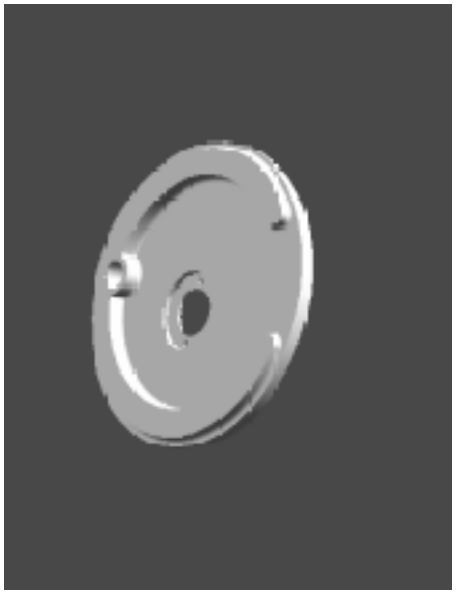
Annual Use: 25,000 units

TEXTRON



Heat Sink
(Front Side)

JADAM Cluster



Heat Sink
(Back Side)

Die Casting P20 Rapid Inserts Made at CAM for the Project

The inserts were fabricated in record time (less than 3 weeks compared to standard 21 weeks) from a CAD model. Textron, the supplier, is very pleased with this **extremely short lead time.**

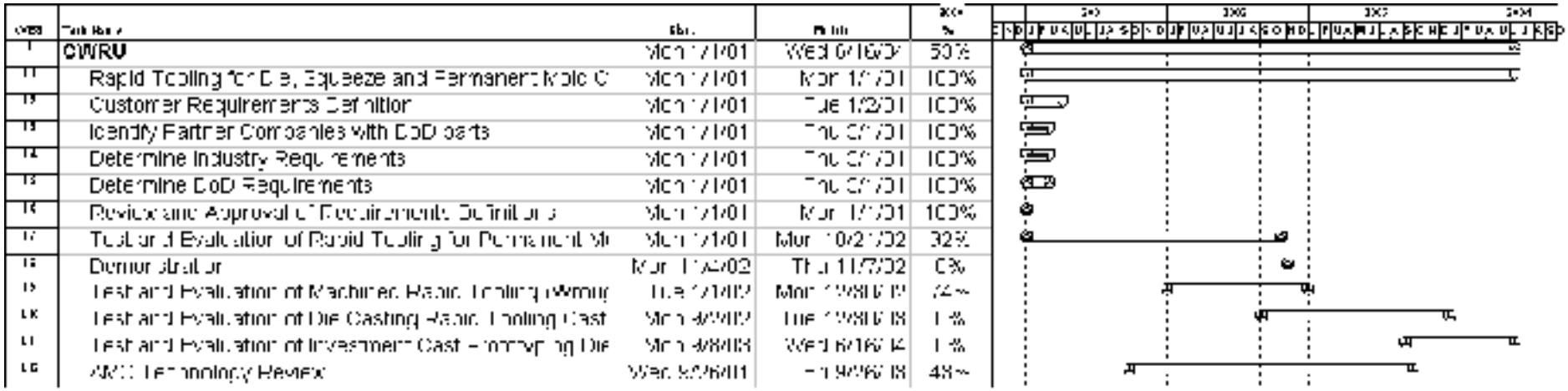
Case Western Reserve University Related R&D Activities

- Long tradition of research and development in die and mold materials with NADCA, AFS and DOE funding.
- CWRU was a participant in a three year USCAR-NADCA project on prototyping dies for die casting and is applying lessons learned to the PRO-ACT project.
- Another recent project with DOE/AFS addressed selection and evaluation of materials for permanent molds. The know how gained is also applied to the PRO-ACT project.
- The CWRU project team is coordinating activities with the CAST-IT team to maximize benefits of the project to DLA.

Commercial Applications

- Rapid metal mold tooling is a high priority technology for the metalcasting industry.
- There is a strong "pull" from the automotive sector. Fast prototypes for safety critical parts that exhibit actual metal mold properties is a priority. NADCA and AFS are assisting technology transfer into this market sector and others.
- NADCA has regular sessions on prototyping at the annual Die Casting Congress and features frequent articles on this subject in the Die Casting Engineer.
- The annual AFS Congress includes presentations on prototyping and Modern Casting often publishes articles on this subject (see article on Rapid Tooling in the July 2002 issue)

Schedule



Criteria Summary

Jointness

- All the branches of the military stand to benefit from better methods of Rapid Tooling.

Metrics

- $5 Million/year military savings are anticipated.

Transition

- NADCA and AFS are supporting the technology transfer to their membership.

Leveraging

- CWRU is applying lessons learned on Rapid Tooling in USCAR and DOE recent projects.

Criteria Summary

Inventory Control Point

- The project has identified multiple military parts.
- Reduce DLA procurement lead time.

Return on Investment

- The short term anticipated ROI is 15:1.

Sponsors

- St. Louis Precision Casting
- Arrow Aluminum,
- SciCast
- CAM Tool
- DCD Technology
- Precision Metalsmith,
- USAF
- Army
- TACOM.
- Bruce Pienkoski, Benet Labs

Industry Interest In Rapid Tooling

- Advantages
  - Reduced time to production
  - Lower part/tooling cost
  - Metal mold casting techniques more available
  - Can tailor technique to volume requirement
- Established how-to guidelines published by NADCA
  - To be included in the new Design for Diecasting CD
- More components designed
- as metal mold castings
- Strengthened supply chain

Acknowledgements

AMC's PRO-ACT program is sponsored by the Defense Supply Center Philadelphia, Philadelphia, PA and the Defense Logistics Agency, Ft. Belvoir, VA.