

# Housing for a Thermoelectric Fan

## Die Casting Study Outline



Thermoelectric Fan

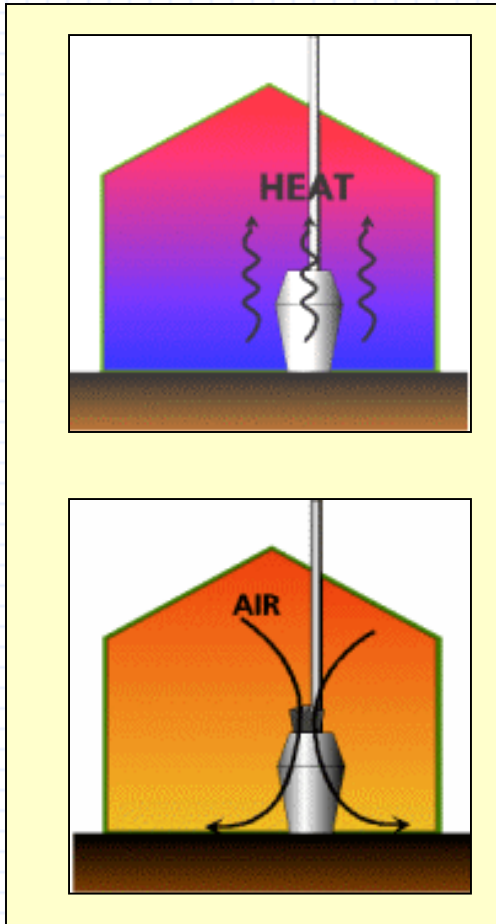
- Introduction to the Fan Housing
- Die Casting Design Issues
  - ▶ Alloy Selection
  - ▶ Vacuum Casting Porosity Control
  - ▶ Die Design - Gates and Overflows
  - ▶ Thermal Management and Die Materials
- Machining and Quality Assurance
- Lessons Learned and Summary

## [Start the Aluminum Die Casting Study](#)

### Acknowledgement --

*The Die Casting design studies are a sponsored by the North American Die Casting Association. Project funding was provided by the American Metal Casting Consortium Project, which is sponsored by the Defense Supply Center Philadelphia and the Defense Logistics Agency, Ft. Belvoir.*

# Introduction



**The Requirement** -- In cold climates, military personnel need warm shelter for protection from the elements. In tents, sheds, and buildings without central heating, the shelters use individual space heaters to provide warmth.

- In such uninsulated structures, the hot air from the heaters rapidly rises to the ceiling without warming the actual living space.
- The comfort level in these shelters is markedly improved if the warm air is directly circulated throughout the shelter, as compared to natural convection conditions.

# Thermoelectric Fan -- Application



**Military Space Heater  
with TEF**

- The Thermoelectric Fan (TEF) from Aspen Systems of Marlborough, MA, sits on the space heater and circulates the hot air from the heater downward toward the floor before it gets a chance to rise to the ceiling.
  - This reduces thermal variations in the shelter and provides warmer conditions for the occupants.

**The TEF saves fuel by allowing the heater to run at a lower fuel rate while achieving comfortable temperature levels throughout the enclosure.**

# Thermoelectric Fan - Operation and Description

- **Fan Operation** --The TEF creates its own power by converting a small amount of heat from the space heater into electricity which drives the motor and turns the fan. No other external power source is needed.
- The bottom surface of the TEF is heated by direct contact with the hot stove, absorbing a small amount of heat.
  - This heat is converted by a solid state thermoelectric generator into electricity, which drives an axial motor. The fan is directly attached to the motor's upper shaft.



The TEF has a 14 inch diameter and 10 inch height, weighs 12 pounds, and moves the air at 450 cfm.

# Fan Housing - Function and Description

**Fan Housing** -- An integral part of the TEF is the fan housing which provides structural support and protection for the motor and fan and acts as the heat sink and thermal transfer link for the thermoelectric generator in the TEF.



**Description** --The fan housing is a 14" diameter open top cylinder with a complex slotted and finned base. The cylinder is 10" high and has a weight of 7.5 lbs. The wall thickness of the housing ranges from 0.880" at the base to 0.124" on the side walls.

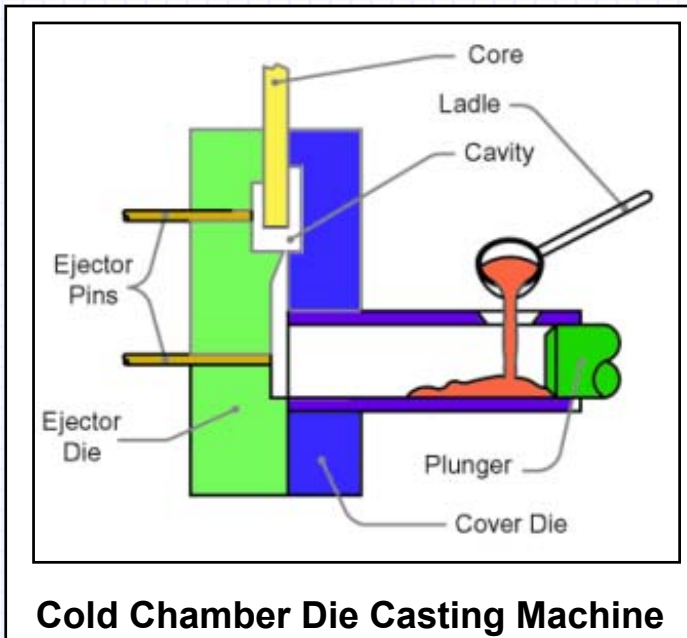
The slots in the base provide paths for the forced air to exit close to the hot surface of the stove, picking up heat and moving down away from the fan

## Performance Requirements

- **Performance Requirements** -- High thermal conductivity in the housing is a key performance factor to maximize heat transfer from the thermoelectric generator.
- The housing need to have controlled wall thickness and uniform metal fill for structural integrity and rigidity.
- Machined features must be free of porosity for good thermal conductivity and to prevent off-tolerance drilling and tapping.
- Dimensional tolerances for precision machined features are +/- 0.005" to meet form and fit requirements.



# The Die Casting Process

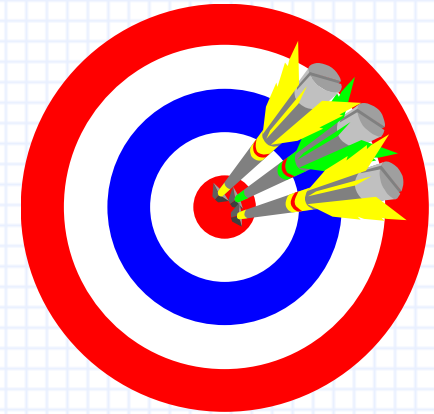


- **Kennedy Die Casting in Worcester, MA was called upon to produce the 7.5 lb fan housing as a precision die casting.**
  - Annual production is 1,500 units cast in a 3-plate precision die.

***Die casting is a manufacturing process in which molten metal is forced under high pressure into reusable, precise tolerance metal dies.***

## Major benefits of die casting for this component are:

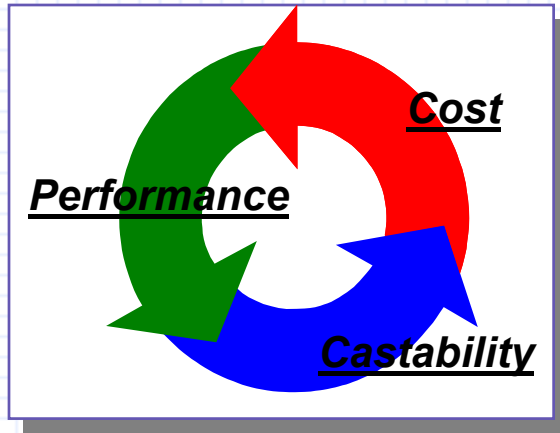
- Production of complex shapes with close tolerances.
- High rates of production at low cost.
- Little or no machining is required.
- Integrated fastening elements, such as bosses and studs.



**Die casting is the production method of choice for this fan housing, meeting the requirements for complex shape, close tolerances, high quality, appearance, and low cost production.**



# Die Casting Design Issues



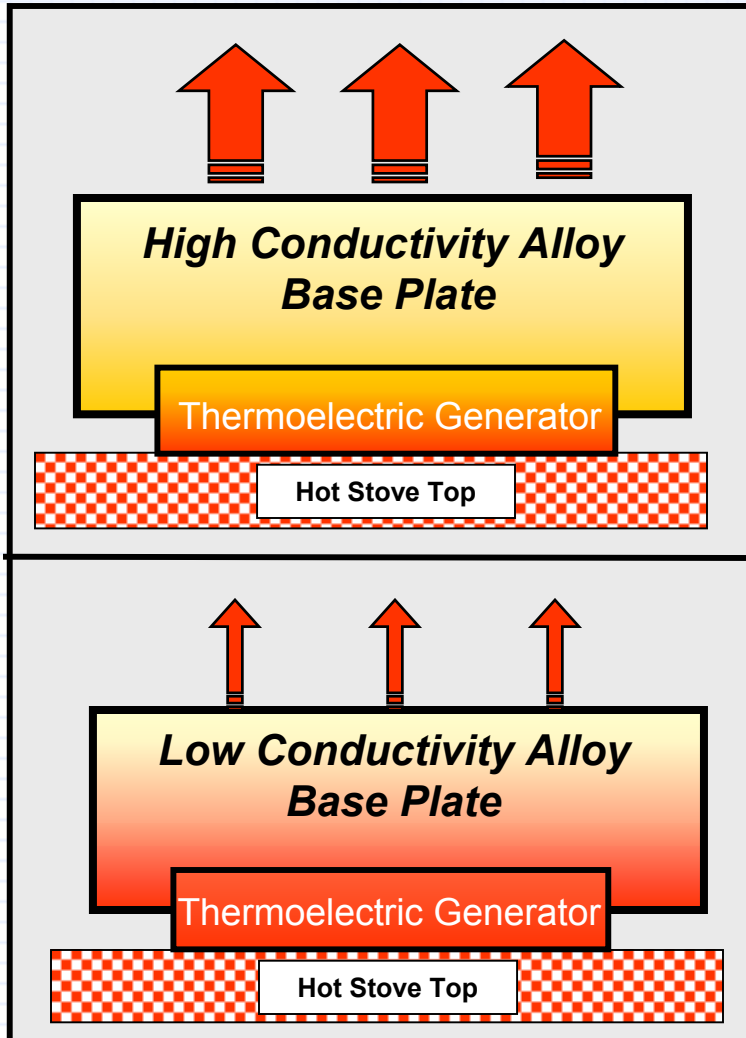
**The die casting design approach** -- The casting engineers at Kennedy Die Casting were given the challenge of producing the fan housing meeting stringent quality, cost, and delivery targets from the OEM producer, Aspen Systems.

- ***The die casting engineers had three design imperatives -- performance, castability, and cost***

**Critical Design Issues** --The requirements for performance, manufacturability/castability, and cost are closely interconnected. Four design issues played a major role in meeting the three design imperatives for the electronic housing components.

- Choose a metal alloy that best meets the performance and castability requirements.
- Optimize the die casting process to reduce porosity.
- Refine the gating and overflows to eliminate shrinkage porosity in critical areas.
- Tailor the thermal management process to ensure quality and reproducibility.

# Thermal Performance

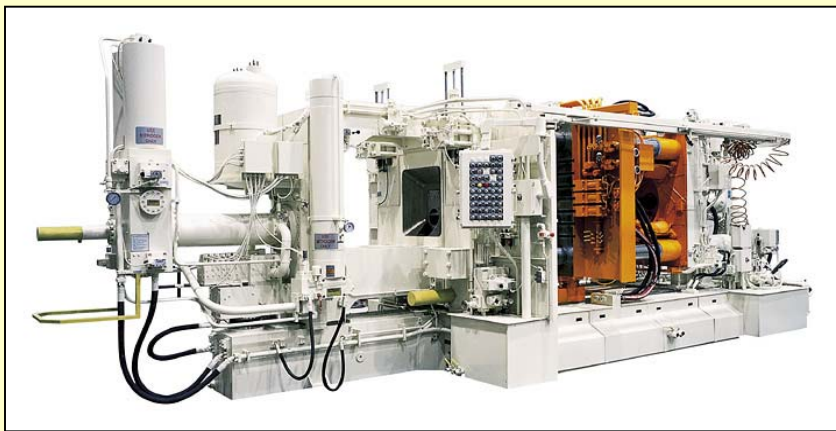


The efficiency of the thermoelectric generator depends upon establishing a large temperature difference between the top and bottom of the generator. The aluminum housing has to act as a heat sink, pulling the maximum amount of heat away from the top of the generator and transferring it to the fan air.

***This requires a high thermal conductivity for the housing alloy.***

**The metal alloy in the housing should have the maximum possible thermal conductivity while meeting mechanical property requirements.**

The die casting engineer has a range of different metal alloys to choose from, carefully considering the performance requirements and manufacturability issues for the component.



**Cold Chamber die casting Machine**

- ▶ For thermal performance, the alloy should have high thermal conductivity.
- ▶ For mechanical performance, the alloy has to be both strong and stiff.
- ▶ The housing has a machined mating surface and numerous screw holes that have to be drilled and tapped. The alloy has to be easily machined.

From the die casting perspective, the thin walls of fins and ribs in the base require an alloy that will flow and fill the die cavity rapidly and easily, but will not solidify too quickly. Early solidification in the die can produce defects (lack of fill, cold shuts, etc.) in the casting.

# Which Metal Alloy Has the Best Combination of Properties?

Three types of metal alloys can be considered for this application -

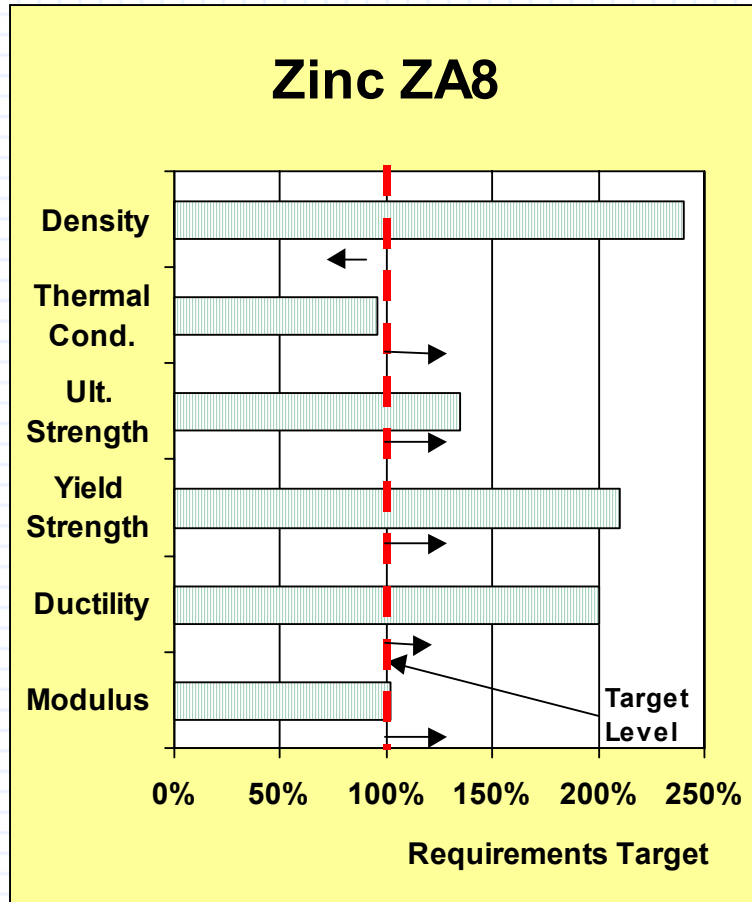
◆ **Zinc ZA8**

◆ **Aluminum *THERMALCAST*® 130**

◆ **Aluminum A380**

Alloy	Target	Zinc ZA8	Aluminum Thermalcast 130	Aluminum A380
Density (#/in <sup>3</sup> )	<0.10	0.24	0.095	0.096
Thermal Conductivity (W/mK)	>120	115	130	96
Ultimate Tensile Strength (ksi)	>40	54	46	47
Tensile Yield Strength (ksi)	>20	42	24	23
Ductility (% Elongation)	>3%	6-10%	4%	4%
Modulus (Msi)	>10	10.2	10.3	10.3

**Choose an alloy (Zinc ZA8, Aluminum-Thermalcast<sup>®</sup> 130, Aluminum A380) for the fan housing, based on density, thermal conductivity, strength, ductility, and modulus as shown above.**



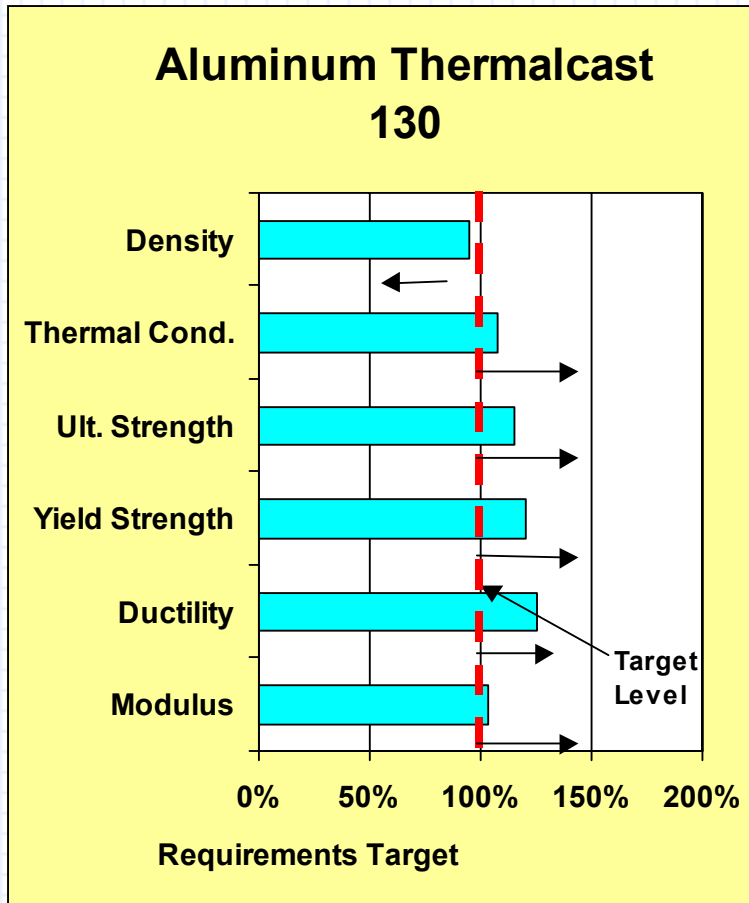
The Zinc alloy ZA8 is a common zinc die casting alloy.

- The zinc meets all the mechanical property requirements -- strength, ductility, and modulus
- But the zinc has 2 major shortfalls against the design requirements --
  - The thermal conductivity is about 4% short of the requirement.
  - The zinc has a major weight penalty, weighing 150% more than the aluminum alloy

**The zinc alloy is not the best choice.**

**Go back to the alloy page and select another alloy!**

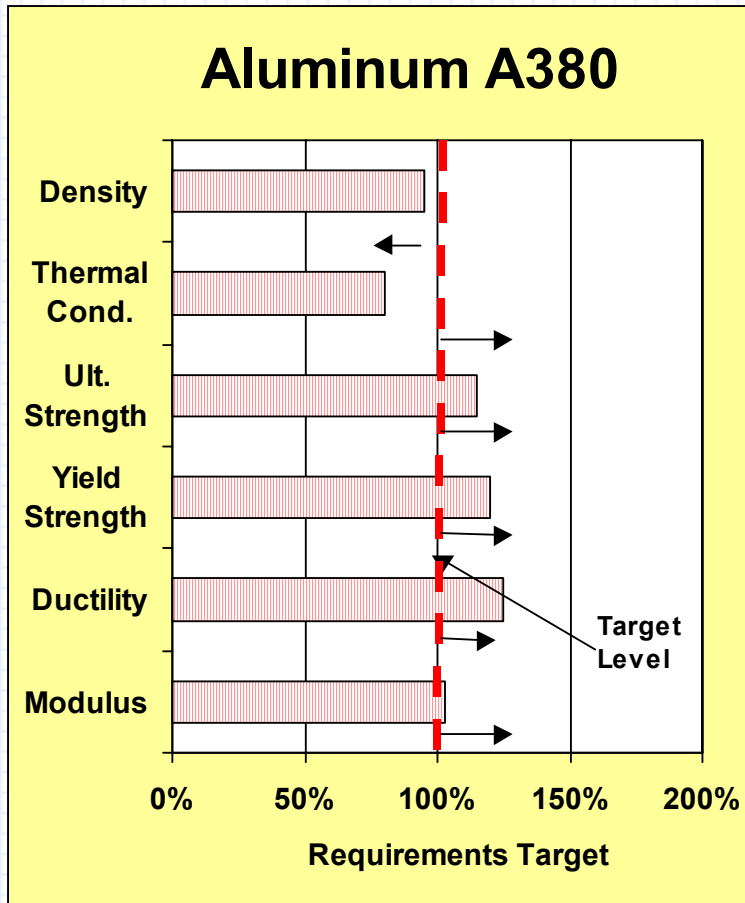
# Aluminum Thermalcast<sup>®</sup> 130



**The Thermalcast<sup>®</sup> 130 aluminum alloy is a proprietary alloy composition from Kennedy Die Casting**

- Thermalcast<sup>®</sup> 130 is specially formulated to have a high thermal conductivity (130 W/mK) with the mechanical properties of conventional aluminum die casting alloys.
- Thermalcast<sup>®</sup> 130 meets all the design requirements for density, thermal conductivity, strength, and stiffness.
- **The Thermalcast<sup>®</sup> 130 aluminum alloy is the best choice.**

**Go on to the section on vacuum assisted die casting.**



The aluminum A380 alloy is a common die casting alloy

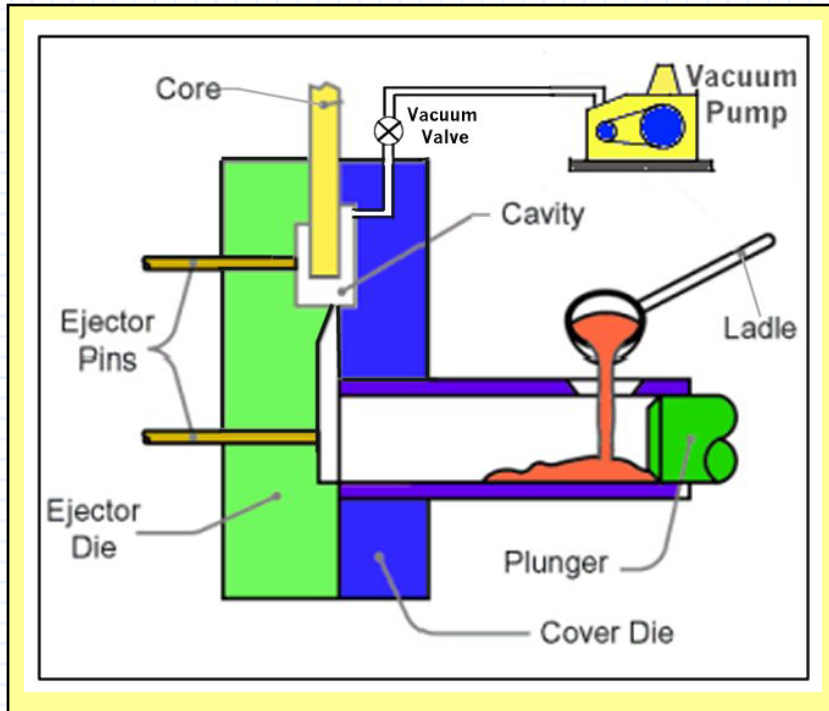
- The aluminum A380 alloy meets the mechanical property and density targets.
  - Ultimate tensile strength is 47 ksi and the yield strength is 23 ksi.
  - The density of the alloy is 0.095 pounds/in<sup>3</sup>.

*But the thermal conductivity of the A380 alloy is 20% lower than the design target.*

The aluminum A380 alloy is not the best choice.

**Go back to the alloy page and select another alloy!**

# Vacuum-Assisted Die Casting



Vacuum-assisted die casting is an important process capability at Kennedy Die Casting.

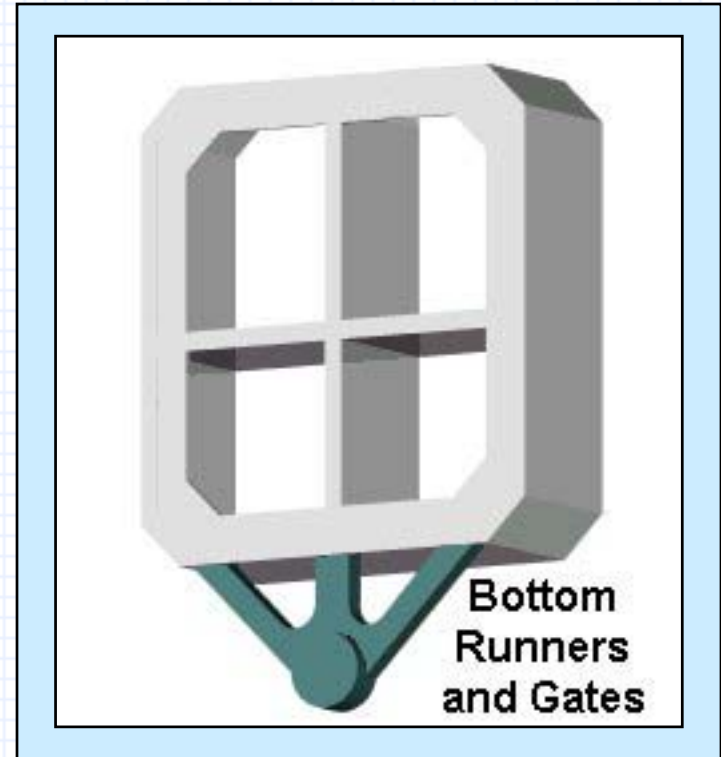
- The vacuum evacuation of the die cavity reduces gas entrapment during metal injection and decreases porosity in the casting. The result is a die casting with a higher level of quality.
- *Vacuum systems are only a supplement. They do not substitute for good die casting design practice in the engineering of the die cavity, runners, gates and overflows.*

**Vacuum-assisted die casting was used for the fan housing, reducing porosity in the casting and producing high quality parts in high volume.**



# Flow Control and Gate Design

- **Control of the metal flow in the die is a key factor in producing sound die castings.**
  - Metal must flow rapidly and uniformly into the die, minimizing turbulence and entrapped air.
- **A key feature in die design is the positioning of the runners and gates -- the passages that feed molten metal into the die cavity.**

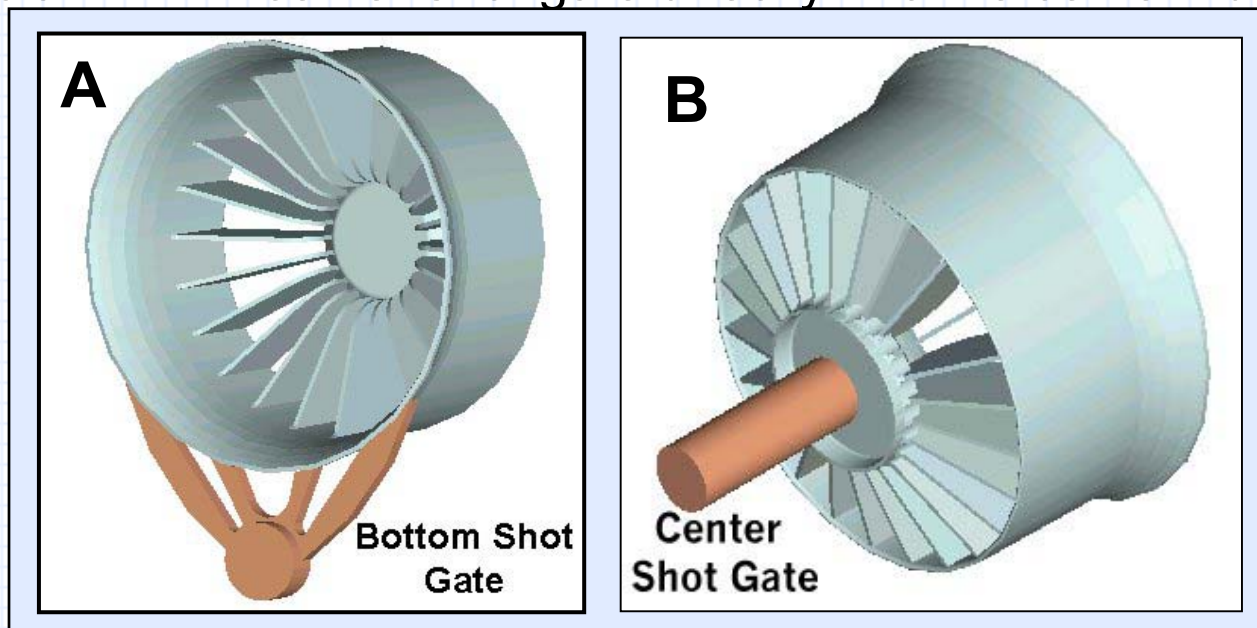


***Well-designed gates are positioned to permit rapid flow into the die cavity, minimizing turbulence and long flow paths for the molten metal.***

# Gating Options

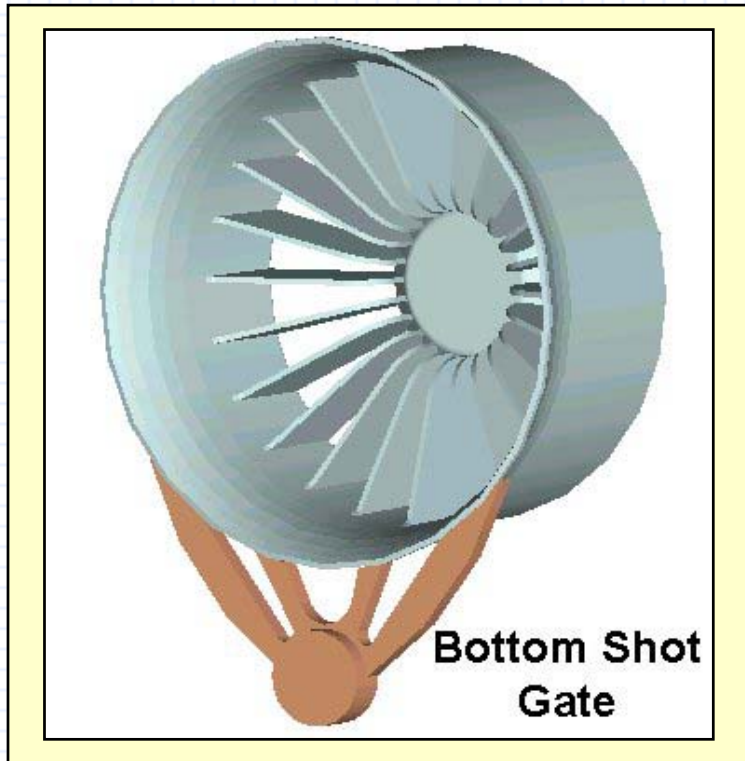
Two gating designs were considered for feed into the fan housing.

- **Option A** -- A bottom shot gate into the outer rim.
- **Option B** -- A center shot gate directly into the center hub.



Choose the gating design (**Option A** or **Option B**) that will provide uniform fill and rapid metal feed into the die.

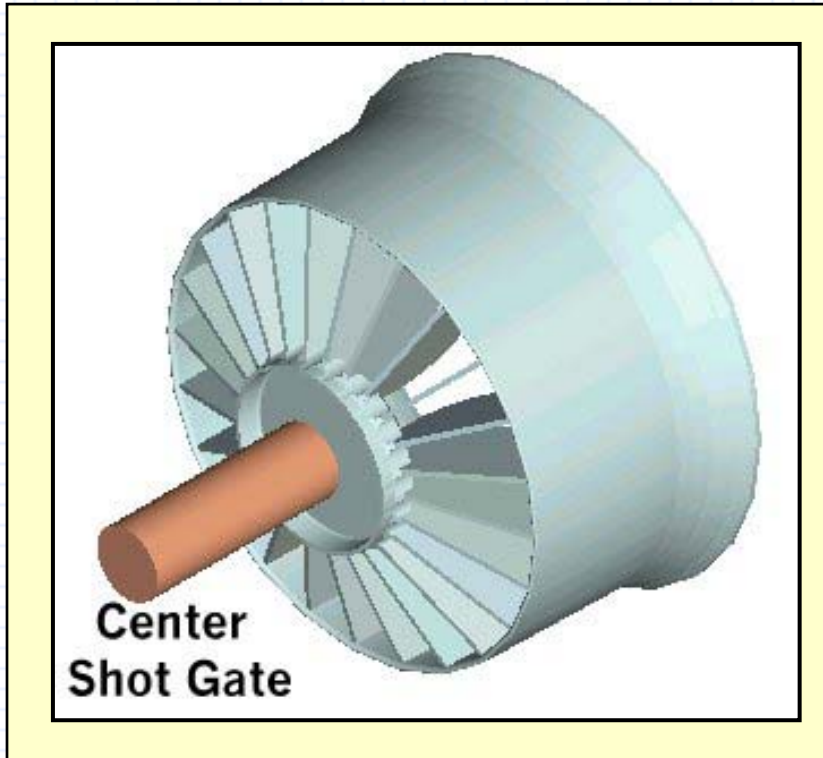
# Option A -- Bottom Shot



- In Option A the gate into the cavity is positioned at the bottom of the casting on the outer rim of the fan housing.
- With the bottom shot, the metal flow into the ribs and the center hub is long and tortuous, risking cold shuts and incomplete fill.

***Go back and reconsider your choice of gate design.***

# Option B -- Center Shot



- In Option B the gate is positioned at the center of the cavity directly into the center hub of the casting.
- With the center shot, the metal flows uniformly and rapidly from the center hub into all the thin wall ribs and outer rim, producing complete fill.
- The center shot gate is the best design

***Go to the next design issue --Overflow Design***

# Overflow Design Options

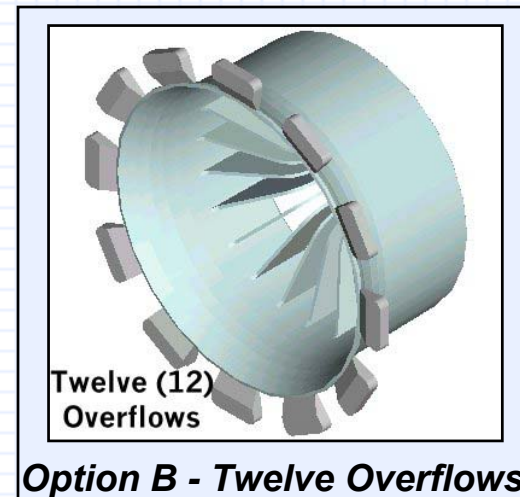
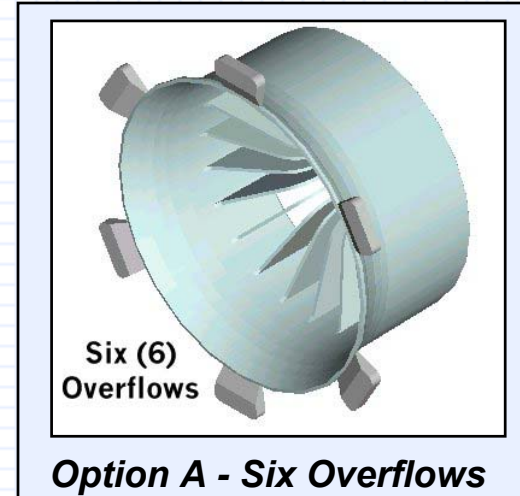
Overflows are cavities and passages in the die which acts as vents for air to escape and cavities for excess metal flow.

- *Overflows reduce porosity and promote complete metal fill into the far sections of the cavity.*

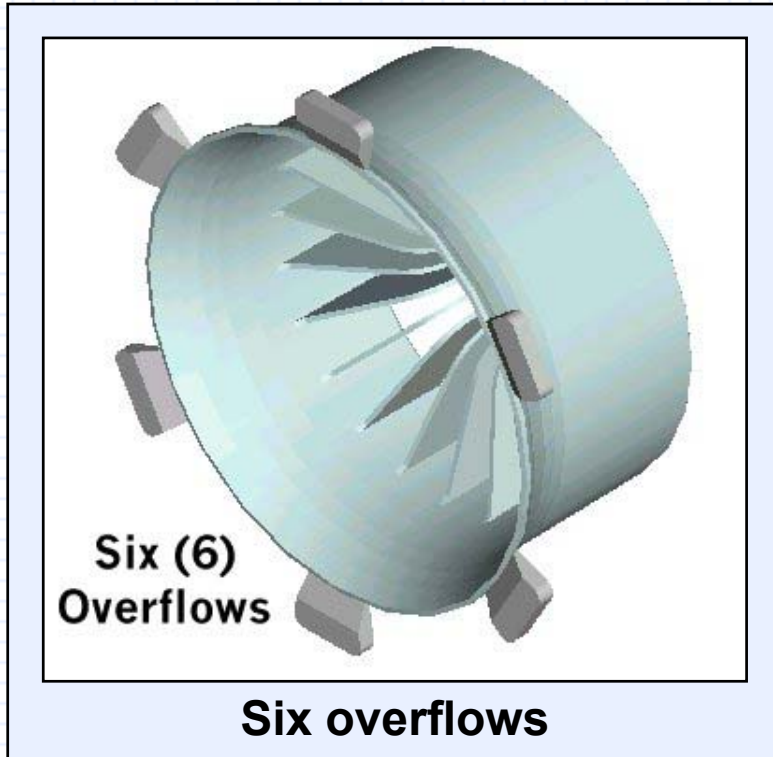
*Two overflow designs were considered for the fan housing with the center shot gate*

- **Option A** -- Six overflows around the perimeter of the rim
- **Option B** -- Twelve overflows around the perimeter of the rim

**Choose the overflow design (Option A or Option B) that will provide complete fill of the outer rim.**



# Option A for Overflows

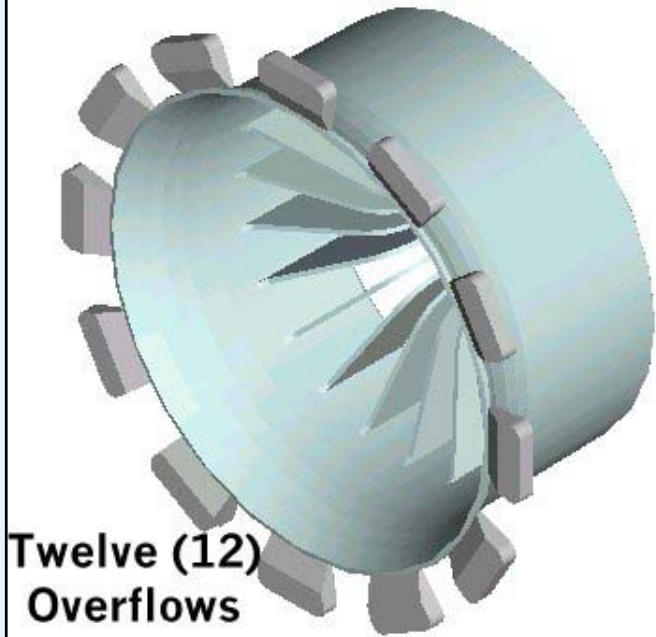


- Option A places six rectangular overflows on the perimeter of the rim.
- These overflows are the right size, but there are too few of them to ensure good venting and complete metal fill.

**Option A is not the best design for the overflows**

**Go back to the overflow selection page and select an alternate design.**

# Option B for Overflows



Twelve (12)  
Overflows

Twelve overflows

- Option B places twelve rectangular overflows on the perimeter of the rim.
- These twelve overflows are the right size and position to ensure good venting and complete metal fill in the rim.

**Option B is the best design  
for the overflows**

**Go to the next design issue.**

# Die Materials - Alloy Tool Steels

Die casting dies are made in at least two sections called the stationary die half and the moving die half. The dies fit together to form the die cavity, which is filled with molten metal.

The dies are made of alloy tool steels. These tool steels have the strength, wear resistance, and thermal durability to withstand thousands of molten metal injections.

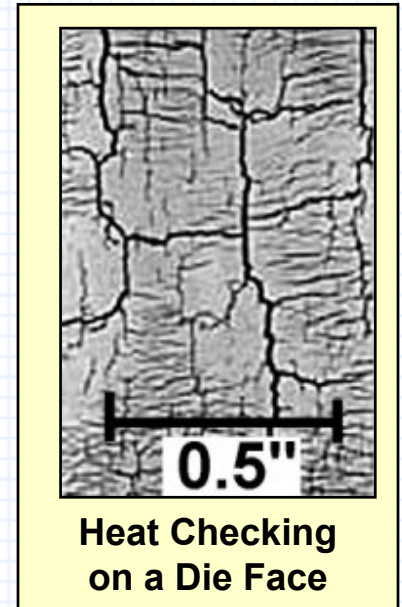
- Two ultrahigh strength tool steels used for dies are H11 and H13. These alloys have tensile strengths and hardnesses as high as 300 ksi and 56 Rockwell C, depending on heat treatment





# Thermal Management of Tooling

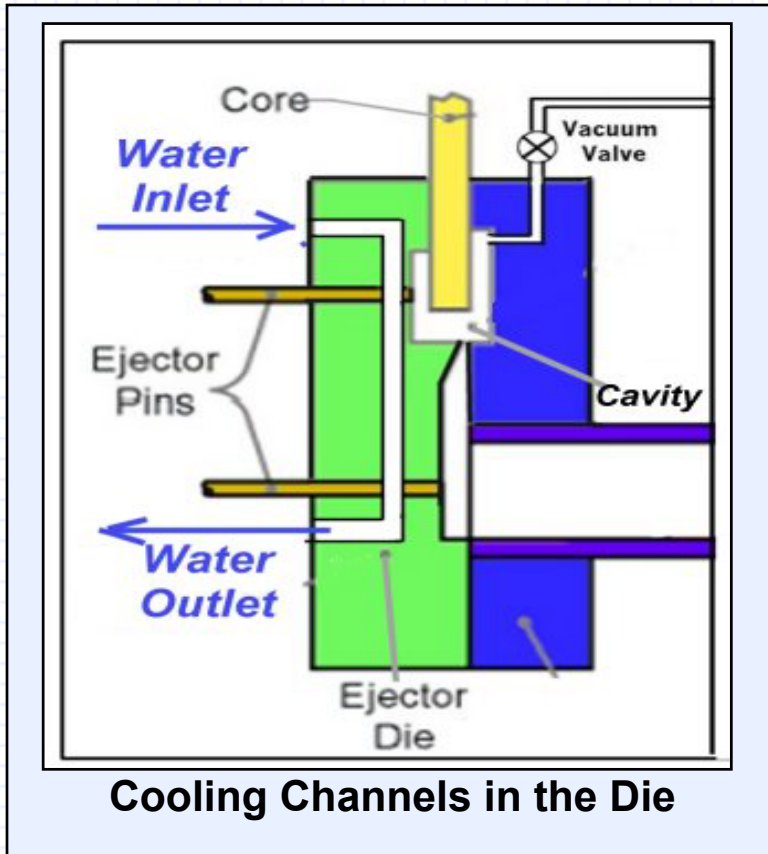
- **Thermal management of the tooling and dies is a critical production factor in die casting.**
  - If die faces overheat during production, “heat checking” can occur.
  - Heat checking is the formation very fine surface cracks on the die faces, which will transfer to the die casting as raised veins.
- The die casting engineer has to consider the thermal loads that occur in production (in terms of the thermal mass and the production rate) and ensure that the die faces do not overheat.



**Two thermal management approaches are used for cooling the dies**

- **Active water cooling** through channels in the die.
- **Spray cooling** on die faces between die casting shots

# Active Cooling Channels

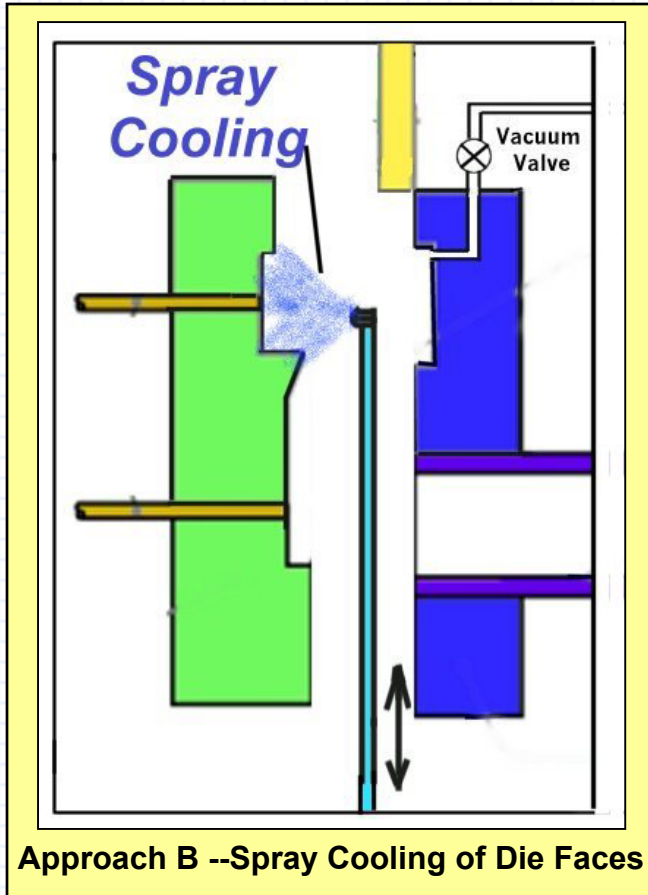


- Cooling channels in the die do increase the cost and complexity of the die. But they are are cost effective for high production rate, high volume jobs.
- For the fan housing, the production rate and volume are high enough to justify the cost of active cooling channels

**Active cooling channels are a good approach for thermal management in this die.**

**Go to the next cooling approach.**

# Die Spraying



- Dies are also cooled between shots by spraying cooling solutions on the faces of the dies.
  - *These solutions also act as lubricants for casting separation and ejection.*

**Spray cooling of the die faces is an economical approach for thermal management for this fan component.**

**Go to the next design issue.**

# Final Design of the Dies



**Ejector/Moving Half Die**



**Cover/Stationary Half Die**

- The housing is cast in a 3 plate die with a cold chamber gating system.
- The photos above show the two die halves -- the cover half and the ejector half.
- The casting dies for the housing were fabricated from premium grade H-13 tool steel.

# Finishing Operations



**Machined Fan Housing**

- After trimming, the fan housing is checked for dimensional tolerances and surface condition.
- The housing is then bead blasted, followed by machining operations
  - Finish machining of the base of the center hub to a 32 RMS finish for good thermal contact
  - Drilling and tapping the necessary mounting and assembly holes.
- The housing is finished with a protective black powder coat for corrosion protection and appearance.

# The Lessons Learned

**There were three important lessons learned in this successful design and production effort.**

**1. *Early involvement of the die casting engineer is an essential part of product design.***

- *When casting engineers are involved in the early stages of the design process, the finished die casting will be optimized for performance, cost, and manufacturability.*



**2. *Die casting alloy compositions can be tailored to enhance mechanical and physical properties.***

- *In this case a standard alloy was modified to provide the customer with the required thermal properties.*

**3. *The challenging geometry (ribs and varying cross sections) of the casting required a center shot technique for proper die filling.***

# Aluminum Thermoelectric Fan Housing

**The die casting for the aluminum housing of the thermoelectric fan provided the following benefits-**

- *Optimized thermal performance*
- *Reduced weight with mechanical durability*
- *Minimal machining costs*
- *High volume production at a cost-effective price.*



For further information on the design and production of this and other die castings, contact -- **Ted Bauer at Kennedy Die Casting**,  
Phone-- (508) 791-5594, FAX -- (508) 791-6338, E-mail --bauert@kennedydc.com

**Web Site = <http://www.kennedydc.com>**

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