Energy Efficiency Improvements for Aluminum Crucible Heating Systems

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Overview

- Background
- Project Description
- Analyses
- Heat Shield Design
- Total Costs
- Conclusion of Project
- After the Project
- Relation to IAC

Background

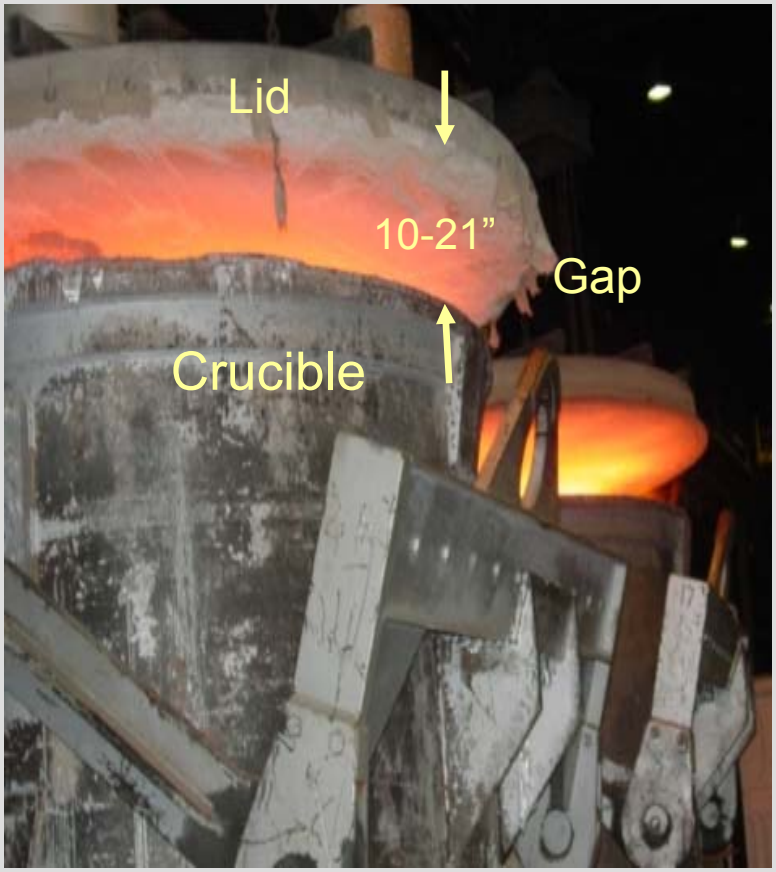
- Wise Alloys LLC
  - located in Muscle Shoals, AL
  - 3rd ranked U.S. producer of aluminum beverage can stock

- Plant site is composed of two main facilities:
  - Alabama Reclamation Operations (ARO)
  - Alloys Plant

- Department of Energy (DOE) conducted Energy Savings Assessment on Wise Alloys LLC in Spring 2006

Background

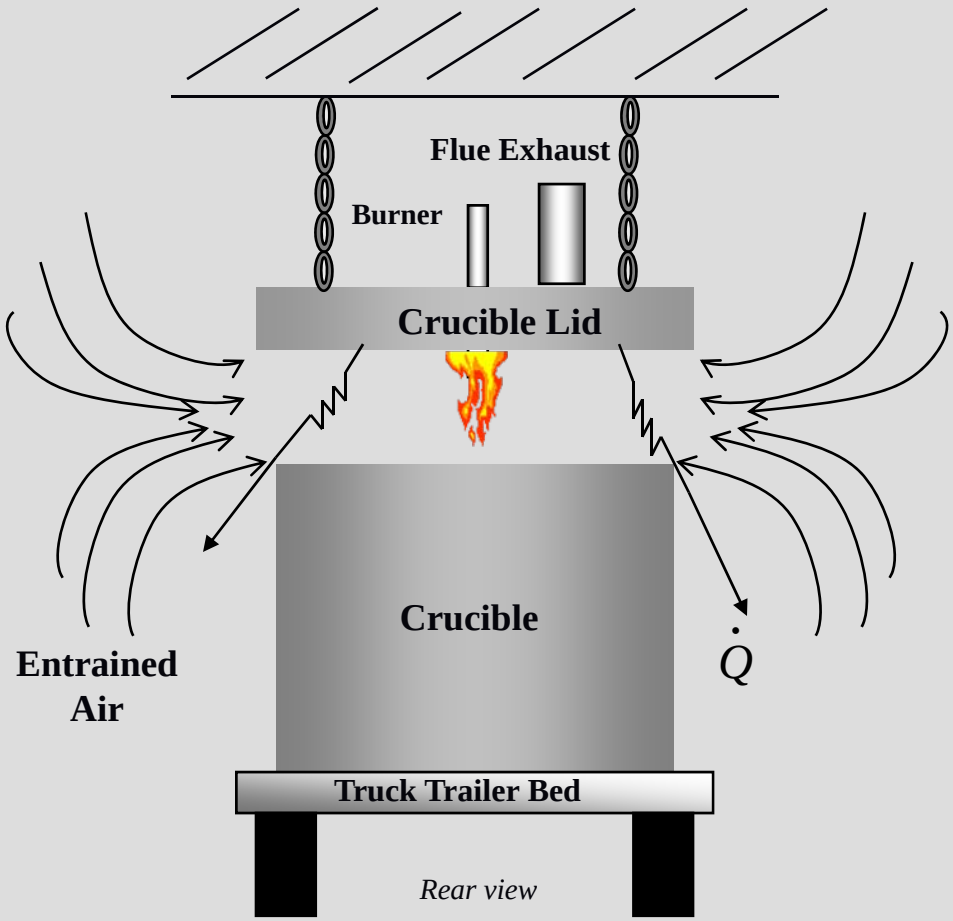
- DOE Energy Savings Assessment cited crucible heating stations area to reduce energy consumption by*:
  - Closing gap between crucible and lid at all 12 heating stations to reduce radiant heat loss
    - Estimated 52,400 MMBtu annual savings
    - Estimated $419,000 annual savings
- In Spring 2007, Wise Alloys partnered with the University of Alabama College of Engineering to have the design of the heat shields as a senior design project



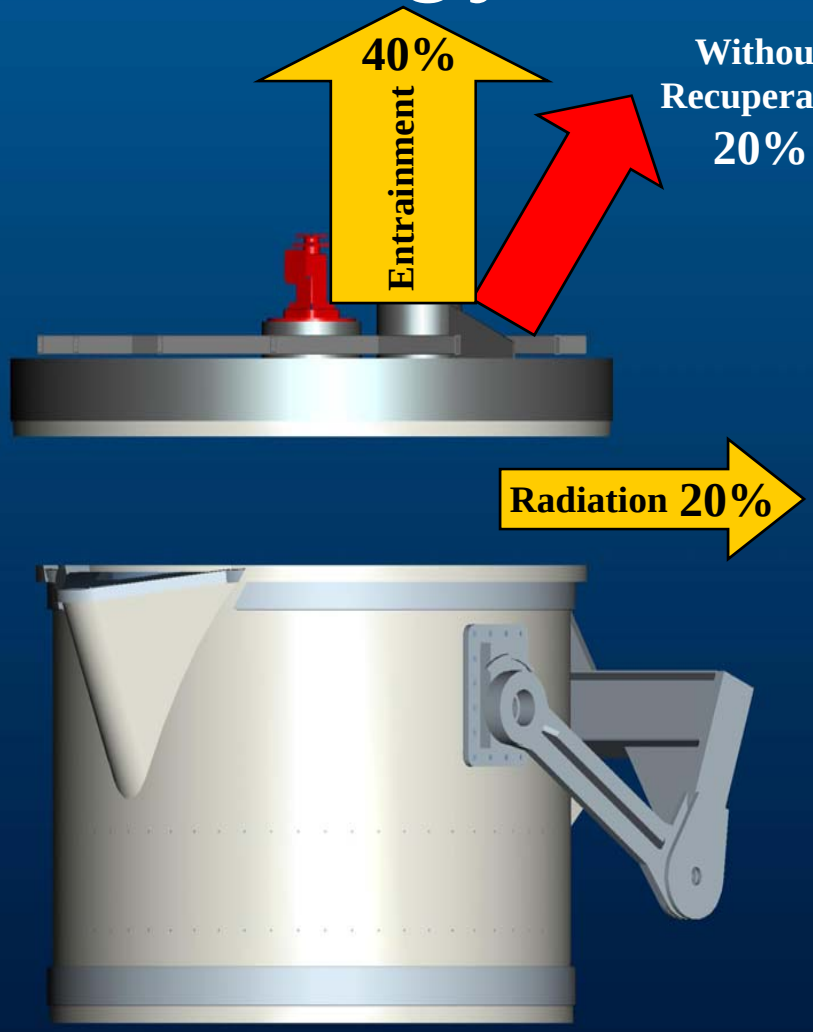
* *Paraphrased from Energy Savings Assessment (ESA-052) Summary Report (draft, 5/18/06).*

Project Description

- Perform assessment & identify ways to reduce energy costs at heating stations
- Perform thermal analyses on:
  - Radiant Heat Loss
  - Air Entrainment
  - Recuperator
- Design fully functional heat shield



Actual Energy Losses



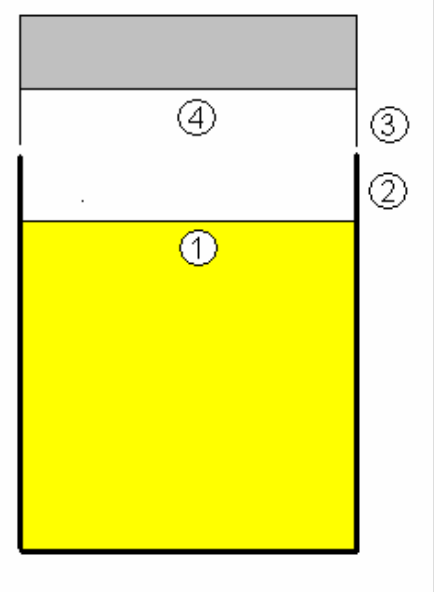
Performed Analyses

- Radiation Heat Loss
- Air Entrainment/Flue Gas
- Design Calculations
  - Bolt
  - Welds
- Recuperator Energy and Cost Savings

Heat Loss by Radiation

- Calculated view factors of system
- Found emissivity and radiosity of system through appropriate heat transfer equations and energy balances
- For simple radiation shield, assumed no internal resistance
- For added insulation, assumed internal resistance based on mid-grade insulation material

Heat Transfer Btu/hr x 10^3	Molten Aluminum **1**	Side of Crucible **2**	Open Air/ Radiation Shield **3**	Heating Lid **4**
No Radiation Shield	-95.4	-342.0	+1768.6	-1331.2
Simple Radiation Shield	-59.2	-212.3	+1097.6	-826.2
Insulation	-3.23	-11.57	+59.83	-45.03

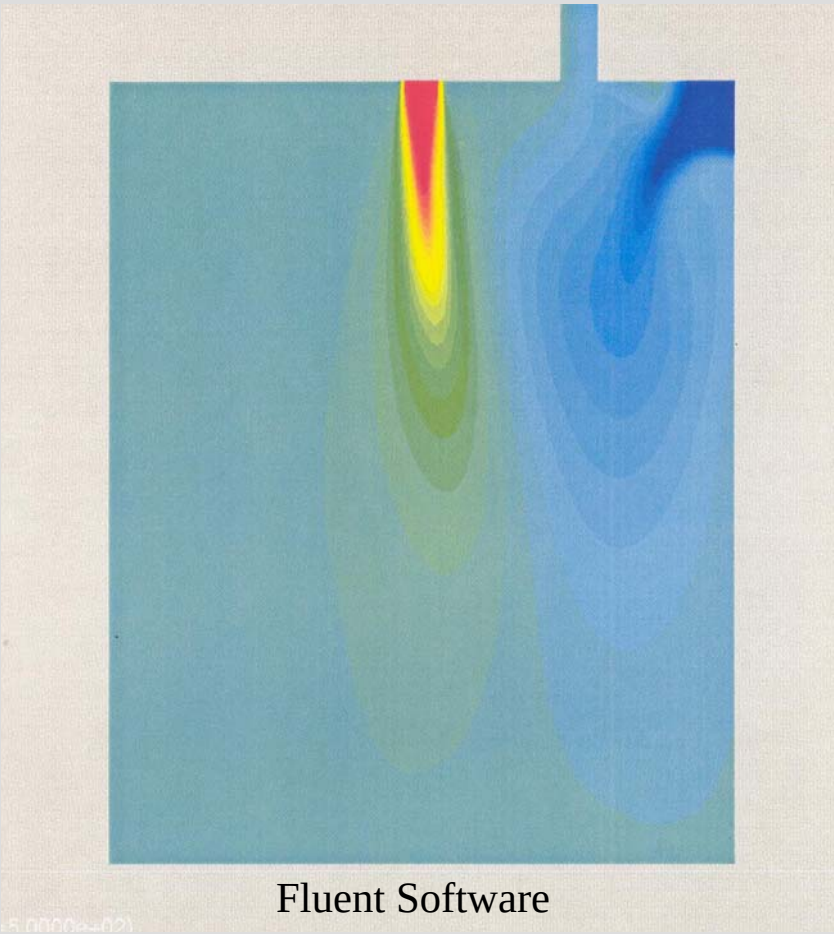


Heat Loss By Radiation

- Results
  - Total loss of radiant heat is currently ≈690,000 BTU/hr
  - 63.9% greater than estimation of DOE estimate
  - Addition of simple heat shield reduces radiant heat loss by 46.2%.
  - Addition of insulation reduces radiant heat loss by 97.6%.

Air Entrainment

1. Air enters crucible through gap.
2. This air cools down crucible temperature.
3. More fuel is needed to maintain crucible temperature.
4. Causes oxidation of molten aluminum.

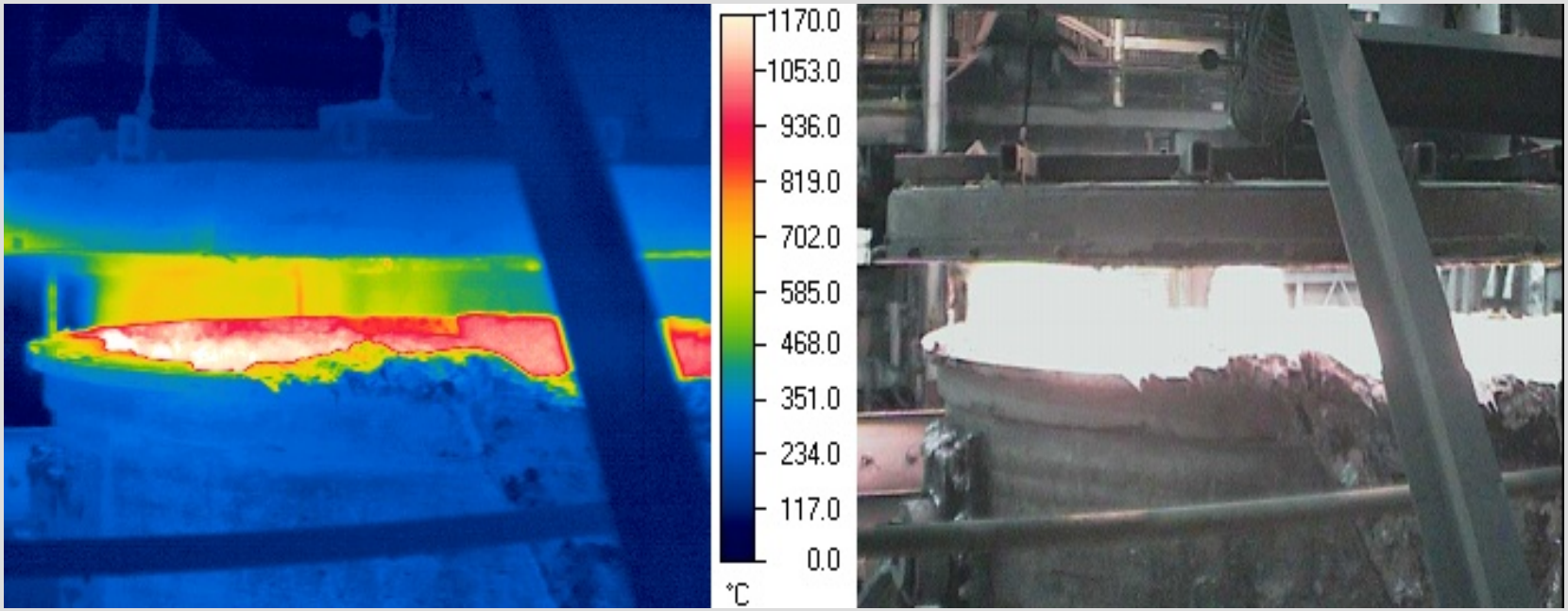


Fluent Software

Courtesy of Troy Dent

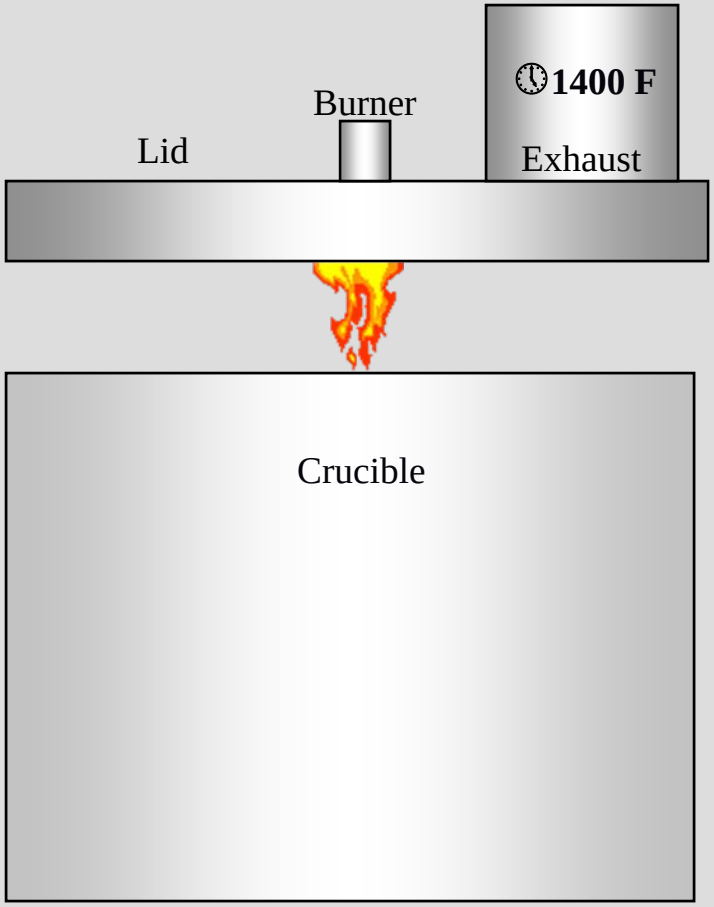
Infrared Crucible Temperature Data

- Temperature near the edge is approximately half of the flame temperature

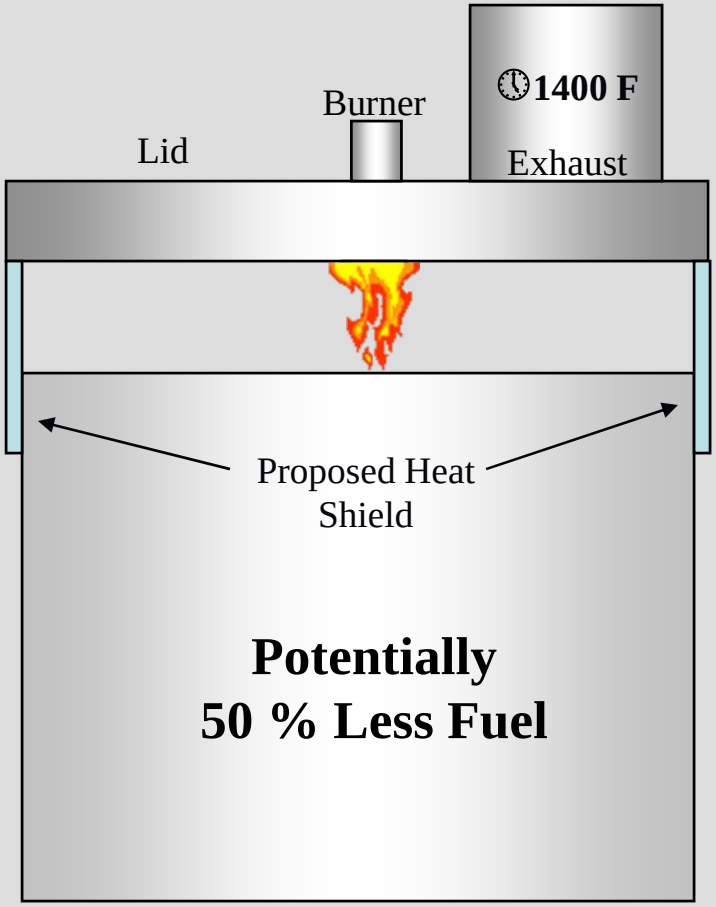


Significance of Air Entrainment

- In order to maintain the same temperature inside the exhaust it will require half the fuel of the current system



Without Shield



With Shield

Flue Gas Analysis

- Flame operates at Stoichiometric Combustion

Methane		*AIR*
CH_4	+	$2(O_2 + 3.76N_2)$

$$\xrightarrow{\text{COMBUSTION}} \quad CO_2 + 2H_2O + 7.52N_2$$

- After Air is Entrained

$$(CO_2 + 2H_20 + 7.52N_2) + a\,(O_2 + 3.76N_2)$$

$$\downarrow$$

$$CO_2 + H_2O + aO_2 + (7.52 + 3.76a)N_2$$

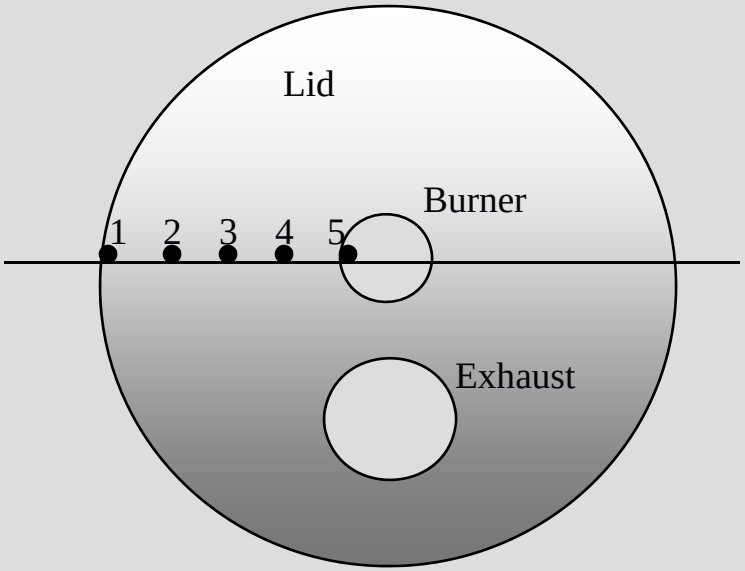
Flue Gas Analysis

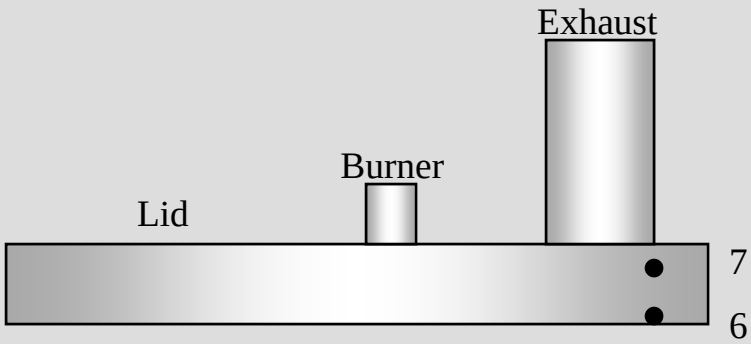
- Combustion product

  $$CO_2 + 2H_2O + N_2$$

- 0% Oxygen near flame proves stoichiometric rxn

	O_2	CO_2		
	%	%		
1	11.5	5.2		
2	5.5	9.2		
3	5.2	9.3		
4	3.1	10.3		
5	0	9		
6	9.6	5.9		
7	11.31	5.2		

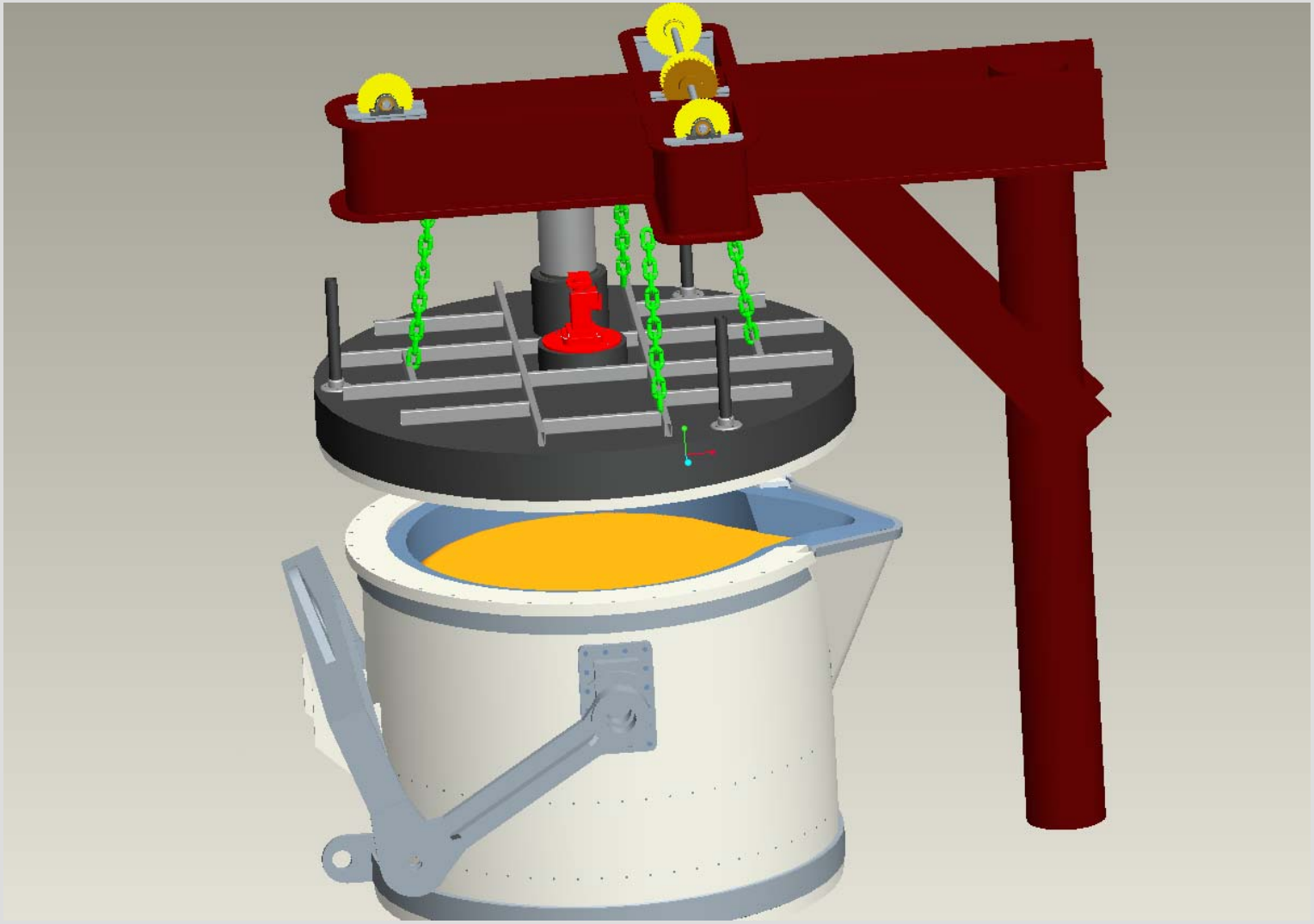




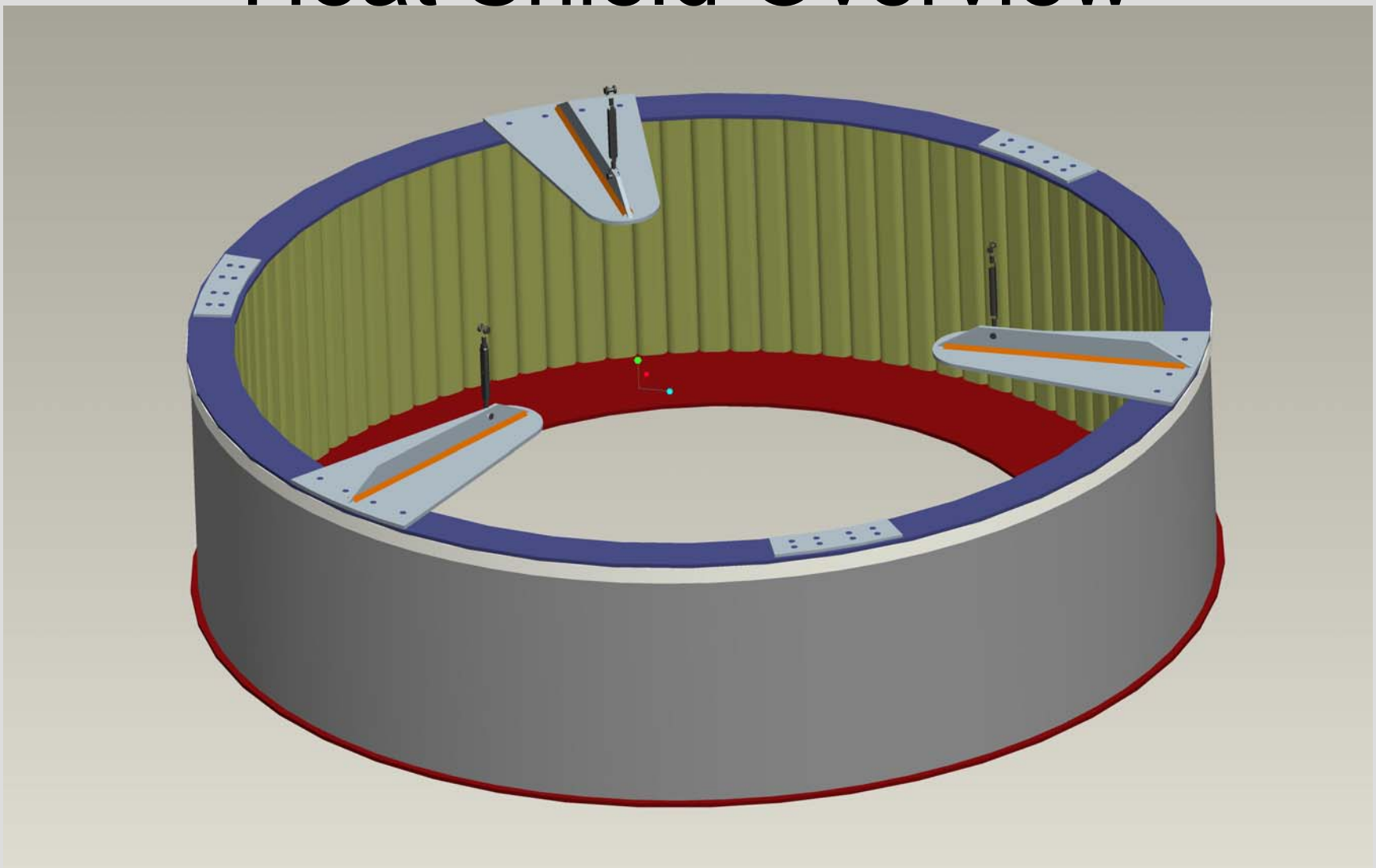
Air Entrainment Results

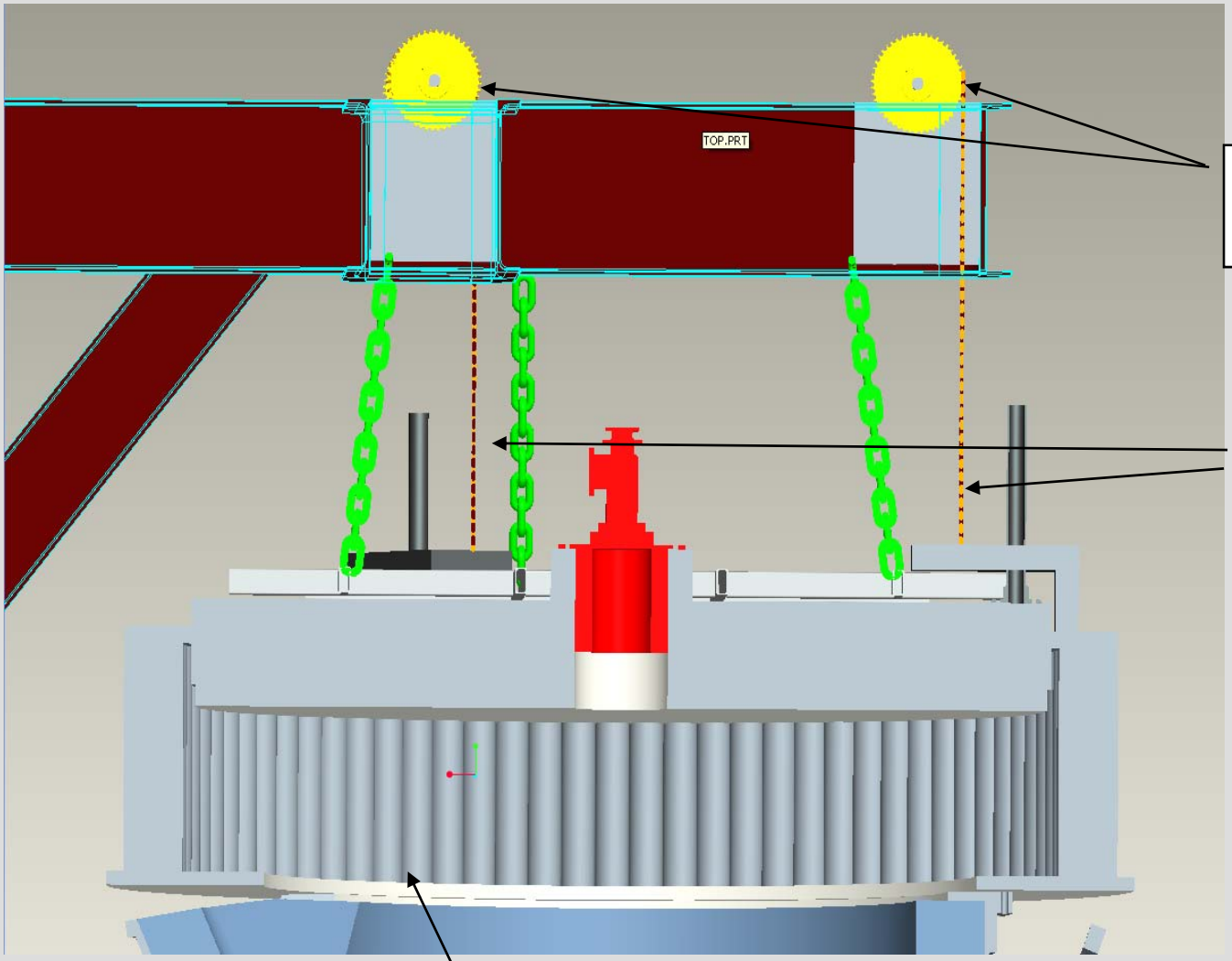
- The analysis showed that 50% of the air near the exhaust was entrained
- The heat shield will nearly eliminate entrainment resulting in fuel savings

Working Environment



Heat Shield Overview





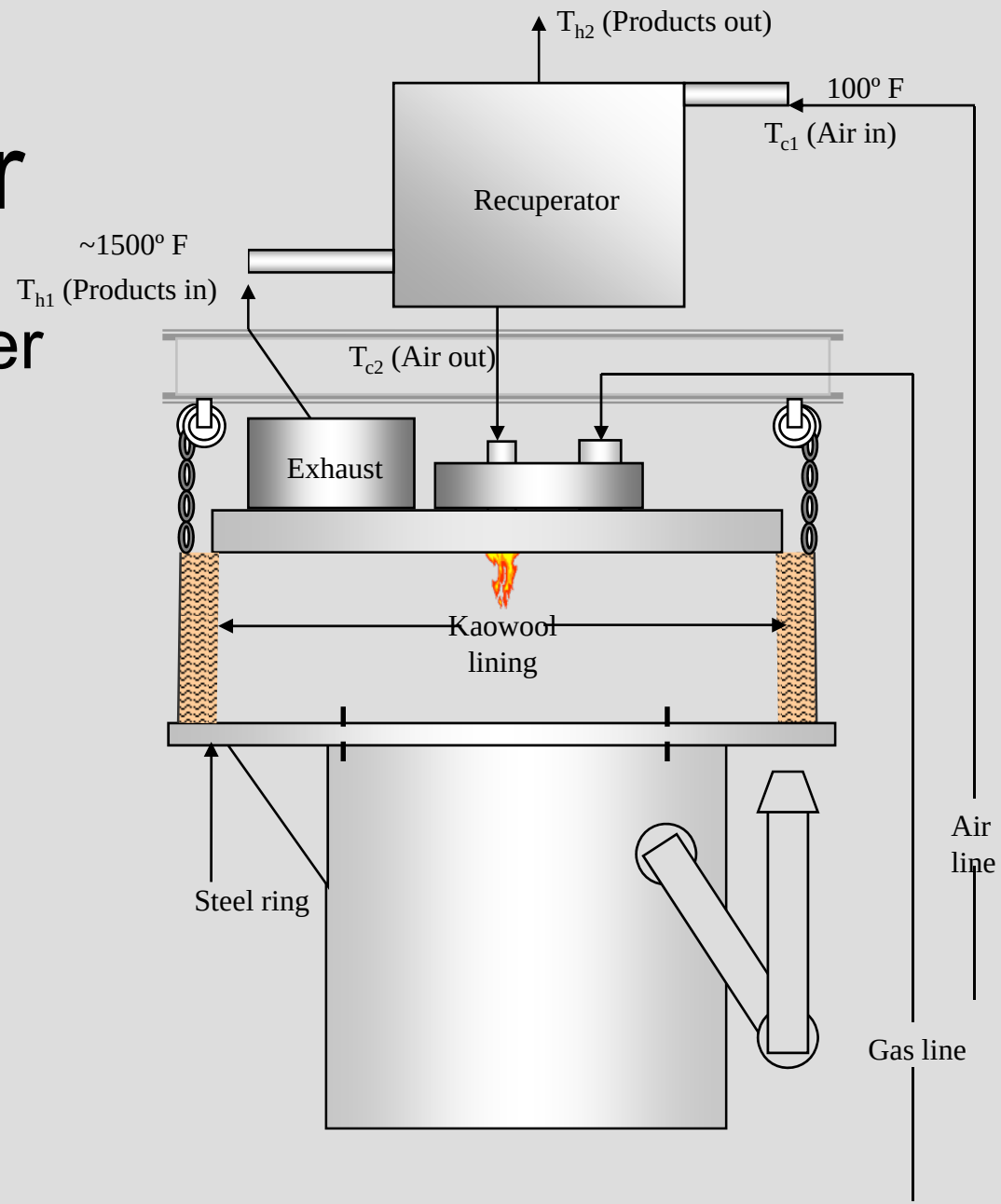
3X #60 ANSI Sprockets

3X #60 ANSI Standard Chain

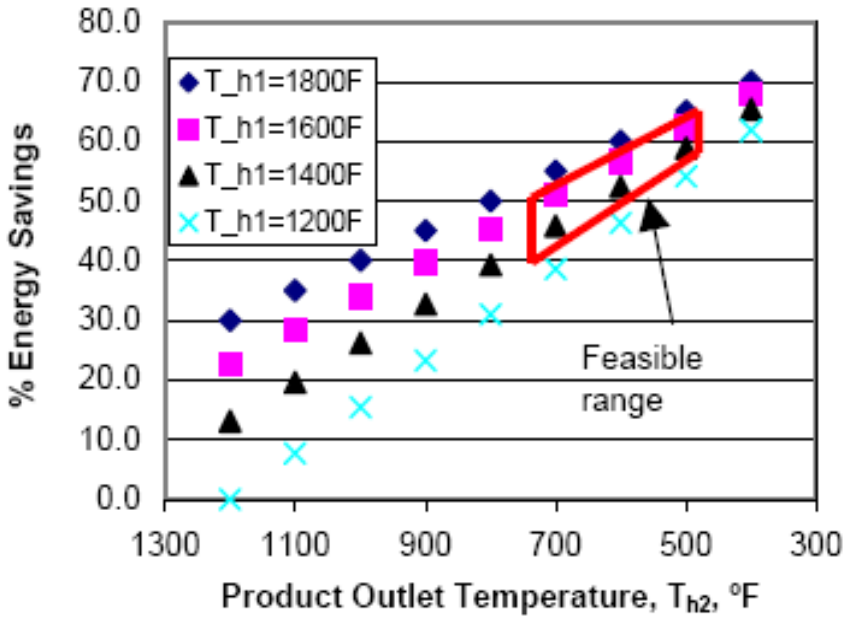
Kaowool Lining “Ribboned”

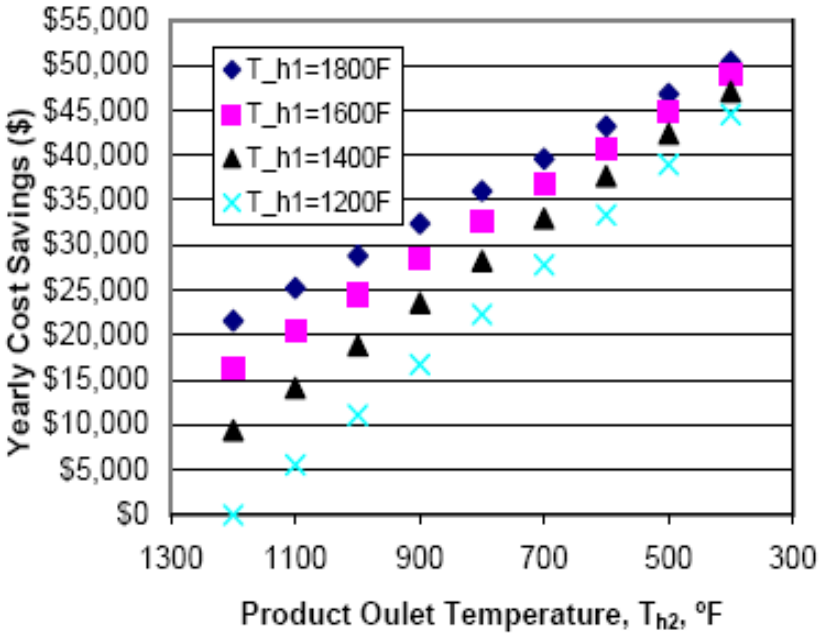
Proposed Recuperator

- Will improve burner system efficiency
- Will save energy
- Will save money



Energy and Cost Savings with Recuperator





Potential Energy Savings

- Annual fuel consumption currently costs $144,000 per crucible.

Upgrades	Savings	
Heat Shield Reductions:	$86,400	60%
-air entrainment ($57,600)		
-radiant heat loss ($28,800)		
Recuperator w/ heat shield	$28,800	20%
Annual Savings per Crucible	$115,200	80%
Total Annual Savings	**$1.38 M**	

Conclusion of Project

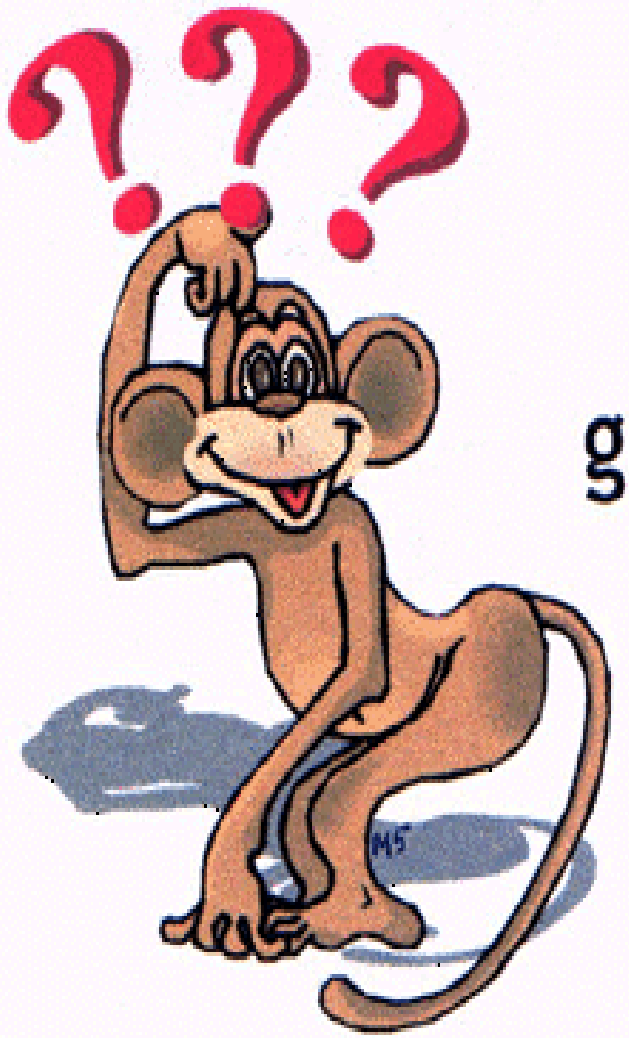
- Heat shield around gap was calculated to have the potential to save Wise Alloys LLC $10,000 per year per crucible
- Recommendation of recuperator adds additional $30,000-$40,000 of savings per crucible
- Heat shield will reduce oxidation of molten aluminum by elimination air entrainment
- Wise Alloys will fabricate and install heat shield and monitor it after installation

After the Project

- In Fall 2007, 2nd senior design team was selected to implement recuperator and perform analyses of system after installation of heat shield on experimental heating station
- Due to issues at plant, heat shield was not fabricated till end of 2007
- The recuperator system designed by 2nd team is scheduled to be installed early 2008

Relation to IAC

- Two of the four man-team of the 1st design group was affiliated with Alabama's IAC
- Two of the faculty advisers of the design team also AIAC directors
- Wise Alloys was pleased with the results that future partnerships were planned
- LEU (Large Energy User) assessment was conducted in December of 2007
  - Focused on air and steam systems using DOE tools



Questions
are
guaranteed in
life;
Answers
aren't.