Environmental Improvements to UCB Binders & the CORDIS Process

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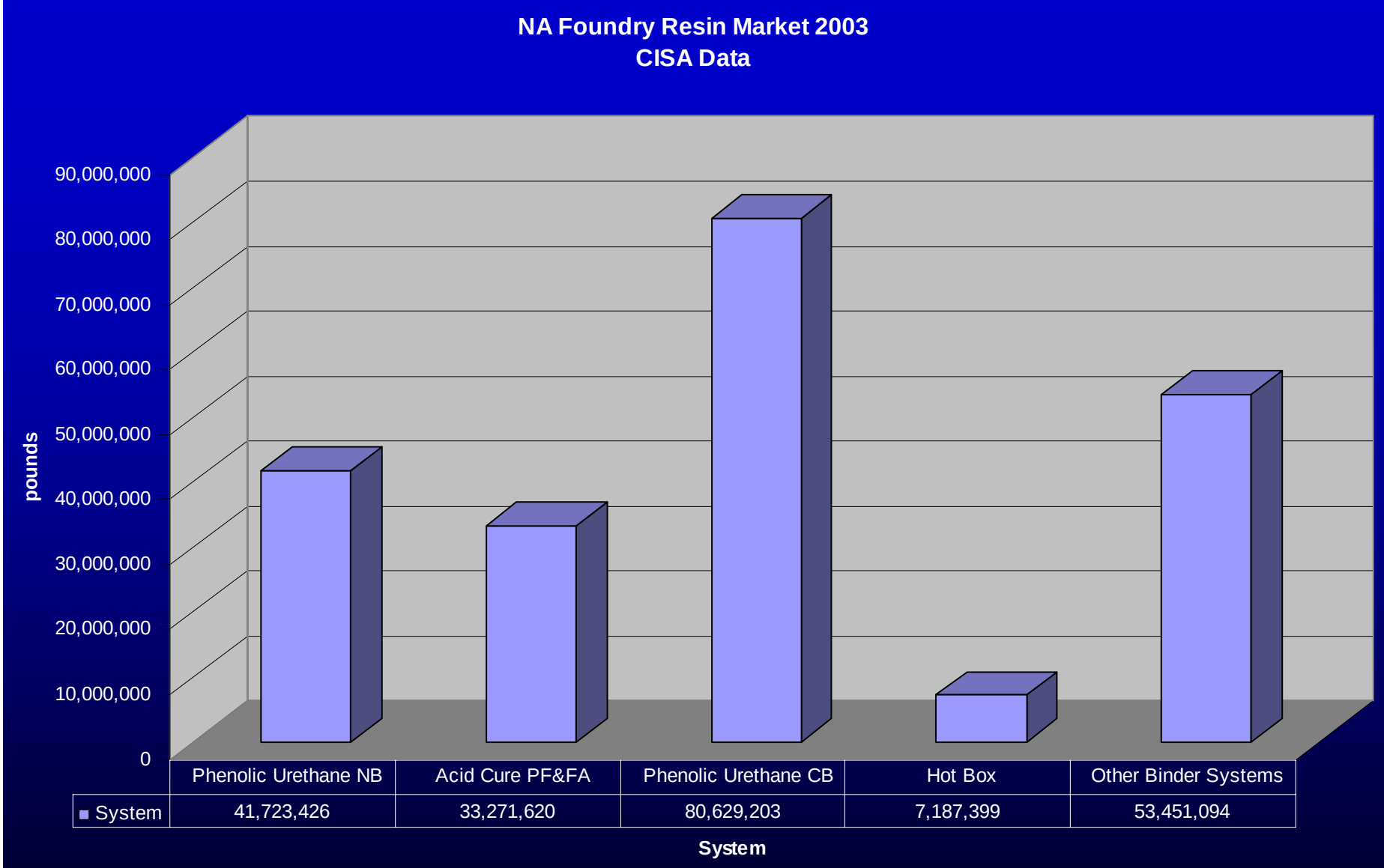
New Product Development Strategies

- **Evolutionary**
  - **Continual improvements to existing foundry binders**
- **Revolutionary**
  - **Breakthrough development of new technology**

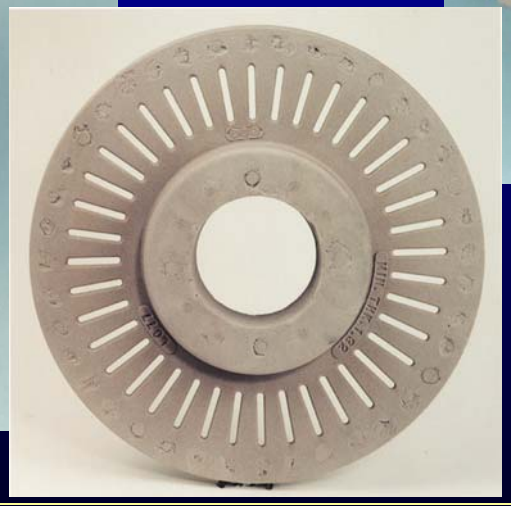
Agenda

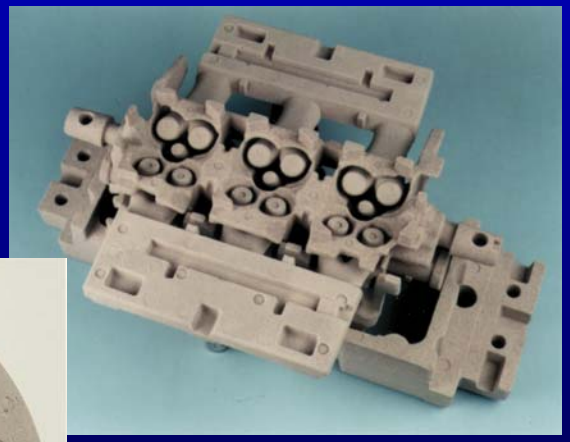
- U.S. Binder Statistics
  - Phenolic Urethanes
- Urethane Cold-Box
  - Biodiesel Systems
- Urethane No-Bake
  - Strategies to reduce emissions
- CORDIS Process


NA Foundry Resin Market 2003
CISA Data
pounds
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Phenolic Urethane NB
Acid Cure PF&FA
Phenolic Urethane CB
Hot Box
Other Binder Systems
System
41,723,426
33,271,620
80,629,203
7,187,399
53,451,094
System

Foundry Resin Markets Served

In Urethane Cold-Box, Automotive market is the largest Segment served…. OEM (Ford, GM, DCX) and Tier 1 Suppliers





Foundry Resin Markets Served

In Urethane No-Bake, steel foundries have become the largest market segment

Phenolic Urethane Resins

- **Urethanes make up nearly 60% of all foundry binder systems used**
- **Urethane Cold-Box**
  - **92MM lbs (42,000 mt) per year market**
    - **75% Automotive applications**
- **Urethane No-Bake**
  - **50MM lbs (22,000 mt) per year market**
    - Nearly 60% steel applications

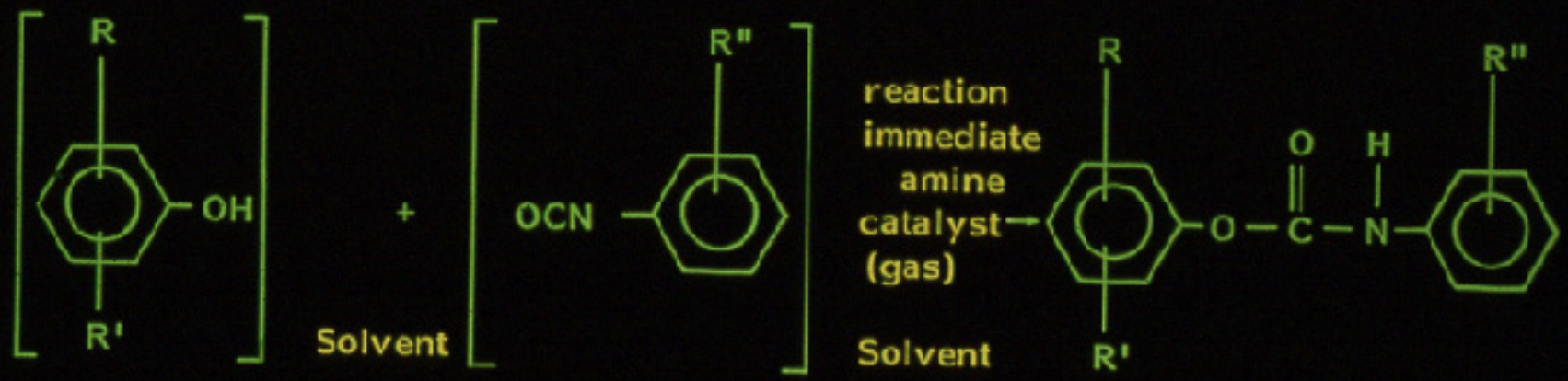
Urethane Cold Box - Reasons Why

- It is the most widely accepted and approved process
- Over 90MM pounds sold in U.S. in 2004

COLD BOX, PHENOLIC/URETHANE

LIQUID Part I + LIQUID Part II → SOLID BINDER

PHENOLIC RESIN + POLY-ISOCYANATE — AMINE Catalyst → URETHANE

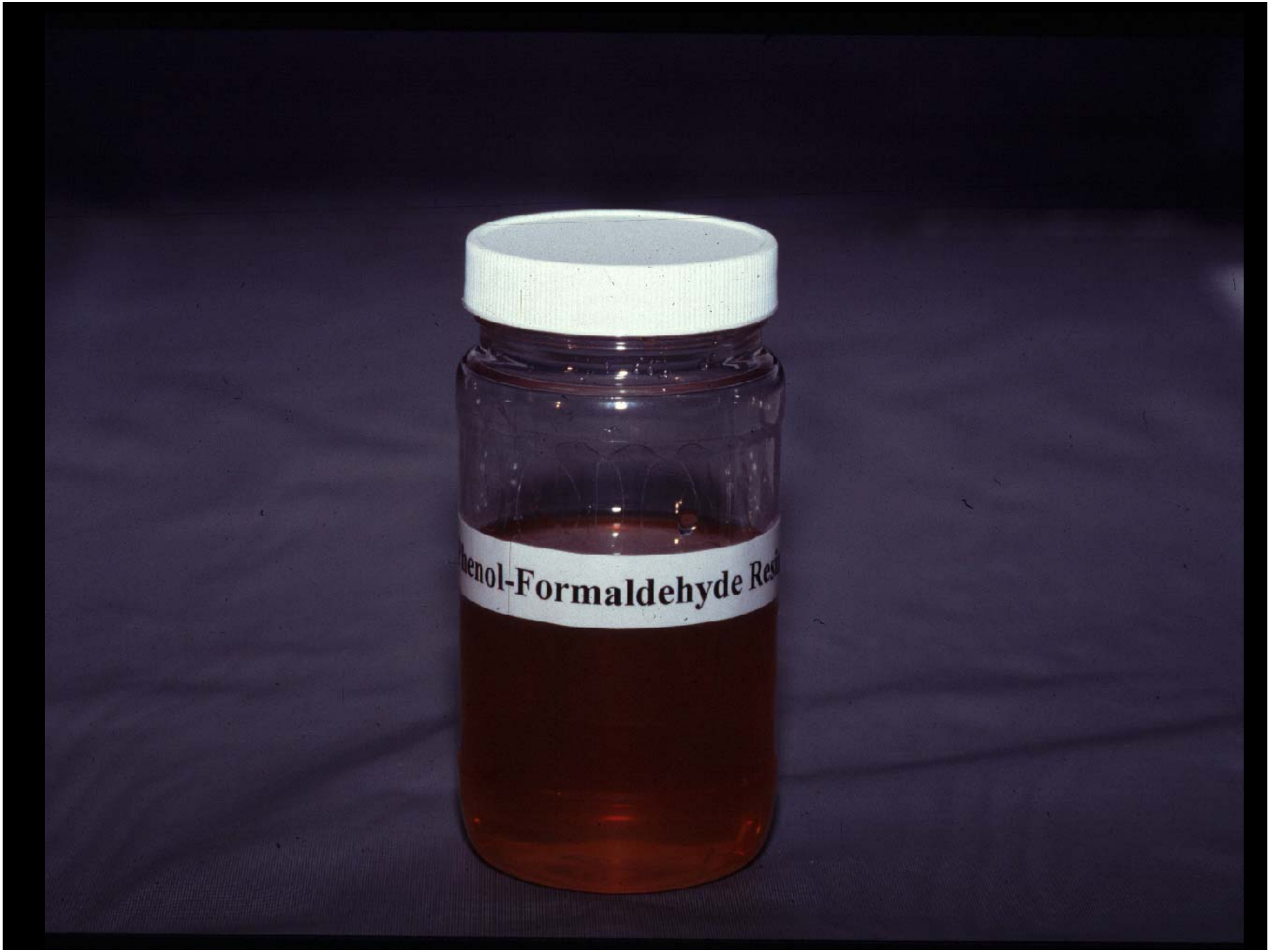


Advantages

- known system
  - first introduced in 1968
- less sensitive to sand type
- good hot strength
- good dimensional accuracy
- sand is reclaimable
- high productivity

Historical Process Limitations

- Environmental
  - Conventional PUCB systems are solvent-based
    - Aromatic hydrocarbons
    - Source of VOC's & HAP's
  - Use of aromatic hydrocarbons as solvent has led to relatively high VOC content
    - 40 to 50% in Part I
    - 20 to 30% in Part II


henol-Formaldehyde Resi

NO
CHECKING

Methyl Esters

- In late 1990s, introduction of a new patented PUCB system that uses vegetable-based solvents to replace aromatic hydrocarbons
- In CERP testing, significant reductions in PC&S emissions

Overview

- This technology utilizes standard phenolic urethane chemistry and may be used for cold-box and no-bake processes.
- Aromatic hydrocarbon solvents are replaced with vegetable-based solvents, like methyl esters of plant oil, or methyl esters of other vegetable oils
  - *Biodiesel Cold-Box*

Overview - Cont'd

- Methyl esters are not HAP's, have low VOC's, low viscosity, are non-flammable, and have virtually no odor
- Performance characteristics of the system are similar to existing cold-box systems
- Methyl ester technology results in VOC reduction of over 50%

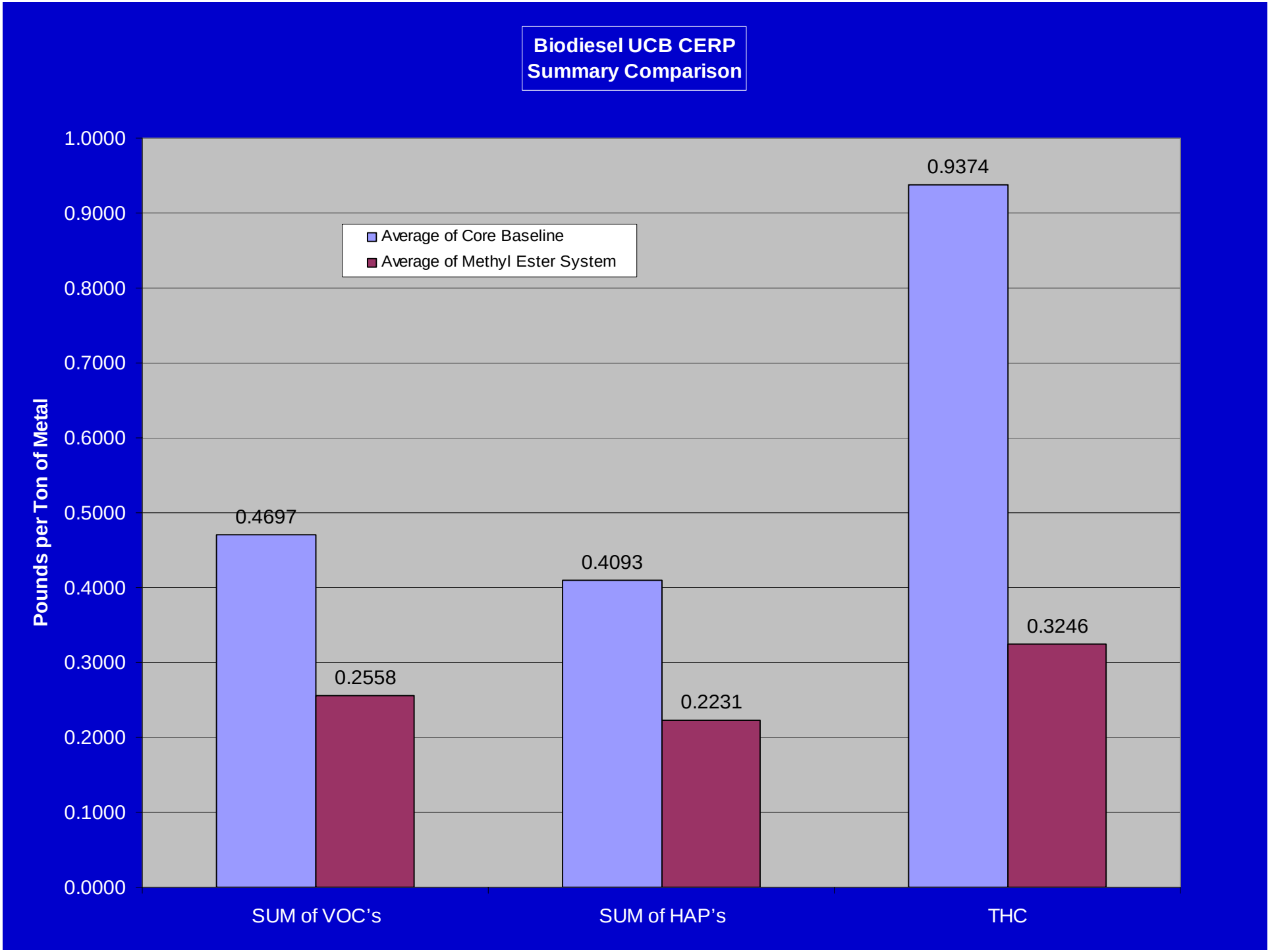
VOC Comparison

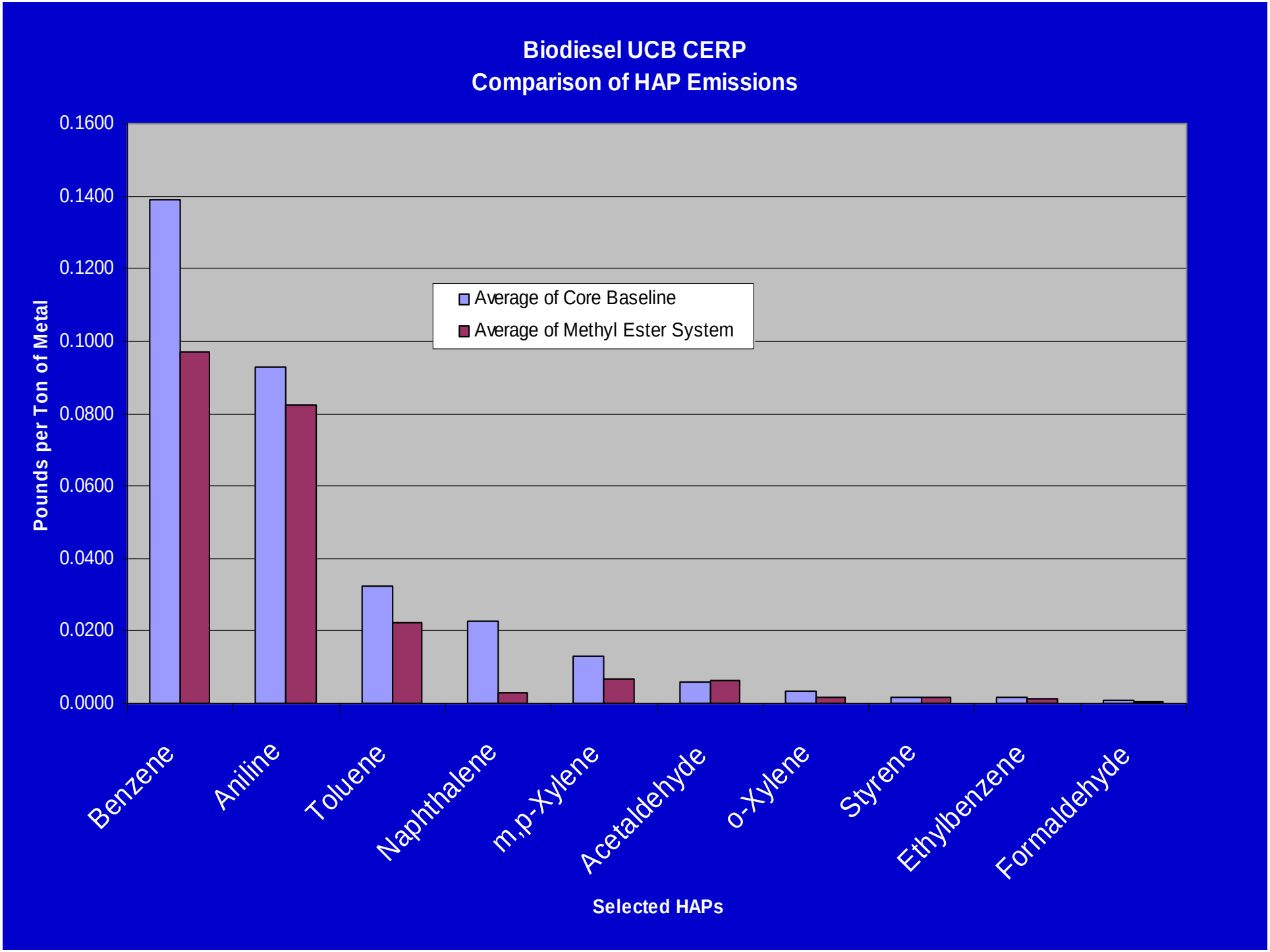
System	% VOC	% reduction
Conventional	33.1	--
Methyl Ester	15.6	52.7

- based on 55/45 ratio

CERP Results

- 45% reduction in total HAP's
  - includes a 30% reduction in benzene (the highest single HAP)
- 46% reduction in VOC's
- 65% reduction in total hydrocarbons
  - CERP Report #RV100024AW
  - CERP Report #RV100081CL
  - *As compared to "older" conventional (aromatic) PUCB system*


Biodiesel UCB CERP
Summary Comparison
Pounds per Ton of Metal
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
Average of Core Baseline
Average of Methyl Ester System
0.4697
0.2558
0.4093
0.2231
0.9374
0.3246
SUM of VOC's
SUM of HAP's
THC

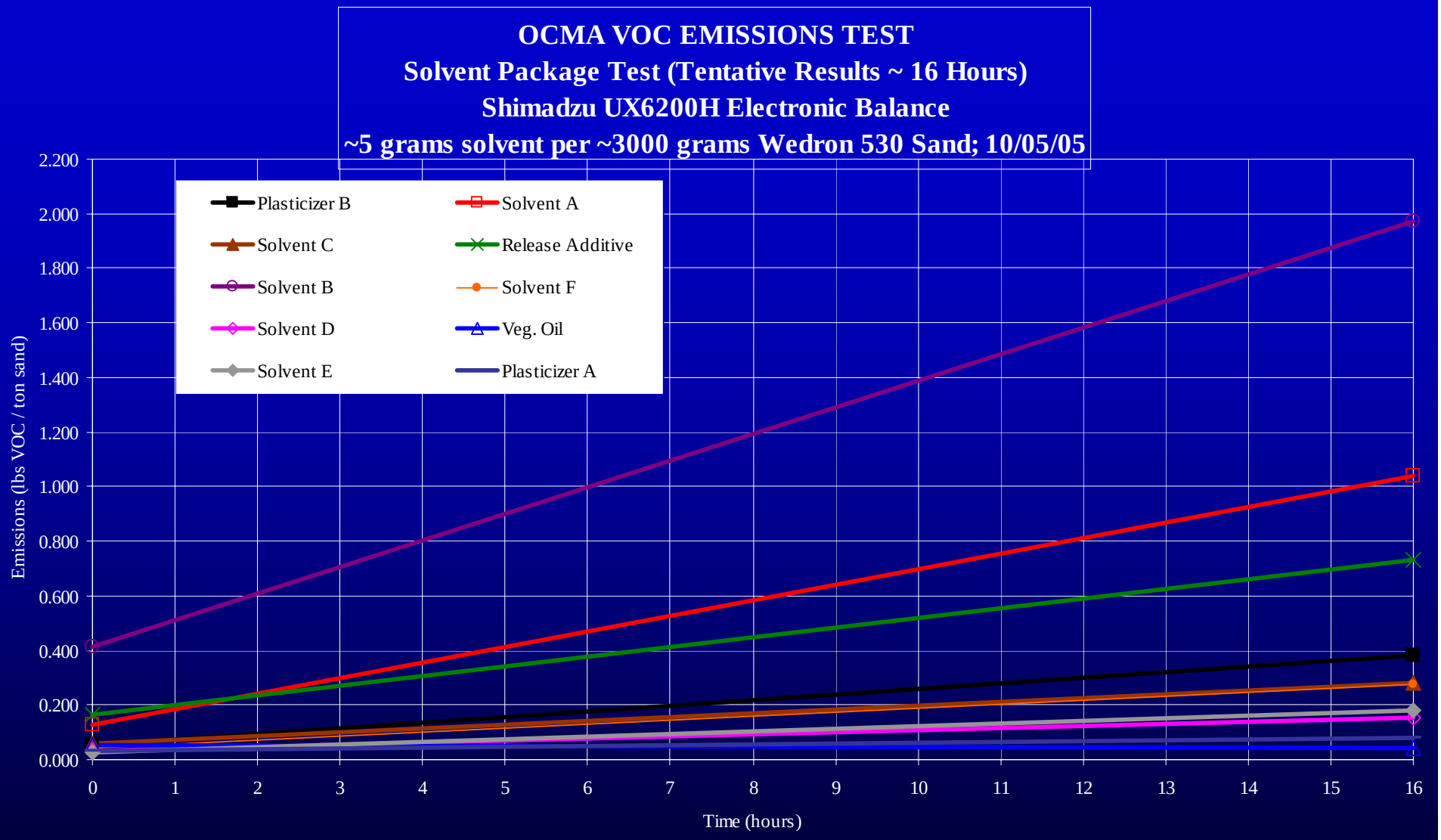

Biodiesel UCB CERP
Comparison of HAP Emissions
Pounds per Ton of Metal
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
Average of Core Baseline
Average of Methyl Ester System
Benzene
Aniline
Toluene
Naphthalene
m,p-Xylene
Acetaldehyde
o-Xylene
Styrene
Ethylbenzene
Formaldehyde
Selected HAPs

Disadvantages

- Methyl esters generally more expensive than aromatic solvents
- Biodiesel systems generally not recommended for aluminum
- Biodiesel systems have been known to cause problems with build-up in bag houses and ductwork
  - Especially foundries pouring very large core to casting weights

Urethane No-Bake Strategies

- Biodiesel solvents generally cannot be used in no-bake applications where sand is reclaimed
- Change solvent “package” to reduce aromatic content
- Increase solids levels in Part 2 to reduce aromatic content


OCMA VOC EMISSIONS TEST
Solvent Package Test (Tentative Results ~ 16 Hours)
Shimadzu UX6200H Electronic Balance
~5 grams solvent per ~3000 grams Wedron 530 Sand; 10/05/05
Plasticizer B
Solvent A
Solvent C
Release Additive
Solvent B
Solvent F
Solvent D
Veg. Oil
Solvent E
Plasticizer A
Emissions (lbs VOC / ton sand)
2.200
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Time (hours)

OCMA VOC EMISSIONS TEST

Solvent Package Test (Tentative Results ~ 16 Hours)

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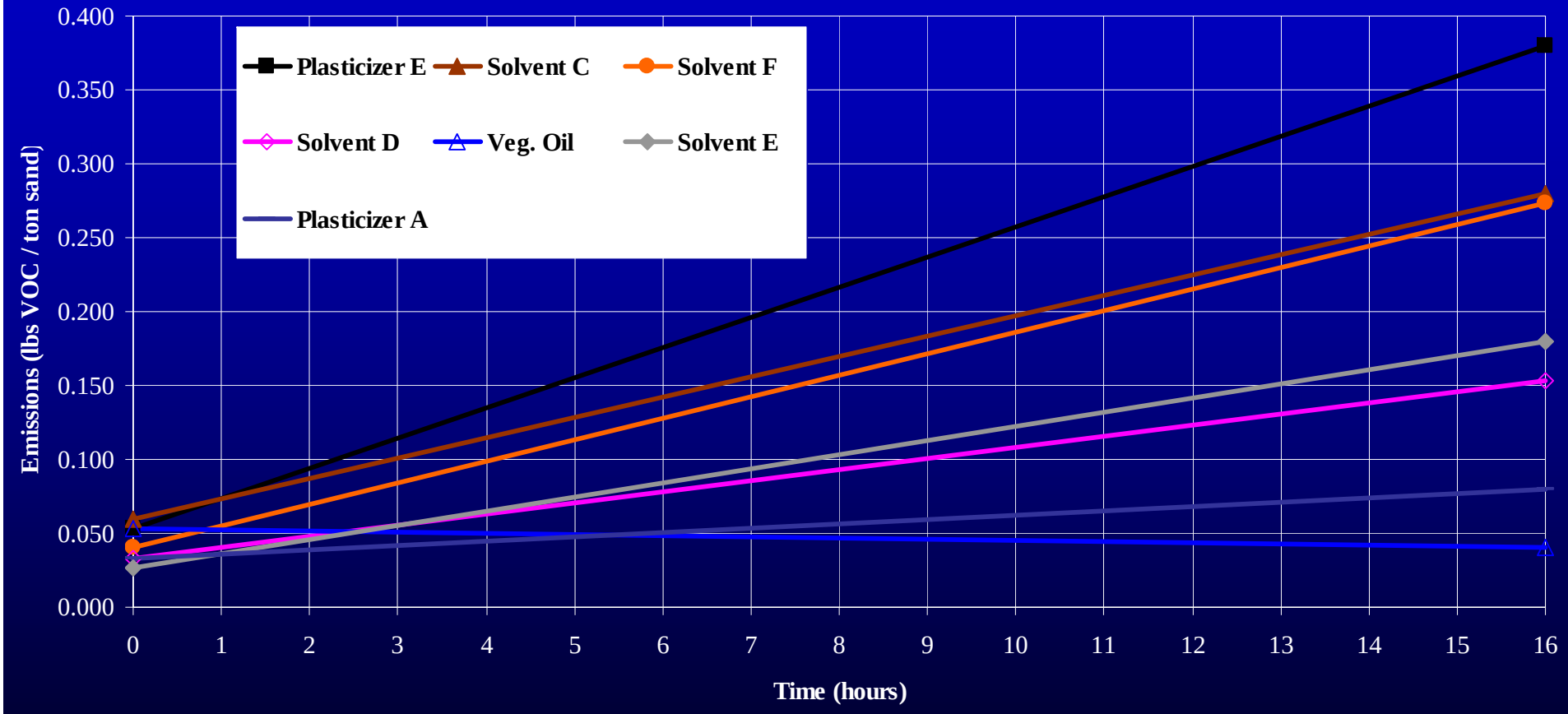
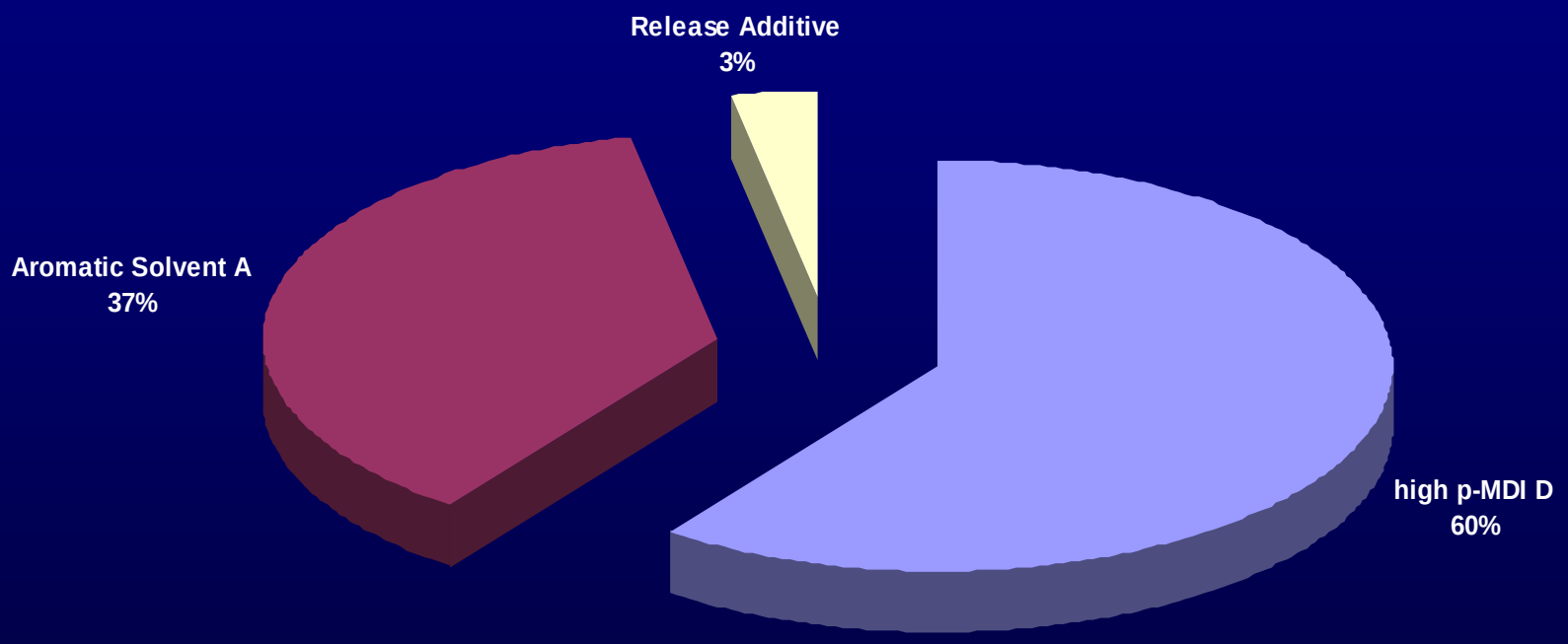


UNB Part 2 type 2



CERP Results

- New formulation (Test FP) shows
  - 25% reduction in Sum of VOC's
  - 16% reduction in Sum of HAP's
  - 21% reduction in TGOC (as propane)
  - 21% reduction in HC (as hexane)
    - *As compared to "standard" Part 1 with low-solids Part 2 system (Test FL)*
    - *CERP Report #1410-113FP*

Figure 3-4 Test Series FL and FP Emissions Indicators – Lb/Tn Metal

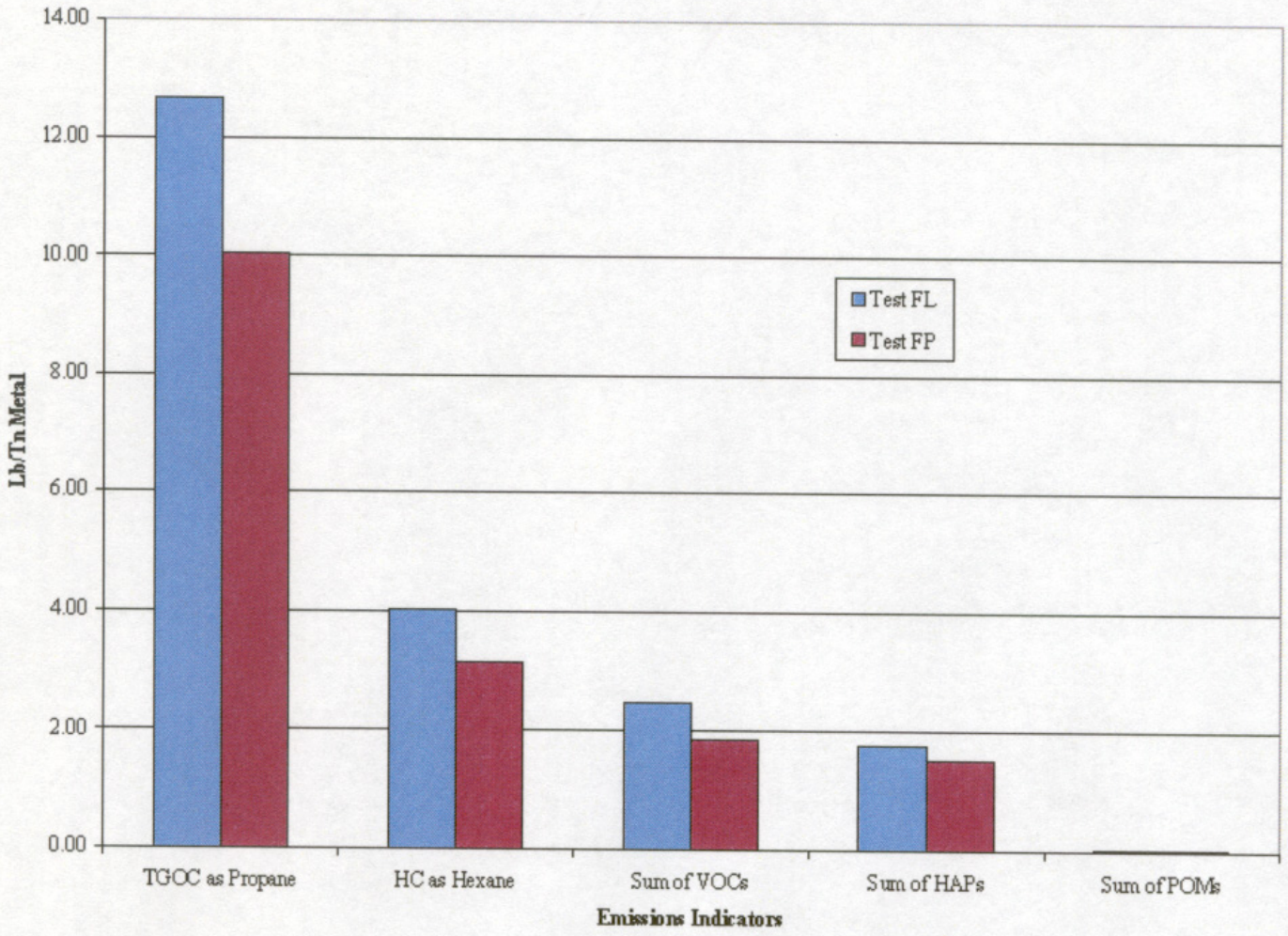
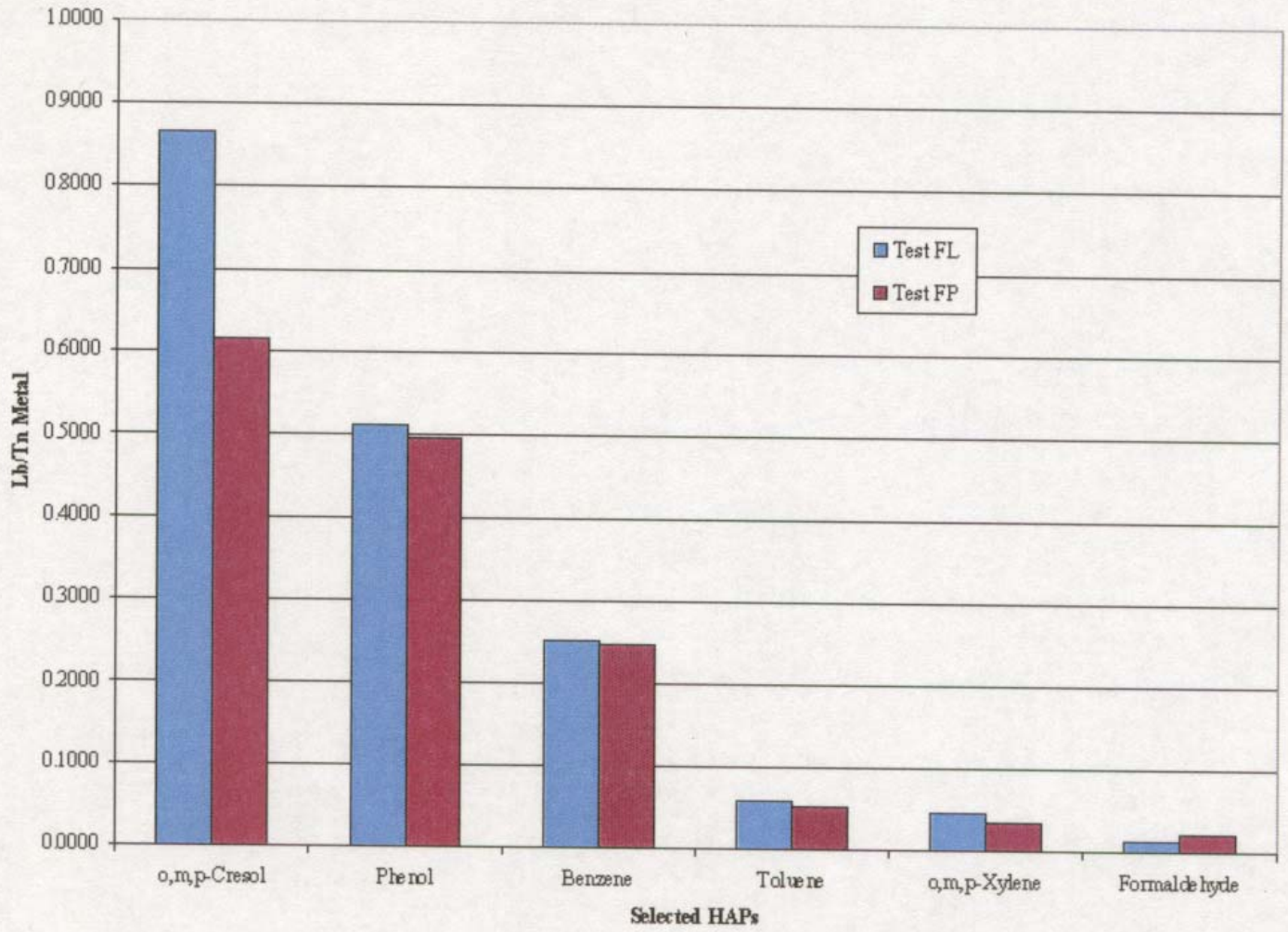


Figure 3-5 Test FL and FP Selected HAPs – Lb/Tn Metal



Disadvantages

- Higher cost
  - Part 2 costs have doubled over the last 12 months
- Mixing issues
  - Reformulated Part 1 resin may have higher viscosity; more difficult to mix

Other Alternatives

- Convert to a completely different chemical binder system
  - FNB
    - Roughly half emissions factor of UNB
    - Completely different sand system requirements
    - Very different handling characteristics
  - PENB
    - Lower emissions
    - Handling strength issues
    - Reclamation issues

Inorganic Systems

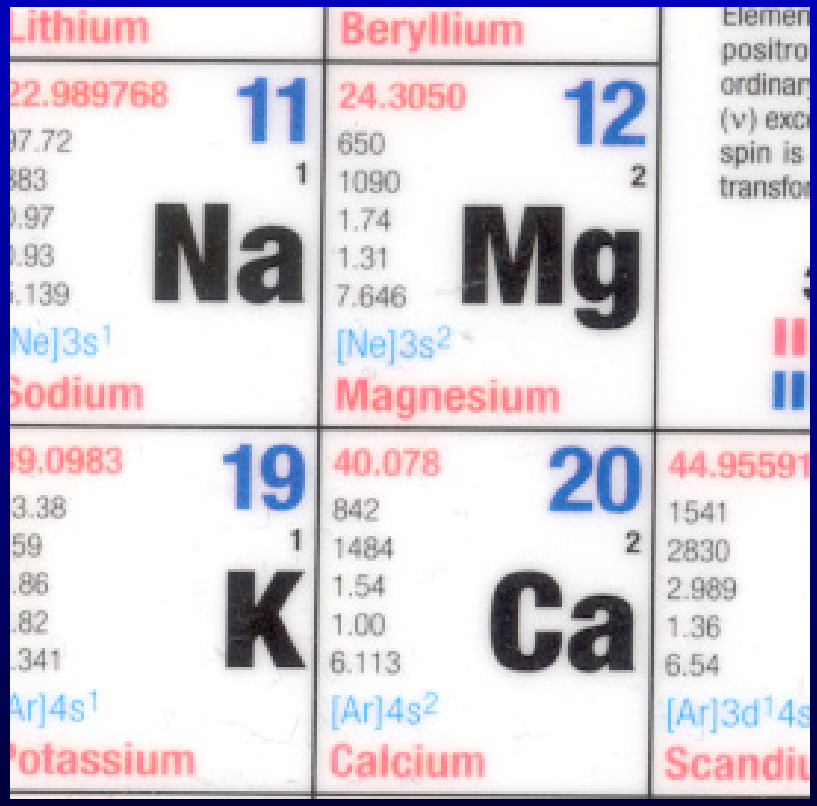
- High interest in inorganic binders to address tightening emissions limits
  - No VOC's from solvents
  - Reduced potential for organic emissions at pouring/shakeout

Inorganic Systems

- In chemistry, structure determines properties.
- Organic systems all have one thing in common: they all contain the element carbon
  - Carbon atoms can attach themselves to one another to an extent not possible for atoms of any other element

Inorganic Systems

- Inorganic systems are made from the following elements:
  - Sodium
  - Potassium
  - Magnesium
  - Calcium
  - Aluminum
  - Silicon
  - Phosphorous



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  - Aluminum
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  - Phosphorous

Inorganic Systems

- In general, these chemicals do not form polymers
  - Inorganics do not possess the same strength characteristics as organic systems
- They do form
  - Carbonates
  - Oxides
  - Salts

Inorganic Systems

- Salts, oxides and carbonates are all water soluble
  - Inorganic binders have higher sensitivity to moisture
- Some systems use dehydration to achieve strength, which depends upon water evaporation, which is slow
  - Water based inorganic binders have inherently slower curing characteristics
- Some inorganic binders can form low melting point fluxes with silica sand making shake-out extremely difficult

Inorganic Systems

- Existing inorganic binder systems have not provided the productivity required by many foundries
  - Cure speeds and strength
  - Operational sensitivity
  - Poor shakeout
  - Reclamation limitations
- Use of existing inorganic systems in U.S. has declined

Development Challenges

- Limited chemistries available
- Can an inorganic system perform like an organic binder?

"Inorganic Binders – breakthrough or everlasting hope?"

- VDG Conference, November, 2002

CORDIS Binders

- Patented system
  - Rights purchased in 1991
  - HA licensed in 2003
- Completely Inorganic
- Solvent - Water
- Low Odors, Low Smoke, Low Core Plasticity
- Cured by Water Removal & Chemical Hardening

Issues with Original Cordis Systems

- Low strength
- Slow curing
- Poor humidity resistance
- Softening at casting conditions

New Chemistry

- Expanded on Phosphate Glass Chemistry
- Allows a “Range” of Formula to Meet Customer Requirements
- Broader Processing Parameters
- Enhanced Properties
- New Chemistry patented in 2000/2001

Improved CORDIS Formulations

- Combination of sodium silicate, sodium polyphosphate, borax and a flow additive
- Sodium silicate – strength
- Polyphosphate – collapsibility
- Borax – humidity resistance
- Flow additive – enhance flow of resin coated sand

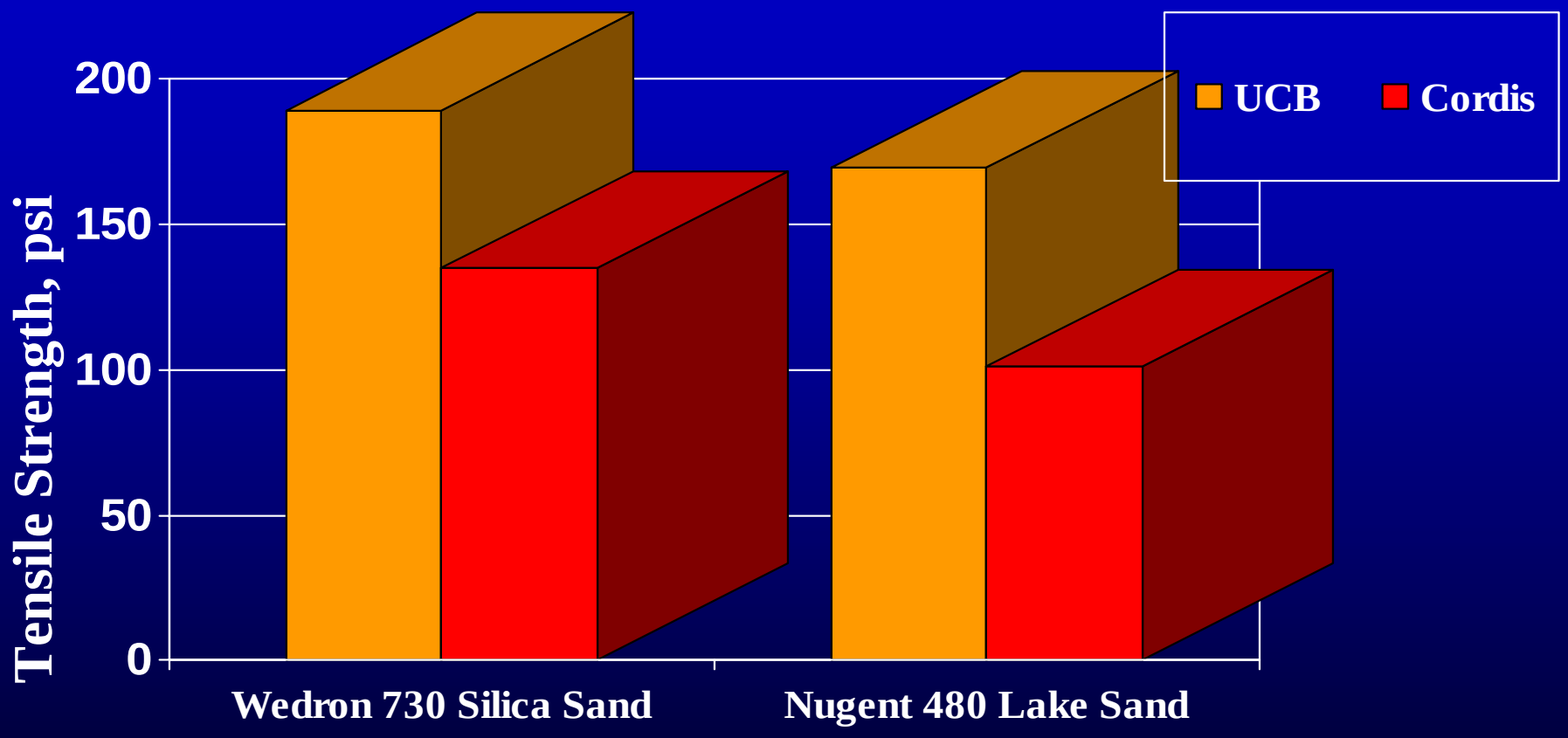
Improved CORDIS Formulations

ADVANTAGES

- Improved Strengths
- Long Bench Life of Resin Coated Sand
- Improved Humidity Resistance
- Improved Mechanical Shakeout
- Faster Cure Speeds
- Broader Processing Parameters (applications in Warm/Hot Box, Warm Box/Warm Air, Nobake)

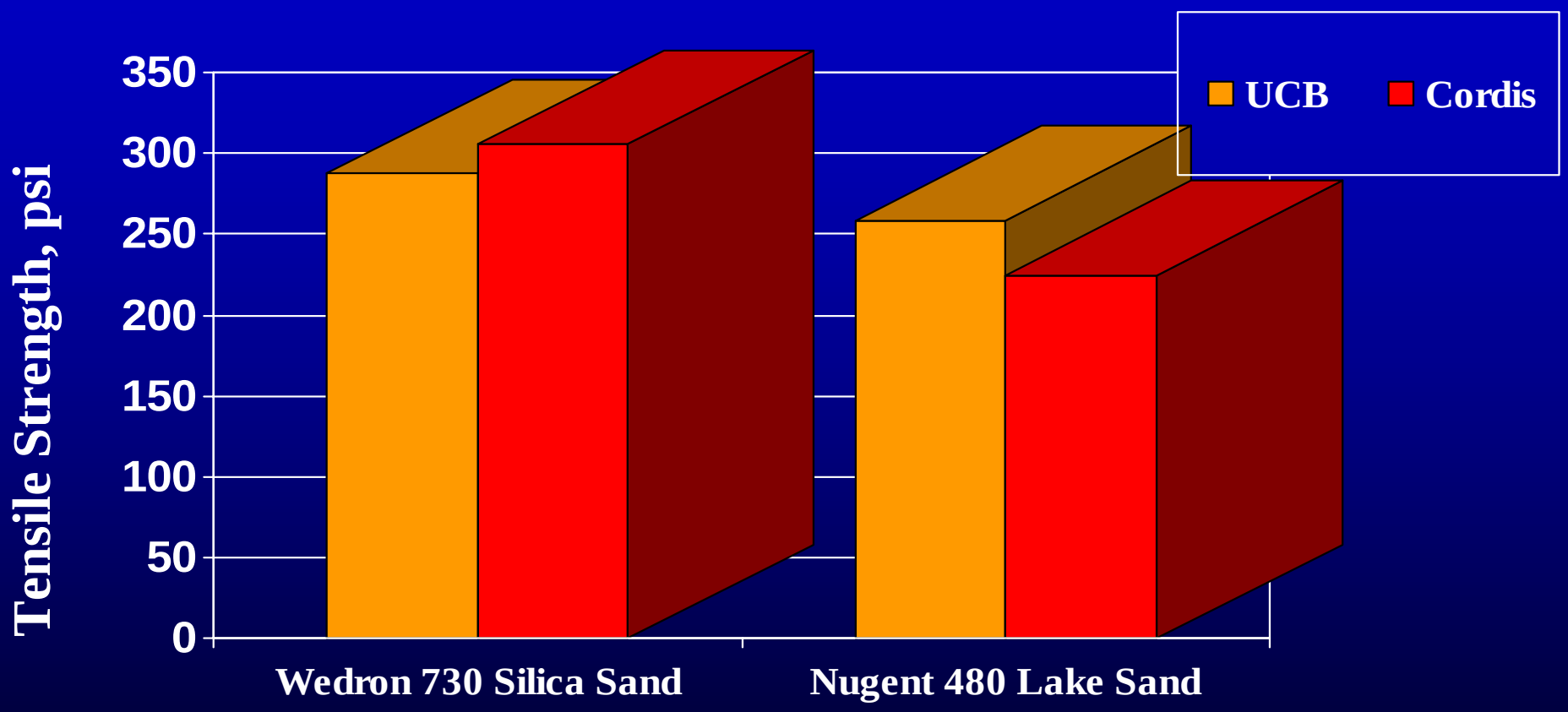
Comparison To Urethane Cold Box

IMMEDIATE (HOT) TENSILES
CORDIS vs URETHANE COLD BOX



Sigma Cure PM11/PM20 (50:50); 1.25% Wedron 730 sand; 1.6% Nugent sand
Cordis 4820BF; 2.5% for both sands

ULTIMATE TENSILES
CORDIS vs URETHANE COLD BOX



Sigma Cure PM11/PM20 (50:50); 1.25% Wedron 730 sand; 1.6% Nugent sand
Cordis 4820BF; 2.5% for both sands

Improved Curing Processes

- **Warm /Hot Box**
  - **Box temperature: 300-450˚F**
- **Warm Box/Warm Air**
  - **Box temperature: 180-400°F**
  - **Purge air temperature: 200-350+°F**
- **No Bake**
  - **With typical organic ester catalysts**
    - ***Under development***

Shakeout Properties

- In Aluminum, Excellent Shakeout Compared to UCB or Shell
- Dry Shakeout
  - 80% savings in time
  - Reduced metallurgical damage
  - Shakeout results dependent on sand to metal ratio

Sand Reclamation

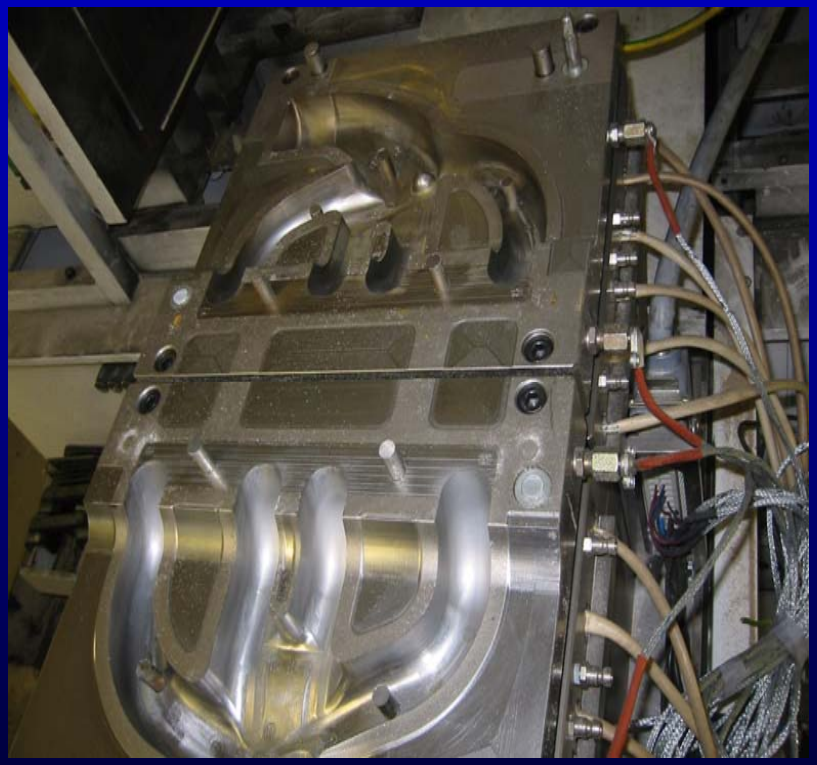
- Dry Mechanical or Wet Process
- Sand is Re-usable After Drying and/or Fines Removal
- Spent Sand Compatible With Green Sand

Core And Casting Results

Alcoa Automotive Castings Hawesville, KY

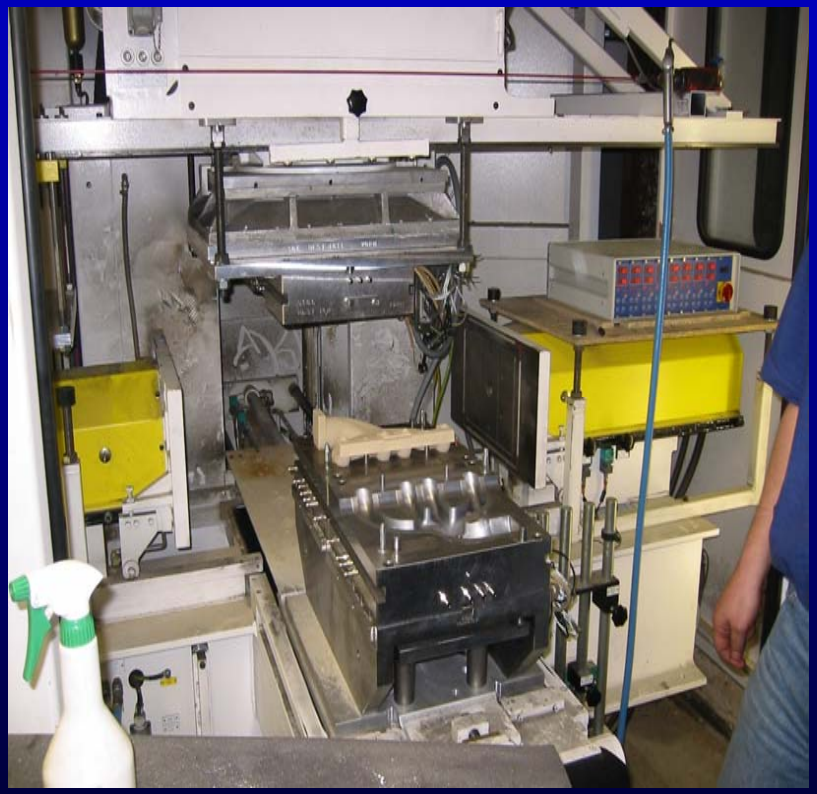
- Swing arm suspension part – BMW
- Used the process for 5 years
  - Alcoa lost contract in 2004
- Castings – 11 lbs, wall thickness ~ 0.2”
- Core – 11 lbs, up to 3 inches thick
- Shakeout – 30-40 seconds
- Cycle time – 180 seconds

HA Development Work



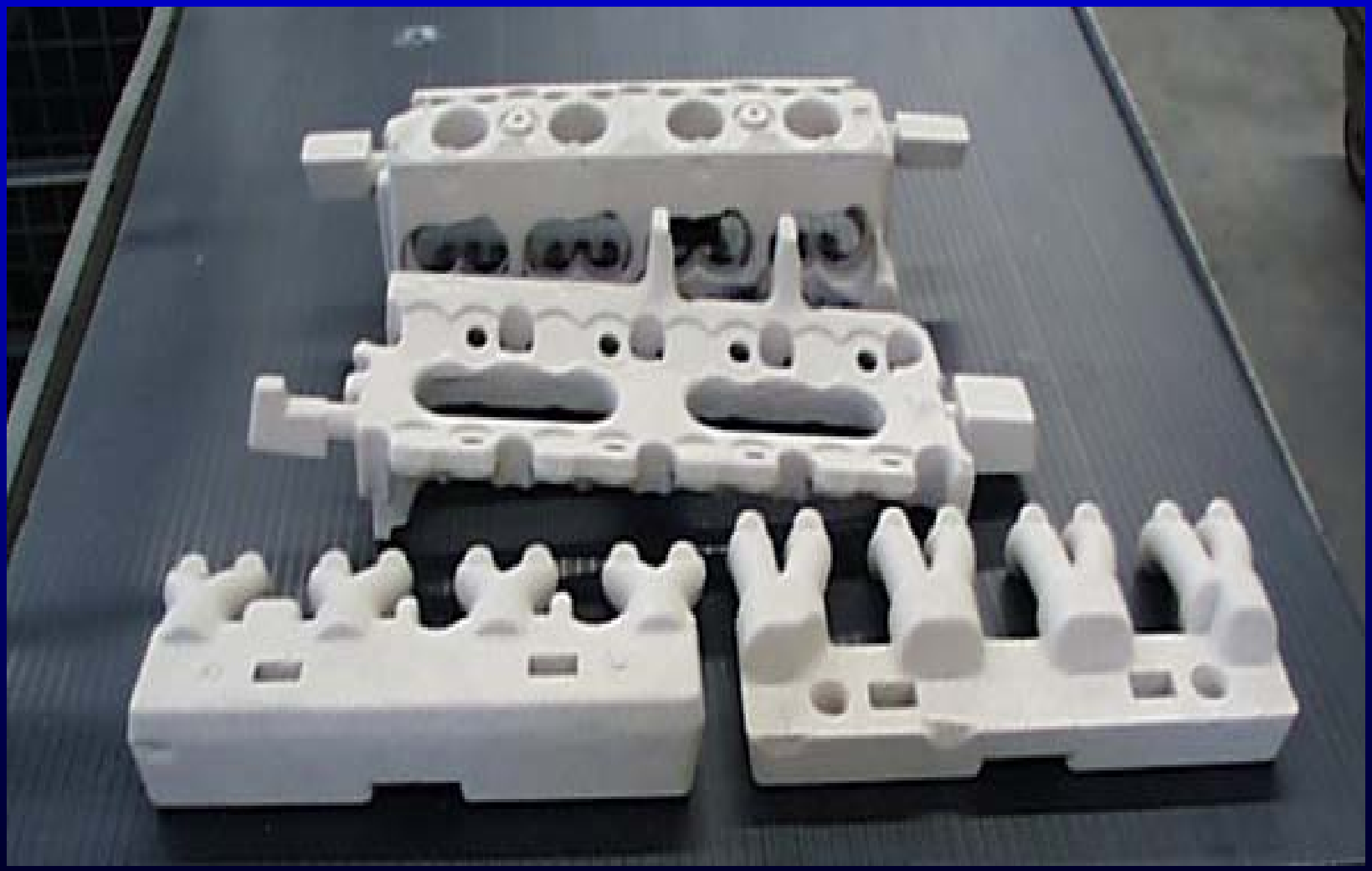
- Heated core box for CORDIS process

HA Development Work



- Production of CORDIS inlet manifold cores using a conventional cold-box machine
- Heated core box

Cores for a cylinder head



Waterjacket

Casting of CORDIS Cores

Aluminium Casting

- Low Pressure Die Casting
- Gravity Die Casting

Iron Casting

- Limited experience, but some experimental success
- Will require coating (alcohol tested successfully)
- CORDIS tendency to be wetted by molten iron
- May require higher cure temperatures

Summary

- Resin manufacturers continue to improve environmental characteristics of existing systems
- Continue to search for the environmentally safe resin

"Inorganic Binders – breakthrough or everlasting hope?"