Ceramics, A Synthetic Non-Silica Alternative for the Metal Casting Process

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Engineered Ceramics – Overview

- Ceramic media has been used for a number of years in the global metal casting market.
- A 1995 DOE/University of Western Michigan study identified two ceramic products tested were viable alternatives to replace silica sand for the US Metal Casting Industry.
- The major use has been as a substitute for silica and specialty sands for core and facing applications where quality requirements warranted the higher performance.
- Aside from Lost Foam, fully charged ceramic systems have been limited in the US, mostly due to:
  - Highly abundant and low cost silica sand
  - An industry reluctant to change
  - Higher cost of ceramics.

Engineered Ceramics – Product Technology

Engineered synthetic ceramic products provide consistent chemical, thermal and physical properties through tightly controlled:

- Composition
- Sizing
- Shape

Resulting in consistent, repeatable casting performance.

CARBO Engineered Ceramic Casting Media

AVAILABLE IN A RANGE OF SIZES AND DENSITIES:

ACCUCAST LD

High-performance, low-density ceramic casting media

ACCUCAST ID

High-performance, intermediate-density ceramic casting media

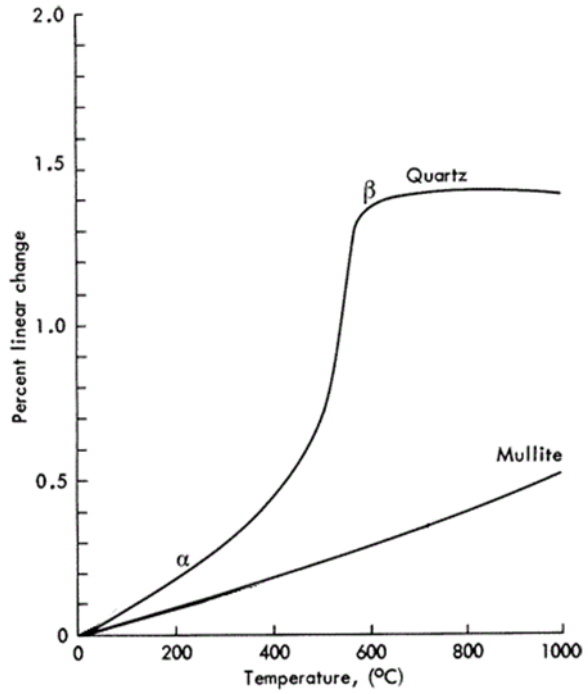
KRYPTOCAST LD

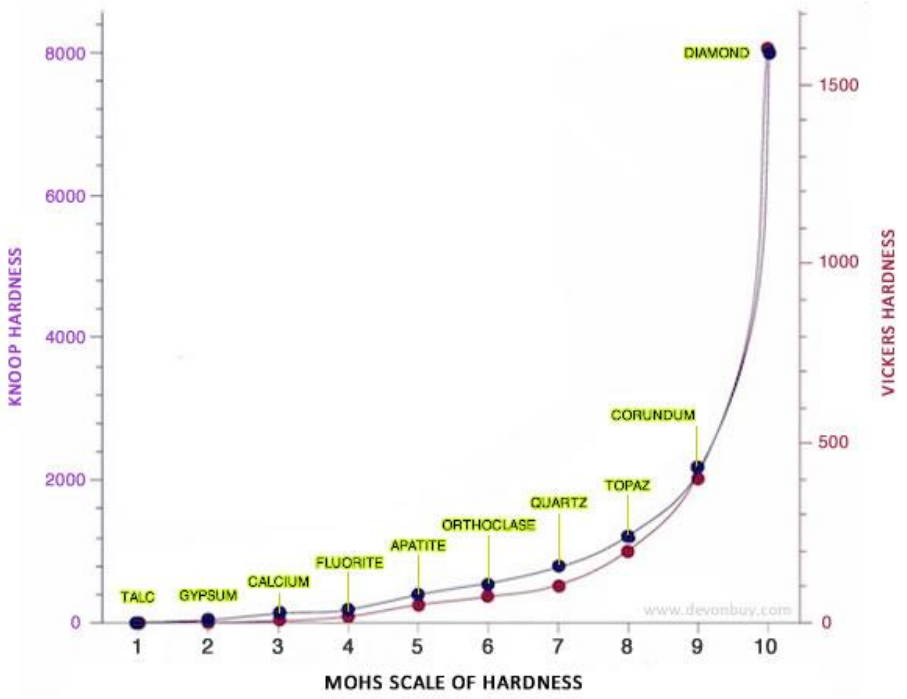
Ultra-high performance, low-density ceramic casting media

Controlled Composition – Creates Mullite and Corundum Crystals

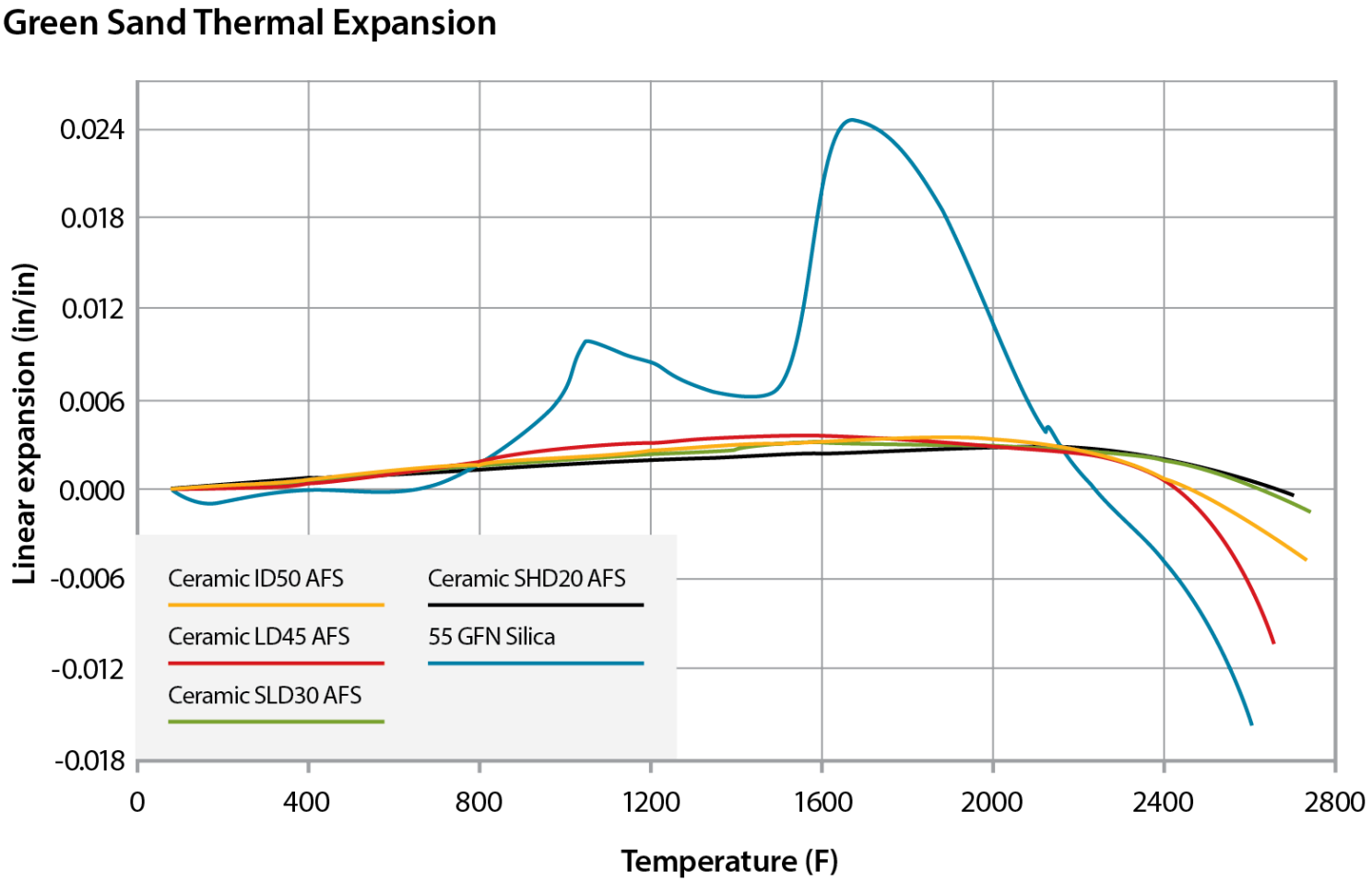
Mullite provides low, linear expansion & high thermal stability.

Corundum provides high hardness & durability & high thermal stability



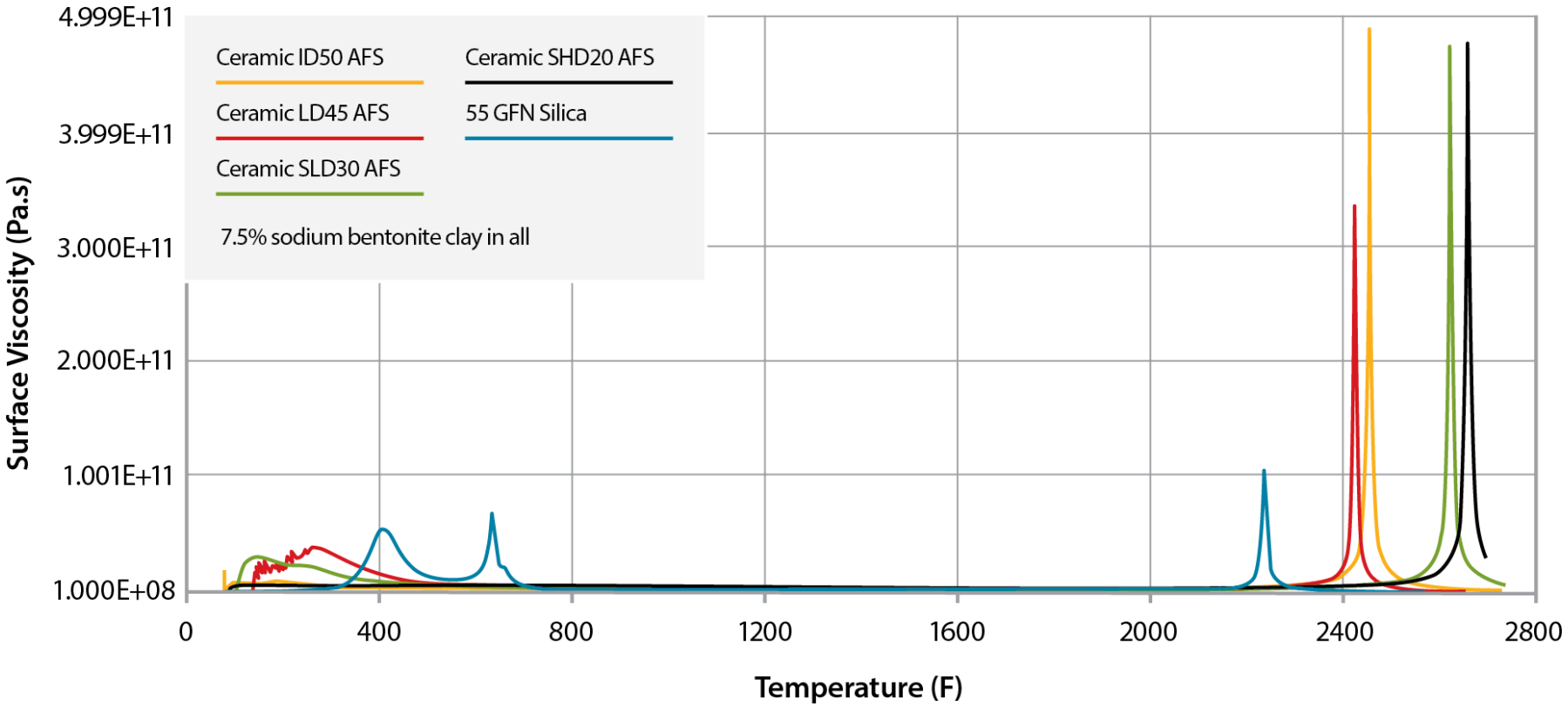


Controlled Composition – Provides Low Linear Expansion



Controlled Composition – Provides High Thermal Stability

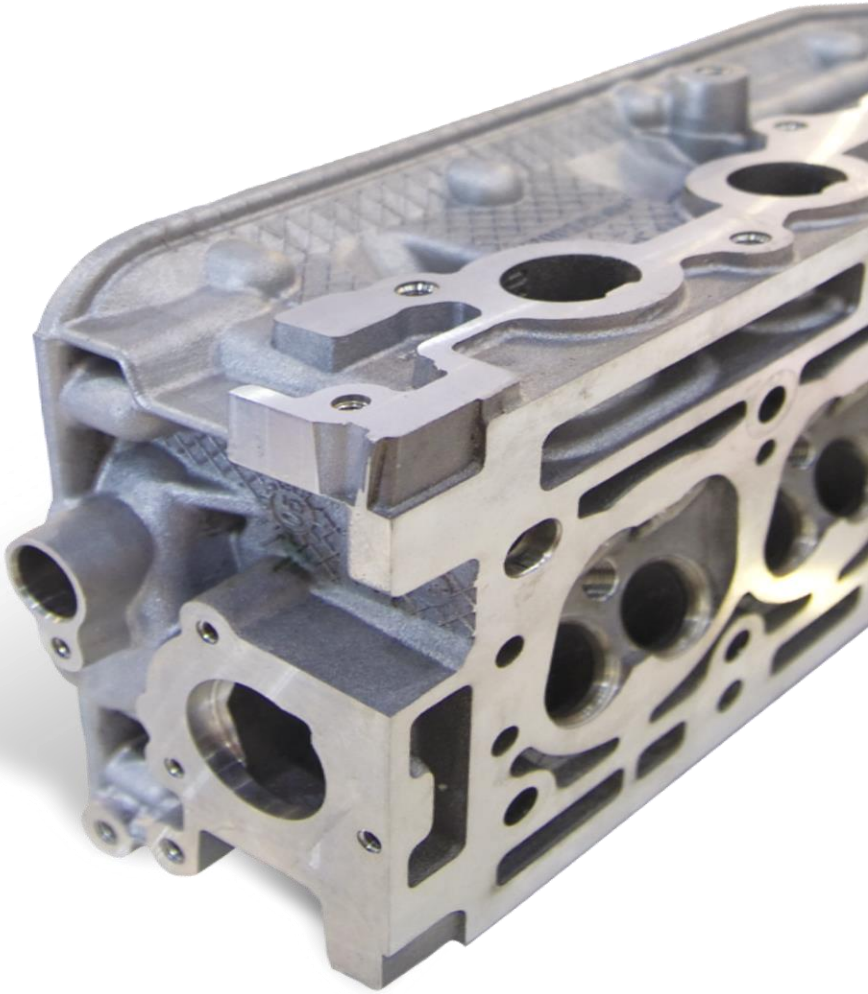
Green Sand Surface Viscosity



Low Linear Expansion and High Thermal Stability

IMPROVES
DIMENSIONAL
ACCURACY

REDUCES ADDITIVES,
DEFECTS,
SCRAP & CLEANING



High Hardness and Durability

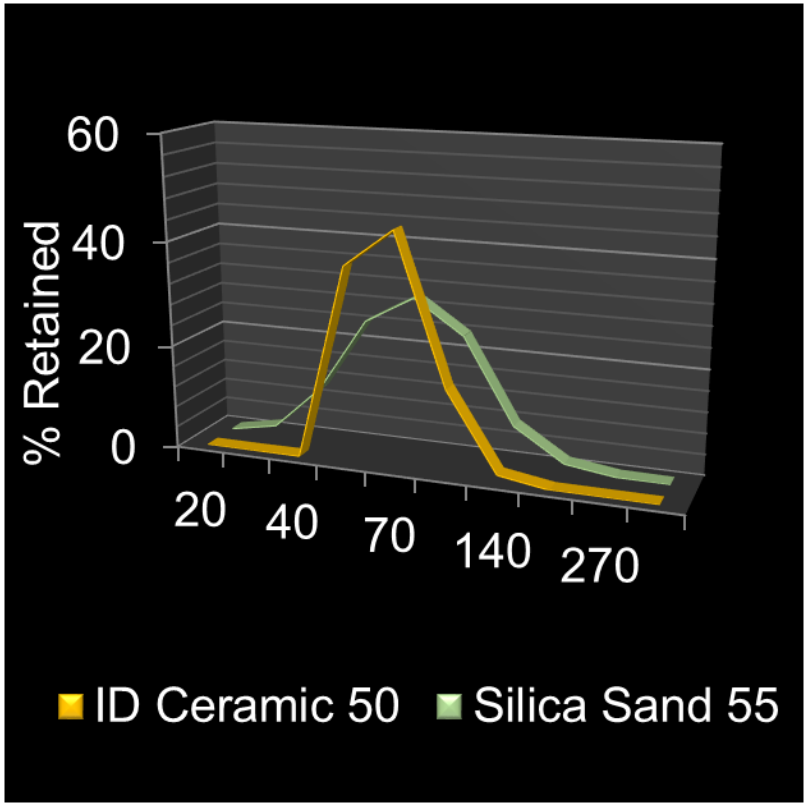
REDUCES MEDIA CONSUMPTION

IMPROVES RECLAMATION, REUSE

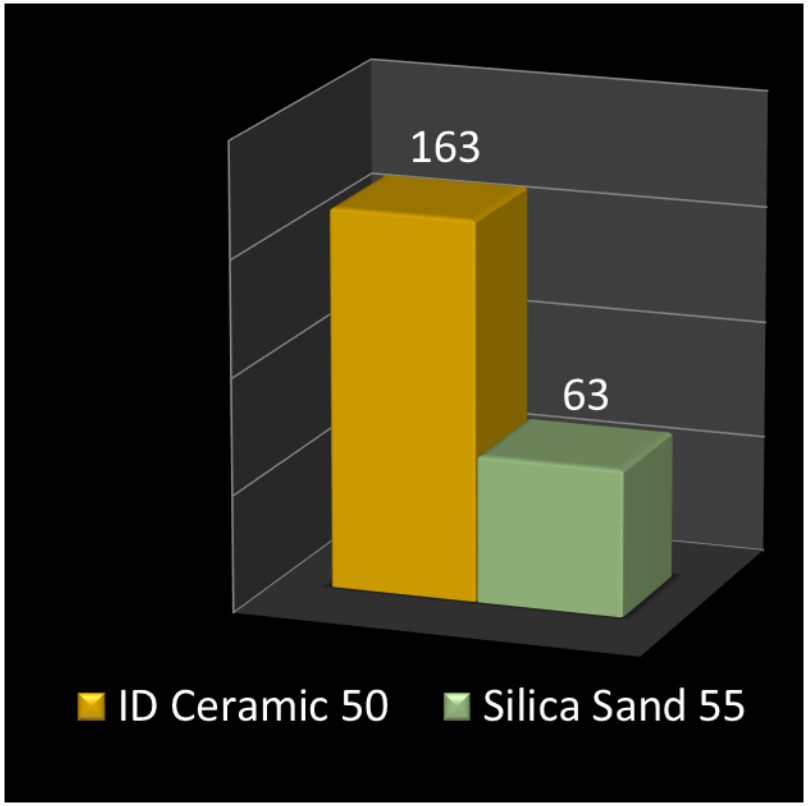
DECREASES TRANSPORTATION, DISPOSAL AND REPLACEMENT MEDIA COSTS

Controlled Sizing – Eliminates the Distributions Fine Tail, Provides Higher Permeability

Size Distribution (mesh)



Permeability

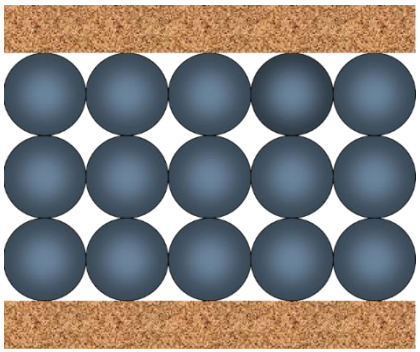


Uniform Size and Shape

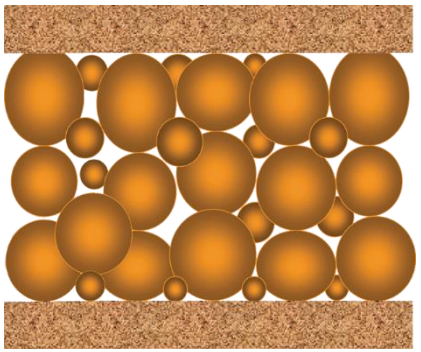
MAXIMIZES MOLD POROSITY

ENHANCES PERMEABILITY

REDUCES GAS DEFECTS



CARBO Engineered ceramic casting media



Naturally occurring silica sand

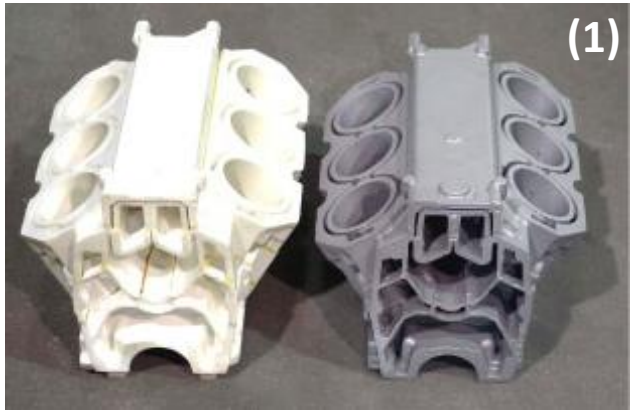
Excellent Roundness

IMPROVES FLOWABILITY

INCREASES PRODUCTION CYCLE RATES

Low Linear Expansion Impact

1. Marine aluminum engine block – improved ***dimensional*** precision, salvaging multi-billion$ project
2. Low alloy carbon steel – minimized hot tear and crack ***defects***
3. Steel gear sprocket – reduced ***cleaning*** time 20–30 to 10 hours

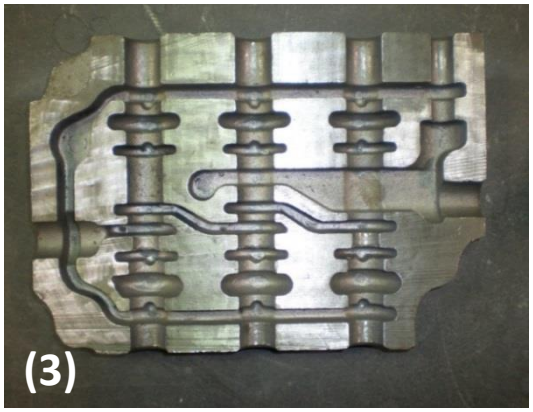


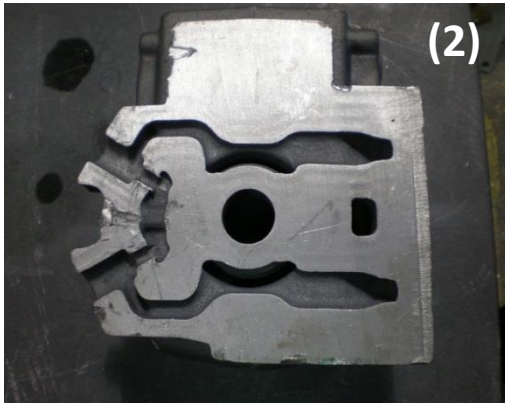
High Thermal Stability Impact

Shell Process, Grey & Ductile

Increases in casting complexity magnifies ceramic thermal impact.

1. Part 1
   - More stable dimensions
   - Cleaner internal passageways
   - Reduced burn in
   - **Eliminated heat stress crack defect**
2. Part 2
   - Eliminated burn in and fins
   - **Provided a 75% reduction in internal cleaning time**
3. Part 3
   - Clean internal passageway and tight dimensional stability.
   - **Avoided capital outlay for new cleaning equipment**





High Flow Property Impact

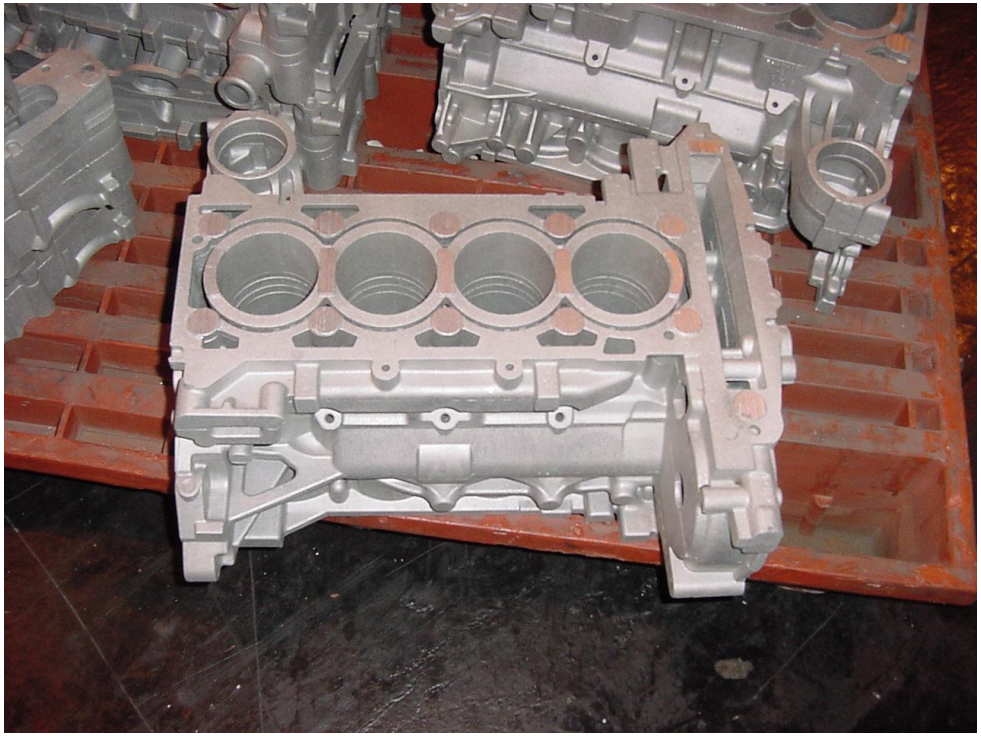
Automotive aluminum engine block

Increased production rate 27%.

Eliminated 9% scrap.

Effectively realized **36% production increase** avoiding new equipment purchase.

Automotive Engine Block

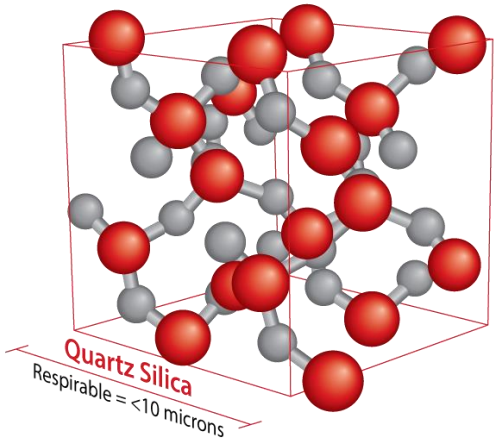


Industry Challenge

Identify and focus on the true “Elephant in the Room”!!!

“PEL”

Permissible exposure limits to ***Quartz*** *silica*



PREVIOUS MAX PEL

~~100 µg/m³~~

NEW MAX PEL

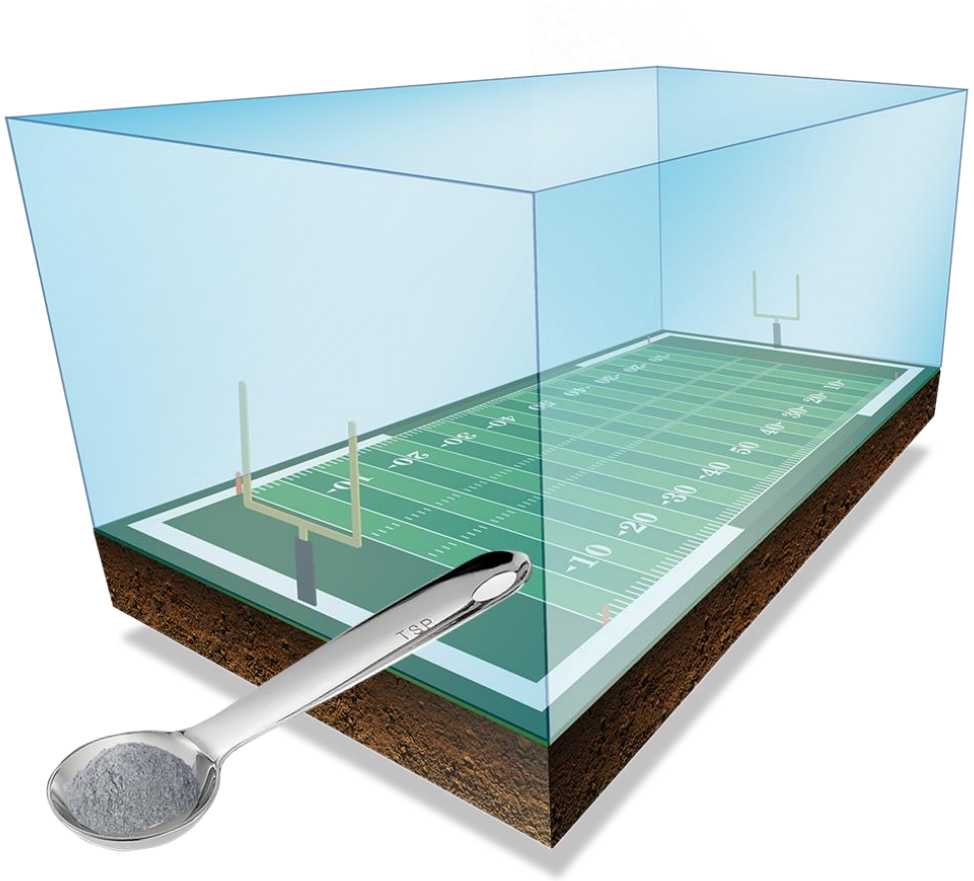
50 µg/m³

SILICA DUST EXPOSURE
(OVER 8 HOUR PERIOD)

New OSHA PEL Regulation

OSHA has lowered the "permissible exposure limit" (PEL) to crystalline quartz silica from **100 to 50 µg/m3.**

This is equivalent to a **teaspoon of silica dust** in the volume of a football field 30 meters high (**157,800 m3**).



Conversion – Approach Options

Extended blending conversion

- Produce **cores w/100% ceramic** casting media.
- Allow ceramic core material to filter into the silica molding system.
- Track ceramic/silica system ratio through conversion completion.
- Estimated time to **achieve full conversion ≈ 4 years**.

Instantaneous conversion

- Clean out entire foundry operation **removing all silica** sand and dust from facility.
- **Introduce 100% ceramic** casting media to both the core and mold systems.

Engineered Ceramics – **Conversion 1**
Steel, Phenolic Ester Jobbing Shop

Approach - **Extended blending**

Status:

- Est. 2-3 yrs. to reach full conversion
- Currently est. 30 – 50% ceramic filled system
- Projecting **2018 to achieve 90 – 100% ceramic**

Benefits Ytd.:

- Less expansion related defects
- Moved from hollow to solid cores
- Reduced gas related defects
- Losses to date from carryout, spills and shot blast

Engineered Ceramics – **Conversion 2**
Steel, Sodium Silicate Jobbing Shop

Approach - **Instantaneous 100% change**

Status

- Have trialed several key parts (**1/2 – 2 Klbs**.)
- Currently testing casting cycles
- Projecting a full conversion by **year end 2017**

Benefits Ytd.:

- All Castings produced to dimensional specifications
- Castings w/ceramics produced cleaner vs. silica sand
- Cleaning times were measurably reduced per part
- Eliminated a burn-in defect
- Physical mold packing reduced/eliminated
- Mold coating reduced 60% to date

Engineered Ceramics - **Conversion 3**
Grey & Ductile Iron, Furan NoBake Jobbing Shop

Approach - **Instantaneous 100% change**

Status:

- Have trialed several key parts (**6 – 30 ton**)
- Have cycled product successfully producing castings w/reclaimed ceramics
- Projects a **2017 end of year** full conversion
- Yet to determine recycle losses & sustaining requirements

Benefits Ytd.:

- All castings produced to dimensional specifications
- Castings w/ceramics produced cleaner vs. silica sand
- Cleaning **times (hrs.) were measurably reduced** for most parts
  - Part 1 Silica sand = 3.25 Ceramic = 0.75
  - Part 2 Silica sand = 5.75 Ceramic = 2.50
  - Part 3 Silica sand = 3.00 Ceramic = 1.75
  - Part 4 Silica sand = 1.75 – 3.50 Ceramic = 2.25

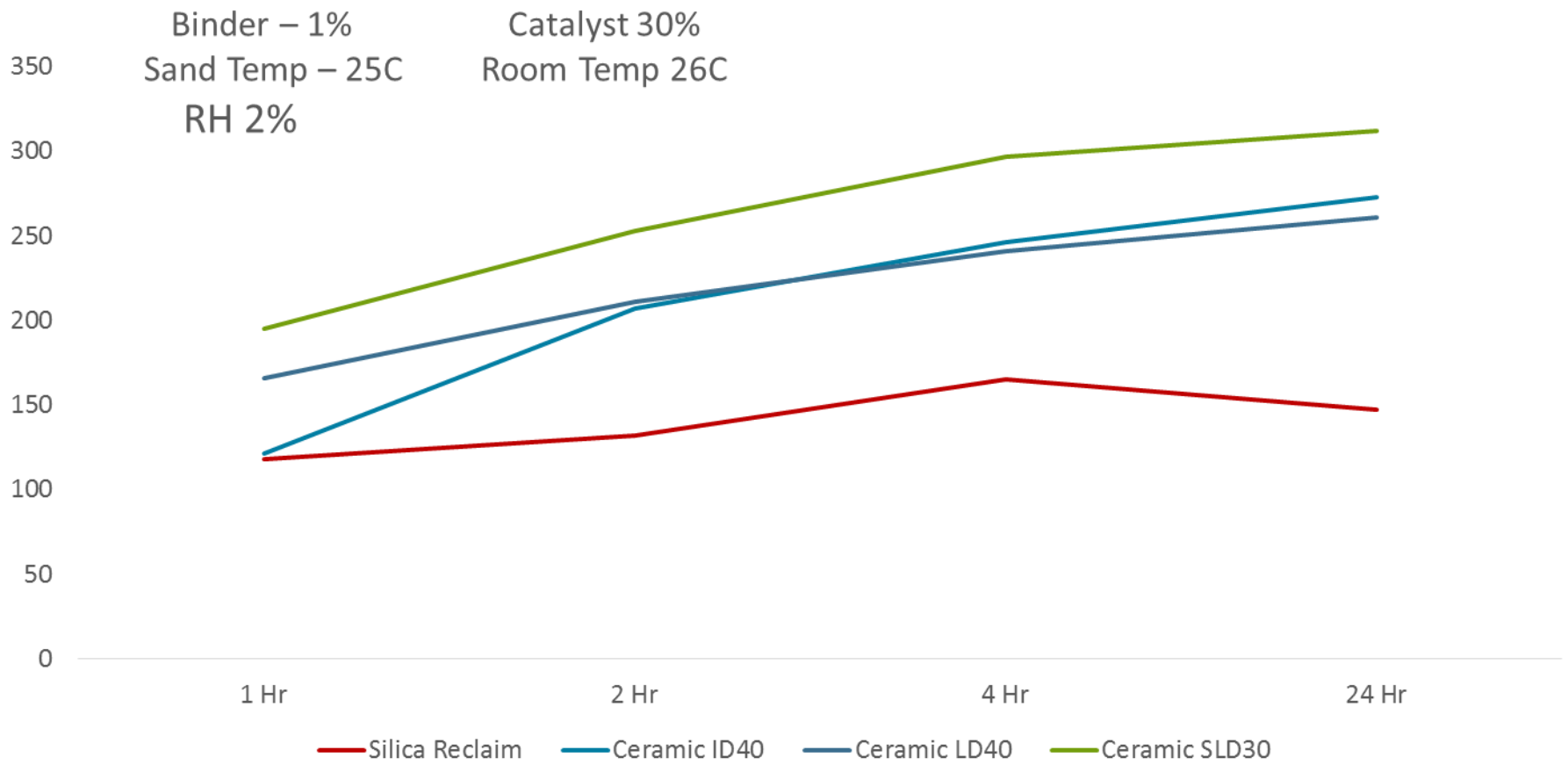
Conversion Trial – 6 ton Casting Ceramic vs. Silica Sand

Ceramic

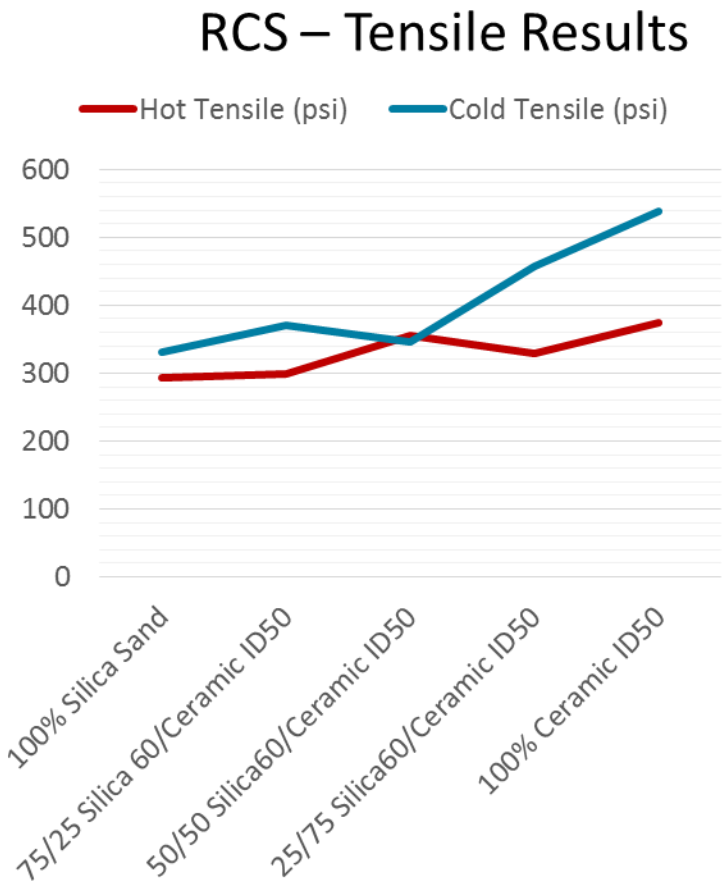
Silica sand

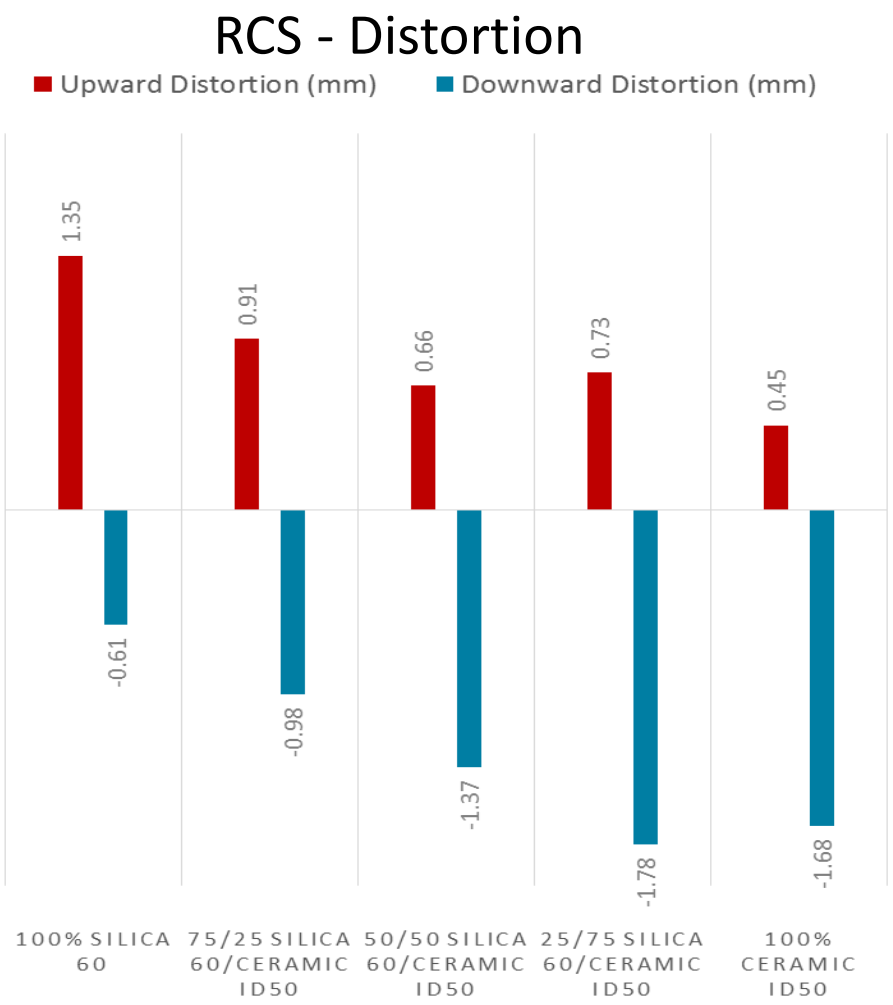
Conversion Trial – 30 ton Casting, Ceramic Post Shake-out/Pre Cleaning

Furan Nobake Tensile (psi)



RCS – Properties



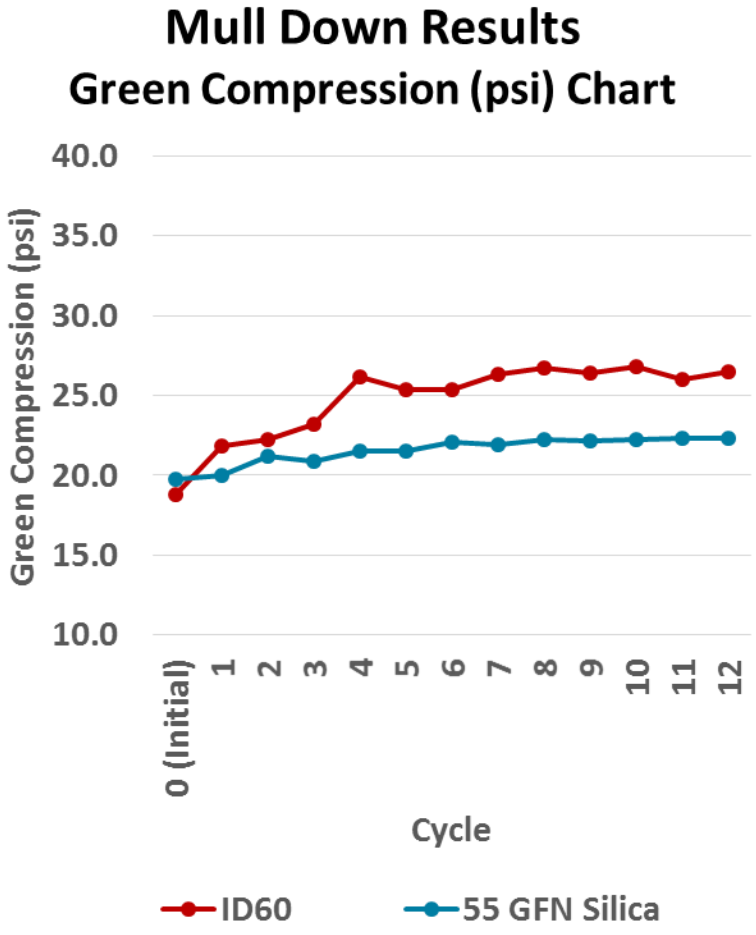


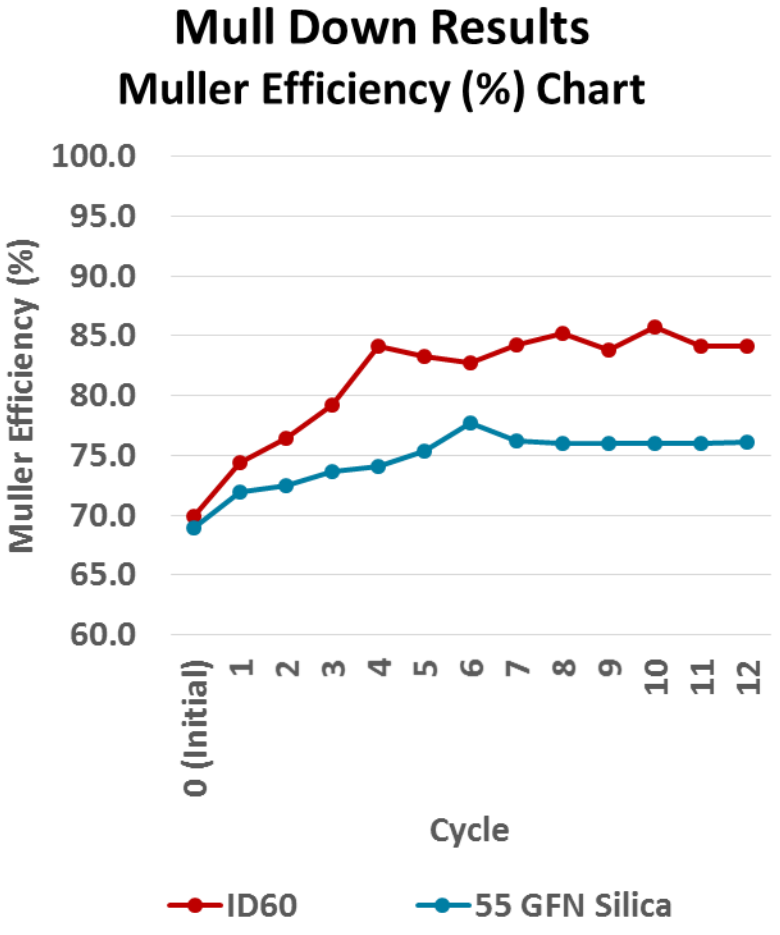
Engineered Ceramics – Green Sand Properties

	Green Compression Strength (psi)	Dry Compression Strength (psi)	Green Shear Strength (psi)	Dry Shear Strength (psi)	Wet Tensile Strength (psi)
Ceramic ID50 AFS	28.31	43.77	6.65	12.56	0.31
Ceramic LD45 AFS	27.45	45.70	6.25	12.60	0.34
Ceramic SLD30 AFS	31.43	54.66	7.52	13.13	0.45
Ceramic SHD20 AFS	30.06	55.97	7.33	12.85	0.44
55 GFN Silica	22.57	46.62	7.25	13.50	0.47

	Mold Hardness (B scale)	Methylene Blue Clay (%)
Ceramic ID50 AFS	76.67	7.46
Ceramic LD45 AFS	92.00	7.37
Ceramic SLD30 AFS	95.67	7.47
Ceramic SHD20 AFS	92.67	7.37
55 GFN Silica	91.00	7.51

Engineered Ceramics - Green Sand Mulling Cycle Impact vs Silica Sand





Engineered Ceramics – Value In Use

Cost Savings

- Reduction/Elimination

- Additives
  - iron oxide, anti-veining, anti-penetration
- Wash coatings
- Shake out time
- Cleaning time
- Defects
  - Gas, veining, penetration, burn-on
- Scrap
  - media, binders, additives and energy required to recast
- Energy
- Equipment installations
- Equipment monitoring and maintenance

Engineered Ceramics – Value In Use

Enhanced Performance

- Increased production
- Dimensional precision (magnified w/casting complexity)
- Capability
- Business opportunity
- Competitive posture

Reclamation (X)factor

- (X)Cycle life increase

(X)Reductions:

- Media purchase
- Material inventory & handling
- Transportation delivery & disposal
- Land field disposal
- Environmental Footprint

FOUNDRIES USING SILICA SAND FACE A COMPLEX AND COSTLY COMPLIANCE PROCESS

Conduct initial silica dust monitoring

Establish restricted areas for authorized personnel only

Install or retrofit engineering controls and implement work practice controls

Enforce stringent housekeeping measures

Implement and maintain a medical surveillance program

Update hazard communicatio n programs

SWITCHING FROM SILICA SAND TO CARBO CERAMIC MEDIA ELIMINATES COMPLIANCE CONCERNS

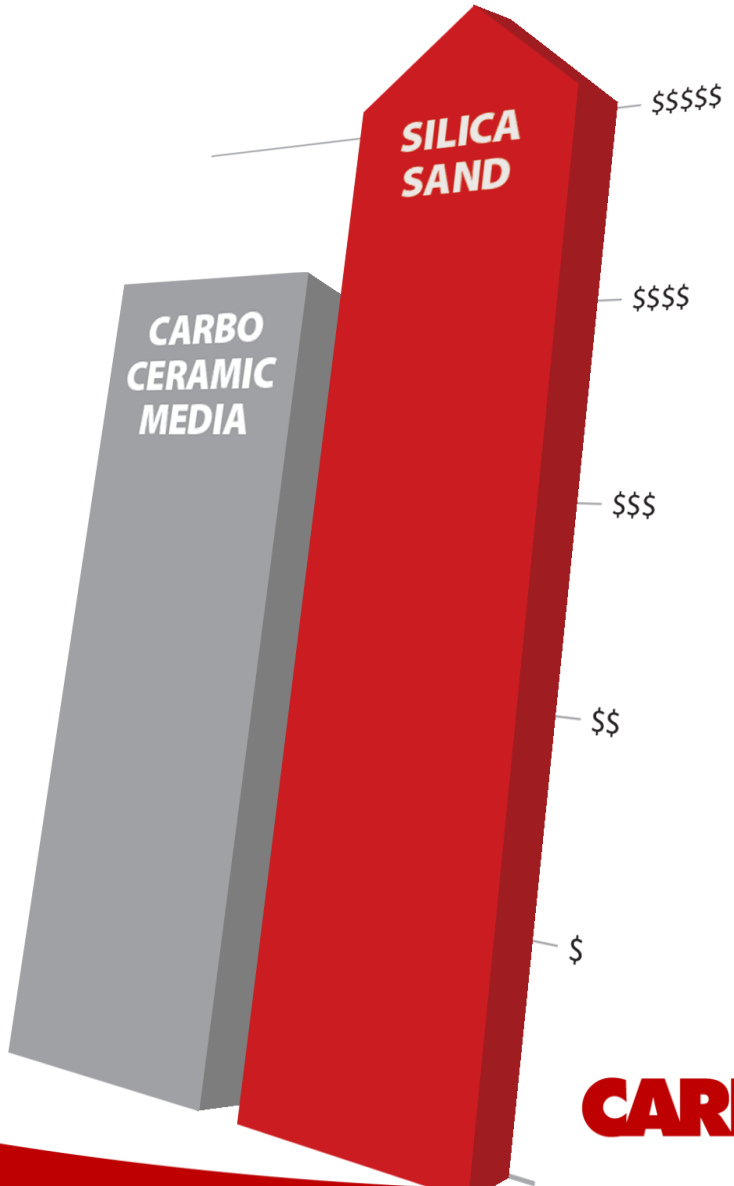
CARBO Engineered Ceramic Casting Media

SIGNIFICANTLY REDUCES LONG TERM COSTS

ESPECIALLY WHEN CONSIDERING COMPLIANCE COSTS TO CONTINUE USING SILICA SAND

&

PERFORMANCE AND RECYCLED USE OF ENGINEERED CERAMICS



CARBO

Engineered Ceramics – Conclusions

US ceramic production plants are OSHA regulated.

A separate study conducted to evaluate the degree of employee exposure to crystalline silica in a ceramic manufacturing facility revealed that:

- The **quartz non-detectable threshold** was 0.0056 mg/m3 – roughly **10X less than the new PEL limit** of 0.05 mg/m^3
- There was **no detectable crystalline silica** (quartz, cristobalite or tridymite) in any of the select critical test areas where samples were collected
- Ceramic casting media **produces no carcinogenic quartz silica dust**. It poses virtually no hazards, reduces HSE concerns and complies with the new silica PEL

Engineered Ceramics provide performance value and create a viable alternative to silica sand for metal casting production.

With Engineered Ceramic Technology – When asked about the big elephant in the room, the reply can be -

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