



Advancements in Carbon Fiber Processing, Research & Development

Composites World, San Diego 2010

December 8, 2010

Presentation Overview

Advancements in Carbon Fiber Research & Development

- Industrial Scale
- Micro Scale Processing Lines – Enabling Rapid Cycle Research
- Going Smaller?

Industrial Scale Carbon Fiber Advancements

- MultiFlow Oxidation Oven Technology
- Benchmarking the Next Generation of Advanced Oxidation Ovens

Carbon Fiber Systems Experience

- Multiple references for complete CF line supply
- Pilot scale (< 100 TPY)
- Production scale (up to >1500 TPY)
- Research Scale – micro (< 1 TPY)
- Hundreds of LT furnace, HT furnace and surface treatment systems worldwide



Carbon Fiber Systems Scale of Operations

Scale of Operations

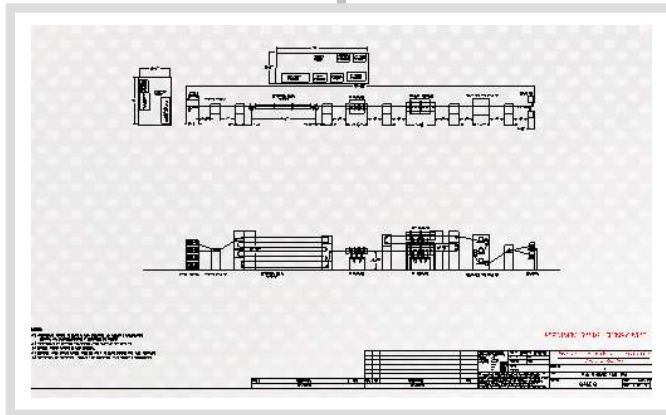
- Industrial Production
- Industrial Research (Pilot Plant)
- Research (Non-Industrial Scale)

Considerations

- Capacity
- Feed Stock Requirements
- Frequency of Use & Staffing
- Investment Costs

Carbon Fiber Systems Scale of Operations

<u>Scale</u>	<u>Size Range (mm Width)</u>	<u>Capacity</u>
Production	1000mm - 4200mm	100tpy to More Than 2000 tpy
Industrial Scale Pilot	300mm - 1000mm	20tpy - 100 tpy
Micro Scale (University, Institute)	<100mm	Less Than 1 tpy

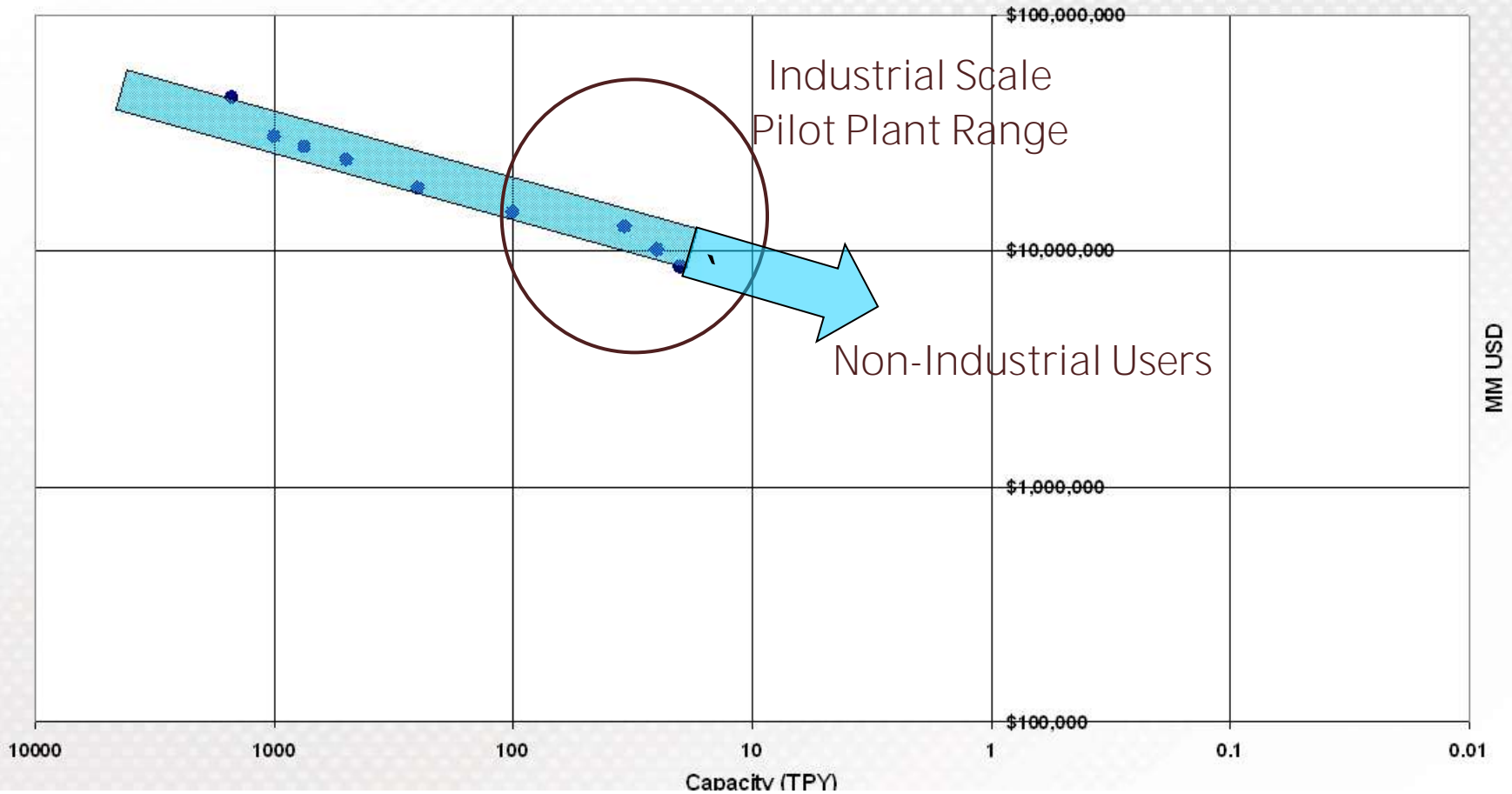


Carbon Fiber Systems Scale

<u>Scale</u>	<u>Size Range (mm Width)</u>	<u>Capacity</u>	<u>Function</u>	<u>Investment</u>
Production	1000mm - 4200mm	100tpy to More Than 2000 tpy	Continuous, Industrial	15MM USD - 45 MM USD
Industrial Scale Pilot	300mm - 1000mm	20tpy - 100 tpy	Continuous, Pilot (Mimics Industrial)	Up to 15MM USD

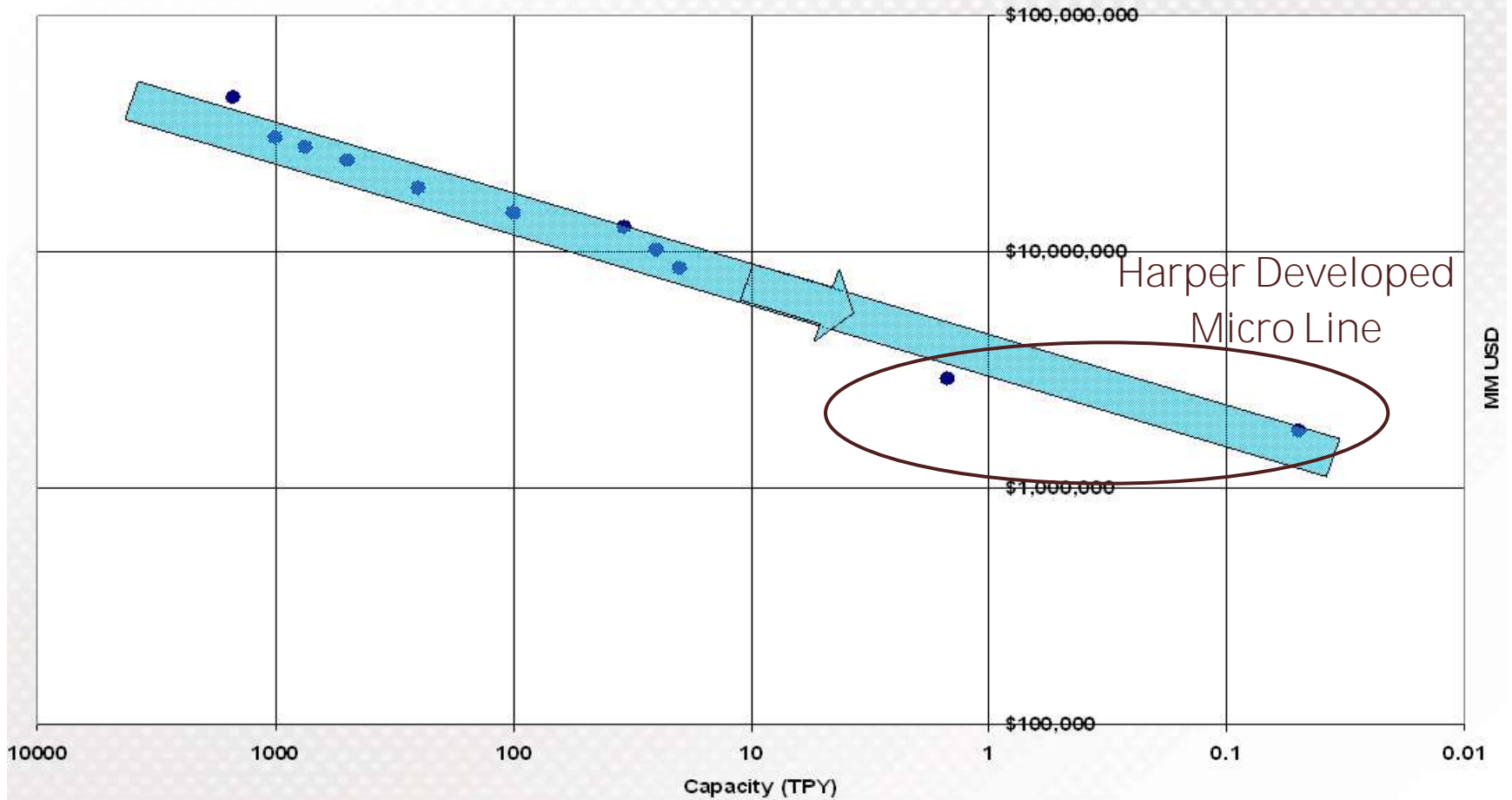
Carbon Fiber Systems Scale of Operations

System Investment

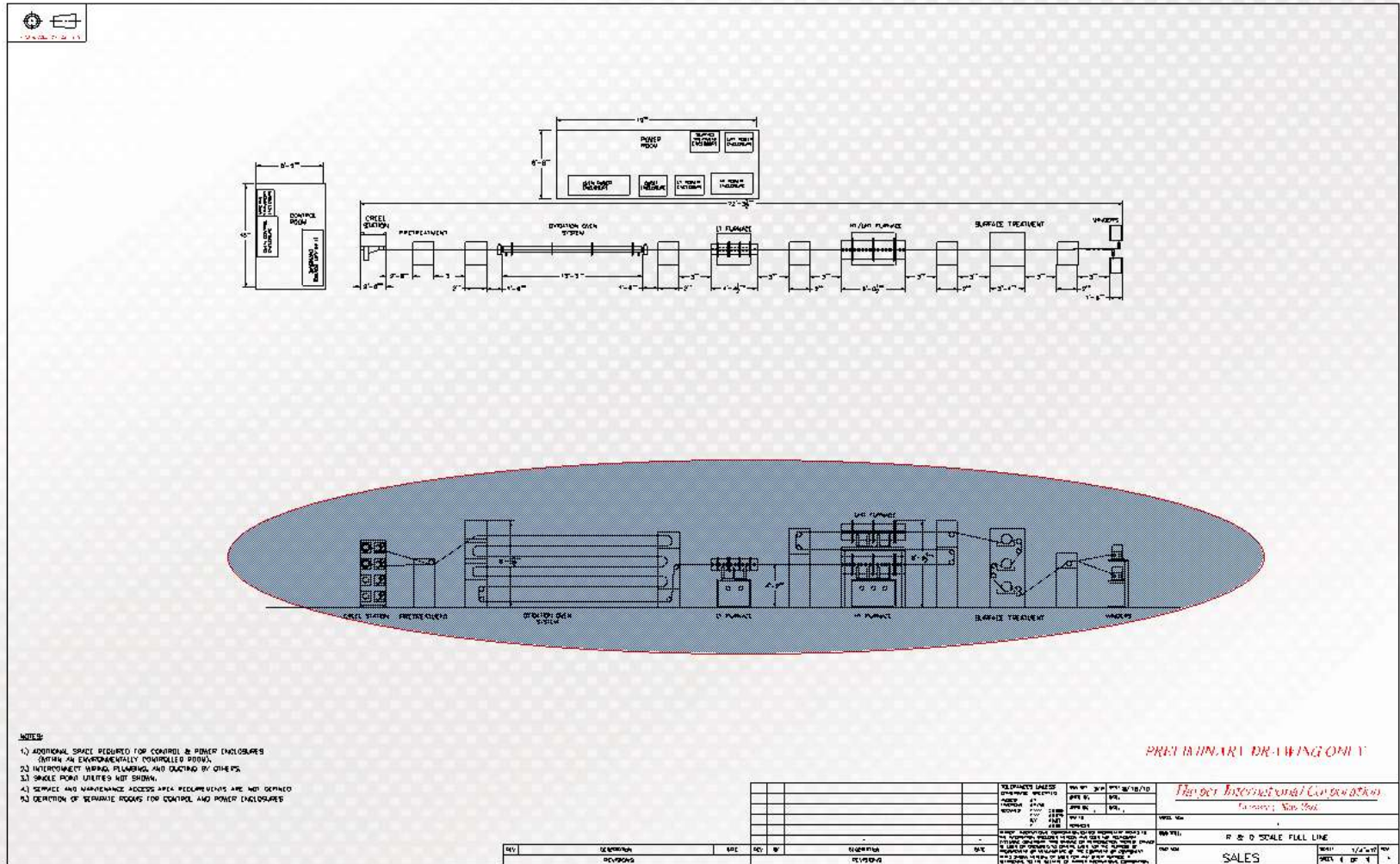


Carbon Fiber Systems Scale of Operations

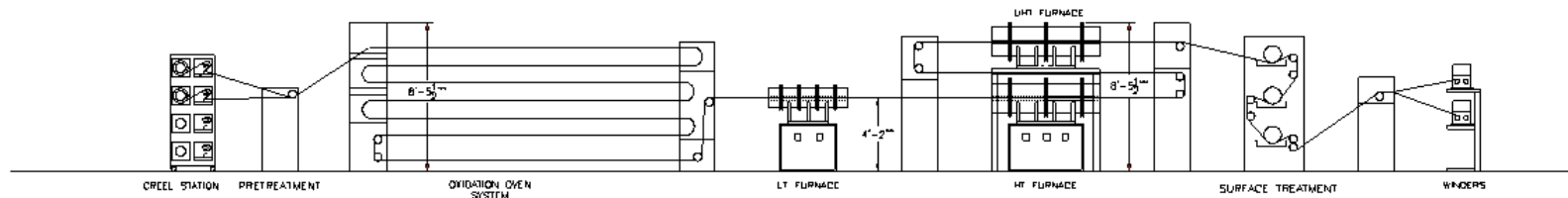
System Investment



Carbon Fiber Systems Scale of Operations



Carbon Fiber Systems Micro Scale Research System



Micro Scale Research System

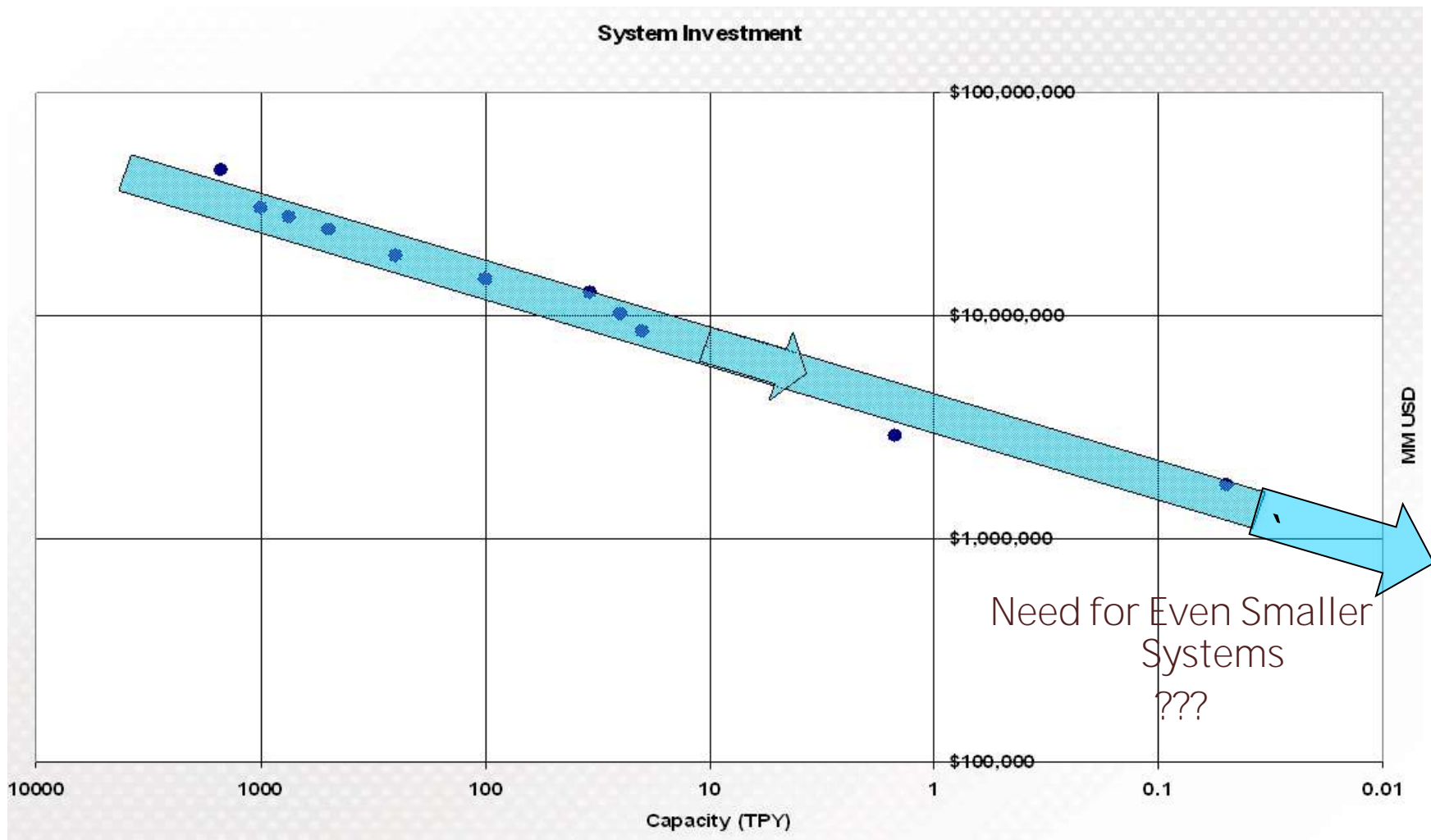
- Fits within a Reduced Foot Print 72'L (22m) x 12'W (3.15m) x 10'H (3.05m)
- Capable to Extremely Low Load Control (grams)
- Enables Processing of Sub 1k Filament Bundles
- Continuous Process
- Equivalent to an Industrial System w.r.t. Number of Material Handling Systems
- Some Variation in Retention Time and Zone Count from an Industrial System

Lower (Lowest?) Practical Limit for Continuous Fiber Draw?

Carbon Fiber Systems Scale of Operations

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Micro Scale (University, Institute)	<100mm	Less Than 1 tpy	Continuous (Some Variance, Zones, Times. Less Feed Stock Required)	Less than 5MM USD

Carbon Fiber Systems Scale of Operations



Carbon Fiber Systems Micro Scale Research System

Potential Table Top Research System

- Continuous or Batch?
- Multiple Cycles of Combined Heating, Atmosphere and Loading within a Single Machine
- Scale-Ability? How to Benchmark performance and Track to Industrial Scale Research
- Enables a Broad Research Community

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Industrial Scale Carbon Fiber Advancements

- MultiFlow Oxidation Oven Technology
- Benchmarking the Next Generation of Advanced Oxidation Ovens



Harper Oxidation Technology

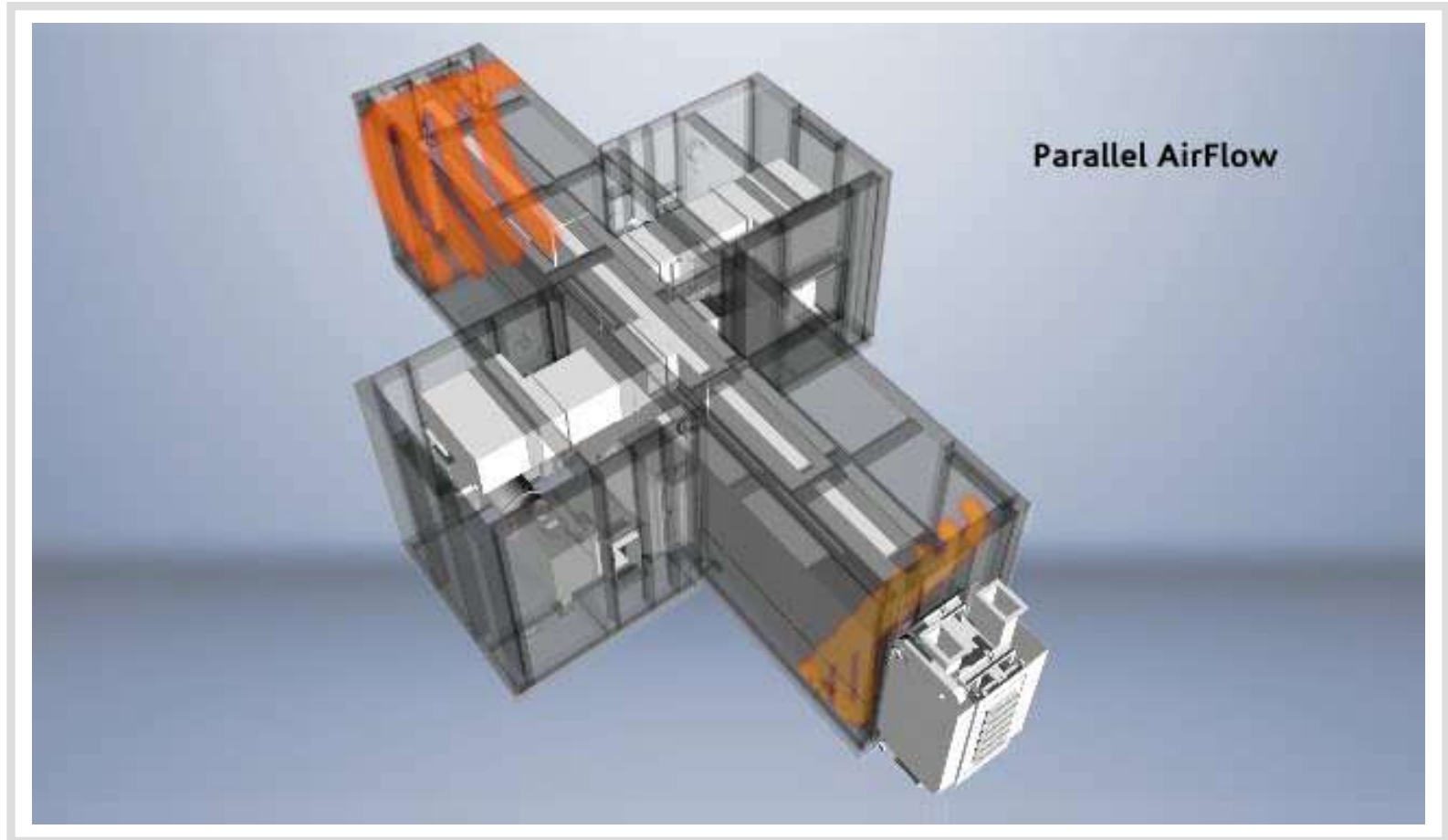
Harper International MultiFlow Research Oven

MultiFlow Research Ovens

- Pertains to Industrial Scale Facilities
- Capable of Operating in Multiple Industry Standard Flow Distributions
- Meets or Exceeds Best In Class for Each Flow Regime
- Allows for True Evaluation of Different Flow Techniques with Balance of Line under Similar Conditions



Harper MultiFlow Research Oven Flow Fields





Harper Oven
Technology Advancements

Harper Oven

Technology Focused Areas for Technology Advances

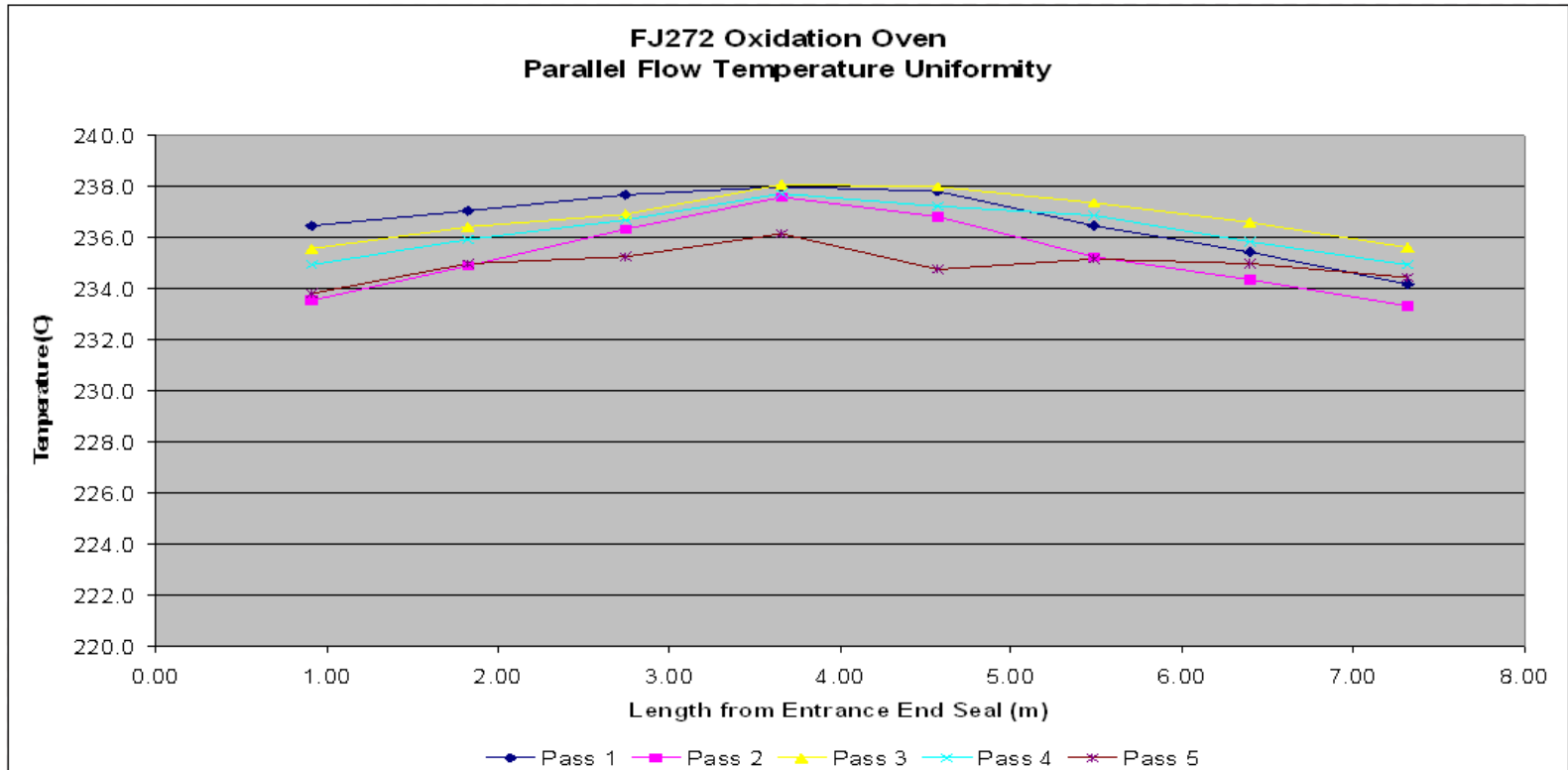
- Most Technologies focus only on Temperature Uniformity
- Harper Oxidation Technology offers Improvements in:
 - Velocity Uniformity
 - Velocities Range Capability
 - Modular Construction Technique
 - Advanced Instrumentation and Control
 - Superior Atmospheric Seals

Harper Oven

Technology Focused Areas for Technology Advances

Concrete Guarantees in Performance

- Temperature Uniformity



- Mean temperature: 236.0 °C Standard deviation: 1.3 °C
- Average variance: 1.2 °C

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Technology Focused Areas for Technology Advances

Concrete Guarantees in Performance

- Wider Range of Operational Velocities

Harper Oxidation Oven
Cold Flow Test - Velocity Uniformity Across Width

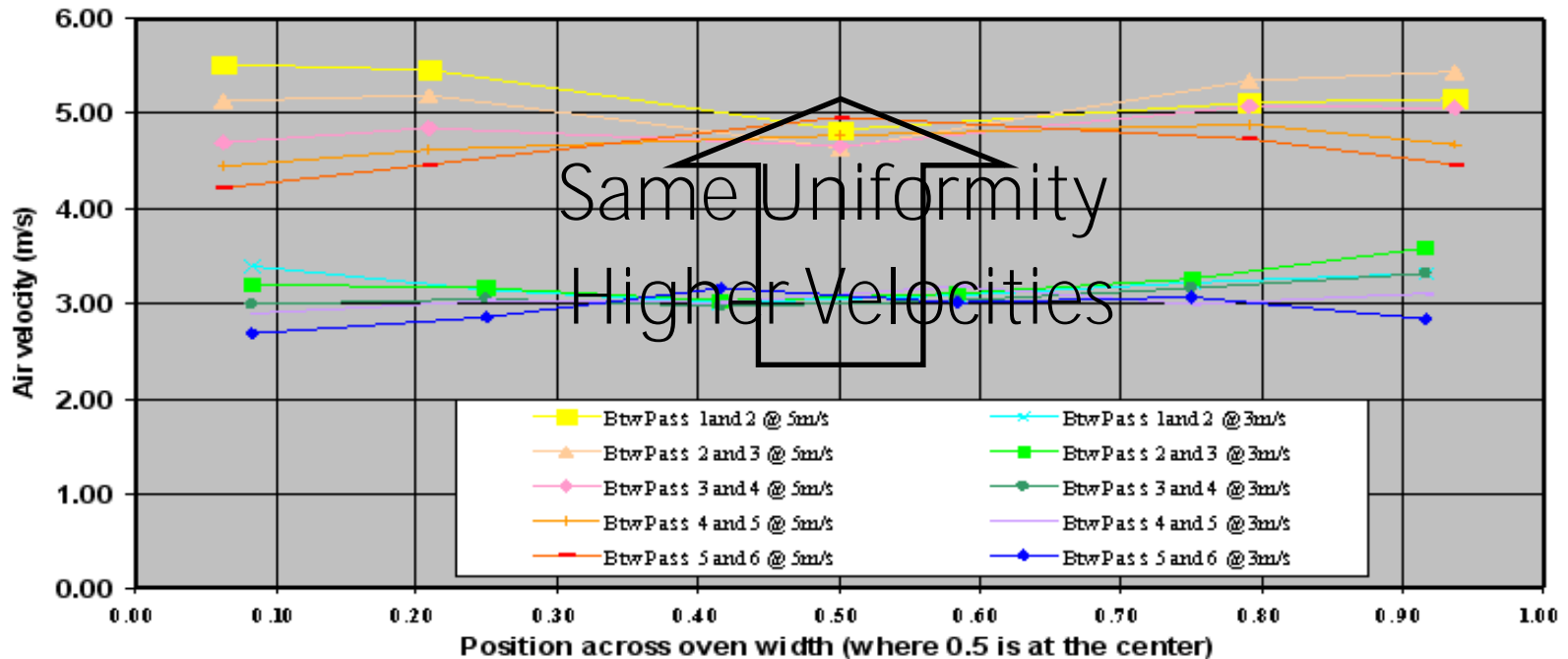


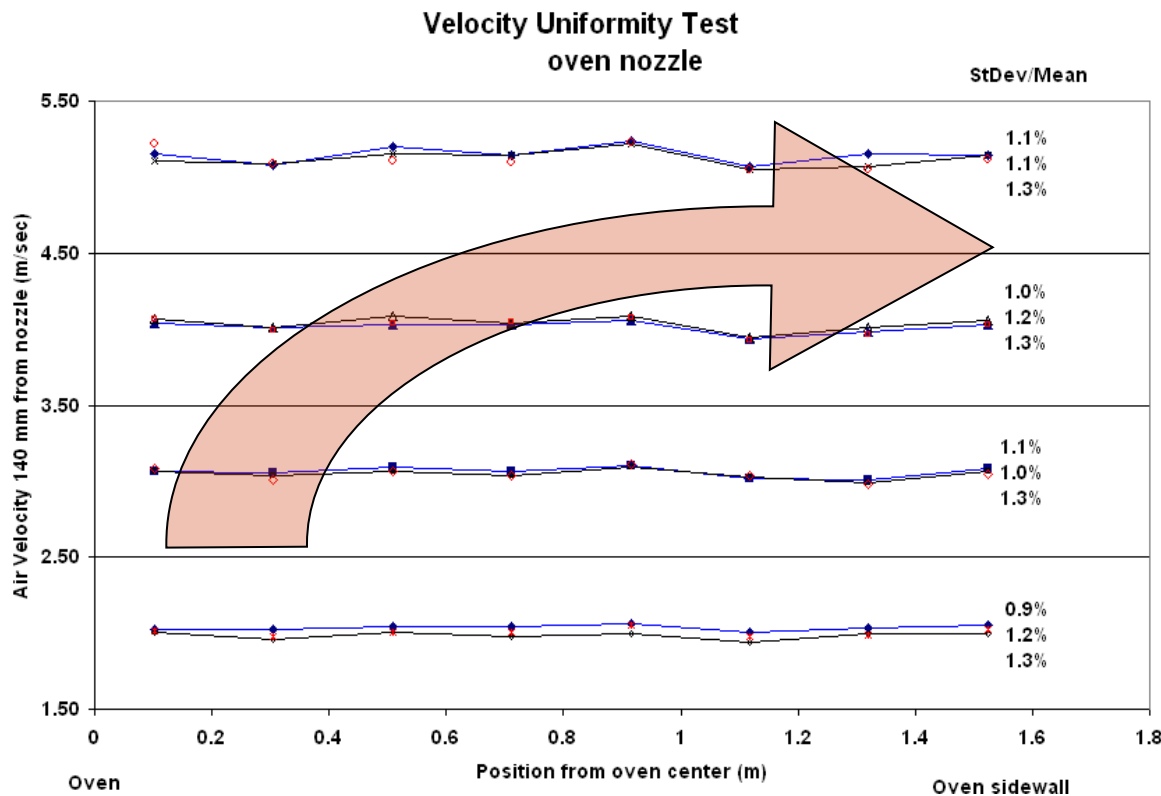
Fig 1. Velocity Uniformity Data – 3 m/s to 5 m/sec Mean Airflow
(Passes are counted from the Bottom of the Chamber Upward)

Harper Oven

Technology Focused Areas for Technology Advances

Concrete Guarantees in Performance

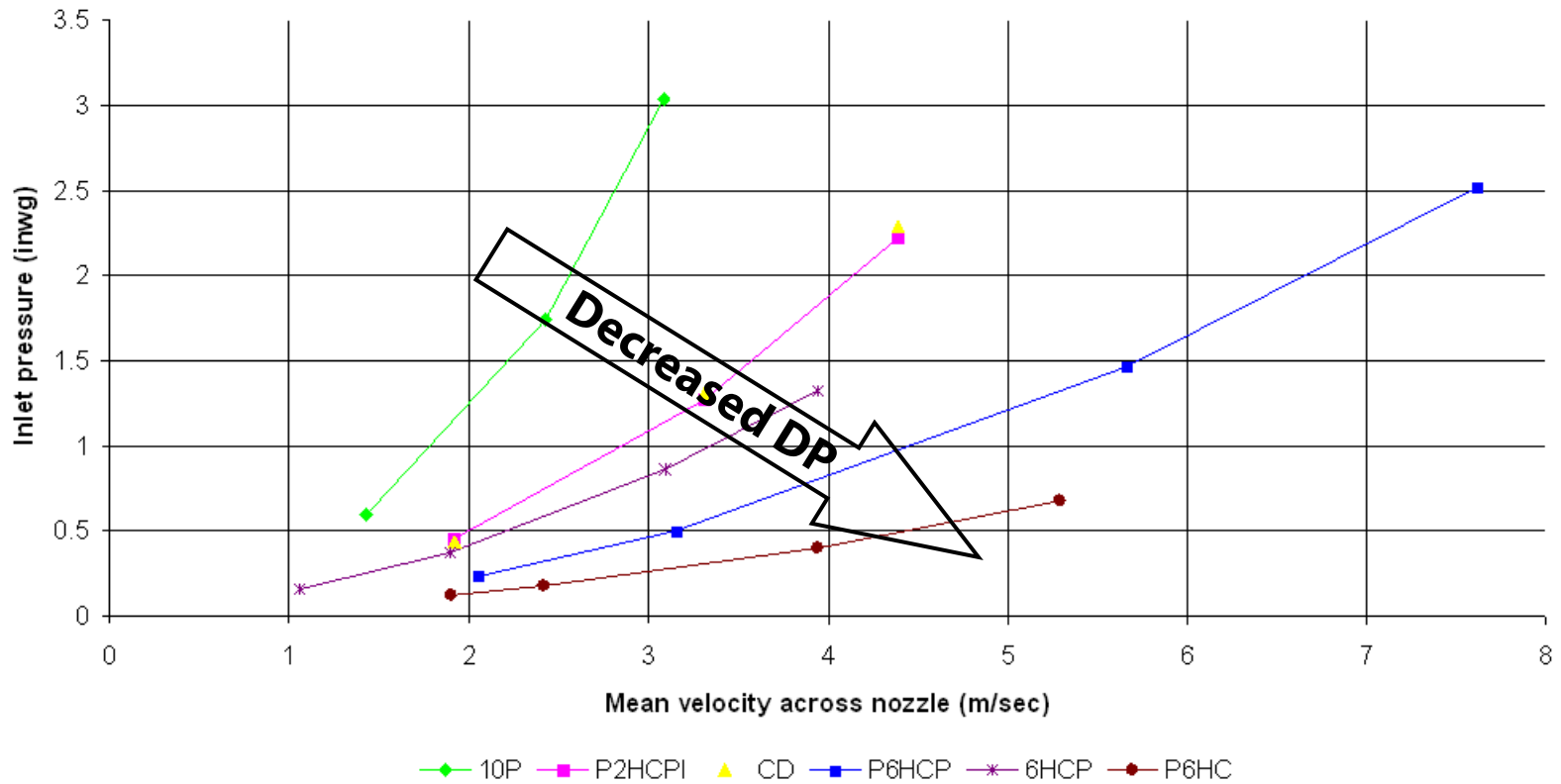
- Velocity Field Uniformity



Equivalent Uniformity
at Higher Velocity
= Faster Oxidation

Harper Oven Technology Nozzle Development

Nozzle Rig DP Data



Lower Energy in Recirculation Through Optimization
of Nozzle Delta P (Pressure Loss)

Harper Oven

Technology Focused Areas for Technology Advances

Concrete Guarantees in Performance

- Velocity Field Uniformity – Vibration Testing



- Parallel Flow - Air Velocity
- Vibration Testing Results Show Low Fiber Disruption, at 2x to 3x Typical Velocities

Harper Oven Technology Pilot System Modular Construction

Full Line Pilot System (300mm) by Harper International

- Harper MultiFlow Oven, Field Erect ~1,000 Manhours
- 90% Reduction in Labor versus similar Field Erection Time



Harper Oven

Technology Focused Areas for Technology Advances

Modular Construction for Optimal Installation Time

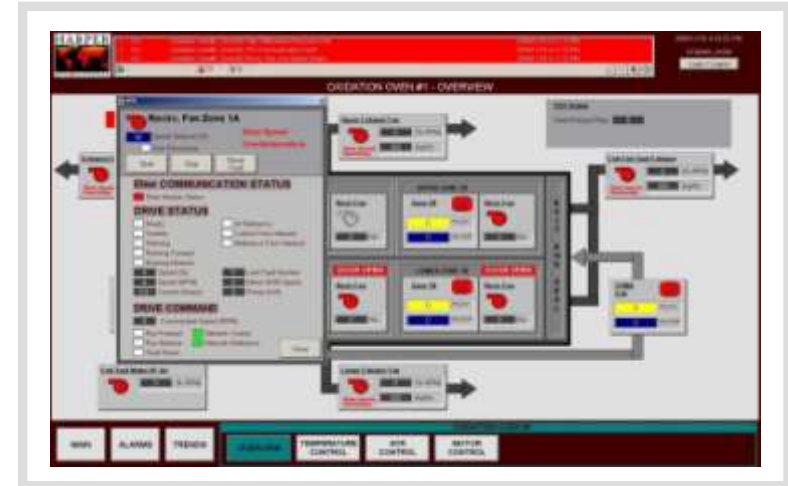
- Actual Install Time ~ 1,000 Man-hours



Harper Oven Technology Instrumentation Advancements

Instrumentation & Controls

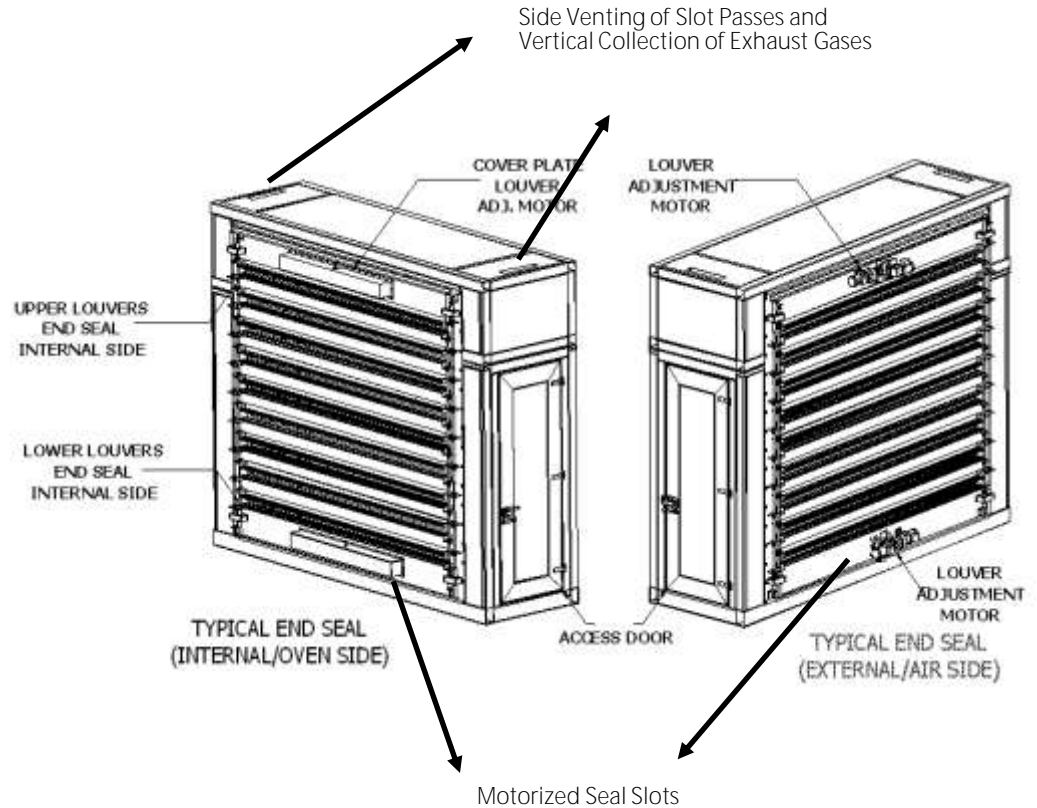
- System Flow Control
- Two-Tier Balancing Methodology
- Responsive Quench System and Rapid Cool Down System
- Emissions Monitoring
- Inherently Safer Pressure Relief System



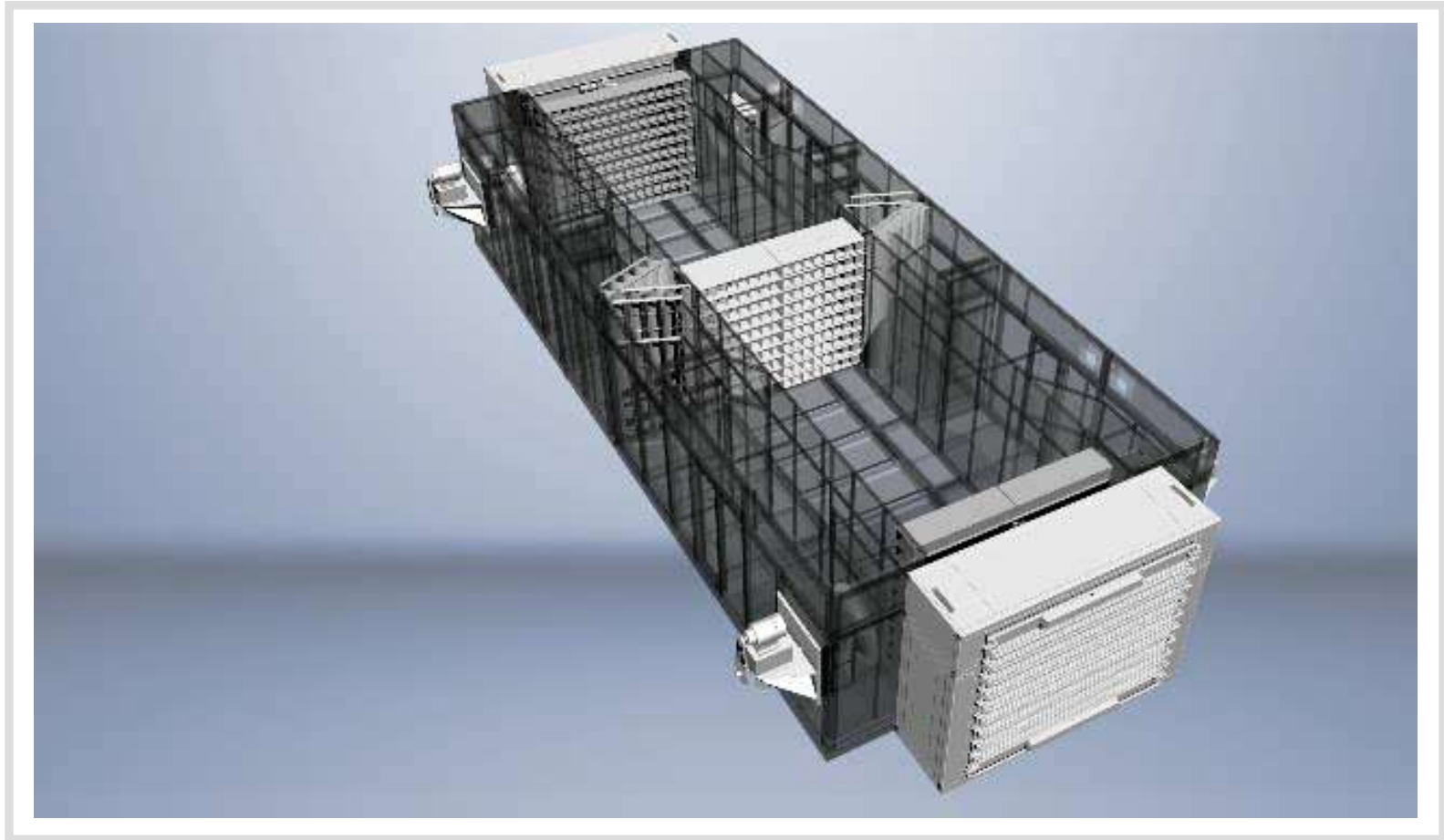
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Technology Focused Areas for Technology Advances

Unique Seal Design



Harper Oven Technology End Seal Function

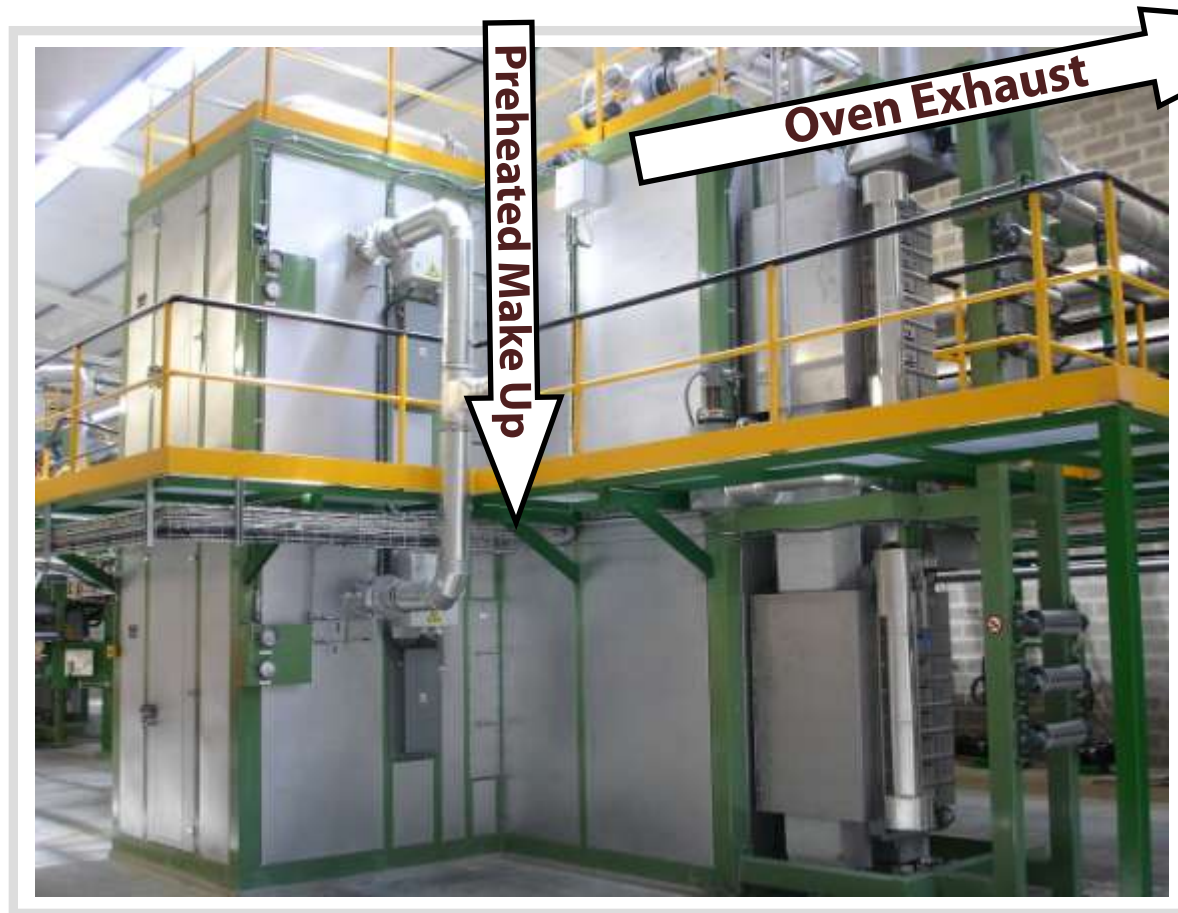


Harper International Oven Seals and Energy Recovery

Why is Improved Seal Technology Important?

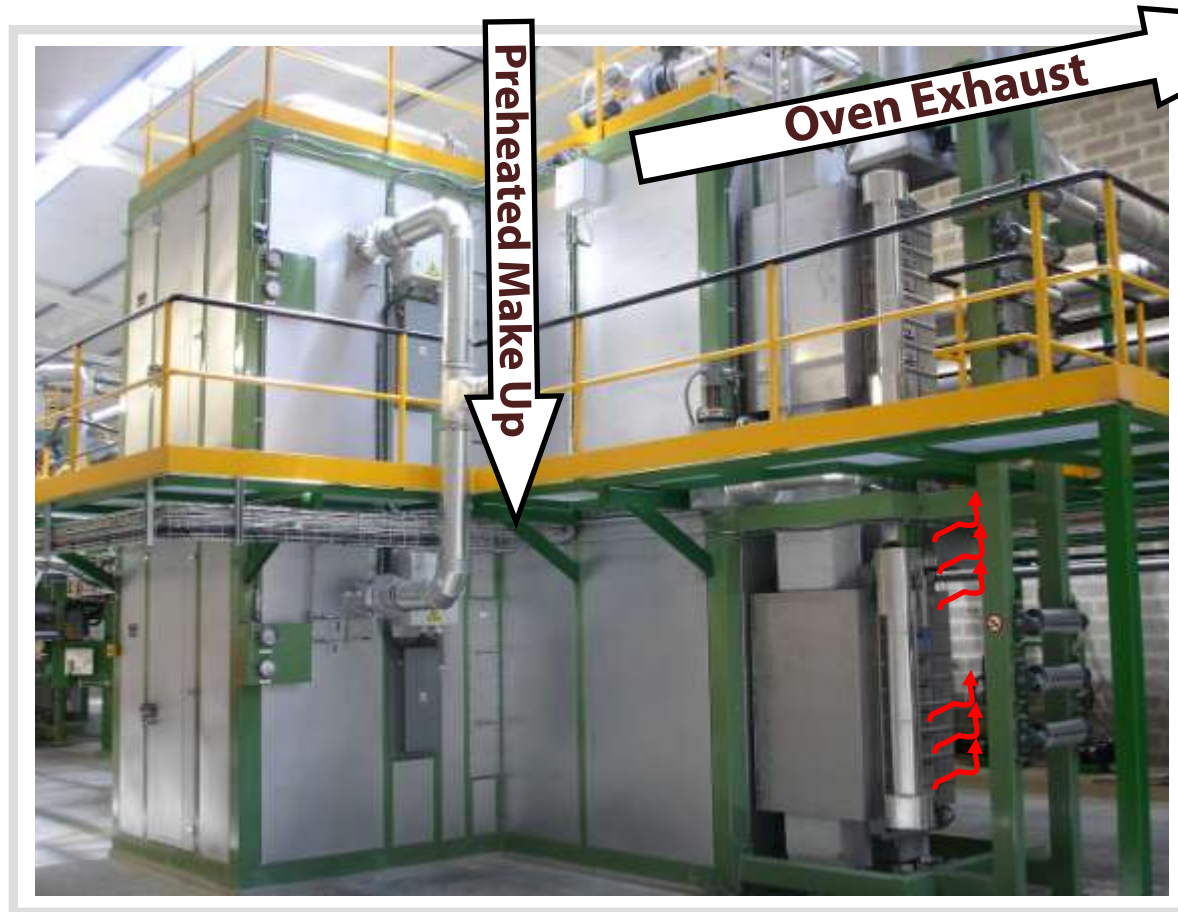
- Reduced Fugitive Emissions
- Increase Active Volume of Oven
- Reduced Energy Consumption

Harper International Oven Seals and Energy Recovery



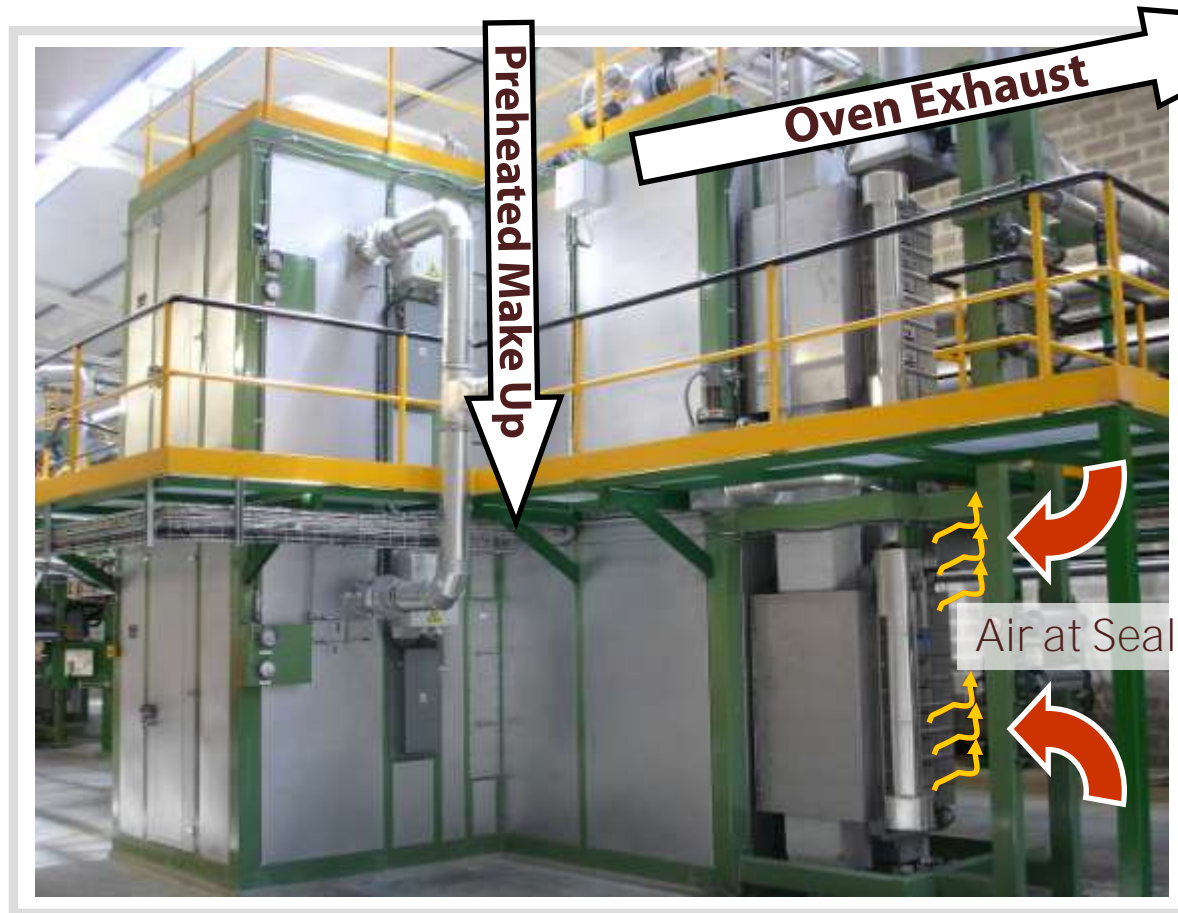
Ideal Situation is Preheated Make-Up Flow is
Approximately Equal to the Exhaust Flow ($MU/E \sim 1$)

Harper International Oven Seals and Energy Recovery



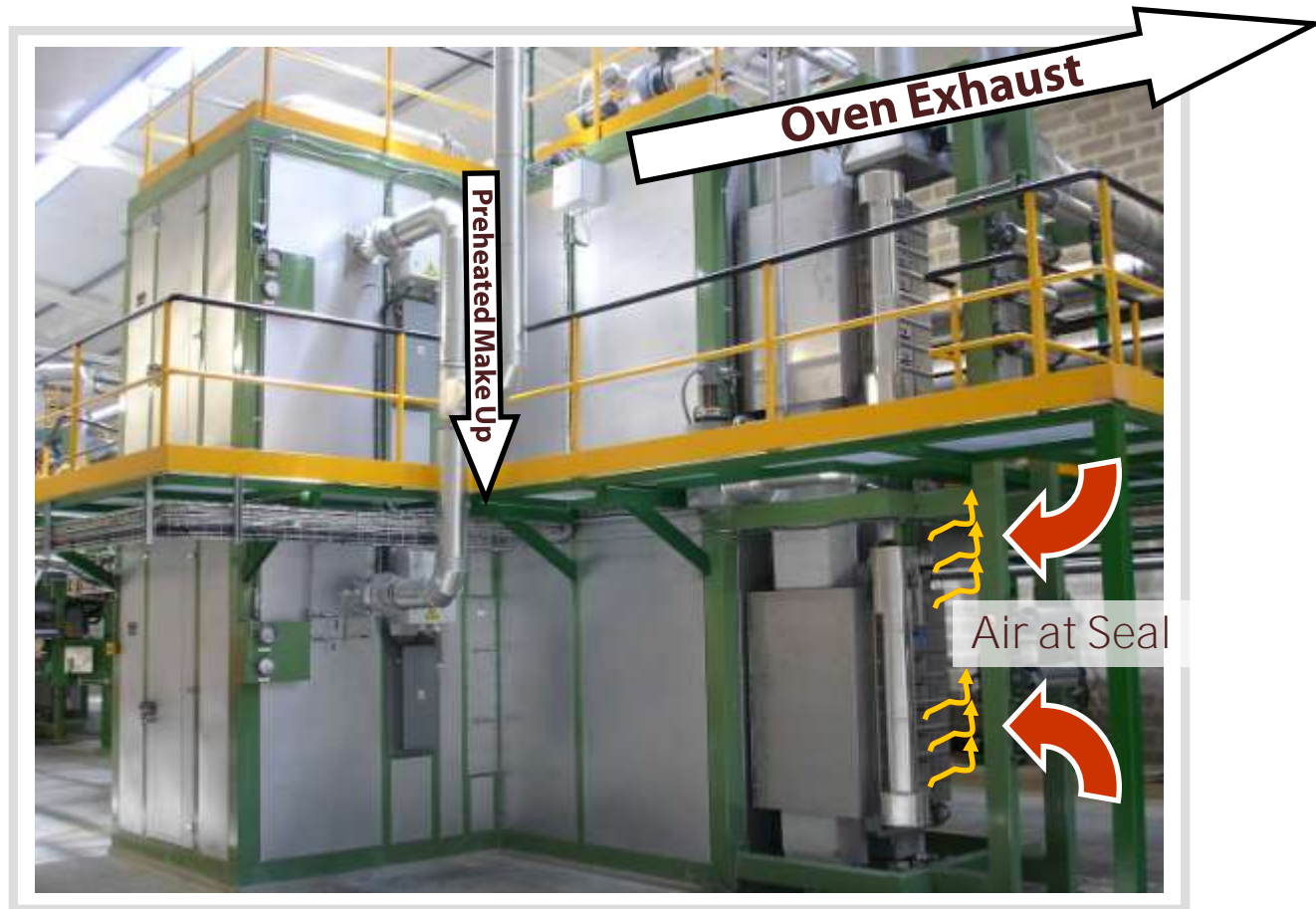
But... As Make-Up Flow Approaches Exhaust Flow Fugitive Emissions Increase

Harper International Oven Seals and Energy Recovery



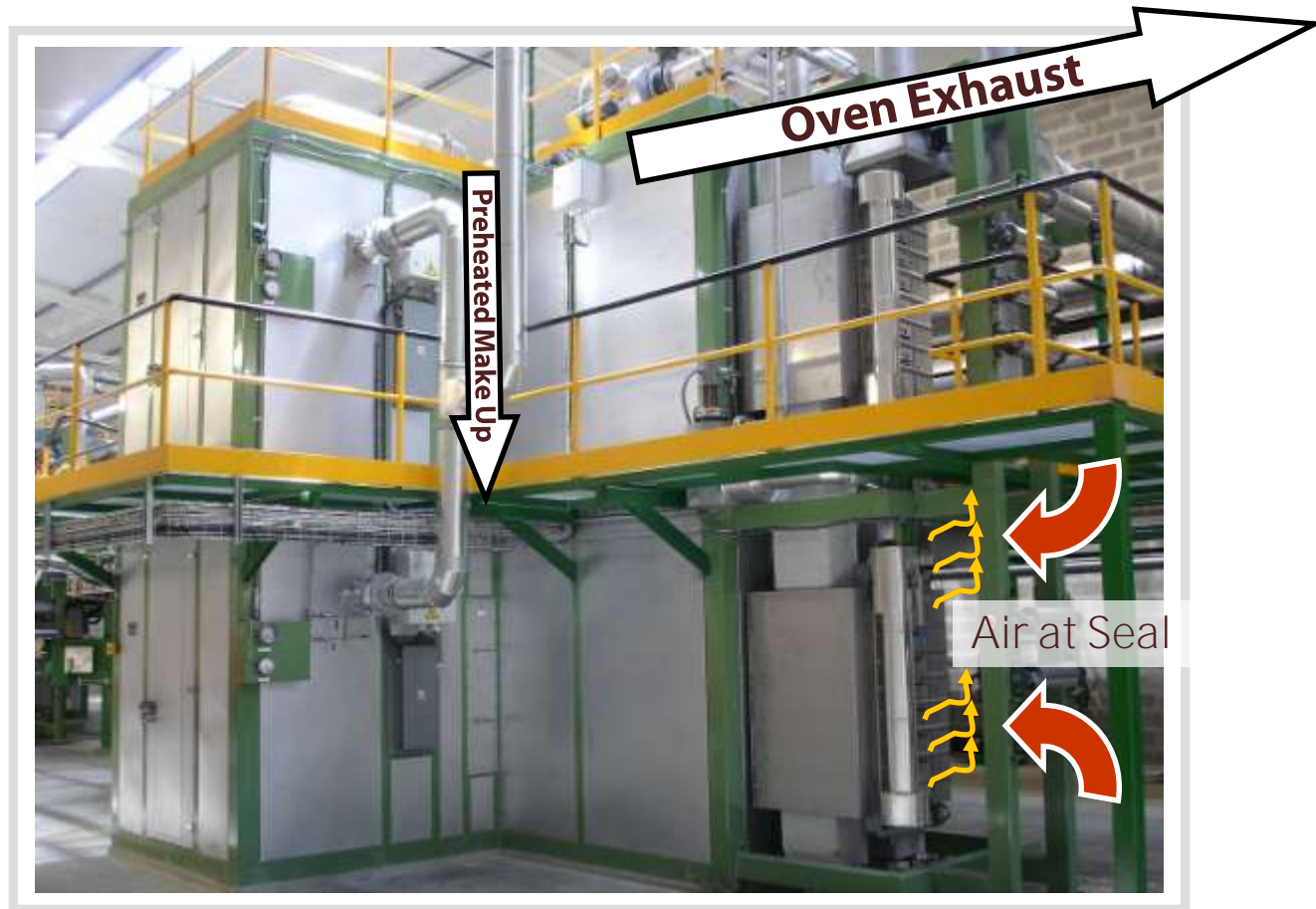
To Reduce Fugitive Emissions, Typical Seals Depend on
Ingress of Cold Air at the Seal Face

Harper International Oven Seals and Energy Recovery



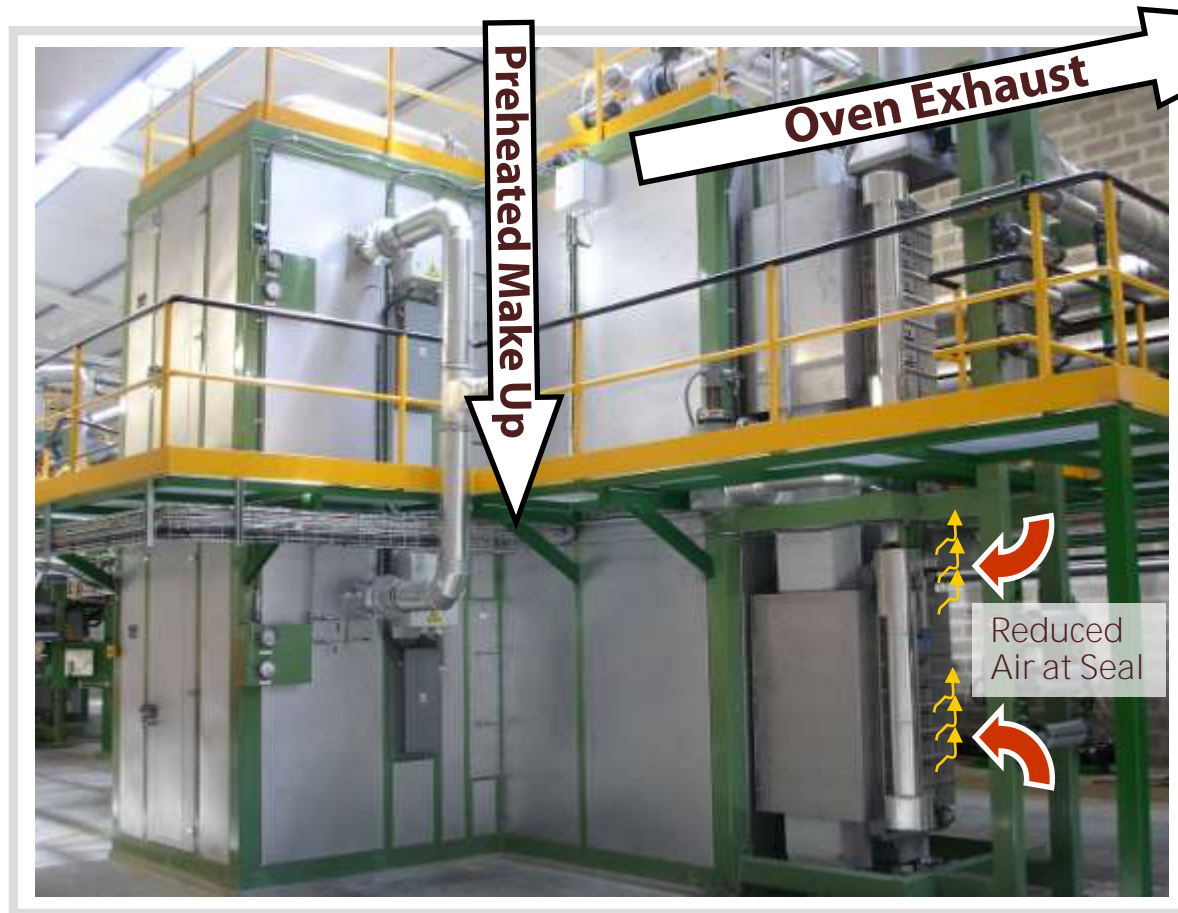
Air Into the Seal Results in Less Preheated Makeup

Harper International Oven Seals and Energy Recovery



The Ratio of Make Up / Exhaust is Critical for
Energy Efficiency

Harper International Oven Seals and Energy Recovery



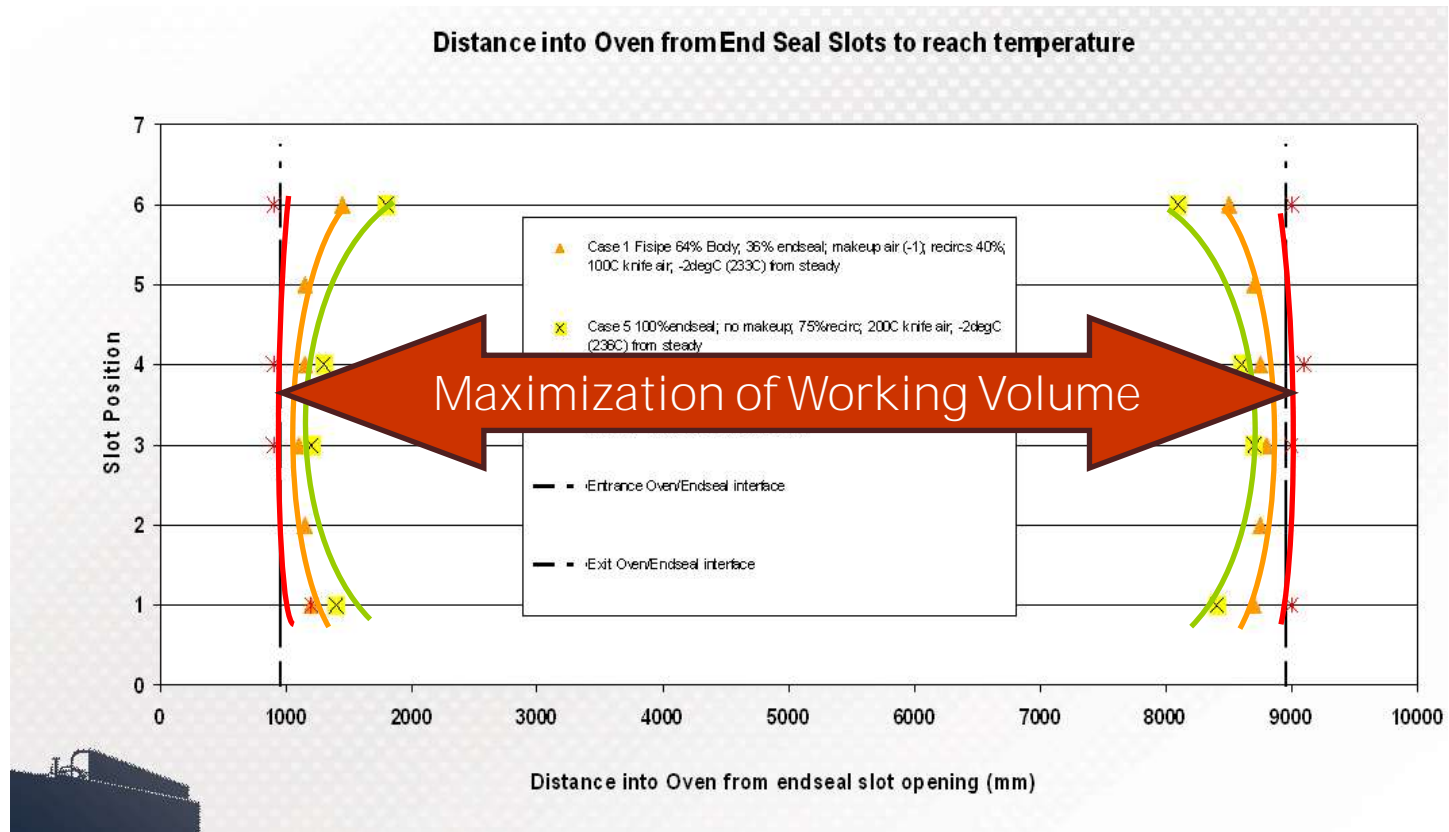
Harper's Seal Results in Reduced Fugitive Emissions and Higher Energy Reutilization. Guarantee Performance w.r.t. M/E Ratios

Harper Oven

Technology Focused Areas for Technology Advances

Concrete Guarantees in Performance

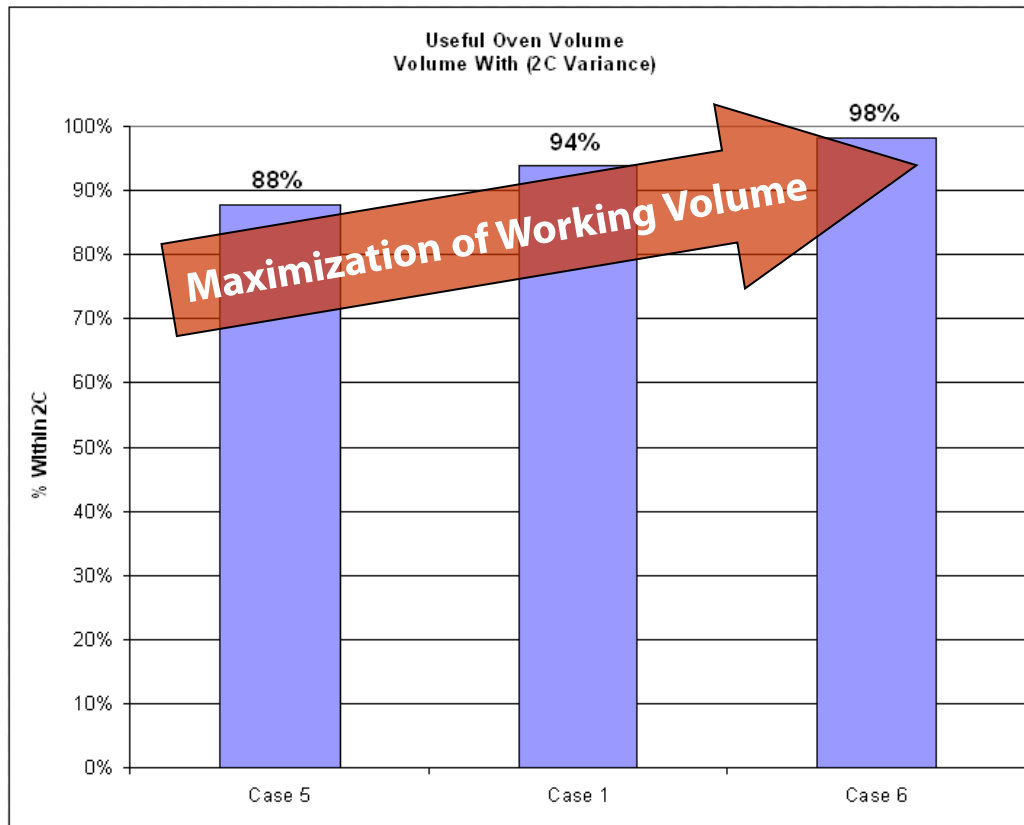
- Greater Active Volume Due to Seal Advances



Harper Oven Technology Focused Areas for Technology Advances

Concrete Guarantees in Performance

- Greater Active Volume Due to Seal Advances



Harper International

Summary

- Emergence of Research Systems for Non-Industrial Users
- Product Development for Further Reduction of R&D Systems
- Emergence of MultiFlow Research Ovens
- Advancement of Oven Technology

Thank You for Your Attention



The greatest
laboratory in the
world is the
human mind.