MIST Technology for Delayed Cokers

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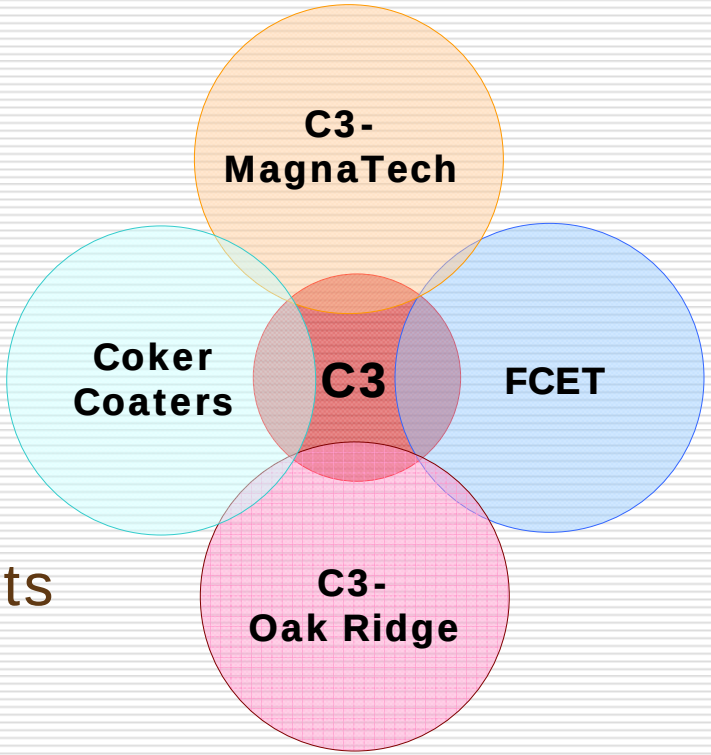
Who is Coker Coaters?

- Utilizes C3's "***MIST*" ceramic coatings** for petrochemical applications such as delayed coking, ethylene cracking, and other processes where inorganic materials are attacked by the harsh nature of their environments
- *MIST* technology is already used commercially & proven in harsh environments outside of the petrochemical industry.



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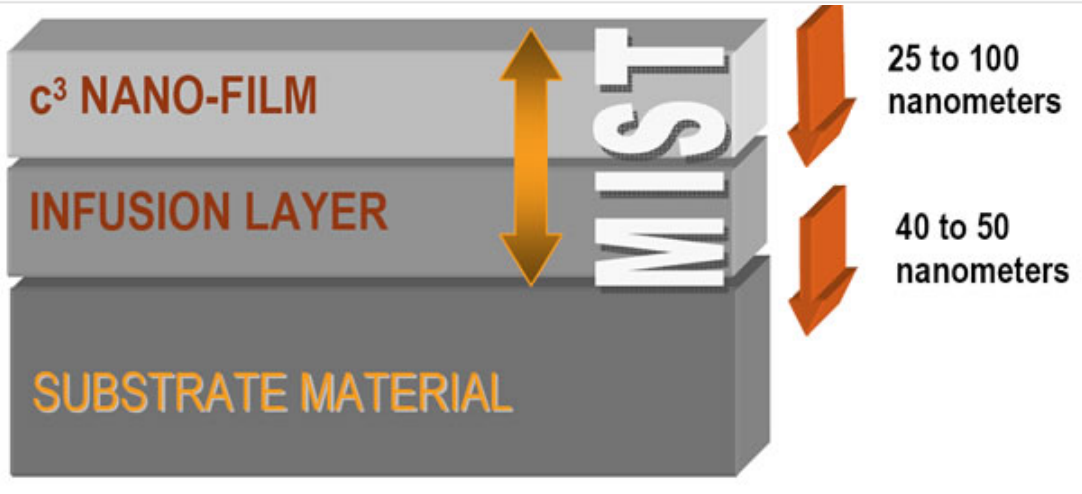
What can ***MIST*** Technology do for Delayed Cokers?

- ***Stabilize Coke Formation***
- ***Eliminate Metal Sulfidation***
- ***Flow Assurance***
- ***Lower Heater Duty***
- ***Reduction in Greenhouse Gases***
- ***Extended Run Lengths***
- ***Extended Equipment Life***

What is ***MIST*** Technology?

- Ultra-thin, ceramic film anchored to an inorganic surface at the molecular level—a Surface Modification and a Coating
- Film remains anchored despite "hostile" environments (sulfur, acid, heat, hydrocarbons, liquid metal, etc.)
- Film is versatile: Harnesses properties of 79 elements to impart customized properties



What is ***MIST*** Technology?

- Winner of 2006 R&D 100 Award
- Winner of 2007 Micro/Nano 25 Award

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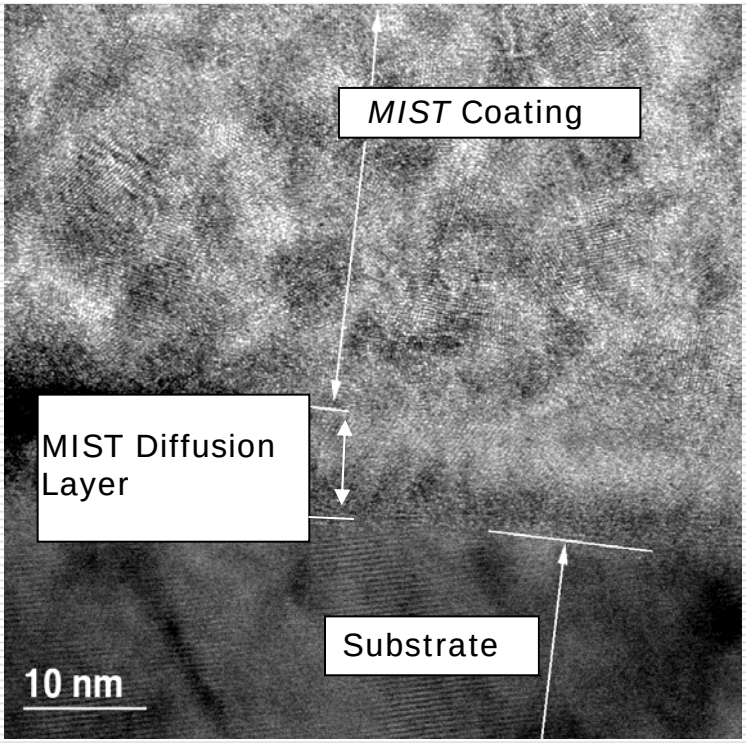
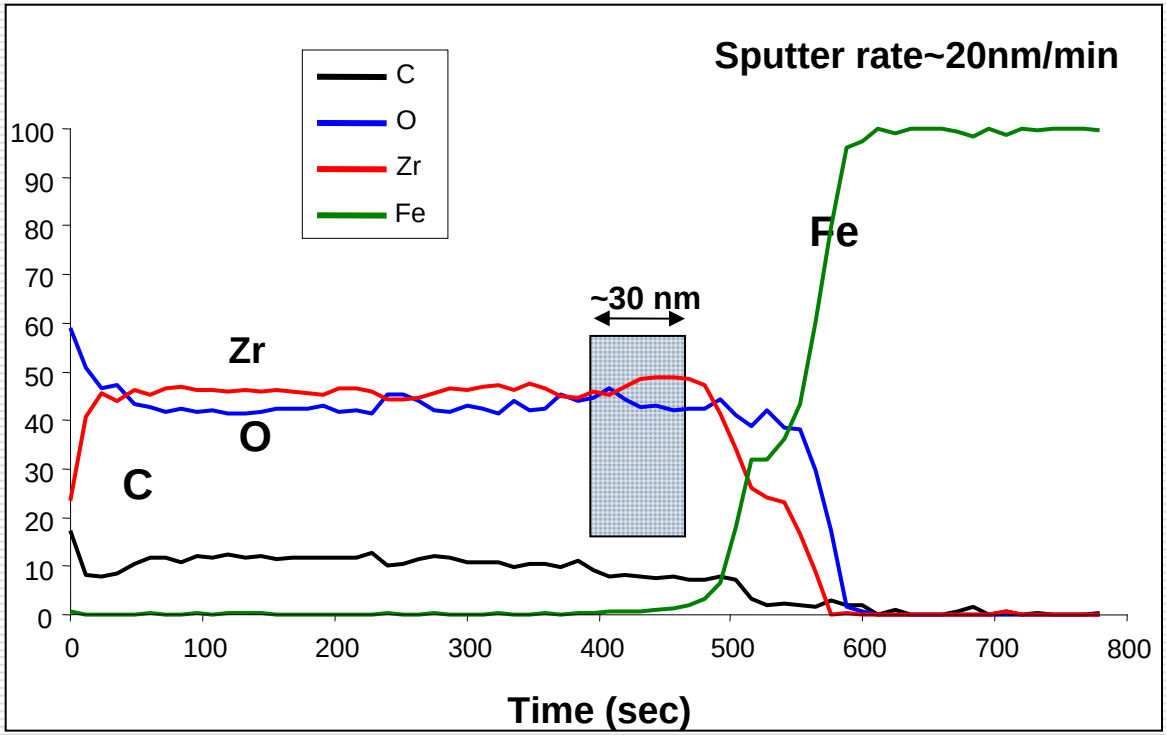
How do we know *MIST* is thin & anchored at the molecular level?

TEM of *MIST*



TEM Image by Dr. Jane Howe, Oak Ridge National Laboratory

SAM of *MIST*



SAM Profile by Dr. Harry Meyer, Oak Ridge National Laboratory

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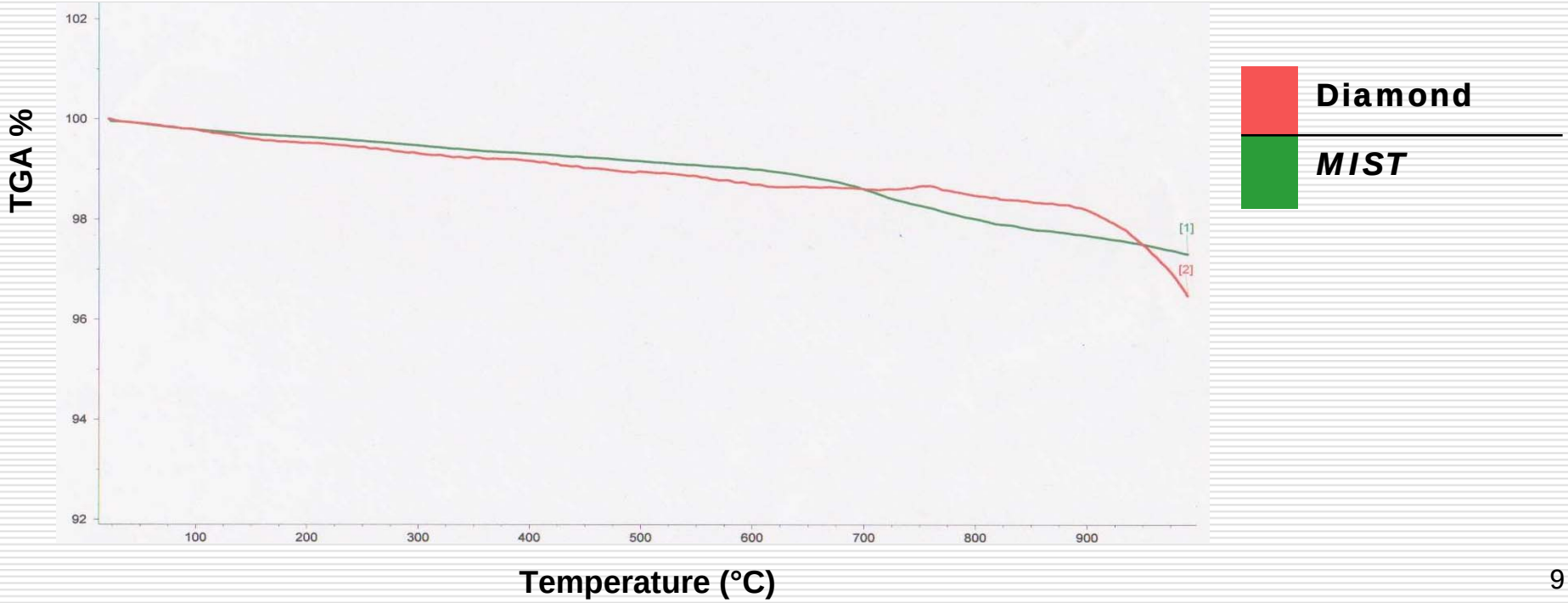
How do we know *MIST* is stable and will not spall off?

- Laboratory Data
  - Scanning Auger Microscopy, Oak Ridge National Laboratory
  - Wallace Dunker Test, Case Western Reserve
  - Thermogravimetric Analysis, Fouling and Coking Technology
  - Physical Nature of Oxides Present
  - Internal Testing: Aqua Regia and High Temp Salt Spray
- Commercial Application Data
  - Aluminum Die Casting
  - Hot Rolled Steel

Thermogravimetric Analysis

- Fouling and Coking Technology determined the thermal stability of the *MIST* coating in air and nitrogen from 68°F to 1832°F
  - **Found coating is thermally stable at 1832°F in both air and nitrogen**
  - **Thermal properties were similar to diamonds**



Aqua Regia Test

- Sample exposed to specific volume of 3 parts HCl to 1 part HNO3 for 1 hour

***MIST* Die Casting Coating**

***MIST* Coker Coating**

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High Temperature Salt Spray Test

- Samples heated to 1652°F in air, then sprayed with 10% salt water solution for 1 hour. Test recommended by Alberta Research Council.

***MIST* Die Casting Coating**

***MIST* Coker Coating**

Aluminum Die Casting

- Liquid Aluminum (1292°F) is poured into the shot sleeve
- A plunger then ejects the liquid Aluminum into a die mold cavity
- 1 cycle takes <3 minutes. During this period the shot sleeve is exposed to temperatures from 600°F to 1292°F
- With *MIST* coating total cycles went from 19,000 to 98,309 (2 months to 9 months)*

Shot Sleeve (Cold Chamber)

***Sleeve was pulled because production run was finished, not because MIST failed**

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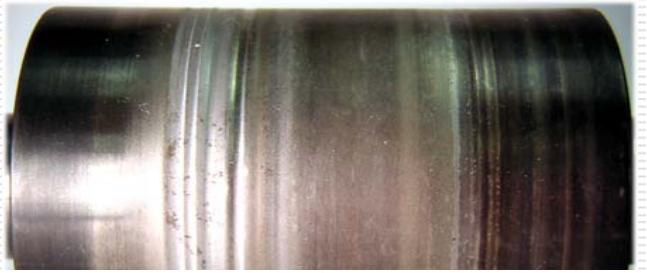
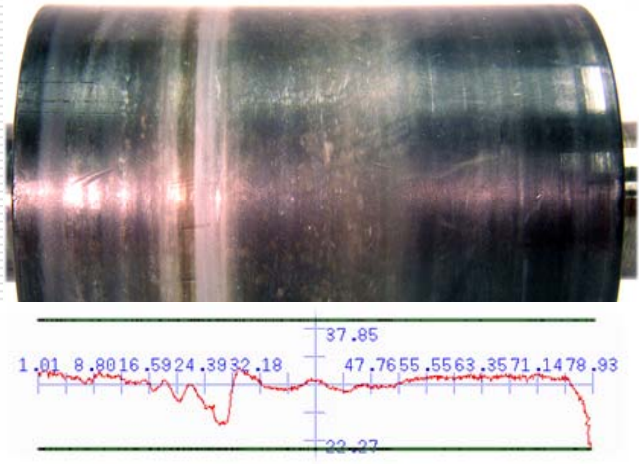
Hot Rolled Steel Application

- Hot Steel moving at 1000 feet/minute rolls down conveyor belts as its thickness is being decreased
- Guide Rollers (seen at right) keep this steel on track on the conveyor and experience significant wear scarring
- Untreated rollers last 1 week while *MIST* treated rollers last 10 weeks and still have 5 times less mass loss than the untreated roller
- This is a 50x improvement in wear resistance*



Untreated Roll, 1 Week



***MIST* Treated Roll, 10 Weeks**

**As determined by Dr. Peter Blau, Tribologist, Oak Ridge National Laboratory, using a Coordinate Measuring Machine to analyze depth profile of scars*

How is *MIST* Applied?

- A patented precursor liquid is mixed with the salts of the desired metals to form a solution
- The solution is then applied to the inorganic surface to be treated. The solution is non-toxic and can be applied by brushing, spraying, dipping, spinning, pigging, etc.
- Once solution is applied, heat material to ~830°F. Heating rate does not affect the coating. Can be done instantaneous with pulsed plasma method or slowly in a conventional furnace.
- Once temperature is reached, the *MIST* coating and surface modification is formed

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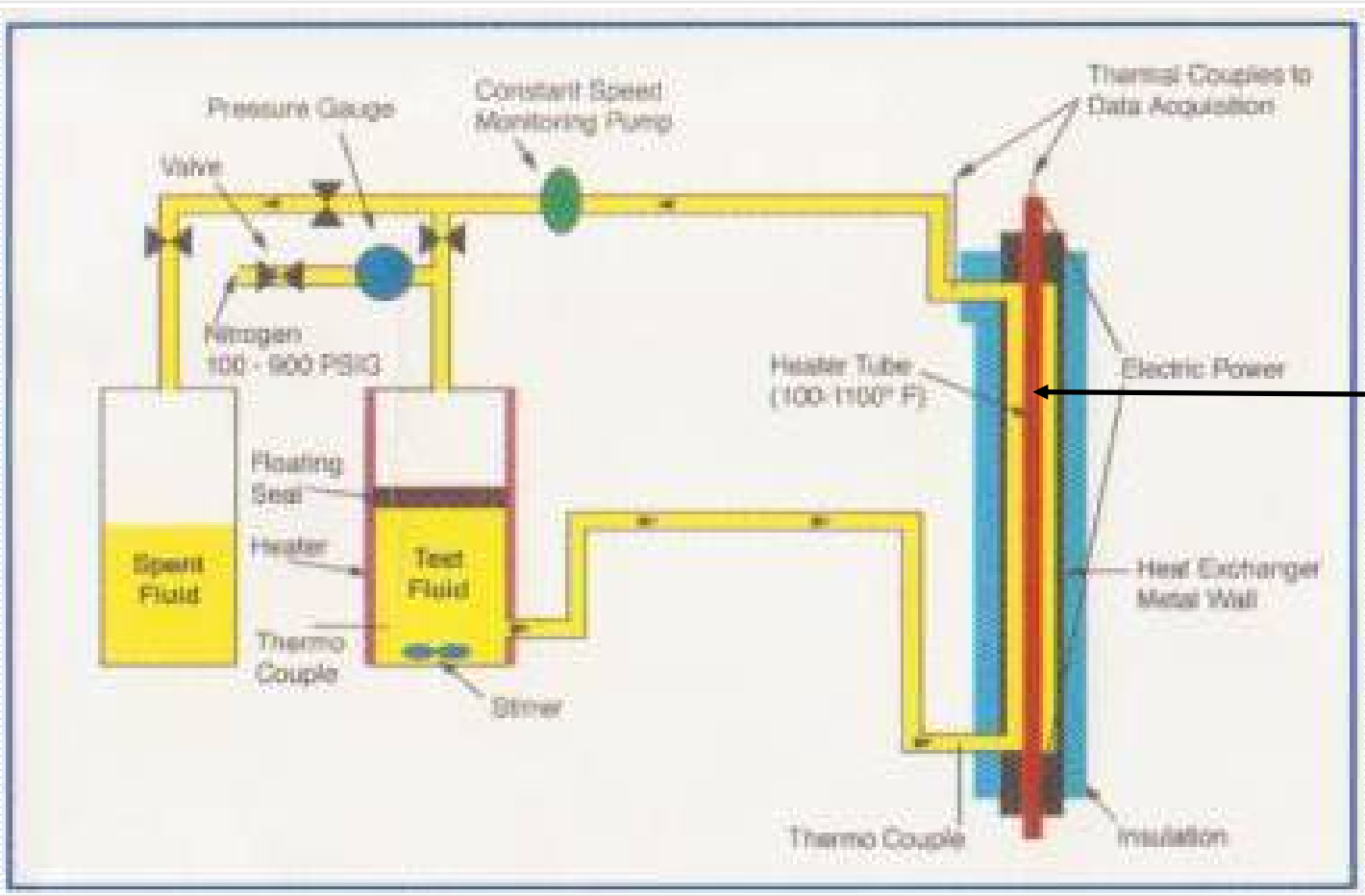
Bench Testing conducted by Dr. Ghaz Dickakian of Fouling and Coking Technology, Inc. (F.A.C.T.)

- Dr. Dickakian worked for Exxon for 35 years in carbon technology & fouling and coking mitigation
- Testing equipment acquired from Exxon
- Expert in South American Heavy and Sour Feeds
- Extensive Library of Testing Data for Comparative Results
- Please refer to Paper for details

F.A.C.T.'s Thermal Fouling Test Setup



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First, F.A.C.T. determines optimum fouling temperature of a given crude on an uncoated heat exchanger (heat exchanger simulates delayed coker furnace conditions).

Thermal Fouling Testing of Carbon Steel Exchanger Heater Tubes			
Test Operating Conditions	**(1)**	**(2)**	**(3)**
Exchanger metal temp. (°F)	**800**	**900**	**1010**
Unit pressure (psig)	**950**	**950**	**950**
Unit atmosphere	**Nitrogen**	**Nitrogen**	**Nitrogen**
Test time (minutes)	**90**	**90**	**90**
Thermal Fouling (? T, ° F)	**18**	**28**	**90**

Exchanger metal temperature of 1010°F was selected for testing the coated exchanger test tubes as this temperature is within the coker furnace metal operation

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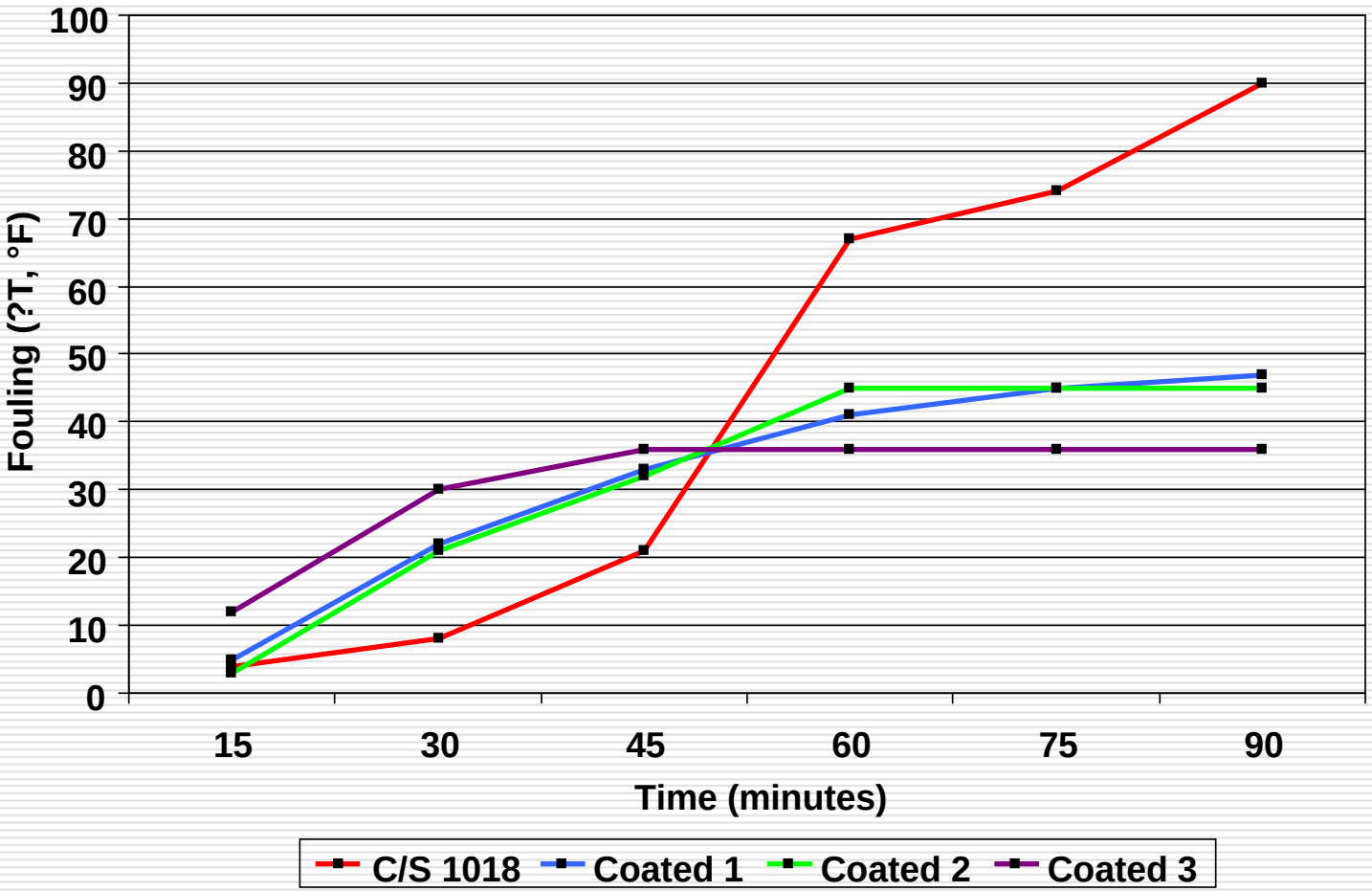
Second, F.A.C.T. tests coated heat exchangers with same parameters for optimum fouling

Exchanger Heater	1	2	3
Exchanger temp (°F)	1010	1010	1010
Unit pressure (psig)	950	950	950
Unit Atmosphere	Nitrogen	Nitrogen	Nitrogen
Oil flow rate (cc/min)	3.0	3.0	3.0
Test time (minutes)	90	90	90
Thermal Fouling Measurements			
15 minutes	5	3	12
30 minutes	22	21	30
45 minutes	33	32	36
60 minutes	41	45	36
75 minutes	45	45	36
90 minutes	47	45	36
Effectiveness (%)	52.0	53.0	62.0

Graph of data from previous slide on fouling results



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F.A.C.T. Conclusions

- ***MIST*** **Stabilizes Temperature Increase**
- ***MIST*** **Retards Coke Formation**
- ***MIST*** **Prevents Metal Sulfidation**
- ***MIST*** **is Stable at Delayed Coker Furnace Operating Temperatures**
- ***MIST*** **does not Spall off and Contaminate the Product**
- **Calculated Effectiveness of 52% - 62% are exceptional and never been seen before using the Thermal Fouling Method**

Questions (so far)?

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MIST Benefits for Delayed Cokers

- ***Stabilizes Coke Formation***
- ***Eliminates Metal Sulfidation***
- ***Flow Assurance***
- ***Lower Heater Duty***
- ***Reduction in Greenhouse gases***
- ***Extended Run Lengths***
- ***Extended Equipment Life***

Stabilizes Coke Formation

- _____
- _____
- _____
- _____

Eliminates Metal Sulfidation

- _____
- _____
- _____
- _____

Flow Assurance

- _____
- _____
- _____
- _____

Lower Heater Duty

- _____
- _____
- _____
- _____

Reduction in Greenhouse gases

- _____
- _____
- _____
- _____

Extended Run Lengths

- _____
- _____
- _____
- _____

Extended Equipment Life

- _____
- _____
- _____
- _____

Questions (so far)?

What is the Procedure for Coating a Delayed Coker Furnace?

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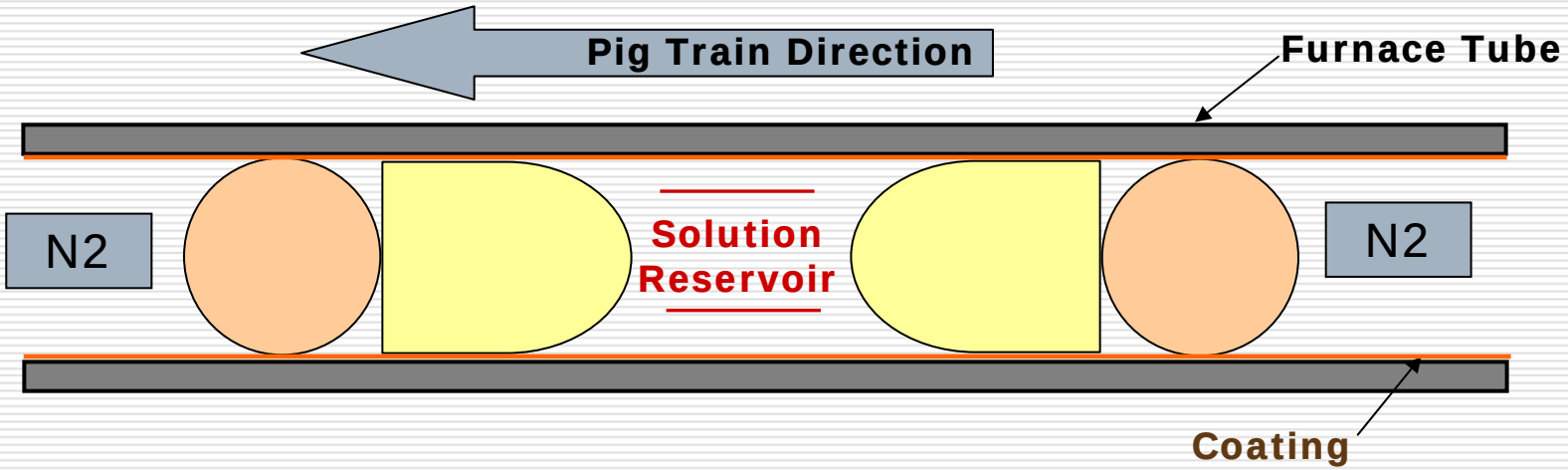
Application Procedure for Delayed Coker

1. DDT does mechanical cleaning of the tubes
2. DDT finishes this with their standard polishing procedure
3. DDT uses Fullkote techniques to ensure the tube ID is dry
4. DDT uses compressed Nitrogen to propel a pig train carrying the *MIST* solution through the furnace, wetting the tube ID with the liquid
5. Equipment is removed, and heaters are fired so that tube ID reaches a temperature greater than 830°F
6. *MIST* Coating and Surface Modification is now in place
7. In field tests, steps 4 and 5 are repeated 6-8 times to ensure full coverage

MIST Solution Application with Pig Train



Requirements of Refinery

- Allow DDT's trucks and personnel access to the refinery with DDT's standard requirements for cleaning projects
- Provide Compressed Nitrogen
- Provide the personnel and energy to follow refinery procedure for heating up furnace tube ID to greater than 830°F and then cooling the tubes down
- In addition to the cleaning procedure, the extra time needed for coating is estimated at 4 days

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Common Questions about *MIST*

- Will *MIST* spall off?
  - *MIST* technology is used commercially in harsh environments around products that cannot be contaminated and has proven it is stable and does not spall off.
- Will *MIST* adversely affect the metal integrity or structure?
  - The thinness of *MIST* ensures that it will not adversely affect product flow or metal structure.
- Will *MIST* affect the product coming into contact with it?
  - The inert nature of the oxides ensure that it will not adversely affect the product coming into contact with it.
- What are the hazards associated with *MIST* application?
  - *MIST* is applied by the Trained Professionals at DDT who are familiar with Delayed Cokers.
  - Project oversight will be provided by Evan Hyde of Becht Engineering, a safety and process expert.
  - Coating by product is a small amount of C02.

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Summary: *MIST* is a **Low Risk / High Reward** Proposition, providing:

- **Longer Runs**
- **Flow Assurance**
- **Lower Heater Duty**
- **Lower Emissions**
- **Extended Equipment Life**
- **One Less Variable for the Refinery to Worry About**

Questions?

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