Coatings for Delayed Coker Heater Tubes

Evan Hyde
President

Coking.com®
2009 Galveston Safety Seminar

1

What can ***C2*** Technology do for Delayed Cokers?

- ***Extend Run Lengths***
  - ***Stabilize Coke Formation***
  - ***Eliminate Metal Sulfidation***
  - ***Flow Assurance***
  - ***Lower Heater Duty***
  - ***Reduce Greenhouse Gases***
  - ***Extend Equipment Life***

2

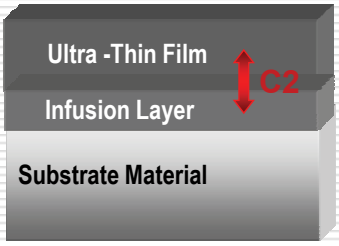
Dr. Arvid Pasto – Director, C3|Oak Ridge

- 37 Years in Materials Science R&D
- Former Director of High Temperature Materials Laboratory, U.S. Dept of Energy (14 yrs)
- Collaborated with C3/C2 Scientists for 5 years prior to retirement

3

What is *C2* Technology?

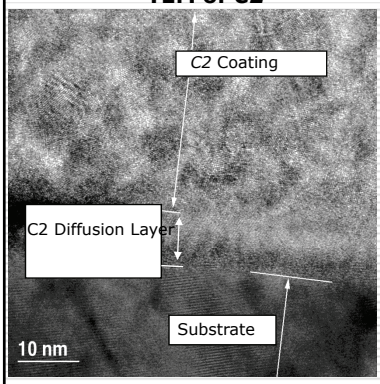
- Ultra-thin, ceramic film anchored to an inorganic surface at the molecular level—a Surface Modification and a Coating
- Film remains anchored despite "hostile" environments (sulfur, acid, heat, hydrocarbons, liquid metal, etc.)
- Film is versatile: Harnesses properties of 79 elements to impart customized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



4

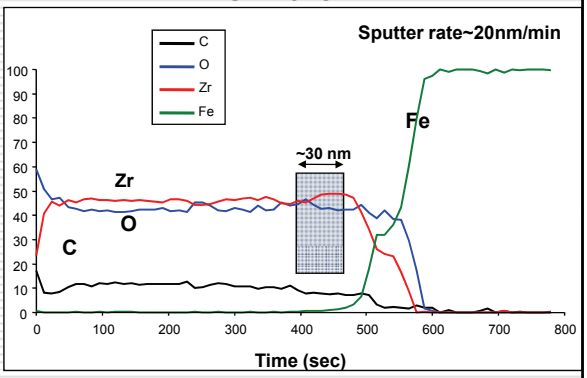
How do we know *C2* is thin & anchored at the molecular level?

TEM of *C2*



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

SAM of *C2*



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

5

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 *C2* coating total cycles went from 19,000 to 98,309 (2 months to 9 months)*

Shot Sleeve (Cold Chamber)

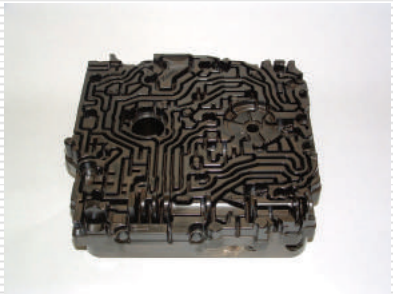
Sleeve was pulled because production run was finished, not because C2 failed

6

Commercialized with:

CHRYSLER

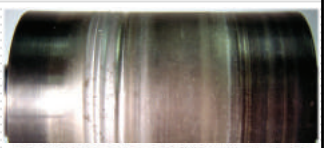
GM

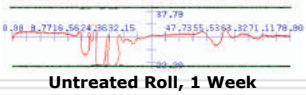


7

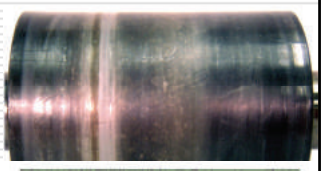
Hot Rolled Steel Application

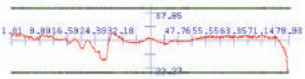
- Hot Steel moving at 1000 feet/minute rolls down conveyor belts as its thickness is being decreased
- Guide Rollers (seen at right) keep this steel on track on the conveyor and experience significant wear scarring
- Untreated rollers last 1 week while *C2* treated rollers last 10 weeks and still have 5 times less mass loss than the untreated roller
- This is a 50x improvement in wear resistance*





Untreated Roll, 1 Week





***C2* 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*

8

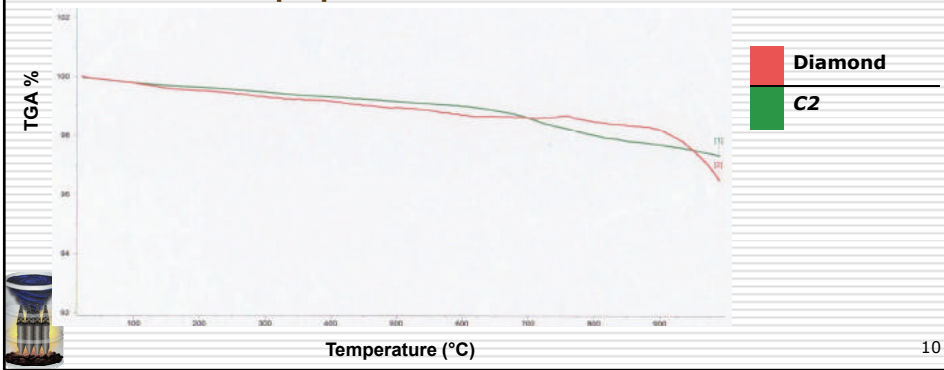
Bench Testing conducted by Dr. Ghaz Dickakian of Fouling and Coking Technology, Inc. (F.A.C.T.)

- Dr. Dickakian worked for Exxon for 35 years in carbon technology & fouling and coking mitigation
- Expert in Fouling and Coking with 40 Years of Experience
- Extensive Library of Testing Data for Comparative Results
- Please refer to Paper for details

9

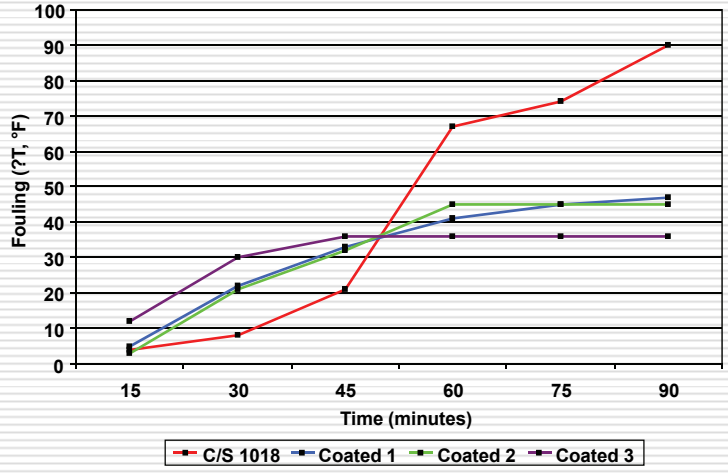
Thermogravimetric Analysis

- Fouling and Coking Technology determined the thermal stability of the *C2* 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**



10

Graph of data from fouling results



11

Untreated Heat Exchanger

"C2" Treated Heat Exchanger

Coke Stabilization Achieved Half-Way Through Testing

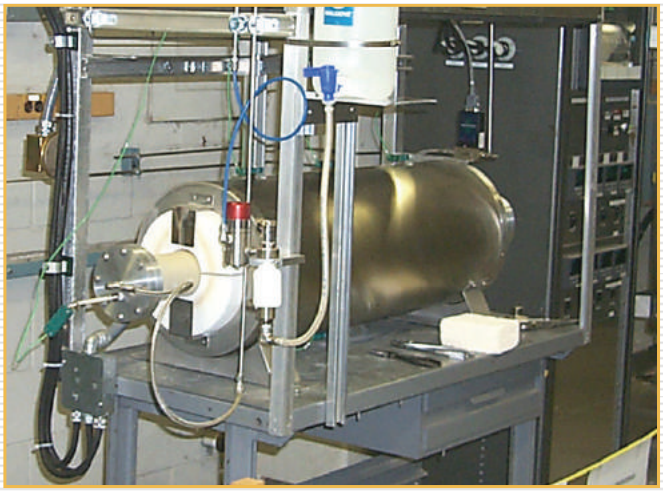
12

F.A.C.T. Conclusions

- **Calculated Effectiveness of the coating in mitigating fouling effectiveness 60%**
- ***C2* Stabilizes Temperature Increase**
- ***C2* Retards Coke Formation**
- ***C2* Prevents Metal Sulfidation**
- ***C2* is Stable at Delayed Coker Furnace Operating Temperatures**
- ***C2* does not Spall off and Contaminate the Product**

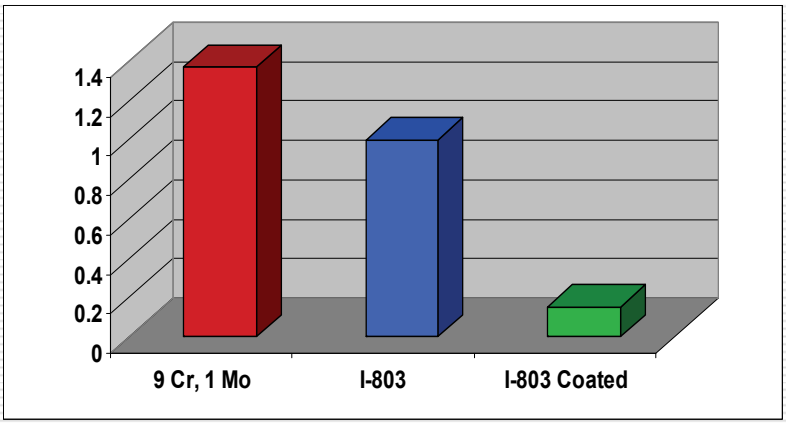
13

Ethylene Cracker Testing at DOE's Oak Ridge Nat'l Lab



14

75% Less Coke Deposition



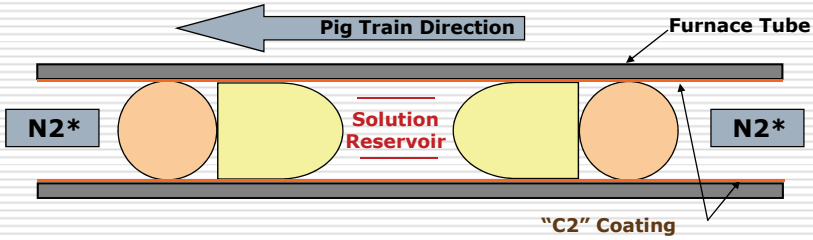
1,000 Hours at 900°C

15

Field Application

16

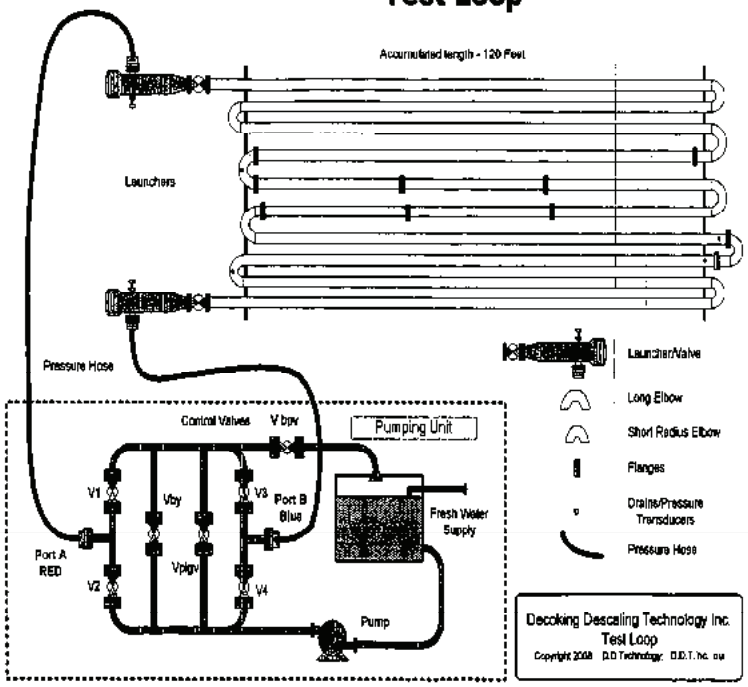
C2 Solution Application with Pig Train



(or dry air)

17

Test Loop



18

19

Application Procedure for Delayed Coker

(DDT is subcontracted & overseen by C2)

1. Finalize & Approve Detailed Coating Procedure with Site Representatives
2. Mechanical cleaning of the tubes
3. Standard polishing procedure
4. Fullkote techniques used to ensure the tube ID is dry
5. Compressed Nitrogen (or dry air) to propel a pig train carrying the *C2* solution through the furnace, wetting the tube ID with the liquid
6. Equipment is removed, and heaters are fired so that tube ID reaches a temperature greater than 830°F
7. *C2* Coating and Surface Modification is now in place
8. In field tests, steps 4 and 5 are repeated ~5 times to ensure full coverage

20

Summary: *C2* is a **Low Risk/High Reward** Proposition, providing:

- **Longer Runs before Decoking**
- **Flow Assurance**
- **Lower Heater Duty**
- **Lower Emissions**
- **Extended Equipment Life**

21

How can you Verify This Technology at YOUR Site?

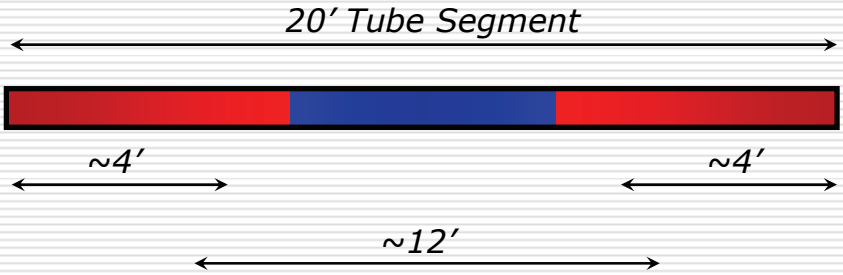
- **Single Cell Coating**
- **Tube Segment**

22

Single Cell Coating

23

Tube Segment



24

25

Other Test Options?

26

Other Petrochemical Applications:

- Hydrocrackers
- Hydrotreaters
- Reformers
- Venturi Scrubbers
- Caustic Attack
- H_2S Attack
- … and many others

27

Petrochemical Industry Symposium at The Woodlands

28

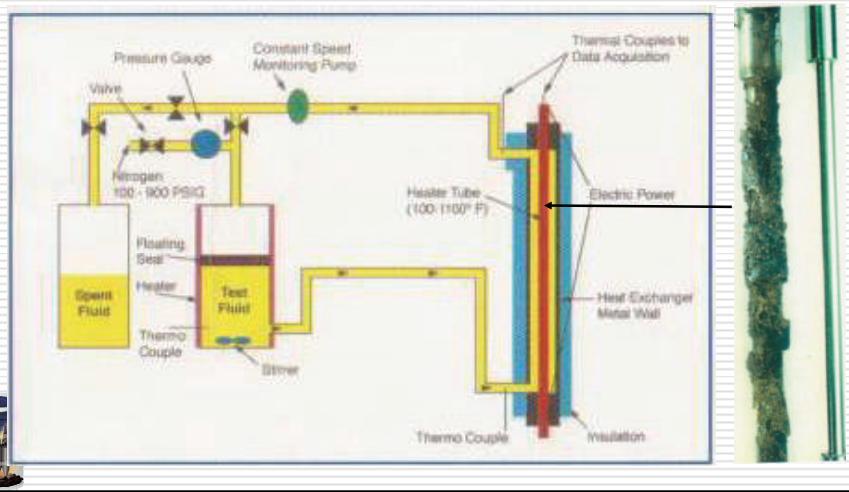
C2, LLC
1370 Union Hill Industrial Court E
Alpharetta, Georgia 30004
678-710-0760
www.c2nano.com
evan.hyde@c2nano.com

29

The Following are Backup Slides if Necessary for Technical Questions

30

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



31

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

32