SAND2011-3201 C

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Evaluate Thermal Spray Coatings as a Pressure Seal

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Specialized Materials & Geopolymer Sealing Materials

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

- Project Overview
  - Timeline
    - Project start date April 2010
    - Project end date April 2012
  - Budget
    - AOP project; funded by DOE geothermal
    - Total budget $300k – FY10 $100k, FY11 $200k

Current Task Financial Summary				
FY11 request	Carryover	FY 11 Costs	Commitments	Available
$200K	$71K	$55K	$0K	$16K

To date FY11 funding not received, operating project on carryover funding. Transferred funds represent internal movement of money within compatible B&R and CPS code activities at SNL.

Objective

- Develop a pressure seal alternative to conventional elastomeric and metal C-rings
  - Thermal spray coating may alleviate sealing issues where metal-to-metal seals can not be utilized
  - Coating can also serve as a redundant seal; ideal for long-term monitoring tools
  - Coating can easily be removed for servicing tool and reapplied
- In accordance with Geothermal Technologies Program goals
  - If successful , coating provides sealing alternative for future high temperature (HT) tools and possibly other downhole drilling components (pipe, etc.)

Relevance/Impact of Research

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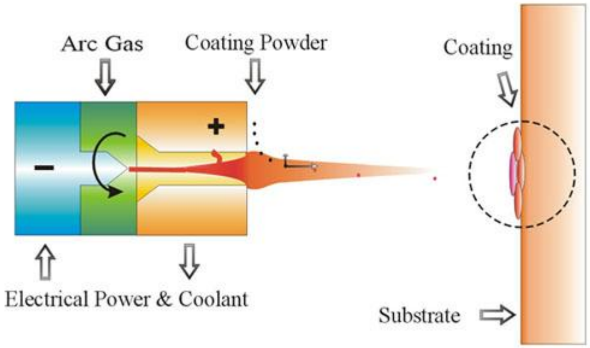
- Pressure seals are required for all downhole tools
  - Elastomeric type seals are commonly used where well temperatures are under 200ºC
- Sealing issues can lead to catastrophic failure costing thousands of dollars
  - Higher temperatures with high pressures can lead to catastrophic failures
  - Failed internal components include: electronics, sensors and Dewars
- Specialized high temperature (HT) tools often have limited availability and can not be easily replaced
  - Resulting delays can severely impact programs

Scientific/Technical Approach

- Sandia has extensive experience in applying thermal spray coatings for a wide variety of applications
  - Based on experience, select thermal spray processes
    - Twin wire arc
    - Atmospheric plasma spray
    - Cold spray
    - HVOF
    - Flame spray



  - Select coatings best suited for application
    - Nickel
    - Nickel alloys

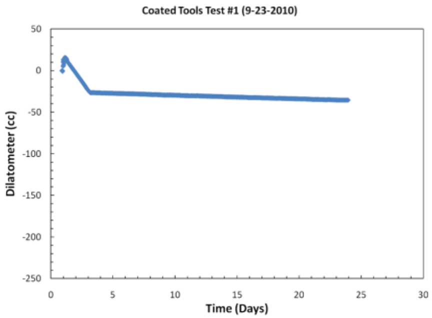
Note: Intent of project was to start with most cost effective coating methodology and depending on results, evaluate other coating processes as needed

Scientific/Technical Approach

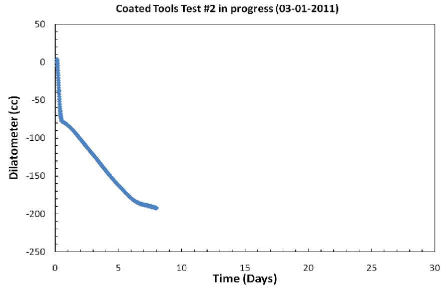
- Statement of work is divided into two phases:
  - Phase I
    - Select thermal spray process and coating
      - Identify potential coating material
      - Coat mock tools
      - Evaluate
      - Identify best three coating materials
      - Evaluate
      - Write report
  - Phase II
    - Deploy mock tools in a geothermal well
      - Coat mock tools
      - Evaluate performance every quarter
      - Write final report

- Accomplishments for this reporting period include:
  - Four sets of mock tools have been coated; Each set consists of 6 coated mock tools and one control sample)
    - First set consisted of two thermal spray processes and three coating materials
    - Second set consisted of one thermal spray process and two coating materials
    - Third set consists of one thermal spray process and three coating materials; essentially a repeat of second set with exception of air supply ; Nitrogen utilized instead of air to reduce oxides and increase coating density
    - Fourth set consists of three thermal spray processes and two coating materials; coatings applied by Thermal Spray Solutions
  - Coatings were test at 5000 psi pressure
    - Mixed results

- First two sets of mock tools were pressure tested at 225ºC with 5000 psi pressure
  - Mixed results
    - First set only one failed
    - Second set of samples failed
    - Differences from first set of samples include:
      - Joint modification to ensure leak, thereby testing coating integrity
        - » First set of mock tools indicated partial sealing due to makeup of mock tool; resulting in uncertainty
      - Reduction in coating thickness (not intentional)
- Evaluation of failed coatings indicate porosity is likely cause



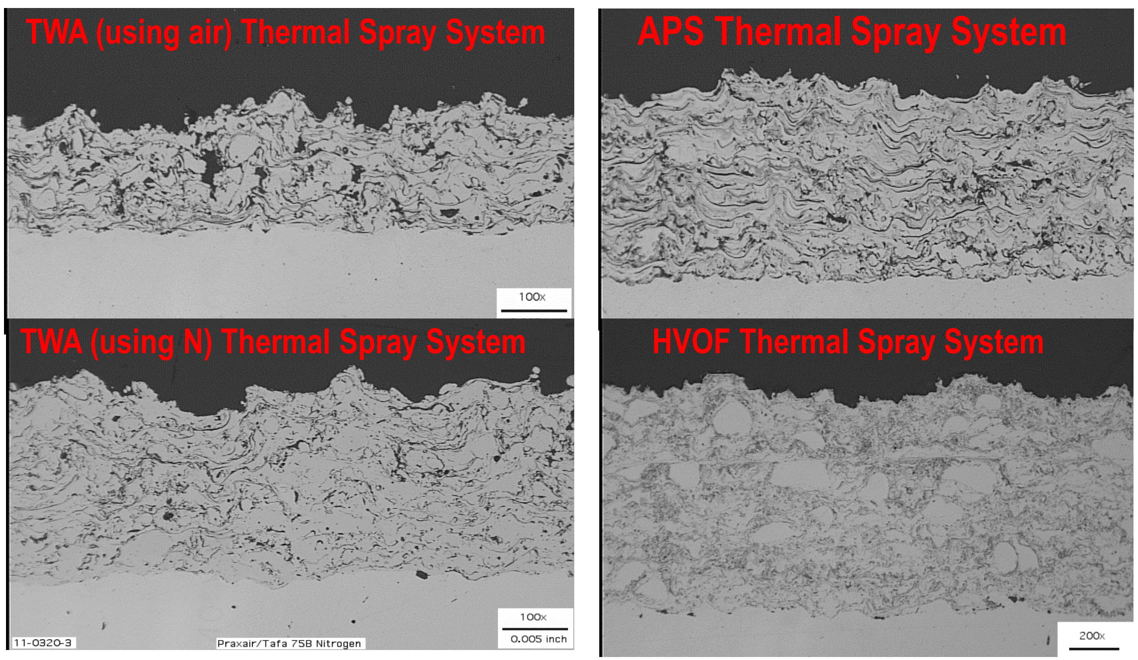
Dilatometer measurements during pressure testing of first set of mock tools



Dilatometer measurements during pressure testing of second set of mock tools – multiple leaks suggested

Accomplishments, Results and Progress

- Preliminary results on last two sets of mock tools shows promise
  - Third set - 5 out of 6 samples failed
    - Twin Wire Arc Thermal Spray Process using Nitrogen
  - Forth set - 4 out of 6 samples failed; TWA and APS failed, HVOF passed
- Micrographs show considerable variation in porosity
- Twin Wire Arc Thermal Spray process appears to have too much porosity; HVOF Thermal Spray process looks promising



Thermal Spray Process	Porosity	Oxide Content	Unmelted Particles
TAFA with Air	3.05%	8.67%	3-4 unmelts observed
TAFA with N; Sample 1 (tube)	0.96%	6.37%	6-7 unmelts observed
TAFA with N; Sample 2	2.75%	6.66%	4-5 unmelts observed
HVOF	0.30%	0.02%	none noted
HVOF	< .5%	16.70%	25-35 unmelts observed
APS; sample 1 (tube)	1.78%	8.35%	3-4 unmelts observed
APS; sample 2	2.09%	7.49%	none noted

Accomplishments, Results and Progress

- Milestone: Determine coating to be sprayed onto the mock tools to be fielded – 4/2011 (Delayed)
  - Due to coating issues, milestone is delayed
  - Coating must be successful before advancement to next milestone
- Sandia's Thermal Spray laboratory had several issues that resulted in closure of laboratory
  - Thermal Spray Laboratory main focus is defense-related program areas and they take priority
    - Backlog due to multiple closures resulted in delay to our program
- Scheduling concerns; project involves four Sandia departments
  - Geothermal as project lead
  - Thermal Spray – coating recommendation and application of coatings
  - Geomechanics - Long-term testing at high temperature and pressure (225ºC at 5000 psi)
  - Materials Reliability – analytical testing of first set of mock tools

Project Management/Coordination

- Schedule
  - Presently work on Phase I activities
  - Success in coatings required before progressing to Phase II
- Application of resources
  - Sandia geothermal department – hardware design
  - Sandia thermal spray department – coating selection and application of coating
  - Sandia rock mechanic department – initial lab testing of coatings
- Project integrated
  - If developed coating can be utilized as a pressure seal, future tools may utilize process for redundant and primary seal applications
- Coordination with industry
  - Working with Pacific Process Systems (PPS) for deploying tools
  - Thermal Spray Solutions for commercialization of coatings

Data Sharing

- Project data will consists of the following:
  - Summary report
  - GRC presentation in 2012
  - Upon project completion, the data will be provided to the DOE Geothermal Data Repository

Collaborations

- Collaborations with industry include:
  - PPS (Pacific Process Systems)
    - Subcontractor for installing mock tools
  - Thermal Spray Solutions
    - Providing coatings for evaluations
      - Cost Share; first set of coatings at no cost

Future Directions

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- Milestones
  - Determine coating to be sprayed onto the mock tools to be fielded – 4/2011
    - Delayed; projected completion 6/2011
    - Considerable progress has been made, but testing is not complete
  - Summary Report on Lab Tests – 5/2011 (Delayed; projected completion 7/2011)
  - Field Mock Tools – 6/2011 (Delayed; projected completion 8/2011)
  - Final Report – 7/2012 (Delayed; projected completion 9/2012)
- Future plans include:
  - Complete tests on last two sets of mock tools
  - Depending on results, coat additional mock tools using HVOF system
    - Continue coating of mock tools both at Sandia and Thermal Spray Solutions
  - Once coating is successful, continue with remaining milestones

Summary

- Several coatings and processes have been evaluated
  - Through testing, twin wire arc coating process has been eliminated due to porosity concerns
  - HVOF coating process is showing promise
- In line with Geothermal Technologies Program goals
  - If successful , coating provides sealing alternative for future HT tools and possibly other downhole drilling components (pipe, etc.)

	FY2010	FY2011
Target/Milestone	First set of mock tools tested to 225ºC	An additional three sets of mock tools have been tested to 225ºC
Results	Completed 10/2010	Second set complete 1/2011, Preliminary tests for third and forth set of mock tools 4/2011

Supplemental Slides

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Thermal Spray Processes at Thermal Spray Solutions

Twin Wire Arc System

Atmospheric Plasma Spray System

HVOF Spray System; Inconel 625

HVOF Spray System; Ni base alloy

Flame Spray system – Fusible coating

- Fusible coating is very dense and is a cost effective process
  - Unfortunately it requires extreme heat to fuse (1800ºF)
  - As such, not ideal for tool seals

Application of fusible coating process at Thermal Spray Solutions facility