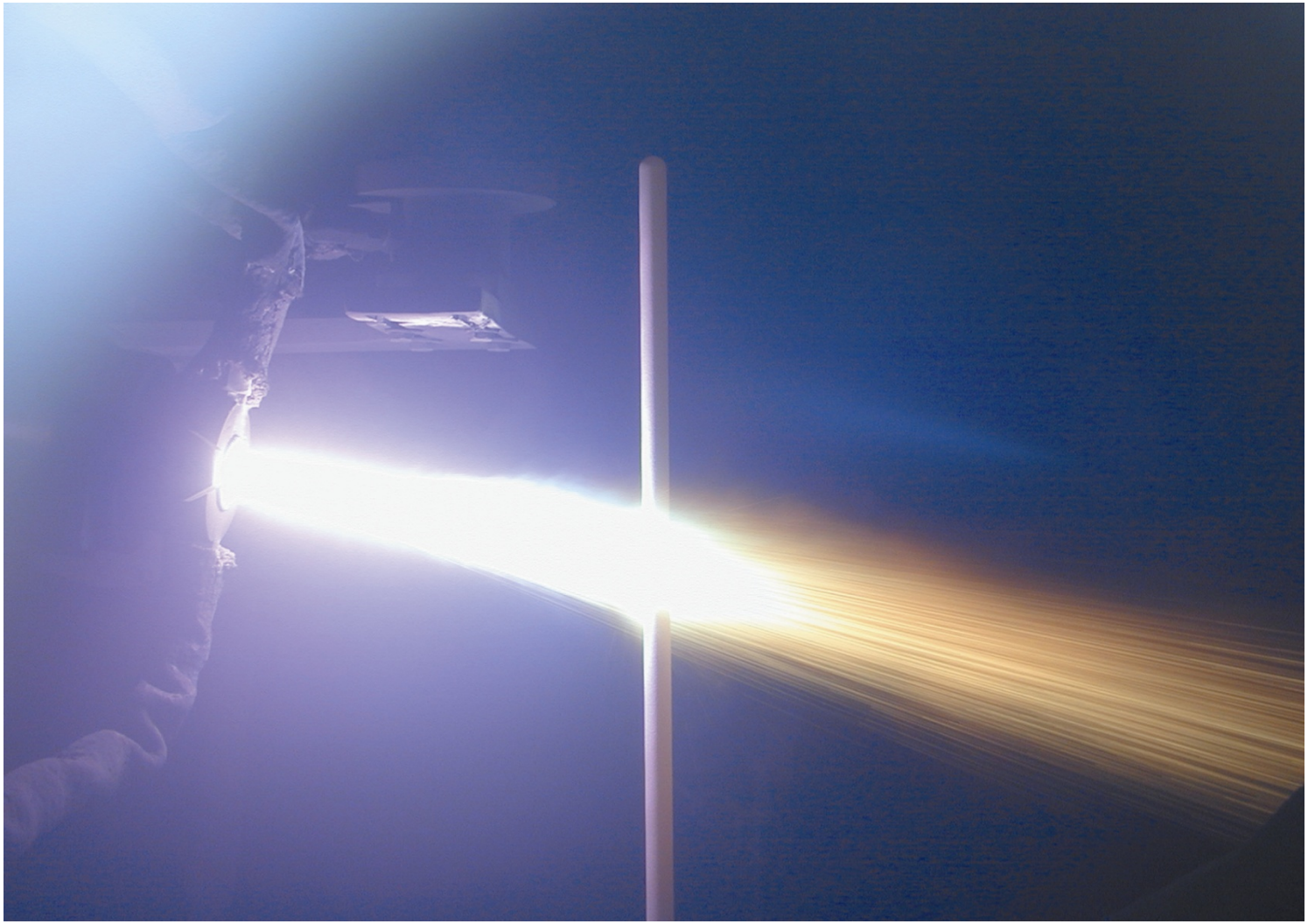
https://ntrs.nasa.gov/search.jsp?R=20090028729 2019-08-30T07:44:34+00:00Z

Rapid Vacuum Plasma Spray (VPS) Closeout of Liquid Rocket Engine Combustion Chamber Cooling Channels for Both Time and Cost Savings

NASA – Marshall Space Flight Center (MSFC)
Dick Holmes
Sandy Elam
Christopher A. Power, Genie Products, Inc.

VPS Forming MoRe Cartridge to Safely Contain Tungsten Alloy at 1600°C



•VPS GRCop-84 Liner Development

•MSFC CDDF Task

•Developed FGM

•with VPS process

•for Space

•Furnace Cartridges

•+

•GRC Task

•Developed Superior

•Copper Alloy,

•GRCop-84

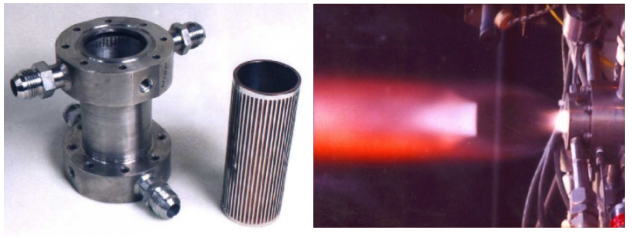
•(VPS = vacuum plasma spray

•FGM = functional gradient material)

•FY97

•MSFC CDDF Task

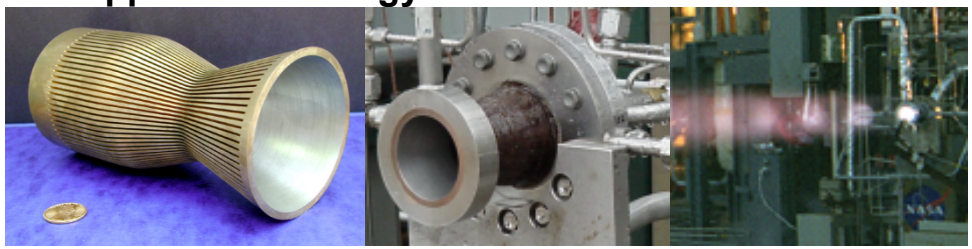
•Combined VPS, FGM, & GRCop-84 on small chamber liners



•FY98-99

•MSFC CDDF + NRA8-21 Tasks

•Applied technology to subscale chamber liners



•FY99-

•FY01

•NRA8-21 Task

•Fabricated midsize chamber liners for

•higher thrust levels

•FY01-

•FY03

•NGLT

•Demonstrating

•technology for

•large,

•"engine class"

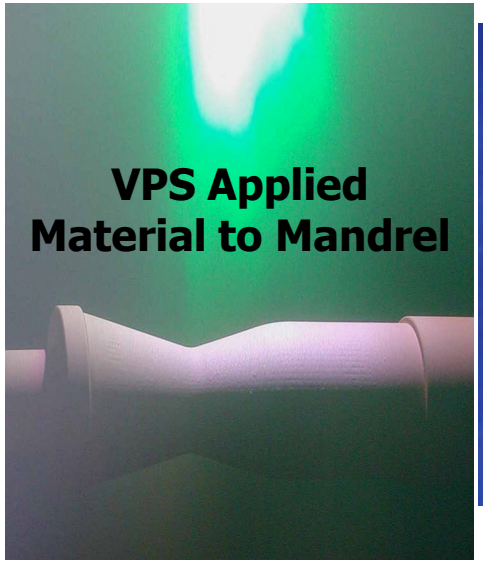
•liners

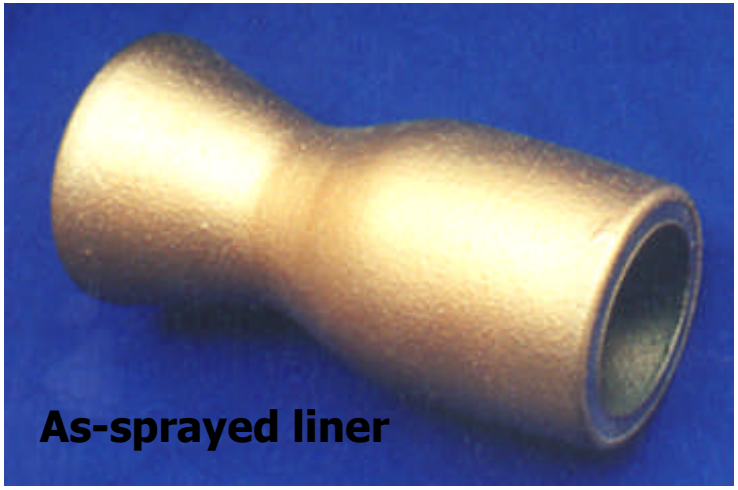
•(SSME

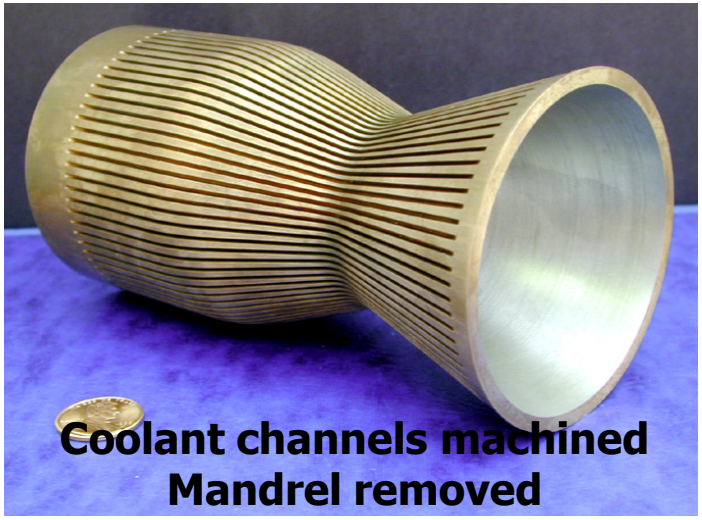
•MCC size)

•FY02-03

5K Hardware Fabrication

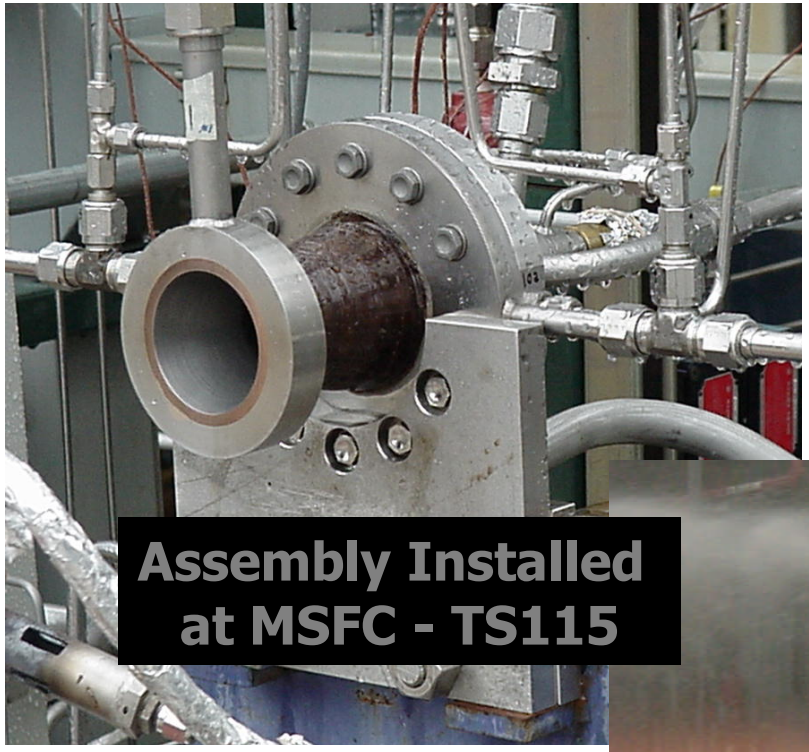






5K Hardware Testing

Plasma Processes, Inc.



Assembly Installed at MSFC - TS115

220 Hot-fire Tests Performed to date
1100 seconds accumulated
P_c range: 750 – 1100 psig
Oxygen/hydrogen propellants
Liner Coolant: liquid hydrogen, water
GRCop-84 temperatures = 900 – 1250 F

Hot-fire Testing at MSFC - TS115

No degradation observed for GRCop-84 liner or NiCrAlY hot wall layer

Alternate Material & Process

Functional Gradient Material (FGM)

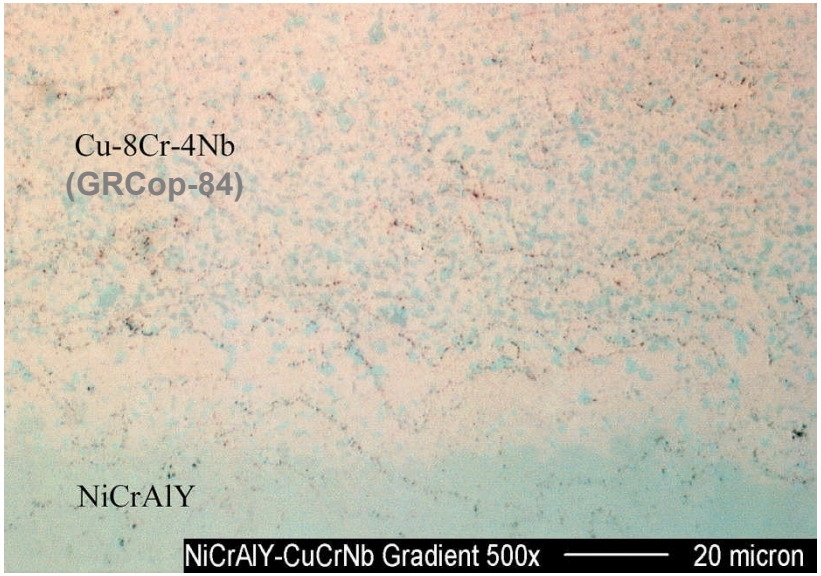
Hot wall layer: NiCrAlY

Gradated to ----

Liner Material: GRCop-84

Formed with ----

Vacuum Plasma Spray (VPS)



Advantages

- **NiCrAlY layer offers maximum blanch protection**
- **No distinct bond joint between material layers**
- **Near net shape part**
- **Reduced fabrication schedule**
- **Higher operating temperatures**
- **Higher reliability, longer life**

5K Hardware Performance

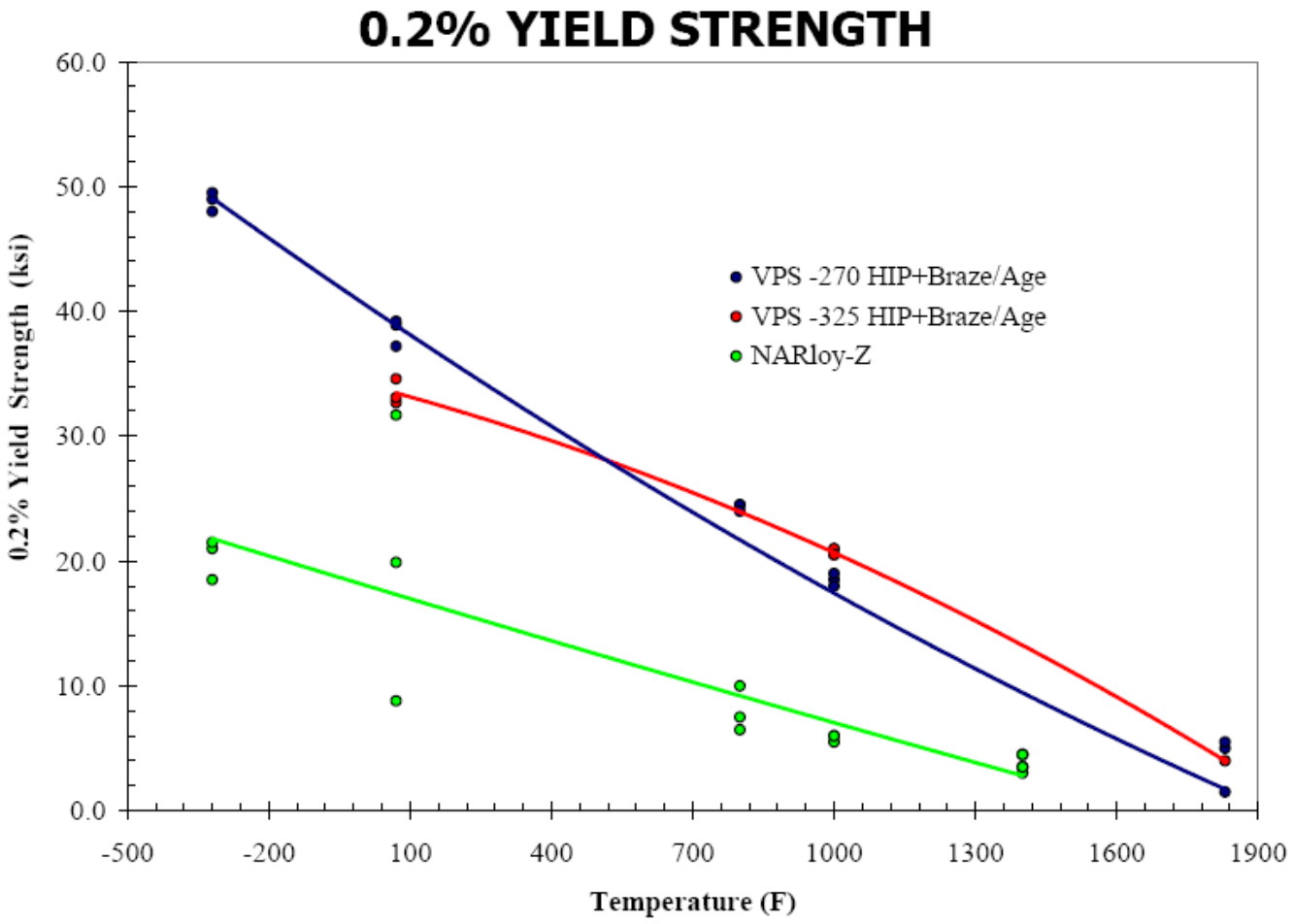
Subscale Cycle Test Comparison

VPS GRCop-84 Liner	NARloy-Z Liner
2003 - Technology Evaluation	1976 - SSME Qualification Testing
108 Cycles (520 sec, total)	118 Cycles (353 sec, total)
Max. GRCop-84 temp = 1250 F	Max. NARloy-Z temp = 1100 F
No hot wall cracks or surface roughening ever initiated – no liner degradation at all	Cycles < 30, Hot wall cracks & Surface roughening initiated
Cycle ~ 55, heat load decreased 30% less coolant required	Cycle ~ 70, heat load increased Surface polishing required

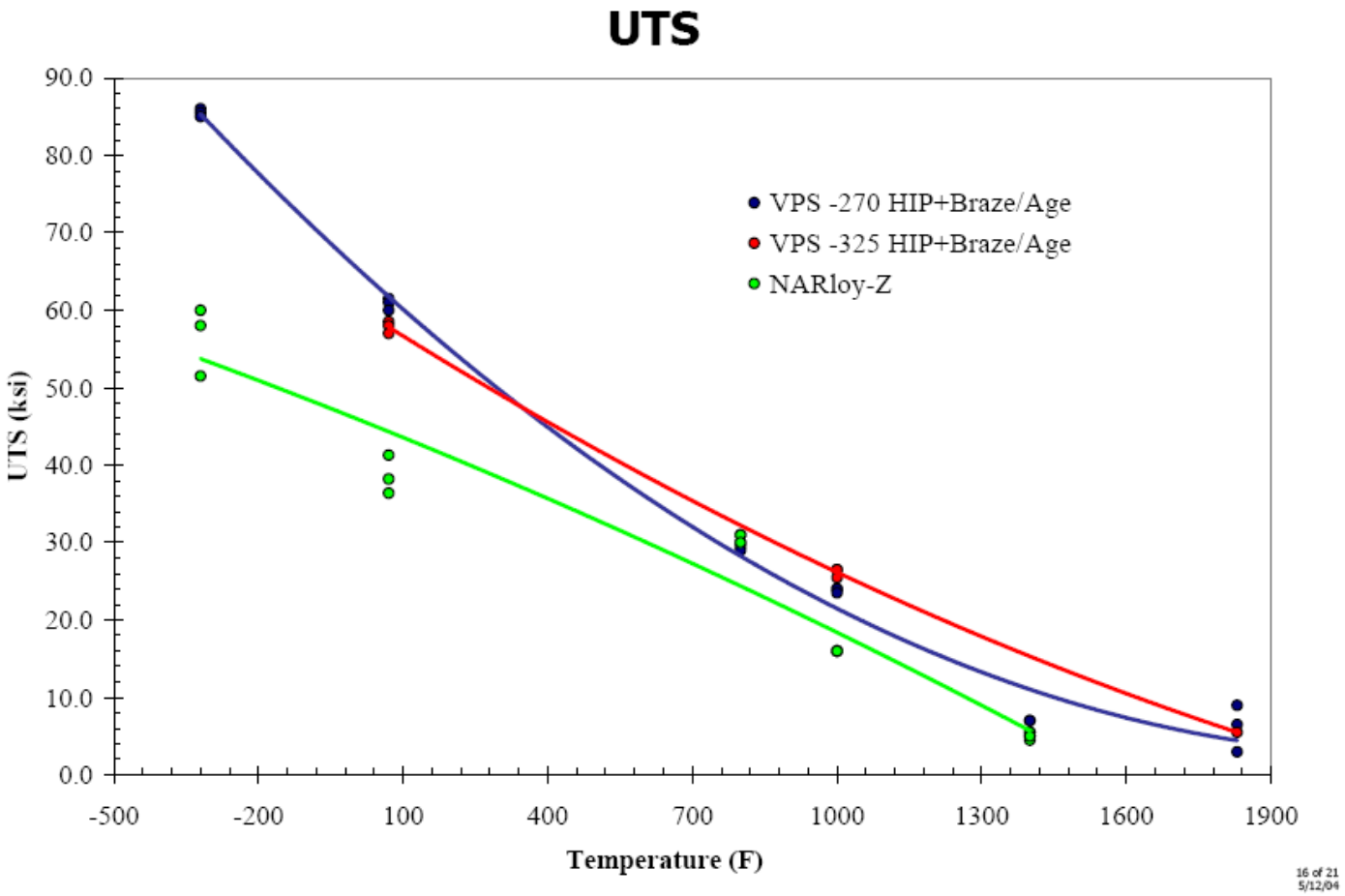
NARloy-Z avoids O_2/H_2 ratios of 8:1 due to blanching.

VPS GRCop-84 liner: 9 tests at 8:1 with no signs of blanching!

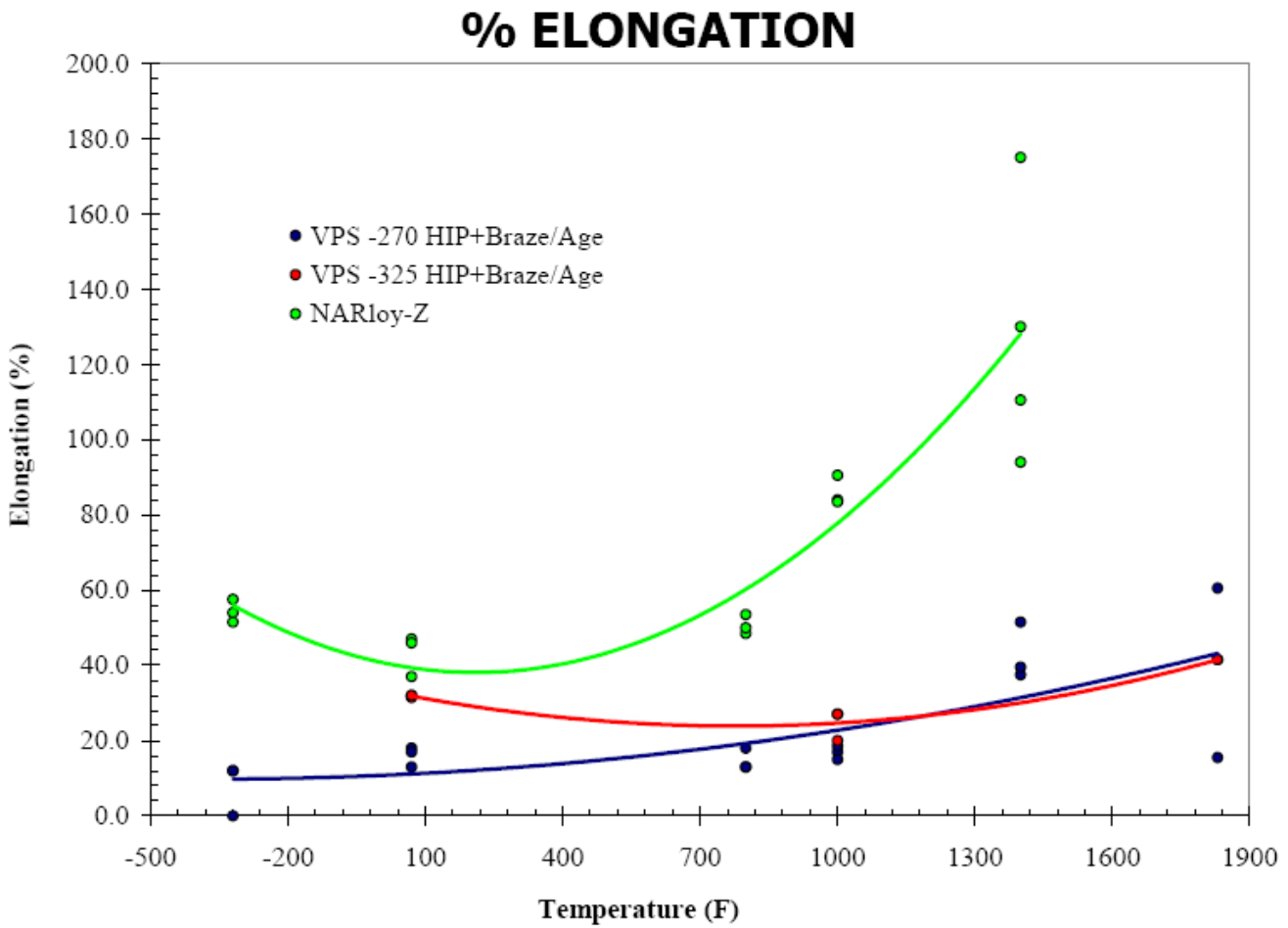
Material Testing Results



Material Testing Results



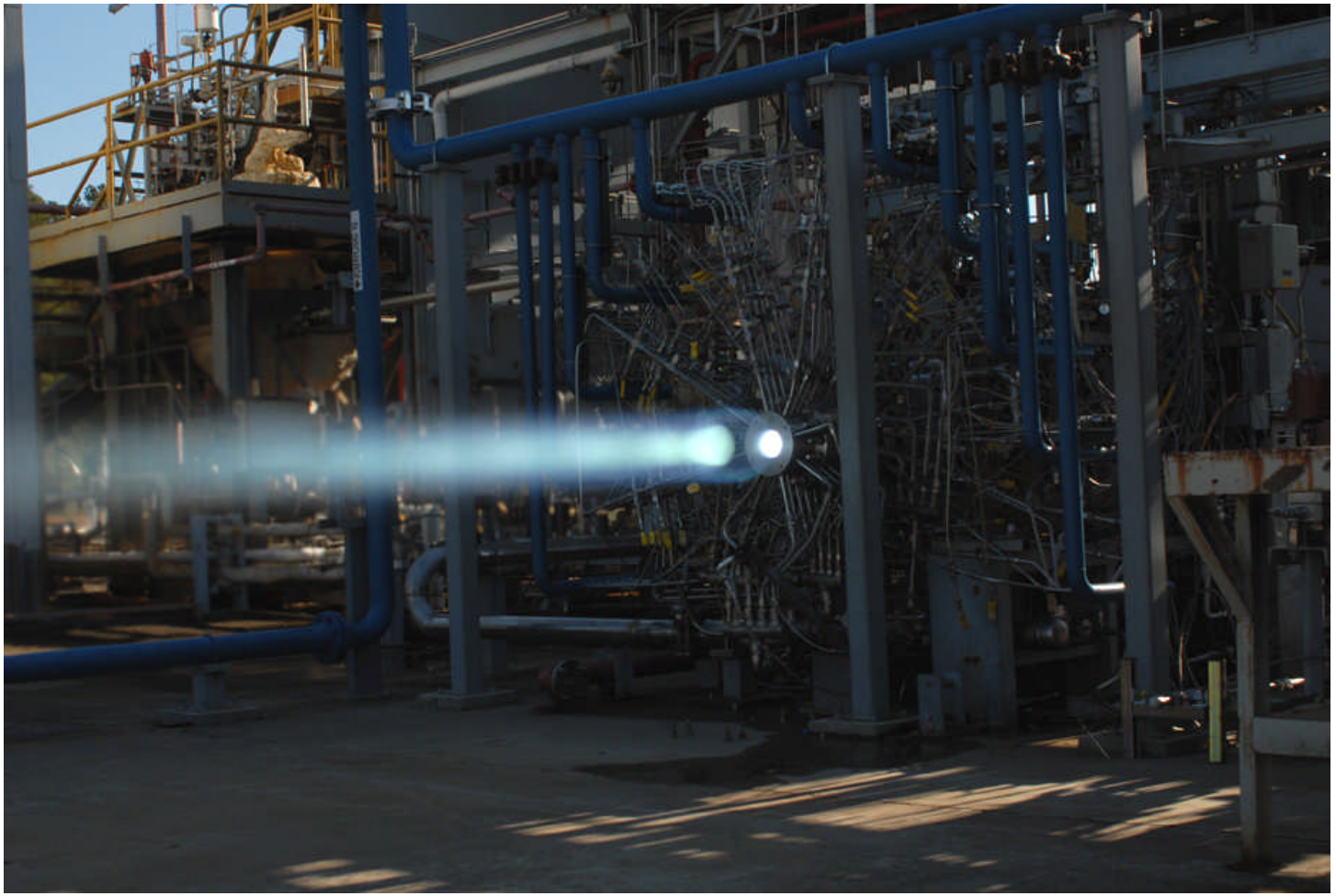
Material Testing Results



40K Thruster with Cooling Channels Cut Circumferentionally

40K Thruster to being Tested as a Calorimeter

Hot Fire Testing 40K Thruster as Calorimeter



Summary

- Demonstrated high performance of VPS FGM with hot-fire cycle testing
- Demonstrated Rapid Closeout of Combustion Chamber Cooling Channels for Reduced Time and Reduced Costs
- Increased VPS material database
- Currently testing 40K thruster as a Calorimeter

Further Information

NASA	NASA	Genie Products
Dick Holmes	Sandy Elam	Chris Power
(256) 544-2722	(256) 544-8902	(256) 505-9667

References

- Holmes, R.R., and McKechnie, T.N., "Vacuum Application of Thermal Barrier Plasma Coatings," 1988 Conference on Advanced Earth-To-Orbit Propulsion, May 10-12, 1988, NASA/ University of Alabama in Huntsville.
- Holmes, R.R., and McKechnie, T.N. "Vacuum Plasma Spray Coating," Advisory Group for Aerospace Research and Development Conference Proceedings No. 449, Application of Advanced Material for Turbomachinery and Rocket Propulsion, 1989, NATO.
- R. Holmes, D. Burns, and T. McKechnie, "Vacuum Plasma Spray Forming NARloy-Z And Inconel 718 Components for Liquid Rocket Engines," Thermal Spray Research and Applications, Proceeding of the 3rd National Thermal Spray Conference, Edited by Thomas F. Bernecki, ASM International, Long Beach, CA, pp. 363-368 (1990).
- Holmes, R. R., McKechnie, T.N. Plasma Spray in the Space Program: Evolution from Thermal Barrier Coatings to Structures and Back. For presentation at Thermal Barrier Coatings for Aerospace Applications, Toronto, Canada, October 22-23, 1992.
- Holmes, R.R., Zimmerman, F.R., Krotz, P.D., McKechnie, T.N., Liaw, Y.K., Thermal Spray of Refractory Metal Powders for High Temperature Furnace Applications for presentation at the TMS Annual Conference, Denver, CO, February 1993.
- T. McKechnie, P.Krotz, Y. Liaw, F. Zimmerman & R. Holmes, "VPS Forming of Refractory Metals and Ceramics for Space Furnace Containment Cartridges," Thermal Spray Coatings: Research, Design and Applications, Proceedings of The 5th National Thermal Spray Conference, edited by C. Berndt & T. Bernicki, ASM International, Anaheim, CA, pp. 297-301 (June , 1993)
- T. McKechnie, P. Krotz, Y. Liaw, F. Zimmerman & R. Holmes, "Near Net Shape Forming of Ceramic Refractory Composite High Temperature Cartridges by VPS," 1994 Thermal Spray Industrial Applications, Proceedings of the 7th National Thermal Spray Conference, edited by C. Berndt & S. Sampath, ASM International, Boston, MA, pp. 457-463 (June, 1994).

References (Continued)

- Holmes, R., Zimmerman, F., McKechnie, T., Krotz, P., Enhanced Near Net Shape Ceramic Refractory Composite High Temperature Cartridges by VPS Metallurgical Alloying Technique. For presentation at the 14th International Thermal Spray Conference, Kobe, Japan, May 22-25, 1995.
- P. Krotz, Y. Liaw, R. Holmes, F. Zimmerman & T. McKechnie, "Enhanced Near Net-Shape Ceramic Refractory Composite High Temperature Cartridge by VPS Metallurgical Alloying Techniques," Advances in Thermal Spray Science and Technology Advances in Thermal Spray Science and Technology, Proceedings of the 8th National Thermal Spray Conference, edited by C.C. Berndt & S. Sampath, ASM International, Houston, Texas, pp. 729-733, (September 1995).
- Gillies, D.C., Reeves, F.A., Jeter, L.B., Sledd, J.D. Holmes R.R., Cole, J.M. Lehoczky, S.L., The Advanced Automated Directional Solidification Furnace (AADSF). For presentation at SPIE's 1996 International Symposium, Denver, CO, August 4-9, 1996.
- J. Scott O'Dell, Timothy N. McKechnie, and Richard R. Holmes, "Development of Near Net Shape Refractory Metal Components Utilizing Vacuum Plasma Spray," Tungsten Refractory Metals and Alloys 4, Metal Powder Industries Foundation, 1998, Princeton, New Jersey. 159 169.
- Holmes, R.R., Ellis, D., McKechnie, T., Hickman, R., Microsturcture and Mechanical Properties of Vacuum Plasma Sprayed Cu-8Cr-4Nb. For presentation at 10th JPL/MSFC/AIAA Advanced Propulsion Research Workshop, Huntesville, AL, April 5-9,1999.
- Holmes, R.R., Ellis, D. McKechnie, T., Robust Low Cost Aerospike/RLV Combustion Chamber by Advanced Vacuum Plasma Process. For presentation at 36th Space Conference, Cape Canaveral, FL, April 27-30, 1999.
- Elam, S., Effinger, M.R., Holmes, R., Lee, J. Jaskowiak, M., Lightweight Chambers for Thrust Cell Applications. For presentation at 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Huntsville, AL, July 17-19, 2000.
- Holmes, R., Elam, S. McKechnie, T., Hickman, R., Robust, Low-Cost Liquid Rocket Combustion Chamber by Advanced Vacuum Plasma Process. For publication in Proceedings of the 2001 Annual TMS Meeting, New Orleans, LA, February 10-16, 2001.

References (Concluded)

- Hickman, R., McKechnie, T., Holmes, R., "Material Properties of Vacuum Plasma Sprayed Cu-8Cr-4Nb for Liquid Rocket Engines". For presentation at the 37th AIAA/ASME/SAE/ASEE/Joint Propulsion Conference, Salt Lake City, Utah, July 8-11, 2001.
- Elam, S., Lee, J., Holmes, R., Zimmerman, F., Effinger, M., "Lightweight Chambers for Thrust Assemblies". For presentation at the 52d International Astronautics Conference, Toulouse, France, October 1-5, 2001. IAF-01-S.3.05.
- Holmes, R., Elam, S., McKechnie, T. Hickman, R., "Robust Low Cost Liquid Rocket Combustion Chamber by Advanced Vacuum Plasma Process". For presentation at the 39th Space Congress, Cocoa Beach, FL, April 29-May 2, 2002.
- R. Hickman, T. McKechnie, R. Holmes, S. Elam, "Material Properties of Net Shape, Vacuum Plasma Sprayed GRCop-84", 40thAIAA/ASME/SAE/ASEE Joint Propulsion Conference, Huntsville, AL, July 2003, AIAA 2003-4612.
- Sandra Elam, Richard Holmes, Timothy McKechnie, Robert Hickman, & Timothy Pickens, "VPS GRCop-84 Chamber Liner Development Efforts" 52nd JANNAF Propulsion Meeting/1st Liquid Propulsion Subcommittee Meeting, Las Vegas, NV, May 10-13, 2004.