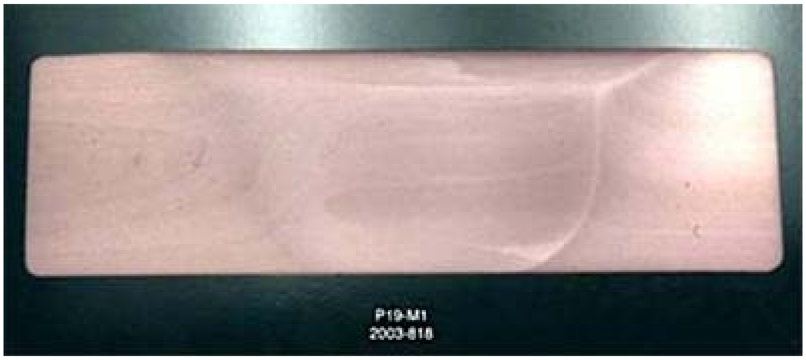
Full-Scale GRCop-84 Combustion Chamber Liner Preform Fabricated Successfully

GRCop-84 (Cu-8 at.% Cr-4 at.% Nb) has been under development at the NASA Glenn Research Center for several years. The alloy possesses a unique combination of good thermal conductivity, high elevated temperature strength, long creep life, and long low-cycle-fatigue. The alloy is also more oxidation resistant than pure copper and most competitive alloys. The combination of properties has attracted attention from major rocket engine manufacturers who are interested in the alloy for the combustion chamber liner in their next generation of regeneratively cooled engines. Before GRCop-84 can be used in a main combustion chamber application, it must be demonstrated that the alloy can be made successfully to the large sizes and proper shape needed and that it retain useful properties. Recent efforts have successfully demonstrated the ability to fabricate a liner preform via metal spinning that retains the alloy’s strength even in the welded sections.

GRCop-84 is a powder metallurgy alloy. Powder is canned and extruded to make a solid rectangular billet. Once consolidated into a solid, GRCop-84 can be processed like most copper-based alloys using conventional techniques. To make these liners, the billet was warm rolled into 1.27-cm (0.5-in.) plates approximately 47 cm wide by 127 cm long (18.5 by 50 in.). The plates were cut to size and formed into half cylinders. The edges of the half cylinders were machined to provide a tight, uniform joint at the mating surfaces between the two pieces.



Cross section of an FSW showing the complete penetration and excellent joining of two 1.27-cm (0.5-in.) plates with a butt joint.

The half cylinders were joined at the NASA Marshall Space Flight Center. Friction stir welding (FSW) was selected to join the alloy because of past experience with aluminum-based alloys and technical considerations that indicated that FSW would not significantly degrade properties in the weld zone. Efforts at Marshall demonstrated that GRCop-84 has a very wide processing window and could be easily welded using FSW. A typical weld cross section is shown in the preceding photograph, and the table lists the strength of welds done on several plates.

ROOM-TEMPERATURE TENSILE STRENGTH OF FSW JOINTS						
Material	**0.2-percent offset yield strength**		**Ultimate tensile strength**		**Elongation, percent**	**Reduction in area, percent**
	MPa	ksi	MPa	ksi		
1.27-cm plate--round samples (average of three welds, six tests)	203.6	29.5	403.4	58.5	18.0	20.3
1.27-cm plate--full-thickness samples (average of two welds, eight tests)	203.7	29.5	404.6	58.6	17.8	Not applicable
As-extruded GRCop-84 bar	225.6	32.7	403.1	58.4	21.4	45.1
FSW properties as percent of baseline properties	90.3		100.2		83.6	45.0

The GRCop-84 cylinders were metal spun at Spin Tech in Paso Robles, California, to a size equivalent to that of a 40,000-lb-thrust rocket engine. The metal spinning was done in two steps. The first step rough sized the cylinders, and the second step produced the final hourglass shape with the proper envelope dimensions. The next photograph shows the cylinder undergoing final metal spinning into the hourglass shape, and the final photograph compares a cylinder not yet metal spun and the finished main combustion chamber liner preform. The weld is clearly visible on the surface of the cylinder but is difficult to distinguish in the metal-spun preform.

Metal spinning of GRCop-84 into the final hourglass-shaped liner preform.

A comparison of a welded cylinder and a liner preform after completion of metal spinning. The cylinder is 18 in. tall.

Inspection using visual and nondestructive evaluation methods did not reveal any failures or defects developing in the welds. One preform was destructively tensile tested to determine the strength of the weld joints. The results in the following table show that the welds were as strong as the annealed plate used as starting stock and actually stronger than the starting stock at 538 °C.

TENSILE STRENGTH OF METAL-SPUN GRCOP-84 LINER PREFORMS IN THE WELD REGION

Material	**0.2-percent offset yield strength**		**Ultimate tensile strength**	
	MPa	ksi	MPa	ksi
FSW and metal spun; room temperature	246.3	35.7	419.5	60.8
FSW and metal spun; 538 °C (1000 °F)	157.3	22.8	176.6	25.6
As-extruded GRCop-84 bar; room temperature	225.6	32.7	403.1	58.4
As-extruded GRCop-84 bar; 538 °C (1000 °F)	107.8	15.6	138.9	20.1

Although additional testing including an eventual hot fire testing of a liner is needed, results so far show that GRCop-84 liners can be produced easily with conventional fabrication methods and that the alloy retains all of its properties even in the weld joint of a metal-spun preform. This makes GRCop-84 an extremely attractive material for regeneratively cooled rocket engine main combustion chamber liners and other high-temperature, high-heat-flux heat exchanger applications.

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