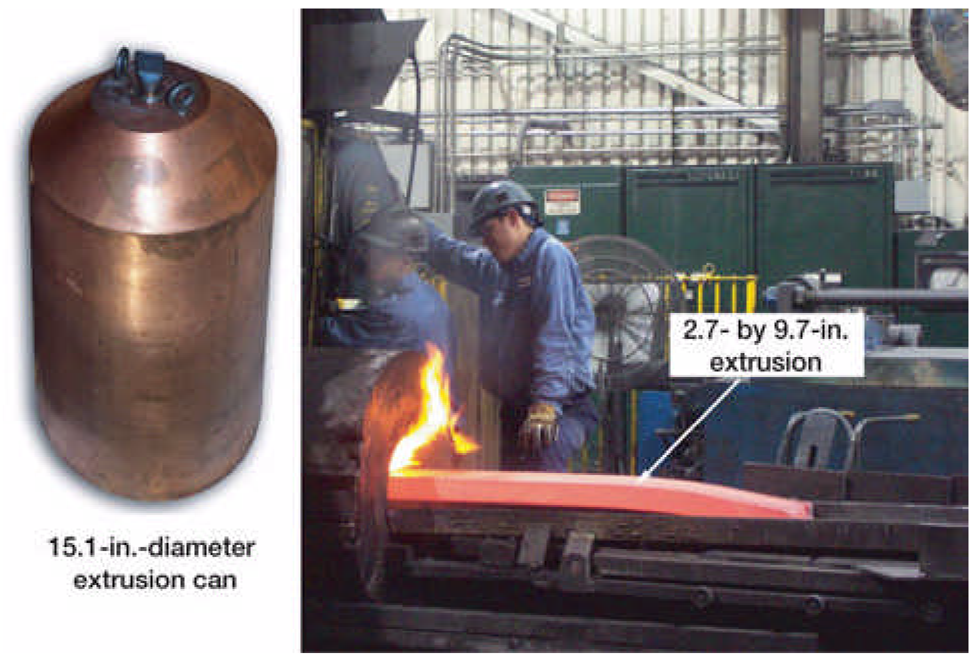
GRCop-84 Scaled Up for Production

GRCop-84 (Cu-8 at.% Cr-4 at.% Nb) was developed at the NASA Glenn Research Center for use in regeneratively cooled rocket engine main combustion chamber liners. The alloy has demonstrated high elevated-temperature strength, excellent creep resistance, long low-cycle-fatigue lives, low thermal expansion, and good thermal conductivity on a laboratory scale. The combination of properties has led to interest from the Rocketdyne Division of Boeing, Aerojet, and Pratt & Whitney for their new engines. Under the Space Launch Initiative/Next Generation Launch Technology program, GRCop-84 is being taken out of the laboratory and put into a full-scale production environment.

Development work spans the entire process from powder production to finished liner preforms ready to be machined and integrated into test engines. Powder production has been increased to 1600 lb and larger production runs. Crucible Research, the producer, has identified and is currently weighing capital expenditures that would increase the production capacity 6 times while reducing the cost of the powder by 40 percent.



Extrusion of GRCop-84.
A 15.1-in.-diameter copper extrusion can filled with 800 lb of GRCop-84 was extruded at a high temperature using a commercial 6000-ton press to produce a piece 2.9 in. thick by 9.9 in. wide by approximately 72 in. long.

Extrusion is used to consolidate the powder into a solid form. As shown in the preceding photographs, the extrusion process has been successfully scaled up to 15.1-in.-diameter extrusion cans with 800 to 1000 lb of powder using the commercially available extrusion press at HC Starck. HC Starck has rolled the extruded GRCop-84 to a 24-in.-wide plate and a sheet as thin as 0.002 in. Additional commercial vendors have been identified to increase both the size of the extrusion can and the width of the rolled product.

Once the sheet and plate are produced, they are incorporated into two production processes to produce the liner preforms. In the first method, Aerojet uses their platelet technology to make the liners. Techniques similar to those used in integrated circuit chip production are used to remove material and make complex cooling passages in the thin sheets. The sheets are stacked and diffusion bonded together to produce liner sections such as the one shown in the photograph on the next page. The sections are electron beam welded together to make the final liner.

GRCop-84 platelet liner.
Aerojet bonded together several sheets using their platelet technology. The bonded sheets were bent to form a quarter section of a liner with a round-round-square cross section. The length of the piece is approximately 15 in.

In a second method under development with Rocketdyne, a 0.5-in.-thick plate is formed and machined into two half cylinders. The half cylinders are friction stir welded (FSW) together at the NASA Marshall Space Flight Center to form a complete cylinder. Spin-Tech, the current producer of the Space Shuttle Main Engine liners, metal spins the cylinder into the hourglass-shaped liner preform. The preform can be machined to final dimensions and cooling channels added. The RS-84 program has expressed interest in hot fire testing one or more metal spun liners in fiscal year 2004.

Testing is underway to fully characterize the microstructure and mechanical properties of the rolled product, the FSW joints, and the platelet technology material. Results to date demonstrate that the commercially processed GRCop-84 retains at least 85 percent of the properties of the as-extruded bars examined under the Reusable Launch Vehicles focused program, and with moderate amounts of cold work, exceeds the as-extruded properties by up to 20 percent. This includes the properties of the FSW and platelet technology joints.

Although work remains to be done to optimize some of the processing steps, the basic ability to scale up GRCop-84 has been demonstrated. The appropriate databases are still being generated, but properties so far are comparable to prior results. Forming and joining technologies needed to make the liners have been demonstrated. With these successes, GRCop-84 is ready for full-scale production to meet the needs of the RS-84 and other engines.

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