Development of Coextruded Fuel and Target Tubes for the Savannah River Plant Reactors

Philip H. Permar

Abstract

The coextrusion process devised by Nuclear Metals, Inc., was adapted to manufacture the 14-foot-long tubular fuel elements for the Savannah River Plant (SRP) reactors. Initially, smooth, aluminum-clad, uranium-aluminum alloy fuel tubes were fabricated. Subsequently, for high-power operation, many different ribbed fuel and target tubes were produced for use at SRP. A computer program was finally created for the design of extrusion dies used for the large-scale production of ribbed tubes.

Background

The designs of the first fuel and target assemblies at the Savannah River Plant (SRP) were based on Du Pont's prior experience at the Hanford Plant with short, aluminum-clad cylinders of natural uranium metal called "slugs". In the initial operation at SRP, four columns of similar short slugs were assembled in 14-foot-long vertical "Quatrefoil" tubes that controlled the flow of heavy-water coolant past the slugs. Hundreds of these fuel assemblies were arranged in a vertical lattice in the reactor. It was recognized that assemblies of Quatrefoil tubes would soon be replaced by fuel assemblies designed for operation at higher power.

Early in 1951, the Du Pont Atomic Energy Division selected Nuclear Metals, Inc. (NMI) as a metallurgical consultant because of NMI's experience in manufacturing fuel elements for a variety of U.S. reactors. NMI also pioneered "coextrusion" for producing reactor fuel elements at SRP. The process simultaneously formed the tubular fuel core and bonded the aluminum cladding to the inner and outer surfaces of the tube, hence the term "coextrusion".

Coextrusion Process Development

Development of Smooth Fuel Tubes

After several years of consultation and countless experiments at the Savannah River Laboratory and Plant (SRL/SRP), the first experimental coextruded smooth fuel tubes were produced in Building 320-M in September 1956. One year later, Building 321-M was completed for the fabrication of highly enriched tubular fuel, and these facilities were used for the remainder of the coextrusion program.

The coextrusion process at SRP employed a conventional 3000-ton extrusion press widely used in the aluminum industry. The extrusion press included an electrically heated container that held the hollow extrusion billet and a hydraulic ram that pushed the billet through a specially shaped die. The Moczik Tool and Die Company of Detroit, Michigan, cooperated with NMI and SRL to design and manufacture the extrusion tooling.

The keys to the development of a satisfactory smooth coextruded fuel tube were the end shape of the uranium-aluminum alloy core and the selection of the aluminum alloy used for the end plugs inside the composite billet (Bebbington 1990.) With properly designed billet components, the coextrusion process produced a smooth extruded tube containing acceptably shaped core ends.

The composite billet also included an evacuation tube to remove air from the assembly before extrusion. The extrusion lubricant, first lead-oil and later tin-oil, was specially selected to promote streamlined flow of the billet components. The outgassed billet was lubricated, heated, and extruded to produce a smooth aluminum-clad coextruded tube. After the tube had cooled, it was cleaned, straightened, cut to length, bond tested, and attached to the end-fittings to form the finished fuel element assembly.

Development of Ribbed Fuel and Target Tubes

Smooth coextruded fuel tubes proved to be excellent sources of neutrons in the SRP reactors. But when the demand for tritium continued to increase, the reactors were required to run at substantially higher power, far beyond the capacity of a single smooth coextruded fuel tube, to remove the heat from each vertical assembly.

The physicists quickly generated many designs for assemblies containing multiple fuel and target tubes that would run at higher power to produce a variety of radionuclides. As many as three fuel tubes and one target tube were included in a single assembly that fit into the original 4-inch-diameter position in the reactor lattice. These new designs required that the concentric fuel and target tubes be spaced by longitudinal ribs that ran the full length of the tubes.

For several years, ribbed tube extrusions were produced using smooth, unribbed billets. In these extrusions, the core was slightly thickened at the base of the ribs, but the local increase in heat generation was tolerable.

By early 1967, again with the help of consultants from NMI and Moczik Tool and Die Company, an improved manufacturing process was developed by SRL/SRP to produce the ideal ribbed tubes. Integral longitudinal ribs were created by using a ribbed extrusion billet in conjunction with specially shaped grooves in the extrusion die that formed the ribs on the tubes. Considerable development was required to establish the relationships among dimensions and shape of the ribs on the billet, the billet container, and the extrusion die as well as other extrusion parameters. For example, the lubrication of the billet and die with a tin-oil mixture was important in producing smooth surfaces, not only on the tube, but also on the sides and tips of the ribs.

In the beginning, the design of ribbed extrusion dies was more an art than a science. By 1967, extensive work had shown empirically that the material to form the ribs should be taken from the outer cladding, but the design and manufacture of a satisfactory die was a problem.

The major achievement at SRL was optimizing the design of the coextrusion dies for a variety of ribbed tube designs. These dies produced tubes with no core thickening at the base of the ribs. Eventually, a computer program was developed to produce the die designs.

Further technical details of the coextrusion process are discussed in Chapter 8 of the *History of Du Pont at the Savannah River Plant* (Bebbington 1990). This chapter contains an excellent description of the process, and also notes "The precise uniformity of thickness of core and cladding achieved in these fabrications is a truly remarkable feat of metallurgy."

Contributors

Assistance in the preparation of this paper was provided by the following individuals, most of whom worked in the Nuclear Materials Division at SRL:

Carl L. Angerman
George R. Caskey
Clinton C. McBride
William R. McDonell
Harold B. Peacock
Frederick C. Rhode

Reference

Bebbington, W.P., 1990, *History of Du Pont at the Savannah River Site,* E.I. du Pont de Nemours & Co., Wilmington, Delaware.

Biography

After graduating from Cornell University in 1943 with a Bachelor's degree in Chemical Engineering and a minor in metallurgy, Philip H. Permar was hired by Du Pont Engineering Department and worked at the Experimental Station in Wilmington, Delaware, on metallurgical problems in various Du Pont plants. He transferred in 1950 to the Du Pont Atomic Energy Division where he worked on design, construction, and process development of 300 Area at SRP. In 1952, he transferred to Aiken, South Carolina, as manager of the Nuclear Materials Division at SRL to work on the development of fuel and target elements to meet the changing demands for production of nuclear materials at SRP. In 1969, he transferred to the market development program for the neutron-emitter californium-252, a product of SRP, and promoted uses for californium-252 in the U.S. and Europe. Mr. Permar retired in 1982 after 39 years of service with Du Pont.

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