**On-site Manufacturing Considerations for Domestic Content Purposes – July 14, 2023**

Context:

* Hydropower facilities, which currently provide electricity to roughly 30 million Americans, are typically engineered for the site-specific topography, hydrology, and geological conditions. Unlike the mass production of wind turbines and solar wafers or cells, each hydropower facility is unique. Generators and turbines can weigh up to 500 tons. “If you’ve seen one hydropower facility, you’ve seen one hydropower facility.”
* The scope and scale of typical hydropower turbines and generators requires final manufacturing on-site to complete the manufacturing process to create a fully functional Component. The scope of supply and install spreadsheet identifies the specific sub-components that require continued on-site manufacturing.

On-site manufacturing basis:

* While in-shop manufacturing is preferred, some on-site manufacturing is often required due to the size, weight and geometry of the sub-components that result in transportation logistics difficulties (consistent with 49 CFR 661.11(d) and (e)).
* On-site work includes many tasks associated with manufacturing: welding, stress relieving, machining, pressure testing, electrical testing, final protective coating and precision assembly of machines (See Buy America Requirements, 56 Fed. Reg. 926, 929 (Jan. 9, 1991)).
* On-site work for turbines and generators is typically conducted by the manufacturer. And manufacturing isn’t complete until the OEM issues a warranty which occurs after all site data and checks have been signed off by OEM engineering.
* In the case of refurbishment projects, some work must be completed at site despite in-shop work preference as components may not be removable from site. An example of this is when a component requires work but is embedded in concrete or cannot fit through openings in the powerhouse for removal.
* One example of the need to allow onsite manufacturing are for components like the generator that, once they are built, cannot be taken apart without destroying the component (in this case the generator). On-site assembly could be defined as those things that can be disassembled without destroying the component for reassembly later. This is simply not the case with the main components of the rotating equipment of a large hydropower project.

Stator Manufacturing:

* A generator is comprised of two primary components – the stator and the rotor. The stator is the portion of the generator that is stationary. Comprised of large parts and pieces, the process of manufacturing a generator stator includes the assembly and alignment of the stator frame, generally a fabricated and machined structure shipped in segments.
* On-site at the facilty, the stator core is stacked continuously, using a manual process of layering each thin lamination in a configuration per the design. As each lamination is laid, it is inspected visually, and quality control is visually checking each layer as it is placed, in addition to paddling in the laminations as they are stacked to ensure alignment of the layers and to produce the slots for the windings with adequate clearance. Throughout the process of stacking the core, stator core presses occur to compress the laminations and to check the height and the tilt of the stator core as it is built.
* After the completion of stacking and the final press, the core is torqued as directed by OEM engineering and confirmed to meet tolerance and other requirements.
* After the core is deemed to be accepted, the winding may begin. Stator core winding is a specialty craft. Each winding, either coil or bar is placed gently into the slot in the correct configuration and packed with OEM specific insulation technology. The individual windings are then connected and each connection jumper is then hand insulated and electrical tested. Support blocks are lashed into place to provide rigidity and support against vibration. Once testing is complete, the stator core is treated on the front and back core faces with insulating materials.

Rotor Manufacturing:

* The process of manufacturing a generator rotor includes the onsite final machining and welding of the rotor spider, generally hub and arms, with precision alignment of the placement of the arms to machined surfaces on the hub to ensure that the arms are placed within thousandths of an inch in radius, chord, elevation, verticality and twist. This may include the process of strategic welding and heating to pull the arms in certain directions while maintaining a high full penetration weld quality requiring nondestructive examination to ensure integrity.
* The rotor rim is stacked each lamination at a time, ensuring alignment of the slots and keyways. The rotor rim is compressed once fully built and signed off by OEM engineering, then heated with precision by wrapping large electrical cables around the rim and insulating.  The rim is heated to allow thermal growth so that a larger key may be inserted between the rotor spider arms and the rim to create an interference fit. The rotor rim is checked before and after heating to ensure that the rim meets tolerance for radius, verticality and elevation within thousandths of an inch using precision equipment.
* The rotor poles are installed one by one onto the rim. The rotor poles are set for elevation and radius using precision equipment. The poles are then affixed to the rim by driving tapered opposing keys together until full engagement is achieved.  The keys are then cut and captured by a keeper plate.  The brake ring is installed and confirmed to have the correct flatness and leading/trailing alignment.  Electrical testing is performed on the rotor poles once installed, then the rotor poles are connected through torch or induction brazing. Further electrical testing is conducted and the leads installed and all joints hand insulated.
* The rotor is installed into the stator and must be confirmed to align to the stator core within thousandths of an inch for elevation and concentricity.  During the commissioning phase of the generator, a rotor imbalance may be identified which requires the welding of weights in strategic locations as specified by OEM engineering.

Turbine Manufacturing:

* During the manufacturing process for hydroelectric turbines, parts are manufactured to the extent possible in a manufacturing facility with restrictions considered for size and weight for transportation.  For many of the components, such as the spiral case, stay ring, draft tube, pit liner and piping systems, raw stock or formed plate is sent to site for welding, grinding, stress relieving, pressure testing, inspection and final qualification and final coating. Though this scope, mainly the embedded components, may not be performed by the OEM, technical oversight and procedural documentation is provided and tolerances must be accepted by the OEM in order for a warranty to be issued.
* Some components require welding and machining on-site such as discharge ring, stay ring flanges and sole plates, wicket gates and bushings, and line boring of head covers and bottom rings.
* The turbines need to be concentrically aligned within thousandths of an inch to the generator. This requires the stacking of all parts that relate to the positioning of the shaft or clocking of the unit (usually, the bottom ring, wicket gates, head cover, turbine guide bearing, shaft seal, lower bearing bracket, upper bearing bracket and stator core), using a centerline wire or highly specialized laser equipment to align the parts to an established centerline by moving parts that may weight 100s of tons and achieving a tolerance that is within thousandths of an inch. The pieces are then removed so that assembly may begin.