DOE Wire Workshop

St. Petersburg, FL

January 21-22, 2003

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HTS Power Transformers

Presented to the

2003 DOE Wire Workshop

For the WES/SuperPower/RG&E/ORNL Team

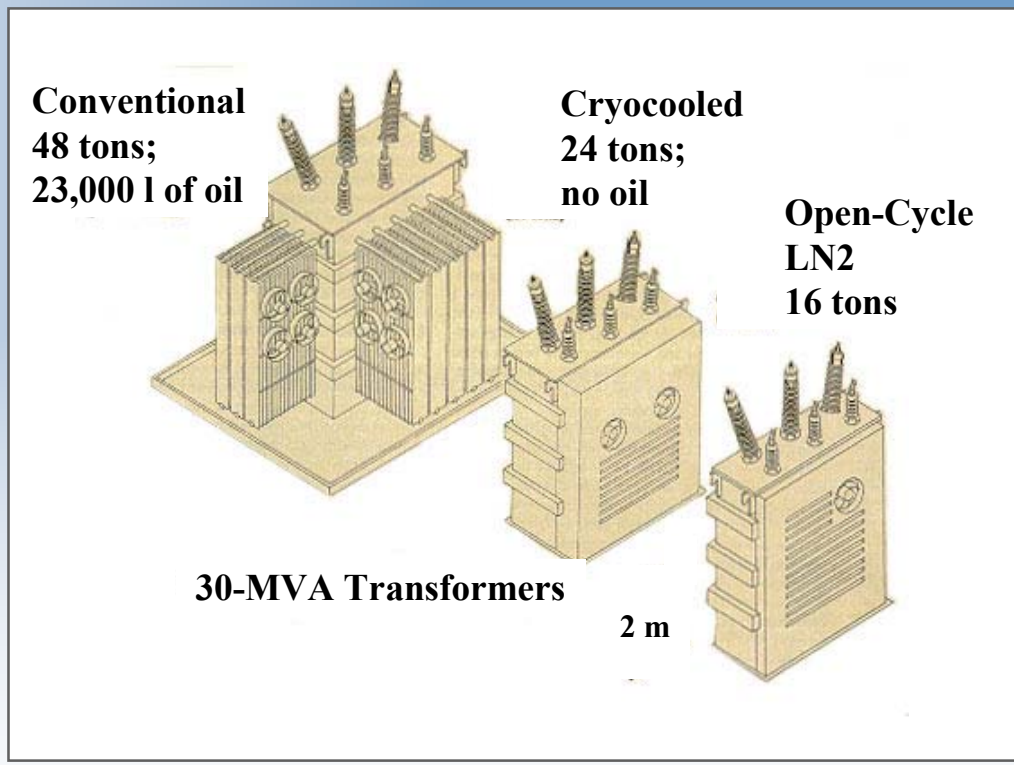
OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Project Participants

- **Waukesha Electric Systems**
- **SuperPower, Inc.**
  - **Rensselaer Polytechnic Institute**
  - **Applied Cryogenics Technology**
  - **Advanced Energy Analysis**
- **Oak Ridge National Laboratory**
- **Rochester Gas & Electric**

HTS Transformers offer economic, operational, and environmental advantages

- **Higher efficiency**
- **2X rating overload capability without insulation damage or loss of life**
- **Lower impedance and better voltage regulation**
- **Potential for fault current limiting capability, allowing reduced cost for associated switchgear, breakers, etc.**
- **Siting advantages and lower environmental hazard due to lack of oil**
- **Lighter and more compact than conventional units**



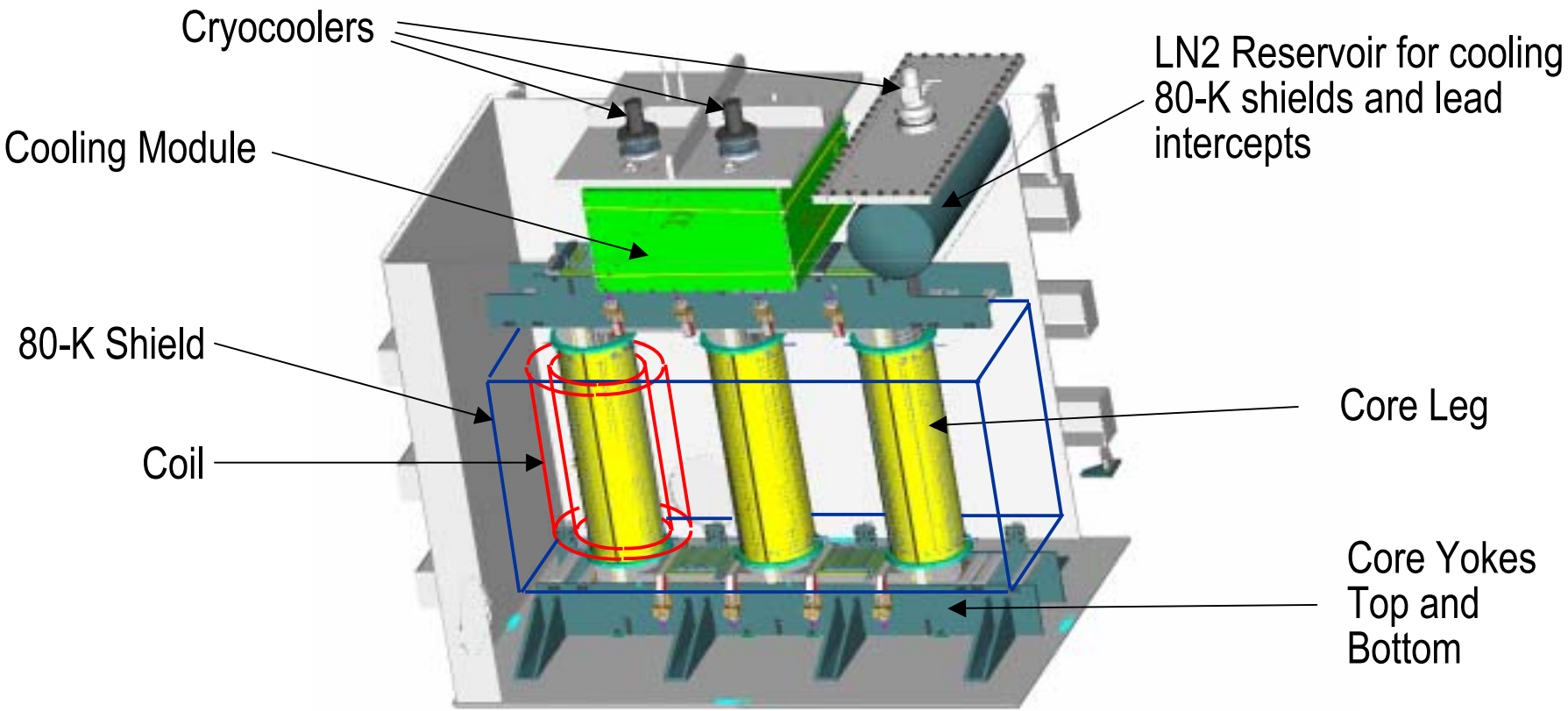
HTS Transformer Program Design Approach and Schedule

- **Cryocooled approach gives design flexibility**
  - **Allows operation from 20 K to 77 K**
  - **Best available conductor at a given time can be operated at its optimum temperature**
- **Progression: 1-MVA → 5/10-MVA → 30/60-MVA; all at full 30/60-MVA scale. For each stage of development:**
  - **Anticipated better conductor and better electrical insulation will allow higher power and higher voltage in same frame size**
  - **Better cryocoolers will provide enhanced performance and reliability**
- **The 5/10-MVA SPI project is approaching completion.**
- **Operational tests of the 5/10-MVA unit are scheduled for March 2003**

Specifications for the 1-MVA, 5/10-MVA, and 30/60-MVA Transformers show a progression in performance and complexity

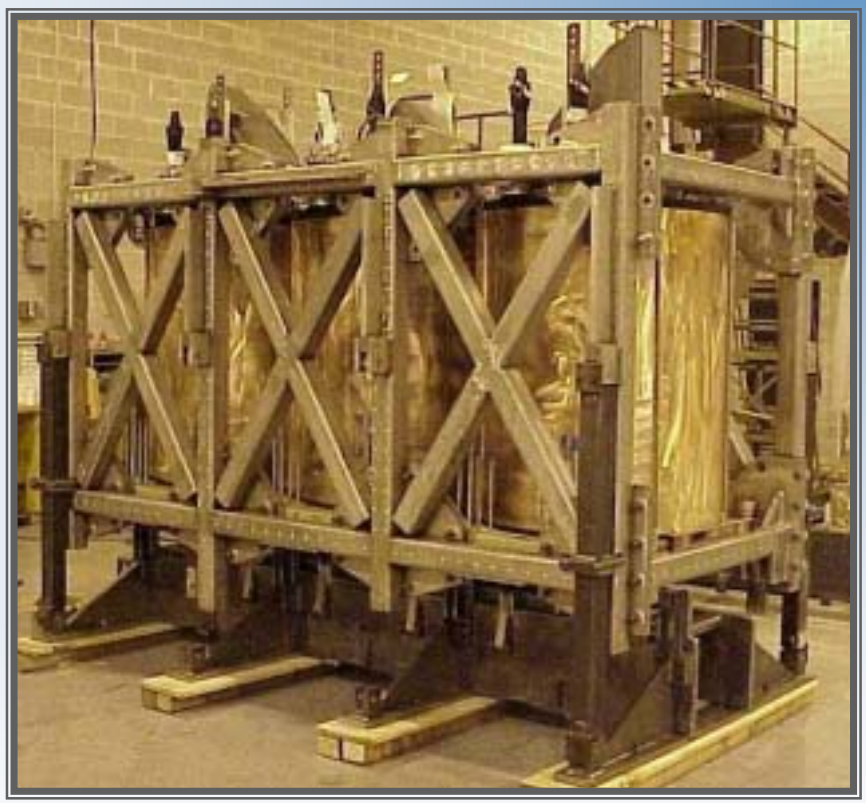
	1-MVA	5/10-MVA	30/60-MVA
Connection	1-Phase	3-Phase, Δ/Y	3-Phase, ΔY
Pri/Sec Voltage	13.8 kV / 6.9 kV	24.9 Kv / 4.2 kV	138 kV / 13.8 kV
Pri/Sec BIL	N/A	150 kV / 50 kV	550 kV / 110 kV
Pri/Sec Current	72.5 A / 145 A	67 A / 694 A	72 A / 1255 A
Overload Ratings	N/A	2-sec 10X, 48-hr 2X	2-sec 10X, 48-hr 2X
3-Day Power Outage Handling	N/A	Backup Motor/Generator	Backup Motor/Generator
Cooling System	Cryocooler	Cryocoolers	Cryocoolers
Instrumentation	Loval	Local	Remote

Cutaway Showing Major Components of 5/10-MVA Design



WES is Assembling the Core, Bushings, and Vacuum Tank

Phase Sets Mounted on Frame Around Iron Core



Summary of Project Status

- **Activities are focused on final design and fabrication of the 5/10-MVA transformer**
- **The 25-K cooling system module for the 5/10-MVA transformer was completed and successfully tested in a two-week period at at WES**
- **AC loss tests on BSCCO sample coils indicate acceptable values for the 5/10-MVA transformer, but not for higher-rated units (as expected)**
- **The 5/10-MVA transformer BSCCO coil sets have been completed and shipped to Waukesha**
- **Core and structural frame have been assembled.**
- **Final assembly of 5/10-MVA cold mass is underway**

Preliminary YBCO Specification for Transformer Applications

Requirement	Value
Physical	
Dimensions – width*	3 – 10 mm
– thickness*	0.05 – 0.15 mm
– piece lengths*	1000 m (no splices)
Substrate	non-magnetic
Solderability	high
*coil design dependent	

Preliminary YBCO Specification for Transformer Applications

Requirement	Value
Electrical	
Critical current*	100 – 500 A (depends on coil design)
Critical current density*	> 10^6 A/cm^2 in YBCO layer > 10^4 A/cm^2 overall
n -Value	>15
Uniformity	All Ic within 10% over length of conductor. In line measurements over short lengths (~10 cm) will be required until uniformity is demonstrated
*at 77K, self field	

Preliminary YBCO Specification for Transformer Applications

Requirement	Value
Mechanical	
Minimum critical bend diameter	100 mm
Minimum critical tensile strain	0.15%
Minimum critical tensile stress	100 MPa
	all 95% Ic retention

Preliminary YBCO Specification for Transformer Applications

Requirement	Value
Operational ac Losses * Stability* Fault scenario Insulation (primary) *coil design dependent	 < 500 W/m^3 (rated operation) integral or co-wound stabilizer 10 x rated capability for 1 sec integral on conductor