Insulated Bus Pipe (IBP) for Shipboard Use

NSRP Electrical Technologies Panel Meeting

March 23rd, 2021

Presenter: Dr. Patrick Lewis, Hepburn and Sons LLC

Overview

- Hepburn and Sons Capability Overview
- Introduction to Insulated Bus Pipe
  - Overview
  - Construction
  - Advantages
  - Existing Applications
  - IBP Development Roadmap
- Current Projects
  - NSRP RA 19-01 – Testing for Shipboard Introduction
  - NSRP RA 20-01 – Interface Design for Navy Equipment
  - SBIR Topic N201-055 – Coaxial IBP for Low Magnetic Signature

Company Information

OUR LEADERSHIP

CAPT Rick Hepburn, USN (Ret)
President, Chief Executive Officer (CEO)

Mr. Scott Hepburn
Principal, Chief Operations Officer (COO)

Mr. Eric Hepburn
Principal, Chief Financial Offer (CFO)

Mrs. Samantha Hepburn Hertel
Principal, Customer Relations Officer

CDR Frank Koye, USN (Ret)
Chief Information Officer

COMPANY INFO

- Founded in July 2010
- Veteran Owned Small Business
- Offices
  - HQ - Manassas, VA
  - Wallops Island - Atlantic, VA
  - Dahlgren - Colonial Beach, VA
- 50+ Employees
- Government Prime Contractor/ SeaPort NxG
- Prince William County Business of the Year 2018
- DC Council of Engineering & Architectural Societies (DCEAS) Engineers of the Year 2017 & 2019

WE ARE A COMPANY BUILT ON TRUST

We honor handshakes as rigorously as contracts. We keep trust at the forefront of every decision we make and customer we serve! We believe there is no greater principle in business than that of building a solid foundation of trust. We hold one another to the highest levels of integrity and ethics. We cherish every opportunity given to us by our clients.

Company Divisions

ADVISORY SERVICES

Tim Crone

Capabilities

- Identify opportunities in defense sector marketplace
- Connect technology companies to government needs
- Highlight opportunities, formulate marketing strategies, and develop plans of action
- Guide clients through the complexities of doing business with the Department of Defense
- Support government processes for requirements validation and budget development
- Conduct organizational analysis and long-range planning on behalf of private sector and government clients
- Provide senior-level counsel to decision makers and expert witness testimony on behalf of corporate clients

TECHNOLOGY TRANSITION

Rob Medve

Capabilities

- Project Portfolio Management
- Technology Transition Campaign Planning
- Technology Development Programs Execution
- Technology Scouting & Forecasting
- Innovation Planning
- Technical Analysis

ELECTROMAGNETIC SURVIVABILITY

Ben Ford

Capabilities

- Support commercial power grid, and Department of Defense (DoD) components, primarily; Air Force, Defense Threat Reduction Agency (DTRA), Missile Defense Agency (MDA), and Navy
- Perform hardness analysis and assessments on systems
- Brief DoD leadership on HEMP effects, hardening status, and validation methods
- Brief DoD leadership to raise awareness of HEMP hardening and effects of HEMP on operations
- Coauthored MIL-STD-4023, HEMP Protection for Surface Ships
- Design hardening solutions for critical facilities and systems
- Oversight for testing and repair of applications

ENGINEERING SUPPORT SERVICES

Jeff Sinclair

Capabilities

- Engineering and Technical Support Services
- Systems Engineering and Integration
- Acquisition Strategy and Planning
- Program Management
- Life Cycle Support
- Strategic Communication
- Test and Evaluation
- Operations and Maintenance
- Project Coordination, Scheduling, and Development

Stakeholders

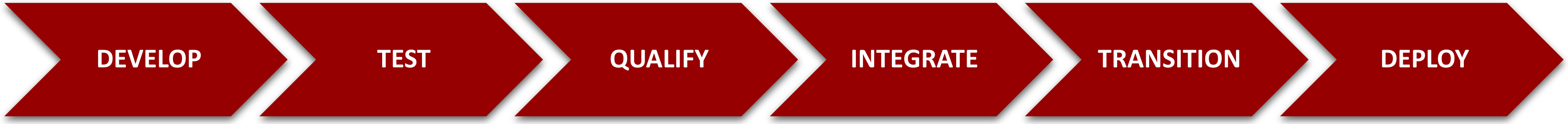
INDUSTRY CLIENTS & PARTNERS

- BAE Systems
- Northrop Grumman
- Leidos
- Huntington Ingalls
- Fire Security
- GD NASSCO & BIW
- CENTRA Technology
- Gryphon Technologies
- CACI
- McKean Defense
- LSP Technologies, Inc
- Interphase Materials
- Frontier Technologies, Inc (FTI)
- Advanced Technologies International (ATI)
- Nichols Brothers Boat Builders
- TEFELEN
- Stäubli
- AeroNav Laboratories, Inc
- Rolls Royce
- ABB
- Roxtec
- RSL Advanced Lighting Technologies
- Leonardo DRS
- KATO Engineering
- VT Halter Marine
- ABS
- Booz Allen Hamilton
- American Society of Naval Engineers

GOVERNMENT CLIENTS

Our Process

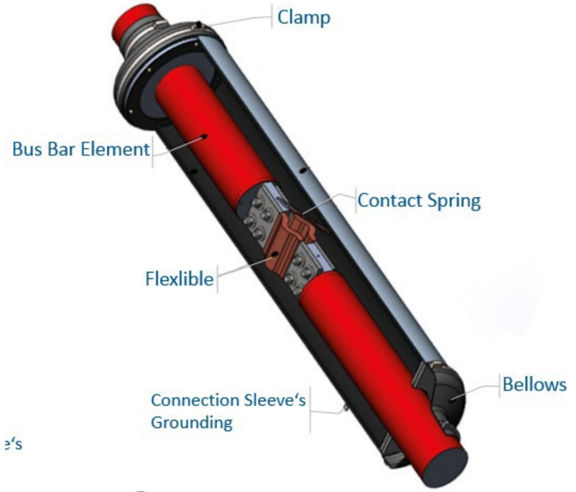
Shepherd Innovation from Concept Definition to Capability Deployment



- No need for technology developer to become experts in DoD acquisition
- ↓ Technology development and integration risks
- ↓ Time from start of technology development to capability deployment
- ↓ Cost of development
- ↑ Likelihood of transition to acquisition & deployment to the DoD and/or industry

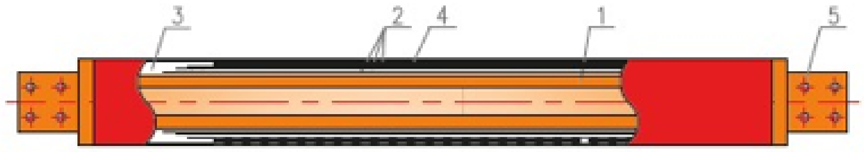
About IBP

- Touch-safe power distribution
- Multiple sizes available
  - AC applications up to 36 kV and 6.5 kA
  - DC applications up to 60 kV and 7 kA
- Shielding/protection options
  - High Temperature, 3 hour gas flame circuit integrity test capability
  - Stainless steel outer layer
  - Developing coaxial IBP to achieve a low magnetic (B field) radiated signature option for MVDC power distribution
- Bend radius limited by mechanical strength of conductor
  - Example: 7.2 kV AC/12 kV DC at 2 kA allows an 8″ bend radius
- Designed for 40+ year life

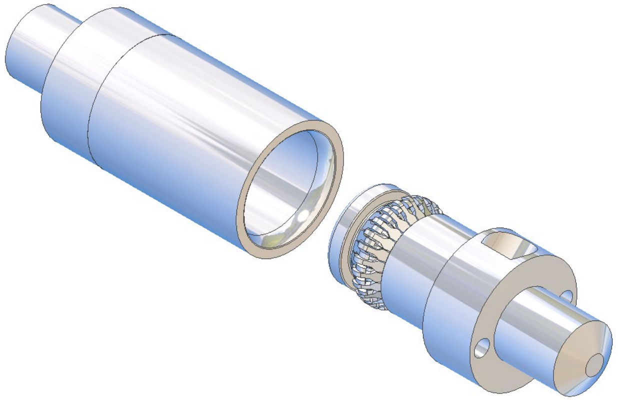


IBP Construction

- Copper or aluminum conductor, solid or hollow for rated current above 2000 amps
- Up to 30-foot sections are currently possible
- Alternating layers of insulating/semiconducting crepe paper vacuum impregnated with resin
- Up to IP68 construction
- 3 Hour Gas Flame Test certified high temperature coatings available
- E Field Shielding options
- Multiple connecting methods to suit application
- Connecting sleeve constructed similar to IBP

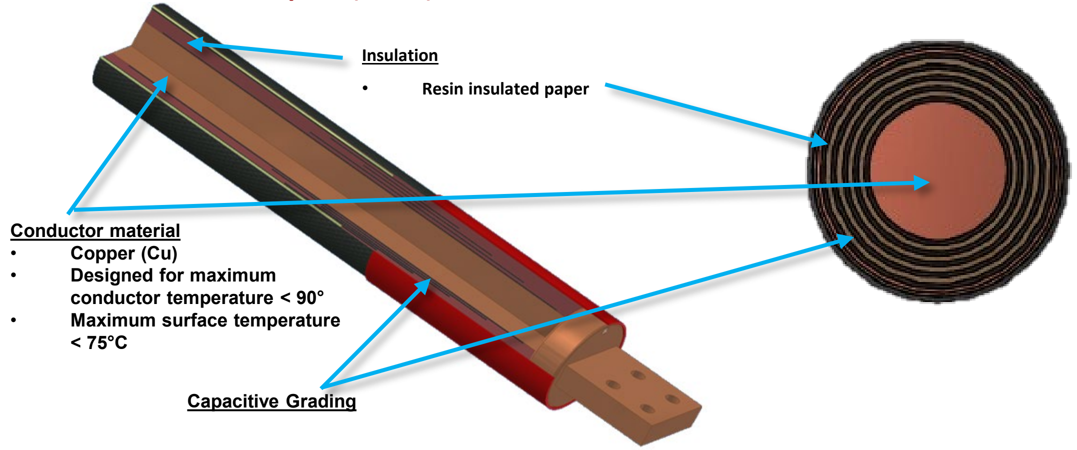


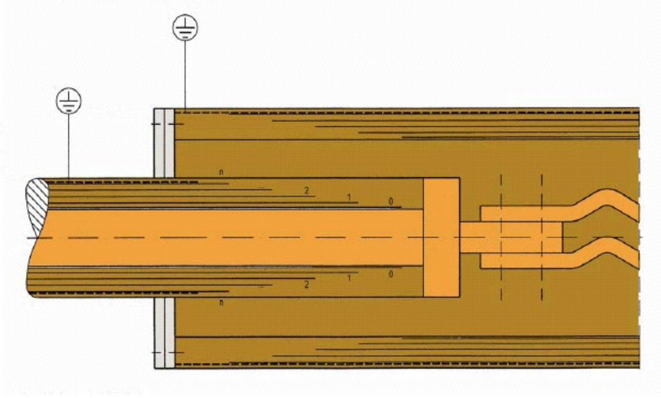
1. Conductor (Al, Cu)
2. Capacitive grading
3. Epoxy-impregnated paper wrapping
4. Earth layer
5. Flat terminal



IBP Construction

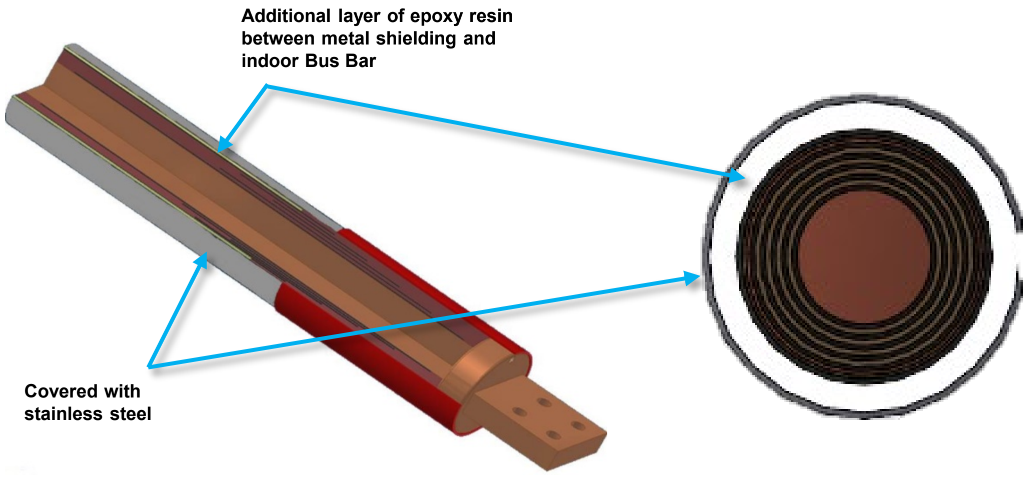
Insulated Bus Pipe (IBP)

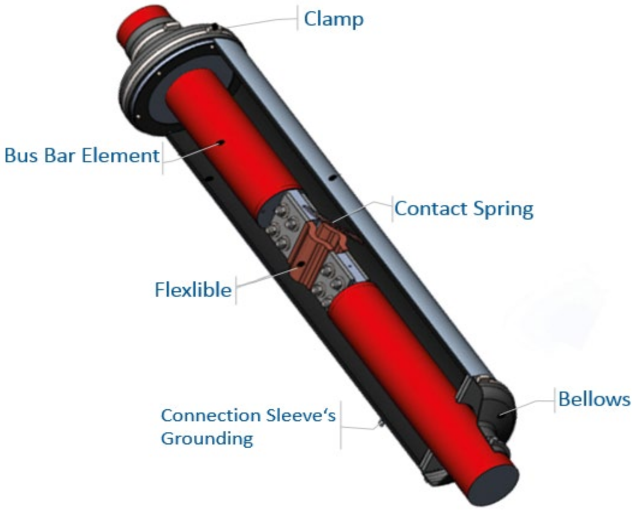




Capacitive Layer Design

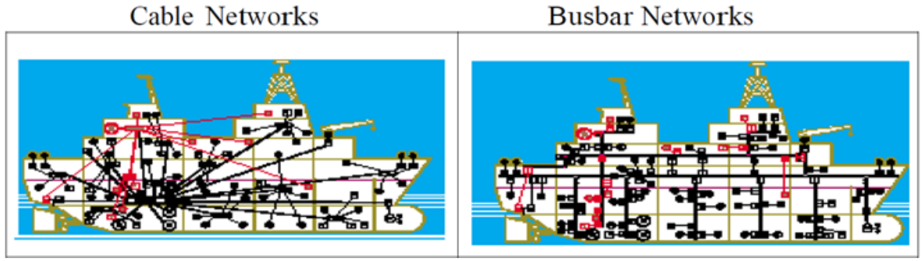
High Temperature Insulated Bus Pipe (HTIBP)

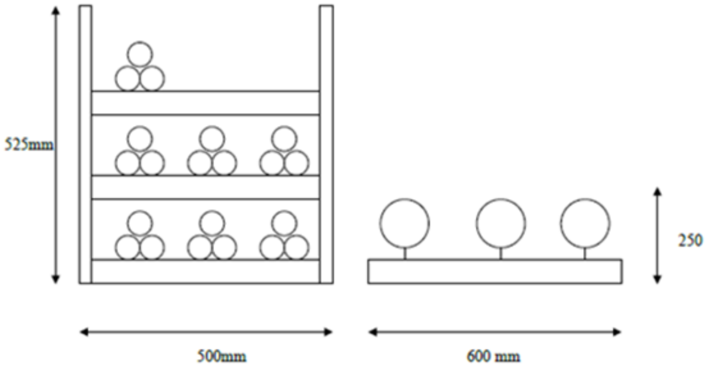




IBP Advantages

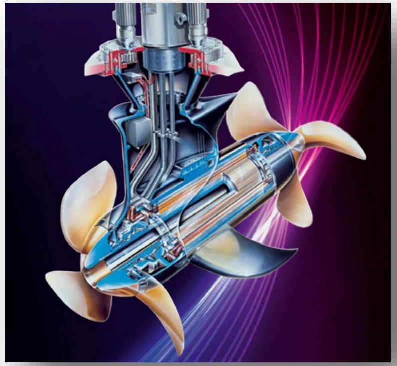
- Provides SWAP-C savings for increased endurance and design margin
- Supports modular ship construction, savings cost, and schedule
- Significant labor and weight savings
  - >20% labor
  - 72% weight
- Manufactured into complex shapes, can be placed in tight spaces
- Rigid construction ensures accurate model
- High abrasion resistance, increased survivability
- Repairs easily accommodated, only the damaged section is replaced

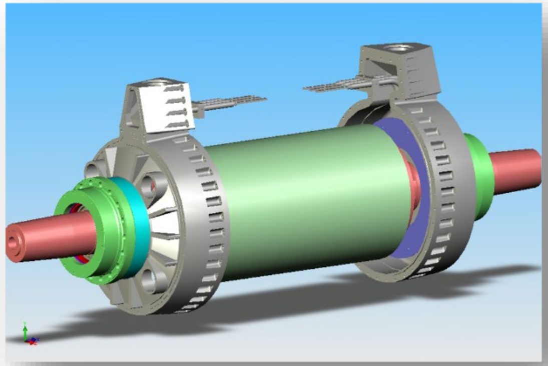




Existing Maritime IBP Applications

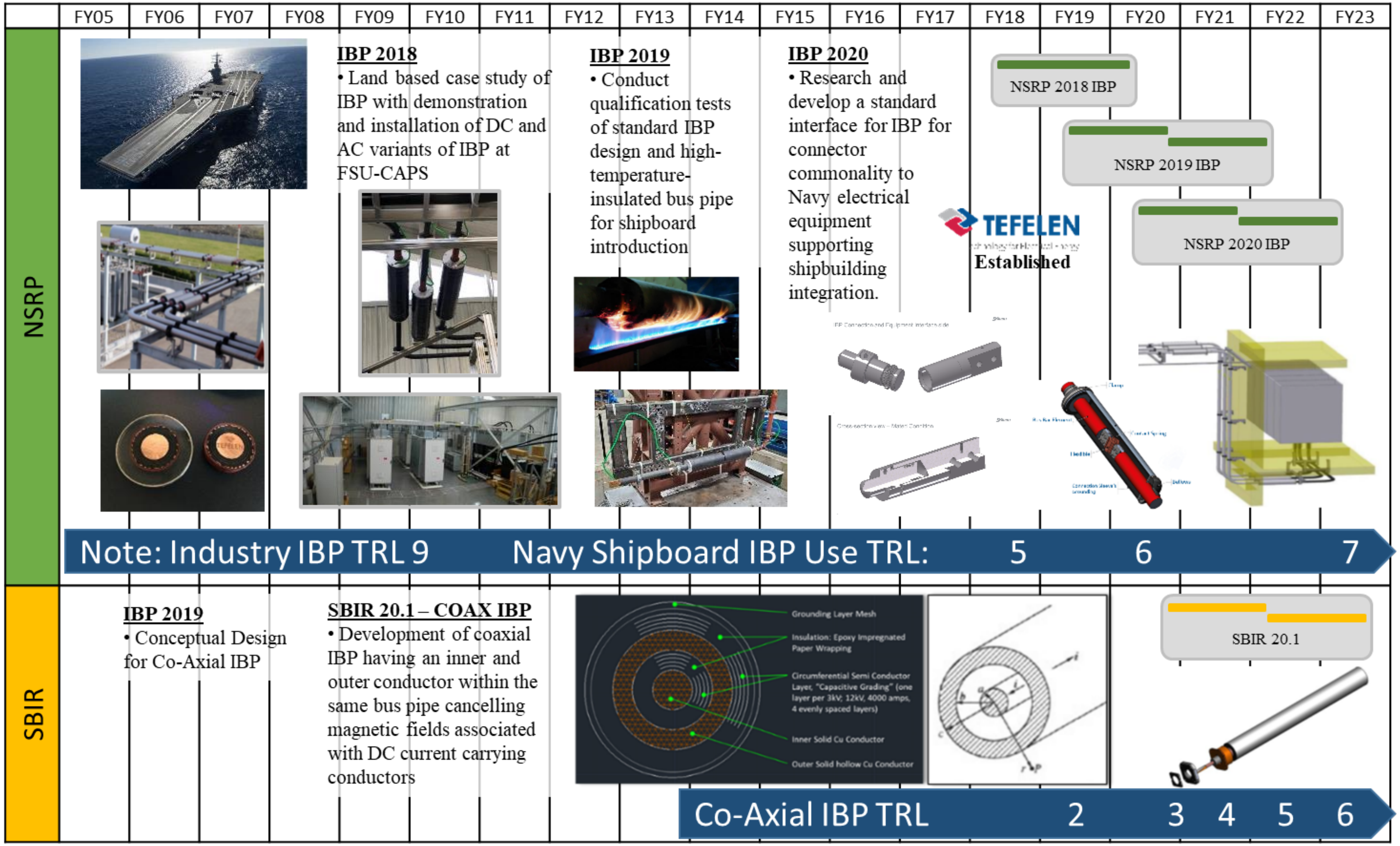
- Royal Caribbean Cruise Ship *Radiance of the Seas*
  - Delivered in 2000
  - 652.8m of IBP used in construction
  - 3.6kV / 3640 A
  - IBP was determined the only low risk option to deliver high power to the Azi pod drives





Connection part inside a power engine due to small space needed contrary to cable solution

IBP Capability Development



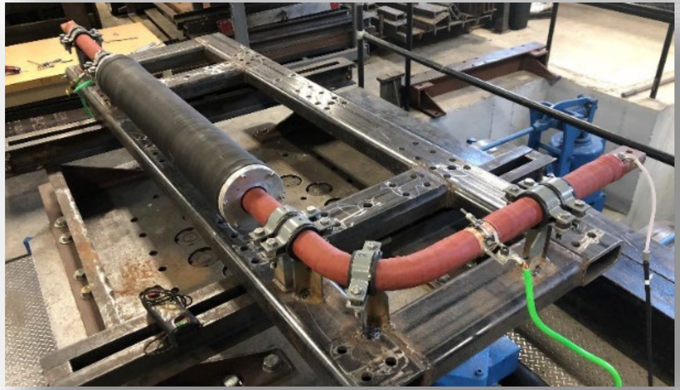
Current Project: NSRP RA 19-01 Testing and Draft Performance Spec

- Conduct IBP qualification tests for Navy shipboard use
  - Shock & vibration
  - Electrical characterization
  - Installation compliance
- Develop a draft IBP specification working alongside NAVSEA tech authorities
  - Working with NAVSEA 05Z33
- Develop a technology development roadmap for transition of IBP to shipboard installation
- Build a proof-of-concept coaxial IBP (CIBP) for direct current power distribution to offer a low magnetic signature solution
  - Proof-of-Concept straight section coaxial IBP successfully manufactured at low voltage and current (600V @ 400A)

Category	Test
Shock & Vibration	MIL-STD-901D Shock, Grade A, Medium Weight-Normal Attitude
	MIL-STD-901D Shock, Grade A, Medium Weight-Inclined Position
	MIL-STD-167-1 Vibration-Exploration Test
	MIL-STD-167-1 Vibration-Frequency Test
	MIL-STD-167-1 Vibration-Endurance Test
Electrical Characterization	Overall Test Guidance from Newport News Specification for Cables
	Shield Continuity
	Insulation Resistance (initial and after AC Voltage Withstand test)
	Partial Discharge (Corona) Level
	Conductor Resistance
	AC Voltage Withstand
	Basic Insulation Test (BIL) to IEC 60502
	Three Phase Bolted Fault to ANSI C37.23
	EMI Radiated to MIL-STD-461E (RE 101)
	Free Air Ampacity
Installation Compliance	Watertight Integrity
	Drip
	Shrinkage
	Gas Flame (3 hours)
	Acid Gas Equivalent
	Halogen Content
	Smoke Index
	Toxicity

Current Project: NSRP RA 19-01 Test Event Progress

- Conducted IBP qualification testing for U.S. Navy shipboard introduction
  - Installation Compliance 1 – Executed 2019
  - Electrical Characterization 1 (EMI) – Executed 2019
  - Installation Compliance 2 – Executed mid-August 2020
    - Gas Flame Circuit Integrity (3 Hour)
      - 5.4mA leakage current maximum reading at 8 kV_{LG} potential
      - No leaking or dripping of IBP resin
      - Little to no visible smoke produced for duration
    - Toxicity Index, Smoke Index, Halogen Content & Acid Gas Generation
  - Shock & vibration – Executed November 2020
    - Successfully utilized an in-situ modification to the connecting sleeve to prevent cantilevered motion, which caused initial failure to occur
  - Electrical Characterization 2 - Executed January 2021
    - Three phase bolted fault test (short circuit), continuous current thermal rise test, voltage withstand, and others executed successfully with good results



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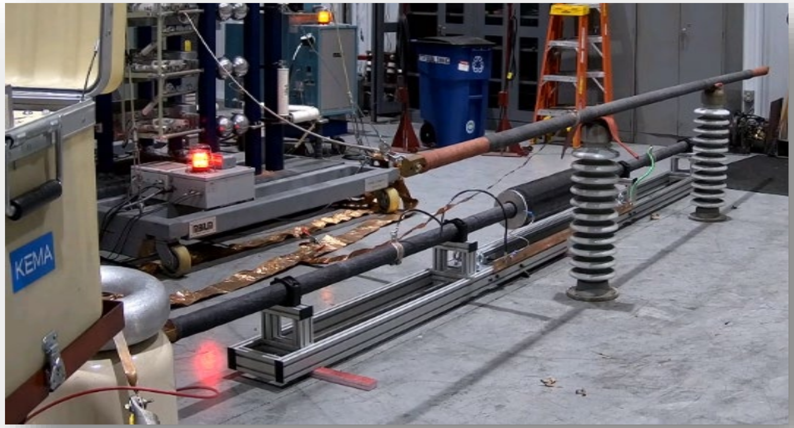
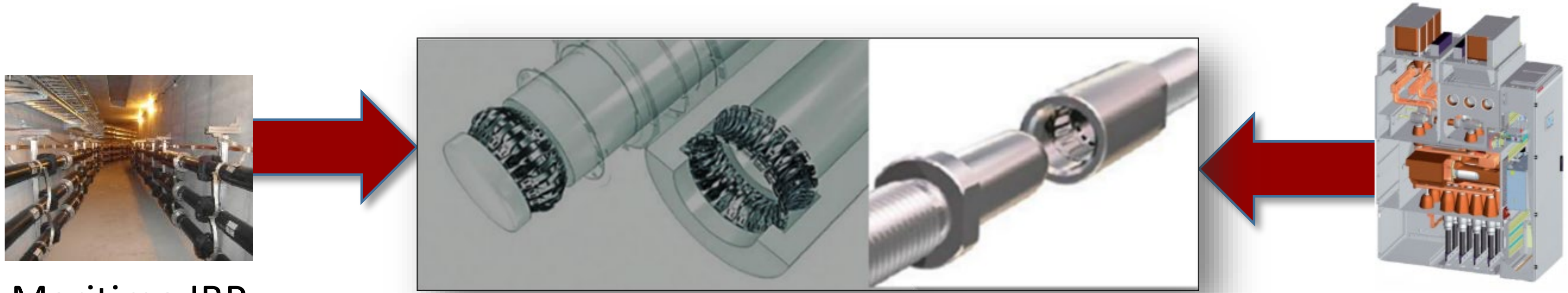


Current Project: NSRP RA 20-01 Common Interface with OEM Equipment

- Research and integrate common interface with Navy OEM equipment
- Minimize bolted connections in modularized IBP assembly design
- Support US Navy electrical systems integration
- Help improve their implementation and transition strategies
- Facilitated teaming of Navy stakeholders, industry, and shipbuilders



Maritime IBP Ships Power Distribution

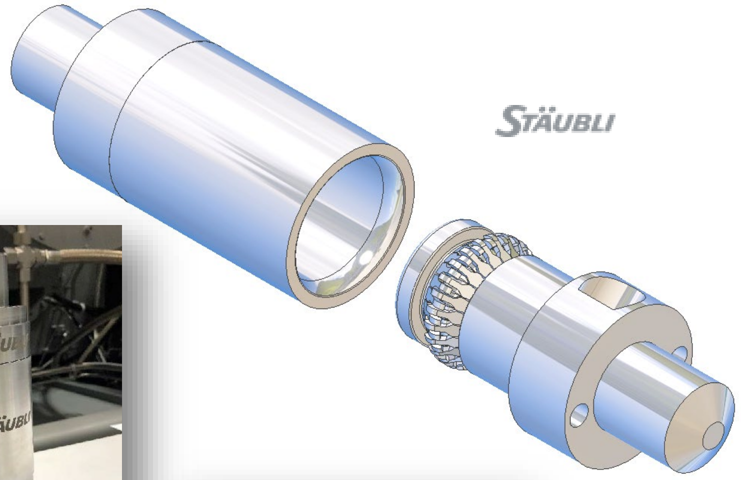
IBP to OEM Interface

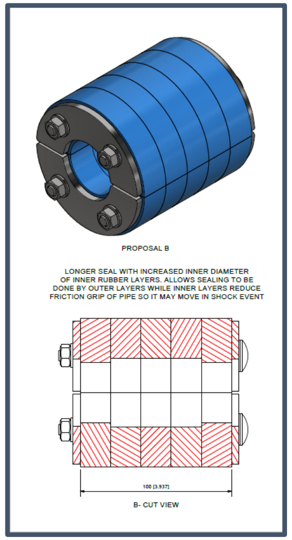
Focus of NSRP 20

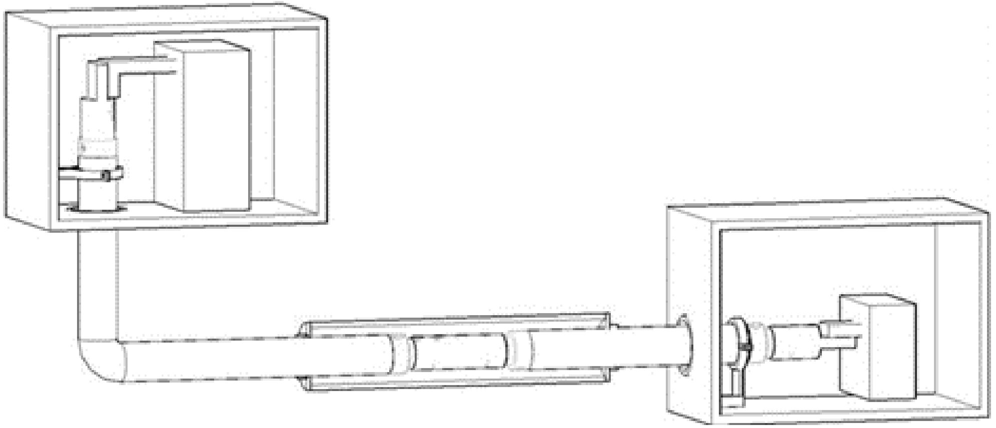
OEM Equipment

Current Project: NSRP RA 20-01 Common Interface with OEM Equipment

- Developing a common IBP connection interface with original equipment manufacturers (OEMs)
  - Shipboard configuration considered with interface design including deck, overhead, and bulkhead entries for both shock and hard mounted equipment
- Removing bolted connection to eliminate shipboard maintenance during life cycle of installations
  - Innovative connector components and penetration seal designs manufactured with partners
- Supporting modular ship construction

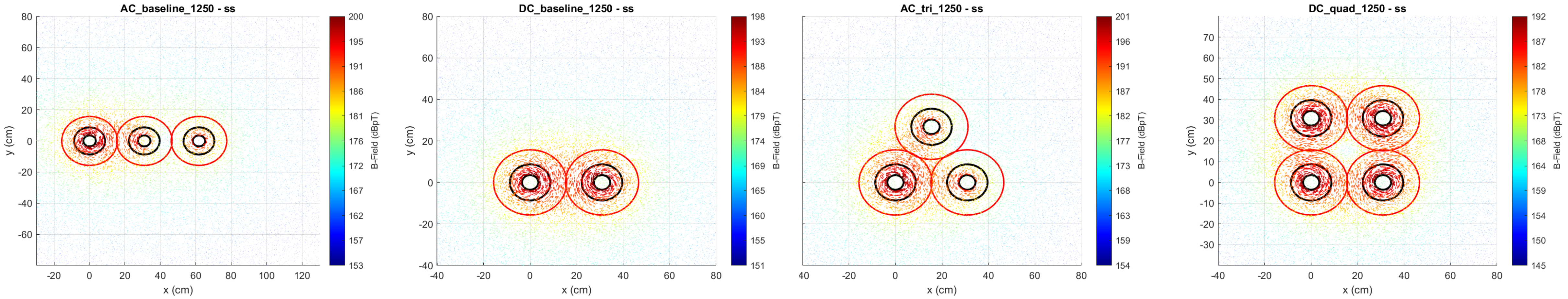






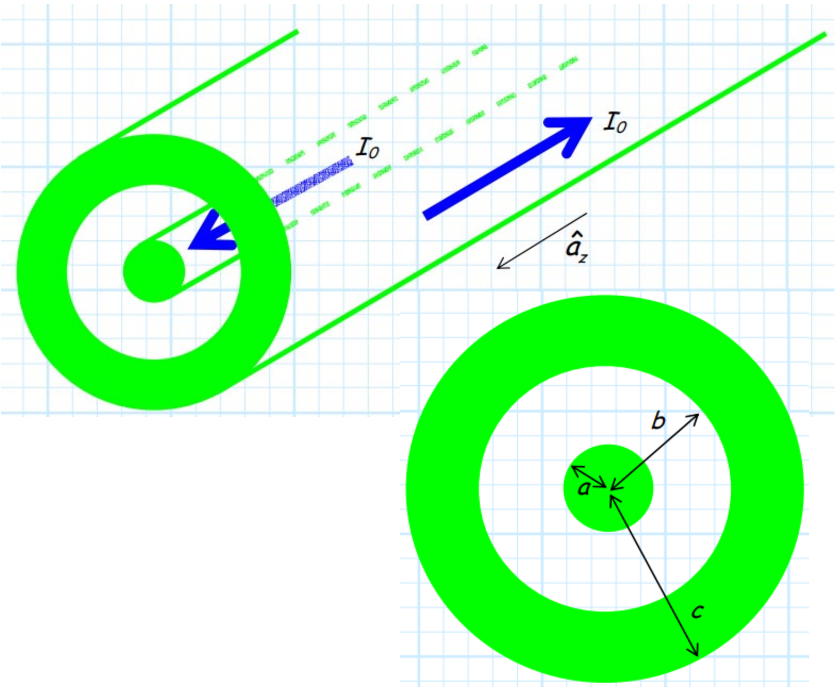
Current Project: NSRP RA 20-01 Common Interface with OEM Equipment

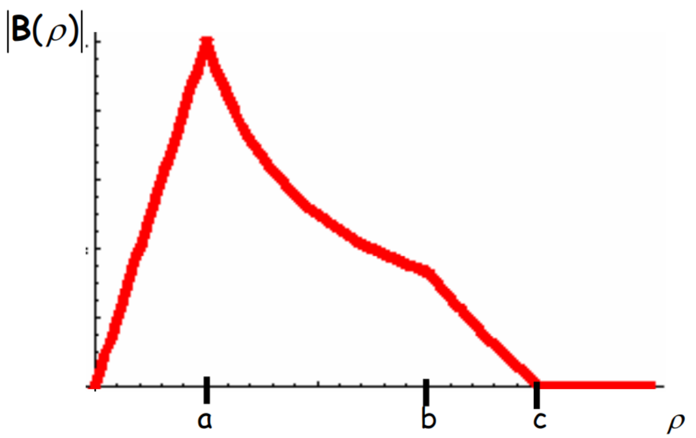
- Florida State University Center for Advanced Power Systems (FSU CAPS) conducted magnetic field modeling and simulation of various IBP installation configurations
  - Modeled results show consistency with tested AC Baseline. Testing other configurations to come.
    - RE101-1 (Army: 60 Hz -> 174 dBpT max)
    - RE101-2 (Navy: 60 Hz -> 148 dBpT max)
  - DC Baseline and Quad
  - AC Baseline and Triad
  - DC Coaxial



Current Project: NSRP RA 20-01 Common Interface with OEM Equipment

- Florida State University Center for Advanced Power Systems (FSU CAPS) conducted magnetic field modeling and simulation of various IBP installation configurations
  - Coaxial IBP: As long as the two opposing currents (i.e. current density) are equal, NO magnetic field is present outside such a design.





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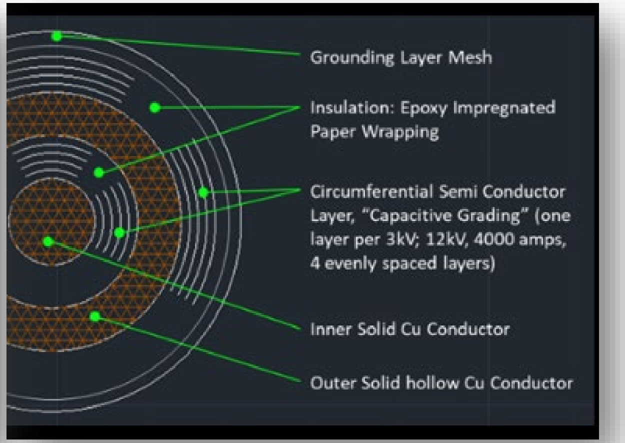
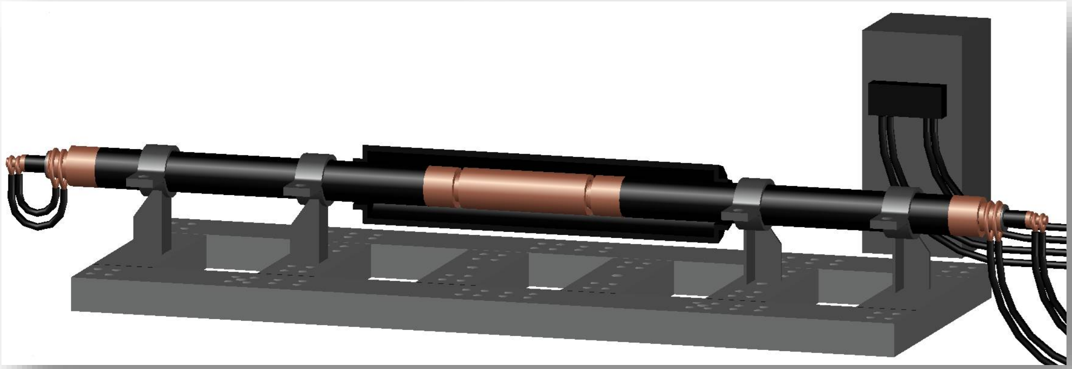
Current Project: SBIR N201-055 Coaxial IBP for Low Magnetic Signature MVDC Integration

- Objective: produce low magnetic signature solution for shipboard power distribution
- Coaxial IBP (CIBP) Design Concept
  - Bulkhead penetrations
  - End termination
  - Coupler connectors
  - Shock excursion mounting capability
- Investigating feasibility of ranges:
  - 6kV to 12kV
  - 2000A to 4000A
- 600V, 400A Coaxial IBP Proof-of-Concept manufactured on NSRP RA 19-01
- Pursuing an effort to design, prototype, and validate MVDC CIBP system design





Questions