Superconducting Partnership with Industry: Readiness Review Update

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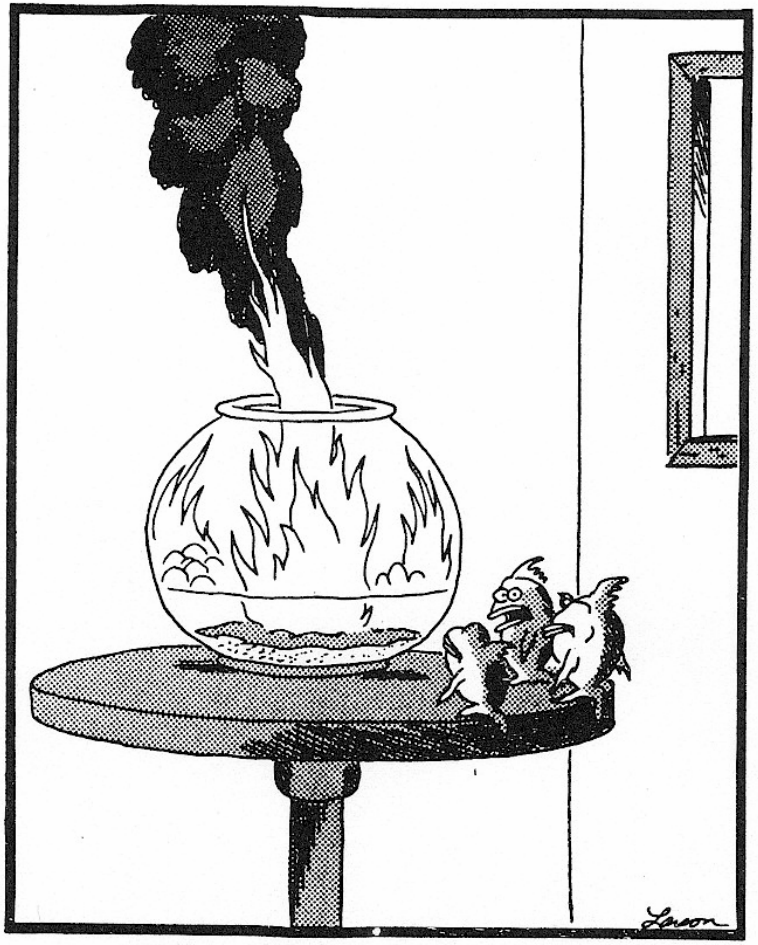
SPI Readiness Review Program

- **Goal: enhance the probability of successful completion of SPI projects.**
- **The major tool is phased readiness assessments:**
  - **Focus is on early identification and resolution of <u>technical</u> issues**
    - issues involving cryogenic temperatures + high voltage are a major concern
  - **Performed by a small group independent of the SPI team being reviewed (from national laboratories, universities, utilities, consultants).**
  - **Emphasis is on an objective technical review: in-depth but not an audit nor confrontational.**
  - **Report goes directly back to SPI team with a copy to DOE only.**



"Well, thank God we all made it out in time. ... 'Course, now we're equally screwed."

Budget: $200 K/year from DOE

$100 K - LANL (3 cable projects)

$100 K - ORNL (all other projects)

Anticipate at least 3 reviews over an SPI time cycle

- **Phase 1**:
  - Shortly after the SPI award (typically during conceptual design), hold initial meeting to review the technical proposal and identify those system aspects potentially likely to repeat past problems or lead to new ones.
  - Identify resources and activities needed to address any potential problems.
    - Is the team organization/resources sufficient to address technical challenges?
    - Are incremental scaled-models and/or prototypes planned to reduce technical risks?
  - Meeting length – about 1 day.

Anticipate at least 3 reviews over an SPI time cycle

- **Phase 2**:
  - Prior to hardware procurement/fabrication (in the final design phase), review those critical areas where redundancy or back-up systems may be needed or where team prior experience may be limited.
  - Potential problem areas are vacuum system integrity, high voltage details, partial discharge, heat loads, unanticipated heating sources, thermal stresses, transient mechanical loads, etc.
  - Requires 1-2 days on-site with discussion of:
    - Risk assessment plans to prevent potential problems and
    - component/subsystem testing to qualify system prior to assembly.
  - Non-disclosure agreements are signed by reviewers if required.

Anticipate at least 3 reviews over an SPI time cycle

- **Phase 3**:
  - Before system operation (for example, tie-in to the grid) do a final review to:
    - confirm that the prior review concerns have been resolved
    - inspect the as-built hardware.
    - At this stage safety systems (to protect personnel and hardware) could be reviewed in some detail.
  - Look over project test plans to ensure completeness (for example, generation of data for technical standards for new technology).

"'Be Careful'! All you can tell me is 'Be careful'?"

Peer Review Interface

- At the annual DOE peer review:
  - Each SPI team should present "readiness" preparation activities in accordance with the revised evaluation criteria.
  - Only non-proprietary information will be presented.
  - Peer reviewers provide feedback on readiness review program implementation (see response to comments by 2004 Peer Review panel in appendix)

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Relevant 2005 evaluation criteria distributed by Energetics

- **FY 2005 Performance/ FY 2006 Plans:** (SPI Panel: Included in this area for SPI projects is how the team is identifying, managing, and mitigating risks to a successful demonstration over the 2-year evaluation window.)

  FY 2005 Results: The presenter should identify major risks to a successful outcome, how they are mitigated (via a focused R&D program and/or redundancy, for example) and progress made during the last year on risk mitigation. (SPI Panel: Included in this area are results and recommendations from the phased SPI readiness reviews by the independent review team chartered by DOE.)

  Research Integration: Private sector presenters will describe how collaborations have accelerated their ability to overcome problems and mitigate risks in progressing towards commercial products and applications.

- **Bottom line**: How well is the team addressing technical risk mitigation?

FY 2003-2005 Results

- Four SPI readiness reviews in FY 2003
- Nine reviews in FY 2004:
  - Four HTS cable project reviews
  - Two MFCL reviews (at SuperPower)
  - HTS Open Geometry MRI review
  - Flywheel electricity system with superconducting bearing review
  - HTS Motor R&D in August
- Eleven reviews in FY 2005:
  - LIPA/Albany cable projects informal review in October at ASC
  - Ultera cable project later in October (Webex)
  - Albany Cable FDR in November 2004
  - Ultera Cable FDR in June 2005
  - WES/SP Transformer "lessons-learned" in May 2005
  - MFCL in November 2004 and June 2005 (integrated with TAB)
  - GE sequence of system mini-reviews (April – coil protection, insulation, winding and July 2005 – mechanical supports, EM shield, vacuum vessel)
  - LIPA Cable Interim Review: pending-July 2005
  - Continuing, informal contacts via phone conversations, e-mail, etc.&.... Also hold mini reviews remotely
- Readiness Review Teams provided valuable technical guidance to these SPI Projects.

SPI Readiness Review 2005 Results

Project	Lead Company	Status (Jul 2005)	Reviews Done	Review Plans
HTS transformer 5/10 MVA	WES/ SuperPower	HTS coils dissected	May 2005: lessonslearned	
HTS motor R&D	Rockwell	R&D	August 2004	FY 2006
Ultera long length HTS cable at AEP	Ultera (Southwire)	Procurement/ install	FDR: Jun 2005	Before operation FY 2006
Reciprocating magnetic separator	~~DuPont~~ AMSC	Magnet complete/ assembly	HTS solenoid CDR: 3/2003	Before operation
Superconducting flywheel	Boeing	Test 5 kWhr- 100 kW (Phase 2)	Oct 2003	TBD
HTS 100 MVA generator rotor	GE	Design/R&D/ fabrication	April and July 2005	PDR ~Fall 2005
Matrix fault current limiter	SuperPower	Design/R&D/ prototypes	Nov 2004 and June 2005	FDR - alpha prototype 2006
Long length HTS cable at LIPA	AMSC/ Nexans	Design/R&D/ procurement	Interim review 10/04	Interim: Jul 2006 FDR- fall 2006
HTS cable at Albany (NYSERDA)	SuperPower/ SEI	Procurement/ install	FDR Nov 2004	Before operation FY 2006

FY 2006 Plans

- **Continue focused reviews as projects complete final design, fabricate/install equipment and commission systems :**
  - At least one review per project is planned in 2006 and in 2007 as the present SPI projects proceed to initial commissioning.
- **We are encouraging all the SPI projects to develop risk identification and mitigation processes such as failure mode and effects analysis (FMEA) to manage risks.**
  - Will review each project's risk mitigation plans in 2006
- **In 2006 a web-site will be implemented that will have:**
  - lessons-learned from prior SPI projects
  - some general design guidance on high voltage, vacuum, etc. and
  - a place where SPI participants can post comments or questions and get feedback.

2006 Plans (continued)

- **Based on continuing issues with the performance of dielectric materials at cryogenic temperatures and at high voltage, <u>more emphasis is needed on R&D and design guidelines in this area for the grid-based SPI projects.</u>**
- **A High-Voltage Cryogenic Dielectric Workshop is planned on October 16, 2005.**
  - At IEEE 2005 CEIDP in Nashville, TN
  - Participation by each SPI team facing high voltage component qualification is encouraged
  - agenda includes overview talks on liquid nitrogen dielectrics, solid dielectrics, HV design practices, etc.

Research Integration

- **Since the reviews contain a large amount of proprietary material, the results and recommendations are typically shared only between the project being reviewed, the reviewers and DOE.**
- **The reviewers, to the extent possible, highlight or flag potential problem areas that they have learned from other project reviews.**
- **The proposed web-site and workshop will be a way to share generic lessons-learned and design information.**
- **Have engaged review staff from 2 DOE labs, 2 DOD labs, a university, NYPA and outside consultants to leverage expertise.**

Challenging Technical Issues

- Fault Currents - cables
  - These are driving cable designs
    - Asymmetric on 1st half cycle – maximum force
    - Integrated I^2 x time: maximum temperature T_{max}
  - Outside limits of experience
  - Not able to test fully
  - Some divergence on allowed T_{max}
- Thermal contraction - cables
  - LIPA cable will contract over 20 feet
  - Japanese 500-m, 77-kV, single-phase cable accommodated with offset section

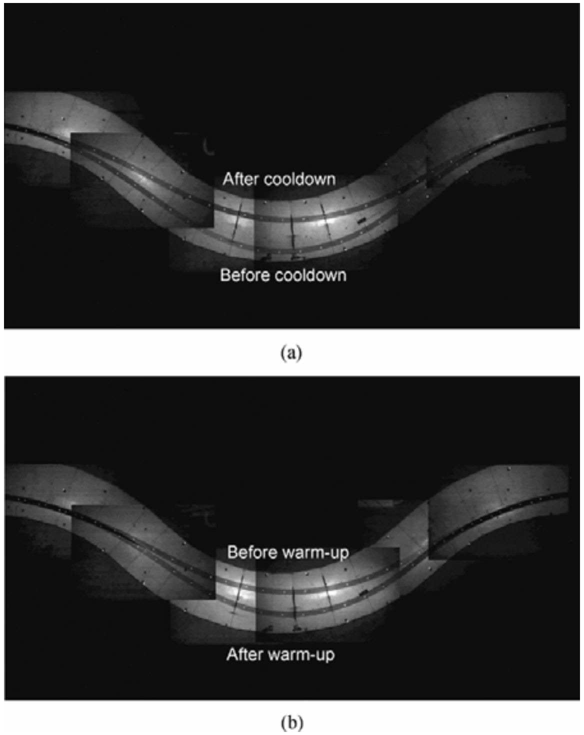
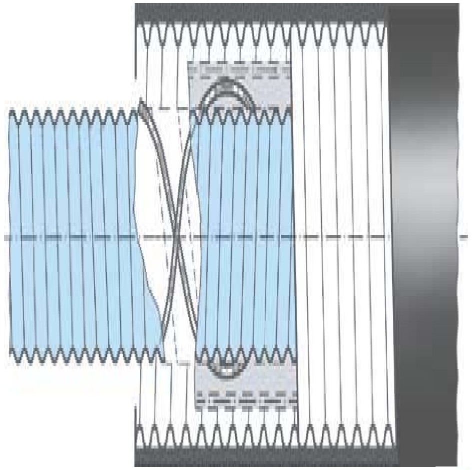


Fig. 7. Images of the behavior of the cable in the offset section. (a) Cooldown; (b) Warm-up

From M. Ichikawa et al., IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 15, NO. 2, JUNE 2005.

Challenging Technical Issues

- Cryostats – mostly cables
  - Damage on installation –recessed pump-out ports every 100-m and burst disks on ends only
  - Reliability proportional to 1/length
    - One manufacturer’s warranty on 100-m flexible cryostats is 2 years
      - A four km cable would have 40 of these sections; for example $(0.99)^{40}$ ~ 67% overall reliability
    - Is a 20-30 year “bury and forget” lifetime achievable (hydrogen out-gassing)?
  - Lightning impact
    - hits on buswork and adjacent ground strikes
    - voltage gradient inner/outer cryostat and exterior strike damage
  - Over-pressure protection on inner corrugated tube internal volume
    - Sub-cooled vs. 2-phase: lower capacity relief valves and burst disk sequence



Cryoflex transfer lines from Nexans

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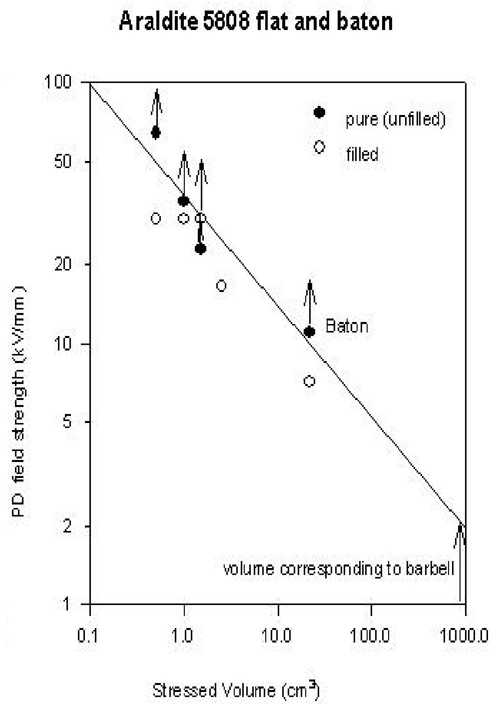
Challenging Technical Issues

- **High Voltage – limited materials and volume scaling**
  - "All 3 phases exhibited PD inception at very low voltages"
  - "Dielectric failure at less than rated voltage"
  - "All three phase sets failed in different places"
  - "Epoxies generally lose strength for large stressed volumes;
    - problem is worse when defects such as bubbles are present; scaling with volume generally not known for most materials"
- Data from R&D:



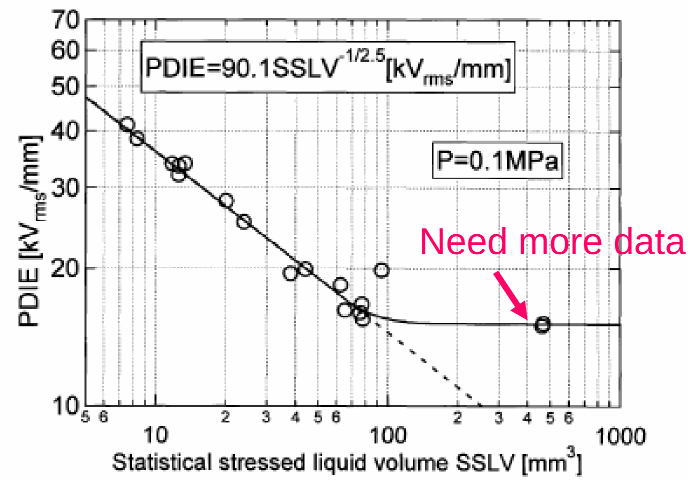
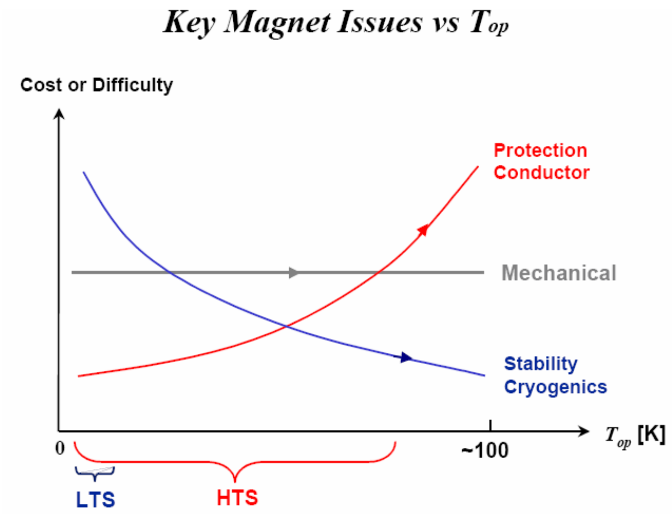


Fig. 2. PDIE as a function of SSLV at $P = 0.1$ MPa.

From N. Hayakawa et al. IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 15, NO. 2, JUNE 2005, pages 1802-1805.

Challenging Technical Issues

- **Quenching in HTS coils**
  - For HTS, stability margin is high: 10-100 J/cm^3 HTS vs. 10 mJ/cm^3 LTS
  - But normal zone propagation is low: 1 cm/s HTS vs. 1-10 m/s LTS
  - Quench event is rare, typically local, but credible and difficult to detect
  - Coil quench occurred in 1600 hp HTS demonstration motor (Reliance)
    - Rapid, catastrophic event
    - Permanent coil damage occurred in less than 10 seconds
  - Also quench damage in two prototype generator HTS coils
  - U. S. Air Force quench and stability workshop on Jan. 27, 2005, in Orlando



From Y. Iwasa, MIT

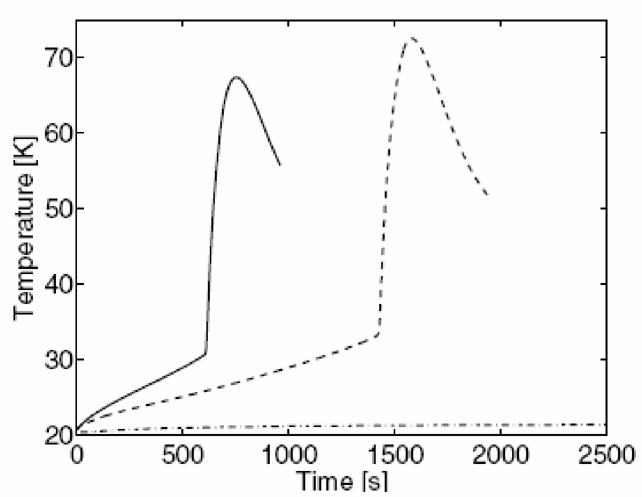


Figure 5. Measured temperatures at the bottom of the magnet at a constant operating current at $T_{op} = 20$ K: (dashed-dotted curve) $I_{op} = 110$ A, (dashed curve) $I_{op} = 160$ A, and (full curve) $I_{op} = 180$ A.

J. Paasi et al., Supercond. Sci. Technol. **13** (2000) 949–954.

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Appendix

Response to 2004 Peer Review Comments

Feedback from 2004 Peer Review-1

- Comment 1: Consider international reviewers on readiness review committee
  - **Response 1**: Cost, intellectual property sensitivities and scheduling difficulties preclude use of international reviewers. This could be considered on a case-by-case basis in the future for unique international expertise that is not available in US.
- Comment 2: The proposed implementation of a website for communication critical findings and recommended actions across the SPI teams is an excellent move.
  - **Response 2**: A web-site with "lessons-learned" and some basic design guidance is planned.
  - Insufficient funding.
  - Results of the readiness reviews are shared with the project being reviewed and DOE but will not be posted on the web-site due to proprietary information/IP concerns.

Feedback from 2004 Peer Review-2

- Comment 3: If not already, clear review criteria should be established to assist the SPI team in preparing for the review. When the reviews have discovered serious problems, this must be communicated to DOE.
  - **Response 3**: General criteria have been provided with an emphasis on risk identification and mitigation.
  - Serious technical problems with a project would be communicated to DOE in the written report from the readiness review team.
  - DOE would also expect the SPI project to report serious problems through official channels via DOE-Golden.
- Comment 4: A workshop on cryogenic electrical insulation might be a good example of expected success.
  - **Response 4**: A cryogenic dielectrics workshop is planned for October 16, 2005 just before the IEEE CEIDP meeting in Nashville.
  - Partial funding for this workshop has been granted by IEEE. The SCENet organization has agreed to send up to four experts from Europe.

Feedback from 2004 Peer Review-3

- Comment 5: Highlighting problem areas and sharing generic issues between projects without violating proprietary information has significant but limited effectiveness*.*
  - **Response 5**: We have not found a way to share solutions to generic issues without producing proprietary information/IP concerns.
  - We have been able to flag potential generic technical issues, especially between cable projects, for resolution by a project that perhaps was not aware of the severity of an issue.
  - We also review the resolution of that issue for adequacy (which may or may not be the best solution).
- Comment 6: The SPI program is a multi-million dollar program. It is important that this effort is properly funded. Compared to the SPI total funding and the number of projects, the funding is small. Should at least be three times what it is today.
  - **Response 6**: FY 2004 funding was $140 K.
  - FY 2005 funding is $200 K; this is just sufficient to do the number of required reviews and engage the appropriate reviewers. Outside reviewers typically need consulting fees and travel funded.

Feedback from 2004 Peer Review-4

- Comment 7: The review team leader should ensure that expertise exists on the team to cover all critical areas of an SPI project.
  - **Response 7**: This is done as much as possible
  - but due to the breadth of the technical areas: superconductivity, cryogenics, vacuum technology, materials, structural mechanics, power systems analysis, sensors, data acquisition, controls, etc. and limited resources we may not be able to cover all the relevant technical areas in a given review.
- Comment 8: An expert from utilities for the SPI cable, transformer, motor, FCL and generator should be added to the review panels.
  - **Response 8**: A reviewer for the three cable projects from NYPA with real world utility experience was added in September 2004 at no cost to the program.
  - Additional experts from industry (equipment manufacturers, HV components, etc.) will be used in FY 2005 as resources allow.
- Comment 9: Add an economic evaluation for the team to perform to judge for market penetration.
  - **Response 9**: This is outside the program scope and would dilute the objective which is risk identification and mitigation for SPI project success.

Feedback from 2004 Peer Review-5

- Comment 10: Care should be taken to avoid conflict of interest, e.g., the RRT leader is from ORNL and team leader for several SPI projects.
  - **Response 10**: Typically the readiness review team members have no involvement in the projects being reviewed. This is one reason why there is a separate review team for the cable projects.
- Comment 11: The Readiness Review process could lead to SPI teams becoming overly risk aversive. The consequence of that outcome is wringing out creativity from the projects. We should not follow “Nuclear QA/QC” footsteps.
  - **Response 11**: QA/QC is useful when inspection or control enhances quality and prevents defects.
  - Creativity has to be evaluated with risk and sometimes a more conventional approach is warranted: this has to be evaluated on a case-by-case basis.
  - In general, creative solutions need to be proven in a laboratory environment before they are promoted to a public setting like a demonstration on the grid.
- Comment 12: The RRT should have the authority to make some recommendations mandatory.
  - **Response 12**: The recommendations provided to the project and DOE are not mandatory as the review team is in an advisory role to DOE. SPI projects are cost-shared cooperative agreements.
  - In practice, this is not much of an issue as everyone wants the emerging HTS applications to work as intended.