Cryogenic Systems Review

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Cryogenic system design status

- Almost complete accounting of cold devices with heat load estimates and locations
  - **Some cold devices still not well defined**
  - **Some heat loads were very rough estimates**
  - **We should refine many of the heat load estimates in several areas**
- Cryogenic plant capacities have been estimated
  - **Plant sizes will be revised after heat loads**
  - **Main linac plant sizes likely to go down a little**
- Component conceptual designs (distribution boxes, end boxes, transfer lines) are needed
  - **Refine space requirements and cost estimates**
  - **Develop transfer line lengths and conceptual layouts**

What's new since Bangalore

- Main linac refrigerator arrangement
- Main linac lattice details
  - **Detailed cryogenic string lengths**
  - **String cryogenic end box slot lengths**
  - **Cryogenic unit lengths**
  - **Main linac vacuum segmentation**
  - **Drift space lengths and positions**
- RTML, source, and damping ring cooling schemes
  - **Heat load estimates**
  - **Cryogenic plant size estimates**
  - **Conceptual system maps with locations**
- Start of cost estimates for cryogenics for main linac, RTML, sources, and damping rings

Decisions still pending (and why!)

- Features for managing emergency venting of helium need development effort
  - **Large vents and/or fast-closing vacuum valves are required for preventing overpressure on cavity**
  - **Large gas line in tunnel?**
- Damping ring gas and cryogen distribution systems need conceptual designs
- Beam delivery system cooling scheme effort has just been started
- Helium inventory management schemes need more thought
- Consider ways to group compressors, cooling towers, and helium storage so as to minimize surface impact

Cryo system major cost drivers

- Main cost drivers
  - **Main linac cryogenic plants (cold boxes and compressors) (43%)**
  - **String end boxes (11%)**
- Relation to the current design -- plant cost basis
  - **Recent Linde ILCTA plant estimate provides a 1.53 factor for scaling up 1998 CHF to 2006 $ from CERN data provided in, "Economies of Large Helium Cryogenic Systems: Experience from Recent Projects at CERN," S. Claudet, et. al., Advances in Cryogenic Engineering, Vol 45, pg 1301, Plenum Press, 2000.**
  - **For comparison, manufacturing labor costs have increased since 1998 by 1.24 (Dept of Labor, Bureau of Labor Statistics), Carbon steel up by 1.5 to 1.8 (http://metals.about.com/), Stainless steel up by 1.44 through 2005 (CRU steel price index, http://www.cruspi.com/).**

Cryo system major cost drivers

- I asked Linde Cryogenics about our scaling of costs from their ILCTA-NML test plant estimate. They suggest that our simple scaling by the 0.6 power may underestimate the large plant costs.
    - The refrigeration requirements for the SRF test facility are relatively small and simple compared to the refrigeration requirements and complexity of the ILC project
    - The recycle compressors & the vacuum screw compressors as used for the SRF test facility are basic Kaeser compressors. Industrial compression systems for recycle and vacuum compression for ILC are much higher in price!
    - Large refrigeration systems, as required for ILC, need to be distributed in two or more (shielded) cold boxes. This requires additional equipment and transfer lines.
    - For large systems, usually more instrumentation and sophisticated control mechanisms are required by the costumer.
    - All these points are cost drivers which need to be carefully reviewed and taken into account for extrapolation for larger refrigeration systems.
- My judgment based on all these considerations (Linde comments, material prices, etc.) is that the conversion factors that we use in our cost spreadsheet are appropriate.
- An industrial cryogenic plant cost study would be useful, but it would not be complete before the end of the year. Do as part of TDR effort for both technical and cost input.

Cost Roll-Up Status

- Main linac and RTML cost estimates complete
  - **But some rather rough estimates could be refined**
  - **Particularly, distribution and tunnel box concepts need more conceptual design work for better cost estimates**
- Source and RTML cryogenic systems are combined with costs attributed by ratio of number of modules in each
- Damping ring plants have been sized and estimated
  - **But damping ring distribution still needs a conceptual design in order to do a cost estimate**
- Beam delivery cryogenic system concepts are just now being addressed

Cost Roll-Up Status (2)

- 50 of 72 WBS lines are filled in
  - **Perhaps a few more lines will be added**
  - **So call it 50/80 or 62% complete**
- Empty lines are almost all in distribution systems (transfer lines, cryogenic boxes, local controls) for areas outside of main linac
  - **Need more information in a few cases, but mostly time to develop better definitions of these items**
- Empty lines represent less than 10% of the total ILC cryogenic system costs
  - **Estimate based on scaling from main linac system**

Possibilities for Cost Reductions

- Cryomodule / cryogenic system cost trade-off studies prior to Valencia workshop
  - **Additional 1 W at 2 K per module ==> additional capital cost to the cryogenic system of $4300 to $8500 per module (depending on whether we scale plant costs or scale the whole cryogenic system). (5 K heat and 80 K heat are much cheaper to remove than 2 K.)**
  - **Additional 1 W at 2 K per module ==> additional installed power of 3.2 MW for ILC or $1100 per year per module operating costs.**
  - **Low cryo costs relative to module costs suggest that an optimum ILC system cost might involve relaxing some module features for ease of fabrication, even at the expense of a few extra watts of static heat load per module.**
    - For example, significant simplification of thermal shields, MLI systems, and thermal strapping systems

Possibilities for Cost Reductions (2)

- Another possible system-level cost reduction to be analyzed before the Valencia workshop:
  - **Overcapacity and uncertainty factors for plant sizing for main linac cryogenic plants should be reviewed**
    - Now a net overall factor of 1.7 on cryogenic plant size
  - **Cryo capacity = Fo x (Qd + Qs x Fu)**
    - Fo=1.4 is overcapacity for control and off-design operation
    - Fu=1.5 is uncertainty factor on load estimates, taken on static heat loads only
    - Qd is predicted dynamic heat load
    - Qs is predicted static heat load
  - **What are the uncertainties on static and dynamic heat loads? Can we formulate a quantitative basis for Fu? Should an Fu also be applied to Qd?**
  - **How important is it cover or exceed predicted cooling requirements? Would like some input here.**

Plans and Goals

- This workshop
  - Continue to collect information from the various areas and technical systems about what devices are cold, where these devices are in ILC, and information regarding heat loads
- Between this and the Valencia workshop
  - More precise concepts for cryogenic boxes and transfer lines
  - Collect more data on recent cryo costs (e.g., SNS) in order to refine cost estimates
  - Should increase effort level to at least 1 FTE from only about half FTE

Towards the TDR

- Continue to refine heat load estimates and required plant sizes
- Refine system layout schemes to optimize plant locations and transfer line distances
  - **Particularly for the sources, damping rings, and beam delivery system**
  - **Develop cryogenic process, flow, and instrumentation diagrams and conceptual equipment layouts**
- Develop conceptual designs for the various end boxes, distribution boxes, and transfer lines
- Refine liquid control schemes so as to understand use of heaters and consequent heat loads
- Consider impact of cool-down, warm-up and off-design operations
- Contract with industry for a main linac cryogenic plant conceptual design and cost study