ILC Engineering Design Phase
WPs for Cryomodule, Cryogenics and Vacuum (DRAFT)
(Oct 24, 2007)

CRYOMODULE

1. **Cryomodule Documentation and Standards for Manufacture and Testing** **A**

    Duration: 2007-2009

    IFNF-PISA
    IFNF-Milano/DESY(XFEL)
    FNAL
    KEK

    - Cryomodule design specification (component specification, alignment and machining)
    - Cryomodule interface documentation (for cryomodules from three regions and groups)
    - Documentation of motivations for all costly precision machining operations.
    - Standards for cryomodule manufacture (HP gas regulation, ANSI/ASME/ISO, etc)
    - Quality assurance plan

2. **Cryomodule Components Development and Design**
    - Cooling pipe design (this study will be done with Cryogenic group) **A**

        Duration : 2007-2008

        KEK
        FNAL
        INFN-Milano/DESY

        1. Calculation of pressure drops for the pipes after designing the complete cooling channels in the cryomodule with consideration of cooling methods.
        2. Defining the maximum pressure of the channels (need the information from cavity group).
        3. Defining with thermo-mechanical calculations the cooling procedures for a rapid cool-down that prevents excessive deformations on all internal components of the cold mass.
        4. Impact of the new piping on the module transverse cross-section, control of interferences due to possible redistribution of the piping.

- Developing and evaluating the thermal model with and without 5K thermal shield (this study will be done with Cryogenic group) **A**

  Target date : 2007-2008
  KEK
  FNAL
  INFN-Milano

  1. Thermal calculation for these two models.
  2. Evaluation of the production cost and operation cost.
  3. Include considerations on different pipe sizing requirements
- Design of cavity string (done with Cavity group) **A**

  Target date : 2007-2009
  INFN-Milano
  INFN-Pisa
  FNAL
  KEK

  1. Finalization of the design of a consistent helium jacket-tuner design fulfilling the ILC specifications and interfaces with module and investigations of materials (Ti or SUS) (with cavity group)
  2. Development of bimetal junction (Ti-SUS junction for Ti jacket, and Nb-SUS junction for SUS jacket).
  3. Design of the interface between cavity-jacket-tuner package and cryostat components.
  4. Study of alignment method of cavities in the cryomodule.
  5. Design and thermal calculation of heat interceptor for input coupler and tuner driver
  6. Electromagnetic Slow and Fast Tuner **(FNAL)**
- Design of assembly of the quadrupole and corrector package with BPM supported from center post (this work will be done with Magnet group) **A**

  Target date : 2007-2009
  FNAL
  KEK
  CIEMAT (Spain)

  1. Quadrupole package design in the cryomodule including magnetic shield (with Magnet group).
  2. Support design of the quadrupole package.

3. Quadrupole and corrector leads.

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4.

- Special cryomodule development C

  Target date : 2010

  FNAL

  1. Conceptual design of separate quad cryostat
  2. Quadrupole package doublet

- Magnetic shielding system **A(design)B(verification)**

  Target date: 2007-2009

  KEK

  FNAL

  IFNF-Milano

  1. Design of the inner and outer cavity magnetic shield w.r.t. the helium jacket.
  2. Optimization of the demagnetization of the vacuum vessel.

- Design of inter-connection between components **C**

  Target date : 2010

  INFN-Pisa

  FNAL

  KEK

  1. Design of the intercavity connecting flange and bolting arrangement, details the spacing

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  2. Design of the interconnection between Module-to-Module

- Vibration analysis of the quad and cavity support structure and comparison with measurements **A**

  Target date : 2008 (design) 2010 (verification of design)

  INFN-Pisa

  FNAL

  KEK

  DESY

- Instrumentation and Vacuum **C**

  Target date : 2007-2010

  FNAL

  KEK

  INFN-Milano

ANL

1. Design of instrumentation for installation into the cryomodule
2. Design of the vacuum components and pump system in the cryomodule (with Vacuum group and Cryogenic group)
3. Development of inexpensive gate valve (with Vacuum group)

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3. **Optimization of the Cryomodule Assembly with Designing Components (for cryomodule in three regions)** **B**

   Target date : 2009
   IFNF-PISA
   IFNF-Milano/DESY
   FNAL
   KEK

- Documentation of procedures and tests of the cryomodule assembly. Design and construction of assembly fixtures
  1. Cold mass string assembly in the clean room.
  2. GRP assembly (as done currently at Zanon).
  3. Assembly of cold mass with GRP. The cold mass includes the cavity string.
  4. Alignment of cavity string and alignment transfer to the GRP
  5. Cold mass transport.
  6. Heat shield connection.
  7. Insertion of the cold mass into vacuum vessel and final alignment.
  8. Realignment of string in the vessel using the GRP references and alignment transfer to the vessel.
  9. Cryomodule transport.
- Design of the assembly facility

4. **Cryomodule Global Design with 3D and 2D CAD on EDMS** **A**

Target date : 2008-2010
FNAL
INFN-milano
INFN-Pisa
LAL-Orsay
IHEP
KEK
DESY

5. **Design of Cryomodule Test** **C**

Target date : 2010 early
FNAL
KEK
DESY

- Defining the test items and planning the schedule of the cryomodule test (for three regions and with the Cavity group)
- Defining the requirements for the test stands
- Design of the cryomodule test facility

6. **Shipping Study of Cryomodule** **C**

Target date : 2010
IFNF-PISA
IFNF-Milano/DESY
FNAL/Jlab
KEK

- Definition of maximum allowed loads and identification of the critical issues and components that would require additional ad-hoc stiffening during transport
- Definition of transport fixtures
- Collecting data from SNS

7. **Cost reduction issues** **A**

Target date : 2008

IFNF-PISA

IFNF-Milano/DESY

FNAL

KEK

- Critical review, at the system level, of all tolerance specifications in the subcomponents, with the intention to eliminate any precision machining not carefully motivated.

~~7.~~8. **Cost estimation of the cryomodule** **C**

Target date : 2010

FNAL

KEK

DESY

INFN-Milano

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CRYOGENICS

1. **Heat loads.**
   - Heat load estimates and uncertainty and overcapacity factors all need refinement.
   - We should quantitatively evaluate uncertainties for dynamic and static heat at each temperature level and incorporate those uncertainties into the plant sizing spreadsheets.
2. **Plant design.**
   - An ILC refrigeration study should be done with industry as soon as funds are available. Integration of the refrigeration cycle with the required flows, pressures, and temperatures in ILC requires some study.
   - Changing heat loads at all temperature levels affect cold box operation, so some special features and control strategies will have to be implemented.
   - Control strategies for temperature and flow in other circuits such as thermal shields will also require some study due to the very long time constants.
   - Cryogenic unit pressure drops, temperature rises, and flow rates need to be re-evaluated and integrated with cryogenic plant cycles.
3. **Maintenance, repair, and reliability**
   - Methods and cost for providing redundancy, such as load sharing among cryogenic plants, should be investigated.
   - Warm-up and cool-down of the 2.5 km long cryogenic units need to be studied.

- Segmentation of the cryogenic unit for warm-up and repair of short sections might be desired. A feasibility study on segmentation has to be carried out with corresponding impacts on filling factor, cost, operation and reliability.

4. **Emergency venting.**
   - Protection from over pressurization due to abnormal operating conditions, such as loss of beam tube or insulating vacuum, power outage, etc., needs to be studied.
   - Vacuum isolation, lengths of vacuum units, and fast-acting vacuum valves all need further investigation.
   - All the cryogenic circuits need study. The 2 K cavity-cooling circuit is most critical due to the low pressure limits imposed by the niobium RF cavities, but the thermal shield flow circuits may be difficult to protect due to the relative high initial pressure.
5. **Grouping major surface components.**
   - The cryogenic system, particularly compressors and associated cooling towers, will be one of the most visible parts of the ILC. Studies of how to minimize the surface impact by means of consolidating as much of the cryogenic system as possible on the central campus and other areas would be valuable.
   - These studies could look at pipe sizes required for grouping compressors, transfer line sizes for grouping 4 Kelvin refrigeration with distributed 2 K cold boxes, etc.
   - Cost tradeoffs for these options should be evaluated.
6. **Mitigation of oxygen deficiency hazards needs to be studied.**
   - Interface with CF&S, all three regions, addressed locally
7. **Cryogenic box design (should include significant designer time).**
   - We need conceptual design layouts and 3-D models for the many cryogenic boxes in ILC. Cryogenic distribution design should be a major EDR effort. These component designs feed back to alcove sizes as well as to cryogenic system design and costs.
   - Interface with DESY for XFEL input.
8. **Liquid control.**
   - Control of the 154 meter long strings of 108 helium vessels filled by means of series flow will present some unique problems due to the large dynamic heat loads and due to very long time constants.
     - I. Dynamic heat loads much larger than static will result in large 2 Kelvin heat load changes with changes in RF power.
     - II. Electric heaters will be required to help offset the impact of sudden changes in dynamic heat loads.

- Electric heaters should be sized, a conceptual design developed (where are the heaters, how are they powered, etc.), and their impact on total heat load evaluated.
- The two-phase superfluid helium flow pattern and cooling limitations with respect to slope and string length should be studied and validated.

9. Cryomodule thermal optimization.

- Costs of the cryomodules per meter are much larger than the costs of the cryogenic system per meter. Optimization studies for capital and operating costs should consider tradeoffs of cryomodule complexity with heat loads.
- For example, thermal shields, thermal intercepts, and MLI can perhaps be simplified for efficient production.
- At a minimum, the 5 Kelvin thermal shield bridges at cryomodule interconnects can probably be eliminated.

10. 2 K heat exchangers.

- Sub-cooling heat exchangers with capacity 10 times larger than the present state of the art have to be developed. Subcooling to 2.2 K by heat exchange with the returning, saturated 30 mbar pumped flow will not be done locally in tunnel feed boxes as in LHC but centrally at the cryogenic plant. (This is another possible collaborative study with industry.)

11. Compliance with engineering standards for the associated component design pressures

- Study with respect to cost, operability and reliability.
- For example, a plan to handle (non-) compliance with the ASME boiler and pressure vessel code should be developed.
- Regional issues may differ, also would like common set of standards.

12. Sources, including the undulators, will require cryogenic design work.

- Cryogenic system design for the sources, including connections to main linac cryogenics, special end and distribution boxes, transfer lines, undulator cryogenics, and special cryomodule cooling.
- Requires interfacing with area people.

Damping Rings and Beam Delivery System Cryogenics

13. Damping ring cryogenic system needs some very fundamental design work.

- We need a conceptual flow schematic, cryogenic distribution plans, concepts for cool-down and warm-up, and a re-evaluation of system heat loads. Like for main linacs, cryogenic distribution design is a major effort. This work would be done in close collaboration with the damping ring area leaders.

14. Beam delivery cryogenic system needs some very fundamental design work.

- We need a conceptual flow schematic, cryogenic distribution plans, concepts for cool-down and warm-up, and a re-evaluation of system heat loads. Like for main linacs, cryogenic distribution design is a major effort. This work would be done in close collaboration with the beam delivery system area leaders. Requires interfacing with area people.

Vacuum Systems

15. Main Linac vacuum system design

- Particularly for the beam pipe and insulating vacuum, vacuum design is closely tied to the cryogenic system design since the various services (valves, instrumentation, vacuum breaks, etc.) are incorporated into cryogenic service boxes of various types. Often distances between features are a combination of cryogenic and vacuum requirements.
- We anticipate that the RDR leaders for ILC vacuum will continue their involvement during the EDR phase.
- Nevertheless, there is considerable design work to be done, and we list Main Linac vacuum here as one more work package for which we are interested in expressions of interest.

16. Vacuum system design for the RTML beam transport systems.

- RTML beam transfer lines from damping rings to main linac are very long beam transport lines requiring high vacuum. Materials, surface treatments, and pumping concepts need development.

CRYOGENICS (continued)

17. RTML cryogenic system

- RTML cryogenic system needs some very fundamental design work.
- We need cryogenic distribution plans, concepts for isolation from main linac, cool-down and warm-up, and a re-evaluation of system heat loads.
- Like for main linacs, cryogenic distribution design is a major effort. Some isolated magnets might best be cooled locally, as opposed to being connected to

refrigeration via transfer lines.

- This work would be done in close collaboration with the RTML area leaders.

18. EDR cryogenic and vacuum system management

- Provide a complete and integrated cryogenic system and vacuum system design.
- Manage EDR cryogenic and vacuum system work packages, monitor progress, coordinate activities among work packages and with other areas as required.

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