Status of the LCLS-II Cryogenic Distribution System

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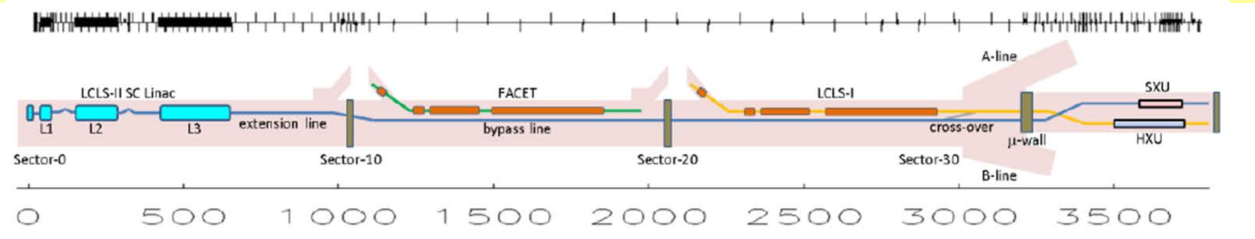
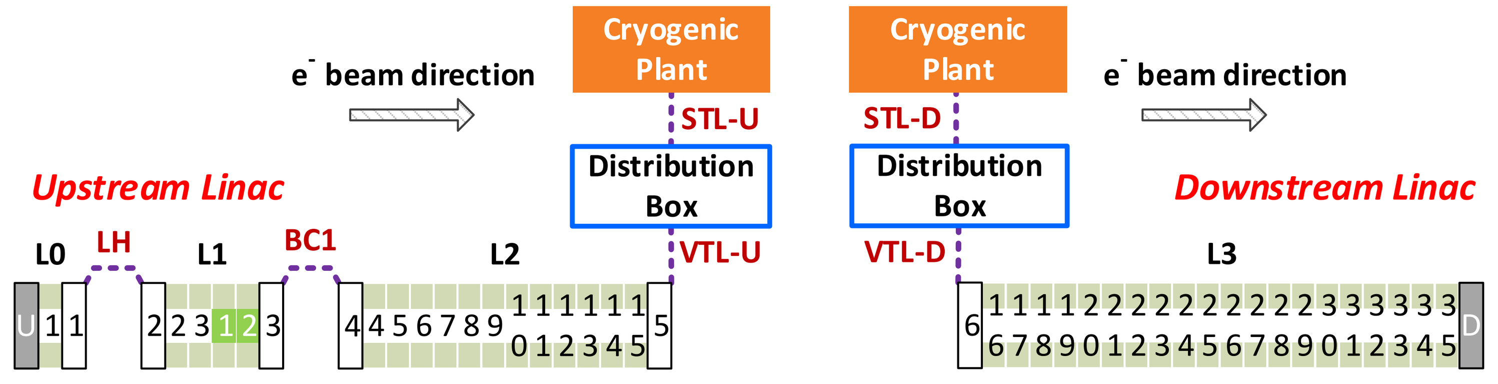
Introduction

Abstract. The LINAC Coherent Light Source II (LCLS-II) located at SLAC National Accelerator Laboratory (SLAC) in Menlo Park, CA, is a U.S. Department of Energy project tasked to design and build a world-class x-ray free-electron laser facility for scientific research. The Linac has superconducting radio frequency cryomodules that are connected to the cryogenic plant by the Cryogenic Distribution System (CDS), which consists of distribution boxes with heat exchangers and reliefs, feed caps, end caps, and surface, vertical, and bypass transfer lines. The CDS components were designed and built to specification by industry. The components have been delivered and their installation at SLAC will be discussed. The as-built relief system design will be presented, showing minimization of relief inlet pressure drops while meeting capacity requirements. The relieving flow pressure drops along the lengths of the CDS to centrally located reliefs at the distribution box were analyzed to satisfy Pressure Vessel and Process Piping Code criteria to ensure relief performance. The sub-atmospheric 2 K circuit relieving approach will be discussed, which includes a three-way diverter isolation valve suitable for sub-atmospheric service. The component anchoring load design approach and installation into concrete floor will be discussed. This addresses loading, including seismic loading, along the component's load path to floor anchoring system.



LCLS-II, in the first 650 m of SLAC Linac tunnel

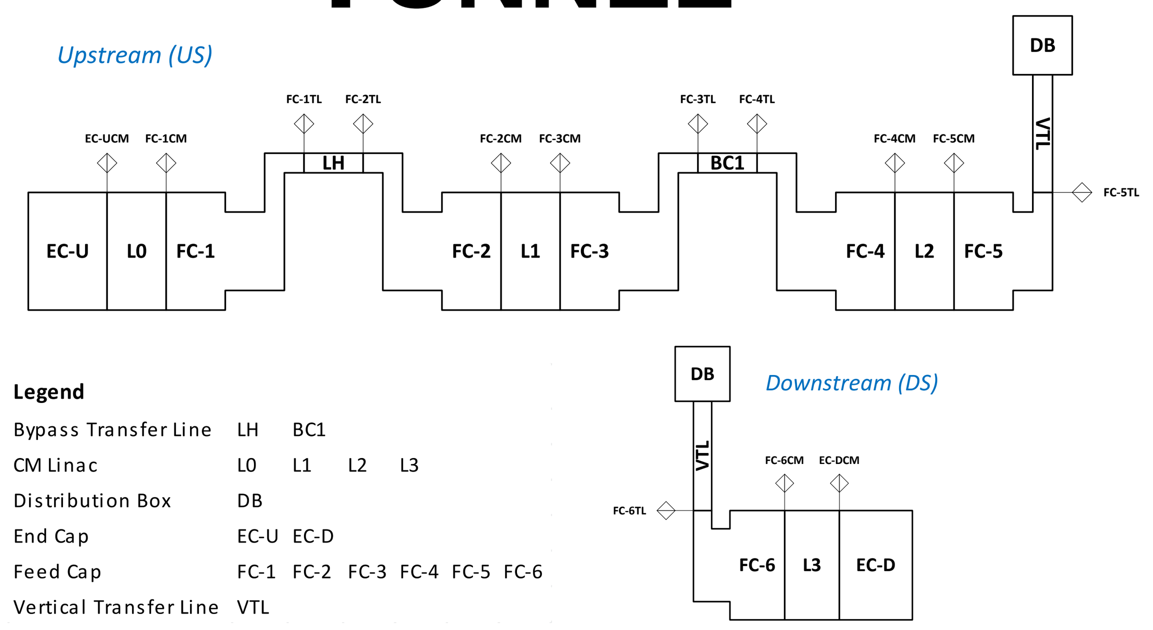
- Cryogenic Distribution System (CDS) supports two independent cryogenic Linac strings with
  - fifteen 1.3 GHz Cryogenic Modules (CM) & two 3.9 GHz CMs on the upstream (US), 390 m
  - twenty 1.3 GHz CM on the downstream (DS), 287 m
- CDS consists of
  - Distribution Boxes (DB)
  - Transfer Lines and bypasses, horizontal and vertical (TL)
  - Feed Caps (FC)
  - End Caps (EC)
- CDS has six cryogenics processes lines for Cryomodule cooling, intercepts, and thermal radiation shield
- Components are designed and built by industry from specifications
- System will have two cryogenic plants, each with equivalent refrigeration capacity of 18 kW at 4.5 K



CDS Process Line Operating Parameters

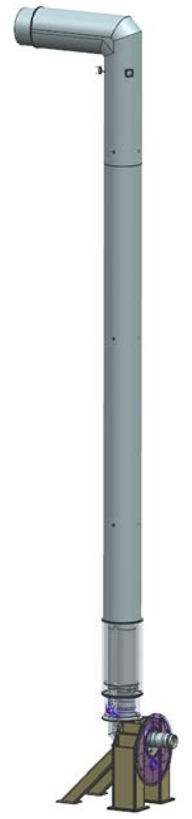
	Line A	Line B	Line C	Line D	Line E	Line F
Purpose	CM cooling supply	CM subatm. gas return	Low temp. intercept supply	Low temp. intercept return	High temp. shield supply	High temp. shield return
Nominal Temp [K]	4.5 to 2.5	2.0 to 3.5	5	8	35	55
Nominal Pressure [kPa]	320	3.1 to 2.7	320	280	370	270
Nominal pipe size [DN]	50	250	50	50	50	50
Nominal mass flow [g/s]	100	100	30	30	80	80
Maximum mass flow [g/s]	215	215	37	37	146	146
Pressure drop budget [kPa]	100	0.4	100		150	
Heat load budget [W]	290		280		4350	

Tunnel



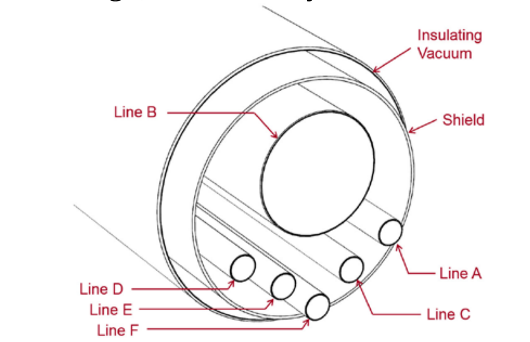
VERTICAL TRANSFER LINE

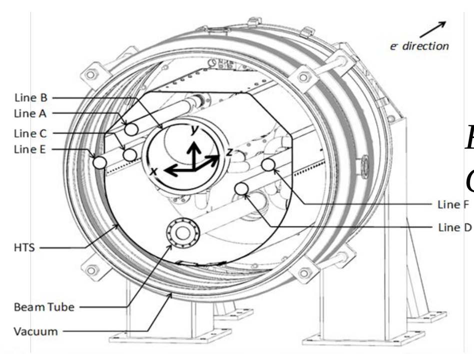
- Through two 0.91 m dia. x. 7.6 m long penetrations
- Made by ***Demaco*** (Netherlands)



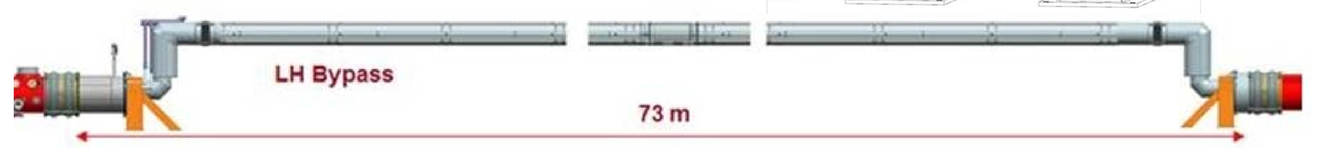
HORIZONTAL TRANSFER LINE

- Independent cool-down and warm-up of each circuit and shield
- Ceiling supports slide for vacuum jacket shrinkage if rupture of cryogenic circuit
- Made by ***Demaco***
- Surface Transfer Lines fundamentally similar in design, also made by ***Demaco***





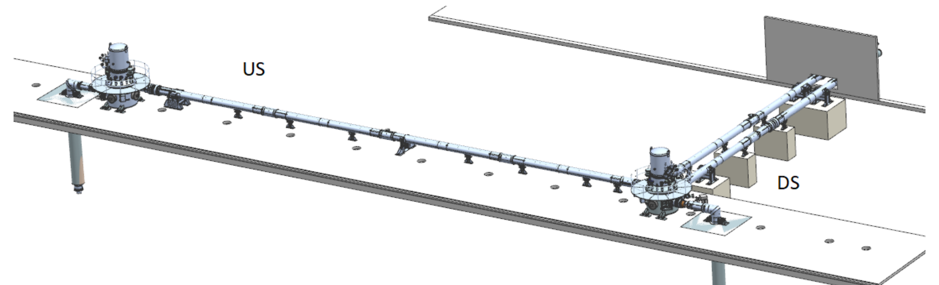
Feed Cap to Cryomodule Interface



FEED CAPS & END CAPS

- Provides rigid internal anchors for all process lines
- Floor supports for pressure, vacuum, and seismic loads from CM outer vacuum shell
- Six (6) Feed Caps to interface cryomodules to transfer lines
  - Made by ***Demaco*** (Netherlands)
- Two (2) End Caps provides turn-around flow path for circuits
  - Has valve for flow control of Line A to Line B return to plant
  - Made by ***Cryotherm*** (Germany)

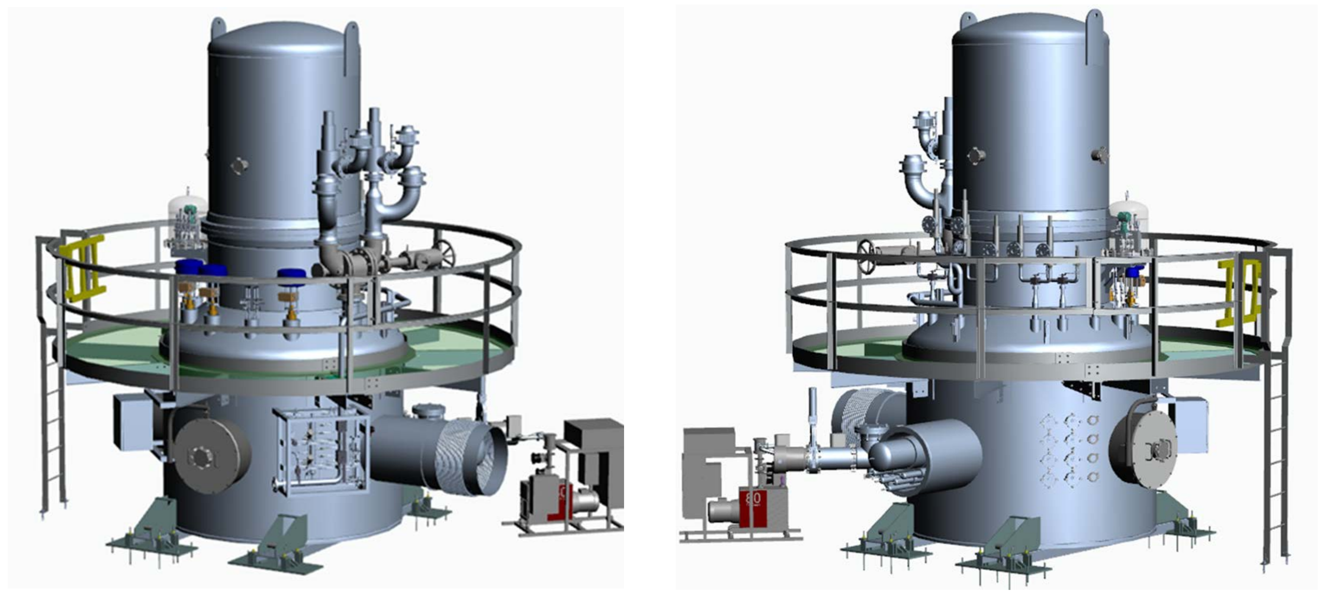
Surface

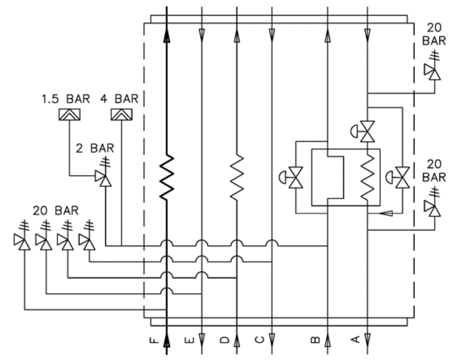


Distribution Boxes and Surface Transfer Lines to the Cryoplant Interface

DISTRIBUTION BOX

- Connects the tunnel with surface portion of cryogenic distribution. 2.4 m dia. x 5.1 m tall.
- Provides
  - Cryomodule and CDS process line relieving
  - Centrally located subcooling 2K heat exchanger.
  - Heaters for HT shield (Line F) and LT intercept (Line D) dynamic load trimming.
- Made by ***Linde Engineering North America*** (USA).





HEAT EXCHANGER

- Uses existing Al plate-fin design
  - proven performance history at TJNL
- Requires effectiveness ≥ 90%
- Made by ***Chart Energy and Chemicals*** (USA)

Description	High pressure side	Low pressure side
Helium mass flow [g/s]	215	215
Inlet temperature [K]	4.6	2.4
Inlet Pressure [bar]	310	3
Maximum allowable pressure drop [bar]	10	0.2
Maximium allowable working pressure[bar]	2000	≥ 500

RELIEVING

- CGA S-1.3 and ASME BPVC Section VIII
- Safety valve inlet $\Delta P \leq 3\%$ of P_{set} at nameplate capacity
- Sudden loss of insulating vacuum rupture of ISO 80 flange
  - Air condensation from choked flow and pipe geometry and mass
- Sudden loss of beam tube vacuum includes build-up of frozen air on the surface
- Includes overfill case for maximum available flow from the Cryoplant

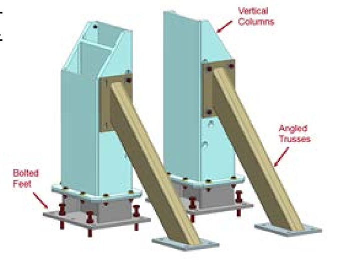
Process Line	Condition	Set Press. [kPa]	Relieving Temp. [K]	Required vent rate [g/s]	Installed vent rate [g/s]	Overcapacity [%]	Inlet Pressure Drop [%]
A surface	SLIV for US	2000	12.7	617	1035	68	1
A tunnel	SLIV for US	2000	12.7	610	674	10	2
B safety valve	supply flow capacity	205	80	645	728	13	3
B rupture disk	SLIV	410	7	11180	33763	202	not applicable RD
C & D	SLIV for US	2000	12.7	617	674	9	3
E & F	supply flow capacity	2000	80	146	168	15	1

Relief 3-way valve for sub-atm. service

Installation

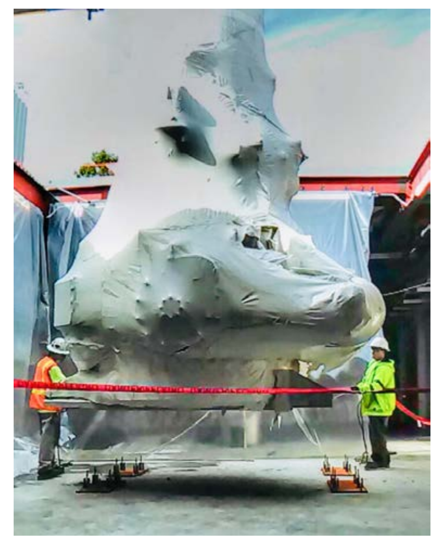
MECHANICAL DESIGN OF EXTERNAL ANCHORS AND SUPPORT

- Commercial concrete anchors
  - Sized by vendor software with steel strength and ductility criteria
  - Any overload plastically yields rods before brittle concrete failure
- Component seismic force resisting elements
  - Have over-strength factor ≥ 2
  - Increases likelihood that anchor rods would first plastically yield
- Tunnel Feed Caps and End Caps anchors designed so vacuum loading
  - deflection < 1mm to not effect beam tube alignment



Feed Cap Support

Distribution Box Installation



Summary

- CDS components designed to specification and fabricated by industry.
- All CDS components have been delivered.
- Tunnel components installed with cryomodule installation in progress.
- Distribution Boxes in place. Surface Transfer Line installation pending

Acknowledgements

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