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Real time heat load calculation software based on EPICS for Fermilab PIP-II CM tests

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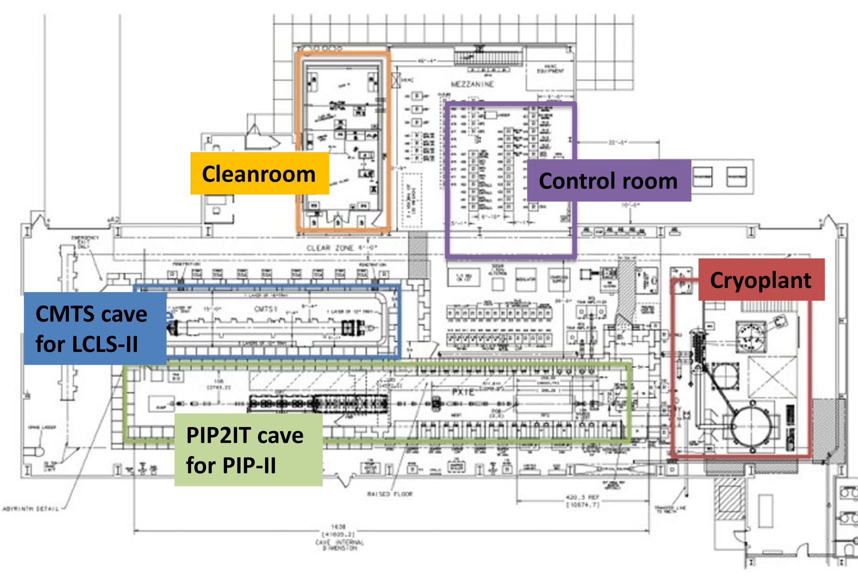
Abstract

Fermilab has a project to improve the proton beam energy which is called PIP-II (the 2nd Proton Improvement Plan). There is a superconducting linear accelerator, LINAC, to improve the proton beam power and the LINAC consists of 5 types of cryomodules (CM), 1 HWR CM, 2 SSR1 CM, 4 SSR2 CM, LB650 CM, and HB650 CM. The prototypes of these cryomodules are being tested at Fermilab's CryoModule Test Facility (CMTF). Heat load measurements are an important part of the prototype CM testing.

The CMTF cryogenic control system was developed based on the ACNET (Accelerator Control NETwork) for CM testing for other projects, but the PIP-II cryogenic control system will be implemented using the Experimental Physics and Industrial Control System (EPICS). As part of the prototype CM testing campaign an EPICS based control system has been implemented at CMTF. This EPICS cryogenic control system includes real time heat load calculation software utilizing the Fortran implementation of Hepak.

This paper details the real time heat load calculation software developed for the prototype CM testing including the first results from the HB 650 CM.

Cryomodule test facility, CMTF[1]



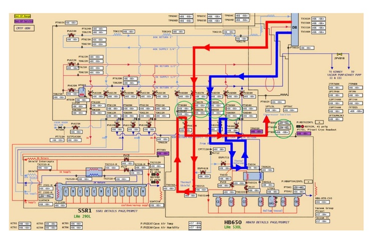
Layout of CMTF

The cryomodule test facility, CMTF has two test caves. One is for SLAC LCLS-II cryomodule tests and the other is for PIP-II cryomodule tests.

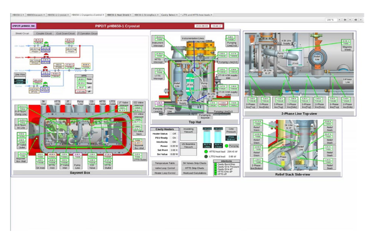
Superfluid Cryoplant, SCP can cover both test caves.

Cryogenic control system in CMTF[2][3][4]

Fermilab used ACNET, but for PIP-II LINAC, EPICS will be a new control system. Fermilab has a plan, ACORN project, to integrate ACNET and EPICS.



ACNET / Synoptics



EPICS / Phoebus

Accelerator Control Operations, ACORN

ACORN (TBD)

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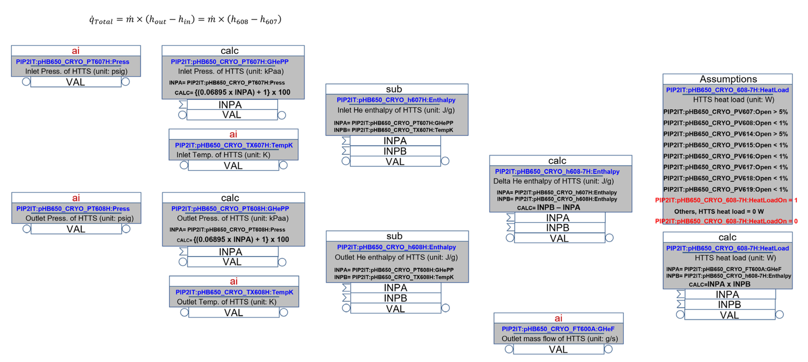
Real-time heat loads[5]

Non-isothermal heat load is defined by "Differential enthalpy x mass flow rate". Enthalpy can be calculated by Hepak fortran which is called from EPICS via C++.

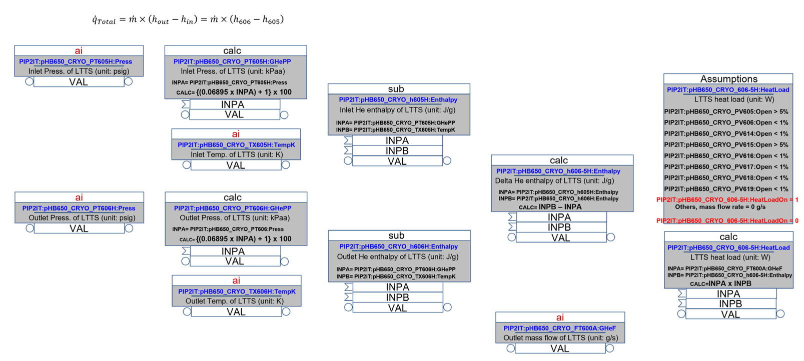
EPICS PVs

New EPICS PVs	Description	Unit	Remark
PIP2IT:pHB650_CRYO_PT607H:GHePP	HTTS inlet pressure	kPaa	Absolute
PIP2IT:pHB650_CRYO_h607H:Enthalpy	HTTS inlet enthalpy	J/g	
PIP2IT:pHB650_CRYO_PT608H:GHePP	HTTS outlet pressure	kPaa	Absolute
PIP2IT:pHB650_CRYO_h608H:Enthalpy	HTTS outlet enthalpy	J/g	
PIP2IT:pHB650_CRYO_h608-7H:Enthalpy	HTTS differential enthalpy	J/g	
PIP2IT:pHB650_CRYO_608-7H:HeatLoad	HTTS total heat load	W	J/s
PIP2IT:pHB650_CRYO_PT605H:GHePP	LTTS inlet pressure	kPaa	Absolute
PIP2IT:pHB650_CRYO_h605H:Enthalpy	LTTS inlet enthalpy	J/g	
PIP2IT:pHB650_CRYO_PT606H:GHePP	LTTS outlet pressure	kPaa	Absolute
PIP2IT:pHB650_CRYO_h606H:Enthalpy	LTTS outlet enthalpy	J/g	
PIP2IT:pHB650_CRYO_h606-5H:Enthalpy	LTTS differential enthalpy	J/g	
PIP2IT:pHB650_CRYO_606-5H:HeatLoad	LTTS total heat load	W	J/s
PIP2IT:pHB650_CRYO_608-7H:HeatLoadOn	HTTS heat load measurement on/off	-	BOOL
PIP2IT:pHB650_CRYO_606-5H:HeatLoadOn	LTTS heat load measurement on/off	-	BOOL

Used EPICS PVs	Description	Unit	Remark
PIP2IT:pHB650_CRYO_PT607H:Press	HTTS inlet pressure	psig	Gauge
PIP2IT:pHB650_CRYO_TX607H:TempK	HTTS inlet temperature	K	
PIP2IT:pHB650_CRYO_PT608H:Press	HTTS outlet pressure	psig	Gauge
PIP2IT:pHB650_CRYO_TX608H:TempK	HTTS outlet temperature	K	
PIP2IT:pHB650_CRYO_PT605H:Press	LTTS inlet pressure	psig	Gauge
PIP2IT:pHB650_CRYO_TX605H:TempK	LTTS inlet temperature	K	
PIP2IT:pHB650_CRYO_PT606H:Press	LTTS outlet pressure	psig	Gauge
PIP2IT:pHB650_CRYO_TX606H:TempK	LTTS outlet temperature	K	
PIP2IT:pHB650_CRYO_FT600A:GHeF	LTTS/HTTS mass flow rate	g/s	



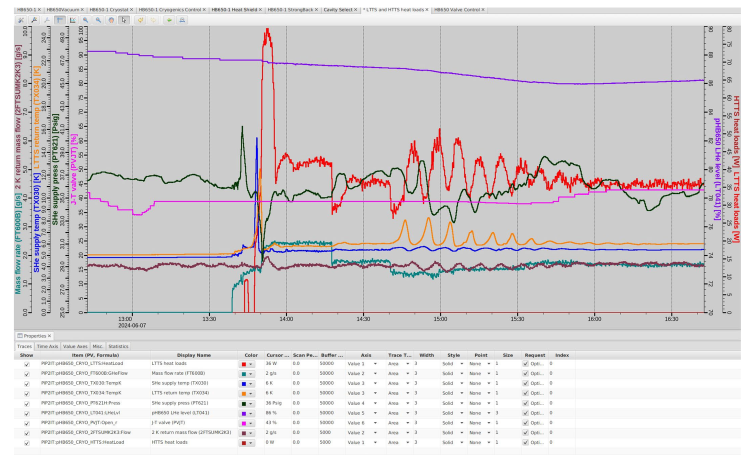
High Temperature Thermal shield, HTTS, heat load calculation with Hepak fortran



Low Temperature Thermal shield, LTTS, heat load calculation with Hepak fortran

Results[6]

HTTS heat loads (24 hours) – 290 W including CDS at LINAC condition 1



LTTS heat loads (4 hours) – 36 W including CDS at standard condition

Conclusion[6][7]

1. To Calculate the non-isothermal heat loads (LTTS / HTTS cooling circuits) in real time.
2. To Compare results from EPICS (in real time) and ACNET (from archiver) which are almost same.
3. Future works to calculate mass flow rate, helium quantity in real time.

References

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