Cryogenics – The Basics

Lesson 2

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Lecture 1 Review

Lesson 1 - Objectives

- Looked at common liquids and gases to get a feeling for their properties
- Looked at Nitrogen and Helium
- Discussed Pressure and Temperature Scales
- Learned more about different phases of these fluids
- Became familiar with some cryogenic fluids properties

ANYONE LOST ANY SLEEP THINKING ABOUT THIS? ANY QUESTIONS?

Lesson 2 - Objectives

- Follow the Atoms/Molecules from arrival on site on their trips through a portion the JLab cryogenic hardware
- Learn more about the END STATION REFRIGERATOR (ESR)
- A little more Engineering
- Instrumentation Types
- Nomenclature
- Helium loss and costs

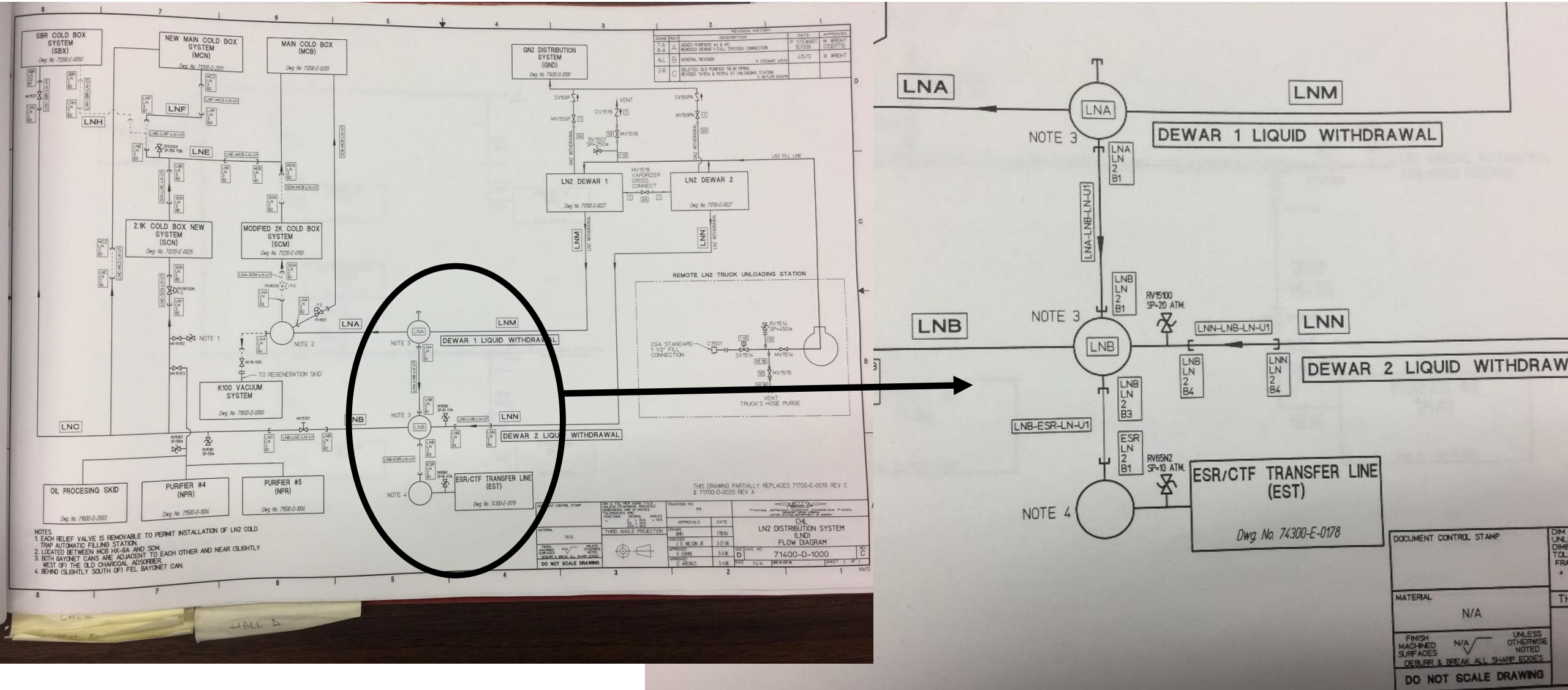
Next sets of slides go through the EPICS screens of the following

- CHL LN2
- CHL Gas management (including storage tanks)
- CHL Main Cold Box 1 (a source for CHL boost)
- ESR Gas management (warm flows to/from CHL and to/from Halls)
- ESR Compressors
- ESR Cold Box
- ESR Valve box Parts 1 and 2

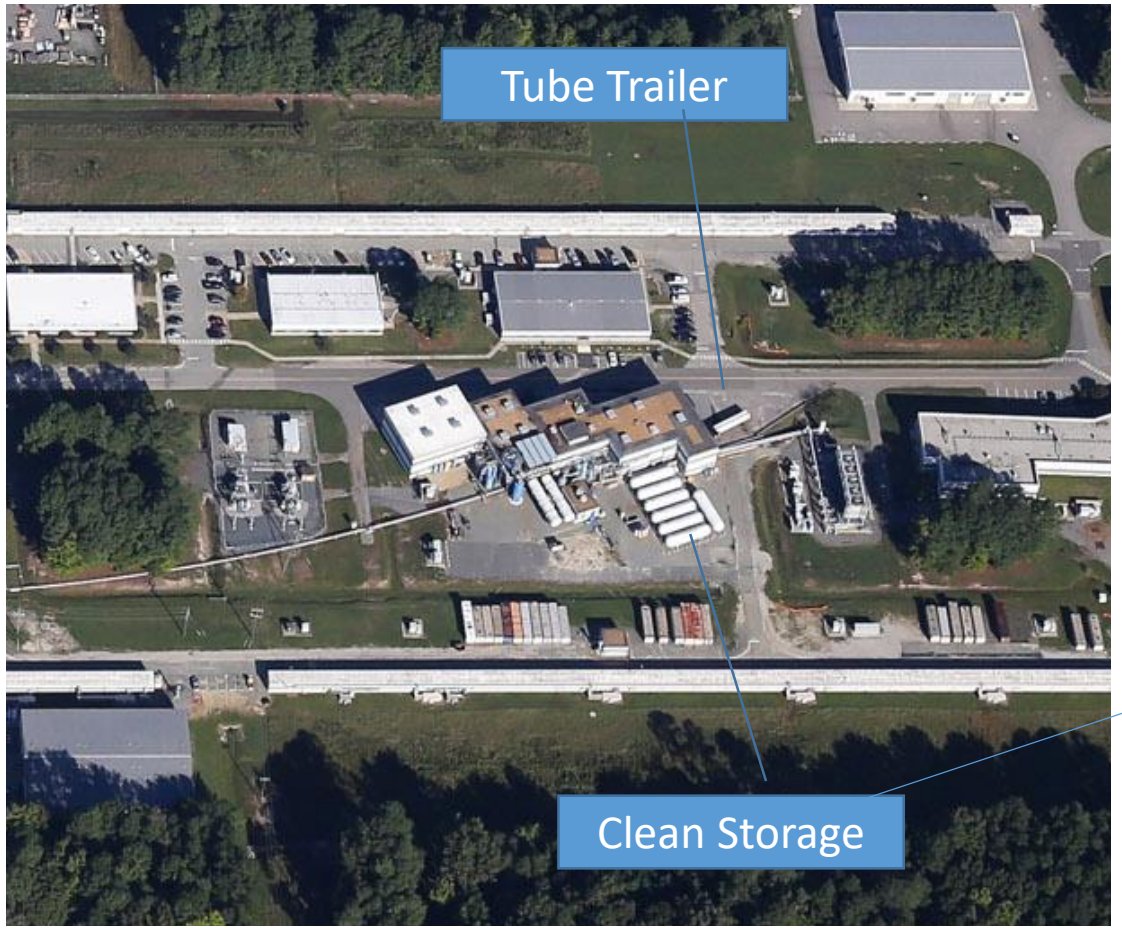
Where/how do we get the cryogens for the Halls?

- Helium is brought in as gas is in high (~3000psig) pressure tube trailers
- Nitrogen arrives as liquid in mobile dewars

LN2 is off loaded into one of two permanent 20,000gallon dewars which are hard piped to the ESTL



The helium is off loaded to 30,000 gallon dirty tank then passed through the helium purifiers



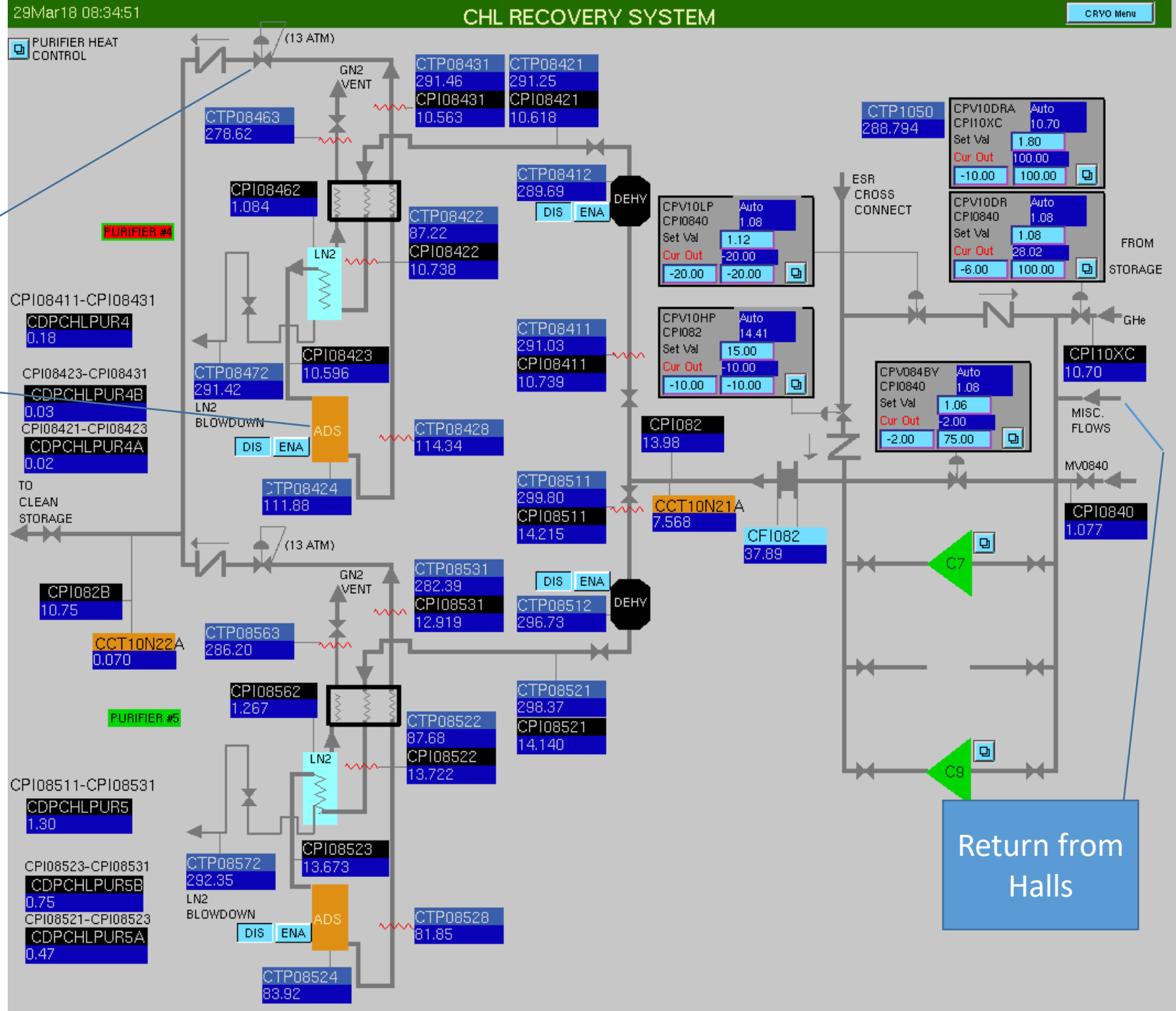
What are purifiers?

- One way I describe these devices is: – The first cryogenic hardware that Bill Chronis assigned a young engineer Dave Kashy to design for the CTF ~1988.
- Simply put they are LN2 cooled charcoal beds that are in vacuum vessels
- Pressurized Helium is cooled to 78K in a set of heat exchangers then flows through the cold charcoal bed (from top to bottom). All non-helium gasses “stick” to the carbon surface in a process called adsorption. The clean helium passes back through the HX to get warmed and then is used as needed. Typically it goes to a storage tank for future use.
- There is lots of instrumentation involved, PI/PT, TP, FI, CT and DP
- There are many valves, some heaters, compressors and dehydrators
- They are “regenerated” by depressurizing, heating and pumping a vacuum on the beds

Purifiers @ CHL

Pressure Control Valve

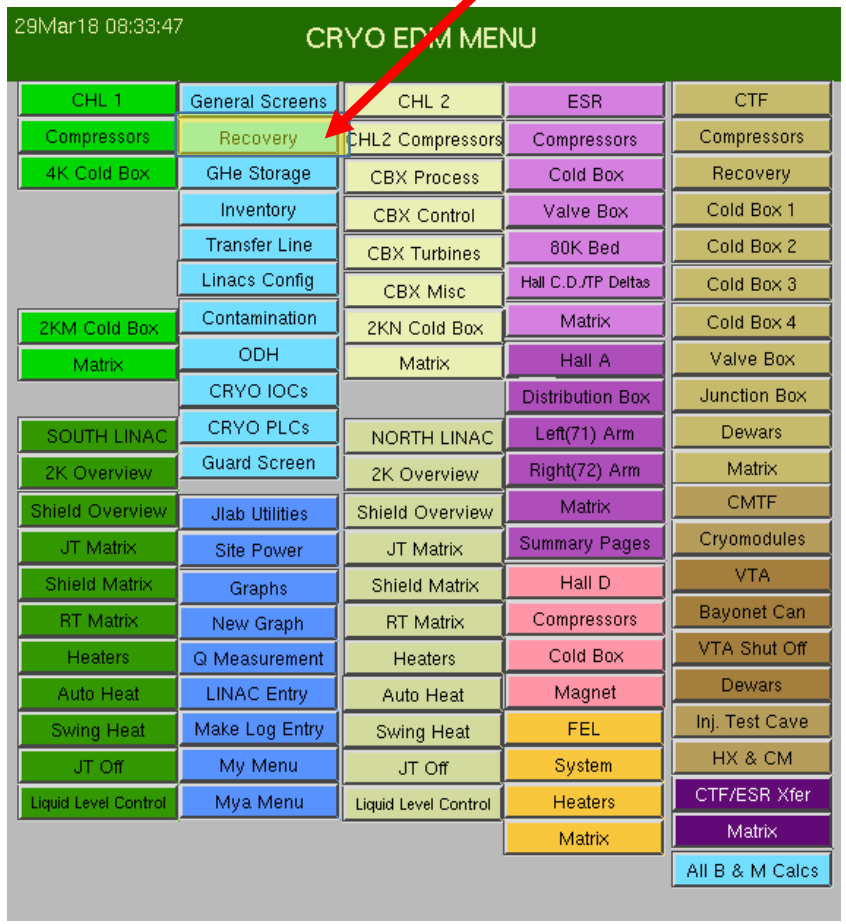
Charcoal bed (Adsorber)



How to get that screen and others?

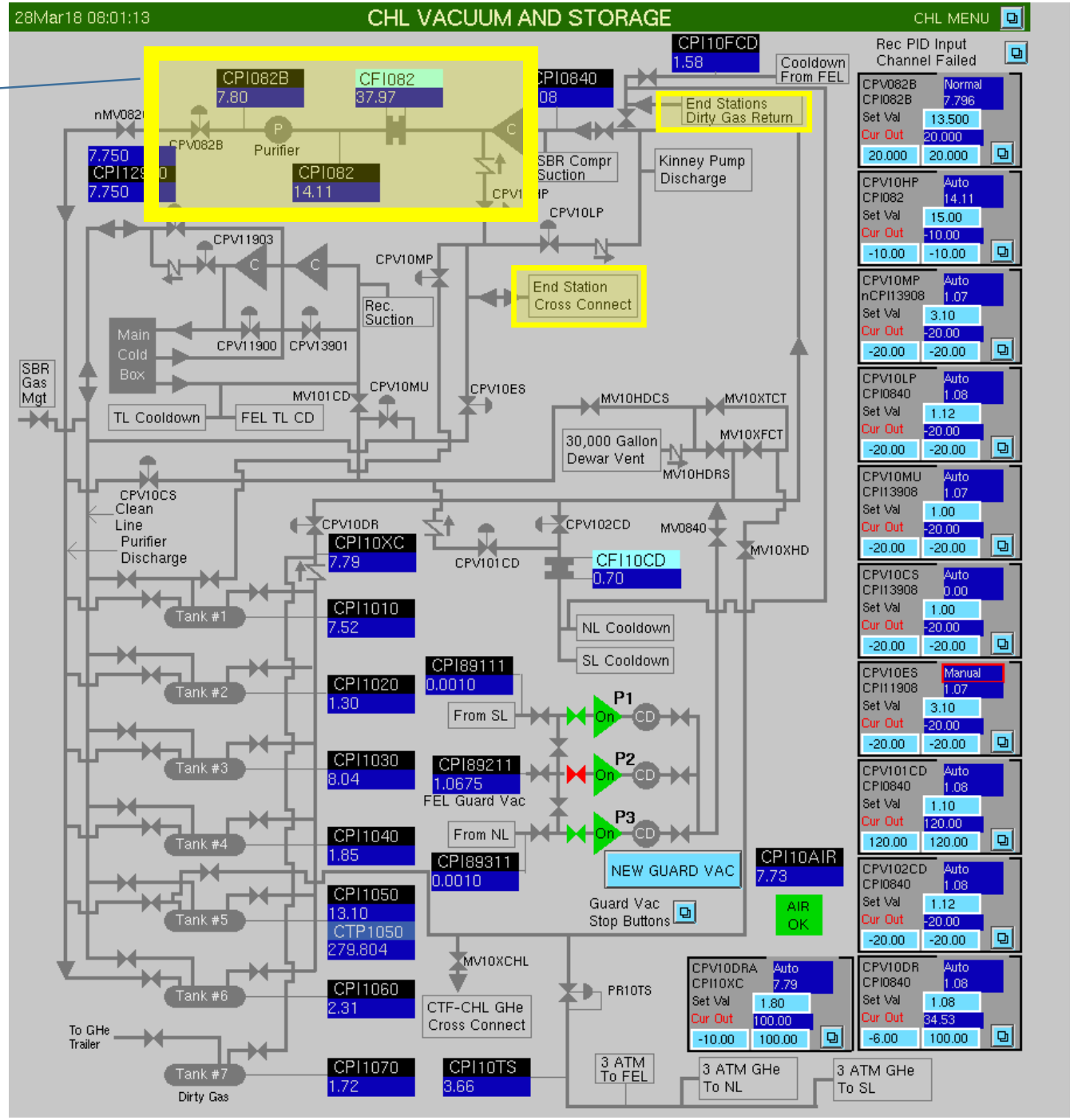
Opens a window, select Operations then select Cryo Main menu

Then select Recovery



Helium storage for ESR is at CHL

Purifers

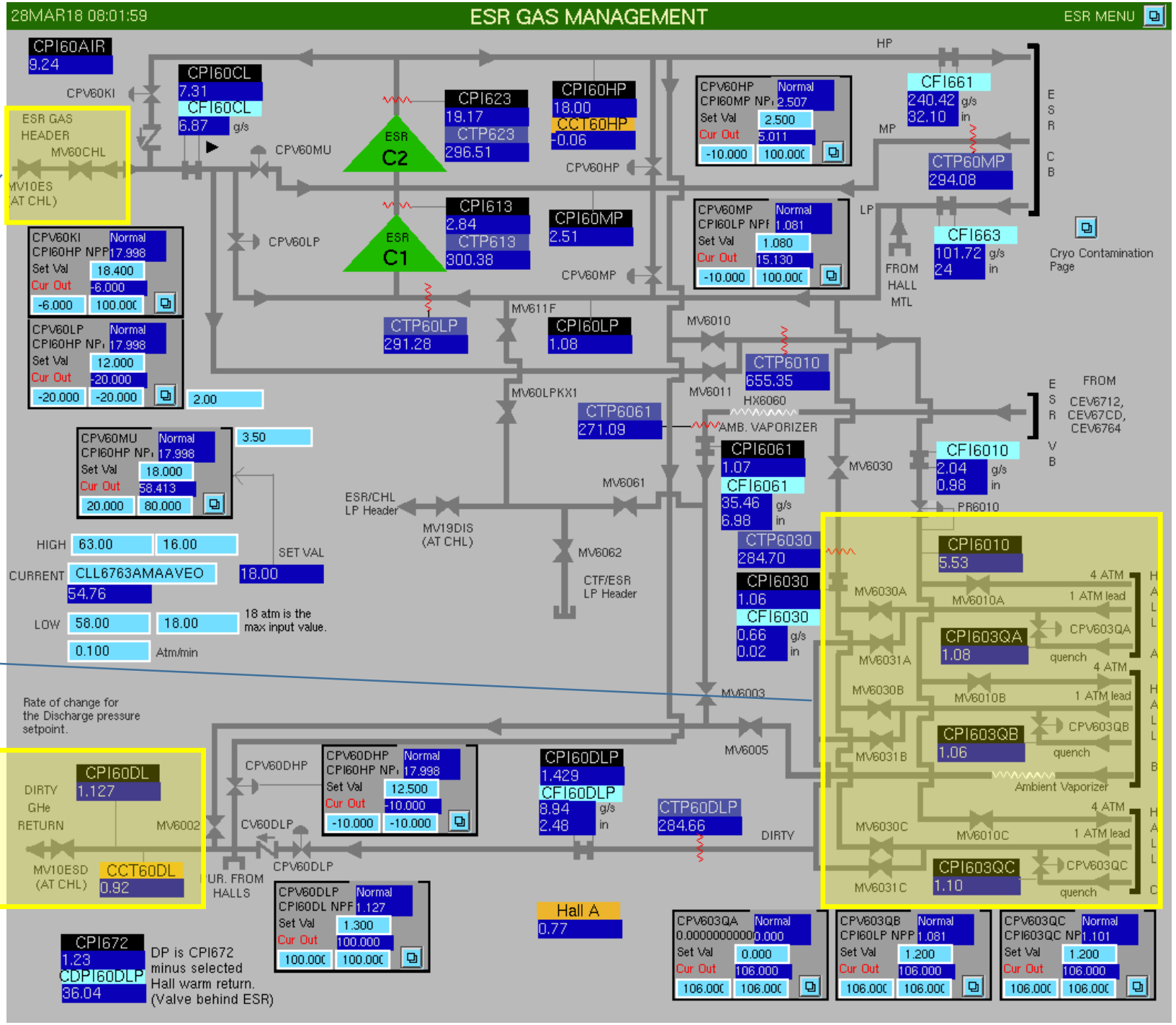


ESR Gas Management

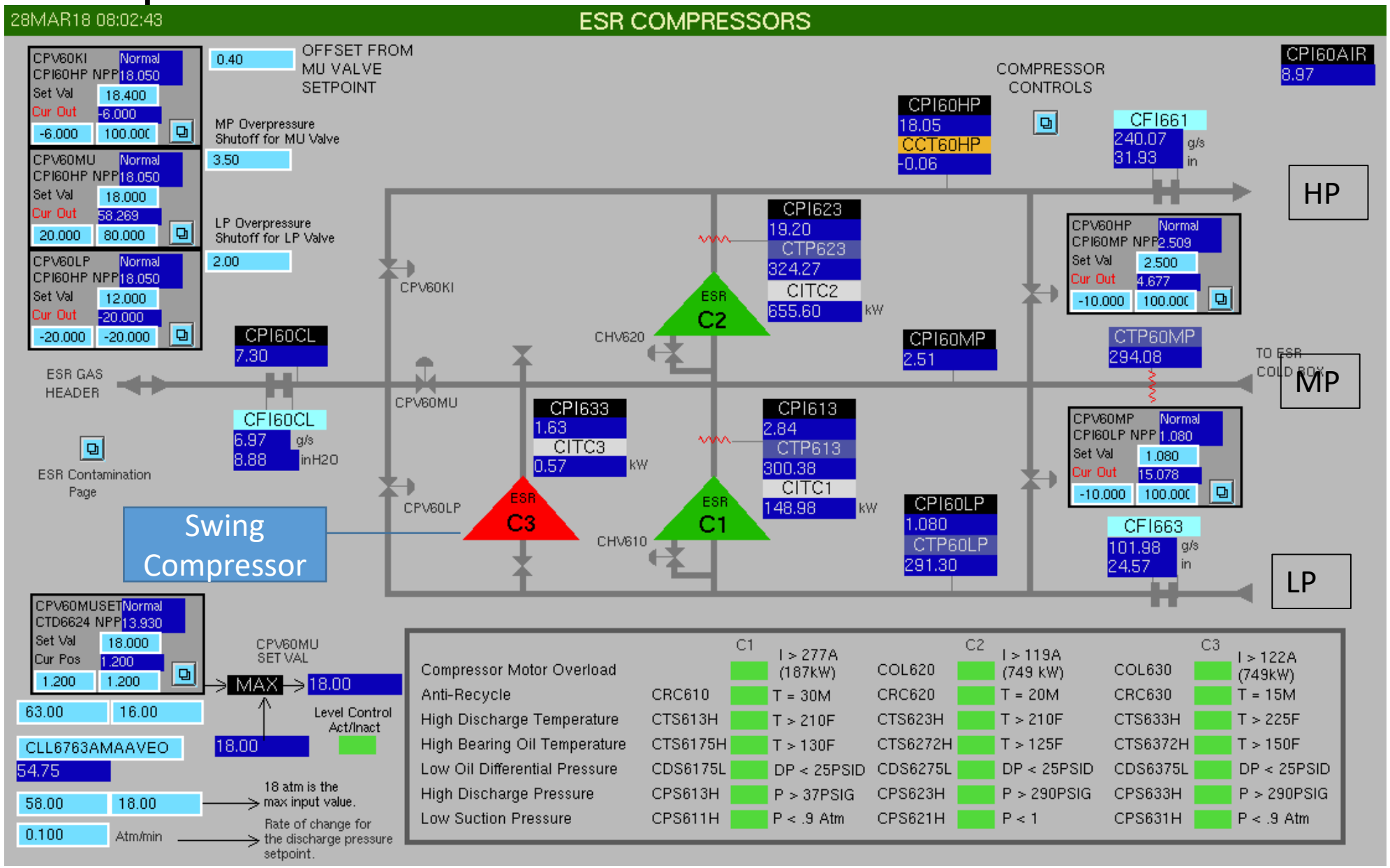
Clean Helium (mass in or out)

Hall Warm Return

Dirty Helium to purifiers



ESR Compressors



ESR Cold Box

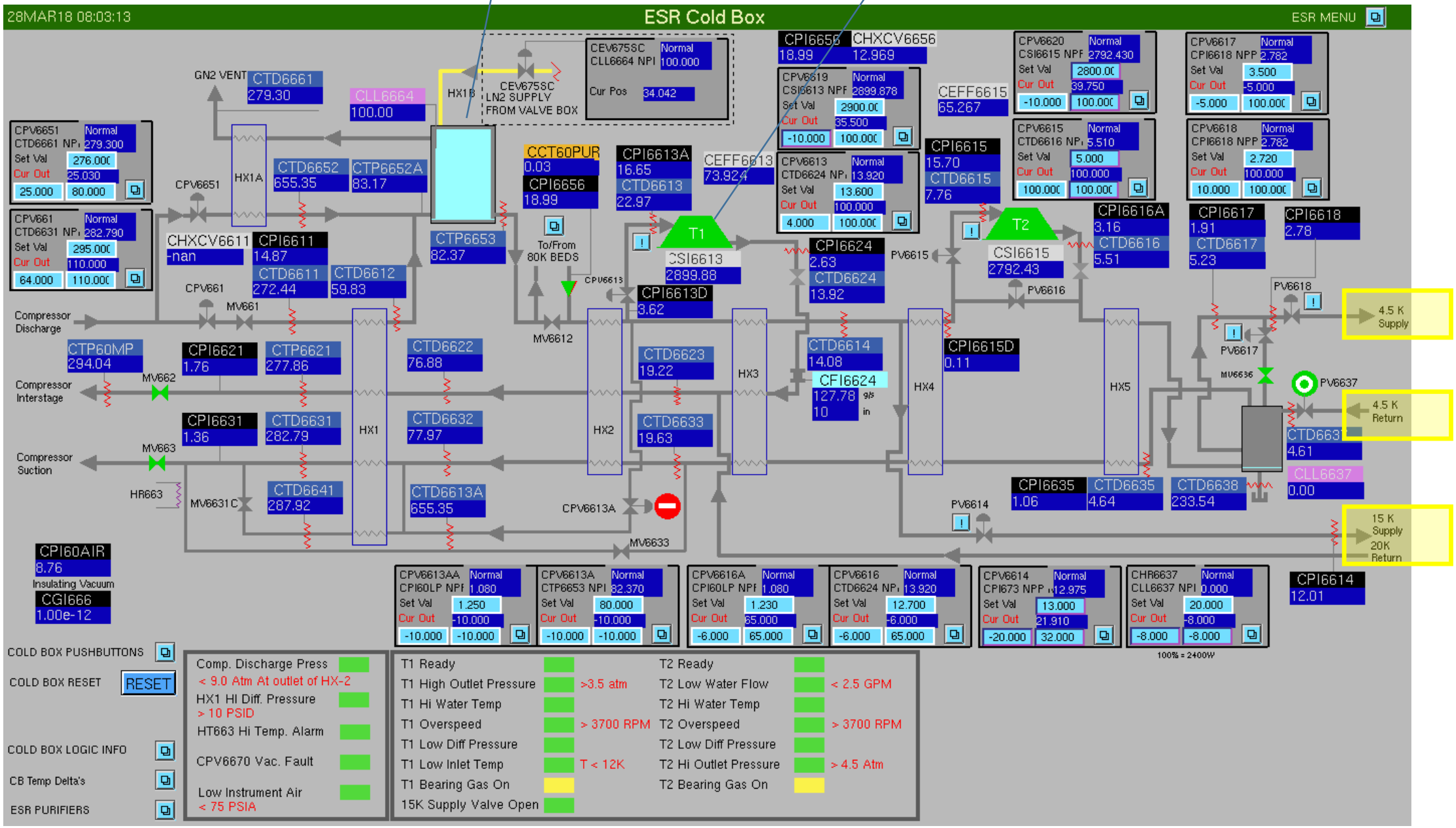
LN2 pre-cooling

Turbine T1

HP

MP

LP



A little more Engineering Here

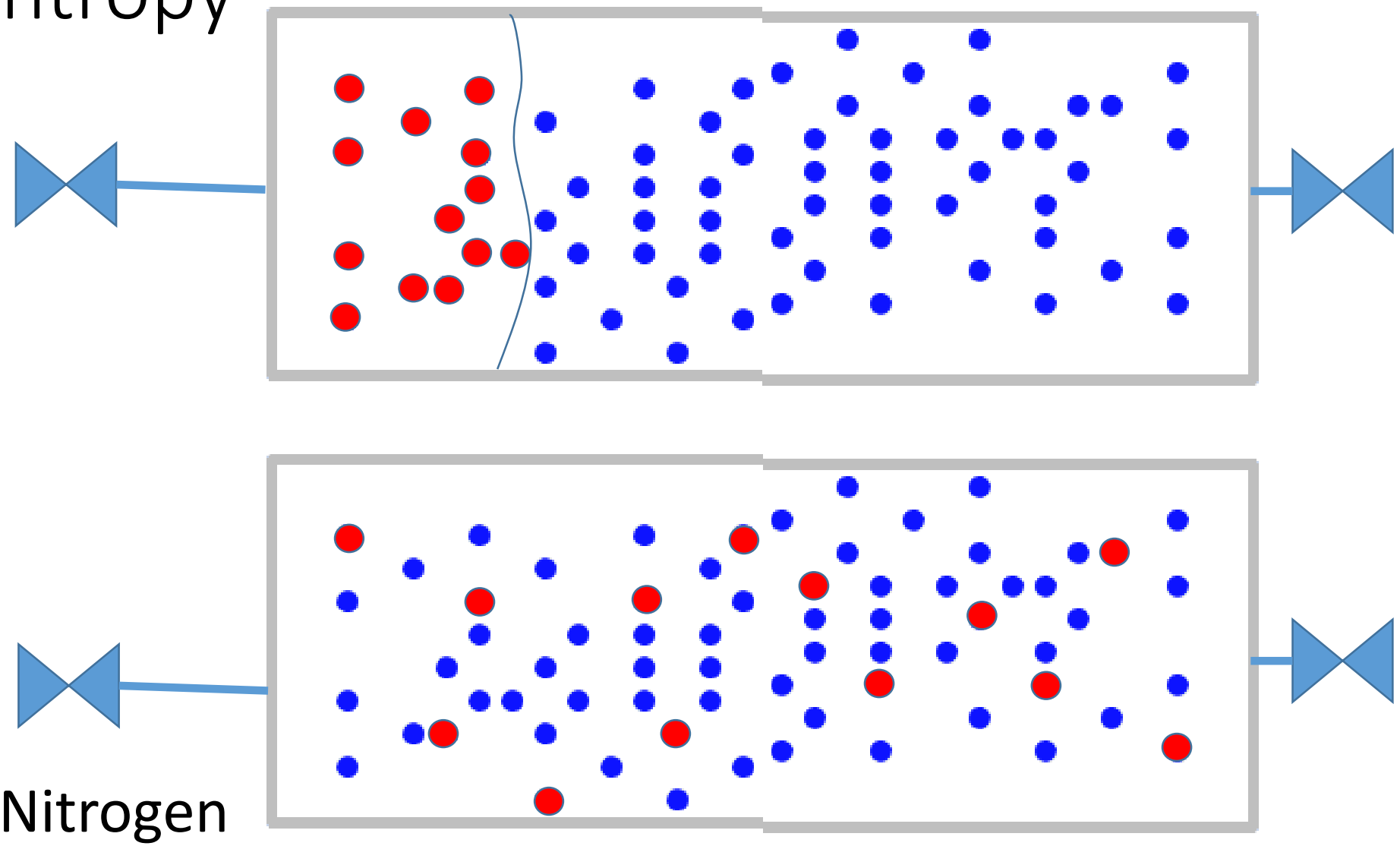
- As mentioned in previous slide the ESR has two turbine expanders. There are other types of expanders:
  - CTF has both turbine and piston type which are also called “expansion engines”
  - A valve is also a way to allow gas to “expand”
- Turbine expansion vs expansion through a valve
  - In lesson 1 we said that valve expansion was Isenthalpic (constant enthalpy) in the ideal case
  - Now we will compare this to turbine expansion which is Isentropic (constant entropy) in the ideal case
- If one knows 2 properties of helium then one can look up any other property.
  - Say you know the Pressure and Temperature, then one can look up the enthalpy, density, specific heat….
  - Or if one knows the enthalpy and pressure then on can find the temperature, and any other property, like: Thermal Conductivity, Entropy, Density…

What is Entropy

- *Entropy* may be understood as a measure of disorder within a macroscopic system. The second law of thermodynamics states that an isolated system's *entropy* never decreases spontaneously. Such systems spontaneously evolve towards thermodynamic equilibrium, the state with maximum *entropy*.
- Think: A measure of chaos, disorder, or how random
- Another way to say it is:
  - You have a project.
  - You pull out tools and use them. You work really hard and finish the project, but at the end your workshop is a mess.
  - The entropy in your garage has increased!
  - It will take work to reduce the entropy of your garage.

Visualize Entropy

- Upper vessel has some entropy and a membrane
- Membrane breaks
- It will take work to separate the gasses, thus Entropy has increased



Oxygen Nitrogen

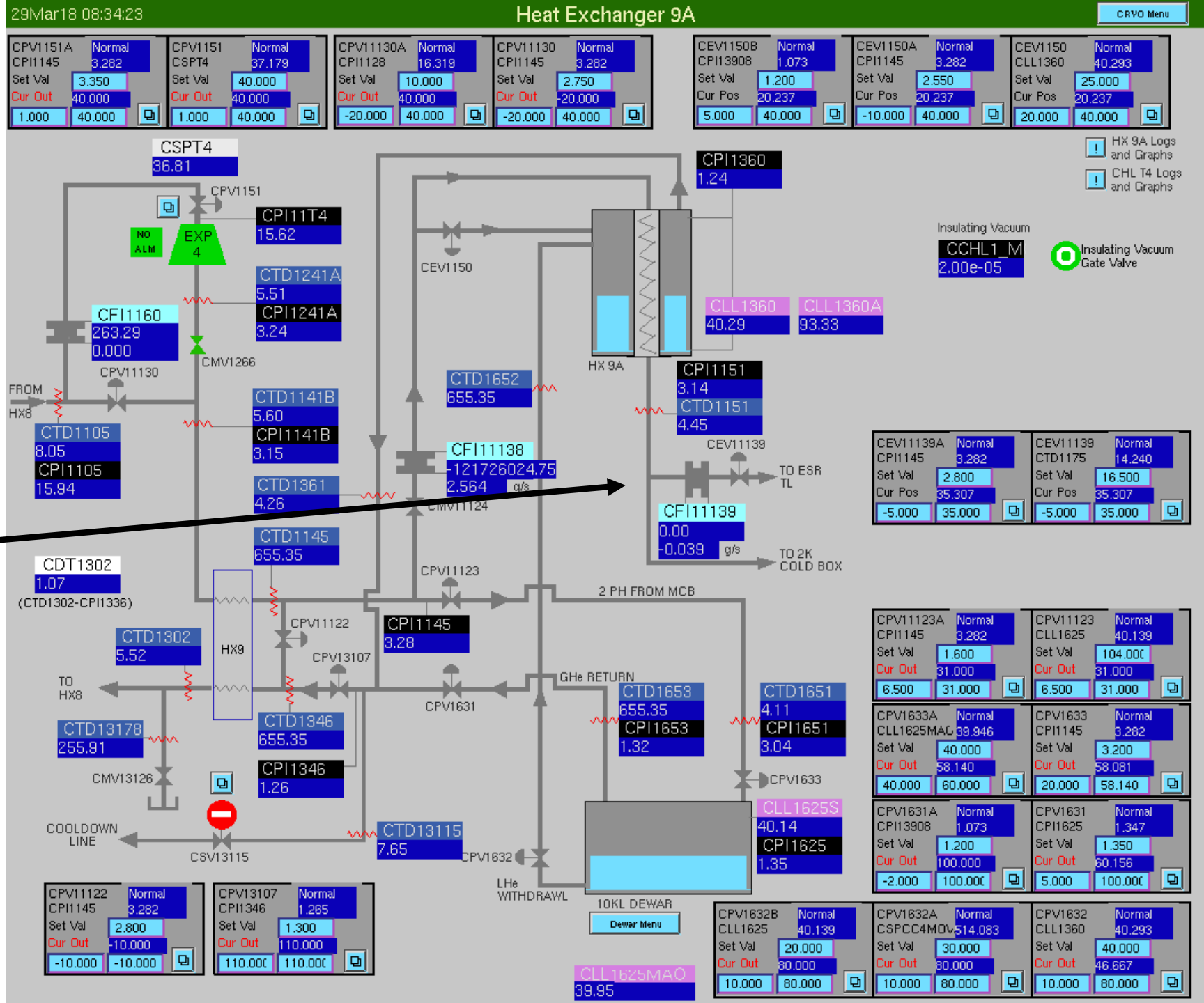
Example ESR T1

- Ideal Expansion
  - No heat load
  - No losses

Inlet temperature	*K*	*23*	*23*
Inlet pressure	*atm*	*16.6*	*16.6*
Inlet enthalpy	J/g	**129.22**	129.22
Inlet entropy	J/(g*K)	12.13	**12.13**
Process		"JT" valve expansion (isenthalpic)	Ideal Turbine expansion (isentropic)
Exhaust pressure	*atm*	*2.6*	*2.6*
Exhaust enthalpy	J/g	**129.22**	***67.82***
Exhaust entropy	J/(g*K)	15.96	**12.13**
Exhaust temperature	*K*	***21.94***	***10.88***

CHL
Main Cold Box

- 4K boost to ESR through CEV11139

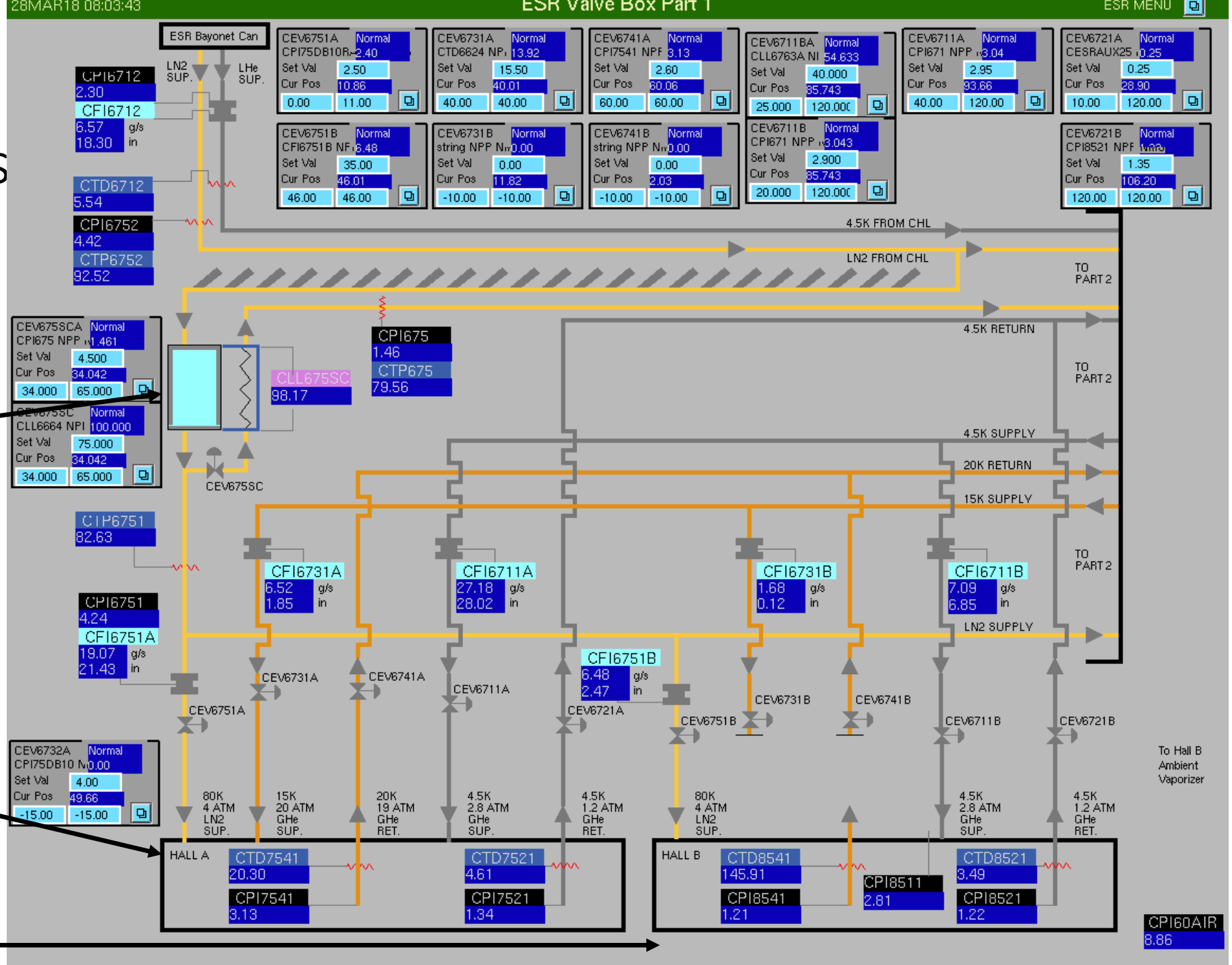


Distributing the Cryogens VB part 1

LN2 Subcooler and Phase Separator

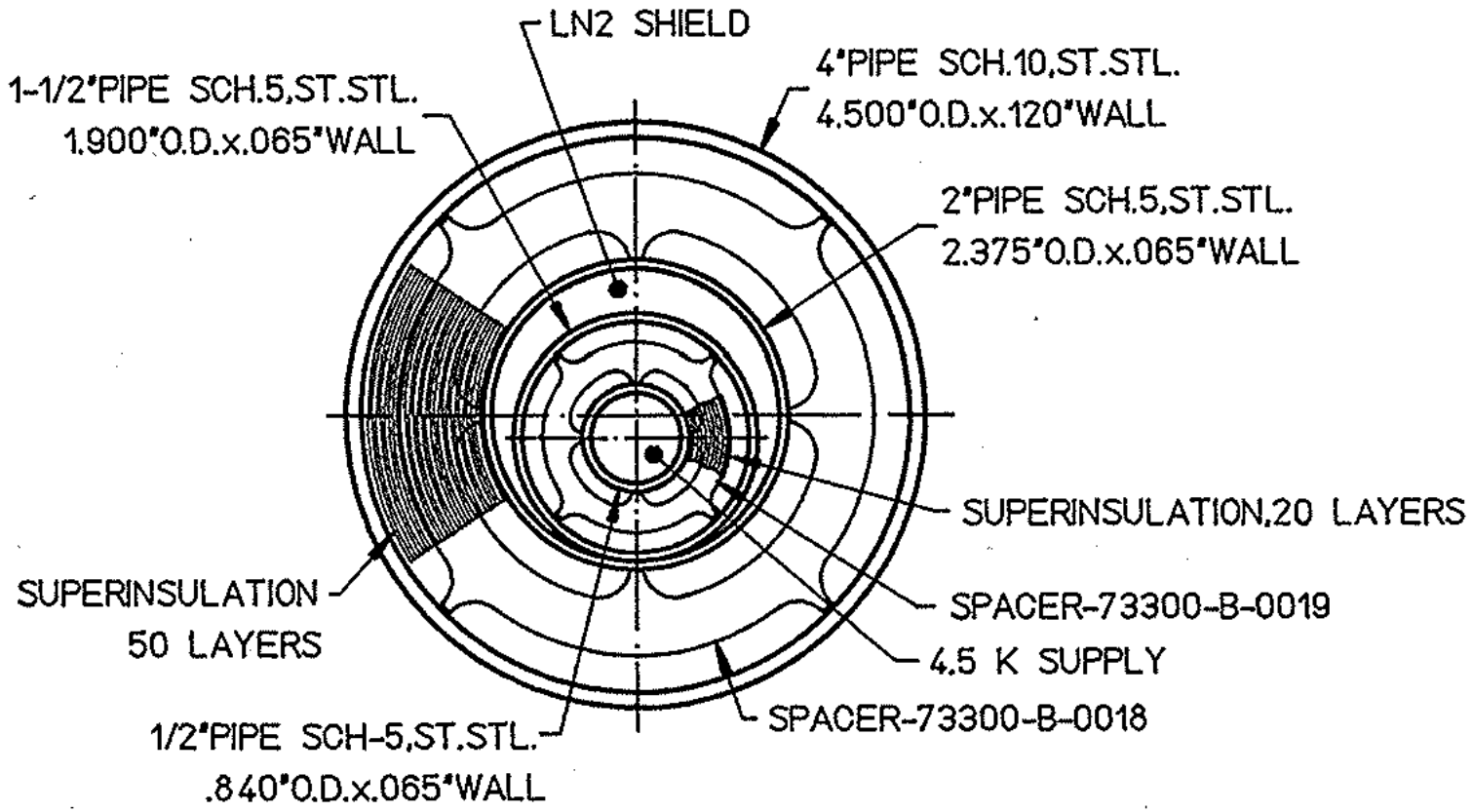
Hall A ESMTL Expansion Can

Hall B ESMTL Expansion Can

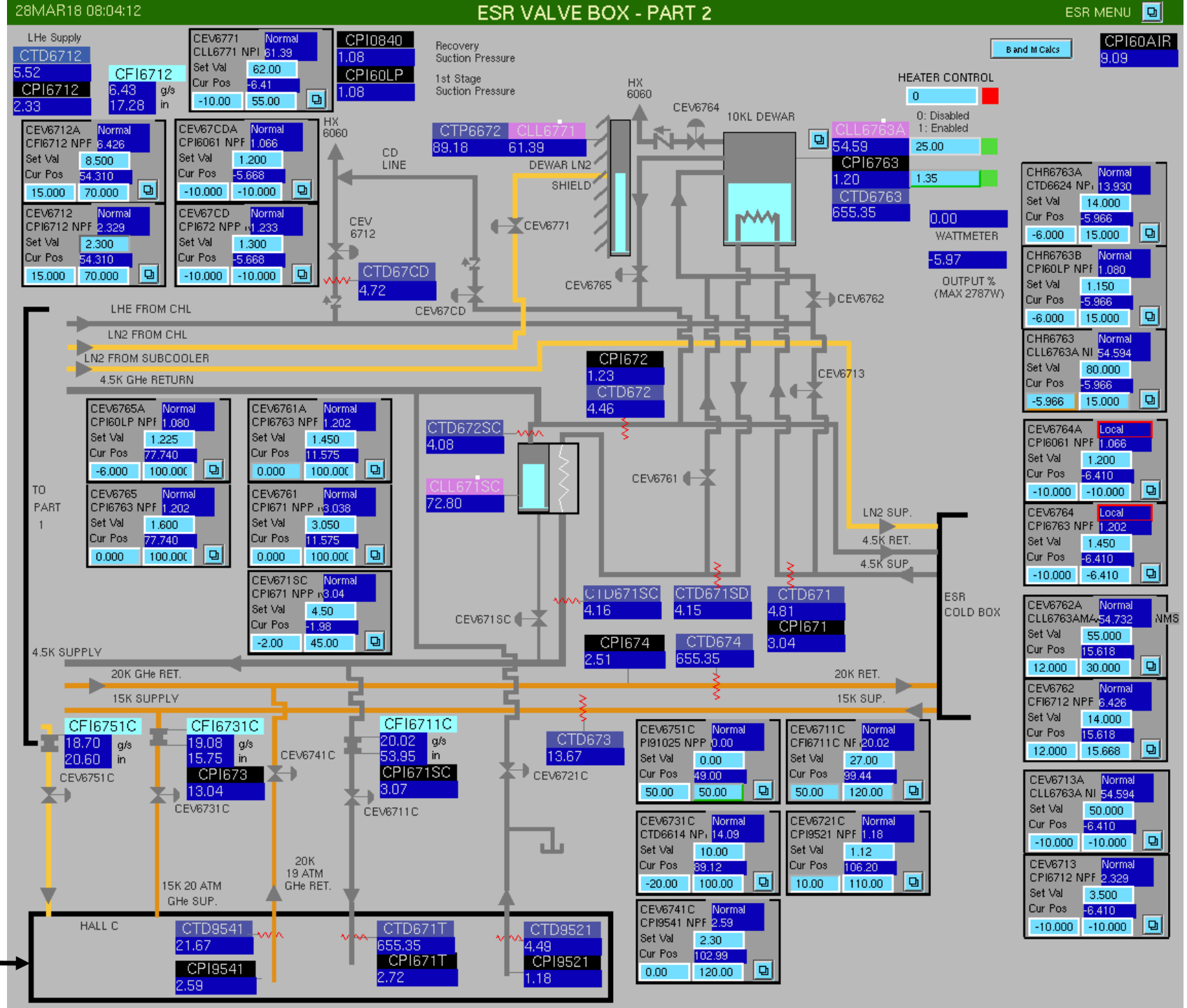


ESTL Transfer Line X-section – 2 flow paths

- 4K Supercritical Helium supply in ½” IPS sch 5
- LN2 supply between 1-1/2IPS sch 5 and 2IPS sch 5
- VJ 4Ips Sch 10



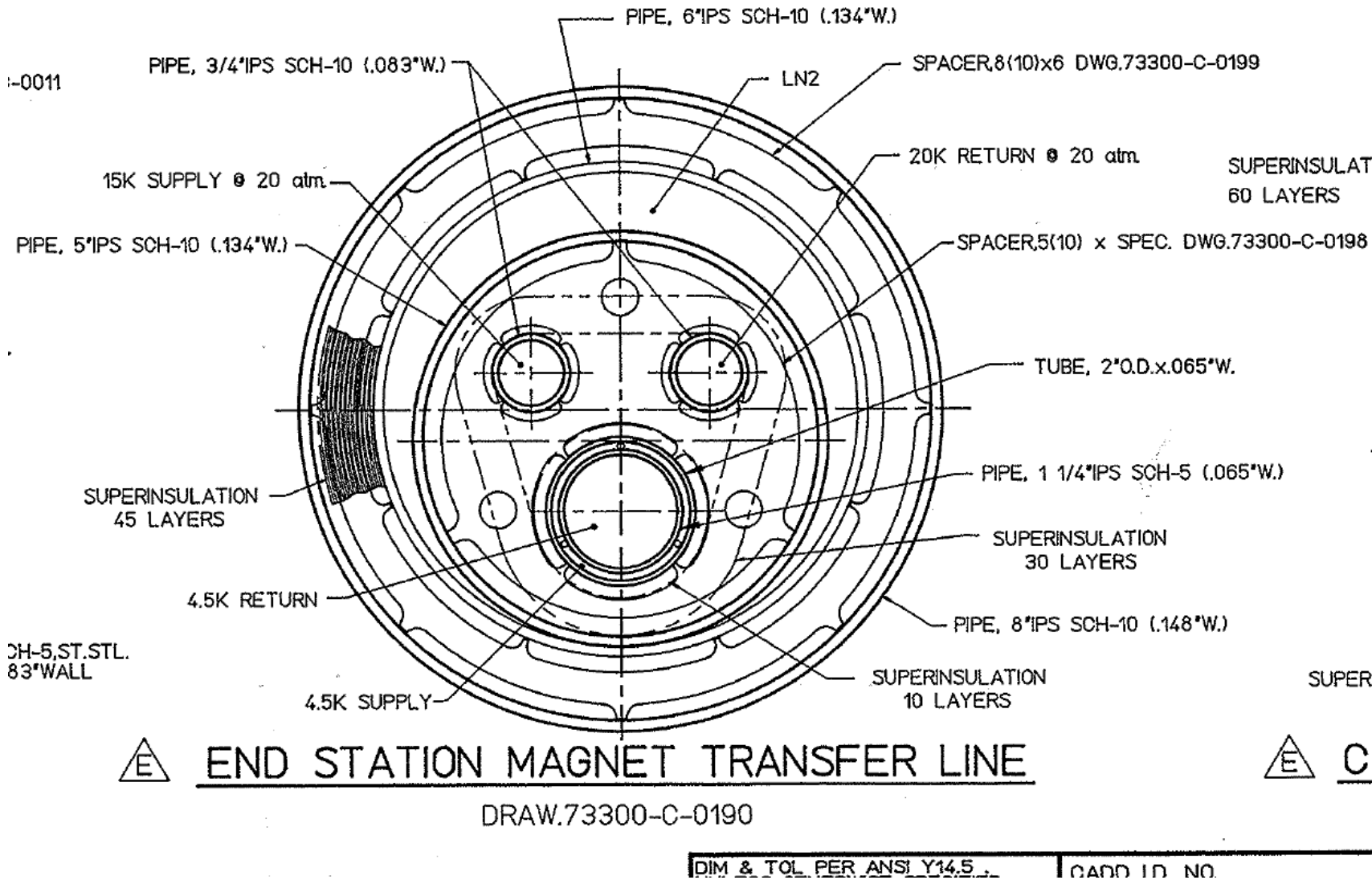
ESR Valve box Part 2



Hall C ESMTL Expansion Can

ESMTL Transfer Line X-section – 5 flow paths

- 4K Supercritical Helium supply between 2”ODx0.065” tube and 1-1/4IPS Sch 5
- 4K Return inside 1-1/4”Sch 5
- LN2 supply between 6 IPS Sch 10 and 5IPS sch 10
- 15K and 20K flow in 3/4IPS Sch 10

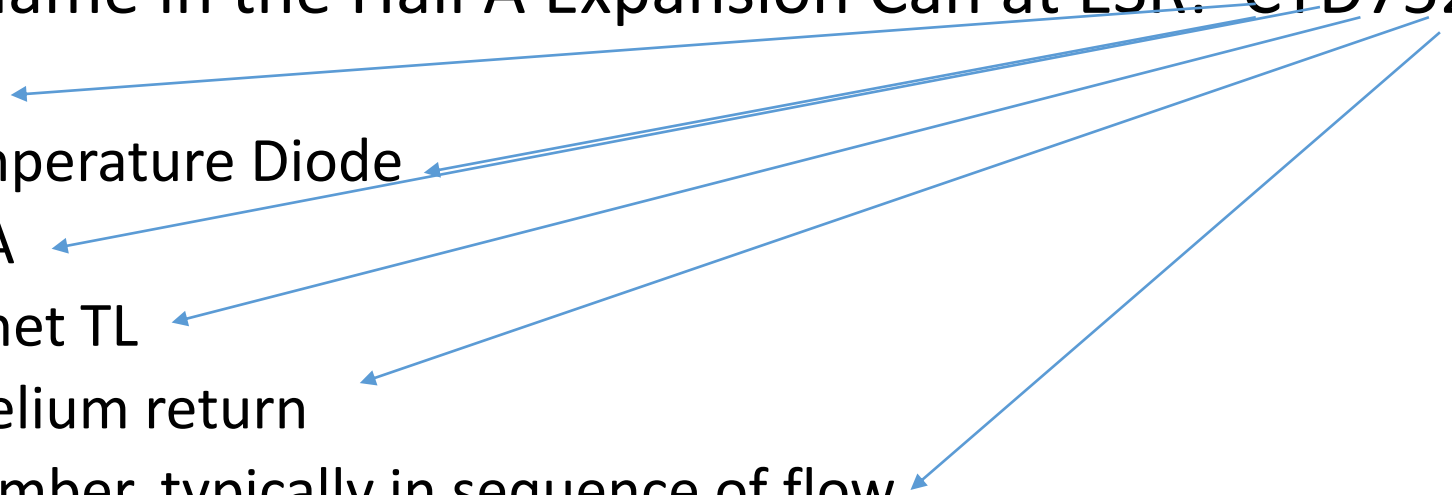


Nomenclature at ESR and CHL (and some Halls)

- A example signal name at ESR is: CFI6711B
  - C Stands for Cryo
  - FI Stands for Flow Indicator
  - 6 Stands for ESR
  - 7 Stands for ESR Valve box
  - 1 Stands for Supercritical Helium supply
  - 1 Is a counting number, typically in sequence of flow
  - B Stands for Hall B

More Nomenclature

- A example signal name in the Hall A Expansion Can at ESR: CTD7521
  - C Stands for Cryo
  - TD Stands for Temperature Diode
  - 7 Stands for Hall A
  - 5 Stands for Magnet TL
  - 2 Stands for 4K Helium return
  - 1 Is a counting number, typically in sequence of flow



Where are these numbers defined?

- **CEBAF Nomenclature Document :** https://www.jlab.org/intralab/nomenclature_document/
  - To find the link google the above (do not search the JLab website)

The purpose of the CEBAF Nomenclature Document (CND) is to provide a standard system of unique names to represent pieces of accelerator and experimental equipment. Naming is mostly limited to objects found along the beam line. Nomenclature identification is used on drawings, schematics, computer software, and other sources of information. IOCs and equipment racks have their own independent naming scheme. Items in the LERF and Halls may be included.

Helium Costs and Loss Rates

- Site wide helium inventory ~163,000 liters or ~20tons
- Site wide JLab loses about 350-400 liquid liters of helium per day.
  - 400ℓ/day x 125g/ℓ x day/24hr x hr/3600sec = 0.58g/s

- Latest helium cost is: 5.17$/ℓ plus trailer rental $2040/month – each tube trailer costs us ~$34,000
- 5.17$/ℓ x 400ℓ/day * 30day +2040 $ = 64,000$/month
- From October 2017 to March 2018 we purchased the following:

  OCTOBER-3 Trailers Tubes

  NOVEMBER-4 Trailer Tubes

  DECEMBER-2 Trailer Tubes

  JANUARY-1 Trailer Tube

  FEBRUARY-1 Trailer Tube

  MARCH-2 Trailer Tube

Find and Fix your Leaks!!

Are there any Questions?

Lectures are posted at: https://userweb.jlab.org/~kashy/

Next lessons –

- Hall B flow paths
- PID control
- Hall B PID control for steady state operation
- Effect of Heat load and more
- What would like me to present in a future lecture?

Thanks for Listening