History of JLab Cryogenics

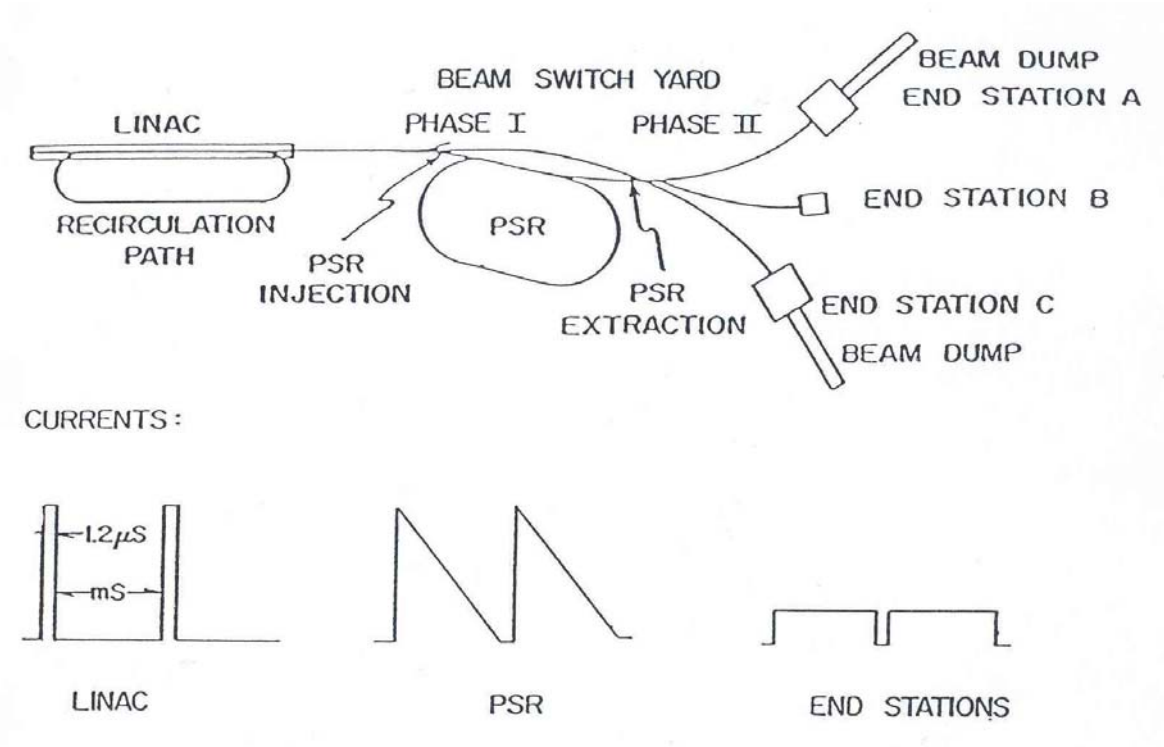
March 30, 2004

Claus H. Rode

Director, Project Management

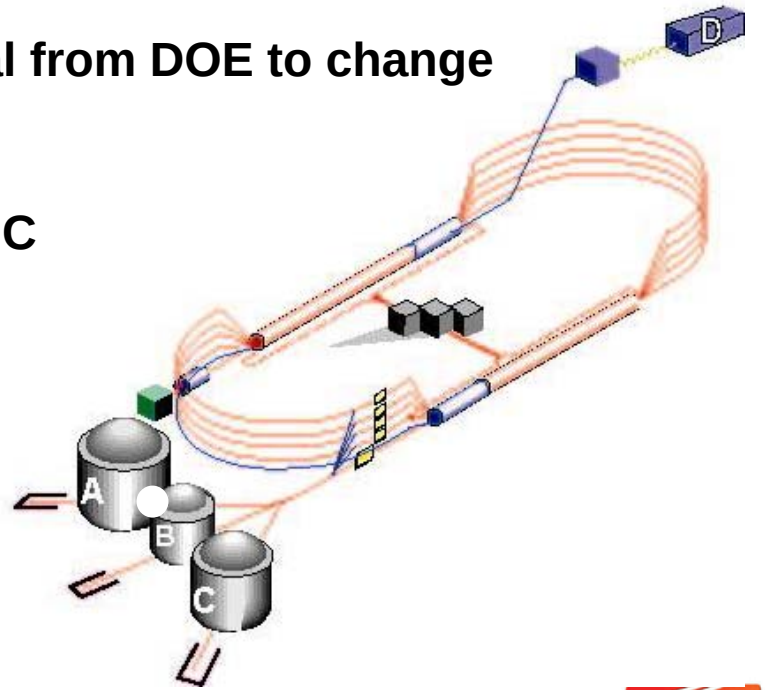
Welcome & Short History of CEBAF

- **In 1982, DOE held a national competition for the National Electron Accelerator Lab**
  - **Virginia's proposal "CEBAF" won it with it's Warm Linac and Pulse Stretcher Ring**
  - **Newport News eventually beat out Blacksburg VA as the site**



Welcome & Short History of CEBAF (cont'd)

- In Aug-85, the initial senior staff arrived in Newport News and immediately asked the question "should the design be changed to a Superconducting Linac"
  - The first external workshop was held in Oct-85
  - Several additional reviews were held in the next three months
  - Feb-86 the CDR was held for the Superconducting Recirculating Linac
  - May-86 we received the approval from DOE to change
- Oct-86 we started construction
- June-94 we delivered beam to Hall C



Cryogenic Timeline

Oct-85	Cryogenic Workshop
Feb-86	CDR
Feb-87	CHL specification to vendors
Jan-88	CHL contract award
Feb-91	**4.5K; NL supply cooldown; start injector beam commissioning**
May-94	Fully operational at 2.08K
June-94	**Beam on target**

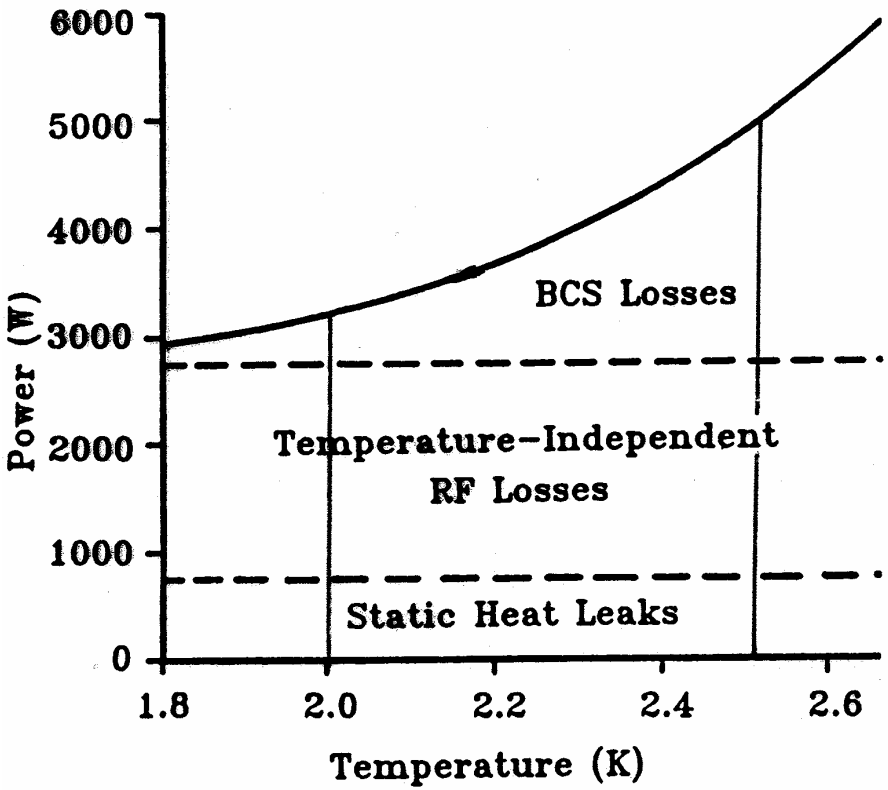
Cryogenic Systems Scope

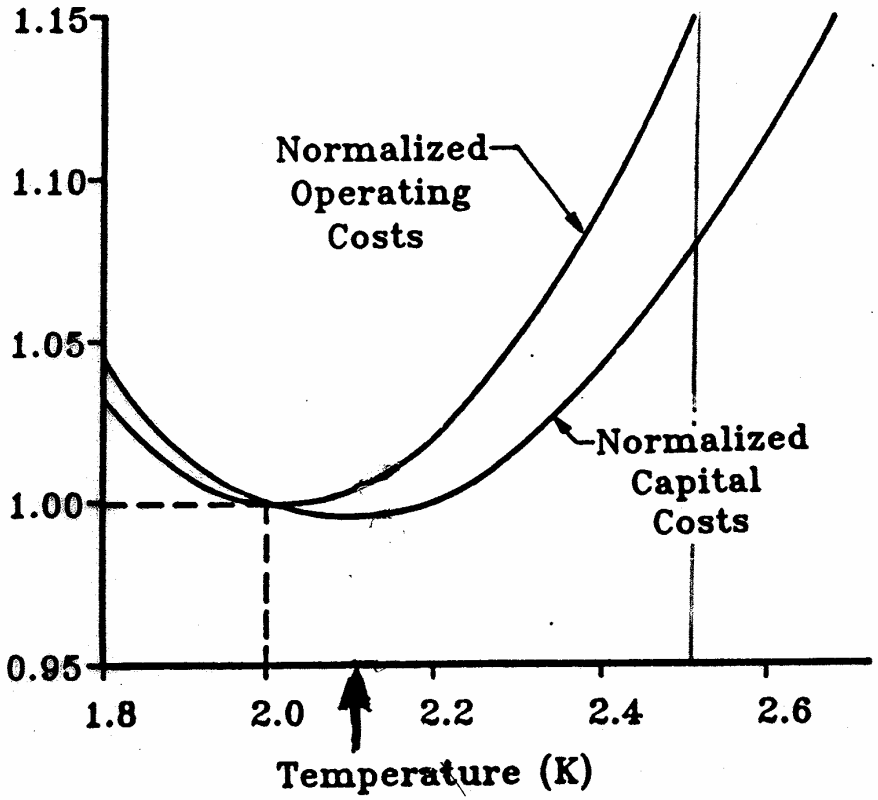
- **CTF**
  - **Liquefaction: 6 g/sec**
  - **Vacuum pumping: 8 g/sec (plus install spare)**
  - **Shield refrigeration: 800 W**
  - **Transfer lines to four areas**
- **CHL**
  - **Liquefaction: 10 g/sec**
  - **2K refrigeration: 4800 W**
  - **50K refrigeration: 12,000 W**
  - **Transfer lines to N&S linacs (plus FEL transfer line)**
- **ESR**
  - **Liquefaction: 6 g/sec**
  - **4K refrigeration: 1000 W**
  - **Transfer lines to three halls**
- **Cross connect transfer line**

1985 Large Helium Refrigerators and Liquefiers

	Temp. (K)	Capacity (kW)	No. Units	Current Status
1. LEP	4.4	4x 12	4	Decommissioned
→HLC	1.9	8 x 18 4K Equ	8	Commissioning
2. Tevatron	4.5	30	2 + 29	Operational
	4.6	10 x 0.6	10	Operational
3. CBA	4.3 (55)	24 (60)	1	Test Runs
→ RHIC	→4.5	→40		→Operational
4. HERA	4.35 (60)	3 x 6.3 (3 x 13)	3	Operational
5. Exxon	~4.4	2 x 2600 L/hr	2	Operational
6. MFTF	4.35	10 + 3.3	2	Decommissioned
7. CEBAF	**2.0 (45)**	**4.8 (12)**	**1**	**Operational**
8. Cities Services	~4.4	2400 L/hr	1	Operational
9. Tristan	4.4	4.5/6.6	1	Operational
~15 TORE-SUPRA	**1.7, 4.0**	**300, 700**	**1**	**Operational**

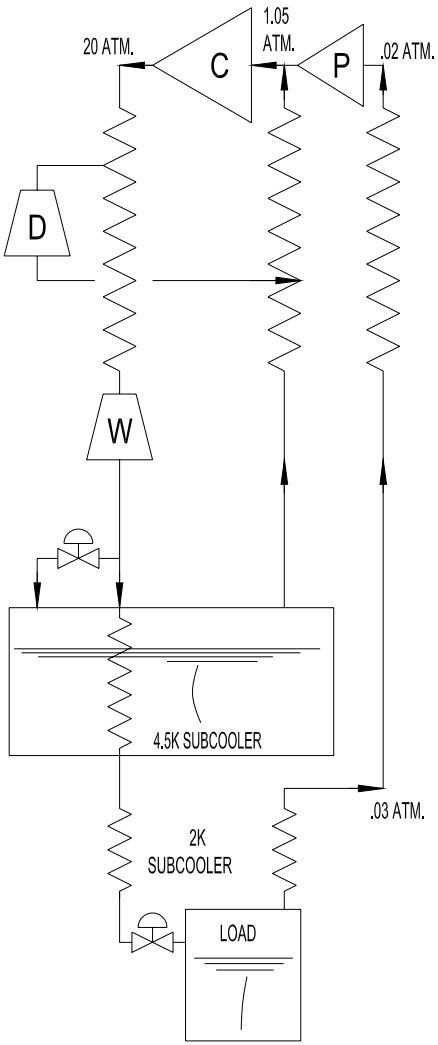
WBS 7.0 – Cryogenics
2K Optimization



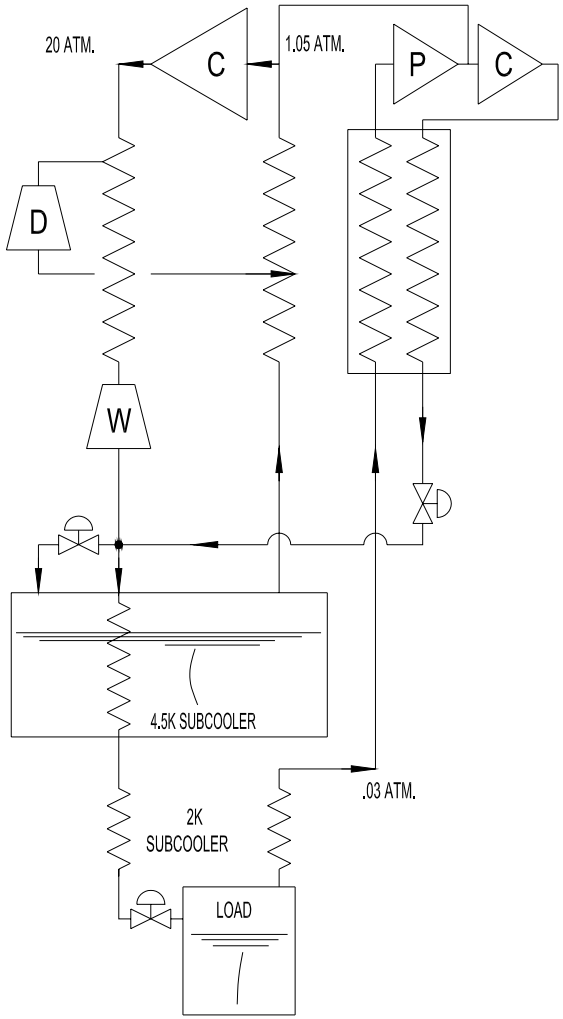


2K Refrigeration Cycles

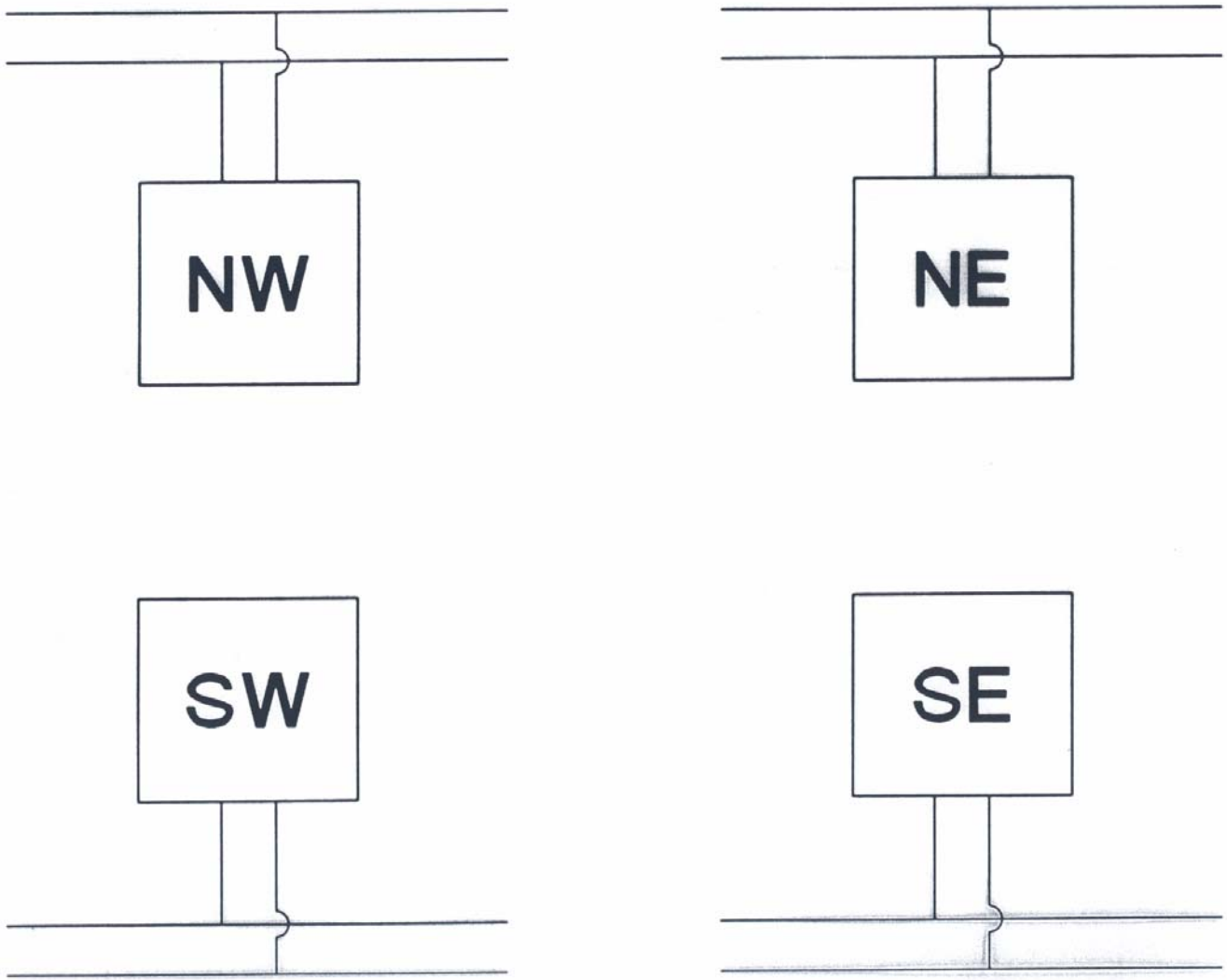
WARM VACUUM PUMP



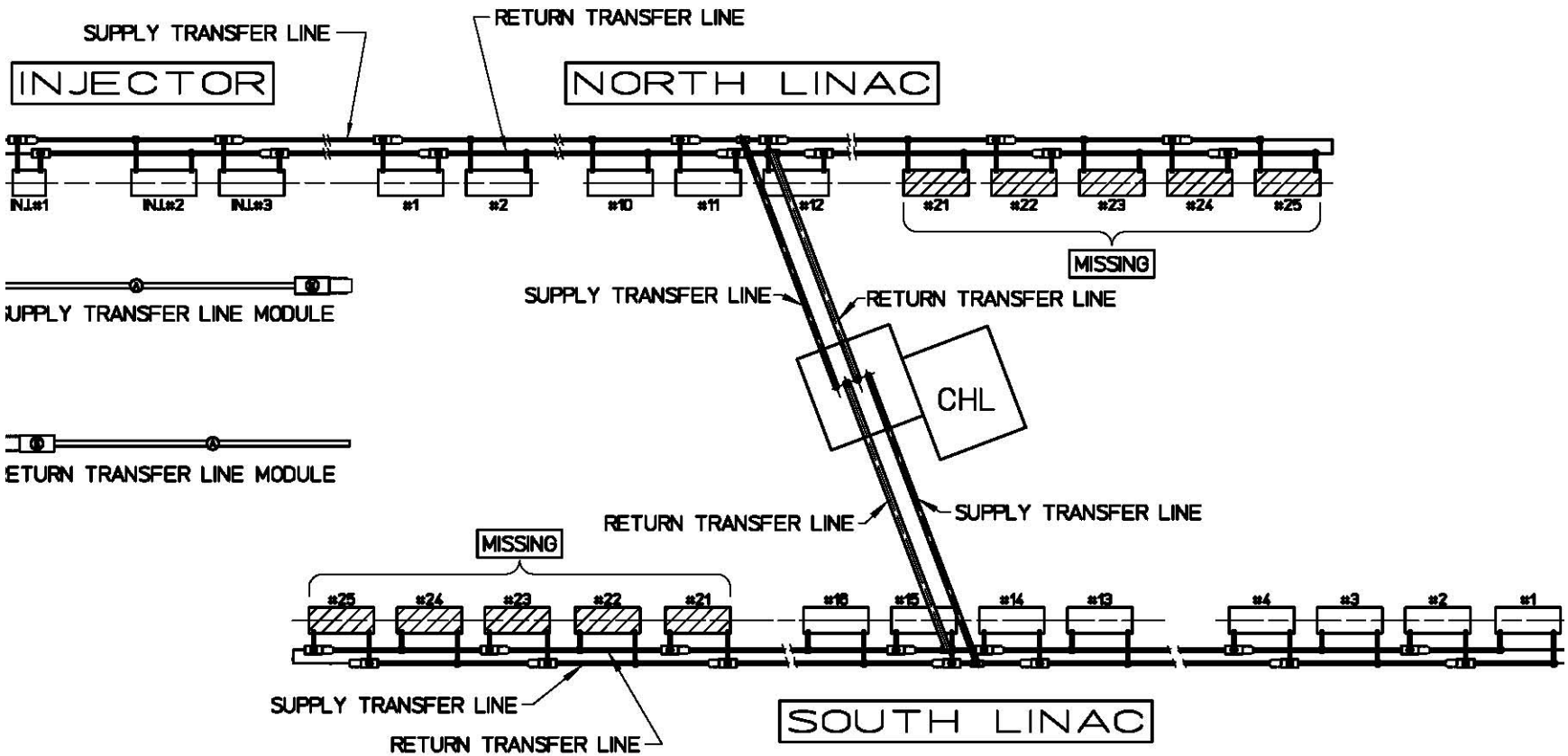
WARM VACUUM PUMP WITH SATELLITE



Four Refrigerator Layout

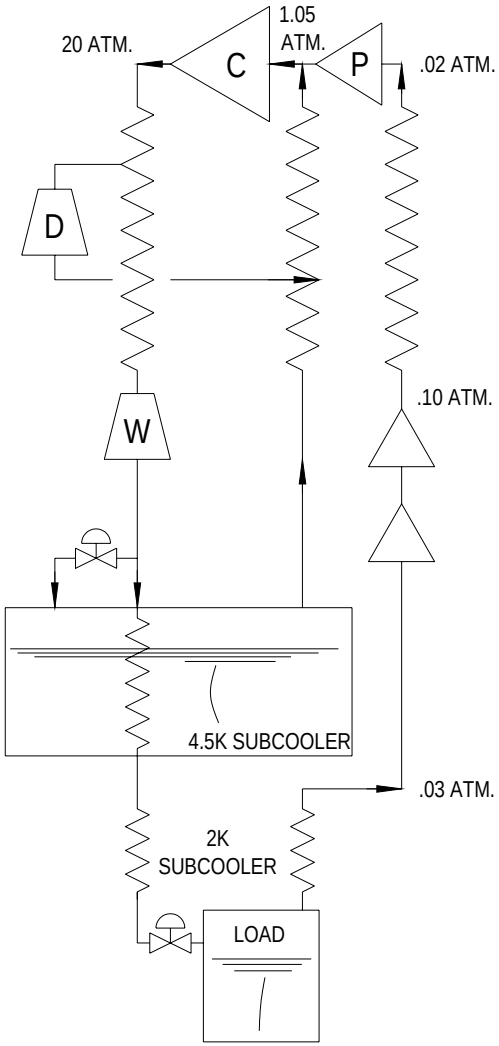


JLab Transfer Lines

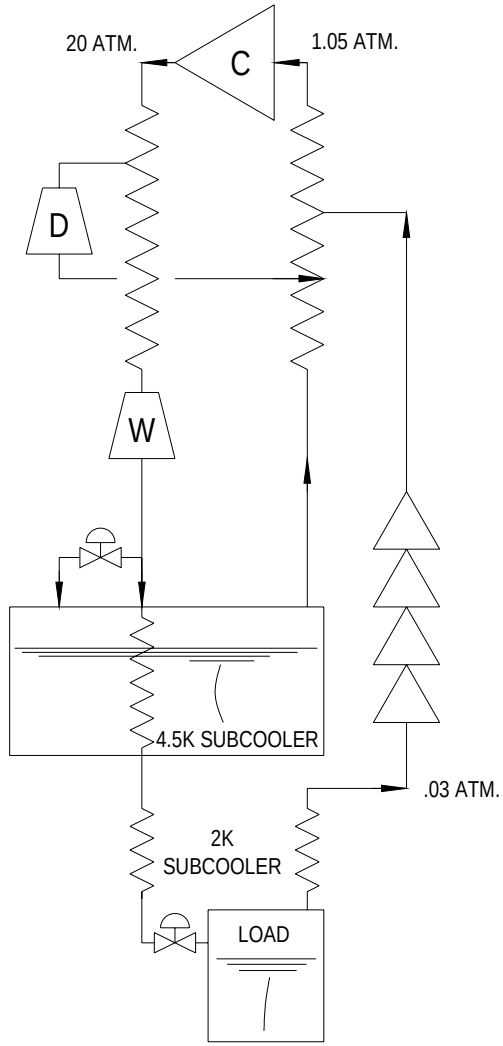


2K Refrigeration Cycles

TORE-SUPRA

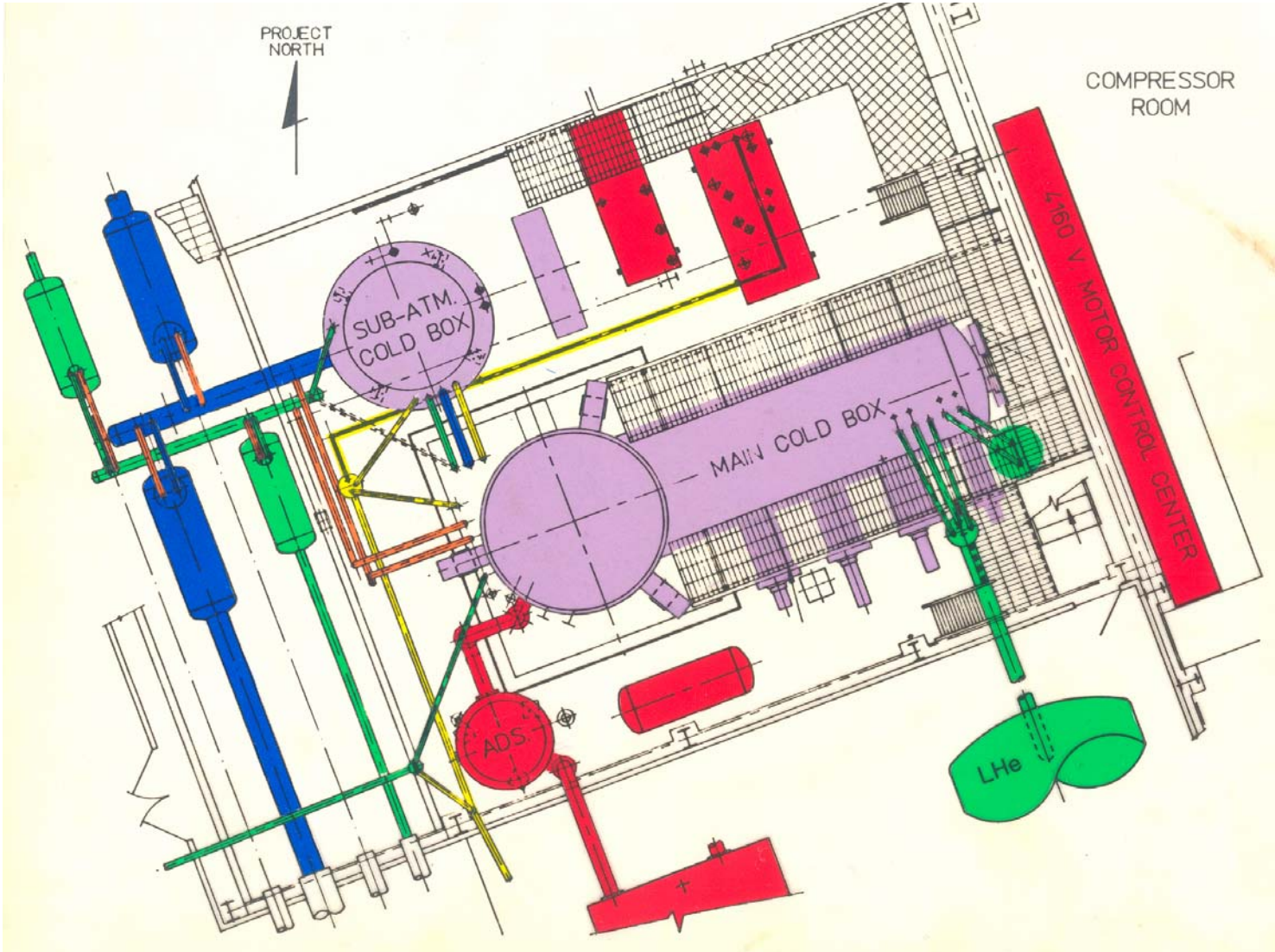


COLD COMPRESSORS

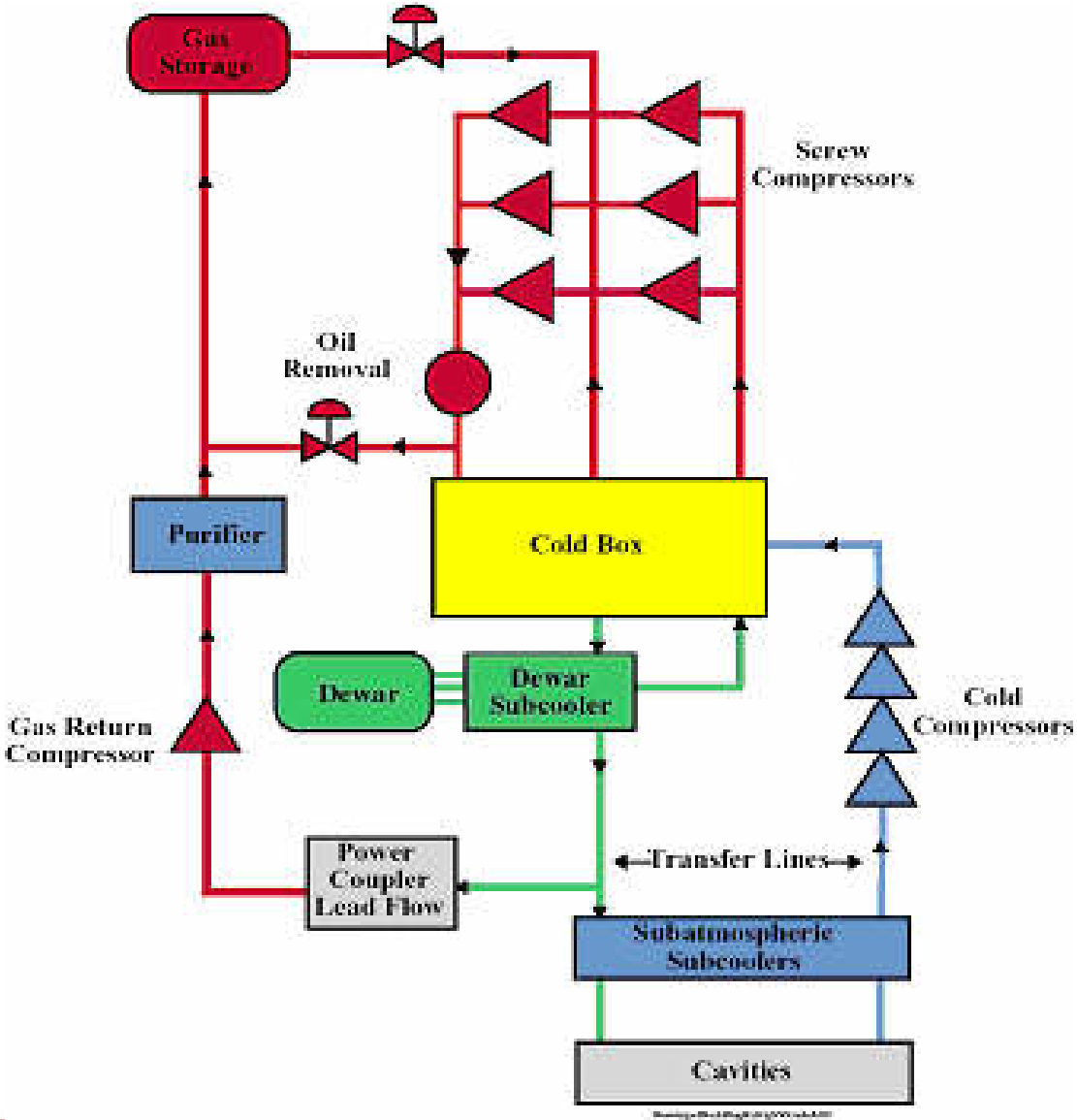


JLab CHL

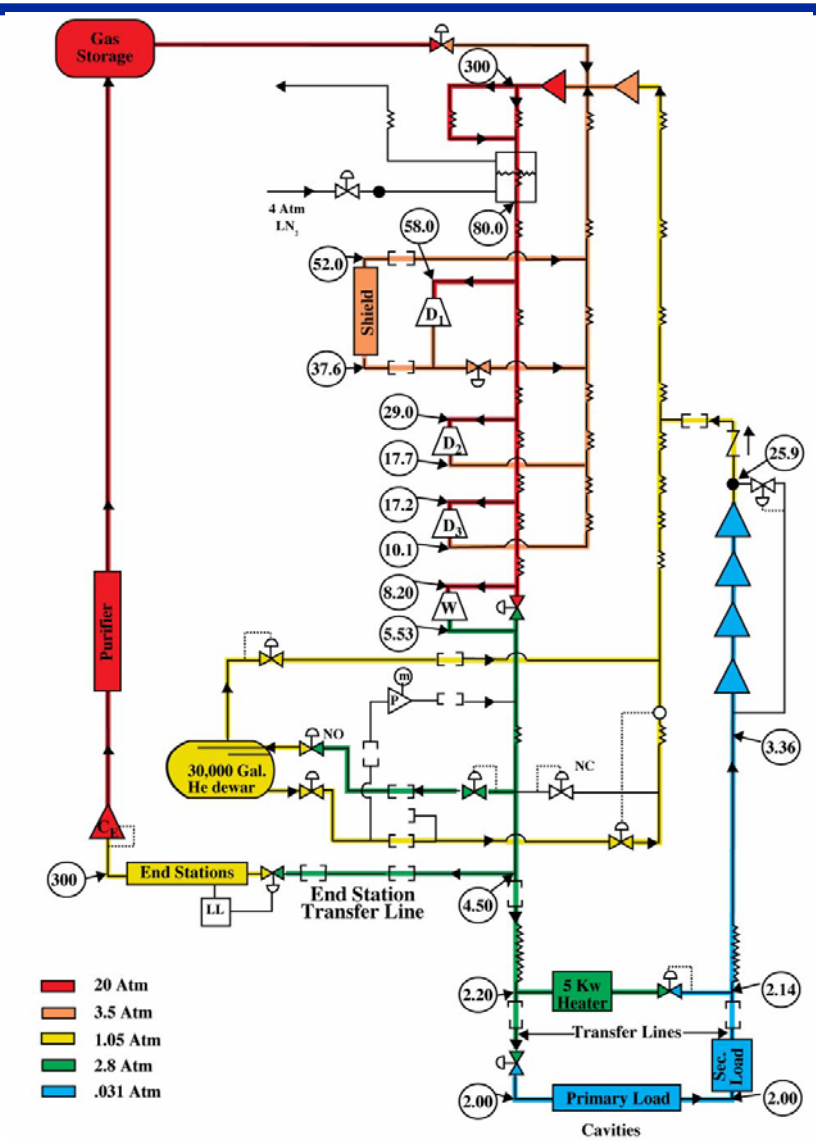
WBS 7.0 – Cryogenics
CHL Plan View



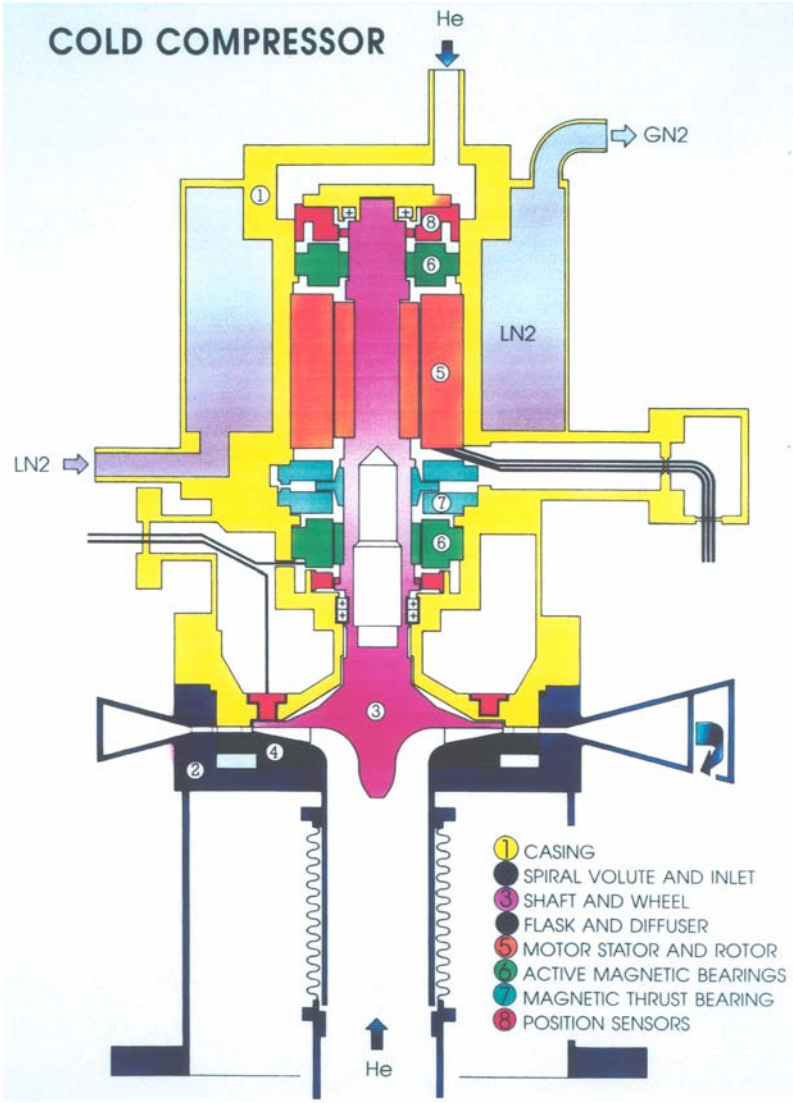
Block Diagram of Refrigerator



Process Cycle



Cold Compressor



TORE SUPRA vs. CEBAF CC

- **TORE SUPRA**
  - **CC start at operating pressure**
  - **CC speed tracks flow and load**

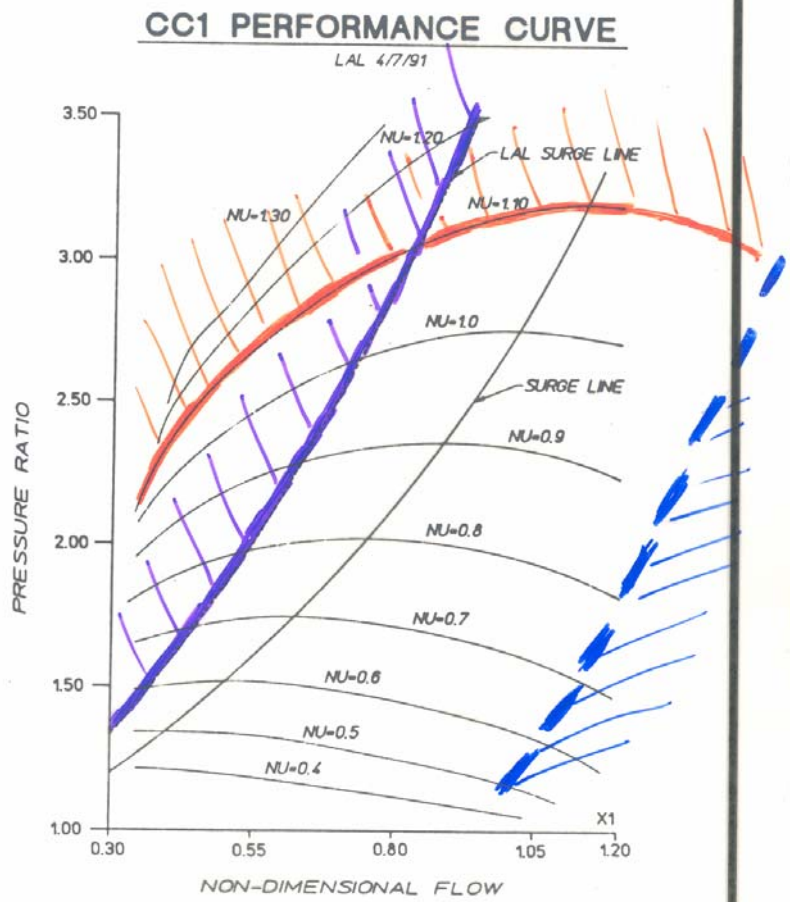
- **CEBAF**
  - **CC #1 starts at 1.2 atm and pumps down to 0.028 atm (factor 43)**
  - **CC #4 starts at 5.0K and goes to 15.0K (factor 3)**

- **This difference was not appreciated in 1987**

CC Limits

CC LIMITS

- Surge
  - $\frac{P_0}{\dot{M}\sqrt{T_i}}$
- Speed
  - $\frac{\dot{M}T_i}{P_i}$
- Torque
  - $\frac{P_i}{T_i}$
- Other
  - Stall
  - Compression ratio
  - Efficiency



CEBAF
The Continuous Electron Beam Accelerator Facility

clh[Rode/VGs]Seminar 6/94 27 June 1994

Cold Compressor Commissioning Timeline

Jan 88: Award contract to CVI/L'Air Liquide/S2M

Mar 93: Redesigned cold compressor motors installed

Apr 93: 3.3K test

Jun 93: 2.9K test

Sep 93: CEBAF assumed responsibility of CC commissioning

- Tested new control algorithm
- 2.2K test

Oct – Dec 93: Modified 4.5 K refrigerator

- Added 4.5K heat exchanger
- Increased warm screw compressor capability

Jan 94: 2.1K test

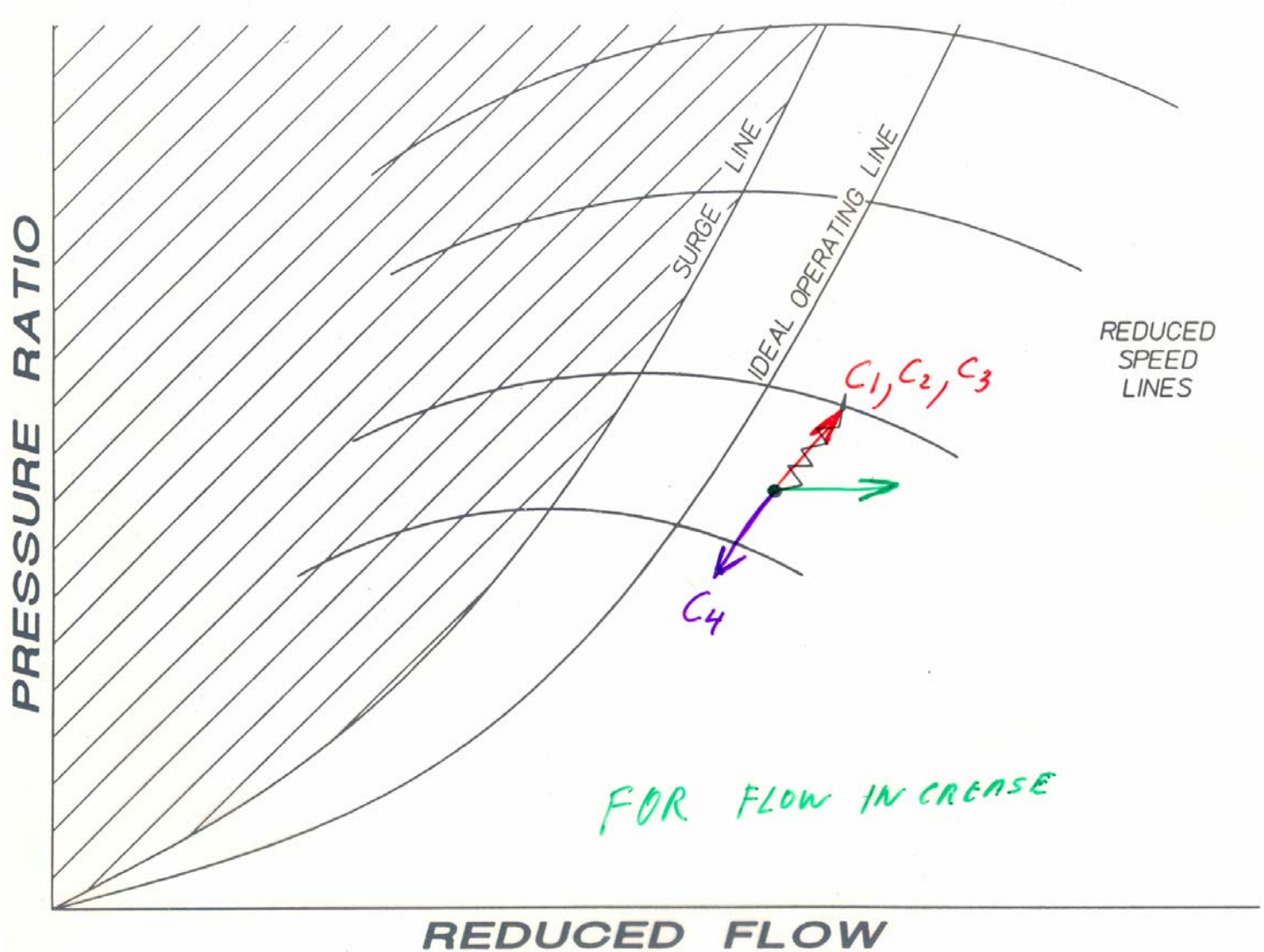
Feb – Apr 94: Intermittent CC testing

- Supported accelerator commissioning using vacuum pumps

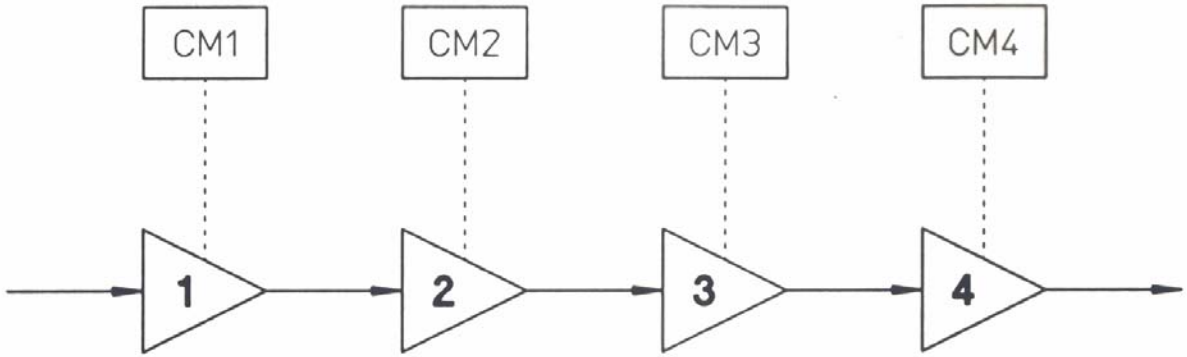
May 94: Supporting accelerator commissioning @ 2.3K

Jun 94: Fully operational 2.1K and 4.8 kW

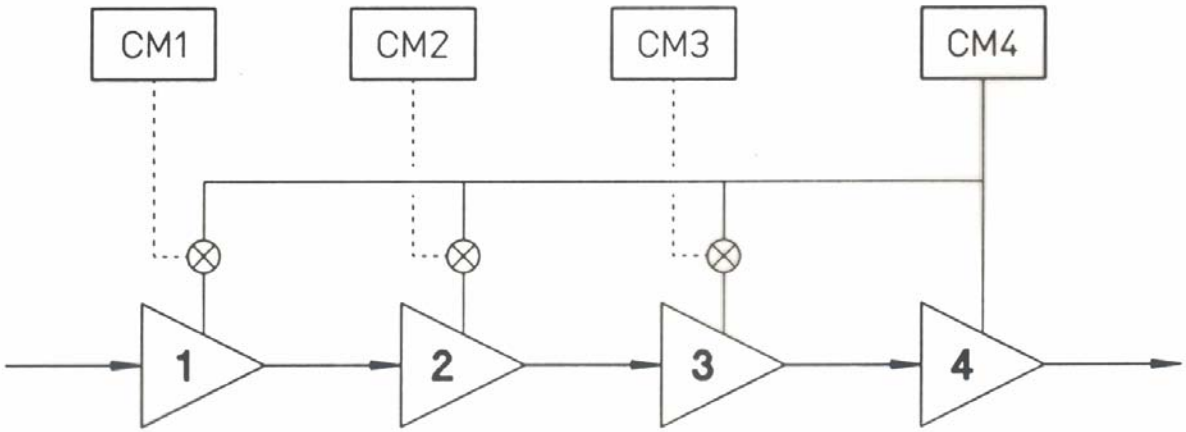
Cold Compressor Start Up



Cold Compressor Control Concept



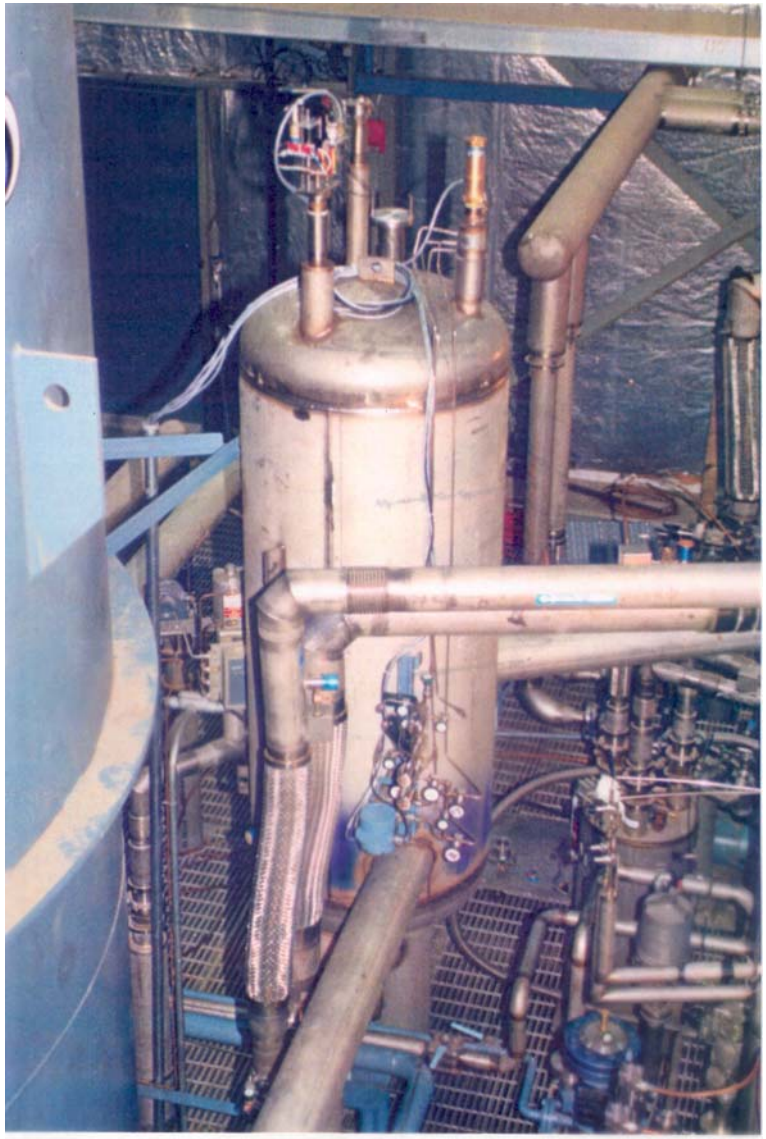
L'AIR LIQUIDE



CEBAF

ELECTRIC GEAR BOX

4.5K Subcooler



Initial 2.1K Operation