Cryogenics Plant Design

A.L.Klebaner and J.C.Theilacker

Session III

Future Photoinjector Development

October 15, 2002

Design Options

- Pure warm compression (like MTF, A0)
- Pure cold compression (like Tevatron)
- Hybrid (New technology for Fermilab)

Major Design Constraints

- Cost
- Part load operation
- Minimal cooldown time
- Availability of key components
- Risk of air contamination

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SCRF Cryogenics

Cryogenic systems for HBPI or CKM require isothermal cooling obtained by evaporization of superfluid Helium II. The process design for this cooling duty has to satisfy several demands including capability of covering a wide range of heat loads. As operation at reduced capacity (RF systems are turned off) can occur for extended time periods, it's too expensive to compensate the heat load by electrical heating at 1.8 K – 2 K.

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SCRF Cryogenics (continue)

Hydrodynamic cold compressors cannot easily match a flow variation. A preferred solution includes combination (hybrid) of cold centrifugal compressors and warm volumetric compressors. In this solution, suction pressure of the warm volumetric compressor will be reduced with the decrease of process mass flow. The process mass flow will be controlled by varying the rotational speed of the cold compressors within the field of operation with a comfortable distance from stall and choke limits.

The hybrid cycles are proven to work effectively at LHC/CERN, Tore Supra/CEA, and ELBE-Quelle/RC Rossendorf.

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Hybrid Option

Cost

Efficient Plant is least expensive.

Part load operation

Efficient capacity turndown up to 50%.

Minimal cooldown time

Increased refrigeration capacity at 4.5K by shifting compressor capacity from vacuum pumps to standard compressors.

Availability of key components

Cold and warm compressors with required characteristics are available on the market.

Risk of air contamination

Hybrid solution utilizes smaller vacuum compression stage than pure warm compression.

Low technical risk

Similar size system has been in operation since 2001 at Rossendorf research center in Dresden, Germany. We have acquired tech spec for this system.

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Cryogenic System Cost (Estimated)

Item Description	No. of units	Cost $ per unit	Total M&S $
Cost Summary			**$ 4,900,156**
Cryogenic Plant			**$ 1,742,836**
4.5 Refrigeration system	1	$ 998,199	$ 998,199
Cold Box, 2K	1	$ 244,940	$ 244,940
Cold Compressor	2	$ 117,723	$ 235,445
Refrigerator Controls	1	$ 144,251	$ 144,251
System installation contracts*	1	$ 120,000	$ 120,000
Ancillary Equipment			**$ 845,000**
30,000 gallon GHe tanks	3	$ 40,000	$ 120,000
20,000 gallon LN2 dewar	1	$ 200,000	$ 200,000
10,000 gallon LHe dewar	1	$ 250,000	$ 250,000
purifier including compressor	1	$ 90,000	$ 90,000
cooling tower system	1	$ 90,000	$ 90,000
Inst. Air, arc cells and hygrometers	1	$ 60,000	$ 50,000
Piping contract	1	$ 50,000	$ 45,000
Distribution System			**$ 1,422,320**
Warm Header, 6"IPS	600	$ 60	$ 36,000
Feed box, feed caps and vac. support	1	$ 500,000	$ 500,000
Surface Transfer Line	250	$ 2,100	$ 525,000
Bayonet, anchor and expansion cans	2	$ 30,000	$ 60,000
Tunnel Transfer Line	100	$ 2,013	$ 201,320
System installation contracts**	1	$ 50,000	$ 50,000
Misc. (ODH sys, instrument air, etc)	1	$ 50,000	$ 50,000
Civil Construction			**$ 890,000**
Cryogenic Buildings	2400	$ 250	$ 600,000
Road Construction trench	0	$ 10,000	$ -
Road Construction elevation	1	$ 40,000	$ 40,000
Moving Expenses	1	$ 250,000	$ 250,000

*No G&A

** No Contingency

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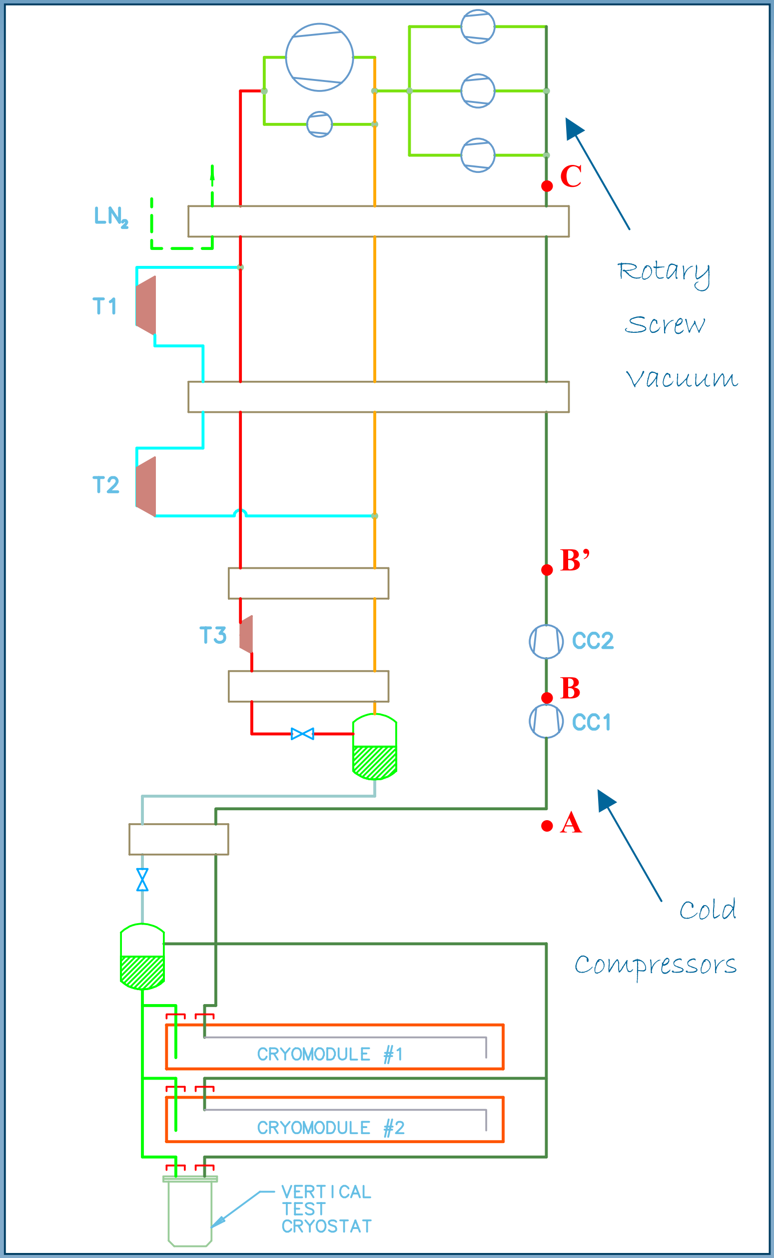
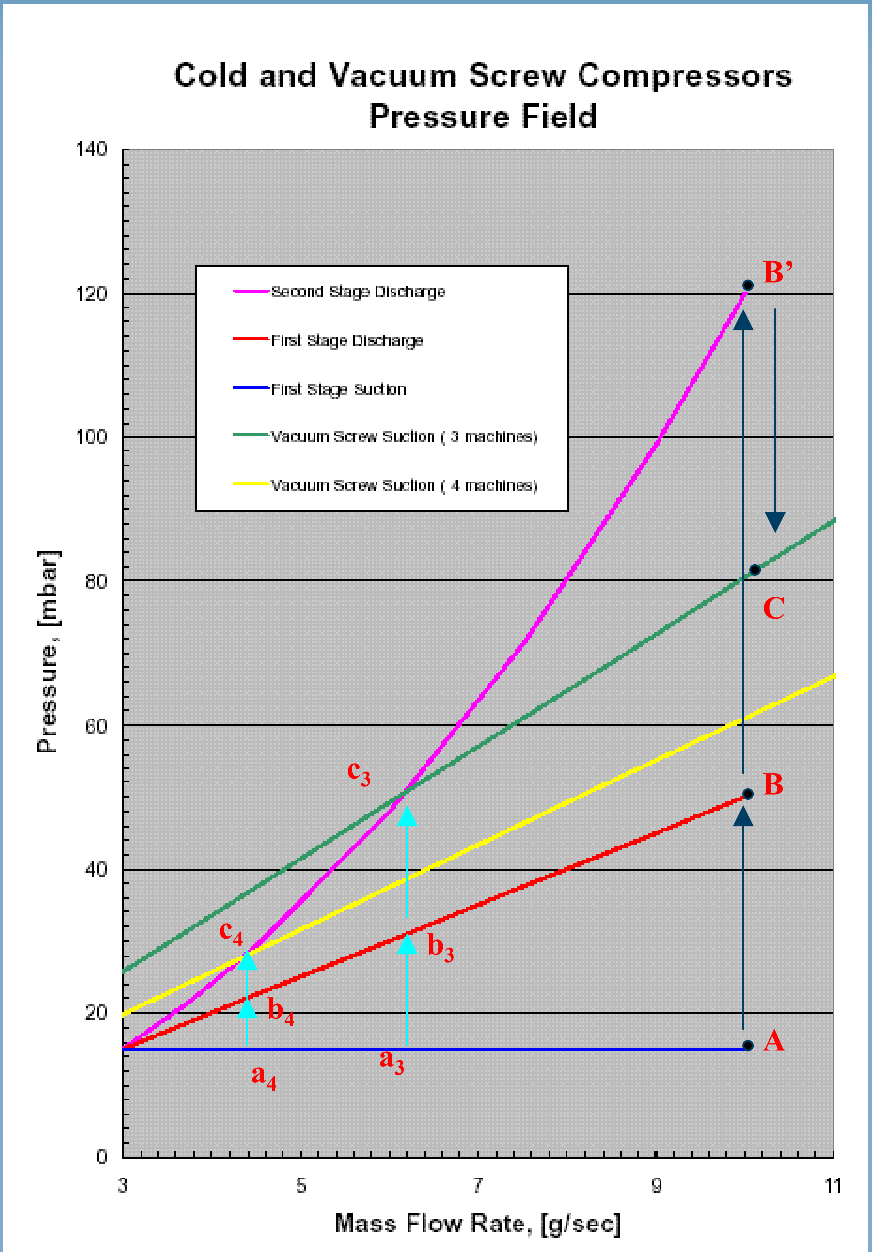
FNPL Advisory Committee Meeting, October 14-15, 2002

Plant Conceptual Design





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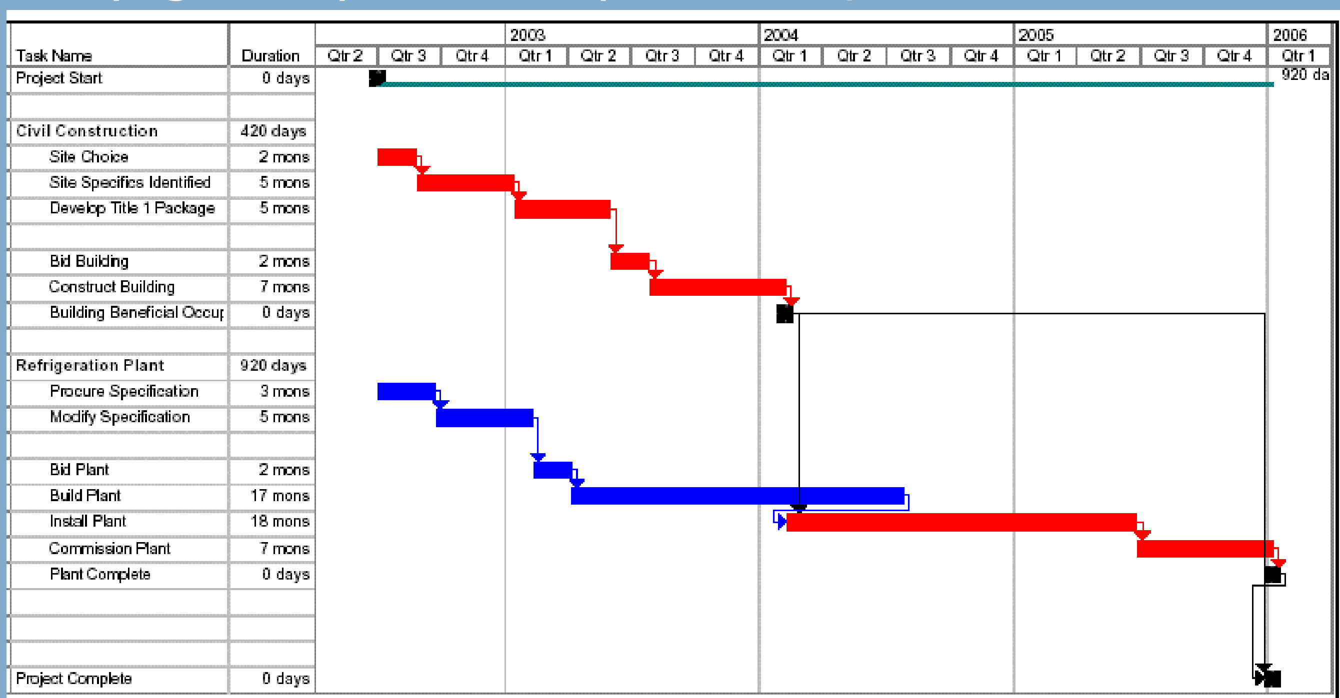
HBPI Cryo Project Schedule v 1.0

(It's all about money)

- $5M is available
  - Start civil construction at KTeV now;
  - Order Cryogenic Plant now;
  - Start Distribution System Design now;
  - Start Plant Commission 3rd Qtr 2005
  - Cryogenic System Complete 1st Qtr 2006



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HBPI Cryo Project Schedule v 2.0

(Time is money)

- $2.3M is available in FY03
  - Plant Part order now - $1.8M

    Cold Boxes, Warm Sub-atmospheric Compressor, Cold Compressors,

    Local Controls.
  - Install at Meson CTF ~ $0.15M;
  - Commission Cryo Plant by 1st Qtr 2006.
- $0M is available
  - Continue with studies …

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Cryogenics Plant Design (support materials)

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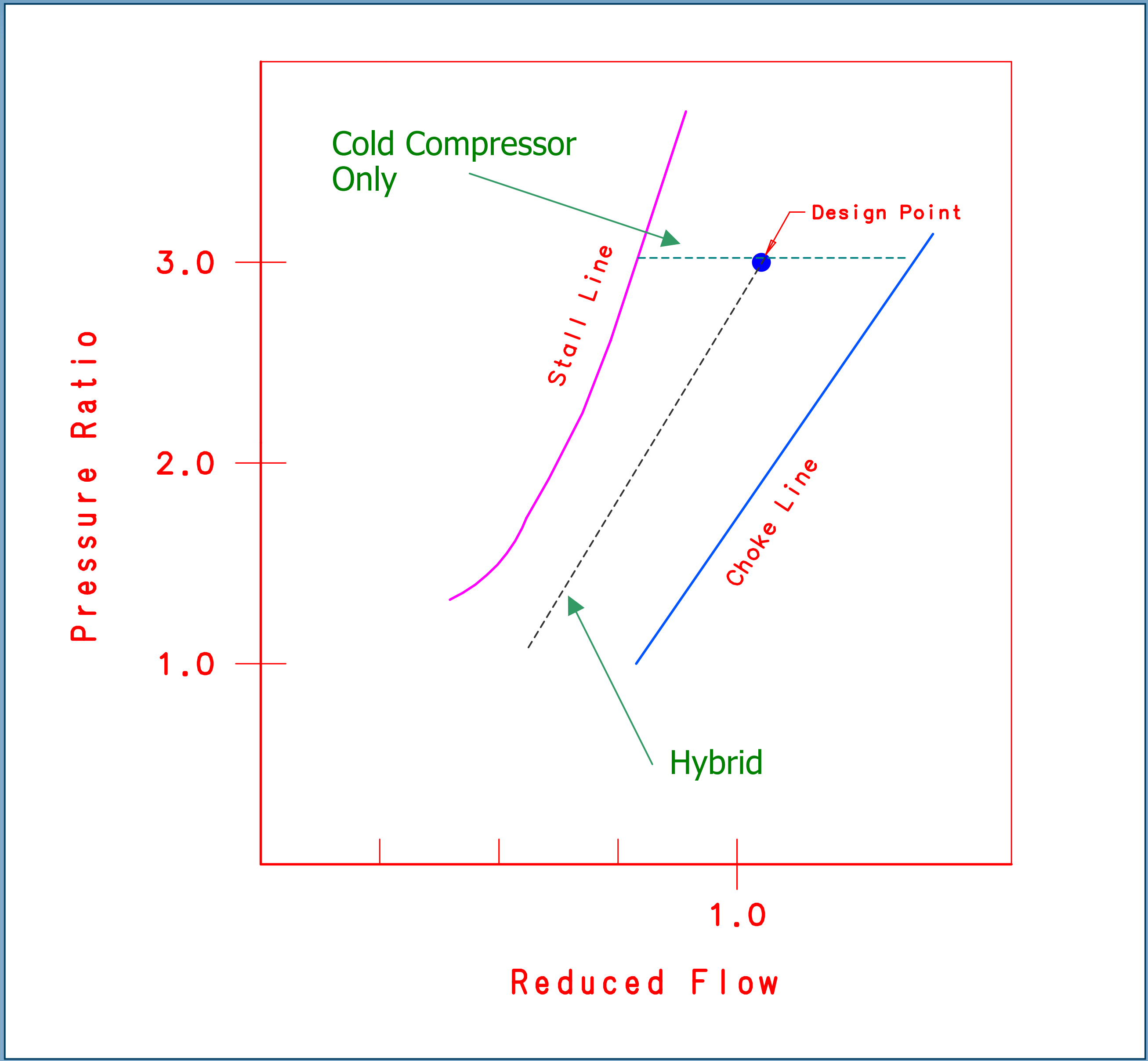
Pressure Field for Hydrodynamic Compressor



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Pay Now vs Pay Later

Category	In-House	Purchased
Capital Cost	0.8	1.0
Operational Cost	High	Low
Energy Efficiency	Very Low	High
Reliability	Very Low	High
Technical Risk	Medium	Low
Capacity	Marginal	Good
Possible R&D	Yes	No
Project Timeline	Increased	Minimal

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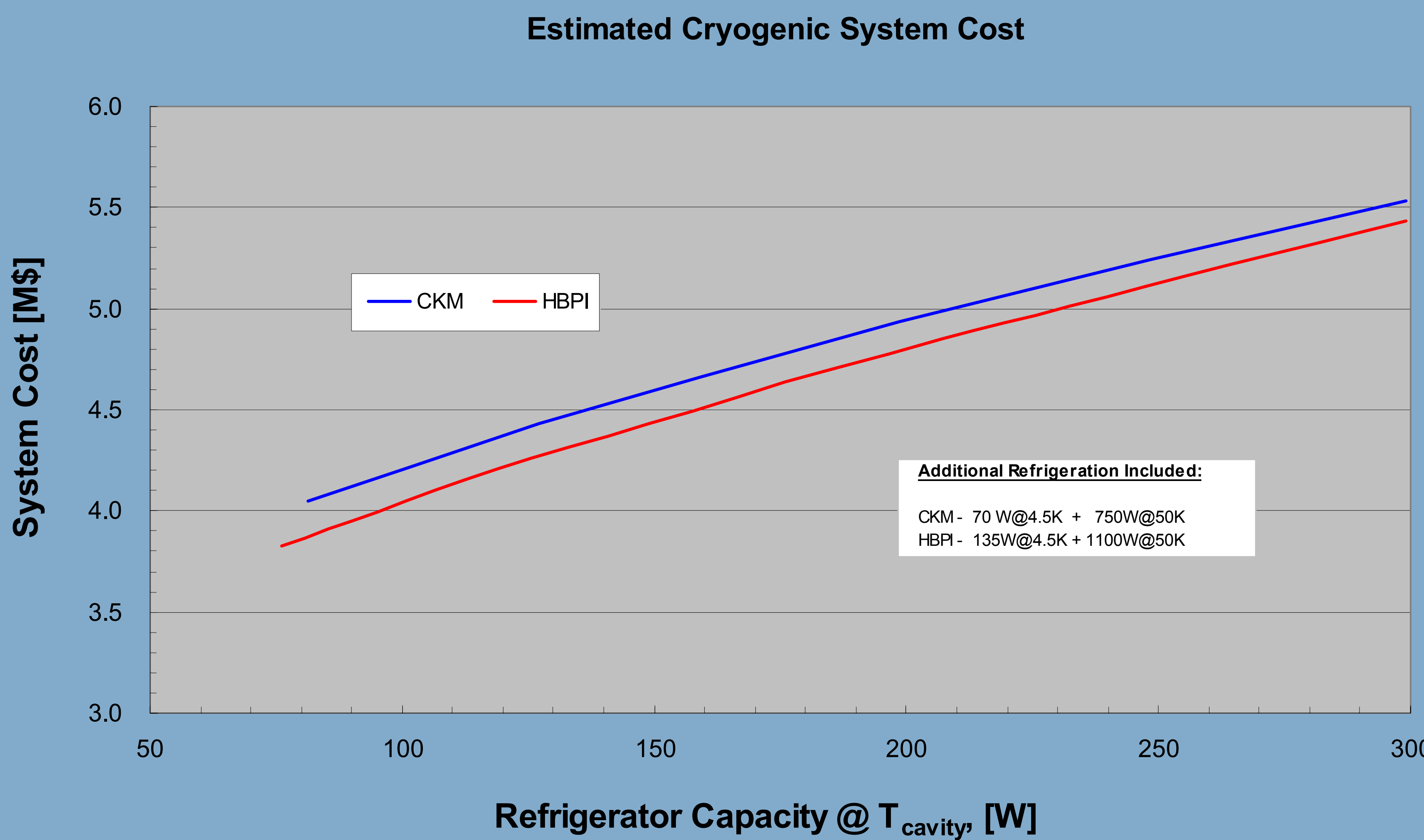
Cost vs Capacity (estimated)



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Key Components
Cold Compressors

1st STAGE

Helium Flow Rate	– 10 [g/sec]
Suction Pressure	– 15 [mbar]
Suction Temp	– 3.6[K]
Compression Ratio	– 3.7
Isentropic efficiency	– 61 [%]
Heat Leak	– 17 [W]
Motor power	– 0.2 [kW]
Wheel diameter	– 76.7 [mm]
Maximum speed	– 42 [krpm]

2nd STAGE

Helium Flow Rate	– 10 [g/sec]
Suction Pressure	– 56 [mbar]
Suction Temp	– 7.8[K]
Compression Ratio	– 2.16
Isentropic efficiency	– 64 [%]
Heat Leak	– 17 [W]
Motor power	– 0.24 [kW]
Wheel diameter	– 75.8 [mm]
Maximum speed	– 42 [krpm]

Prvni Brneska Strjirna Aircraft DivisionVelka Bites, Czech Republic

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Key Components

Subatmospheric Warm Compressors

Capacity(up to)	– 388 [SCFM Air]
Min. Suc. Pressure	– 10 [mbar]
Suction Temp	– 300[K]
Motor power	– 30 [kW]

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Heat Load (estimated)

Tom Peterson, Bill Soyars, Roger Rabehl

HBPI Heat Load in [W]			
Item	75 K	4.5 K	1.8 K
Modules Static	642	95	38
Modules Dynamic	179	9	21
Modules Peak load	821	104	59
70 m of Transfer line- Static	139	10	0
Verticle Test Dewar- Static	180	0	20
Verticle Test Dewar- Dynamic	?	?	?
System Static	961	105	58
System Peak	1139	114	79
Static/Peak ratio	0.84	0.92	0.73
Heat Uncertanty factor	1.3	1.3	1.3
Overcapacity factor	1.5	1.5	1.5
Capacity required	**2221**	**223**	**154**

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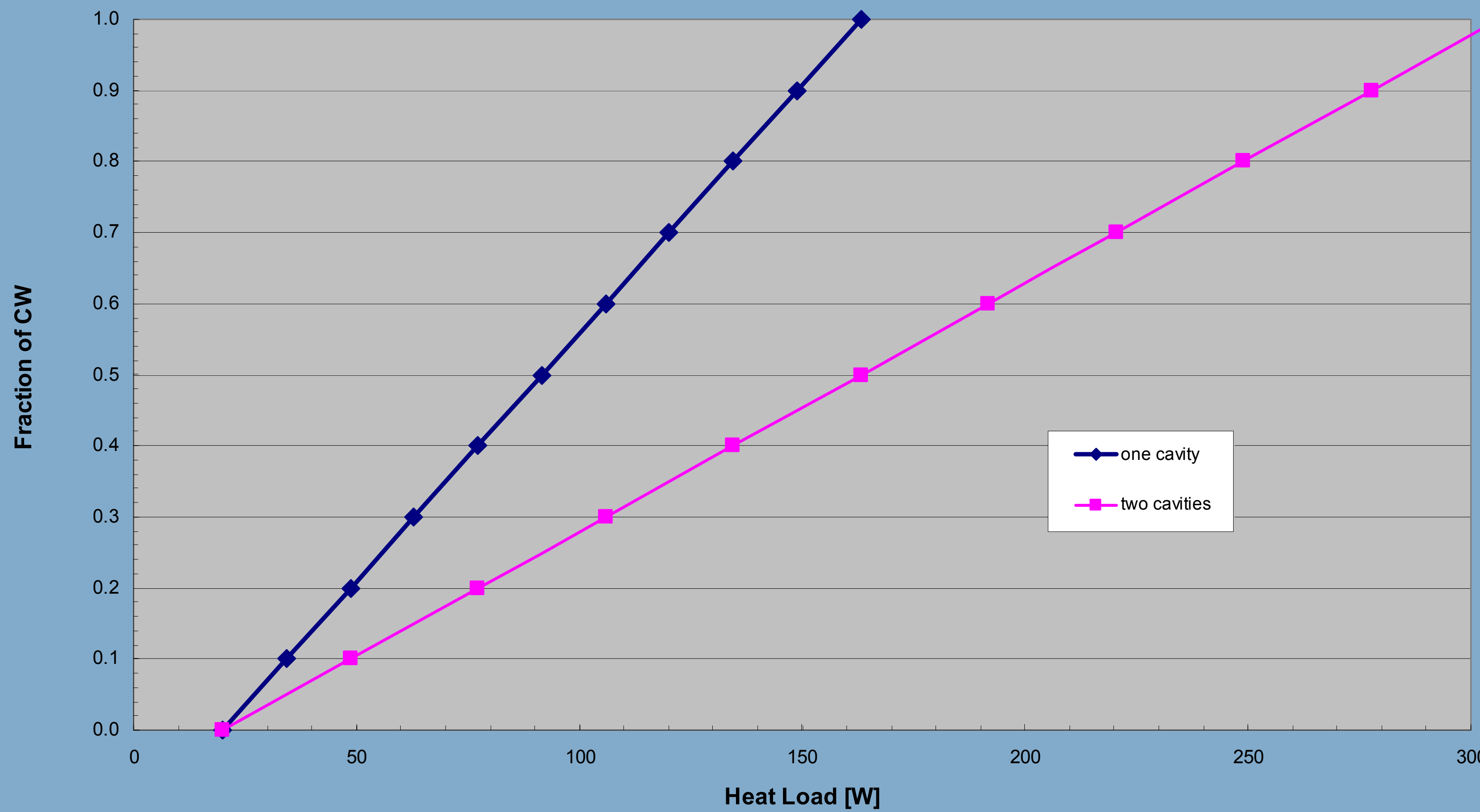
Test Dewar Heat Load

9 cell Tesla cavity at 2K, 25 MV/m, Q=5e9



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http://www-bd.fnal.gov/3.9GHz_Scrf/CDR98.pdf

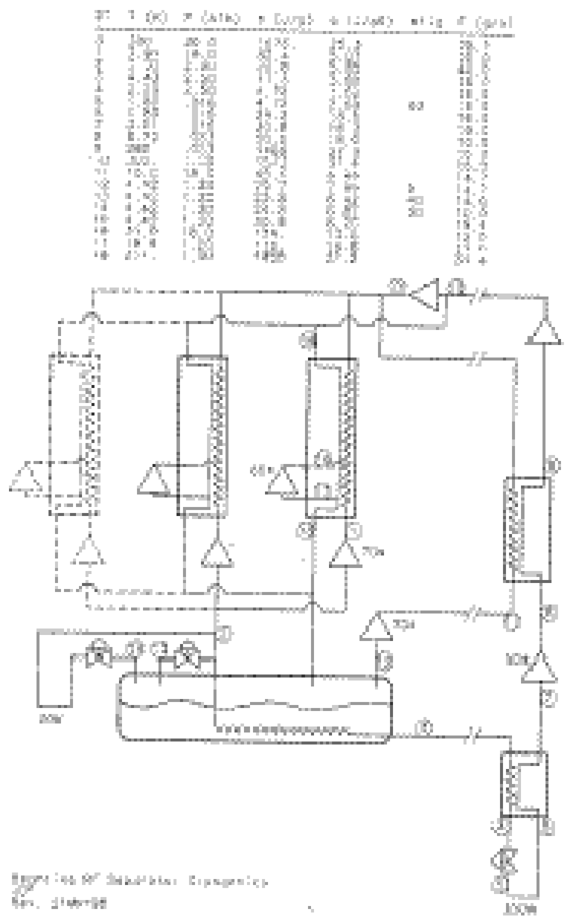

Figure 5.31: Process calculations for the refrigeration system.

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