RHIC 56 MHz SRF Cavity Cryogenics

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CRYOGENIC SYSTEM

CAVITY

- COOLING
  - Flux Densities
  - Trapped volume
- DESIGN PRESSURE
- CAVITY DETUNING

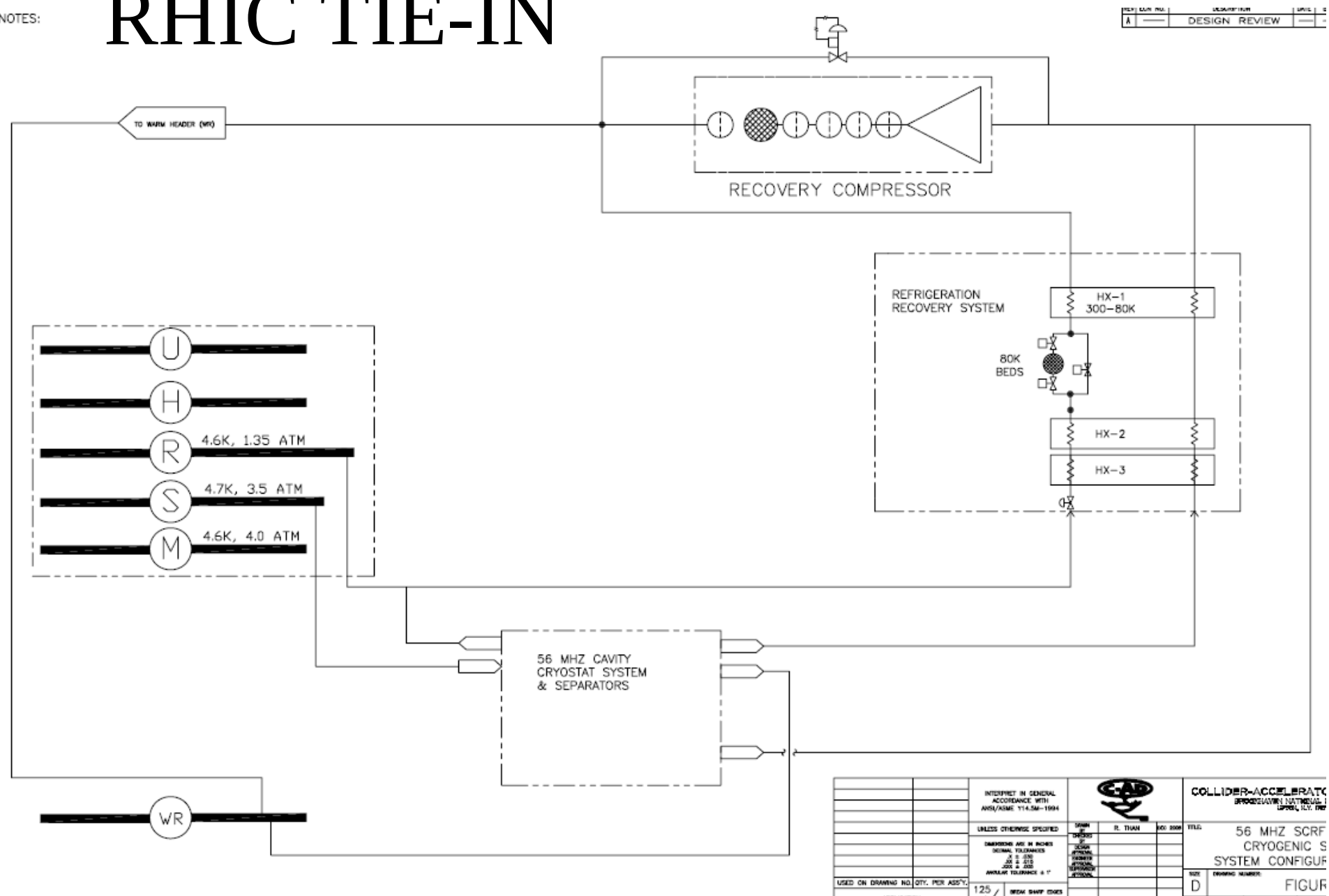
Mechanical Vibration
Microphonics
Pressure Variations
TAO

SYSTEM CONFIGURATION

INTERFACE WITH RHIC CRYO SYSTEM

- Pressure pulses from RHIC main liquid supply
- RHIC Vapor return header 1.30 atm
- Cavity design pressure / RHIC Design pressures 18 atm

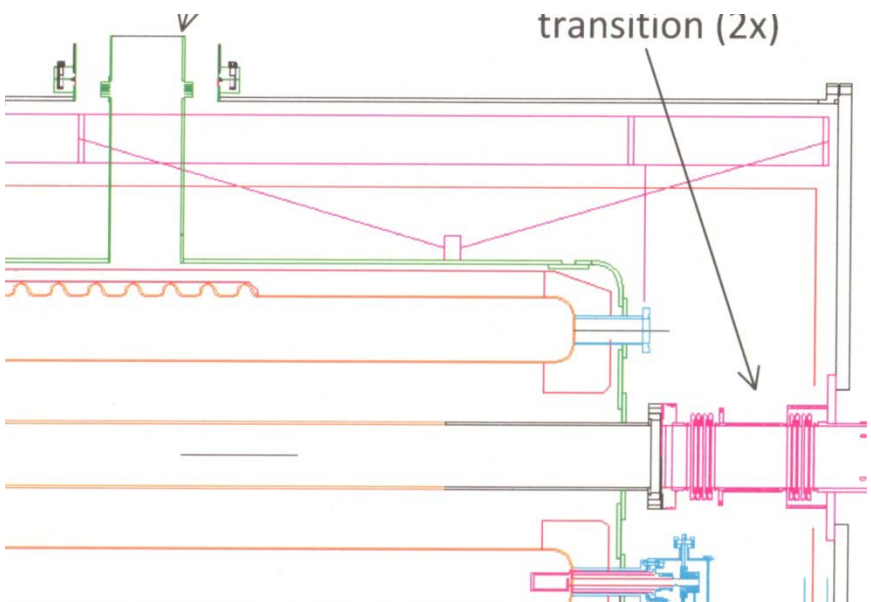
RHIC TIE-IN


NOTES:
DESIGN REVIEW
TO WARM HEADER (WR)
RECOVERY COMPRESSOR
REFRIGERATION
RECOVERY SYSTEM
HX-1
300-80K
80K
BEDS
HX-2
HX-3
U
H
R
4.6K, 1.35 ATM
S
4.7K, 3.5 ATM
M
4.6K, 4.0 ATM
56 MHZ CAVITY
CRYOSTAT SYSTEM
& SEPARATORS
WR
COLLIDER-ACCELERATO
56 MHZ SCRF
CRYOGENIC S
SYSTEM CONFIGUR
FIGUR

CAVITY COOLING

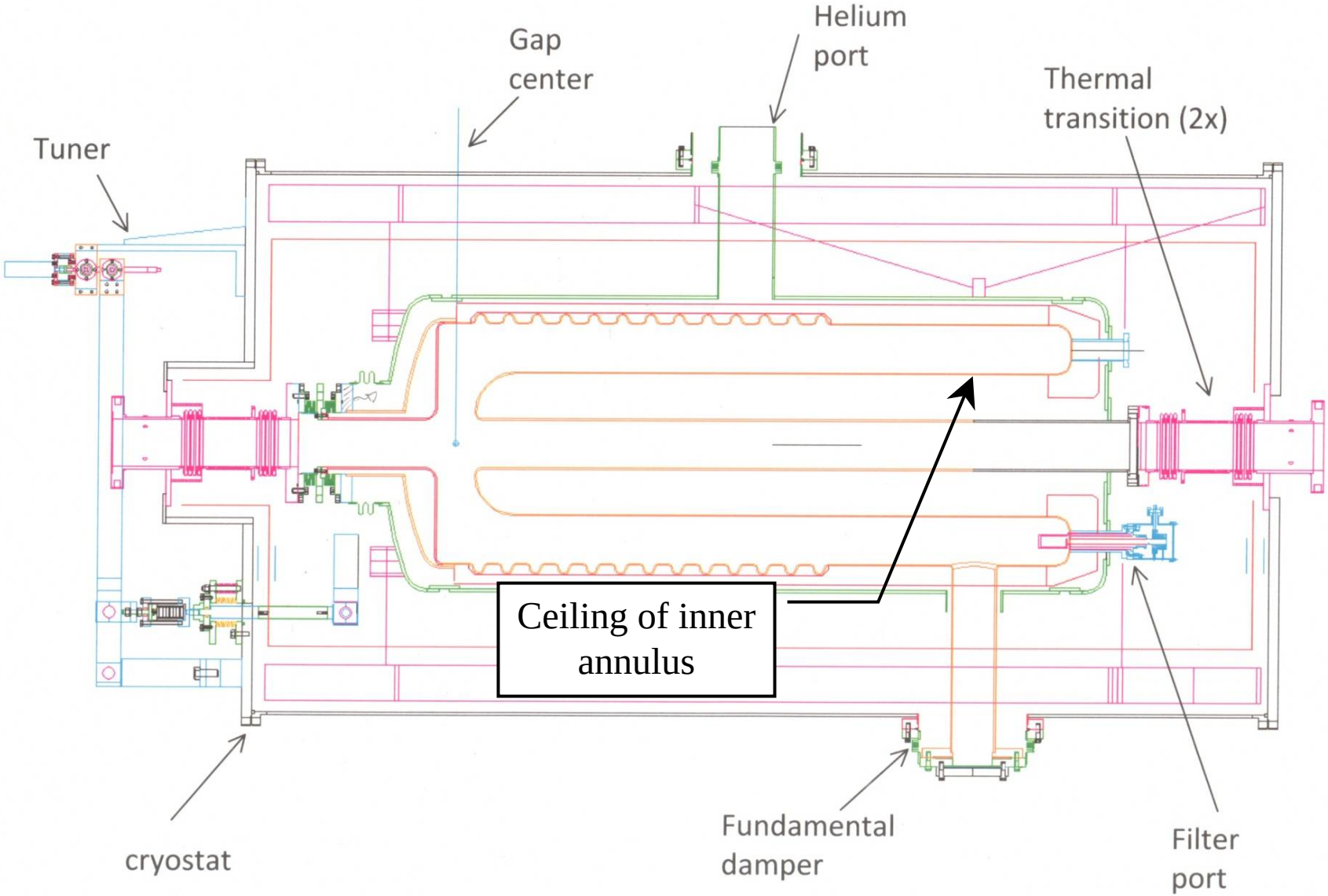
HEAT TRANSFER

- Q/A= 0 - 40 W/m^2
- Mostly Free Convection Regime
- Nucleate boiling regime
- Highest heat flux at Damper / power coupler end 40 W/m^2

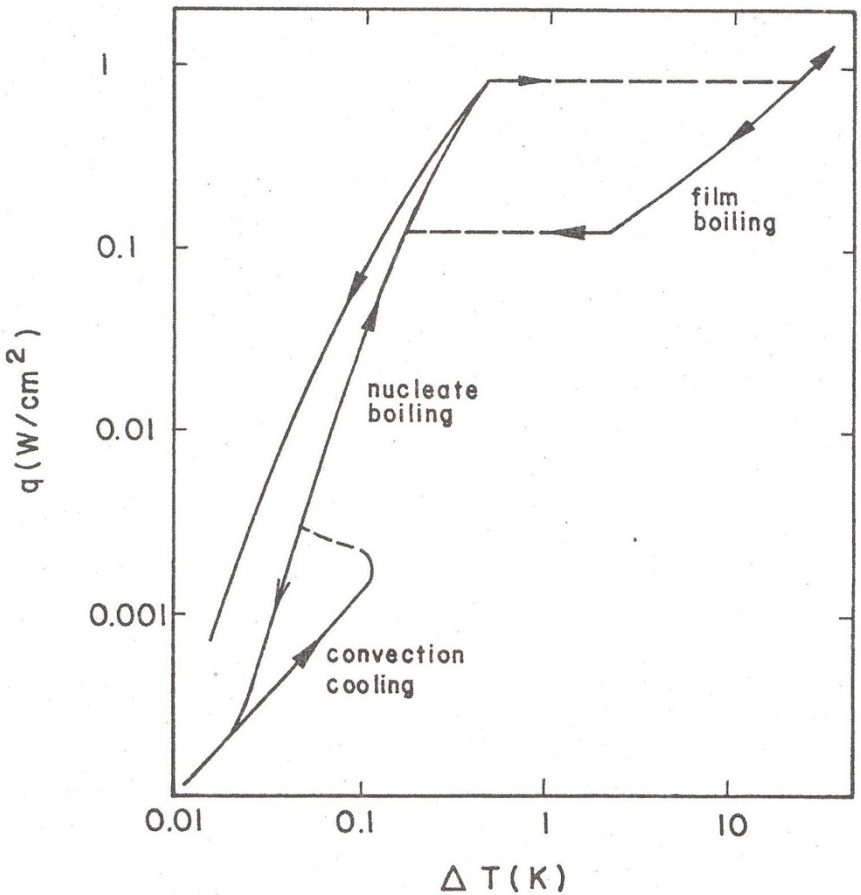


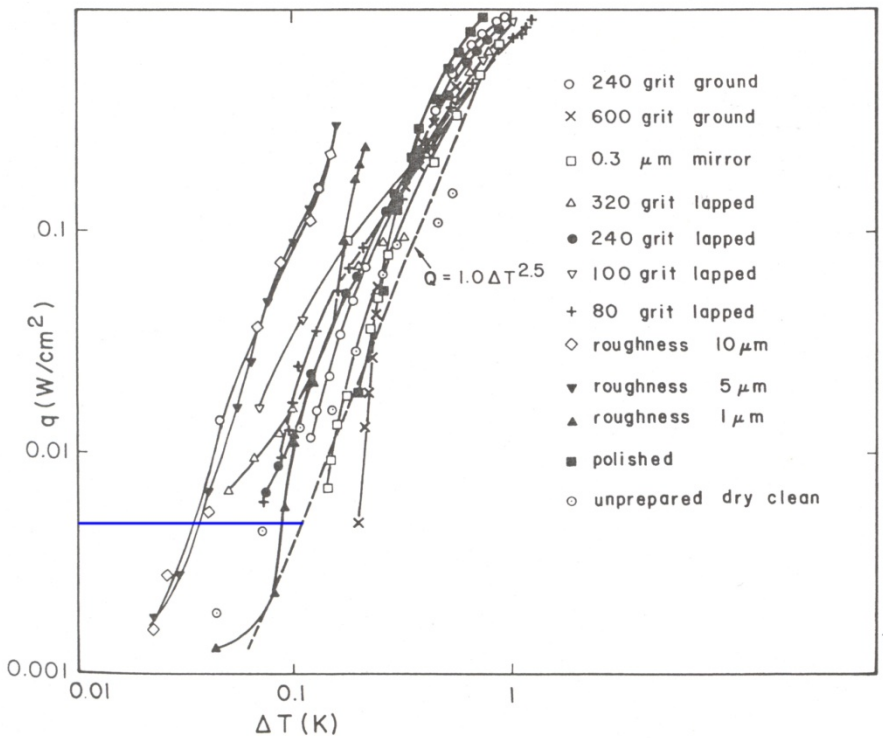
- TRAPPED VAPOR
  - GEOMETRY
  - Inner annular volume
  - High point
  - Deep (long) volume
- Experiment to test trapped vapor.
  - Mimics the curved surface
  - Heaters to apply flux density

CAVITY COOLING



Heat Transfer Regime

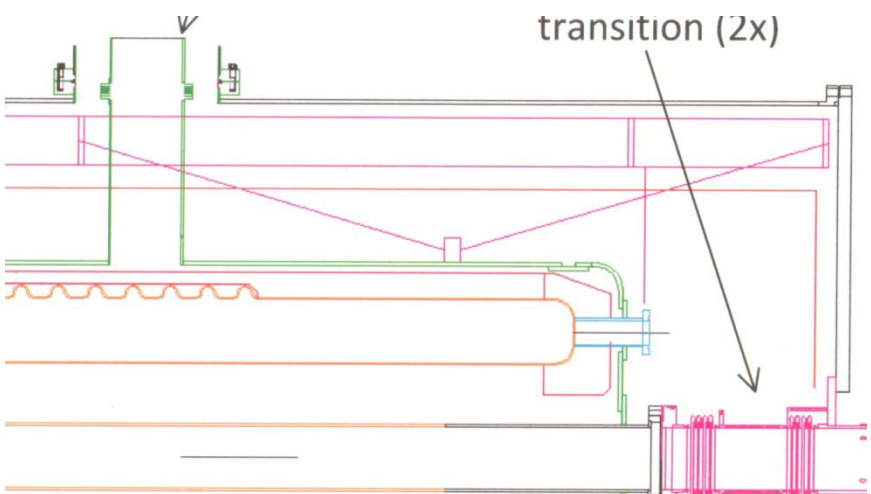


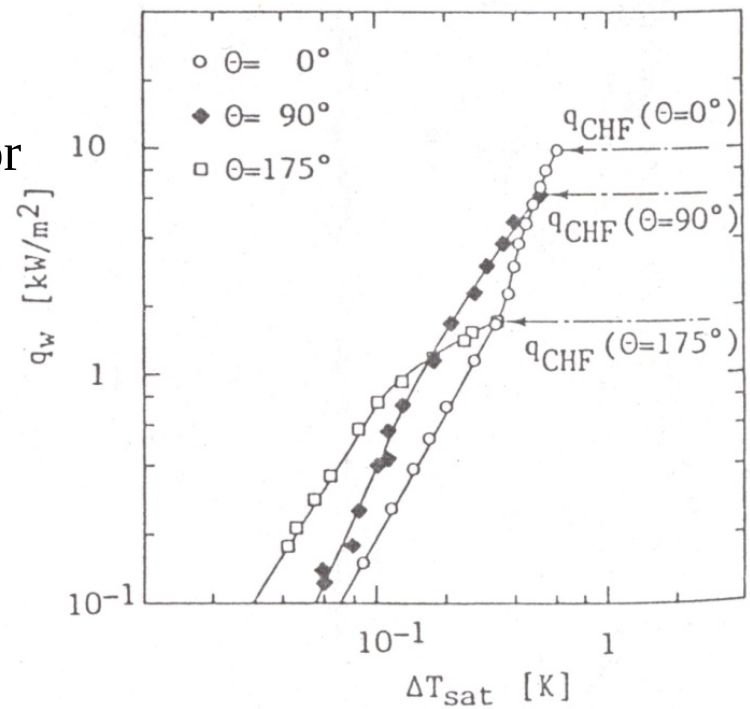


Ref: Van Sciver, S.W., "Helium Cryogenics", Plenum Press,1986

TRAPPED VAPOR /Orientation

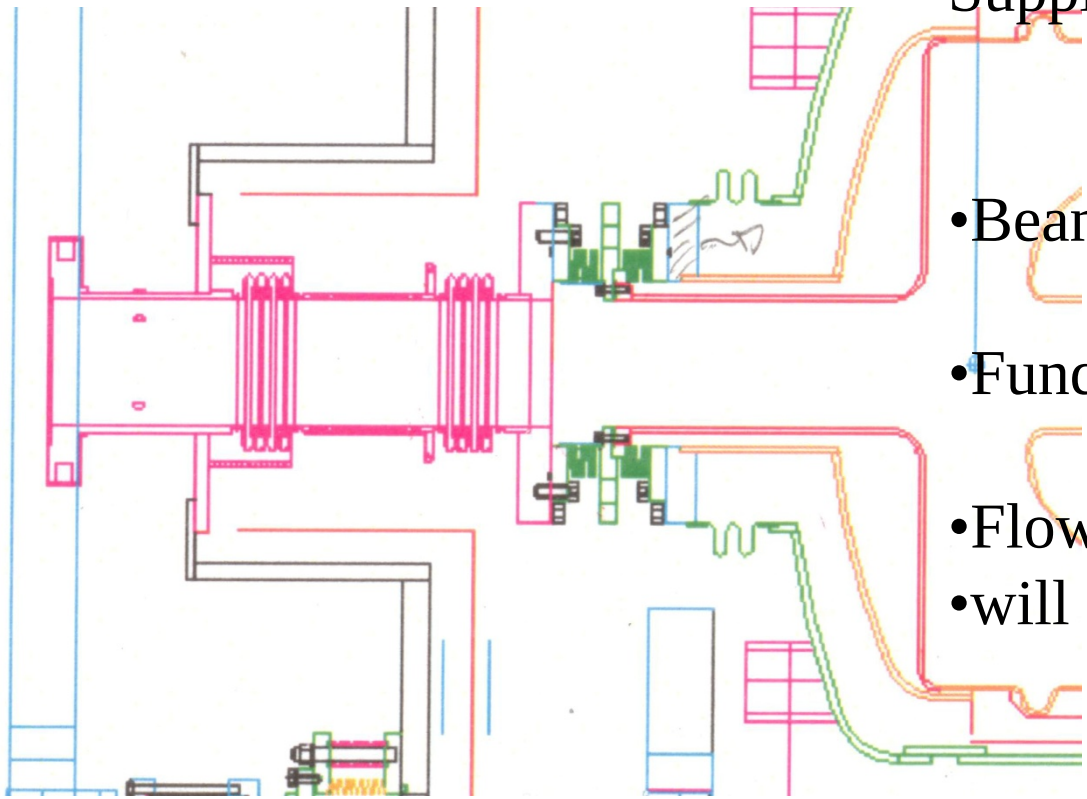
- Experimental set-up to thermal performance with trapped vapor.
  - –Mimics the curved surface
  - –Heaters to apply flux density
- Data from other horizontal cavities, vapor bubble flows lateral and upward





Nisho, S. and Chandratilleke, G.,
JSME I. Journal, p.639-45, Vol 32. No. 4, 1989

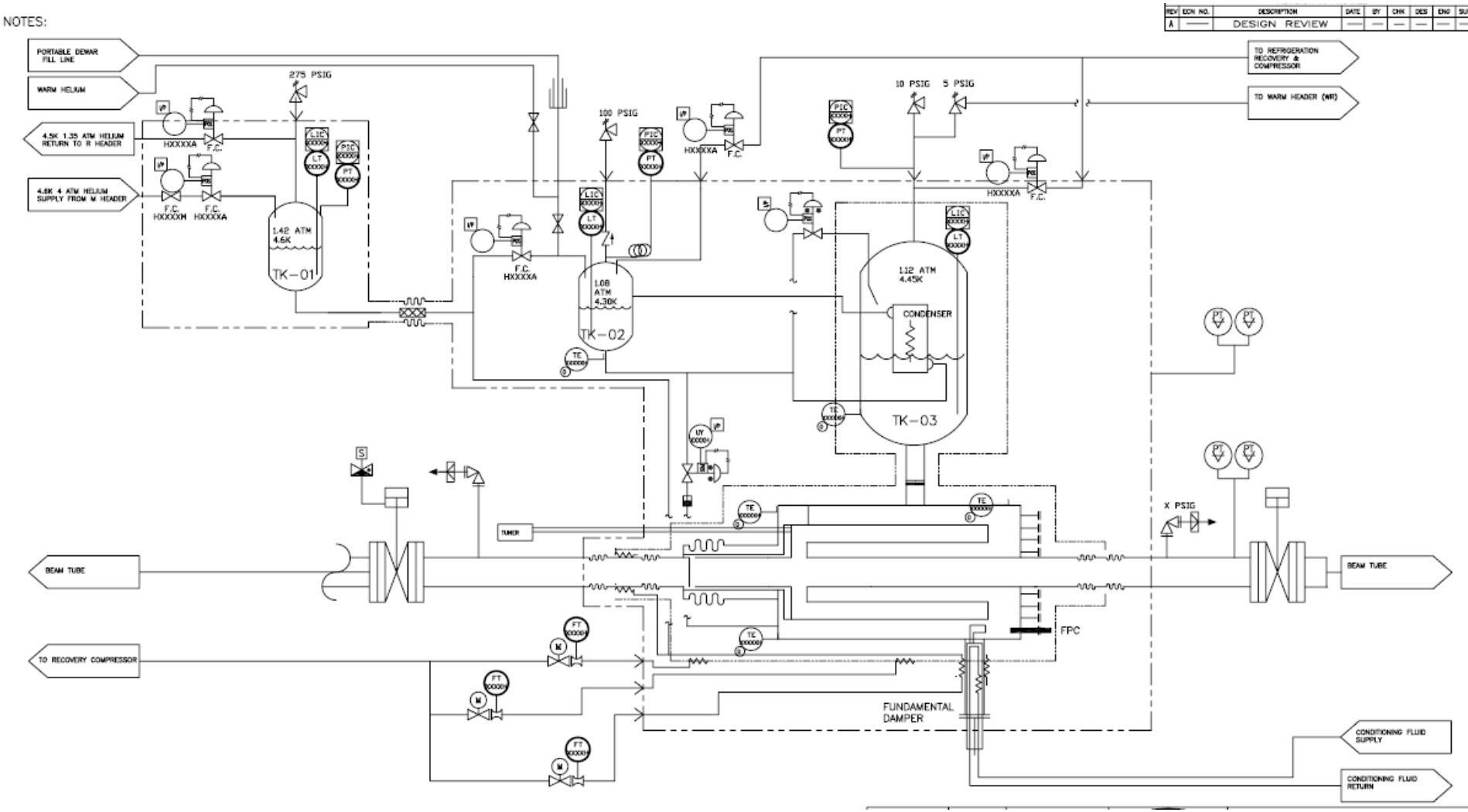
INTERCEPTS & SHIELD



Supplied from Separator #1
@ ~1.5 atm

- Beam tube thermal transitions
- Fundamental Damper
- Flow from beam tube intercepts
- will go to thermal shield

CRYOSTAT SYSTEM



ISOLATION

SEPARATOR #1			CONDENSER		
RHIC Liquid Supply Pulse	1 68	psi mbar	H condense	600	W/m^2-K
Psupply from RHIC	3.5	bar	H_{boil}	~1400	W/m^2-K
Peak flow	10	g/s			
Vapor space volume	100	Liter	Fast Transient		
Sat Conditions	1.65	bar	Vapor space	500	Liter
	4.8	K	ΔP	0.1	mbar
Separator pressure pulse	~1	mbar	dQ/dP	200	J/mbar
			Slow Transient		
			Load Shift	40	W
			ΔT	50	mK
Supplies cooling to beam tube thermal transition intercepts			dP/dT (vapor pressure slope)	1	mbar/mK
			ΔP	50	mbar
Supplies flow to fundamental damper			Δf	~ 15	Hz

ISOLATION

NO CONDENSER	CONDENSER
Two separators	
•Isolate only supply from RHIC	•Isolate supply from RHIC and return line to recovery compressor
•Recovery compressor acoustics potential problem, although located large distance away	•Recovery compressor pressure : Low Due to additional 100 mK gradient across condenser
	Heat load shift: leads to a vapor pressure shift due to increase DT across condenser
Vapor space can also absorb fast transients	Vapor space can also absorb fast transients

COOLING

TEMPERATURES **PRESSURES**

	K	atm	psia	
Separator #1	4.80	1.652	24.3	Also supplies intercept
Warm Compressor		1.010	14.84	
Separator#2, Boiler side	4.30	1.075	15.80	
Cavity bath, Condenser side	4.41	**1.188**	**17.45**	
Relief 1,		**1.361**	**20.0**	**Design Pressure**
Relief 2, Loss of vacuum		1.647	24.2	
RHIC Vapor Return	4.7	1.3		

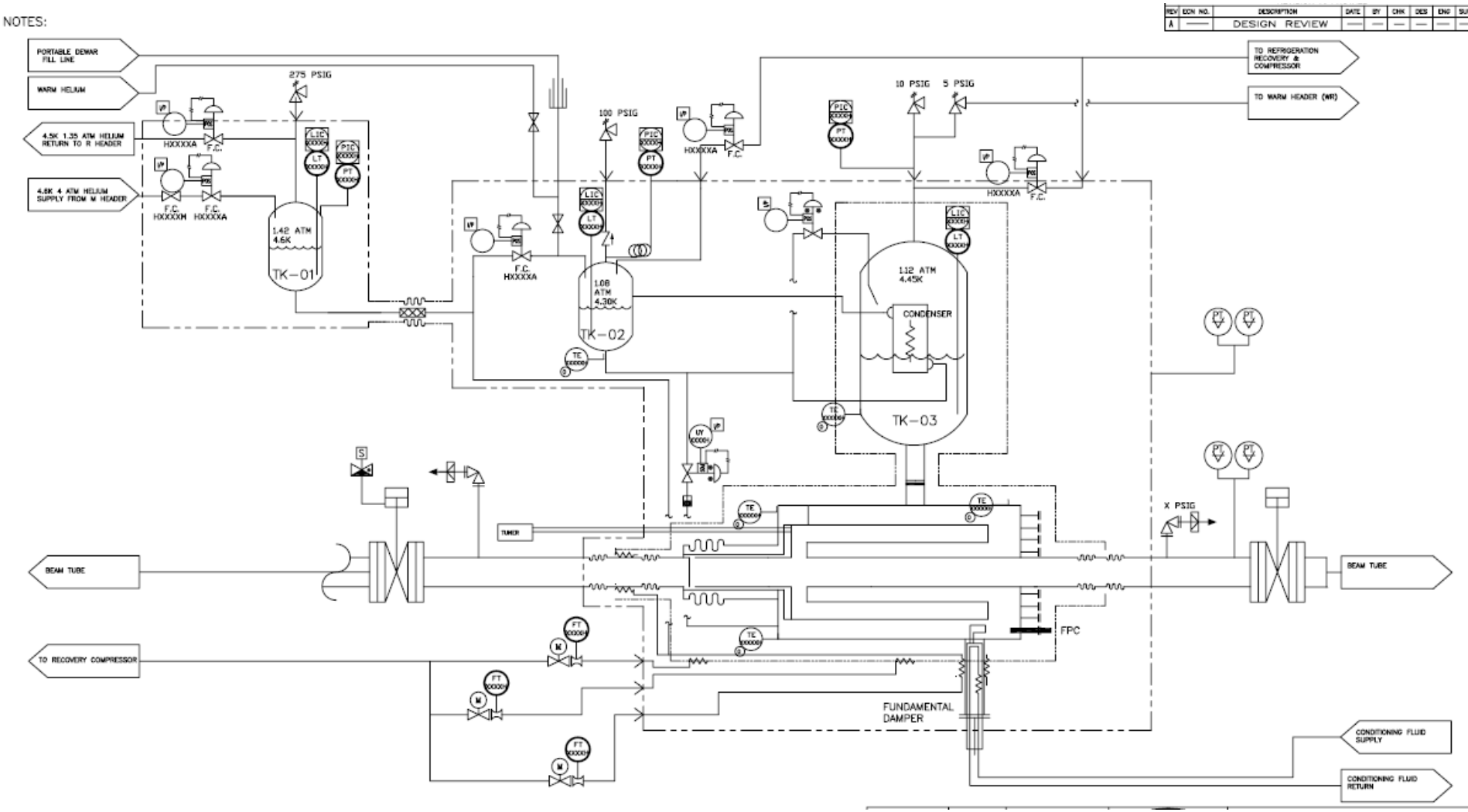
LOADS

LOAD 1 (Recovery System)			LOAD 2 (Cold return to RHIC)	
	4.5K W	LIQ (g/s)		
Cavity Cryostat & Separator #2,3				
DYNAMIC	42		Transfer lines to/from	15
FUND DAMPER	2	0.075	Supply Valves	3
POWER COUPLER	0.5		Return Valves	10
BEAM TUBE ENDS (+Radiant)	6	0.1		
Supports & Tuner	4			
Separator#2/Condenser & Holdup vessel			Separator #1	9
Helium Vessel Radiant	2			
Hold-up vessels Rad	4			
Valves & lines	9			
Relief line, supports	7			
TOTAL	76.5	0.175	TOTAL	37
BUDGET	100	0.2	BUDGET	40

RECOVERY TRADE OFF

With Refrigeration Recovery			No Refrigeration Recovery	
Liquefaction Load	1.5	g/s	6	g/s
Refrigeration Load	100	W		
Carnot work	16.5	kW		
RHIC Plant Compressor	84.5	kW	202	kW
$ ~ 350 - 400K			4000 hr x $85/M-hr x 0.2 MW = $68K	

SUMMARY

- COOLING
  - Low flux densities
    - Upto (40 W/m^2)
  - Vapor trapping on inner annulus
    - Surface roughness
    - Experiment to verify
- SYSTEM
  - 6 g/s boil-off
  - 18 g/s Recovery compressor
  - Recovery heat exchangers Budget, payback and schedule
- ISOLATION (Vibration)
- Separator #1
  - Isolates RHIC Lhe supply pulses
  - Supplies intercepts
- Condenser
  - Isolate supply and return to compressor
  - Heat load change: shift ΔT and Psat

CRYOSTAT SYSTEM