SSC DETECTOR SOLENOID DESIGN NOTE #10

TITLE: Preliminary LN_2 Shield Cooling

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DATE: January 26, 1988

A Preliminary Look At Nitrogen Shield Cooling.

I First consider the size of tube available

Use $P = 300$ psi (20 ata)
$t = 0.035''$ wall
$S = 18800$ psi (> 0.8 of Fermi mode) - Sol SS
E = joint efficiency = 1
R = inside radius

$$R = \frac{(SE - 0.6P)t}{P} \quad \text{- cir}$$

$$= \frac{(18800 - 0.6 \times 300)(0.035)}{300}$$

$$= 2.17 \text{ in}$$

$$R = \frac{(2SE + 0.4P)t}{P} \quad \text{- long}$$

$$= [(2)(18800)(0.6) - 0.4 \times 300] \times 0.035 / 300$$

$$= 2.65 \text{ in}$$

We will certainly not need a tube with an ID greater than 4.3 in. It is unlikely we would need to use a wall thickness much less than 0.035". Therefore possible pressure requirements should have little effect on the choice of a cooling tube

I What is the heat load to the LN_2 shield

As far as possible scale up from CDF

CDF Heat Load	Axial supports	24 w
	Radial supports	67 w
	Radiation to shells	84 w
	Conduction to shells	176 w

CDF solenoid 3 m ϕ x 5 m long

Super solenoid 10 m ϕ x 16 m long

For a first approximation radiation and conduction to the shells will scale with surface area

The support loads are more complicated. There are forces present here that were not a problem for CDF. The modularization of the coil may require a change in support scheme. A complete helium vessel will add more cold mass. However more space is available for the supports. For a first estimate double the support heat load and then scale up with surface.

Radiation and Conduction

CDF = 260 w

Surface of the Super Solenoid / CDF = $\frac{10 \times 16}{3 \times 5}$ = 10.6

Use 3000 w for SS (10.6 × 260 = 2756 w)

The length of cooling channel on the CDF shield was ~ 260. Scale this up by surface also use 3000 ft of cooling channel.

Since there are two completely independent cryostats assume two parallel circuits. Each circuit would have half the cooling channel length (1500 ft) and would have to remove half of the heat load. It may turn out to be desirable to have a seperate circuit for the inner and outer shields but initially will look at them combined

Supports

CDF = 91 W

Doubling and the sealing up by surface results in a heat load of 2000w (91 × 2 × 10.6 = 1929)

The design and placement of the supports is unknown at this time. It is unlikely that the flow path in each cryostat would be greater than 500 ft.

At this point removing the heat load due to the supports will not be considered. At first glance the shield requirements appear more stringent.

III Choose LN_2 cooling similar to the SSC

Under normal operating subcooled liquid is used

A subcooler and a circulating pump are located near coil level.

Only gas is returned to the surface.

Durning cooldown the pumps are not used.

Gas is vented after passing through the coil.

See Fig 2

The actual operating pressure will be dependent on the head and the operating pressure of the dewar at the surface

For the moment choose ring conditions

In 6 ata and 78 K $H = 31.05$ j/g

Out 4.7 ata " 89 K $H = 53.64$ j/g

Required flow $= 1500\,w \div (53.64 - 31.05)$ j/g $= 66.4$ g/sec.

Choose a 1" x 0.065" wall tube

Fig 2 shows ΔP through this tube for single and 2 ϕ flow.

The highest ΔP will be ~ 3 atm. This is not a problem durning cool down when a ΔP of ~ 5 atm would be available.

While operating the nitrogen flow should be subcooled by ~2 atm when it exits the magnet so 2φ flow is unlikely.

The pressure drop caused by less than 30% gas is small enough not to cause a problem and the heat exchanger could be sized to be able to handle this amount. Beyond 30% gas would probably be vented.

Consider room temperature gas at 6 ata. A flow of 40 g/sec (per tube) would have a pressure drop of ~ 4.5 atm. ΔH from 78 K liquid to 300 K gas is ~ 430 j/g. This would allow an initial cooling rate of 34 kw.

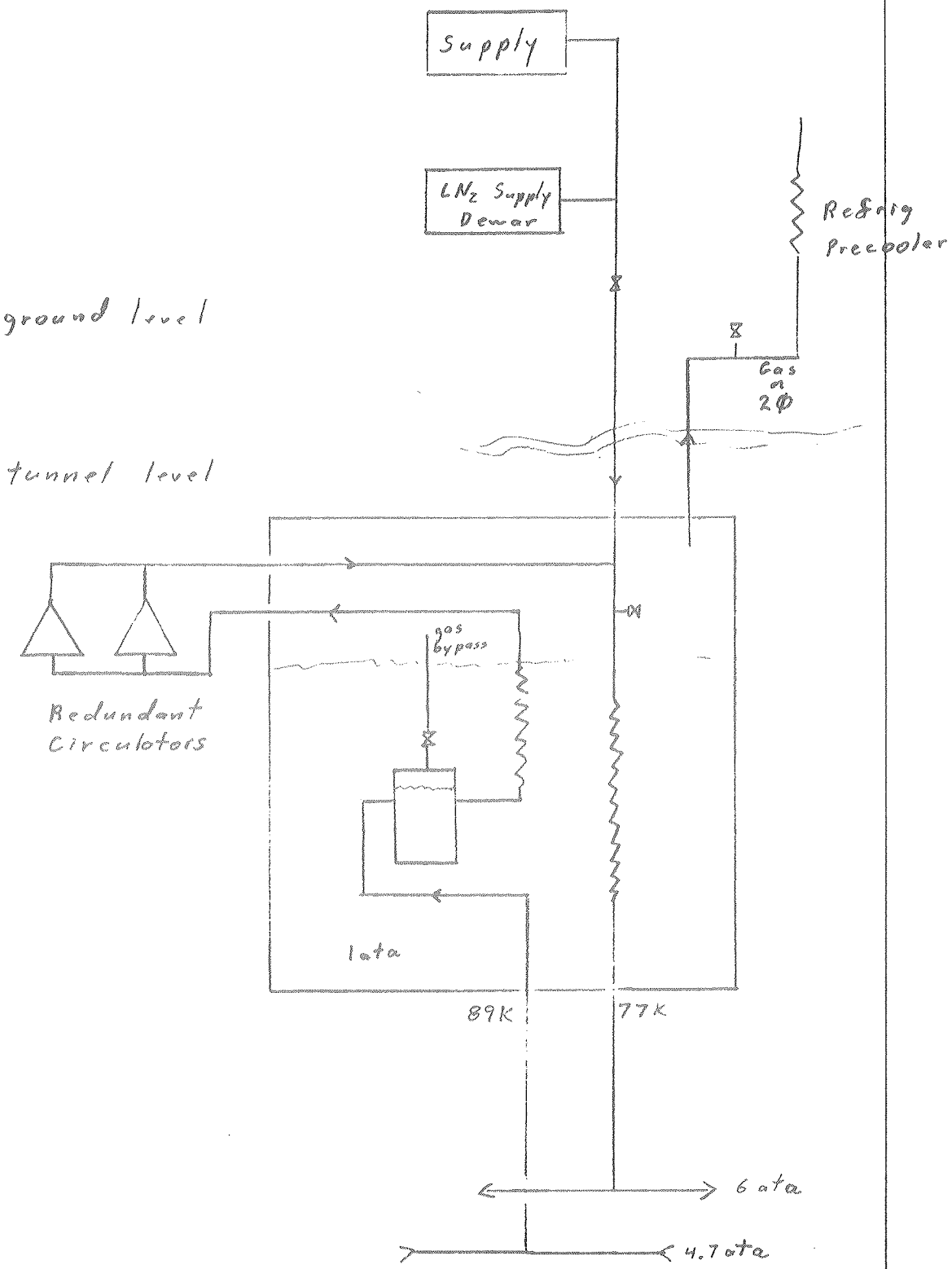
Supply
LN_2 Supply Dewar
Refrig Precooler
ground level
Gas or 2Φ
tunnel level
gas bypass
Redundant Circulators
1ata
89K
77K
6 ata
4.7ata

Fig 1

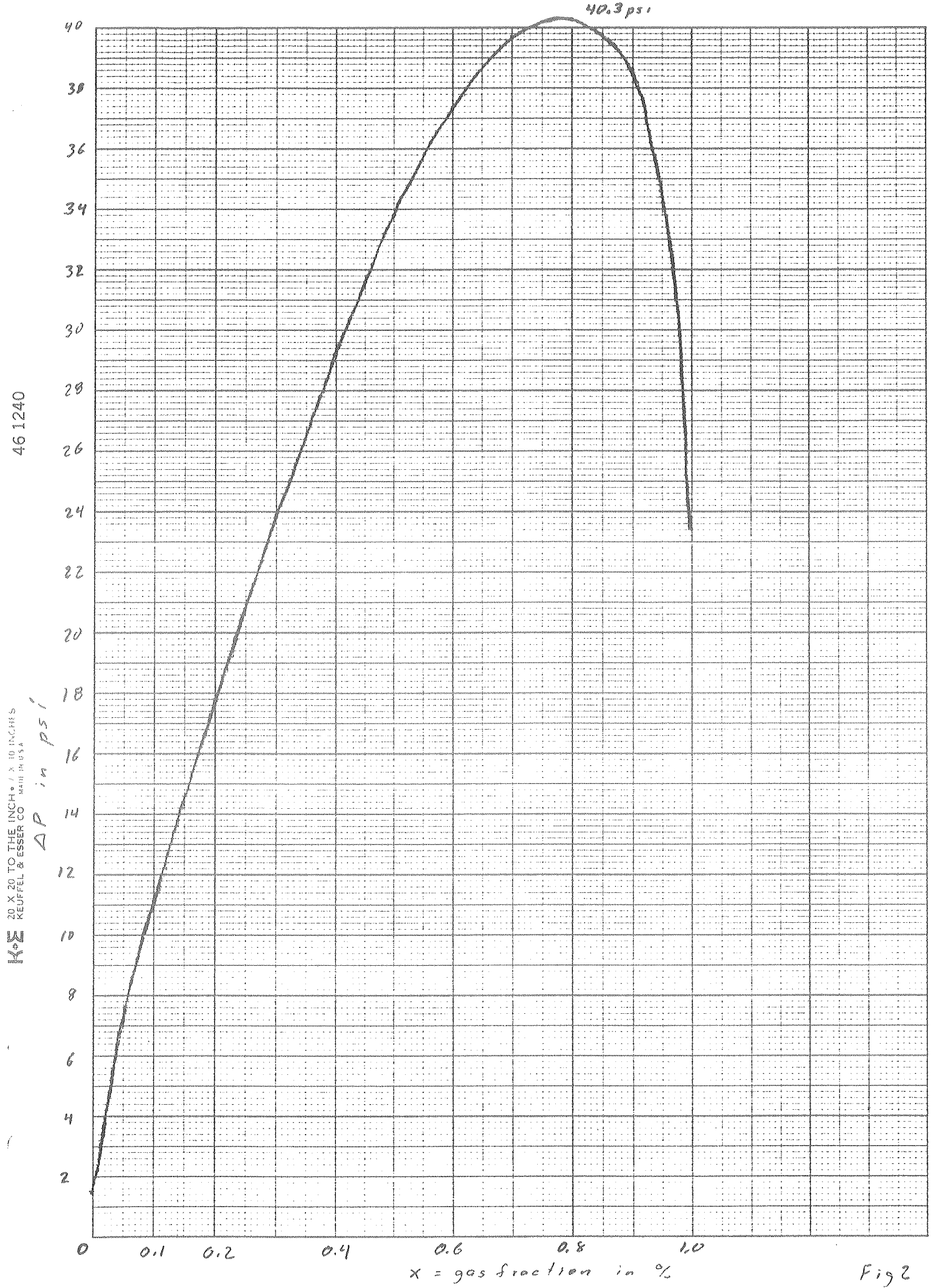
40.3 psi
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0.1
0.2
0.4
0.6
0.8
1.0
ΔP in psi
x = gas fraction in %
46 1240
K+E 20 X 20 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

Fig 2