Cooling System Facilities for the ATLAS ID at SR1 Bldg.

[SCT & PIXEL part only- evaporative C.S.]

2st draft concept prepared by V. Vacek for a discussion

[Status by end of November 2002]

SR meeting on Wednesday 27/11/2002

Changes and Some Extras:

[Referring to the previous presentation available at: http://perneg.web.cern.ch/perneg/SR/vicCS_forSR1_Bldg.pdf]

Respecting some changes, feedbacks and discussions after the presentation on November 13, 2002 several modification have been considered, namely:

- Repositioning of the Compressor-Condenser Unit
- Option to the standard ATLAS rack in the main TEST AREA may be considered [custom made rack just for SR1 test facilities]
- Changes in manifoldings [for pixels]
- "Cold and Warm" testing modes were considered:
  1. Multiple refrigerant use within the same equipment [Q&A to the last meeting discussion – warm and cold mode]
  2. Additional implementation of separate C4F10 warm circuit in the Bldg. SR 1

  Notes: "Our margins" {Reducing the flow via implementation of the HEX inlet/outlet tubes}, *" Thermal Enclosure ??"*
- Power & Chilled water supply for the new position of the C_C_Unit
- Boundaries and responsibilities between cooling power distribution and "Users", i.e. SCT and Pixel

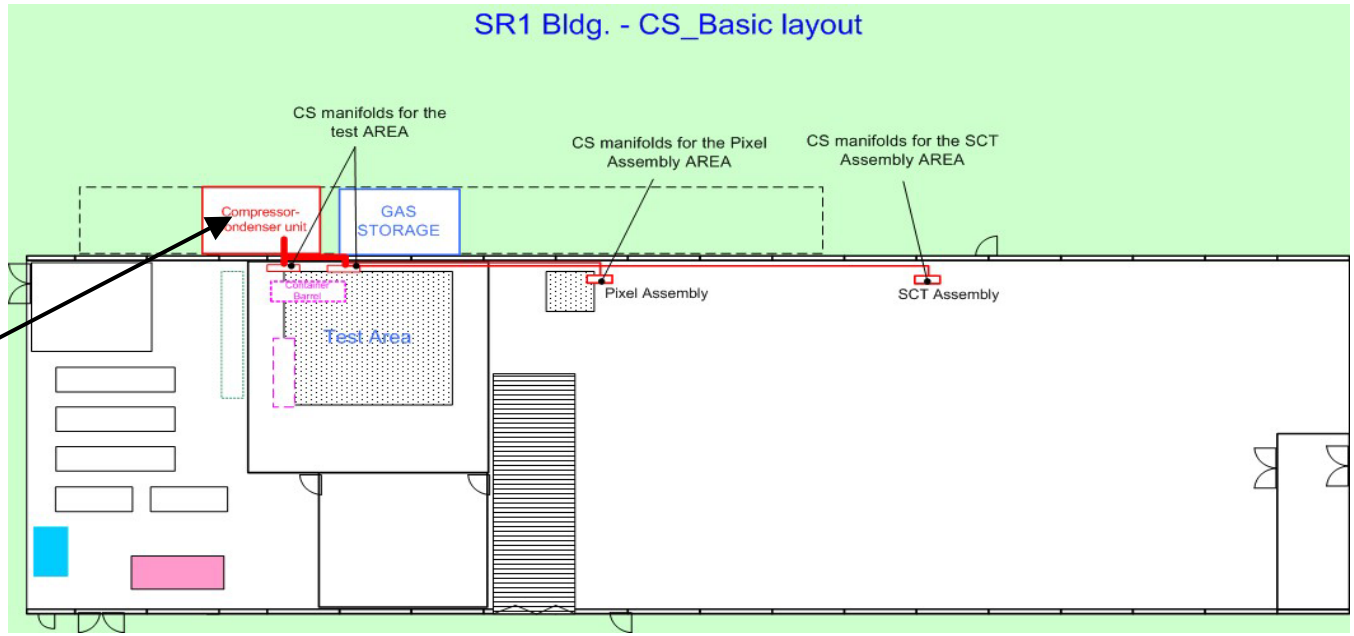
What remains unchanged for evaporative part (SCT and Pixel only),

- three main tube lines will be needed (hopefully one main manifolding rack):

- For the main Test Area (covering needs up to whole SCT barrel test and also for complete SCT end-cap ~ 22 kW)
- Partial tests at SCT assembly area (request up to 96 barrel modules, i.e.. min. 2 loops and up to 132 forward modules, i.e. one complete disk ~ 1.5 kW to evacuate)
- Partial tests at Pixel assembly area (new request up to 7 cooling loops, i.e. approx. **3** kW to evacuate)

- **Repositioning of the Compressor-Condenser Unit**

As announced by Friday Nov 15, 2002 we will not be able to utilize the place behind the main test area

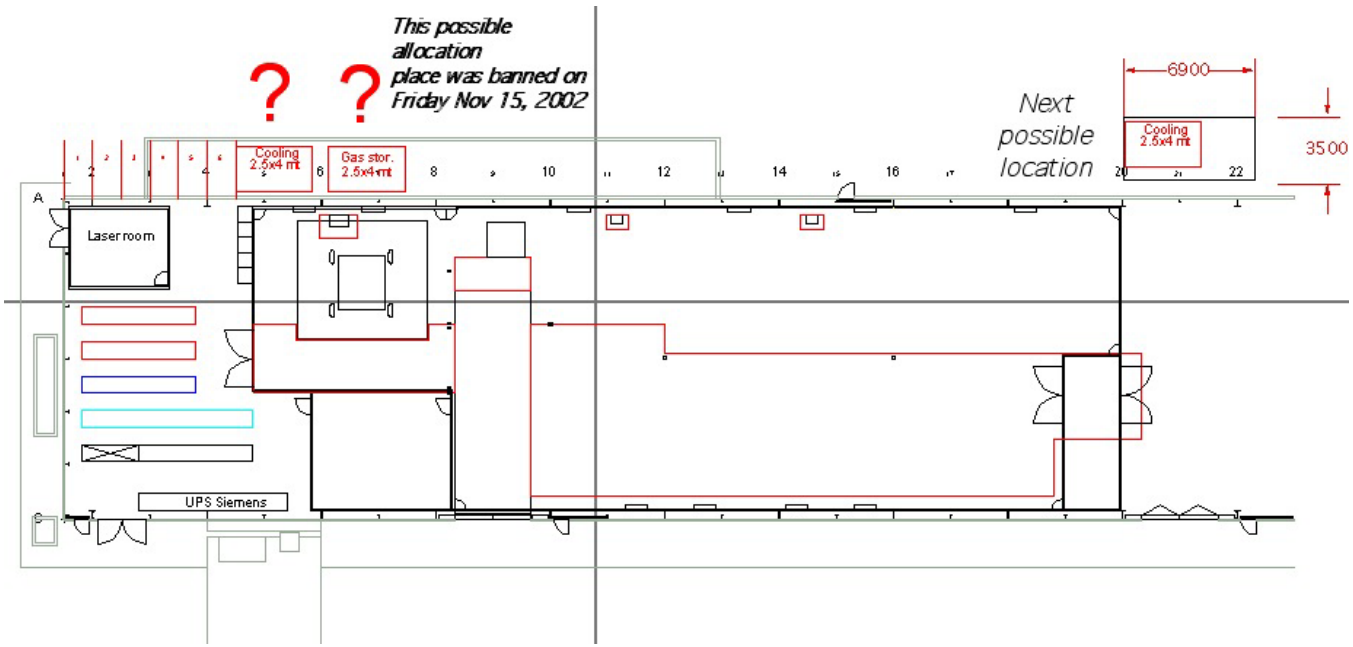


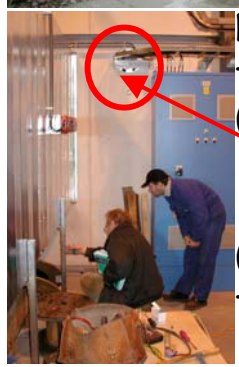
• Present situation @ SR1 site [25/11/2002]

Place we have lost

Transformers taking the place

[Will they remain useful ???]





New possible location for the C_C_Unit (Outside view)

(Inside view) entrance for the tube lines

• Impact on the main three tube lines

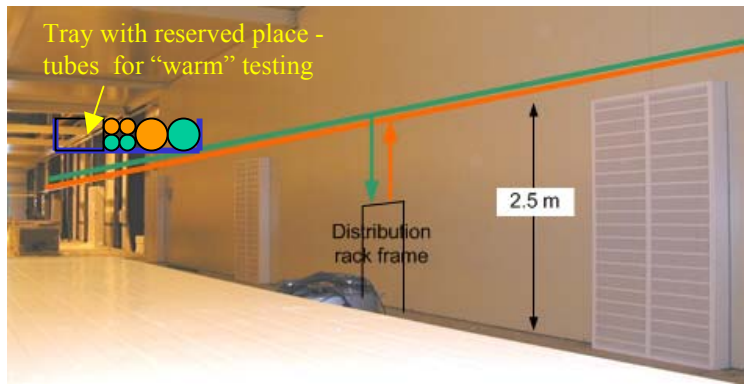
Layout of tubes has to be extended [significantly] and rerouted due to the

- new position of the C_C_Unit
- slight shifts of racks both in the main test area and two assembly locations

(with respect to the actual air ducts positions) (and placement of tube lines in the Bldg.)

Tube lines placed on a tray Above the air ducts

(preferred solution)



or

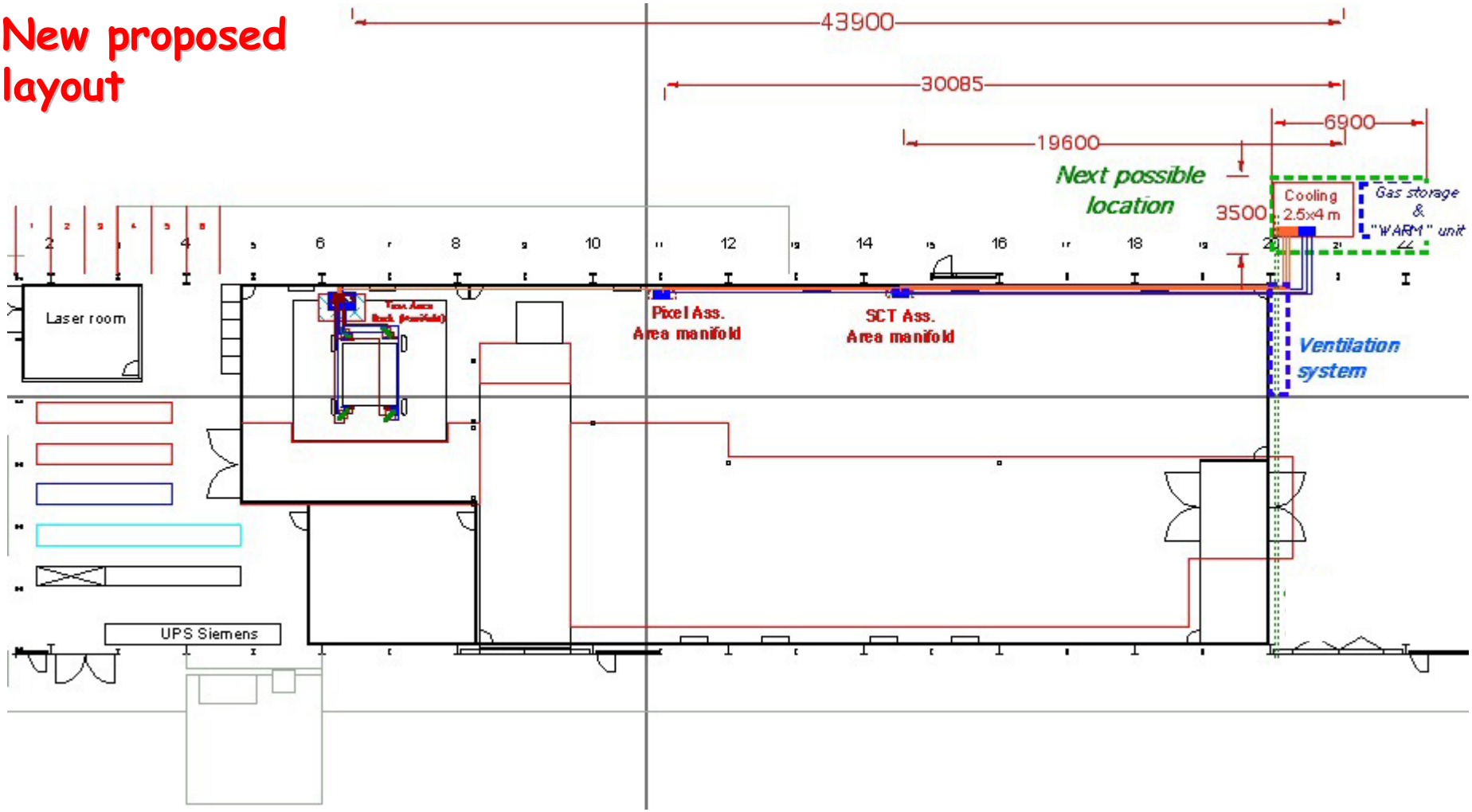
Other options for the tube lines:

- Behind the wall, feasible but relatively limited space

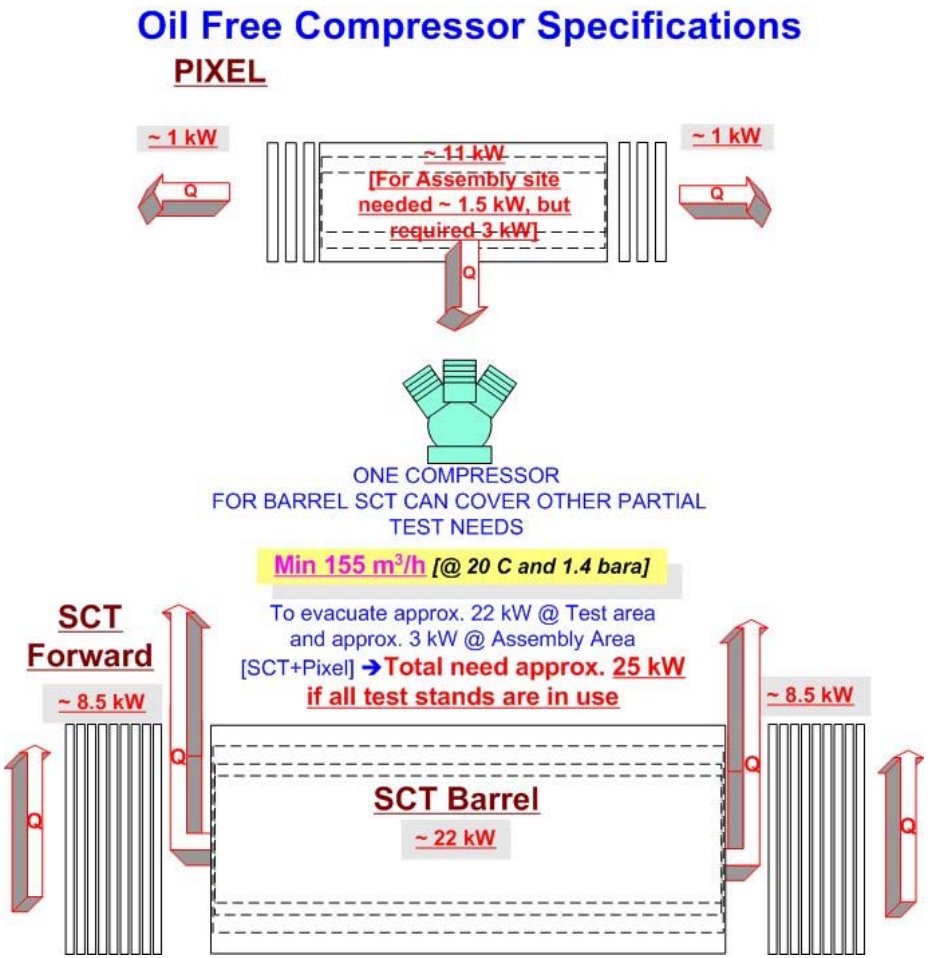
- Below the floor, possible but the available space is already densely occupied

Rack @ Test Area between 6th and 7th pillar in the middle of two air ducts; Pixel manifold close to the 11th pillar [to minimize interference with TRT system test area; SCT manifold between 14th and 15th pillar

New proposed layout



SR1 Bldg. Test and Assembly Areas



Estimation of the Compressor size

- Evap. @ T_{sat}= -25°C; P_{sat}=1.74 bar_a
- Full available latent heat /=101.5 [kJ/kg]
- If no sub-cooling then [throttling @ 20-25 °C] reduced latent heat

$$l_{reduced} = 52 \text{ [kJ/kg]}$$

To evacuate 25 kW requires to evaporate approx.

0.4807692 kg/s of C_3F_8

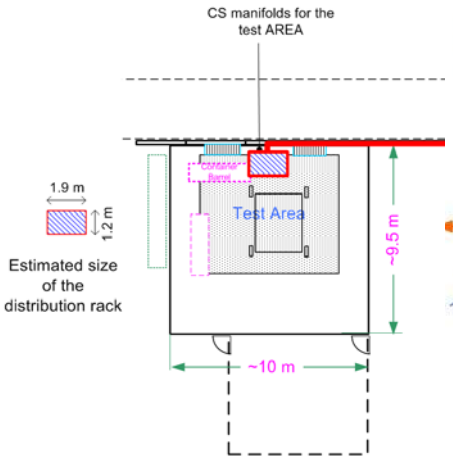
Compressor size is very dependant on pressure condition at its inlet due to the density change [$\rho(P, T)$ – very sensitive to P but less to T]; assuming P_{inlet}= 1.4 bar_a and $T \in (16\text{-}22°C)$ then $\rho \cong 11$ kg/m³ and we may need compressor with pumping capacity around

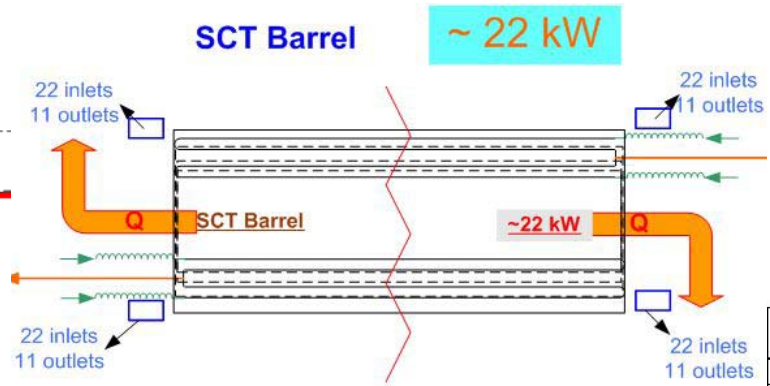
155 m³/h of C_3F_8 vapor

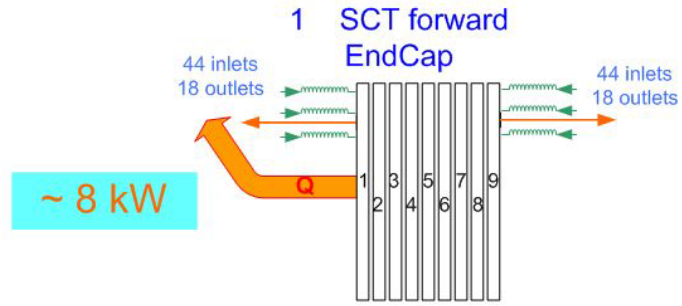
This value can handle 1 compressor, type HAUG QTOG 180/100 LR

Test Area [only SCT needs, no changes requested up to now – Nov. 27, 2002]

Vic_2002_11







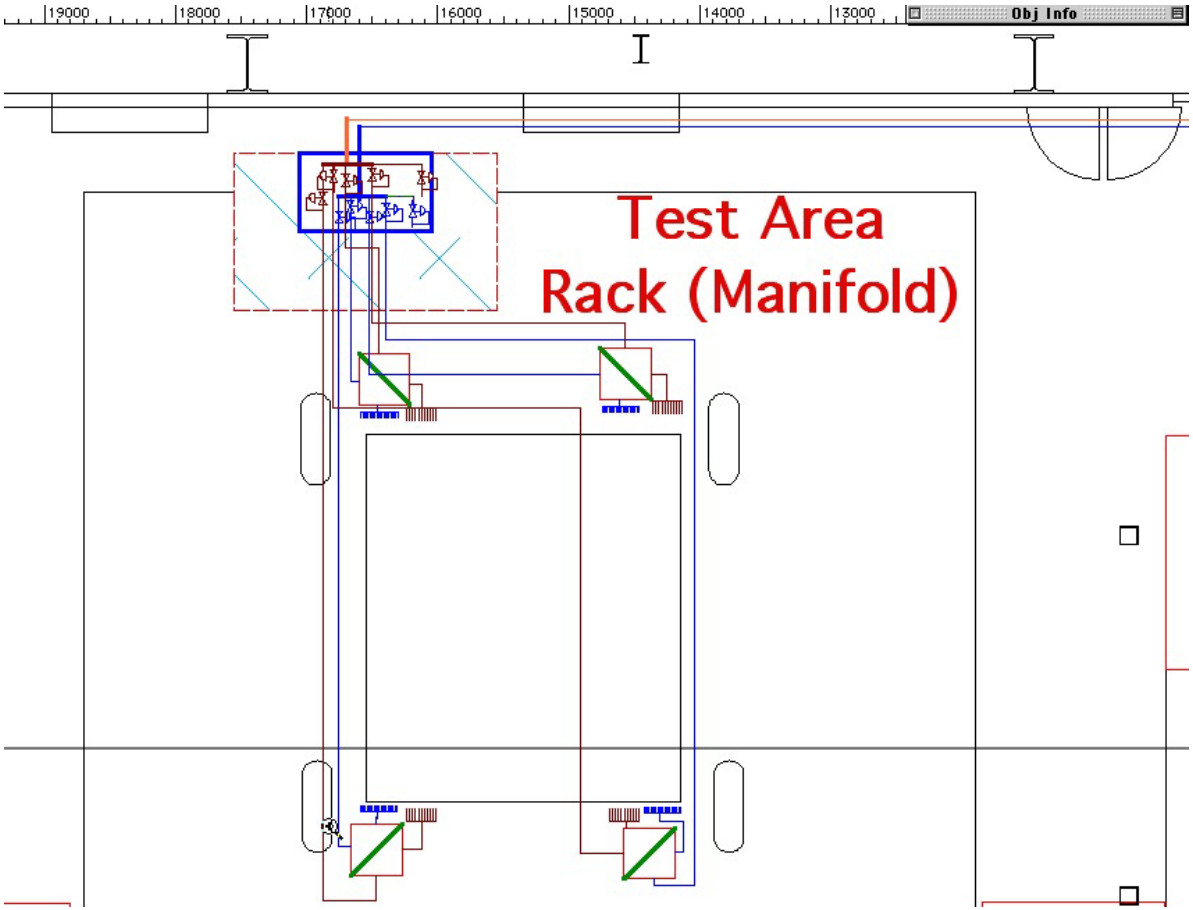
Barrel		Staves	Loops	Inlets	Outlets
B6	SCT_4	56	14	28	14
B5	SCT_3	48	12	24	12
B4	SCT_2	40	10	20	10
B3	SCT_1	32	8	16	8
Total		176	44	88	44

Disc No.	Inlets/Quadrant	Outlets/Quadrant	Inlets/disc	Oulets/disc
1	2	1	8	4
2	3	1	12	4
3	3	1	12	4
4	3	1	12	4
5	3	1	12	4
6	3	1	12	4
7	2	1	8	4
8	2	1	8	4
9	1	1	4	4
All Discs	22	9	88	36

- **The first option - with "standard ATLAS cooling Rack":**

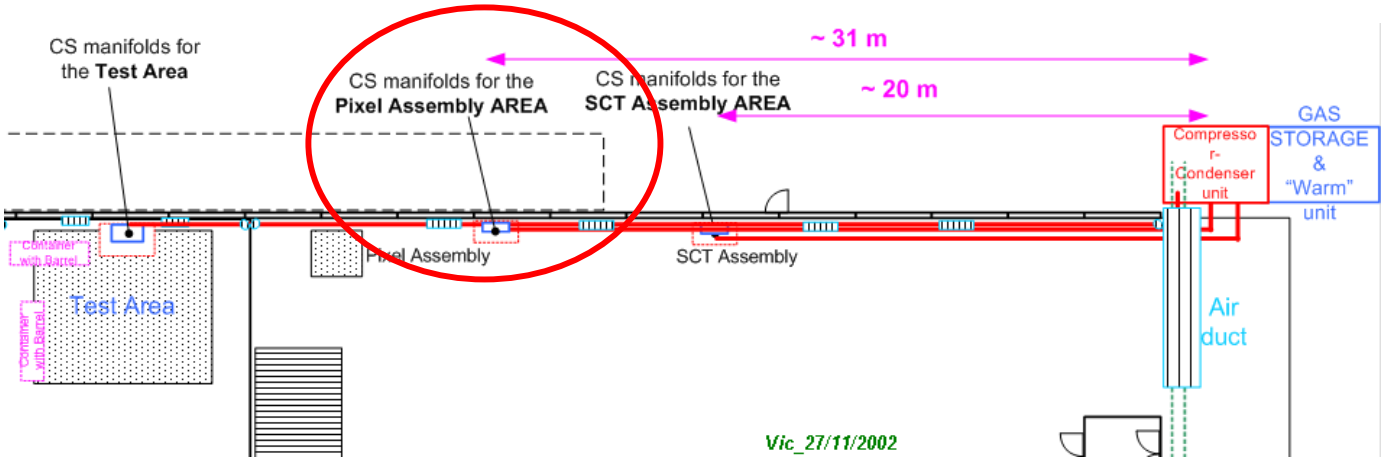
Utilization of the distribution rack prototype for a final system, being designed by Pierre Bonneau, is proposed. It has **96 inlet** lines with pressure regulators and **48 outlet** lines with back pressure regulators *(assuming that we still require them for all inlet lines and common return lines)* – It might serve as the rack for SR1 **Test AREA** purposes (It could be **a useful verification test** for final ATLAS ID cooling system).

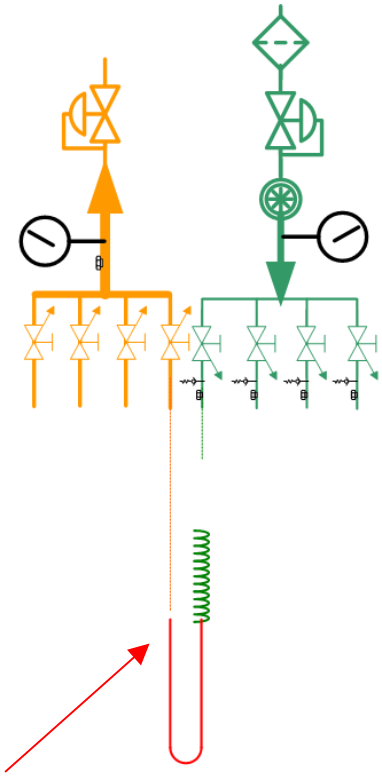
- **The second option** (proposed by Michel Bosteels)
  - **"custom made manifolding" just for the SR1 Test Area:**



- Refrigerant is being distributed into 4 edges around the ID support structure, then divided into an appropriate inlets (22 at each corner) and outlets (11 at each corner) loops
- Plate heat exchanger might be used for a inter-stage heat exchange between vapor and liquid lines

Assembly Area - Pixel





Estimated cooling power to be available at

Single Inlet/outlet unit

Pixel Assembly Area:

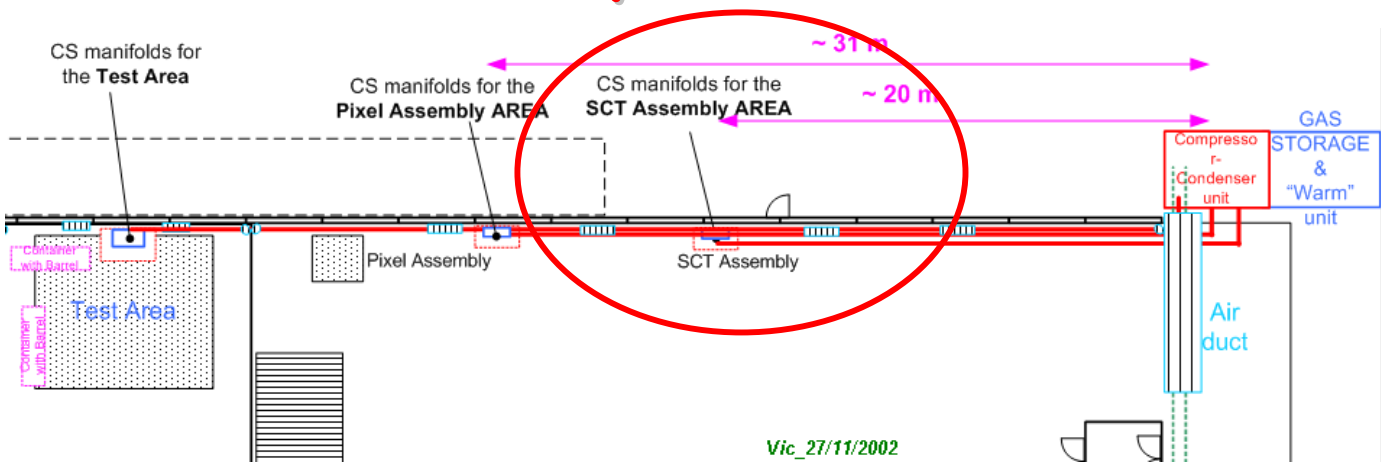
~ 3 kW

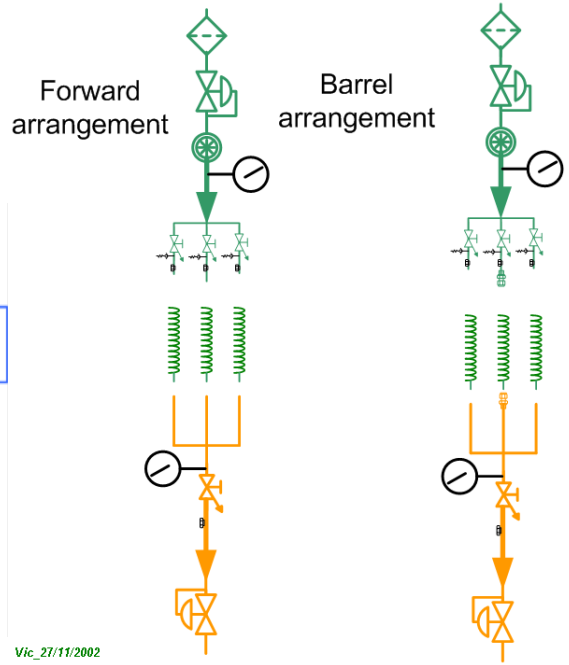
[increased by request on Nov. 22, 2002]

requirements for partial tests

[up to 15% of needed cooling power, i.e. approx. 7 loops] – **two single** inlet/outlet units to be installed, i.e. **eight** Loops available

Assembly Area - SCT





Estimated cooling power to be available

ONE Inlet/outlet unit (line)

at SCT Assembly Area: requirements for partial tests

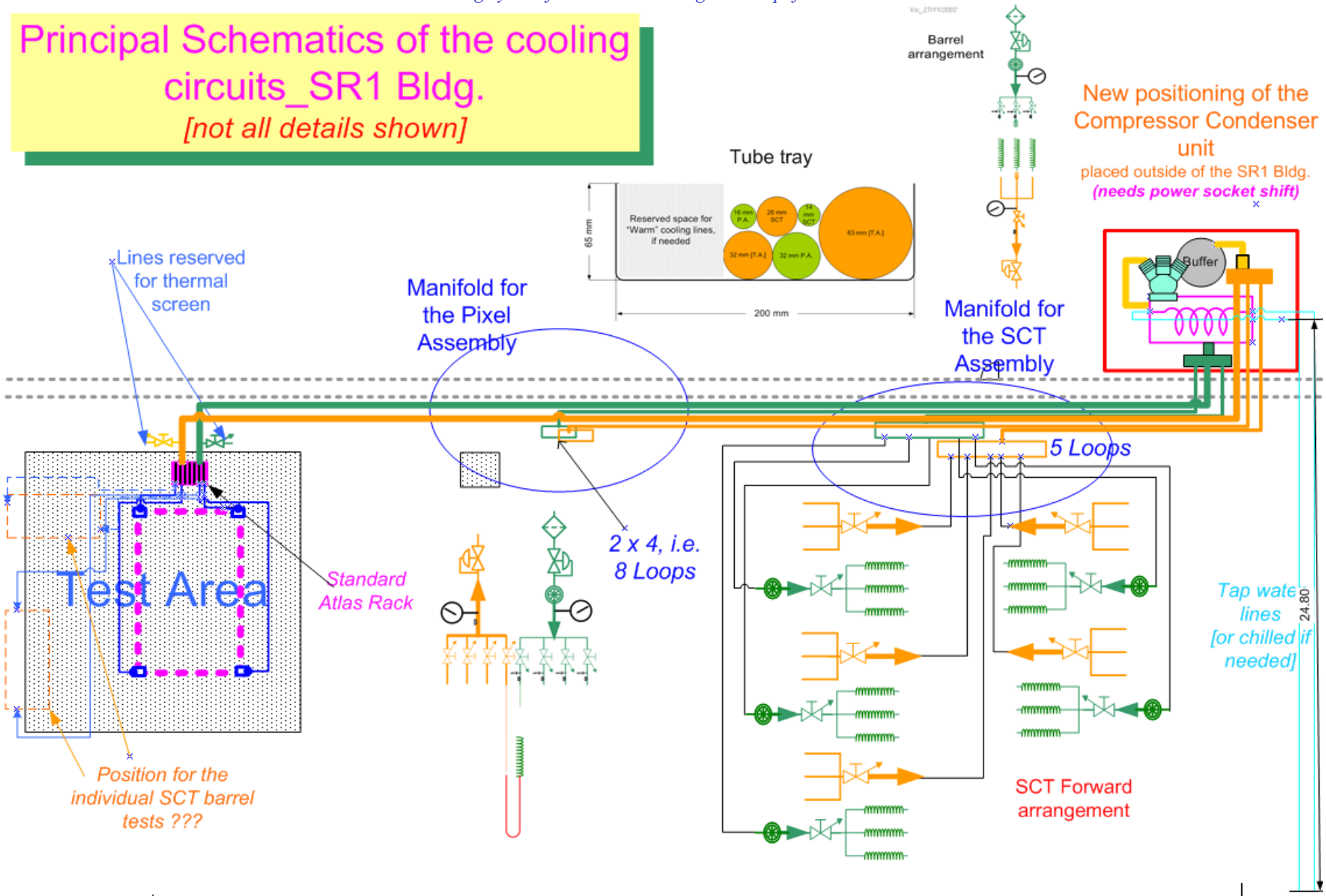
~ 1.5 kW

With 5 inlet/outlet units up to ~ 1.8 kW

- 96 barrel modules (i.e. 2 loops or 4 inlet lines and 2 outlet lines)
- 132 forward modules (i.e. one disc or 12 inlets and 4 outlets)
- Rack capacity would not cover forward needs – additional tubes needed; suggested number **5 inlet/outlet unit**, each with manifold {3}; **5 outlet lines**

Principal Schematics of the cooling circuits_SR1 Bldg.

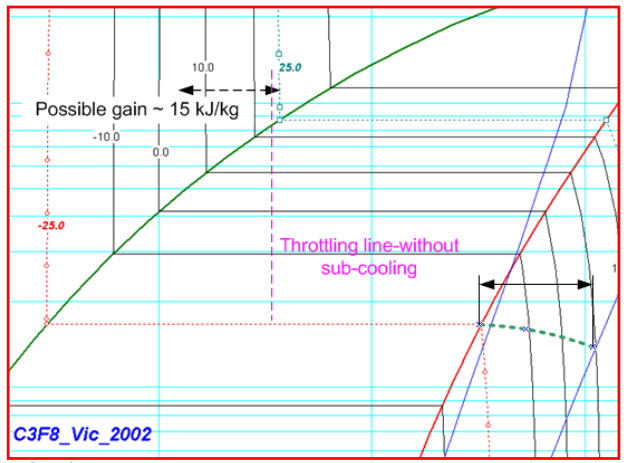
[not all details shown]



Tube main lines from Compressor_Condenser Unit to racks [manifolds]

Fluid_C_3F_8						
TEST AREA	**P_{cool} [kW]**	**25**	**Flow [kg/s]**	**0.481**		
	ID $_{comp}$	**ID $_{selected}$**	OD	L $_{estimated}$	c	*Press. drop*
	[mm]	[mm]	[mm]	[m]	[m/s]	*approx.[bar]*
Liquid line	21.22	**26.0**	32	54	0.7	0.098
from condenser to rack						
Vapor line	51.83	**54.0**	63	54	18.4	0.195
from rack to compressor						
Pixel Assembly Area	**P_{cool} [kW]**	**3**	**Flow [kg/s]**	**0.058**		
	ID $_{comp}$	**ID $_{selected}$**	OD	L $_{estimated}$	c	*Press. drop*
	[mm]	[mm]	[mm]	[m]	[m/s]	*approx.[bar]*
Liquid line	10.40	**11.5**	16	38	0.4	0.115
from condenser to rack						
Vapor line	25.39	**26.0**	32	38	9.5	0.110
from rack to compressor						
SCT Assembly Area	**P_{cool} [kW]**	**1.8**	**Flow [kg/s]**	**0.035**		
	ID $_{comp}$	**ID $_{selected}$**	OD	L $_{estimated}$	c	*Press. drop*
	[mm]	[mm]	[mm]	[m]	[m/s]	*approx.[bar]*
Liquid line	8.05	**8.0**	14	28	0.5	0.138
from condenser to rack						
Vapor line	19.67	**20.0**	26	28	9.7	0.113
from rack to compressor						
Tap water lines	**P_{cool} [kW]**	**12.5**	**Flow H_2O [kg/s]**	**2.49**		
[or chilled,if needed]	ID $_{comp}$	**ID $_{selected}$**	OD	L $_{estimated}$	c	*Press. drop*
	[mm]	[mm]	[mm]	[m]	[m/s]	*approx.[bar]*
	56.1	56	70 [with insul.]	23	~ 1	0.07

- Tube dimensioning for the Test area includes margin for Thermal enclosure circuit [up to 4 kW]
- Other margins can emerge once properly functioning heat exchangers [under the tests at the moment] are fully implemented; flow might drop to ~ 0.38 kg/s, i.e. 13 % decrease from the presently considered value



Tubes - Suggestion:

Coated Geberit tubes

[ID: 11.5; 15;20;26;33;42,54]

Alternative: Copper

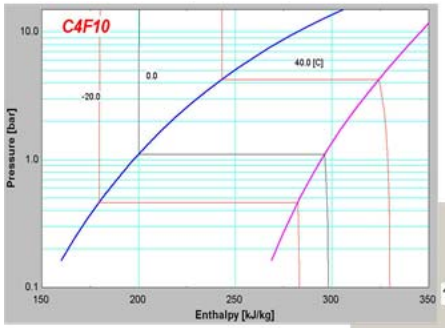
ESTIMATED LENGHTS

INCLUDE 5% MARGIN

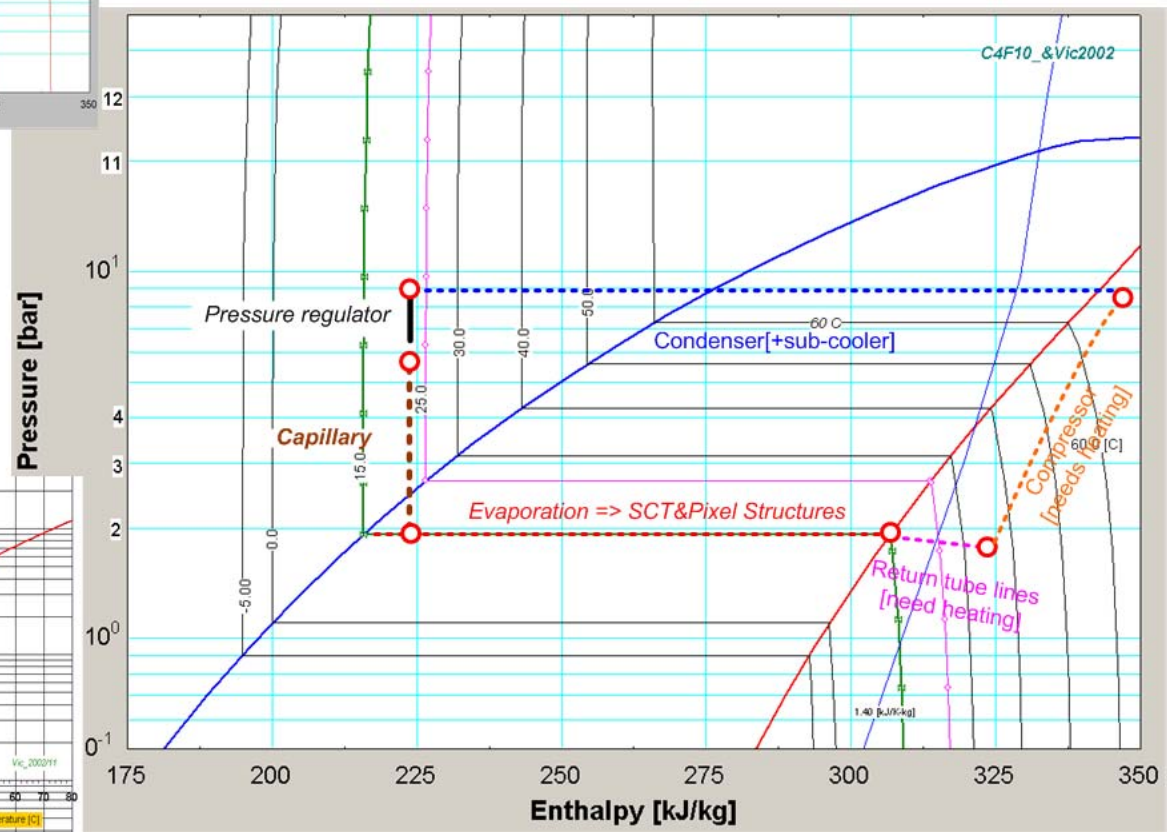
- **"Cold and Warm" testing modes were re-considered:**
  - **"Cold" testing mode (final) – *C.S. already selected***
    - All structures are being tested under the specs conditions and cooling circuit with chosen refrigerant, i.e. C_3F_8 is used (evaporation temperature around –25 °C & pressure around 1.8 bar_a)
    - Dissipated power is taken away from the modules/SCT and Pixel/ placed under the thermal enclosure in the ambient with inert and dry gas at low temperature (~ -10°C ???)
    - Properly working and pre-tested, both SCT and Pixel, parts of the ID, would be advantage, since any interruption of these test for additional repairs and maintenance on ID installation is difficult & time consuming.
  - **"Warm" testing mode (preliminary)** ***C.S. under development as an additional system***
    - All structures being tested under the room temperature and dissipated power is taken away from the modules/SCT and Pixel/ at elevated temperature above a dew point in the relative dry ambient.
    - target evaporation temperature in the range from +15 to 18 °C & pressure around the specs value. i.e. 1.8 bar_a)
- **Tempting question – COULD WE DO BOTH WITH ONE EQUIPMENT ??? (Hardware)**
- **Tempting answer – POSSIBLY "YES" BUT ……..**

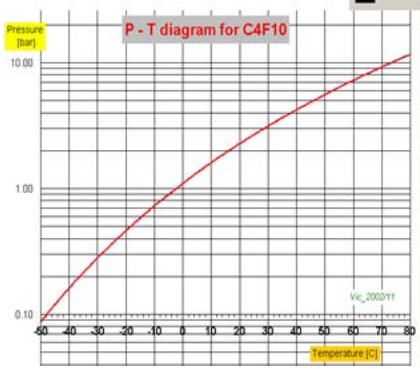
Calculation performed for SR1 C.S.installation ONLY !!!

(~ 25 kW of cooling power)



Cooling Circuit for 'Warm Testing" @ SR1 Building





4) Pressure drops were recalculated for the first pipe line scheme prepared for C_3F_8 [for the meeting on 13/11/2002]; as expected slightly lower due to flow reduction see 3)

Recalculation of the C.S. parameters with different fluid, C_4F_{10} shows:

1) desired evaporation temperature can be achieved at reasonable pressure around 1.9 bar_a

2) high condensing temperature at the pressure around 9 bar_a enables to sub-cool liquid in condenser sufficiently even with tap water

3) due to the sufficient sub-cooling we could use nearly all latent heat of evaporation [83 kJ/kg, compared to 52 kJ/kg for C_3F_8 in a "cold" circuit], resulting in significant reduction of the flow from 0.30 kg/s compared to 0.48 kg/s for C_3F_8 in a "cold" circuit

TEST AREA with Atlas rack					**c3f8**	**c4f10**
Liquid line	ID $_{comp}$	ID $_{selected}$	OD	L $_{estimated}$	*Press. drop approx.*	*Press. drop approx.*
from condenser to rack	19.907	20		7	0.036	0.025
from rack to SCT loops	2.940	3		8	0.134	0.070
Vapor line						
from SCT Loops to rack	8.080	8		8	0.133	0.050
from rack to compressor	39.697	40		10	0.130	0.040
Pixel assembly area						
Liquid line	ID $_{comp}$	ID $_{selected}$	OD	L $_{estimated}$	*Press. drop approx.*	*Press. drop approx.*
from condenser to rack	7.178	8		20	0.200	0.040
from rack to Pixel loops	2.246	3		4	0.300	0.030
Vapor line						
from Pixel Loop to rack	7.641	8		5	0.100	0.090
from rack to compressor	12.191	12		22	0.200	0.080
SCT Assembly Area						
Liquid line	ID $_{comp}$	ID $_{selected}$	OD	L $_{estimated}$	*Press. drop approx.*	*Press. drop approx.*
from condenser to rack	8.053	8		40	0.200	0.090
from rack to SCT loops	4.026	4		6	0.100	0.050
Vapor line						
from SCT Loops to rack	8.418	8		8	0.220	0.090
from rack to compressor	19.169	20		44	0.200	0.100

Connectors:

Swagelok or Parker

OD to be filled once the material of the tube is selected and approved

Suggestion: Copper

or coated Geberit tubes

[ID: 11.5; 15;20;26;33;42,54]

Tube sizes were calculated for a cooling circuit with buffer and therefore the simple equation was used
$V\{m^3/s\}=m[kg/s]*v[m^3/kg]$, otherwise the mean piston speed should be used for V determination

Note: Calculations were performed for the pipe line scheme prepared for C_3F_8 [presented at the SR1_meeting on 13/11/2002], just before the layout became obsolete. Pressure drops were calculated on the bases of recommended speeds for refrigerants in round tubes from literature.

True story comes on the next slide:

Potential problems and difficulties

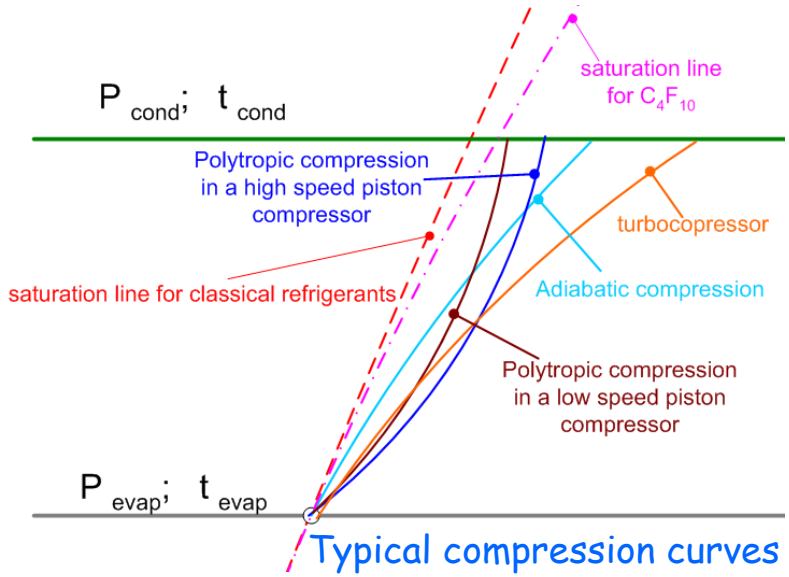
• main difficulty consists in maintaining a proper conditions during the compression of the C_4F_{10} – vapor has to stay in superheated state [buffer helps, but the intake tube has to heated and compressor itself probably as well]. Temperature after the compression [at 9 or 10 bar] has to be well above 80 °C. [We might also face problem with a "cold compressor" start up].

• **minor problems:**

  • heat transfer coefficient of the C_4F_{10} – is lower than for C_3F_8 – this will not slightly affect Warm testing process (typical temperature differences observed between "silicon" and C_3F_8 fluid were ranging between 10 and 12°C). So for C_4F_{10} we expect them ranging between 14 and 16°C. It would bring the surface "silicon" temperature up 30 °C during Warm testing

  • capillaries – no major problems foreseen, needs some analysis

• **Perhaps, we can but try it !**



Typical compression curves

Typical Average values of the HTC

FLUID	C3F8	C4F10	MIX_50/50	CF3I
AVERAGE	6759	4881	3232	4892
RATIO	2.1	1.5	1.0	1.5

It is obvious that one can easily make some mistakes or misguided conclusions, so I will be glad if somebody will perform a similar exercise and he or she, on the bases of numbers, either confirms these considerations or displaces it by evidence

[Pure statement "it will not work" is not enough].

•"Warm" testing mode (preliminary) *C.S. under development as an additional system*

• **Another option for the warm testing** in the SR1 Bldg. is to use an additional independent cooling set-up working with C_4F_{10} [Condenser type with circulation pump] being developed by at M.Bosteels lab

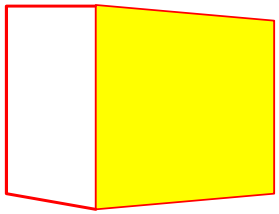
- •some extra space needs to be allocate
- • independent tube lines to the Test Area and Assembly place needed

• space was reserved on the tray, supporting C3F8 main pipe lines,

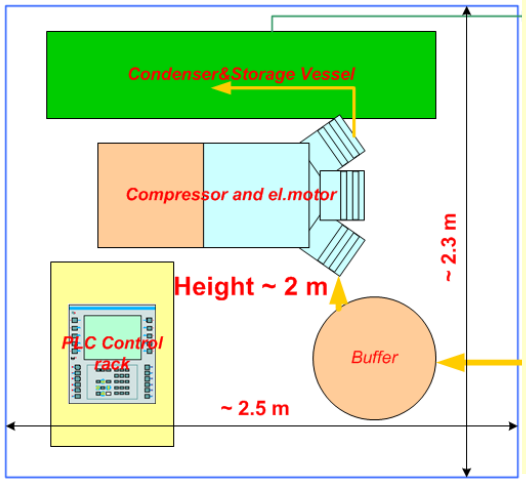
Distances-lengths between new positioning of the cooling base [Compressor-Condenser Unit and possibly a "Warm cooling unit"] are following:

• to the Test Area	54 m
• to Pixel Assembly Area	38 m
• to SCT Assembly Area	28 m

Reminder of the sizes- not changed

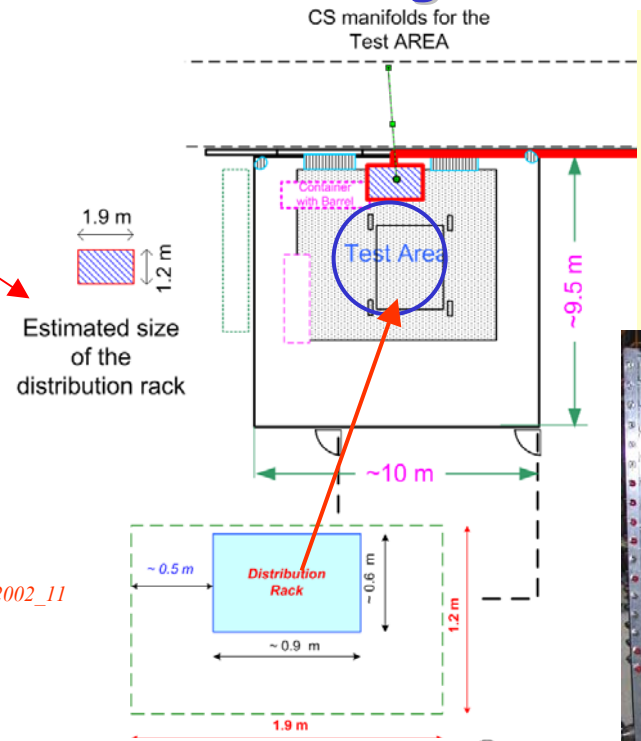


Outer Box for Compressor Condenser unit has to accommodate:



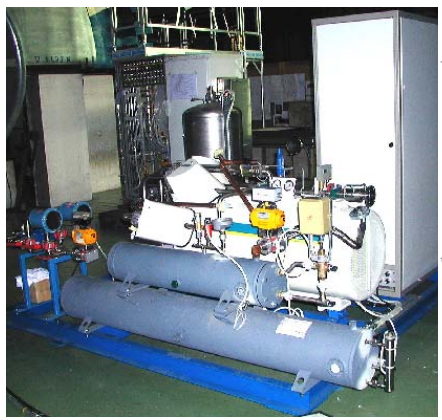
Side or roof of the Outer box is to be removed (problematic with standard available barracks) to install the unit

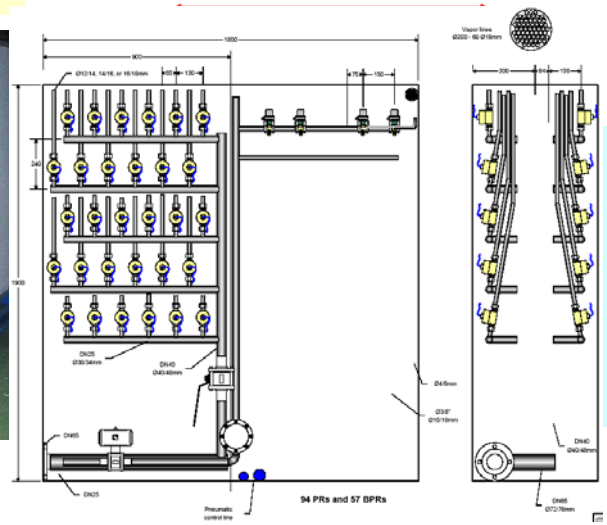
Or more likely we have to build a box around the installation.



Vic_2002_11

Estimated dimensions are based upon the experience from installation of the Phase II setup at Bldg. 175





A new standard ATLAS rack, just under the design by Pierre Bonneau has following dimensions:

[w]1800x[d]600x[h]1900

Parts needed to be available and installed:

1. **Compressor–Condenser Unit with PLC Control rack** – outside of the SR1 Bldg. (expected min. hydrostatic head – all at one level, except of tube trays@ ~ 2 m); One modular building unit (box) needed, or easier way is to build box around installation
2. **Tube system** (some parts insulated – before capillaries), **manifolding rack**, **plate HEX** (heat exchangers ; liquid-vapor), **heaters** (for outlet tubes), **dummy heater** for all installed power of the Compressor-Condenser Unit
3. **SCT** structures come placed in the transport box. **Insulation (and sealing)** for the **transport boxes** has to be considered. To proceed with a "Cold" testing mode, **flushing system** will be necessary:
    - with a pre-cooled either dry air (system needed) or N_2; probably existing liquid cooling unit (originally planed for thermal screens) could be used to pre-cool flushing gas (either air or N_2)
    - or each box could be equipped with a small mobile cooling unit (similar to the system to cool and to dry an air in the cold box at Bldg. 175)

4. **Power supplies**
   - for the heaters after the HEX
   - for dummy heater of the Compressor-Condenser Unit
5. **DAQ system** – for monitoring of the structural parameters (at the test area and assembly areas) and cooling circuit control parameters => communication with PLC control possible
   - Some fractions available from Phase II:
     - 6 eLMB' s for SCT and 1 eLMB for pixel (some more needed, plus adequate adaptors – Pt1000, NTC, V_divider)
   - one PC set available, **one new PC set needed**.
6. **Extras** (but necessary):
   - working table&cabinet with basic tools and bits (connectors, tubes, wires, multimeter, etc.)
   - vacuum pump, leak tester
   - container with spare fluid of the C_3F_8
   - filling manifold for refrigerant, spare sensors – temperature, pressure, humidity ones; flow meter
   - N_2 flasks at all three cooling places/stations for flashing the structures

SUMMARY:

- New status of the facilities at SR1 Bldg. was outlined
- Test Area and Assembly Areas cooling power were updated and new tube line layout was proposed, tube sizing was determined
- Options for the "Cold" and "Warm" test modes were considered
- Additional needed equipment list was updated
- Very first estimation of price [substantial portion for Compressor-Condenser Unit, racks with pressure regulators, Warm cooling set up unit] for installations indicates figures

close to 180 k CHF, not counting a manpower

- **Next steps** (after the new comments):
- More detailed tube layout is going to be prepared, namely parts from the racks/manifolds to the position of structures prepared for the tests
- Final decision about compressor and possible ATLAS distribution rack should be taken as soon as possible to enable further steps in calculations and design
- Additional "needed equipment" list is to be verified and further complemented