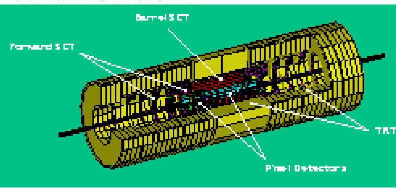
ATLAS
EXPERIMENT

ATLAS
Inner Detector



Atlas ID Cooling Review at CERN laboratory in June 14, 2000

CERN

June 2000

Created by Vaclav Vacek

ID Cooling review.

Wednesday 14.6. 2000 there will be an internal ATLAS ID review meeting for the small scale evaporative system setup in the cooling lab. The review will be limited to the system aspects and will not include the structures, except that they are used as load and their temperatures are monitored to verify that the system operates correctly.

The purpose is to :
- review the results obtained with the small scale setup (studies of system performance at startup, stop, sudden load variations, varying loads from standby to 100%).
- review of baseline system, including cooling services and control.
- identify key issues yet to be studied.
- review the phase two program leading up to the FDR in January 2001.

Format and agenda :

9:00-12:00 : Demonstration in the lab with the cooling group, seeing the system in action under varying conditions. The following will be present : The reviewers, Tyndel, Rossi, Turala, Stapnes, Tappern, Brenner (part time), Bosteels, plus possibly a few others. We will have to limit the attendance of this session to make sure the reviewers get a good impression of the system.

14:00-17:00 : In 40-RD-10 (this meeting is open).
This will be followed by 3 hours of presentations of the small scale system and its performance. The following will be covered (informal and with reasonable time for discussions):
- **Postmortem of the Counter Current Heater Exchanger tests.**
- **Description of the May setup in the lab.**
- **Results from the tests early May.**
- **Description of the current setup (shown in the morning).**
- **Results.**
- **Description of a baseline system with regulated input / output for each channel (as tested).**
- **Phase (2) plans - some comments.**

An outline of the above (results as of the IDSG 12.05.00) is available on :
http://edmsoraweb.cern.ch:8001/cedar/doc.info?document_id=111369&version=1
(all above G.Hallewell and V.Vacek)

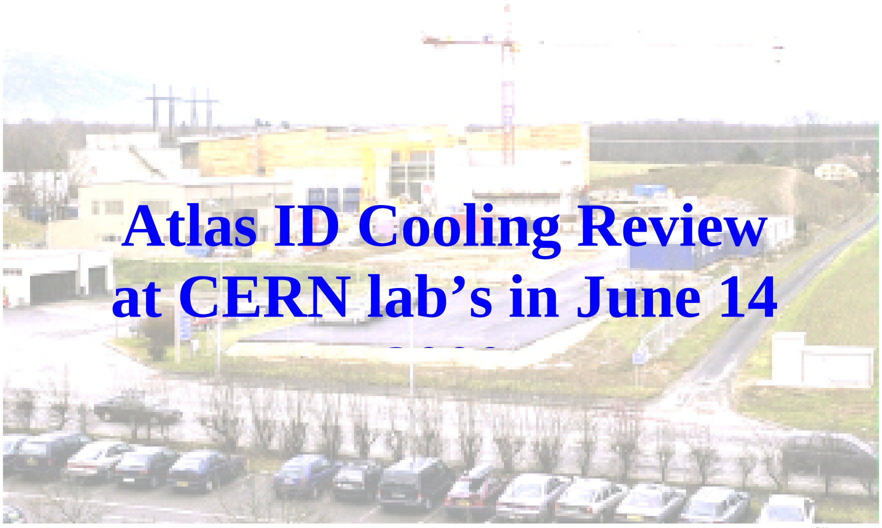
- The services associated to the cooling (space limitations and current estimates). (G.Tappern)

17:00-18:30 Review Group meet.
19:00 Dinner.

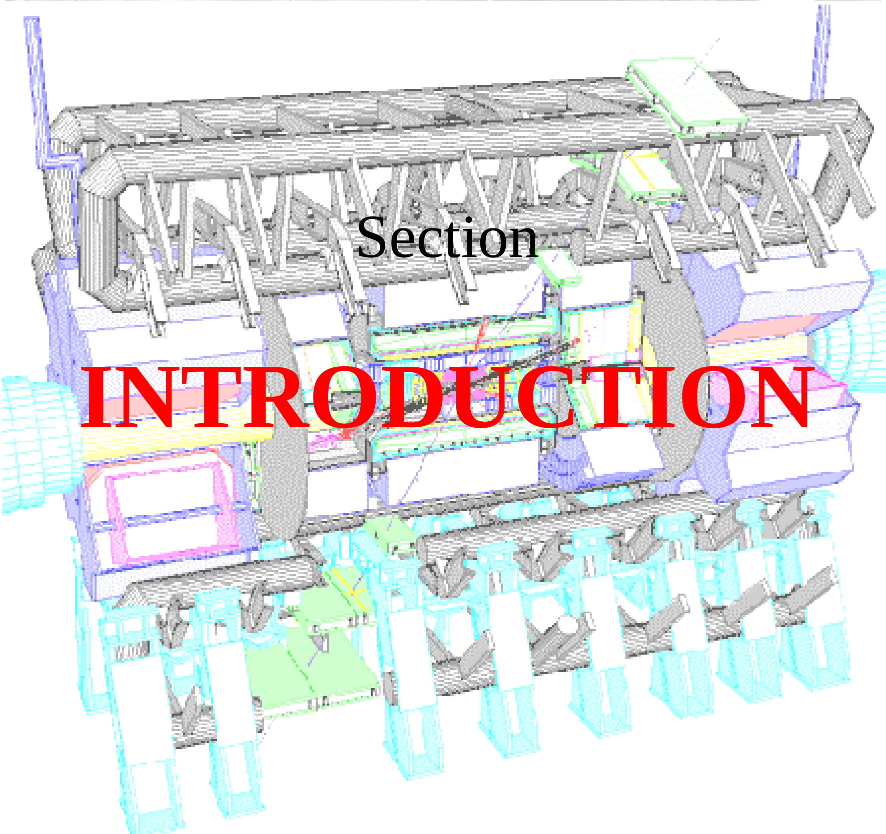
The review group will consist of :
PIXELs: : E.Anderssen, G. Gilchriese, M.Olcese.
SCT : R.Apsimon, R.Nickerson, E.Perrin, D.Greenfield, J Godlewski
TC: : G. Bachy, W.Witzeling.
The ID PE will be present ex-officios : **G. Tappern, M. Tyndel, L. Rossi**, the same with the SCT and PIXEL PLs.
The review will be chaired by Steinar Stapnes.

Reporting :
A report will be produced and sent to the ID community by the end of the month. All documents will be also available on EDMS

ATLAS
EXPERIMENT



Atlas ID Cooling Review at CERN lab's in June 14



Section

INTRODUCTION

June 2000

SCT& Pixel Evaporative Cooling System Review
June 14, 2000

Presentation at the Review

(1) Basic Principles, Historical Overview and System Baseline

(2) Developments Since the May 1999 Cooling Review

(2.1) Recent (January ➔ May 2000) Thermal Measurements on SCT and Pixel Test Structures

(2.2) Investigations of Control System & Services Thermal Management

(3) Present Status and Multi-channel Demonstrator Program

(1) Basic Principles, Historical Overview and System Baseline

Basic Aims

Cooling with non-(conductive/flammable/toxic/ozone-depleting) fluorocarbons

Use of Latent Heat (~100 Jg^{-1}) (c.f. : liquid C_P ~1-4 $Jg^{-1}K^{-1}$)
➔1/10-1/20 mass flow & << $\%X_0$ of coolant + tubing in a liquid system ➔➔

THIS MOTIVATED 1997 LHCC REQUEST FOR STUDY OF EVAPORATIVE COOLING FOR SCT AND PIXELS

C_4F_{10} Studies for Pixel Structures Reported in Inner Detector TDR (April 1997)

RECCOMMENDATION BY 11/1997 ATLAS COOLING REVIEW TO ELIMINATE ACQUEOUS COOLANTS IN THE INNER DETECTOR

Pixel Baseline C_4F_{10} Evap., SCT interest in C_3F_8 <u>EVAP COOLING GROUP SET UP 2/98</u>
➔ Extensive tests on SCT & Pixel Structures with C_4F_{10}, C_3F_8, C_4F_{10}/ C_3F_8, CF_3I

RECCOMMENDATION TO 5/99 ATLAS COOLING REVIEW TO STANDARDIZE ON C_3F_8 EVAPORATIVE COOLING FOR SCT & PIXELS

More Tests on Pixel Structures: Pixels Confirm C_3F_8 Evaporative Cooling baseline 11/99

(2) Developments Since the May 1999 Cooling Review

Late 1999 ➔ **Tests on Pixel "Baseline" Carbon-Carbon Barrel Stave**

("Old" (non-manifolded) D_H ➔ excessive ΔP along 2 staves in series

((2 x 107) Watts: layers 1, 2; (2 x 134) Watts: B layer)

Structures: Pixels Confirm C_3F_8 Evaporative Cooling baseline 11/99

(2.1) Recent (January ➔ May 2000) Thermal Measurements on SCT and Pixel Test Structures

(2.1.1) **Verification of "final" D_H for SCT barrel cooling tubes using Geneva "Full Length Prototype" (24 modules on 2 staves + 2 "ghosts")**

(2.1.2) **Tests on Pixel "Back-up" Barrel Stave (Constrained Al tube,"final" D_H, grease joint to C-C module carrier)**

(2.1.3) **4/5 new pixel disk sectors in series/parallel combinations (June 2000)**

(2.1.4) **New SCT forward Disk Sector (Mid-late July 2000)**

(2) Developments Since the May 1999 Cooling Review (cont.)

(2.2) Investigations of Control System & Services Thermal Management

Baseline Evaporative Circulator Control System as Proposed by Michel Bosteels at May 99 Cooling Review:

(i) **Remote, Hermetic, Oil-less compressors (personnel accessible area USA 15)**
Local PID controllers regulating aspiration pressure (motor speed control) and condenser pressure (chilled water flow rate)
Advantage of compressor parallelism for prior use in assembly sites.

(ii) **In inaccessible area UX15 (high B, radiation fields):**
Dome Loaded Pressure Regulators for Liquid Delivery on each circuit (Linear Flow regulation between Saturated Liquid Line and Condenser Output Pressure)

Dome Loaded Back Pressure Regulators to individually control boiling pressure (operating temperature) on each circuit, (depending on radiation damage).
THIS FLEXIBILITY IMPOSSIBLE IN A LIQUID COOLING SYSTEM!
NO SPEC. ON SUB-COOLING/OUTPUT ➔ INPUT HEAT EXCHANGE

(2) Developments Since the May 1999 Cooling Review (cont.)

(2.2) Investigations of Control System & Services Thermal Management (cont.)

Studies of Services Thermal Management/ Fluid Sub-cooling/ Output ➔ input heat exchange

Originally Envisioned for demonstrator phase.
However, these tests brought forward upon request of IDSG

(2.2.1) First Tests (output ➔ input heat exchange) made in 12/99
Enthalpy Positive feedback gave very long time constants (see post-mortem)

Circulator rebuilt with separated input cooling and exhaust heating

(2.2.2) Tests (input flow tuned to stave power dissipation of staves: 5/2000)

Demonstrated possibility to keep exhaust tubes above dew point with flow variation and little (if any) heating. Short (50cm) heater required high surface temperature to keep following tubes above dew point, if flow variation not used.

(2) Developments Since the May 1999 Cooling Review (cont.)

(2.2) Investigations of Control System & Services Thermal Management (cont.)

Studies of Services Thermal Management/ Fluid Sub-cooling/ Output ➔ input heat exchange

(2.2.3) June 2000 Heater, Fixed Flow, No pre-cooling tests

Requested (5/2000) to test another (coaxial, two-part) heater arrangement: (l = 1.5 +0.5) m.

Inner elements for tube heating, outer simulate active insulation, and can be PID regulated in temperature. FIRST RESULTS 061200

MISSING INFORMATION FROM ENGINEERS:

(1) Maximum acceptable temperature on heater surface
(if heater attached directly to exhaust tubes: FEA thermal model of gap services req.?)

(2) Minimum temperature on the exhaust tube downstream of the heater
(determines whether further active/passive insulation is necessary)

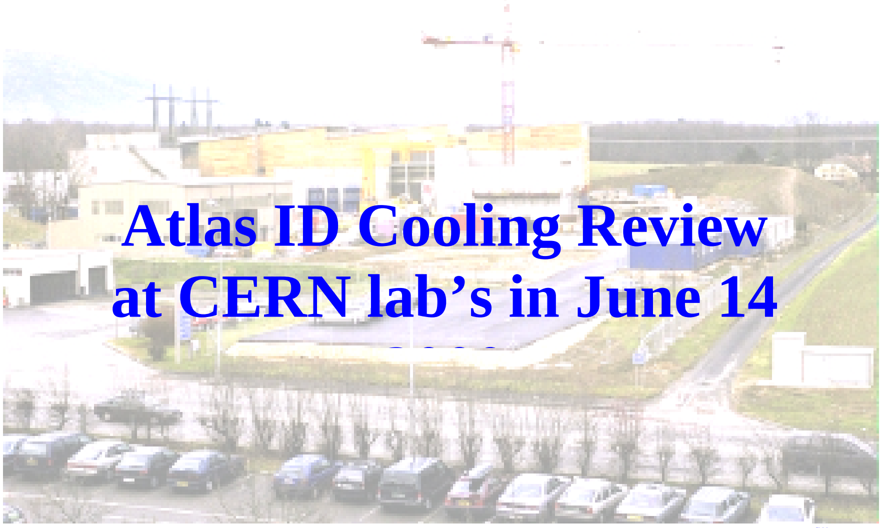
(3)Present Status and Multi-channel Demonstrator Program

(3) Cooling Demonstrator Status and Program

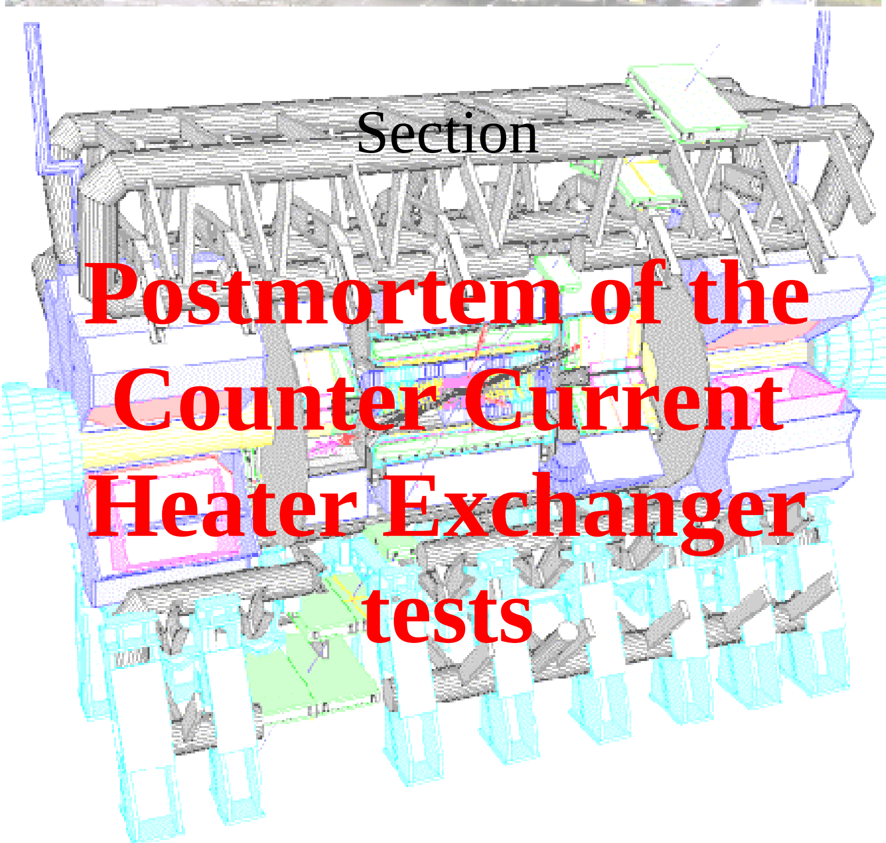
(i) **Compressor Status & Major Component Requirements**

(ii) **Four Stave Manifolds & Pixel Dummy Staves for Demonstrator**

ATLAS EXPERIMENT



Atlas ID Cooling Review at CERN lab's in June 14



Section

Postmortem of the Counter Current Heater Exchanger tests

June 2000

Postmortem of Dec '99 Input Liquid/Exhaust Vapour Counter-Current Heat Exchanger Test

Are heat exchangers needed? If so, what type?…Should we use the exit vapor (*and more dangerously? any unevaporated liquid*…) to sub-cool the input liquid ?

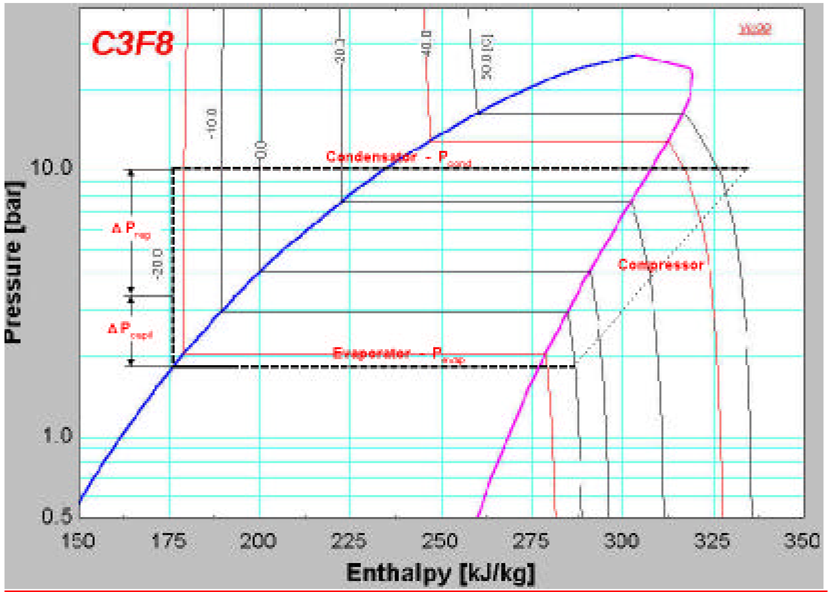
RISK OF A POSITIVE FEEDBACK (FLOOD) SITUATION?

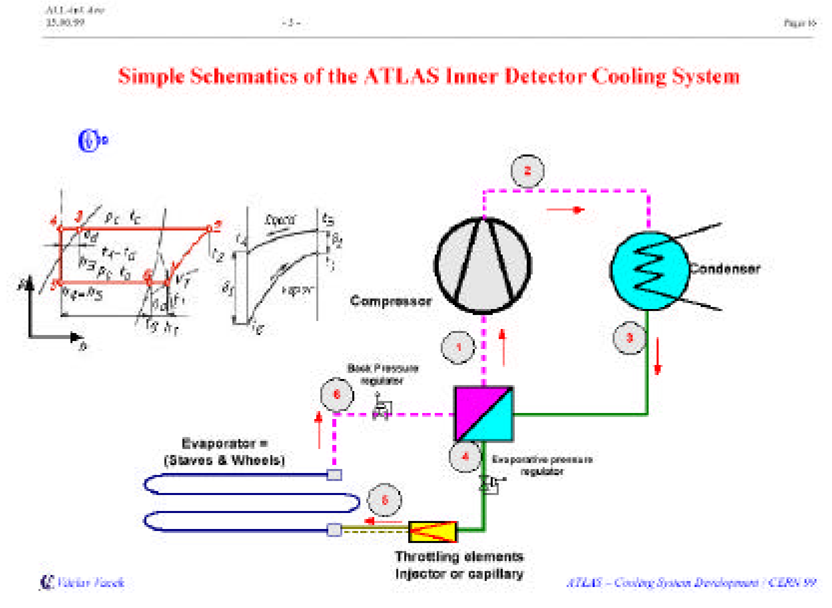
Role of a(ny) heat exchanger should be to minimize the mass flow of coolant necessary to evacuate a given heat dissipation, by optimizing the arrival condition of the liquid coolant.

LIMITATIONS TO RESPECT IN OUR EVAPORATIVE SYSTEM

(1) We have a fixed orifice reducing element that is not accessible;

(2) The pressure of liquid upstream of this (P_{EVAP}) cannot drop below the saturated liquid pressure (P_{SL}) at the liquid temperature, or boiling will occur (saturated liquid line crossed in cycle diagram);➔ ➔



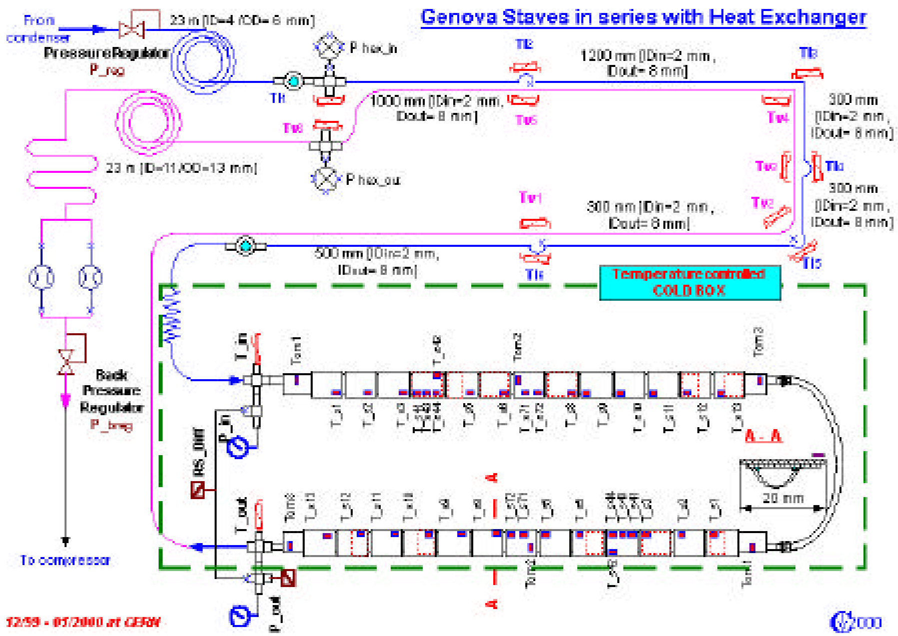


(3) Above the S.L.L. a range of pressure ((P_{COND}) - (P_{EVAP})) is available for the linear regulation of mass flow rate (There is an advantage to having the lowest liquid temperature that is reasonable, upstream of the orifice since this extends this linear range); ➔ ➔

(4) The evaporative circuit behaves like an enthalpy potential divider. If too much enthalpy (heat take up potential) is available for the heat to be evacuated from the evaporator (stave), it will be used up elsewhere (i.e.) downstream in the exhaust tubing at a rate (length) depending on insulation level and additional heat sources. Boiling liquid in exhaust line, but << %X0 all liquid.

Reaction time in an evaporative cooling system depends on the time to adjust enthalpy *(rather than mass flow)* to a varying heat load…

- **At a given mass flow, an exhaust vapor → supply liquid HeX alone can (depending on its efficiency) cause a *positive feedback* in enthalpy availability (seen in the HeX tested by Olcese and Vacek→).**



This excess enthalpy is mainly available in the form of extra liquid that cannot be evaporated in the evaporator stave at its given power dissipation (rather than sensible heat of any cold, already evaporated vapor).

- **Reducing the mass flow by variation of the pressure upstream of the orifice will take a long time to give a visual effect on temperatures on the stave since, even in the absence of any new liquid at all, it will take time to evaporate the excess liquid that has built up.**
-

ORIGIN OF A LONG TIME CONSTANT EFFECT OBSERVED…

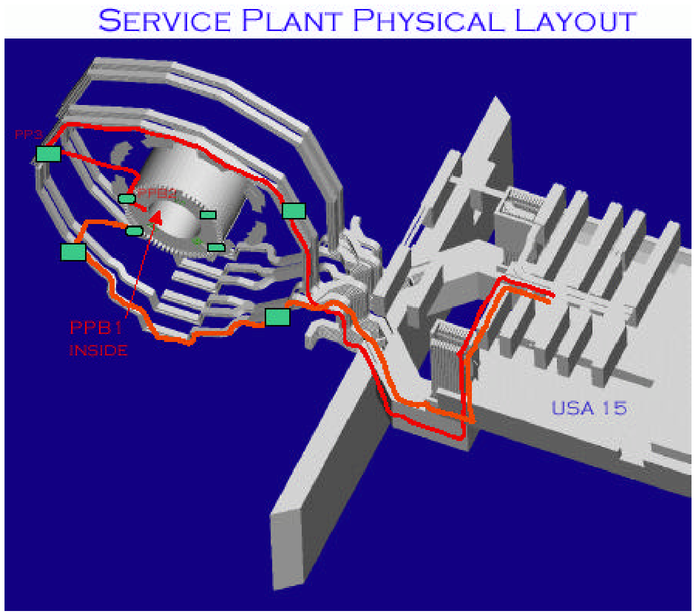
THIS HEAT EXCHANGER WAS REPLACED BY MORE FLEXIBLE ARRANGEMENT

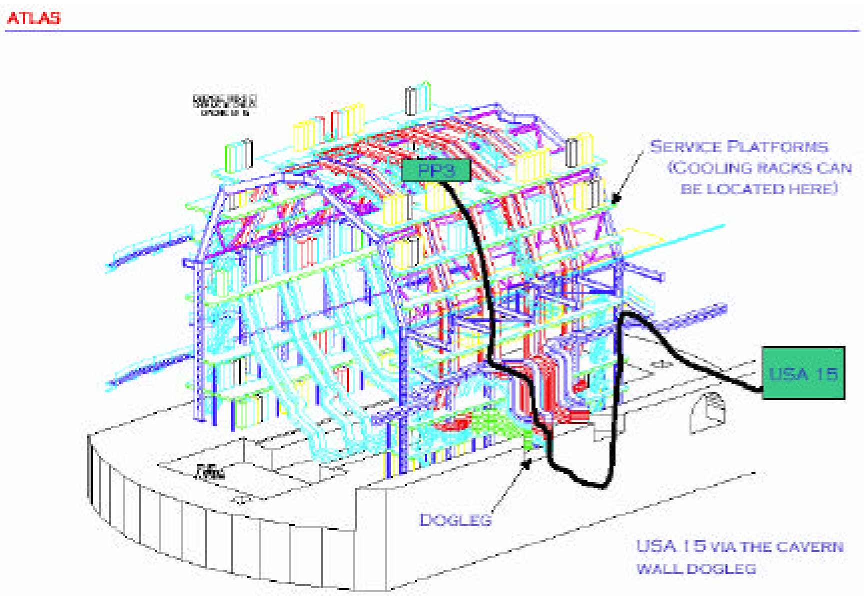
- **Aim of the modifications – to bring design of the cooling circuit closer to the final arrangement within the ATLAS detector**

Modifications to Lab Circulator to study New Flexible Supply/Exhaust Configuration

Foreseen Implementation of the Cooling Circuit

Aim of the modifications **– to bring design of the cooling circuit closer to the final arrangement within the ATLAS detector**

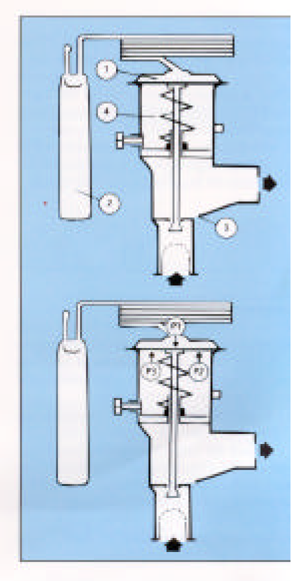


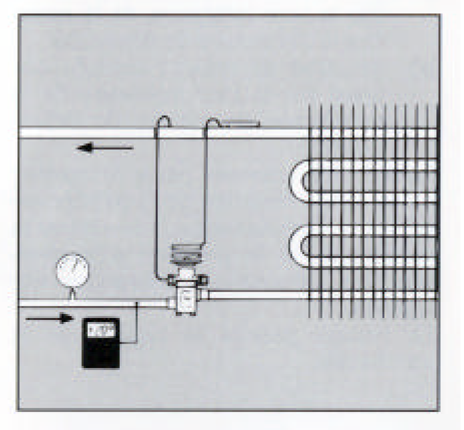


Comparison with Industrial Practice

In an industrial system, a thermostatic valve is often used to regulate mass flow.
Three parts…

(a) Valve body with membrane and connected stem tip





(b) Vapor pressure bulb containing the same fluid as the process fluid, and connected to (a) through a capillary.
The bulb is clamped to the exhaust tube of the evaporator

(c) Injectors or varying sizes that are variable over a certain range by pressure from the stem tip of (1)HOWEVER… IN COMMERCIAL SYSTEMS, SUB-COOL/SUPER HEAT HeXs ARE *OUTBOARD, NOT INBOARD* OF THE REGULATION VALVE AND BULB (WHICH ADJUSTS (DECOUPLES) MASS FLOW FOR A GIVEN SUB-COOLING)

Range of Options of Liquid Delivery & Vapour Exhaust Configurations to Test (→ → May 2000)

Varying between:

- **variable mass flow over the full range of circuit power dissipation;**

Cold liquid delivery preferable:
→ → Evaporation temperature for maximum effect:
a few additional cooling lines per bundle may be
required to keep liquid cold right to point of use…

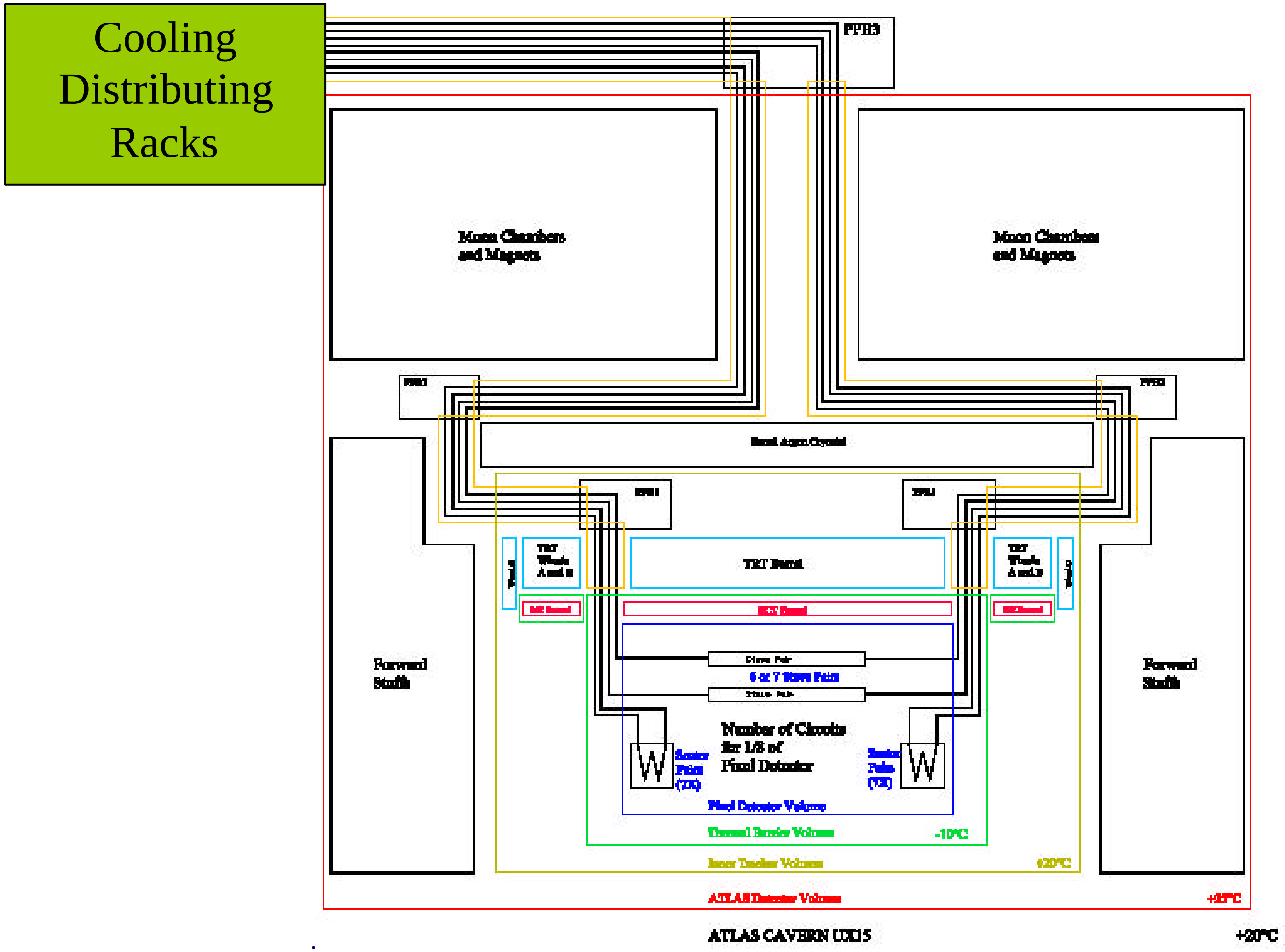
And:

- **fixed flow: exhaust heater attached to each circuit exhaust line;**
- **Exhaust heater power ≥ circuit dissipation + sensible heat;**

→→Investigate tuning mass flow and/or heater power to number of powered modules on circuit →→

New heater has been manufactured [heating elements soldered on the cooper tube] with better thermal contact and section of the tube with the heater was "separated" by stainless steeel swagelok connectors from rest of the exhaust tube.

Approximate tube routines:



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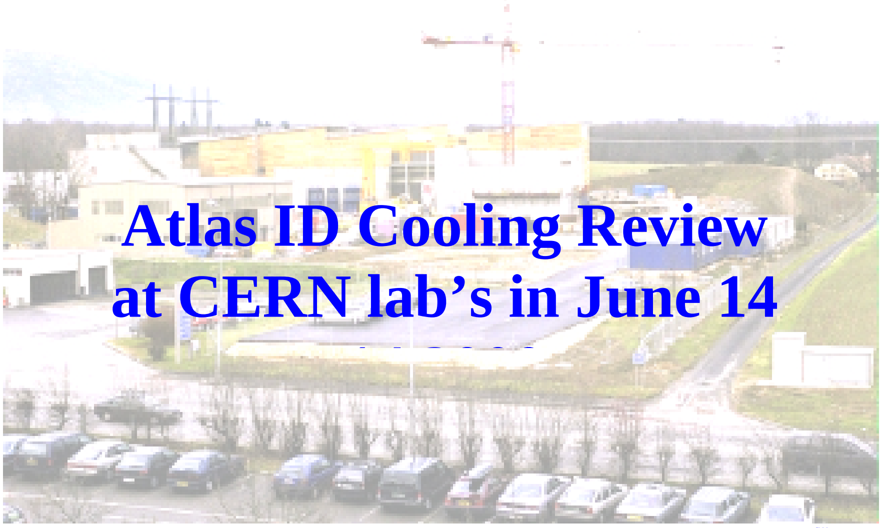
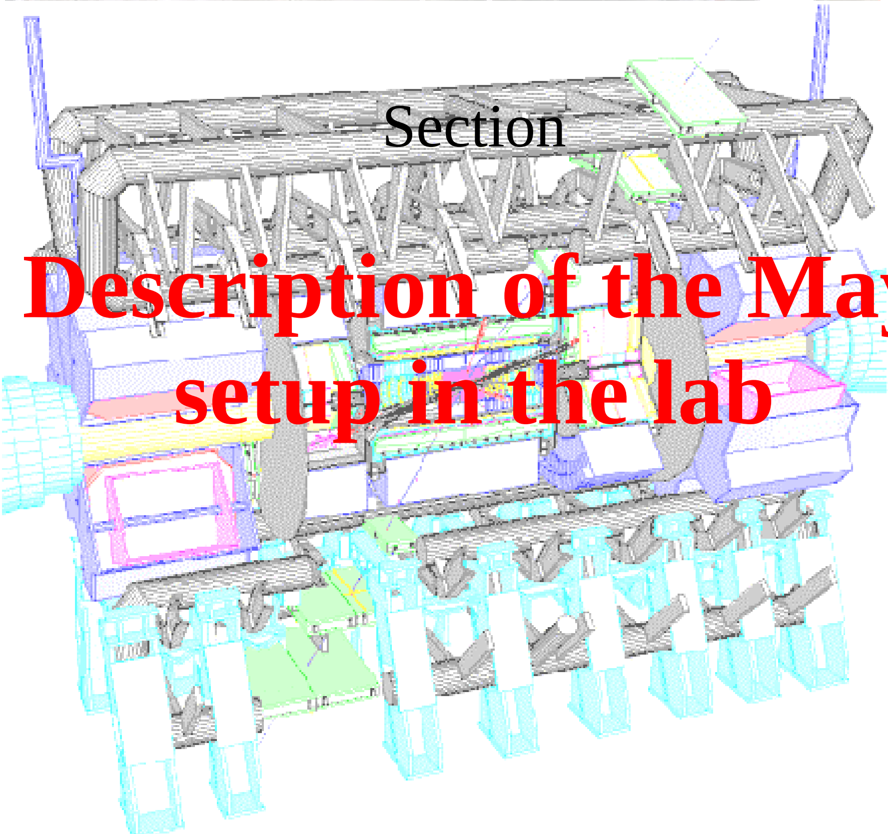


Atlas ID Cooling Review at CERN lab's in June 14

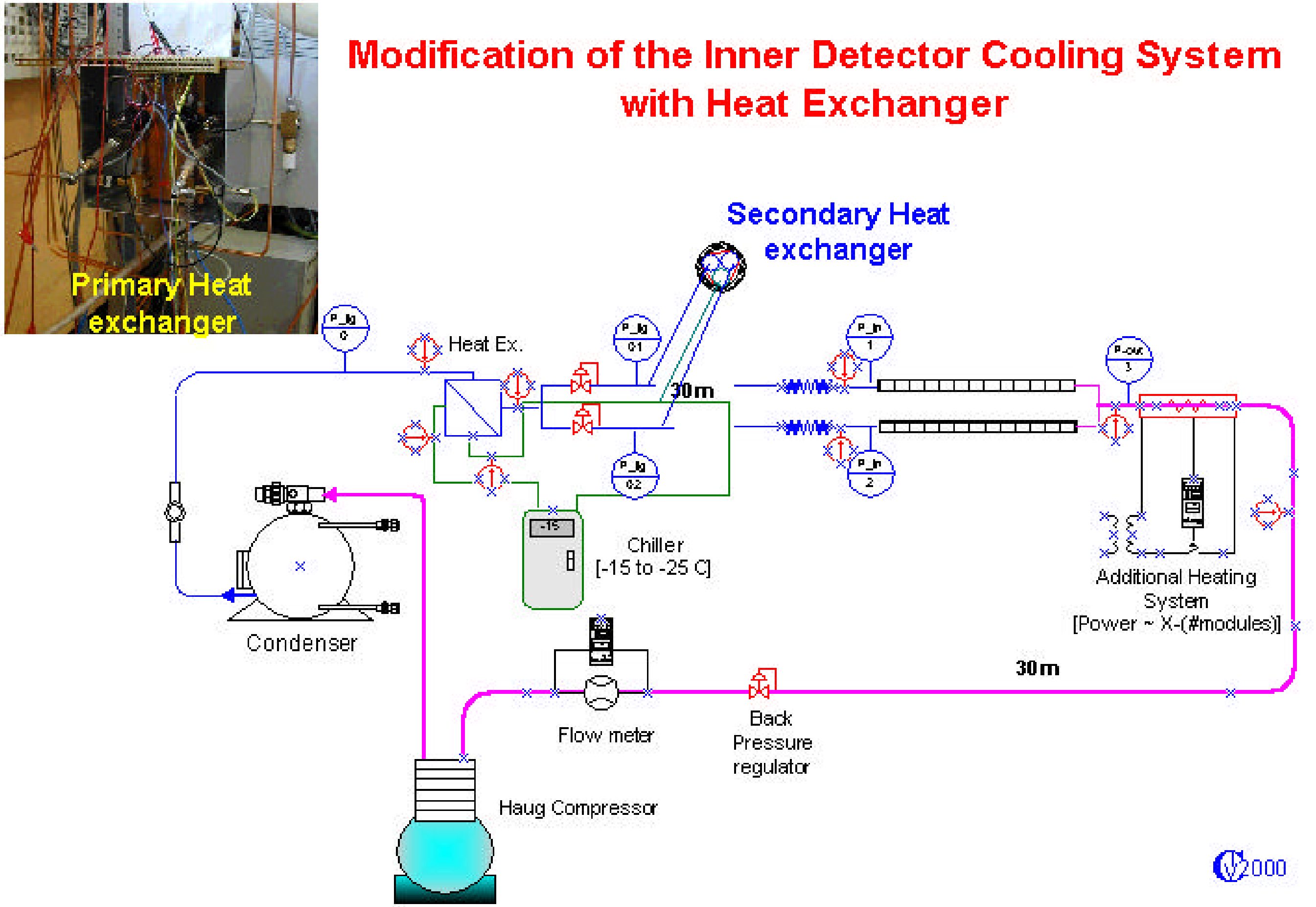


Section

Description of the May setup in the lab

June 2000

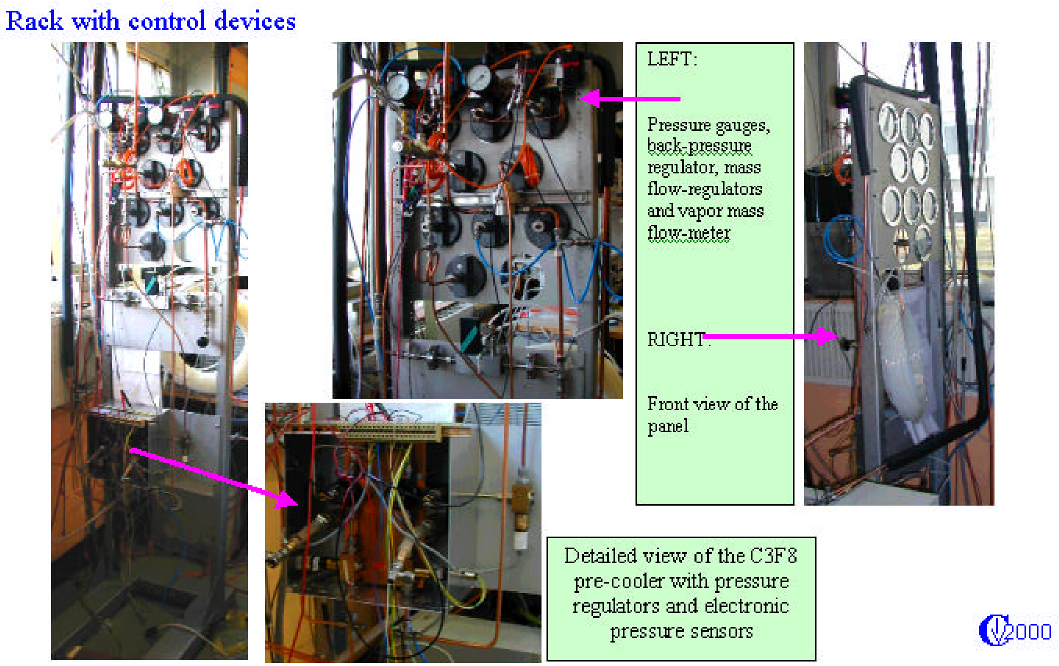
Current Cooling System Setup - early May 2000



HeX Geometry Tested

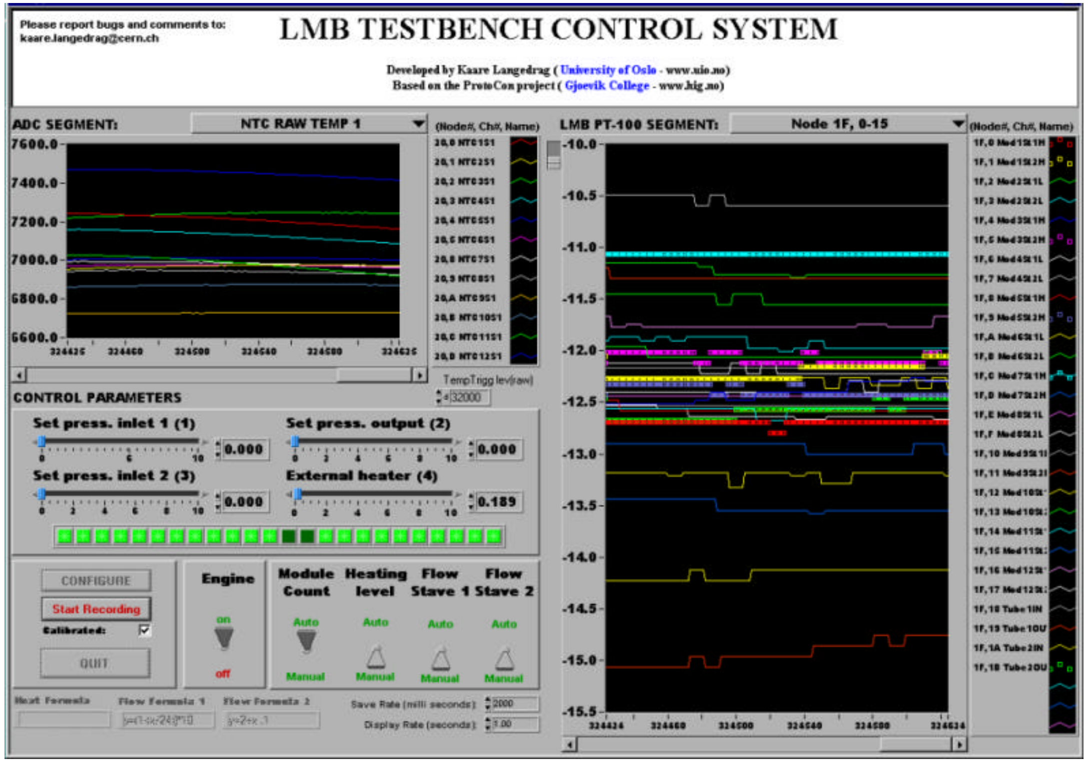
- **Chilled liquid HeX (to –25 C) cooling of liquid upstream of flow regulator valve, with coolant tracer tube with C_3F_8 tube under same overall insulation jacket**
- ***FLOW REGULATORS ATTACHED TO PARALLEL PLATE HeX CONTINUATION BUNDLE COOLING TUBE (l=25 m) INSTALLED ➔ ➔***

Present status of the installation in the lab – part one



Implemented Control System

BridgeView Software (CanBus, LMB DAQ) commissioned (K. Langedrag, Oslo) to vary flow regulator output pressures via: $P_{(ORUP1,2)} = P_{(SV)} + m_{1,2} * (n_{modules1,2})$ ➔➔



$N_{modules1,2}$ counted via "module OK" bits from Wuppertal Power Interlock Box (BIT = module on and Temp Correct)

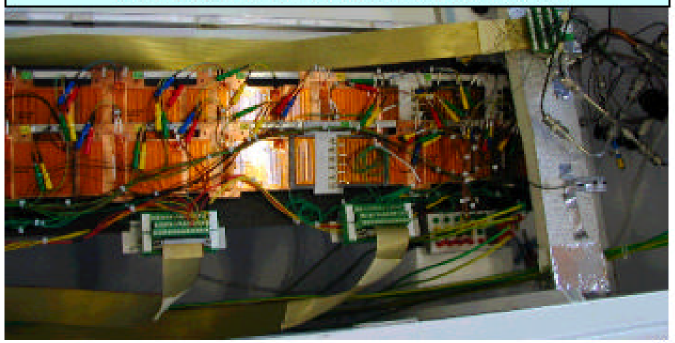
Installed Test Structures and DAQ/Control System

Present status of the installation in the lab – part two

LMB and WAGO based CanBus DAQ System that enables monitoring of the temperatures and basic control parameters of the Cooling system

2 SCT thermal model staves and 2 "parallel ghost" SCT staves placed in the temperature controlled box

Detail of the manifolding into the staves, temperature sensors and heater wiring



Control System Status and Test Plans

Extensive Tests made with control system for evaporative cooling.

Geneva FLP as test vehicle, with additional NTC sensors driving 22 individual module power interlocks.

Flexible control system with Bridgeview DAQ & user interface
Allows..

(1) Flow rate to staves to be tuned over full range to number of powered modules using dome loaded (analog air driven) fluid supply regulators ;

(2) Fixed Fluid Flow with variable heater power on exhaust tubes : attempt to raise exhaust tube temperature above local dew point ;

(3) Combination of (1) and (2)

(4) Variation of liquid precooling to adjust enthalpy for a given flow rate (refrigeration power = enthalpy*mass flow), used with (1), (2) & (3)

First Results from Control System Tests

Highly (!) Satisfactory Demonstration of Cooling Varying Numbers of Modules (9.5W units) on 2 stave assembly with coolant mass flow variation.

Proportional Flow Equation :

$$P_{CAPUP} = P_{SL} + DP*(\#\text{modules powered})$$

depends on liquid precooling, but we have verified formula at several precooling temperatures :

EXAMPLE: Precooling to ~ -8C:

$$P_{CAPUP} = 3.5\text{bar (abs)} + 0.11\text{ bar}*(\#\text{modules powered})$$

(DP depends on capillary length (1.7m) and diamater(0.8mm))

However, we have found it difficult to couple heat into exhaust fluid with heaters on exhaust tube ➔ ➔ :

First Results from Control System Tests (Cont)

Difficult to couple heat into exhaust fluid with heaters on exhaust tube

IN FIXED FLOW STUDIES, EXHAUST HEATER SURFACE GETS VERY HOT (> 50C) TO KEEP FLUID WARM ABOVE DEW POINT FOR VARYING STAVE POWER DISSIPATON

WHY ?

We believe that any unevaporated liquid exhaust fluid becomes a mist on entry into the larger diameter exhaust tube.

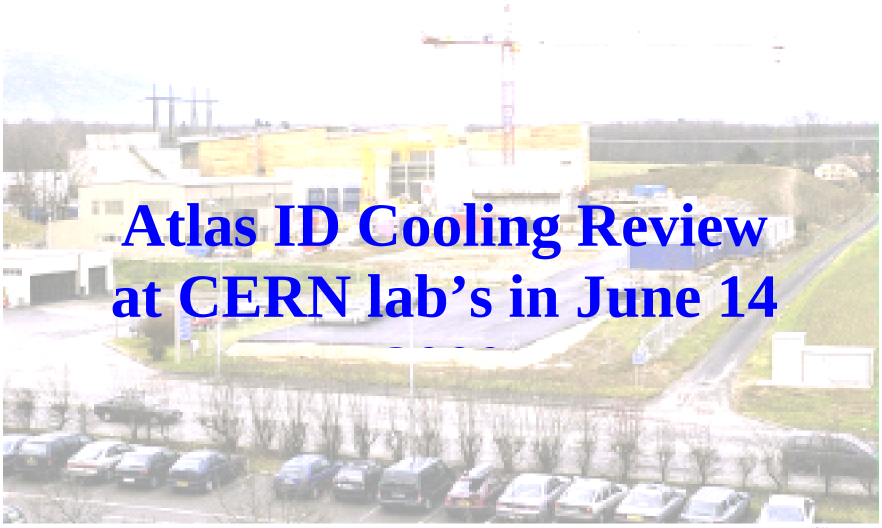
PREVIOUS EVIDENCE (1996) : Stave Evaporation Temperature did not increase, even with significant oversupply of refrigerant into 4m high exhaust extensions, although these tubes got cold (visible frost).

Fluid in exhaust tube is volatile, is in reflux and suspended by NPSH of compressor (i.e. Torricellian, not gravitational)

PROOF ?

Installed transparent vac. insulated section (h=2 m) after first exhaust heater. Looked at DP and fluid characteristics inside it with heater off/on.

ATLAS EXPERIMENT



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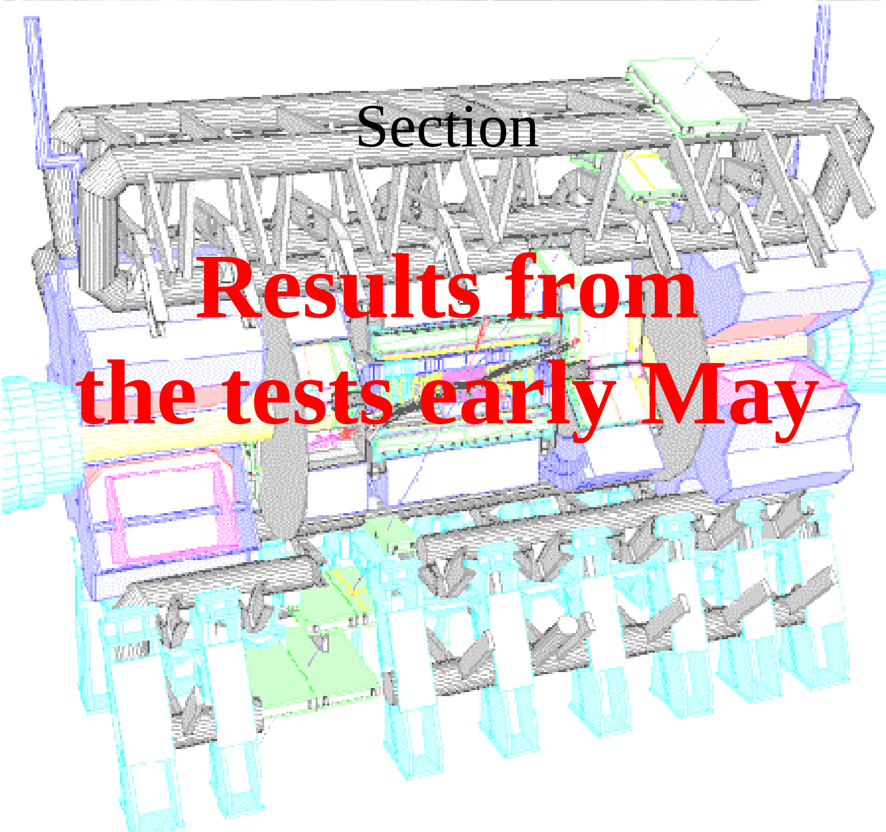
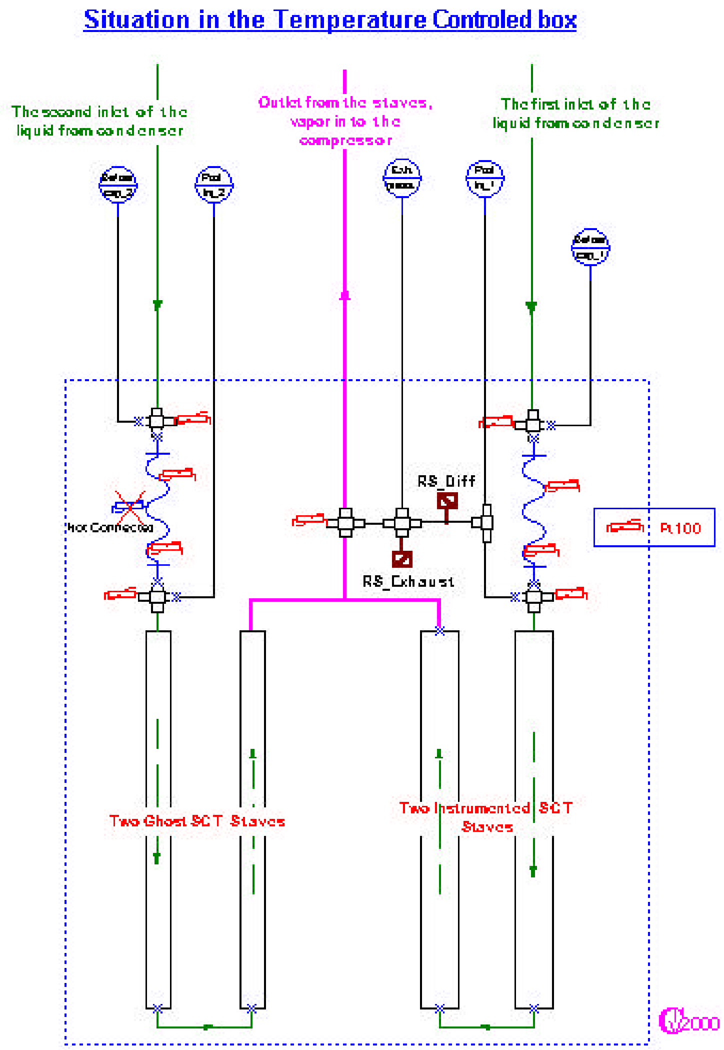


Section

Results from the tests early May

June 2000

Tests in May 2000 & Current results & Additional tests to come



Various tests were performed with 50 cm heater [the only dimensional specs we obtained] attached to the exhaust tube of the setup. They included runs:

With pre-cooling:

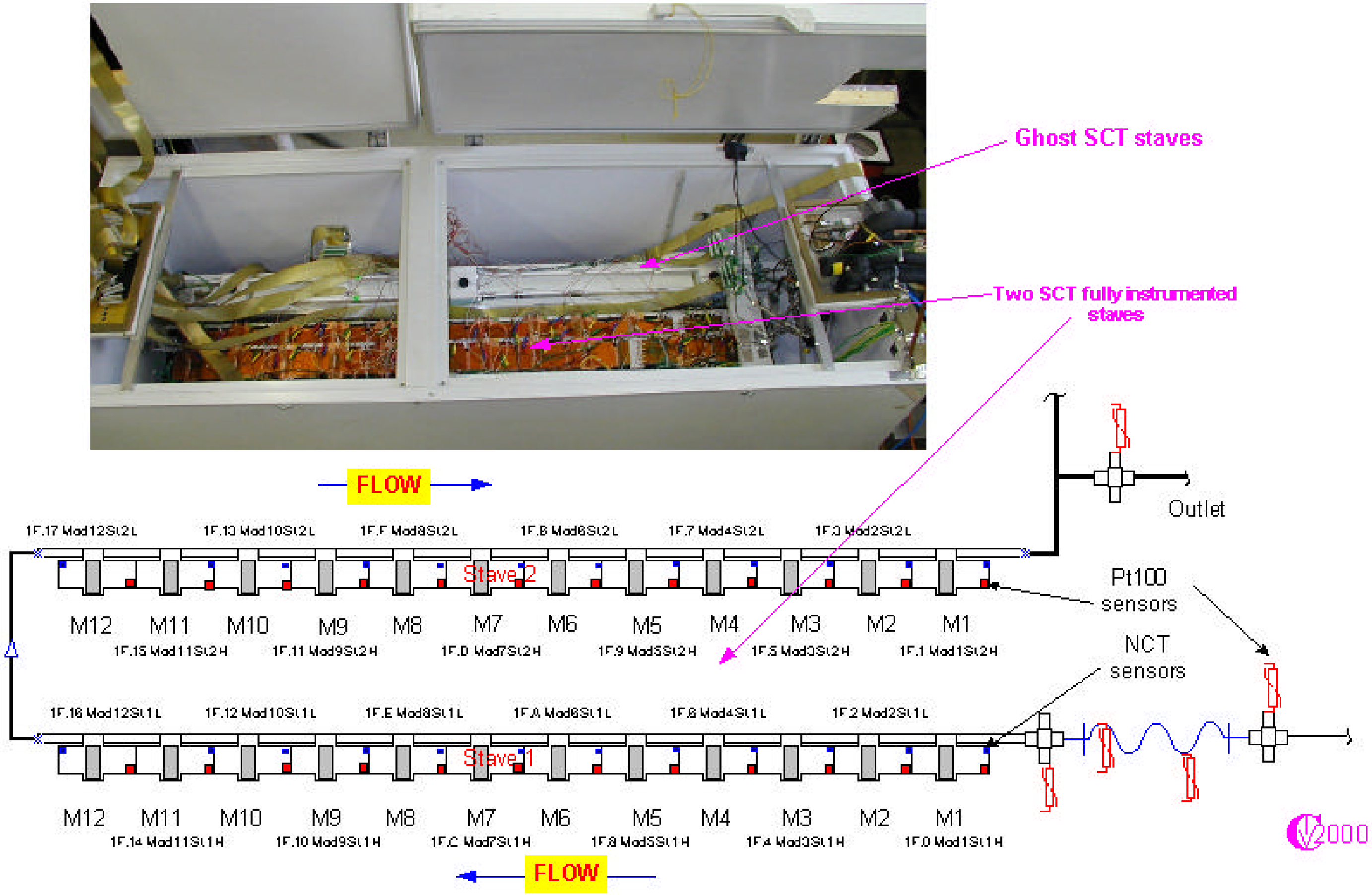
- **Start-up** procedure and **shut-down** procedure
- **Steady state runs** with flow regulation and power on the external heater ranging from 100W to 150W {with surface of the heater temperature PID control [20-25 °C} while power introduced into modules was set to:
  100%, 50% and 10% of the nominal power or one module; plus accidental switching of the modules "on" and "off"
- **Standby runs** were investigated
- **Fixed flow** runs with external heater power variation were tested

Without pre-cooling:

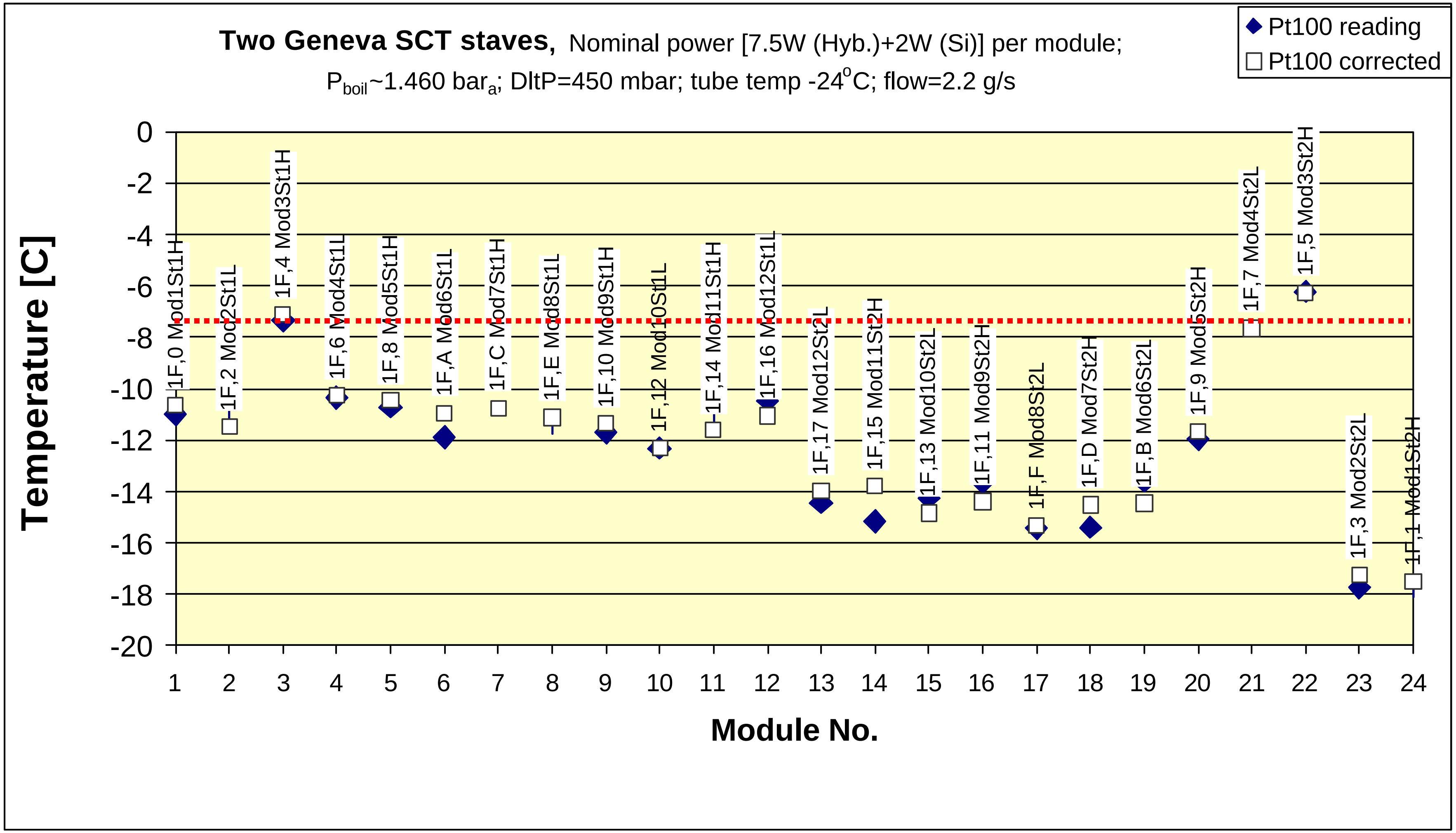
- **Start-up** procedure and **shut-down** procedure
- **Steady state runs** 100%, 50% less of the nominal power

One Half of Stave Quartet Heated and Cooled ➔

Map of NTC and Pt100 Sensors



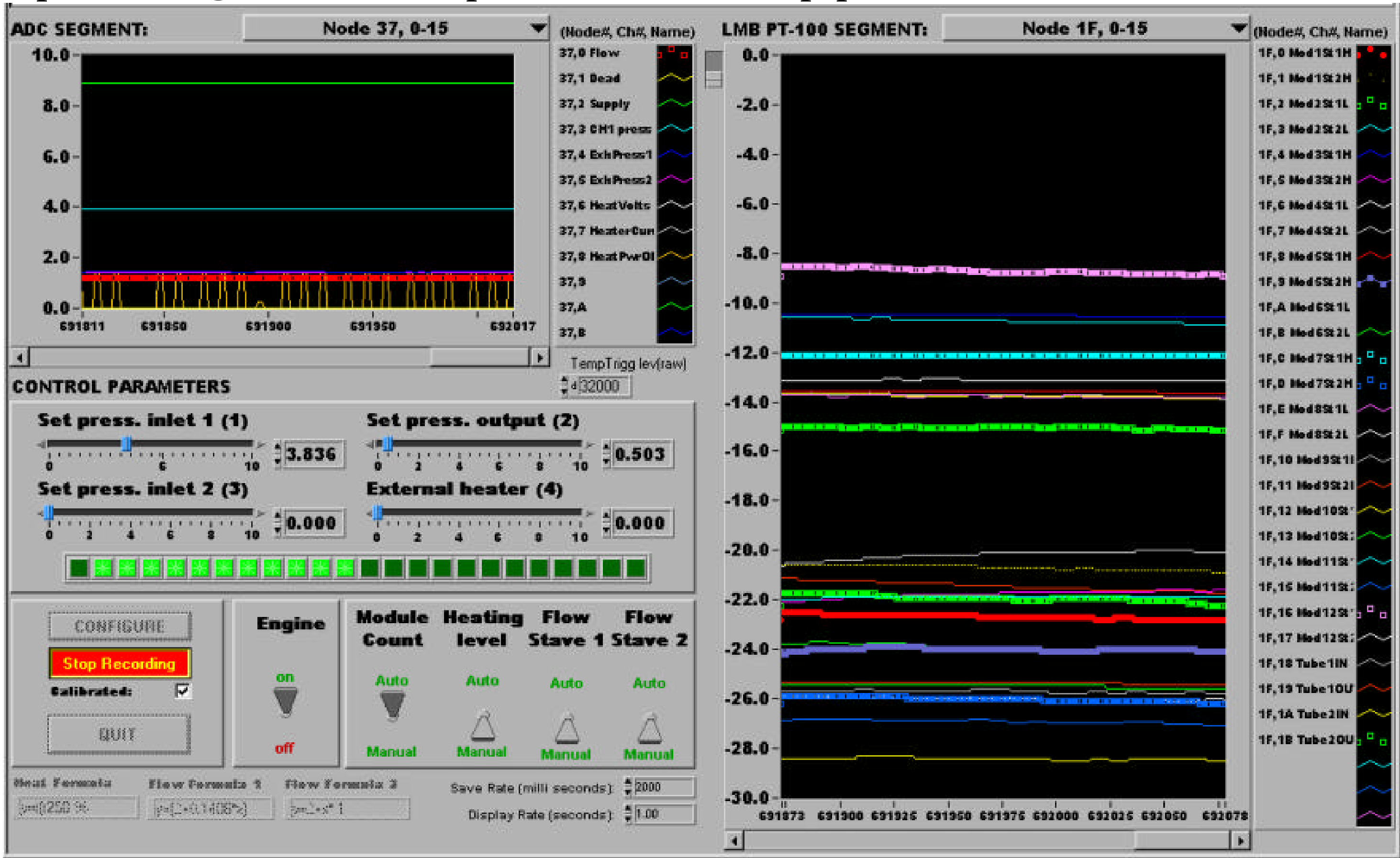
Typical SCT stave temperature profile at steady state conditions

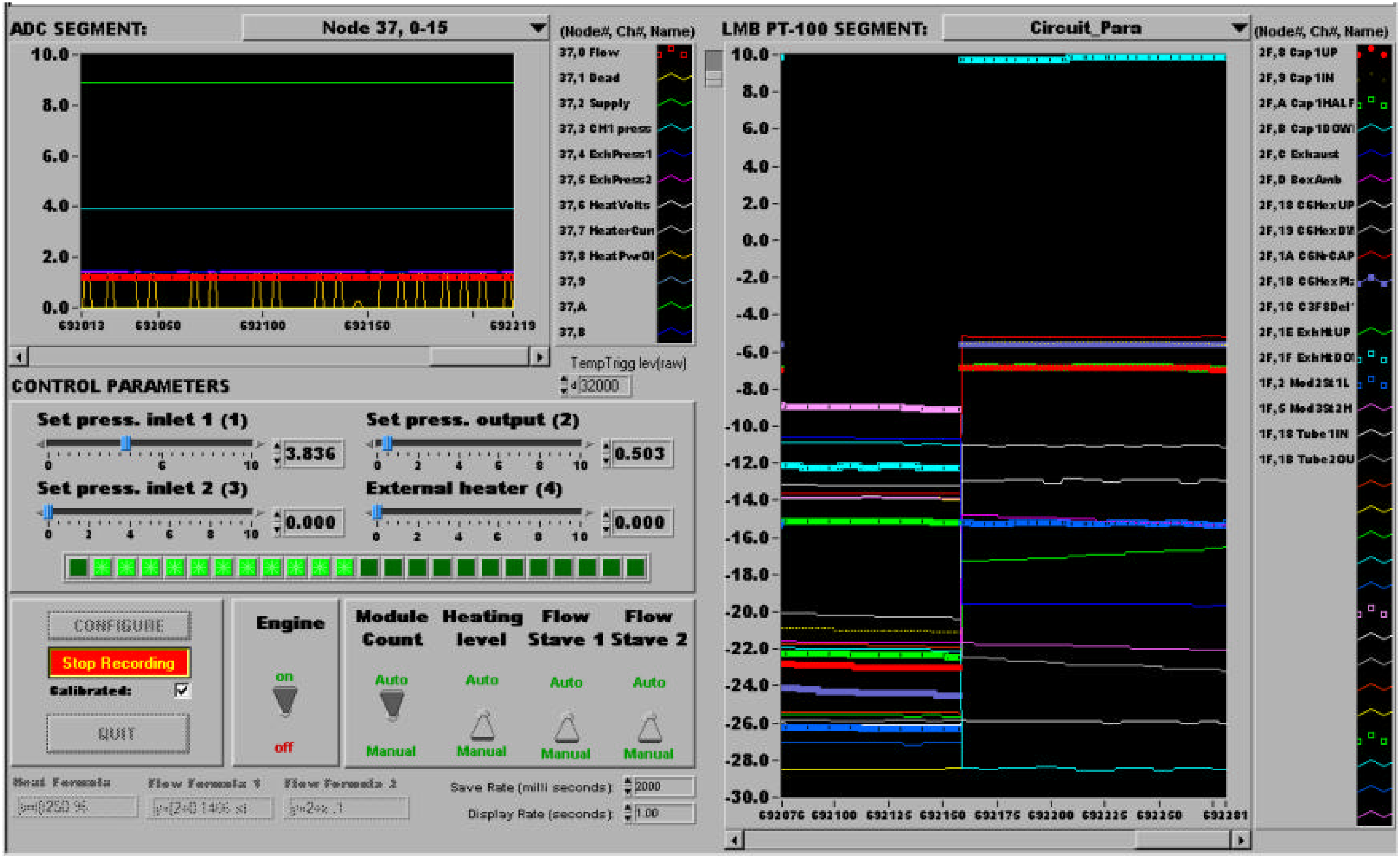


Short summary of the test runs:

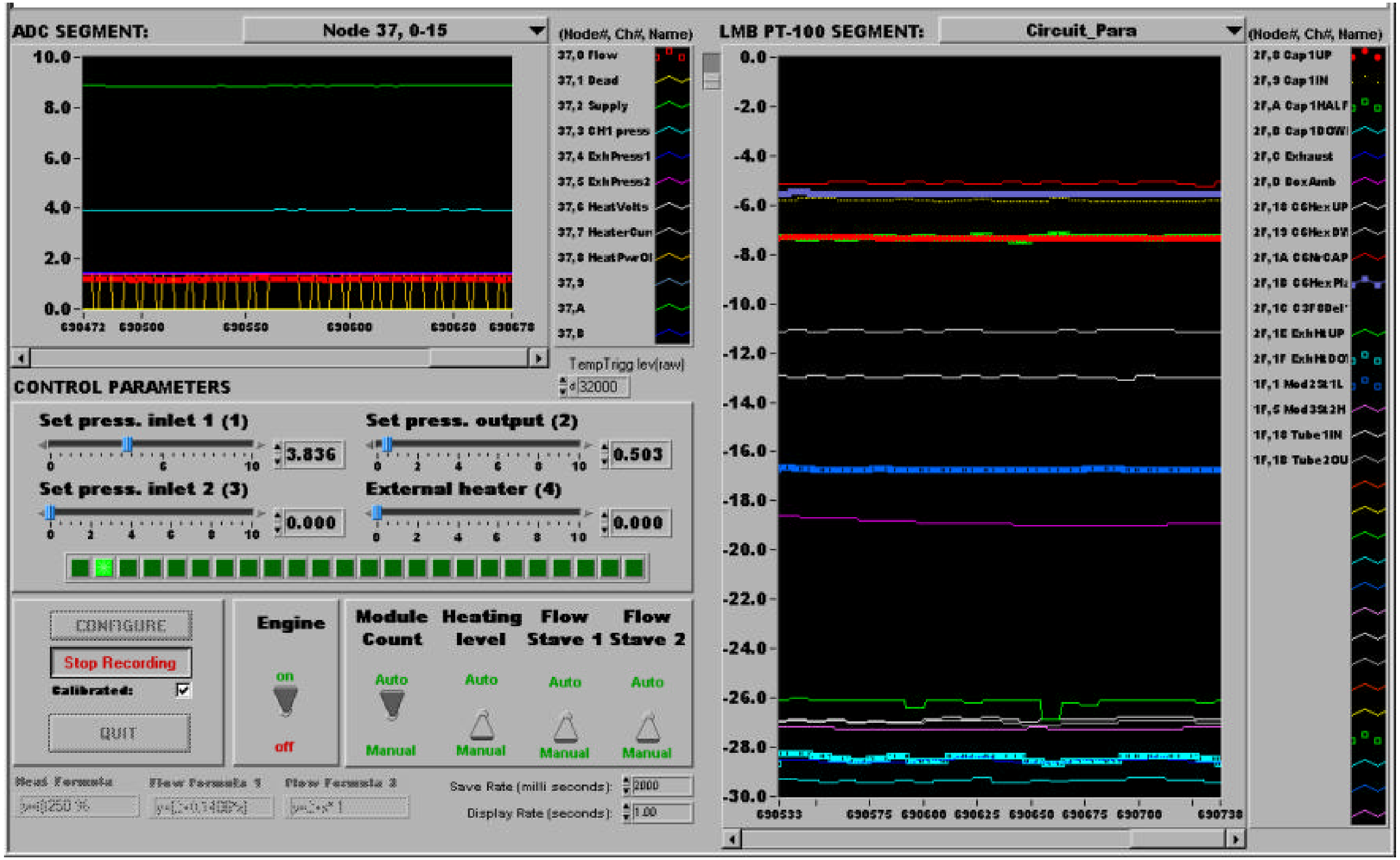
- With pre-cooling and refrigerant flow regulation

1. For 50%, 100% power; External heater & 100 W and PID for the heater surface temperature @ +20°C; temperature of return pipe ≤ 10°C;




ADC SEGMENT:
Node 37, 0-15
(Node#, Ch#, Name)
LMB PT-100 SEGMENT:
Circuit_Para
CONTROL PARAMETERS
Set press. inlet 1 (1)
Set press. output (2)
Set press. inlet 2 (3)
External heater (4)
TempTrigg lev(raw)
CONFIGURE
Stop Recording
Calibrated:
QUIT
Engine
Module Count
Heating level
Flow Stave 1
Flow Stave 2
Auto
Manual
on
off
Save Rate (milli seconds)
Display Rate (seconds)

2. Standby /one module “ON”; External heater & 100 W and PID for the heater surface temperature @ +20°C; temperature of return pipe slowly cools down to -27°C [but does not cause any problem to the stability of the cooling system]



3. Standby /one module "ON"; External heater has to be set permanently [no PID] to 100÷150 W to hold return pipe @ ≈ 0°C (still very slowly raising); temperature of the heater goes up to 60°C (still raising when test was stopped)

Stave temperatures under control and within the SPECS [all modules below -7°C]

Other Typical Circuit Parameters

Condenser: P_{cond} = 8÷9 bar_g t_{cond} ≅30°C

Compressor $P_{bufferSET}$ =1100 torr P_{buffer} = 1200÷1300 torr

$P_{exhaust}$ = P_{evap} = 0.45 bar_g

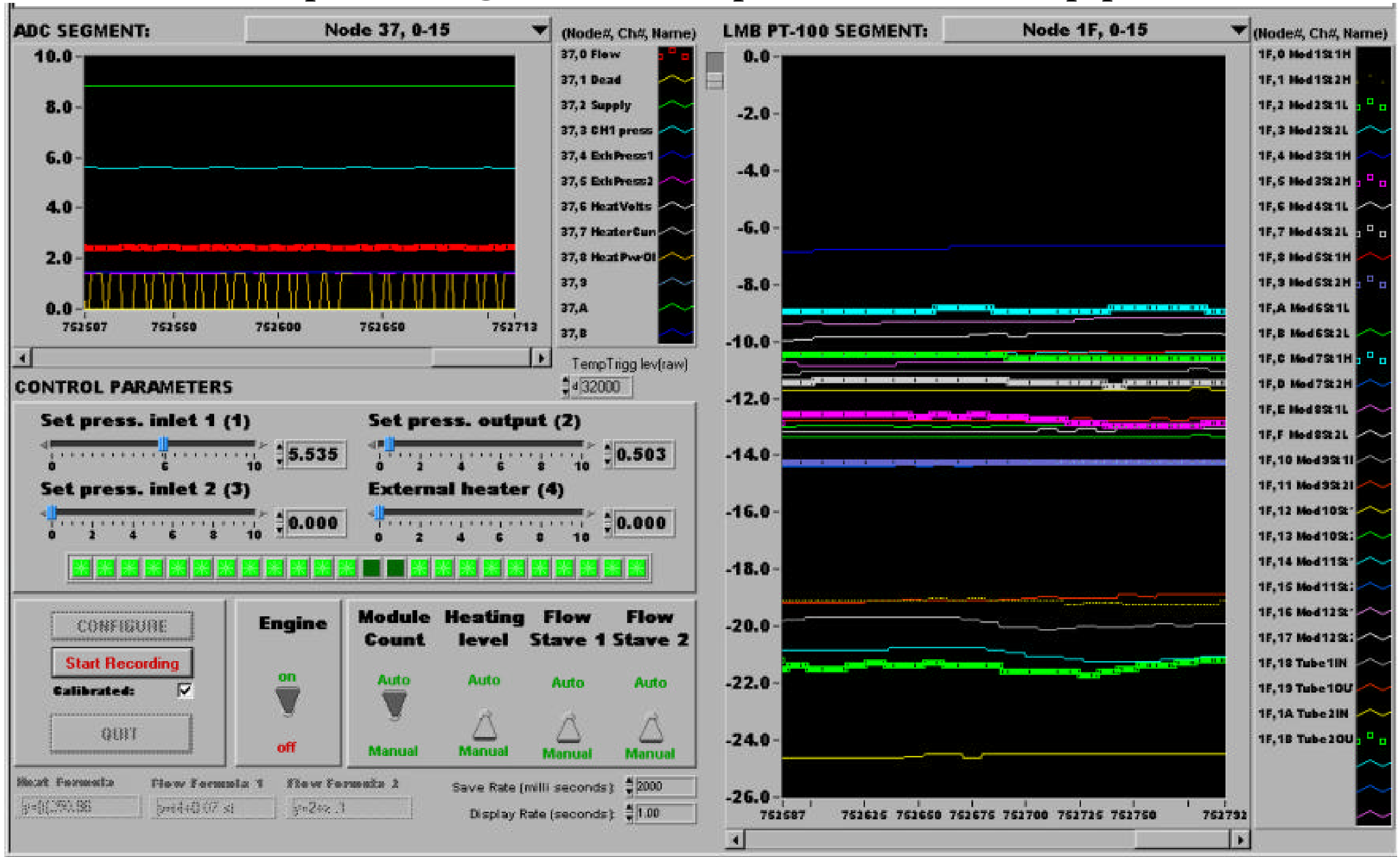
Pre-cooling t_{SET} ≅ - 29°C t_{out} ≅ - 14.6 °C Flow = 54 l/h

Pressure drops over staves:

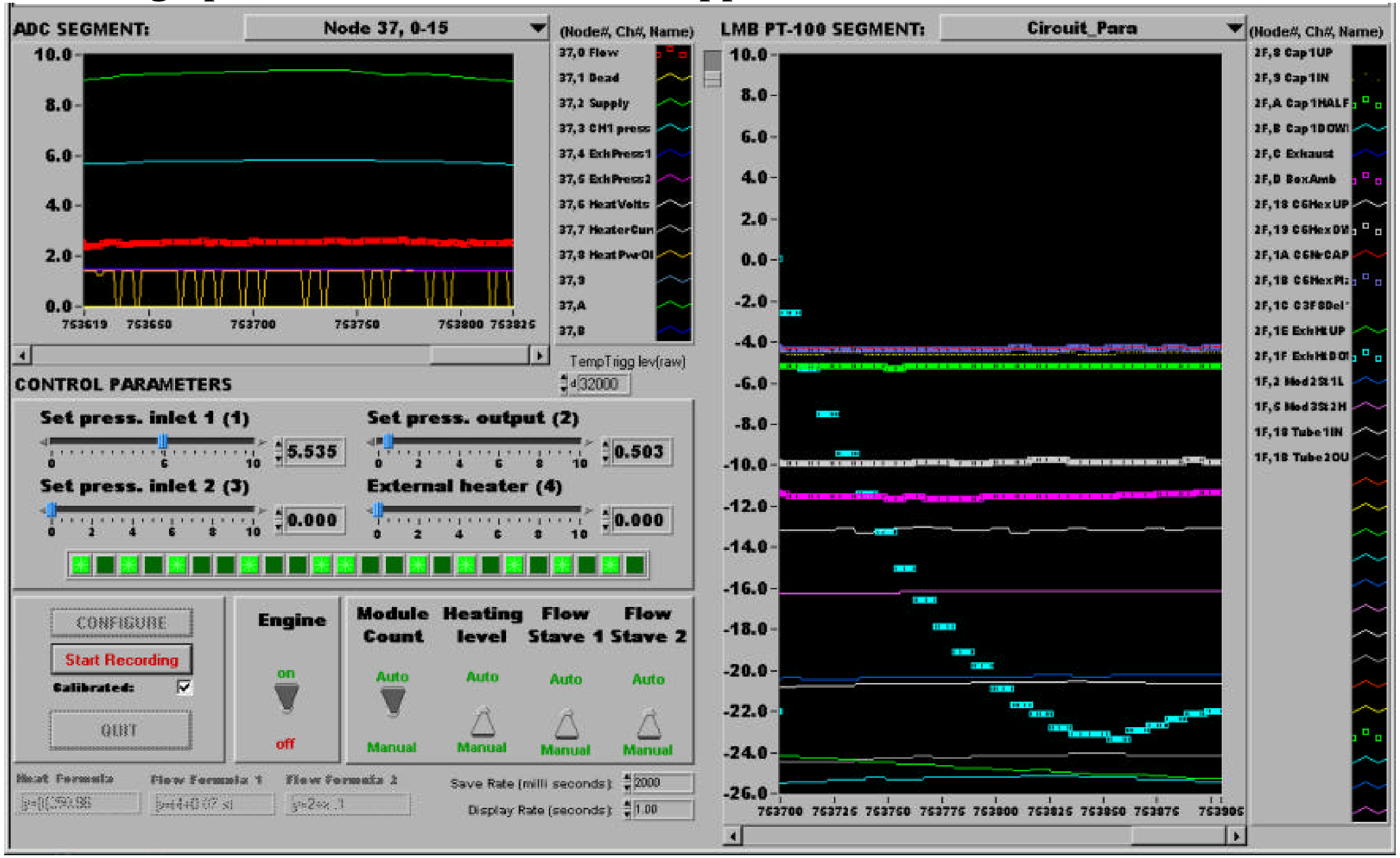
Standby ΔP = 0.08 bar or less Steady runs ΔP = (0.3÷0.35) bar

- With pre-cooling; fixed flow of refrigerant (adequate to the 100% power dissipation in the staves, approximately 2.2 g/s)

1. 100% power dissipation in the staves; External heater & 100 W and PID for the heater surface temperature @ +20°C; temperature of return pipe ≅ 10°C;



2. 50% power dissipation in the staves; External heater has to be set permanently [no PID] to 150 W to get return pipe temperature to ≅ 10°C; temperature of the heater increasing up to 40°C when test was stopped



3. Standby /one module "ON"; External heater power has been gradually increased up to 300 W; temperature of return pipe ≅ - 25 °C; run was stopped when surface temperature of the heater, raising continuously, reached 80°C.

Stave temperatures within the SPECS [all modules below -7°C]

Other Typical Circuit Parameters

Condenser: P_{cond} = 8.5 bar_g t_{cond} ≅29°C

Compressor $P_{bufferSET}$ =1060 torr P_{buffer} = 1280 torr

$P_{exhaust}$ = P_{evap} = 0.45 bar_g

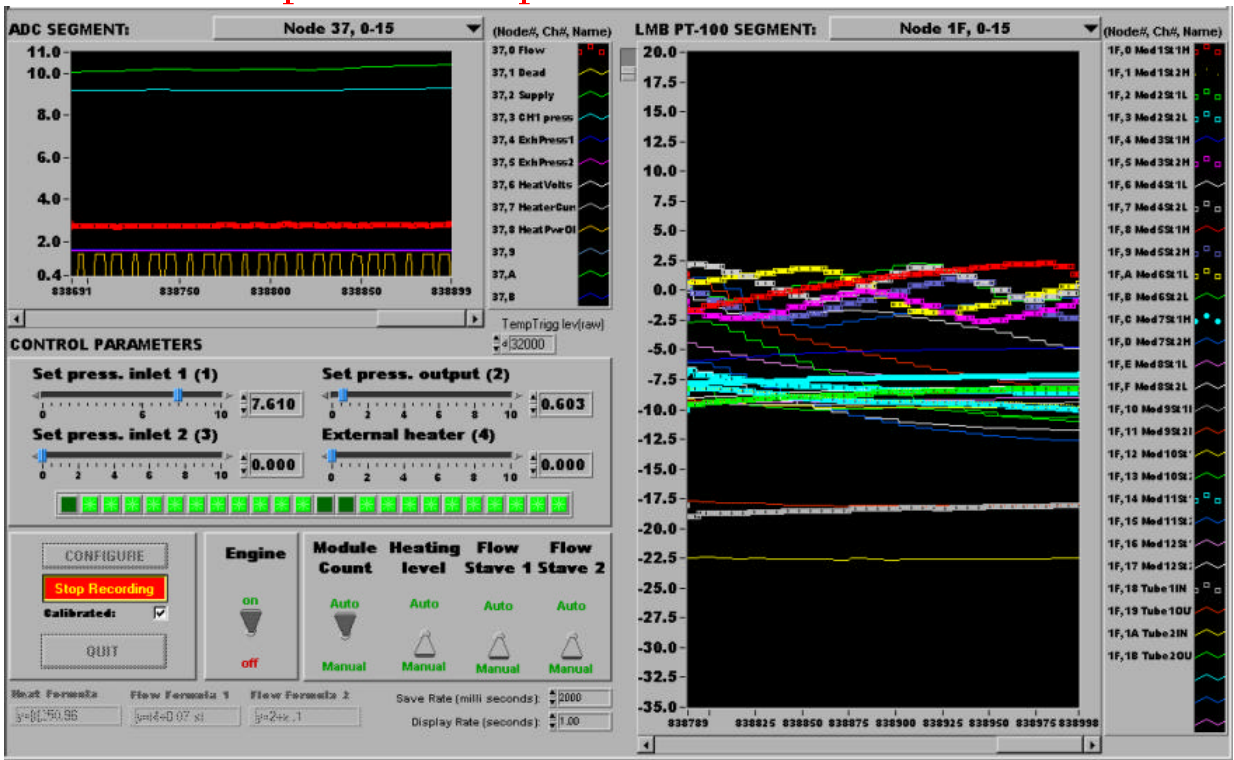
Pre-cooling t_{SET} ≅ - 29°C t_{out} ≅ - 14.3 °C Flow = 53 l/h

Pressure drops over staves:

Steady runs 100% ΔP = 0.4 bar Steady runs 50% ΔP = 0.29 bar

- No pre-cooling [refrigerant @ 22°C];

1. 100% power dissipation in the staves; External heater & 100 W and PID for the heater surface temperature @ +20°C; flow of refrigerant close to the limit of the compressor capacity @ 2.6 g/s at needed pressure and temperature conditions; significant increase in pressure drop across the staves ≈ 0.46 bar



Problematic to cool down all modules [LMB acts on more then half of modules]

General observation:

- No change of pressure in the staves [i.e. evaporative pressure] has been observed even if cool "liquid/mist" [i.e. wet vapor with quality factor less then 1] fills return pipe. It indicates a proper and reliable behavior of the dome-loaded back pressure regulator

- Unless a surface temperature of the heater is controlled its surface temperature will continuously rise [max. value achieved was 90 °C, then we stopped heating]

Status of new Pixel Engineering Structures & Test Timescale

- **Evaporator Control System Tests to Continue**

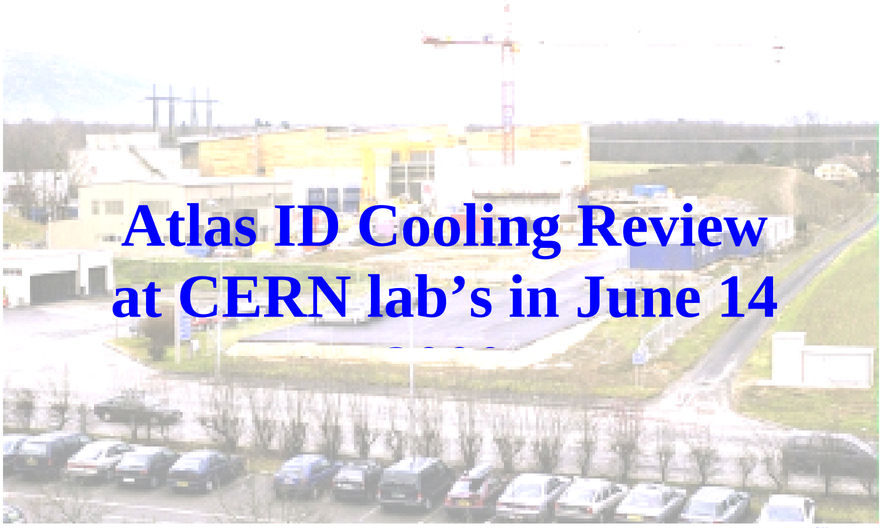
➔ May-June

- **CPPM back up stave available mid May (?) for tests.**
- **Pixel C-C Baseline Staves with Final Hydraulic Diameter**
- **NEW SCT disk sector cannot be tested before June**
- **4 Pixel disk sectors prototype announced for middle of June – via videoconference with LBL on May 4, 2000**

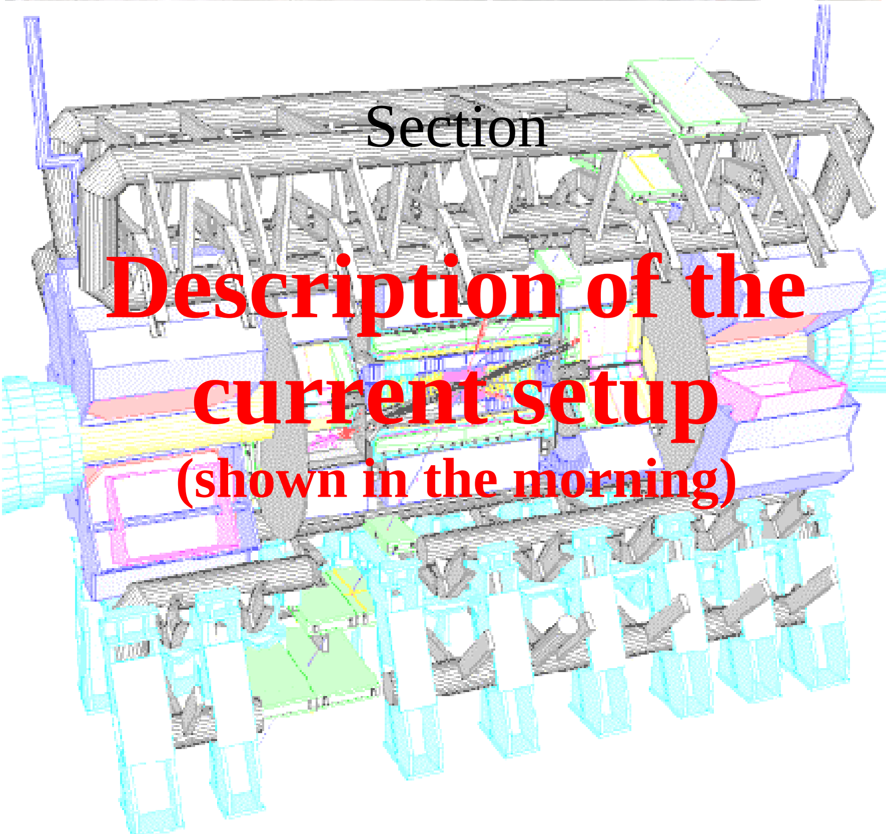
Pixel Local Support FDR 6/2000…

Not enough circulator time and manpower available for tests on final diameter pixel staves at CERN (?)

ATLAS
EXPERIMENT



Atlas ID Cooling Review at CERN lab's in June 14



Section

Description of the current setup

(shown in the morning)

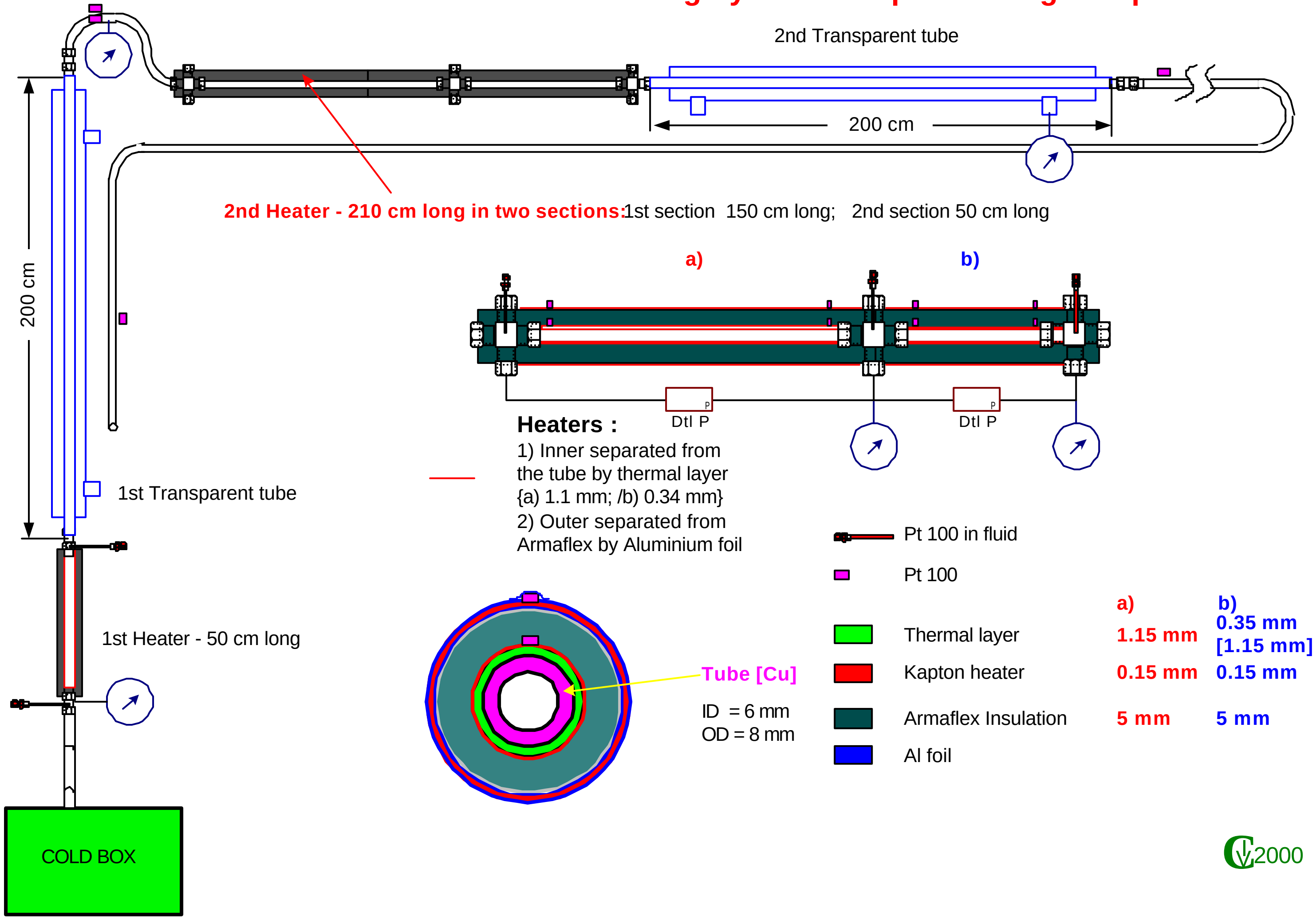
June 2000

Description of the Current Setup

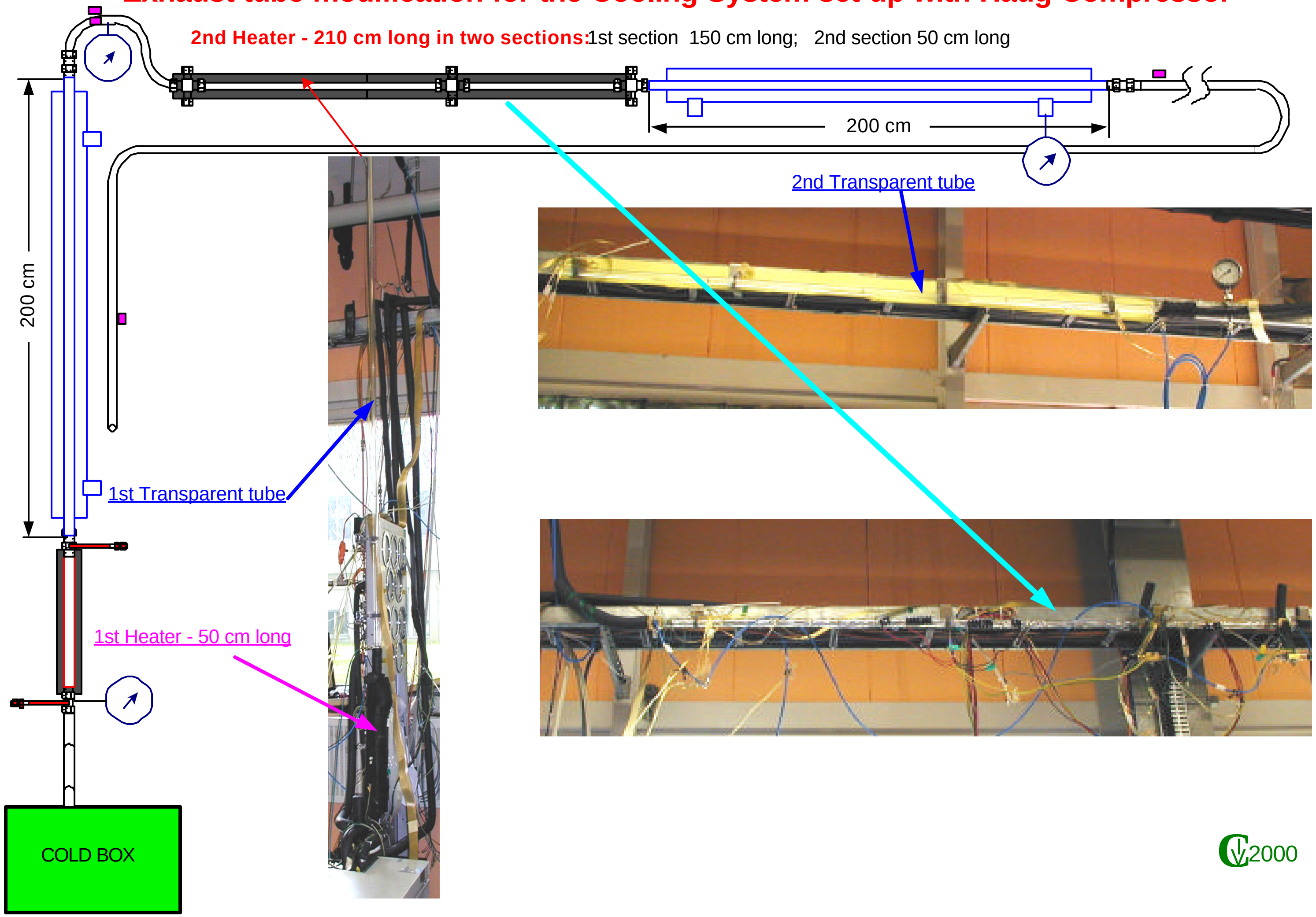
As in May and with some additional implementations:

- Two transparent tubes in exhaust line
- 2 m long heater divided in two sections
- Additional temperature and pressure sensors
- 3 PID controllers [for heaters control and flow control]

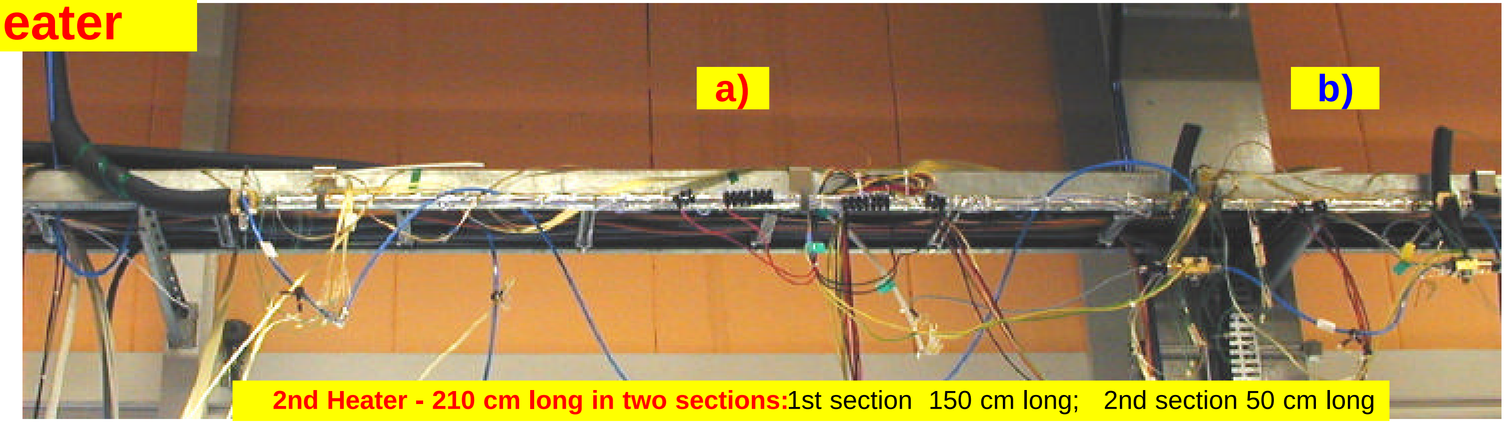
Exhaust tube modification for the Cooling System set-up with Haug Compressor



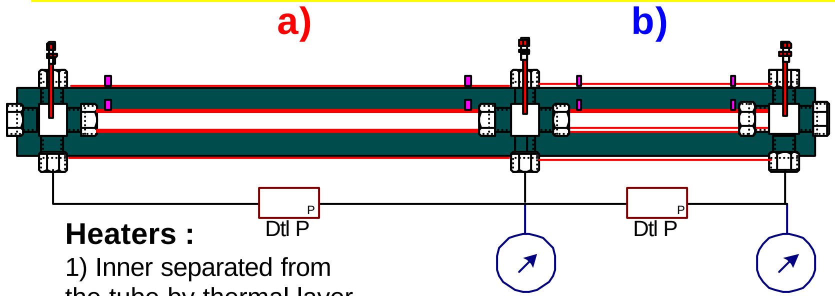
Exhaust tube modification for the Cooling System set-up with Haug Compressor



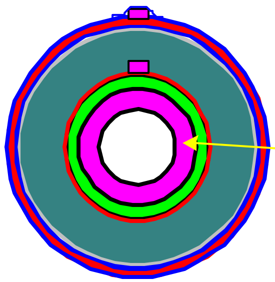
Heater



2nd Heater - 210 cm long in two sections:1st section 150 cm long; 2nd section 50 cm long



Heaters :
1) Inner separated from the tube by thermal layer {a) 1.1 mm; /b) 0.34 mm}
2) Outer separated from Armaflex by Aluminium foil



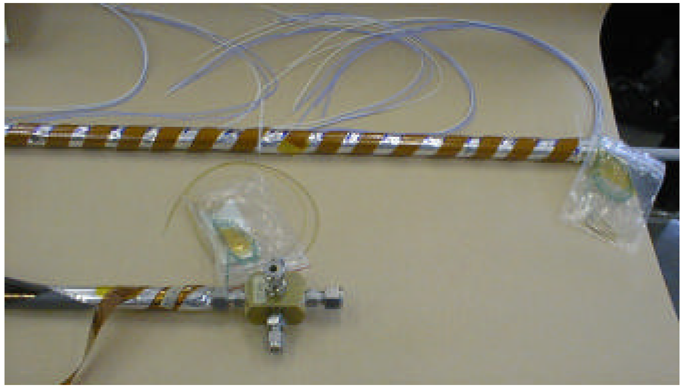
Tube [Cu]

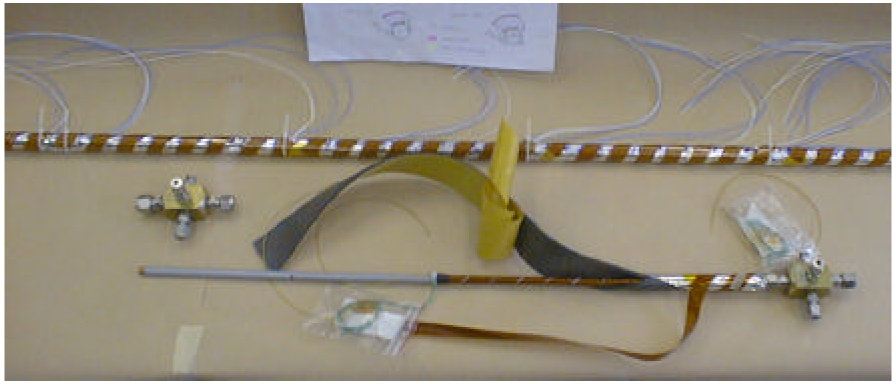
ID = 6 mm
OD = 8 mm

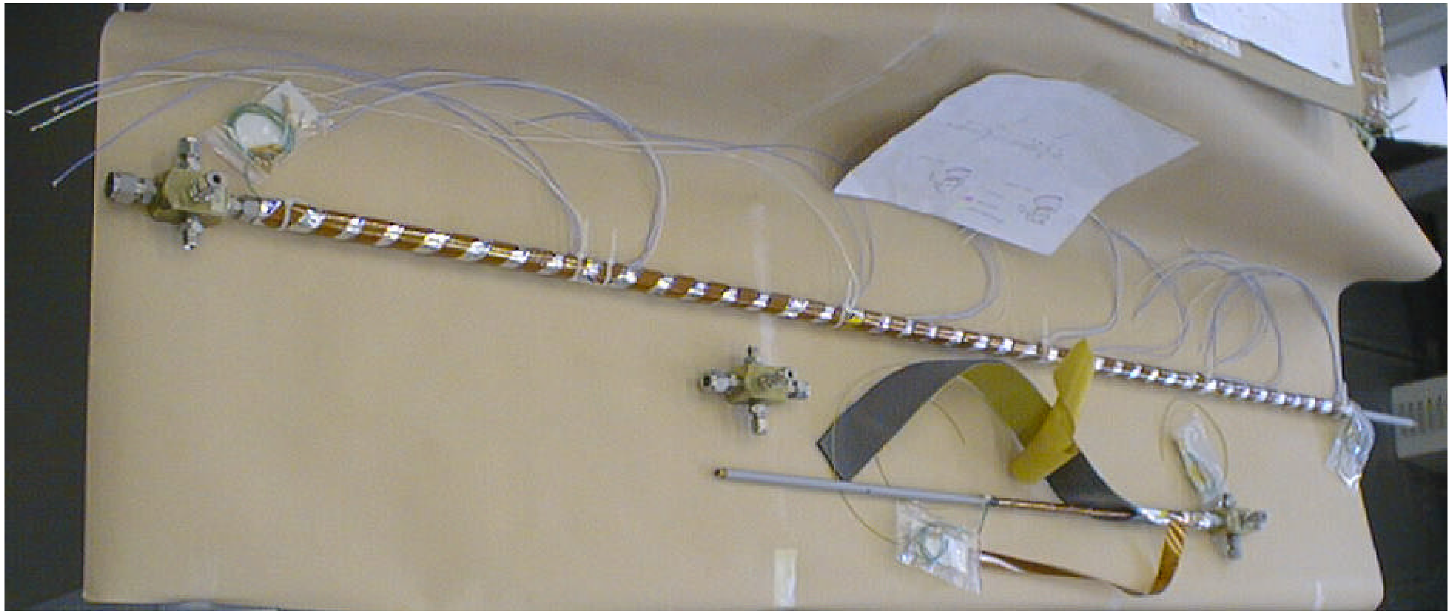
	a)	b)
Pt 100 in fluid		
Pt 100		
Thermal layer	1.15 mm	0.35 mm / [1.15 mm]
Kapton heater	0.15 mm	0.15 mm
Armaflex Insulation	5 mm	5 mm
Al foil		

CV2000

Heater preparation *(Designed by M. Olcese and manufactured by J.Thadome)*







Recent Engineering Structure Tests & Scheduled Tests

(i) Pixel Back-up Stave (Constrained Al tube): (Vacek/Vigeolas) ➔ ➔

Preliminary : promising results with 200mm wall D section tube in C-F Omega Channel, sliding grease to C-C pixel module carrier. Applicable to SCT barrel ?

(ii) 4/5 new pixel disk sectors in series/parallel combinations (Flattened Al tubes sandwiched beteween C-C carriers : Mid June 2000)
(Anderssen, Glichriese et al)

(iii) New Forward SCT disk sectors (Greenfield / Temple)

3 Cooling Cricuits (3 in ➔ 1 exhaust) : 33 modules, parellel wiggly pipes

Module Blocks received by RAL and Cu plated,
Lancaster manufacturng bending jigs for tubing.
Tube attachment zones need Cu plating
Assembly : 100+ PT100s, 33 heaters Delivery CERN mid July earliest ?

(iv) C-C pixel barrel 'baseline' staves with final D_H (Date N.N/but after FDR)
(Olcese et al)

(v) Continuation Studies on Geneva FLP (Bouvier/Hallewell/Vacek)➔ ➔

Continuation Studies on Geneva FLP

Question that has surfaced recently.

(1) Why is temperature gradient between tube and modules higher than in tests with old DH tube ?

Tubes start from same round precursors :
to be deeper, the flat face shrinks in width by about 10%

Philippe Bouvier has observed 80mm (convex) out-of-flat on a new tube

➔We dont know the flatness of tubes in FLP,
or how their flatness has been affected by vacuum, repressurisation etc.

➔ ➔ Need independent pressure study of tubes in a precision measuring machine. Cold Cycling ?

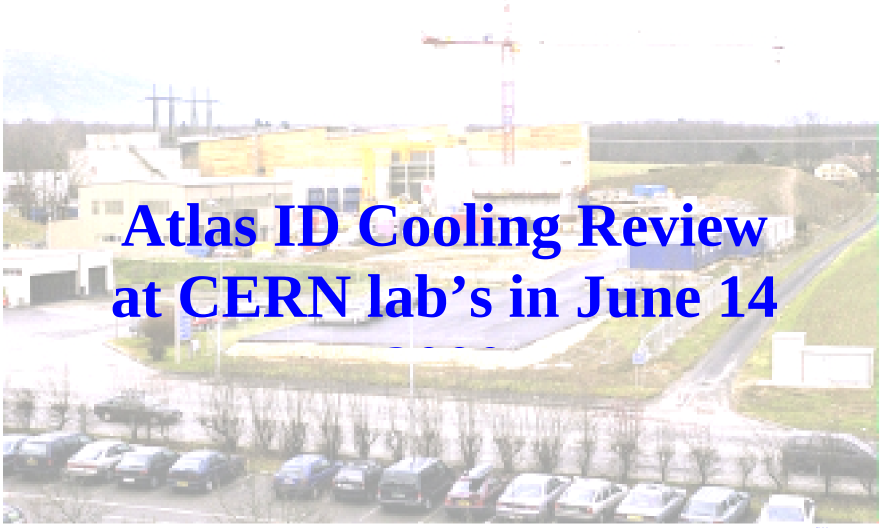
WILL CONSTRAINT BE NECESSARY ? CAN IT BE ACCOMMODATED IF NEEDED ?

Barrel SCT Cooling Structure Test Results : Recap

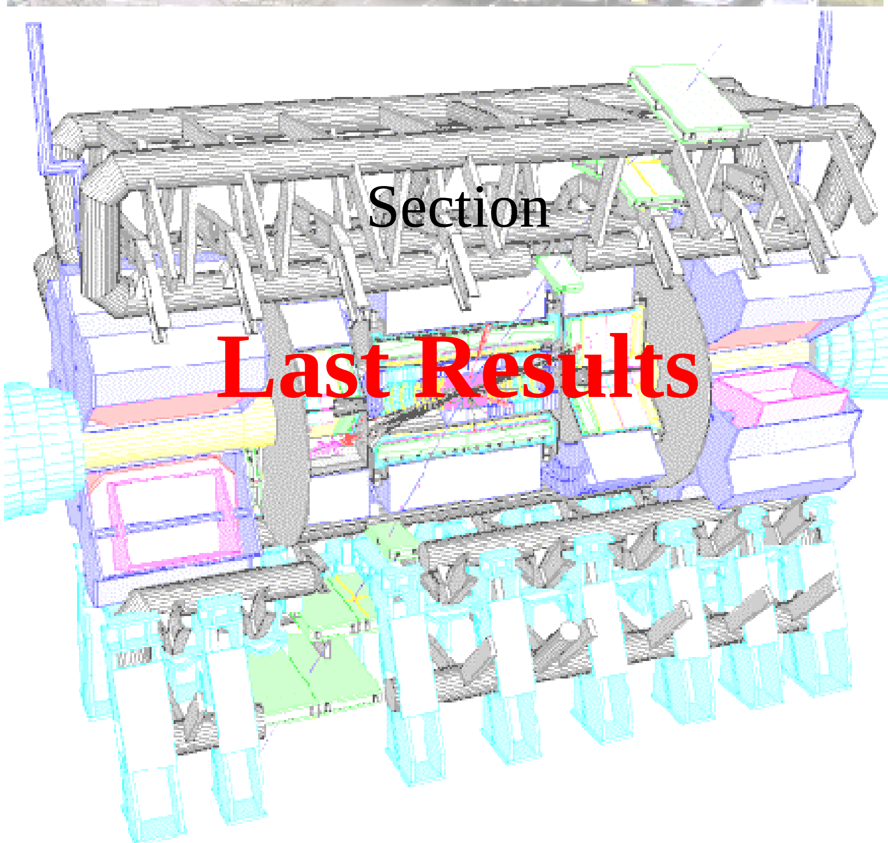
- Pressure drop much less than in earlier cooling tube.
- New hydraulic diameter acceptable for final system.
- (4+1)W/module: Average $DT_{(Si\text{-}Tube)} < 8C$, $DP < 200$ mbar
  Average $DT_{(Si\text{-}Tube)}$ in liquid tests with one smaller tube ~ 6 C
- (7.5+2)W/module: Average $DT_{(Si\text{-}Tube)} \sim 12C$, $DP < 500$ mbar
  Earlier tests with plates glued on old (1.5 x 9.2mm) tube…
  (10W/module: Average $DT_{(Si\text{-}Tube)} \sim 12C$)

ATLAS

EXPERIMENT



Atlas ID Cooling Review at CERN lab's in June 14



Section

Last Results

June 2000

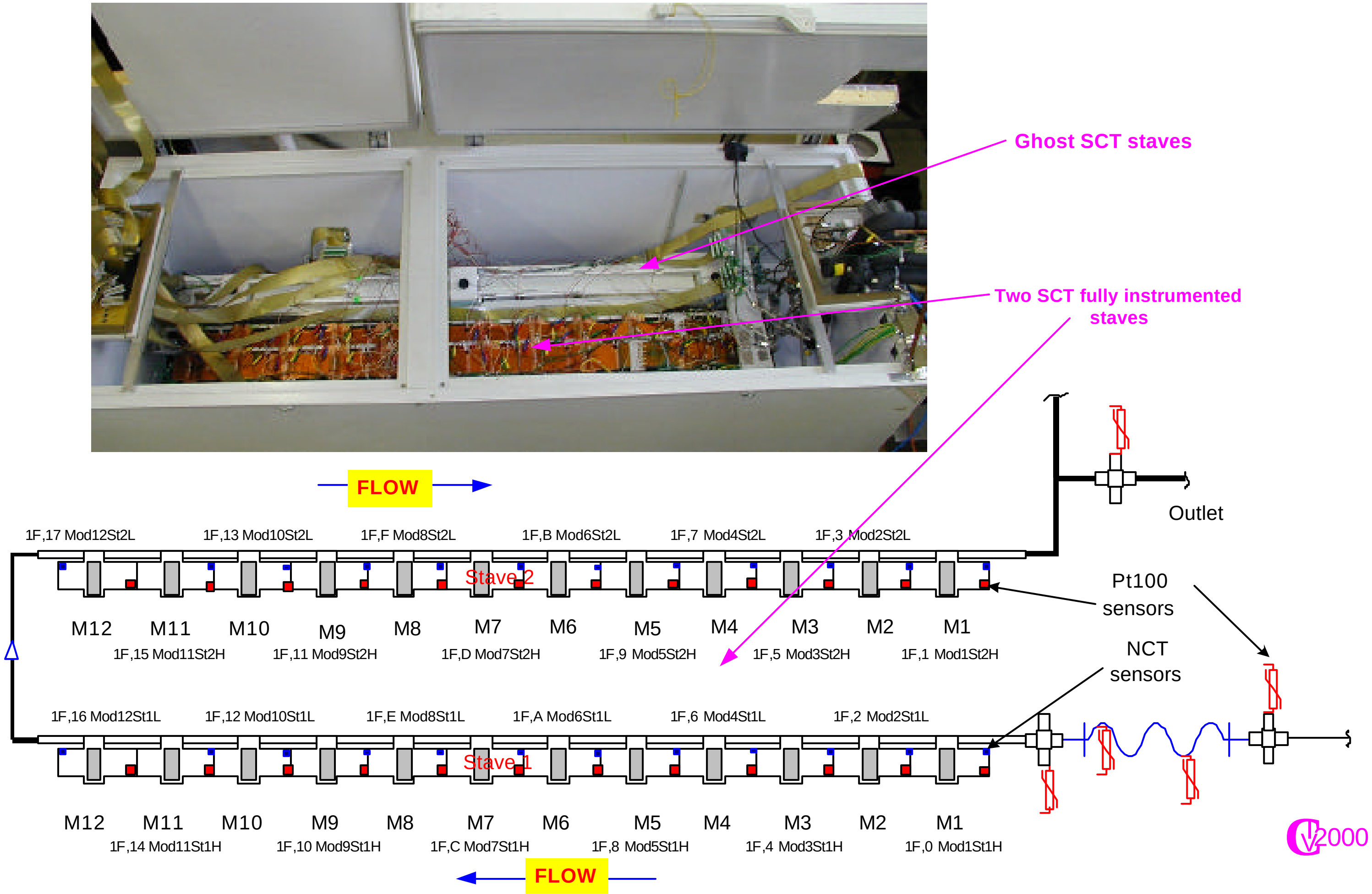
Measurements performed on structures during May 2000

(besides the cooling system tests)

- **SCT barrel prototype [Geneva University]**
  - **Thermal performance measurements**
  - **Control features [ILB tests – Wuppertal University]**
  - **Staves were also used as a load during cooling system parameters measurements**
- **Pixel stave backup measurements [CPP Marseille]**

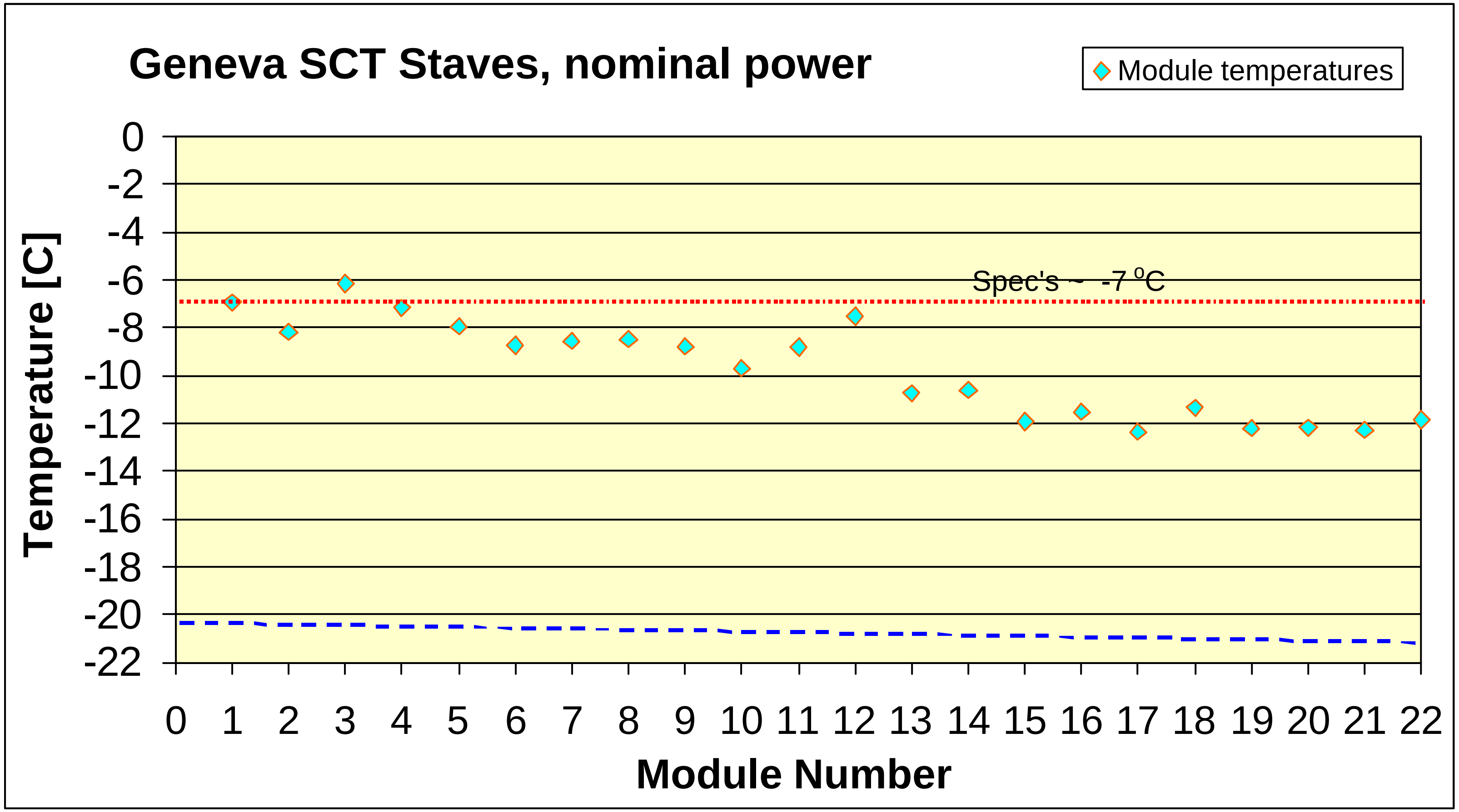
Geneva University SCT stave prototype measurements

Map of NTC and Pt100 Sensors



Typical Temperature profile along the SCT stave at nominal power dissipation

Nominal power [7.5W (Hyb.)+2W (Si)] per module;



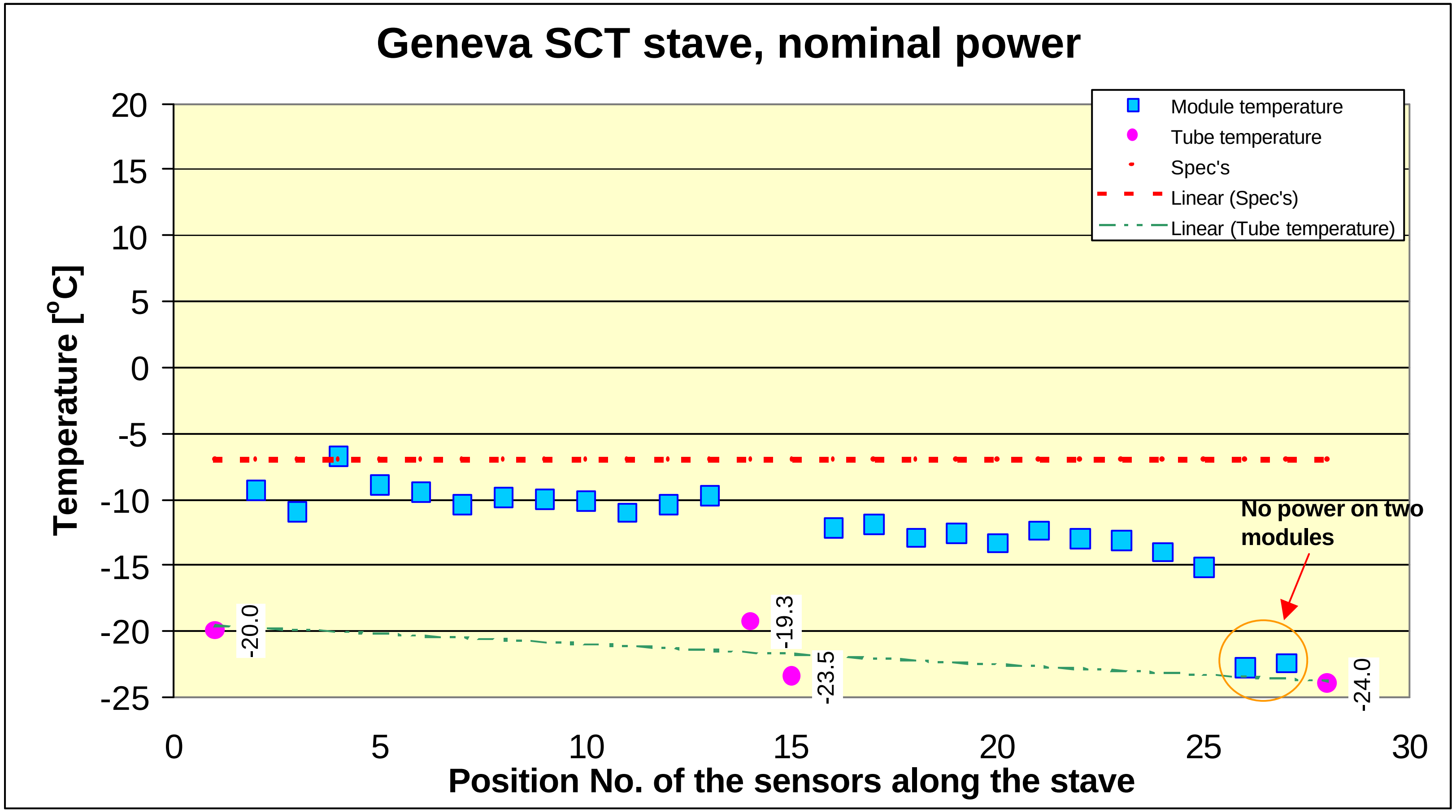
Run conditions: ***p_{evap}= 1.54 bar_{abs}; Δp_{stave}=0.4 bar; Refrigerant flow = 2.7 g/s;***

$p_{condenser}$ = 8 bar_g; $t_{condenser}$ = 30 °C; p_{buffer} = 1260 tor

Sub-cooling: *t_{set}= -10°C ; t_{fluid}= -11°C ; flow = 60 dm^3/hour*

Temperature profile along the SCT stave at nominal power dissipation

Nominal power [7.5W (Hyb.)+2W (Si)] per module; *LONG AND STABLE RUN*

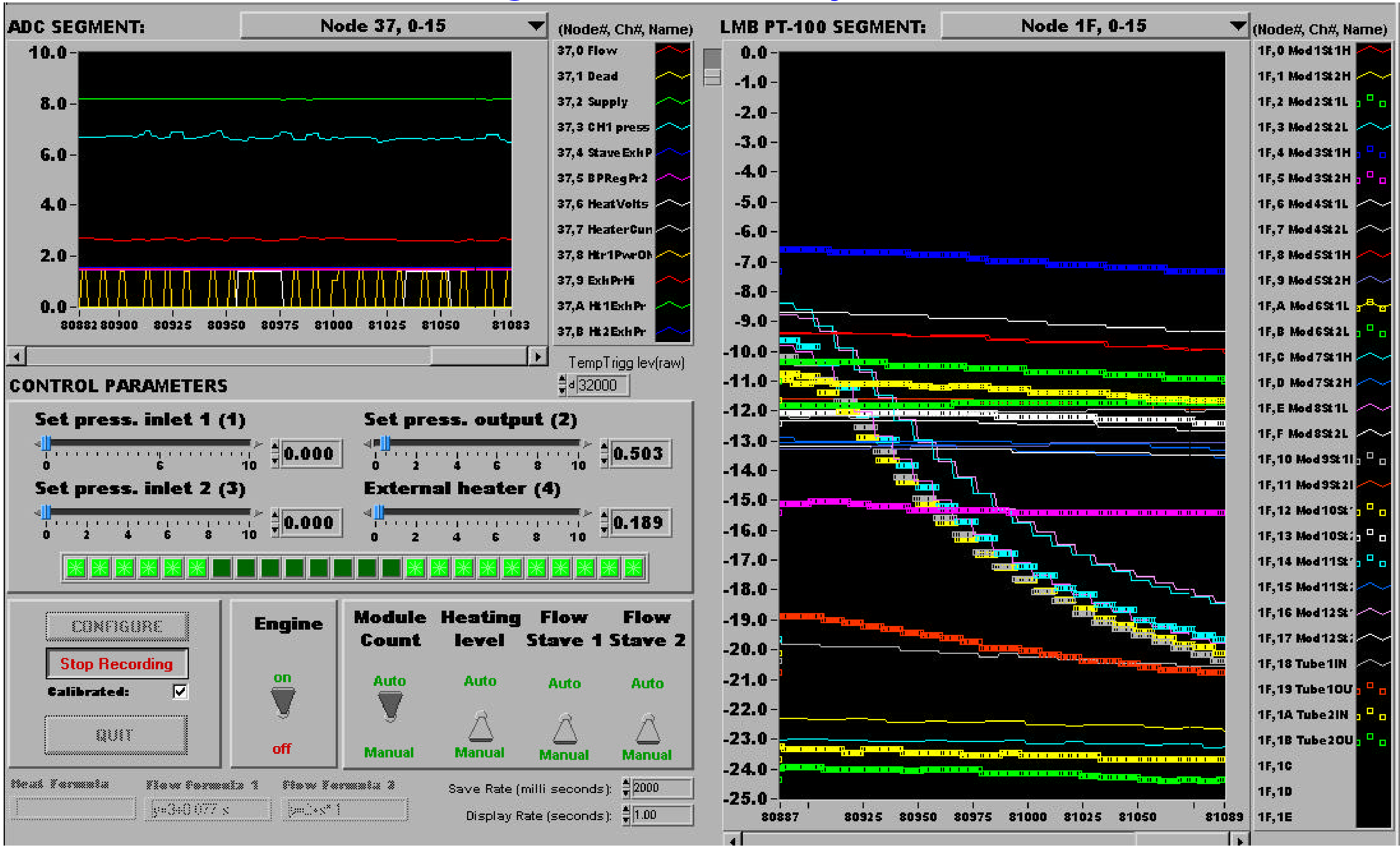


Run conditions: ***p_{evap}= 1.55 bar_{abs} ; Dp$_{stave}$=0.38 bar; Refrigerant flow = 2.66 g/s;***

$p_{condenser}$ = 8.3 bar_g; $t_{condenser}$ = 31 °C; p_{buffer} = 1220 tor

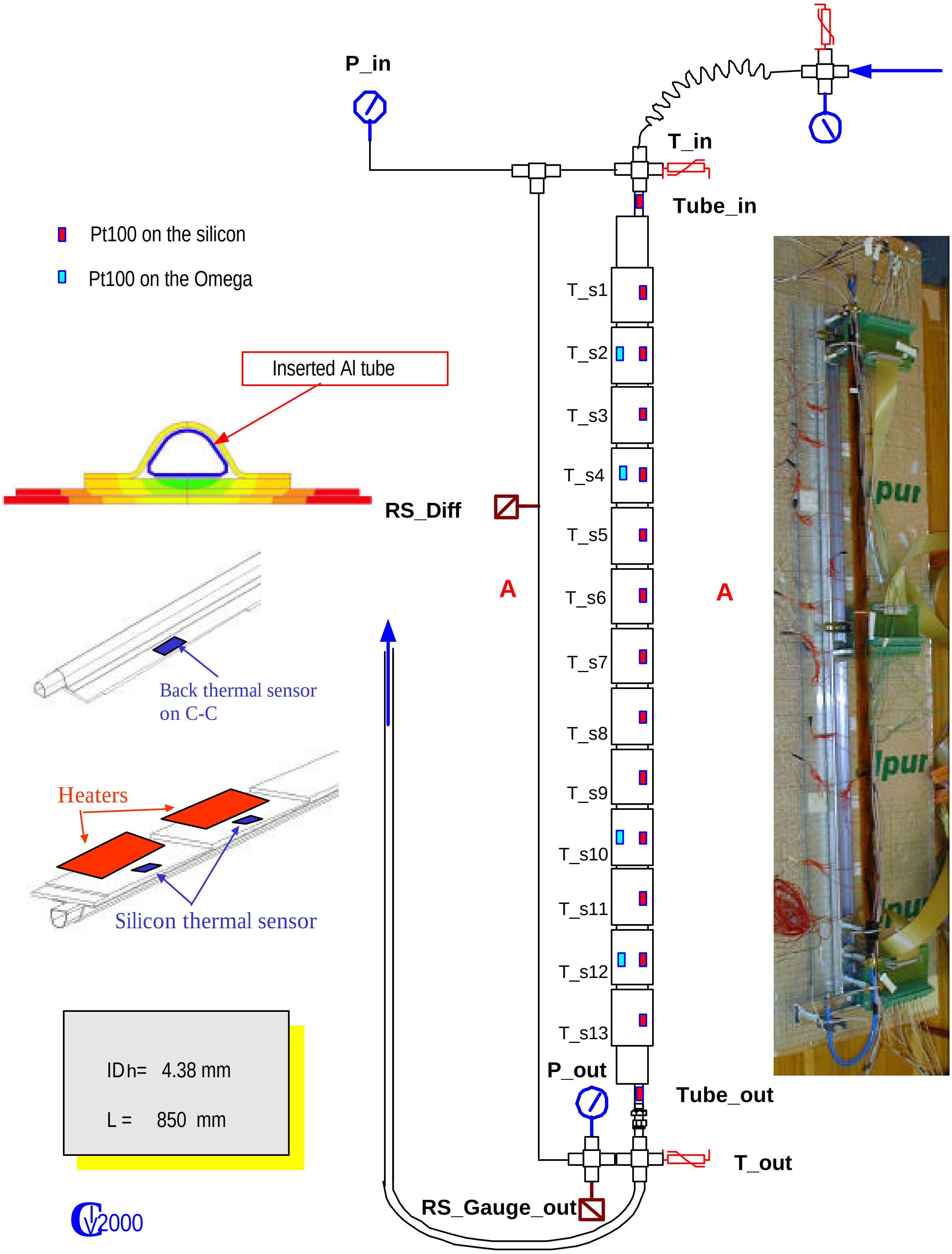
Sub-cooling: *t_{set}= -10°C ; t_{fluid}= -9.8°C ; flow = 58 dm^3/hour*

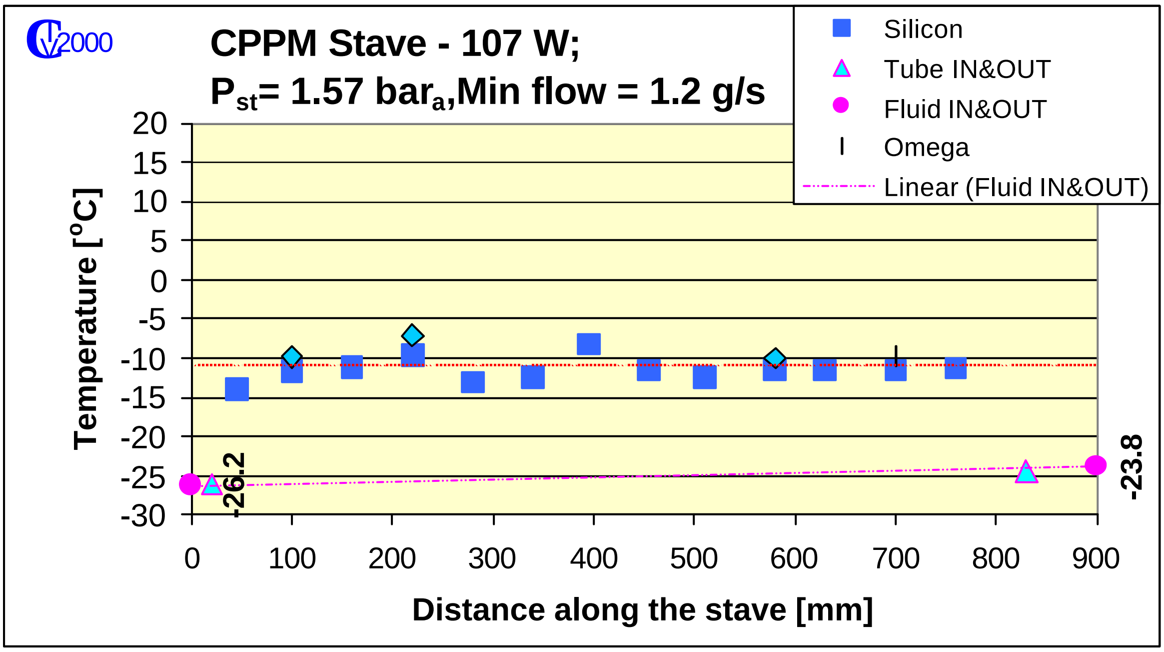
Monitoring and Control System Screen



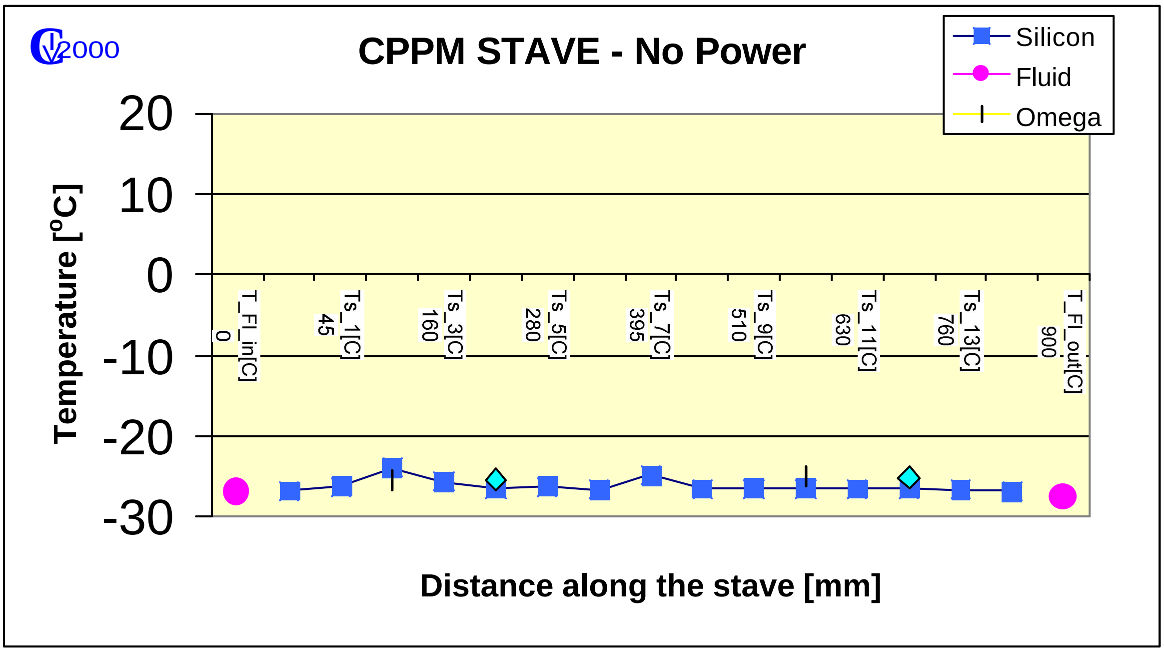
CPPM Stave - backup prototype

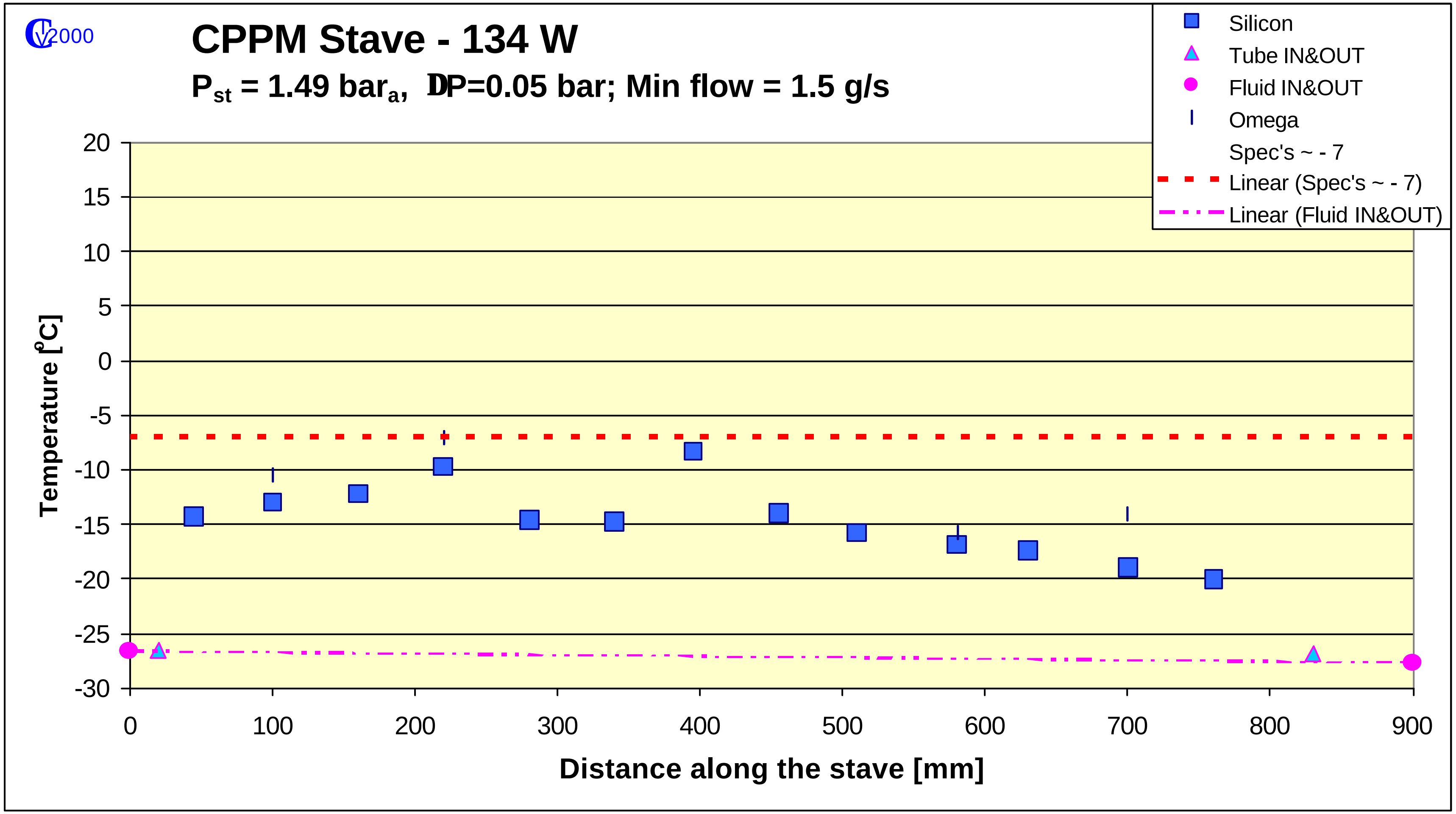
Arrangement for Evaporative Cooling - C_3F_8





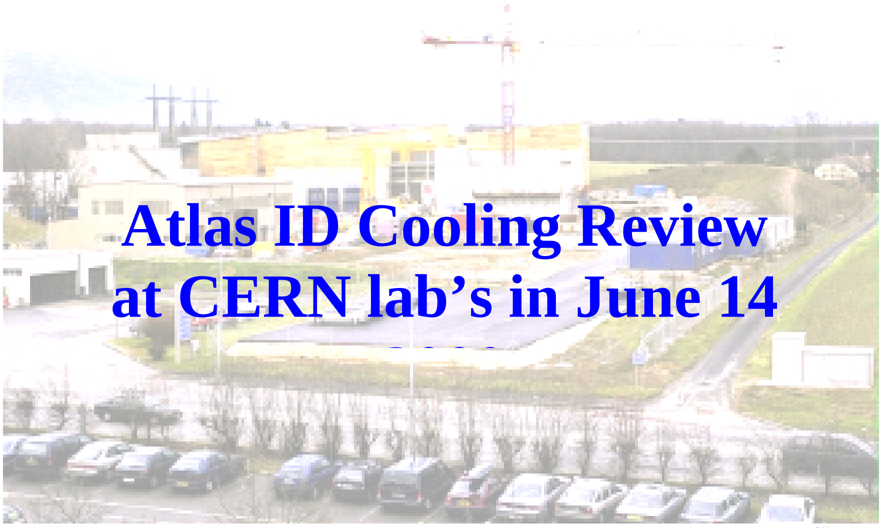
Pressure drop over the stave $\Delta P = 0.011$ bar$_g$; T_box = -11.6 °C;
$P_{bef\ CAP}$ = 3.4 bar$_g$; $T_{after\text{-}hex}$ = -10 °C; $T_{condenser}$ = 25; $P_{condenser}$=6.3 bar$_g$



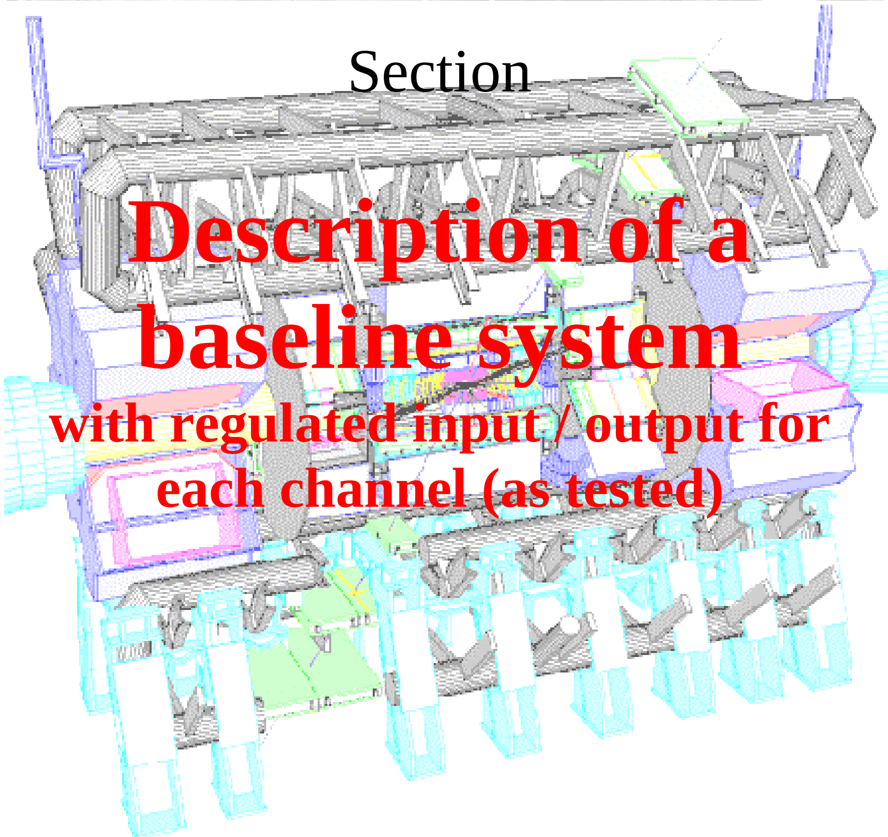


Pressure drop over the stave $\Delta P = 0.05$ bar_g; T_box = -10.6 °C;
$P_{bef\ CAP} = 3.8$ bar_g; $T_{after\text{-}hex} = -10$ °C; $T_{condenser} = 26$; $P_{condenser}$

ATLAS EXPERIMENT



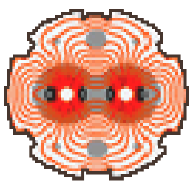
Atlas ID Cooling Review at CERN lab's in June 14



Section

Description of a baseline system

with regulated input / output for each channel (as tested)



June 2000

Results from Early June 2000 Test Program

Circulator Modifications:

(1) Two coaxial transparent exhaust sections

(1 Horizontal, 1 Vertical) added

RESULTS:

Even with no powered modules, see little Backpressure stave loading

Fluid in reflux boiling on tube walls (SEE DEMONSTRATION)

ΔP (top-bottom: $[\Delta H = 2m]$ ~ 100 mbar ($2gs^{-1}$ flow)

Made up of flow pressure drop & vapor (ρ.g.h)

ΔP hydrostatic C_3F_8 liquid > 300 mbar

(2) New coaxial two stage exhausts heater added

$L_1 = 1.5$ m, $L_2 = 0.5$ m

Inner & Outer ("active") Heating Elements

Tested in following configurations:

(2.1) "Stand-by" Condition: H_1 (Inner) 169 W, H_2 (Inner) 56 W
(no modules powered, no-pre-cooling T_{inj}=20C, flow = $2.5gs^{-1}$)

(2.2) "Full Power" (staves) Condition
H_1 (Inner) 86 W, H_2 (Inner) 29 W
(~105W module power, no-pre-cooling T_{inj}=20C, flow = $2.5gs^{-1}$)

(2.3) "Stand-by limited" Condition
H_1 (Inner) 169 W, H_2 (Inner) 56 W
(no modules powered, no-pre-cooling T_{inj}=20C, flow = $2.5gs^{-1}$,
Heater outer surface temperatures limited to 35C)

(2.4) "Active Regulation" Condition
PID control of H_1 (Outer: 19W), H_2 (Outer: 7w)
(~105W module power, no-pre-cooling T_{inj}=20C, flow = $2.5gs^{-1}$,
Heater outer surface temperatures limited to 25C)

COAXIAL EXHAUST HEATER RESULTS

Sensor	Length (cm)	"Full Power" Temps		"Stand-by" Temps		Standby	Full Power
		Predicted	Measured	Predicted	Measured	(limited) Meas	Active Reg
Fluid (0)	-100	-	-29	-	-29	-29	-16
Fluid (1)	0	-25	-24	-25	-24	-24	-8
Inner Heater (1, IN)	10	5	-8	33	-1	-1	3
Active heater (1, IN)	10	15	4	25	8	8	15
Inner Heater (1, OUT)	140	35	8	57	34	47	8
Active heater (1,OUT)	140	26	15	34	29	42	22
Fluid (2)	150	2	-6	-10	10	27	4
Inner Heater (2, IN)	160	21	14	25	44	36	11
Active Heater (2, IN)	160	21	18	23	36	34	27
Inner Heater (2, OUT)	190	29	21	44	57	42	11
Active Heater (2, OUT)	190	24	23	29	46	38	31
Fluid (3)	200	15	-2	15	19	32	5
Fluid (4)	420	-	7	-	22	32	11
Fluid (5)	2500	-	20	-	21	25	23

CONCLUSIONS (ALL FIXED FLOW, NO-PRECOOL)

(1) Some disagreement between prediction & measurement: (at “full power”, prediction optimistic about heat coup-ling to boil fluid). At “standby”, heater power too high

(2) On “standby”, heater outer surface temperature exceeds safe value: surface temperature limit applied, which helps, but may not be possible in final system…

(3) With active only (surface temperature 25C), exhaust tube temperature downstream of heaters not above cavern dew point.

➔WILL NEED AT LEAST PASSIVE INSULATION BEYOND ID CAVITY (PROBABLY NEEDED ANYWAY TO ALLAY CONCERNS OF OTHER DETECTORS THAT ID HEATER FAILURE COULD CAUSE EXTERNAL CONDENSATION)

(3) Direct PID Control of Flow Rate Using DLRs and Temperature Sensor on Exhaust Tube

Flow Variation Via Module "ON" bit counting Demonstrated Successfully in May '00 Tests

Flow Formula:

$$P_{CAPUP} = P_{SL(Tinj)} + DP * \#\ (\text{powered modules})$$

Where

$$DP = (P_{NORUNOUT} - P_{SL(Tinj)}) / \#\ (\text{modules on circuit})$$

In principle, DCS can track changes in module power consumption via $S(I_i*V_i)$ from individual modules, but maybe would like flow to be independent of this information.

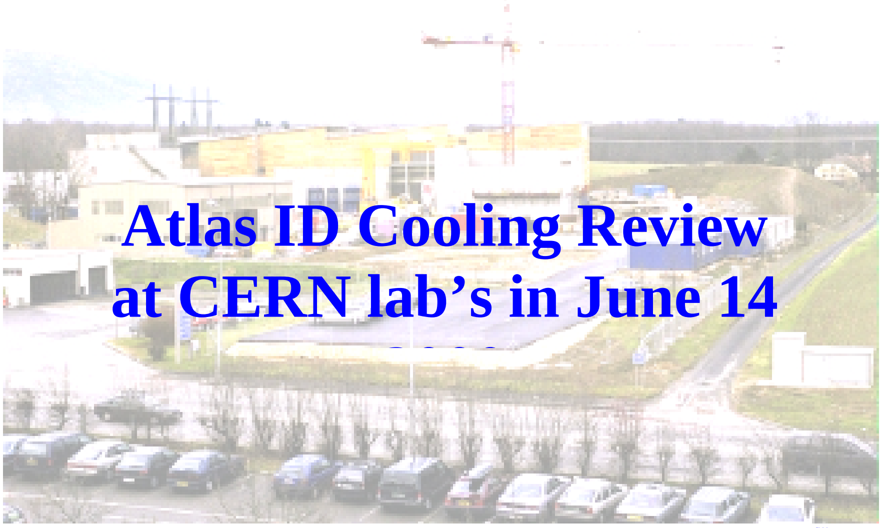
First Tests Indicate that

$$P_{CAPUP} = P_{SL(Tinj)} + DP\ (PID)_{Texh}$$

Should also work, provided PID controller not expected to vary P_{CAPUP} across $P_{SL(Tinj)}$

… STUDIES TO CONTINUE …

ATLAS EXPERIMENT



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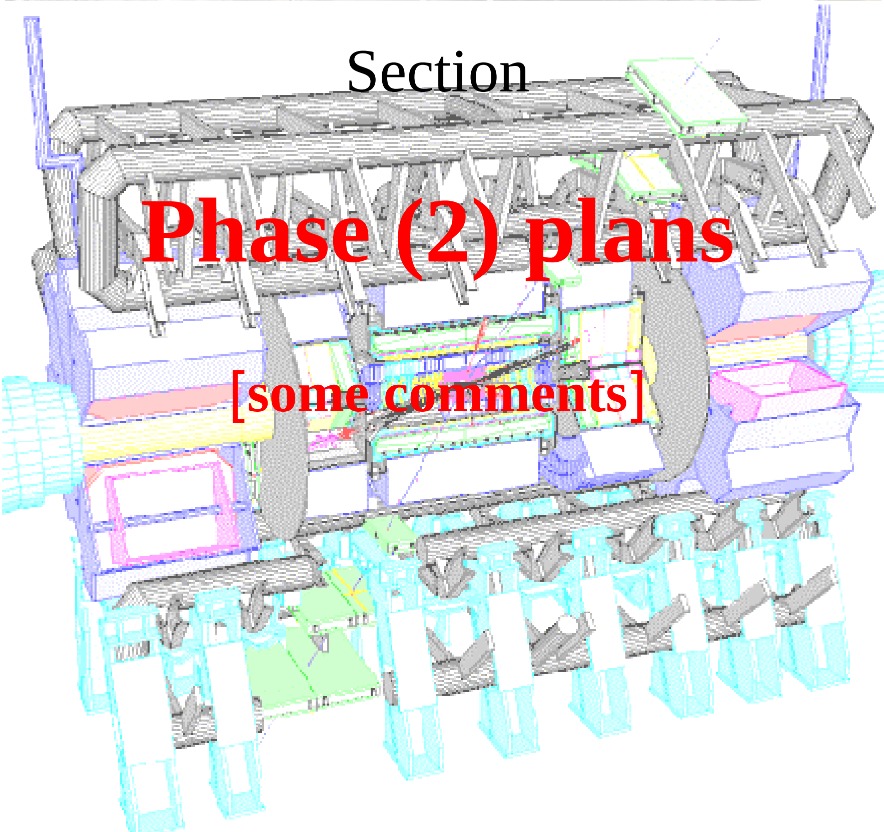


Section

Phase (2) plans

[some comments]

June 2000

Demonstrator Phase of C_3F_8 Evaporative Cooling Project Plans and Status.

The evaporative cooling FDR is planned for January 2001.

AIM of phase II :

Simulate representative part of SCT&Pixel silicon… Thermally

(include optimum scalable power compressor),

In cooling channel (manifolds) count,

With Final Controls &DAQ electronics,

With Realistic Thermal Screens,

tube lengths, Height Differences

and Heat Exchangers

One eighth (~6 kW dissipation)

6 SCT barrel manifolds and 16 pixel staves

in 17 circuits represent similar power (5 kW) &

cooling circuit count (14) to outermost SCT layer ➔

Thermal structures

6 Barrel SCT 4 folds in fabrication

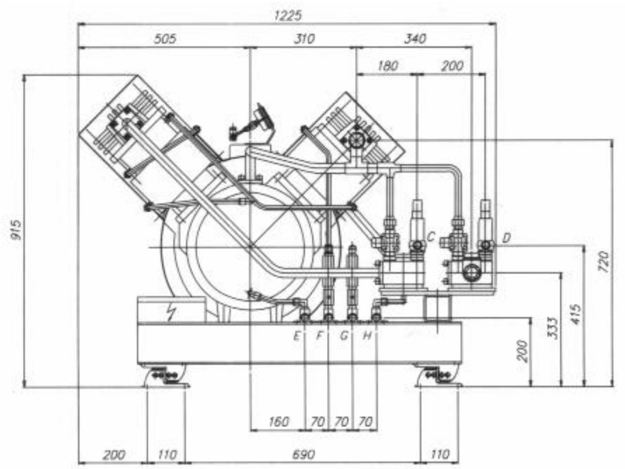
(modular block construction, with new D_H tube)

16 aluminum pixel staves already fabricated

Other components :

Compressor : Haug 3 cylinder hermetic, oilless: ➔ ➔

$80 m^3 hr^{-1}$ C_3F_8 pump speed at 1 => 10 bar (abs) ratio



(i) Compressor contract being prepared by CERN PURCHASING
(ii) Market survey for remaining series published by May(CERN money)
First Compressor Delivery Required Sept 2000

25 dome-loaded flow & 17 dome-loaded back-pressure (boiling temperature) regulators
(Part of final count already ordered, (Vespel, PEEK seats)

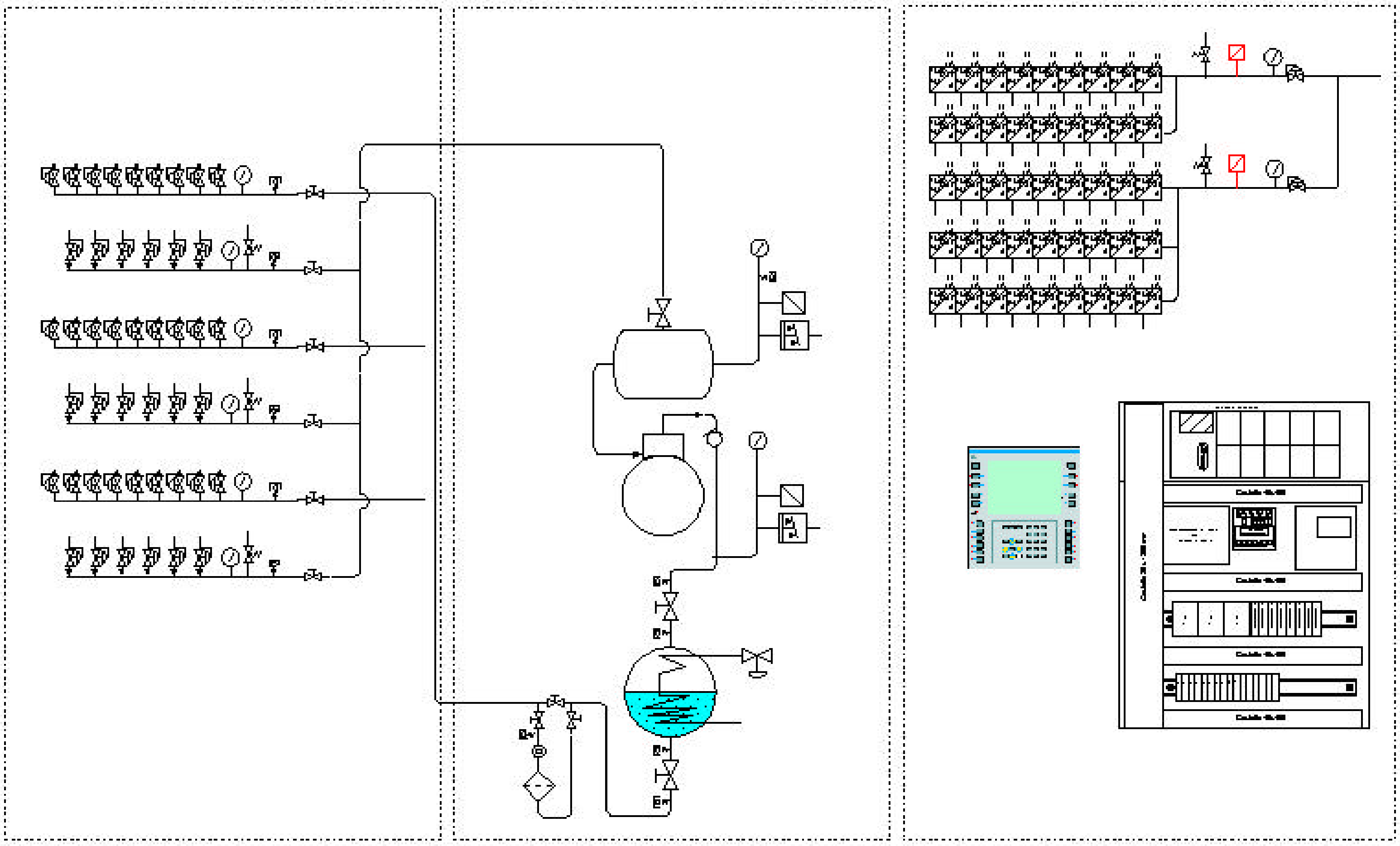
500 channel PT1000 sensor & analog input acquisition (delivered)
42 V→P air converters and DACs

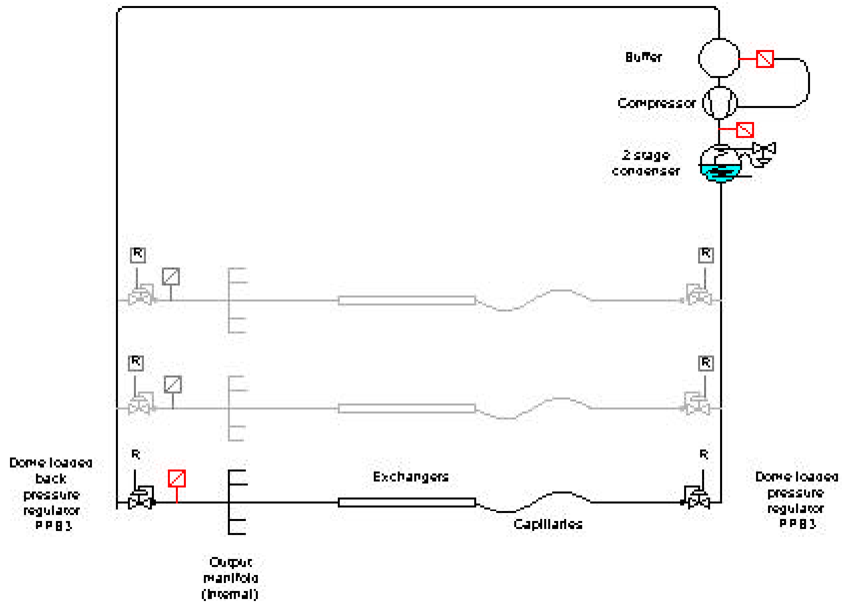
Modularity of Circuits and Analog flow elements in Phase (2) Demonstrator.

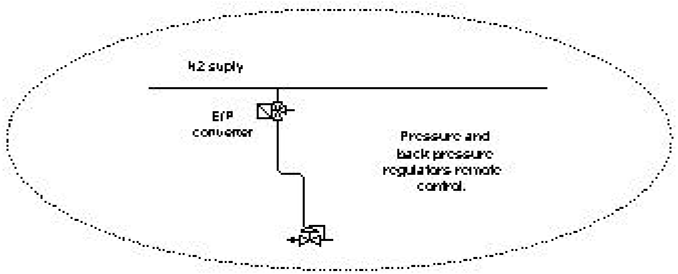
Cooling Circuits and Analog Flow Elements for SCT+Pixel Evaporative Cooling Demonstrator

Layer	No. elements	elements/ cool circuit	Staves / 8	Supplies (regs) / circuit	Exhausts (b.p. regs / circuit	Phase 2 No. circuits	Power /cct (W)	Phase 2 No. regs	Phase 2 No. b.p. regs
SCT 4	56	4	7	2	1	2	480	4	2
SCT 3	48	4	6	2	1	2	480	4	2
SCT 2	40	4	5	2	1	1	480	2	1
SCT 1	32	4	4	2	1	1	480	2	1
Pixel 2	56	2	7	1	1	4	208	4	4
Pixel 1	42	2	6	1	1	3	208	3	3
B layer	18	1	2	1	1	2	144	2	2
SCT disk/4	2	2	-	2	1	2	160	2	1
Pixel disk/6	2	2	-	2	1	2	96	2	1
TOTALS						19	5136	25	17
COMPARISON: TOTAL FOR SCT 4						14	6720	28	14

Positioning of Evaporative Cooling Recirculator Components in Final Installation




Buffer
Compressor
2 stage condenser
R
Dome loaded back pressure regulator PPB3
Exchangers
Capillaries
Dome loaded pressure regulator PPB3
Output manifold (internal)


N2 suply
E/P converter
Pressure and back pressure regulators remote control.

Demonstrator Timescale and Planning

ITEM	Time to Completion
Circulator Definition & Technical Specification	➔ end 1999 COMPLETE
Market Survey of Components & Purchases	Jan ➔ Sept 00

WAS ON HOLD PENDING TESTS OF HEAT EXCHANGE AND CONTROL SYSTEM :

SIGNIFICANT RISK OF MISSING MILESTONES IF COMPRESOR ORDER DELAYED (13 WEEK DELIVERY A.R.O.)

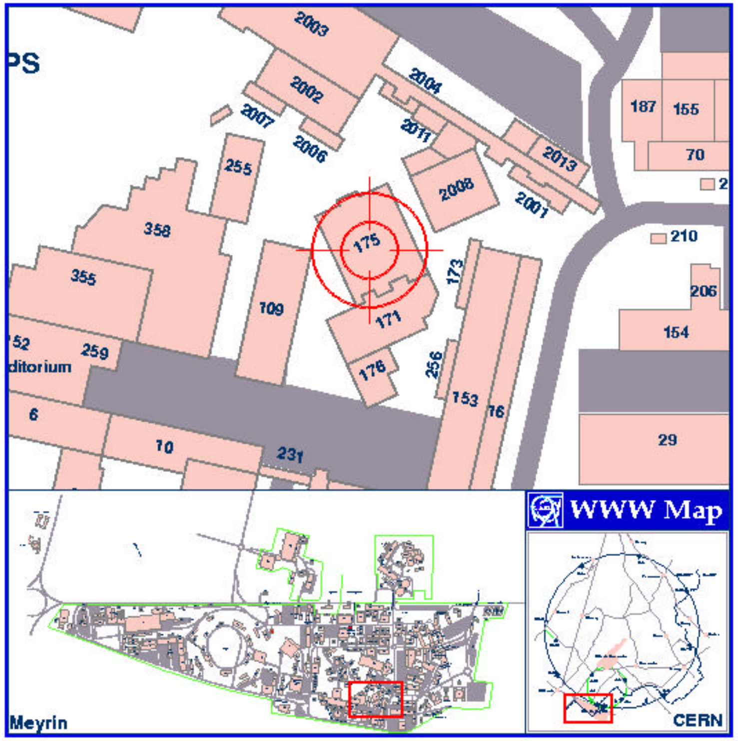
Circulator Fabrication & Installation in B175	July ➔ Sep 00
Detailed Tests	Oct 00 ➔ Feb 01

****This compressor will be first used at the first SCT assembly site, starting mid 2001.**

Cooling Demonstrator Test Location

Building 175 ;

(agreed 30/9/99, space clearing started 2/2000, chilled water plant sizing started)



Share supports with services mock-up

(incl. Simulated cryostat bore , Magnet crack)

& implement active coolant tubing thermal environment, incl. Cryostat wall heating

(Note : unlike a liquid system, an evaporative system needs evaporators (thermostructures) to set up correct tube thermal environments)

Build system with possibility for input pre-cooling.

Final definition of active heaters and return heaters needed, to live inside envelopes defined by the services group.

Estimated Cost of Components (phase II)

(i) Compressor with local condenser

Cost Estimate from Haug Received: 15 kW unit :	CHF	59000
Condenser (Paulus Model 17-75)	CHF	1000
Accessories: valves, filters etc	CHF	2000
Pressure, Temperature, Flow Sensors	CHF	3000
Input Buffer Tank and Valves	CHF	3000
SUBTOTAL	**CHF**	**68000**

(ii) Control Rack for Compressor

Figures from P. Bonneau, based on similar installations for CERES RICH and CMS Pixels.

Rack Body, Accessories, Cabling etc:	CHF	6500
PLC	CHF	12500
Frequency controller: 15 kW	CHF	5000
SUBTOTAL	**CHF**	**24000**

(iii) – (v) Racks or panels containing dome loaded pressure regulators for supply of liquid C3F8; dome loaded back pressure regulators for control of C3F8 boiling pressure in individual cooling circuits and "E=>P" analog compressed air drivers for dome loaded regulators

For phase 2 a requirement for 25 dome loaded pressure regulators and 17 dome loaded backpressure regulators is estimated. To drive these with analog compressed air, 42 Hoerbiger analog E=>P air actuators and 42 WAGO analog output channels are required.

25 dome loaded pressure regulators est. CHF 200*/piece:	CHF	7500
17 dome loaded backpressure regulators. CHF 900*/piece	CHF	15300
42 Hoerbiger E=>P controllers. CHF 650*/piece	CHF	28350
42 WAGO analog output channels CHF 100*/piece	CHF	4200
SUBTOTAL	**CHF**	**54650**

*all prices are based so far on very small orders of less that 5 pieces. Costs might be expected to come down a factor 2 for volume orders: particularly for very large orders for full SCT/pixel system, and also by possible component substitutions. The market survey will decide this.

(vi) Data Acquisition: LMB's (ADC version analog input modules), Digital I/O and analog output modules.

A budget of CHF 5000 has been approved, which is sufficient for and LMB system with 7 Can Nodes and up to 450 analog input channels or the LMB ADC variety (16 analog inputs per card: 4 cards per Can Node). This cannot also pay for the analog output channels for flow and boiling pressure control (see (vi) above).

SUBTOTAL CHF 5000

(vii) Thermal Test Structures representing one eighth of the barrel SCT and pixel detector and part of the forward SCT and pixel assemblies

To be built in collaborating SCT and pixel institutes

(viii) Intermediate tubing representing realistic length, height differences and thermal environment of the tube runs in ATLAS

Unknown at this stage

NOTE: PLATFORM CONSTRUCTION MAY BE REQUIRED IN BUILDING 175 UNLESS THESE TUBES FOLLOW
THE SERVICE ROUTING MOCKUP PLANNED TO BE INSTALLED IN THE SAME BUILDING.

(ix) – (x) Thermal Screen Prototypes enclosing the SCT + Pixel Thermal Volume

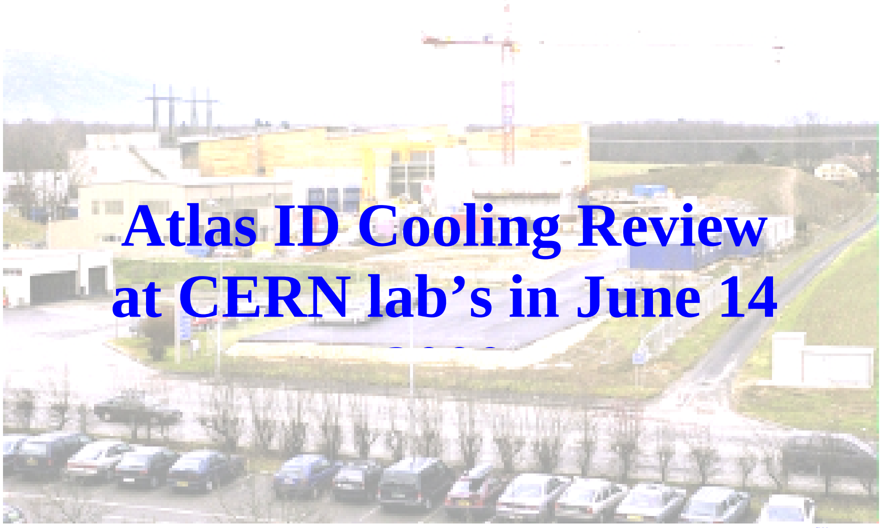
It is assumed that a liquid recirculator can be found or borrowed for these tests. One Possibility might be the Geneva liquid recirculator. A liquid circulator is therefore not costed to the project. The cost below reflects screens and their tubing services only.

RAL responsibility est. 10000 UK pounds CHF 22000?

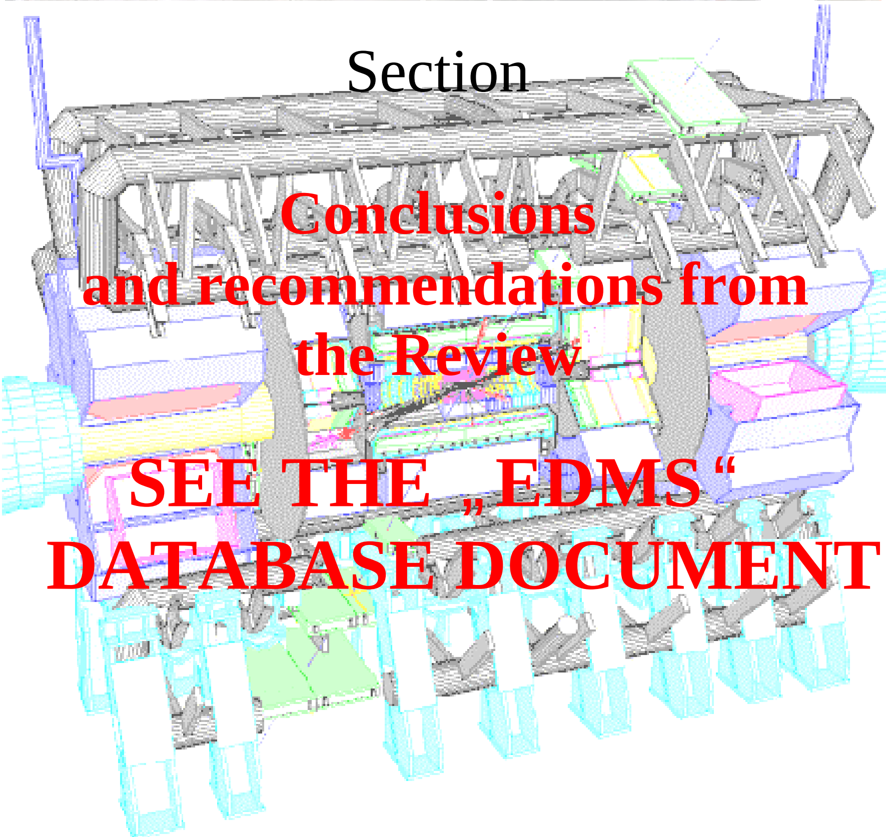
EQUIPMENT TOTAL (NO PLATFORMS, THERMAL STRUCTURES): CHF 174000

UPPER LIMIT BEFORE QUANTITY SAVINGS

ATLAS EXPERIMENT



Atlas ID Cooling Review at CERN lab's in June 14



Section

Conclusions and recommendations from the Review

SEE THE „EDMS“ DATABASE DOCUMENT

June 2000