Experience from Construction and Operation of the LHC Experiments Detectors Cooling Systems

Michele Battistin
CERN Engineering Department
Cooling and Ventilation Group
Detector Cooling Section

Workshop on Quality Issues in Current and Future Silicon Detectors
CERN
4th November 2011

Agenda

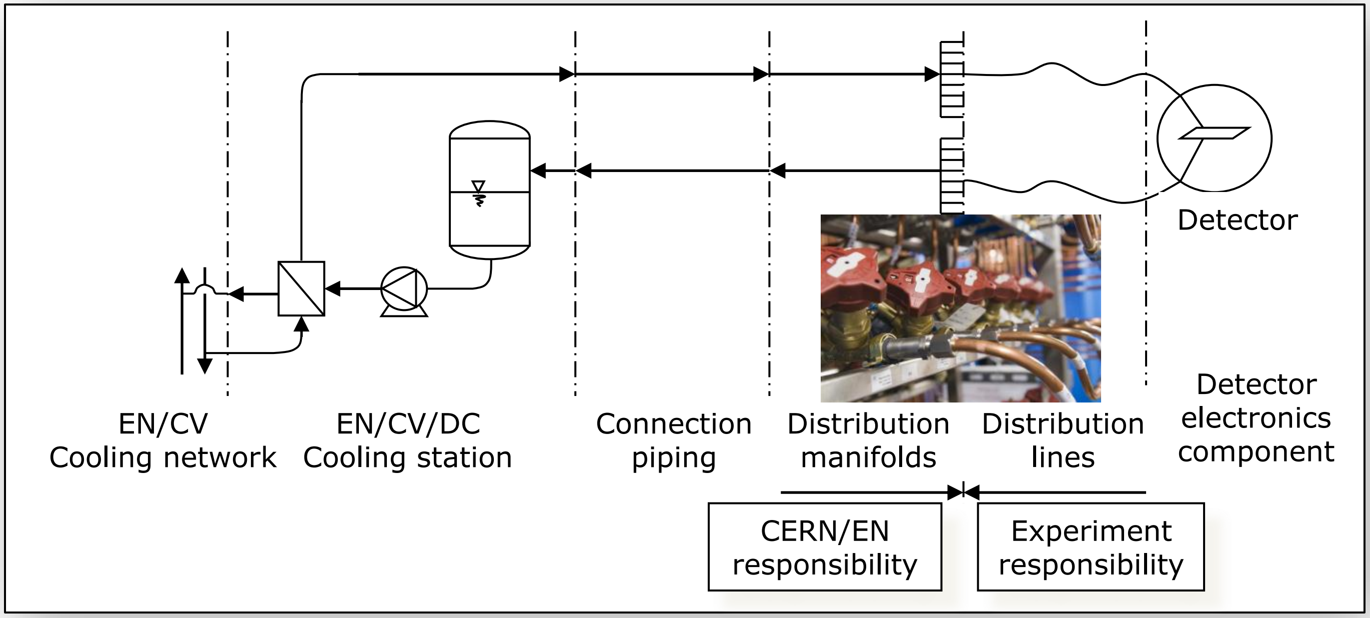
- The contest: LHC Experiments Detector Cooling installations
- Examples from LHC construction
- The life of a project for Detector Cooling installations
- Document management in EN/CV/DC
- Conclusions

EN/CV/Detector Cooling Installations

	Water leak-less	Monophasic PFC	Biphasic PFC	Biphasic CO_2
ALICE	5		2	
ATLAS	6	3	3	1
CMS		8		
LHCb	1	3		
TOTEM			1	
Others	5	1		
Total	17	15	6	1

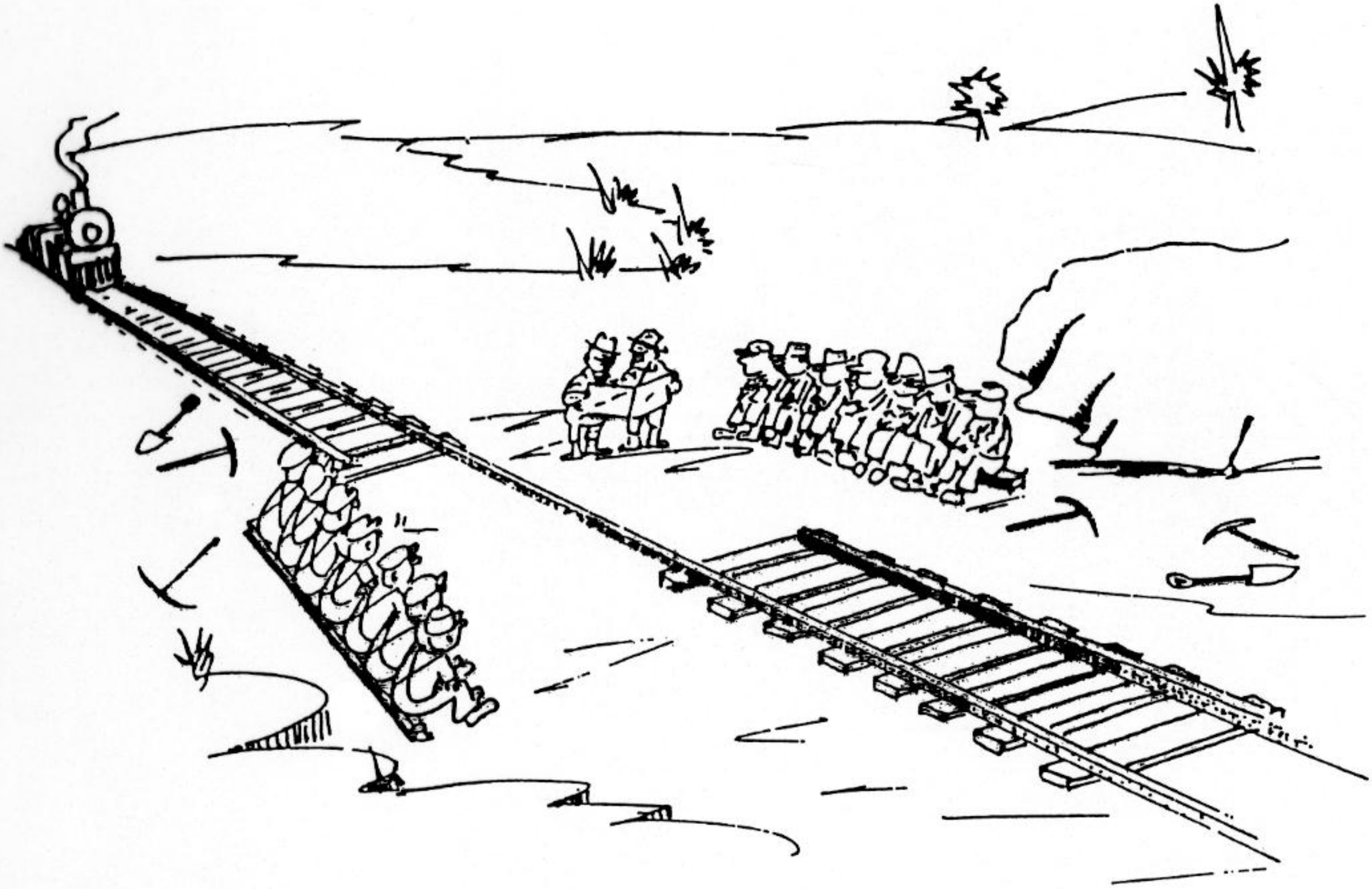
- 39 cooling stations built from 2001 to 2011
- Cooling power: 1 to 150 kW
- Distribution lines: 2 to 204 per installation
- Overall installations value about 10 MCHF

An integration of competencies



- Fluid energy cycle: ↗ inside the detector ↘ inside the cooling station
- Specific competencies: hydraulic components, electricity, control, …
  structural design, silicon technology, electronics technology…
- Shared competencies: heat transfer, connections, …

Underestimate quality during the R&D and construction phases can lead to…



Some example

- Pixel cooling loops: 8 bar ➔ 4 bar
- Leak-less circuit @ 1.2 bar. Pressure test.
- Components ware: filters
- Connections selection: different solutions for each sub-detector. Leaks.
- ...

To recover conformity: major works or main operation problems…

Could we do better?

Synergy
- engineering
- components
- control
- supervision
- technical documentation
- CAMMS
- resources optimization

Flexibility
- planning adaptation
- technical aspects

Solutions across Experiments
- cross-fertilization
- debugging

Cost
- material selection (technical-cost drivers)

Integration with the experiment
- leak requirements
- pressure test
- connections
- commissioning procedure
- quality management

Lay-out
- M&O approach

Communication with detectors communities
- technical consulting
- specification evolution

Which problems have we (TS and Experiments) faced during these years?

During the Project Development

Many different detector communities have dealt at least with the following issues:

- How shall I do a **leak test**? What is the **leak tightness** level I have to assure?
- What is the pressure value I have to test my detector?
- How shall I perform a **pressure test**?
- Which kind of **connections** are good for the pipes inside my detector?
- How can I assure the **cleanliness** of my pipes? How can I measure it?
- Which phases I have to perform during **commissioning**?
- …

Did the detector communities have resources to deal and solve these issues?

- Yes: high quality standard for the correspondent detector
- Partially: the technical solution has NOT been uniform across the detectors
- No: the problem has been partially solved or simply neglected

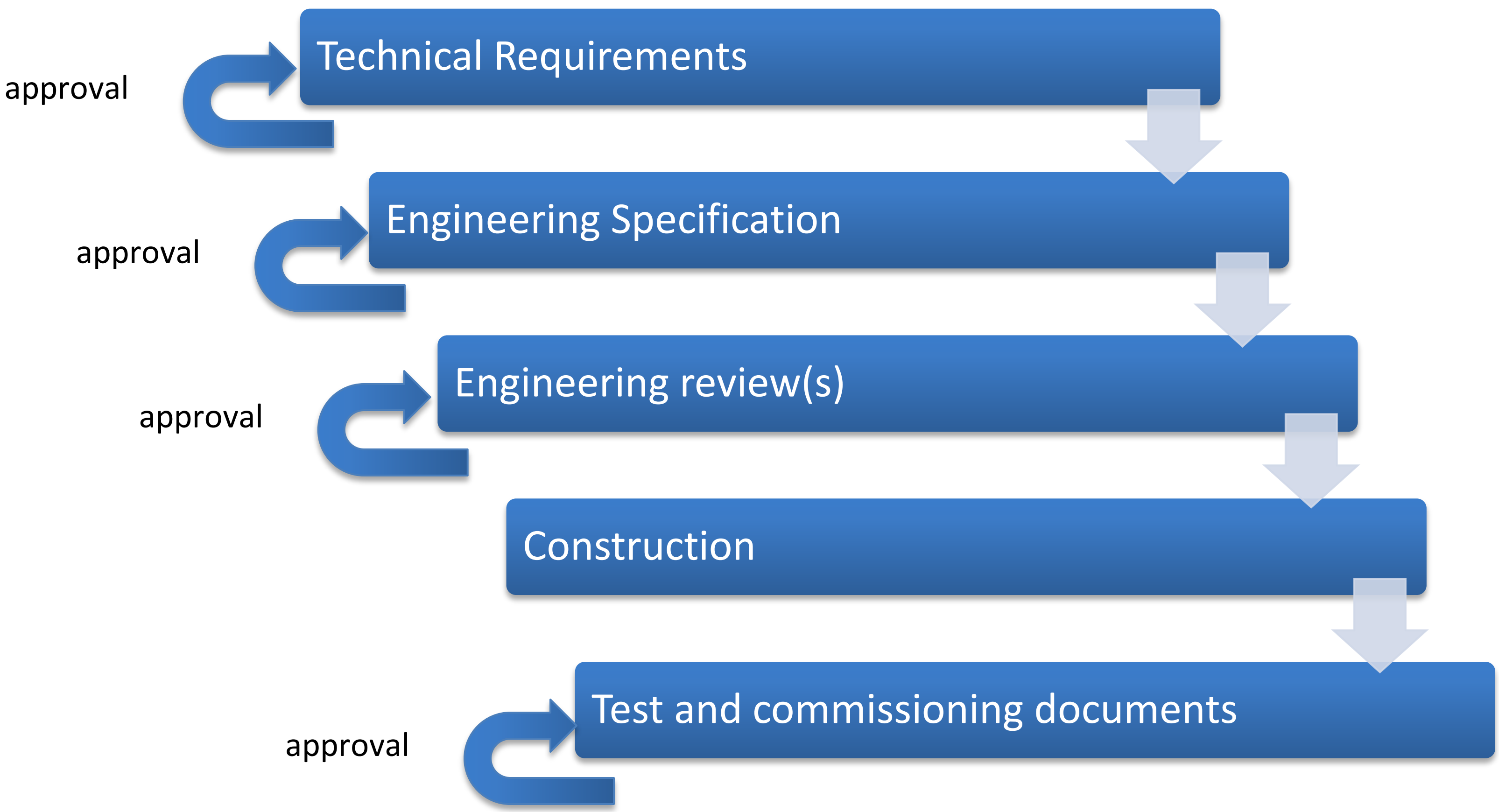
Proposal from our experience

End of 2007 - TS/CV/DC proposals

- Collaboration to the LHC upgrade projects of the Experiments (connections, pressure tests, leak test, cooling performances, cooling path evaluation, etc.): active participation to the debates and **reviews**; follow up the cooling need evolution; definition of the new specifications.
- Agreement for the construction of cooling system **prototypes.**
- Structured integration of the **CFD** (Computational Fluid Dynamic) activity into the R&D process since the beginning.
- Definition of **roadmaps** with common "**<u>validation</u>**" steps to reduce or avoid the sliding of the project.
- Development of knowledge on **new cooling concepts**.
- Set-up and coordination of common a "**cooling test facility**" at CERN to validate the cooling performances on the detectors' prototypes.

In the meantime EN/CV/DC improved the quality approach to project management

Project management for a DC cooling station



Earned Value Management (EVM) technique

Definition	• Engineering Specification
PBS	• Project Breakdown Structure • Equipment coding convention
WBS & WU's	• Work Breakdown Structure • List of Working Units
RRM	• Resource Responsibility Matrix
WU	• Work Units dictionary
Project coordination schedule	• Planning & Cost Follow-up

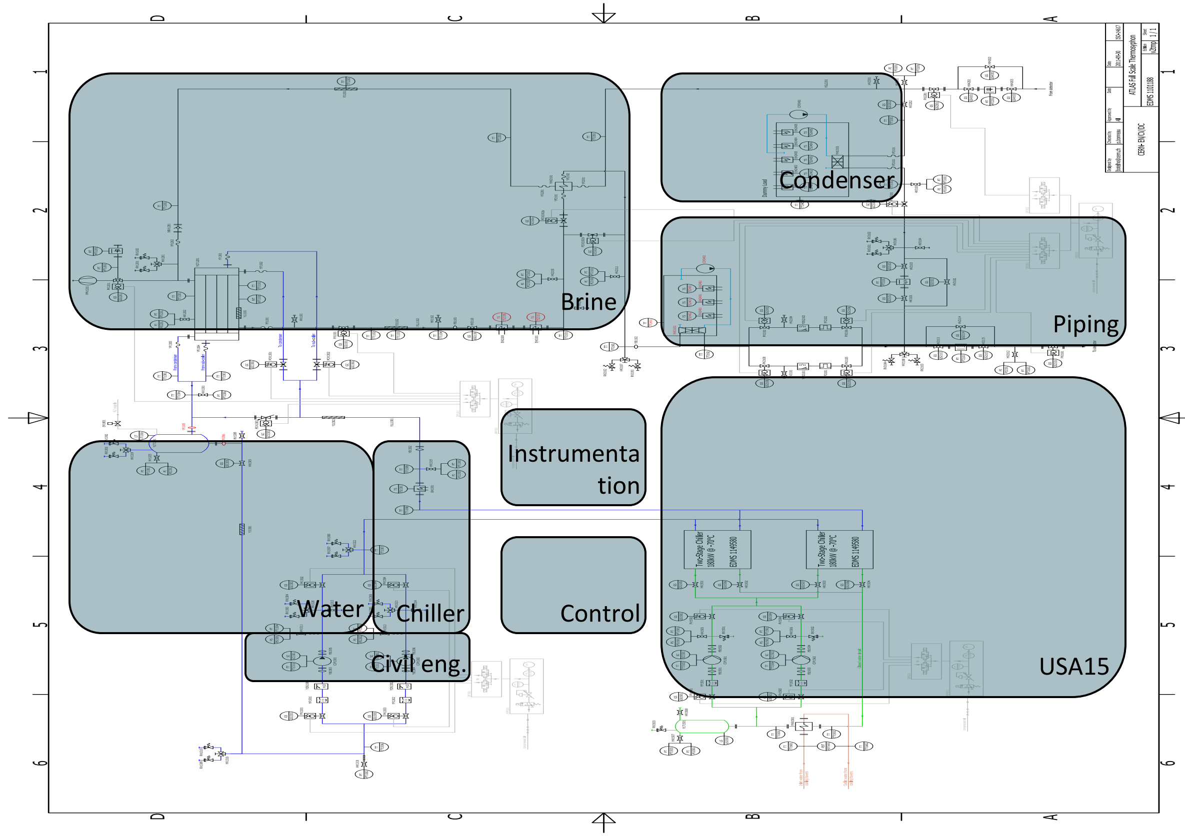
European Organization for Nuclear Research - Organisation européenne pour la recherche nucléaire

EN Engineering Department

Project Breakdown Structure

Product Breakdown Structure

Work units	
Code	**Label**
2	**Water circuit**
2.1	Water piping
2.2	Water pumping station
3	**Chiller Circuit**
3.1	Chiller N1
3.2	Chiller N2
4	**Brine circuit**
4.1	Brine piping
4.2	Brine Piping Insulation
4.3	Brine pumps
4.4	Brine Tank
4.5	Brine Electrical Heater
4.6	Brine Components
4.7	Brine Assembly
4.8	Brine Station Insulation
5	**Thermosyphon Condenser**
5.1	Condenser
5.2	Degassing System
5.3	Sonar System
5.4	Condenser Components
6	**Thermosyphon Piping**
6.1	Thermosyphon Piping
6.2	Pipe Engineering
6.3	Thermosyphon Piping Supports
6.4	Thermosyphon Piping Insulation
6.5	Thermosyphon Piping Installation
7	**Thermosyphon USA15**
7.1	Recuperation Heat Exchanger (RHX)
7.2	Heaters Before the RHX
7.3	Heater after the RHX
7.4	Components (valves, filters, etc.)
7.5	By-pass Piping
7.6	Dummy Load
7.7	Flowmeters
7.8	Thermosyphon USA15 Assembly
7.9	Thermosyphon USA15 Installation
8	**Instrumentation**
8.1	Instrumentation components
9	**Electricity**
9.1	EN/EL Power Supply
9.2	EN/CV/DC Power Supply
10	**Control**
10.3	Pneumatic system for the Chillers
10.4	Pneumatic system for the Thermosyphon Circuit
10.5	Pneumatic system for the Brine Circuit
10.6	Interface between evaporative and Thermosiphon
11	**Civil Engineering**
11.1	Chiller N1 Support Structure
11.2	Condenser Roof Structure
11.3	Chiller N2 Support Structure
11.4	Crio Truck Access Road



European Organization for Nuclear Research - Organisation européenne pour la recherche nucléaire

EN Engineering Department

WBS & RRM

Responsibility and Resources Matrix

X -> Execute the work.
R -> Review the work done.
I -> Must be informed.
H -> Can provide help or tuitions.
N -> Needed to have the work completed.

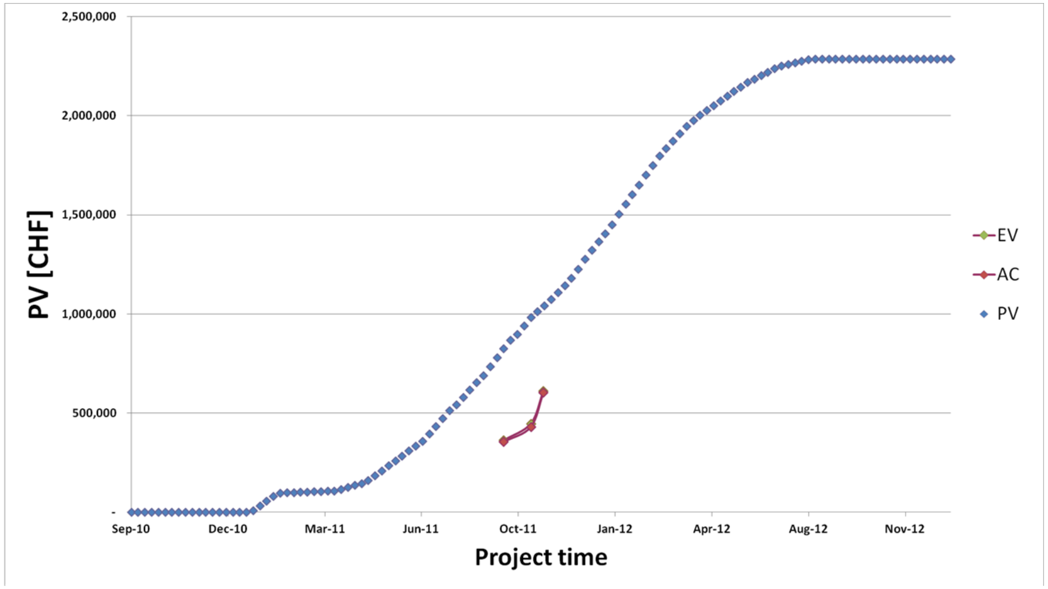
black b.g -> Lead working unit and monitor progress.
grey b.g -> contribute to decisions

Working units		Resources: EN/CV/DC										PH			Other													
		Michele Battistin	Jose Botelho Direito	Kirill Egorov	Florian Corbaz	Stephane Berry	Pierre Bonneau	Sylvain Nichilo	Daniel Lefils	Sebastien Roussee	Olivier Crespo	Jan Godlewski	Alexandre Bitadze (3D drawings)	Lukasz Zwalinski	Gregory Hallewell	Olga Beltramello (Safety)	Rene Necca (EN/EL)	I.I. (Domenico Alemanno)	Said Atieh	Marina Malabaila (cleaning)	Stefano Moccia	J&Ehall (Chiller contractor)	Delio Duarte Ramos / Mael	TESI (Ext.)	Iwanski (ATLAS)	Ouvaroff (Ext.)	Phillip Santos Silva	Eliseo Perez-Duenas (GS/CE)
1	**Project management and integration**																											
1.1	**Project management**																											
1.1.1	Manage the project	X										X																
1.1.2	Issue project management documents	R	X									R		X														
1.1.3	Prepare Technical Note Document	R	X	X			X					R	X	X													I	
1.1.4	Prepare P&ID and part list	R	X		I	I	X					R		I													I	
1.1.5	Prepare Risk Analyses Document	R	R									R		X													I	
1.1.6	Prepare Hydraulic Dossier Document	R	X	X			X		X		X	R	X	X													I	
1.1.7	Prepare Electrical Dossier Document	R	I		X	X						R		X													I	
1.1.8	Prepare Thermosyphon Safety File Document	R	I									R															X	
1.2	**Integration Studies**																											
1.2.1	Integration of the Water Circuit	R	X						X			R				I												
1.2.2	Integration of the Chiller N1 Circuit	R	X									R	X			I												
1.2.3	Integration of the Chiller N2 Circuit	R	X									R	X			I												
1.2.4	Integration of the Thermosyphon Condenser	R	X									R	X			I												
1.2.5	Integration of the Thermosyphon Piping	R	X									R	X			I												
1.2.6	Integration of the Thermosyphon USA15	R	X	X								R	X			I												
2	**Water circuit**																											
2.1	**Water piping**																											
2.2.1	Design of the water piping	I	R				R		X												X							

Cost tracking

	Actual Cost	Planned Cost
Project management and integration		
Project management		
Integration Studies		
Water circuit		
Water piping		
Water pumping station		
Chiller Circuit		
Chiller N1		
Chiller N2		
Brine circuit		
Brine piping		
Brine Piping Insulation		
Brine pumps		
Brine Tank		
Brine Electrical Heater		
Brine Components		
Brine Assembly		
Brine Station Insulation		
Thermosyphon Condenser		
Condenser		
Degassing System		
Sonar System		
Condenser Components		
Thermosyphon Piping		
Thermosyphon Piping		
Pipe Engineering		
Thermosyphon Piping Supports		
Thermosyphon Piping Insulation		
Thermosyphon Piping Installation		
Thermosyphon USA15		
Recuperation Heat Exchanger (RHX)		
Heaters Before the RHX		
Heater after the RHX		
Components (valves, filters, etc.)		
By-pass Piping		
Dummy Load		
Flowmeters		
Thermosyphon USA15 Assembly		
Thermosyphon USA15 Installation		
Instrumentation		
Instrumentation components		
Instrumentation Installation		
Electricity		
EN/EL Power Supply		
EN/CV/DC Power Supply		
Control		
Chiller Control Cupboard		
Thermosyphon Control Cupboards		
Pneumatic system for the Chillers		
Pneumatic system for the Thermosyphon Circuit		
Pneumatic system for the Brine Circuit		
Interface between evaporative and Thermosiphon		
Civil Engineering		
Chiller N1 Support Structure		
Crio Truck Access Road		
Condenser Roof Structure		
Chiller N2 Support Structure		
Commisioning		
Comissioning Brine Circuit		
Comissionning Thermosyphon Circuit		
Comissionning Switching with Evaporative Cooling Plant		
TOTAL		

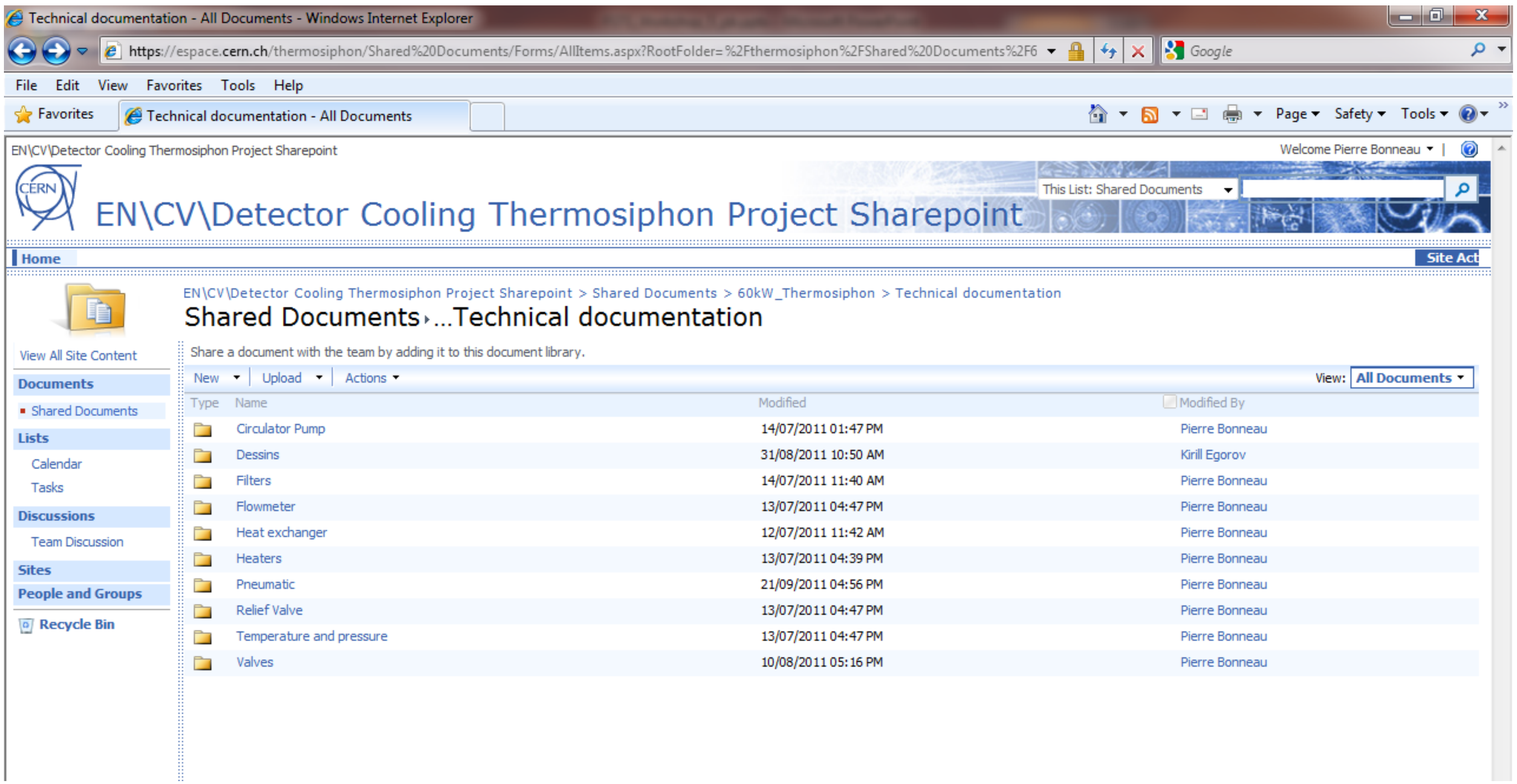
- Cost variance
- Schedule variance



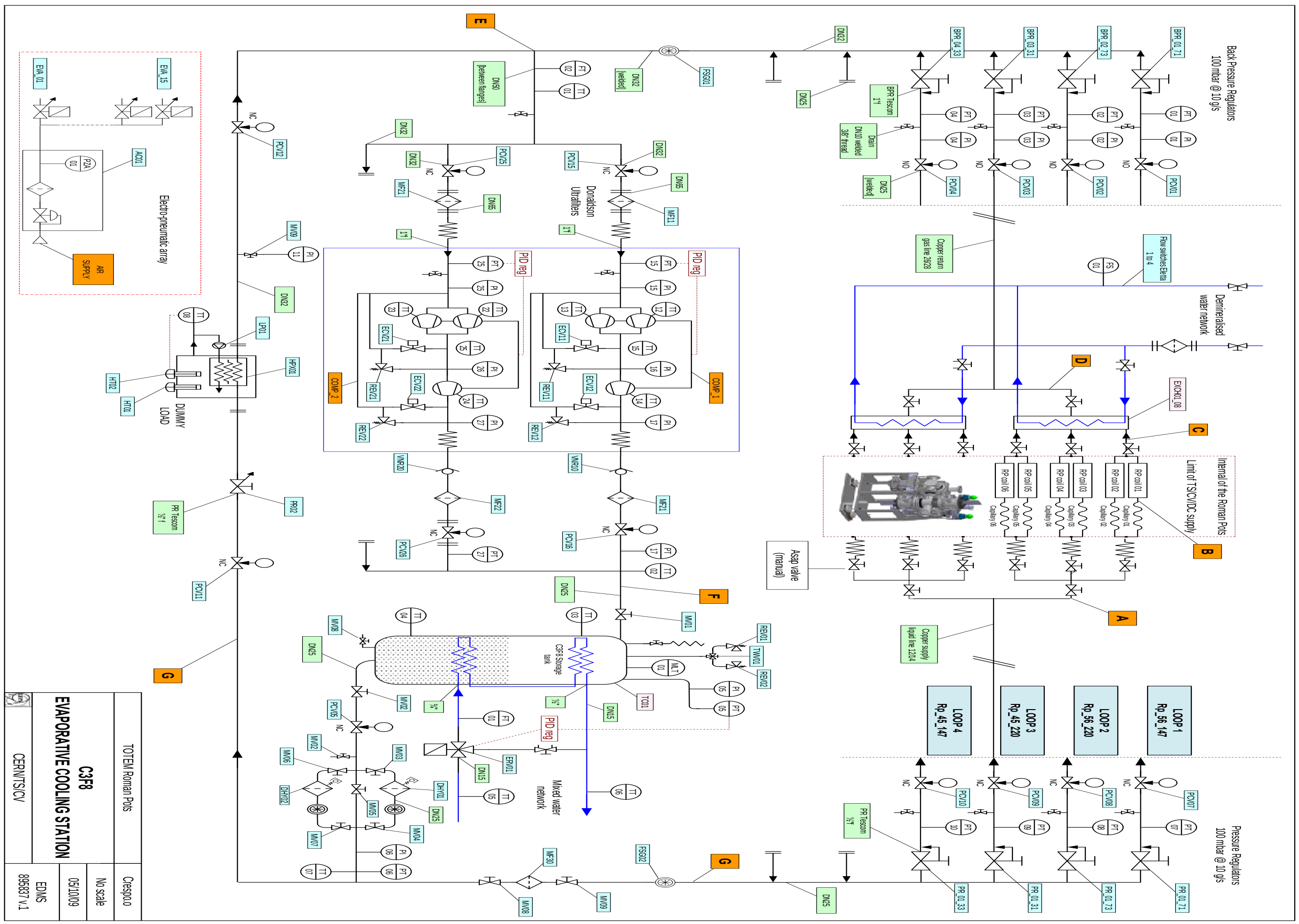
European Organization for Nuclear Research - Organisation européenne pour la recherche nucléaire

Engineering Department

Working document are stored on sharepoint



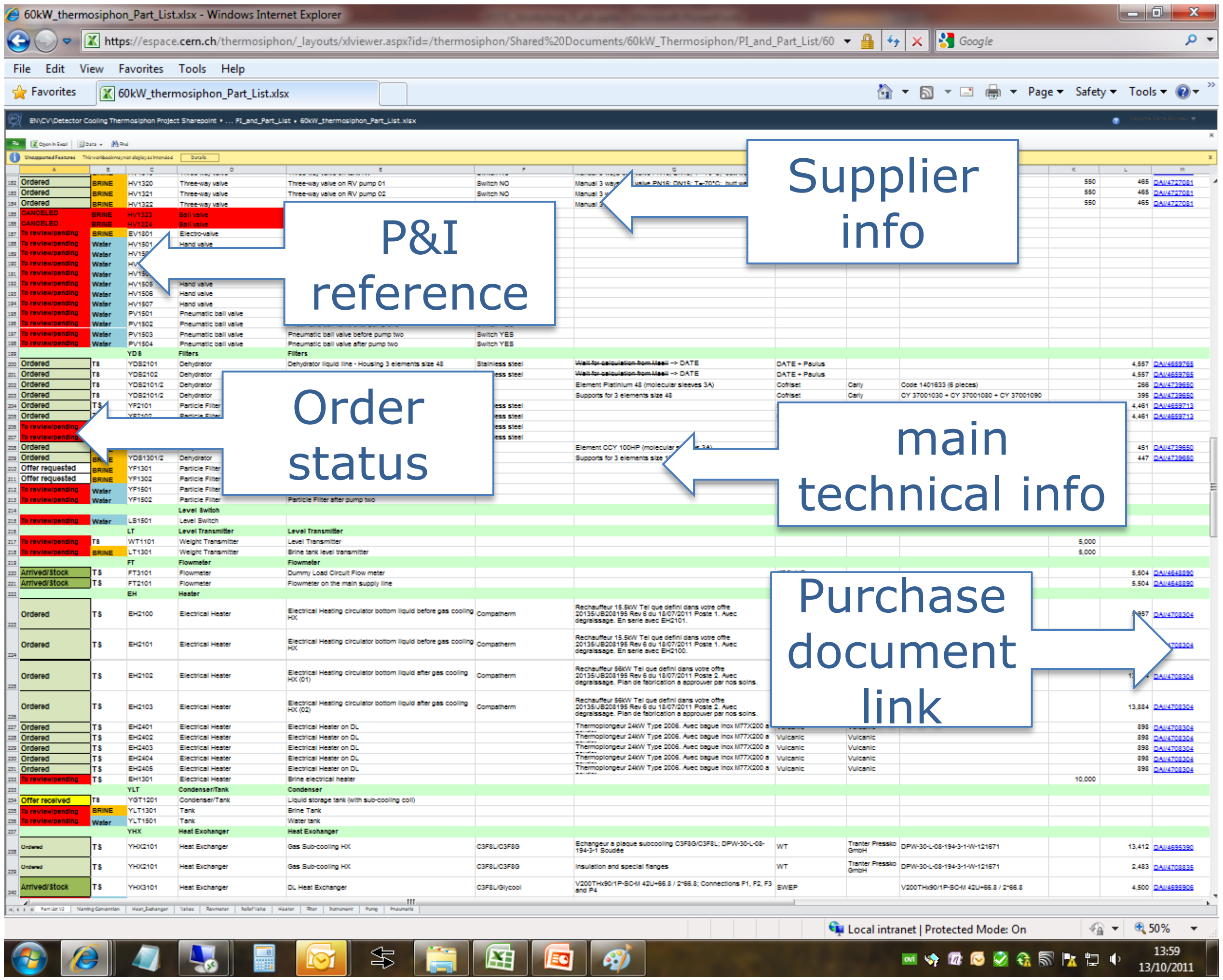
Installation P&I – component unique name



European Organization for Nuclear Research - Organisation européenne pour la recherche nucléaire

EN Engineering Department

Excel to manage the components supply



<u>Part list for all components</u>

Circuit:
- TS
- Brine
- Water

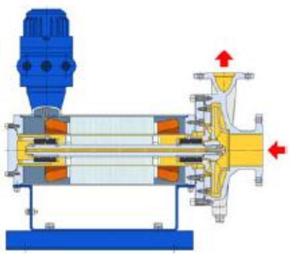
Status of the order:
- Review/Pending
- Offer requested
- Offer received
- Ordered
- Arrived/Stock

Description of the components
Function
P&I reference
Supplier
Price
Order number

Technical Purchase Specifications are defined for each component

Canned Motor Centrifugal Pumps designed for Refrigeration Systems

HN Model



Very low maintenance

Stainless Steel models for clean room application

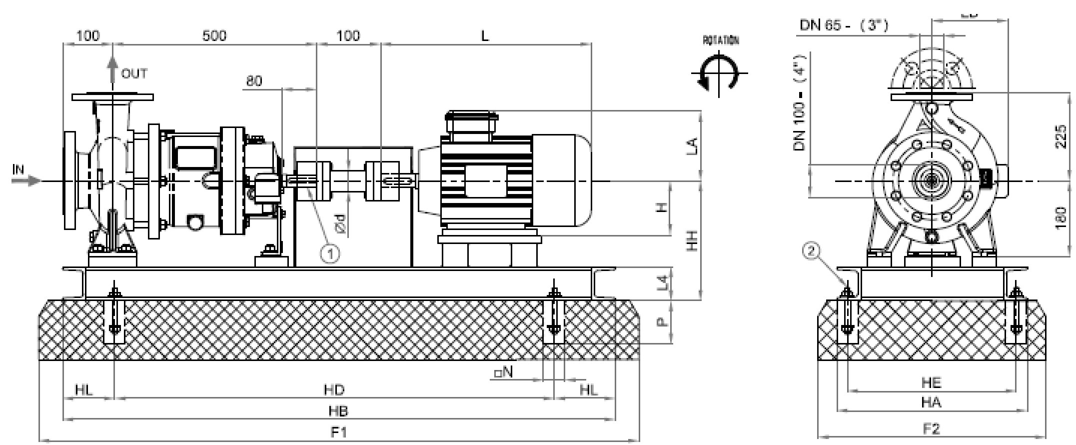
For temperatures down to -100°C

Designs for 20 Bar and 40 Bar system pressure

PN20, PN40

Fluid	C6F14
Flow [kg/s]	40
Flow [m3/h]	75
T[°C]	-70
Density [kg/m3]	1920
Head [m]	40
NPSHa [m]	7.5
NPSHr (pump) [m]	<<7.5

Pompes Certifiées



Final technical dossier are stored on EDMS for the cooling system operation

- Perfluorocarbons
- Material
- Technical Dossiers
  - ATLAS Evaporative
  - ATLAS TRT
  - ATLAS Cables
  - ATLAS Liquid Argon
  - ATLAS Tile
  - ATLAS Diffusion Pumps
  - ATLAS Rod Rack
  - ATLAS Muons
  - ATLAS SR1
  - ALICE SPD
  - ALICE SSD-SDD
  - ALICE HMPID
  - ALICE TOF-PHOS
  - ALICE TRD
  - ALICE TPC
  - CMS Tracker & Preshower
  - CMS TIF
  - LHCb Inner Tracker
  - LHCb Trigger Traker
  - LHCb Rich 1&2
  - LHCb Outer Tracker
  - TOTEM Roman Pots
- CFD Studies

Documents

Sort by: Positio

499062 v.1 — Doc. page

490532 v.1 — Doc. page

781403 v.1 — Doc. page

781414 v.1 — Doc. page

1026710 v.1 — Doc. page

Date: 4/23/2009

EN

EN-CV-DC

CERN
CH-1211 Geneva 23
Switzerland

TS/CV Detector Cooling Project Document No.
FCUL-00007 (183/08) EN/CV/DC

EDMS Document No.
781421 V.2

TECHNICAL FOLDER

ALICE – HMPID COOLING PLANT
HYDRAULIC PART
FCUL-00007

General description and functionalities

This plant supplies cooling water to the front-end electronics of the High Momentum Particle Identification Detector, HMPID, of the ALICE experiment. In nominal operating conditions, the plant delivers 4.2m³/h of water at 18ºC and 1bar(a) to the detector inlet (the pressure throughout the detector is sub-atmospheric). The cooling plant is expected to remove some 4.9kW (7circuits×700W) from the detector.

Prepared by :	Checked by :	
stephane.berry@cern.ch	Michele.battistin@cern.ch	

The stable URL link guarantees the long term link consistency

https://edms.cern.ch/document/1016399

We assumed a "mantra" as a general rule

ISO 9000

AN OVERVIEW

ISO 9000 is a universally accepted system of organizing, manufacturing / service activities by writing out those which affect the quality of the product. This is because the system is based on the premises,

WRITE WHAT YOU DO;
DO WHAT YOU WRITE.

The standard, 9001:2000, consist of a set of clauses, which are in the form of guidelines. Against each of these a simple and short narration of how, e.g. raw materials are purchased is recorded. In this manner all clauses are covered. Then follows the 'DO' part of it that is the

Write what you do

Do what you write

document:
- Who
- When (date)
- Doc Number
- Version number (+ history)
- Consistent link to referred documents
- References to international standards

Conclusions

- Quality shall enter in the day-by-day habits of Detector Cooling design and construction on both cooling station and detector sides.
- Quality is not a constraint! Quality can guarantee the success of our work!
- Quality costs! Training and resources are needed.
- Quality allows to communicate effectively in large communities.
- When "the cooling is not working" we cannot say: