Future Circular Collider
Technical Infrastructure

Cooling and Ventilation Status Report and Perspectives

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FCC week 2021

1 / July / 2021

European Strategy for Particle Physics 2020 update document

Core paragraph and main request "order of the further FCC study":

"Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update." **(Feasibility study to be delivered end 2025 as input for ESPP Update expected for 2026/2027,)**

From Benedikt's talk last year referring to CERN DG:
Technologies of machine and experiments: First priority of feasibility study: magnets; minimise environmental impact; energy efficiency and recovery

Main topics and milestones for CV activities

Main system design activities

Feasibility Design Report

2021	2022	2023	2024	2025	2026

Review, collection and update of CV **user requirements for FCC-ee** for each surface point, including CV building and plants specification (assuming no change on FCC-hh requirements); this is

→ input for iteration in particular with safety concepts

→ starting point for external consultant contract(s) for CV concept plan and design

Refined concept design of CV infrastructures, also taking into account later evolution to FCC-hh; this is

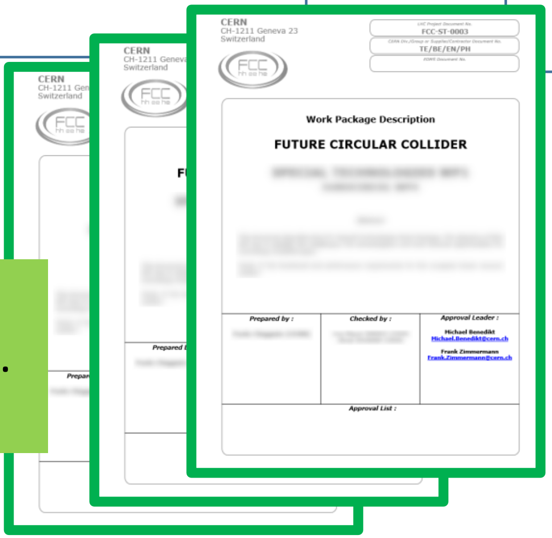
→ input for start of Environmental Evaluation process

(Pre-)technical design of CV infrastructures, installation time plan, cost estimate; this is

→ input for a full iteration of the design with all users, CE and other systems

→ input for the Feasibility Design Report

«Work package descriptions»
with deliverables, planning/milestones, ...
(useful for planning and follow-up)



M. Benedikt, 18.1.2021

Main topics and milestones for CV activities

IN PARALLEL: Environmental aspects (energy and resource management), partially R&D related, possibly with external consultants or R&D partners

2021	2022	2023	2024	2025	2026

Analysis of waste heat recovery methods and alternative use

Alternative concepts for cooling water management

Concrete concepts for FCC-ee waste heat and cooling water management, integrated in the design (3rd block on previous slide)

Feasibility Design Report

Some of the aspects that need to be addressed in the above context:

- Origin points of cooling water
- Cooling water distribution
- Cooling water disposal
- Water for firefighting
- Confirmation of ventilation concept (including validation of all devices, in particular specs for heat resistance and deep-temperature operation in case of e.g. He leak.
- Cooling concept for FCC-ee RF sections

M. Benedikt, 18.1.2021

Cooling FCC-ee (Users' requirements)

- USERS' REQUIREMENTS (INPUT FOR CV)
  - Thermal loads to water from magnets, synchrotron radiation, electrical racks, cables, etc.
    - Location and value;
  - Cooling water temperature constraints : maximum and minimum values;
  - Circuit materials;
  - Maximum allowable working pressure in the users' circuits;
  - Maximum flow (vibration or erosion);
  - Type of water: Demineralised or industrial water, other? ;
  - Firefighting needs (surface, tunnel and other underground areas);
  - Cooling Plants underground and CV buildings need to be dimensioned to cope with FCC-hh requirements, therefore the mentioned requirements are needed for FCC-ee and FCC-hh configurations.

Cooling FCC-ee

Main circuit types to be considered:

- ❑ Raw water : make up for all circuits, firefighting circuit
- ❑ Primary cooling water
- ❑ Demineralised water
- ❑ Chilled / Mixed water
- ❑ Clear and Waste water sumps

Raw water

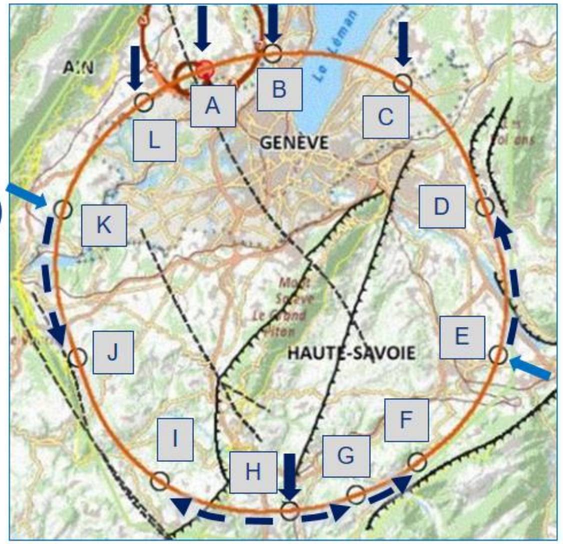
- Raw water
  - Supply points location and flow, decision to be taken according to:
    - Position of the surface points;
    - Water availability per point;
    - Water need per point;
    - Maximum diameter of the raw water pipe in the tunnel;
    - FCC-hh needs.
  - Firefighting system;
  - Pumping Stations and distribution systems are needed;
- Up to now only an exercise has been done to show how we would carry out the study once the needed data is known.

Raw water supply (From 2016 FCC week)

Water supply in FCC Points

- Main user: make up water for cooling towers
- Around half of the Points should be directly fed by water from local network.
- Other Points supplied by underground pipeline cast in the concrete slab of the tunnel.

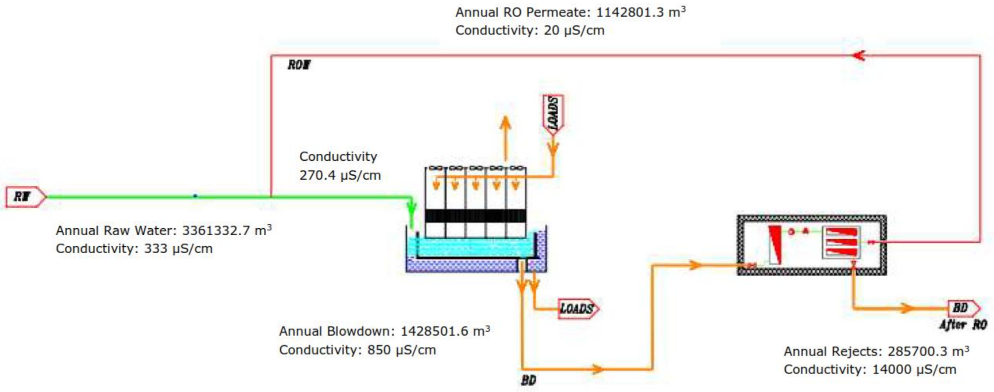
- Fire fighting in underground:
  - make up water pipe (where existing)
  - dedicated pipe in other sectors.
- Fire fighting in surface:
  - preferably from local network.



Primary Cooling Water

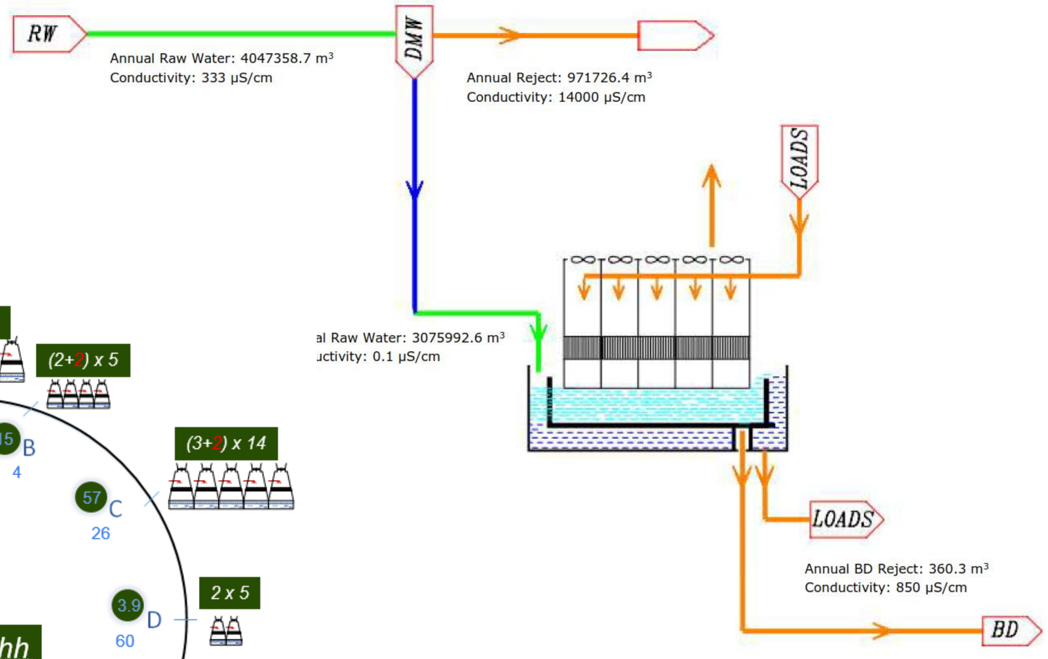
- Primary water
  - Cooling Towers combined with alternative cooling solutions
    - Reducing water consumption, visual pollution, noise…
    - Waste Heat Recovery options:
      - District heating as for LHC;
      - Other applications (medical, industrial, agricultural, leisure, …);
      - Combined or not with thermal energy storage.
  - Water treatment:
    - Reducing corrosion;
    - Scaling, fouling and legionella;
    - Environmentally friendly.
- Blowdown water:
  - Finding reject water points;
  - Treatment before rejection.
- Maintenance strategies

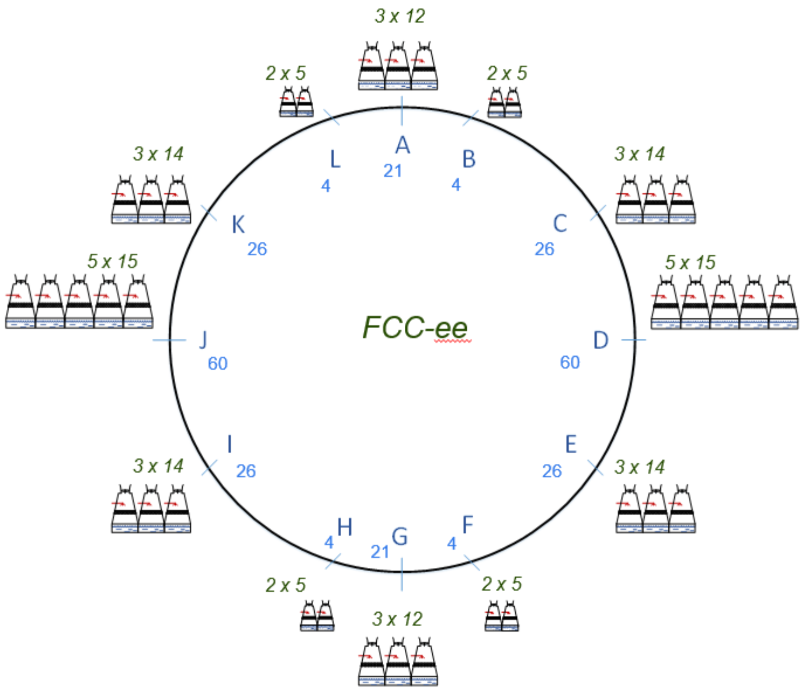
Primary Water : Cooling Towers (I)

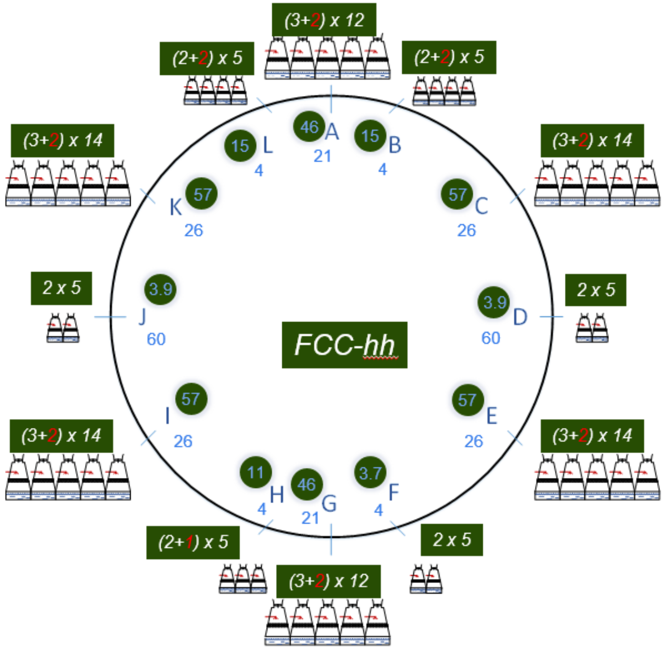


Recycling blowdown water

Make-up with demineralised water



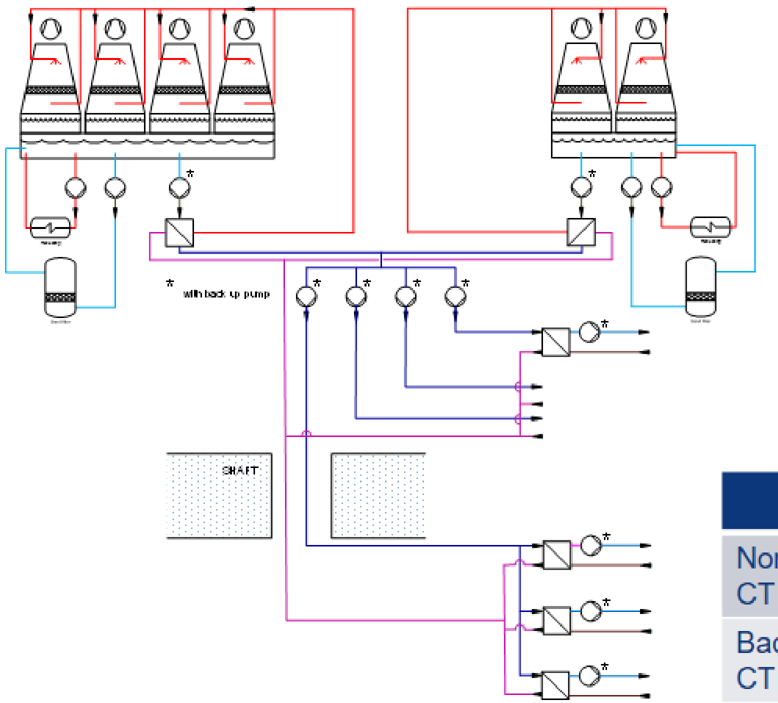




Primary Water : Cooling Towers (II)

Double Cooling Tower Circuit

Normal CT Winter back-up CT



Wet Bulb T (ºC)		Avg	Std	Min	Max	95% L	95% H
Cold Season	Dec.	1.6	3.6	-13.1	12	8.7	-5.6
	Jan.	0.6	3.7	-18.7	11.6	8.1	-6.9
	Feb.	0.9	3.8	-17.2	10.9	8.6	-6.8
Mid Season	Mar.	3.9	3.7	-10.5	14.1	11.3	-3.5
	Apr.	6.8	3.3	-5.2	16.3	13.4	0.2
	Oct.	9.4	3.5	-4.6	17.7	16.3	2.4
	Nov.	4.4	3.6	-9.4	14.5	11.6	-2.9
Hot season	May	10.8	3.2	-0.3	20.4	17.2	4.4
	Jun.	13.8	3.2	2.3	22.5	20.2	7.4
	Jul.	15.6	2.8	5	22.6	21.1	10.1
	Aug	15.4	2.8	5.2	22.7	21	9.8
	Sept	12.7	3.1	1.1	21.4	18.8	6.5

From: Weather Conditions in the Geneva Area, Doubek, EDMS 1714932 v 1.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Normal CT	Maintenance	Maintenance	N_m+ 1	N_m+ 1	N_s	N_s	N_s	N_s	N_s	N_m+ 1	N_m+ 1	Maintenance
Back up CT	N_W+ 1	N_W+ 1	Maintenance	Maintenance	+1	+1	+1	+1	+1	Maintenance	Maintenance	N_W+ 1

Demineralised Water

- Demineralised water
  - Production and distribution
    - Central production vs Local production vs On truck production
    - A mix of solutions to be used differently according to:
      - The need : first filling or coping with major or minor leaks
      - Access to the point (distance and access roads)
  - Main Cooling circuits in the FCC-ee underground
    - For copper circuits (quadrupoles, sextupoles, photon absorbers)
    - For aluminium circuits (dipoles)
    - RF cooling circuits
    - Experimental Area
    - … others ?
    - Pipes nominal pressure, circuit pressurisation, balancing, etc.

Chilled Water

- Chilled / Mixed water
  - Identification of users (besides air cooling and dehumidification);
    - Temperature ranges, cooling power, location;
  - Production and distribution
    - Chiller alternatives;
    - Back up strategy;
    - Number of circuits.

Table 5.3. Main characteristics of chilled water circuits.

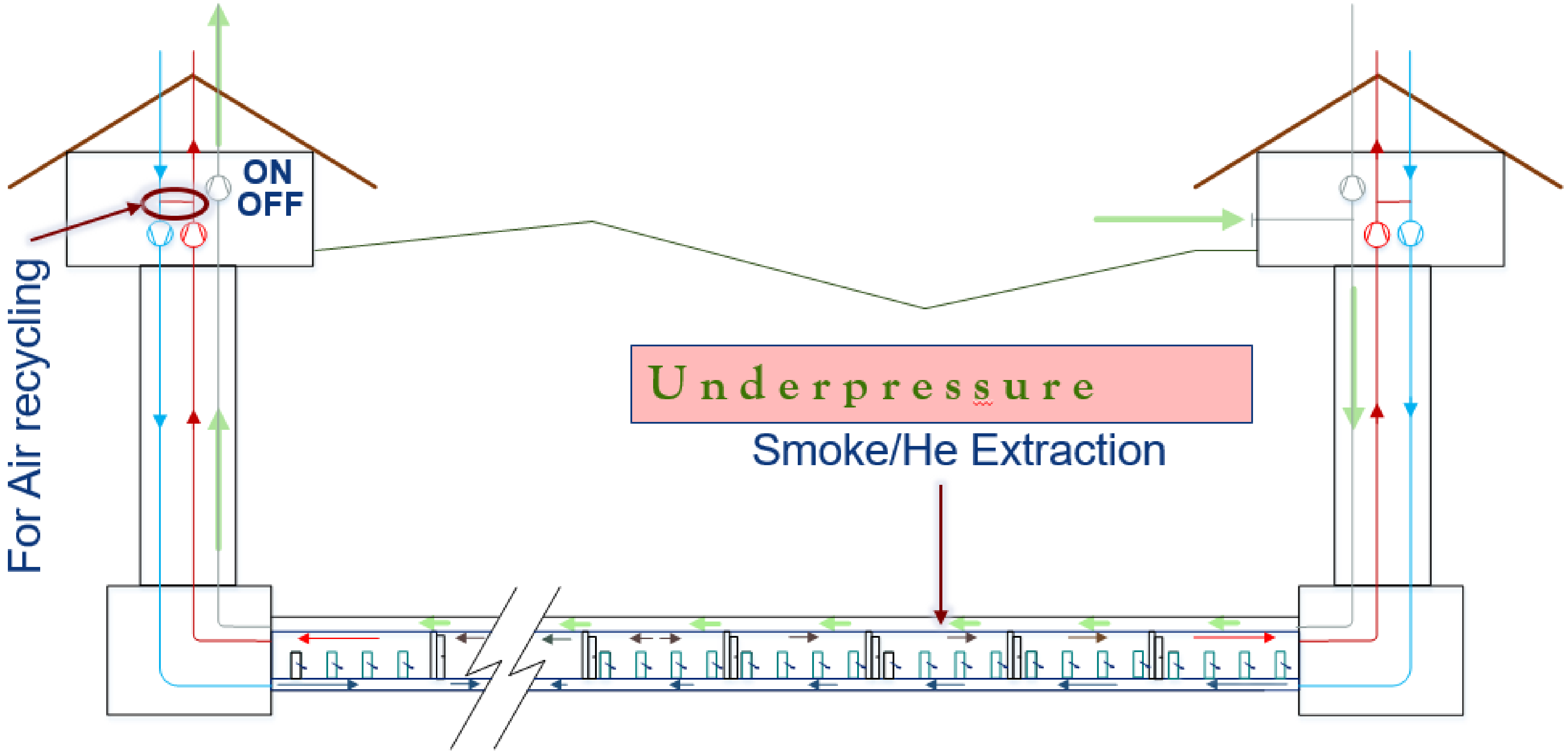
Point	Cooling power (kW)	Flow rate (m^3/h)	Number of chillers	Cooling power/ chiller (kW)
PA	1780	255	3	900
PB, PL	1500	215	3	800
PC, PK	1850	115	3	900
PD, PJ	5440	781	4	2000
PE, PI	1860	267	3	1000
PF, PH	1490	214	3	800
PG	3460	497	4	1200

Ventilation (Users' requirements)

- USER'S REQUIREMENTS (INPUT FOR CV)
  - Modes: Run, Access, Flushing;
  - Thermal loads to air from magnets, synchrotron radiation, electrical racks, cables, etc. ;
    - Location and value;
  - Air temperature constraints : maximum and minimum values;
  - Maximum air speed (vibration);
  - Access mode: Air renewal rate, air quality requirements;
  - Flushing mode:
    - Radiation rate at exhaust air and in the tunnel (HSE);
    - Delay between accelerator stop and access to the tunnel;
  - Ventilation Plants underground and CV buildings need to be dimensioned to cope also with FCC-hh requirements, therefore the mentioned requirements are needed for FCC-ee and FCC-hh configurations.

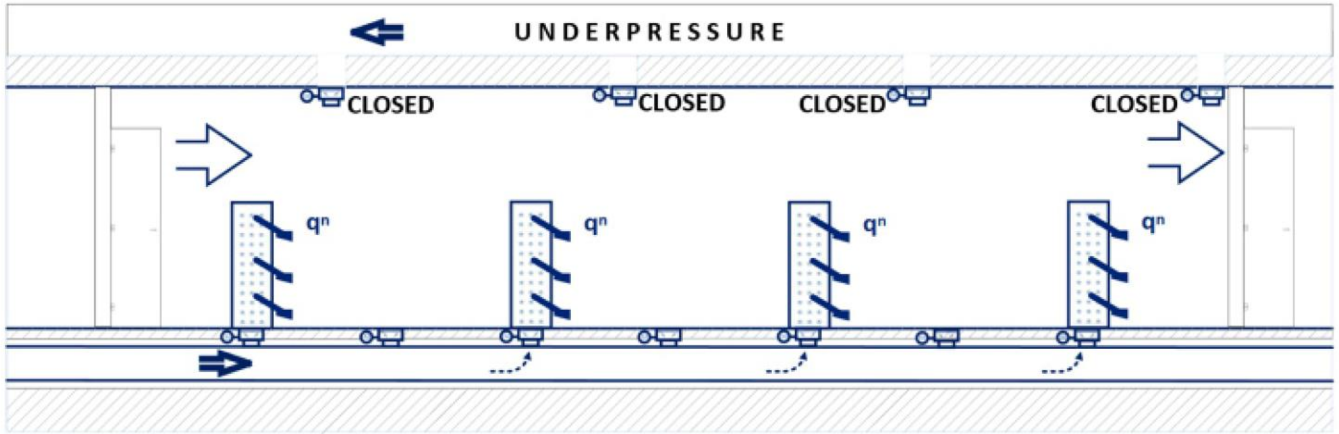
Ventilation

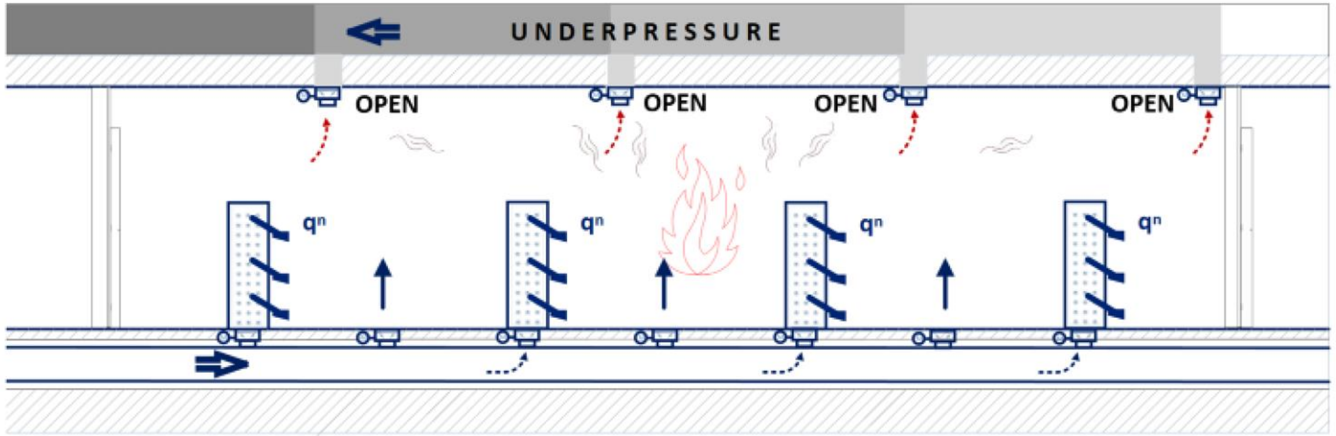
- Air handling units configuration
- Back up units
  - Working strategy in case of breakdown



Ventilation FCC-ee: Safety Aspects

- In case of fire
  - Actions to be made by:
    - Fresh air system
    - Extraction system
    - Compartmentalisation system
- In case of helium leak
  - Actions after triggering detection signal from:
    - Fresh air system
    - Extraction system
    - Compartmentalisation system

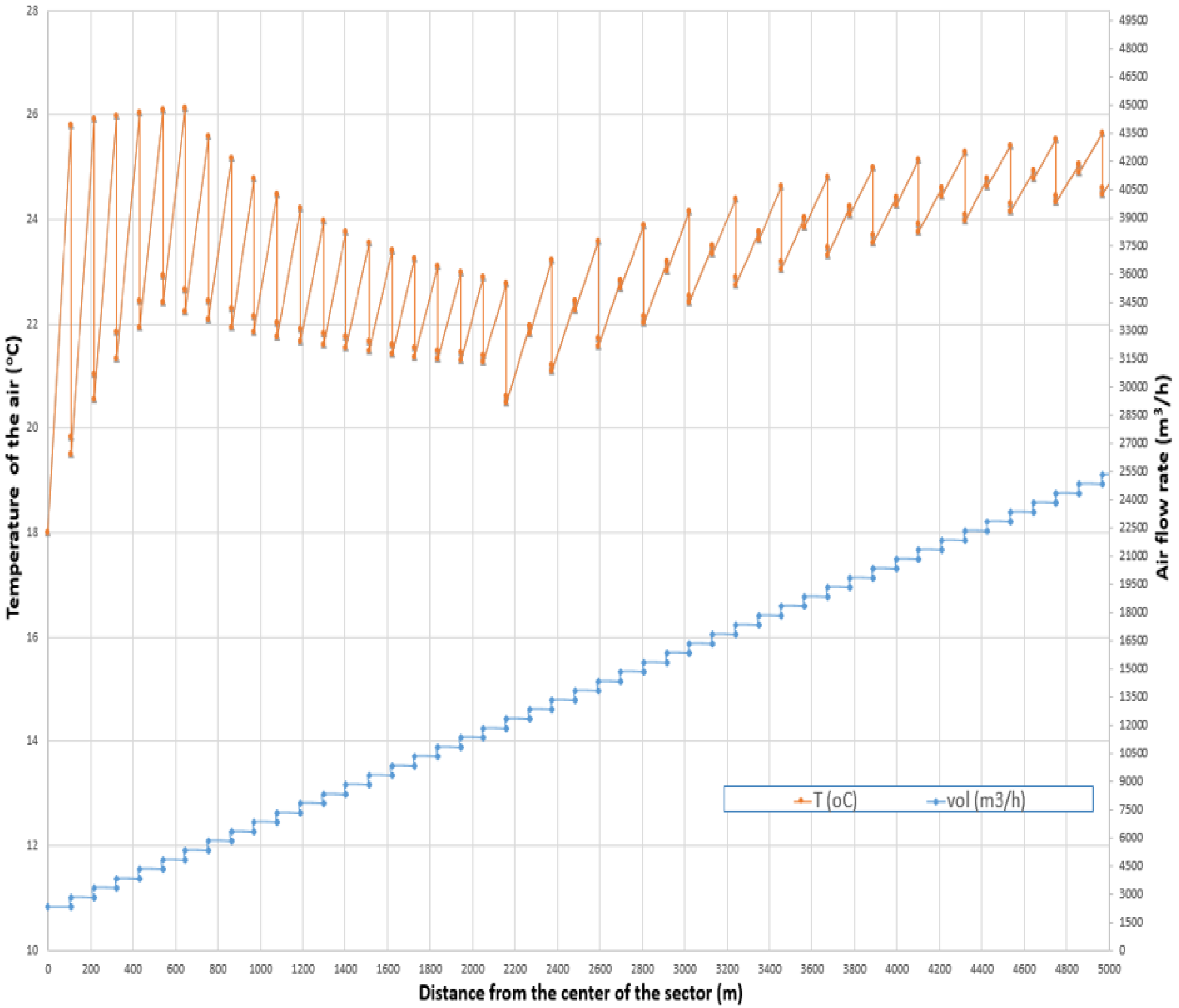




Ventilation FCC-ee: Particular Aspects

- Extracting heat load without generating high temperature gradients (Survey constraints)
  - Heat loads distribution over the tunnel
  - Local cooling distribution over the tunnel
- Thermal impact from the tunnel wall

Distance (m)	Power (kW)	Distance (m)	Power (kW)
108	-4.6	1944	-5.6
216	-4.6	2052	-5.6
324	-4.6	2160	-8.6
432	-4.6	2376	-8.6
540	-4.6	2592	-8.6
648	-5.6	2808	-8.6
756	-5.6	3024	-8.6
864	-5.6	3240	-8.6
972	-5.6	3456	-8.6
1080	-5.6	3672	-8.6
1188	-5.6	3888	-8.6
1296	-5.6	4104	-8.6
1404	-5.6	4320	-8.6
1512	-5.6	4536	-8.6
1620	-5.6	4752	-8.6
1728	-5.6	4968	-8.6
1836	-5.6	TOTAL	-221.8



Ventilation FCC-ee: Other aspects

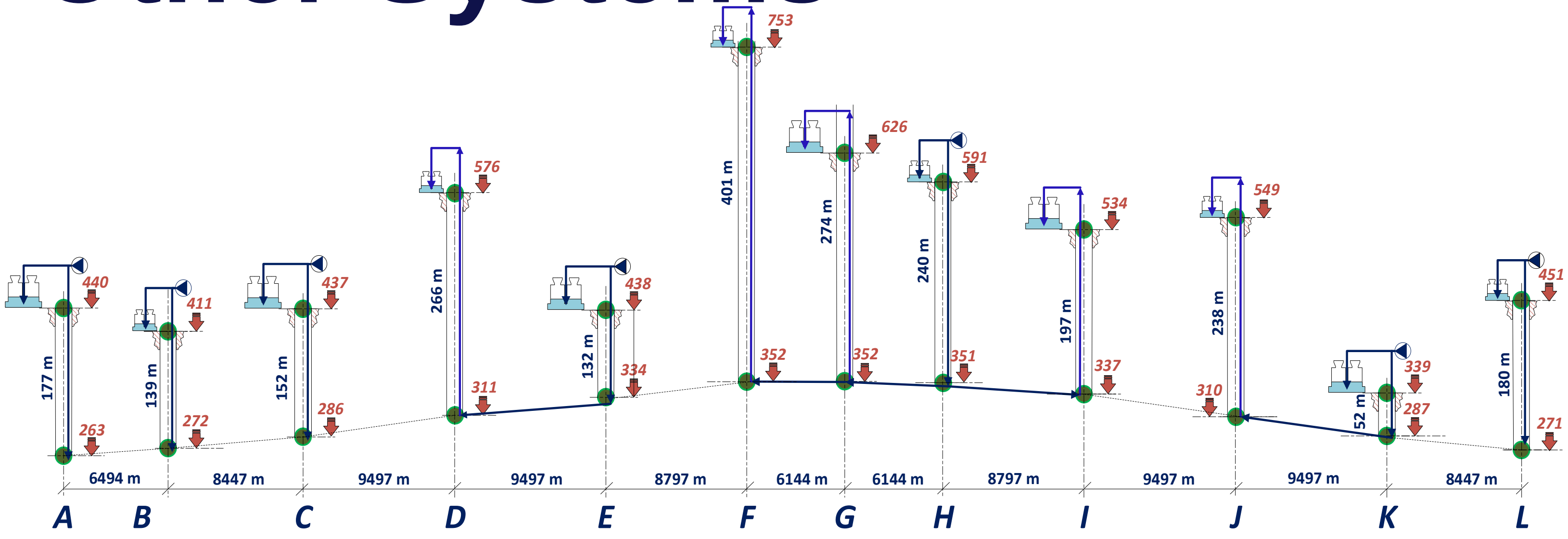
- Fresh air duct in the tunnel slab and distribution
  - Take-offs (Connection to distribution branches);
  - Motorised dampers for balancing of the fresh air circuit;
    - Powering and control systems;
  - Balancing method;
  - Air terminal devices.
- Emergency extraction duct
  - Material;
  - Mechanical design:
    - Negative pressure (avoiding buckling)
    - Thermal constraints (high and low temperatures)
      - Temperature in worst case scenarios
  - Motorised dampers for emergency extraction:
    - Reaction time vs evacuation time;
    - Powering and control systems.

Other Ventilation Systems

- Ventilation of the Experimental Caverns
- Ventilation of the RF areas in the underground
- Ventilation of the auxiliary areas
  - Connecting caverns
  - Alcoves
- Pressure cascade between zones
  - Sense and pressure difference between zones
  - Air locks location

Other Systems

- Sumps
  - Shaft depth;
  - Drain water flow



- Compressed air systems
  - Flow;
  - Pressure;
  - Quality:
    - Solid particulates, water and oil content.

CV needs

- ❑ CV Needs
  - ❑ Civil engineering :
    - ❑ Cooling and Ventilation Plants underground;
    - ❑ Needs in the cross sections:
      - ❑ Tunnel, RF caverns, shafts, surface galleries;
    - ❑ Needs in electrical alcoves;
    - ❑ CV Surface buildings;
    - ❑ Cooling Towers (different between FCC-ee and FCC-hh);
    - ❑ Buried pipes.
  - ❑ Electrical needs (Chillers, pumps, cooling towers, fans,…);
  - ❑ IT services.

Work Packages

Work Package Description

FUTURE CIRCULAR COLLIDER

INFRASTRUCTURE WPXX

TUNNEL VENTILATION SYSTEM

Abstract

This document describes the FCC Infrastructure Work Package. The objective of this WP was to identify the challenges, the showstoppers and look towards opportunities for Infrastructure breakthroughs and alternative solutions

Study the feasibility of the currently proposed ventilation system and study another alternative solution for the FCC-ee and FCC-hh

Prepared by :	*Checked by :*	*Approval Leader :*
Guillermo Peon (CERN) **Ingo Ruehl (CERN)**	(CERN) (CERN)	**Michael Benedikt** Michael.Benedikt@cern.ch **Frank Zimmermann** Frank.Zimmermann@cern.ch

Work Package Description

FUTURE CIRCULAR COLLIDER

INFRASTRUCTURE WPXX

FCC PRIMARY WATER COOLING

Abstract

This document describes the FCC Infrastructure Work Package. The objective of this WP was to identify the challenges, the showstoppers and look towards opportunities for Infrastructure breakthroughs and alternative solutions

Study the feasibility of the currently proposed primary cooling system and study another alternative solution for the FCC-ee and FCC-hh

Prepared by :	*Checked by :*	*Approval Leader :*
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- Other possible WP:
  - Demi water production and (re)filling options
  - Local air conditioning in the FCC-ee tunnel, ventilation of particular underground zones (RF zones, experimental areas, …), pressure cascade.
  - Sump systems
  - …

Next Steps

- Finalise Work Package Descriptions;
- Get needed data from users and other services;
- Write MS and Price Enquiries or Call for Tenders for consultants;
  - Selection criteria: Experience, Qualified Personnel, Software,…
  - Define deliverables:
    - What :
      - New design;
      - In depth design of an existing design;
      - Variants of an existing design;
    - When : Planning;
    - Why (justification) :
      - Calculations;
      - Previous experience;
      - Measurements.
- Analysis of Consultants' results and integration in our design.
- Installation time plan and cost estimate

Thank you
for your attention.