Future Circular Collider

Technical Infrastructure

Cooling and Ventilation in the FCC Tunnel

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(EN/CV)

FCC week 2023

06 / June / 2023

Outline

- Introduction;
- A reminder: Tunnel ventilation figures and concept;
- Ventilation: thermal aspects in an FCC sector;
  - Normal Operation;
  - Flushing;
- High Pressure losses for the Supply units;
- Simplifying regulation of the air supply dampers;
- Emergency extraction;
- Demi Water cooling in the FCC tunnel;
- Raw water distribution and firefighting water in the tunnel;
- Chilled water in the FCC tunnel;
- Next steps

Introduction

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,)**

Ventilation in FCC week 2022

Tunnel Ventilation

General Input data	
Cross section area	15.2 m^2
Sector length	11,396 m
Max. Temperature (running conditions)	32ºC (to be confirmed)
Max. dew point Temperature	12ºC (to be confirmed

Compartment Input data		
Number of Compartments	~~26~~ →	28 + 1/2
Compartment length	~~440 m~~ →	400
Volume Compartment	~~6,688 m^3~~ →	6080

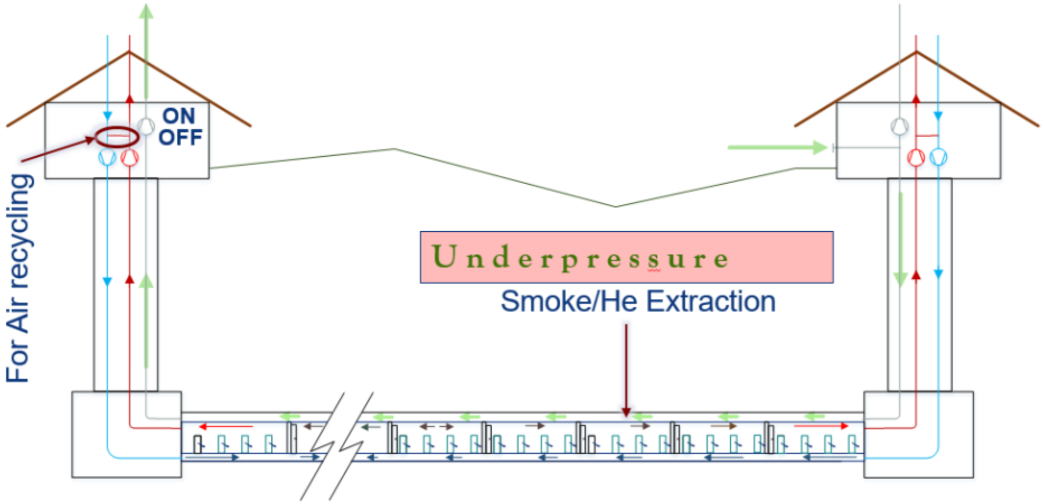
Ventilation parameters	
Normal operation air flow per sector	2 x 27,000 m^3/h
Flushing air flow (longitudinal) per sector	100,000 m^3/h
Air supply points per compartment	4
Air flow per supply point (normal operation)	~~520~~ → 474
Time to complete air renewal (flushing)	1.7 h
Maximum air speed (normal operation – flushing)	0.5 m/s – 1.8 m/s
Cooling capacity in normal operation for ΔT = 15 K per sector	271 kW

Tunnel Ventilation (Users' requirements)

- USER'S REQUIREMENTS (INPUT FOR CV)
  - Modes: Run, Flushing, Access;
  - Thermal loads to air from magnets, synchrotron radiation, electrical racks, cables, etc. ; (Run)
    - Location and value;
  - Air temperature constraints : maximum and minimum values (Run, Flushing, Access);
  - Maximum air speed (vibration) (Flushing);
  - Flushing mode:
    - Radiation rate at exhaust air and in the tunnel (HSE);
    - Delay between accelerator stop and access to the tunnel;
  - Air renewal rate, air quality requirements (Access);

Ventilation principle

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



Ventilation: thermal aspects in an FCC sector

Heat loads on air (kW)

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In underground areas

POINT	Cryogenics	RF	Experimental Areas	Power Converters	Ventilation UW	TOTAL
A			50	220	200	470
B				220		220
D			40	220	200	460
F				220		220
G			50	220	200	470
H	~~180~~ → 200	~~3,200~~ → 4600		220	200	~~3,800~~ → 5220
J			40	220	200	460
L	~~180~~ → 100	~~4,800~~ → 75		220	200	5,400 → 595

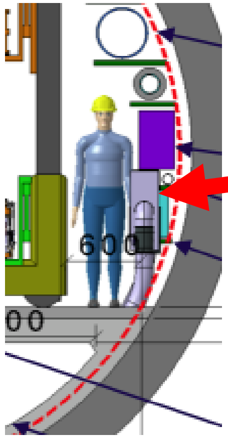
… and for EACH SECTOR

Magnets	Cables	Synchrotron radiation absorbers	TOTAL
352	1,763	250	2,364

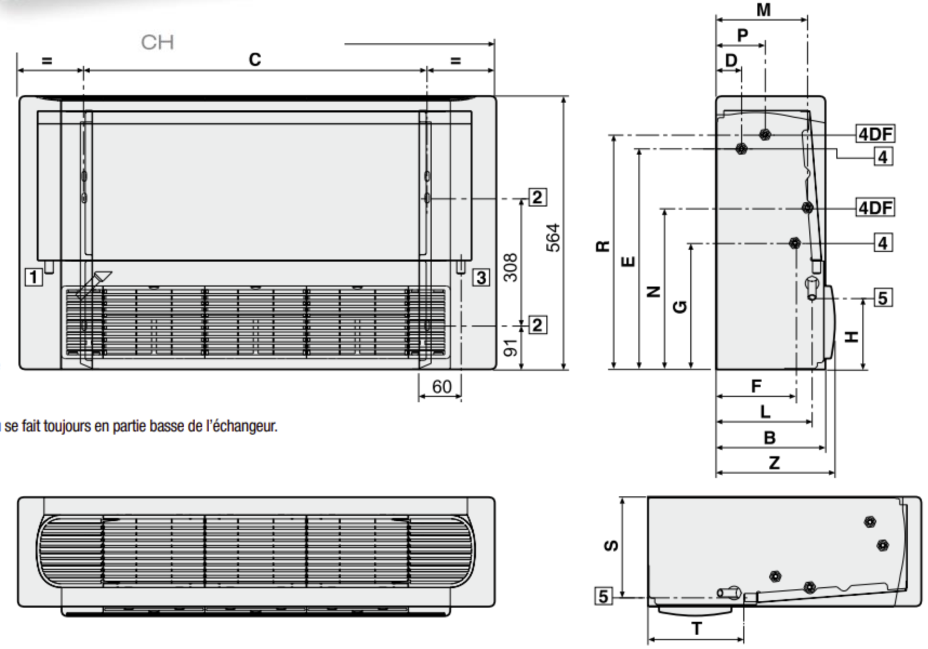
- For the sectors, we keep on having the 602 kW coming from Magnets and SR absorbers;
- The cables is still an issue but electrical people are working to reduce drastically the cable power dissipation:
  - Water cooled cables is an option?;
  - Water cooled cable trays?;
- Heat loss or gain from the walls not considered, temperature of the tunnel wall is unknown and depends on the location but there shouldn't be a big difference with the target air temperature;

Ventilation: thermal aspects in an FCC sector

- Local cooling for the remaining 331 kW per sector is needed;
- An example: Technibel TWN CH 06, 5 kW, max. depth 271 mm, 66 per sector
- Chilled Water: Isolated DN100 pipes from both sides of each sector
- CFD calculations to be done for detailed design to optimize the location of the fan coils



■ TWN - CH



1 : Espace nécessaire aux raccordements hydrauliques.
2 : Trous de fixation.
3 : Espace nécessaire aux raccordements électriques.
4 : Raccords hydrauliques batterie standard.
4DF : Raccords hydrauliques batterie additionnelle (système 4 tubes).
5 : Évacuation des condensats.

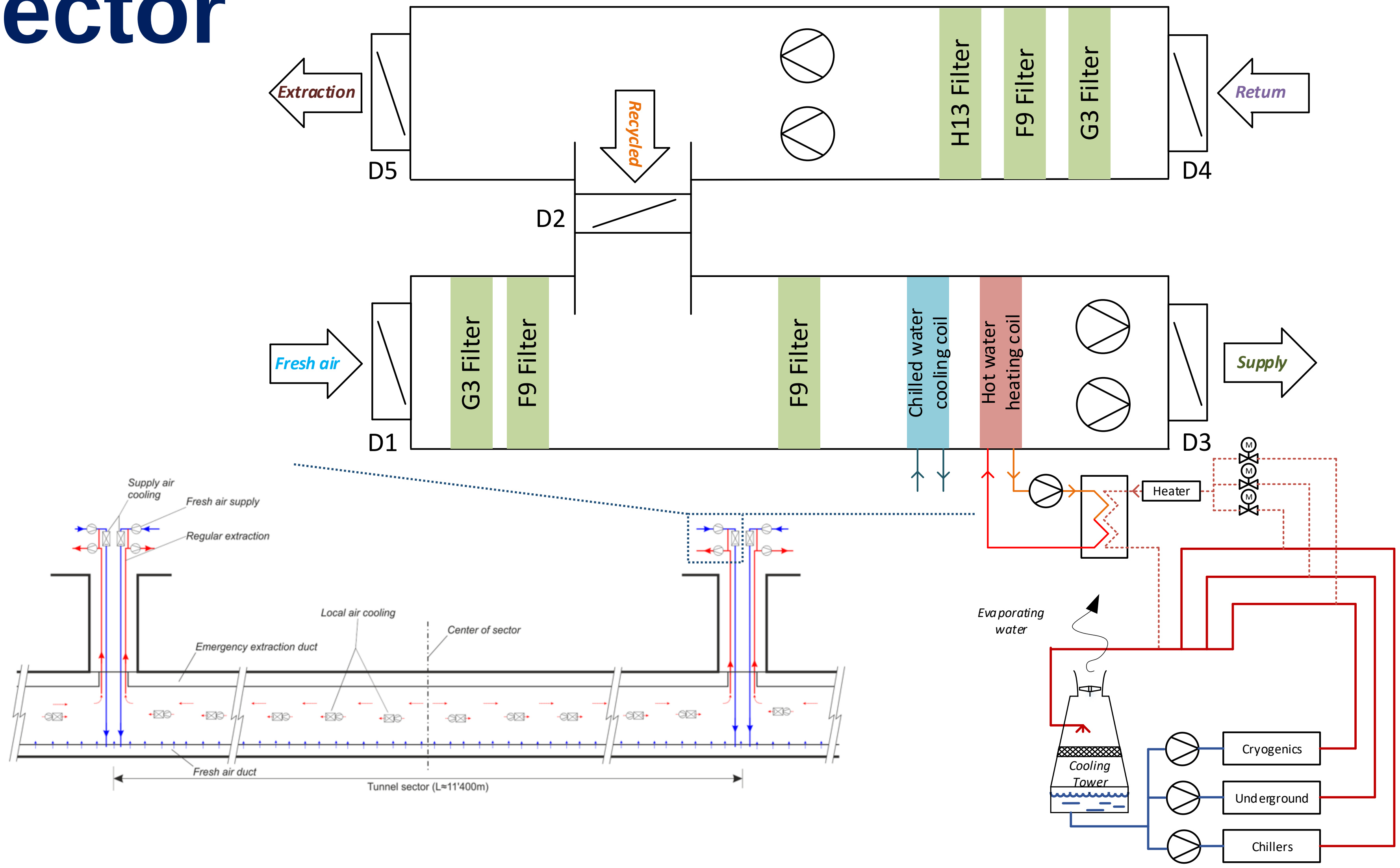
Pour les raccordements hydrauliques, l'entrée d'eau se fait toujours en partie basse de l'échangeur.

		TWN						
TAILLES		02	03	04	05	06	08	11
▼ Puissances frigorifiques en kW (1)								
Puissance totale 7/12°C	(GV)	2,09	2,93	4,33	4,77	6,71	8,71	10,95
	(MV)	1,81	2,38	3,27	3,87	5,27	6,78	8,77
	(PV)	1,45	1,76	2,51	3,17	3,97	4,49	6,97
Puissance sensible 7/12°C	(GV)	1,51	2,11	3,15	3,65	4,91	6,38	8,07
	(MV)	1,31	1,70	2,45	2,92	3,83	4,94	6,46
	(PV)	1,05	1,26	1,8	2,32	2,84	3,25	5,12
▼ Caractéristiques aérauliques (3)								
Débit d'air (m³/h) (PV/MV/GV)		211 / 271 / 344	241 / 341 / 442	361 / 497 / 706	470 / 605 / 785	570 / 771 / 1011	642 / 1022 / 1393	1010 / 1317 / 1850
Pression statique disponible maximum (MV/GV)		40/60 Pa		40/60 Pa				
▼ Caractéristiques hydrauliques & raccordements								
Débit d'eau à puissance maxi en froid (m³/h)		0,36	0,50	0,74	0,82	1,15	1,49	1,88

(mm)	A	B	C	D	E	F	G	H	L	M	N	P	R	S	T	Z
TWN 02	774	226	498	51	458	163	263	149	198	187	335	99	486	208	198	246
03	984	226	708	51	458	163	263	149	198	187	335	99	486	208	198	246
04-05	1194	226	918	51	458	163	263	149	198	187	335	99	486	208	198	246
06-08	1404	251	1128	48	497	185	259	155	220	195	348	120	478	234	208	271
11	1614	251	1338	48	497	185	259	155	220	195	348	120	478	234	208	271

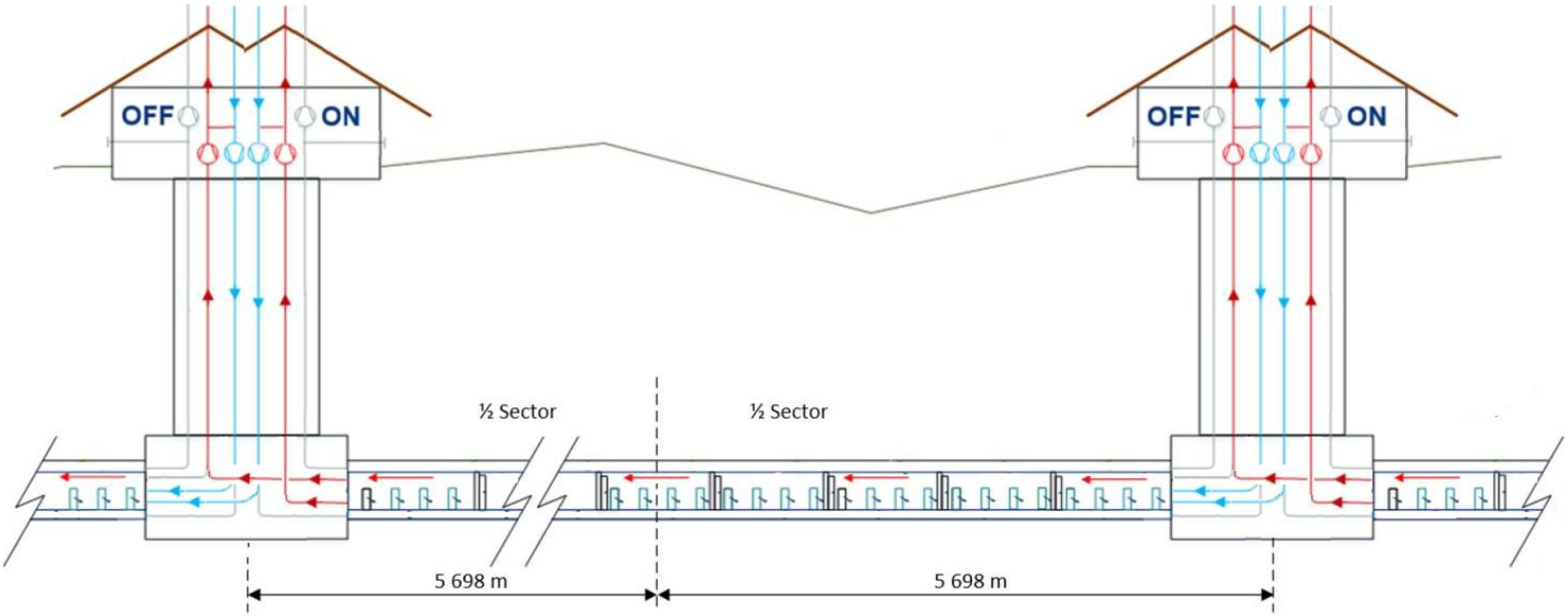
From: *Unité terminale ventilo-convecteurs TWN.pdf (technibel.com)*

Ventilation: thermal aspects in an FCC sector

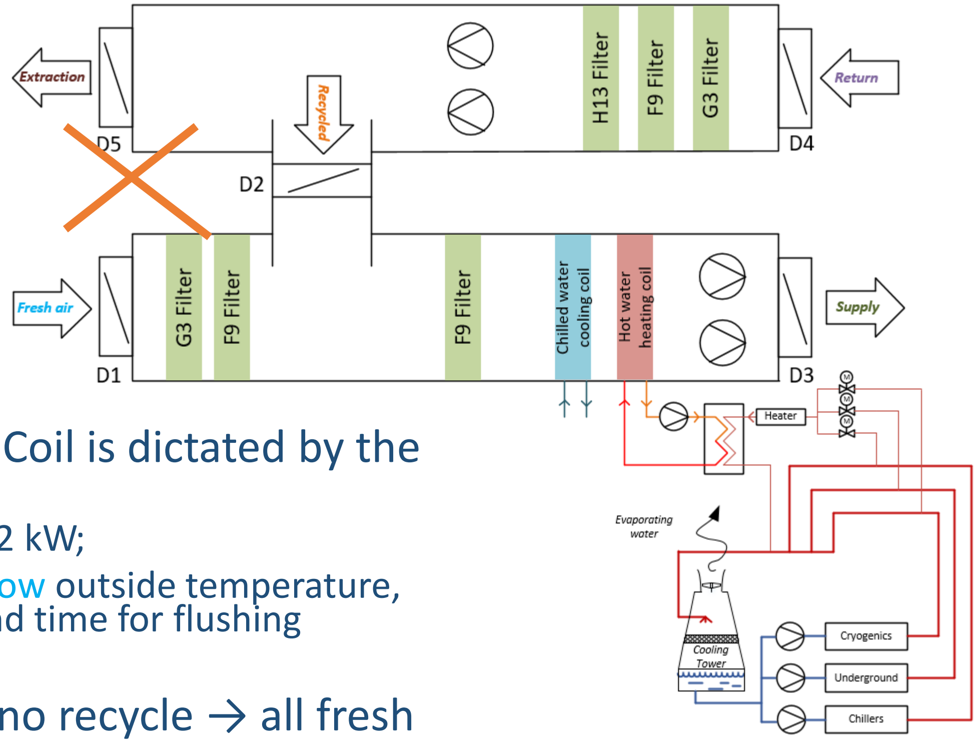


	RUN	FLUSHING	ACCESS
D-1	Modulating	Fully Open	Modulating
D-2	Modulating	Fully Closed	Modulating
D-3	Fully Open	Fully Open	Fully Open
D-4	Fully Open	Fully Open	Fully Open
D-5	Modulating	Fully Open	Modulating

Ventilation: thermal aspects in an FCC sector, Flushing



Ventilation: thermal aspects in an FCC sector, Flushing



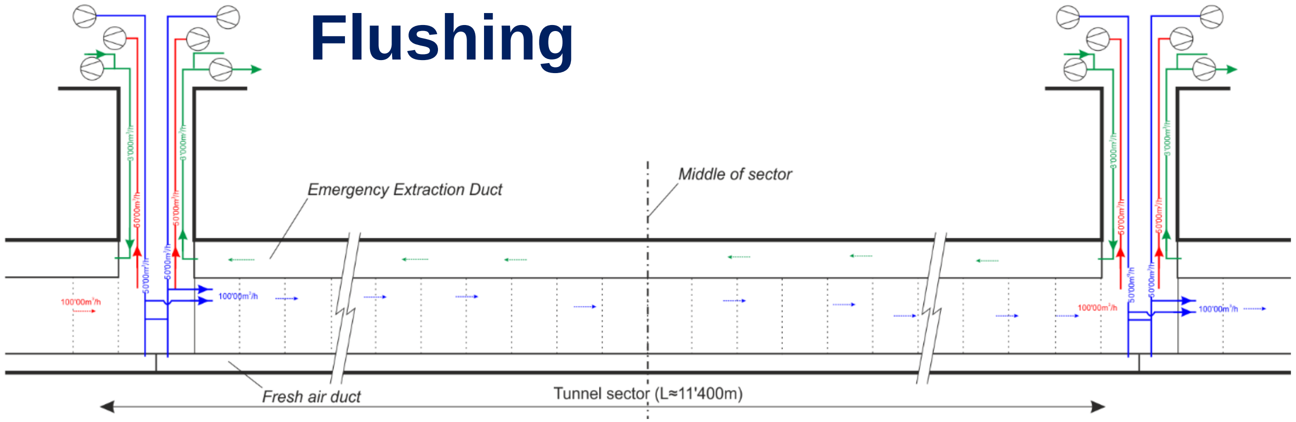
	RUN	FLUSHING	ACCESS
D-1	Modulating	Fully Open	Modulating
D-2	Modulating	Fully Closed	Modulating
D-3	Fully Open	Fully Open	Fully Open
D-4	Fully Open	Fully Open	Fully Open
D-5	Modulating	Fully Open	Modulating

- The power of the Heating Coil is dictated by the Flushing needs:
  - 50,000 m^3/h, DT=15K, 262 kW;
  - But in case of extremely low outside temperature, air flow rate decreases and time for flushing increases to keep T=15°C
- During Emergency mode, no recycle → all fresh air needed, max DT=20K
- In Normal mode (run or access):
  - Free cooling,
  - Minimum fresh air required will be determined based on the readings from the air quality sensors

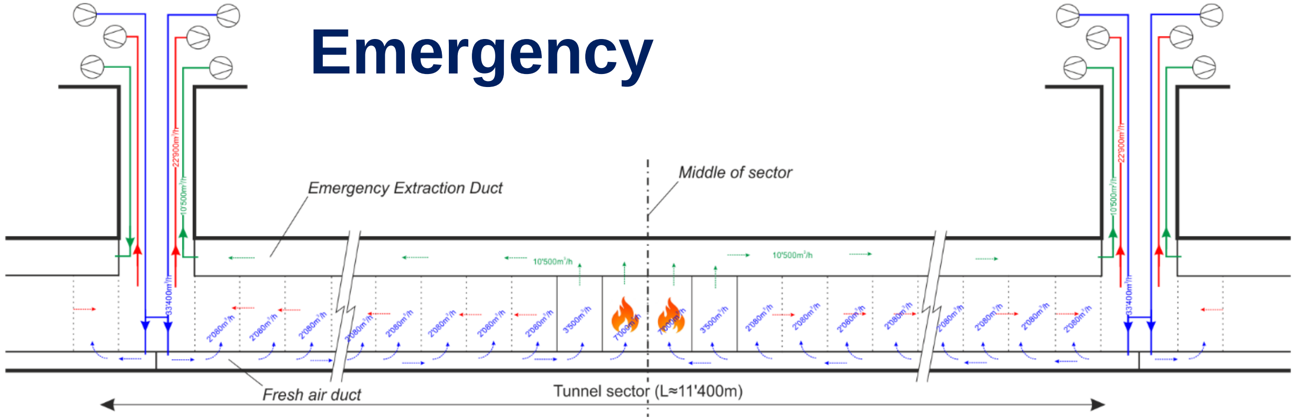
Mode	Variable	T (°C)
Run	Max. return T	32
	Min. Supply T	17
Access	Max. T in summer	26
	Min. T in winter	18
Flushing	Min. supply T in winter	15
	Max. supply T in summer	26
Emergency	Min. supply T in winter	15
	Max. supply T in summer	26
All modes	Max dew point T	12

High Pressure losses for the Supply units

Flushing



Emergency

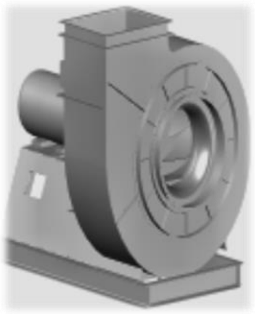


Gesamtdruck / Total pressure 5000 Pa

Volumen-strom	Ventilator-größe	Dreh-zahl	Wellen-leistung	Motor-leistung	Schall-druck
Volume flow rate	Fan size	Speed	Shaft power	Motor power	Sound pressure
m³/h	DN	min^{-1}	kW	kW	dB(A)
400	HRZ 125	2827	1,1	1,5	79-1 m
500	HRZ 125	2838	1,2	1,5	79-1 m
630	HRZ 125	2838	1,4	2,2	79-1 m
800	HRZ 125	2842	1,6	2,2	75-1 m
1000	MRZ 180	2863	2,3	3,0	79-1 m
1250	MRZ 180	2863	2,6	3,0	79-1 m
1600	MRZ 180	2871	3,0	4,0	76-1 m
2000	PRZ 250	2892	4,3	5,5	84-1 m
2500	PRZ 250	2900	4,9	7,5	84-1 m
3150	PRZ 250	2900	5,6	7,5	84-1 m
4000	PRZ 250	2921	7,7	11,0	79-1 m
5000	LRZ 355	2927	9,1	11,0	84-1 m
6300	LRZ 355	2927	11,0	15,0	80-1 m
8000	RNN 450	2931	15,3	18,5	89-1 m
10000	RNN 450	2948	17,9	22,0	
12500	RNN 500	2948	22,7	30,0	
16000	PRZ 560	1474	27,3	37,0	
20000	LRZ 710	1474	37,1	45,0	
25000	LRZ 710	1478	42,3	55,0	
31500	LRZ 800	1478	50,7	75,0	
40000	LRZ 900	1480	71,0	90,0	92-1 m
50000	LRZ 1000	987	81,1	110,0	86-1 m
63000	LRZ 1120	990	112,1	132,0	88-1 m
80000	LRZ 1250	990	131,9	160,0	93-1 m
100000	PRZ 1000	990	170,4	200,0	90-1 m

WITT & SOHN IGW Ventilatoren

https://www.wittfan.de/

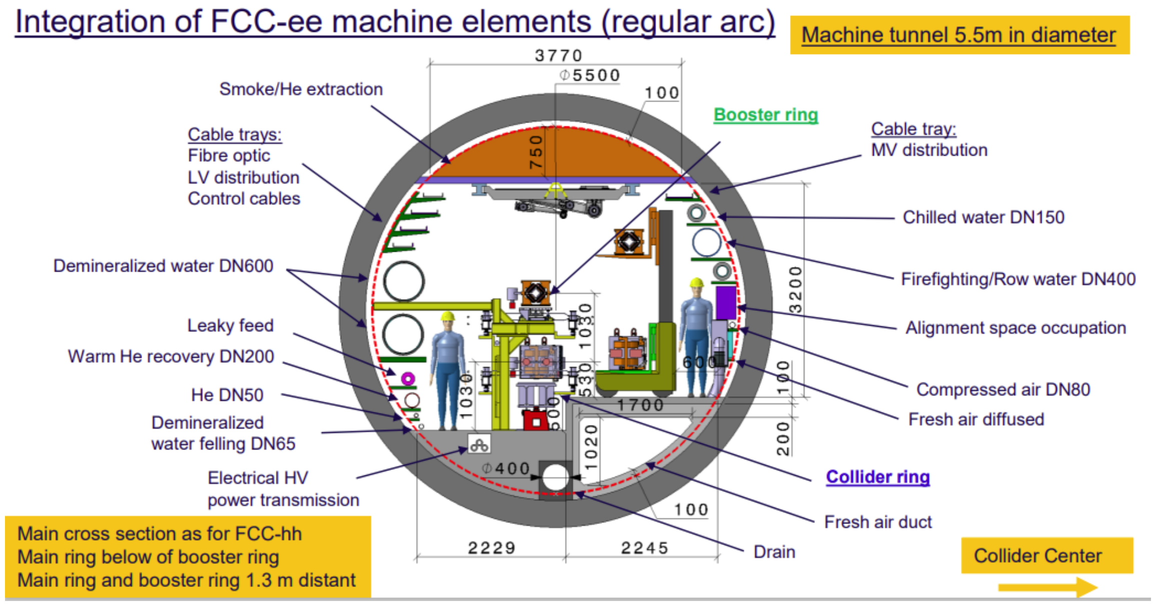


Inlet diameter	180 – 1.400 mm
Impeller diameter	280 – 2.240 mm
Pressure range	800 – 8.000 Pa
Volume flow rate range	100 – 200.000 m³/h

AIR FLOW RATE & PRESSURE DROP					
		Supply		Extraction	
	Air flow rate (m³/h)	DP Ducts (Pa)	DP In AHU elements (Pa)	Ducts (Pa)	In AHU elements (Pa)
Run or Access	27,000	1520	Around 1800-2100 Pa	570	Around 800-1200 Pa
Flush	2 x 50,000	1800		1620	
Emergency	36,708	3140		NA	NA
Emergency Duct	2 x 13,500	NA	NA	430	NA

Simplifying regulation of the air supply dampers

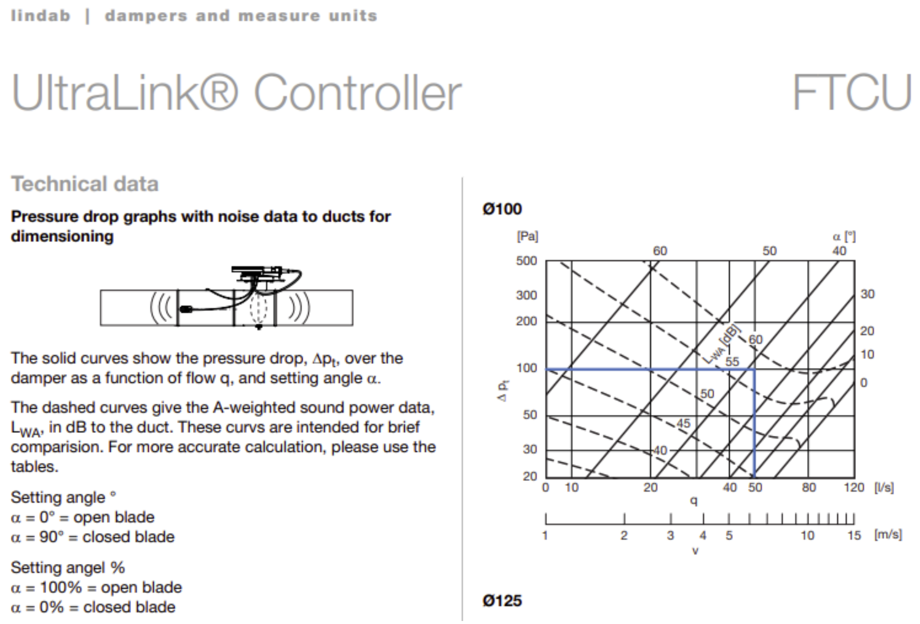
- Large number of dampers in a sector for:
  - Air supply Run and Access Modes
  - Air supply for extra fresh air in case of Smoke Detection
  - For Emergency Extraction
- Powered by compressed air and cabled (rad hard) or wifi signal is a plausible option



	Total per sector	Controlled from each extreme end of a sector	Controlled per each of the 7 Alcoves
Dampers for fresh air normal ventilation	4*28.5 + 7 * 2 = 128	8	14+2
Dampers for extra fresh air in case of emergency	128	8	14+2
Dampers for emergency extraction duct	128	8	14+2
TOTAL number of Dampers	**384**	**24**	**48**

Simplifying regulation of the air supply dampers

- To maintain the same flow rate as in Normal mode during an Emergency Situation in the non-affected compartments:
  - Regulating dampers with prefixed positions according to the smoke-affected compartments imply more than 40 prefixed positions per damper -> big complexity for the control system or
  - Flow measurements for each damper → big complexity, risk of unstable systems
  - Pressure independent Variable Air Volume (VAV), autonomous system that can maintain a constant flow rate -> risk of instability


lindab | dampers and measure units

UltraLink® Controller FTCU

Technical data

Pressure drop graphs with noise data to ducts for dimensioning

The solid curves show the pressure drop, Δp_t, over the damper as a function of flow q, and setting angle α.

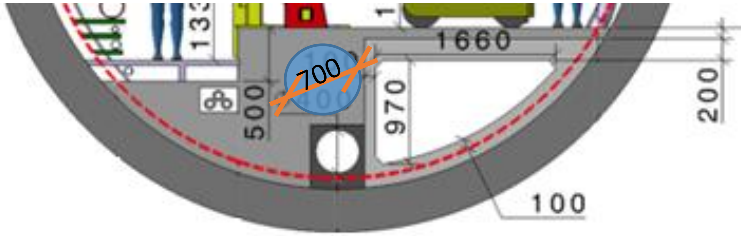
The dashed curves give the A-weighted sound power data, L_{WA}, in dB to the duct. These curvs are intended for brief comparision. For more accurate calculation, please use the tables.

Setting angle °
α = 0° = open blade
α = 90° = closed blade

Setting angel %
α = 100% = open blade
α = 0% = closed blade

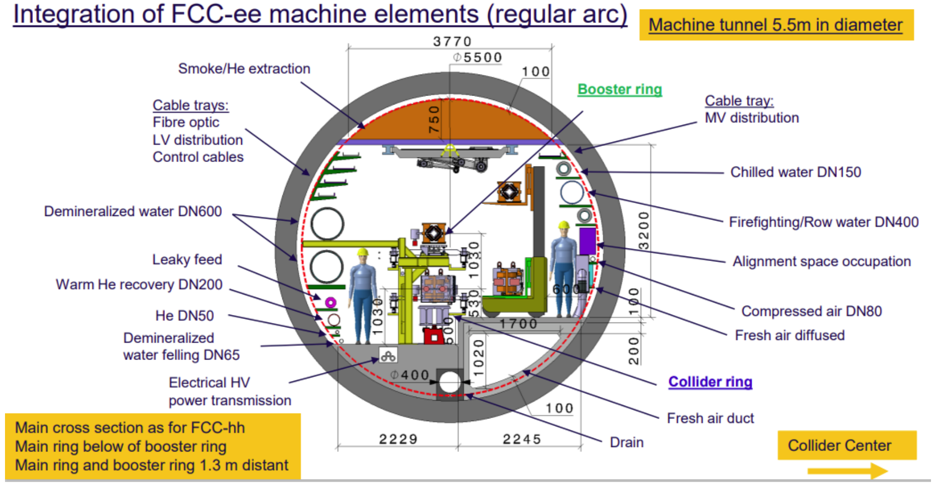
Ø100

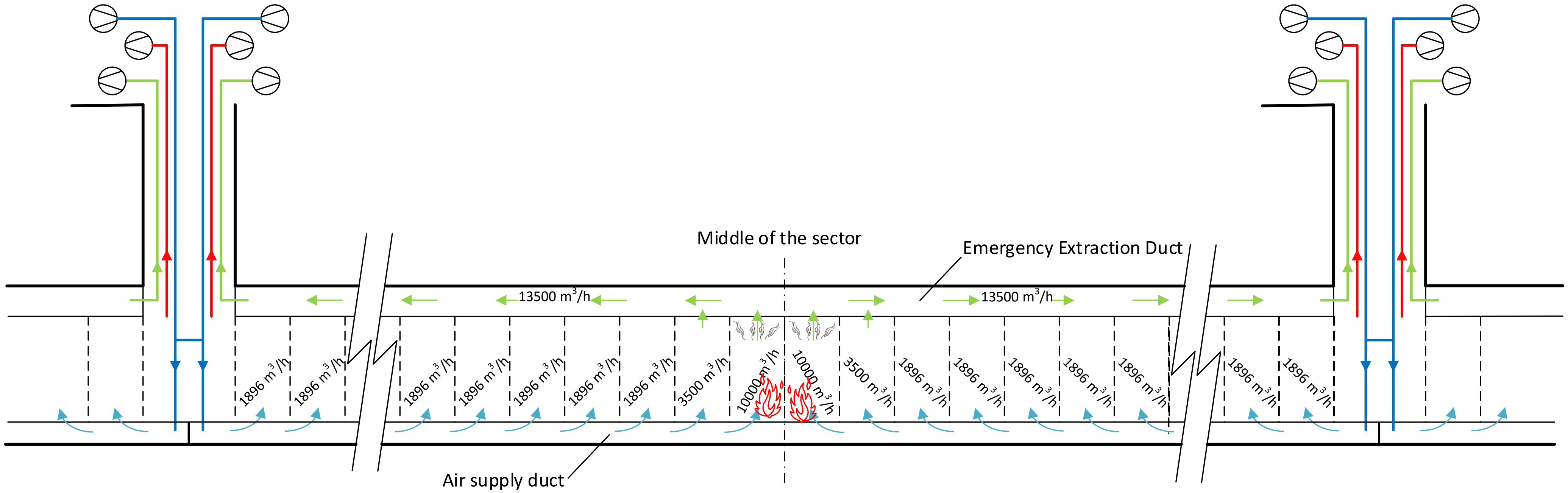
- Other options:
  - A parallel passage in the slab for emergency air supply only → Civil Engineering additional cost to be quantified;
  - Change the aperture of the dampers to a so-called *emergency position*, independent from the affected compartment(s):
    - Easy solution (only two prefixed positions);
    - But the air flow rate different for each situation. Nevertheless it can be estimated to assess this proposal;
  - Eliminate ventilation of the unaffected compartments



Emergency Extraction Duct

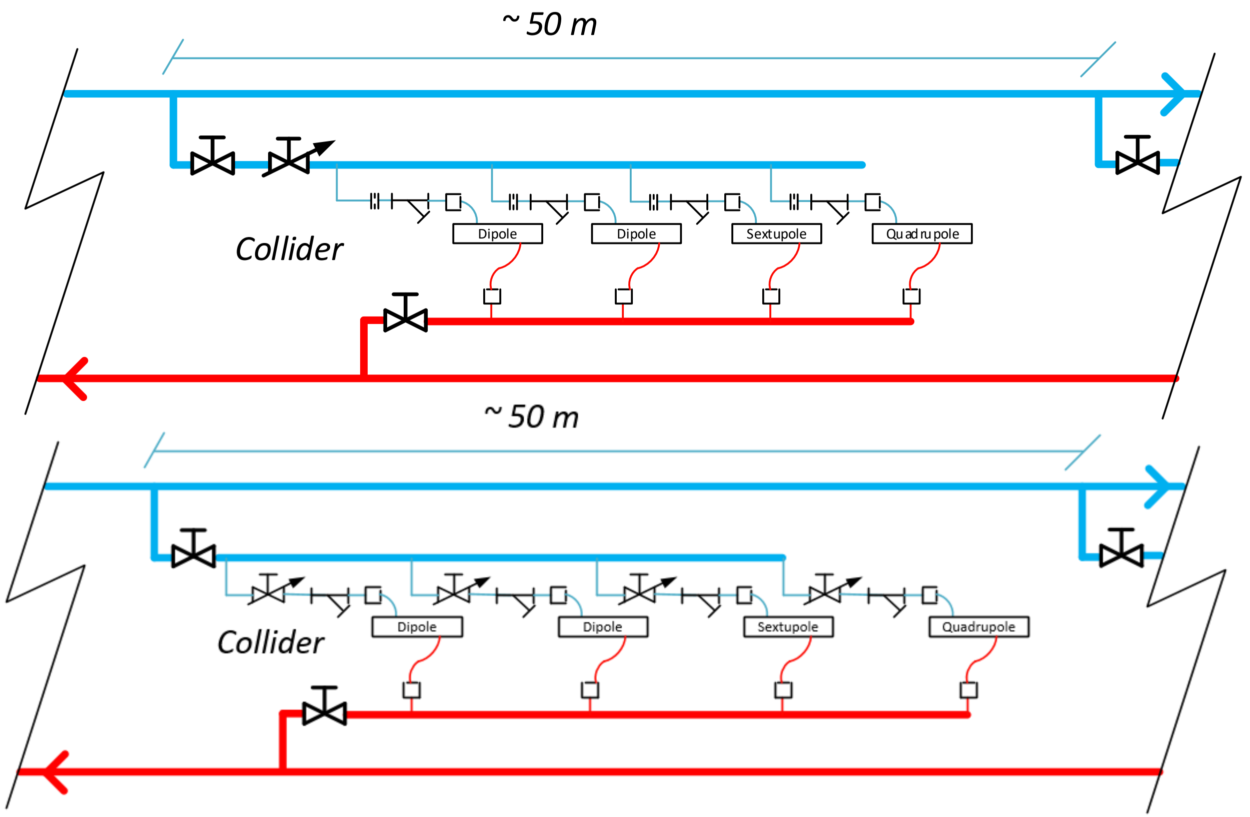
- Smoke management limited by the fresh air supply to:
  - 2 compartments, 10,000 m^3/h.
  - 2 adjacent compartments 3,500 m^3/h
- Smoke / He extraction foreseen for Helium leak management (22,000 m^3/h per side)

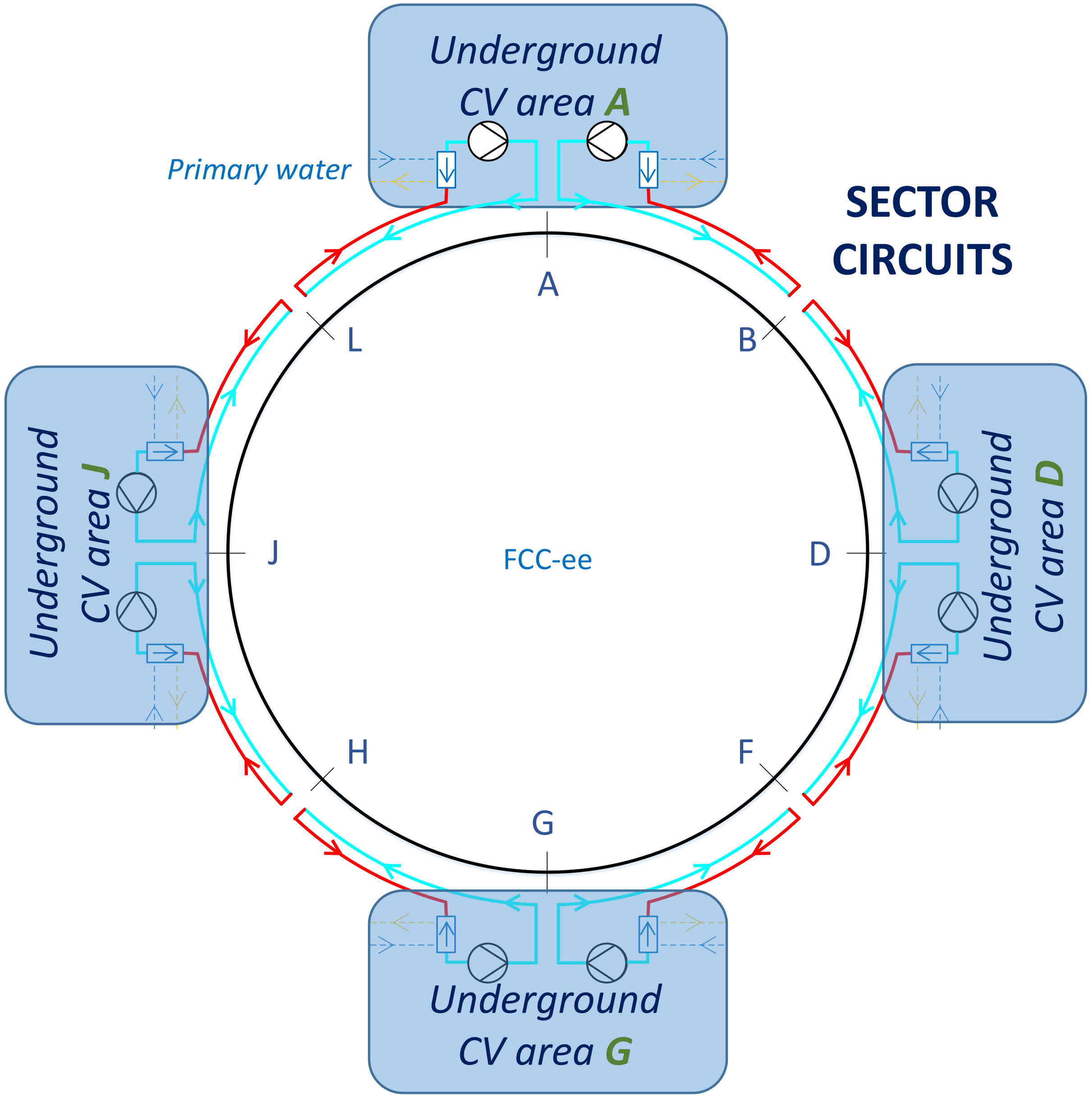




Demi Water cooling in the FCC tunnel

- Decreasing diameter; DN550, 5km DN400, 4km DN200, 2km
- Manifolds every ~ 50 m for Collider, Booster and SR absorbers for modularity, prefabrication, easy isolation of elements. In the example, girder with one sextupole.





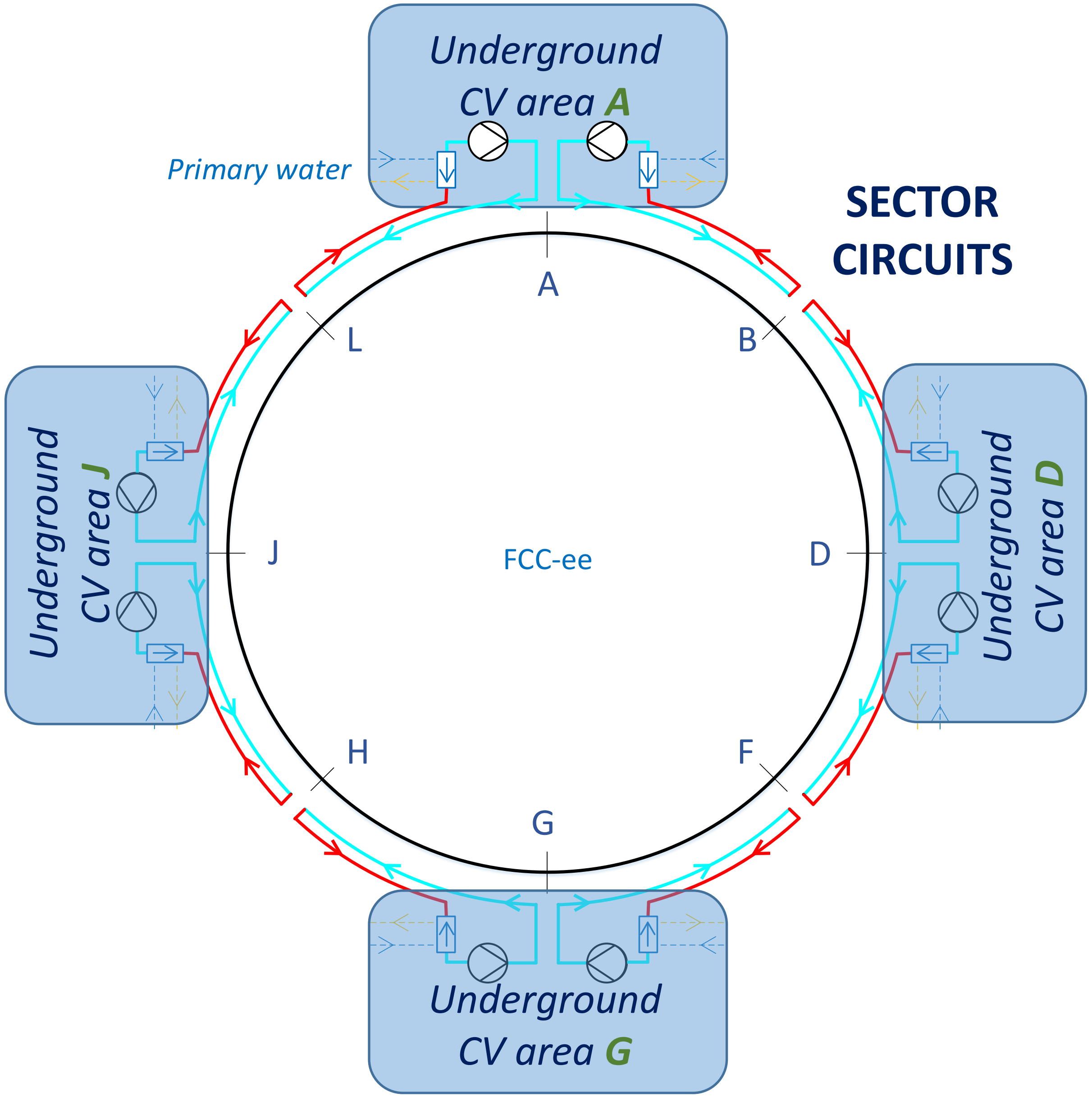
Demi Water cooling in the FCC tunnel

FCC-ee COOLING POWER NEEDS FOR A SECTOR (MW)				
	Magnets	Alcoves	Synchrotron Radiation Absorbers	TOTAL
Heat Load per Sector	~~6.6~~ → 7.1	0.9	12.5	~~20~~ → 20.5

Including Booster

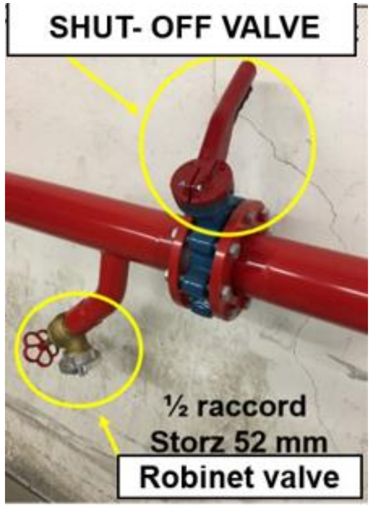
For a DT of 20 K -> 887 m^3/h

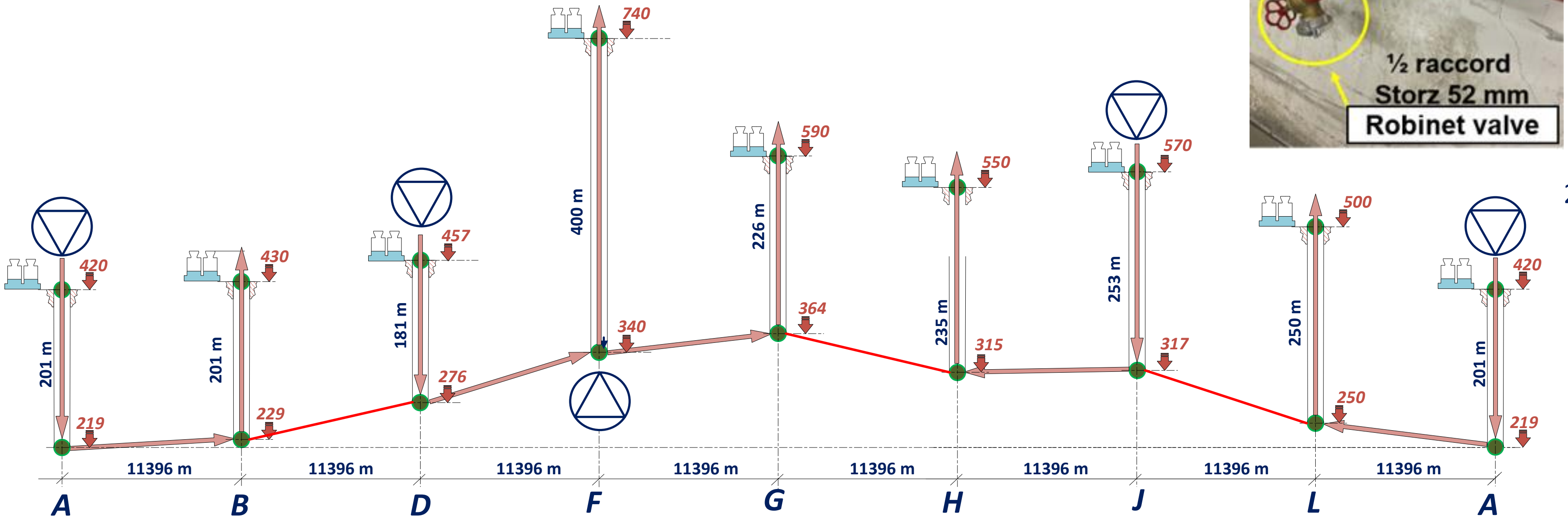
Magnets	No. Magnets/sector	Heat load/sector (MW)
Collider Dipoles	710	1.256
Collider Quadrupoles	362	1.256
Collider Sextupoles	584	3.875
Booster Dipoles	736	0.0332
Booster Quadrupoles	368	0.3921
Booster Sextupoles	396	0.2963
TOTAL	3156	7.11

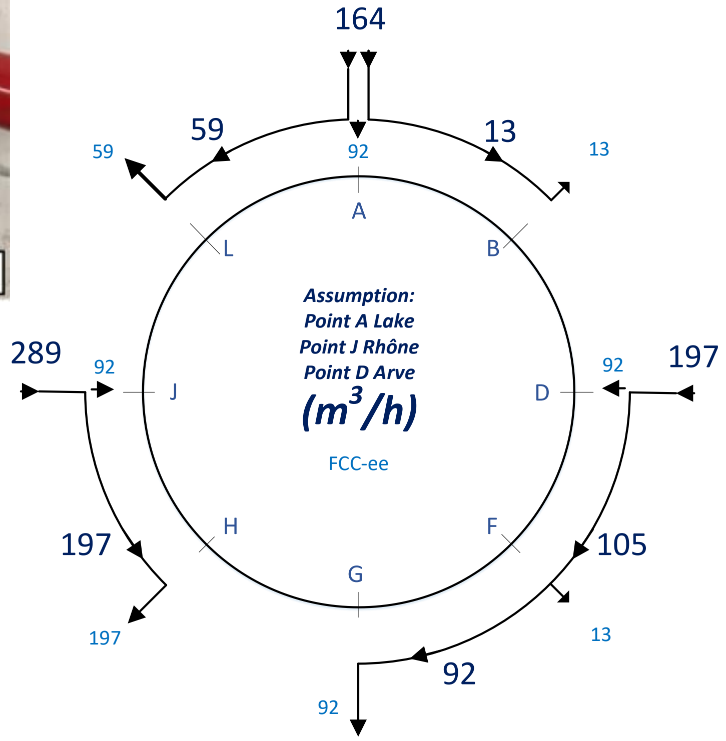


Raw water distribution and firefighting water in the tunnel

- All sectors except for BD, GH and JL have raw water pipes in the tunnel
- Dedicated firefighting pipes to be installed in BD, GH, and JL;
- High pressure ratings (PN40 and PN63) needed
- One booster pump needed at point F underground
- One storz connection evey 80 m → 143 per sector

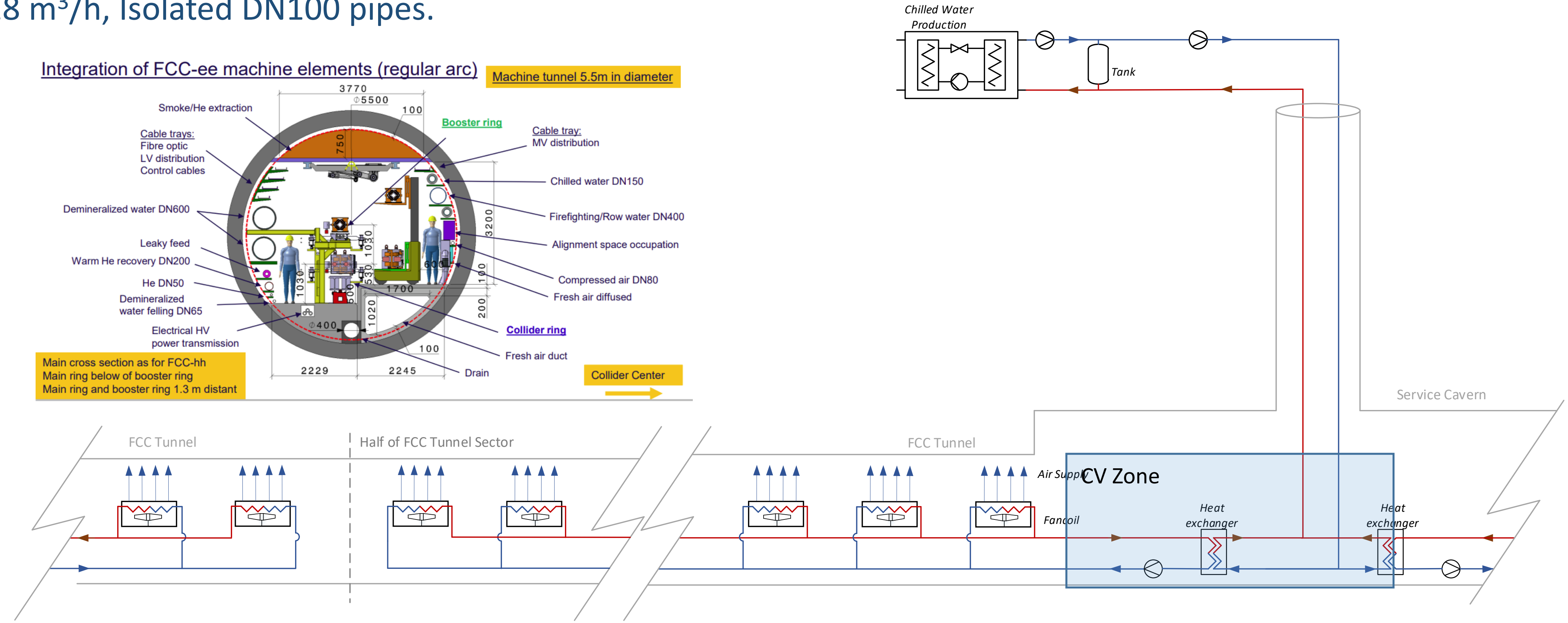






Chilled water in the FCC tunnel

- Two *half sectors* served from each Point;
- A heat exchanger at the CV zone at the bottom of each technical shaft;
- Around 33 Fan Coil Units supplied per each sector endpoint (165 kW), 28 m^3/h, Isolated DN100 pipes.



Conclusions and next steps

- The cooling and ventilation strategy for the FCC tunnel has been validated by two Engineering Consulting Firms;
- Thermal loads and geometry are evolving but at a slow pace now;
- Air supply to the tunnel needs high pressure fans but off-the-shelf industrial fans can cope with our requirements;
- Power consumption optimised by heat recovery and recycling;
- Search for further optimisation in terms of energy savings, space occupancy, costs and reliability;
- Prepare documentation for ESPP.

Thank you
for your attention.