Transport and Handling Considerations for the FCC

Ingo Rühl / CERN - EN-HE

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Washington D.C., 23-27 March 2015

Topics

- General issues
- FCC geographical data
- Vertical handling aspects
  - Lifts
  - Cranes
- Tunnel transport aspects
  - Automatic guided vehicles (AGVs)
- Conclusion

General Issues
Need to consider all transport and handling phases

- Delivery of components
- Assembly
- Test
- Storage (just on time?)
- Transfer to shaft (road transport)
- **Surface** ⟺ **Underground transfer (crane or lift)**
- Loading underground
- **Transport along tunnel**
- Unloading / Transfer onto supports
- Removal for repair

➢ Integrate transport and handling design requirements into equipment and infrastructure design as early as possible.

FCC Geographical Data - Option 1a (93km)

Alignment | **Shaft Tools**

Choose alignment option

93km quasi-circular

Tunnel depth at centre: 299mASL

Gradient Parameters

Azimuth (°): -15

Slope Angle x-x(%): .5

Slope Angle y-y(%): 0

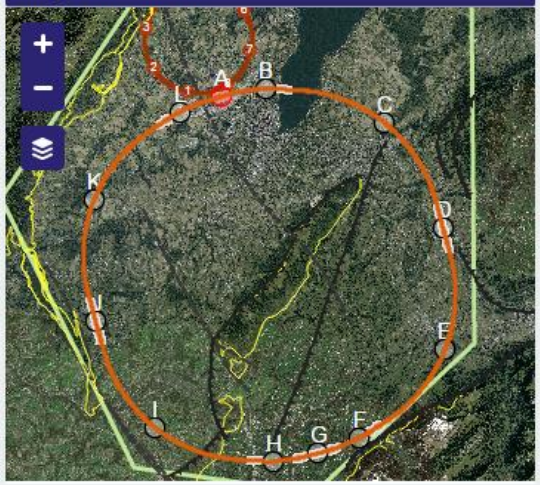
CALCULATE

Alignment centre

X: 2499812 Y: 1106889

LHC Intersection	CP 1	CP 2
Angle		
Depth	586m	587m

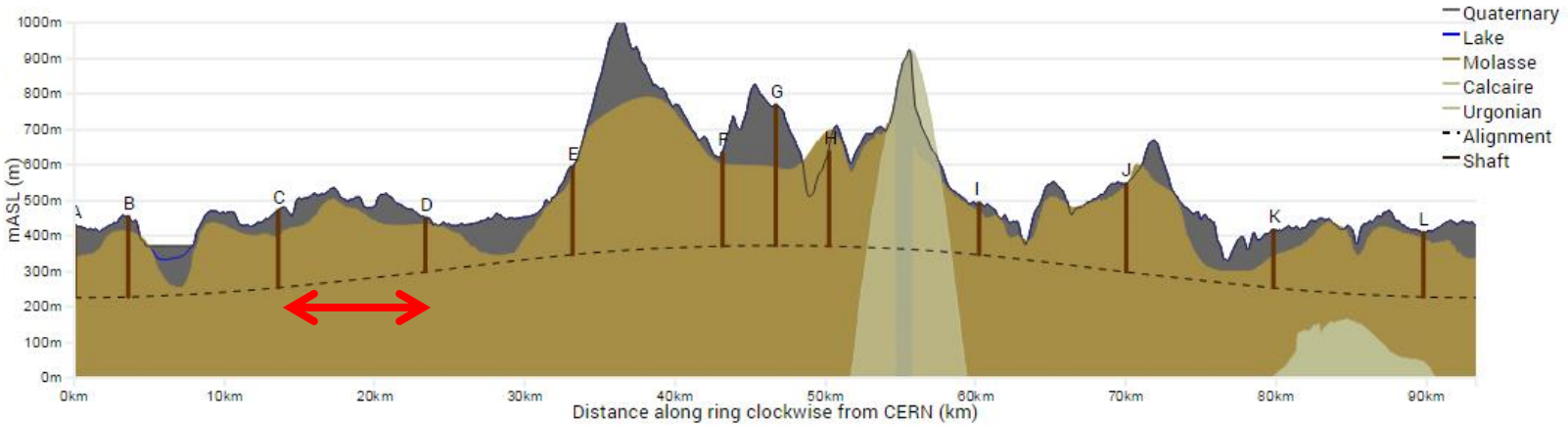
Alignment Location



Geology Intersected by Shafts | **Shaft Depths**

Point	Actual	Min	Max	Quaternary	Molasse	Urgonian	Calcaire
	Shaft Depth (m)			Geology (m)			
A	203		204	93	111	0	0
B	226		224	42	185	0	0
C	218		217	75	143	0	0
D	153	0	154	19	134	0	0
E	247	3	249	24	223	0	0
F	262	1	269	32	230	0	0
G	396	2	393	177	220	0	0
H	266	1	274	0	325	0	0
I	146	1	144	26	120	0	0
J	248		251	6	242	0	0
K	163		159	76	87	0	0
L	182		184	17	165	0	0
Total	2711	26	867	586	2184	0	0

Alignment Profile



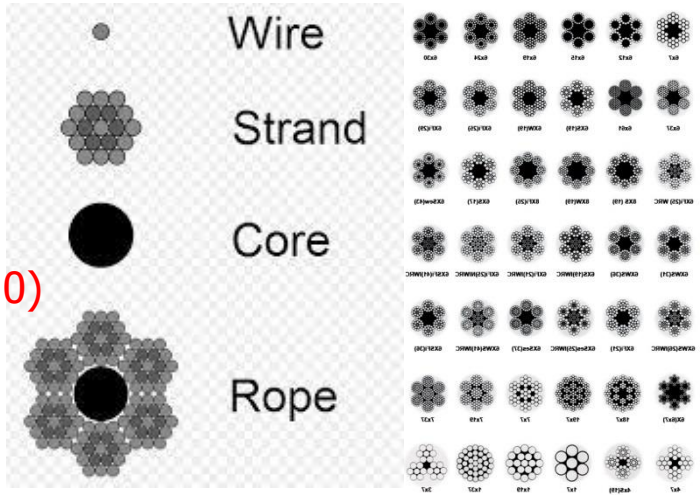
Geology Intersected by Tunnel

Wire Ropes – Safety Factor

Safety Factor: Ratio strength of rope / working load
wire rope strength 10,000 pounds / working load 2,000 pounds → safety factor 5

Safety Factor depends not only on the loads applied, but also on:

- speed of operation;
- the acceleration and deceleration;
- the length of rope;
- number, size and location of sheaves and drums (bending radius / forces);
- the type of fittings used for securing the rope ends;
- the factors causing abrasion and corrosion…

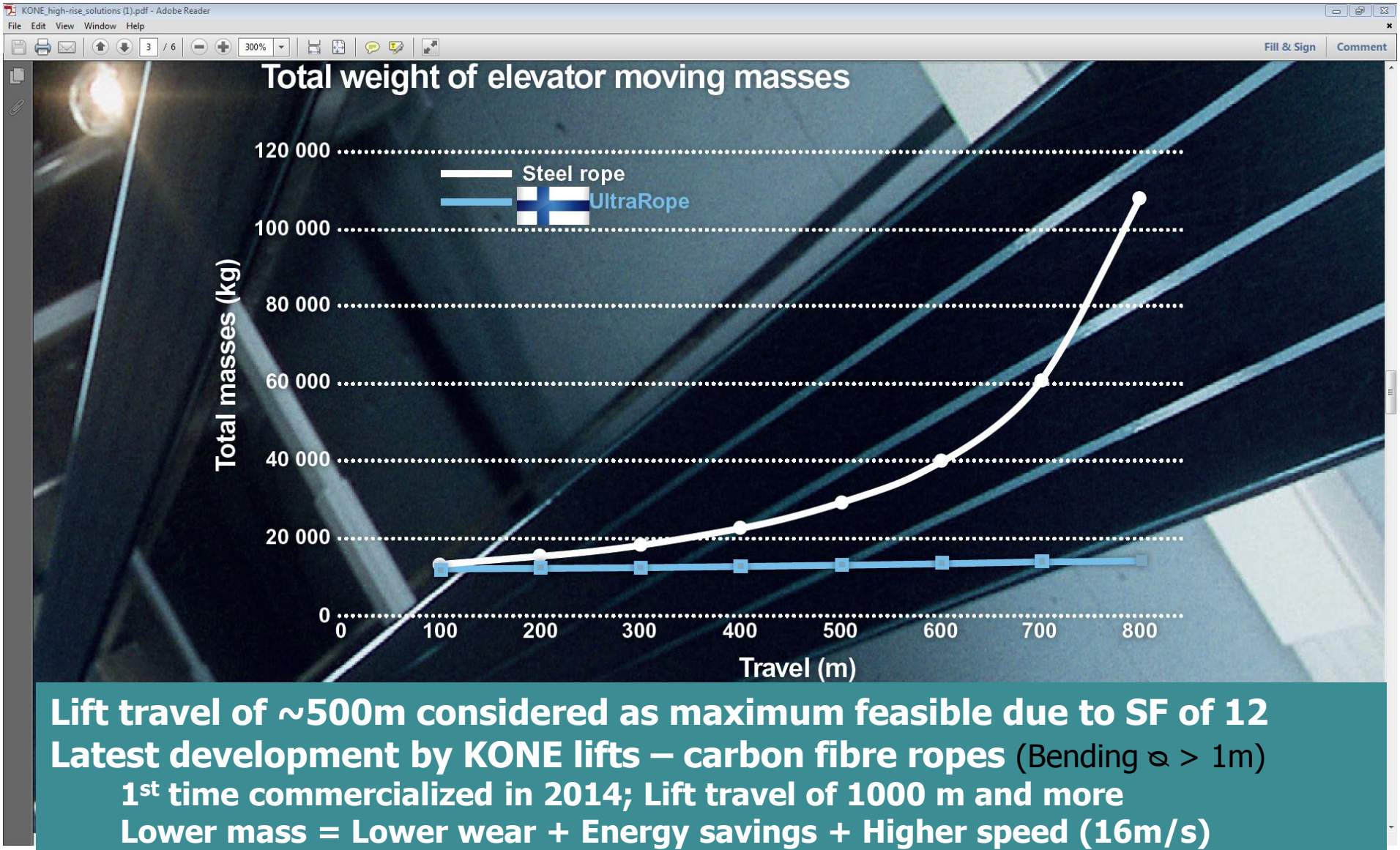


Safety Factors (only a guide)

- Miscellaneous Hoisting Equipment 5 to 6
- LIFTS 12 (US + Japan 10)
- Mine Shafts 8.0 for depths to 500ft.
  - *7.0 for depths 500-1000ft.*
  - *6.0 for depths 1000-2000ft.*
  - *5.0 for depths 2000-3000ft.*
  - *4.0 for depths 3000ft. and more*

http://www.seile.com/

Wire Ropes for Lifts



Lift travel of ~500m considered as maximum feasible due to SF of 12

Latest development by KONE lifts – carbon fibre ropes (Bending ⌀ > 1m)

- **1st time commercialized in 2014; Lift travel of 1000 m and more**
- **Lower mass = Lower wear + Energy savings + Higher speed (16m/s)**

FCC Shaft Lifts

- Lifts with standard steel wire ropes should still do for shaft depths of 400m but
  - Will require fix landing systems for 3t lift due to rope extension/flexibility when loading/unloading lift cabin
  - Lift redundancy a must (i.e. one 3t/35people and one 350kg/4people lift operating next to each other in the same shaft)
  - Higher lift speed (min. 5 m/s for 3t lift and 10 m/s for 350kg lift) requires more pit depth and top clearance
  - n° of people in tunnel depends on evacuation means → lift capacity and speed
  - ➢ Will not be possible to simply take over the shaft, pit & machine room dimensions from LHC!
- By the time of the FCC construction carbon fibre cables in lifts could have become a standard …

FCC Shaft Cranes

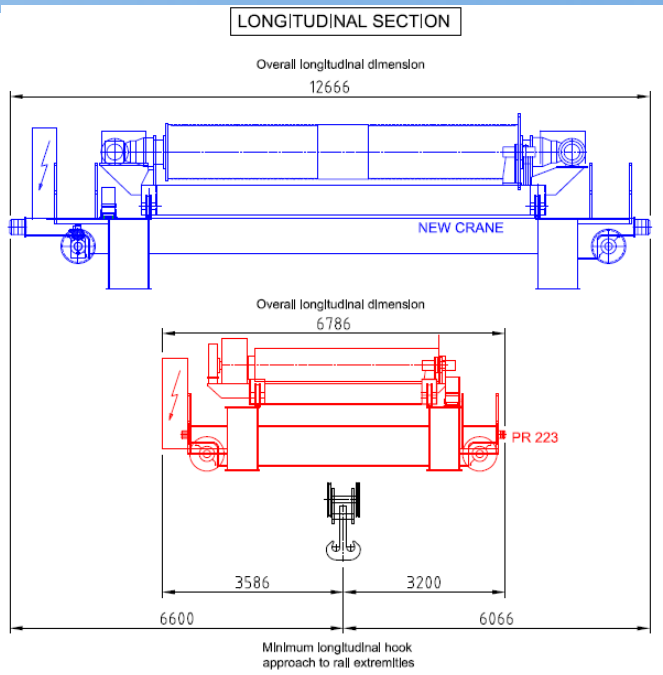
- Crane lifting heights of ~3000m currently feasible and in operation - offshore and mining industry

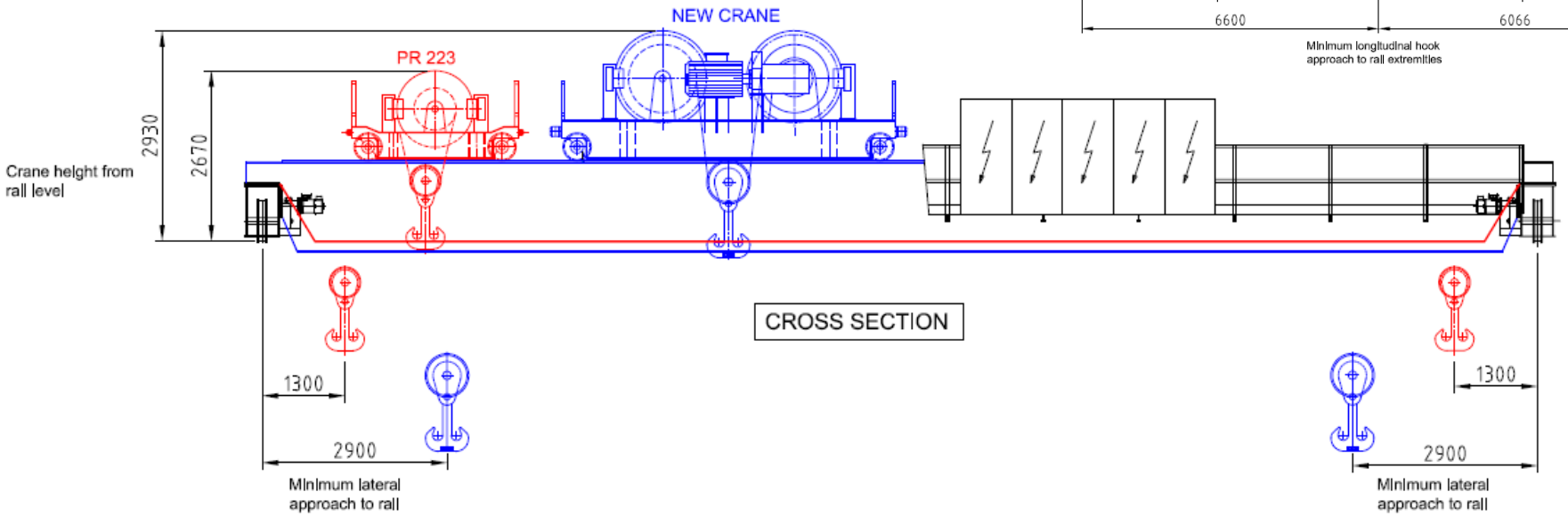
➢ Lifting heights of 400m is in itself is not a problem but problematic with standard EOT crane layout

  - Twin rope drum system → major impact on bldg. height and width
  - Or multiple layers of ropes … normally not applied on EOT cranes
  - Push and pull system combined with strand jack lifting systems as applied for CMS also remains an option for handling heavy detector components

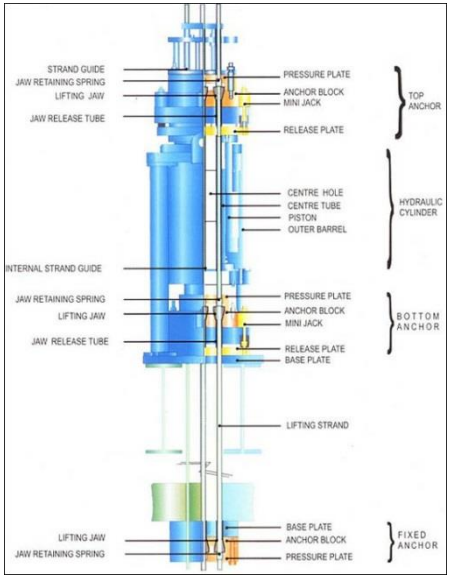
40t EOT Crane Comparison LHC vs. FCC

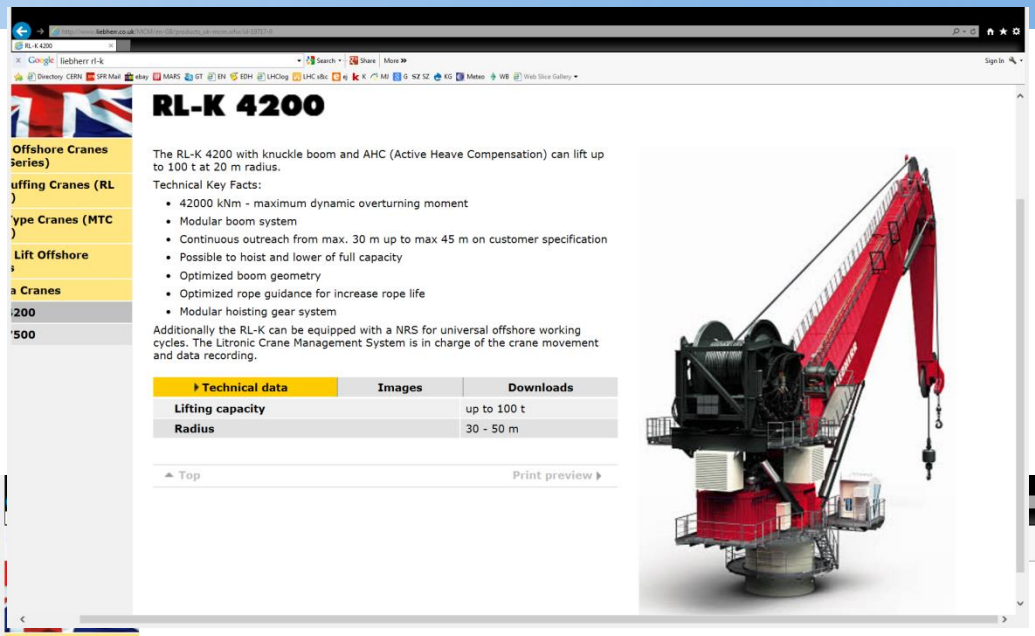
CRANE	PR 223 (SMI2 CRANE)	New crane
CAPACITY	40 TON	40 TON
SPAN	19,76 m	20 m
LIFTING HEIGHT	52,5 m	300 m
HOIST CONCEPTION	Single rope drum with emergency brake	Two rope drums operating simultaneously (no mechanical connection) ; emergency brake on both drums
DRUM DIAMETER/LENGTH	660 mm / 3800 mm	1070 mm / 7000 mm
LIFTING MOTOR POWER	90 kW	2 x 75 kW
LIFTING SPEED	10 m/min (100% load) / 20 m/min (25% load)	10 m/min (100% load) / 20 m/min (25% load)
CROSS TRAVEL SPEED	20 m/min	10 m/min
LONG TRAVEL SPEED	16 m/min	20 m/min
TOTAL WEIGHT	30,500 kg	~ 48,000 kg

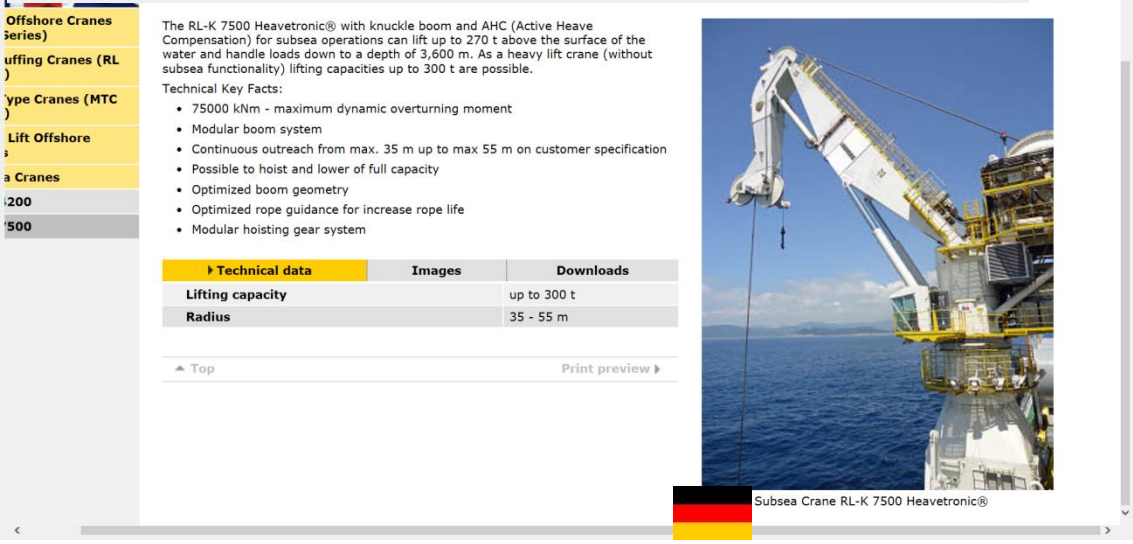




Alternative Crane Solutions







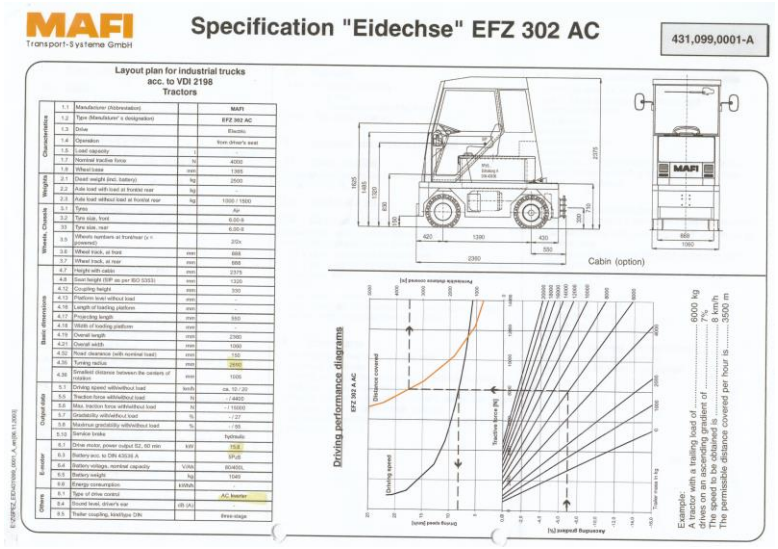
Subsea Crane RL-K 7500 Heavetronic®

NOTES ON SLOPES

Encyclopedie de la Manutention (~1980)

- "rampe ≥ 7% = problème délicate"
  - needs for example continuous forced ventilation for brakes and motors
- with increased slope the load capacity or the use factor reduces
- Effect of 2% slope is to double traction force needed compared with flat surface
  - ➢ stronger / bigger equipment

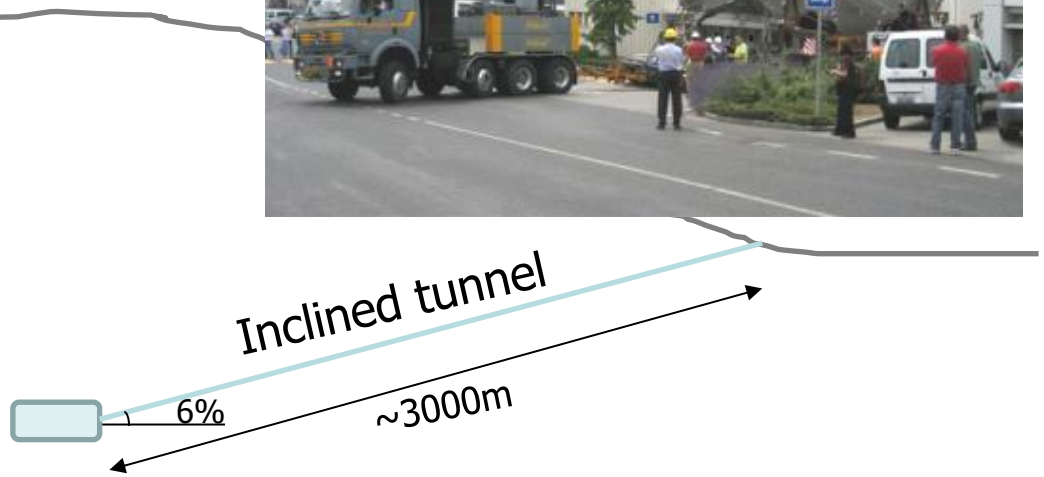
Example:
Towing tractor nominal capacity 20t at 10km/h
At a 7% slope
towing capacity 6 t at 3.5 km/h



Detector cavern access

Vertical Shaft vs. Inclined tunnel?

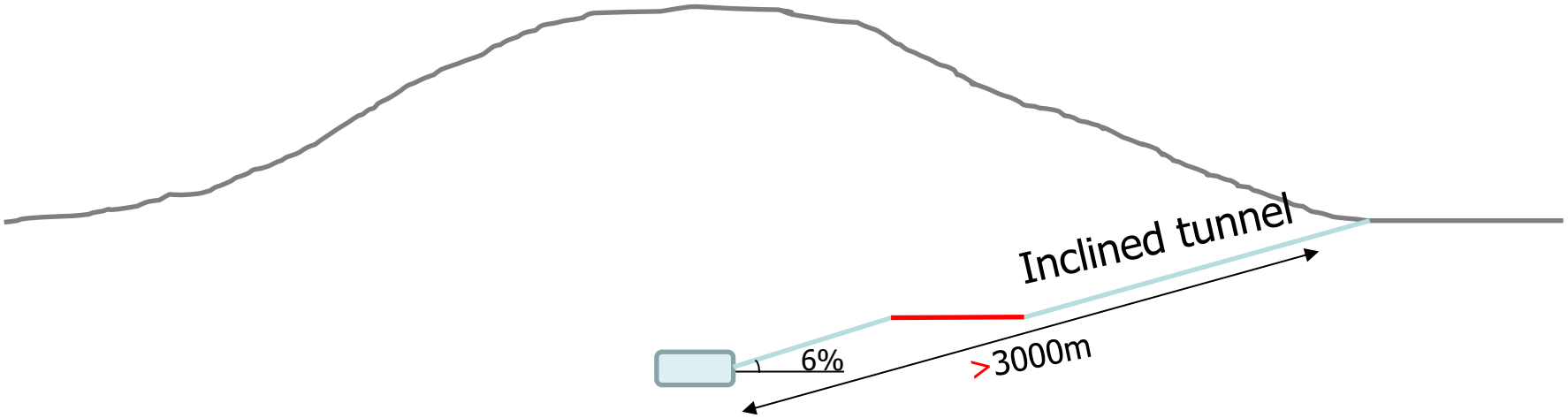
Tunnel ⌀ = Biggest component
+ Transport equipment
+ Safety clearance(s)
+ Tunnel infrastructure (ventilation ducts etc.)



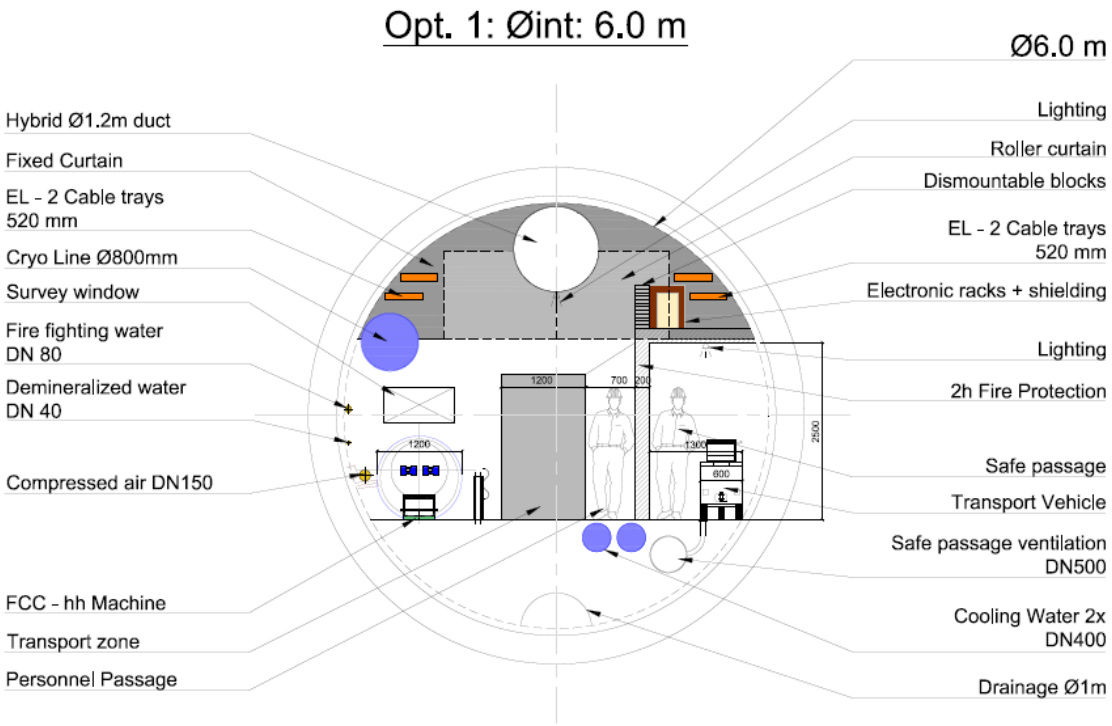
Detector cavern access

Vertical Shaft vs. Inclined tunnel?

Need of flat 'parking' station(s) (escape lane(s)!) somewhere along the inclined tunnel!



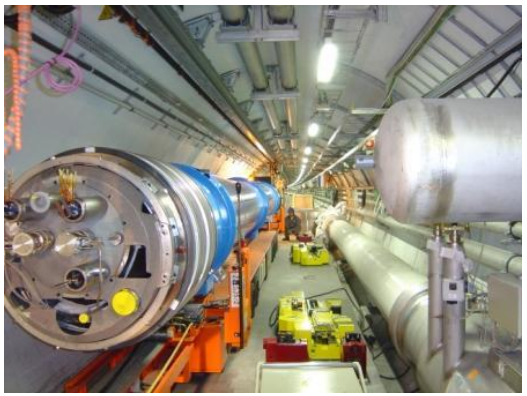
FCC-hh Single Tunnel Option



GS-SE CIVIL ENGINEERING	E	20.02.15	A.SANCHEZ		LIGHTNING ADDED, GENERAL UPDATE	"PLAN FOR INFORMATION"	ECHELLE SCALE 1/150	DES/DRA.	A. Sanchez	04/02/2015
	D	05.02.15	A.SANCHEZ		ALL PIPE DIMENSIONS CHECKED	FCC-HH POSSIBLE TUNNEL CROSS SECTION OPT.1: SINGLE TUNNEL LONG. VENTILATION Ø6m FCC-HH TUNNEL POSSIBLE CROSS SECTION OPT.1: SINGLE LONG. TUNNEL VENTILATION Ø6m		CONTROLLED	R. Fernandez	16/02/2015
	C	04.02.15	A.SANCHEZ		OPTION 1B ADDED. GENERAL UPDATE			RELEASED	J. A.Osborne	16/02/2015
	B	03.02.15	A.SANCHEZ		FIXED CURTAIN, ROLLER CURTAIN AND TRANSPORT VEHICLE ADDED. 400MM WALL FIRE PROT.			APPROVED		
	A	29.01.15	A.SANCHEZ		FLOOR HEIGHT CHANGED TO HAVE 300mm MORE OF WIDTH			DRAWING UNITY	MM	
	IND.	DATE	NOM/NAME	ZONE	MODIFICATION					
	PROJECTION				Ce dessin ne peut être utilisé à des fins commerciales sans autorisation écrite. This drawing may not be used for commercial purposes without written authorisation.	CERN	NOT VALID FOR EXECUTION NON VALABLE POUR EXECUTION	QAC -	FCC-.CE-1.0000.0001	SIZE 3 / IND. D

Tunnel Transport & Handling Equipment

CERN LHC conventional-magnet installation
Capacity: 9 t per buggy
Eq. height: 560 mm



CERN LHC cryo-magnet installation
Capacity: 35t/20t
Eq. height: 500mm (TES 300mm)

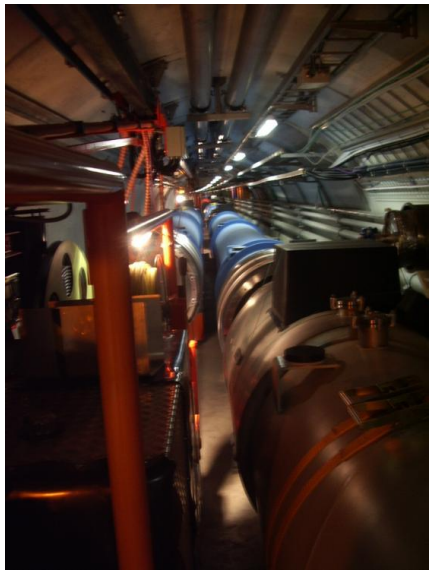
These **4** solutions incorporate the longitudinal transport and lateral transfer!
Boundary condition:
Sufficient clearance under the accelerator components!!!

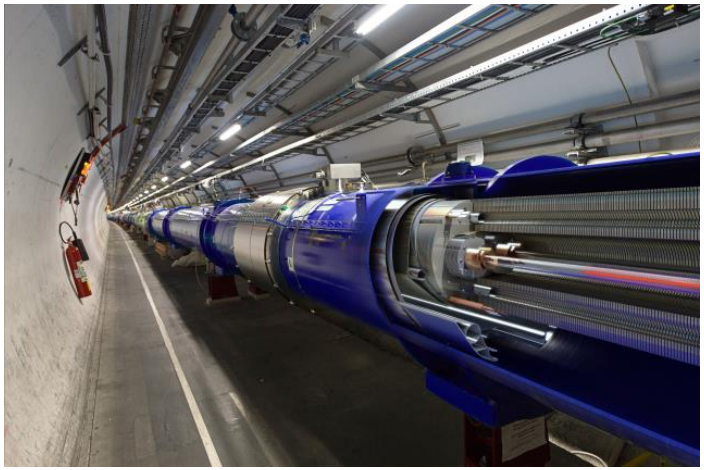
CERN SPS conventional-magnet installation
Capacity: 20 t
Eq. height: 800 mm

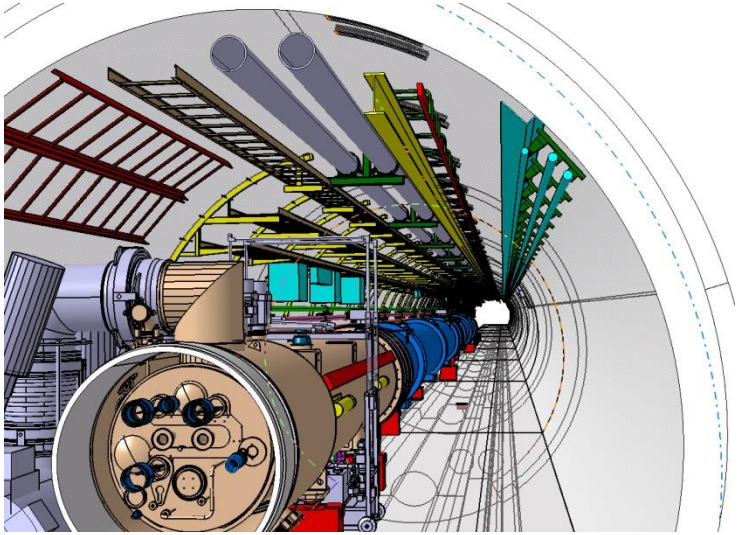
DESY XFEL installation
Capacity: 6.t per lifting platform
Lifting height: 2.4m

DESY conventional-magnet installation
Capacity: ???
Eq. height: ???

LHC power feed rail

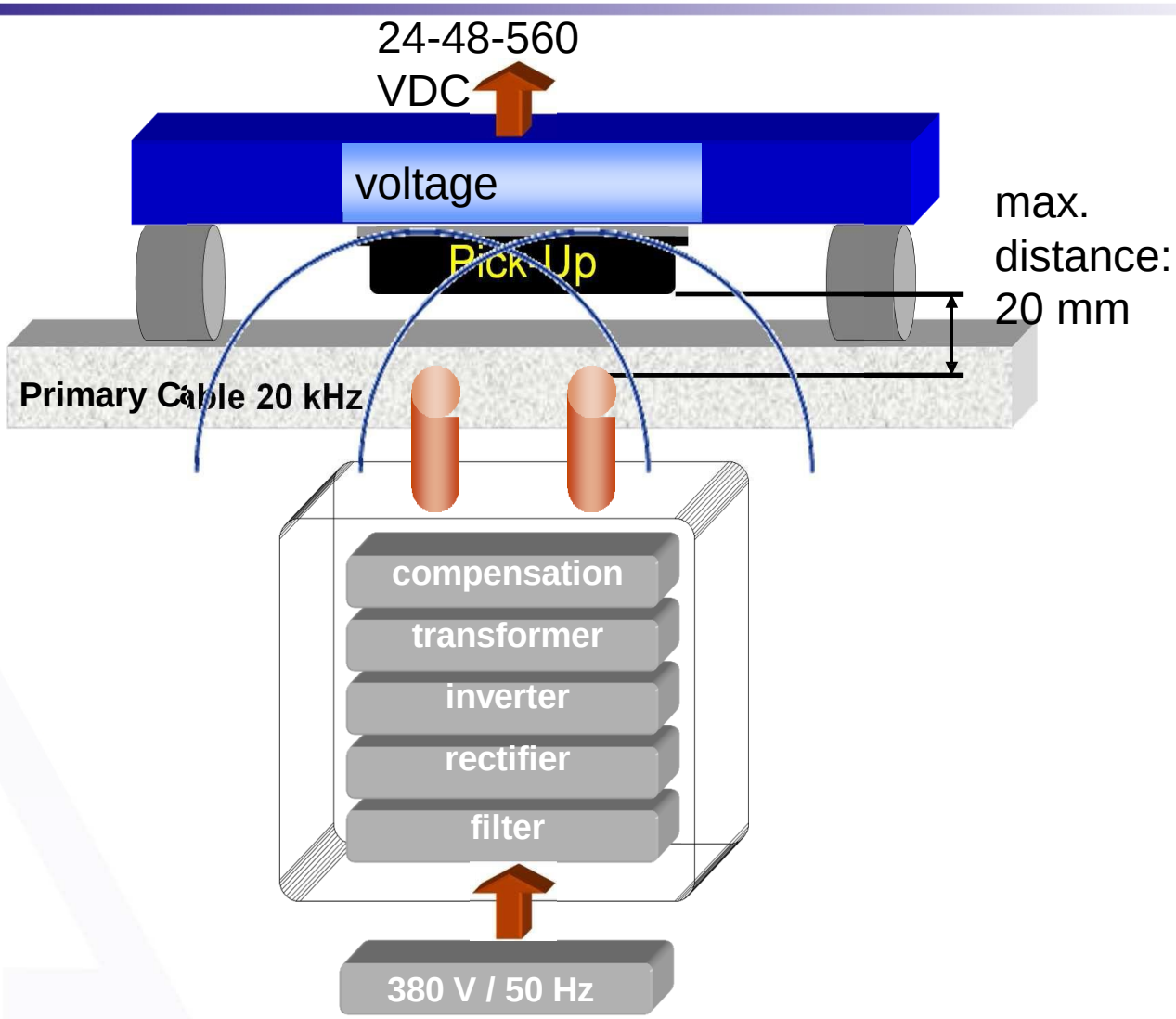




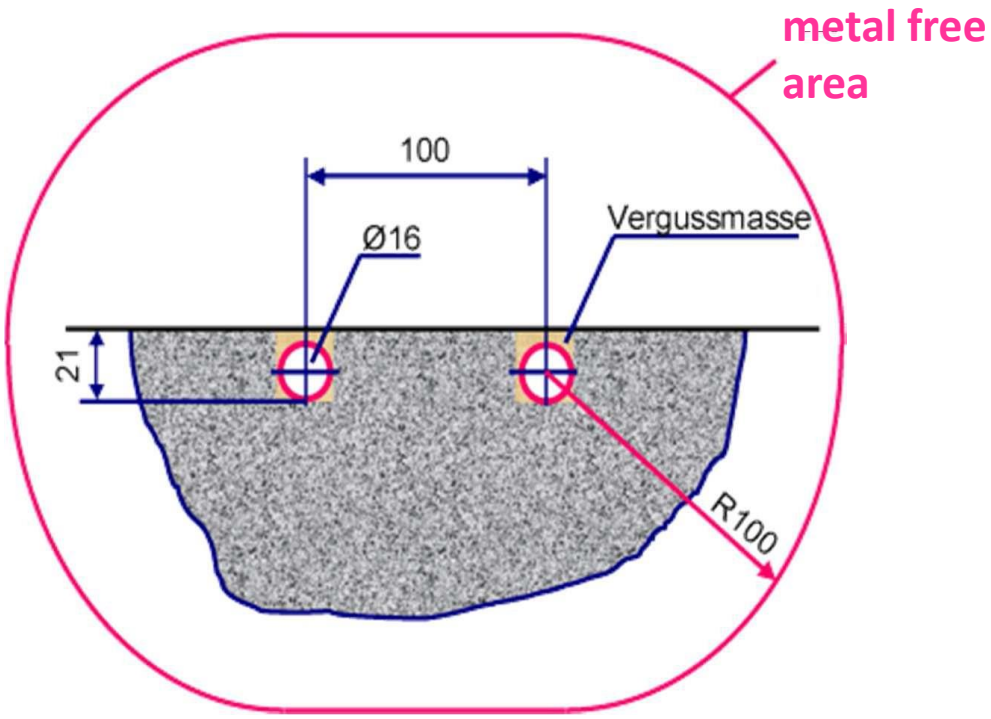


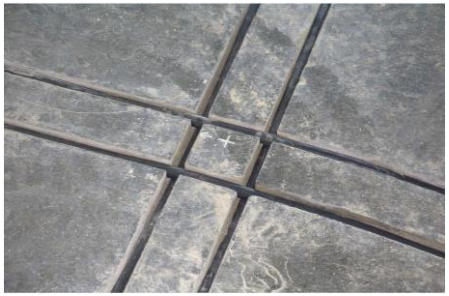
Principle of function

AGV application



Under floor primary cable installation





Min. clearance of 100mm to surrounding steel

Flat-style Pick-Up

PS 08

Output:
24 VDC 500W or
24-27 VDC with battery charging system

Primary Inverter cabinet

available power: 11, 45, 90 KW

flat version

PS19

compact version

Output:
560-680 VDC 3000W, &
24VDC auxiliary power supply

UCAP‘s

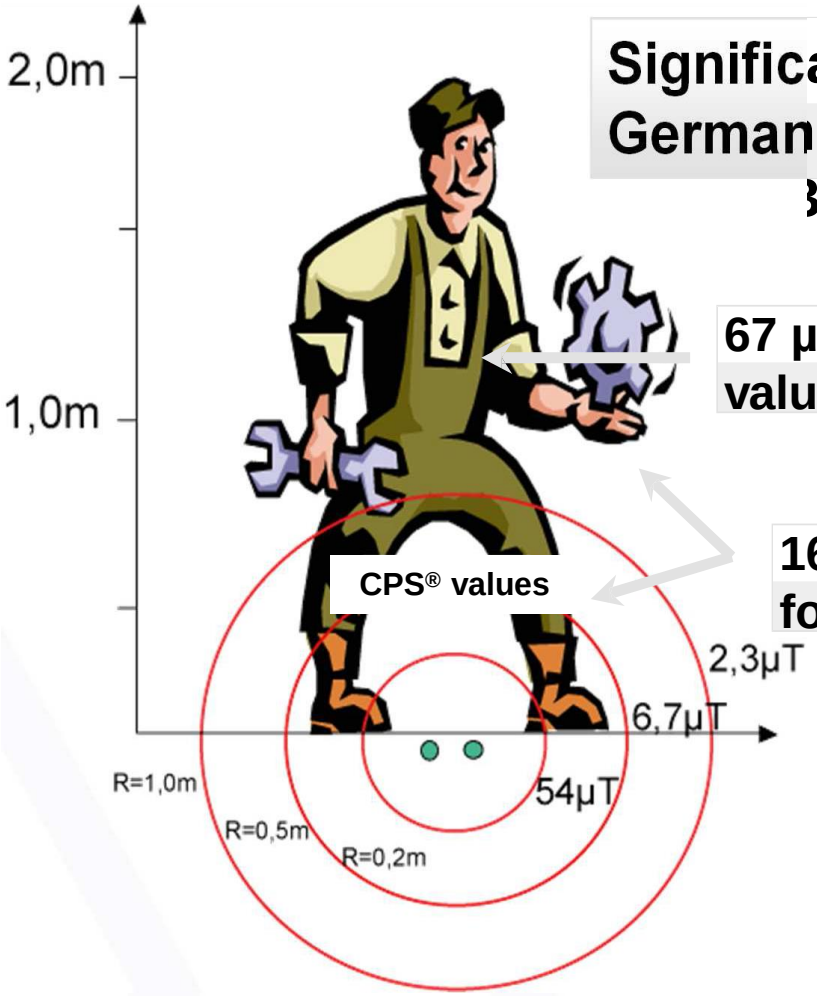
Track Guiding Sensor for detecting the electro-magnetic field of the Primary cable

analog output signal,
0-5V, 0-10V and 0-20mA for vehicle steering control

digital output signal Profibus, RS485

suitable for curves and track switches

Magnetic flux density (EMF)

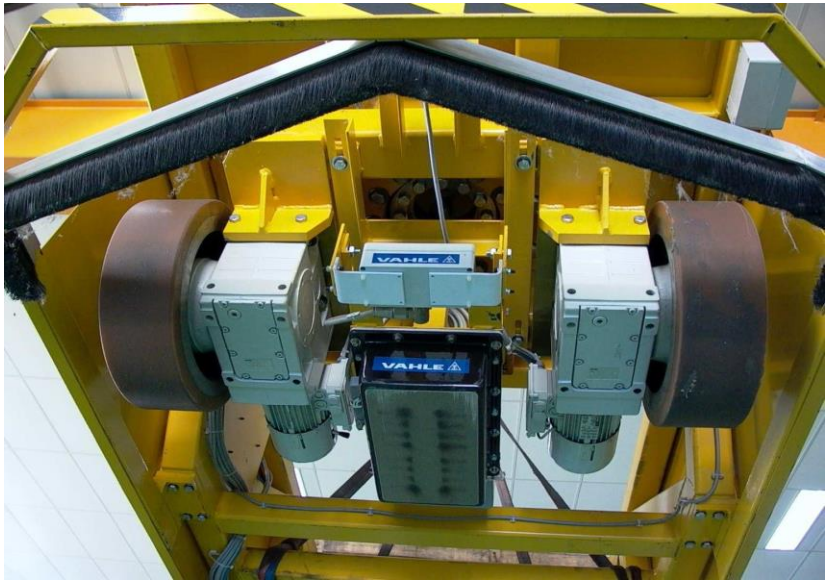


Significantly below the German Regulation BGV11:

67 µT - limit value for trunk

169 µT - limit value for extremities

CPS®forAGV



Comparison LHC vs AGV systems

	LHC system	AGV system	Remarks
Installation powering & guiding system			
time	-	+++	AGV power supply cabinets at a distance of ~1km - less frequent than for LHC but bigger in size. Component compatibility when machine on?
costs	-	+	
integration	-	++	
Maintenance	-	+++	Practically no mechanical wear
Operation			
safety	+	+(?)	EMF limits to be confirmed
manpower	-	++	Very limited operation manpower required for AGVs
acceleration / speed	o	+	Not really an issue for heavy accel. component transports. Higher speeds possible with AGVs (up to 20 km/h) for smaller/lighter components and passenger transport
Powering			
Conductor	+	-	Direct power supply or via Battery or **Hybrid** possible for both solutions
Inductive	-	+	
Battery	+	+	
Guidance			
Optical	+	-	Very cumbersome & maintenance intensive
Inductive	-	+	Low maintenance; variable tracks
Manual	+	+	Always necessary for a few manœuvres
Machine Interference			
installation phase	+	+	Not an issue
Techn. stops / operation phase	+	?	AGV/EMF interference when machine in stand-by?
Remote Monitoring & Control System	-	+++	Small team of operators and maintenance staff can operate several AGV convoys at a time

If not compatible, then

inductive guiding system

plus

defined charging stations,

which requires important battery capacities

for the AGVs.

Conclusion

- Lifts for shaft depth of up to 400m should be feasible with standard solutions but will require some additional technical features
- Cranes for shaft depths of up to 400m still feasible with standard EOT cranes but will require more studies regarding existing industrial equipment / applications
- For both cases the standard LHC layout for buildings and shafts cannot be applied!
- Keep tunnel slope as low as possible (<2%)
- Allow for sufficient clearance under accelerator components to allow transport and handling vehicles with incorporated lateral transfer systems
- Compatibility between an inductive guiding and powering system and accelerator components when in stand-by mode to be further assessed

Summary

There are plenty of technical challenges regarding transport and handling aspects for the FCC that need some in-depth studies but no show stoppers so far (based on the present tunnel and shaft configurations)!!!

Thanks

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