Conceptual plan of ILD solenoid magnet on-site manufacture

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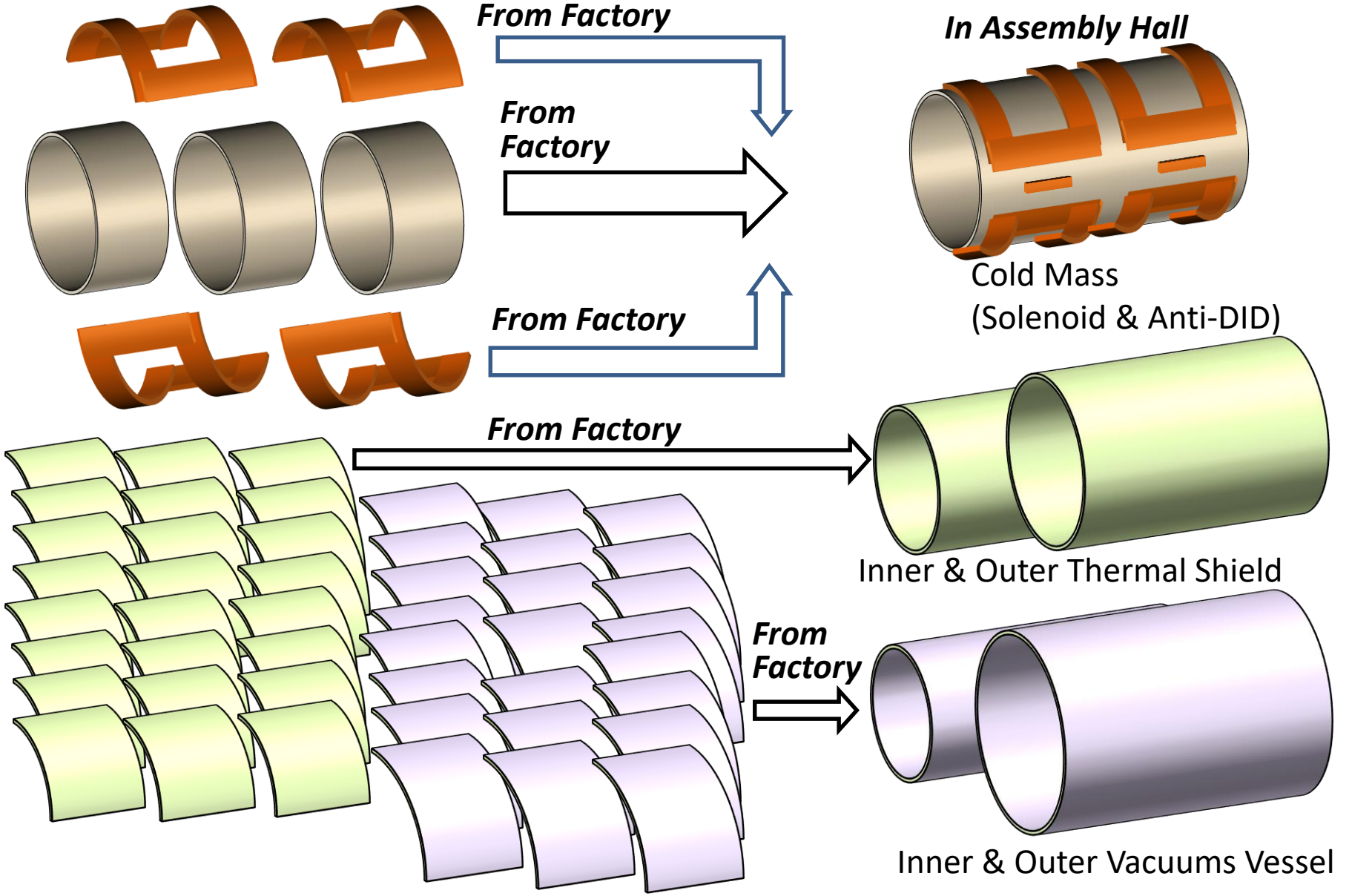
Yasuhiro Sugimoto, Tomoyuki Sanuki

Final assembly of the ILD solenoid should be carried out at an assembly hall which is ground floor of the experimental cavern, because the completed ILD solenoid is too huge to be delivered from the factories.
One third block of coil winding module made in a factory is transported to the assembly hall, then the composed coil is installed into a cryostat.
We have investigate a possible transportation method. That require huge number of preparations must be done before the transportation. Removal signals, fences and traffic signs. Reinforcement of bridges.
So, we are now discussing an alternative plan to reduce a transportation weight of the coil parts by on-site winding.
Status of research about on-site winding will be presented.

Contents

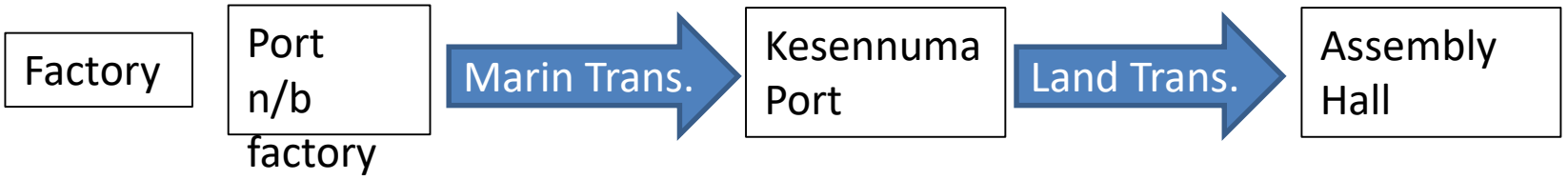
1. Manufacture & Transportation Plan presented in LCWS2021.
2. New Proposal with on-site winding process.
3. Conclusion.

Outline of ILD Coil manufacturing process
presented in LCWA 2021



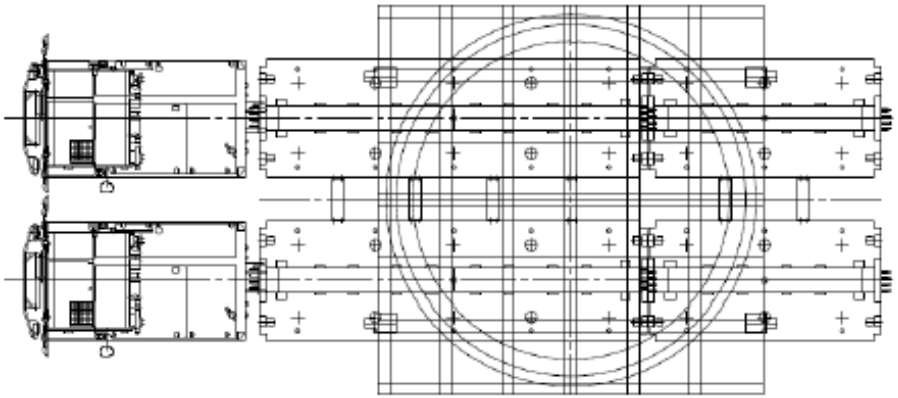
Module Transportation presented in LCWA 2021

- Transportation of CMS coil modules (7.4 ×7.4 ×3.0 m^3) was a hard task (at the limit of what can be transported on the road).
- ILD module has larger dimensions (8.0 ×8.0 × 2.5 m^3)
- Possible route and cost for transportation have been investigated by Hitachi Transport System (https://www.hitachi-transportsystem.com/en/).



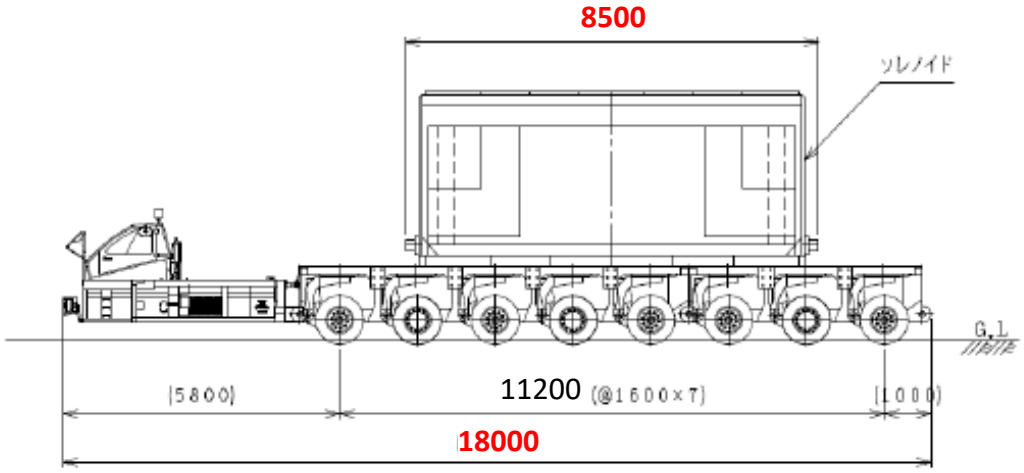
Land Transportation of Solenoid Coil Module

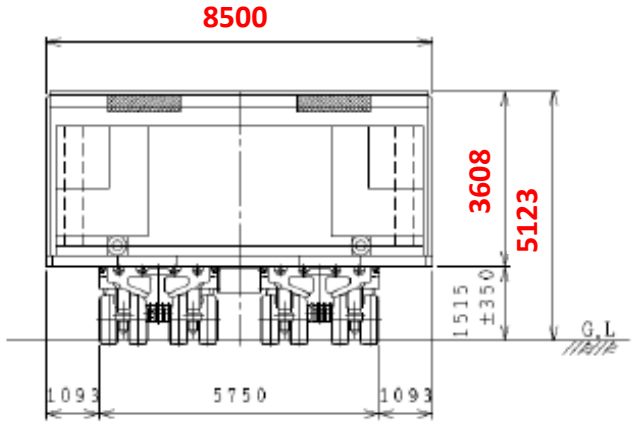
presented in LCWA 2021



Solenoid Coil Module Package	
Dimension	8500 × 8500 × 3608 mm^3
Weight	90.0 ton (module 57 ton)
Package No.	3

Carrying condition		Per axle 8 wheels	Total 64 wheels
Axle load w/o goods		12,15 kg	97.200 kg
Goods weight		11.25 kg	90,000 kg
With goods	Axle load	23,400 kg	187,200 kg
	Wheel load	2,925 kg	
Ground Pressure	Pressurized area	1.60m × 7 × 4.86m = 54.43 m^2	
	Pressure	3.4 ton /m^2	



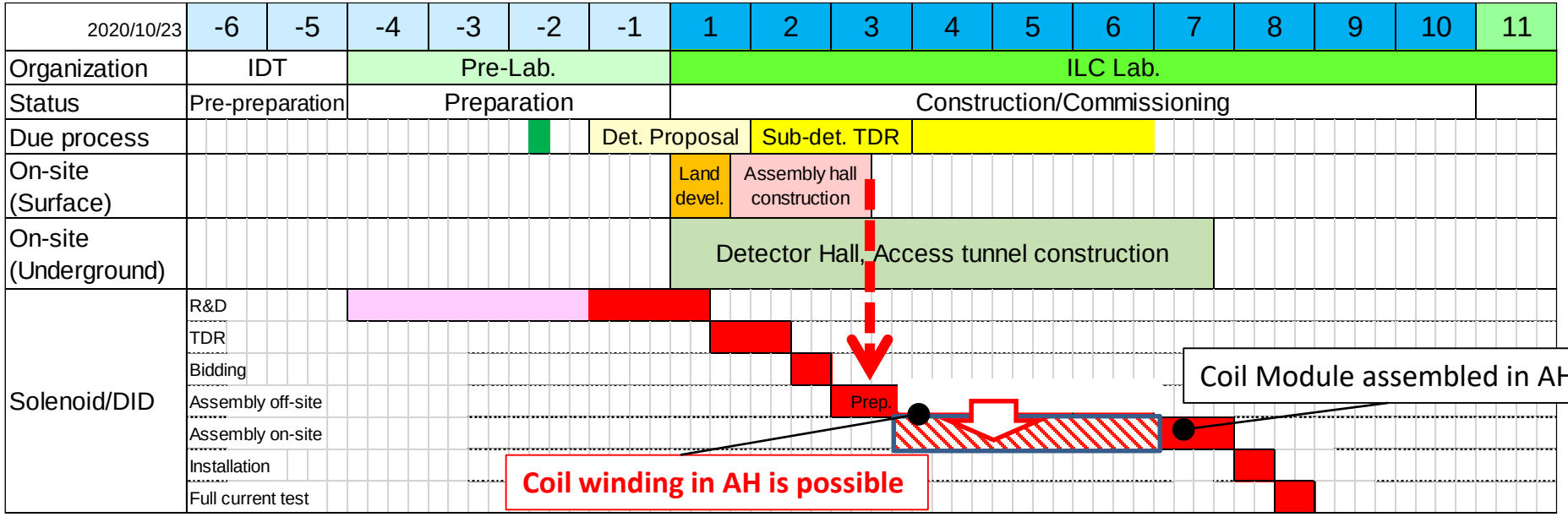


Many Obstacles presented in LCWA 2021

- There are many traffic signs, signals, poles, lights and fences to be temporally removed.
  - 154 points (upper obstacle 60 points)
  - Trees are not counted.
  - Preparation and recovery cost may be comparable with transportation fee.
- Some bridges must be reinforced.
  - Reinforcement cost may be huge.
- Permissions and public approvals are necessary to occupy the road and removing road instruments.

Motivation of manufacture reconsideration

- Discussion with magnet products about coil winding in AH has been started, too.
  - Not only transportation cost but also preparation cost.
  - Risk of transportation which needs permissions and public approval should be reduced.
  - Contract by Pre-Lab has been rejected in AWLC2020. Contract will be made 2 year after ILC-Lab starts. So AH completion will meet a start of coil winding.



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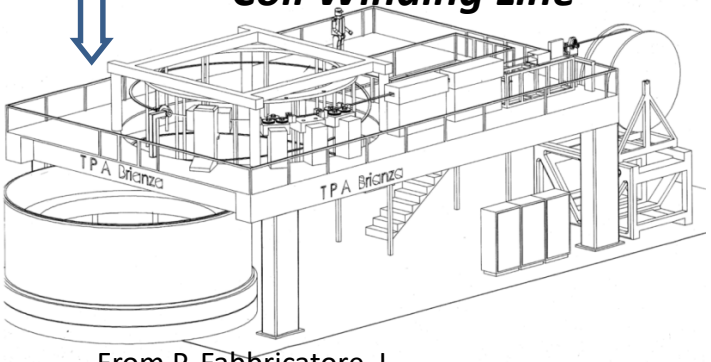
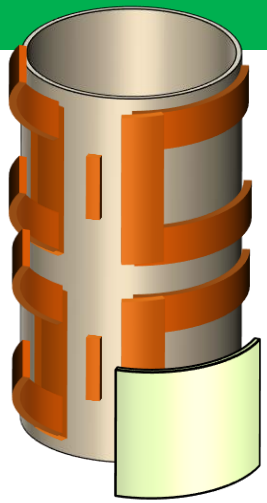
Outline of ILD Coil manufacturing process
Onsite winding option

SC conductor From Factory

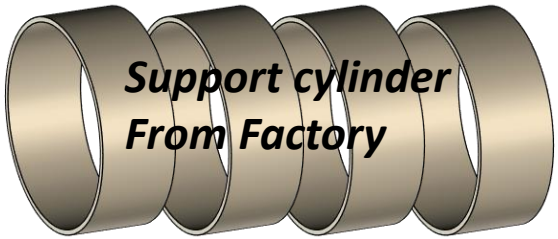
In Assembly Hall
Coil Winding Line



From P. Fabbricatore, I
EEE Trans. Appl. Super., Vol. 12, p.358

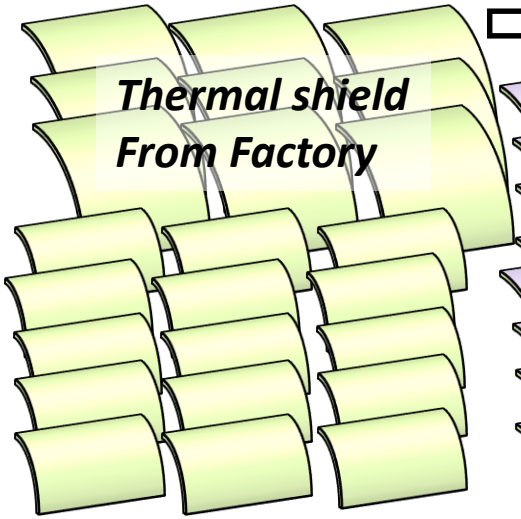


Cold Mass
With outer T.Sh.

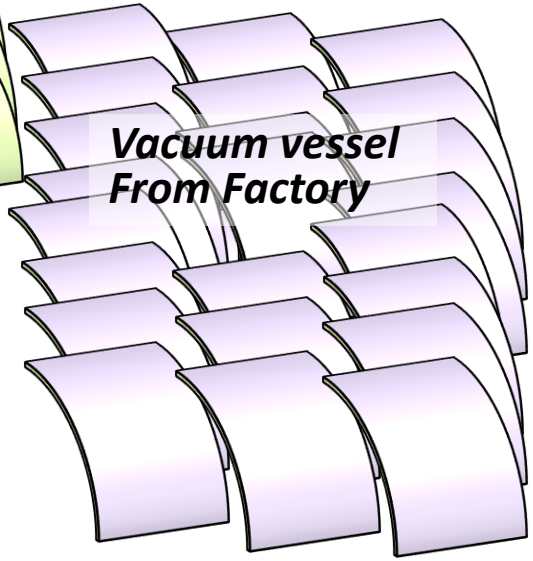


Support cylinder From Factory

In Assembly Hall
T.Sh. setting onto C.Mass and I.V.V.

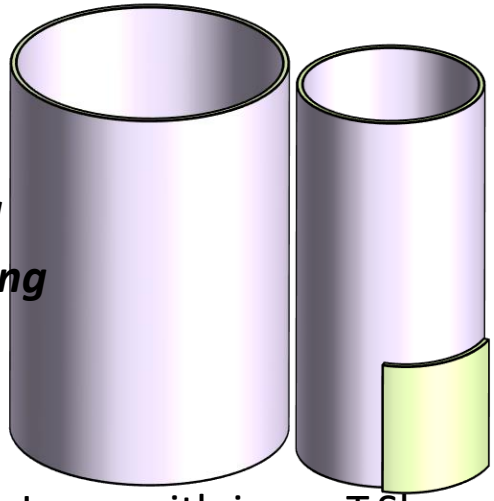


Thermal shield From Factory



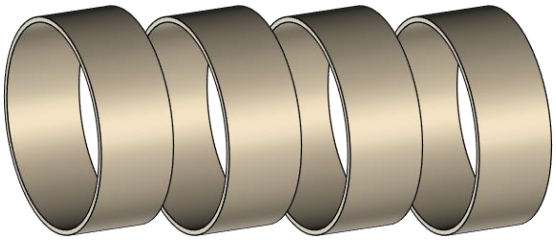
Vacuum vessel From Factory

In Assembly Hall
V.Cylinder Welding

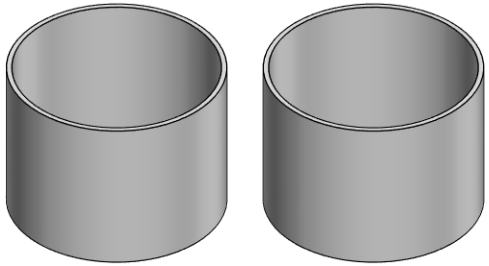


Inner with inner T.Sh.
& Outer Vacuums Vessel

Onsite manufacture of cold mass (solenoid coil and Anti-DID)

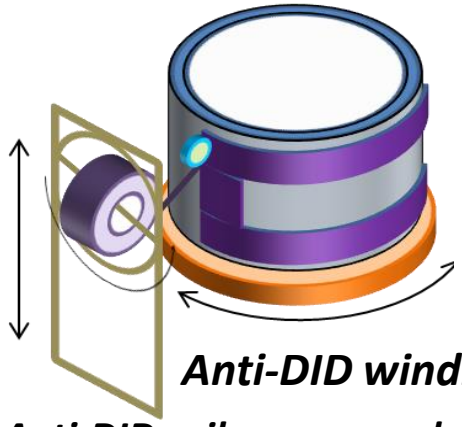


Support cylinder From Factory



Welding each 2 cylinders into a coil mandrel.

Solenoid winding device (CMS based machine)



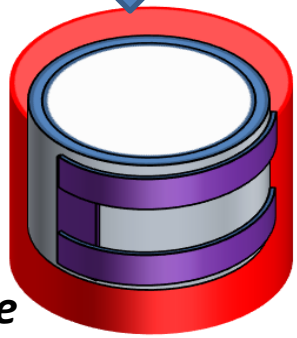
Anti-DID winding concept

4 Anti-DID coils are wound on the same turning table vertically with special spool holder

Lathe
to make flat surface for stacking

½ Solenoid curing

Auto clave

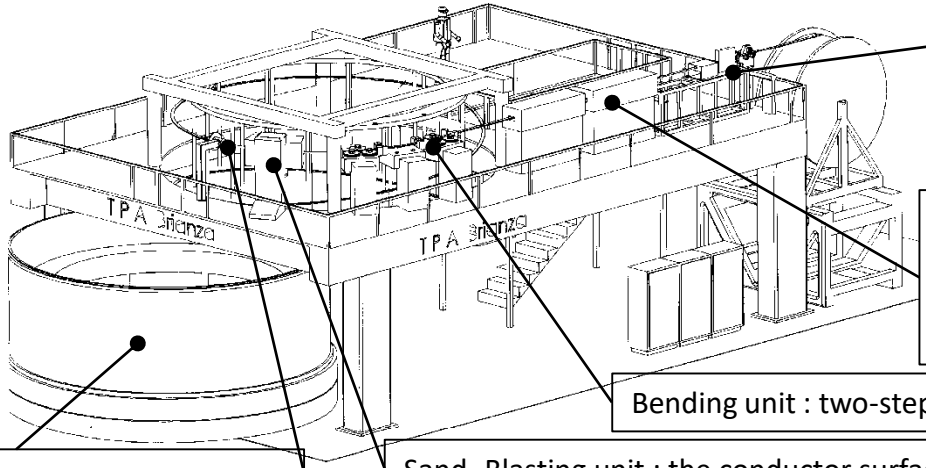


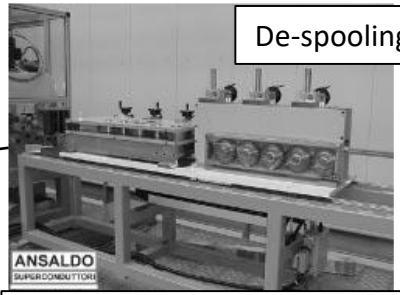
Anti-DID curing

Stacking 2 modules

Direct inner winding line(1)

"IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 12, NO. 1, MARCH 2002
TheWinding Line for the CMS Reinforced Conductor" by Fabbricatoreより





De-spooling and Straightening

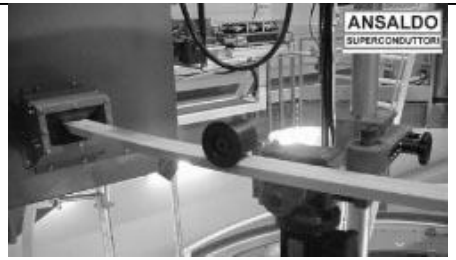
De-spooling the conductor and making it as straight as possible.

Cleaning unit
Solvent bath coupled with ultrasonic device.
To prepare conductor surface for adhesion through epoxy resin.

Bending unit : two-steps 3 points bending

Sand- Blasting unit : the conductor surface is sandblasted to maximize the adhesion surface.

Winding table :
A fixed table supports a rotating table.
Both tables can move in vertical position (through the large rods attached to the central structure),



Sand – Blasting Unit

Milling machine, placed aside the cleaning unit : Removing Al-alloy to prepare electric joint at the beginning and at the end

Insulation tape wrapping unit : Wrapping two insulation tapes

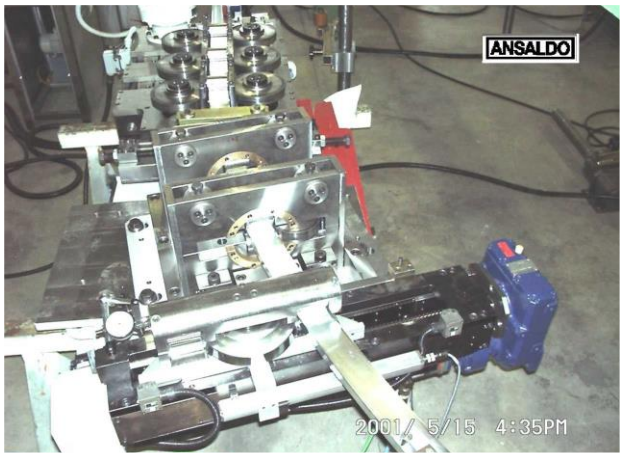
Taping unit

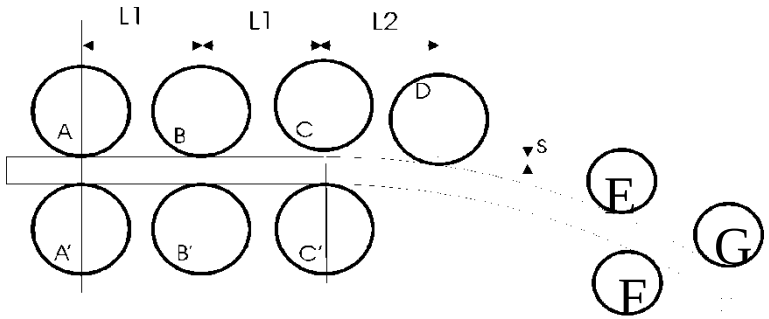
Direct inner winding line(2)

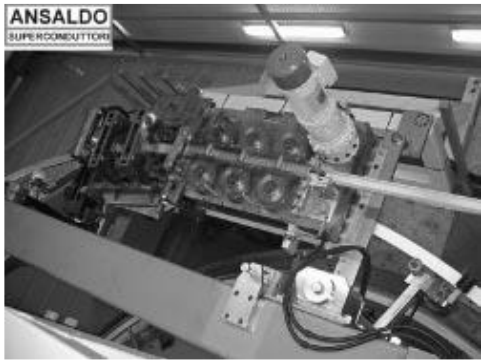
"IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 12, NO. 1, MARCH 2002
The Winding Line for the CMS Reinforced Conductor" by Fabbricatoreより

Bending Unit

Working principle of the two-step bending unit. Rollers A, A' drive the conductor. Rollers B, C' and D bend the conductor at a radius R_1(Roller B' and C are not active). Rollers E, F and G bend the conductor at the final radius $R2 < R_1$.







Conductor Driven Unit :
This unit is a structure made of rods and motorized rollers, driving the insulated turn, from the top of the mandrel to the turn location inside the winding.

Direct inner winding line(3)

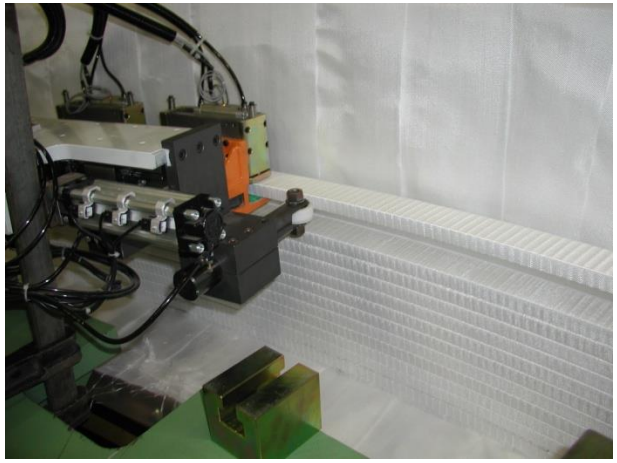
Final positioning

“Coil Winding Issues” by Fabbricatoreより

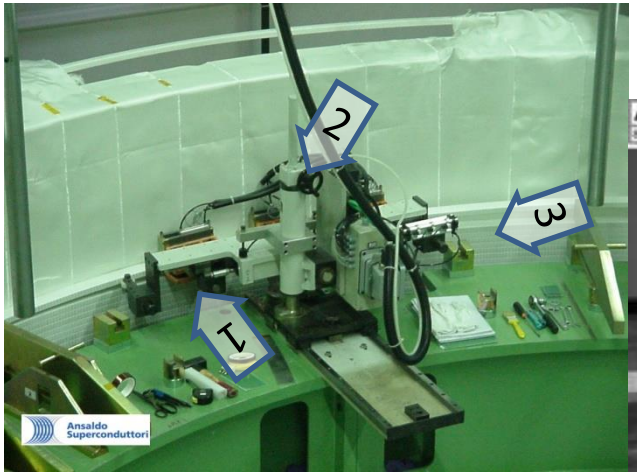
Once each turn is led to approach the winding (internally against the mandrel or existing layer), it is necessary to push it longitudinally and radially. This is done by a special unit, working as three hands, which clamp the conductor and push it. The system is always kept (by a hydraulic circuit) in operation, so to avoid releases of turns.

Arrow 1

Arrow 2



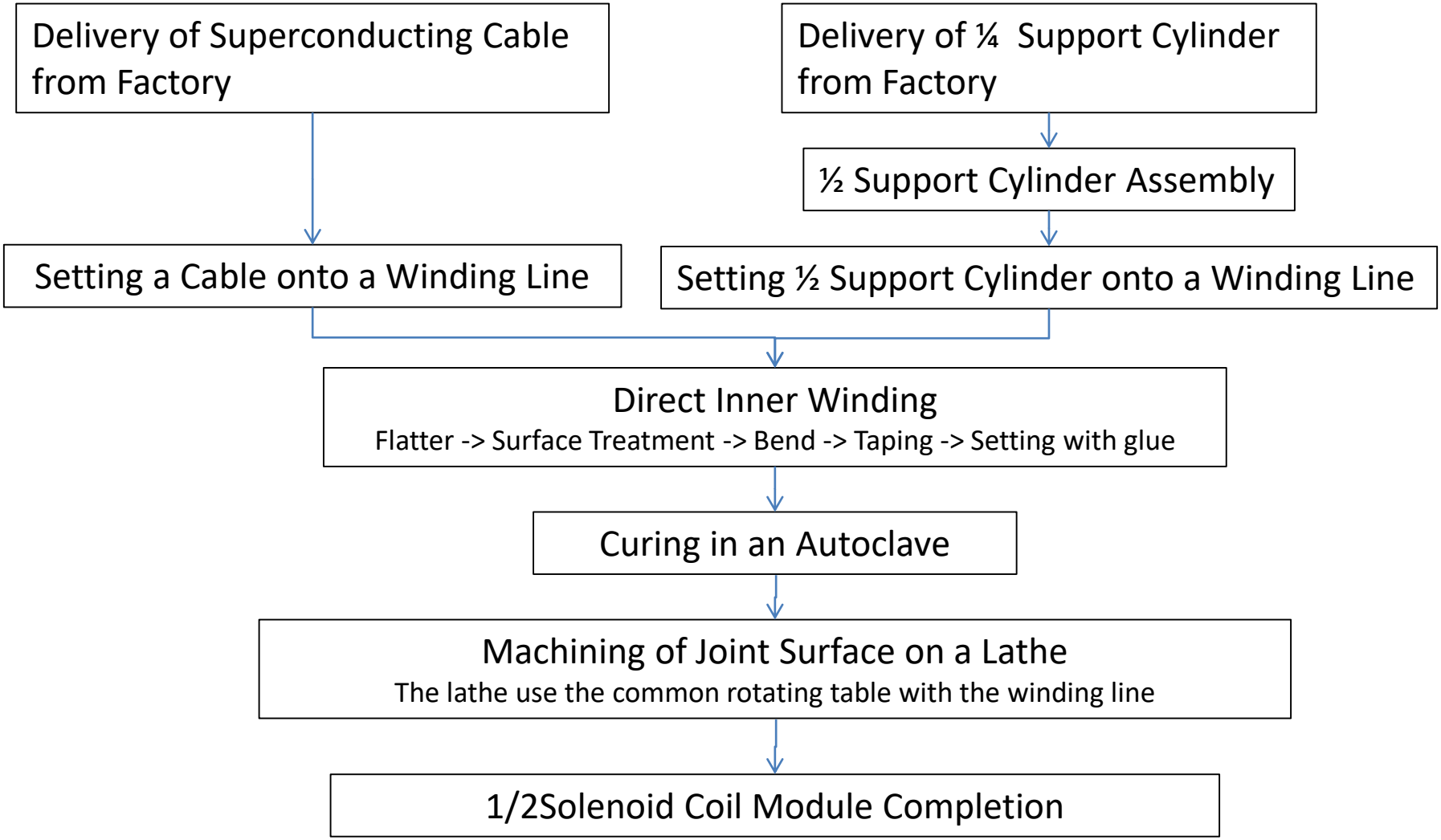
Arrow 3



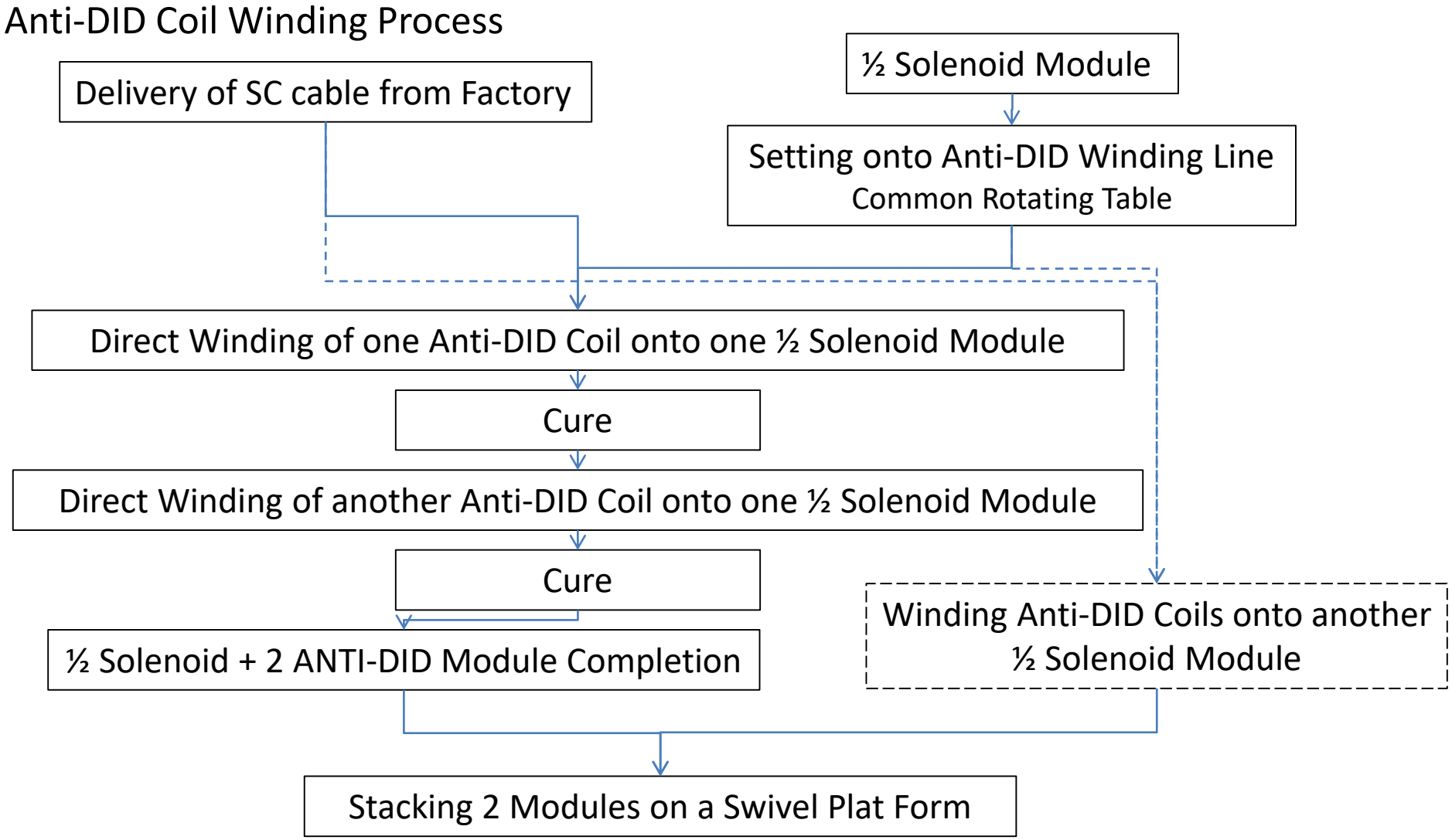
Final Positioning

Process of cold mass manufacture (1)

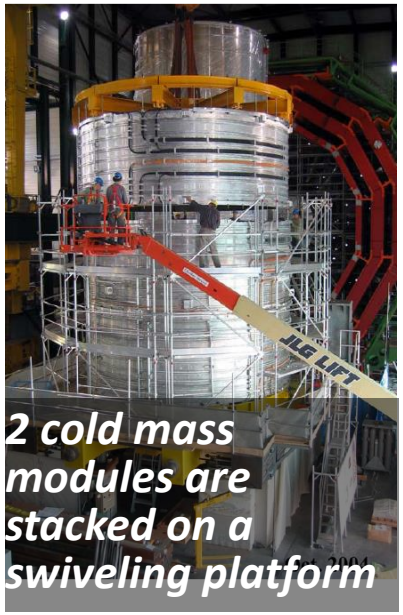
Solenoid Coil Winding Process at the Assembly Hall



Process of cold mass manufacture (2)



Cryostat Assembly (Learning by CMS experience)



2 cold mass modules are stacked on a swiveling platform

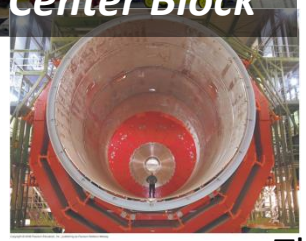
Setting outer thermal shield Horizontal position

Inserting the cold mass + O.Th.S
Inserting Inner V.V + I.Th.S

Descent to cavern

Cryostat welded

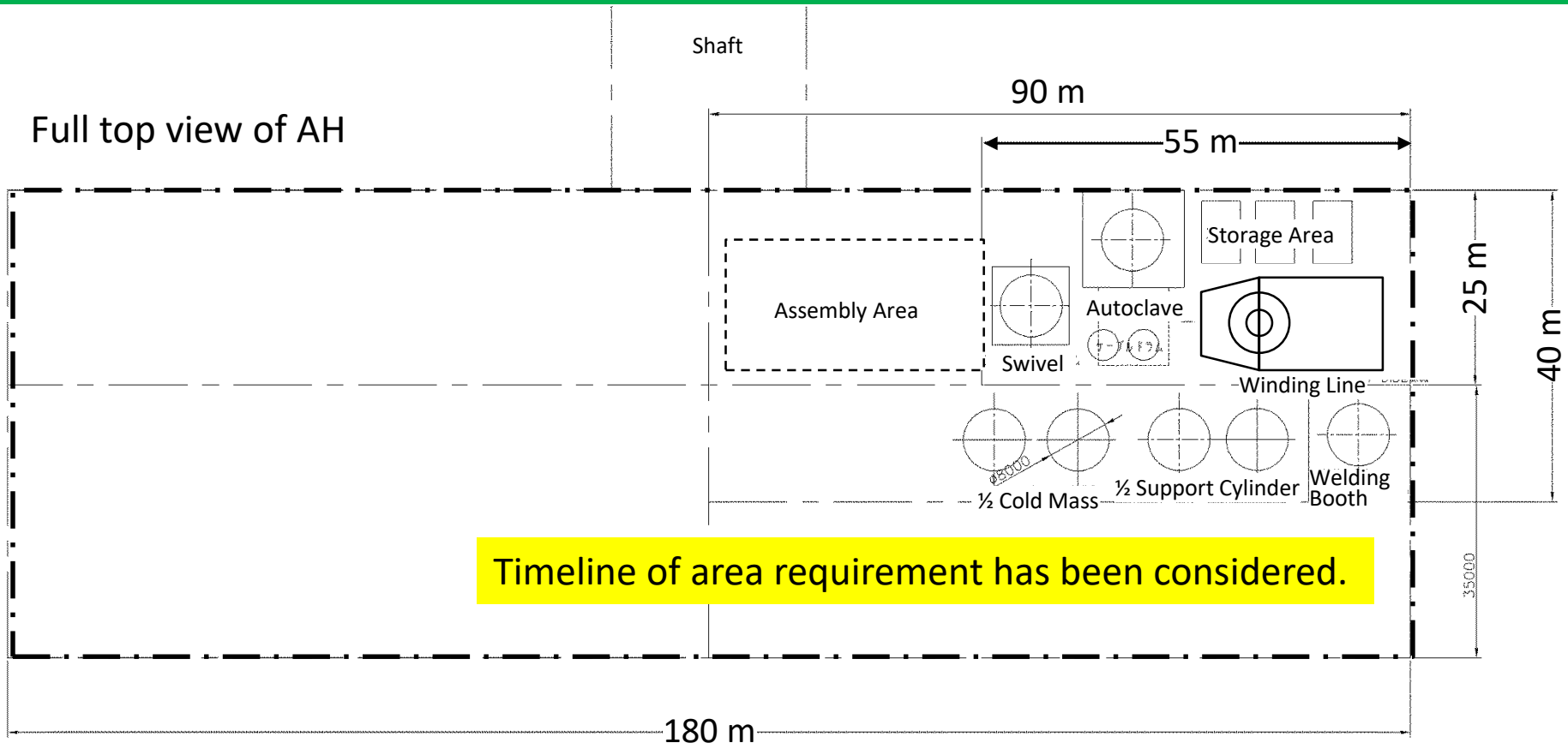
Setting Outer Vacuum V in Barrel Yoke Center Block



These photos are copied from CMS web sites.

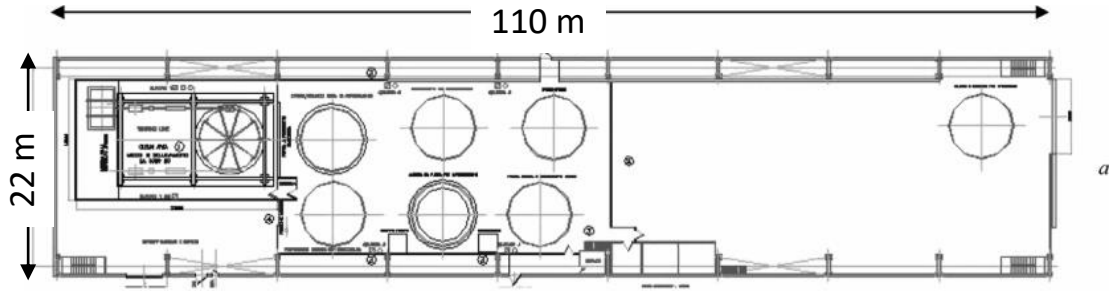
Workplace in AH for SC Magnet

Full top view of AH

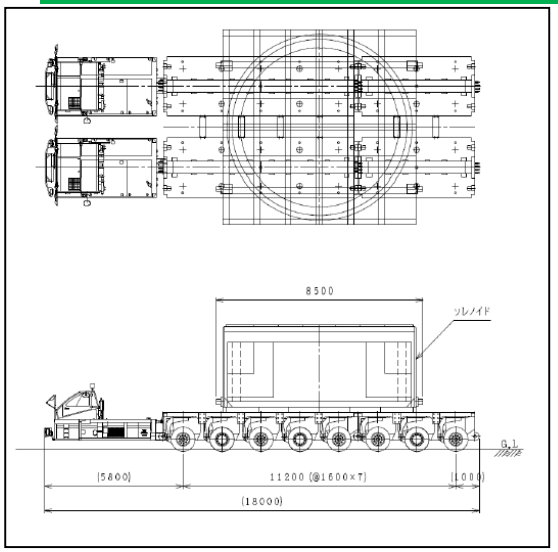


Timeline of area requirement has been considered.

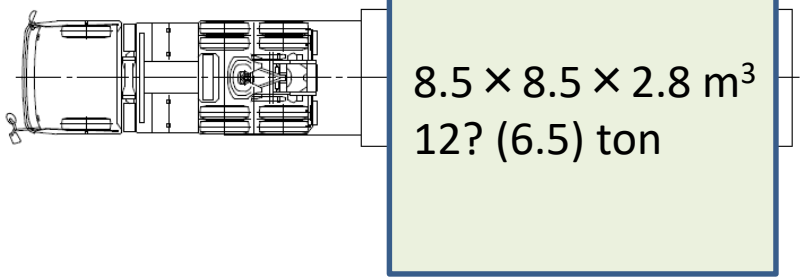
CMS Case



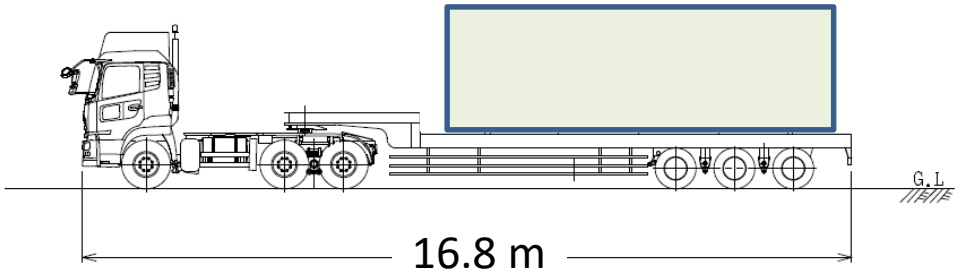
Land Transportation of Support Cylinder
Lighter and Smaller

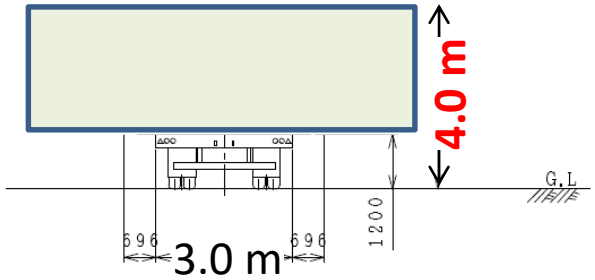


Solenoid Coil Package	->	Support Cylinder Package
Dimension	$8.5 \times 8.5 \times 3.6\ m^3$	**$8.5 \times 8.5 \times 2.8\ m^3$**
Weight	90.0 (module 57) ton	**12? (module 6.5) ton**
Package No.	3	**4**



Signals, traffic signs and lights are placed to **5 m** in height.





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Conclusion

- On-site winding process has been considered to reduce risks at the module transportation from the factory to the assembly hall.
- That can reduce the weight and height of transported module from 57 ton to 6.5 ton and from 5.2 m to 4.0 m. That can reduces number of temporal removal of road instruments and bridge reinforcements.
- Max 90×40 m^2 space for magnet manufacture, including the main assembling area, is required from 3^{rd} to 8^{th} year (6 years).
- Hopefully, it may be possible to arrange the space.

3. サイトインフラ

○巻線環境の温度管理

ex1　ITER製造　20℃±5℃（15℃～25℃）
ex2　巻線室　　24℃±3℃（21℃～27℃)
ex3　湿度の制限：なし

→ILC　温度制限：21℃±6℃　（15℃～27℃）
　　湿度制限：　無し

○乾燥炉

ex1熱風循環型乾燥炉　最大210℃　2．3m×3m×3．5m　（24．2m3）
　　25kW×6系統＝150kW
ex2熱風循環型乾燥炉　最大180℃　3．9m×3．9m×3．5m（53．2m3）
　　40kW×6系統＝240kW

3. サイトインフラ

○巻線後樹脂熱硬化用乾燥炉

仕様

雰囲気：大気
形式　：熱風循環型乾燥炉
最大温度：180℃
サイズ：10m×10m×10m（1000m3）

コイル重量　　最大200ton
アルミ熱容量　905 J/kg・K
ΔT　　160K
として24Hrで温度上昇するためには、放熱を無視して
905J/kg・K*2E5kg*160deg/(24Hr*3600sec)=335kW

放熱係数　　1W/m2とすると
乾燥炉表面積　600m2
最大温度差　　200K
として　最大放熱ロス
600*200=120,000=120kW

結果　(335kW+120kW)＊1.2安全率　＝550 kW

＊ それらしい値だが確証が無いので、炉メーカに問合せ中

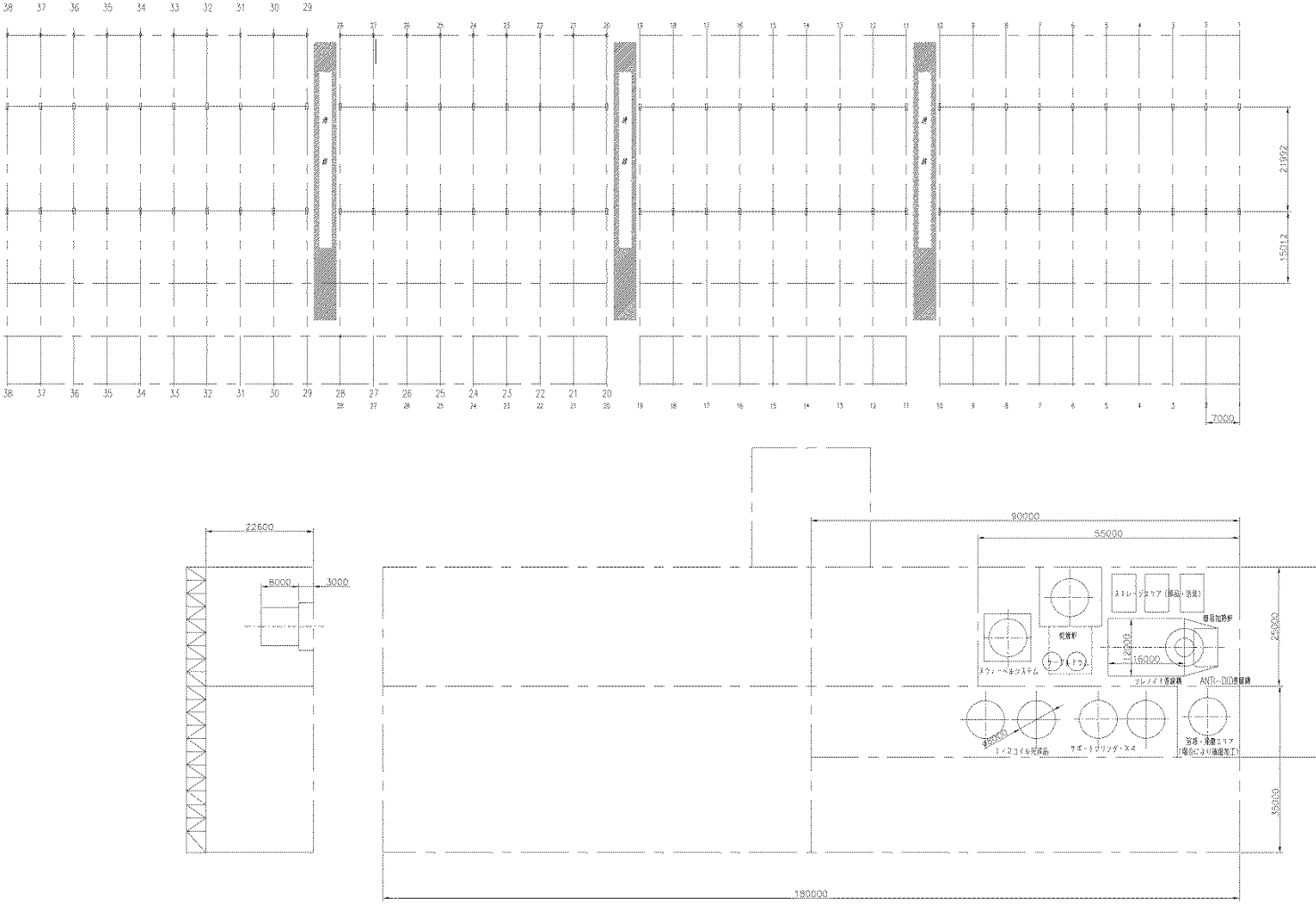
4. スペース

〇メモ
・ケーブル仮巻きは行わず、巻線機上でﾌﾟﾘﾍﾞﾝﾄﾞを行う
・スウィベーリングシステムは中央寄りに設置
　ヨーク下半作成後、真空容器を置き、その後マグネットを挿入して行く。
・熱処理炉は建屋端としない
　クレーンが寄り付かないため
・多目的　溶接、発塵エリアを設ける
　端面機械加工が必要な場合は同エリアを使用

〇その他
・クレーン
　ヨーク用　250ton
　コイル用　80ton
・電力
　建設中　2MW（仮）　＊上がっても良い

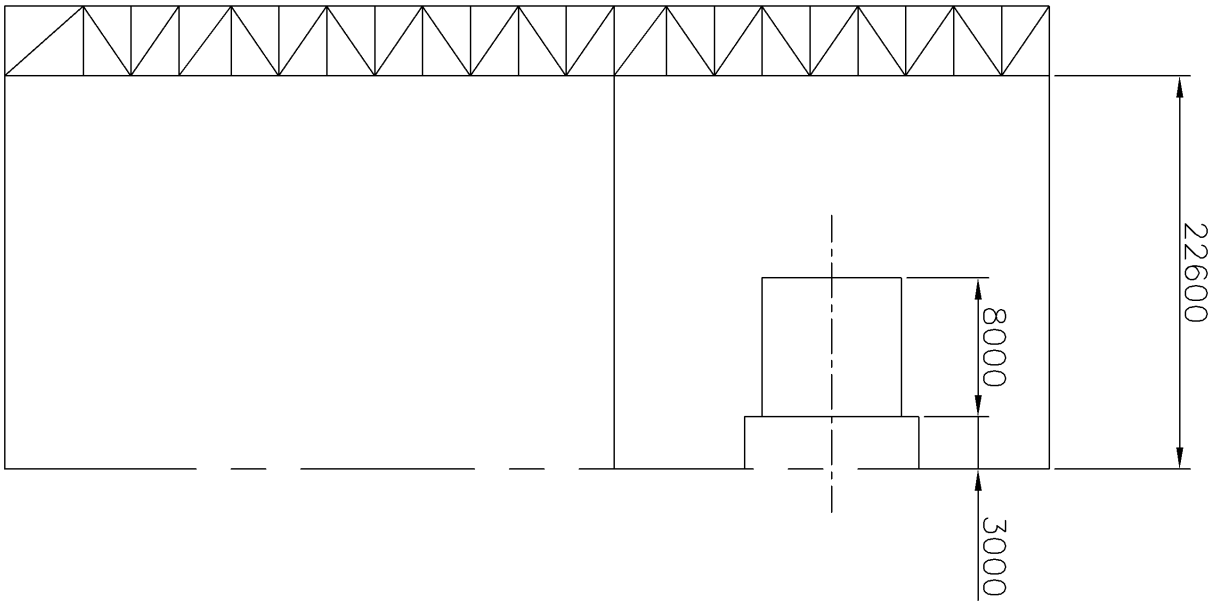
4. スペース

○全体

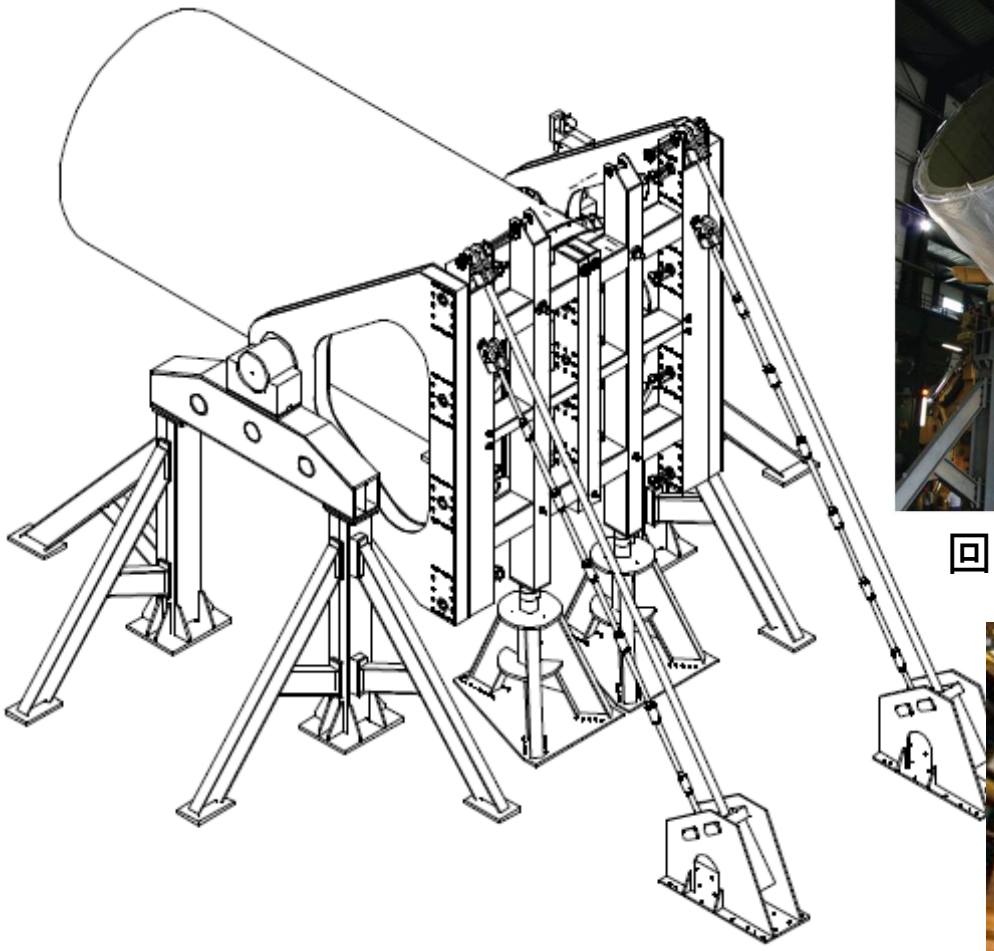


4. スペース

○高さ方向



5.クライオスタット組立(2)



回転片持ち梁が必要（ソレノイドで整備）

（別案）中央の梁で挿入