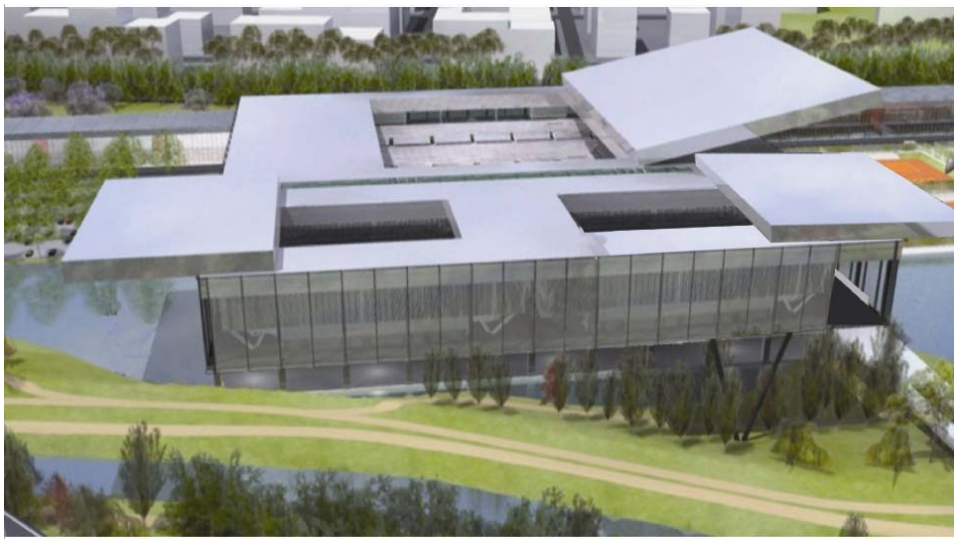
Indoor/Outdoor Tennis Stadium Caja Magica in Madrid

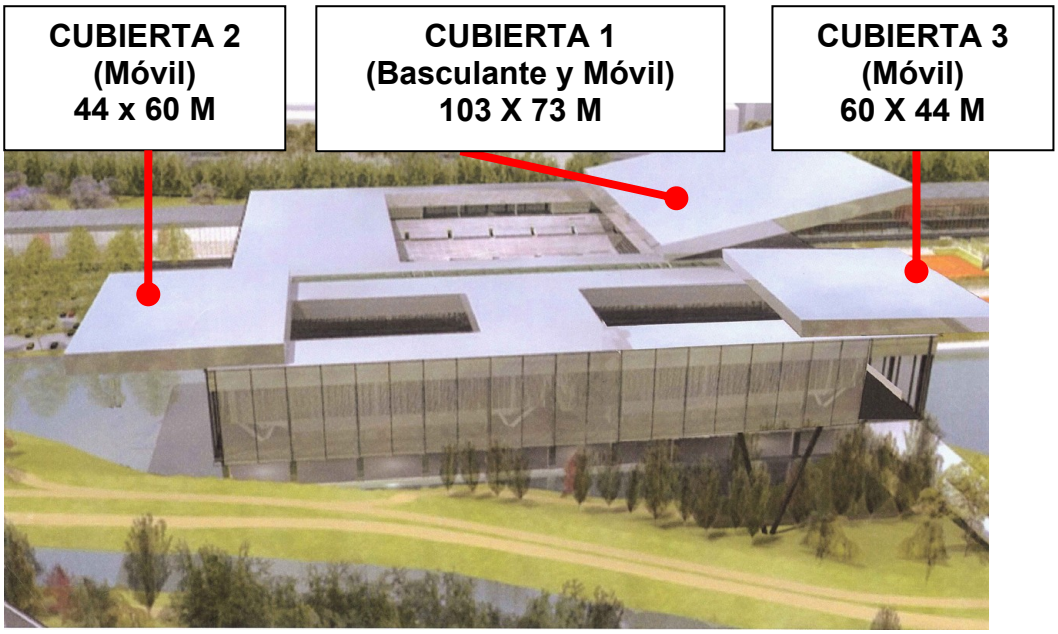
The City of Madrid has decided to build a new indoor/outdoor tennis stadium for big international tennis tournaments.



Caja Magica

The project has been designed by the architect Dominique Perrault.

The building, which is to be made of steel, wood and glass, will be organized around a single area with three covered stadiums and stands with capacity for 12,000, 3,500 and 2,500 spectators, respectively.



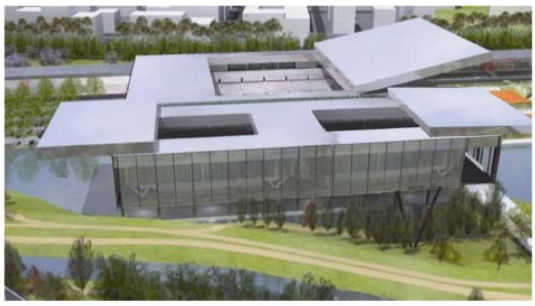
Perrault´s design combines high technology with a respect for the environment. As such, the pavilions will have a protective covering which will change according to the seasons, the light, the temperature and the different sorts of events held there.

The architect called this building “Magic Boxes” because the 3 roofs of the stadium will open like the covers of boxes, in 2 different directions.

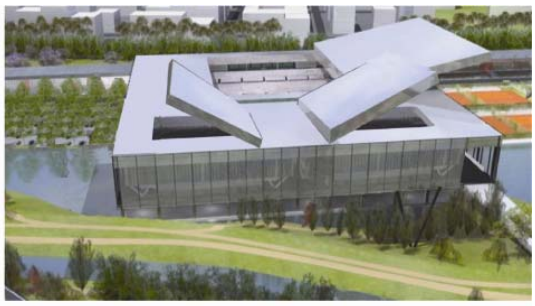
The roof of the main stadium is tilted by 12° and shifted sideways by 65 metres.

The dimensions of the main roof are: Width: 103 m
Length: 73 m
Weight: 1725 metric tons

The roofs of the two small stadiums can be tilted to an angle of 25° or shifted in horizontal position sideward’s by 43,2 m.



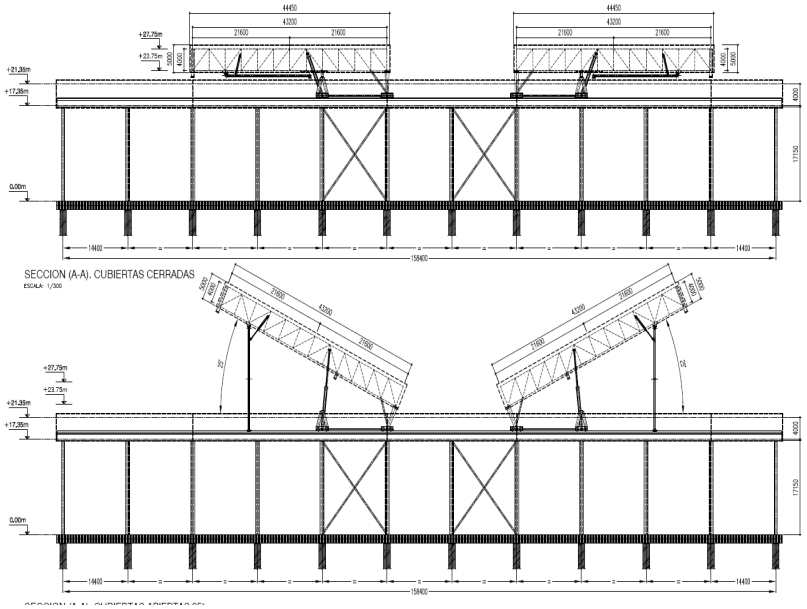
POSICION 1 (DESLIZAMIENTO HORIZONTAL)



POSICION 2 (APERTURA DE 25°)

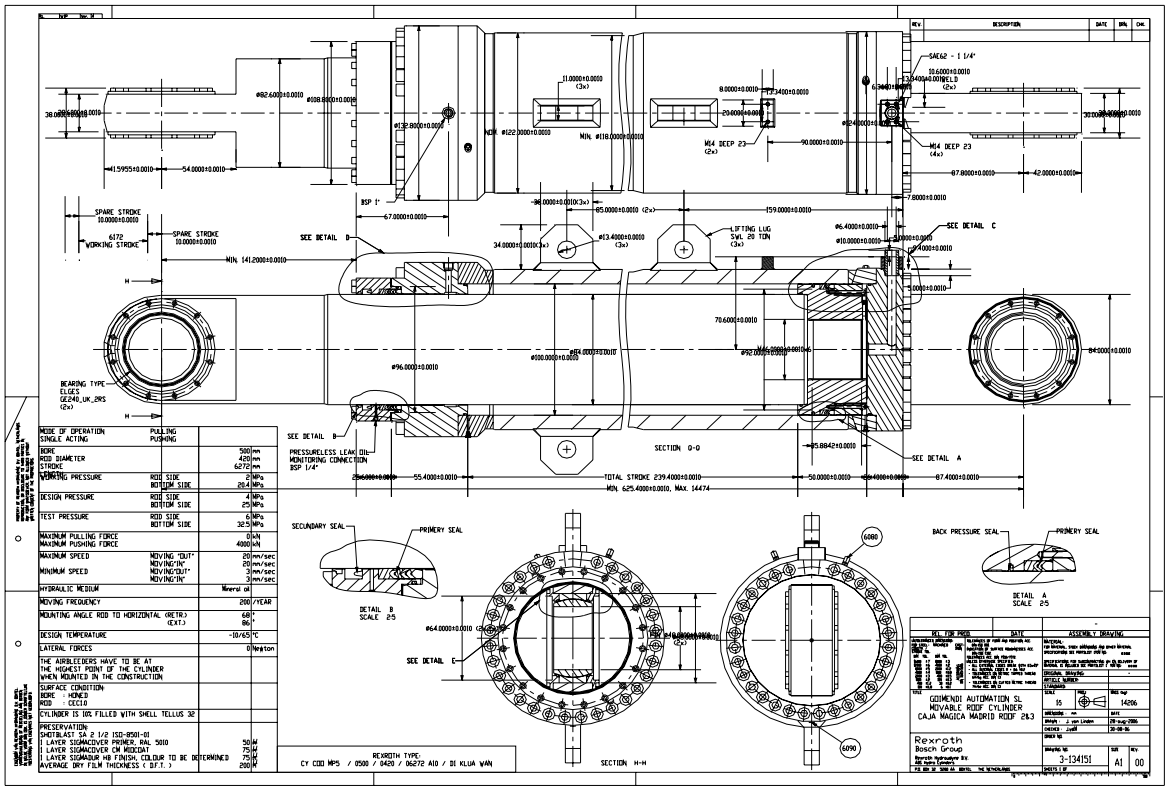
The dimensions of the small roofs are: Width: 60 m
Length: 44 m
Weight: 652 metric tons

The tilting of all 3 roofs is done by hydraulic cylinders. For roof 2 and 3 the cylinders are arranged in vertical position on each side and these cylinders will open the roof to an angle of 25°. The max. pushing force for each cylinder is - 4000 kN
stroke – 6300 kN

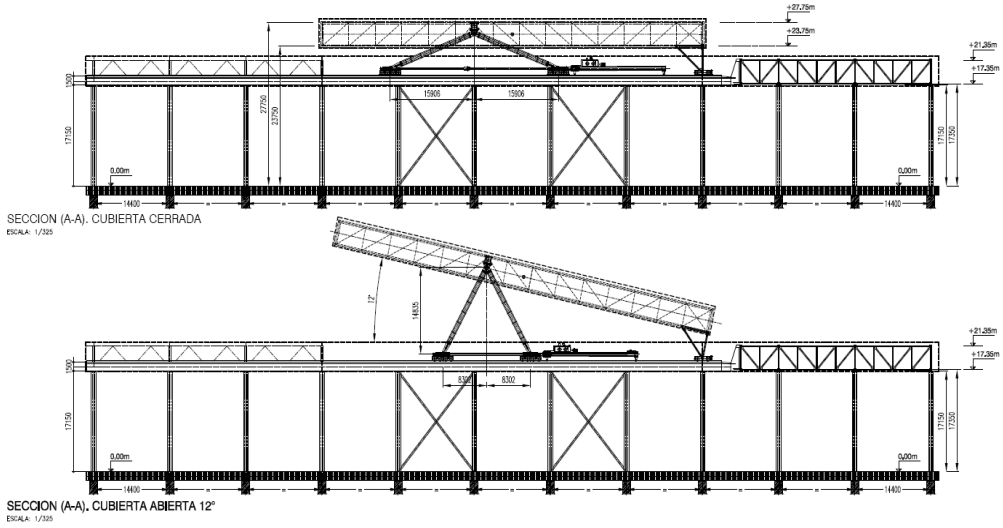


This results into a cylinder with

- piston ø 500mm
- piston rod ø 420 mm
- max. working pressure 205 bar
- weight 16 metric tons

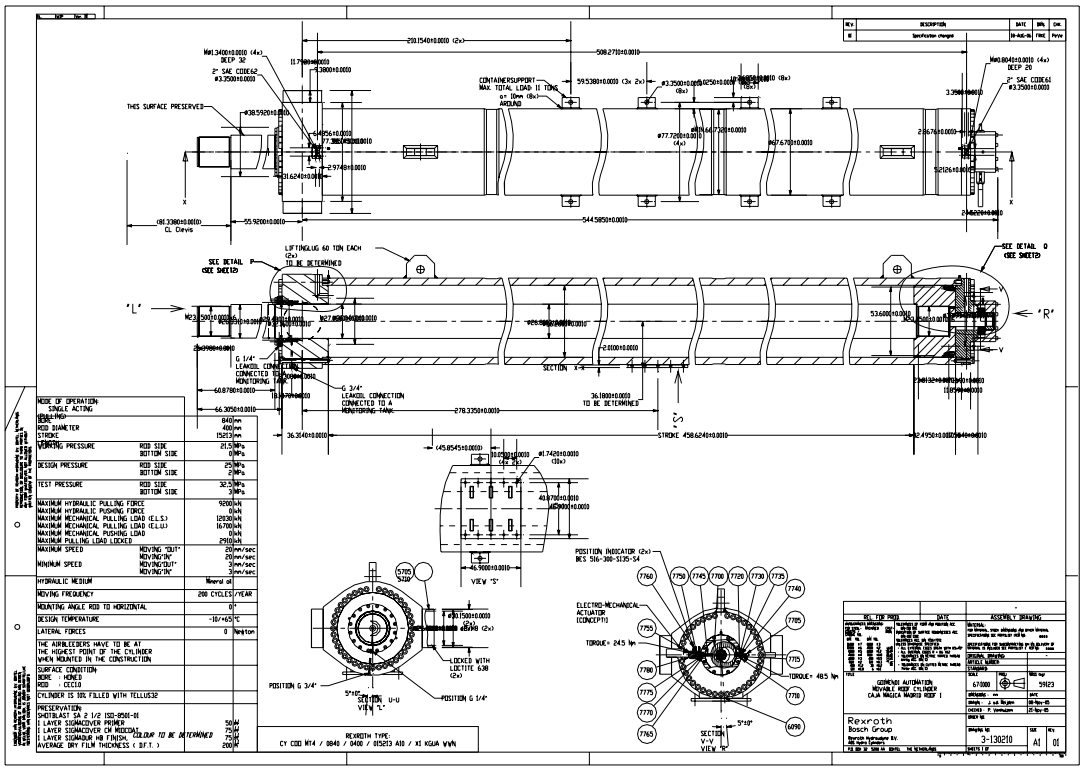


For the main roof the cylinders are located on one of the bogies in horizontal position on each side. The bogies are connected via levers to the roof. By pulling the bogies together the roof is lifted to an angle of 12 °. To tilt the main roof up to 12° each cylinder must pull with 9200 kN. The stroke of the cylinder is 15200 mm.

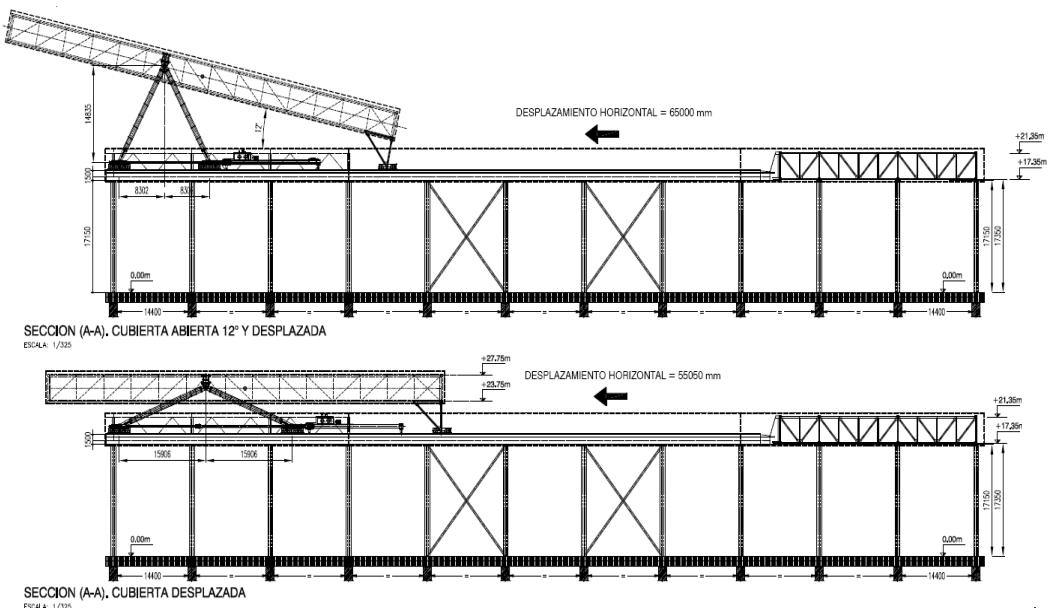


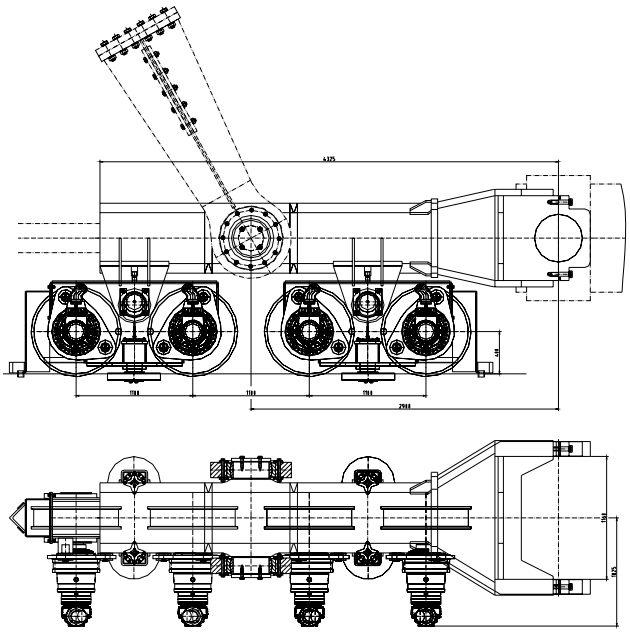
This results into a cylinder with

- piston ø 840 mm
- piston rod ø 400 mm
- max. working pressure 215 bar
- weight 60 metric tons



As already mentioned, roof 1 is shifted sideward's in tilted position by 65 metres. This rolling sideward's is done with the help of 4 hydro motors on each side with gear boxes driving the wheels of 2 bogies. The max. torque to accelerate the roof in horizontal direction is 40 kNm per wheel.





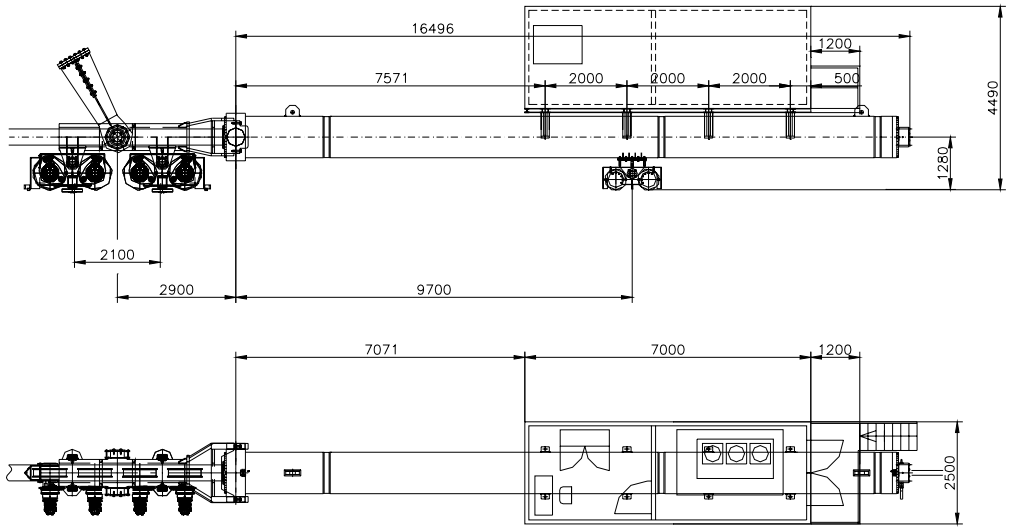
The movement of both sides must be synchronized with a tolerance of max. +- 2 cm. The synchronization will be realised by the hydraulic system that means the speed control will be done by proportional flow control valves. In order to achieve such a high accuracy for the synchronization the measuring system must be very accurate. For the long distance of 65 metres we selected 2 different independent working laser systems on each side.

The first system is a optical laser distance measuring system and the second system is working with a bar code, similar to those of supermarkets. The bar code is arranged on the rail and the scanner is assembled on one of the bogies.

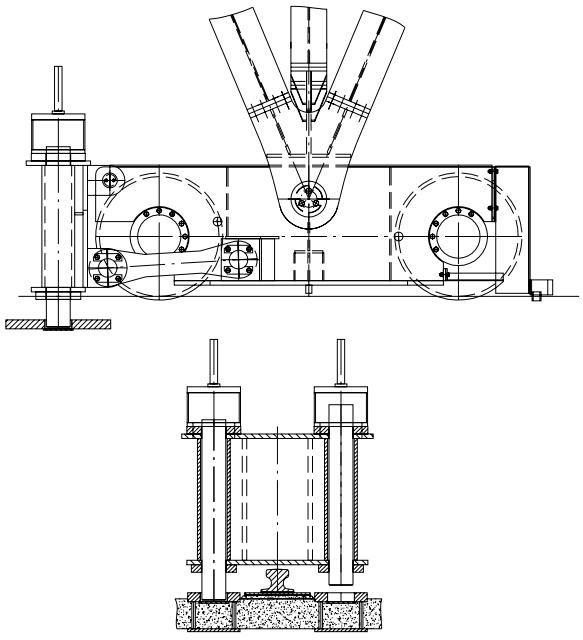
The tolerances of such measuring devices are in a range of +- 2 mm for a distance of 65 metres.

The hydraulic power packs and electrical control cabinets for roof 1 are installed in cabinets on top of the hydraulic cylinders and moved together with the roof, from

closed to open position and reverse. The electrical power supply for the drive and control mechanism is carried via a cable loop.

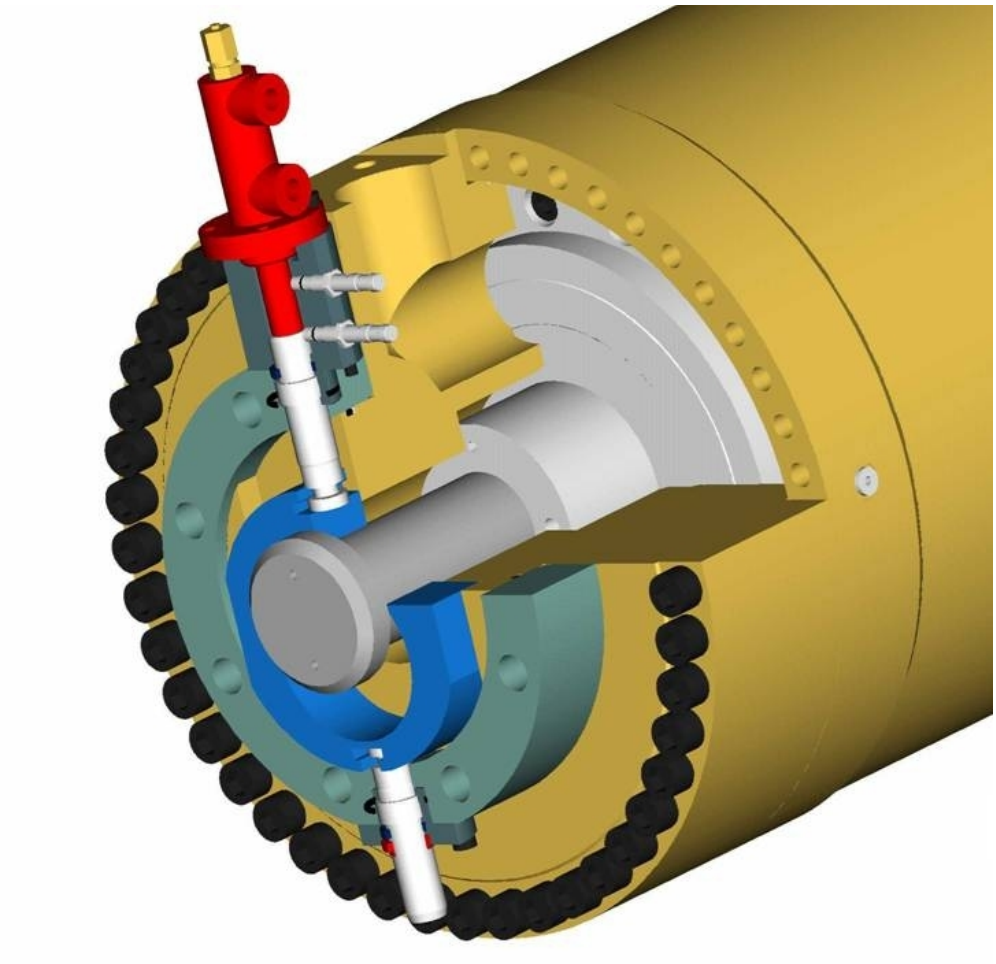


In the end positions the roof 1 is locked with locking pins operated by hydraulic cylinders.

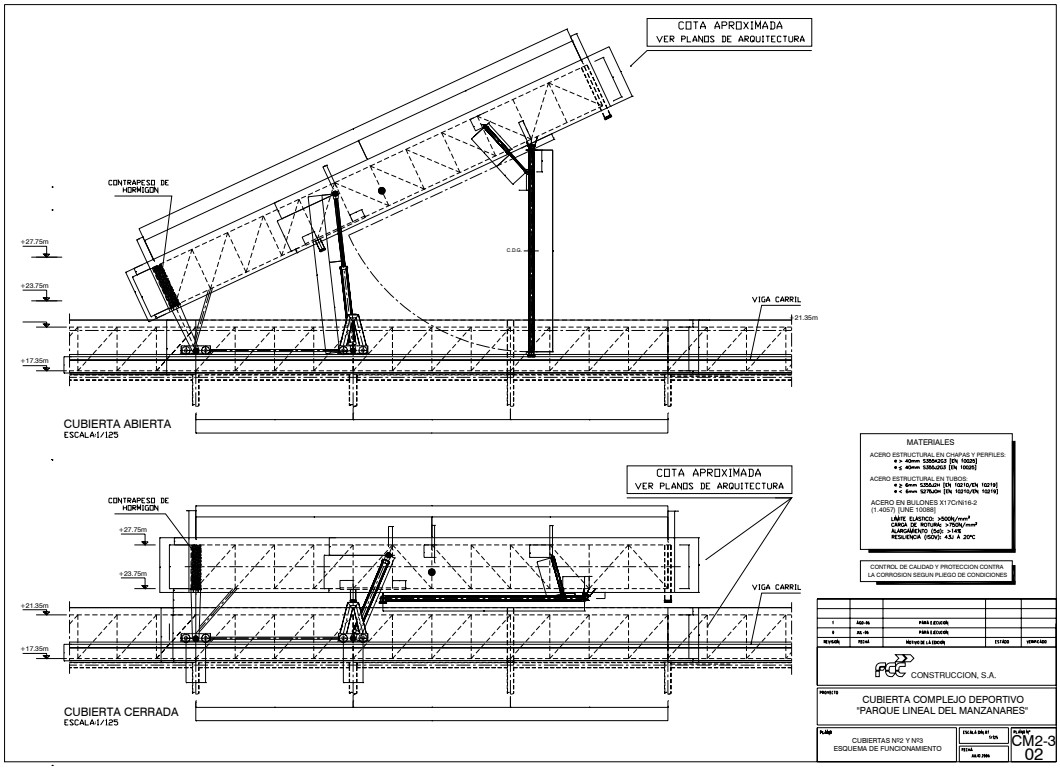


The tilting of roof 1 is done with the help of two (2) horizontal hydraulic cylinders as mentioned earlier. The tolerance between the two (2) cylinders during opening and closing is max. +- 10 mm also. The synchronization as well as the speed control is realised by proportional flow control valves. As measuring system we use the same laser systems as for the horizontal movement.

The locking of roof 1 in tilted position is done with a hydraulic locking device installed in the cylinder bottom.

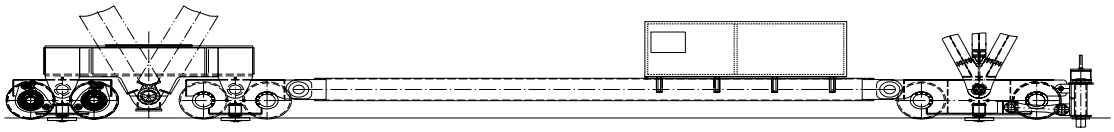


Roof 2 and 3 are working nearly similar to roof 1. During tilting of the roof the 2 cylinders must be synchronized, within a tolerance of +- 2 cm. The stroke measuring system is also done via laser measuring, also here we have 2 redundant systems. As soon as roof 2 and 3 are tilted into the open position they will be locked via locking stem, which is brought into position by hydraulic cylinders.



The shifting of roof 2 and 3 is only done when the roof is in horizontal position. The movement of the roof is similar to roof 1. On each side we have 2 hydraulic motors with gears connected to the wheels. The 2 sides have to be synchronized with a tolerance of +- 2 cm. The stroke measuring device is the same as on roof 1.

Also roof 2 and 3 are locked in the 2 end-positions. The power pack and the electrical control cabinet are assembled in a housing on top of the intermediate stem between the 2 bogies and the electrical connections are done in the same way as in roof 1.



The challenge for the drive and control of these 3 roofs are mainly:

1) The high masses to be moved especially for roof 1. With cylinders of this size and weight piston diameter 840 mm, piston rod 400 mm, stroke 15200 mm and weight of cylinder 60 metric tons.

We are on the limits of our manufacturing capacities.

2) Synchronization of all the cylinders for tilting the roofs with a tolerance of +- 2 cm, as well as the measuring devices with tolerances max. +- 2 mm.

Synchronization is even more complicated because the power packs are located on each side of the drives and there is no hydraulic connection between the 2 power units.

Synchronization between the 2 cylinders of the different roofs is realised via flow control valves proportionally controlled.

The pumps of each side are Axial piston pumps and deliver nearly the same oil flow to the cylinders.

The proportional flow control valves bypass the required oil from the faster cylinder to the tank in order to realize the synchronization between the 2 cylinders during opening.

During closing we always have a positive load on the cylinder, so the pumps are only used to open the pilot-operated check valves.

With the help of the proportional controlled flow control valves we also realise acceleration and deceleration of the hydraulic cylinders.

The shifting of the roofs is done via hydraulic motors.

The hydraulic motors are fed by 2 (two) axial piston pumps. Speed control and synchronization is done via proportional control valve.

Additionally we have flow dividers to single hydro motors in order to realize a axial load distribution to all the hydraulic motors.