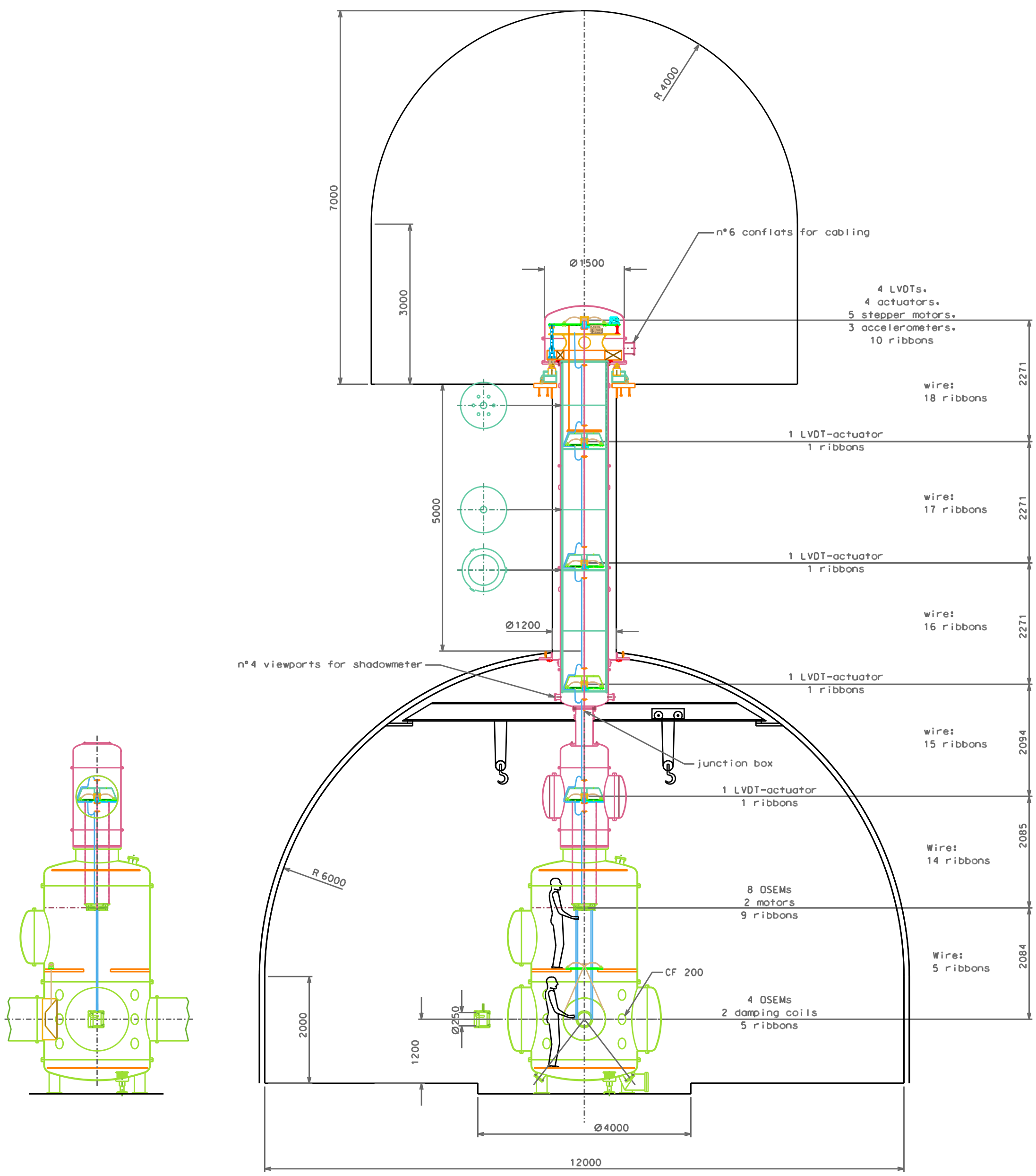
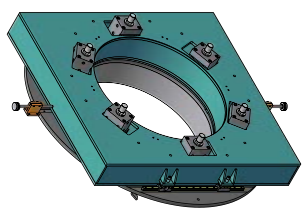
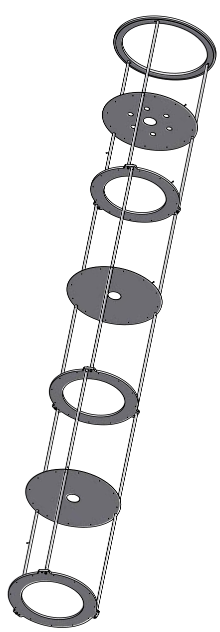
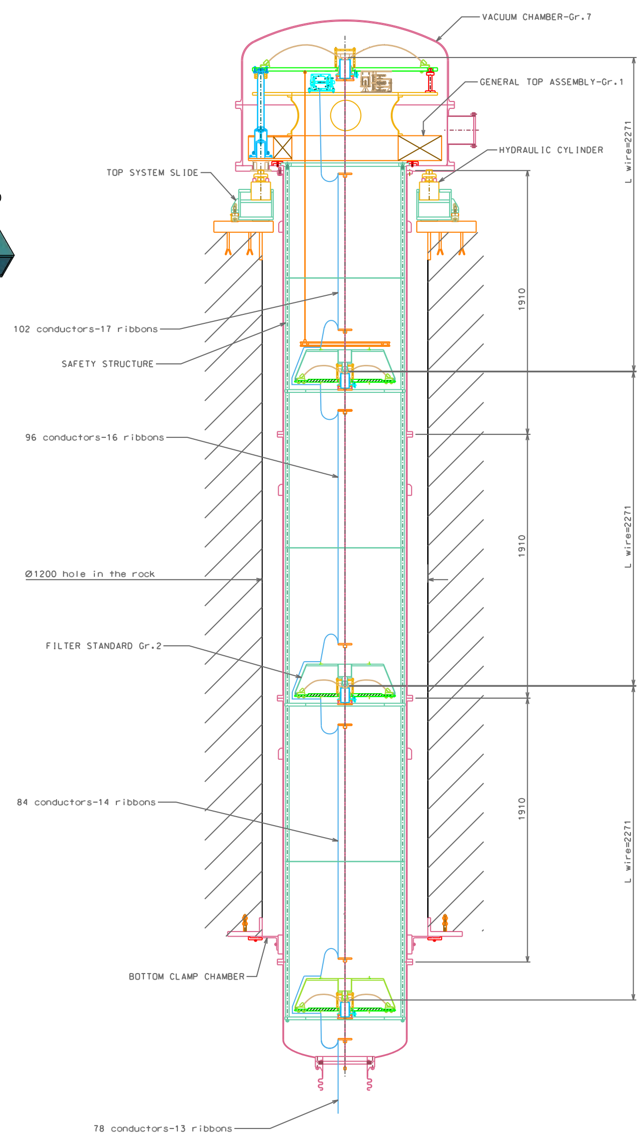
This documents illustrates the type-A SAS installation sequence down the well, how it and its payload can be effectively and safely implemented in the well between the two caverns. The aim is to assure that every step is easily and safely feasible. Particular care is spent to assure clean, reliable, soft and low-mechanical-noise electrical cabling, which is probably the biggest challenge in the SAS scheme.
This first image shows the final configuration. It also gives the wire count, the ribbon count and the listing of each instrument at every step of the attenuation chain.



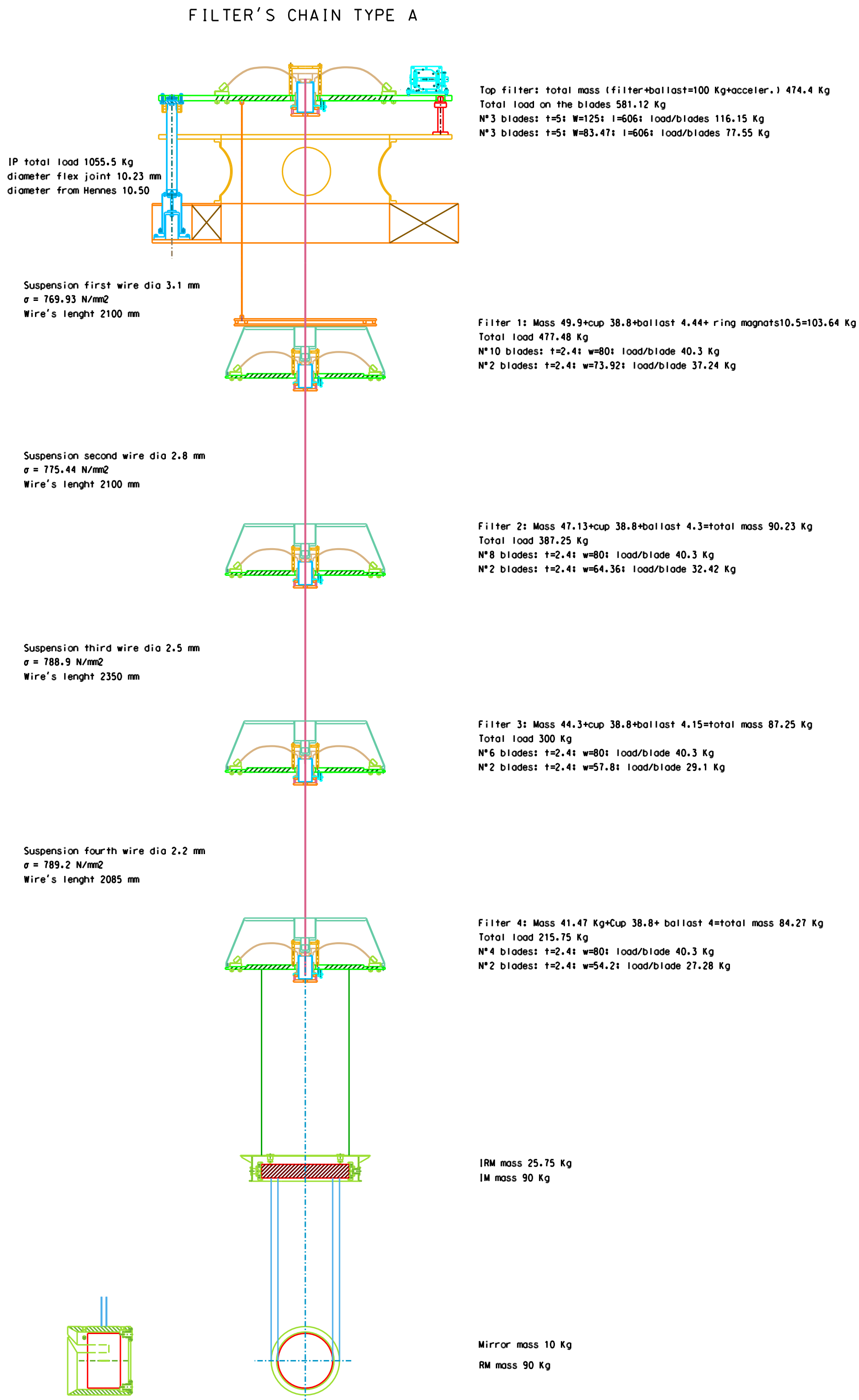
This (on the right) is a zoom into the hardware down the well section.
For convenience, to avoid obstructing the view, in this and the following figures the struts of the safety structure, actually spread at 120º, have been placed at 180º from each other.
The structure shown top left is the sled that position and levels the vacuum chamber and the Inverted Pendulum structure.
The structure on the bottom left is the safety structure that catches the filters in case of catastrophic failure (e.g. earthquake) and guides the chain during installation.
It is made out of stainless steel rods connecting spacer rings that stiffen the structure transversally. The rings are positioned just below each standard filter, if the suspension wires are released the filters sit on these rings.
Half way between the filters, the structure incorporates disks acting as thermal baffles, which make that each filter is effectively in its own thermal bath. This is useful for thermal micro-tuning of each individual filter's load.



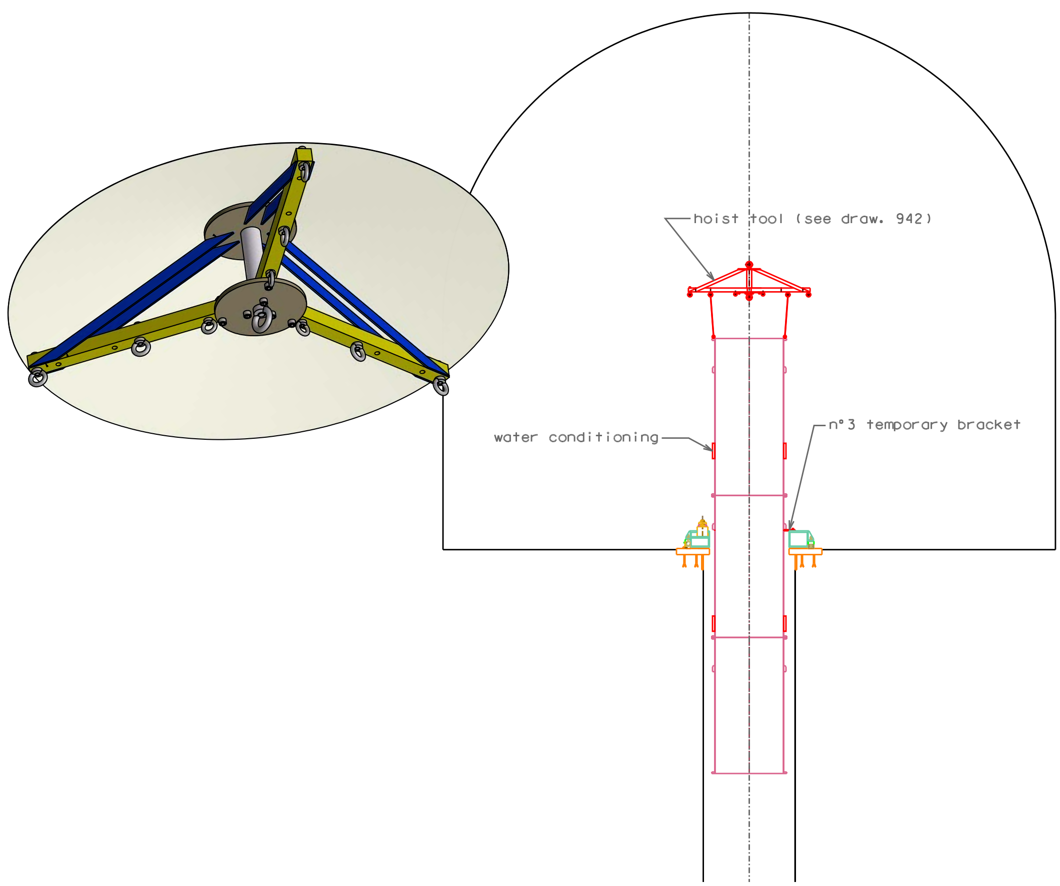




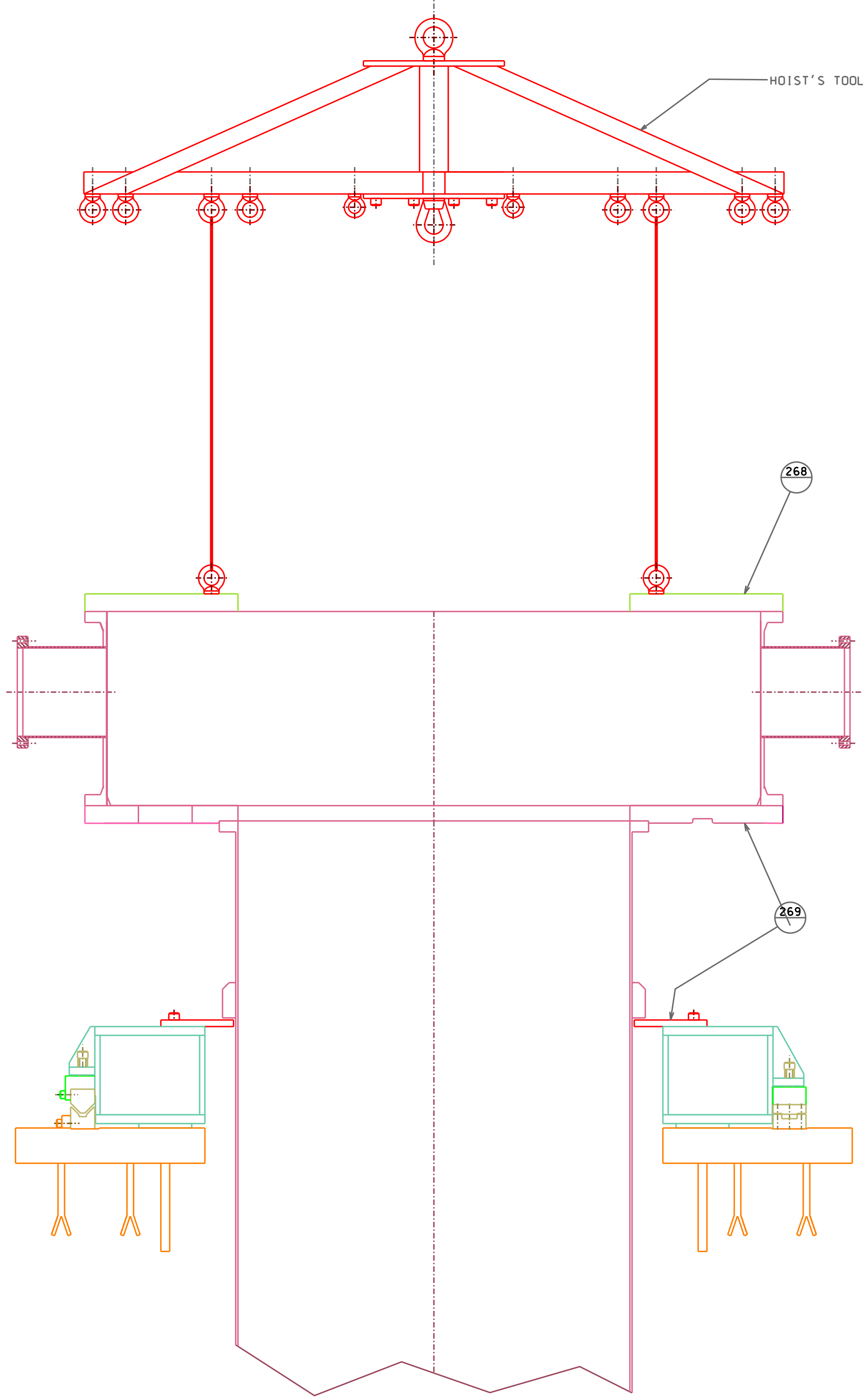
In this figure, load, stress, suspension wire length and electrical wiring data are listed.



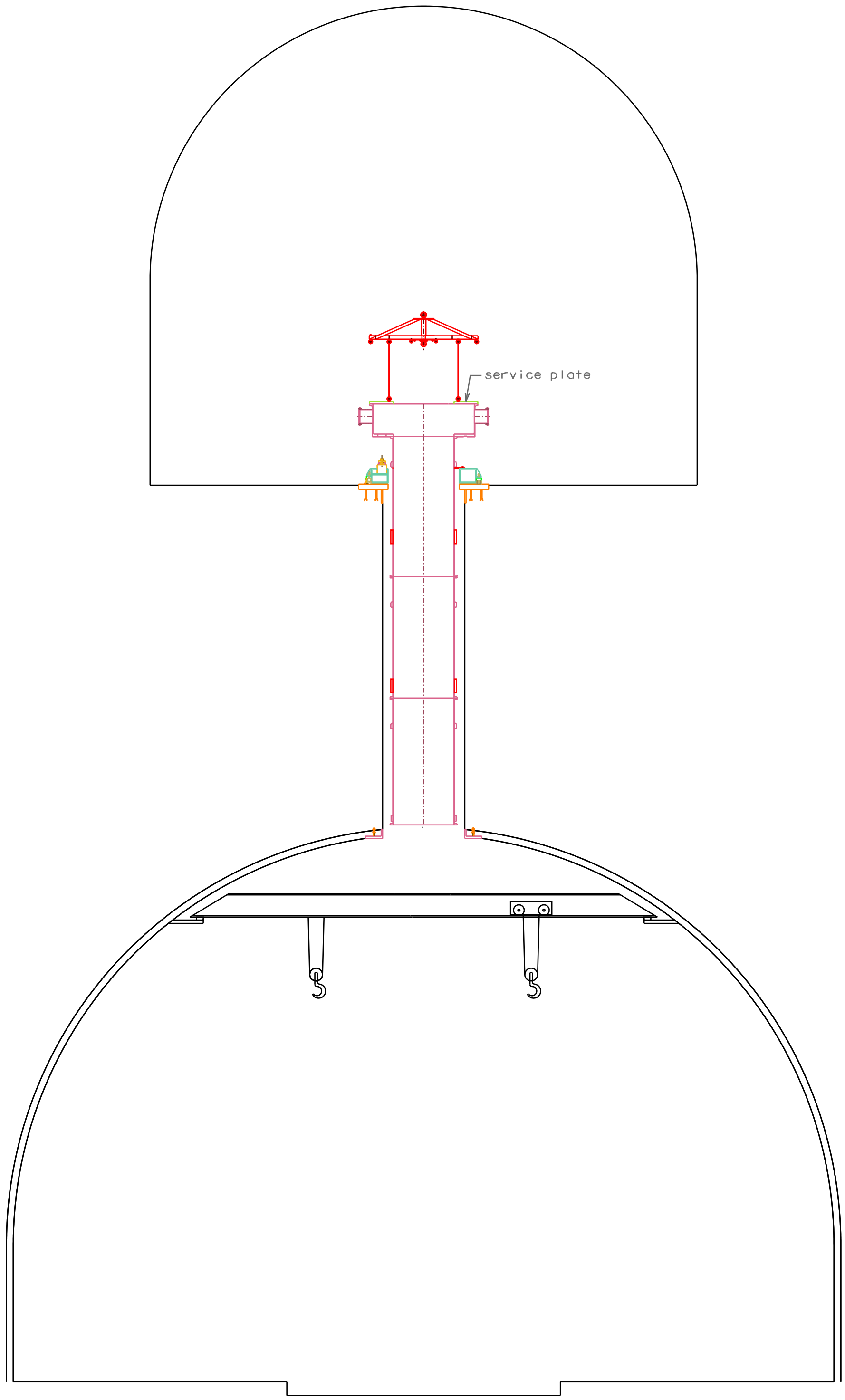
The installation procedure starts with empty caverns. Note that in all figures the top chamber has been rotated 90º for illustration only. Underground the top and bottom chambers would be built at 90º from each other, for rock stability reasons. The green sled is mounted first on its rails on the floor of the top chamber.
Using the overhead crane, the individual vacuum chamber spools are lowered in the well, temporarily supported on brackets bolted on the sled while the next spool is brought in and bolted on, then the spools are lowered one step deeper, and the operation is repeated until all three spools are assembled.
Note that in three locations the spools are provided with water conditioning piping. These are stainless steel tubes, fastened on the outside surface of the spools, in correspondence of the three standard filters. The feed piping is routed to the top chamber. The working temperature of each standard filter can be tuned individually by changing the flowing water temperature, to finely tune each standard filter's working point (changing by 10 to 20 mm per ºC) without recurring to its internal voice coil actuator.
The crane spreader shown on the left is used over and over throughout the operation to handle all large components. It is provided with eyebolts at different diameters to match all components.



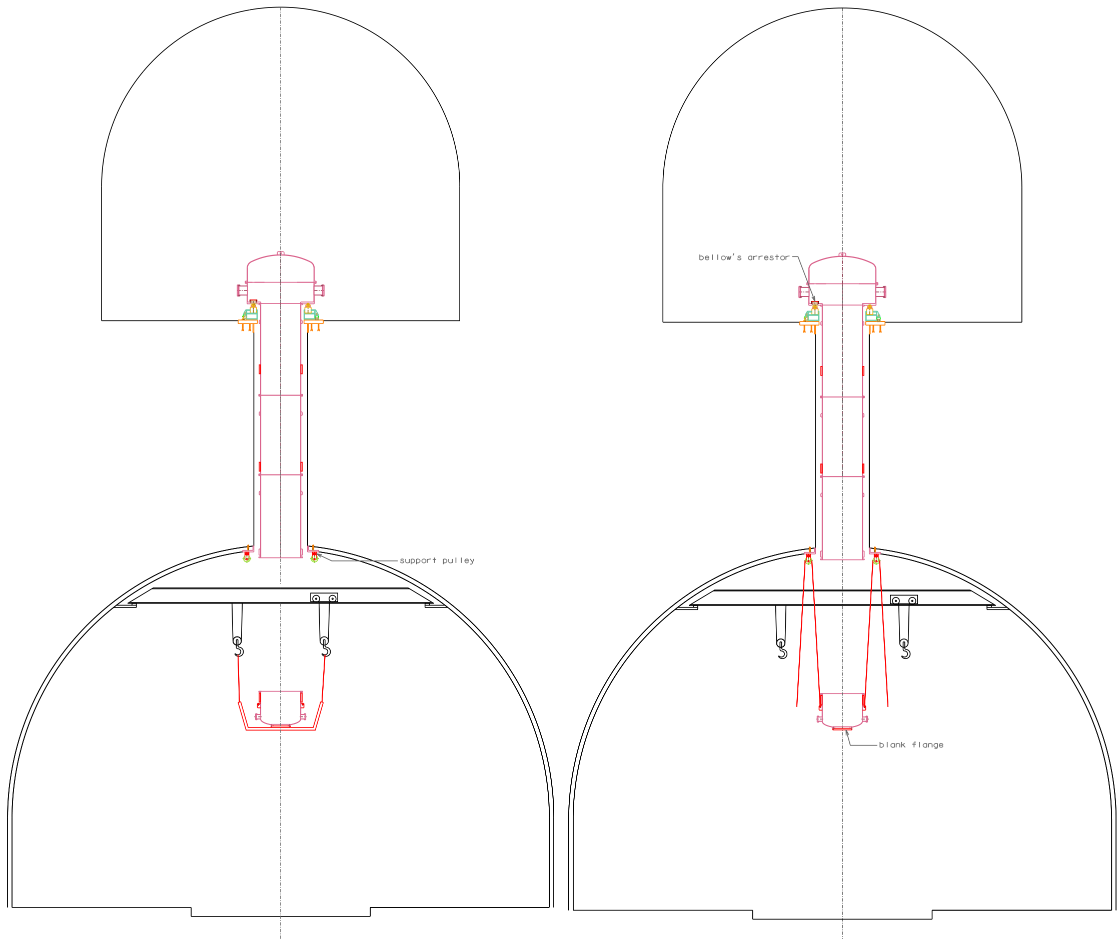
When all the spools are in place, the top chamber “bath tub” is installed.



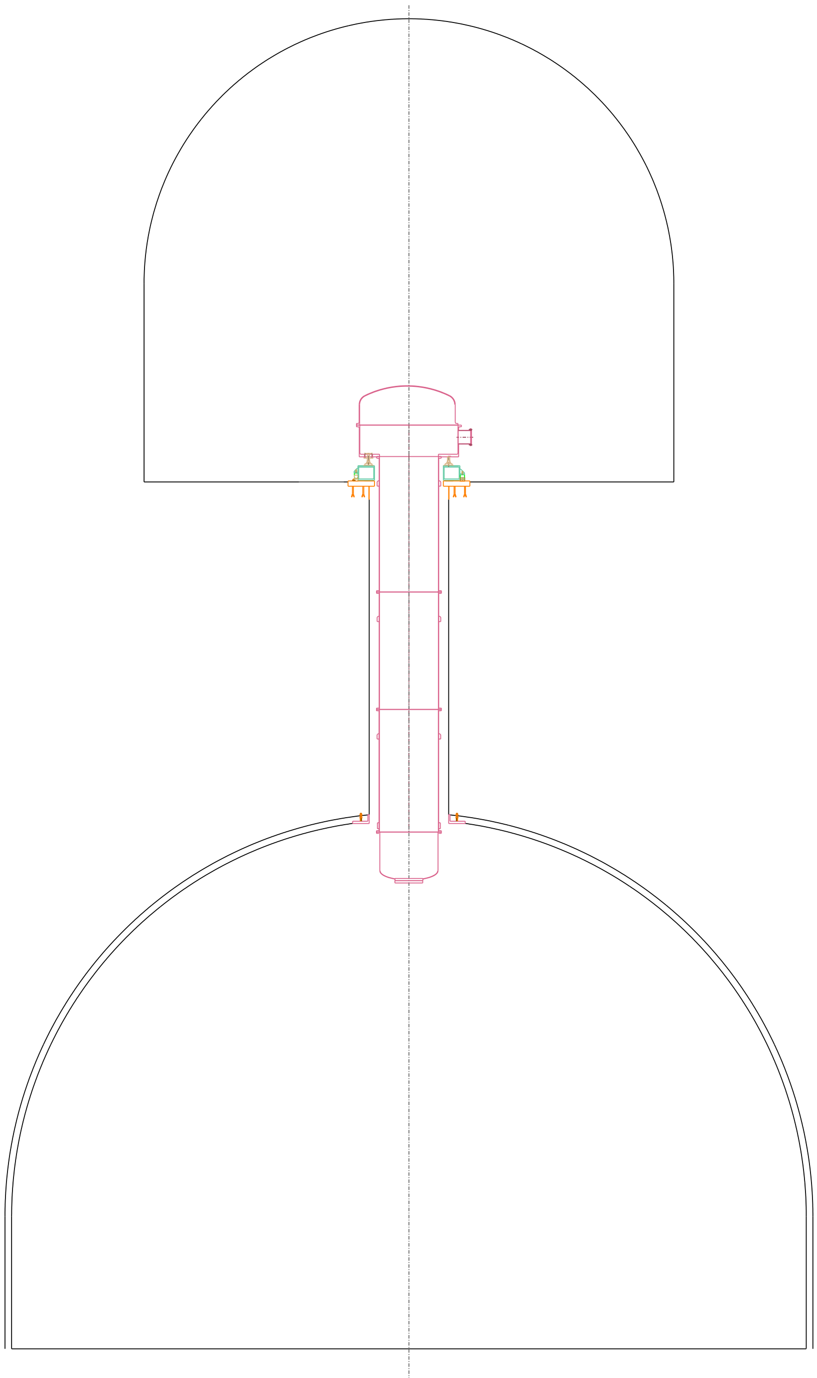
The hydraulic jacks supporting the vacuum chamber and the Inverted pendulum are positioned in the sled, the Inverted pendulum bellows are installed, and the vacuum assembly is lowered on its stand.



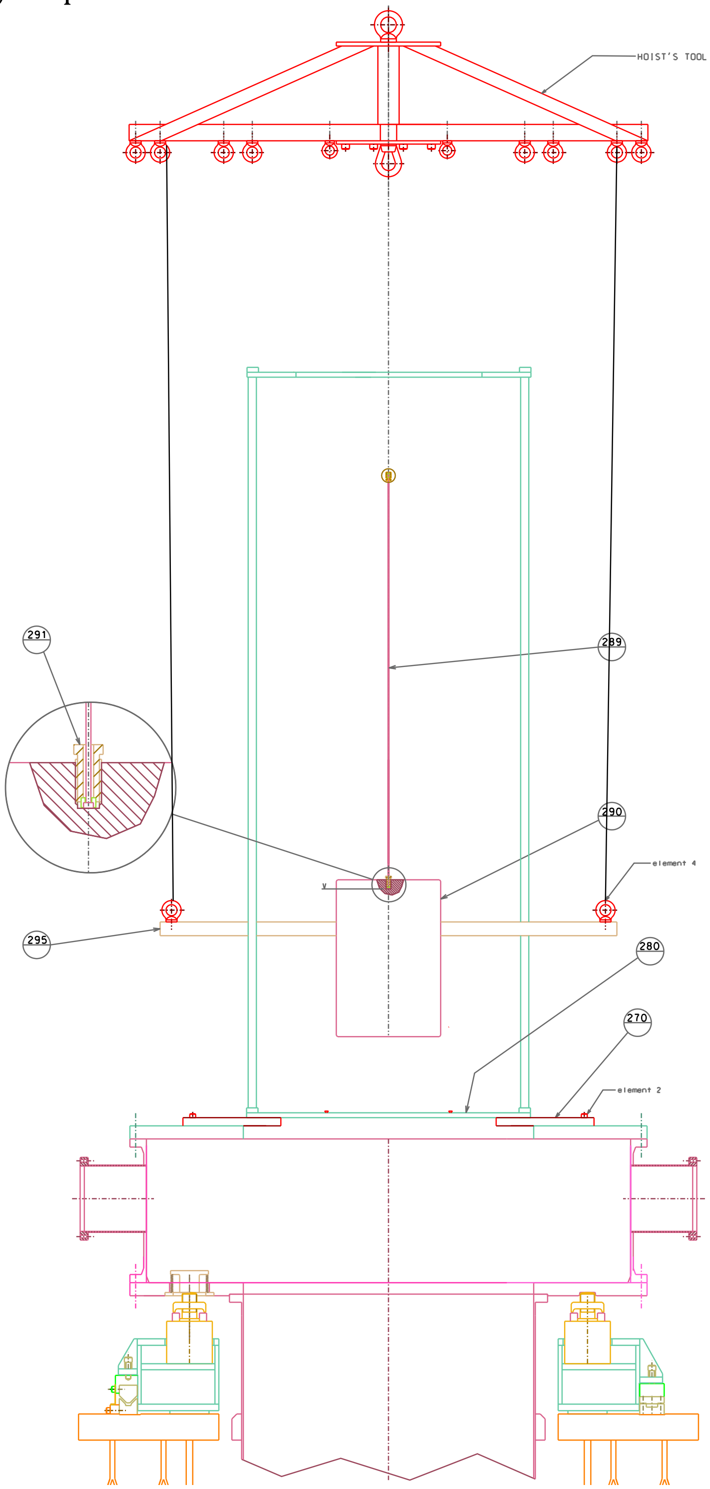
The top dome is mounted on the tub, the lower dome is raised by means of the two cranes of the lower chamber so that it can be hooked to manual chain hoists, and connected to the lower spool.
Note that in the lower chamber two independent cranes, one of each side of the vacuum chamber are needed, because of the suspension chimney impeding the way.



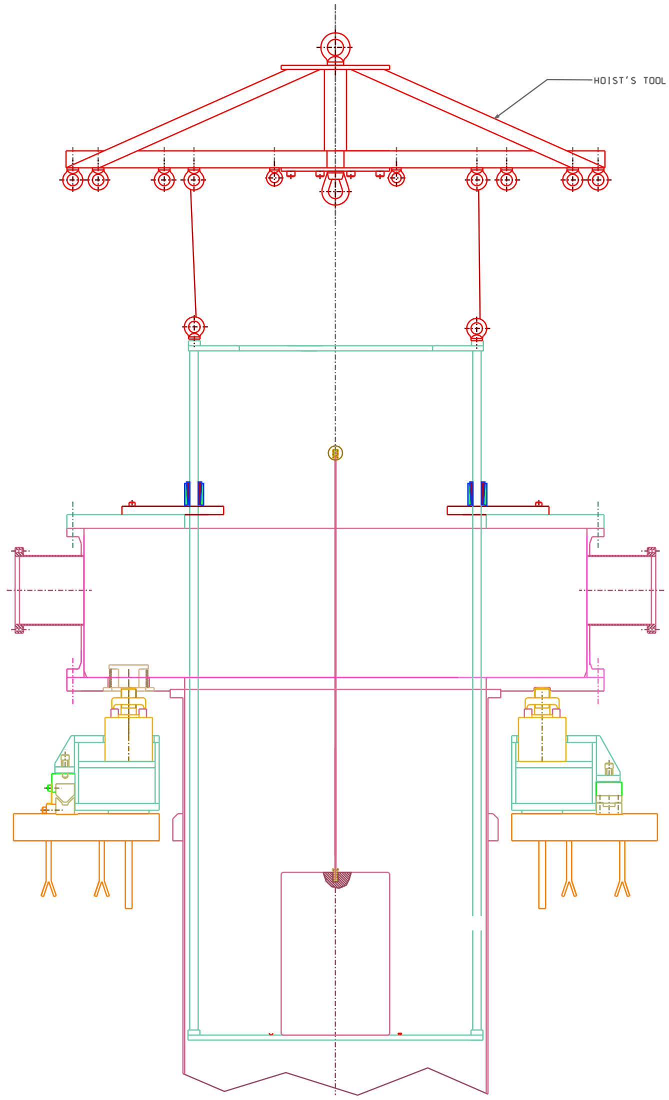
All viewports are sealed. The chamber is connected to a vacuum pumping unit. When the vacuum assembly is closed it is UHV tested for leaks, to make sure that all unreachable flanges are perfectly sealed. Plastic foil lining taped to the cylindrical surface of the spools, and thin plastic tubes allow blowing Helium around each unreachable flange, to identify location of possible leaks.
After the vacuum tests are successfully completed, the top and bottom caps are removed to continue the installation of the seismic attenuation hardware.



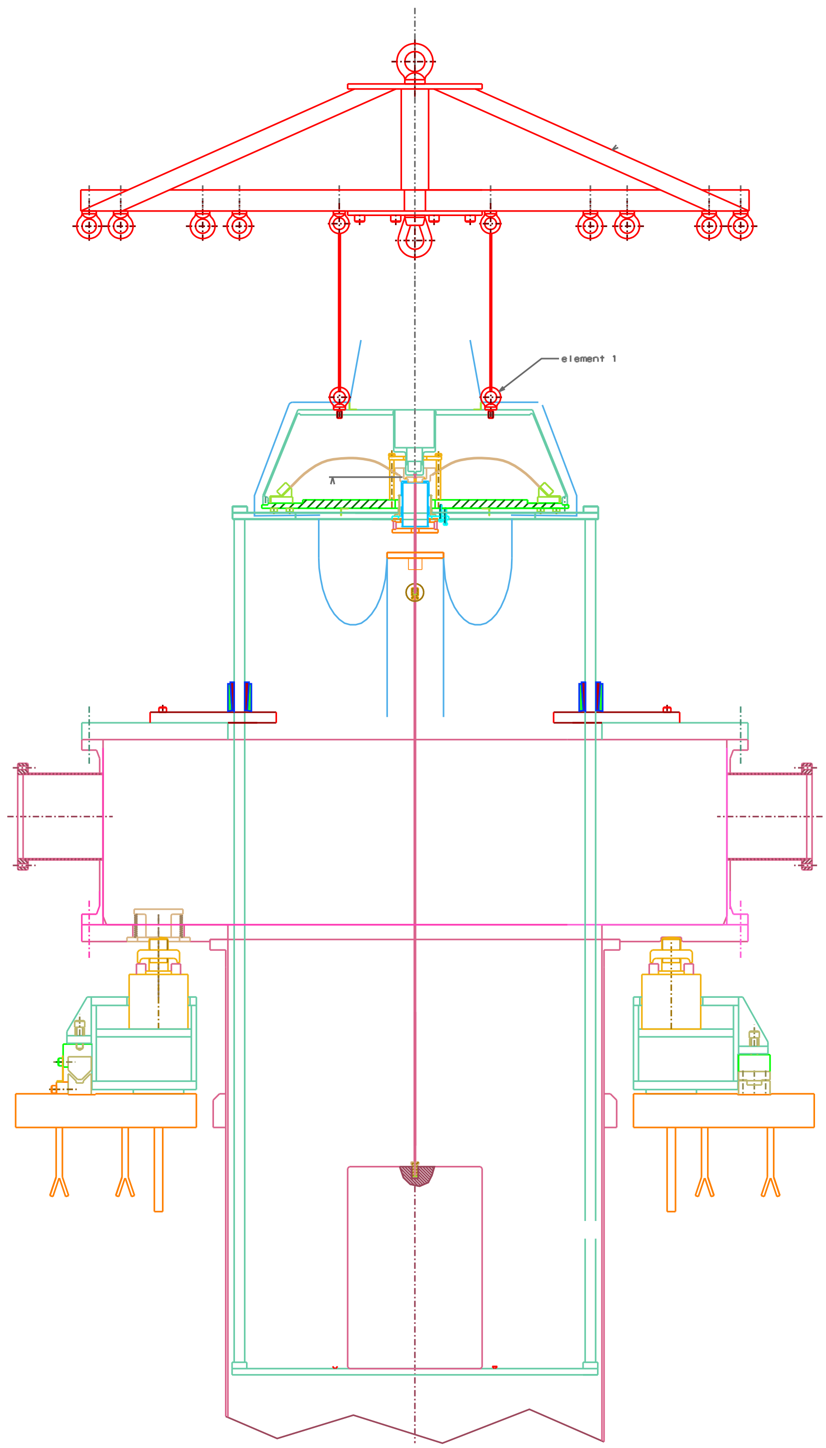
The ballast mass (~300 kg, precisely adjusted to the lift load of filter 3 at 21°C) is lowered over a temporary safety disk, a temporary safety structure is built, the ballast temporary suspension wire is mounted.



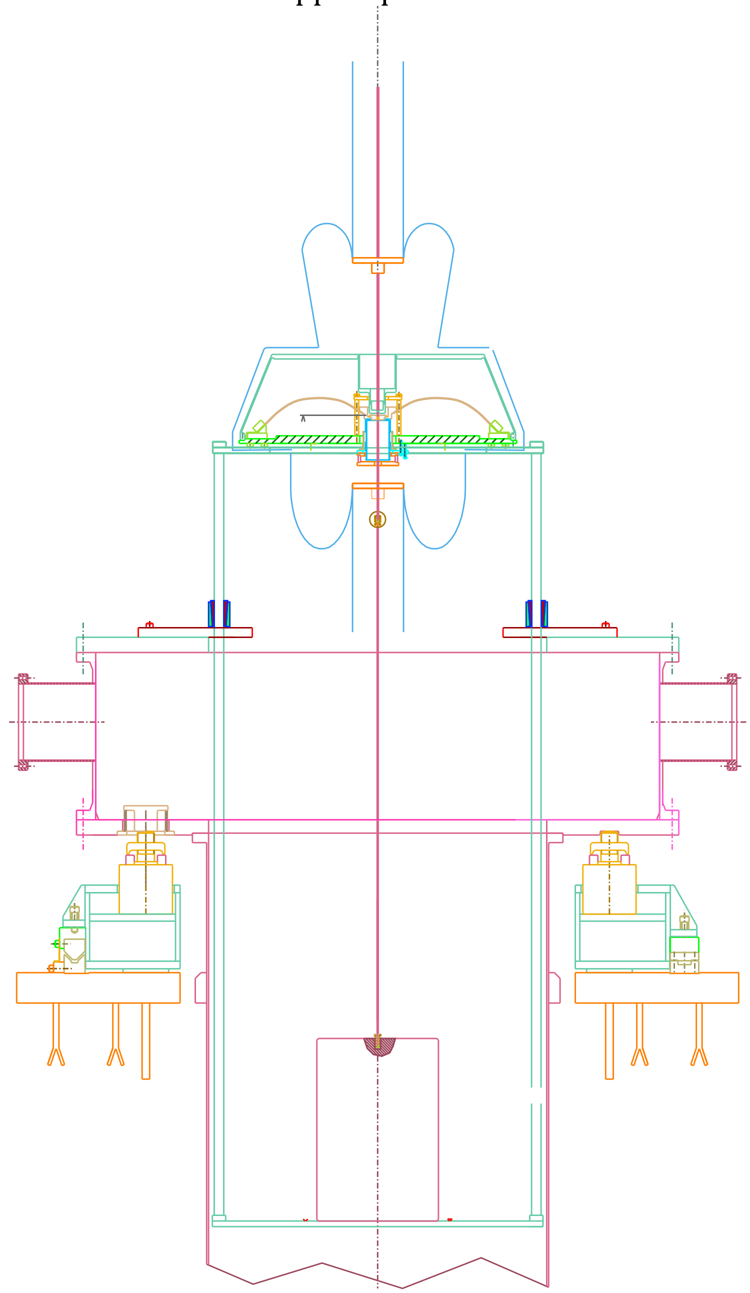
The temporary ballast safety structure is lowered in the well ¾ way, and fastened with three safety conical clamps to the top of the tub.



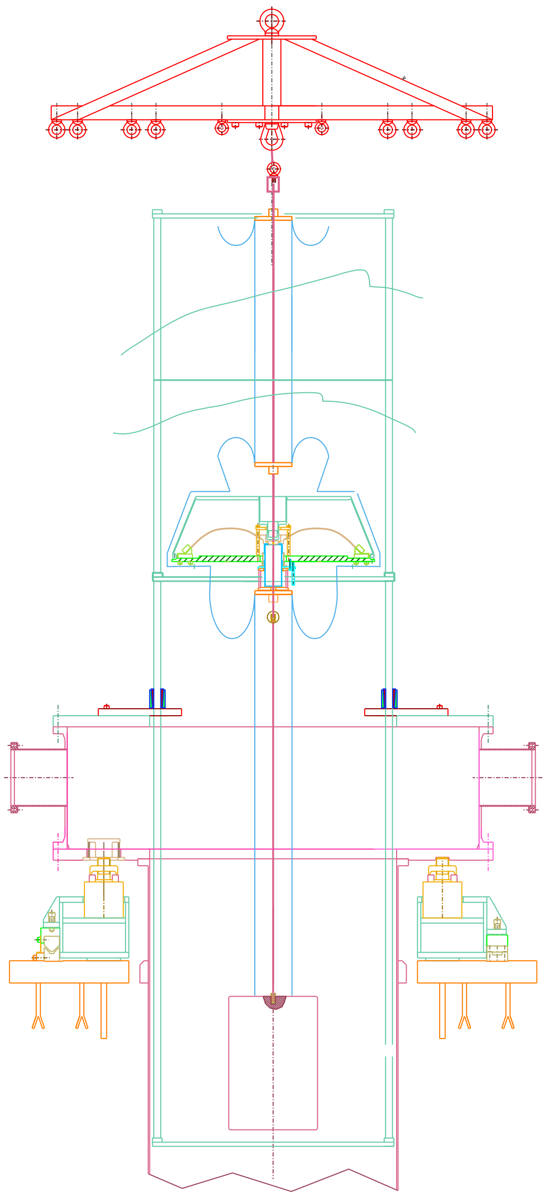
The filter number 3 is craned in, sat over the safety harness, connected to the ballast mass temporary wire using the wire connection box. The lower wiring spider of filter 3 has to be in position already.

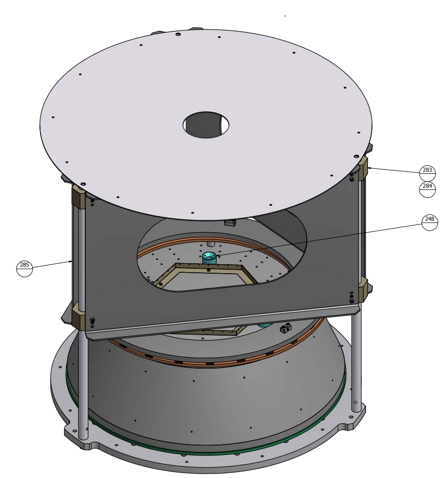


The filter 3 suspension wire, and its spiders are mounted. Cabling is done around filter 3 and between its lower and upper spiders.



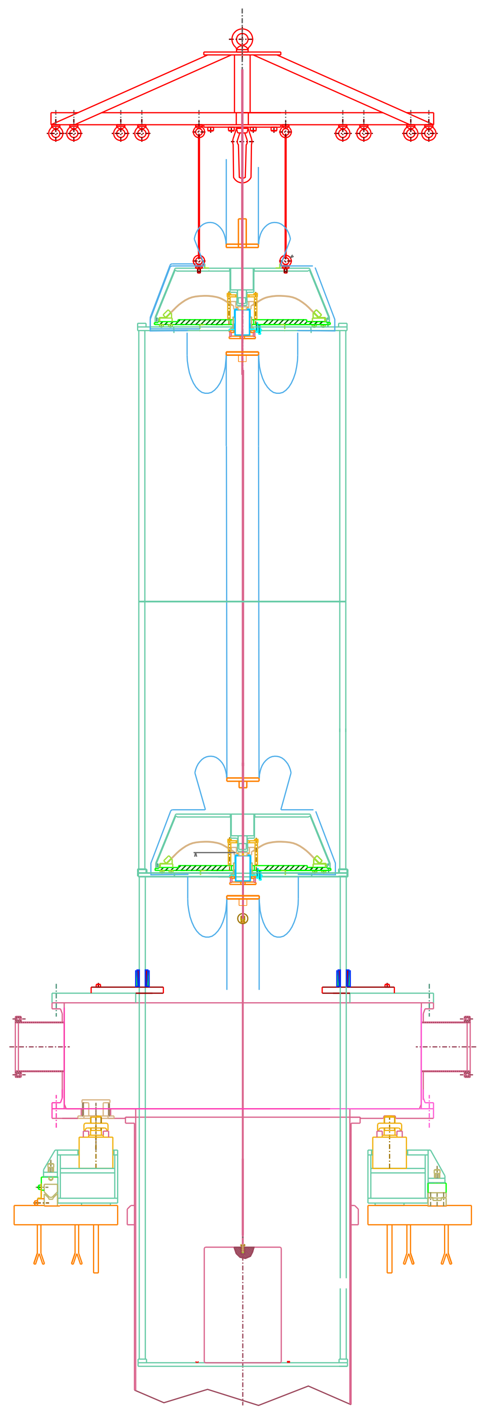
The safety structure between filter 3 and filter 2 is built, and stiffened with two pairs of three temporary panels, as shown in the side figure.
The stiffening is necessary to safely support the weight of filter 2 while changing harnessing. One panel at a time can be removed for wiring. Wiring is made up to the lower spider of filter 2.
The filter 3 and the ballast mass are lifted and the functionality of filter 3 is checked (vertical oscillation frequency and damping constants) using the internal LVDT and actuator. The tilt frequency is tested and adjusted shifting some of the internal filter ballast mass.



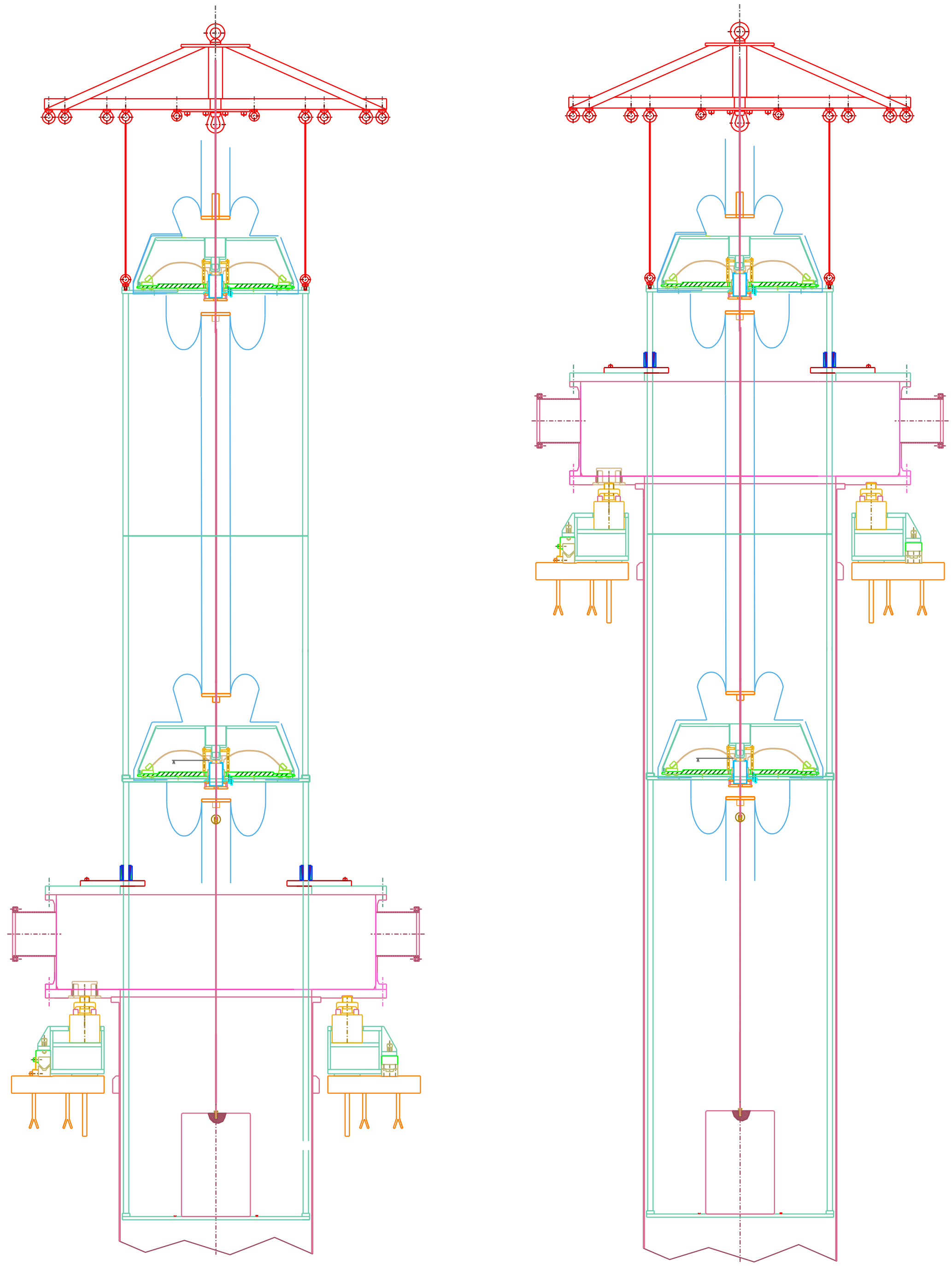


Filter 3 is lowered on pads sitting on its safety ring. The pads keep it lifted by several cm, so that its suspension wire sticks out sufficiently above the safety ring of filter 2 to be easily attached to filter 2.

Filter 2 is brought over and connected to its suspension wire, electrical wiring is performed around filter 2. Filter 2 is raised again to remove the pads supporting filter 3.
The vertical functionalities of filter 2 and filter 3 are checked (vertical oscillation frequency and damping constants) using their internal LVDT and actuators.
The ballast mass of filter 3 is adjusted to precisely match the payload of filter 2.



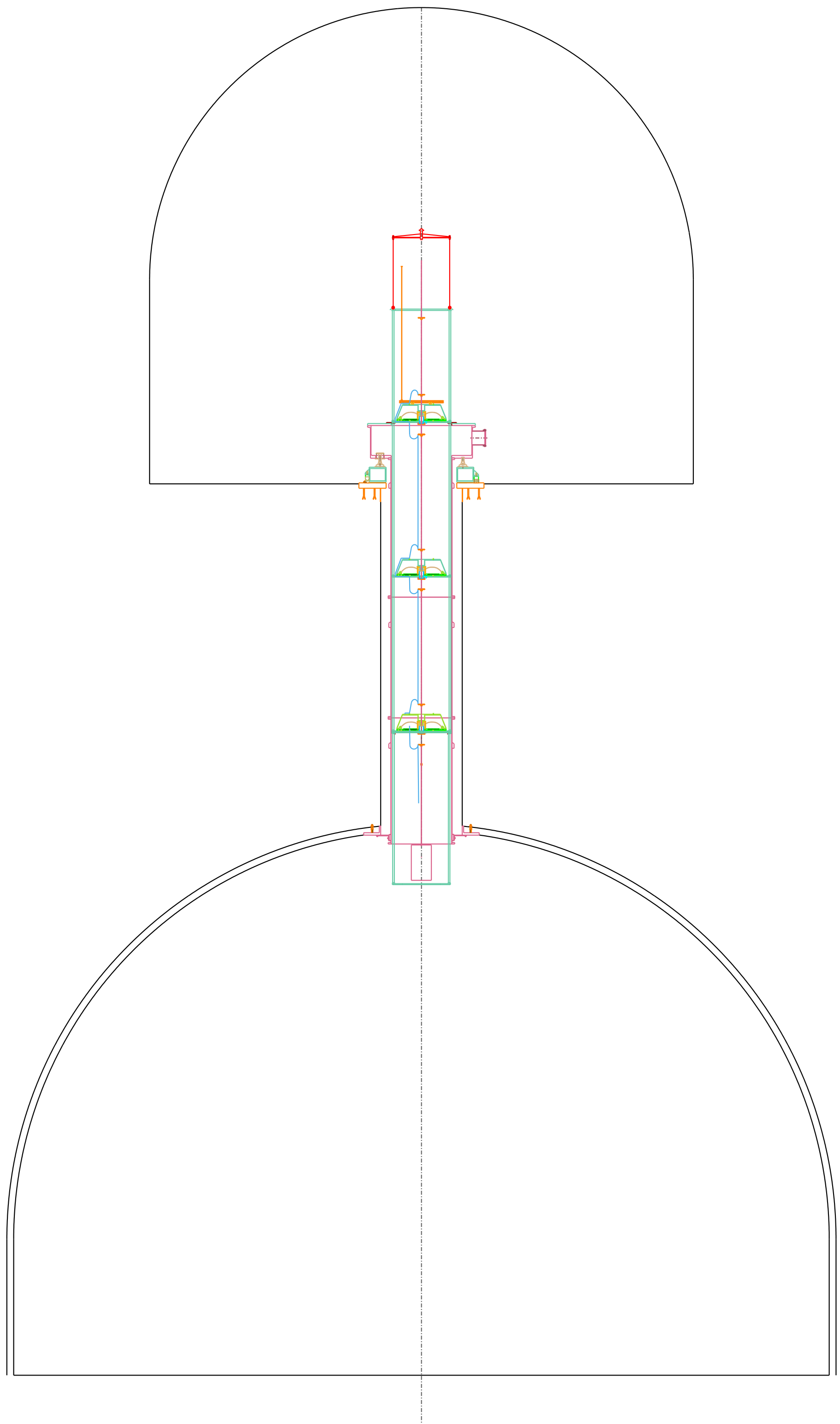
Filter 2 and 3 are lowered on their safety rings, the safety structure is lifted, the conical clamps are removed so that the structure can be lowered by one step and re-clamped.



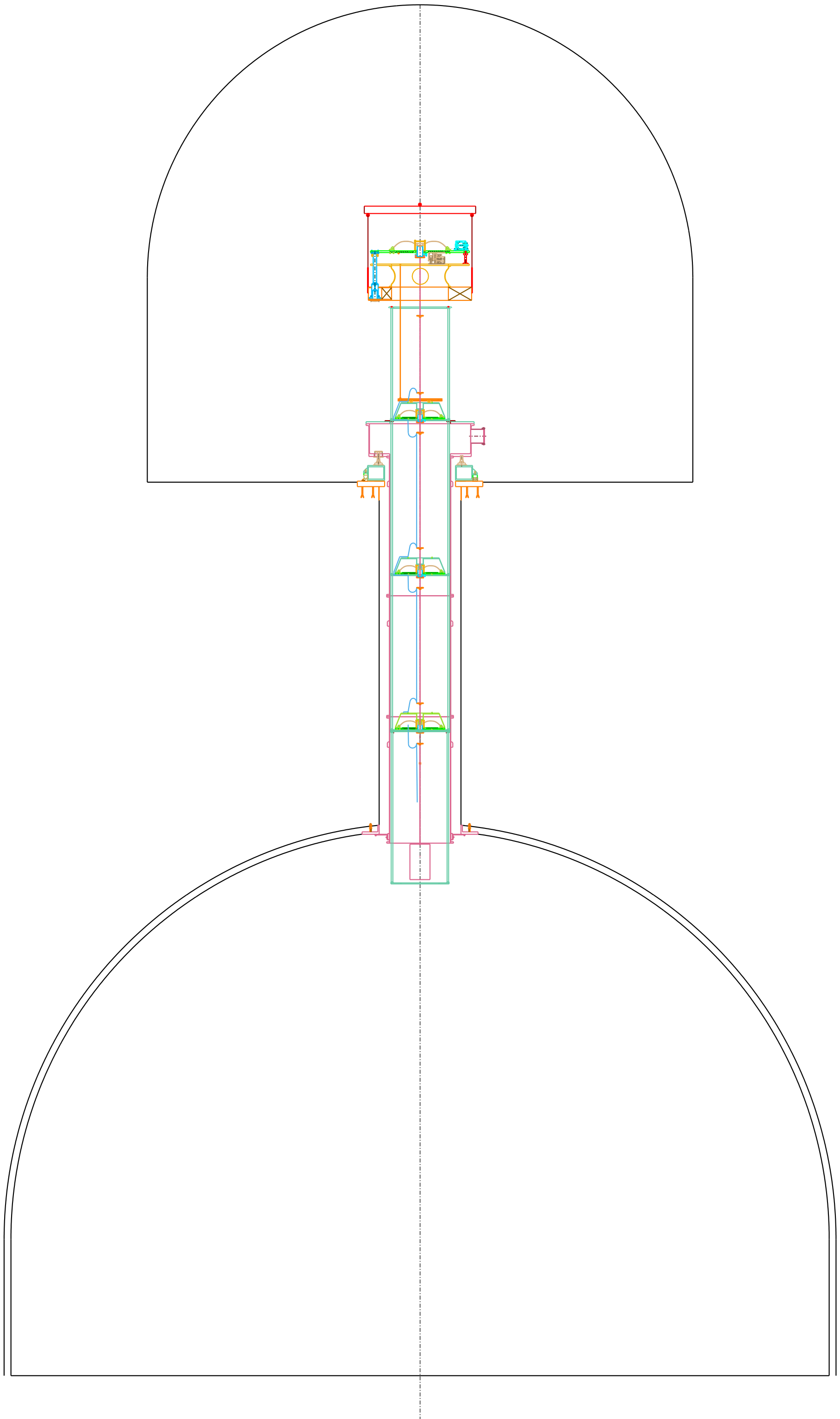
The same sequence is repeated to install filter 1.

MORE EDITING TO BE DONE BELOW

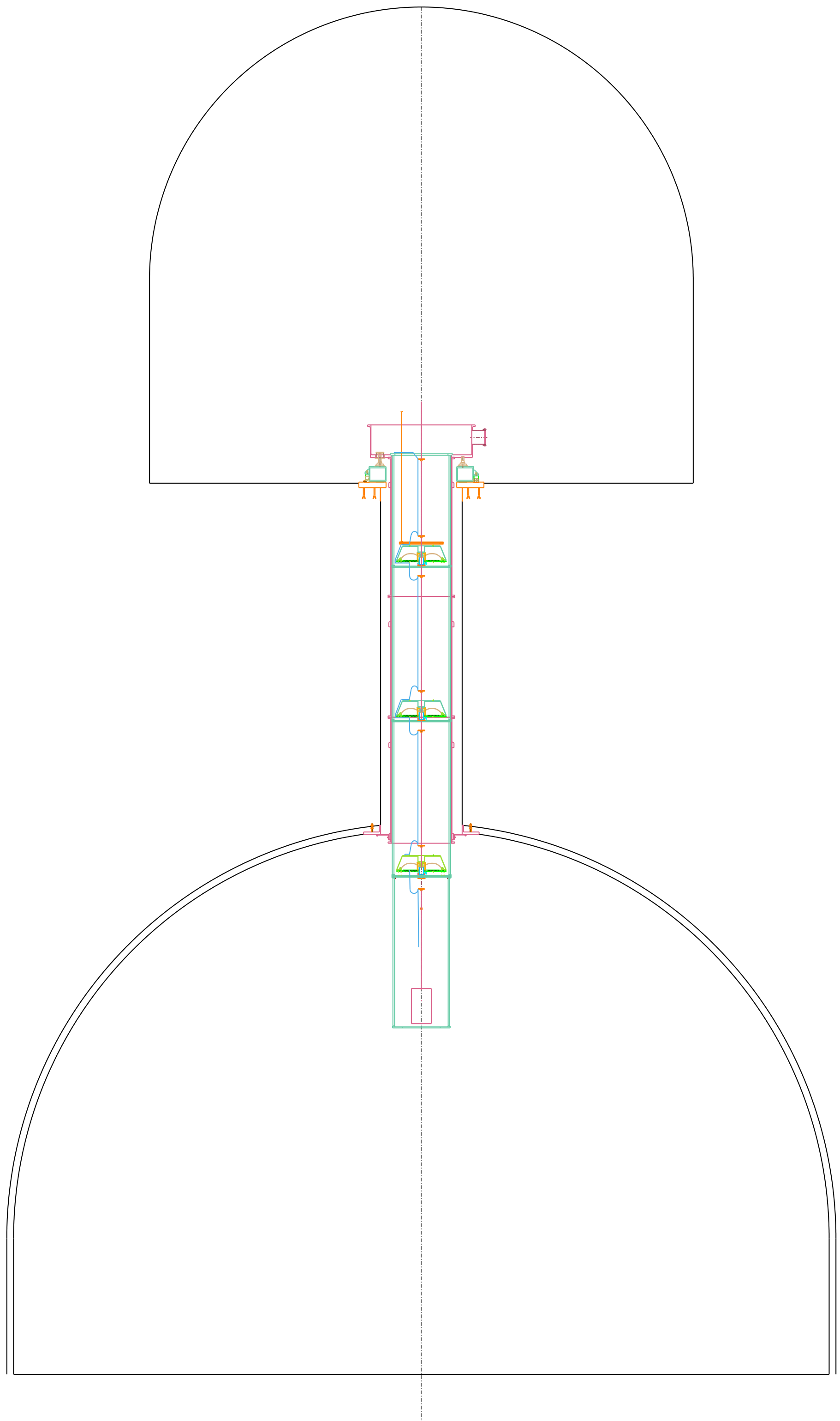
The assembly between filter 1 and the top filter is somewhat different because the magnetic damping ring and its suspension wires need to be implemented.



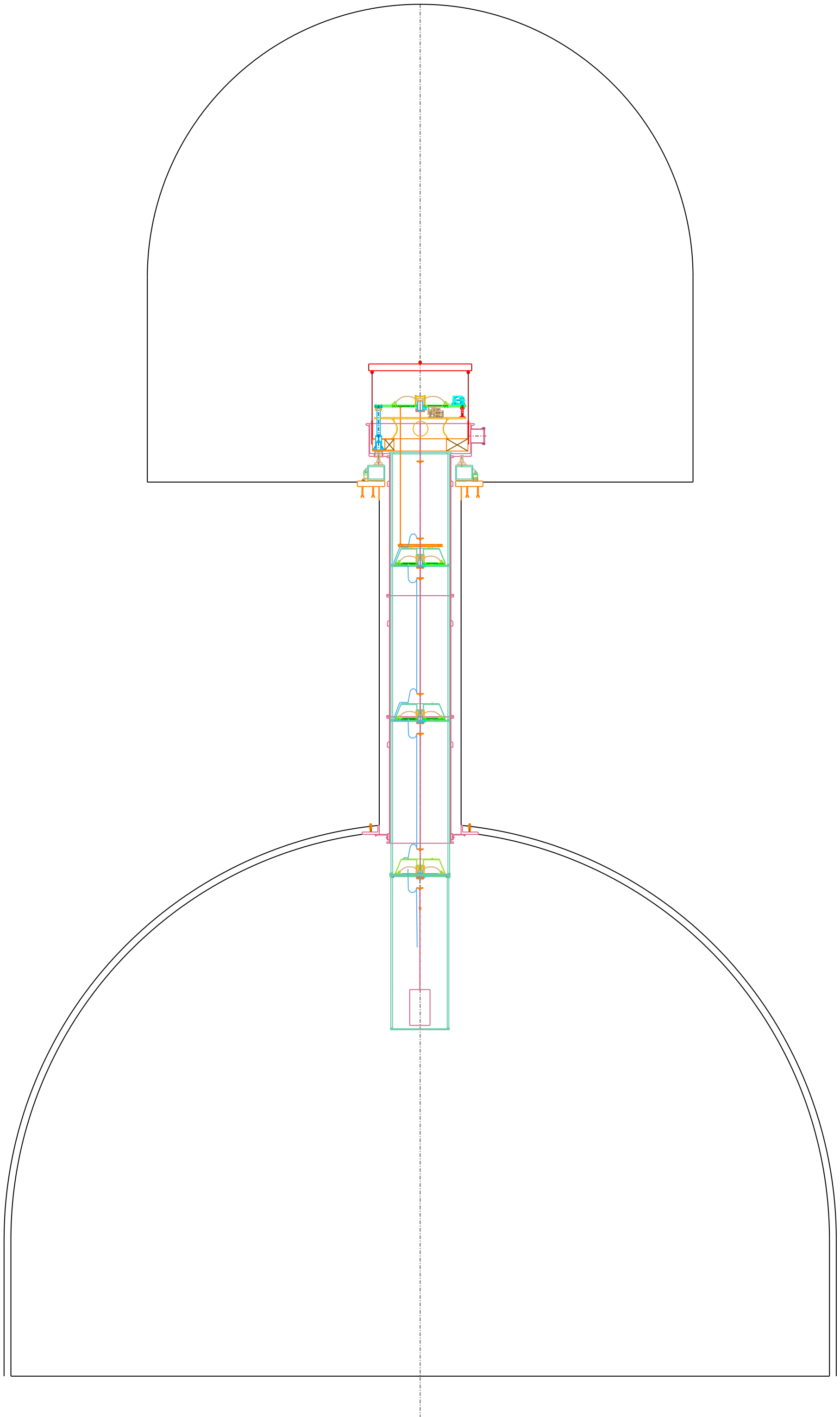
The safety structure between the Top filter and filter 3 is assembled, as well as the suspension wire of filter 3, electrical wiring, and its Eddy current damping ring.



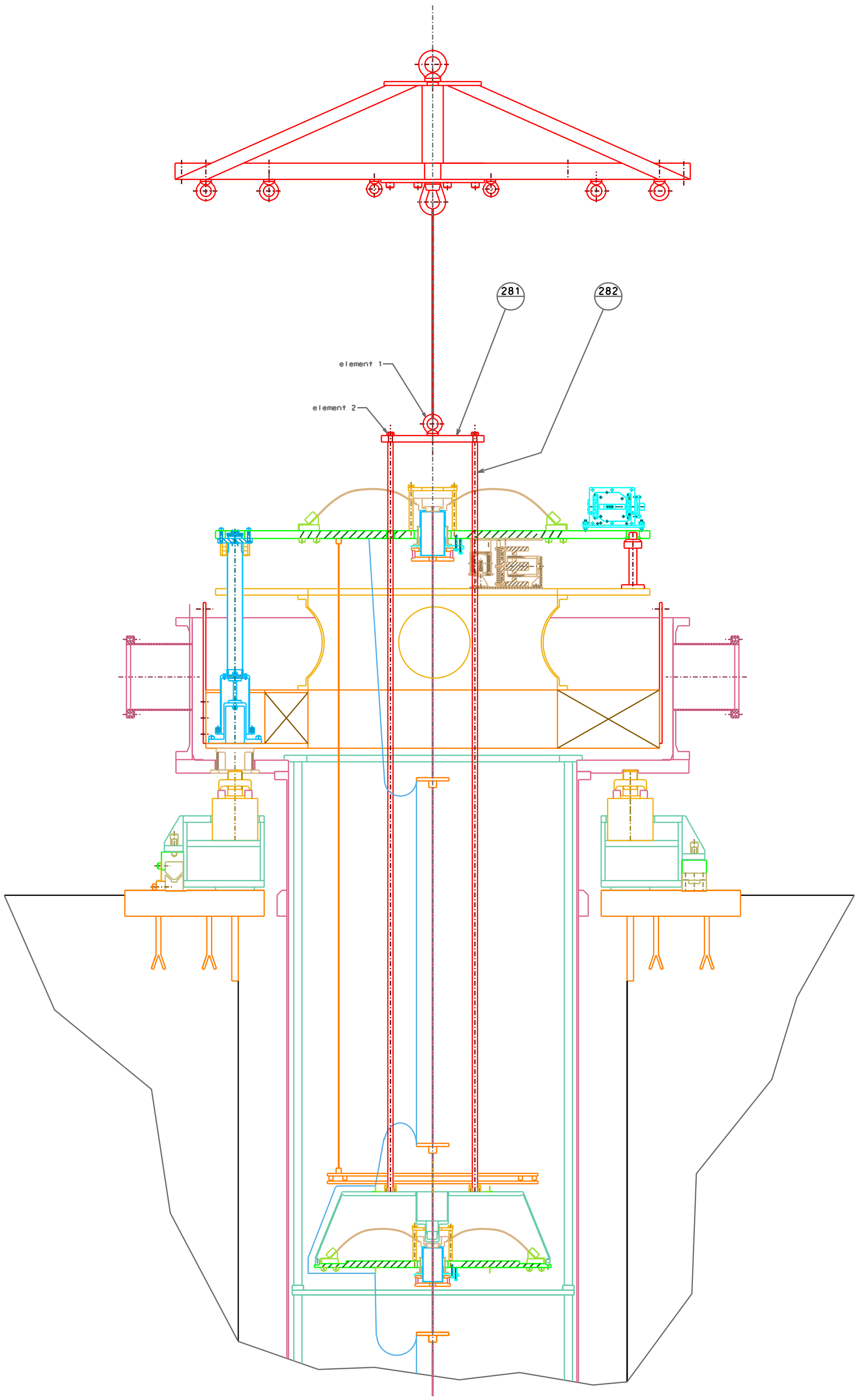
The top filter is brought in, attached to its payload, its functionalities tested, then it is removed.



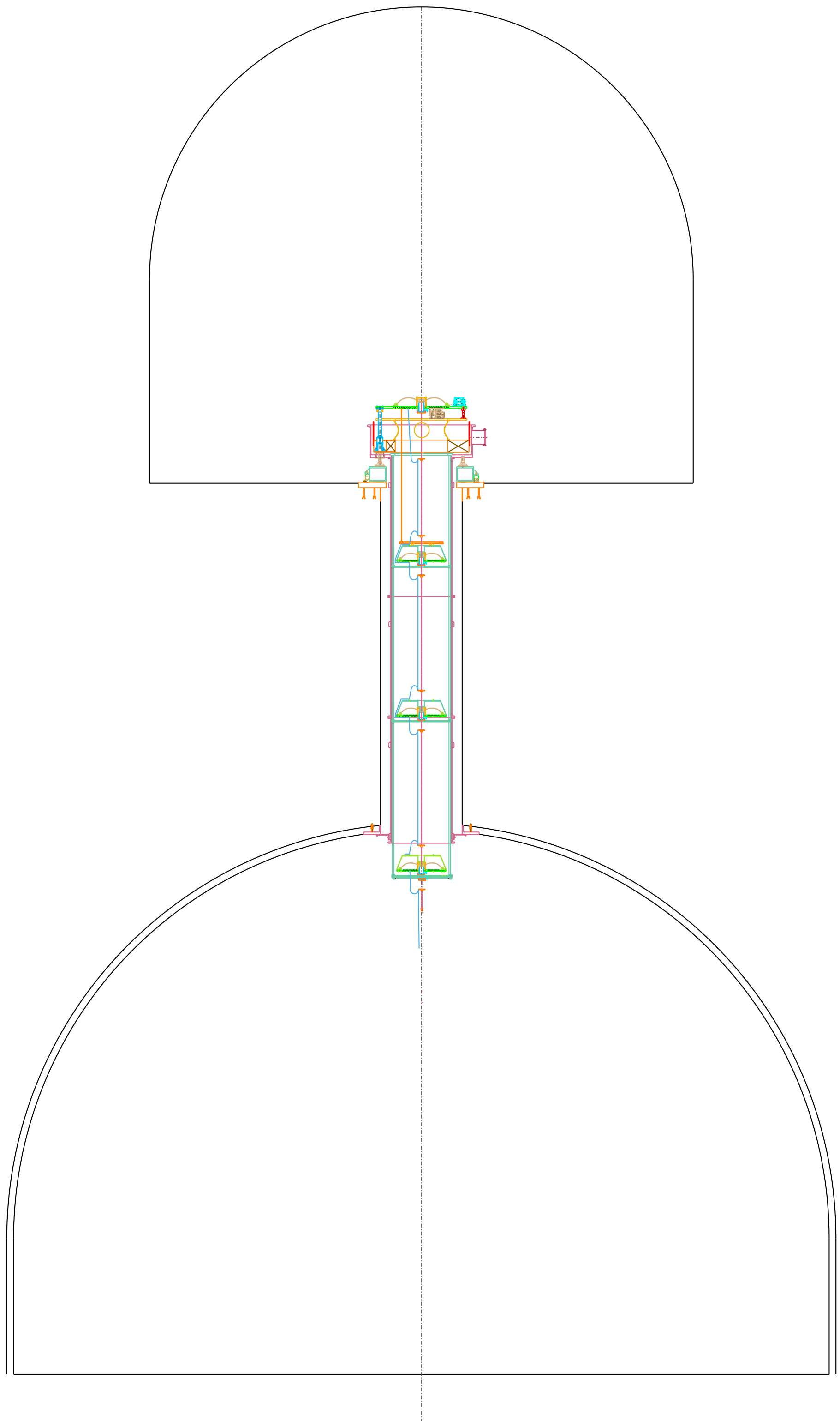
The structure containing filter 1 to 3 is then lowered in place and secured.



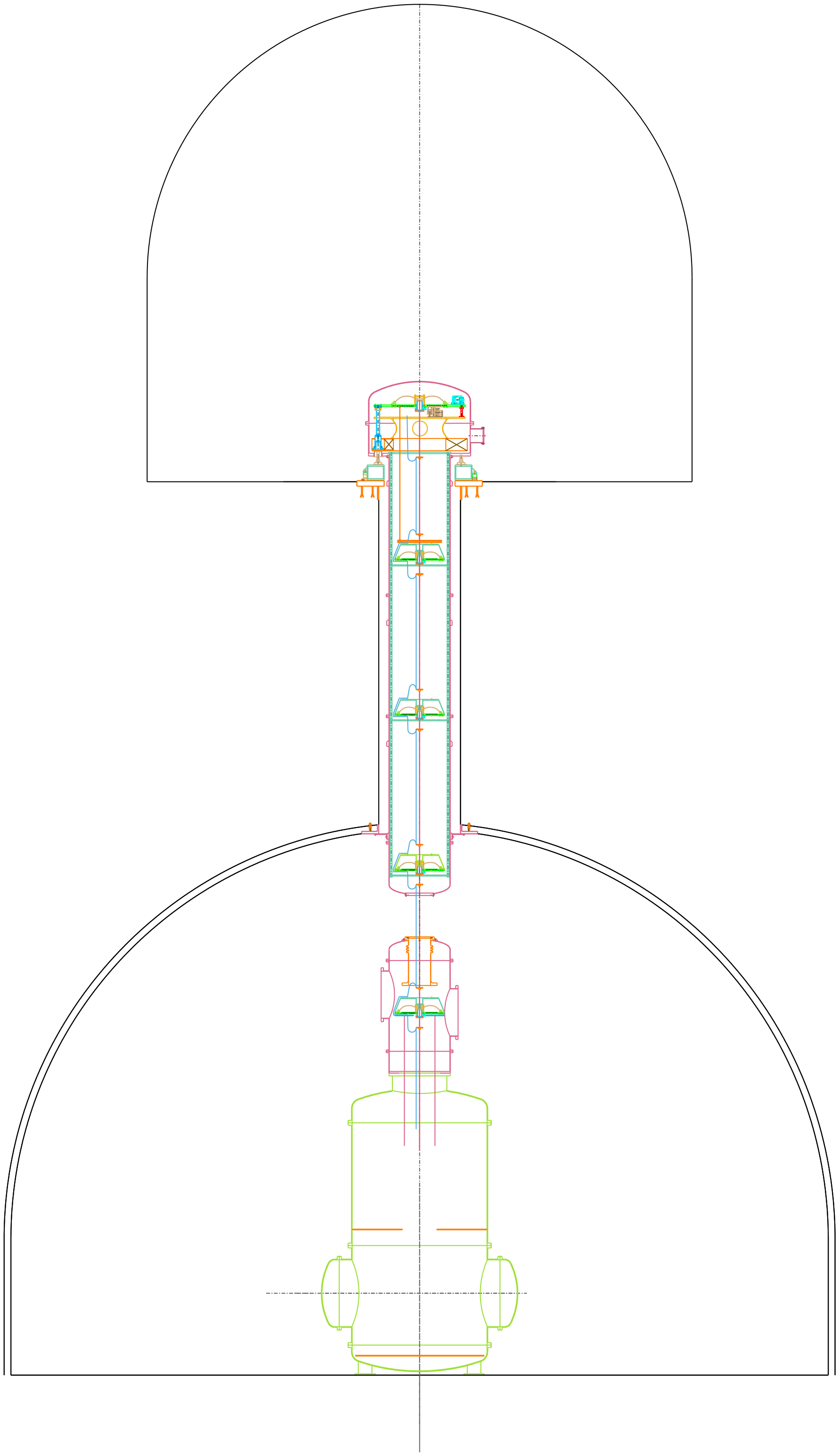
The unit Top filter and Inverted Pendulum is lowered in place, but is still disconnected from filter 1.



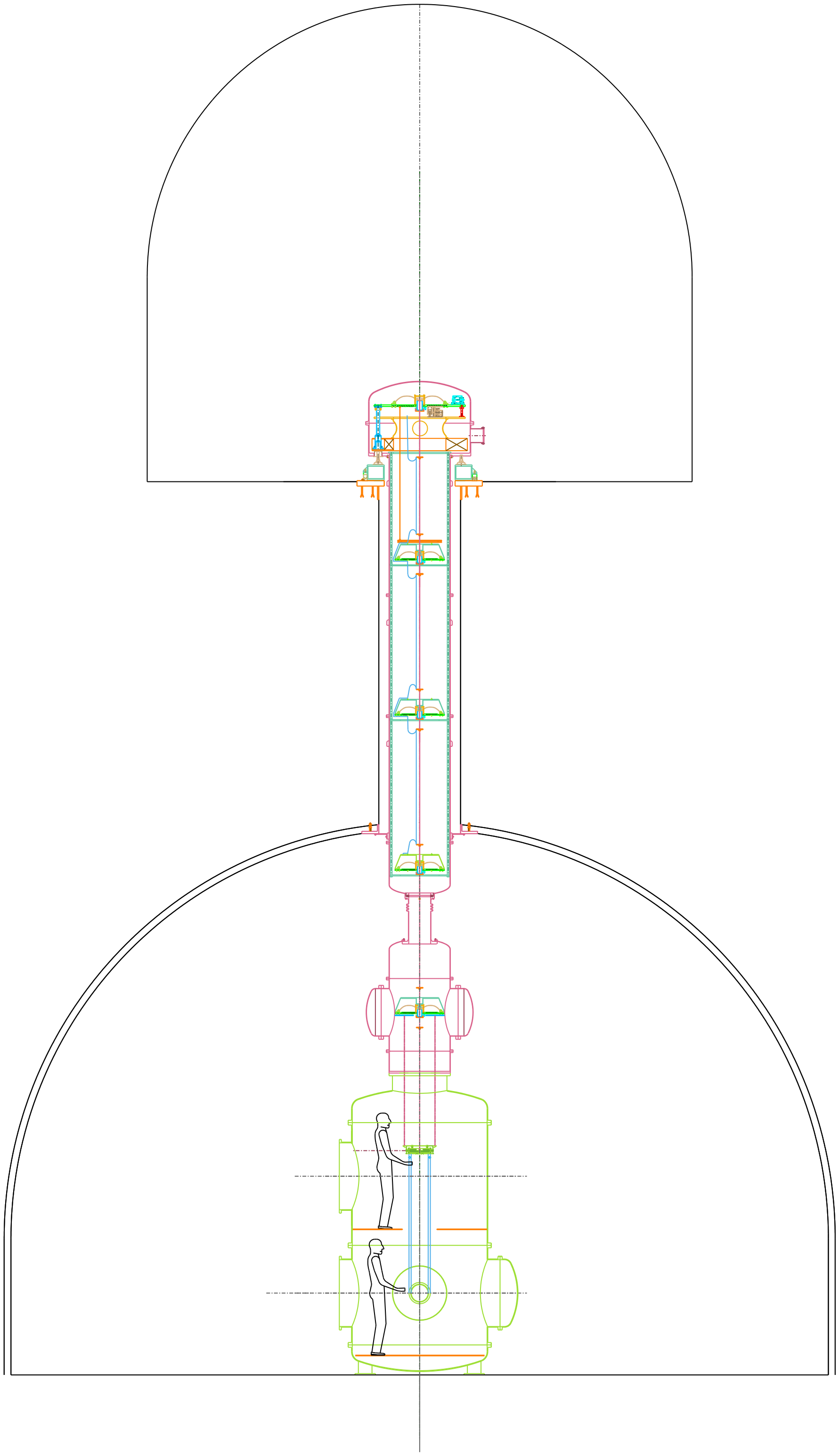
Special lifting rods are inserted through holes into the top filter, are screwed into the roof of filter 1, and used to lift it, so that its wires can be attached to filter zero. The functionalities of all filters are re-checked.



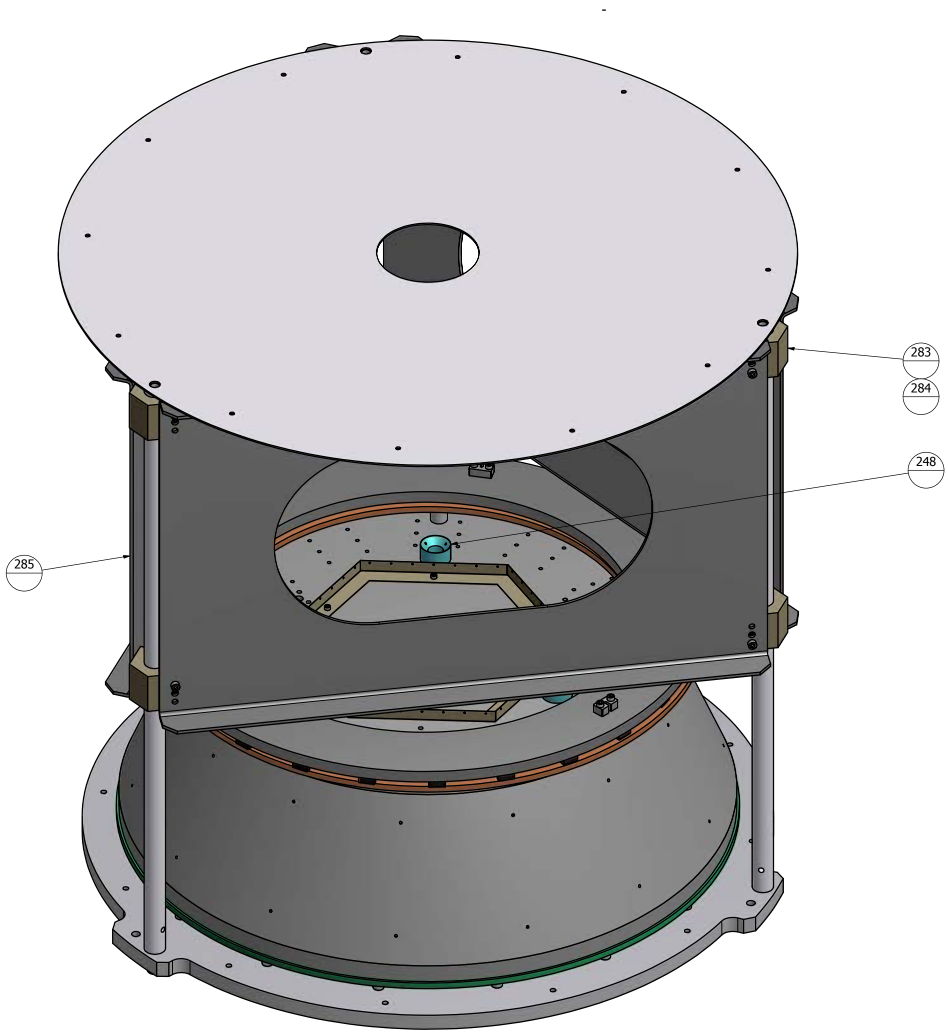
Then the 300 kg payload and its temporary safety structure are removed and the suspension wire is disconnected at the wire junction box. The system is ready for installation of the payload.



The vacuum chambers are positioned (note only the top, pink, part needs to be removed to insert the SAS chain). Filter 4 is inserted on a stretcher, connected at the junction box and electrically wired. Then the vacuum neck above is closed.



Finally the intermediate mass and the mirror are inserted and suspended.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