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# Use of flexibles for the cooling circuit of ECAL ENDCAPS

The CMS detector consists of three parts, with the general shape of a barrel. The central part is cylindrical and there are two endcaps, which close the detector on both sides. These Endcaps are mobile, but they will move only during maintenance period or if reparations are needed inside the detector. The Endcaps have to move axially by approximately 10m[1].

Every sub-detector of CMS is linked to the outside by services (electrical cable, pipes for gas and cooling water…). The displacement of the Endcaps creates problems concerning the path of these services. The solution proposed is to use cable chains[1] that will guide the services in every position of the Endcaps (even during displacement).

For the Ecal sub detector, the cooling circuit is very important because of the thermal stability requirement. It could be considered to supply the endcaps with water only when they are in a fixed position, open or close, but not during the displacement. In this case, short flexible (some meters) will link the detector to the cooling circuit in the UX cavern. It means that the cooling circuit will be closed and opened again each time the Endcaps will move. These manipulations create security problems. Air may enter the cooling circuit, which may require a purge. Furthermore, it appears difficult to purge the circuit inside the detector. For these reasons, it seems better to have a closed cooling circuit, as much as possible. The solution of putting flexible pipes in cable chains will be studied in this document for the Ecal Endcap, but this study can be used for the other sub detectors in the Endcaps.

## <u>Technical requirements:</u>

Length: up to 11m [2]
Bending radius: about 950 mm [1]
Traction to support: unknown, but as the cable chains will handle delicate cable (fibre optics), this should not be a problem. The translation speed of the cable chains in the current design is 0,5m/min [1].
Radiation: integrated level for 10 years 1Gy[3]
The flexible is supposed to be in movement 20 hours/year during 20 years[1].

Pressure: working pressure 5 bars, must support 20 bars without damage (pressure test)
Flow speed: maximum of 2 m/s
Thermal conductivity: Must be small enough for the regulating circuit because of temperature stability. Otherwise, insulation has to be added.
Coolant: demineralised water at 18°C
Flow: 1.65 l/s, 0.98 l/s and 0.6 l/s for respectively the power circuit, the back plate regulating circuit and the crystal housing regulating circuit.
Diameter: DN32, DN25, DN20 for each circuit above, respectively.
For each diameter, 8 flexibles are needed. Feeding + return, for 4 Dees.

The thermal conductivity in the flexible wall should be small enough for the regulation circuit, because the temperature has to achieve a stability of ± 0,1K. For the same reason, the pressure loss has to be limited. To give an order of magnitude, a heat flux of 13 W or a head loss of 0,2 bars along the flexible will rise the temperature 0,005K.

The surface taken by the flexible will be approximately 100 $cm^2$ in each cable chain where the total space available is 2000 $cm^2$ (the insulation has not been included).

## Solutions found

Two different existing technologies seem to be suitable. The first one one consists of a plastic hose used at CERN for the magnet cooling. The other one is a metallic undulating tube, surrounded with a metallic braid.

### 1 EPDM kevlar

For the cooling of the LEP magnets, the flexibles that are actually used are called EPDM Kevlar. It consists of two layers of synthetic rubber (ethylene propylene) separated by a kevlar frame (see Figure 1 and Figure 2).
These flexibles are referenced in the CERN store (ref: 38.20.10). The supplier is the society Maagtechnic based in Switzerland. The flexibles can be purchased at the main store by length of 40 m. They can be cut to the right size and the hydraulic fittings can be made at the CERN workshop[4]. To give an approximate price, the tubes cost 80 CHF/m[5], which makes 800 CHF per flexible and 20000 CHF for all the Ecal Endcaps.

Technical specifications

Concerning radiation, the flexibles have been tested[6] to levels of 1MGy to 3Mgy. They have received the agreement for LEP 200 environment[6]. A particular attention must be taken when they are installed, because torsion and flexion reduce resistance to radiation. The level of radiation in our case (1 Gy) is small enough to say that no degradation on the flexible is expected.

According to the technical sheet of EPDM kevlar[7], the pipes are suitable for demineralised water, for 18°C and for the pressure and the flow requirements. They are available for the required diameters.

The bending capacity of the flexible is suitable for the use.

The traction resistance should not be a limitation as mentioned above.

To ensure a good thermal stability to the coolant, the thermal conductivity of the flexible wall should be comparable to 0,04 W/m.K. Unfortunately, no data is available from the manufacturer. It means that some tests have to be performed to know this parameter. We can also roughly estimate this coefficient and then insulate the flexible, but it will increase its cross sectional area. It will also reduce its bending capacity, but not significantly in case of foam. The foam that can be used at CERN (because of safety requirement) is Armaflex NH. An insulation of 32 mm would lead to an increase in temperature of ~ 0,01°C.

The pressure loss has been calculated for each diameter (for an assumed the friction coefficient $\lambda$=0,024), and the results give values between 0,1 and 0,2 bars. This is comparable to the value waited for a neglectible influence of the head loss on the temperature.

Another very important point is that the manufacturer does not guarantee the lifetime of the flexible during 20 years, mainly because of the displacement that will occur.

## 2 Stainless steel flexible hoses

It consists of corrugated metallic hoses with braid (see Figure 3 and Figure 4). Several companies manufacture this type of flexibles but we focused our study on a pipe made by the company Tubest[8], called Parrap.
The price of this material can be estimated to 600 CHF for one flexible, that makes 15000 CHF for all the Ecal Endcaps.

### Technical specifications

As they are metallic, they don't suffer any problem to the exposure on a level of radiation of 1 Gy.

They are available in every required diameter and suitable for demineralised water (stainless steel).

They respect the norm ISO 10380 for flexible pipes that specify (among others) a minimum bending radius and a maximum pressure for 50000 cycles of displacement, called dynamic radius (Rd) and dynamic pressure (PMA).
For the Parrap flexible in DN 20 to DN 32, the values are Rd=300mm and PMA=40 bars. They appear to be highly reliable for our purpose.

The pressure loss has been evaluated[9] to be in the order of 0,2 bars, that is acceptable.

Several connections can be added to the flexible, flanged, screwed or smoothed.

These flexibles have to be handled with care, because the braid is sharp. Furthermore, the connections cannot be assembled at CERN.
A similar type of hose has suffered reliability problems at CERN, when it was subject to frequent and rapid change in the flow rate. It created vibrations that damaged the flexibles.

# **Conclusion**

Both solutions present advantages.
The EPDM kevlar are well known at CERN and can be assembled in the workshop. But no strong guaranties can be obtained concerning its lifetime.
On the other hand, the metallic pipes seem to be very reliable but similar pipes suffered a bad experience at CERN.
As these hoses are not supposed to be replaced, metallic hoses seem to be the more appropriate, especially concerning bending capacities and lifetime.
Insulation is needed for the regulating circuit, independently from the solution chosen.

Figure 1: Cross section of a flexible

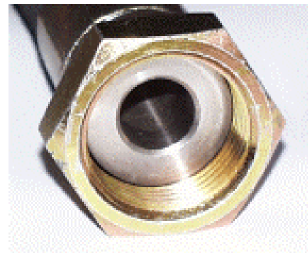

Figure 2: Detail of a screwed

Figure 3: Parrap DN32 bent

Figure 4: Detail of braid and corrugated hose

[1] MS-2849 / EP-CMS, Pintus Ron, *Manufacture of fourteen large and medium sized cable chains for CMS.*
[2] According to Stephane Bally and Ron Pintus
[3] According to Mika Huhtinen.
[4] Contact, Laurent Catin.
[5] C. Saint-Jal, Group 38 Manager at CERN shop.
[6] TIS-CFM/MTR/95-08, M. Tavlet, *Rapport de test sur materiaux*.
[7] CERN, Logistic Group, Technical sheet n°519, 23.06.1998.
[8] Tubest, www.tubest.fr.
[9] Calculation included in a price quotation of Tubest.