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Surface detector construction and installation at the Auger Observatory

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Abstract. The basic detector unit of the Auger Observatory ground array is a water tank of 12,000 liter capacity, used as a Cerenkov detector. This contribution describes the construction of the polyethylene rotomolded tanks, the procedure for treating the water prior to filling the tanks as well as water quality control.Finally, the installation of the tanks and their components is described.

1 Introduction

Water Cerenkov detectors were chosen for the ground array of the Auger Observatory 2 (@). The detector is basically a volume of clear water acting as a Cerenkov radiator, viewed by three 20 cm photomultipliers. Our detector requires a cylindrical volume of water 1.2 m deep and 10 m^2 cross-section area, correponding to a diameter of 3.6 m. Such tanks have to endure the agressive weather conditions of a desert, with high salt content on the ground, strong winds, hail, temperature extremes and prolonged exposure to sun light. The tanks are designed to survive 20 years under those conditions. The presence of high chloride levels on the ground ruled out the use of thin stainless steel tanks as a cost effective alternative due to the possibility of chloride-induced stress corrosion cracking. The developing technology of rotational molding provided an economical alternative. Polyethylene tanks made with this technology are resistant to corrosion, robust (wall thickness between 12 to 15 mm) and cost effective. Advances in ultraviolet light resisting chemistry extend the lifetime of polyethilene tanks to approach our required 20 years.

Mechanical robustness, UV resistance and the need to be totally opaque to external light, combined with the necessity of storing the 12,000 liters of water in an environment which inhibits biological activity led us to the selection of the polyethylene resin, and to the concept of storing the water in a separate volume, a sealed bag, made of biologically inert material, while at the same time providing an effective diffusive reflecting surface for light in the 300 to 400 nm wavelength range.Our choice for the bag, hereafter called liner, material has been Tyvek, a fibrous polyolefin non-woven fgabric manufactured by DuPont.

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2 Polyethylene Resin

The requirement of high tensile strength and of avoiding cracks and consequent mechanical failure of the tanks led to the choice of a high-density polyethylene resin while the need to have an impact resistant tank recommends a low melt index resin. The combination high density and low melt index severely limits the choice of resin.(The melt index measures the flowability of the resin and decreasing it increases the difficulty in the molding of the tanks while improving the physical properties of the finished tank.) The resin we have selected, Escorene HD-8771, manufactured by by Exxon Chemical, Canada, has a density of 0.942g/cc and a melt index 2.0g per 10 minutes as measured by the standard test procedure ASTM D-1338. This resin also has a reputation for producing tanks with a long lifetime and for having exceptionally good molding properties, resulting in a very smooth interior to the tanks despite the very high viscosity of the melted resin indicated by the low melt index. Opacity of the tank walls is guaranteed by hot compounding this resin with 0.5% carbon black pigment. A black appearance of the tanks, although satisfactory from the point of view of their use as Cerenkov detectors, presents an undesirable appearance which strongly contrasts with the landscape of the desert site, dominated by sand and yellowish vegetation (Pampa Amarilla). Therefore we adopted the solution of rotomolding the tanks in two layers, the inner one black, as described, and the outer layer made with the same resin but now compounded with a beige pigment containing titanium dioxide, giving the tanks a more matching color. The black layer has about twice the thickness of the beige outer layer. Some resistance against damage by UV exposure is provided

Fig. 1. 12,000 liter Polyethylene rotomolded tank for the Auger ground array

by the UV-absorbing pigment elements, carbon black and titanium dioxide. Doping the resin with a HALS (Hindered Amine Light Stabilizer) UV-stabilizer, which functions by a radical trapping mechanism rather than by UV absorbtion, substantially increases the resistance to UV degradation.

Figure 1 shows a picture of one of the Auger tanks. Although the water volume is required to be in a cylindrical shape, the tank itself, as seen in Figure 1, is more complex. The top surface is designed to contain the three photomultipliers on the upper surface of the water, at a radius of 1.2 meters and separated by 120 degress. The complex shape allows space for the photomultipliers, their bases, and a suitable housing, and also provides rigidity to the top of the tank. This was a challenge because the height of the tank is limited to a maximum of 1.6 mm by shipping restrictions. In addition to being able to support people working equipment on the top of the tank, the tank top supports solar panels required to power the electronics.

3 The Liner

The material of the liner is Tyvek, a trade name of DuPont for a fibrous polyolefin which presents very good diffuse reflectivity 4 (@). The liner is manufactured as a laminate of 3 layers:

Layer 1: Tyvek 1025BL 142 microns thick. The ”BL” grade does not contain the chemicals usually added to make the material suitable for other applications, leaving a pure polyolefin material.

Layer 2: Dow 722 LDPE (a low density polyethylene film) 28 microns thick

Layer 3: Special black co-extruded film composed of three layers totaling 178 microns. The inner and outer layers are unpigmented, metallocene catalyzed linear low density polyethylene (LLDPE) films, whereas the central layer is LLDPE pigmented with 10contact the water, so that the carbon black, a potential nutrient for bacteria, is not available to contaminate the water. The metallocene catalysis is selected to provide optimum melting temperature for manufacture of the liners from the laminate. Optimum mechanical properties so that the liner will be very flexible and yet structurally strong result from the careful material selection 6 (@).

Manufacture of the liner from the laminate is done by welding pieces of the laminate to form a cylinder q1.2 m high and 3.6 m in diameter. At three symmetric locations on the top, at a radius of 1.2 m, window assemblies are welded in to house the photomultipliers and bases. The PMT’ s are optically coupled to the windows with RTV. Water fill fittings are also part of these assemblies. The liners are sealed afetr being filled with water preventing contamination from entering.

4 Water

The 1,600 tanks comprising the Auger Observatory ground array will need about 20,000 tons of water that has to maintain good light transmissivity over along period of time (20 years) without being replaced. The sources of turbidity are chemical and biological activity. Chemical activity, rust, is avoided by not using a metal tank and by containing the water inside the inert Tyvek liners. Biological activity is inhibited by eliminating as many nutrients as possible. There is no additive (such as plasticizers) in the materials used for the liners, which are laminated without the use of adhesives (other than the polyethylene itself) that may feed micro-organisms. It is also mandatory that the handling of the materials during the manufacture of the laminate and finally of the bags has to be kept under strict control so as to avoid contamination with dirt and grease. In addition to these precautions we still require that the water filling the tanks be suitably purified.

We use ultrapure water to provide both initial clarity and an environment in which there are insufficient nutrients for micro-organisms to flourish. The purity of water can be assessed by measuring its particulate content, its resistivity and its organic carbon content. We require water of very high resistivity, over 15 MOhm-cm, and less that 10ppb organic carbon residues.

For this purpose a water purification plant has been installed in the Auger Central Building in Malargüe with the goal of producing ultrapure water at an initial rate of 36,000 liters per day, reaching 58,000 liters per day after a planned upgrade. Although such a plant is, of necessity, rather complicated, we may summarize the main steps in the water purification process : filtration, water softening, de-ionization by reverse osmosis, destruction of organic carbon by short wavelength (185 nm) ultraviolet light so that it may be removed in the following de-ionization step, and electrodeionization, which is de-ionization using a resin bed which is regenerated electrically. The water is put in a storage tank with a continuously re-circulating loop through a sub-micron filter, long wavelength (254 nm) UV light for sanitization, and a de-ionizing resin bed.

References

The Pierre Auger Observatory Design Report, 1997.

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see http://omega.physics.colostate.edu:80/ warner/SDDWG.html for drawings of the liner and information on the lamination.