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Construction and properties of acrylic vessels in the RENO detector

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ABSTRACT

The aim of the RENO (Reactor Experiment for Neutrino Oscillation) is to measure the smallest neutrino mixing angle, θ_{13}. The RENO detector consists of four concentric cylindrical layers: the target, γ-catcher, buffer and veto. Acrylic is used for the target and γ-catcher vessels, both of which contain liquid scintillator. Acrylic was chosen because it has good transmittance in the wavelength range of 400−430 nm and also does not react with liquid-scintillating solvents. In order to reduce systematic uncertainties, the target volume should be identical to a level of less than 0.1% between the near and far detectors. Furthermore, the acrylic vessel should not have any leaks. In this paper, we investigate the optical properties, design and construction of the acrylic vessels used in the RENO detector.

1. Introduction

The RENO experiment is designed to measure the smallest, unknown neutrino mixing angle θ_{13} using anti-neutrinos emerging from the Yonggwang nuclear power plant located on the west coast of the southern part of Korea. The power plant consists of six reactors and it produces a total thermal power output of 16.4 GW_{th}, the second largest in the world. The six reactors are lined up with roughly equal distances between adjacent reactor and span a total distance of $\sim$1.3 km.

The RENO facility has two identical detectors to reduce systematic uncertainties. The near (ND) and far detector (FD) are placed roughly 290 m and 1.4 km away from the center of the reactor array, respectively. The RENO detector consists of four concentric cylindrical layers; the target, γ-catcher, buffer and veto layers, listed from the innermost to the outer most [1]. The target and the γ-catcher vessels are made of a transparent acrylic plastic. The neutrino target vessel contains Gd (gadolinium) loaded liquid scintillator and is surrounded by the γ-catcher vessels which are also cylindrical and filled with unloaded liquid scintillator. The acrylic vessels should hold aromatic liquids without any leakage. Any physical and optical properties should remain unchanged over a long period including over the duration of the experiment. Furthermore, there should not be any chemical reaction of the acrylic vessels with the scintillating liquids.

2. Properties of acrylic vessels

2.1. Acrylic

The RENO transparent vessels holding organic liquids are made of an acrylic plastic called polymethylmethacrylate (PMMA $(C_5O_2H_8)_n$); Plexiglas GS233 produced by Degussa Company GmbH, Germany. This acrylic is made by a casting method. Acrylic

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sheet made by a casting method is known to have better mechanical and chemical properties than extruded acrylic sheet. GS233 has good impact resistance strength and is highly transparent. It transmits up to 92% of visible light at 3 mm thickness and reflects about 4% from its surfaces [2]. The measurements of the optical transparency in the RENO detectors are reported in Section 2.5.

Table 1
Dimensions of the RENO detector.

	Target	γ-Catcher	Buffer	Veto
Material	Acrylic	Acrylic	Stainless steel	Concrete
Thickness (mm)	25	30	6/8/12[a]	400
Height (mm)	3150	4340	5780	354
Inner diameter (mm)	2750	3940	5388	8400
# of PMT			354 × 2	66 × 2

[a] The buffer vessel thickness is 6 mm for the barrel, 8 mm for the top, and 12 mm for the bottom section.

2.2. Vessel dimensions

The target vessel is a cylindrical acrylic container with a 140 cm radius, 320 cm height, and 25 mm thickness. Its total volume is 19.2 m^3 with a target mass of 16.1 tons. The target vessel holding 0.1% gadolinium-loaded liquid scintillator (GdLS) is surrounded by the γ-catcher vessel, which is filled with normal liquid scintillator (LS). The γ-catcher vessel has a radius of 200 cm, a height of 440 cm, and a thickness of 30 mm. A buffer tank of stainless steel contains a non-scintillating mineral oil (MO) to reduce accidental backgrounds coming from outside, which are expected mainly from radioactivity in the photomultiplier tubes (PMT) and from surrounding rocks. The buffer vessel is a cylindrical tank 270 cm in radius and 580 cm in height, and 6 mm thickness. The dimensions of the RENO detector are listed

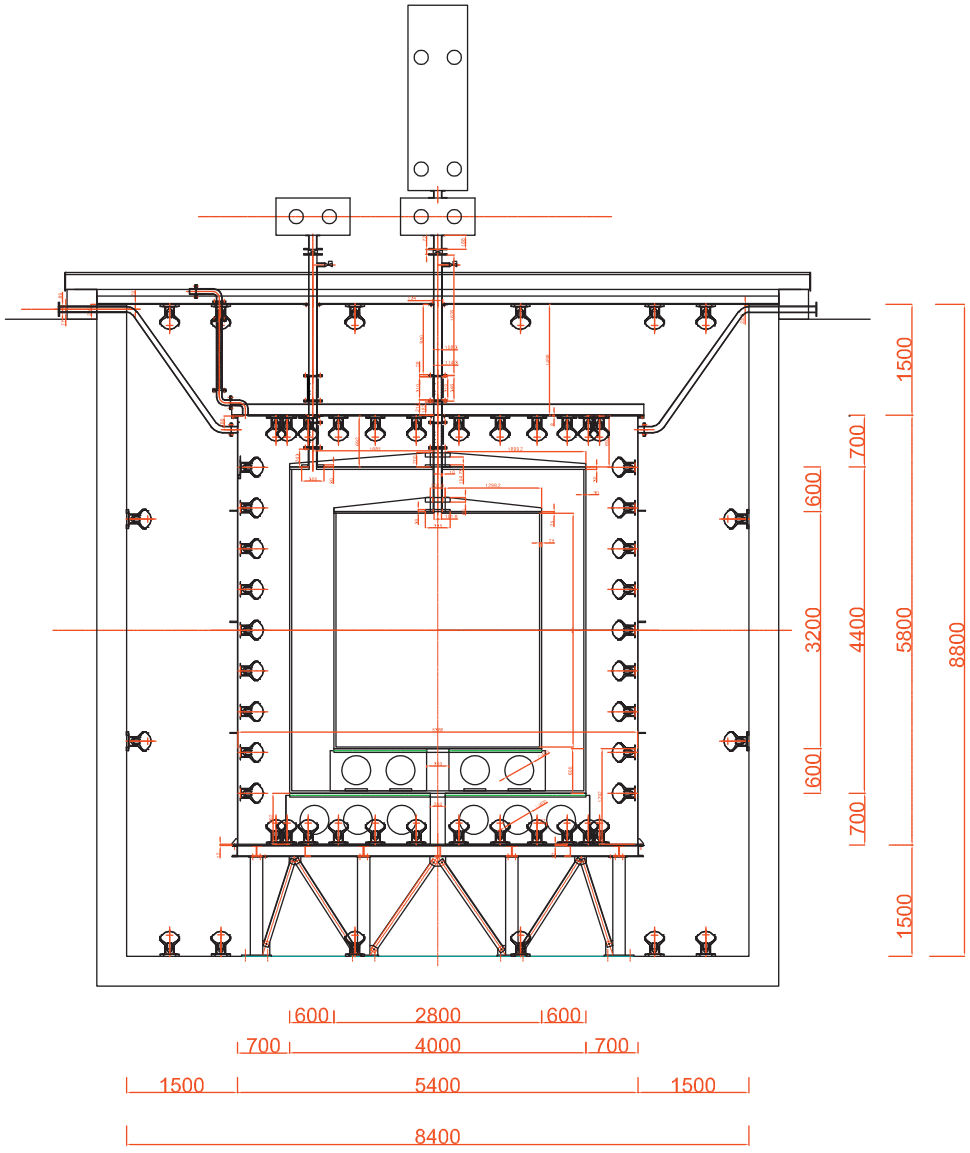

Fig. 1. A drawing of the RENO detector (unit is mm). Chimneys and two calibration devices can also be seen. The supporting structures are made from the same transparent acrylic as the vessels.