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Manufacture Details of a SWGO Double-Layer Tank Design - Water Cherenkov Detector Prototype

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Water-Cherenkov detectors (WCD) have been manufactured in Australia by the company AQUA-MATE as part of the RD activities for SWGO. They consist of a steel tank frame with a bladder on its interior satisfying the SWGO double-layer tank design. Tanks and bladders have been custom designed to optimally accommodate the bladder inside the tank and with minimal material usage. They are delivered in compact boxes that are easy to transport. These boxes are designed to fit 24 tanks in a 20-foot container. The double-layer tank design has introduced new features to improve the discrimination between gamma-rays and cosmic rays. Some of these features created challenges for the manufacturing. Some units have been delivered to one of Peru's candidate sites at 4800 m and to Mexico (the HAWC Observatory, 4100 m) for prototype tests in real conditions. In this contribution we will describe manufacturing and construction details of the first SWGO prototype WCD. These details were envisaged to facilitate: the transport of the units, the assembly, the deployment and maintenance activities of the detectors. Furthermore, the units need to be resistant to strong winds, rain, snow and earthquakes.The costs are scalable with the detector volume. This information could be of interest to other Observatories that are in RD phase, such as the Global Cosmic Ray Observatory (GCOS) for the study of the highest-energy particles in the Universe and the Tau Air Shower Mountain-Based Observatory (TAMBO) for the search of PeV neutrinos.

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1. Introduction

The first experiments using water Cherenkov detectors (WCD) for air shower detection began in the 1960s. A pioneering example is the Haverah Park experiment in the United Kingdom [1], that operated from 1967 to 1984. It was a WCD array consisting of galvanized steel cylindrical tanks of 1.7m of diameter and filled with water up to an altitude of 1.2m. Since then, other experiments have used the WCD arrays to detect high energy cosmic rays (e.g. Auger [2]) and gamma rays (e.g. Milagro[3], HAWC [4]). The design and manufacture of the SWGO steel tanks and bladders has profited to a large extend from experiences in HAWC and Auger, and future experiments (e.g. TAMBO [5] and GCOS [6]) might benefit from it.

When an extensive air shower passes through the water tanks, Cherenkov light is produced by the shower particles and it is detected by PMTs. From the distribution of light intensities and arrival times over the array, the energy and direction of the primary cosmic rays or gamma-rays are determined.

The Southern Wide-field Gamma-ray Obsevatory (SWGO) is evaluating a few alternatives for the WCD designs. PVC and steel made tanks are being considered for the ground array, and floating bladder detectors are being considered to form an array of WCD [7]. The floating array could be deployed on a natural lake or on a pond. In this note, we will focus on the design and manufacture of steel tanks WCDs.

2. The SWGO double-layer tank design

We have manufacture a steel tank that has on its interior two independent chambers that are light tight, this is called the double-layer design. The upper chamber with black walls is larger in order to absorb the electromagnetic particles. The lower chamber, Tyvek lined, is intended detect the signal produced by penetrating muons. The separation of the electromagnetic from the muon signal is important to improve the gamma/hadron air showers discrimination. The performance of the double-layer design has been evaluated with simulation in [8].

Figure 1 shows the suggested dimensions for the two compartments of the double-layer design. The suggested height dimensions took into account not only the performance for the separation of the electromagnetic and muonic components of the shower, it also considered the cost. The diameter is restricted by the size limit to transport the detector by road. However, this limitation is only valid for PVC tanks, since steel tanks are assembled on site.

3. Basic steel-tank/bladder concept.

The basic steel-tank/bladder concept is illustrated in Figure 2. The purpose of the steel tank is to support the bladder. The bottom 30cm of the steel panel goes in the ground. It provides the needed earthquake anchor. The top 30cm of the tank is empty (i.e. no water, no bladder) providing enough headroom for wave building during an earthquake. The roof and bladder hatch line up as does the divider hole for the double layer PMT. The bladder is water tight and it provides two compartments. We have in consideration a double layer design with a bottom chamber of 0.8m height, lined with Tyvek, and a top chamber of 2.2m with black walls. The steel tank wall has a

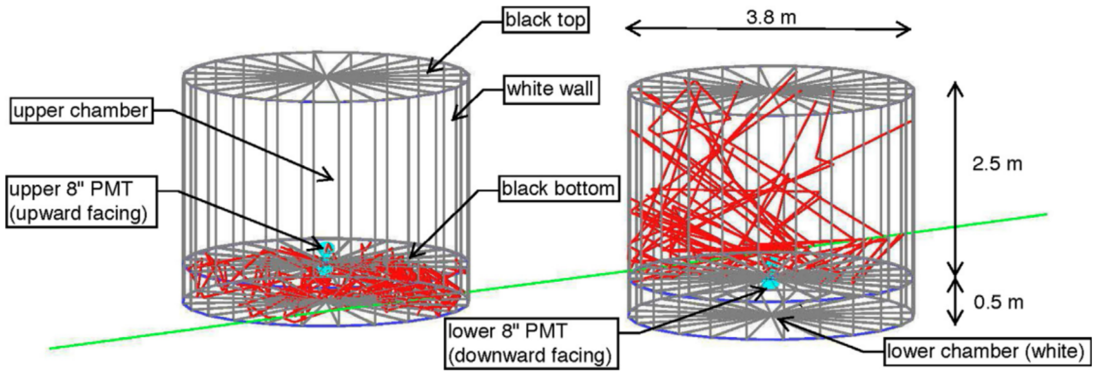

Figure 1: Cylindrical double-layered WCD doncept design with an upper chamber of 3.8 m diameter and 2.5 m depth, here with white reflective walls and black bases (top and bottom) and an entirely white refkective lower chamber of 0.5 m depth. The upper chamber contains a PMT facing upwards, and the lower chamber has a PMT facing downwards. For illustration, a simulated muon (green track) is shown that passes through both units and produces Cherenkov photons (red tracks) [8].

total height of 3.6m and a diameter of 3.6m.The roof and bladder hatches have a diameter of 45cm. The hatch should be big enough if a man access is needed.

4. General steel tank requirements

The steel tank needs to fulfill the following requirements:

1. The tank supports the bladder and creates a protective shield for the bladder.
2. The tank should be easy to produce and constructed in a modular way.
3. The steel tanks need to have a solid roof with access in the center to the bladder.
4. The roof must be strong enough to hold a snow load and withstand wind gusts.
5. The tank must have a lifetime of a minimum of 25 years and withstand corrosion and UV.
6. The tanks must be able to withstand class D earthquakes.
7. The tanks must be able to be placed close to ensure a high-density array.
8. If desired, the outer color should be to blend into the environment.

5. Available steel tank options

There are several steel tank providers world wide available. However, only one manufacturer was so far identified to be able to deliver a complete SWGO kit to be assembled on site. An SWGO kit includes all the parts to build a steel tank including a bladder based on our design and delivered films. We have worked on a design with Aquamate Australia[9] to be scalable from the base line design to much larger diameter steel tanks.

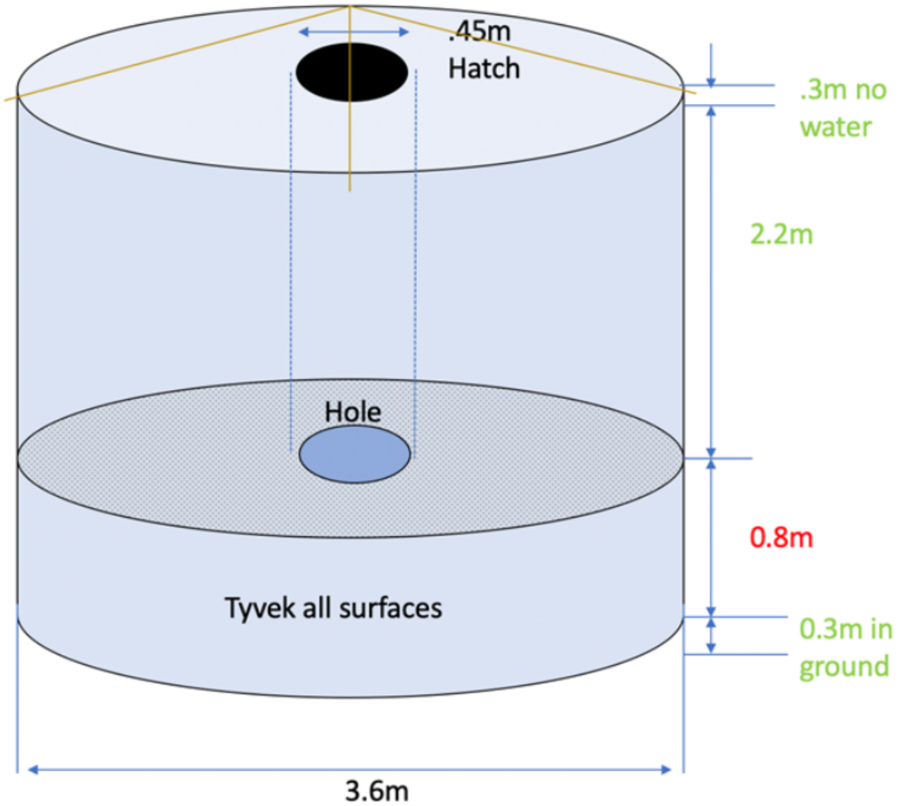

Figure 2: Tank bladder concept. These dimensions correspond to the WCD that were sent to a Peruvian site for testing. These dimensions are slightly different from the reference design described in Figure 1.

6. SWGO steel tank kit details

A photograph of the Aquamate shipping crate is shown in Figure 3. The total kit shipping crate weight is 690 kg and measures 230cm long x 96cm wide x 110cm high which is 2.428m^3. A 40' shipping container can transport 24 of these crates. The bladder weight is about 50kg (Enviro liner). The kit has the following parts listed in the Check Sheet shown in Figure 4. A mechanical drawing provided by Aquamate for the SWGO tank is shown in Figure 5.

Figure 3: Shipping crate showing contents of SWGO kit for steel tank including (Enviro liner) bladder.

Group	Item Description	Qty	Unit
Walls	Tank Wall Panels - 0.6mm Galvanised	25	each
	Tank Wall Panels - 0.6mm Laminates	5	each
	Tank Wall Bolts (5 spare)	235	each
	Tank Wall Nuts (5 spare)	235	each
	Tank Wall Nut 15mm Impact Socket	1	each
	Tank Wall Tape - High Tensile	4	rolls
	Tank Wall Poly Cover Strips	10	each
	Tank Wall Desiccants	1	set
	Tank Wall SWGO Decal	1	each
	Tank Wall AQUAMATE Decal	1	each
Bladder	Bladder - Enviro Liner 6020 - 3.6m D x 3.4m H	1	each
	Bladder - Base Positioning Ring Conduit	6	pieces
	Bladder - Access Port Floats	4	each
	Bladder - Access Port Lid Only	1	each
	Bladder - Repair Kit	1	set
	Bladder - Geotextile Underlay - Small	1	each

Group	Item Description	Qty	Unit
Roof	Roof Edge Beam - 50x50 Suit Eyelets	5	each
	Roof Edge Beam - Bracket 50mm SWGO	5	each
	Roof Edge Beam - M10 x 100 Cup Bolts (5 spare)	40	each
	Roof Edge Beam - Tank Nuts (5 spare)	40	each
	Roof Sheet - Screws 12G-14x20 SDS (100 spare)	200	each
	Roof Sheet - Precut Corrugated Panels	10	each
	Roof Rafter - Ridge Brackets	2	each
	Roof Rafter - Tank Nuts (2 spare)	50	each
	Roof Rafter - Tank Bolts (2 spare)	50	each
	Roof Rafter - Wall Mounts Right Hand	2	each
	Roof Rafter - Wall Mounts Left Hand	2	each
	Roof Rafter - C15012 Right Hand	2	each
	Roof Rafter - C15012 Left Hand	2	each
	Roof Access Port Lid & Screw Riing (1 spare)	2	set
	Roof Dust & Vermin Foam	3	rolls

Figure 4: Aquamate steel tank/bladder kit list for a SWGO tank prototype.

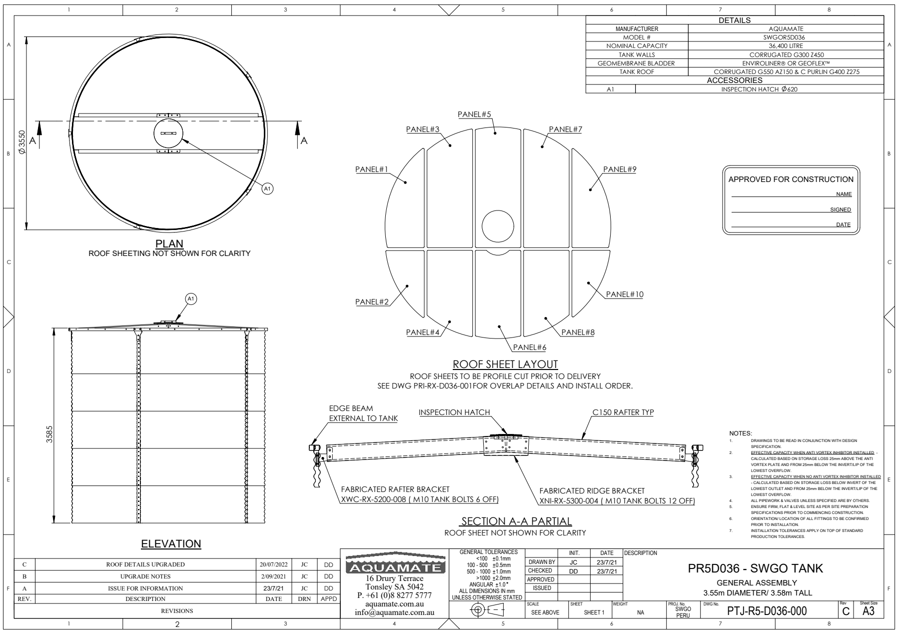

Figure 5: Mechanical drawing of Aquamate steel tank.

7. Safe assembling of steel tanks

Steel tanks are typically built out of multiple rings which are bolted together in two ways. Top-down or bottom-up. Top-down adds the upper panels first and then lift it with jacks to add the next panel layer under it. This way the personnel works on the ground and it is considered the safest way for construction. Bottom-up starts with the bottom panel ring and then adds the next one on top. For this the personnel needs to lift the individual panels up and bolt them together at the same time. With height, the requirements for a safe support of the workers increase dramatically. Also, lifting support for the parts is needed. This construction mode is also very sensitive to wind. Out of safety reasons, the preferred method is TOP DOWN.

8. Assembling the SWGO kit - Top-Down assembling

Top-down starts with the construction of the top ring on the ground by bolting the individual panels together to form the upper ring. These panels are typically around 0.9m tall. For a 3.6m water tank, one would construct five rings. The top ring then gets added on all the supporting edge beams needed to strengthen the tank and the roof. For SWGO, we added the edge ring on the top outer edge. Typical this ring is on the inside of the top panel to be not visible. Since we have a bladder on the inside, which needs to be protected, the ring was designed to be outside and be at the same time the support for the metal roof panels. This ring is 5cm wide and creates a strong connection to the roof. To this strong edge, the crossbars for the roof is attached. These bars provide the needed holding fixture for the individual roof panels but also support and access to the center of the tank. A second critical support is provided also to the bladder, which is attached to the top ring and in the center to the rafters to line up the opening of the tank and the bladder. The distance between the roof hatch and the bladder hatch will be about 40 cm so that a person on the roof can reach down to open up the bladder hatch.

The slope of the roof is kept to the minimum needed to ensure personal safety but also to let water and snow drain to the sides.

Figure 6 shows photos indicating the different assembling stages. Current estimate for the assembling time, based on recent experience, is that a trained crew of 4 can build a complete tank in 4 hours. This time could be reduced to 3 hours if not including the trench digging and back filling after construction. The current construction is calling for 5 jacks (Peru). The test tank at HAWC was constructed as a test with only 3 jacks. A fewer number of jacks allows for a denser tank placement. For larger construction numbers, like for SWGO, the jack method should be replaced by a local movable crane bay. This bay could be enclosed to support construction during windy days and protect the crew from rain and or sun. We also will reviewed if the tank could be placed directly on compacted leveled soil or needs to be placed into a trench for anchoring. Most tanks are placed, according to Aquamate, directly on compacted soil. The requirements for this are given by them in the foundation preparation.

9. Manufacture and shipping costs

The cost per kit is well understood but is influenced by material cost and shipping challenges. The cost for a single baseline kit will be better known if quotes for the new developed SWGO film become available.

A larger order could potentially reduce the manufacturing and shipping costs. Aquamate is able to produce 200 kits per month which include the bladder for the base design size. They also have the shipping and exporting knowledge to deal with a very large order. The kit for this size is optimized for 20’ container which can hold 24 kits.

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Figure 6: Steps followed to assemble the SWGO kit in HAWC and in Peru. a) bolt the top ring of the wall and the roof support bars, b) dig a trench and move the top ring in place, c) place the bladder inside the tank and bolt bladder support straps, d) bolt the roof panels and install the roof hatch and e) use the jacks to lift the tank and bolt lower rings. The photos in the bottom shows two different fully assembled SWGO kits at HAWC (4.3m height) and in Peru (3.6m height), both tanks have the same diameter of 3.6m.

10. Conclusion

The production of steel tanks using panels is mature and used worldwide. The current SWGO design is based on off-the-shelf products which have been worldwide deployed and are in use with an expected and observed lifetime of over 30 years. There is no maintenance required. No tank failures have been seen with properly constructed tanks. The current SWGO baseline size has been produced and delivered already 5 times and more orders are being placed for testing.

At this time the development for the SWGO baseline design is revised to address improvements discovered during the first tank constructions. The current design can be easy adapted to larger steel tanks (or smaller ones). The next step is to get the bladder ready for PMT deployment and fill it with water. A detailed construction guide will be developed. A review of trenchless construction without jacks will follow.

Acknowledgement

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