Def Sci J, Vol 33, No 3, July 1983, pp 229-235

Gunnery Surface Target

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Received 12 August; 1981, revised 19 November 1982

Abstract. The functional and technical requirements of the Gunnery surface target for Naval firing practice are given. The design evolved, and the raw materials required for its various components are described and discussed in detail. The target designed can withstand the sea state of seven in all operating conditions while being towed at a speed of 15 knots in a wind speed of 25 knots. It is visible upto a distance of 18 km and has radar responsive characteristics upto 22 km.

1. Introduction

The Gunnery surface target is a sea-worthy floating structure supporting radar reflecting screens. It has no self propulsion system and is towed using 1500 m long tow line. The target consists of two numbers of similar MS floats connected by tubular trussed bracings and supporting frame work for Radar Responsive Fabric (RRF) screen. The floats are filled in with buoyant filler.

The Gunnery surface target is used by Indian Navy for firing practice with both, conventional and guided long range weapons. The firing practice drill involves two ships and a target. One ship takes target in deep sea and tows it at any speed, and in any direction, using a long tow line. The storage, assembly, launching, towing and recovery of the target is the task of this towing ship known as mother ship. The other ship carrying weapons and men follows the target with the help of radar and other visual aids. The firing is conducted by this ship when it locates the target within the range of weapons. This ship is known as tracking ship.

2. Design and Development

The Gunnery Surface Target must meet the following operational/qualitative requirements for satisfactory functioning. (Fig. 1).

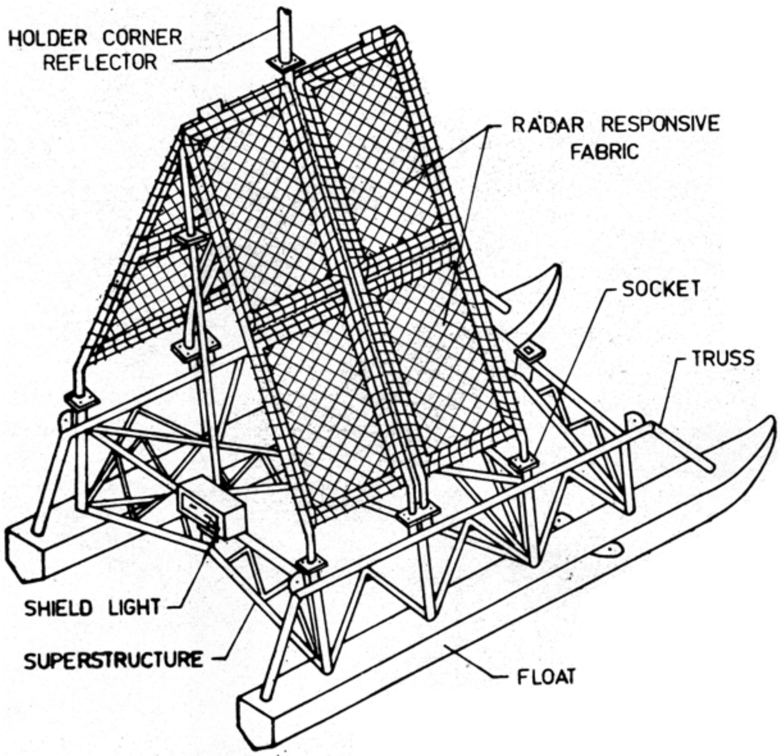

Figure 1. Gunnery Surface Target

1. Capability of being recovered, dismantled and stored on the board.
2. Capability of being assembled on the board and being launched from the ship.
3. Capability of being operative in the depths as shallow as 3.3 m.
4. Capability of being towed at a speed of 15 knots in a sea state of seven against a wind speed of 25 knots.
5. Capability of turning through 90° in seven minutes at a speed of 10 knots with a 5° radar used on the towing ship.
6. Stability against veer during towing.
7. Capability of being picked up by radar at a range of 21850 m. and visually at a range of 16400 m in the sea mist.

The conventional targets under use at present do not meet the required performance standard. The design of the equipment involves study and solution of the following aspects:-

1. Hydrostatic stability of floating structure.
2. Unsinkability of the structure even after mechanical damage.
3. Easy storage, assembly , launching & recovery from board.
4. Manouverability i. e. easy and controlled towing at desired speed.
5. Radar responsive characteristic of required range.
6. Sturdiness.
7. Capability of visual detection.
8. Maintainability.

3. Structures & Functional Analysis

The ship structure is estimated to have a total buoyancy of 4,000 kg (displacement), at a free board of 5 cm. This consists of 2000 kg payload (radar responsive screens and the supporting structure) and self weight of 2000 kg. Instead of single pontoon of required buoyancy two floats of 2000 kg displacement have been used. This provides transverse stability against rolling. Fig 1 describes the general arrangement of structure. The moment of statical stability of a floating structure is proportional to the moment of inertia of the water plane cut by the structure. The connecting trussess have been designed for the web shear of 2000 kg, being the individual vertical reaction and the direct compressive bucking load induced by horizontal component of briddle pull. This provides strong and stable floating structures.

The base of framework, supporting the radar responsive screens is elevated by 1.2 m above the average draught line by selecting truss and brace height of 1.15 m. This ensures the visual range against the tides of sea state seven. The size of RRF screen frames is selected as 3.6 $\times$ 3.6 m which is the optimum for distinct visibility at a distance of 20 km.

The floats having ship shape conical bow with square hull are made from standard quality MS plate conforming to IS : 226 by conventional steel fabrication methods. Five numbers of transverse bulk heads are provided to reduce the probability of sinking due to mechanical damage by single hit. The eight piece collapsible supporting structure is made out of MS tubes conforming to IS : 1239. Each component is of easily transportable size and weight. The assembly uses standard nuts and bolts galvanised by hot dip process to impart a coating of zinc of 300 gm/sqm to withstand the corrosive salty weather. The arrangement to install battery boxes is located at 2 m above water level with a view to protect them from salt water.

Buoyancy Tanks

Hitherto boats, yatchs and flotilla were made with built-in air tanks which provided buoyancy to the floating unit. These tanks however were vulnerable to damage due to mechanical and other means such as firing shots. The cork and expanded polystyrene can not be used for buoyancy as these materials do not entirely fill the buoyancy tanks. Intricate curvatures and crevices are left unoccupied as blocks and sheets had to be cut and stuffed in. Moreover cork is weak and expanded polystyrene absorbs moisture; their buoyancy is thus gradually reduced. Besides, none of these are resistant to corrosion, solvents and oils and have low flame resistance.

In contrast, rigid Urethane foam while providing excellent buoyancy, adds to the structural strength, does not absorb moisture or water, protects the material against corrosion as it adheres to the complete inner surface of buoyancy tank when foamed in-situ. It occupies the entire tank filling all the intricate curvatures and crevices and is resistant to oils, solvents besides being self extinguishing.

Rigid Urethane foam of 60 kg/m^3 has therefore been used for buoyancy. In case of punctures, there is practically no loss of buoyancy since very small number of individual cells are affected. Retention of buoyancy, inspite of physical or surface damage, constitutes one of its chief advantages.

4. Radar Reflecting Screen

Though the standard radar reflectors as developed by Aerial Delivery Research Establishment are available, their use for the target needed intensive trials and testing. This is because the data on resistance of these fabrics to the salty weather and to the salt water immersion was not available. The strong winds on sea makes their use difficult due to limited tearing strength. Requirement of visibility needed further improvisation of the screens. These improvisation were to be achieved without affecting the radar responsive qualities. The metallic nylon fabric, metallic cloth quality No 10050 and metallised nylon fabric with *jari* have been intensively tested for reflectance co-efficient at CIL, Bangalore. The samples tested after salt-mist test as per IS 589 at a severity temp. of 35 $\pm$ 2°C in four cycles, the co-efficients in 'S' & 'X' Band were found to be 82-92 percent.

The metallic nylon fabric with *jari* is found capable of giving radar echoes upto a distance of 21.93 km. This fabric is lined with cotton canvas to strengthen it against tearing due to wind. Lining of cotton canvas of 37 kg BS has been found suitable during full scale trials. The *jari* fabric is dyed in international orange to improve visibility. Climate is controlling factor of its durability. As such to increase the shelf and field life, investigations are being conducted to explore the suitability of a method of lacquering or sandwiching of these screens in polythene or other protective sheets without much sacrificing of radar reflecting qualities. Also the use of indigenously available protected brass mesh, metallised polyester sheet and silver metallised nylon fabric etc as radar reflective material is being investigated. These have given good response to radar waves during preliminary trials. The comparative reflectance properties of these materials (observed during preliminary testing) are given in Table 1.

Table 1. Comparative reflectance properties of some of the indigenous materials

Sl. No	Material used	Reflectance coefficient			
		'X' Band Frequency 9 GHz		'S' Band, Frequency 3 GHz	
		Fabric weave parallel to field lines	Fabric weave 45° to field lines	Fabric weave parallel to field lines	Fabric weave 45° to field lines
1.	Nylon fabric with *jari*	93%	98%	96%	94%
2.	Matallised nylon fabric	More than 95%	More than 95%	91.4%	91.4%
3.	Silver matallised polyester sheet	97.51%	97.51%	98.1%	98.1%
4.	Brassmesh	96.87%	97.21%	97.50%	97.77%

5. Rope and Fittings for Tow Lines

The tow line to pull the target with a speed of 15 knots should withstand a pull of 1975 kg. This pull with a safety factor of five needs a rope of 10,000 kg strength. For easy recovery and storage the tow line is divided into eight segments to be joined by standard rigging fittings of this strength, with swivel arrangement. Extensive details for different types of ropes used for marine purpose have been studied. The comparative properties of ropes of various materials for 7.6 cm circumference (2.5 cm dia) are tabulated (Table 2). This advantage of the new polypropylene tow line over the existing manila tow line can be seen by comparing their characteristics from table 2. The polypropelene is selected due to its floating quality, specific gravity being less than 1. This floating rope does not impart vertical reaction to the bollards, at its ends and does not affect longitudinal stability of the target. This floating property also prevents its possibility of getting entangled into the propeller blades.

However the twisted rope segments when under load with swivel joints are likely to get untwisted and loose their strength as well as form. Also due to their resiliency of ropes made of synthetic fibres show a tendency to kink. This problem can be overcome by high frequency heat treatment. However this becomes useful only for lower construction ropes and for higher construction ropes it is found that this cursory passing of ropes through heat treatment is not sufficient to make the rope non-kinking, non-tangling and hockle free. As such the ideal structure in eight strands has been developed with the help of M/s Garware Wall Ropes, Pune. This typical

Table 2 Comparative Typical Properties of Ropes for Marine Purpose (75 mm Circumference)

Sl. No.	Characteristics	Type of rope				
		Manila	Sisal	Polyethylene		Polypropylene
1.	Strength					
	(a) Dry (kg)	4,090	3,270	11,360	5,730	6,360
	(b) Wet (kg)	4,910	4,000	10,250	5.700	6,450
2.	Elongation					
	(a) Permanent elongation at working load (%)	4.8	4.9	8.0	5.8	3.8
	(b) Working elasticity (%)	5.0	5.0	16.0	6.0	9.0
	(c) Elongation at 100% load (%)	13.0	13.0	35.0	22.0	24.0
3.	Weight/density					
	(a) Specific gravity	1.5-1.6	1.25	1.14	0.95	0.91
	(b) kg/100 m	40.0	40.0	38.0	27.0	27.0
4.	Surface characteristics	Excellent	Excellent	Poor	Requires extra wraps	Fair
5.	Water obsorption (%)	100	100	9		
6.	Resistance to rot, mildow and marine organisms	Poor	Very Poor	100%	100%	100%
7.	Resistance to chemicals					
	(a) Acid	Very Poor	Fair	Very Good	Good	Good
	(b) Alkali	Very Poor	Very Good	Excellent	Very Good	Very Good
	(c) Solvents	Good	Poor	Excellent	Good	Good
8.	Resistance to temperature					
	(a) Melting point	Loses strength rapidly	Loses strength rapidly above 180°F	482°F, progressive strength loss above 300°F	280°F, seftens above 250°F	330°F, softens above 300°F.
	(b) Low temperature properties	No change	No change	No change	Becomes brittle below −150°F	No change
	(c) Flamability	Burns like wood	Burns like wood	Burns with difficulty	Burns with difficulty	Burns with difficulty

eight strand braided construction comprises four left hand and four right hand strands woven together to give the rope perfect balance and greater weaving surface thus ensuring that the rope remains torque free under all load conditions. If any pull on the rope getting converted into untwisting moment in one rotational direction, untwists four strands then the other four get twisted and stop untwisting of the rope. The newly developed closing machines eliminate the twist variation in thick ropes so as to ensure maximum efficiency and prevent local damage to the hawsers. This type of braided construction is adopted for the tow line segments of the Gunnery Surface Target. The bridges are provided on the thimbles to avoid slippings/coming out of the ferruled eye of rope due to elastic elongation. The difficulties faced due to use of Manila ropes in the existing patt targets have been overcome.

The development cost of this indigenously developed item has been Rs. 1,08,000/- including all accessories and five sets of radar responsive screens. Since the raw materials used in construction of the targets as well as techniques of manufacture are available in India, these can be conveniently and economically produced.

6. Results of Performance Trials and Conclusions

The gunnery surface target manufactured as described above has been tried in the required operational conditions, in sea state seven and has satisfied the performance requirements of William Sled targets being used by US Navy. It has been found that :

(a) The ship-shape floats in an arrangement having equal transverse and longitudinal stability withstand the sea state of seven in all operating conditions while being towed at a speed of 15 knots, in a wind speed of 25 knots and can be manoeuvred satisfactorily.

(b) The provision of elevated super structures by about 1.2 m above average draught line is enough to ensure the visibility of the screen in the tides of sea state seven.

(c) The polypropelene eight strand braided 'PARAPRO' construction of rope retains the twist under working load while pulling the target.

(d) The metallised nylon fabric made out of nylon thread with *jari* and dyed in international orange satisfies the requirement of radar responsive quality upto a distance of 22 km and provides visibility upto 18 km. However, the durability of this material in sea water as well as a suitable alternative to this needs to be investigated.

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