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Special issue on

Lighter-than-Air Systems

Guest Editor

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LIGHTER-THAN-AIR SYSTEMS

DRDO has made its mark in lighter-than-air technology by successfully developing balloon barrage system for air defence applications. The necessary expertise and infrastructure is being built up to design, develop, fabricate, modify, re-engineer, test, evaluate, and productionise balloons, floats and related sub-systems required by the Indian Armed Forces, from indigenous sources.

A unit of relocatable balloon barrage system

CHIEF OF THE NAVAL STAFF

Naval Headquarters
New Delhi-110 011

Admiral Vishnu Bhagwat, PVSM, AVSM, ADC
Chief of the Naval Staff

30 Apr 97

MESSAGE

The research and development work carried out by the Defence Research & Development Organisation has led to the indigenous development of a large number of technologies, products, processes and systems. These achievements have substantially contributed to India's defence, self-reliance and technological freedom. Our Navy is associated with DRDO in several programmes in its quest for modernisation and to enhance its operational effectiveness.

Our technologies and products are now comparable with the best in the world, and can be very competitive in the international market. I am happy that *Technology Focus*, DRDO's bi-monthly publication, is projecting these achievements at national and international level in proper perspective.

On behalf of the Navy, I wish the DRDO every success in your endeavor.

(Vishnu Bhagwat)
Admiral
Chief of the Naval Staff

Guest Editorial

Lighter-than-Air Systems—Changing Direction?

Interest in technologies related to lighter-than-air (LTA) systems kept spurting up during various stages of History of Science. These systems also played a major role during the Gulf War. In the recent past, budgetary constraints in military spending across the Globe have resulted in resurgence of much higher level of activity in applications of LTA systems in surveillance, communication, missile defence and command and control systems. In our own battlefield theatre, looking at both external and internal threats, and the problems posed by terrains, LTA systems are emerging to play a very significant and important role in the overall defence scenario, particularly considering their cost-effectiveness. The LTA systems will also have very crucial roles in humanitarian applications like those during and after natural calamities of the type of cyclones, floods and earthquakes, by providing urgent and immediate needs of communication and damage assessment. Civil security measures like border security, custom surveillance, and drug and narcotics traffic control are some other areas where these technologies shall find a significantly active role. DRDO is poised to meet all these technology challenges by planning a series of platforms which could be suitably adopted to meet the specific needs through the use of necessary tools from the technology fountainhead.

M.L. Sidana

Lighter-than-air (LTA) systems essentially work on the Archimedes principle and use buoyancy as the primary source of lift (as against aerodynamic lift in aircraft). In airborne applications, these systems require a lighter-than-air gas for their operation and hence the name LTA. For underwater applications, these systems are filled with either air, nitrogen, carbondioxide or helium for achieving buoyancy and are called floats. In the above systems, the gases are retained in an envelope made of inflatable materials of high strength and gas-impermeable coated or laminated fabrics. These systems are designed to carry scientific/military payloads for a range of applications.

Balloon Barrage System

Balloon barrage system (BBS) is an air defence application of tethered balloons where it acts as a physical hindrance in the path of a low flying intruding aircraft, forcing it to either entangle and damage itself or pull up and come on radar view. A BBS consists of a number of tethered balloons strategically placed around a vulnerable area. The BBS comprises several sub-systems. These are :

Balloon barrage system

Balloon

The balloon is an aerodynamically-shaped inflatable structure with three stabilising fins in an inverted-Y configuration. The envelope of the balloon is made of polyurethane-coated nylon fabric of 245 gsm weight category. The balloon is sealed in 10-gore construction. The fin construction is based on modified NACA-0018 shape and has rib construction to maintain its shape. The load attachment is made through five load patches on each side of the balloon hull which forms a confluence point for attachment with the tether through a swivel to allow wind-waning and facilitate its orientation in the direction of wind. This helps in minimising the structural loads. Each balloon is fitted with a hydrogen charging valve, a mechanical relief valve, a deflation flange and a manometer attachment tube, and is inflated using hydrogen gas at a pressure of 5 m bar. The balloon has an elastic bungi line under its belly to provide the provision for expansion during altitude and temperature rise to minimise loss of gas during operation.

Gas Manifold System

The gas manifold system comprises 14 (Nos) hydrogen gas seamless cylinders each having 9 m^3 gas capacity. The cylinders are manifolded together with master charging valve, master discharging valve, flashback arrester, pressure gauge, and overpressure relief valve. The whole system is in module form for ease of transportation and could be charged or discharged *in situ*. A nitrogen gas cylinder with 7 m^3 gas capacity is provided separately for attachment at charging valve for purging of air in the manifold and the hose pipe inflation by hydrogen. The manifold system and the hose pipes are properly earthed to dissipate the static charge.

Winching System

The winching system consists of a direct winding mechanical winch mounted on a trailer. It has a drum capacity of 1500 m of 3.17 mm wire rope in 7x19 construction to the specification MIL-W-83420 D. It uses a 37 hp diesel engine to provide the power. Its level winding arrangement helps in laying the wire rope evenly on the drum. Its 4-roller type flying sheave with a 360° freedom of rotation around the vertical axis minimises the damage to the tether. It has a variable speed (sweep) 0-60 m/min both in winding and unwinding modes.

Ground Support Systems

- A 1000 l water trailer for wetting the ground at the time of inflation/deflation to dissipate static charge.
- Ground sheets for spreading the balloon for inflation so as to avoid contact with hard surface.
- Halon type fire extinguishers.
- Walky-talky sets for communication among various balloon sites and their HQrs.
- Hydraulic swagging machine for splicing of wire ropes.
- Binoculars for visual monitoring of balloon during flights.

- Necessary tool kits and puncture kit for field repair of the sub-systems.

Gas Module Van

The gas module van is used for transportation of the gas manifold systems from the balloon site to gas filling station and back. The module van comprises a modified TATA 1210 vehicle with seven arches to carry a 2 tonne capacity traveling hoist for loading and unloading of gas module van.

The van can carry eight manifold systems in two layers. It is also provided with a water tank and a water pump and two halon type fire extinguishers. Presently two Air Force stations are equipped with this system each having 16 units of tethered balloons.

Relocatable Balloon Barrage System

The BBS cannot be quickly relocated during emergency as its various sub-systems are kept separately and require loading and unloading during transportation from one location to another. This problem has been overcome by developing a relocatable balloon barrage system wherein all the required sub-systems have been appropriately mounted on a suitable vehicle along with accessories, instruments and tools necessary for inflation/deflation of the balloon. Some modifications have also been incorporated in the sub-systems. These include :

- The mechanical winch has been replaced with hydraulic winch having self-locking capability. The operation of this winch is easy and smooth.
- A balloon anchoring mast is provided to properly harness the balloon during mooring. This mast can rotate 360° in horizontal plane and 7.5° up and down in vertical plane to provide wind vaning during mooring. This eliminates the sway of balloon during mooring and therefore avoids damage to the balloon.
- Four hydraulic and mechanical jacks are provided to the vehicle to raise the vehicle above the ground during prolonged operation. This helps to (a) avoid damage to the tyres and (b) provide anti-toppling support to the vehicle during high wind.

The vehicle-mounted system thus becomes self-reliant in quick deployment of the balloon in terms of inflation, raising, lowering, mooring and transporting the moored balloon within the desired premises, deflation of balloon, and packing and storing of balloon. This system has also been converted into a trailer-mounted version wherein all the sub-systems have been mounted on a trailer.

The system is under advance stage of development.

Aerostat

Another important application of LTA technology is in aerostats—the payload-carrying tethered balloons. The line-of-sight range of the electronics and optronics equipment is limited because of horizon effect due to earth's curvature. To enhance this range, it is necessary to mount these equipment on elevated platforms. The equipment mounted on the elevated platform may also overcome physical obstructions, if any, like hills, mounts, buildings, etc. The surveillance equipment mounted on hill tops, aircraft and satellites provide much longer ranges within the power of the surveillance equipment. The tethered balloons or aerostats provide a cost-effective solution in this respect.

With the experience gained and infrastructure developed so far, DRDO is confident to develop suitable sizes of payloads for a variety of civil and military applications, viz., airborne early warning, command and control centre, electronic intelligence, battlefield surveillance, cruise missile defence, off-shore and mountain logistic support, TV and communication aerials, and extended useful range of remotely piloted vehicles by serving as communication relay.

In the beginning, DRDO will undertake the development of an experimental aerostat of 350 m^3 for a payload capacity of 50 kg up to an altitude of 300 m. The LTA is an emerging technology of great strategic importance.

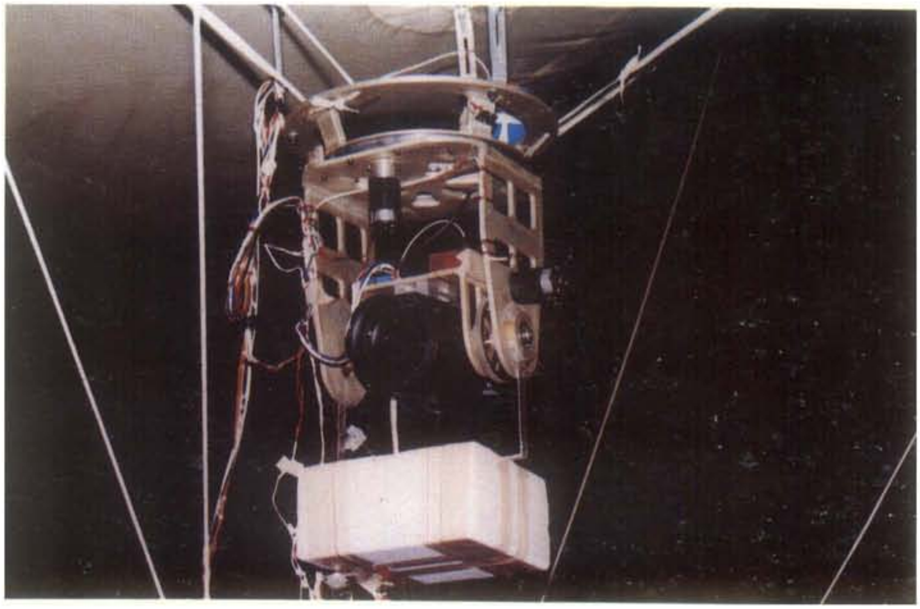
In addition to balloon barrage and aerostat applications, the other applications, viz., airship (steerable aerostat), high altitude surveillance platform application and high altitude antenna are likely to be pursued by DRDO.

STOP PRESS

SUCCESSFUL COMPLETION OF PROOF OF CONCEPT OF BLISS

DRDO successfully conducted experimental trials of an aerostat-based balloon imaging and surveillance system (BLISS) under development. In a multilaboratory collaborative experiment conducted recently, the 95 m^3 aerostat was evaluated for a platform for optical reconnaisance. A daylight/LLTV camera payload was successfully flown with the low-weight compact platform stabilised with the help of a low-cost sensor instead of a conventional gyro.

The results show promise for using these technologies for low-cost border surveillance. More experiments are planned with 160 m^3 aerostat with larger payload capacity.



A view of the imaging and surveillance system on a stabilised platform on an aerostat

Hydrogen Permeability Test Equipment

Gas retention property of a balloon basically depends on the permeability characteristics of the balloon fabric. The gas-permeability is an intricate phenomenon accuring through leakage and diffusion. Its accurate measurement therefore assumes great importance.

The hydrogen-permeability measuring equipment has been developed. This equipment has an aluminium plate with a thin cavity connected with two valves through a 3 mm diameter hole. The fabric sample is placed along with a rubber gasket over the gas chamber and clamped for gas tight sealing. One valve is connected to hydrogen gas cylinder through a rubber tube. The another valve is connected to a four-way junction.

The other three ends of the four-way junction are connected to : (a) a capsule type pressure gauge 0-50 cmWC (to provide gas chamber pressure), (b) a valve to purge out air, and (c) a graduated glass tube, water bottle and piston arrangement (for measurement of gas displacement).

Initially, the sample is pressurised to 25 m bar and allowed for 24 h in this state when the pressure drops down due to the leakage of gas through fabric. In this condition, the piston is used to raise water level in the graduated glass tube and hence to increase the pressure of the fabric back to 25 m bar. The displacement of water in the column so observed is the measure of the gas permeability of the fabric.

Balloon Fabrication

Balloons are inflatable structures and because of their airborne applications their fabrication is comparatively complex. These are required to be light weight yet strong. Also, they must be capable of holding highly permeable gases like hydrogen and helium. For this, the joints must be perfectly sealed to avoid undesired leakage. The selection of sealing method has been made on the basis of reliability, ease of manufacture and production cost trade-offs.

The balloon is a composite structure of hull, fins, load patches, ballonet, and hardware interfaces, each requiring special skill and technique during fabrication. The balloon hull and fins are sealed by radio frequency (RF) sealing technique which gives excellent sealing integrity and speed of production. RF sealing can provide strength better than the strength of a base fabric. However, for closure of hull and for some inaccessible parts of fins, the adhesive bonding method is used. Load patch, fin rib and elastic bungie patch construction require sewing techniques along with adhesive bonding.

Fabric Coating for Balloon Application

The balloon fabric is a critical fabric with respect to its mass, strength, hydrogen gas permeability, adhesion, environmental resistance, abrasion, hydrolysis and thermal resistance. No single fabric is suitable in meeting all these requirements. Hence composite fabric structures in coated/laminated forms are used for these applications.

The balloon fabric used in BBS is a single ply fabric coated on both sides. The base fabric is nylon in plain weave having suitable tensile and tear strengths. It is coated with thermoplastic polyurethane of polyether grade with melt extrusion process on one side and polyester grade with knife over roll solvent coating process on the other side. The uniformity of coating is achieved by proper adjustment of viscosity, fabric speed and pressure of rollers.

Coating of balloon fabric on zimmer coating machine at Entrmonde Polycoaters, Nasik

Emergency Flotation System for Mi-8 Helicopter

The emergency flotation system is an add-on feature to the helicopter airframe structure which enables the crew members to evacuate immediately during emergency ditching. The flotation system consists of six floats which pop out and inflate within 10 s, after its gas management system is triggered by an electrical activation system.

Float System

The float system consists of three pairs of floats, namely, nose float, wheel float and main float. All the floats are made using coated fabric in spherical/cylindrical shape.

The size and the location of the floats are decided on the basis of stability requirement at Sea-State 5.

The nose floats are of around 2 m^3 volume each, anchored under the front portion of the fuselage. The main floats are about 4 m^3 volume, attached on tubular frames under the helicopter under-carriage structure. The wheel floats are of 1 m^3 volume integrated with the axle-hub assembly extension of the helicopter.

Gas Management System

The gas management system comprises four filament wound fibre reinforced plastic cylinders suitable to store nitrogen at 300 bar. Each cylinder has a pyrovalve mounted on the cylinder neck. There are three cylinders of about 20 l water capacity. Two of these fill each of the main floats while the other discharges the gas to the two nose floats. The other cylinder of about 10 l water capacity delivers the gas to the two wheel floats.

The pyrovalves, once electrically energised, perforate the rupture discs of the valve and allow the gas to be charged to the packed floats at high velocities. All the pyrovalves are activated simultaneously so that the floats are filled up smoothly at the same time.

Ground testing of floats for emergency flotation system for MI-8 Helicopters on a mock-up

Sea Water Electrical Activation System

The sea water electrical activation system draws power from a 28 V DC source. A 5 amp all fire current is required to activate each of the pyro valves. The electrical circuit is keyed through three salt water switches which would complete the circuit during a ditching event. In case of a failure in this automatic mode, the pilot has the option to activate the system by manual override switch.

Flotation System for Underwater Recovery of Payloads

A flotation system has been designed and developed for underwater recovery of aerospace payloads. The flotation system integrated along with the recovery system is deployed at a height of around 1 km. The float so deployed would impart necessary buoyancy to the payload after splash down to accomplish a positive recovery.

The flotation system comprises about 1 m^3 volume float made out of coated fabric and is inflated with carbondioxide gas. The carbondioxide cylinder, along with the float is packed inside the container of the payload. During its deployment, the lanyard of the carbondioxide cylinder is pulled out, thus initiating the flow of the gas to the float. The float starts inflating in the packed condition and pops out and acquires its full shape in the air. The flotation system enters the water in this condition known as overwater inflated system.

Flotation system for underwater recovery of aerospace payload

The buoyancy trials of the float along with the mock-up was carried out successfully in a water tank for 24 h duration.

Regd with RNI, No. 55787/93

DRDO PATENTS

Metallic Materials

Process for Adhesion Improvement of Aramid Fibres

The Kevlar aramid fibres are widely used as high strength fibres for making fibre reinforced polymer matrix composites for applications in aircraft, helicopters, space systems rocket motor casings, etc. Poor surface adhesive property is one of the limiting factors for the development of advanced aramid fibre reinforced structural composites. Coupling agents and coatings like silicon-based materials polyurethane have been used for improvement of adhesive property of aramid fibres. However, none of these agents have been effective in improving the inter-facial bonding of resin. Various chemical treatments like acid or alkali treatment for partial hydrolysis of aramid fibre surface have been used. These chemical treatments have the drawback that the fast chemical reaction rate is difficult to control and deep penetration of acid or alkali molecules results in loss of strength due to hydrolysis of inner fibre structure.

DRDO has developed a biotechnological process wherein the improvement in adhesive property of Kevlar fibres is achieved by a bio-transformation using a bacteria-produced reactant. In this process, Kevlar fibre is exposed to the culture filtrate of bacterial isolate in complex organic medium in presence of aramid fibers. The DRDO process has definite advantage over other conventional methods in ease of operation and minimum damage to fibre structures thereby minimising the loss of strength of the fibre. Using epoxy resin, DRDO process results in 30 to 50 per cent improvement in adhesive property of the aramid fibres.

Non-Metallic Materials

Process for Fluoroacetamide

Fluoroacetamide is one of the most effective quick acting rodenticide specifically used against commensal rodents. Fluoroacetamide is known to be prepared by the fusion of chloroacetamide with anhydrous potassium fluoride. For this purpose, two approaches are known, namely, inert carrier process and dry fusion process. The inert carrier process involves chlorine-fluorine exchange reaction in xylene as a solvent. The drawback of this process is that chlorine-fluorine exchange remains mostly incomplete and causes impurities. Besides, xylene is a fire hazard.

Dry-fusion processes already known involve heating under vacuum of thoroughly ground and mixed mixture of anhydrous potassium fluoride with chloroacetamide. The drawback is that fluoroacetamide obtained is impure, as unreacted chloroacetamide, which has boiling point close to that of fluoroacetamide, distills over along with fluoroacetamide. The yield of fluoroacetamide obtained by the known dry fusion processes is relatively low.

DRDO has developed an improved dry fusion process for preparation of fluoroacetamide which leads to higher yield of fluoroacetamide and also of higher purity of the order of 99 per cent. The process does not use any carrier like cetyltrimethyl ammonium bromide used in some of the known dry fusion processes to bring the reacting mixture to molten form so as to increase the yield. The process also does not employ any secondary steps of purification and isolation of the compound. The process is eco-friendly, as left over potassium fluoride is isolated and reused in the subsequent batch of preparation of fluoroacetamide thereby eliminating environmental pollution and the problem of disposal of waste product.

Food Technology

Process for Cooked *Dhal* Concentrate

Cooked *dhal* gets spoiled rapidly at room temperature and can be stored only for 2-3 days. To prevent spoilage and to make *dhal* as quick-cooking, the dehydration of cooked *dhal* is practised or *dhal* is flaked prior to dehydration. The known process of dehydration is carried out by drying at 70-80 °C in a cabinet dryer or in a fluidised bed dryer or in any other dryer so as to bring down the moisture content to the level of 5-8 per cent. In some processes, prior to dehydration, *dhal* is soaked in salt solutions containing various salts such as sodium bicarbonate which have adverse effect on colour and flavour. For preparation of *dhal* flakes, flaking is carried out prior to dehydration. The dehydrated *dhals*/flakes available at present require about 10-20 min of boiling for satisfactory reconstitution.

DRDO has developed a process for preparation of concentrate/mash of cooked *dhal* with or without spices. This concentrate/mash of cooked *dhal* can be instantly reconstituted to liquid or semi-liquid by stirring with warm/hot water or even with tap water. Besides, the concentrate is shelf-stable for several months.

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