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Technology Focus

टैक्नोलॉजी फोकस

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Battlefield Protection System

High Energy Materials (HEMs) exhibit high rate of release of energy, which is used for destructive purposes in battlefields, but the energy released can be tamed to develop protection capabilities, against destructive forces. High Energy Materials Research Laboratory (HEMRL), Pune, one of the establishment of Defence Research & Development Organisation (DRDO) has developed many systems for the protection of tanks and aircrafts. This issue of *Technology Focus* is bringing out features and current state of development of five such protection devices.

Product Name	**Protection for**
Explosive Reactive Armour	Tanks
Smoke Grenade	Tanks
Canopy Severance System	Aircraft
Infrared Decoy Flare	Aircraft
Chaff Cartridge	Aircraft

Explosive reactive armour (ERA) has capability to significantly reduce the penetration of shaped charge warheads and kinetic energy (KE) projectiles, thereby ensuring the non-perforation of tank armour and protection of crew. Smoke grenades can be treated as last line of defence for tanks in battlefield to run away in distressed conditions by camouflaging and blinding the enemy's thermal imaging (TI) and laser sights. Canopy severance system (CSS) uses high explosives for cutting canopy of fighter aircrafts for safe ejection of pilot in distress in flight as well as on ground. For protection of aircrafts, against latest heat seeking missiles, decoy flares with high infrared intensities and spectrally matching emissions have been developed. The chaff cartridge disperses payload in air to create unclear signature for deceiving radar and radar homing missiles.

Explosive Reactive Armour

Be it a tank, an infantry vehicle or a soldier, there is always a continuous race between weapon designer and armour designer. With advent of shaped charge warheads around WW-II, the weapon designer appeared to get edge over the armour designers of fighting vehicles. The shaped charge jet produced by these warheads is capable of penetrating any armour and thickness more than protection available on any of the tanks. To counter the threat of shaped charge warheads, an innovative armour, making use of explosives was reported, which is known as explosive reactive armour. In simple configuration, ERA consists of an explosive layer sandwiched between metal plates (Fig. 1).

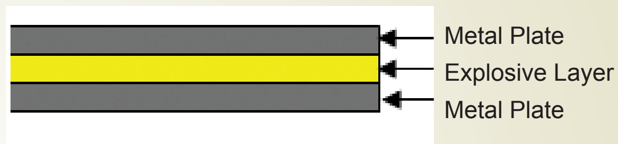

Figure 1. ERA Basic Configuration

On impact by the shape charge jet, the explosive layer detonates, driving the sandwich metal plates in the path of shaped charge jet (Fig. 2). The interaction of the jet with forward and backward moving plates disturbs the coherency of the jet, causing disruption as well as deflection of the jet. In addition, the angular interaction leads to a longer cut along the length of the moving plate, consuming some portion of the jet. The high density detonation products also cause disintegration and disturbance of the jet. All these phenomena cause significant reduction in penetration capability of the shaped charge jet.

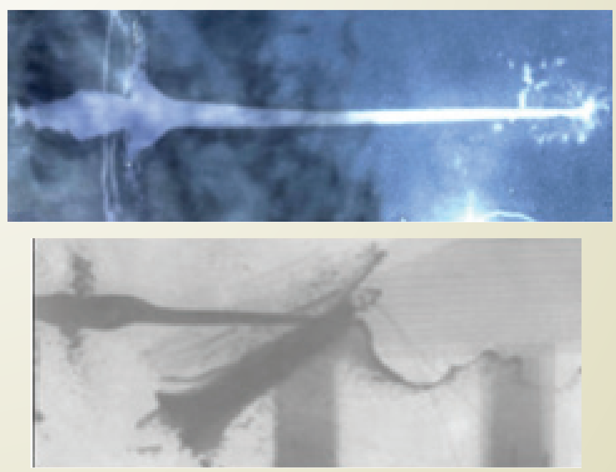

Figure 2. Incoming Shaped Charged Jet Disrupted by ERA

ERA Mk-I

In 1980s, the concept of reactive armour was reported in literature and patents were obtained by some researchers. Being the lab working with explosives, studies were initiated at HEMRL on reactive armour. Different explosives as well as sandwich materials were studied and effect of various parameters like charge to mass ratio, explosive properties, sandwich plate material, angle of attack, etc. on performance were studied. After generating data on various aspects, HEMRL in association with Combat Vehicles Research & Development Establishment (CVRDE) and Defence Metallurgical Research Laboratory (DMRL) undertook the developed ERA Mk-I for adaptation to tank T-72. The development was completed and user trials were successfully carried out in 1996. The technology for production of different components has been transferred to ordnance factories in the year 2002 and till date more than 1000 numbers of T-72 tanks of Indian Army has been equipped with ERA Mk-I. There are three types of panels on tank, namely standard, tapered and top panels (Fig. 3) as per design constraints and protection requirement.

The standard and tapered panels consist of two reactive cassettes, placed at an angle, whereas top panels consist of multi-layers of explosive and metal plates. Total 165 numbers of panels are mounted on one tank by bolting arrangement. The adjacent panels are separated by metallic barriers to avoid sympathetic detonation. Figure 4 shows a tank T-72 fitted with ERA Mk-I.

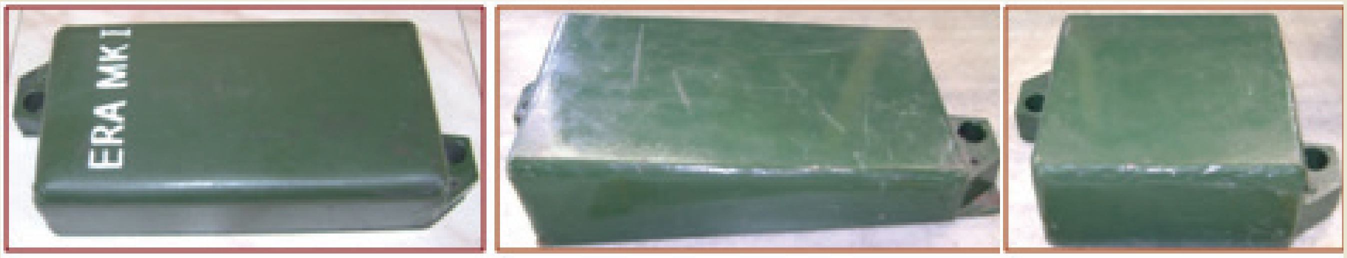

Figure 3. Standard, Tapered and Top ERA Panels

Figure 4. Tank T-72 Fitted with ERA Panels

ERA Mk-II

ERA Mk-I was developed for protection of tanks against shaped charge warheads as per users requirement. However, with enhanced penetration capability of KE projectiles, there is a requirement to provide additional protection from KE projectile in addition to shaped charges. Accordingly, the development of ERA Mk-II was undertaken by DRDO in 2011 with HEMRL as nodal lab and CVRDE, DMRL and PXE as project partners. HEMRL has developed the reactive elements, DMRL carried out development of armour materials for panels and CVRDE has finalised the layout and fitment of panels on tank T-72 and Arjun Mk-II. PXE provided the experimental facilities for dynamic evaluation of ERA Mk-II panels against 125 mm FSAPDS ammunition. The user trials of the ERA Mk-II were carried out in 4 phases during November 2015 to January 2016. DRDO has developed ERA Mk-II for adaptation on T-72 tanks, having equivalent performance as that of ERA on T-90 tanks (imported from Russia).

ERA Mk-II has an integral type configuration on hull glacis, in which the panels have been welded to tank surface with a provision for positioning of reactive elements, using a window (Fig. 5). This type of arrangement has significantly reduced the time for uparming the tank. The size of panels is larger than ERA Mk-I and the reactive elements inside the panel are separated by metallic barriers to avoid sympathetic detonation (Fig. 6).

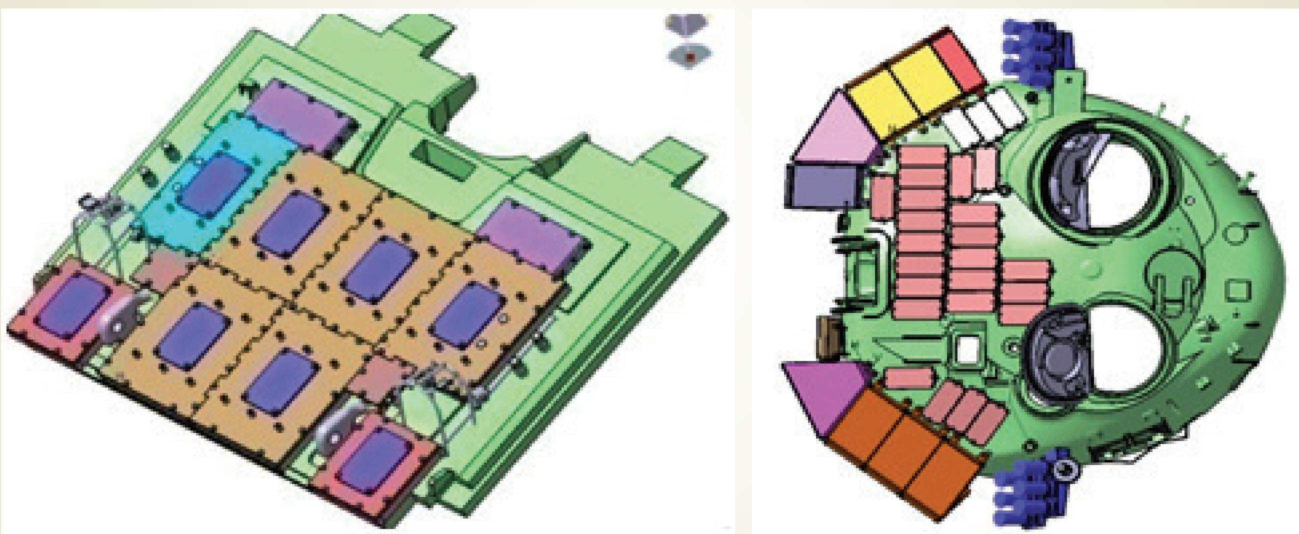

Figure 5. Arrangement of ERA Mk-II on Tank

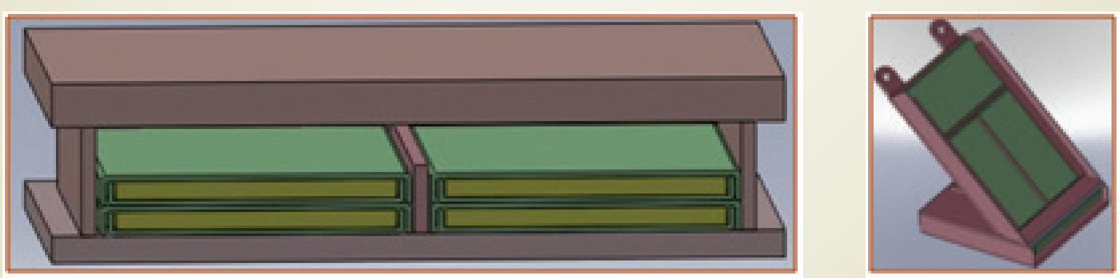

Figure 6. Internal Configuration of Reactive Elements of ERA Mk-II

The design has minimised blind zones (distance between the reactive elements) and the larger size of panel results in longer interaction with projectile or jet. With improved explosive properties and armour materials, the performance of ERA Mk-II against shaped charge warheads and KE projectiles has been significantly enhanced. The panels on turret front have been mounted at an angle to get the desired angle of attack for optimum performance.

The turret top panels are designed to take care of top attack submunitions. Though the size of panels is different on different locations, the size of reactive elements is same in all the panels. The user trials were carried out in four phases during November 2015 to January 2016. During the trials, ERA Mk-II was evaluated against 84 mm heat, 125 mm heat, Milan warhead and AMK-339 ammunition. The experimental set-up for various trials is shown in Fig 7. In all the trials, performance of ERA Mk-II was observed within the acceptance criteria as per the quick response (QR).

One tank T-72 was fitted with ERA Mk-II panels (Fig. 8) and evaluated by Army for various performance parameters, like mobility, turret traverse, gun stabilisation, etc. as per trial directives. All the requirements were met during the user evaluation. The enhanced protection has been achieved keeping the weight same as that of ERA Mk-I.

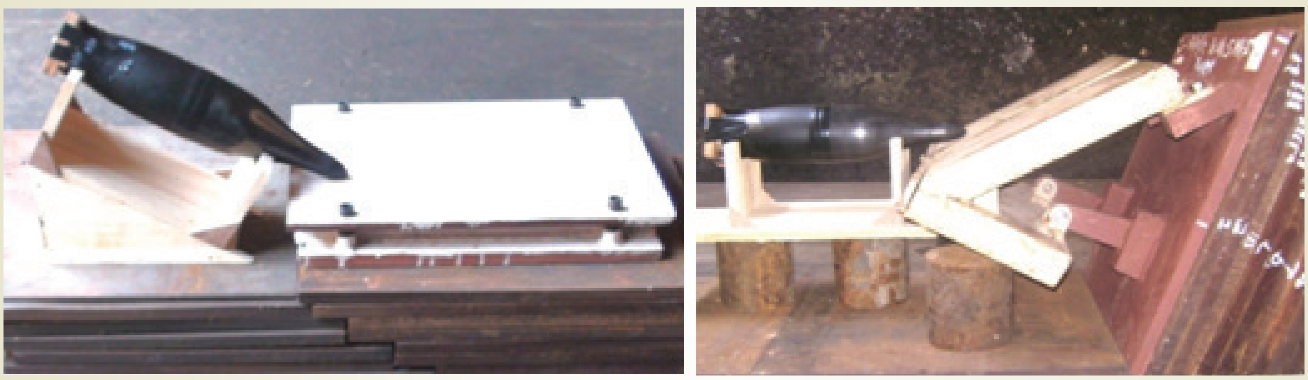

Figure 7. Static Testing of ERA Panel

Figure 8. T-72 Tanks fitted with ERA Mk-II Panels

Salient Features

- Adaptable to all the three tanks, i.e. T-72, T-90 and Arjun Mk-II of Indian Army
- Integral type configuration on hull glacis, in which the panels are welded on tank surface, having a provision for insertion of reactive elements
- Protection of the tank from advanced shaped charge warheads and KE projectiles
- No sympathetic detonation between adjacent elements inside the panel
- Immunity to detonation against small arms and artillery fragments
- Safe in handling and storage
- High shelf life of explosive
- Less weight penalty on one tank (1.5T for T-72)

DRDO has successfully completed the development of ERA Mk-II for protection of tanks from heat and KE ammunition, meeting the user requirement. Adaptation of ERA Mk-II will significantly enhance the protection level of tanks. The induction of indigenous technology will results in saving of huge foreign exchange.

Anti-thermal Anti-laser Smoke Grenade

For survivability of tanks in the battlefield from enemy fire, creation of aerosol smoke screen for short-duration obscuration has been the last line of defence. The present inventory, in use for last 25 years by Indian AFVs have 81 mm burning type smoke grenade (3D6) based on Hexachloroethane (HCE). The grenade after launching from the smoke grenade discharger (Fig. 9) functions on the ground at a distance of approx. 300 m from the AFVs.

The time of flight of this grenade is 8-10 s and the effective smoke screen is built in 18-20 s, i.e., the total smoke screen build up time is about 30 s after launching which is excessive particularly when confronted by enemy tanks where the main armament has a quick response time. Present day AFVs and other weapon system use TI sights and laser sights for the detection and engagement of targets. The HCE produces white smoke screen, which does not obscure in higher regions of electromagnetic spectrum. So, an attempt is made to develop bursting type smoke grenade with low smoke build-up time and capability to have anti-thermal and anti-laser obscuration capabilities.

Figure 9. Smoke Grenade Dischargers on Tank

HEMRL has designed and developed bursting and burning type of 81 mm Anti thermal-Anti laser smoke grenade Mk-I (Fig. 10) which bursts in mid air/ ground at a distance of 50-70 m from firer tank and produce a dense white smoke screen. This smoke screen is capable to obscure the visual and all bands of infrared regions (0.4 to 14 microns) and also confuse laser range finders.

Figure 10. 81 mm Anti-thermal Anti-laser Smoke Grenade

Operational Features

The sectional view of grenade with various components is shown in Fig. 11. The grenade is electrically ignited by 24 V DC supply from tank, which initiates primer, which in turns initiates propellant, which builds up sufficient pressure behind the grenade for its ejection from SGD at a velocity of 20-35 m/s. The delay tube is initiated by propellant gases. After a preset delay of approx. 3.8 s, during which the grenade travels a distance of approx. 60 m, bursting composition is initiated. The smoke grenades burst open and smoke screen is created from the burning compositions. Figure 12 shows obscuration of the target as seen through the visual camera after creation of the smoke screen. Figure 13 shows defeat of thermal imager by the created smoke screen, as thermal imager is not able to detect the objects on the other side of the smoke screen.

Design Features

The grenade consists of three different red phosphorus based smoke compositions, for instantaneous smoke screen the leaflet technology is developed for the first time in smoke technology. Two types of red phosphorus based pellets, viz., fast burning and slow burning are developed for achieving the smoke screen for quick and longer duration

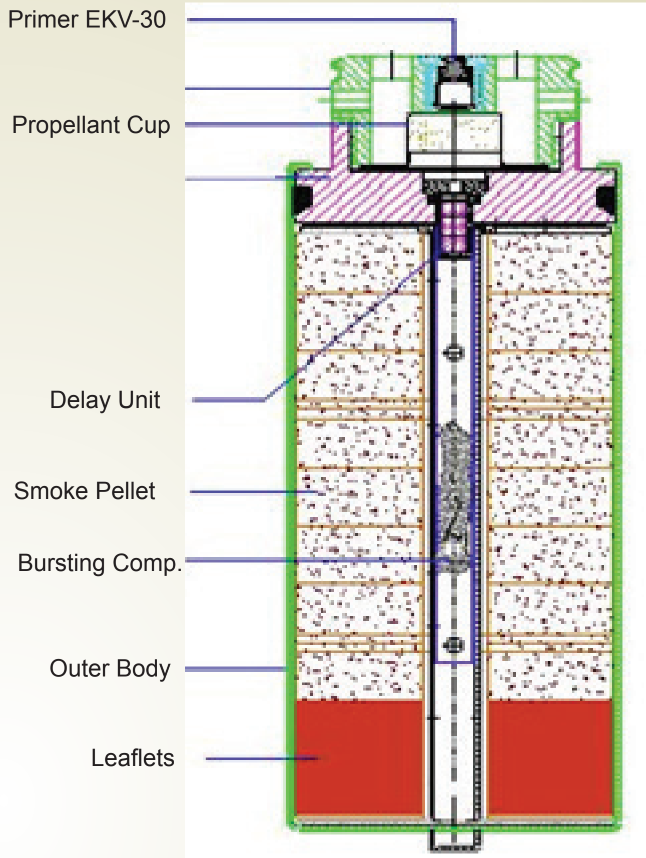

Figure 11. Sectional View of 81mm AT-AL smoke grenade Mk-I

Figure 12. Visual Obscuration: Before and After Smoke Formation

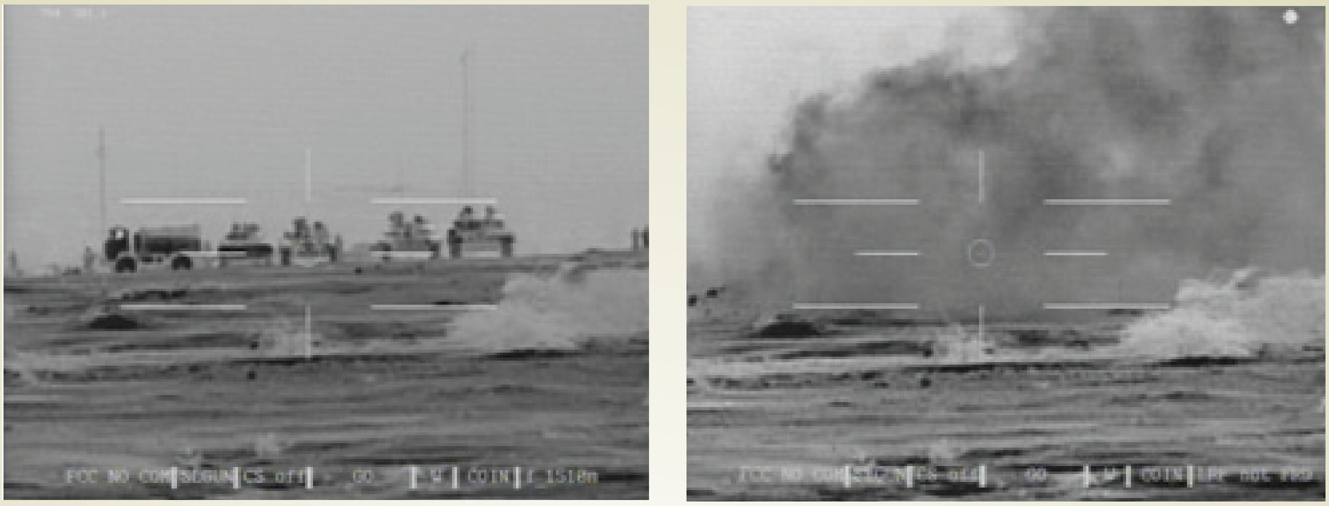

Figure 13. Thermal Obscuration: Before and After Smoke Formation

respectively. When grenade electrically actuated from the grenade discharger, the explosive train starts. The sequence starts with electrical primer, the propellant charge, delay charge, burster charge and finally pellets and leaflets. Propellant charge propels the grenade to a distance of 60 ± 10 m in about 3.8 ± 0.3 s time and explodes in mid air, approx. 8 m above the ground. The close variation in height of burst is achieved by developing an improved accuracy pyrotechnic delay element. A white dense smoke screen of approx. 15 m width x 10 m height is formed with single grenade which is capable of obscuring the night vision equipments in the range of 0.4 to 14 microns for duration of not less than 20 s. The size and effectiveness of the smoke screen depends on the number of grenades fired, relative humidity of the air, ambient wind speed and direction. The launching of grenades should be in the line of the target.

On bursting in mid air, the burning leaflets float in air producing instantaneous and well spread smoke screen. It merges with emerging smoke of pellets burning on ground. The smoke screen blinds effectively the TI sight and LRF of the enemy AFVs. To facilitate easy bursting, the outer metallic container is preformed with four equidistance longitudinal grooves on the inner wall.

The smoke screen is formed due to the burning of red phosphorus which produces P2O5 and subsequently converts into ortho-phosphoric acid by reaction with atmospheric moisture. Therefore, the change in atmospheric humidity affects the grenade performance. The smoke composition has been extensively studied and the anti-laser and anti-thermal capabilities have been tested satisfactorily against Nd-YAG laser range finder (peak power 1 MW, λ=1.064 µ), laser designator (peak 5 MW) and various TI of T-90 and BMP-II. It has been confirmed that these instruments have been blinded for the effective duration of smoke screen. User assisted technical trials are conducted and effectiveness of smoke screen is demonstrated.

Canopy Severance System for Fighter Aircrafts

During development of LCA-Tejas, Aeronautical Development Agency (ADA) approached Armament R&D Establishment (ARDE) and HEMRL for design and development of a canopy severance system (CSS) to rescue the pilot during emergency in shortest possible time. The broad specifications and type test schedule were framed by ADA in consultation with certification agency RCMA (AA); and developing agencies ARDE and HEMRL. The major technical requirements were:

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- CSS shall cut stretched acrylic sheet of thickness 7 mm
- CSS shall not produce noise level more than 180 dB for a duration of not more than 20 ms and
- CSS shall have a total life of not less than 7 years and installed life of not less than 4 years

It was decided that the above requirements can only be met by high explosive based system. Therefore, HEMRL took the responsibility of developing explosive based components and ARDE was given the task of developing rest of the components of CSS. The CSS was configured in two independent sub-systems namely; ground egress system (GES) and in-flight egress system (IES). As names indicate, GES shall be operated when the aircraft is on ground and emergency arises; IES shall be operated when aircraft is flying and emergency arises. GES is designed in such a way that it can be operated either from the cockpit by the pilot or from outside by crew members. When GES is operated, it produces a clean cut on the canopy bubble along its circumference thereby allowing the crew members/ pilot to dislodge the canopy bubble and enabling the pilot to come out of the cockpit.

The IES is designed such that it is actuated by the gaseous products tapped from power cartridge of seat ejection mechanism. Therefore, IES gets actuated when seat ejection mechanism is operated by the pilot when he/she wants to eject out from the aircraft. When IES is actuated, it produces a straight clean cut along the centre line of the canopy bubble thereby weakening it and enabling the pilot to eject out smoothly from the cockpit. The cutting of canopy bubble is achieved by metallic jet produced by a inverted v-shape lead sheath filled with RDX called shaped miniature detonating cord (SMDC). The CSS is a multiple component system and comprises of internal initiator, external initiator, pressure actuated initiator, junction boxes, explosive transfer lines (ETL), SMDC, initiating booster and tip booster, silicon rubber attenuator. The ETL (Fig. 14) consists of a lead sheath filled with RDX; called circular miniature detonating cord braided with various layers

Figure 14. Explosive Transfer Line

of fibre glass, steel wire and nylon tube. An ETL is fitted with tip boosters along with connecting rods and sleeve at both the ends. ETL performs the task of transferring the explosive shock from initiator to junction box/one junction box to other, and finally to SMDC. Tip booster consists of PETN and initiation booster consists of RDX/wax pellet. The SMDC is a shaped lead sheathed cord with 0.8 g/m loading. Its performance is established by capability to cut 7 mm stretched acrylic sheet. Silicone rubber attenuator is designed to attenuate the shock developed during functioning of SMDC. The hardware components such as internal initiator, external initiator, pressure actuated initiator and junction boxes have been designed and developed by ARDE.The challenging task of design and fabrication of high precision machine for manufacture of ETL and SMDC as well as selection of lead alloy for sheathing and explosives were accomplished to realise the system. The development work also involved selection and testing of adhesive for interconnecting/sealing of components, and particularly for integration of SMDC on canopy.

Salient Features

- Creates a clear passage to rescue pilot in shortest possible time
- Functions both in-flight or on ground
- Sound intensity inside helmet is 164 dB for 5 ms against permissible limit of 180 dB for 20 ms

- Shock pressure inside helmet is 0.35 N for 5 ms
- Causes no damage to sensitive equipments in the cockpit and no injury to pilot due to explosive shock or fragments
- Optimised minimum quantity of explosive without penalty on reliability under all environmental conditions

Qualification Testing

Canopy severance system was subjected to rigorous testing as per the type test schedule formulated by RCMA (AA) and CEMILAC. The major tests include radiographic examination of ETLs, CMDC and SMDC; flexing trials of flexing ETLs up to 7000 cycles, shock test on models of GES and IES at 20 g and 40 g for 11 ms each, vibration & air exposure, salt test, sand and dust test, rain test, functional test of IES, system verification test, lifing trials, hazard classification test along with package, etc. to meet high standards of quality and reliability. All weather performance of the system has been proved by evaluation after exposure to simulated environmental conditions. The IES has been tested in association with seat ejection system of Martin-Baker U.K. as well as Zvezda of Russia (Fig. 15). GES has been tested at Hindustan Aeronautics Limited (HAL) Bengaluru and parameters such as noise level and duration were recorded.

Achievements

The state-of-the-art CSS is developed indigenously by HEMRL and ARDE to rescue pilot in the shortest time in an emergency during flight or on ground. The CSS has met all the system requirements formulated by RCMA (AA), CEMILAC and ADA. The reliability of IES with dual mode has been estimated as 0.99925 with 90 per cent confidence level.

In a major technological achievement, the state-of-the-art CSS technology is developed indigenously by DRDO to rescue pilot in the shortest time in an emergency during flight or on ground. The major crux of CSS technology is high reliability in operation with minimum optimised quantity of explosive without endangering man and machine. Presently, CSS is integrated to LCA fighter (Tejas), LCA Trainer and IJT aircraft which are flying.

Infrared Decoy Flare

Protection of aircraft, against heat seeking missiles requires creation of infrared signatures similar or more lucrative than aircrafts, for the incoming missiles to lure them away from aircrafts. Infrared decoy flare development started with indigenisation effort (conventional flare development to defeat 1st and 2nd generation missile seekers) for the existing

Figure 15. IES and GES Testing of Developed CSS

stores of IAF, but the technology have been mastered to an extent at HEMRL that now advanced decoy flares to defeat 4th and 5th generation of missiles seekers are also within development capabilities. The technology started with indigenisation activity has now culminated into making India self-reliant in the field of spectrally matched flares. The conventional and advanced flares have been developed in two configurations–(i) Rectangular 218 flare, and (ii) 50 mm diameter flare for deployment on both NATO and Russian aircraft.

Rectangular 218 Flare

The decoy flare 218 is expendable passive countermeasures for protection of aircrafts against 1st and 2nd generation IR guided missiles. This single rectangular flare (Fig. 16) is used in five different aircrafts of IAF, namely on MiG-21 (Bison), MiG-27, Jaguar, Mirage 2000 and Embraer aircrafts. This flare is compatible with various counter-measure dispensing system (CMDS) like TAAS, TRACOR, BDL of 2”x1”x8” size. The flare has been indigenously developed successfully with advanced features like higher safety against EMI-EMC problems by incorporating 1A-1W no-fire impulse cartridges. To avoid ignition of flare in CMDS, safety and functioning unit (which was not available in imported flare) has been designed and introduced. Flares were evaluated in static mode and very high rate of IR intensity emission is achieved. The flares are tested from various aircrafts (Fig. 17), like MiG- 21 (Bison), MiG-27, Jaguar, Mirage 2000 and Embraer aircrafts along with imported flares. Indigenous flares performed better than imported flares with respect to IR intensity, burn time and rise time. Efficacy trial completed with Igla (SAM) and R-73 (AAM) and ‘lock break’ achieved in all trials.

Figure 16. IR Flare 218 for CMDS

Figure 17. Dynamic Firing Trials from Bison Aircraft

Infrared 50 mm Decoy Flare

After success of 218 decoy flare, work was initiated for the development of flare compatible with APP-50 UV Mk I 30 (Russia) CMDS, which is installed on SU-30 Aircrafts. The flare is to be realised in 50 mm diameter (Fig. 18) and processing techniques have to be evolved. The flare must have in-built safety features like 1A-1W no-fire current capability and safety functioning units (SFU).

The flare is evaluated in static mode and its radiation intensities are confirmed by radiometer in

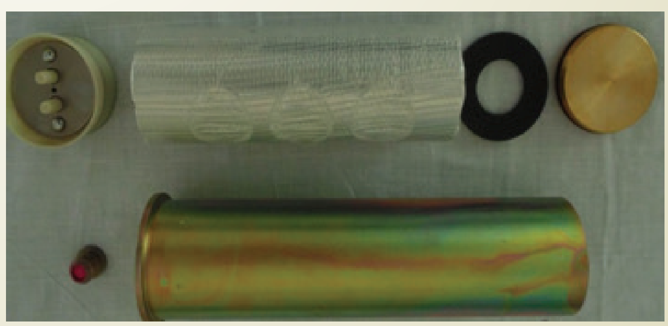

Figure 18. Infrared 50 mm Decoy Flare for SU-30

different wave-bands. For dynamic firing of this flare, firing set-up is designed and fabricated in-house and flare is dynamically evaluated from the single launcher (Fig. 19) for full functioning trials. The flare has higher radiation intensity than imported flares for the defeat of 1st and 2nd generation missile seekers. The dynamic firings from ground based static single launcher for the flare is complete. The flare is undergoing design qualification trials as per JSG 0102.

Figure 19. Dynamic Firing of Flare from Ground Based Single Launcher

Advanced Flares

Considering global trend, HEMRL has embarked on the development of IR flare having radiation intensities spectrally matching to that of the aircrafts. These flares are being developed under title "Multi-Spectral Flares". These flares are passive countermeasure for 3rd and 4th generation IR guided missiles for aircraft protection. The flares are being developed for same CMDS. No such flare is available with IAF with multi-spectral capabilities. This development is moving in the direction of equipping Indian fighter aircrafts with indigenous advanced flares. The flares are being developed in 218 mm and 50 mm configurations. As this is an ab-initio development, a technical specification is evolved, based on literature survey and global developer's pamphlets.

The flare composition has been finalised after rigorous trials. A patent is filed with Indian Patent Office, New Delhi on 'Pyrotechnic composition based on organic fuels for spectrally balanced decoy flare'. During static trials, performance parameters as per devised technical specification have been achieved. Ground based dynamic trials completed in all respects.

Chaff Cartridges

Chaff cartridge 118 (Fig. 20) forms part of a CMDS to protect the host aircraft from radar guided missile threats by providing a suitable alternative and preferred target or 'decoy' (as chaff cloud). The function of the decoy is to lure the radar guided missile away from the intended target such that it passes the target aircraft at an effective miss distance. Ejection of the chaff payload is triggered either manually by the pilot or automatically by the CMDS. There was a requirement from IAF for the indigenous development of chaff cartridges for IAF. Defence Laboratory Jodhpur (DLJ) and HEMRL has taken joint efforts to develop chaff cartridge 118. DLJ has been developing indigenous chaff payload, while HEMRL is developing impulse cartridges, containers and safe dispensing mechanisms.

Design Features

Chaff cartridge 118 is a non-metallic (fiber reinforced plastic) rectangular container of size 1''X1''X8'' filled with millions of chaff fibres of different cut-off lengths. Chaff fibres are fine aluminium fibres of individual diameter 25 ± 4 μm. The chaff cuts are loosely wrapped in glazed kraft paper. The wrapped chaff cuts or packs of different resonance length (8 numbers) are arranged in such a way that upon dispensation the chaff fibres are released to form a cloud like arrangement. The chaff ejection end of the cartridge is closed by a plastic cover (end cover),

Figure 20. Microwave Chaff Cartridge 118

which fits snugly in to the container by means of two projections provided on the cover. The complete chaff payload (chaff packs) with a piston and cushion are loosely inserted into the container with chaff elements (microwave dipoles) lying parallel to the length of the container. The chaff cartridge is shown as Fig. 21. An impulse cartridge assembled into the base of the cartridge. The impulse cartridge contains a pyrotechnic squib charge and propellant pressed into the base of the cartridge, which when fired generates gas pressure to eject the chaff payload with ejection velocity 25-50 m/s. Impulse cartridge is the heart of the system.

Impulse Cartridge

The impulse cartridge (Fig. 22) is supposed to develop sufficient pressure behind chaff payload to eject it with velocity ranging from 25 m/s to 50 m/s. This is a press-fit component in the FRP cartridge end and the compositions are sufficient to generate sufficient pressure for achieving ejection velocity and at the same time peak pressure is limited by strength of the FRP body of the cartridge. The impulse cartridge has been designed with performance matching to the imported cartridges and ejection velocity with indigenous chaff payload (developed by DLJ) has been achieved. The cartridge has been subjected to limited qualification and it withstood vibration, shock, air-exposure, visual and x-ray examinations (Fig. 23). The ejection velocity set-up for chaff cartridge has graduated checker-plate (grid size 25 cm x 25 cm) as background (Fig. 24). The motion of payload after ejection from dispenser is captured by high speed video at the frame rate of 1000 fps and ejection velocity is measured. The ejection of chaff material from in-house designed single cartridge dispenser is also observed (Fig. 25). The cartridge is undergoing air-worthiness trial through aircraft.

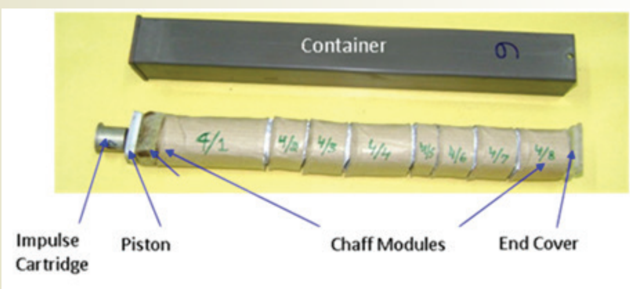

Figure 21. Components of Chaff Cartridge

Figure 22. Impulse Cartridge for Chaff 118

Figure 23. Real Time Radiography after Limited Qualification Trial

Figure 24. Test Set-up for Ejection Velocity

Figure 25. Simulated Dynamic Firing at HEMRL Test Ranges

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