

Chapter 7

Development of mock-up (1:1 scale decoy) of a combat vehicle with thermal signature simulation

7.1 INTRODUCTION

The observations of present research work, analysis and results of thermal signatures of exhaust emissions of the two diesel vehicles will be useful for developing effective deception devices of military vehicles with thermal signature simulation. As per camouflaging and deception strategy, such deception devices will be helpful for creating false impression, in the minds of opponent, about the presence of many military equipments in field conditions. Thus, the use of decoys as force multiplier is expected to enhance the survivability of military equipments.

In modern warfare, thermal IR signature simulation in military mock-ups is very important requirement of defence services such as Army, Navy and Air Force for deceiving the thermal IR seeking missile and thermal IR guided weapons of enemies. Exhaust of vehicle is the most prominent feature in the thermal signature of the vehicle, with which it can be detected by thermal imagers.

In general, military equipments and vehicles are powered by diesel engine or aviation fueled turbines. Presently, we have developed a decoy of military tank with thermal signature simulation, without the exhaust emission, as per service requirements. This section documents the details of development of a military decoy of a tank with thermal signature.

Inclusion of exhaust thermal signature makes the decoy tank mimic the thermal signature of real tank in day and night time effectively. Considering the importance of exhaust thermal signature, it has been taken up for investigation as part of the current research work. The IR study and analysis of diesel exhaust emission carried out in previous chapters of this thesis will add a new dimension in the area of research and development of decoy of military equipments such as Tank, Gun, fighter Aircraft, Missile launcher, Radar, etc, with thermal signature simulation. Measurement of composition of diesel engine exhaust emission and its thermal signature visualization using thermal IR imaging camera in 3-5 μ m and 8-14 μ m wavelength bands provide significant information for thermal signature simulation in military decoys. The exhaust thermal signature simulation, including the exhaust thermal signature, in decoys of tank and fighter aircraft will be carried out as a future project work.

7.2 MILITARY DECOYS

A multispectral decoy of a military object simulates multispectral signatures of the real military object in various wavebands such as visual, microwave and thermal signature of EM Spectrum, along with acoustic and other features. Thermal signature simulation is very important aspect to deceive enemy's thermal imagers, especially during night time.

7.3 USE OF MILITARY DECOYS

Military Mock-ups are very important tool for deceiving, diverting and dividing attention of enemy resulting into enhancement of survivability of troops and equipments. They are used as tactical tools to deceive enemy's surveillance sensors about the actual deployment of locations & numbers of strategically important military equipments. Military mock-ups also

make a realistic assessment of an attack difficult to the enemy by rapid replacement of decoys with the damaged equipments in the war field area. Hence, the deployment of multispectral military mock-ups provides substantial gain in operational planning of an attack during war. Using cutting edge technologies, military mock-ups are being developed with close resemblance to the real equipments such as aircraft, gun, tanks and other equipments with simulated signatures in complete EM spectrum. Military Mock-ups are required to be easily portable, quickly deployable, durable and economical for use.

7.4 DESIGN AND DEVELOPMENT OF TANK Mock-up (DECOY 1:1 SCALE)

DLJ (DRDO) was entrusted by the defence services to develop a tank Mock-up having required specifications as given in **Appendix “B”**. In order to achieve this important task, DLJ has successfully carried out design and development work of tank Mock-up along with specified signature simulation capability.

7.4.1 Design of the Mock-up:

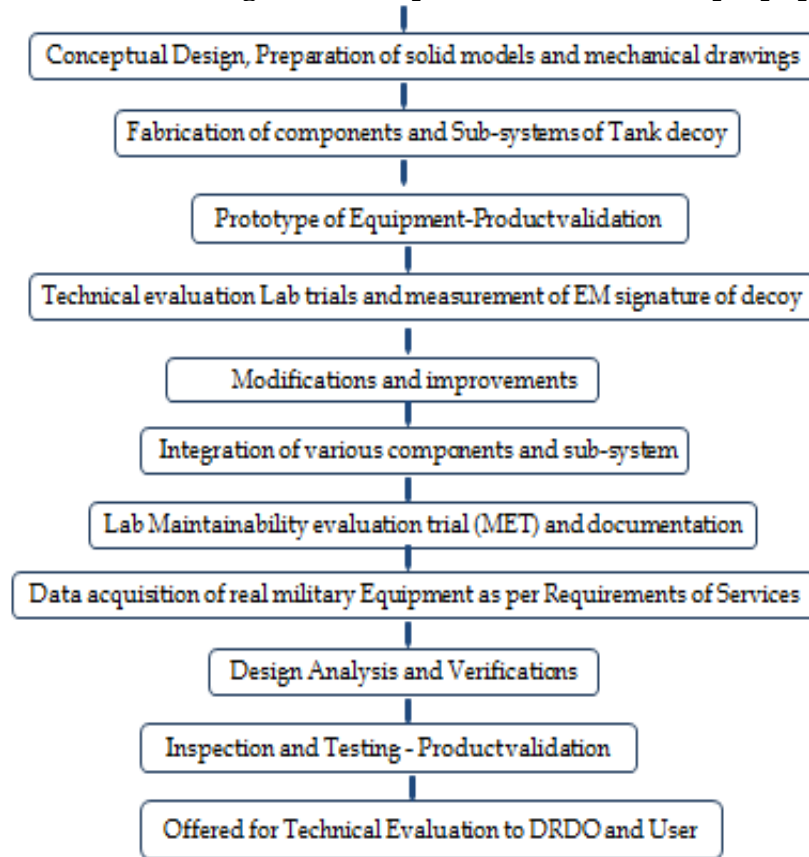
Design work has been carried out considering all specified technical requirements and actual end use during field deployment of the Mock-ups. The main design consideration was taken such as strength, selection of material, weight, cost, visual appearance, thermal properties, manufacturability, quick assembly and dismantling, man portable parts, rapid deployable, maintenance, and reliability. Tank Mock-up design and fabrication of various Parts, sub-systems and integration have been carried out in-house, keeping in view to maintain secrecy in the development work.

The steps in the design are followed as mentioned in flowchart. The 1st step is analysis and understanding of requirement received from services. The specifications of tank Mock-up has been finalized in terms of feasible, unambiguous, measurable quantities and consistency. In 2nd step, collection of technical data on the tank carried out from designated Army unit by physical dimensional measurements, collection of drawings, obtaining visual and thermal images etc. In 3rd step, conceptualization of design was carried out. Based on the past experience, the best approach for design was selected. In the subsequent steps, we carried out design, design analysis and design verification. In the process of design verification, we theoretically checked the compliance with respect to all minute details of specifications pertaining to tank Mock-up.

Once the design is finalized, in next step, we fabricated various parts, sub-systems and carried out integration to make prototype of tank Mock-up. Further, we carried out product validation trial in Lab (Lab trial) to verify whether physical characteristics and functional requirements of the product have been met as per the user given requirements. We incorporated all observed improvements during Lab trial and ensured maintenance & safety aspects. Once prototype of Mock-up was ready in all aspects, we offered the equipment for DRDO internal trial and subsequently completed field evaluation trials(FETs) and other trials as per SOP-conduct of trial, which is enclosed as **Appendix “C”**.

The following flowchart exhibits the design approach adopted for the development of Tank Mock-up.

FLOWCHART: Design & Development of tank Mock-up equipment



7.4.2 Salient Features of the Mock-up:

The Mock-up of tank has the following specifications: -

- (i) To be assembled in 45 minutes by four personnel
- (ii) Capable to simulate visual, MW and thermal signature
- (iii) Towable for rapid deployment
- (iv) Able to withstand low intensity storms, rain falls and extreme temperature conditions.
- (v) Cost effective

7.5 IMPORTANCE OF THERMAL SIGNATURE SIMULATION IN DECOY

Modern war is fought throughout day and night. Enemy uses various sensors to detect and identification of military equipments and personnel. Thermal IR sensors are used to detect the military objects in the night time. Thermal Imager detects the heat energy radiated by the military equipments due to their thermal contrast with respect to the deployment area and displays the target-to-background contrast as a real time image in different shades and in pseudo colours. In night time, thermal IR seeking weapons are severe threat to the military equipments as well as personnel. In order to protect them, appropriate number of decoys with thermal signature simulation is used in order to enhance their survivability. Thermal signature simulation of engine exhaust is carried out precisely to divert enemy's weapons away from actual military equipments.

7.6 GENERATION OF THERMAL SIGNATURE IN A TANK DECOY

The details of thermal signature and smoke simulation in a tank decoy are given below.

7.6.1 Thermal signature simulation in a Tank decoy

The detection, recognition and identification of a vehicle using thermal imager depends on various parameters such as size, type, operating condition of the vehicle, environment condition and background. In day time, due to solar heating, thermal signature of the vehicle increases and simultaneously background thermal clutter also increases. Consequently, the thermal contrast between the vehicle and the background will be low. But, in night time, due to difference in thermal inertia, background gets cooled quickly in comparison to the vehicle, resulting in higher contrast. Therefore, vehicles are easily detected during night time.

In the initial phase of development of the decoy, temperature profile of real equipment was obtained using non-contact thermometer & hand held thermal imager (HHTI) in various operating conditions of the equipment. Based on the thermal profile, thermal signatures are produced in the decoy using electrical heating based thermal panels.

7.6.2 Surface Temperature profile measurement of real tank (1100hrs)

Temperature surface profile measurement was carried out using non-contact thermometer in day time at certain time interval. Tank engine was turned on at 1000hrs and gradually accelerated for 45minutes in stationary condition of tank. RH was noted as 30% at 1100hrs and Temperature was recorded in deg Celsius ($^{\circ}\text{C}$). Details of temperature measured on different parts of tank are given in **Table 7.1**.

Table 7.1 : Surface temperature ($^{\circ}\text{C}$) profile recorded of real tank (1100hrs)

Sl. No	Time (hrs)	Ambient Temp.	Front Mud-Guard	Front Glassis	Front Hull	Gun-barrel	Front Turret	Rear Turret	Fuel Tanks	Rear Mud-Guard	Rear Hull (Engine)	Exhaust/ Exhaust smoke
1.	1100	35	52	40	36	41	34	40	49	56	55	70
2.	1130	36	53	49	50	42	35	37	49	41	52	87
3.	1200	37	57	50	57	40	35	38	50	41	42	90

7.6.3 Surface Temperature profile measurement of real tank (1800hrs)

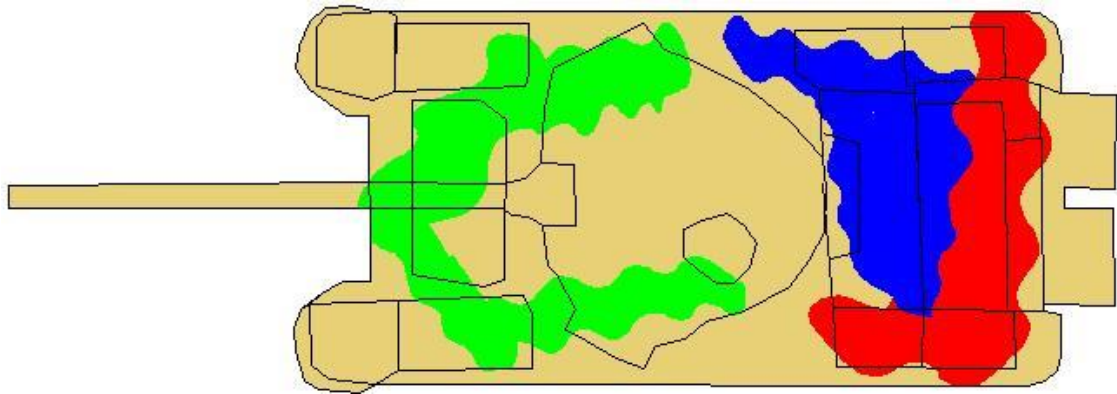
Surface temperature measurement was carried out using non-contact thermometer in day time at certain time intervals. Tank engine was turned on at 1730 hrs and had a short run for 30 minutes and parked for temperature measurement. RH was noted as 40% at 1800hrs and Temperature was recorded in deg Celsius ($^{\circ}\text{C}$). Details of temperature measurement on different parts of tank are given in **Table 7.2**.

Table 7.2 : Surface temperature ($^{\circ}\text{C}$) profile recorded of real tank(1800hrs)

Sl. No	Time (hrs)	Ambient Temperature	Front Mud-Guard	Front Glassis	Front Hull	Gun-Barrel	Front Turret	Rear Turret	Fuel Tanks	Rear Hull (Engine)	Rear Mud-Guard	Exhaust/ Exhaust smoke
1.	1800	29	33	38	37	38	35	36	40	39	36	57
2.	1900	27	34	35	35	32	35	36	41	42	38	56
3.	2000	26	30	30	29	30	33	29	40	42	38	55

7.6.4 Result and discussions on surface Temperature profile of real tank

It is observed from temperature measurement of tank surface that in different ambient conditions, tank generates different exhaust emission temperature. From Table 1 it is noted that the exhaust emission temperature has gradually increased and reached up to 90°C at ambient temperature of 37 °C. It is also observed from Table 2 that the exhaust emission temperature got gradually reduced and reached down to 55 °C at ambient temperature of 26 °C. Thermal signature of tank exhaust emission varies with ambient temperature during a day. On the basis of the surface temperature measurement of Tank a surface temperature profile was prepared to develop thermal panels for tank Mock-up.



Red colour pattern shows	Temp range 70-90 ° C
Blue colour pattern shows	Temp range 55-70 ° C
Green colour pattern shows	Temp range 40-50 ° C

Figure 7.1 : Surface Temperature Profile of real Tank

7.6.5 Development of Thermal Panels:

Design and fabrication of the thermal panels and automatic temperature controller is successfully carried out in the in-house workshop. Thermal panels of various sizes comprising heating element of FeCrAl alloy, mica sheet, asbestos sheet, MS Sheets, MS flat etc. are fabricated. Thermal panels are rugged to withstand the shock and vibration during towing of the Mock-up. Construction detail of the thermal panel is shown in **Figure 7.2**.

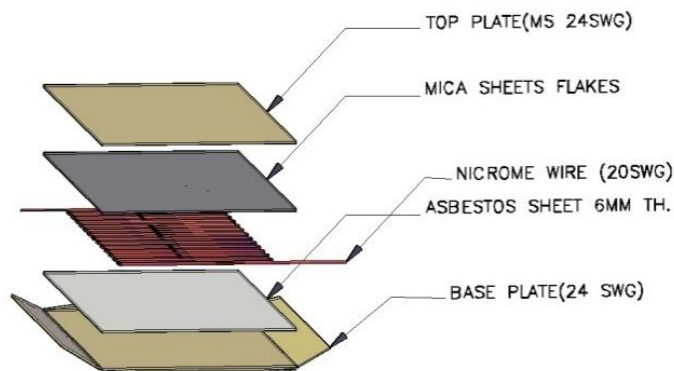


Figure 7.2 : Thermal Panel

7.6.6 Development of Automatic Temperature Controller (ATC)

ATC comprises resistance based temperature detector (PT-100), universal temperature controller, voltmeter, Ammeter and on/off switches. The Voltmeter (0- 500 V) AC and digital single phase Ammeter (0-1000A) are used for measuring each set of thermal panels current and voltage supply. A temperature controller maintains desired temperature in thermal panels as per requirement at different locations of the decoy. In actual Tank, temperature of various parts varies with operation mode and ambient conditions. Therefore, ATC is fitted in the decoy to maintain and control the desired temperature at various parts. The details of ATC are given below **Table 7.3**.

Table 7.3 : Specification of Automatic Temperature Controller (ATC)

S. No.	Nomenclature	Specification
1.	Temperature Sensor	PT 100 with following specifications. ○ Temperature range – 50°C to 500°C ○ Resistance: 80 to 170Ω ○ 3 Wire PT-100
2.	Temperature Controller	Universal Temperature Controller (Model EX9-2H-U) with ON/OFF function
3.	Measuring Instruments	Voltmeter (0- 500 V) AC Digital single phase Ammeter (0-1000A)

The ATC is shown below in **Figure 7.3 (a) & (b)**.



(a)



(b)

Figure 7.3 : Automatic Temperature controller

7.6.7 Validation trial of Automatic Temperature Controller Functioning

A field experiment was carried out at Lab premises to validate the ATC performance. Temperature was measured by non-contact Thermometer and compared with the temperature indicated by Automatic Thermal Controller (ATC). The power Supply from Generator (3KVA) was started at 10am and ambient temperature was recorded was 18°C at 10am. All temperatures measured in °C are listed below in Table 7.4.

Table 7.4 : Temperature measured by ATC and Non-contact thermometer

Sl. No	Time (hrs)		Ambient temperature	Exhaust thermal panel (66Ω)	Radiator (Engine) panel (89Ω)	Fume emitter panel (78.5Ω)	Gun-barrel panel (82.3Ω)	Remarks
1.	10:15	Measured by ATC	18	42	34	40	40	In the beginning, measured surface temperature of thermal panel by the ATC sensor indicates less temperature difference in comparison to the temperature measured with Non-contact Thermometer.
		Measured by Non-Contact Thermometer		40	33	42	38	
2	10:30	Measured by ATC	19	59	40	55	43	Measured surface temperature of exhaust thermal panel by the ATC sensor indicates marginal increase in temperature difference in comparison to the temperature measured with Non-contact Thermometer.
		Measured by Non-contact Thermometer		63	41	59	45	
3.	10:45	Measured by ATC	19	60	43	56	45	Measured surface temperature increases. However, temperature differences remain almost similar to Sr No.2 reading
		Measured by Non-contact Thermometer		63	46	60	47	

7.6.8 Result and discussions:

- It is observed that ATC was working satisfactorily during testing, getting auto cut-off when measured surface temperature reached a set value of the thermal panel.
- There was a minor temperature differences were observed in comparison with the Non-contact temperature thermometer.
- Desired value of temperature, at exhaust thermal panel, is achieved within half an hour.
- Exhaust panel resistance deliberately kept less, therefore, it is heated up faster than other thermal panels and shown maximum temperature of 63 °C .

7.7 THERMAL SIGNATURE MEASUREMENT OF REAL TANK AND MOCK-UP TANK

Thermal image was taken of real tank and tank mock-up using thermal imager. The exhaust simulation in tank Mock-up is shown in Figures 7.4 and 7.5 respectively and real tank is shown in Figures 7.6.



Figure 7.4 : Thermal IR Image of engine & exhaust of the tank decoy in 8-14 μ m waveband

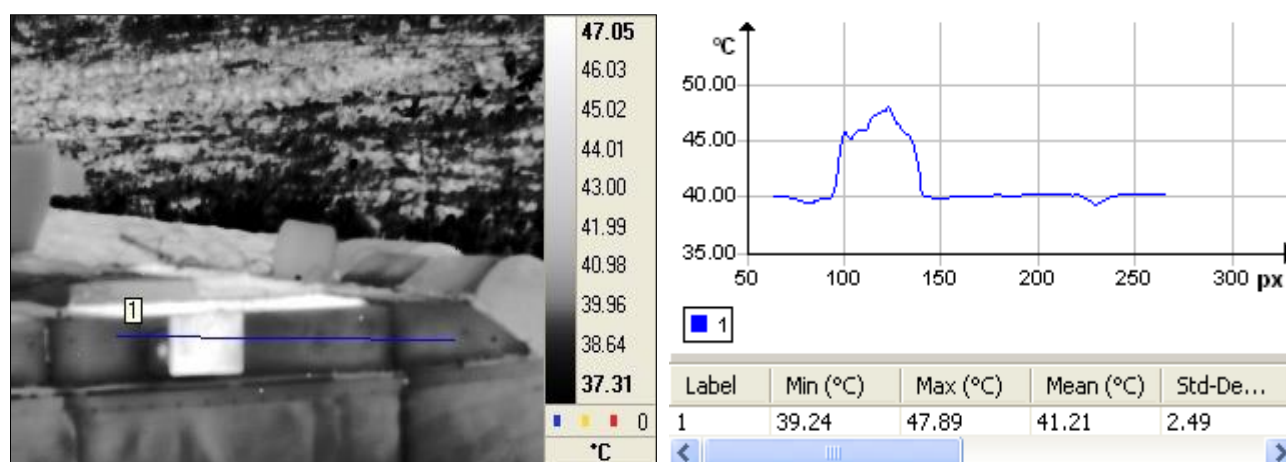


Figure 7.5 : Thermal IR Image of engine and exhaust of tank decoy in 3-5 μ m wavelength



Figure 7.6 : Thermal IR Image of the Tank decoy in 3-5 μ m wavelength

7.8 REAL TANK EXHAUST SMOKE SIGNATURE STUDY

The study of real tank exhaust emission was carried out at Army unit. It is observed that engine exhaust smoke cloud is evidently visible while starting of tank engine from ground distance of 1000m using binocular and from aerial view of 500m altitude. The smoke emission of tank in close range is shown in **Figure 7.7 (a) and (b)**.



(a)



(b)

Figure 7.7 : Exhaust smoke emission of real Tank from close range

Thermal image was recorded using Thermal imager (LORROS) and shown in **Figure 7.8**. The thermal signature of tank exhaust emission is clearly captured in thermal image.



Figure 7.8 : Thermal imagery of Exhaust smoke emission of real Tank

7.9 SIMULATION OF SMOKE SIGNATURE IN THE TANK DECOY

The exhaust smoke simulation was carried out as per the requirements given by the services. Visual smoke signature is generated in the military mock-up using a simple device. Details of development work are given below.

7.9.1 Development of smoke simulation system

The smoke is produced by a fog unit of 1200 W by burning liquid wax (paraffin) as the fuel. The fog unit requires 230V, AC power supply which is provided from the generator which is being used for smoke signature simulation. The fog unit is mounted conveniently on the chassis of Mock-up and smoke pipe outlet is connected with the exhaust pipe of tank Mock-up. Smoke signature simulation unit is placed near the exhaust of the tank. The smoke unit is operated by the remote control as per the requirements. Fog machine is shown in below **Figure 7.9**.



Figure 7.9: Fog machine for smoke generation in tank decoy

7.9.2 Visual image comparison of real tank exhaust smoke and Mock-up tank

Visual image comparison of exhaust emission (smoke) of the real tank and tank decoy is shown in **Figures 7.10 & 7.11** respectively. It is seen from the figures that smoke generated by the Fog Machine using paraffin based fuel is capable to simulate visual signature of smoke.



Figure 7.10 : Visual image of exhaust smoke of real Tank



Figure 7.11 : Visual image of exhaust smoke of Tank decoy

7.9.3 Thermal image comparison of real tank exhaust smoke and Mock-up tank

Thermal IR images of the tank decoy and the real Tank are given in **Figures 7.12 & 7.13**, respectively. The thermal signature of the smoke generated will not be similar to that of

smoke in the actual Tank, due to difference in fuel composition and exhaust gas temperature. Hence, engine based smoke generating device with same fuel is required for thermal signature simulation in night time. Analysis of diesel engine exhaust emission was required for simulating similar thermal signature of real Tank in the Tank decoy.



Figure 7.12: Invisible of exhaust smoke in thermal IR image of tank decoy



Figure 7.13: Visible of exhaust smoke in thermal IR image of real tank

The thermal image of tank decoy in **Figure 7.12** shows that exhaust smoke is not visible and exhaust black spot is clearly visible. However, it is evident from **Figure 7.13** that exhaust smoke of tank is visible and covers exhaust black part of tank. Outcomes of the analysis in the current exhaust emission investigation of diesel vehicles provide very important information in terms of exhaust gas composition and its thermal signature. This will be extremely helpful for simulating thermal signature of exhaust gas in the Tank decoy as well as other diesel engine based military vehicle mock-ups.

7.10 FIELD EVALUATION TRIAL OF THE TANK MOCK-UP:

Mock-up of tank has undergone field evaluation trials as per SOP: conduct of user trials, enclosed as **Appendix "C"**. User trials of the Mock-up were rigorously conducted in association with nominated trial unit as per trial directive issued by Army as under: -

- (i) Phase-1, Winter trial
- (ii) Phase -2, Summer Trial
- (iii) Phase-3, Confirmatory User trial

Mock-up was extensively evaluated for its functionality requirements during User trials. Comparison of Mock-up spectral signatures with original tank was carried out in visual, NIR and thermal (IR) regions using ground equipment such as binocular, LORROS, RADAR and Aerial Recce at different timings during day & night.

7.11 OUTCOME OF THE USER TRIALS:

Mock-up was recommended for induction into services after conducting extensive user trials by the Army as per user trial directives. Production Agency (PA) has been identified, it will be mass-produced as per service requirements. Developed tank decoys met all the user requirements, however, it was observed that smoke simulation during night time is an essential requirement in decoy to be included to deceive the enemy thermal sensor during night time. The results obtained in the previous chapters provide guidance to make modifications to the existing design. This will be carried out in future.

7.12 IMPORTANCE OF R&D WORK:

The R&D work carried out is immensely useful in various types of defence applications.

- (i) Deployment of rapidly deployable thermal signature simulated military vehicles Mock-ups (deception devices)
- (ii) The development of this technology will enhance deception capabilities (stationary or mobile) in battlefield.
- (iii) The deception device tactics using new misleading strategies will reduce the probability of detection and provide protection to soldiers, military vehicles and equipment during combat operation. Consequently, it increases survivability of the original equipment.
- (iv) The deception devices will also useful as a training aid to soldiers for identification purpose in the battlefield.
- (v) In addition, it can be used as a test device for IR signature measuring equipment and IR based firing systems.

7.13 CONCLUSIONS

Deception needs to be incorporated as an integral part of peacetime and wartime operations under national deception policy. Deception should be intentional, meaningful and well planned to target enemy's decision-making system. In present time, battlefield transparency has increased manifold during day as well as night time. Advanced sensors & surveillance equipment, capable of operating round the clock, under adverse weather conditions created serious threat to survival of troops & weapons. It has been experimented and proved that effective deployment of military decoys will certainly enhance the survivability of the personnel, installations and equipment against enemy's attack. Developments of advanced military decoys require holistic R&D efforts in order to meet futuristic requirements of armed forces. It is expected that the thermal signature analysis of diesel exhaust emission of diesel vehicles that has been carried out in the current investigation will help to redesign military decoys.