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Design Qualification of an External Store for a Fighter Aircraft

V.B. Goley, B. Dakshina Murthy, K. Sadananda Upadhya, and N. Guhaprasad
Defence Avionics Research Establishment, Bangalore–560 075

ABSTRACT

Defence Avionics Research Establishment (DARE) has designed and developed an external store for fitment on a fighter aircraft. The external store has the poded structure and can be used for installation of a variety of payloads up to 250 kg. The mechanical details of the electronics to be fitted inside the pod can be worked out as per application. The pod has been designed keeping this in mind and based on the functional, mechanical, structural, and aerodynamic requirements. The designed and fabricated pod has undergone various qualification tests. The paper brings out the details of the pod design, and the various structural and environmental qualification tests carried out. The pod thus designed and qualified has been validated through carriage trials by fitting the pod on the platform intended for it. The pod is likely to be inducted into the Services shortly.

Keywords: External store, qualification tests, radome, fighter aircraft, pod, design and fabrication

1. INTRODUCTION

Defence Avionics Research Establishment (DARE), Bangalore, has been involved in the development of avionics and electronic warfare (EW) systems to meet the needs of the Services. Of the substantial number of EW systems already developed, and being developed by the DARE, the high accuracy direction finding (HADF) system is one of the major developments. The HADF system consists of a pod controller unit and a 3-element antenna array system.

Recently, DARE, has designed and developed an external store with a poded structure. The designed pod is generic in nature and a payload of about 250 kg can be installed inside the pod. As an immediate application of the designed pod, the HADF system is to be installed inside the pod. The pod is intended to be fitted on a fighter aircraft,by means of pod pylon. For fitment of the pod on the aircraft, it had to be structurally and environmentally qualified and certified by the CEMILAC, Bangalore. The details of the pod design have been brought out, and the structural and environmental qualification details are also explained. A brief on the carriage trials carried out on the pod has also been provided.

2. POD DESIGN

The pod is designed based on the following major requirements:

- Aerodynamic requirements
- Weight and centre of gravity (cg) balance for the aircraft
- Mechanical and electrical interface requirements

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- System functional requirements
- Electrical performance and structural integrity requirements.

The pod is modular with different modules assembled together with coupling rings and screws. It has the following five major structural modules:

- Front radome (sandwich) module
- Antenna-mounting bracket module
- Front module
- Rear module
- Tail cone module

Each of the above modules has different parts and assemblies. An exploded view of the pod is given in Fig.1.

2.1 Description of the Modules

The materials used for the pod are glass fibre-reinforced plastic (GFRP) sandwich foam core for the radome, steel for bulkhead, front lug, rear lug, front hook, and rear hook, forged aluminium alloy for the rings, and aluminium alloy for all the other parts and assemblies of the pod.

2.1.2 *Front Radome (Sandwich) Module*

The front radome module consists of one hemispherical radome and a metallic ring, which is moulded onto the cylindrical portion of the radome. The radome is of sandwich construction, which is sandwiched between thin layers of glassfibre-reinforced plastic (GFRP).

2.1.2 *Antenna-mounting Bracket Module*

The antenna-mounting bracket module houses the antennae and is fastened to the front radome (sandwich) module.

2.1.3 *Front Module*

The front module consists of one female ring, ring1, front and rear bulkheads, longerons and stiffeners, left hand (LH) and right hand (RH) skin assemblies, hatch door assemblies, longeron plate, and connector

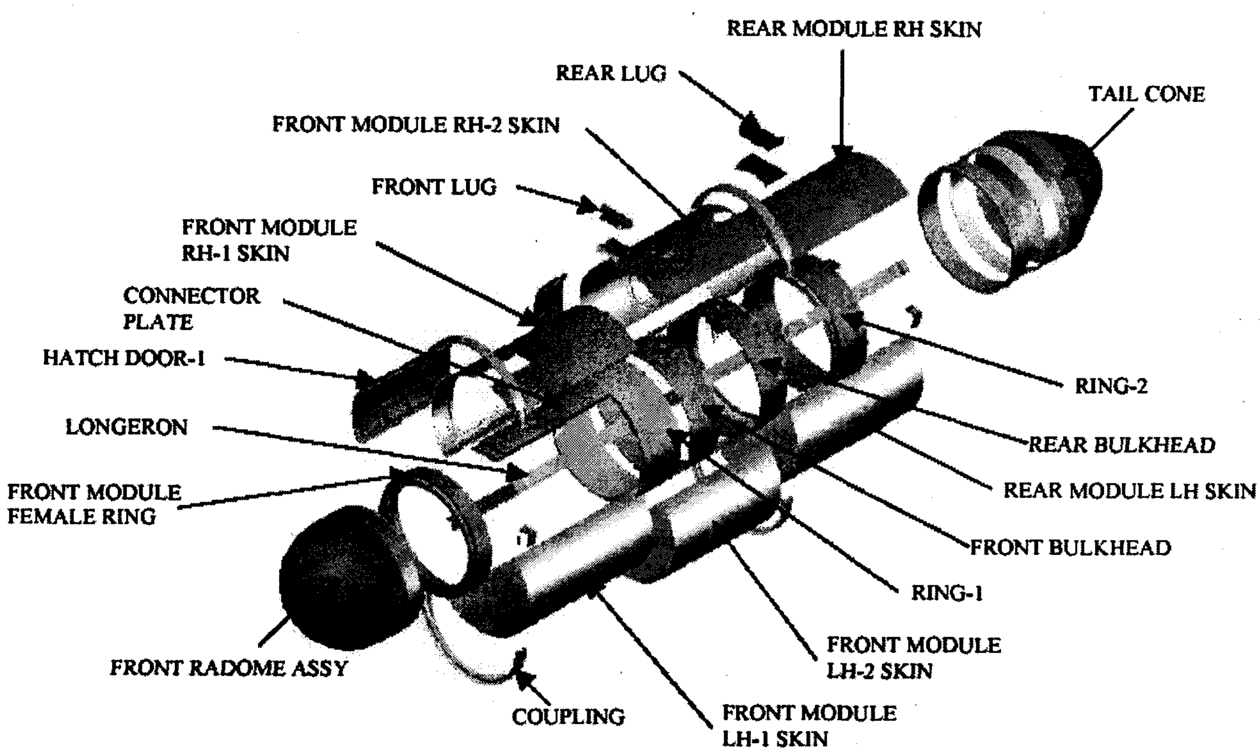

Figure 1. An exploded view of the pod

plate. The front module female ring has grooves suitable for clamping the front module to the antenna-mounting bracket module with couplings. The front module female ring and ring-1 are connected through four longerons and stiffeners, which are riveted to both the rings. The ring-1, in turn, is connected to the front bulkhead through longeron plates, which are riveted to both ring-1 and front bulkhead. Four longerons and stiffeners are riveted to the front and rear bulkheads.

The bulkheads are the main load carrying members and house the suspension hooks. The rear bulkhead has grooves suitable for clamping the front module to the rear module with couplings. The front module skin LH and RH assemblies have suitable cutouts for hatch doors, connectors and suspension hook, and are wrapped over the rings, and bulkheads and riveted. Hatch door assembly[1] and hatch door assembly[2] provide access to the electronics. The connector plate with suitable cutouts for electrical connectors is riveted to the front module female ring and ring-1. One tray is used for mounting the controller LRU unit inside the pod. The controllers LRU unit is fixed to the tray-mounting brackets which are fixed to the front module female ring and ring-1[1].

2.1.4 *Rear Module*

The rear module consists of ring-2 and ring-3, LH and RH skin assemblies, longerons and stiffeners, and mounting segments. Ring-2 has grooves suitable for clamping the rear module to the front module with couplings. The ring-2 and ring-3 are connected by means of four longerons and stiffeners, which are riveted to the rings. The rear module skin RH and LH are wrapped over the rings and are riveted. Four mounting segments are riveted to ring-3 and are used for fixing the balancing weight. The balancing weight assembly consists of a ring and a balancing weight. The ring is fixed to the mounting segments. The balancing weight is fixed to the studs on the ring and clamped. Ring-3 has anchor nuts riveted on the inner diameter, which are used to fasten the tail cone module to the rear module.

2.1.5 *Tail Cone Module*

The tail cone module consists of a tail cone ring, a tail cone-end ring, stiffeners, and half skins. The tail cone module is connected to the rear module with screws. The tail cone ring and the tail cone-end ring are riveted to four stiffeners and two half skins.

2.3 Mounting Scheme for the Pod

The rocket pod mounting arrangement is adopted for mounting the pod to the pylon. Two suspension hooks are placed 250 mm apart and are used to attach the pod to the pylon. The hooks are housed in the front and rear bulkheads. The pod centre of gravity lies at the centre between the two suspension hooks. The front and rear lugs fixed to ring-1 and ring-2 on the pod match with the respective mating parts on the pylon, which help in repeatability for the assembly of the pod with the pylon. The front lug takes care of the normal and axial loads experienced by the pod. The rear lug takes care of only side loads that would be experienced by the pod. Adequate ground and side clearances are made available for the pod so that no interference problem with the ground is faced during takeoff and landing.

3. DEVELOPMENT OF THE POD

Design reviews were held at various stages of development of the pod like the conceptual stage, intermediate stage, and the critical stage for finalising the pod design. The structural analysis of the entire pod was carried out by classical analysis method as well as using finile element method. By doing all these exercises, the pod design was found adequate, and hence, it was fabricated. The pod thus developed is shown in Fig. 2.

4. QUALIFICATION OF THE POD

The qualification of the pod included the qualification of the following:

- Structural qualification tests of the pod
- Structural qualification of the radome

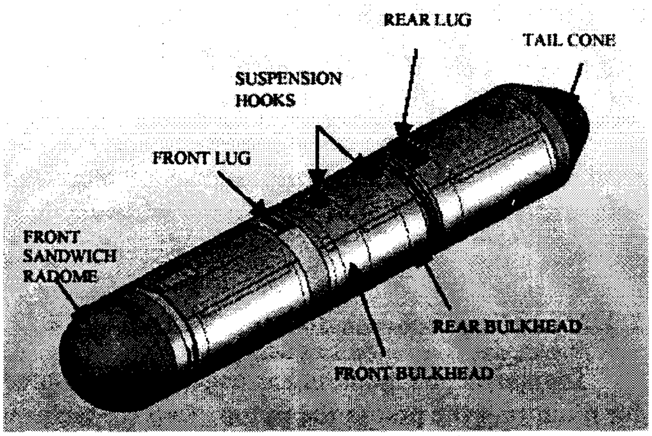

Figure 2. HADF pod

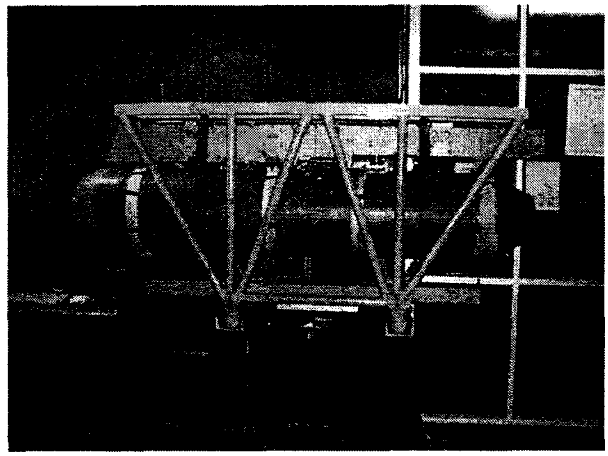

Figure 3. Vibration test setup for the pod

- Environmental qualification of the radome
- Other tests

4.1 Structural Qualification Tests of the Pod

Under the structural qualification tests, the static strength test and the vibration test were carried out.

4.1.1 *Static Strength Test*

The static strength test was carried out to validate the design for proof load, and ultimate load conditions. Proof load was 120 per cent of the limit load, which is the maximum load that the aircraft would experience in a normal operation. The ultimate load is 150 per cent of the limit load. In practice, the aircraft structures are designed for such ultimate load conditions.

The pod along with the pylon was mounted on the test fixture, which, in turn, was mounted on the shaker as shown in Fig. 3. Two accelerometers were fixed at the fore and aft locations of the pod. Before starting the structural tests, the pod was subjected to impulse response measurement test. The first two natural frequencies were then obtained through impact hammering.

For measuring the strains during the static test at the critical locations of the pod, the strain gauges were fixed (Fig. 4).

The critical locations were the ones, wherein the pod was expected to experience maximum inertial and aerodynamic loads. The critical locations and the actual loads to be applied on the pod during the static test were obtained by the structural analysis of the pod[2]. The pod was then mounted on the static test tree as shown in Fig. 5.

The load was applied along the vertical, lateral, axial direction, and simultaneously on both vertical and lateral directions. Initially, loads were applied up to 100 per cent of the limit load in steps of 10 per cent of the limit load. Then, the pod was loaded up to the proof load conditions, ie, up to 120 per cent of the limit load in steps of 5 per cent, and then up to the ultimate load, ie, up to 150 per cent of the limit load in similar steps. Then, it was unloaded in similar steps.

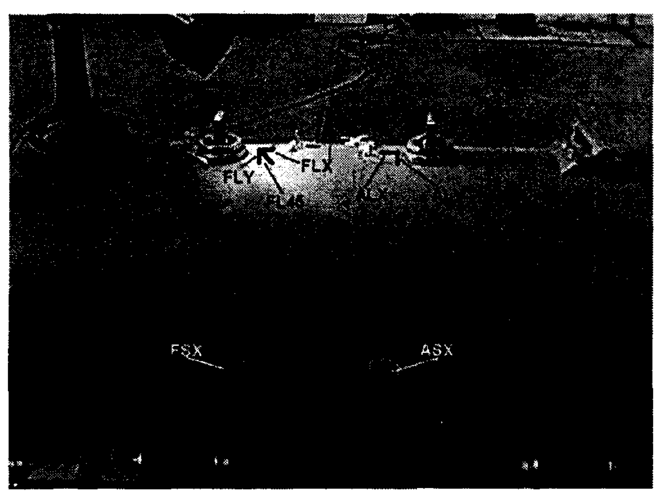

Figure 4. Strain gauge locations of the pod for the static test

Figure 5. Pod on the static test tree

At each step, the strains observed at the strain gauge locations were noted. The maximum observed strain was found to be well within the acceptable limits, which were obtained by design calculations. After the test, the impulse response measurements were once again obtained and found to be coinciding with the natural frequencies obtained prior to the test.

4.1.2 *Random Vibration Test*

The random vibration test for the pod was carried out to qualify the pod for vibration levels that would be experienced by the pod in operational flight and service environment, and to check for any structural failure, wear or looseness in the pod structure due to vibration. The vibration test specifications were obtained from the military standard[3] MIL STD 810F. The vibration test setup has been shown in Fig. 3. Accelerometers were fixed at the fore and aft sections of the pod. The test was conducted for 1 h. The total G rms to be observed at the fore location was 7.80 g and at the aft location, it was 9.72 g as per the MIL STD 810F. Taking the time history of the data for 2 s in the frequency range 0 Hz to 2000 Hz, the maintained G rms at the fore and aft locations were found to be 7.22 g and 10.20 g respectively.

The response of the test was measured in terms of graphs of auto spectrum, both at the start and at the end of the test and the transfer function magnitudes. It was seen that the auto spectrum, which gives the vibration signature at the accelerometer location in the beginning and at the end of the test, coincides. The transfer function magnitude graphs were obtained by keeping the signal at the fore location as input and taking the signal at the aft location as output. These graphs were obtained both at the start and at the end of the test. The transfer function magnitudes remained the same at the start and at the end of the test.

After the test, the pod was inspected for any failure, wear or looseness. As no noticeable failure, wear or looseness were observed after the test, the test was deemed successful. After the random vibration test, the pod's natural frequencies were once again obtained and found to be satisfactory.

4.1.3 *Gunfire Vibration*

The level of gunfire vibration experienced by any equipment on the aircraft depends on the vector distance of the located equipment from the gun muzzle. The vector distance of the pod cg from the gun muzzle was calculated and found to be more than 3.5 m. From MIL STD 810F, it was seen that for vector distance more than 3.5 m, the reduction in vibration level was nearly 99.9 per cent. That means, the gunfire vibration level at the pod location will be less than or equal to the flight vibration level. Taking the clause from the military standard that "when the item will be installed in a location, where the gunfire vibration is less than the normal flight vibration, no gunfire testing is recommended".

Therefore, no gunfire vibration test was required to be carried out for the pod as it was away from the gunfire vibration region of the aircraft gun.

4.2 Structural Qualification of the Radome

Though the radome along with the pod had undergone structural tests, the certification authority had insisted that the radome, which is the nose of the pod and houses the antennae, has to undergo pressure test. The actual pressure acting on the radome was worked out based on the expected

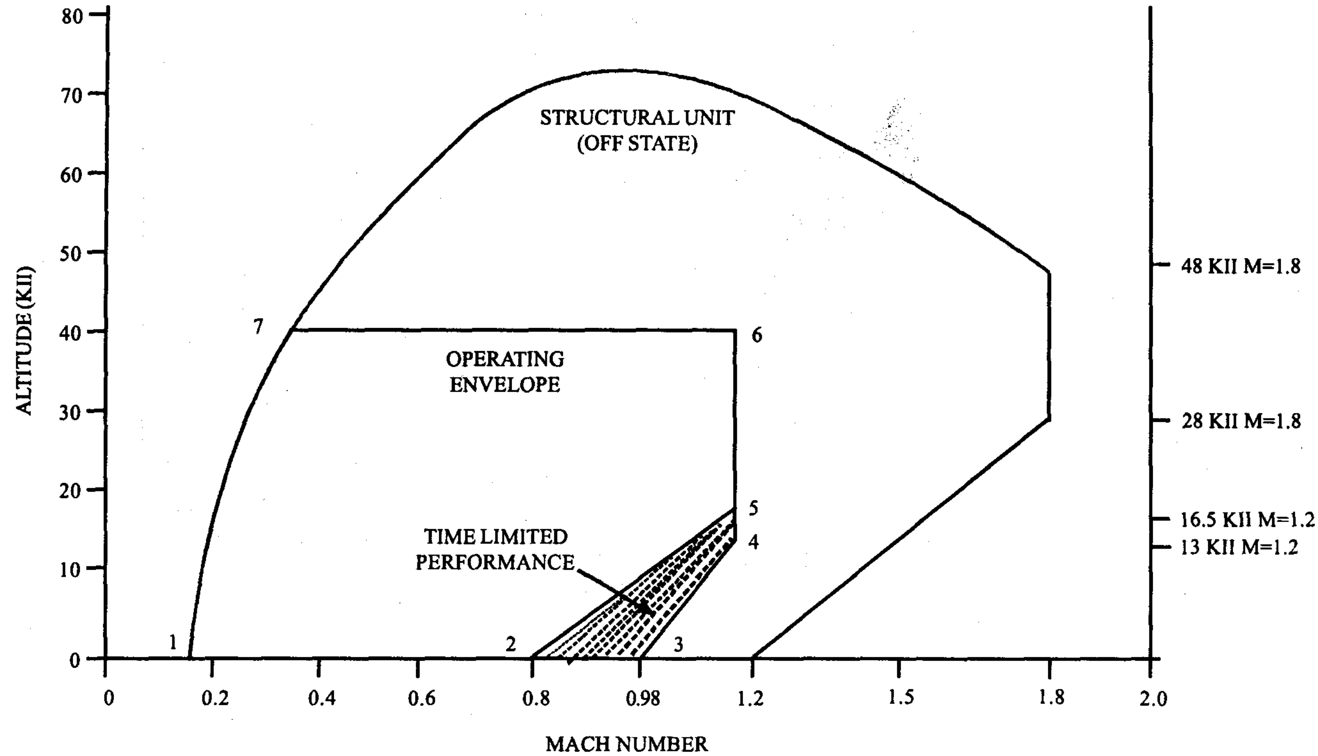

Figure 6. Pod's operational flight envelope for obtaining the expected pressure action on the radome

pressure that would be experienced by the radome during the operational flight.

The operational flight envelope considered for obtaining the expected pressure acting on the radome is provided in Fig. 6. The maximum pressure acting on the radome was worked out to be 2.5 kg/cm^2. The temperature at the location of radome was not expected to exceed 70 °C. However, a conservative value of 90 °C was considered for the test. Therefore, pressure tests at room temperature and high temperature (ie at 90 °C) with a pressure of 2.5 kg/cm^2 were outlined. The electrical measurements of the radome such as transmission loss, reflection loss, and change in phase difference, were obtained before the pressure tests. These measurements were found to be satisfactory with the electrical specifications outlined during the radome design. After the electrical measurements, the radome was subjected to an x-ray radiography test for the appearance of any structural defects such as delamination and porosity.

The radome pressure testing was done at (i) room temperature and (ii) high temperature, ie, at 90 °C. The two strain gauges, one on the side and the other on the top of the radome were fixed (Fig. 7). The radome with the pressure cap in the high temperature test chamber is shown in Fig. 8. Firstly, the test was conducted at the room temperature. A pressure of 2.5 kg/cm^2 was applied in steps of 0.25 kg/cm^2, and it was decreased in similar steps. The observed strains at the strain gauge locations in both X and Y-directions were noted. The radome

Figure 7. Strain gauge locations on the radome

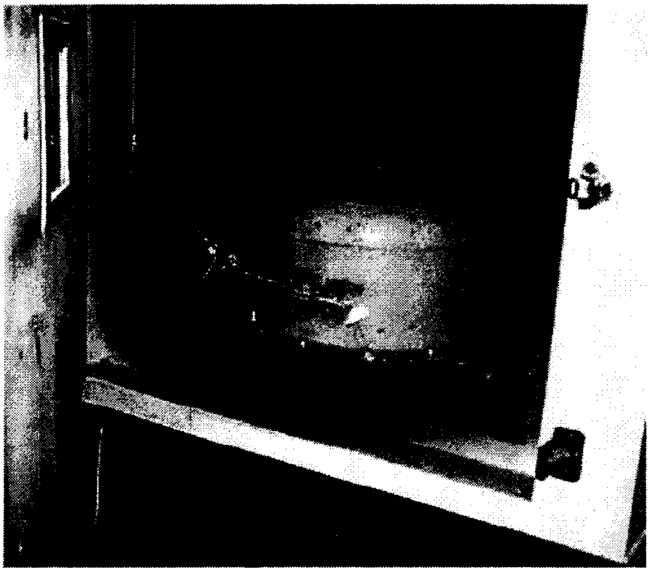

Figure 8. Radome with the pressure cap in the high temperature test chamber.

was then placed inside the chamber and the temperature was increased slowly with no pressure being applied and finally, the temperature was maintained at 90 °C. Once the temperature was 90 °C, the pressure was applied as earlier. The strain gauge readings were noted. The strains observed were within the acceptable limits obtained by the radome structural analysis. Further, the residual set of strains was observed to be zero.

At the end of each test, the radome was inspected for any physical damage and no physical damage or deterioration was observed. The radome was then subjected to an x-ray radiography test to detect any defect such as delamination and porosity that might have been developed after the pressure test. The radiography test did not reveal any such development and the test was found successful. Further, the post-pressure test electrical measurements were in agreement with the measurements taken before the pressure test.

4.3 Environmental Qualification of the Radome

The radome was subjected to certain environmental tests as outlined in the qualification test plan for the radome[4]. As the radome had undergone both the static strength test and the random vibration test along with the pod, the tests, namely the random vibration test, acceleration test, and the mechanical shock test, were not outlined for the radome qualification. Thus, the environmental tests for the radome included high temperature test, thermal shock test, combined altitude, humidity, and temperature test, humidity test, transit drop test, bench handling test, blowing rain test, and sand and dust test. A radome sample material was subjected to fluid contamination test, salt fog test, solar radiation test, and fungus test. For all these tests, the test specifications and the test procedures were derived from the MIL STD 810F. In cases, where the test facilities as per the MIL STD 810F were not available in India, the tests were conducted[5] as outlined in Joint Service Specifications (JSS) No. JSS 55555. For such changes, approval of the certifying authority was obtained. The radome was painted with the CEMILAC-qualified radome paint RDM1, which was developed by the Defence Laboratory (DL), Jodhpur.

Before commencing the environmental tests, radome electrical measurements such as transmission loss, reflection loss, and change in phase difference, were taken. Further, before and after each of the high temperature test, thermal shock test, combined altitude, humidity and temperature test, and the humidity test, the reflection loss measurements of the radome, were also taken. After completion of the environmental tests, the radome's electrical measurements were once again obtained. The variation in the electrical measurements observed was negligible, and thus, the radome was environmentally qualified. A brief regarding the sequence of tests conducted as per the MIL STD 810F is given below.

4.3.1 *High Temperature Test*

This test was required to evaluate the effects of high temperature conditions on radome material safety, integrity, and performance. The test temperature was kept at 90 °C for one cycle of 8 h duration. After the test, the radome was visually examined and no physical damage or deterioration was observed. The reflection loss measurements with and without radome were taken and were also found to be satisfactory.

4.3.2 *Thermal Shock Test*

The aim was to determine whether the radome material could withstand sudden changes in temperature of the surrounding atmosphere without experiencing physical damage or deterioration in performance. The test was conducted in two chambers, ie, one cold chamber which was maintained at –54 °C and the other chamber at 90 °C. Once the temperature was stabilised in the chambers, the radome was kept for 1 h. The transfer time of the radome from one chamber to the other was less than 5 min. The test was carried out for three cycles. After the test, the radome was inspected for any physical damage or deterioration and was found to have no such damages. The reflection loss measurements with and without radome were found to be satisfactory.

4.3.3 *Combined Altitude, Temperature & Humidity Test*

The objective was to determine whether the radome material could withstand the combined effects of temperature, altitude and humidity. The test was conducted for 10 cycles with the test profile given in Table 1. At the end of the test, the radome was physically examined and found to be satisfactory. The reflection loss measurements were also found to be satisfactory. Hence, the test was deemed successful.

4.3.4 *Humidity Test*

The aim was to determine the resistance of the radome material to the effects of a warm, humid atmosphere. The test duration for one cycle 24 h and it was conducted for 10 cycles. The test profile considered is given in Fig. 9.

Table 1. Test profile for combined altitude, temperature, and humidity test

Time (min)	Temperature (° C)	Altitude (km)	RH (%)
0-30	– 54	-	-
30-60	– 54	20	-
60-90	– 40	-	-
90-150	40	-	75
150-180	90	-	-
180-210	90	-	-
210-240	55	20	-

After completion of the test, the radome revealed no physical damage or deterioration. The reflection loss measurements were also found to be satisfactory.

4.3.5 *Transit Drop Test*

The objectives was to determine whether the material is capable of withstanding the shocks normally induced by loading and unloading when it is

(a) Outside of its transit or combination case, eg, during routine maintenance, when being removed from a rack, being placed in its transit case, and

(b) Inside its transit or combination case.

The test was conducted with the radome being kept in the transit box designed for the radome. From all the corners of the box, the box was dropped from a height of 1.22 m amounting to a total of 26 drops. After the drops, the radome was removed from the box and examined for any physical damage or deterioration. No such damages were observed.

4.3.6 *Bench Handling Test*

The objective was to provide a degree of confidence that the material can physically and functionally withstand the relatively infrequent, non-repetitive shocks encountered in bench handling, bench maintenance, or packaging. The test was conducted on a wooden bench of 4 cm thickness. The radome was dropped freely four times at each face of the radome from about 10 cm height. The physical

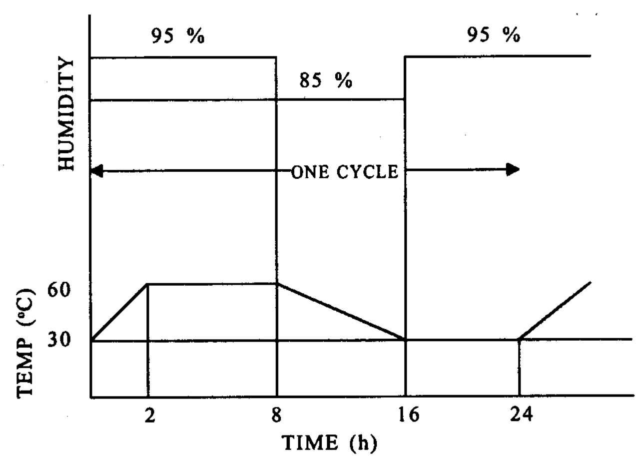

Figure 9. Humidity test cycle profile

examination of the radome after the test revealed no damage to the radome.

4.3.7 *Blowing Rain Test*

The aim was to determine the capability of the radome material to satisfy its performance requirements during and after exposure to rain water and the extent of physical deterioration of the material caused by the rain, if any. The radome was kept at the centre of the rain chamber so that the rain water falls on the radome from all the corners of the chamber. The nozzle pressure of the water-spraying pipe was kept at 200 kPa. The test was conducted for 30 min. After the test, the radome was inspected and found to have no damage or deterioration.

4.3.8 *Sand & Dust Test*

The purpose was to evaluate whether the material can be stored or operated under blowing sand/dust conditions without degrading its performance, effectiveness, and maintainability due to abrasion (erosion) or clogging effects of large, sharp-edged particles. The external surface of the radome was exposed to blowing sand/dust in the velocity range 4m/s to 5m/s in the sand/dust chamber for 90 min. The chamber temperature was maintained at 40 °C. After the test duration, the chamber was turned off and the radome allowed to attain the ambient temperature. The collected dust on the radome was cleaned and and radome was found to have no damage or deterioration.

4.3.9 *Fluid Contamination Test*

This test on the radome sample was conducted to determine whether it is unacceptably affected by temporary exposure to contaminating fluids (liquids) such as may be encountered during its life cycle, occasionally, intermittently or over extended periods. A sample radome material was kept immersed for 4 h in the generally used four different kinds of aircraft fuels such as kerosene oil, lubricant oil, hydraulic fluid, and soap solution. After the test, the radome sample was inspected and found that it was not softened or permanently damaged.

4.3.10 *Salt Fog Test*

The objective was to determine the effect of salt deposits on the physical aspects of the radome material. The salt solution used was *NaCl* containing not more than 0.1 per cent sodium iodide, and not more than 0.5 per cent total impurities. The radome sample material was kept in the salt chamber with continuous salt spray for 24 h and then it was dried for 24 h. The cycle was repeated once again. It was found the radome sample removed from the chamber was not corroded, deteriorated, or physically damaged.

4.3.11 *Solar Radiation Test*

The objective was to determine the heating effect of direct solar radiation on the radome material. The test was conducted as per JSS 55555. The chamber had the capacity of simulating the solar radiation of an irradiance of 1.20 ± 0.10 kW/m^2. The test duration was 24 h with temperature varying from 30 °C to 55 °C. After the test, the radome sample was visually checked and found to have not deteriorated or physically damaged.

4.3.12 *Fungus Test*

The purpose of conducting this test on the radome sample was to assess the extent to which the radome material will support fungal growth and how any fungal growth may affect the performance or use of the material. The test sample was incubated at constant temperature of 30 °C ± 1°C and a relative humidity of > 90 per cent but below 100 per cent for the test duration of 28 days. At the end of the incubation period, the radome sample was inspected immediately. No fungal growth was found on the test sample and physical characteristics of the radome material were also not deteriorated.

5. OTHER TESTS CONDUCTED

The following are some of the other tests conducted:

- The suspension hook was subjected to its ultimate tensile strength test. The test result was found satisfactory.

- The pod was subjected to the leak test with the compressed air jet being forced at 5 kg/cm^2 along with water jet. Water seepage was noticed inside the pod through the fasteners used for lug mountings, suspension hooks, and tail cone-fixing screws. To overcome this, drain holes were provided at the bottom surface of the pod.
- The rubber gasket used in the hatch door assembly was subjected to high temperature, low temperature, and fluid contamination tests. The test results were found satisfactory.

6. CARRIAGE TRIALS

The pod thus designed, fabricated, and qualified underwent carriage trials with the pod being fitted on the station number designated for it on the fighter aircraft intended for this purpose. Two sorties of 90 min were carried out at the Air Force Station. The carriage trials were found satisfactory. In addition, lot of design-related data were collected during the sorties and the results were found to be validating the design.

7. CONCLUSIONS

Given the time frame, requirements, and with the available resources, DARE, Bangalore, has thus designed and fabricated an external store having poded structure for fitment on a fighter aircraft. The designed pod is generic in nature and is capable of taking a payload of up to 25 kg. Currently, the pod is being used for housing the electronics of a high frequency direction finding (HADF) system. The pod along with its constituent parts has been structurally and environmentally qualified and found satisfactory. Further, the design has been validated by conducting carriage trials of the pod. The pod is likely to be inducted into the Services shortly.

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REFERENCES

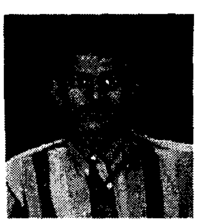
1. Qualification test plan for HADF structural pod. MED, Defence Avionics Research Establishment (DARE), Bangalore, 2004. Report No. DARE/MED/REPORT/17/04.
2. Document for structural design for HADF pod. MED, DARE Bangalore, 2005. Report No. DARE/MED/REPORT/18a/04.
3. Test method standard for environmental engineering considerations and laboratory tests. Department of Defence, USA, 2000. MIL STD 810F.
4. Qualification test plan for HADF radome. MED, DARE, Bangalore, 2004. Report No. DARE/MED/REPORT/25/04.
5. Environmental test methods for electronic and electrical equipment. Directorate of Standardization, Ministry of Defence, New Delhi, 2000. JSS 55555.

Contributors

Air Cmde V.B. Goley obtained his BE (Electronics) from the Regional Engineering College (RCE), Bhopal, in 1975 and MTech (L&EO) from the University of Pune in 1991. He was commissioned at the Aeronautical Engineering (Electronics) branch of the Indian Air Force in January 1976. He has 20 years experience of working on aircraft and missile systems of Russian and western origin, and electronics warfare systems. He joined DRDO in 1996 at the Advanced Systems Integration & Evaluation Organisation (ASIEO) [now Defence Avionics Research Establishment (DARE)] and permanently seconded in 1998. Since then, he has been working on development, integration, evaluation, and induction of EW systems of DARE as Project Manager and Project Director. Currently, he is working as Group Director (ESM).

Mr B. Dakshina Murthy holds AMIE (I)-Mechanical from the Institute of Engineers (Kolkata) in 1987. He joined DRDO at the Combat Vehicle Research & Development Establishment (CVRDE), Chennai, in 1974, and later, he joined Aeronautical Development Establishment (ADE), Bangalore in 1980. Since 1990, he has been working as Scientist at the DARE, Bangalore. He is a member of the Aeronautical Society of India (ASI), Bangalore.

Mr K. Sadananda Upadhya received his MSc (Statistics) from the Bangalore University in 1993 and MPhil (Statistics) from the University of Pune in 1995. He joined as Scientist at the Centre for Aeronautical Systems Studies Analyses, Bangalore (Now merged with ISSA, Delhi) in 1998 and was subsequently transferred to DARE, Bangalore, in 2003. He has many publications in national and international journals to his credit. He is a life member of the System Society of India, ISRO, VSSC, Thiruvananthapuram, Aeronautical Society of India, Bangalore, and Society for Aerospace Quality and Reliability, DRDL, Hyderabad. His research interests are: Statistical inference, modelling and simulation, and reliability engineering for defence.



Mr N. Guhaprasad obtained his BE (Mech Engg) from the Mysore University and postgraduation in Tool Engineering from the GT&TC, Mysore. He joined DRDO in 1991 at the ADE, Bangalore, and currently, he is working at DARE, Bangalore.