CORROSION CONTROL AND PRESERVATION THROUGH DEHUMIDIFICATIION AND FLEXIBLE BARRIER STORAGE SYSTEM WRT AIRCRAFTS

Abstract

Corrosion control is essential for ensuring high MTBF and battle worthiness of defence hardware at all times. The major cause of both inorganic and organic corrosion in high humidity.

Defence hardware, software, ammunition, clothing and rations are high-value items and must be in battle-worthy condition at all times. This means that the 'mean time between failures' (MTBF) must be high, as otherwise it impairs the availability of equipment at short notice. The situation is often further aggravated by non-availability of requisite manpower to undertake preventive maintenance at regular intervals for the purpose. Also the future trend of training on simulators means that most equipment will lie idle until the time of need with no or minimal maintenance.

The main cause of equipment deterioration is corrosion caused by humid air, salts, pollutants, sand, dust, etc. as also the effect of ultraviolet light, insects and micro-organisms.

Humidity plays a major part in the corrosion process. All air contains some degree of moisture and, due to wide fluctuations between day and night temperatures, this moisture condenses as dew on the equipment and hastens corrosion of metals and electrical contacts, reducing electrical resistance of insulators and wire harness, spoiling surface finishes, etc.

This paper describes a novel approach to corrosion control and preservation by maintaining a desired RH level (25-40%) through a dehumidification systems in a space enclosed by a flexible barrier with special reference to Airforce related application. A light durable barrier with low MVTR and resistance to elements of nature, made of a specially developed polymer

material is used. The RH value is maintained and regulated by a well proven physical absorption based dynamic dehumidification system, available in a wide range of ratings and capacities. The system and different application options are described.

Introduction

Defence hardware, software, ammunition, clothing and rations are high-value items and must be a battle-worthy condition at all times. This means that the ‘mean time between failures’ (MTBF) must be high, as otherwise it impairs the availability of equipment at short notice. The situation is often further aggravated by non-availability of requisite manpower to undertake preventive maintenance at regular intervals for the purpose. Also the future trend of training on simulators means that most equipment will lie idle until the time of need with no or minimal maintenance.

The main cause of equipment deterioration is corrosion caused by humid air, salts, pollutants, sand, dust, etc, as also the effect of ultraviolet light, insects and micro-organisms.

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In the past, when the equipment was less complicated and movement was not at short and frequent intervals, one could afford to follow conventional techniques, i.e. preservation coatings such as greasing, oil spray, etc. In the present day scenario, this will not prove effective due to requirement of very short response time. Thus, perforce, one has to think of a better approach, viz preservation and storage in a controlled humidity environment, yet in readiness to return to service at short notice.

Such a system has to be based on the scientifically proven fact that corrosion can be effectively prevented by protecting the equipment through suitable barriers coupled with the use of a dehumidifier. Such system has the advantage of maintaining the equipment in a high state of readiness without the need of daily maintenance, which would otherwise be the case.

Problems of Airforce in Air and on Ground

In Air

Reliability and availability of an aircraft while ‘in storage’ or ‘standby’ is greatly dependent on the environment within and outside the aircraft.

Today’s fixed and rotary wing aircrafts are of advanced construction incorporating sophisticated hi-technology components all of which have to be protected during storage periods and event when they are fitted in to the aircraft.

On Ground

Surface to Air Missiles require a response time quicker than the speed of an attacking aircraft. These missiles are located often in places exposed to elements of nature. In due course of time uncontrolled humidity takes its toll on electronic system, fuel area and the warhead bay. The command to activate the weapon gets thwarted by the damage caused by humidity.

Radar systems are usually located on high and remote locations exposed to severe and hostile weather conditions. Rapidly changing temperatures lead to condensation on the radar surface and hence the performance of the Radar is affected.

A vast number of spares and replacements are needed by Airforce. The storage of these parts, to keep them free from corrosion and mould growth is a constant problem. The results are high running costs and loss of valuable equipments. Some of these typical problems arise in storage of batteries, tyres, uniforms, parachutes, films/microfilms/propellant and rocket fuel.

Other affected areas due to uncontrolled levels of humidity are computer rooms, communication network, antennas, waveguides and electronic instrumentation.

This leads to less and less meantime between failures resulting in high maintenance manpower

and replacement costs.

Similarly in assembly of jet engines, avoinics and electronics assemblies components which have to be incorporated must be kept in dry environment until the assembly is completed.

Oxidizer and binders in solid rocket propellants can be adversely affected if processed within uncontrolled moisture levels.

Moisture is the hidden enemy leading to corrosion, spoilage and breakdowns during storage, production and operations.

Importance of Humidity Control

High humidity causes both inorganic and organic corrosion. Inorganic corrosion in the present context mainly pertains to rust formation, which is essentially an electro-chemical phenomenon. Such corrosion mainly affects metallic hardware such as those listed in Annexure-I.

Organic corrosion is a biological phenomenon, where ubiquitous micro-organisms grow in a conducive habitat. Most such micro-organisms are aerobic in nature and, again, high humidity is a major factor that induces their growth, e.g. in the form of moulds, fungi and mildew. Such organic corrosion mainly affects rations, clothing, footwear, etc.

High humidity also leads to easier condensation on the surface of electrical and electronic components and the concentration of the tonic water molecules increases the surface conductivity, for instance, in insulators. The more modern problem is low-voltage breakdown between adjacent circuits in printed circuit boards (PCB), the developing micro-miniaturization of circuits making the problem a growing one.

Extensive field trials, actual usage and literature survey have revealed that controlled humidity environment of 25-40% relative humidity (RH) is the optimum for preservation of military hardware. The merits of maintaining such an environment are the following:

(a) Main elements of deterioration, i.e. corrosion, rot and mildew, are fully inhibited.

(b) Corrosion that had started prior to preservation of the equipment is effectively arrested.

In course of time, under less than 30% RH condition, the rust film becomes a dry powdery residue and can be easily removed.

(c) Chances of failure of insulators, PCBs and other avionics are virtually eliminated.

(d) Surface finishes are preserved intact.

(e) Maintaining RH below the above limits is not necessary; it also does not yield additional benefits commensurate with the additional investment and subsequent operating and maintenance costs.

Methods for Control of Relative Humidity

In order to maintain a controlled environment in an enclosure at the desired RH level, supply air to the enclosure has to be dry enough to offset the moisture ingress into the enclosure. The process of physically removing moisture from the air is called dehumidification.

Lowering of RH can be accomplished in several ways, viz. :

a) Heating the air;

b) Application of vacuum

c) Refrigeration;

d) Chemical Dehumidification

Heating the air increases the temperature, and since RH is a function of temperature, apparently lowers the RH without actually removing the moisture from the air. It is impractical to maintain such conditions, hence this approach is not desirable and not followed. Futile attempts have been made to supplement such efforts by placing bags of desiccant in the enclosure for static adsorption, but these are not effective without provision for reactivation.

Vacuum systems essentially work on the principle of humidity denial rather than humidity control. The environmental barrier and its very complex sealing, by virtue of its design, dictate a very heavy (a few tons) approach, which makes site handling almost impracticable. The energy consumption for creating and maintaining the vacuum is also very high. This

approach, therefore, has been more or less abandoned the world over.

Refrigeration system of dehumidification does actually remove moisture, by condensing it, but has some inherent limitations unless one makes major compromises in application needs.

The limitation are :

a) It is suitable for maintaining RH upto 45% or above;

b) It continues to pump heat into the enclosure, since the heat of compression is rejected continuously within the enclosure;

c) High ambient temperature reduces the efficiency of the condensing system and requires high energy consumption for RH control.

Chemical dehumidification emerges as the best choice for RH control.

Equipment Options for Adsorption-based Dehumidification

The size of the enclosure in which the RH is to be controlled, the supply air quantity and the degree of dehumidification required vary from situation to situation. Therefore, it is necessary that a wide range of equipment be available to meet the specific requirements of a given situation.

Adsorption-based dehumidification systems operate on the principle of an adsorbent bed rotating between two sections ; a ‘process’ section in which the supply air is dehumidified, and a ‘reactivation’ section in which the adsorbed moisture is removed and the bed is regenerated for a fresh process cycle.

A wide range of ratings and capacities are available to built from small to very large enclosures, such as storage sheds, warehouses etc. Bry-Air India (BAI) offers several options to suit the user needs. viz. :

* Compact (80 to 500 CMH dry air)

* Portable

* MVB (Modular Vertical Bed, 850 to 85000 CMH dry air).

* Specially Engineered Systems (for large warehouses, hangars, etc.)

These dehumidifiers use a special adsorbent with high dynamic response, specially produced for the specific purpose,. Other features of these dehumidifiers are :

- low energy consumption
- easy maintenance
- ability to maintain critically low humidity conditions.

Aircraft Protection Using FBS Systems

Aircraft protection using flexible barrier storage system has been used successfully for the protection of fixed wing aircraft and helicopters since the 1970's. The first prototype was made and tested successfully in 1960's for a Hunter aircraft, and since then is being followed as an established practice world wide, for long term preservation.

Dehumidification applications on operational as well as stand by aircrafts can result in upto 300% increase in system mean time between failures (MTBF).

Environmental protection also increases MTBF of equipment ranging in size and sophistication from the smallest piece of electronics to modern computer guided bomber aircrafts and armored fighting vehicles (AFV's) and from batteries to radars and missiles.

Shrouding of aircrafts, helicopters and missiles using the Flexible Barrier System protects them from the damaging effects of moisture, dust and ultra violet rays.

Currently, Sea Harrier Aircrafts and Sea King Helicopters are being preserved at INS Hansa using FBS.

The ""**Sea King**" helicopter and **"Sea Harrier"** aircraft, both ship-borne aircrafts form an important part of Naval Aviation. However, prolonged exposure to the moisture and salt-laden sea air takes its toll by hastening the corrosion process. In the aviation industry, the failure of structures, components and systems (despite high levels of sophistication) has been

attributed to corrosion.

A survey carried out on Sea King helicopters showed that in spite of regular daily and weekly preventive maintenance, the corrosive effects were visible on the main rotor blades, landing gear system, wheel bearings, shock absorbers, chrome-plated areas, tail nylon bush and fitting assembly. This corrosion could lead to catastropic failures. It is not an exaggeration to say that the primary function of naval maintenance was to combat corrosion until Bry-Air offered an effective solution to preserve material against corrosion.

No special buildings or preservation procedures are required for preservation with FBS. Need for maintenance is considerably reduced or eliminated altogether. Very few personnel are required to keep the aircrafts and air defence equipment in a state of permanent readiness. In an emergency they are operational within a few minutes.

Additional benifit of providing FBS is that canabalisation has been absolutely reduced.

Flexible Barrier Storage System

A protective barrier is required to contain the controlled environment for protecting the stored aircraft/combat vehicle from harmful elements enumerated earlier. The controlled environment is created and regulated by the Bry-Air dehumidification system and contained by the Bryclad flexible barrier. Thus, the overall Flexible Barrier Storage (FBS) system consists of the following main elements :

(a) Flexible cover

(b) Internals

(c) Dehumidifier

(d) Trolley

(e) Air Distribution System

(f) Sensor Device

The Flexible Barrier

The flexible barrier is a specially fabricated cover in one or two parts, which are joined together by the closure, and provided complete with stress books, instruction pockets, humidity

indicator window, inspection window and repair kit, etc. The material for the flexible barrier - Bryclad - is a calendered/supported polymer specially developed for the purpose, which is durable and easy to handle.

The material in general has the following characteristics :

(a) **Appearance** : The material is substantially free from foreign matter and manufacturing faults and is uniform in color.

(b) **Colorado** : Olive green-textured with requisite color fastness and no appreciable color bleeding.

(c) **Moisture Vapor Transmission Rate (MVTR)** : The Brypol material has inherent resistance to moisture vapor transmission and ambient temperature etc. A low MVTR is Brypol's inherent characteristic.

(d) **Structural Strength** : Sufficient tensile strength, elongation at break, tear strength etc.

(e) **Resistance** : Adequate resistance to biological attach, flame, abrasion, ultraviolet light, flexing, fuels, mineral/synthetic oils and weatherability.

(f) **Dimensional & Mass Stability** : Adequate dimensional and mass stability conforming to design consideration.

All these above characteristics of the basic material play a major role in determining the useful life of the barrier and its proper functioning/performance.

Flexible Cover Design Considerations

The following essentials have been catered for in designing the flexible barrier :

(a) **Basic Configuration** : The barrier is fabricated to the general line and shape of the stored aircraft/equipment.

(b) **Assess** : Easy access to the stored vehicles is provided for any necessary inspection or maintenance when required particularly so far under carriage.

(c) **Ease of Installation** : Adequate markings are provided so that the adjacent parts of the barrier can be easily fitted together.

(d) **Humidity Indicator Window** : Easily accessible humidity indicator window is welded to the barrier to house the humidity indicator papers provided for periodically checking the RH in the enclosure.

(e) **Brylok Closure/Slider** : A heavy duty tract closure, with removable sliders, having properties compatible with the barrier, is used for connecting barrier sections.

f) **Weather Flaps and Stress Hooks** : The closure is protected by weather flaps. The mechanical stress on the closure is relieved by stress hook devices. The straps for the stress hooks are strong and durable.

Internals

Internals of flexible barrier are provided as per specific needs of the stored aircraft.

However, these boards are not required in case of aircrafts/helicopters.

Blankets/paddings are provided to protect the barrier from sharp projections on the aircrafts.

Dehumidifier and Air Distribution

A dehumidifier (MIL version) is provided to ensure corrosion free humidity levels inside the enclosure. It is an electro-mechanical equipment working on 220 V/ single phase on 415 V/ 3 phase power supply, depending upon the model, provided with all necessary controls and indicators. A humidistat is provided to control the RH at 25-40% as per requirement. Initial pull down period in about 2-3 hours, thereafter it automatically cycles on and off depending upon the humidity level inside the barriers.

A specially designed trolley is provided for carrying and housing the dehumidifier, to ensure its adequate protection from weather. Required openings are provided to connect the air distribution system without disturbing the dehumidifier.

The air distribution system comprises the air distribution box, flexible reinforced PVC pipe and take-off points. A well designed dynamic air distribution system is provided to ensure

that no stagnant air pocket exists inside the barrier or the stored aircraft/vehicle. Optimum quantity of air is inducted and recirculated through the air distribution box.

Application Options

The application options available are mainly according to the user's preference and requirements. The options available are either/External/Cluster or Internal/One-to-One approach. Both these approaches have their relative merits which should be borne in mind in selecting the right approach to serve the intended purpose and the need.

In the external approach, the dehumidifier is placed outside the flexible barrier and serves more than one barrier. The salient features of this option are as follows:

a) Most economical approach as one unit will serve two or more barriers.

b) Reduction in inventory, as the number of dehumidifiers required are at the scale of one per two to four vehicles.

c) Ease of maintenance : removal of flexible barrier is not required, thus maintaining the internal environment during maintenance of the dehumidifier. Vulnerability to weather and unauthorized personnel is overcome by housing the dehumidifier in the trolley.

In the internal/one-to-one approach, the dehumidifier is placed inside the flexible barrier and is dedicated to that barrier only. This increases the cost per vehicle system but there are corresponding benefits too. The salient features are :

a) Smaller, compact dehumidifier will do the job.

b) The dehumidifier becomes an integral part of the aircraft/vehicle and can be used when moving out of the permanent location i.e. on when and where basis.

c) Safe from weather, unauthorized personnel and pilferage.

d) Increase in inventory i.e. one dehumidifier for each vehicle.

e) Only well planned maintenance at regular predetermined intervals possible as it will

involve removal of the flexible barrier and subjecting the machine to external environment.

Both approaches are possible in case of combat vehicles, but in case of aircraft/helicopters only external approach is possible because of space constraints inside the barrier. In general, external approach would be preferred because of greater flexibility and ease of application.

Conclusions

Corrosion control and preservation through dehumidification and flexible barrier storage (FBS) system is ideally suited for preservation of aircrafts, helicopters, aero-engines, combat vehicles, etc. It is cost effective by way of reducing maintenance cost and enhancing life of the equipment. It is simple, easy to install and can be operated and maintained with no additional infra-structure. Initial investment is inappreciable compared to the cost of hardware being preserved.

Bry-Air leads the way ..... in the region

Bry-Air India has supplied and successfully installed eight numbers of complete Flexible Barrier Storage Systems (FBS) for preservation of Sea King, helicopters and Sea Harrier aircrafts for the Indian Navy.

Bry-Air Dehumidification & FBS System increases MTBF, minimises reactivation and down time capacity in the following sectors.

Bry-Air Dehumidifiers can protect the engines and electronic equipments in an aircraft from atmospheric corrosion and other moisture damages. This reduces maintenance cost automatically.

While on “standby” the aircraft can be protected as Bry-Air Dehumidifier blows dry air into the engines and electronic system. Aircraft armaments are stored in an environment where the relative humidity is maintained at 50% or lower, irrespective of temperature.

Bry-Air Dehumidifiers protect surface to air missiles which are often located in places exposed to elements of nature. If humidity is uncontrolled, the command to activate the weapon gets

thwarted by the damage caused.

Radar systems are usually located in high and remote areas exposed to severe and hostile weather conditions. Rapidly changing temperature leads to condensation on the radar surface. Controlling the humidity with Bry-Air Dehumidifier ensures that the performance of the radar is not adversely affected.

In the storage of spares and replacements, it is vital to keep batteries, tyres, uniforms, parachutes, films, microfilms, propellant and rocket fuel free from corrosion and mold growth — with Bry-Air Dehumidifiers.

Bry-Air controls levels of humidity in computer rooms, communication network, antennas, waveguides and electronic instrumentation. This reduces mean time between failures resulting in lower maintenance, manpower and replacement costs.

In the assembly of jet engines, avionics, electronic components — a dry environment is essential until assembly is completed.

Bry Air India, a joint venture with Bry-Air USA, leaders in dehumidification and product drying, have the complete knowhow to provide complete Flexible Barrier Storage systems in India.

ANNEXURE. I

Equipment and Components Liable to be Affected by High Humidity

* Standby Aircrafts/Helicopters
* Missiles
* Communication systems
* Propellants/Rocket fuel
* Radars/Antennae/Waveguides
* Computers/Electronic Instruments
* Replacement/Spare parts
* Jet Engines
* Uniforms/Parachutes
* Films/Micro-films
* Avionics
* Cockpit instruments
* Wing electronics
* Substructures