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Design, Realisation and Validation of Antenna Pressurisation System for Radars

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Abstract:
An Antenna Pressurisation System has been designed and developed for Medium Power Transportable Radar. It is designed to supply the antenna cabin with dehumidified air so that the Active Array Antennae electronics inside the antenna cabin works properly and enhances the reliability of the system. Active array antennae generates lot of heat and requires liquid cooling. Kilowatts of heat generated by these units are removed by circulating chilled water through cold plates on which antenna electronics are mounted. Chilled water is supplied at around 20ºC. Moisture present in air inside antenna cabin can condense in contact with low temperature and can cause short circuit in components. It is also found that fungus and mold growth is minimal in absence of excess moisture. It has been found that complete absence of moisture is also harmful for the life of PCBs, which will release all its moisture and gets churned if kept in contact with totally dry air. It is found that 30-40 % RH in air is best for maximum life of electronics. Antenna Pressurisation System has been developed to supply dehumidified air to the Antenna Cabin, and it will maintain the cabin air above atmospheric pressure so that outside humid air will not enter the antenna cabin. System has been designed with PLC interface so that its operation can be monitored remotely. Its operation is automated for switching on and off controlled by feedback loop with pressure and humidity sensor.

Key Words: APS (Antenna Pressurisation system), Relative Humidity, Moisture, Dew Point, PLC, Remote control.

I. INTRODUCTION

The Antenna Pressurisation System is required to deliver the dry air to the antenna cabin and to maintain the pressure inside antenna cabin. The antenna pressurisation system removes the water vapor from ambient air and delivers the dry air. The water vapor is removed from the air to prevent the condensation and humidity effects on antenna electronic units mounted inside the antenna cabin.

The APS is mounted on the pallet of Pedestal Assembly. The unit supplies dry air at a required pressure to antenna cabin to maintain the relative humidity of air inside the antenna cabin. It is designed to supply the dry air at a pressure just above the atmospheric pressure so that external humid air will not enter into the antenna cabin. All the components of Antenna Pressurisation System is housed inside a sturdy box, and doors/covers are provided for easy accessibility and maintenance.

This paper describes the detailed design of Antenna Pressurisation System designed for Medium Power Transportable Radar. It has been designed with hundred percent redundancy and maintenance free components. System has been designed with weight and dimension constraint. It has pressure sensor to sense the antenna cabin pressure and start automatically when the pressure falls below prescribed pressure and stop the system automatically whenever the cabin pressure is above prescribed upper limit.

II. ANTENNA PRESSURISATION SYSTEM DESIGN REQUIREMENTS & CONSTRAINTS

Requirements:

- Unit should take ambient air and provide dust free dehumidified air to the system with a minimum flow rate of 1650 liter per hour.
- Output air should have RH level between 30 to 40 percent at 20 mBar gauge pressure.
- System is required to be compact within a dimension of 600 X 600 X 500 mm.
- Ethernet control for health status checkup and remote operation and control.
- The system should qualify Environmental and EMI/EMC requirement.

Constraints:

- Overall height of the system shouldn't increase 500 mm in order to clear rotating platform.
- Weight of the unit should not be more than 80 kg.

III. VARIOUS METHODS OF AIR DEHUMIDIFICATION

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Moisture trapped in air can be removed by any of the following methods. Each method has their own pros and cons.

A. By passing air through chilled region:
When moist air is passed through refrigerated space, where temperature is low moisture in air condenses and are separated from the bottom of the tank. We need refrigeration system to get the low temperature and hence the system based on this principle becomes bulky. Also not all of the moisture is condensed out. Due point of purified air is slightly above the low temperature available in refrigeration.

B. By passing air through desiccants:
There are some substances which has high affinity for water molecules called as hygroscopic materials, these material are made into small balls to increase surface area and hence increase the adsorbing power are commonly known as desiccants. When moist air is passed through such desiccants, water molecules are attached to its surface due to hydrogen bond formation. To increase the effectiveness of adsorption air is flowed at high pressure through the desiccants. The process of adsorption is highly temperature dependent and can be reversed by increasing temperature.

C. By deliquescent absorption:
Some of the material absorbs moisture chemically and makes strong bonds with it, removal of moisture from these materials are tedious. Such material are called as deliquescent material and can be used once for moisture removal.

D. By passing air through hollow membrane:
Moist air is passed through hollow membrane at high pressure, moisture permeates through porous membrane. A bypass air is needed to scavenge permeated air on the outer surface.

IV. RADAR CONFIGURATION & SPACE DETAILS

The radar sensor vehicle and space available for APS mounting is shown in figure 1 & figure 2 respectively. The maximum size of which can be accommodated below rotating platform is 800x800x500 mm.

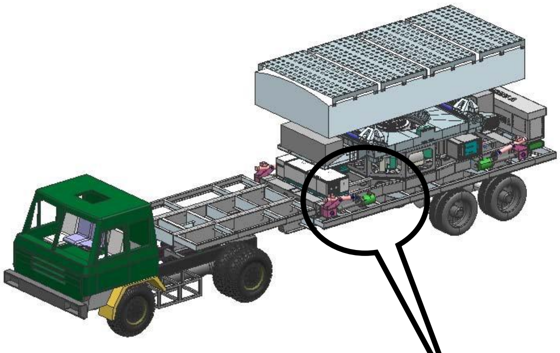
Figure 1 Radar Sensor Vehicle

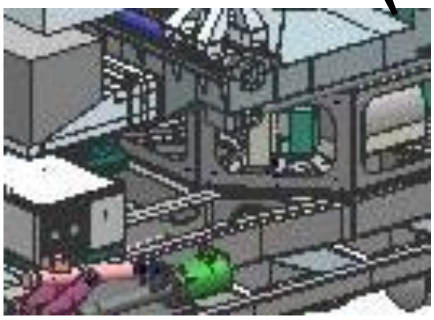
Figure 2 Space available for APS integration

Radar has huge antenna rotating on a Pedestal which is leveled on four outriggers. APS is to be placed on stationary pallet. The gap between the rotary frame and stationary pallet is 600 mm. It is required to accommodate APS within 500 mm height.


Figure 3 Radar configuration in operation

V. CONCEPTUAL DESIGN OF ANTENNA PRESSURISATION SYSTEM

A detailed study was carried out to design of the APS. The refrigerated type dehumidification has been ruled out for refrigerant involved in the system for

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chilling and also system becomes bulky. Membrane type air dryer requires very high pressure of air for its functioning and hence it is not suitable. Deliquescent type dryers will need frequent material change which is not suitable.

Desiccant type air dryer is best suitable since desiccants can be regenerated and used again and again. The size of the unit can also be managed within the dimensional constraints. Desiccant based system can further be of two type depending on regeneration technique. Once the desiccants get saturated with moisture, moisture from it can be removed either by heated dry air or by dry air circulation. Regeneration of desiccants by dry air circulation consumes at least 15 percent of the dry air output of the system. To reduce the wastage of dry air output, regeneration can be accelerated by use of hot air. Still wastage of air is present but is minimized to maximum up to 5 percent. When heating is not involved it is called as heatless desiccant air dryer and it employs high pressure. Moisture from high pressure air is trapped by adsorption to the desiccant surface, while regeneration desiccant is brought in contact with low pressure dry air. Two compartment of desiccant is needed for continuous generation and regeneration process.

VI. MECHANISM OF DESICCATION

Desiccation is a surface phenomenon where moisture is adsorbed not absorbed. Higher the surface area higher amount of moisture is adsorbed. There are so many materials which has affinity to polarized water molecule. In fact on the surface of such material water molecule is attached with weak bond known as H-bond.

One of the desiccant is silica gel available most abundantly on earth crust. Zoomed view of silica gel at molecular level is shown below in figure 4.

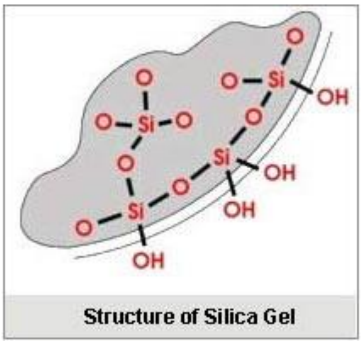

Figure 4 Zoomed view of desiccant surface

Silicon atom being highly electronegative pulls electrons towards itself leaving partial positive charge on hydrogen which attracts the oxygen atom of water molecule. The process of hydrogen bond formation with silica gel is illustrated in the figure.5 below.

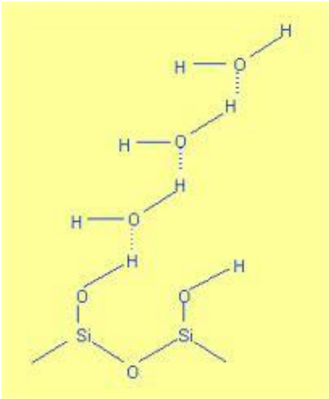

Figure 5 H-bond formation

Normal surface of silica gel when it is completely dehydrated is shown in figure6.

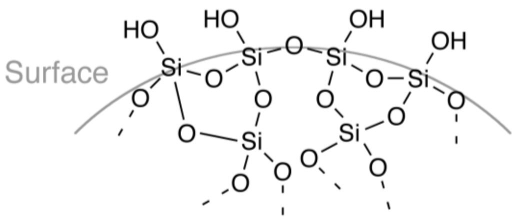

Figure 6 Surface of Silica Gel

Figure 7 shows the hydrated silica gel when it traps water molecules from the humid air.

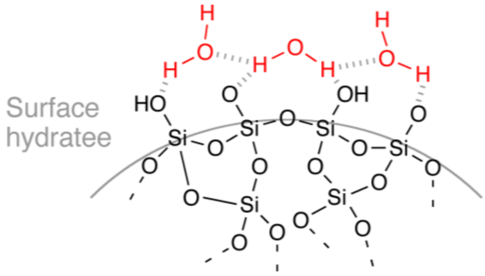

Figure 7 Surface Hydrate of Silica Gel

VII. ANTENNA PRESSURISATION SYSTEM DESIGN

From the conceptual design the essential parameter were arrived to carry out the detailed design. It requires two tower filled with desiccant so that one tower will remove moisture from air (Charge cycle) and the other tower will get regenerated simultaneously with purge air with or without heating. Schematic of the generation and regeneration is shown in figure below.

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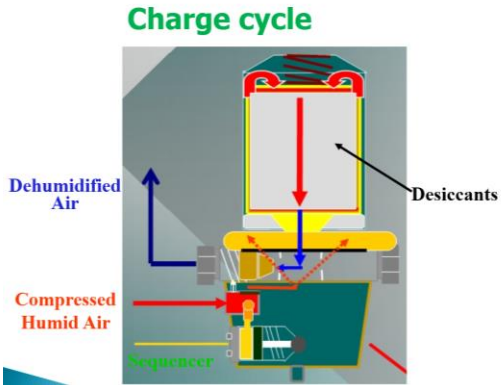

Figure 8 Schematic of Generation Cycle [4]

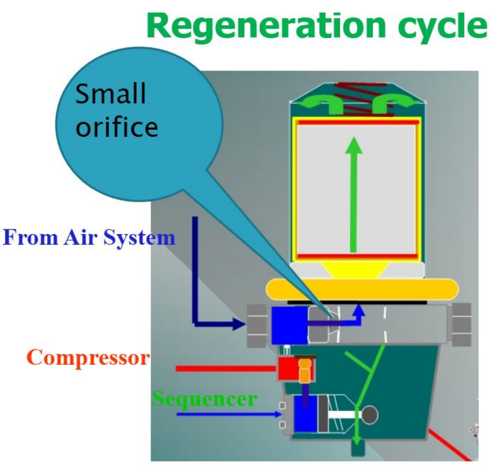

Figure 9 Schematic of Regeneration cycle [4]

Generation and regeneration of desiccants alternate from tower to tower without interruption of air supply. One tower generates dehumidified air and other tower purge out the moisture trapped in the desiccants. The process of alteration from generation and regeneration is time sequence basis.

Generation and regeneration cycle is controlled by outlet air quality. As soon as the desiccants get saturated with humidity, its outlet air humidity will increase which is sensed by humidity sensor placed in the delivery line.

Schematic diagram of the Antenna Pressurisation System is shown in figure10. System is required to be hundred percent redundant, because of space constrain all components couldn't be accommodated in duplicate. Only active components has been identified and stand by for that has been provided in the system.

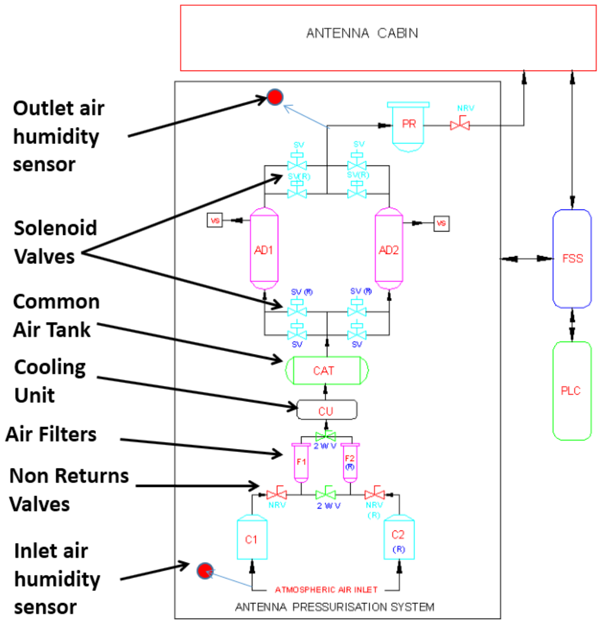

Figure 10 Schematic diagram of Antenna Pressurisation System

APS System is equipped with inlet and outlet humidity sensor, to check and monitor the supply air quality. Compressor has been chosen to be oil free, with diaphragm valves to make it quite. There are two compressors, one is active and other one is redundant. Air filters are fitted before and after compressor. Since the compressed air gets heated after cooling arrangement is also employed. Compressed air is stored in a common air tank (CAT), from where it is passed to desiccant towers. Desiccant towers are fitted with heaters internally for its regeneration. Solenoid valves being active component are placed in duplicate, controls the flow direction. In the end air needs to be depressurized before it is supplied to Antenna Cabin. Low pressure regulator does this function and supplies air at 20 to 30 mBar to the antenna cabin.

VIII. APS REALISATION & VALIDATION

A detailed design was carried out for the development of APS. The realised system is shown in figure11, it has total weight of 74 kg. The system has undergone all qualification tests. It has performed under high as well as low temperature conditions. Since the system is mounted on Radar vehicle which is required to be road transportable, APS has undergone all environmental tests including vibration tests required for road transport. Figure12 shows the system on vibration table being tested. Figure 13 shows the working parameters of the system on a local display fitted with the system. These working parameters are also available, accessed from Radar shelter through Ethernet link. Since

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the ambient humidity is lower 44%, dehumidified air output of the system is lower at 24%. The cabin's humidity preferable range is 30-40%. Supply air mixes with cabin humid air and brings humidity to the above range.

Figure 11 Realized Antenna Pressurisation System


Figure 12 APS under testing (Vibration test)

Figure 13 Local display showing working parameters

CONCLUSION

The Antenna Pressurisation System is conceptualized and developed to pressurize the antenna cabin with conditioned air (dehumidified air), which is required for increased life and reliability of antenna electronics. This system has been designed for Medium Power Transportable Radar, it is also being used for other similar ground based radars with active array technology. The components are selected in such a way that maintenance of the system is least, it can perform in all extreme weather conditions. The APS was realized and tested for Environmental and EMI/EMC tests. It was integrated with the Radar for functional tests. User trials are also completed successfully.

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