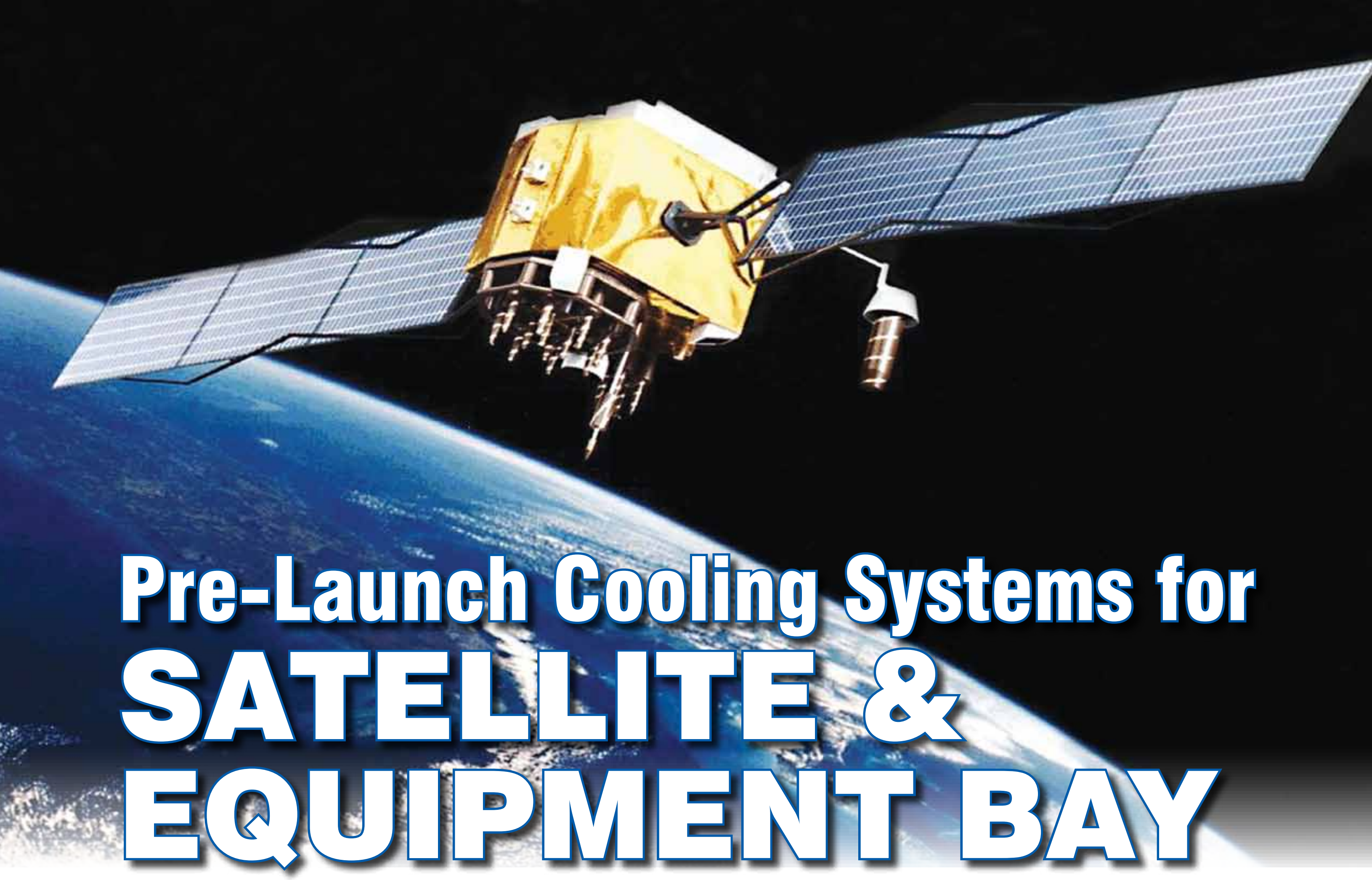

Pre-Launch Cooling Systems for SATELLITE & EQUIPMENT BAY

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The developmental Polar Satellite Launch Vehicle (PSLV) was first flown with the intention of orbiting the IRS Class Remote Sensing Satellite. The multistage launch vehicle, weighing around 276 tonnes, is required to inject the 850 kg IRS Satellite into a 900 km sunsynchronous orbit. In order to function efficiently,both the satellite and its related instrumentation are required to be kept in an optimally controlled environment. This article deals with the ground based pre-launch cooling system for the Satellite and Equipment Bay. (The thermal control of the IRS Space Craft in orbit is beyond the scope of this article).

Launch Configuration

The satellite sits atop the launch vehicle and is integrated to the vehicle inside the mobile service tower (MST). The MST is air-conditioned and the area housing the satellite inside the MST is maintained as a clean room. Once the heat shield is fixed, a separate cooling system is required to maintain the environment inside the heat shield at an optimum level. This cooling system is the subject of this article.

Figures 1 and *2* show the general disposition of the MST, Umblical Tower (UT), the launch vehicle and the satellite/equipment bay.

Heat Load Computation

The satellite heat shield is 3.2m in diameter, 11M in height and envelops the satellite and equipment bays as indicated in *Figure 2*. The heat shield is fabricated out of cork lined aluminium honey comb structure, and is covered by a thermal blanket once the MST is retracted 4 to 5

About the Author

Parmesh Iyer is a mechanical engineer from Bangalore University with specialization in AC&R. He worked with York India and Blue Star for 5 years before joining the Department of Space in 1975. He held several positions including Head (AC&R) and Chief Construction Engineer before assuming his current position.

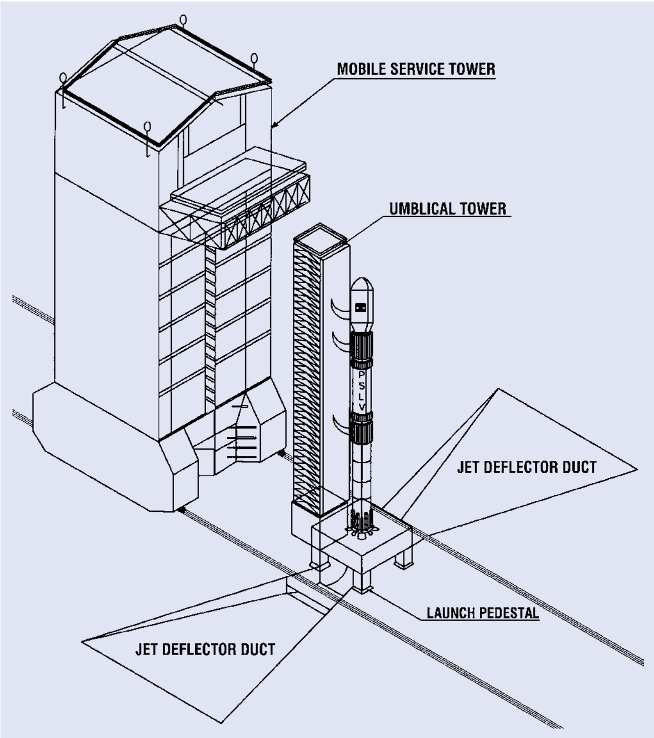

Figure 1 : General arrangement of the mobile service tower, umbilical tower and launch vehicle.

hours before the launch. This thermal blanket consists of expanded polystyrene placed around the cylindrical part of heat shield. The heat load inside the heat shield is contributed by the following:

- Solar insolation falling directly on the heat shield, when vehicle is exposed.
- Heat dissipated due to power generation of satellite system.
- Heat dissipated due to equipment bay power systems.

The solar insolation is calculated considering the solar constant, absorptivity of the material and the area, and the temperature inside the nose/cone by simultaneously solving equation for heat balance,considering convection/ conduction/radiation. Suitable assumptions are made while arriving at the heat load. The total solar load so arrived at amounts to 4167 W. In addition the heat dissipated due to the power generation inside the satellite and the equipment bay is around 1150 W. The space around the satellite is required to be maintained optimally around 20°C and that around the equipment bay at around 35°C.

Plant Design Parameters

The above data has been used to arrive at the air quantity required, which works out to 1450 kg/hr for the satellite and 350 kg/hr for the equipment bay. Considering the heat dissipation due to power generated inside the heat shield by the satellite and equipment bay, and heat input due to solar insolation, the temperature of air at inlet to the heat shield was fixed at around 10°C-15°C. The lower limit of 10°C was specified to maintain required temperature when the vehicle was exposed to sunlight, and the upper limit of 15°C to maintain temperature when vehicle was inside the MST. Considering the prevention of static electricity generation, the relative humidity was fixed at 45±5%

An air pressure of +125 mm wg at the air inlet to satellite and +625 mm wg at equipment bay air inlet are required to be maintained to overcome frictional losses inside heat shield/equipment bay and ensure that air is maintained at a positive pressure inside the heat shield to prevent ingress of dust particles when vehicle is outside MST.

Finally, quality of air is to be maintained at Class 10,000 cleanliness.

All the above mentioned parameters of air quantity, temperature, humidity, pressure and cleanliness are required to be maintained at the air inlet to satellite/ equipment bay.

The outside design conditions of dry and wet bulb, are those pertaining to Sriharikota, A.P.

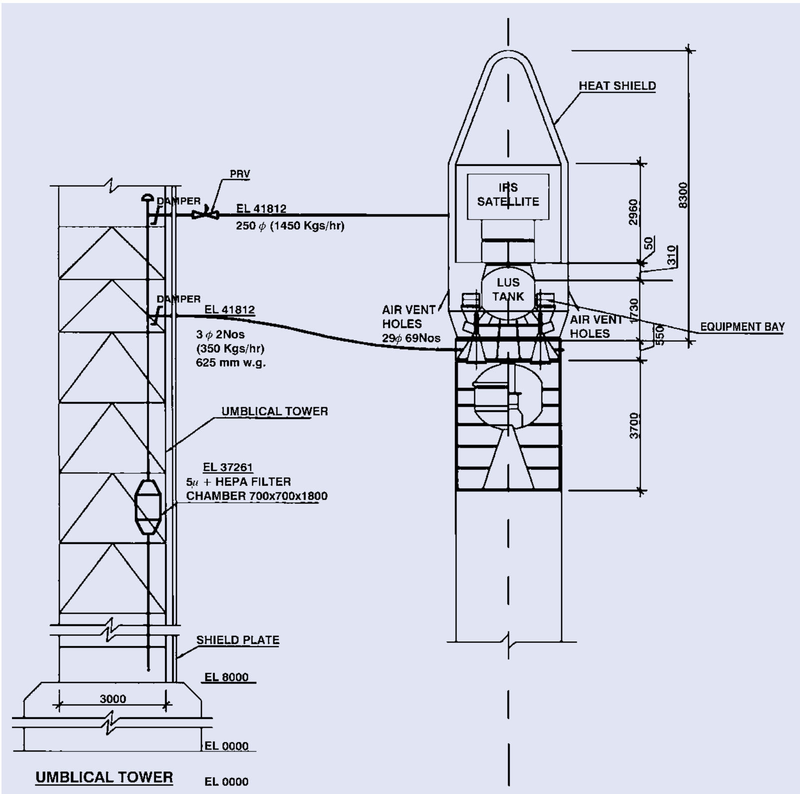

Figure 2 : Air flow arrangement for the launch vehicle satellite prior to launch.

continued on page 92

continued from page 90

Equipment Configuration

Considering the low dew point, it was decided to go in for moisture removal through a desiccant, instead of going in for a conventional refrigeration system. This necessitated the use of a solid adsorbent dehumidifier using silica gel as the desiccant. Secondly to meet the low temperature, brine was selected as the medium to achieve this cooling. To reduce the load on the dehumidifier, a pre-cooling coil was used. Even though, dual air pressures at UT were originally specified, it was decided to select a centrifugal fan to deliver the larger of the two air pressures, and provide a PRV at the air outlet to the satellite to reduce the pressure to the required level. This was done since space requirements for running two ducts from the equipment room to the UT, through a pipe/cable trench, was limited. To convey the air to the vehicle/UT, a PVC pipe to withstand the required pressure was selected upto the base of the UT. Beyond the UT base, and upto the top of the UT, an aluminium duct of required gauge was selected. The insulation to cover the air ducts was also suitably selected to withstand the searing heat generated by the blast-off.

A schematic diagram showing the equipment configuration is shown in *Figure 3*, which also indicates the calculated required air parameters. It can be seen from the schematic that there is considerable addition of heat to the air through the processes involved. This includes heat gains at:

- The solid absorbent dehumidifier due to adsorption process.
- The fan due to pressurisation of air
- The supply air duct, which is around 150 m in length to the top of the UT.

It is thus seen that to achieve an air temperature of 10°C at the top of the UT, the air temperature leaving the equipment room should be around 6°C. This forms the basis for the selection of the refrigeration equipment which comprises of a brine package chiller of adequate capacity, primary and secondary brine pumps, condenser water pumps, cooling tower, brine tank, chilled water tank and associated electrical works. The brine tank storage capacity was for 10 minutes and would supply brine to the after cooling coil. The chilled water storage tank (receiving chiller water from an existing source) would supply water to the pre-cooling coil. This configuration was selected considering economy. The chilled water tank was sized with sufficient storage capacity to take care of 5 hours of cooling after retraction of the MST. Adequate redundancy for package chillers and pumps etc. was provided. The temperature of the brine leaving the package chiller was fixed taking into account the surface temperature of the secondary coil to prevent further dehumidification, and resultant lowering of the relative humidity inside the heat shield.

Program Management

Required inputs and functional parameters were laid out by the user group in association with the ground facility group. After freezing of the preliminary design in house, a committee consisting of leading experts from the air conditioning field and the users, was formed to carry out a design review to verify the soundness of the design. The committee cleared the design with a few modifications, viz:

- Users to review their requirements to take into account the lowering of RH inside heat shield with air entering at 45% RH as specified.
- Installation of dedicated A/C plant for the total cooling requirements instead of chilled water storage for cooling after MST is retracted.
- Redundancy for the centrifugal fan.

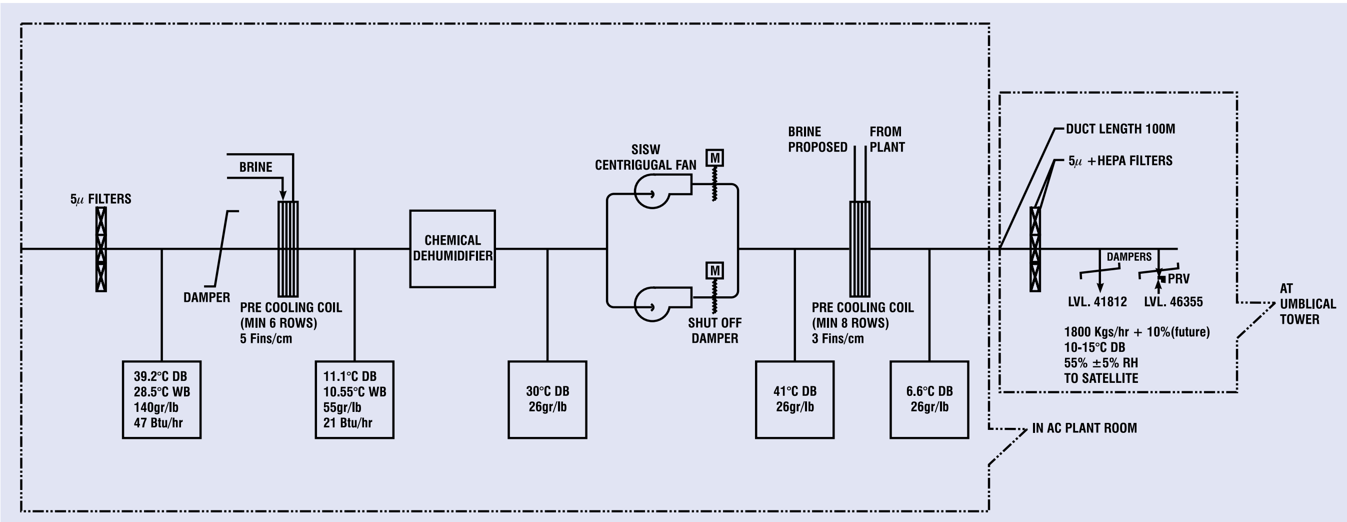

Figure 3 : Schematic air-flow diagram for satellite cooling (as per modifications suggested by the review committee).

continued on page 94

continued from page 92

- Provision of pan humidifier and strip heaters in SA duct.
- Replacing vertical ducts at UT with 16 g aluminium instead of 22 g aluminium.

The above modifications were incorporated in the design which resulted in:

- Requirement of relative humidity of 55±5% at inlet to heat shield with all other parameters, like air quantity, pressure, temperature and cleanliness remaining unchanged.
- Selection of a dedicated brine chilling plant to supply brine to both pre and after cooling coils.
- Inclusion of pan humidifier and strip heaters in the system.
- Changing aluminium duct from 22 g to 16g at the UT level.

Plant Selection

Considering the above, the plant was suitably reconfigured. The total refrigeration capacity for the brine chiller package was increased to 20TR, with R-22 reciprocating compressor, shell and tube condenser, prime surface DX chiller suitable for ethylene glycol, condenser water pumps, primary and secondary brine pumps. A hot/cold well with a cold well capacity of 10 minutes brine storage was selected.

A solid adsorbent chemical dehumidifier with a rotating carousel bed was selected for moisture removal. The dehumidifier was provided with 2 centrifugal fans (one redundant) of single inlet type, with backward curved blades to generate the required pressure. It was also decided to maintain one common pressure (625 mm wg) upto the heat shield. A PRV is fitted to bring down the pressure to 125 mm wg at the air inlet to the satellite bay.

An operational requirement was that the plant should be automatic in operation, including the change-over to the redundant system, for the launch phase when the MST was retracted and no operational staff was permitted near the launch site. This automatic operation is carried out by means of suitable relays and timers in the control circuit.

To make the system more reliable, a redundant set of controls like HP, LP, OP, and AFT were specified for parallel installations, in case of failure of any one of the controls.

The total refrigeration system was housed in a plant room which is around 100m away from the actual launch pad and the UT. The conditioned air is ducted by means of 300 mm dia PVC duct to the base of UT and by 16g aluminium duct to the top of UT and the heat shield. The cooling tower and hot/cold well were located adjacent to the plant room.

Testing and Commissioning

During precommissioning phase of the plant, a few problems areas were encountered, as discussed below:

- The required pressure of 625 mm wg at the heat shield was not being developed, as per design, in one of the fans. This was due to turbulence and loss of pressure at the outlet due to faulty outlet connections. The outlet connection was reconfigured and redone to attain design pressures.
- The crankcase of the compressors including the suction line were frosting heavily. This was traced to faulty piping at the chiller, which was rectified, and changing the power element of the expansion valve.
- The air outlet temperature at the after cooling coil was high compared to the design values. This was traced to less than specified number of rows and was rectified by adding two more rows of cooling coil.
- The flow rate through the brine circuit was not meeting the specified quantity. The pumps were found to be undersized and these were replaced.
- The flow rate through the condenser water circuit was less. The pumps were found to be undersized and were suitably replaced.
- After carrying out all the rectification as indicated above, the plant was tested and found to meet the design specifications in all respects.

The plant was operated without any problems, including a non-stop unattended 30 hour automatic operation of the plant during final countdown leading to the launch.

Upgrades

For meeting the Geo-synchronous Satellite Launch Vehicle (GSLV) requirements, an enhanced satellite cooling system has been commissioned subsequently. The GSLV which has a weight of more than 400 tonnes, can hurl a 1500 kg communication satellite payload into a geo-stationary transfer orbit. Consequently, the satellite cooling requirements needed to be upgraded. An enhanced satellite cooling system ,capable of delivering 4000 kg/hr of conditioned air, with 5 air outlets to the vehicle, was commissioned and saw service during the first successful launch of the GSLV –D1. Parameters for GSLV and PSLV satellite cooling air requirements remain unchanged except for the refrigeration plant which is larger at 45 TR for GSLV. The enhanced satellite cooling system was operated continuously for 45 days during the launch campaign.

A large number of launches have taken place involving both PSLV and GSLV launch vehicles for placing indigenous as well as foreign satellites into orbits. Commercial launches for third parties require that the satellite cooling parameters are rigorously met to meet customer requirements and satisfaction.

Performance of the satellite cooling systems has been exceptional. ❖