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Scientific & Engineering Activities of R & D E (Engrs), Pune at Maitri, Antarctica, XVIII ISAE (16" W O T)

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ABSTRACT

Research and Development Establishment (Engrs) Pune, one of the premier lab under D R D O, has been actively participating in Indian Antarctic Program since 1983. The lab has shouldered the expeditions, both on scientific and logistic fronts from time to time, thus enabling, achieving the goals and targets set by Expedition Leaders and Department of Ocean Development.

Experiments on Pollution free Polymer Electrolyte Membrane Fuel Cells were continued in order to explore the possibility of developing environmental friendly source of power for futuristic use. Health Monitoring of Generating sets was continued being, lifeline for the Maitrians. The prestigious "Spectrophotometer" one of the costliest equipment of I M D was housed in a special shelter developed by R & D E. Health Monitoring of Maitri Foundation and 28 m Mast was carried out. New, plate type, thermostat controlled Radiators were provided in the rooms which enhanced the comfort levels. New bathing modules were installed and commissioned.

INTRODUCTION

Research & Development Establishment (Engineers). Pune, is one of the Premier Laboratory under Defence Research & Development Organisation (D R D O) involved in Indian Antarctic Programme since 1983. During the period of XVIII ISAE, Experiments on P E M F C Fuel Cell, which were commenced in 199.7, were further continued. Condition Monitoring of the Generating Sets using Compass Software and Health Monitoring of 28 m Mast using Strain Gauges were also continued. Further a new study on Health Monitoring of Maitri Foundation was taken up by XVIII ISAE. In addition to the Scientific Activities, the tasks of Erection of Spectrophotometer Shelter for I M D & New Bathing Modules in Maitri were successfully completed. The team has rendered its best help in the activities related to the Maintenance of the Station and other activities for the benefit & success of the expedition.

The following Scientific Programmes and Engineering/ Technical tasks were taken up and successfully completed.

1. Experiments on PEMFC Fuel Cell
2. Condition monitoring of Generating Sets
3. Health monitoring of Maitri Foundation
4. Health monitoring of 28m Mast
5. Erection & Commissioning of Spectrophotometer Shelter for IMD
6. Erection & Commissioning of New Bathing Modules in Maitri (Type 'A')
7. Installation of New Radiators

1. EXPERIMENTS ON POLYMER ELECTROLYTE MEMBRANE FUEL CELL

AIM

To study the Polymer Electrolyte Membrane Fuel Cell (PEMFC) in the Cold Region & its application as futuristic Power Supply source.

INTRODUCTION

Fuel cells are electro-chemical devices that produce electricity by reacting hydrogen and oxygen together electro-chemically rather than combustion. The exhaust from this process is water and there are no noxious pollutants such as carbon monoxide and oxides of nitrogen. Fuel cell power source thus could play a significant role in preserving the pristine nature of Antarctica. With this objective in mind R&DE (Engrs) has developed Proton Exchange / Polymer Electrolyte Membrane Fuel Cell (PEMFC) stacks of 500 watts, 12 volts in association with SPIC Science Foundation, Chennai, for scientific studies and experimentation in cold climatic conditions of Antarctica.

PEMFC has been chosen in preference to Phosphoric Acid Fuel Cell (PAFC) because there is a possibility of crystallizing phosphoric acid below -5 deg. C which will effect the electrode structure and destroy the performance. Moreover today PEMFC is the most promising technology to compete with diesel power generators because of its high power density.

PEMFC fuel cell stack developed contains 18 cells with two humidifiers for humidification of oxygen and hydrogen. The temperature of the stack is maintained by circulation of water through it. A temperature indicator is provided to indicate fuel cell stack temperature. It has also been provided with voltmeter and ammeter for monitoring voltage and current.

Fuel Celt power source has successfully undergone experiments at Antarctica during XVII Expedition for lighting a bank of incandescent lamps and charging of 12 V lead acid batteries which get discharged rapidly at low temperatures. Moreover study has been conducted for behavior and performance of dc-dc converter at low temperature and over a range of loads and efficiency of charging lead storage batteries.

Scientific experiments were conducted during XV1I1 Indian Antarctic Scientific Expedition, covering safe storage of hydrogen fuel, internally humidified electrolyte membrane, optimization of humidification temperature of hydrogen and oxygen and air cooling system and experimentation with static inverter for producing AC output.

At present, electricity is being generated using Generating Sets, at Maitri - Indian Antarctic Station. The fuel used in these generators is Aviation Turbine Fuel (ATF). The pollution level of the existing generators is 3.5% of Carbon Monoxide & Carbon Dioxide. The percentage level will be increasing if the system is not maintained properly. Apart from the gas pollution, the noise level of generators is very high, to the order of 100 db. The start up time for the generators is also very high and the wear and tare is more due to mechanical movements.

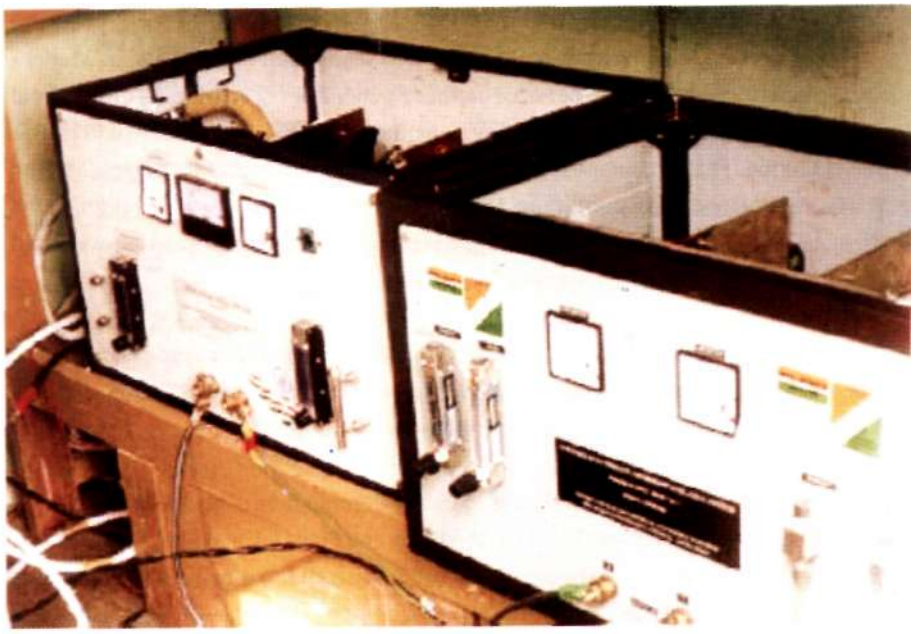
In the place like Antarctica, to maintain the clean environment and pollution free zone as per the Antarctic Protocol, it has become necessary to look for the alternate energy source which can give minimum pollution.

R & D E (Engrs) Pune and SP1C Science Foundation, Chennai have entered into M o U to study the Polymer Electrolyte Membrane Fuel Cell at Antarctica. P E M F C . has been chosen for the study because, the solid electrolyte known as Nafion-117 is used in this Fuel Cell. Electrochemical reaction, which takes place is exothermic, so that the Fuel Cell can be activated even at low temperatures. Apart from this, the power density of P E M F C is higher than the other types of Fuel Cells, These types of Fuel Cells are being used extensively as one of the power source for Space shuttles, Electric vehicles, U P S, in the countries like U S A Canada etc. India is the first country to study P E M F C at Antarctica. P E M F C was first installed & demonstrated successfully by XVII Antarctic Expedition, which was inaugurated by Mr. Alexander Kochin, the Russian Team Leader on 15th Aug98.

The brief technical spcci fication of the cell is as under: -

* Type - Polymer Electrolyte Membrane Fuel Cell
* No. of cells- 18
* Open circuit voltage-20 V
* Operating voltage- 12 V
* PowerOutput-500 Watts
* Power conditioner - DC - DC converter
* Fuel - Through hydrogen cylinder with 99.9995% purity
* Oxidant - Through oxygen cylinders

Controls- Humidifier for humidifying Electrolyte membrane with flow meters for control offlow of hydrogen and oxygen.



Following experiments were planned and carried out :-

1. Optimization of humidification temperature for the reactants (Hydrogen and Oxygen)
2. To eliminate the existing humidification system.
3. To study the air cooling system in lieu ofwater cooling system.
4. To study the humidification of gases using membrane as a medium.
5. To study the charging and discharging characteristics of metal hydride
6. Fuel cell coupled with DC - DC Converter and Inverter
7. To study the single cell performance at low temperature.

EXPERIMENT NO. 1&2

Optimization of humidification temperature for the reactants (Hydrogen and Oxygen) & elimination of the existing humidification system:

The electrolyte used in the PEMFC is required to be humidified for the better performance. The reactants (Oxygen & Hydrogen) used are generally passed through the water before it enters the inlet of the fuel cell. The present system is based on an external humidification system which requires electrical energy to maintain the humidification temperature. It also requires additional engineering hardware like pipelines, insulation & connectors etc. For initial activation of fuel cell the humidification bottle is heated through the strip heater. The water inside the bottle gets frozen almost everyday due to low ambient temperature. This gives additional problems to the fuel cell stack and more energy is needed to melt the ice i.e. frozen water in the humidification bottle. In order to avoid this problem, after initial humidification of the stack, the water in the humidifier has been removed totally. All the experiments were carried out without humidification, and there was no change observed in the performance of the stack. In order to check the durability of the stack performance without humidification, the experiments were continued during winter period and the performance was found to be satisfactory

EXPERIMENT NO.3

To study the air cooling system in lieu of water cooling system:

As the fuel cell reaction is exothermic, it generates lot of heat, hence the stack has to be cooled to reduce the temperature for its better performance. The new fuel cell stack which has been brought here is designed for water cooling and has a capacity of 500 watts. To maintain the stack temperature around 40°C the water flow rate required is 350 ml per minute in place like Chennai were the ambient water temperature is 25" to 30" C. As the ambient temperature of water in Antarctica is very low in summer (3" to 5" C), the water flow needed to cool the stack is only 100 ml per minute. When the

temperature goes down to 0" C and below, it again encounters problem of freezing of water. It requires additional energy source in order to melt the Frozen water before it enters into the stack for cooling. It was therefore decided to use air cooling system instead of water cooling. The small blower. Bosch Taiwan Model No GBL 550 of capacity 2.7 m^3 /min has been used for cooling the stack. The cold air is passed through the stack & the temperature of the stack is maintained around 40" C by varying the air flow. Based on this experiment it is clear that air can be used as a cooling media. However, this also requires additional power source. Since the highly chilled wind is always available, it is suggested to make use of this natural source for cooling the stack. Hence the present PEMPO stack design needs modification which can be incorporated in the future stack design.

EXPERIMENT NO. 4

To study the humidification of gases using membrane as a medium:

To humidify the Hydrogen & Oxygen gases the small assembly consisting of membrane placed between two grooved graphite plates was made. Gases were passed through the graphite plate and it was further passed over one side of the membrane and water was passed other side of the Membrane. The initial humidity of the gases is measured without passing water in the experimental setup. Then water was introduced through the graphite plates. The membrane took up water, in turn gases passed over the membrane got humidified by taking up the moisture from the membrane. This process was repeated twice to increase (he humidity of the gases. It was observed that the gas humidity has been increased from 5% to 80%. This clearly. indicated that the internal humidification was possible even at low water temperatures.

The present humidification system requires external heating and other auxiliary sub-system. This adds weight to the fuel cell & also causes inconvenience for handling & operating the fuel cell at high temperature. For effective humidification and for simplification, it has been suggested to design an internal humidification system, which could be the integral part of the fuel cell configuration.

EXPERIMENT NQ. 5:

To study the charging and discharging characteristics of metal hydride:

Presently. Metal Hydride unit is used for storing the Hydrogen. From the safety point of view handling metal hydride is easier than direct handling of Hydrogen cylinder. There is only physical absorption of the Hydrogen gas. so whenever required hydrogen can be relased without any difficulty. When the metal hydride is charged a heat is generated which is called asexothermic reaction and

when gas is released the system gets cooled. which is known as endothermic reaction. Since the charging is exothermic, it takes longer time to charge metal hydride unit in hot regions of the country. It was found after few experiments that, in the cold region like Antarctica, the charging and discharging was much easier since the unit got cooled immediately due to prevailed climatic conditions.

EXPERIMENT NO. 6

Fuel cell coupled with DC-DC Converter and Inverter:

Unlike other battery power source the Fuel Cell starting voltage and operating voltage are variable. In order to get a constant power output of DC or AC. we require DC-DC converter for constant DC supply which could be useful for battery charging. The Inverter output (AC) could be useful for stand alone power source. For carrying out this experiment, the two fuel cell units having voltage of 18 volts each, were connected in series electrically which were in turn connected to a specially designed Inverter with DC-DC converter. The input voltage from the Fuel cell varied from 36 Volts to 22 Volts. However from the Inverter, constant voltage of 230 Volts AC was produced. In addition to AC output, the constant DC output of 24 volts was also produced. The AC load was used to glow the bulbs in the Shivalik Hut. The DC load was used for charging the batteries as well as it was used for dummy load for glowing 24-volt bulbs.

EXPERIMENT NO. 7

To study the single cell performance at low temperature:

This experiment could not be carried out due to failure of Electronic Load Box' which was found to he damaged during transportation. Efforts were made to repair the unit at site but same could not be rectified.

Few experiments were also carried out during the winter as per the guidelines received from Director. R&DE. (F.ngrs) to observe behavior of the.Cell in low temperatures.

CONCLUSION

Fuel Cells with the present configuration worked satisfactorily. However experiments conducted showed that certain modifications in system design for application in cold region engineering are required, such as thermal insulation of gas pipe connection, air cooling of fuel power stack instead of water cooling and internal humidification of fuel cell stack. For requirements of large outputs, hydrogen and oxygen manufacturing plants will have to be installed at site since carrying these gases in cylinders on large scale may pose handling & logistic problems. Also manufacturing of the gases at site on large scale, will require sophisticated set up & trained manpower. Considering the present technology in the country, use of Fuel Cell power source for bulk power requirement may not be cost effective. However, this could be used as a Hybrid power source in conjunction with Diesel Generating sets and Wind power for a step forward towards environmental friendly power source.

2. CONDITION MONITORING OF GENERATING SETS

INTRODUCTION

At present, electricity is generated, at Maitri, using Generating Sets running on Aviation Turbine Fuel (ATF). The Generators are running through out the years. & are the lifeline for Maitri. During the running of generators, vibrations of engine, alternator and coupling produce some specific vibration signatures/signals. These vibrations Signatures are captured & analysed daily using COMPASS software.

PRINCIPLE

Vibration signatures of any machine can be analyzed to find out the health of the running machine thereby early detection of developing fault and initiate appropriate action for the protection of the machine. When fault begin to develop, the dynamic process in the machine changes and some of the forces acting on machine parts, also change thereby influencing variation in vibration level. Regular vibration measurements and analysis indicate machine health trends and the need for maintenance. By means of regular vibration measurements, the fault in the machine is detected. Vibration measurements are extrapolated in order to predict when an unacceptable vibration levels are likely to be reached and forecast as to when machine may need servicing. This is called TREND MONITORING and it allows the engineer to plan for repairs well in advance.

To provide optimum cost effective monitoring and assure total machine protection and early recognition of faults OFF LINE, machine monitoring system consisting of COMPASS software, Pentium work station and intelligent data logger model 2536 of B & K Denmark was used.

During XVIII IAE one generating set was run continuously for 9 days from 28th Jan.99 to 4th of Feb.99. Vibration measurements were taken daily at predetermined measuring points on the housing of the genset. The acquired vibration spectrums were analysed and showed safe operation of further 1800 hours.

POTENTIAL FAILURE MODES (PFiVIs):

Potential failure modes envisaged are given in the Table No.1 with the possible remedies.

Table -I

Potential Failure Modes	Description	Remedy
Cracked Shad	Crack develps in shaft due to fatigue or corrosion damage	Major repair required to shaft
White Metal Bearing Failure	Rubbing between rotating and stationary components due to thermal distortion and misalignment (Hgh Vibrations)	Correct fault and restore clearance
Generator rotor earth	Rotor winding insulation wears and fails causing earth rings End rings damaged due to arcing and overheating	Replace end rings. Long delivery period for this
Shaft bend	Temporary bend in shaft due-to thermal distortion. Prevents run ups and loading of machine	Strip down to check gland clearance, key wear
Loss of rotating part	Blade or cover band fails causing minor unbalance. Major repairs are expected if not attended in time.	Long repair damage
Alignment shift	Changes in Shaft alignment and shaft to casing alignment. Due to guide key wear, foundation movement etc.	Major maintenance
Foundation or Pedestal crack	Cracking in the support structure changes the flexibility of the support and vibration results	Outage to locate and repair the cracking
Generator end ring replacement	Generator end rings can move after maintenance causing bal-	Require Re-balancing

Considering above modes of failure faults and the corresponding frequencies of the dominant vibrations, have been calculated and given in Table No.2.

Table 2

Nature of Fault	Nature of Fault	Nature of Fault
Rotating Members out fo Balance	25 Hz	Radial
Misalignment and Bent Shaft	Usually 25 often 50 sometimes 75/100	Radial and Axial
	Bearing SKF 6319	Bearing SKF 6316
Inner race Defect Outer race Defect Ball Defect Cage defect	122.6 77.4 104.95 97	Radial and Axial 7.14 9.6
Journal Bearings Loose in Housing	125 8.33	Primarily Radial
Oil Firm Whirl or Whip in Journal Bearings	12 Hz	Primarily Radial

After the introduction of health monitoring system during XV expedition and further followed by acquisition of vibration signatures over past two expeditions, it was proposed to transmit the generated data over SATCOM using online connectivity during XVIII expedition. In order to achieve this, the following mode of operation was planned:

1) Connect the COMPASS CVM to SATCOM terminal using MODEM.
2) Install the necessary software on present COMPASS CVM at Maitri.
3) Make necessary changes for MODEM communication.
4) Make connection to SATCOM telephone line, which is available at Maitri.
5) Trial Communication with R& DE (E), Pune, over the same line by giving them Dial in Access rights in COMPASS CVM at Maitri and vise versa.

The plan was to be executed during SUMMER period at Maitri. However due to constraints of using present telecommunication setup & provision of independent telephone connection to CVM terminal, it was proposed to transfer the generated data using only email facilities.

The Spectrum Data was collected & analysed daily during summer as well as winter for finding out the probable faults in the Engine & Alternator of the Generators.

No major faults were detected. The data generated in UNIX platform was transmitted from time to time to R & DE (E) through email after converting it in DOS CP mode.

CONCLUSION

With the recurring data acquisition we were able to help and guide the maintenance team in diagnosing the probable faults in the engine & alternators. No major faults were detected during the tenure. Minor faults like loosening of fan belts, pulleys etc were detected and rectified by the maintenance team.

3. HEALTH MONITORING OF MAITRI FOUNDATION

INTRODUCTION

Maitri-Indian Antarctic Station was built during the three consecutive expeditions commencing from 1986 and was commissioned during IXth expedition i.e. in 1989 since then the structure has undergone cyclic stresses due to extreme cold and high wind conditions during the last 10 years. Hence the proposal was made by R & DE (E) to monitor the health of foundation during XVIII ISEA based on Computer controlled Strain measuring system.

Following tasks were carried out during summer:

1) Identification of extrems stress bearing columns of Maitri Foundation.
2) Preparation of columns surfaces prior to strain gauge installation.
3) Installation of 120 Ohms Strain gauges.
4) Cabling work pertaining to above tasks.
5) Installation of Multi channel Computer Controlled Data Acquisition System.

The multi channel computer controlled system consisting of Computer add on data acquisition card and Strain gauge controllers with scanning facility was installed Total 7 channels were possible to be acquired. The eighth data channel was kept reserved for wind speed and direction. The stresses were monitored continuously by Winter Over Team, upto 31 Dec 99.

In addition to monitoring, thorough visual examination of all the columns and foundation framework was carried out for probable cracks & deformations. It was observed that no cracks/deformations were developed even after exposure to severe winds and climatic conditions. No uneven settlement of columns was noticed. The painting was in good condition, however, application of two coats of

Epoxy based red oxide paint is recommended for maintenance which will give better protection to the foundation system and thus increase the life span.

CONCLUSION

More sophisticated computer based automated systems may be developed in Future, for online monitoring of Stress/Strain and other parameters like Wind speed, Temperature etc.

4. HEALTH MONITORING OF 28m MAST

INTRODUCTION

The 28m mast designed and developed by R & DE (Engrs) was erected during XI expedition for mounting NPL and NAL antennas. The mast also has been used for mounting various sensors and instruments for various studies being carried out by different laboratories. The structural parts of the mast have been subjected to very high wind speeds, during blizzards and extreme low temperatures for the past several years. To study the effect of various stresses caused by the prevailed adverse climatic conditions, FLA-6-11 type strain gauges having gauge resistance of 120 ohms were mounted during XVII th expedition. The strain data has been collected on daily basis, upto 31 Dec 99 using Digital strain indicator model 3500, and Switch & balancing unit. The instruments were installed at Nandadevi hut. Visual inspection of various structural parts was carried and no deformation was noticed.

CONCLUSION

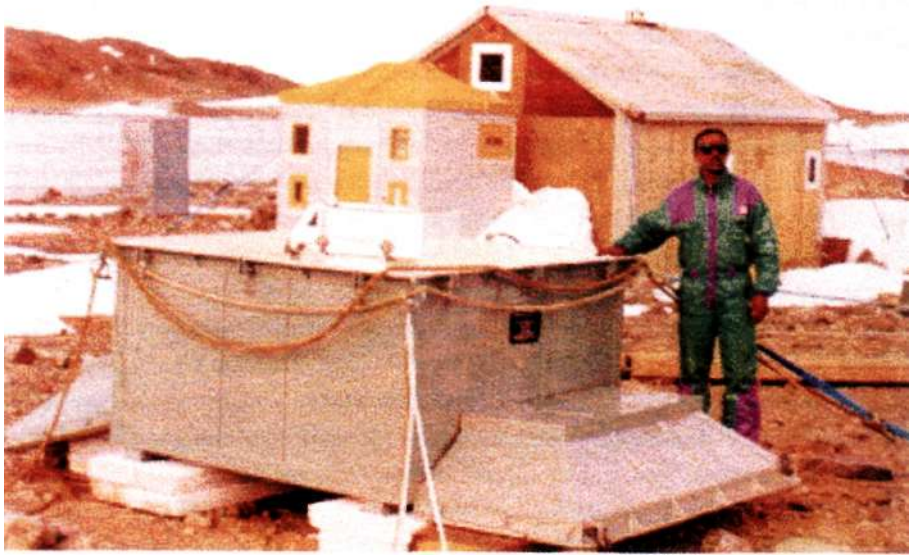
At present the data was collected manually. More sophisticated computer based automated systems can be developed, for online monitoring of Stress/strain and other parameters like Wind speed, temperature etc, in future.

5. ERECTION & COMMISSIONING OF SPECTROPHOTOMETER SHELTER FOR IMD

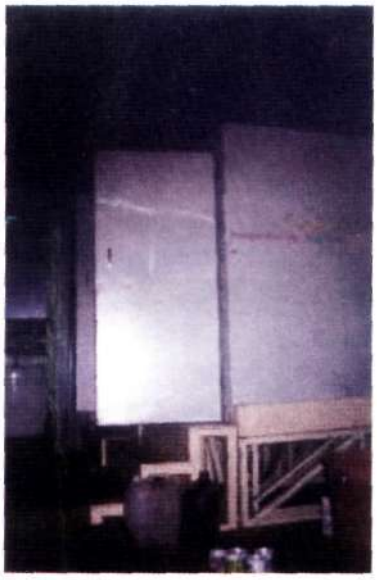
Appropriate Site was selected for erection of shelter in consultation with IMD Representatives. The shelter was shifted to the site & mounted on Siporex concrete slabs. It was then properly anchored with nylon straps at appropriate locations. The shelter has undergone several Blizzards during winter reaching beyond 100 knots. Some of the blizzards lasted for more than two to three days. The shelter was found to be intact even after the blizzards. The Spectrophotometer instrument was installed & commissioned by IMD. The top cover of the shelter was modified suitably so as to fulfil requirement of IMD.

Hrict technical Specifications

* Material : Lightweight Aluminium alio) weldablc extrusions & sheets (RDE-40)
* Insulation : Rigid Polyurcthane foam ot'density 40 kg/m3 with FRP lining 2.5 thk.
* Locking : SS Wing bolls Tor lop lid
* Anchorage : Nylon strapping with locking system (Zebra Weblift)
* Overall : L80m(L) x 1.80m(D) x 1.40m(H) Dimensions
* Design to withstand max. wind speed of 200 KMPII & ambient temperature of 500 C



6. ERECTION & COMMISSIONING OF NEW BATHING MODULES



The existing old Bathing Modules and old Chemical toilet modules along with its accessories were dismantled & removed out of 'C Block. Two panels near the C" block were cut opened to enable removal of the same.

The construction of new bathing modules (Type A') was completed sequentially as per the guidelines given in the L^ser Handbook which includes laying of foundation beams. Erection of panels, sealing of all the joints. Plumbing work & provision of miscellaneous fitments. The modules were commissioned after Inspection & trials. These are functioning satisfactorily.

Bathing Modules (Type B). Qty 04 Nos., have been kept aside for futuristic use.

Brief Technical speci Mentions

Steel Beams for foundation

Plastic coated Gl sheets with PU foam insulated sandwich panels for walls, roof & flooring .

C A M type locking systeii'i forpanels

* FRP bathing tub

7. INSTALLATION OF NEW RADIATORS

All the existing old Radiators were removed & new Plate type Radiators with thermostat control (De Longhi make), 40 Nos were installed in Living rooms, Ml Room, Office, Lounge, Central passage & Toilet corridor. These radiators are functioning satisfactorily. These Radiators are likely to choke frequently due to the suspended particles of corroded pipe/Tank material. In view of this, it is suggested to replace the existing Hot water, Expansion tanks, & the pipelines at the earliest since they were found to he highly corroded and pitted. These items have been demanded for replacement during XIX Expedition.

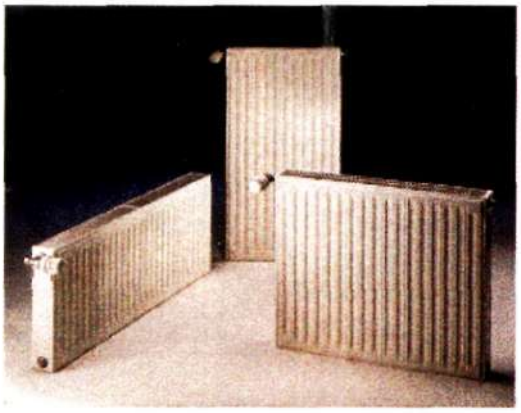
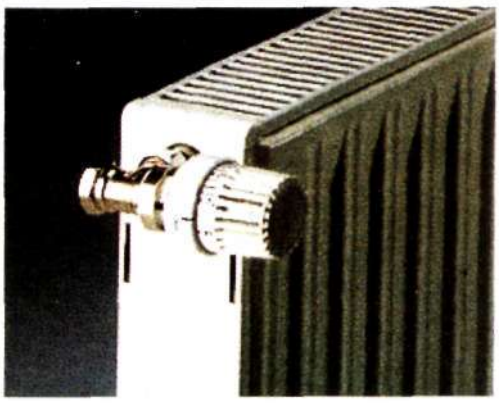


PLATE TYPE RADIATORS



THERMOSTATIC CONTROL ON PLATE TYPE RADIATOR

ACKNOWLEDGEMENT

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