Council of Scientific & Industrial Research

National Aerospace Laboratories, Bangalore, India

ADVANCED COMPOSITES DIVISION (ACD) AND CENTRE FOR SOCIETAL MISSIONS AND SPECIAL TECHNOLOGIES (CSMST)

Vidhya V P

CSIR-NAL

- Premiere research institute under CSIR
- Established : **1959**
- Headquarters: **Bangalore**
- **Mission:**
  - Development of national strengths in aerospace sciences and technologies, infrastructure, facilities and expertise
  - Advanced technology solutions to national aerospace programmes
  - Civil aeronautics development
- Two divisions of NAL visited – ACD and CSMST

DIVISIONS

- **ADVANCED COMPOSITES DIVISION (ACD)**
  - Design and development of composite structures for both military and civil aircrafts
  - Pursuing R&D activities in the areas of Structural Health Monitoring, Damage Tolerant Structures, Processing of Thermoplastics, 3D Composites and Nano Composites
- **CENTRE FOR SOCIETAL MISSIONS AND SPECIAL TECHNOLOGIES (CSMST)**
  - Adaptation of high end aerospace technologies in the societal missions
  - Areas - Wind energy, Autoclaves, Micro air vehicle technologies, Ground and air borne radomes
- Autoclave technology was developed under ACD & CSMST

AUTOCLAVES

- Pressure vessels used to process parts and materials which require exposure to elevated pressure and temperature
- NAL uses autoclaves for curing of aircraft parts made from high performance composites
- Curing ensures superior structural integrity, elimination of stress concentration due to drilling, shorter assembly cycle
- Autoclaves are costly, used only when isostatic pressure is needed and if the shape of the material is complex

PRINCIPLE OF OPERATION

- Autoclave applies both heat and pressure to the workload placed inside it
- Two classes of autoclaves
  - Pressurized with steam
    - Should withstand exposure to water
  - Pressurized with gas
    - Greater flexibility and control of the heating atmosphere

Indigenous Autoclave Technology

Autoclaves at NAL

- CSIR-NAL has the capability of building large, computer controlled, state-of-the-art autoclaves along with associated subsystems.
- Operational autoclaves
  - Mark I
  - Mark II
  - Mark III
  - Mark IV
- Mark IV has largest space
- Mark III operates at high pressure and high temperature

Transfer of technology

- CSIR-NAL has supplied 4m dia x 8m length to HAL, Bangalore
- Revamped autoclaves for Vikram Sarabhai Space Centre, Trivandrum
- Manufacturing and marketing right of autoclaves is given to Unique Chemoplant Equipments, Mumbai
- Fabrication of electrical, control and instrumentation systems for autoclaves by Datasol, Bangalore

Mark IV

- India’s largest autoclave for composite processing
- 2009

Specifications

- 4.4 m dia x 9 m length
- 7.14 kg/cm² pressure, 250°C temperature
- Rate of heating : 0-5°C/min
- Rate of cooling : 0-3°C/min
- Control system : Dual computer, Recorder, PLC & PID controller based; In-house developed software

Design drivers

- Simplicity, Fail-safe & fault-tolerant, Open communication system (non-proprietary), Easy Maintainability

Mechanical system

- Davit arm door with innovative steering mechanism & bearing design
- Lock ring-less door locking system
- Optimized spherical dished door
- Air circulation duct on the entire circumference for better temperature uniformity
- Heat exchanger with variable heat transfer area & extruded finned tubes for maximum heat transfer
- Gland-less pressurized blower motor
- 3-level loading trolley with pneumatic bridge & electromechanical loading system
- Nitrogen gas pressurization system with proportional control valves & exhaust silencer with 276 m3 at 17 barg storage capacity
- Thermal insulation system with ceramic fibre blankets
- 3-tier layout of sub-systems

C & I System and electrical system

- Fail-safe design (Redundancy)
- PC, PLC, PID controller and Recorder based
- Auto, semi-auto and manual modes of operation
- Master and stand-by computer control
- Redundant control sensors for temperature and pressure
- DC power supplies with redundancy
- Identification and management of single point failures
- Remote monitoring through Local Area Network
- Stand-by system for vacuum pump, cooling pumps, hot water pumps, blower drive, SCR controller etc.,
- Blower operation through Speed Drive or Star-Delta starter
- Heater power steering logic
- Modular and expandable LTPMCC

Safeties

- Man-in-clave
- Fool-proof door lock safety device with alarm
- Emergency dump and shut off switches
- Separate Earth leakage trip for each heater bank
- Interlocking of door operation and pressure application.
- Health checking
- Auto-hold in case of higher temperature gradient
- Multiple modes including manual override if the computer, PLC and the control system fails
- Fire (Nitrogen gas for pressurization)
- Over pressure (Pressure switch, emergency exhaust & safety valves)
- Power failure management
- Over temperature
- Fault alarms
- Fault diagnostics

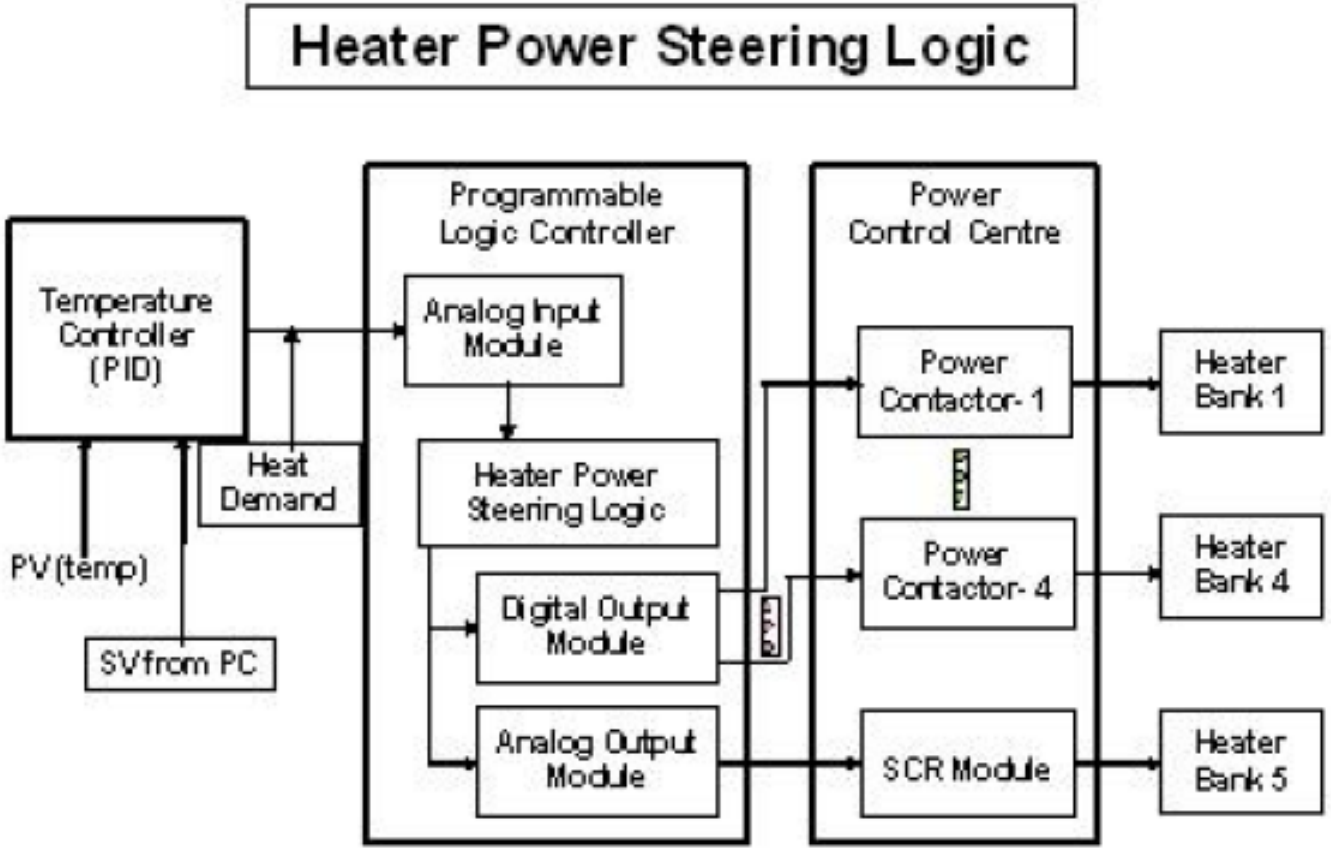
Electrical heating

- Electrical heating – clean, compact, precise control, operating cost is high
- Heater grouped into banks to reduce load change and improve operability, controllabilty and reliability
- Each heater bank controlled through thyristor controller
- No. of SCR controller equal to no. of heater banks, common control signal from temperature controller – expensive, results in decreased pf and increased harmonic distortion

Heater Power steering logic

- Heat input required to maintain the temperature is much lesser than the total heater capacity
- SCR controller for one heater bank (typically about 20% of the total heater power) and contactors for the rest.
- Implemented on PLC and standard electronic cards

Heater Power steering logic



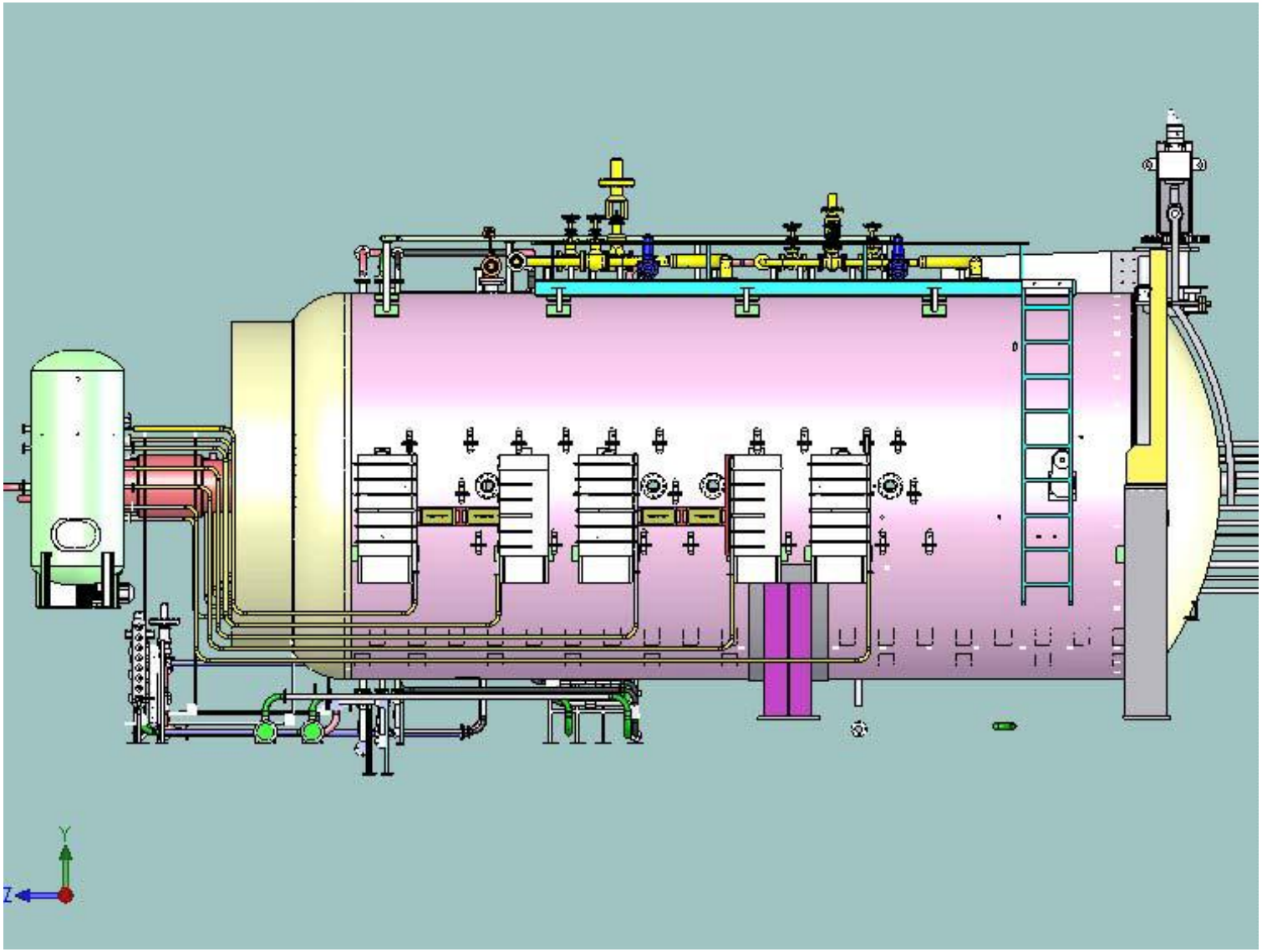
Heater Power steering logic

Heat demand Signal in (%)	HB1 (on / off)	HB2 (on / off)	HB3 (on / off)	HB4 (on / off)	SCR Signal in (%)
0 to 20	Off	Off	Off	Off	0 to 100
21 to 40	On	Off	Off	Off	0 to 100
41 to 60	On	On	Off	Off	0 to 100
61 to 80	On	On	On	Off	0 to 100
81to100	On	On	On	On	0 to 100

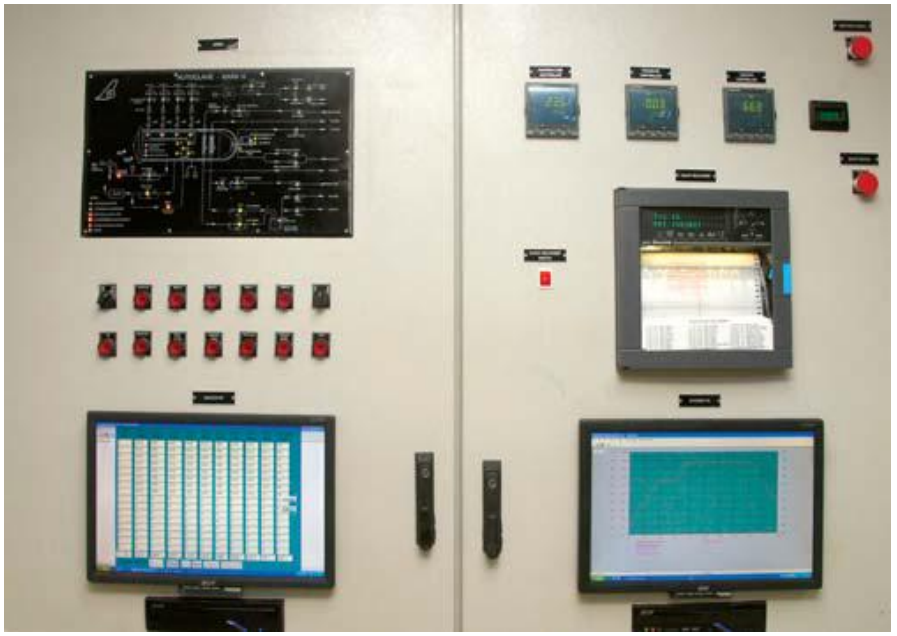
Mark III

- 2010
- High Pressure and High Temperature Autoclave
- 2 m dia x 4 m length
- 350^{o}C temperature, 15 Barg pressure
- Rate of heating : 0 to 4°C/min
- Rate of cooling : 0 to 3°C/min
- Control system : Dual computer, PLC & PID, controller based software, exclusively developed in-house

C & I System and electrical system



MARK III



Mark II

- First Indigenous Computer Controlled Autoclave

Specifications

- 1996
- Working space : 2.8 m dia x 5.2 m / 7.5 m (Variable) length
- 250^{o}C temperature, 7 Barg pressure
- Heating Rate : 0 to 4^{o}C per min
- Cooling Rate : 0 to 3^{o}C per min.
- Vacuum lines : 14 suction lines and 4 measurement lines
- Maximum vacuum at source : 2 Torr (˜3 mbar)
- Modes of operation : Auto, Semi-auto and Manual
- Control System : PC, PLC, PID and Recorder based
- Air circulation system : Fixed speed Blower
- Heater Power : 3 phase, 415V, 210KW

Features

- Variable working volume autoclave with unique twin door technology
- Integrated Door with Loading crab
- Gas and Water cooling medium adapted for optimum temperature control rate

Mark I

- First Indigenous Autoclave Built in 1986 & in Use Till Date

Specifications

- Working space : 1.8 m dia x 4 m length
- Autoclave Door : Hinged Door
- 200^{o}C temperature, 7 Barg pressure
- Number of Thermocouples : 15
- Modes of operation : Auto, Semi-auto and Manual
- Control System : PC, PLC, PID controller and Recorder based
- Air circulation system : Fixed speed Blower
- Heater Power : 3 phase, 415V, 75KW (In 5 banks: 5KW x 15)
- Total Power Rating : 123 KW

References

1. G.M.Kamalakannan, Amit Kumar Gupta, "An improved technique and its implementation for control of high power heaters in large autoclaves and similar plants", Journal of Instrument society of India, Vol. 40, No. 2, June 2010
2. http://www.nal.res.in

Thanks