Mechanical Design Review of the Multiplicity and Vertex Detector Cooling Systems

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Presentation Outline

- Introduction - Cooling requirements and review of preliminary designs

- Experimental Testing of Cooling Concepts - Experimental verification of the operation performances of the primary air and liquid cooling systems for the preliminary designs to permit the final mechanical design

- Final Mechanical Design of the MVD Cooling Systems - General system layout, performance specifications, and monitoring/safety subsystems

Introduction

Three Cooling Systems for Various MVD Components:

1. Primary air cooling system for multichip modules (MCMs)
2. Liquid cooling system for low dropout voltage regulators
3. Secondary air cooling system for silicon detectors and enclosure

Full-scale tests performed to:

- Observe operating performances of systems
- Identify potential assembly problems and system limitations
- Provide necessary information for designing and sizing the final MVD cooling system components

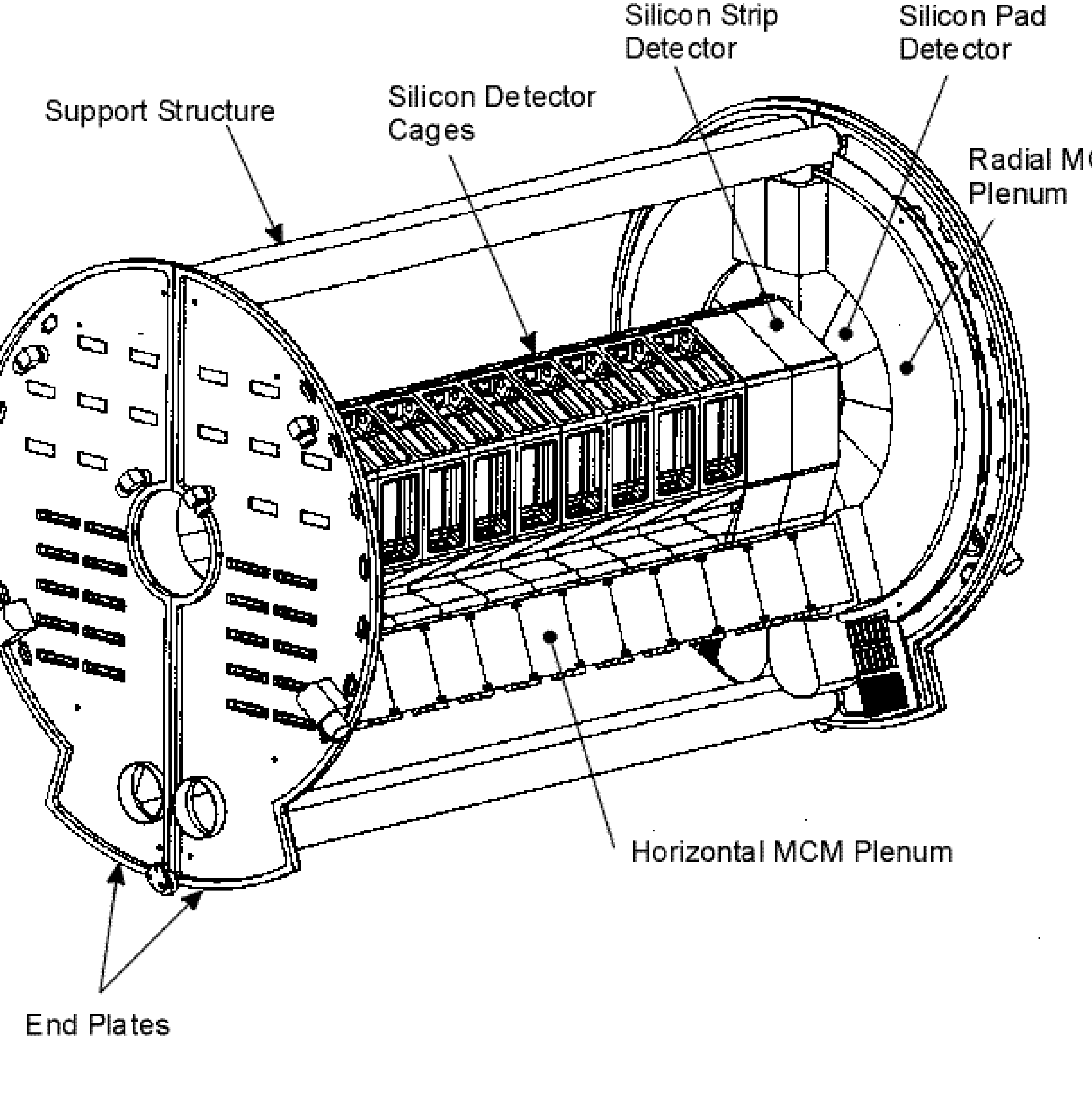


Figure 1. Schematic diagram of the MVD showing the full set of silicon detector cage assemblies, horizontal MCM plenum, support structure, and end plates including motherboards, pad detectors, and radial MCM plenums.

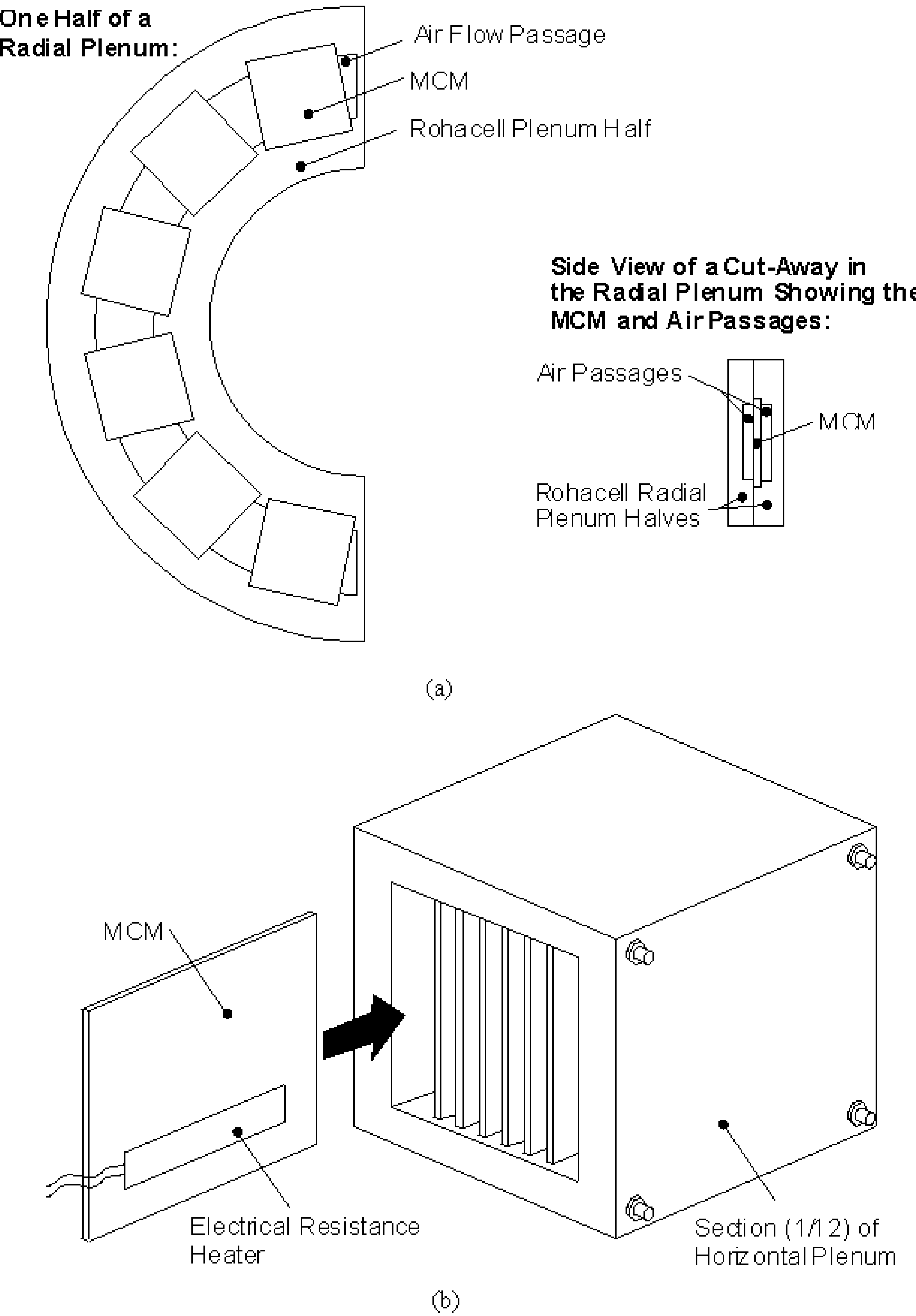


Figure 5. MCM placement in the (a) radial and (b) horizontal plenums.

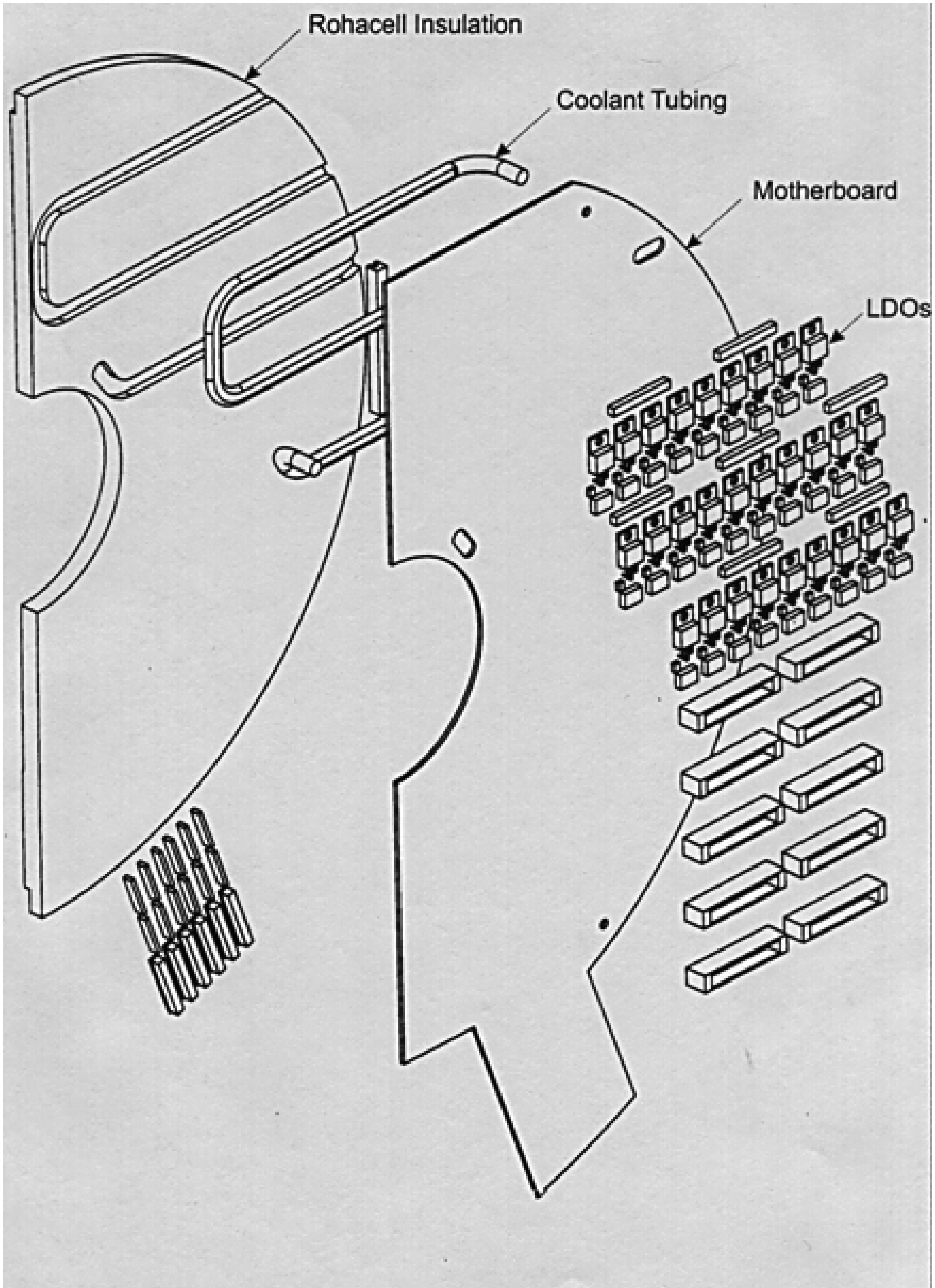


Figure 2. Exploded view schematic of the proposed liquid cooling scheme for the LDOs, showing the relative placement of the various components with respect to the

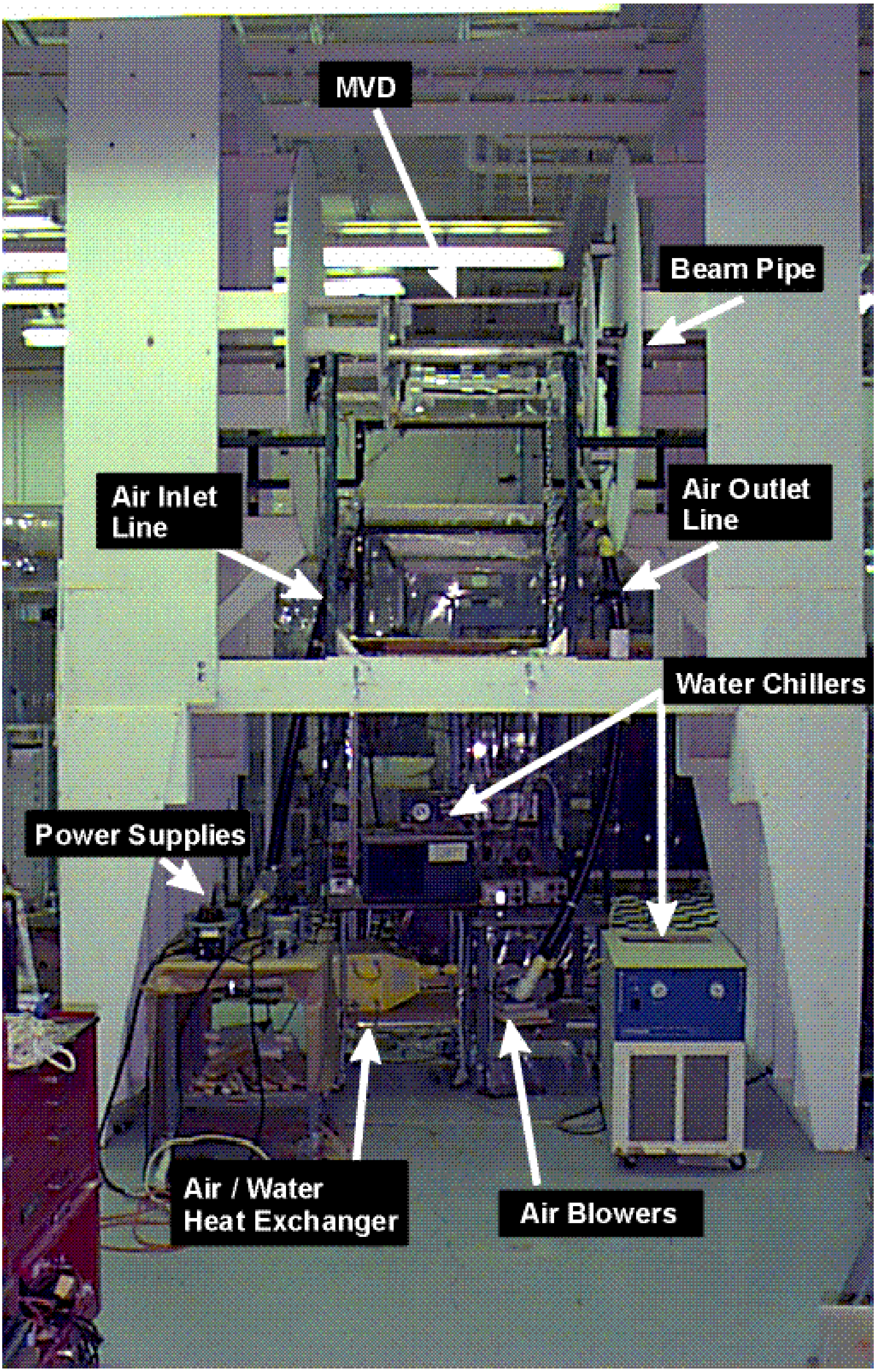


Figure 2. Photograph of the experimental MVD air cooling system set-up.

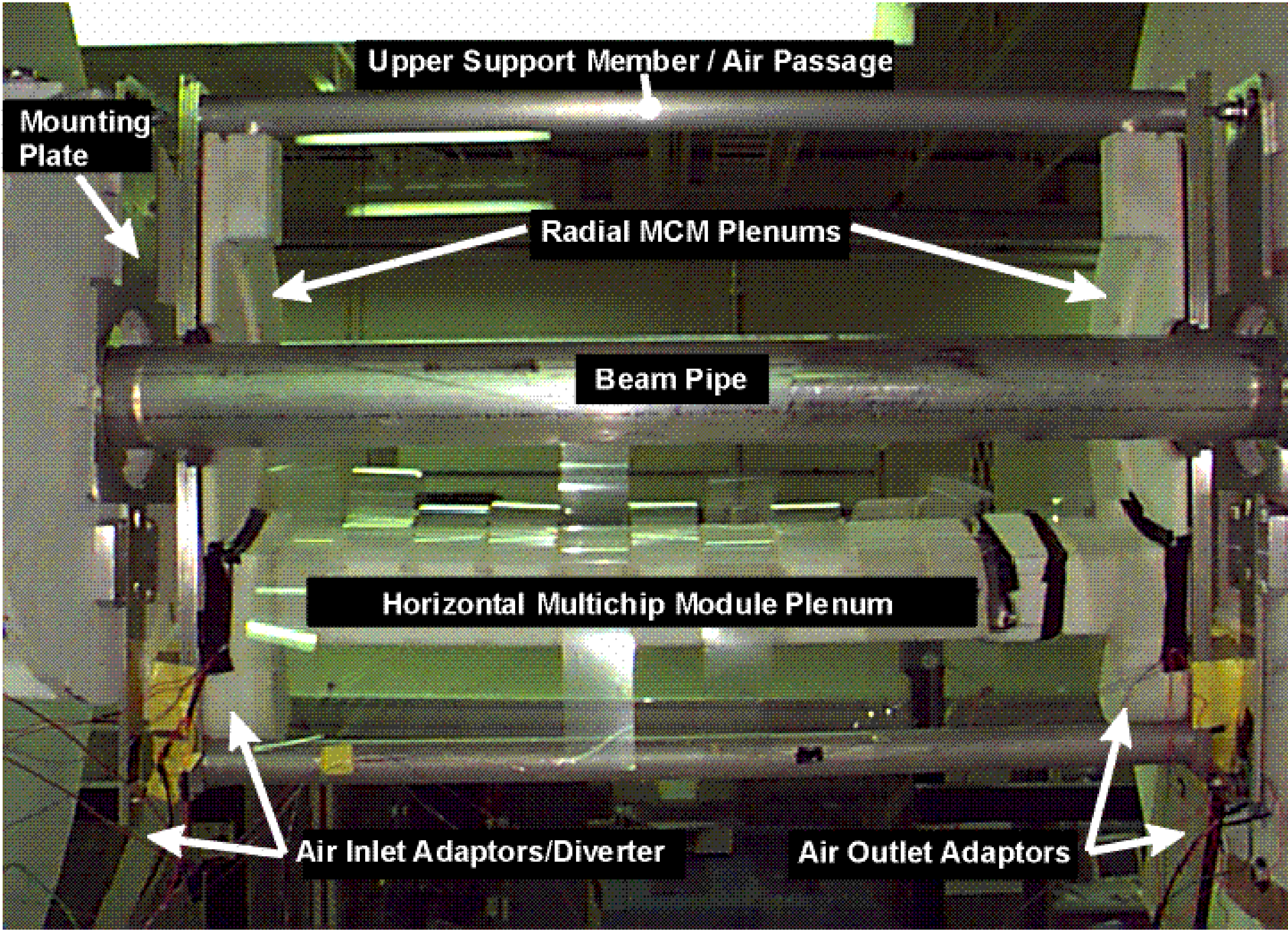


Figure 4. Photograph of the experimental MVD used in the air cooling tests.

Experimental Testing of Cooling Concepts

Primary Air Cooling System for MCMs

Design Criteria

- Maximum allowable MCM operating temperature------------- 50°C
- Cooling system design goal for maximum MCM operating temp.40°C
- Approximate power dissipation of single MCM -------------- 3.8 W
- Cooling air supply temperature -------------------------- 10 to 20°C
- Dimensions of MCM------ 50 mm (H) by 48 mm (L) by 1.7 mm (T)
- Equal and uniform heat dissipation from each side of all MCMs

Parameter Variations

- MCM operating power
- Air volumetric flow rate
- Air inlet temperature

Measurements

- Radial and horizontal plenum MCM operating temperatures
- MVD air inlet and outlet temperatures
- MVD air inlet volumetric flow rate
- Horizontal plenum air velocities
- Accelerations and displacements of subcomponents

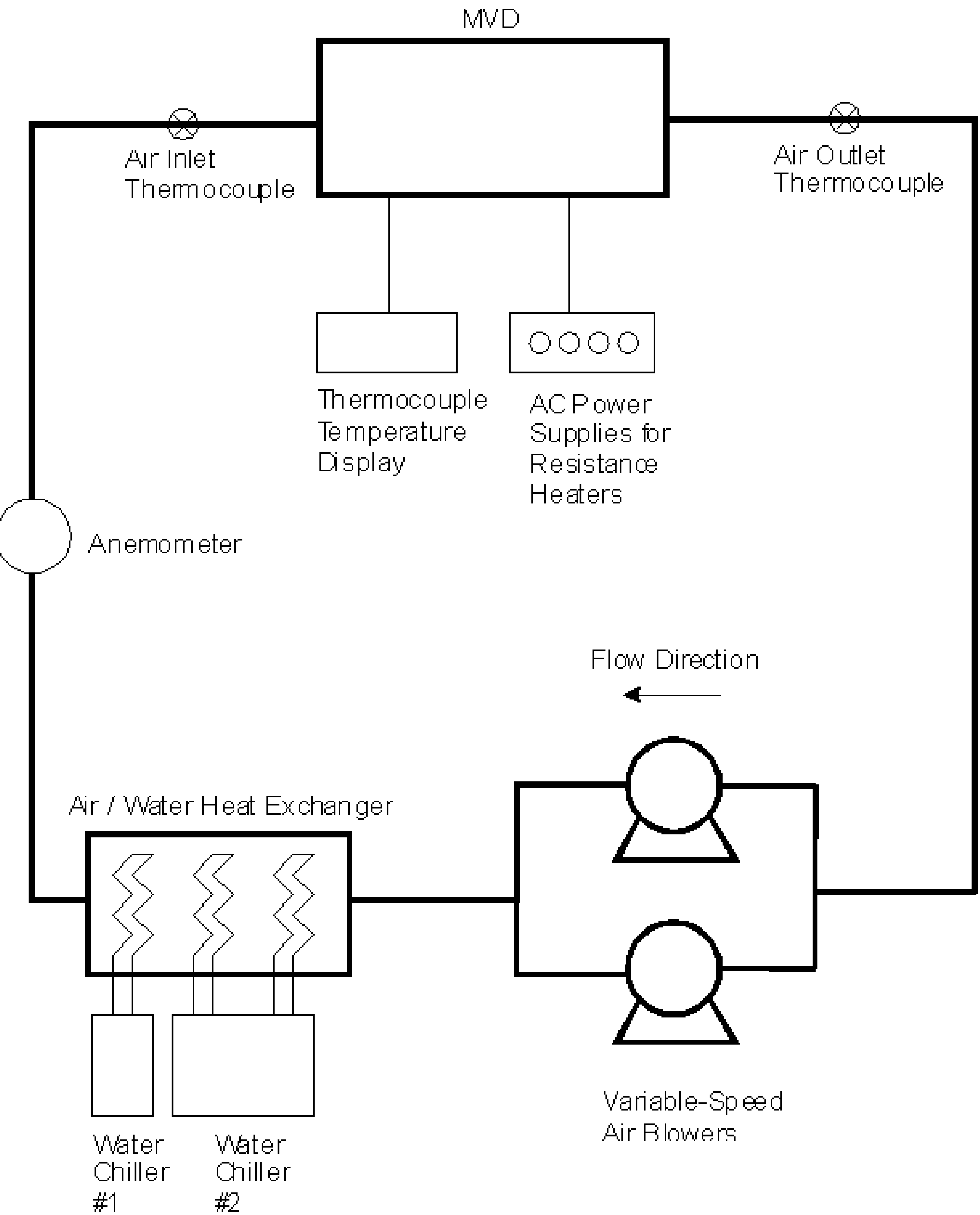
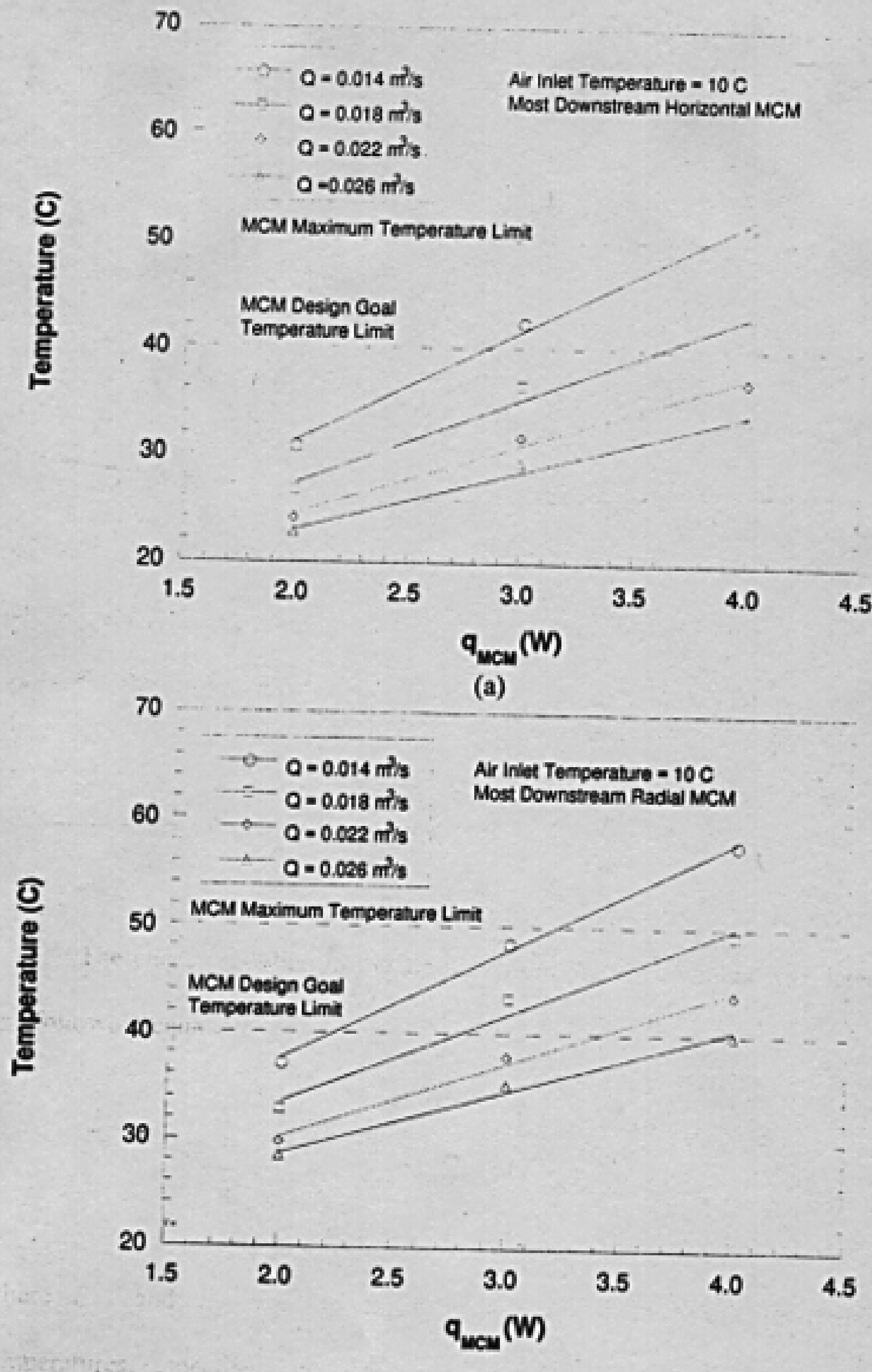


Figure 3. Schematic diagram of the experimental air cooling system for the MVD electronics



(b)

Figure 6. Plots of temperature versus individual MCM operating power for various air volumetric flow rates and an air inlet temperature of 10 C for the most downstream (a) horizontal plenum MCM and (b) radial plenum MCM.

Table 1. Summary of minimum MVD inlet air volumetric flow rates required to maintain the last radial MCM (worst-cooled MCM) at an operating temperature of 40°C for various MCM heat dissipation rates and inlet air temperatures, assuming no changes in the current air flow adapter design.

Individual MCM Heat Dissipation Rate (W)	MVD Inlet Air Temperature (°C)	Minimum Required MVD Inlet Air Volumetric Flow Rate (m^3/s)
2	10	0.013
2	20	0.020
3	10	0.021
3	20	0.026
4	10	0.026
4	20	0.035

Table 2. Summary of maximum accelerations and displacements of several components within the MVD.

Component	Dominant Vibration Frequency (Hz)	Maximum Acceleration (m/s^2)	Maximum Displacement (μm)
MCM	1,111	60.2	1.24
Aluminum Structural Support	200	2.5	1.60
Rohacell Air Inlet Plenum	459	12.1	1.45

Liquid Cooling System for LDOs

Design Criteria

- Cooling system design goal for max LDO operating temp. ----- 40°C
- Maximum power dissipation of a single LDO---------------- 1.0 W
- Cooling liquid supply temperature ------------------------ 5 to 10°C
- Dimensions of LDO main body 9.0 mm (H) by 10.4 mm (L) by 4.5 mm (T)

Parameter Variations

- LDO thermal adapter design
- Coolant tube shape
- Water inlet temperature

Measurements

- 5^{th}, 10^{th}, 15^{th}, and 20^{th} downstream LDO temperatures
- Water inlet and outlet temperatures
- Water flow rate

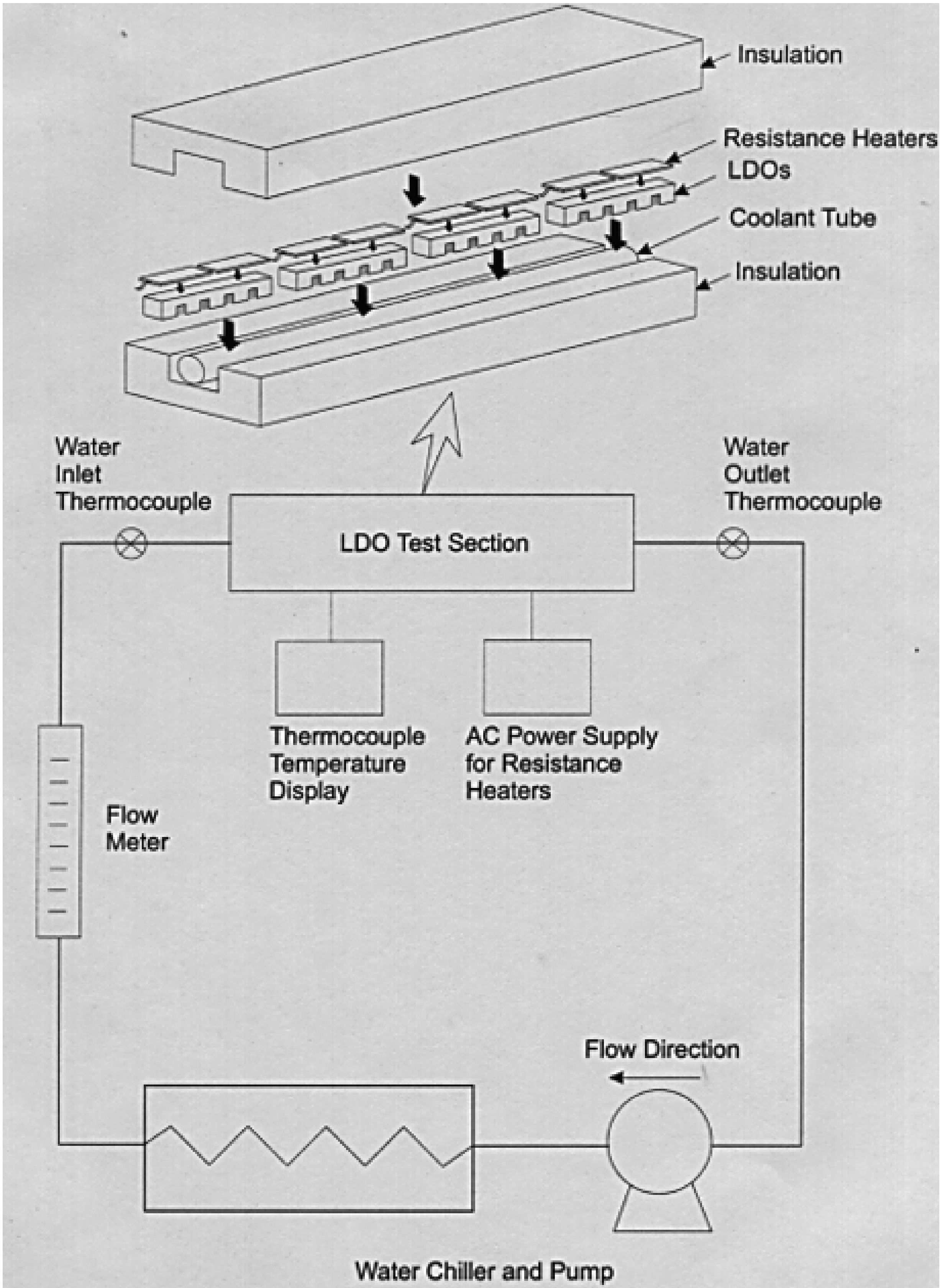


Figure 3. Schematic diagram of the experimental liquid cooling system for the low dropout voltage regulators in the MVD.

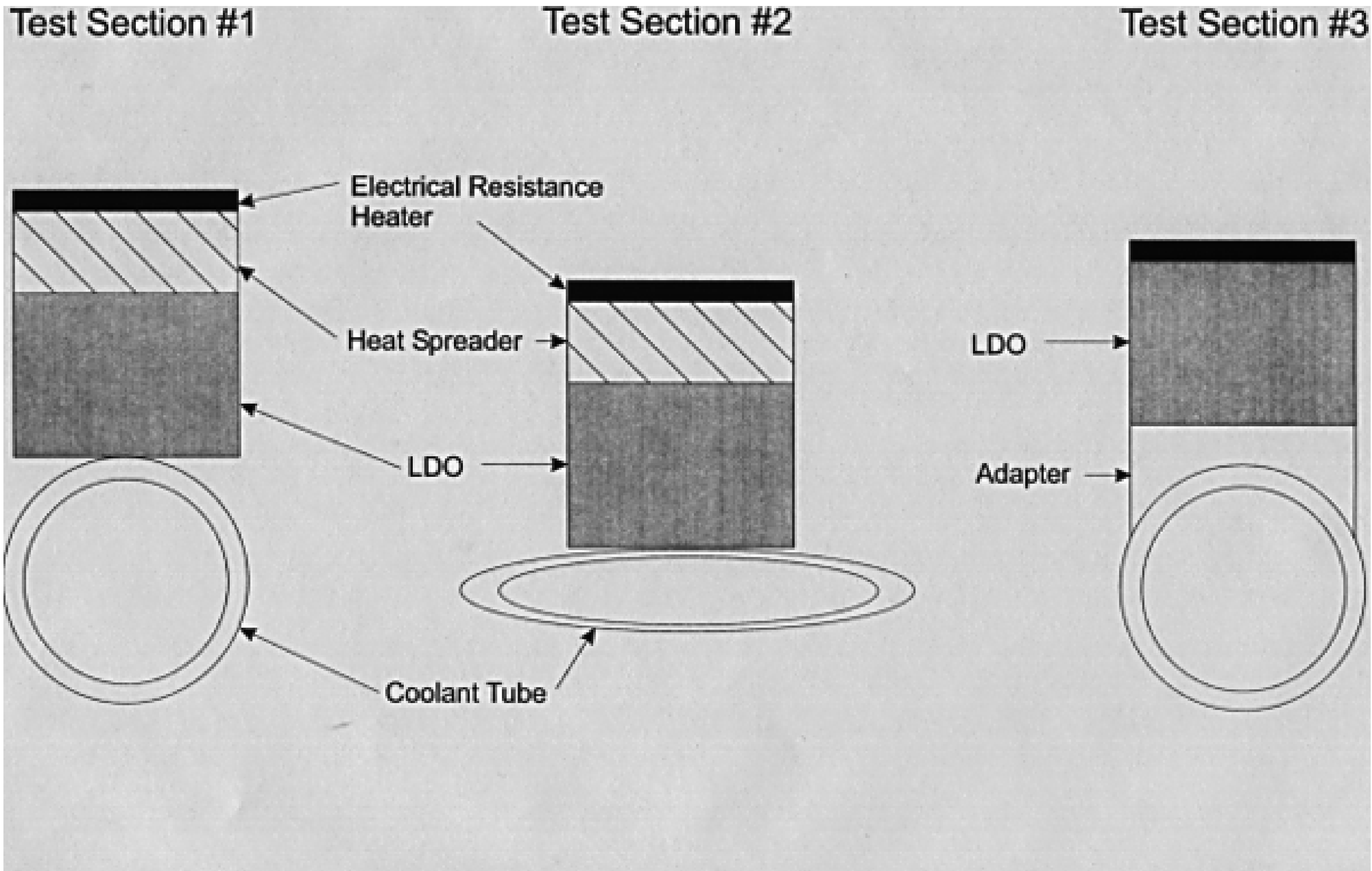


Figure 5. Cross-sections of the three different test sections used in the experiments.

Table 1. Summary of experimental heat transfer data and energy balance checks using Equation (1) for an individual LDO power dissipation of 1 W and a water flow rate of 220 cc/min.

LDO/ Coolant Tube Config. *	Inlet Water Temp. (°C)	Outlet Water Temp. (°C)	5th downstream LDO Temp. (°C)	10th downstream LDO Temp. (°C)	15th downstream LDO Temp. (°C)	20th downstream LDO Temp. (°C)	% Diff. In Energy Balance of Eqn. (1) (%)
1	6.6	> 10.0	> 70.0	> 70.0	> 70.0	> 70.0	
2	6.6	8.1	40.0	40.9	47.6	48.3	15.4
3	5.1	6.4	32.7	27.2	32.0	30.0	> 0.1
3	6.4	7.9	32.6	27.1	34.8	29.6	15.4
3	9.9	11.1	36.3	31.4	36.5	33.8	7.6

*1. Round tubing, no LDO adapter
2. Flat tubing, no LDO adapter
3. Round tubing, LDO adapter

Final Mechanical Design of the MVD Cooling Systems

General System Layout (See figure)

- Two primary air cooling systems for each half of the MVD to cool MCMs
- One liquid cooling system for entire MVD to cool LDOs
- One secondary air cooling system for entire MVD to cool enclosure and silicon detectors

Control and Monitoring

- Pumps, blowers, and refrigeration thermostats set prior to start-up.
- Continual monitoring of coolant temperatures, flow rates, and air relative humidities.

Placement of Components (see figure)

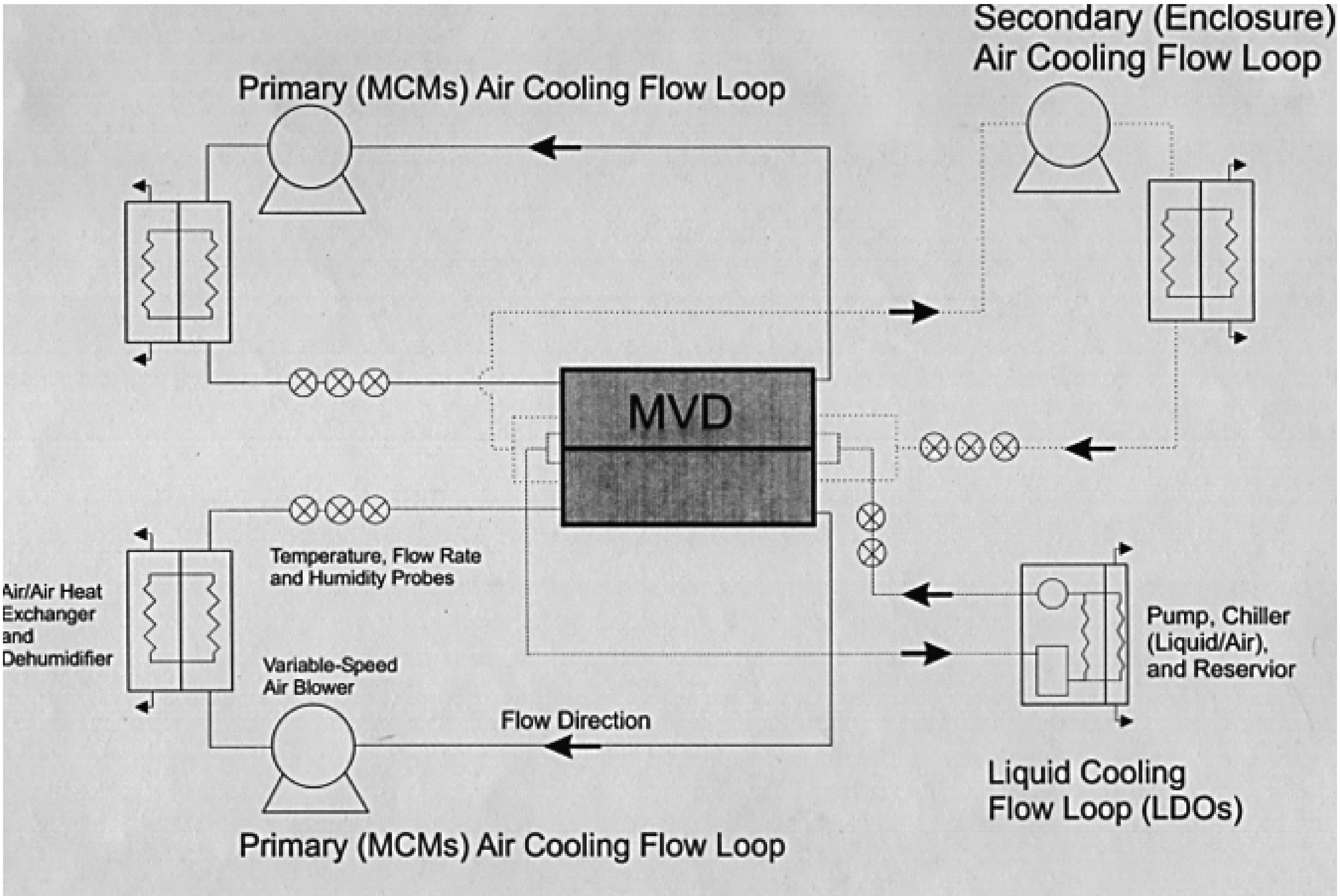


Figure 2. Schematic diagram of the MVD's three different cooling systems.

References

Bernardin, J. D., Bosze, E., Boissevain, J., and Simon-Gillo, J., 1997, “An Experimental Investigation of Air Flow Induced Vibrations within the Multiplicity and Vertex Detector,” Technical Report LA-13319-MS, Los Alamos National Laboratory, Los Alamos, NM 87545.

Bernardin, J. D., Bosze, E., Clark, D., Boissevain, J., and Simon-Gillo, J., 1997, “An Experimental Investigation of an Air Cooling Scheme for the Multi-Chip Modules of the Multiplicity and Vertex Detector,” Technical Report LA-13320-MS, Los Alamos National Laboratory, Los Alamos, NM 87545.

Bernardin, J. D., and Bosze, E., 1997, “An Experimental Investigation of a Liquid Cooling Scheme for the Low Dropout Voltage Regulators of the Multiplicity and Vertex Detector,” Technical Report, Los Alamos National Laboratory, Los Alamos, NM 87545.