NATIONAL CENTRE FOR RADIO ASTROPHYSICS

Ver 1.0 Date : 11/01/2017.
IMH/AKB

Internal Technical Report

Report on Efficient Cooling Arrangement for GSB system.

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Document history :

Revision	Date	Modification / Change
Ver. 1.0	11/01/2017	Initial version

Objective : To propose a suitable cooling arrangement for the GMRT Software Backend (GSB) system to bring down the components like Computer Harddisks failure. Also the GMRT Wideband Backend (GWB) receiver for the uGMRT co-exists with the GSB in the Central electronics building (CEB).

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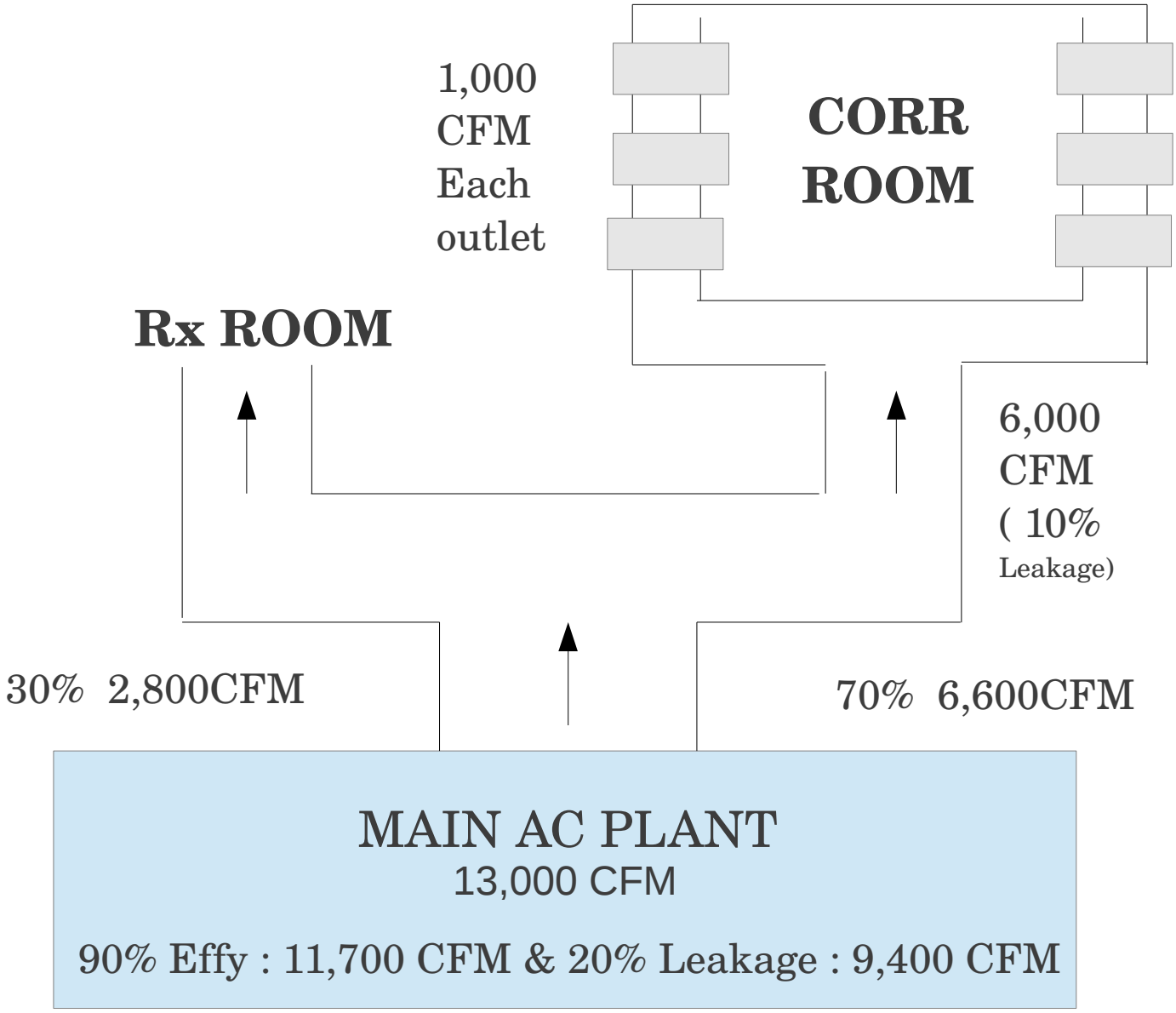
1. Introduction :

A GMRT software backend (GSB) is a real-time or off-line processing pipeline that runs on a super-computer or cluster of computers. The rapid growth in general purpose computing power during the last few years had made it possible to compete with the processing speeds of dedicated hardware. Besides this, fast data transport links between computers are now possible due to the availability of high speed gigabit networking. Storage media have also gone through a revolution in the last few years, in terms of capacity and throughput. All these recent advancements have made it attractive to attempt designs of software backends for radio astronomy. This is aided by the fact that the computing required for the processing of signals from a multi-element interferometric array is very well suited for implementation on multi-processor computers. Use of commercial off-the-shelf (COTS) components and software processing blocks significantly reduces the several years of development time required for hardware backends. It also makes the upgrades much easier, by replacing with faster computers without spending effort in rebuilding the processing blocks again. The algorithms implemented in software are much more flexible; new features can be added easily, and new regions of parameter space can be explored very conveniently.

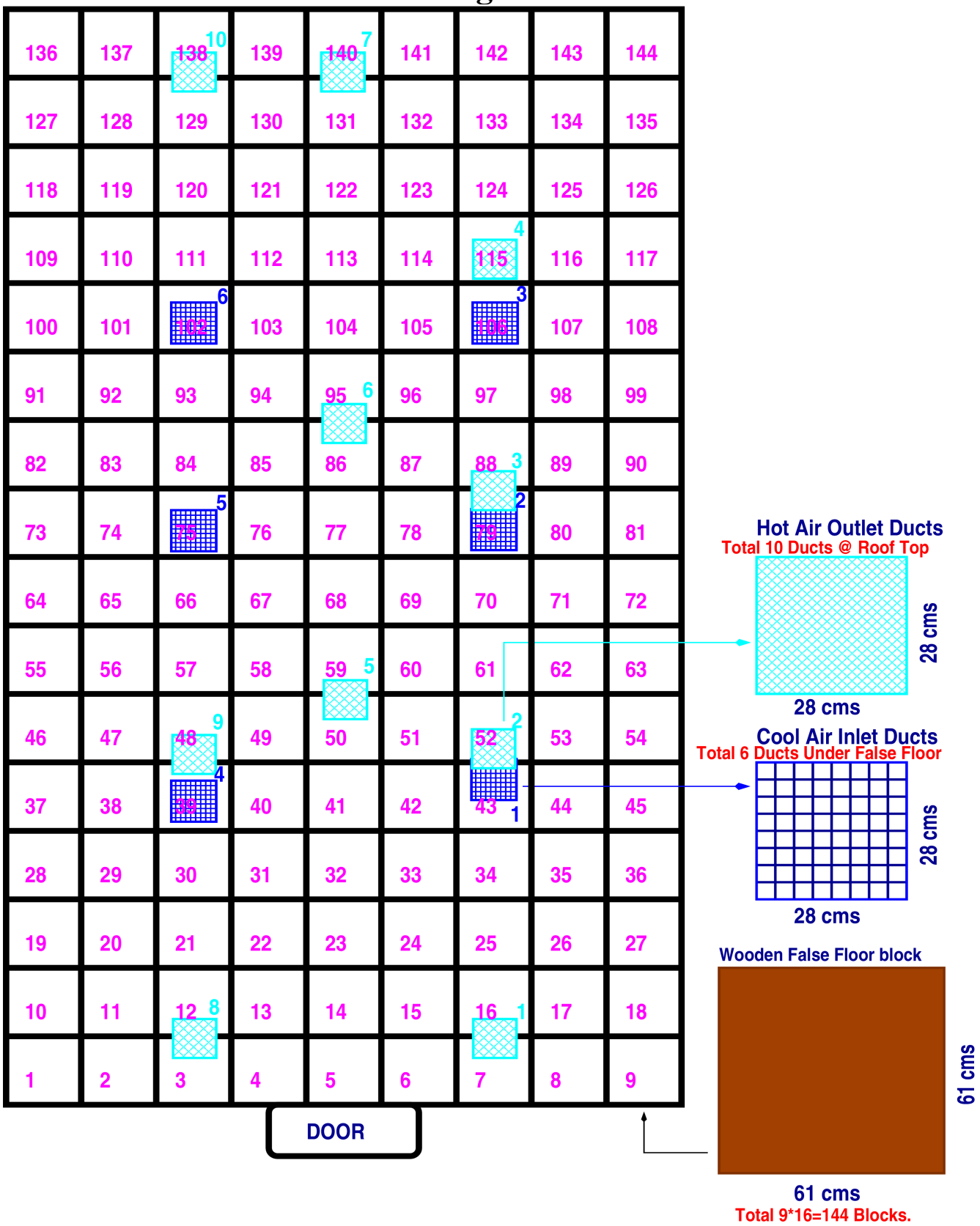
The recently developed GMRT software backend (GSB), built using mainly COTS components, is a fully real-time backend that supports all the features of the existing hardware backend of the GMRT. In addition, it provides substantially enhanced spatial and temporal resolutions. Furthermore, it supports a baseband recording mode where raw voltage signals from all the antennae can be recorded to disk for specialized off-line processing to maximize the science return. In this paper, we describe our design and implementation of this 32 antennae, 33 MHz, dual polarization, fully real-time software backend for the GMRT.

2 AC distribution layout :



AC Plant : Air Handling Unit (AHU) capacity 13,000 Cubic Feet per Minute (CFM).

3 Correlator Room Floor diagram :



Note : outlet rooftop duct number 2 has been moved at above the floor tile number 75 in the month of October 2016 to facilitate the outlet hot air from GWB racks 1 & 2 to go out through hot air duct.

4 Power Consumption as per Datasheets :

a. Modelwise Power Consumption :

Modelwise Power Consumption by GSB 30 Antennae system as per datasheets.

Note : Since, couldn't get the details of these models/units, refer the actual measurements. Ignore the numbers mention here, which are assumed by referng the nearest models/units.

		Power Consumption in Watts			Total Power Consumption	
Sl No.	Model Name	Typical	Maximum	Total Models	Typical	Maximum
1	1U, Xeon Dual processor, single core,2.4GHz,ACQ nodes		80	16		1,280
2	iADC cards	2	2	32	64	64
3	Dell Power Edge 2950 nodes		449	33		14,817
4	10G uplink module Dell Power connect 6248	70	100	4	280	400
5	Model No. CGSC-002, 32 ch. Corr.		449	8		3,592
6	Dell Power Edge R710 nodes		287	8		2,296
7	ALTUSEN Model No. KH1516Ai, 16ports, cat5 switch	12.7	15	1	13	15
8	gsbm1 to gsbm6 intel core2 Duo		1100	6		6,600
9	T7500 Dell m/c's		1100	4		4,400
10	casper m/c's		1000	4		4,000
11	Small units (Trig & clk units, eth s/w & computer monitors)		160	1		160
				Grand Total in Watts		33,464

b. Rackwise Power Consumption :

Rackwise Power Consumption by GSB 30 Antennae system as per datasheets.
Note : Since, couldn't get the details of these models/units, refer the actual measurements.

			Total Power Consumption	
Rack No.	Rack Name	Model/Unit Names	Typical	Maximum
1	Acquition	1u,Single core,Dual processor,xeon 2.4 GHz - 16+1		
2	Compute	DellPowerEdge2950-16, PowerConnectSwitches-2		
3	Co.+Record	DellPowerEdge2950-8,CGSCnodes-8,PCs/w-2,ppm		
4	Co.+Record	DellPowerEdge2950-9,DellPER710-8,16pS/w-1		
5	Ctrl+Record	gsbm1 to gsbm6 m/c's & 1 monitor & extra HDD's		
6	Nodes+misc	nodes51 to nodes54 T7500 m/c's & casper m/c's		

5 Power Consumption (PC) Measurement :

UPS 2 – 20KVA & UPS 3 – 12.5KVA.
UPS 2 – feeds power to Racks 2,3 & 6. UPS 3 – feeds power to Racks 1,4 & 5.

			Total Power Consumption	
Rack No.	Rack Name	Model/Unit Names	P in Watts	P in KVA
1	Acquition	1u,Single core,Dual processor,xeon 2.4 GHz - 16+1	2649.6	3.31
2	Compute	DellPowerEdge2950-16, PowerConnectSwitches-2	4360.8	5.45
3	Co.+Record	DellPowerEdge2950-8,CGSCnodes-8,PCs/w-2,ppm	2704.8	3.38
4	Co.+Record	DellPowerEdge2950-9,DellPER710-8,16pS/w-1	2520.8	3.15
5	Ctrl+Record	gsbm1 to gsbm6 m/c's & 1 monitor & extra HDD's	1104.0	1.38
6	Nodes+misc	nodes51 to nodes54 T7500 m/c's & casper m/c's	956.8	1.20
7	Misc..	Extensions 1,2,3 and Lamps,CCTV etc..	993.6	1.24
	Grand Total (UPS2 + UPS3) (49Amps+34.1Amps=83.1Amps)		15290.4	19.11

Note : As per UPS outputs, UPS2's 56% of 20KVA and UPS3's 60% of 12.5KVA ie. 11.27KVA & 7.5KVA respectively. So total power consumption by GSB system is 18.77KVA ie 15.01624KW (if PF=0.8).

As per Output Current of UPS 2 & 3 ie. 49Amps+32.61=81.61Amps, ie 15.01624KW / 18.77KVA.

Extension1 has Temperature Display – 1no., Extension2 has one spare ACQ node and computer monitor etc.., and Extension3 has 2 plugs couldn't be traceable.

Conclusions : So maximum of these two is 19.11KVA or 15,290 Watts is considered for calculations. But sometimes it is noticed UPS2's % reaching to 60 and UPS2's 61%. So +10%added to 19.11KVA. **Hence maximum Power Consumption can be considered as 21.021KVA or 16816.8 Watts (~17KW). This is excluding the surge current/power while switching on the racks. Also PC by Racks 1,3 & 4 will be around 2.7KW+10%= ~3KWs. Where as Rack 2's PC is ~4.4KW+10%= ~4.8KWs and Racks 5 & 6 's PC will be around 1KWs each and misc.. will be around 816 watts. So total power consumption from GSB system excluding racks 5 & 6 (1KWs each) will be around 14 KWs.**

6 Air flow Measurement using anemometer :

For air flow measurement in the correlator room, we have used " Pitot Tube Anemometer + Differential Manometer HD350" from Extech Instruments. The air flow measurement procedure is explained in apendix "II Air Flow Meter User Manual"

Measured the air flow volume over the duct number 3 and 6 which are close to GSB system. Using this meter, we measured air flow at 5 points in the duct (4 corners and at the centre about half a foot height) and took average of those readings. It was around 1200cfm & 900cfm from duct number 3 & 6 respectively.

7 Temperature monitoring arrangements :

Temperature measuring and reading arrangements and alerts. Presently Temperature measurement is done using temperature sensors with display above the GSB racks. Remote temperature monitoring and alert arrangements needs to be added.

8 Heat generated cum absorption Calculations :

For this theoratical calculations, we have considered the following as inputs :

1. Maximum heat energy from GSB system is 14,000 watts.
2. Cool air entering the correlator room is 6000 CFM (Cubic Feet per Minute).
3. Difference in temperature of air in the corr room = 15 DegCel from inlet to outlet.
4. Constants :
   a. 1 Joule = 0.238902957619 calories.
   b. 1 ft^3 = 0.02832 mtr^3
   c. average Air density is 1.128666667 kg/mtr^3 for average temperature of 17.5 DegCel.
   d. Specific Heat of air @ 20 DegCel & 1 pascal is 240 calories/kg degree celsius.

A. Maximum Total Heat Energy in calories/min. from the GSB system.

Total Heat Energy in Joules/min. = Total Power consumption * 1 minute
= 14,000 watts * 60 sec. = 8,40,000 Joules/min.

1 Joule = 0.238902957619 calories , 1 calorie = 4.186 joules .

Total Heat Energy in calories/min. = 8,40,000 * 0.238902957619 = 2,00,678 calories/min.

B. Heat Absorption of the cool air in calories/min. from the AHU(AC Plant).

Heat Absorption = mass * Specific Heat of air * Diff. in temp.
of the cool air kg/min. Calories/kg degree cel.
degree celsius

a. "mass"
mass = Air Density kg/mtr^3 * Volume mtr^3/min. = kg/min.

i. Air Density in kg/mtr^3 :

http://www.weatheronline.in/weather/maps/city & http://www.denysschen.com/catalogue/density.aspx

Air Density @ Pune (above sea level of 1837 feet or 560 mtrs and relative humidity varies between 24 to 94 % in the year 2014) for average relative humidity of 59%) is ....

Temperature in DegCel	Air Density in kg/mtr^3 @ pressure of 1 pascal
10	1.16
17	1.13
25	1.096

So average Air density is 1.128666667 kg/mtr^3 for average temperature of 17.5 DegCel.

ii. Air Volume in mtr^3/min :

1 ft^3 = 0.02832 mtr^3 & 1 mtr^3 = 35.31467 ft^3
So volume of cool air reaching corr. Room = 6,000 ft^3/min. = 169.92 mtr^3/min.

So mass of cool air = 1.128666667 * 169.92
reaching corr. Room kg/mtr^3 mtr^3/min.

= 191.783040057 kg/min.

b. "Specific Heat of air = 240 calories/kg degree celsius.
@ temp. of 20degree cel. &
pressure of 1 pascal
www.usc.edu/org/.../Heat%20Capacity%20and%20Specific%20Heat.pdf , http://www.engineeringtoolbox.com/specific-heat-capacity-d_391.html

c. "Diff. in temperature = 25 – 10 = 15 degree celsius
of corr. Room

So,

Heat Absorption = 191.783040057 * 240 * 15
of the cool air kg/min. Calories/kg DegCel.
per DegCel.
= 6,90,419 calories/min.

So,
Heat Absorption of the cool air from each outlet = 6,90,419 / 6
in the correlator room = 1,15,070 Calories/min.

Conclusion :

a. Heat absorption of cool air from each inlet of 1000 CFM and inlet to outlet temperature difference of 15 DegCel is 1,15,070 Calories/minute.

b. So to absorb 2,00,678 calories/min. of heat generated by GSB system, we need 1.74 (200678÷115070) cool air inlets. Each inlet of 1000 CFM cool air.

9 Final conclusions :

Theoratically each inlet gives 1000CFM of cool air. So we need 1.74 cool air inlets to absorb the heat generated by GSB system of 14,000 Watts (2,00,678 calories/minute). But the cool air from inlets 3 & 6 (which are near to GSB racks) is 1200cmf and 900cfm respectively. Heat generated by racks 1,3 & 4 is about 3KWs ie 43,000 Calories/minute. So each racks need about 400cfm of cool air. Whereas heat generated by rack 2 is 4.8KWs ie 68,800 Calories/minute. So this rack needs 600cfm.

10 Suggestions on required modifications in GSB racks :

Heat generated from GSB racks 1 to 4 is 2,00,678 calories/minute. To compensate this heat, we need the cool air of 1800 cfm. We have cool air ducts 3 & 6 having a cool air outflow of 1200cfm and 900cfm, which is 2100cfm. While cool air ducts 4 & 5 are being used for GWB racks 5,6 & 1,2 respectively using aluminium funnel . And duct number 1 reserved for the GWB racks 3&4 (no funnel) , whereas duct number 2 reserved for future expansions. And GSB racks 5 & 6 having gsbm and casper machines will get general cool air in the correlator room.

The number of fans required in racks 1,3 & 4 is two fans of 200cfm each and in rack 2, two fans of 300cfm based on the heat generated and cool air requirement.

So the cool air from cool air duct number 3 can be fed to GSB racks 3 & 4 equally, whereas cool air from duct number 6 can be fed to GSB racks 1 & 2 in the ratio of 1:2 using aluminium funnel below the false flooring.

11 Implementation of modifications in GSB racks :

A metal frame will be made ready in the GMRT workshop. This will be fixed to GSB racks 1 & 4 to cover the GSB racks 1 to 4 with frame resting on floor at 3 places where two racks joins to each other. This frame will have provision to mount doors to each racks. And fans mounting arrangement to suck the cool air fed from cool air ducts using the aluminium funnel at the botoom front of each rack.

Also temperature sensors mounting arrangement at the bottom and top of the frame. Temperature sensors can be mounted, about 1 feet above the fans to monitor the cold air temperature and at the top backside to monitor the output hot air temperature.

The gaps between the units in the racks should be closed using the aluminium plates. Also an arrangement should be made to restrict the mixing of cold and hot air above the GSB racks 5 and 6.

This frame with doors needs to be powder coated usning a black or GSB rack's colour.

Appendices :

I Auto calculator

please use the file auto_calc_temp.ods to change the input parameters to get output values. Sample file attached here for standard input parameters...

User Parameters :	**INPUTS**	**Output Parameters**	**OUTPUTS**
PowerConsumption in Watts -->	14000	**Total Heat Energy** in calories/minute -->	**2,00,678**
Difference in Temperature -->	15	**Heat Absorption of Cool Air cal/min -->**	**1,15,070**
Volume of Cool Air in ft^3 -->	1000	**Number of cool air inlets required..**	**1.74**
Heat absorption in watts -->	4,800		
Difference in temperature deg. Cel. -->	15.00	**Volume of Cool Air in ft^3 :**	**598**

Constant Parameters :	**Constant Values**	**Intermittent Calculation Parameters :**	**int'nt. results**
1 Joule equal to --> Calories	0.2389029576	Volume of Cool Air in mtr^3 -->	28.32
1 Cubic feet equal to --> Cubic mtr	0.02832	Mass of cool air in kg/minute -->	31.963840009
Air Density kg/mtr^3 @ 25dC & 1 Pascal	1.128666667		
Specific Heat of Air cal/kgdC @ 20dC & 1 Pascal	240		

Tables :

Total Heat Energy in Cal./min.	
For 1000 watts of Power Consumption -->	14,334
For 1500 watts of Power Consumption -->	21,501
For 2000 watts of Power Consumption -->	28,668
For 2500 watts of Power Consumption -->	35,835
For 3000 watts of Power Consumption -->	43,003
For 3500 watts of Power Consumption -->	50,170
For 4000 watts of Power Consumption -->	57,337
For 4500 watts of Power Consumption -->	64,504
For 5000 watts of Power Consumption -->	71,671

Volume of Cool Air in ft^3 @1KW heat if :	
Temperature difference of 3 deg. Cel.	2,990
Temperature difference of 3.5 deg. Cel.	2,563
Temperature difference of 4 deg. Cel.	2,242
Temperature difference of 4.5 deg. Cel.	1,993
Temperature difference of 5 deg. Cel.	1,794

Heat Absorption of Cool Air in cal./min.	**For 1000ft^3/ min. Cool air**
For Temperature difference of 1 deg.Cel.	7,671
For Temperature difference of 1.5 deg.Cel.	11,507
For Temperature difference of 2 deg.Cel.	15,343
For Temperature difference of 2.5 deg.Cel.	19,178
For Temperature difference of 3 deg.Cel.	23,014
For Temperature difference of 3.5 deg.Cel.	26,850
For Temperature difference of 4 deg.Cel.	30,685
For Temperature difference of 4.5 deg.Cel.	34,521
For Temperature difference of 5 deg.Cel.	38,357
For Temperature difference of 5.5 deg.Cel.	42,192
For Temperature difference of 6 deg.Cel.	46,028
For Temperature difference of 6.5 deg.Cel.	49,864
For Temperature difference of 7 deg.Cel.	53,699
For Temperature difference of 7.5 deg.Cel.	57,535
For Temperature difference of 8 deg.Cel.	61,371
For Temperature difference of 8.5 deg.Cel.	65,206
For Temperature difference of 9 deg.Cel.	69,042
For Temperature difference of 9.5 deg.Cel.	72,878
For Temperature difference of 10 deg.Cel.	76,713

II Air Flow meter User Manual

Visit the webpage :
http://www.extech.com/instruments/product.asp?catid=1&prodid=600
and click at the

English User's Manual

under Downloads & Software

for complete User Manual.

OR

Documents available with the Meter.

OR

file "HD350_UM.pdf" attached with this Report.

Introduction :

Extech HD350. This handheld meter measures and displays air velocity (speed), air flow (volume), ambient air temperature, and gauge/differential pressure. This meter is shipped fully tested and calibrated and, with proper use, will provide years of reliable service.

Features :

- Pitot tube Anemometer measurements for Air Velocity and Air Flow (volume).
- Manometer (Differential Pressure) Measurements.
- Simultaneous display of Air Flow or Air Velocity, Temperature, and Pressure.
- 5 selectable pressure units of measure.
- Record up to ninety-nine (99) readings (in meter's internal memory) for each of the three measurement types (Air Velocity, Air Flow, and Pressure) for a total of 297 readings.
- USB port for connection to a Personal Computer (PC) for real time datalogging of up to 5500 readings stored on the PC.
- Large backlit LCD display.
- Data Hold and Maximum, Minimum, Average memory (MIN/MAX/AVG).
- Auto Power OFF (can be disengaged).