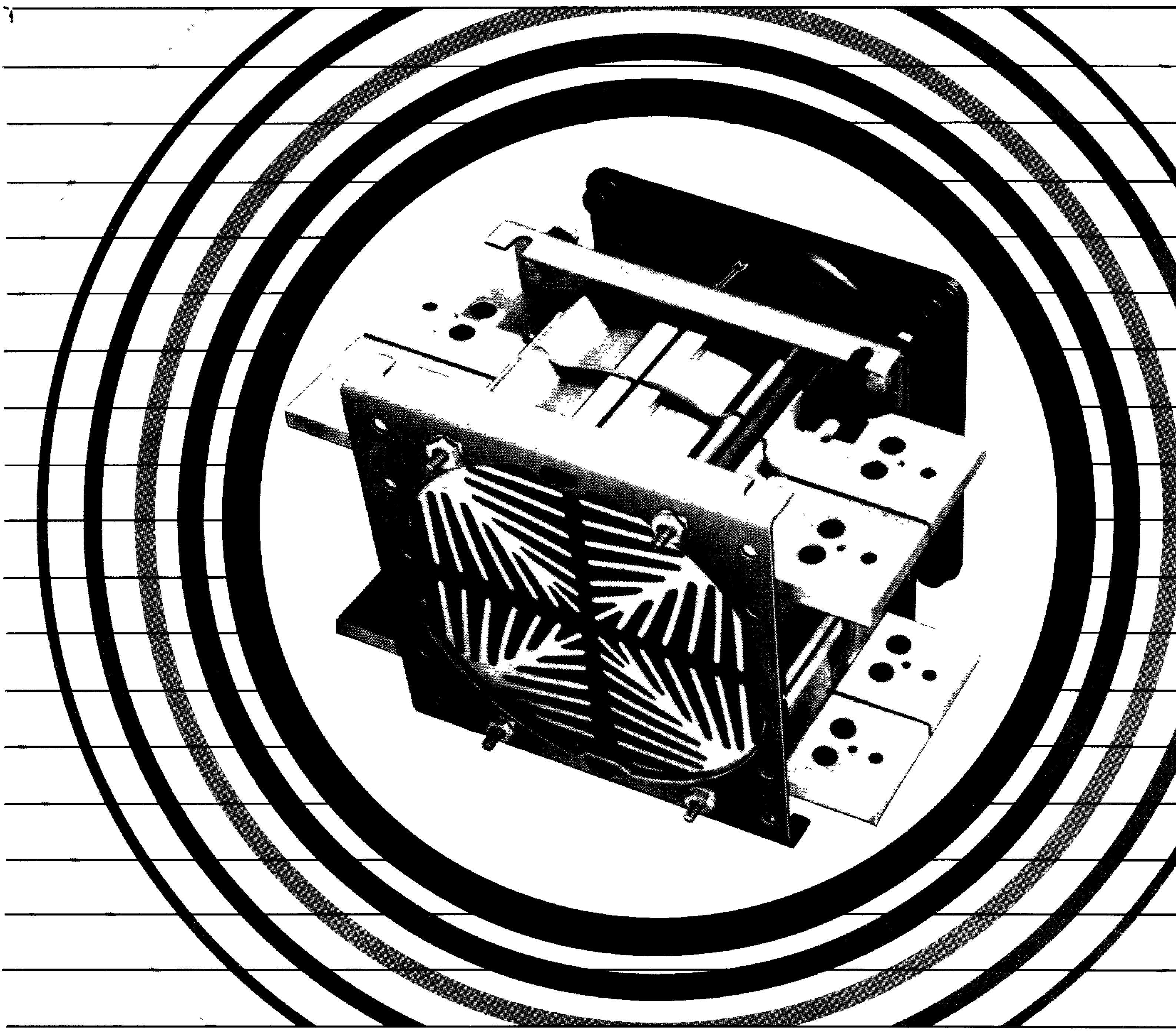
148-449 TO 148-457

Marston Palmer

FORCE COOLED HEAT SINK ASSEMBLIES



for Electronics Cooling

Marston Palmer
ELECTRONICS COOLING

FORCE COOLED HEAT SINK ASSEMBLIES for Electronics Cooling

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Marston Confined Flow Force Cooled Heat Sink assemblies using 24WF and 25WF extruded aluminium heat sinks.

Introduction

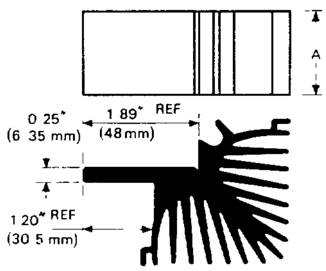
When it becomes impossible to dissipate heat from a group of semi-conductors by natural convection because the space available for the heat sink is too small, the next logical step is to consider using a smaller heat sink in a moving airstream to achieve at least the same performance.

To provide cooling for up to 40 "stations" per assembly (one semiconductor per station or more than one station per semiconductor), heat sinks made from 24WF and 25WF extrusions (see Fig. 1) may be assembled in a variety of ways to obtain the desired cooling system. A modular system of building is employed so that the resulting assembly contains the correct module lengths for all the semiconductors in a given circuit. No baffles or ducts are needed; individual "modules" (a given length of extrusion containing one or more semiconductors) are electrically isolated from each other and from ground

The low thermal resistance of these efficient assemblies reduces the number of semiconductors needed for given regulating circuitry

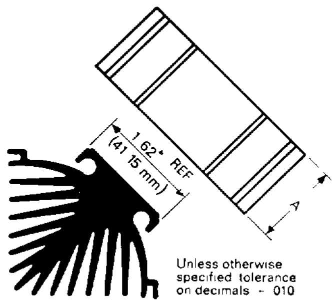
The Heat Sinks. The basic modular "Building Brick".

Two extruded aluminium shapes are used for making heat sink modules which form the basic component in any assembly. 24WF is a "shelf" type heat sink designed for easy semiconductor mounting and maintenance. 25WF gives a lower thermal resistance and is designed for stud type devices. Both are illustrated in figure 1 below and the codes are given for standard heat sink lengths in "Table" 1.



24WF Module

Figure 1



25WF Module

Table 1

No of Device Stations**	CODE			LENGTH A		CODE		
	Shape	Length				Shape	Length	
		Inches	mm	Inches	mm		Inches	mm
1	24WF	—0137	*00349*	1·375	*34·925*	25WF	—0137	*00349*
2	24WF	—0281	*00714*	2·812	*71·425*	25WF	—0281	*00714*
3	24WF	—0424	*01079*	4·249	*107 925*	25WF	—0424	*01079*
4	24WF	—0568	*01444*	5·687	*144 425*	25WF	—0568	*01444*
5	24WF	—0712	*01809*	7·123	*180·925*	25WF	—0712	*01809*
6	24WF	—0856	*02174*	8·560	*217·425*	25WF	—0856	*02174*
7	24WF	—0999	*02539*	9·997	*253·925*	25WF	—0999	*02539*
8	24WF	—1143	*02904*	11·434	*290 425*	25WF	—1143	*02904*
9	24WF	—1287	*03269*	12·871	*326 925*	25WF	—1287	*03269*
10	24WF	—1430	*03634*	14·308	*363·425*	25WF	—1430	*03634*

**More than one station can be occupied by a single device

Four Force Cooled assemblies using basic modular "Building Bricks".

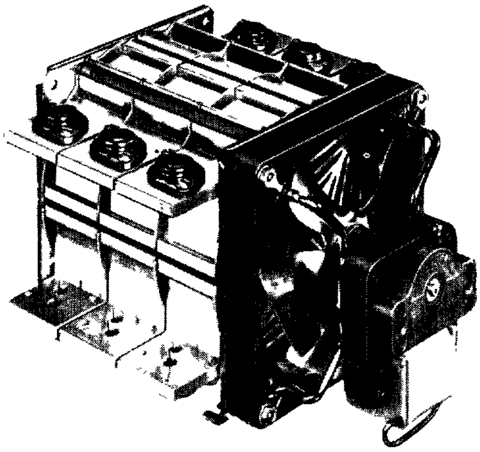


Figure 2–illustrates an assembly having 12–24WF heat sink modules each electrically isolated from one another and from ground and each dissipating the heat from a single semiconductor device The module is the standard 24WF–0137 in each case and the assembly length is No 3 The shorthand specification for this assembly is as follows —

UI, Sectors (1 to 4), 24WF - 0137AC1 × 3, UI — Fan (see page 8 specifying 24 & 25WF assemblies)

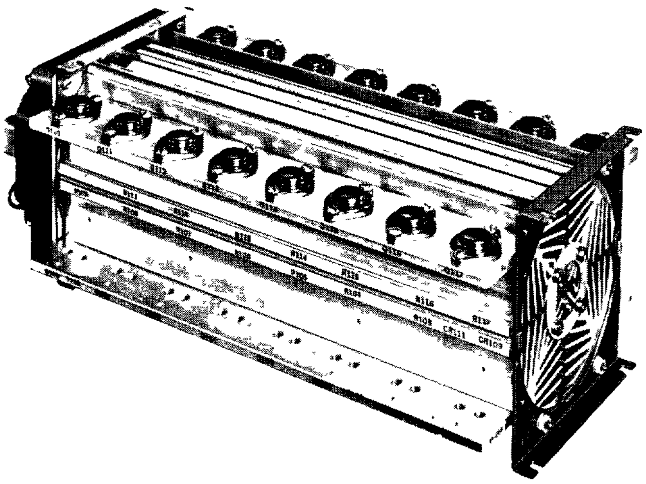


Figure 3–illustrates a longer assembly using 4–24WF heat sink modules each electrically isolated from one another Each module carries 8 semiconductors having their collectors common to one another – the assembly length is No 8 The shorthand specification for the assembly is as follows —

U2, Sectors (1 to 4), 24WF-1143AR (Rep × 2) 1, UI + Fan.

(Hole Pattern AR (Rep × 2) – see page 10–std device hole patterns)

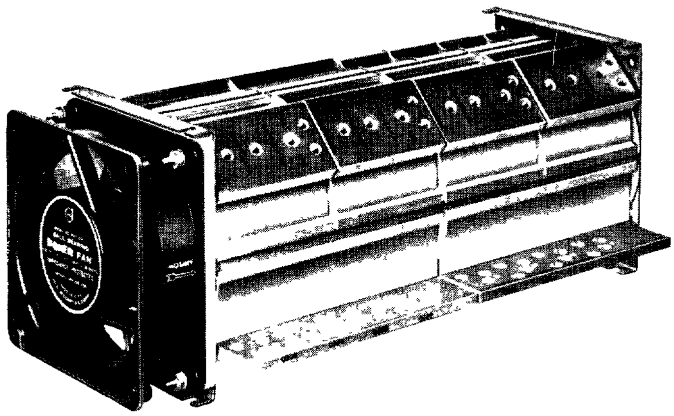


Figure 4–illustrates how 24WF and 25WF heat sink modules may be mixed in the same assembly The assembly length is No 8 and the shorthand specification for the assembly is as follows —

UI { Sectors (1 & 4), 25WF - 0281S - 1 × 4
Sectors (2 & 3), 24WF - 0568AK (Rep × 4) 1 × 2 } U2
+ Fan

(Hole Pattern S – because no std hole pattern to suit – therefore dwg required)

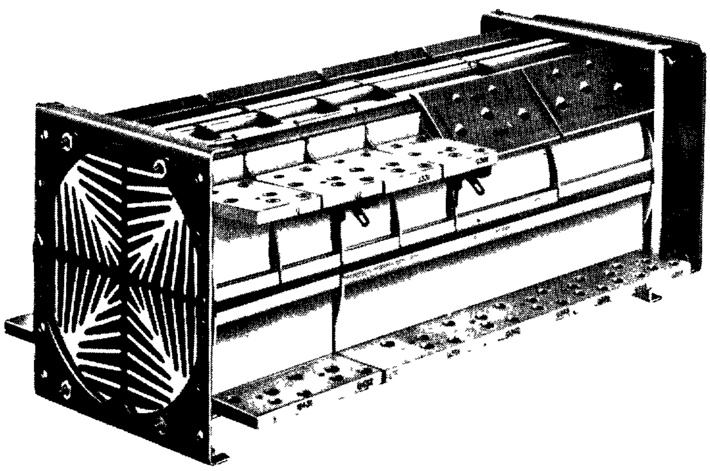


Figure 5–illustrates how 24WF and 25WF heat sink modules can be mixed in the same sector (or quadrant). The assembly length is No 8 and the shorthand specification is as follows :—

U1 {
Sector (1); 25WF - 0281S - 1 × 4;
Sectors (2 & 3), 24WF - 0281 AD (Rep × 2) 1;
24WF - 0856 AD (Rep × 6) 1;
Sector (4); 24WF - 0137AD 1 × 4;
25WF - 0281S - 1 × 2;
+ Fan.
} U2

Selection of the right heat sinks situated in the right place in an assembly.

As the Force Cooled Heat Sink assembly is a compact self contained unit, occupying as little space as possible yet being capable of dissipating a large amount of heat, the best results can only be obtained when the right amount of heat sink is situated in its correct position in the assembly. The procedure for designing a force cooled heat sink assembly for a given group of semiconductors is a four step process as follows:—

STEP A – ESTIMATE the size of module required to cool each semiconductor.

STEP B – ARRANGE the modules into sectors (quadrants in the case of 24WF and 25WF assemblies).

STEP C – ANALYSE and tabulate the performance of each module using performance data in figures 7, 8, 9 and 10.

STEP D – REFINE and adjust the estimated design as necessary, and as a final check carry any changes back through steps B and C

Original estimates must be based upon an assumed airflow. The arrangement step involves *equally* fitting each sector with modules. The analysis step requires understanding and proper use of the data included in the performance curves. A suggested analytical table is given in figure 6.

An elaboration of the step process is as follows:—

A ESTIMATE – For each semiconductor to be cooled determine the thermal resistance required from its heat sink (i.e. temperature difference ambient to case/stud temperature against the wattage to be dissipated —°C/Watt). Then from figure 8 determine the airflow per sector available for an 8 unit length package for the particular fan desired. Using this airflow per sector, proceed to Figure 7 and choose the heat sink module for each semiconductor having a sufficiently low thermal resistance – keep in mind that 25WF modules are for stud mounting devices only. Enter this data on the analysis table (Figure 6).

B ARRANGE – When the correct modules have been chosen for each semiconductor, these modules must be arranged into an assembly. *The assembly length must be at least as long as the longest module,* and is expressed in terms of the shortest module (24 or 25WF – 0137). Therefore a four length assembly describes one which could contain 4 × 24/25WF – 0137 modules per sector or 2 × 24/25WF – 0281 modules per sector or 1 × 24/25WF – 0568 modules per sector. The total number of modules (heat sinks) in each of these assemblies would be 16, 8 and 4 respectively. Furthermore each module will be electrically isolated from any other module in the assembly. There must be an equal number of unit lengths of modules in each sector even though it is permissible to fill adjacent sectors with any combination of 24WF × 25WF modules having the same length. In order to fill an assembly it may sometimes be necessary to use one or two modules which are larger than thermally required.

C ANALYSE – From the curves of figures 8 and 9 the actual airflow per sector can be obtained. Having determined the correct airflow per sector refer to figure 7 and list the corrected thermal resistances (case or stud to ambient) of the chosen modules. By multiplying these thermal resistances and the known power to be applied to each module, the direct or self-produced temperature rise above ambient for each module can be calculated. This direct temperature rise is that which would occur *if there were no other upstream modules heating the airstream.* The temperature rises induced by upstream units must now be calculated by using the curves in figure 10. These must be added to the direct temperature rise to obtain the total temperature rise of each downstream module.

In order to explain the logic of the figure 10 curves consider the following:—

As air proceeds along the assembly accumulating thermal energy from the individual modules, its temperature increases. Therefore the increased airstream temperature must be considered when calculating the actual temperature rise of a downstream module. The temperature of a downstream module cannot be accurately predicted by considering only the four quantities namely:—

(a) upstream input power

(b) flow rate

(c) specific heat of the air

and (d) the inlet air temperature.

A fifth parameter, the locations of the various upstream power inputs must also be considered.

The reason is as follows:—

If one considers cooling air flowing along a hot fin it can be appreciated that the air passing close to the fin will be hotter than air passing along further from the fin. As the flow proceeds along the fin, this hotter air will mix with the cooler air, but a finite amount of time and distance is required for this mixing to take place. If this mixing has not been completed before the airstream reaches the fin of a successive module, then the temperature of the air to which the succeeding module fin surface is exposed will be greater than the average airstream temperature. The curves of figure 10 are provided to permit accurate computation of the semiconductor mounting surface temperature of any downstream module. Each module upstream of a given downstream module induces to that downstream module an incremental temperature increase which may be calculated by the use of these curves. The induced temperature increase caused by each upstream module must be considered separately and then all the increments summed to yield a total temperature increase of the downstream unit being considered. Because there is very little mixing of air between adjacent sectors, the only modules which need to be considered are those upstream modules which are in the same sector as the module whose temperature is being calculated. If a group of semiconductors running at equal power in a sector is to be kept cooled with equal case temperatures, the downstream devices must be assigned a greater length of module than the upstream devices. Equally effective spacing can also be carried out on a long module with a number of common collectors or common stud semiconductors mounted on it each dissipating the same power.

D REFINE – having finally determined the correct length of module, and having considered the effect of upstream modules on downstream modules, work back through steps B and C to ensure each module is performing in the required way.

Figure 6

Suggested Analysis Form for Recording Details of all Semiconductors to be Cooled

Specification Data
24 and 25WF Assemblies

Device Type and Manufacturer (Bracket together devices with electrically common cases or studs)	Outline for Hole Pattern (see Fig 12)	Max Power to dissipate Watts	Max permissible Tc in °C at power level in Col 3 or Max Tj °C and $\Theta_{(j-c)}$ in °C /Watt	Tc if only Tj °C $\Theta_{(j-c)}$ stated °C	Required Heat Sink Thermal Resistance °C /Watt	Length of Module (See Table 1) Choices (Delete previous choice) 1	2	3	Sector No. assigned

Summary

Sector	Record of Modules (Each Col. — 1 Unit Length) 1	2	3	4	5	6	7	8	9	10		
1												
2												
3												
4												

Each sector must contain the **same** number of units

Specify End Plate Type: Fan End .... .. Remote End

Max. Ambient or Inlet Air Temp. °C.

Max. Altitute at which assy. is to be operated . . ft m

Max. Dimensions Permitted Overall Length . . in . mm

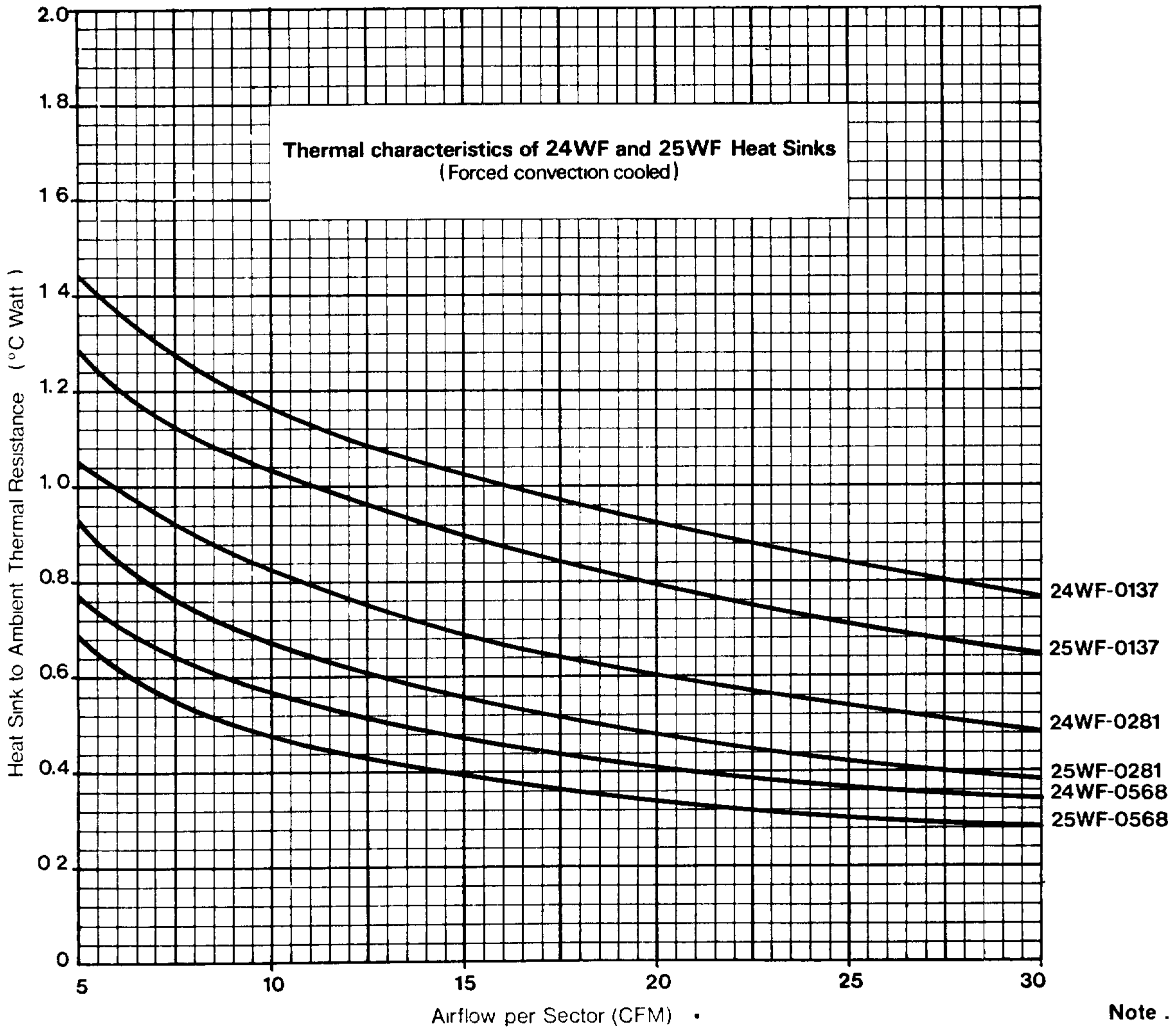
Overall Height . in mm

Overall Width . . in . . . . mm

Fan Power Available Watts . Volts Frequency

. . Phase.

Figure 7



Note . . .

Airflow per sector (CFM

Figure 8

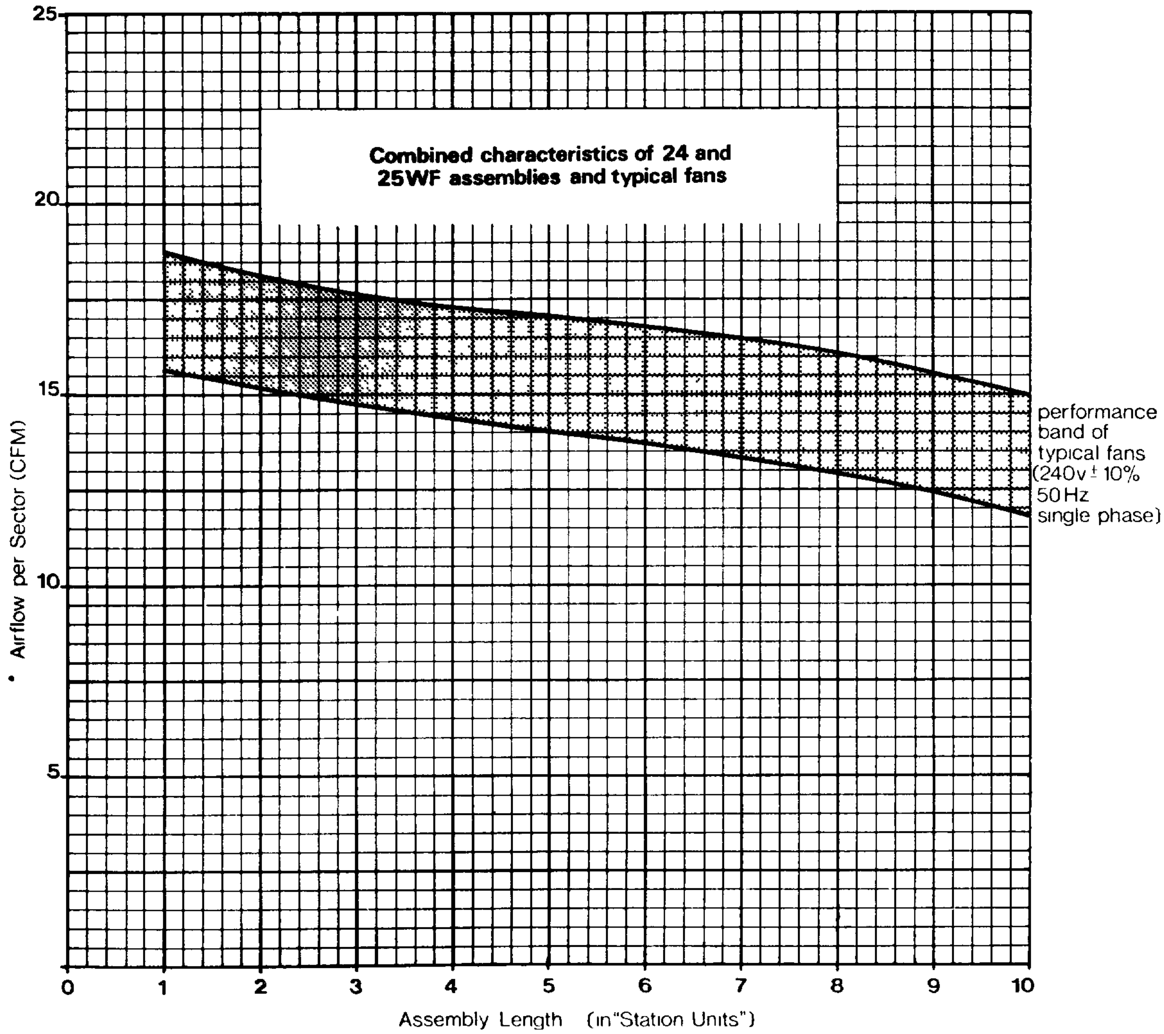
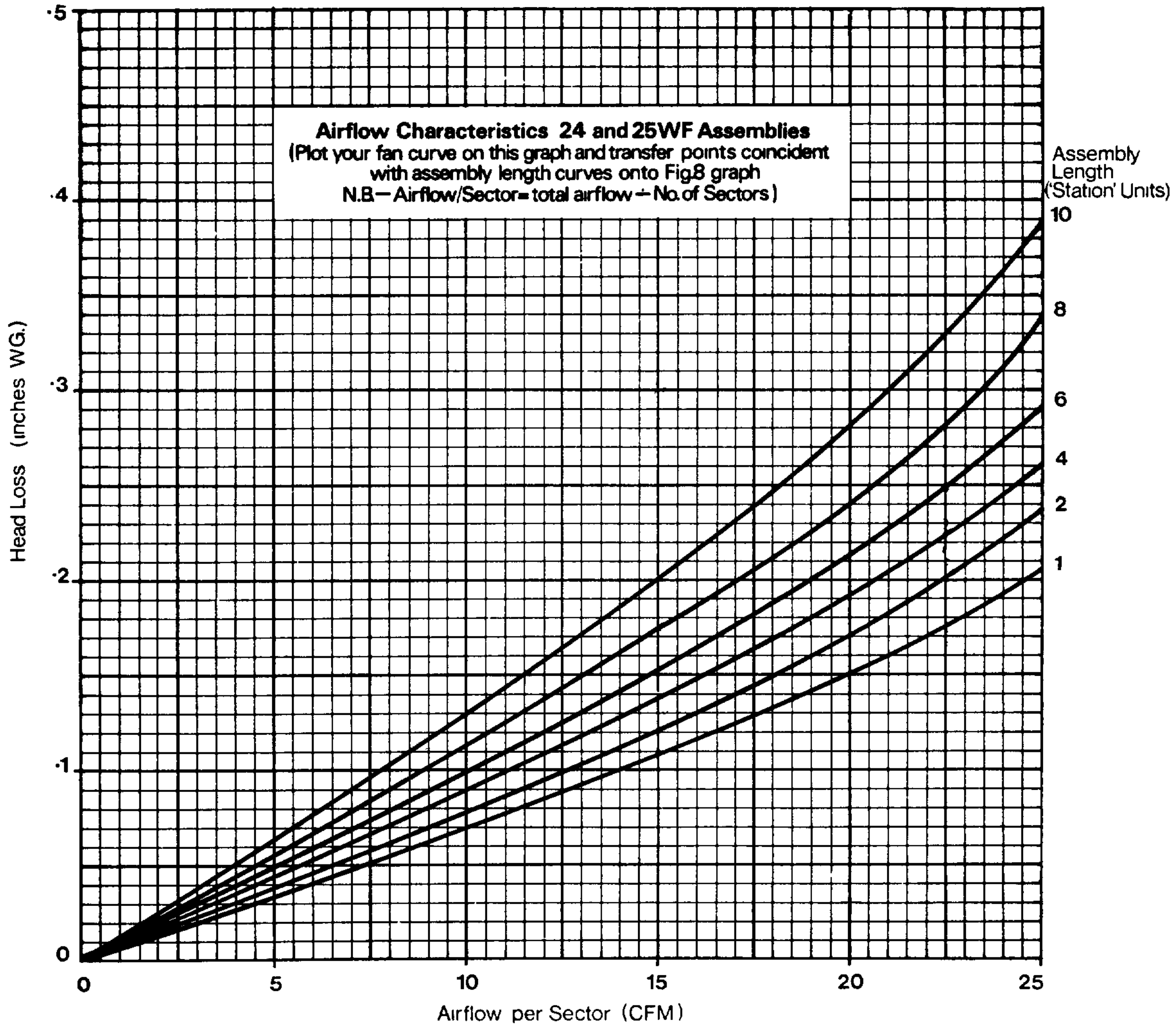
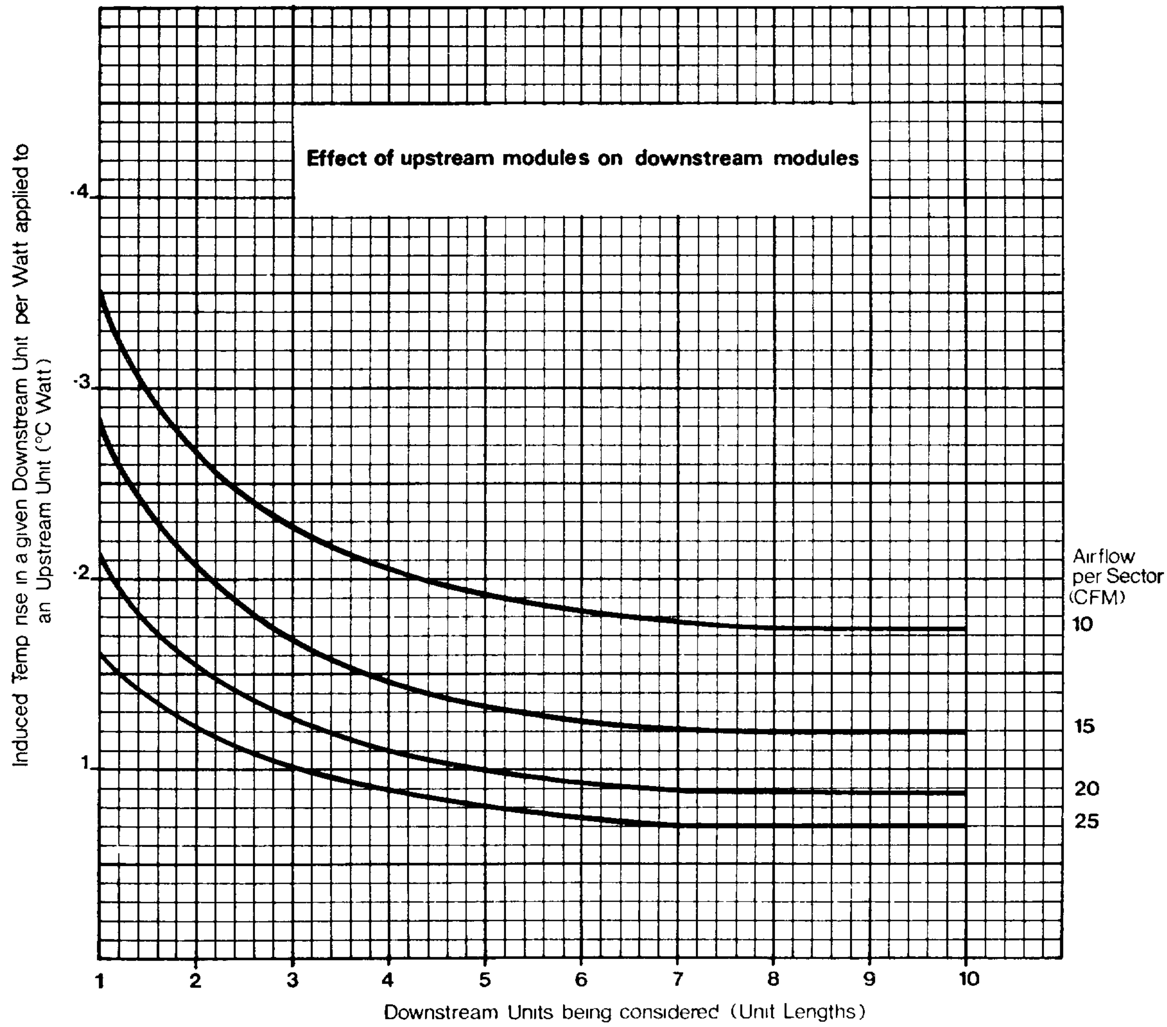


Figure 9



= **Total fan airflow (CFM)** / **4**

Figure 10



Specifying 24 and 25WF assemblies.

It can be seen that a force cooled assembly is a complex arrangement of many separate heat sinks or modules The position of each heat sink in the assembly is important if each one is to perform in the most effective way Customers may send their requirements to Marston Palmer Ltd in the form of the Specification Summary shown in Figure 6, or, by following the few simple instructions given below, complete assemblies may be specified in shorthand form Details of assemblies are also acceptable in the form of working drawings It will always be understood that separate modules will be electrically separated

Specify an assembly in the following way

1 Always view an assembly from the fan end (i.e. on the end to which the fan will be fitted).

2 Number the sectors (in the case of 24 and 25WF assemblies the sectors are quadrants) in a clockwise direction; the top right hand sector is No. 1.
(See figure 11).

3 Select the orientation of the end plate (U1 or U2) Commence and finish the total specification with the code for the end plate (see figure 11) thus —

UI, sectors (1 to 4) 24WF – 0137AD1 × 4; UI

4 (a) Commencing with sector 1., specify the module *furthest* from the fan first and then in sequence to the module next to the fan in code (see paragraph c below) on the same line ensure this information refers to sector 1 thus.—

Sector (1) 24WF – 0281S – 1; 24WF – 0137S – 1

Specify modules in the next sector in the same way and write the data for each sector beneath the data for the previous sector ensuring that the sector number is quoted, until the data for all sectors is given. When all sectors contain the same modules in the same sequence it is only necessary to write the specification thus·—

Sectors (1 to 4) 24WF – 0281S – 1; 24WF – 0137S – 1

When each sector contains a succession of modules alike in every respect then it is only necessary to write the specification thus:—

Sectors (1 to 4) 24WF – 0137AD1 × 4

(for method of specifying a module see (iv) (c) below).

(b) Ensure each sector contains the same overall length of modules.

(c) Specify each module in the same way as follows:—

24WF	—0137	AC	1
Extrusion Shape shelf model – 24WF Platform model – 25WF (see fig 1)	**Length of module** – Inches (to two decimal places, express as hyphen and 4 digits) Millimetres (to one decimal place, express as 5 digits including zeros) (For standard module lengths see Table 1)	**Hole pattern** (see figure 12) if no standard to suit write S – and send drawing	**Surface finish** 1 – Plain (as extruded) 2 – Matt Black Anodise 3 – Alocrom

(d) Specify any added parts (e.g. fan) below the assembly specification and if added parts are complex send drawing.

(e) Check specification against figures 2, 3, 4 and 5 to see if all details are given in the correct way.

Standard Sector Orientations and Standard End Plates.

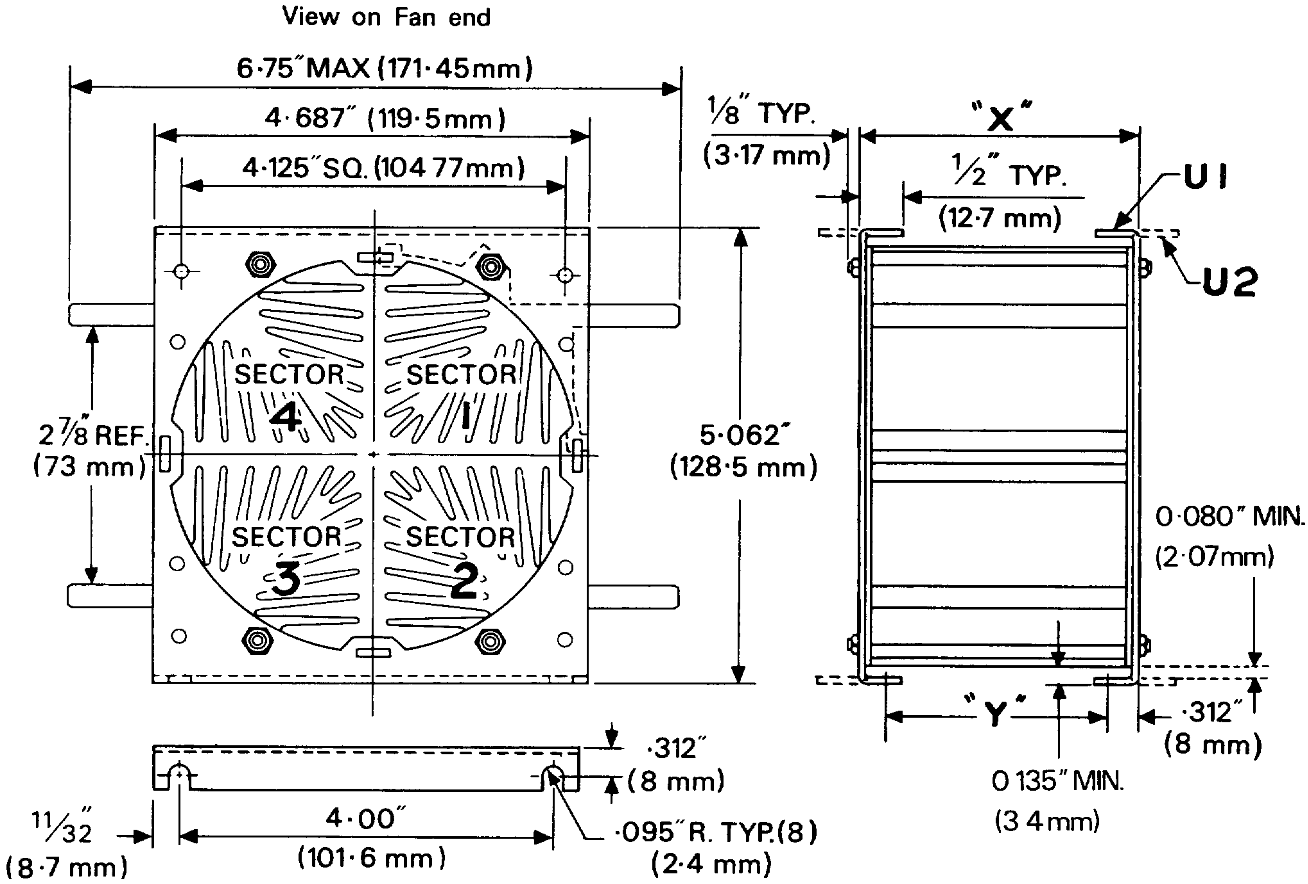


Figure 11

Two types of End Plate are available and both are flanged top and bottom. These are U1 and U2 short end plates:

U1 has feet turned inwards

U2 has feet turned outwards.

Table 2 Standard lengths of assemblies.

Assembly No. (No. of "Stations" in length).	DIMENSION (See Figure 11) "X" in	"X" mm	"Y" in	"Y" mm
1	1·62 ± ·030	41 ± 0·8	1·00 ± ·030	25 ± 0·8
2	3·06 ± ·055	78 ± 1·4	2·43 ± ·055	62 ± 1·4
3	4·49 ± ·070	114 ± 1·8	3·87 ± ·070	98 ± 1·8
4	5·93 ± ·085	151 ± 2·2	5·31 ± ·085	135 ± 2·2
5	7·37 ± ·110	187 ± 2·8	6·74 ± ·110	171 ± 2·8
6	8·80 ± ·115	224 ± 2·9	8·18 ± ·115	208 ± 2·9
7	10·24 ± ·130	260 ± 3·3	9·62 ± ·130	244 ± 3·3
8	11·68 ± ·145	297 ± 3·7	11·05 ± ·145	281 ± 3·7
9	13·12 ± ·160	333 ± 4·1	12·49 ± ·160	317 ± 4·1
10	14·55 ± ·175	370 ± 4·5	13·93 ± ·175	354 ± 4·5

Standard device hole patterns.

A variety of device hole patterns to suit standard device outlines can be provided. Quote the reference in the module specification applicable to the hole pattern required (see 4c page 8). Note that only one hole pattern has a repeat reference for 2, 3, and 4 stations If it is required to repeat any other hole pattern over 2 stations or more, state HP (Rep × X) in module specification In this event the same hole pattern will be repeated at the centre of each "Station" e.g Hole pattern AC on a 5 station length module repeated at each station :–

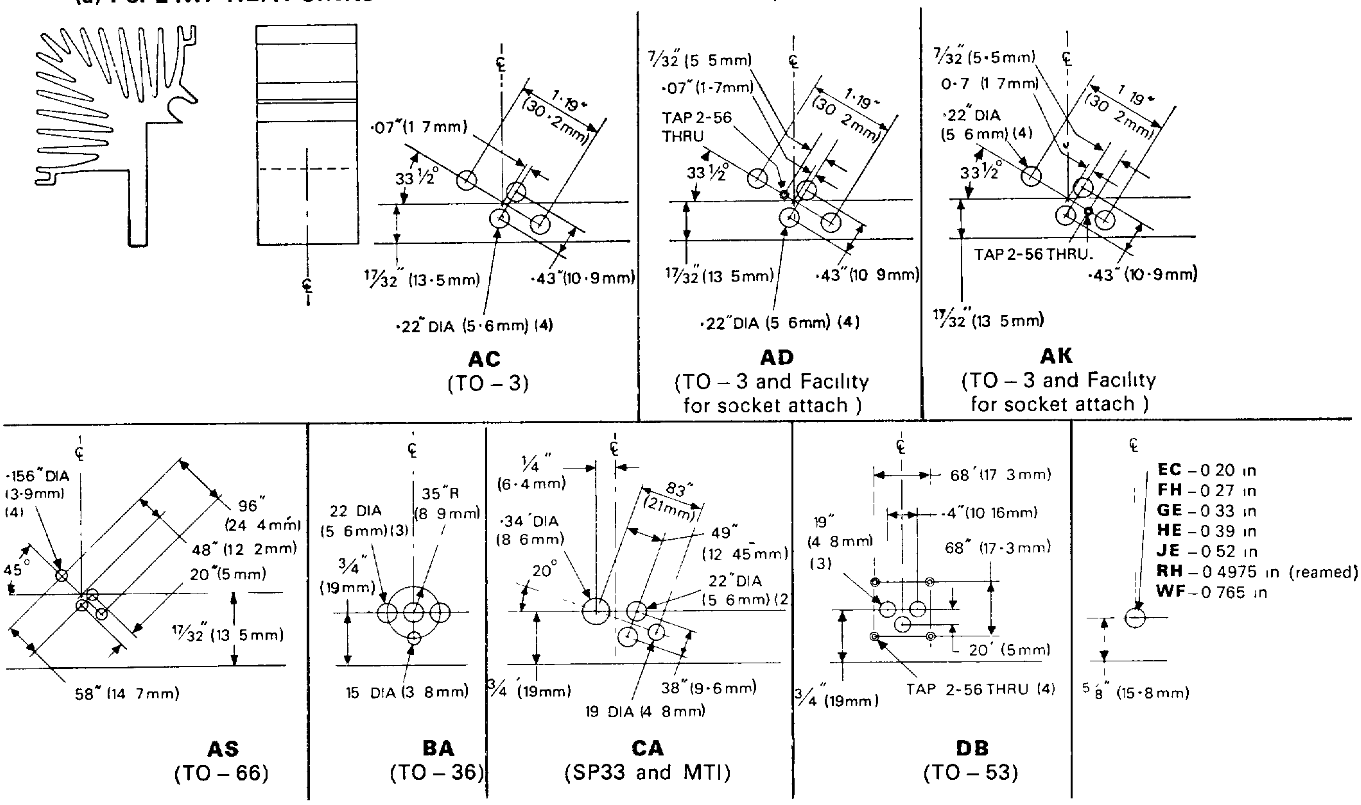
State AC(Rep × 5)

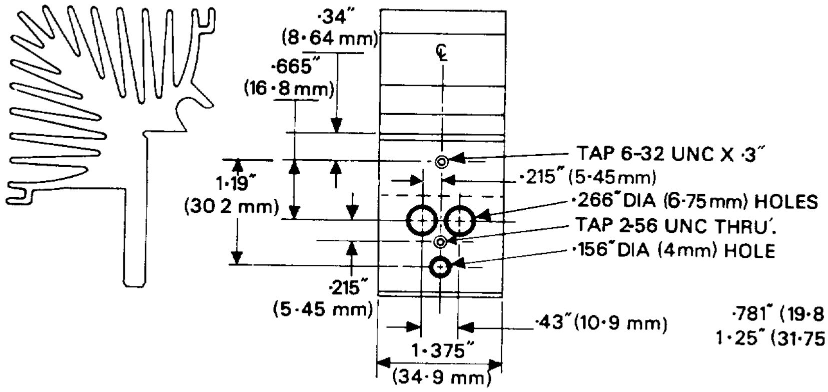
The full module specification will read :— 24WF – 0712 AC (Rep × 5)1.

Figure 12

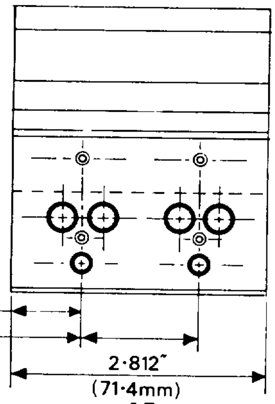
Standard device hole patterns

(a) For 24WF HEAT SINKS (For no Hole Pattern Quote A –)

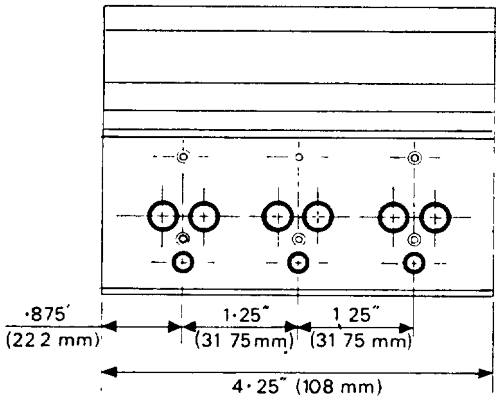


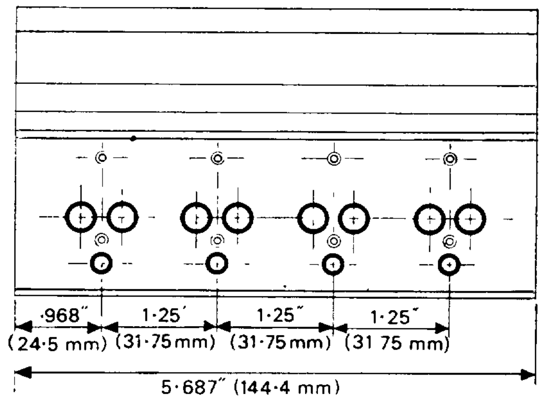


AN
(TO – 3)



AP
(2 × TO – 3)



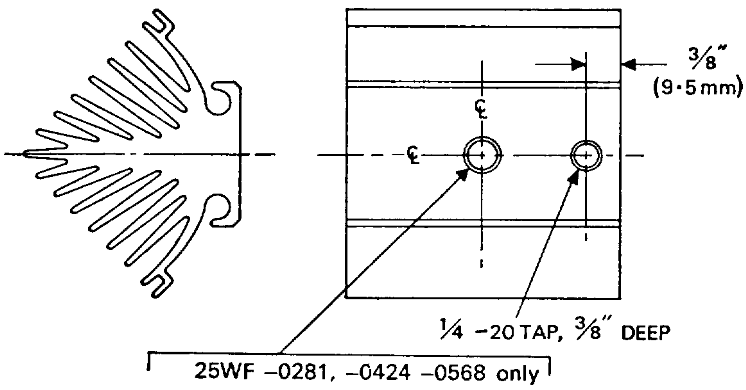


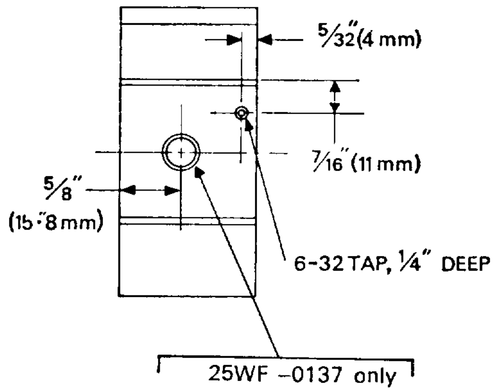
AQ
(3 × TO – 3)

AR
(4 × TO – 3)

(b) For 25WF HEAT SINKS

(For no Hole Pattern Quote A –)





LG	– 8	– 32 UNC × 5/8"	Deep
ME	– 10	– 32 UNF × 5/8"	Deep
ND	– 1/4	– 28 UNF × 5/8"	Deep
PC	– 3/8	– 24 UNF × 3/4"	Deep
QC	– 1/2"	– 20 UNF × 7/8"	Deep
SB	– 3/4"	– 16 UNF × 1·0"	Deep
XC	– 5/16"	– 24 UNF × 3/4"	Deep

LF	– 8	– 32 UNC × 5/8"	Deep
MD	– 10	– 32 UNF × 5/8"	Deep
NC	– 1/4"	– 28 UNF × 5/8"	Deep
PB	– 3/8"	– 24 UNF × 3/4"	Deep
QB	– 1/2"	– 20 UNF × 7/8"	Deep
SA	– 3/4"	– 16 UNF × 1·0"	Deep
XB	– 5/16"	– 24 UNF × 3/4"	Deep

(Tap Depth + 1/4 – 0)

Special hole patterns.

If the hole pattern chosen cannot be quoted as a standard, quote S – in module specification and send a drawing.

Notes:
Location of mounting groups on coolers to be within 1/32" of true position

Worked Example Demonstrating Method of Design and Specification

REQUIREMENT
An assembly of 25 WF heat sinks required to cool 12 thyristors

DATA PROVIDED
Each thyristor dissipates 46 Watts
Max. acceptable case temperature = 123° C
Temperature difference between device case and heat sink @ 0 2° C/W × 46 Watts = 9 2° C
Ambient temperature = 55° C
Standard performance fan to be used
Due to the physical size of the device each unit will be cooled by 2 standard module lengths i e 25 WF - 0281

DESIGN
In order to check that a 2 module length of heat sink is capable of cooling each of the respective thyristors, performance calculations are performed for one sector (Note - each sector is symmetrical in this case, therefore, only sector no 1 is considered i e 3 devices in the air flow direction See figure 11)

1 Total section length = 6 standard lengths (3 devices × 2 module lengths)
A typical fan would provide 60 CFM airflow hence from figure 9 using one quarter air flow we have 15 CFM versus 0 15 inches W G This falls within the performance bands in figure 8

2 For the first thyristor the allowable temperature difference (heat sink to ambient air) is -
123 - 9 2 - 55 = 58.8° C
° C/W (R^{th} allowable) = $\frac{58.8}{46}$ = 1 278

∴ From figure 7 this performance would be achieved with 25 WF - 0137, however we must use 25 WF - 0281

3. For the second thyristor, refer to figure 10 to assess the increase in effective air temperature There are two standard lengths upstream cooling 23 Watts each
First upstream unit produces 0 285° C/W
Second upstream unit produces 0 21° C/W
Total temperature rise = 23 (0 285 + 0.21) = 11 4° C
∴ Available temperature difference (heat sink to air)
123 - 9.2 - 55 - 11 4 = 47 4° C
° C/W (allowable) = $\frac{47\ 4}{46}$ = 1 03

∴ From figure 7 this performance is again achieved by 25 WF - 0137 although a 25 WF - 0281 is necessary

4 For the third thyristor there are four standard lengths upstream cooling 23 Watts each Hence from figure 10
Third upstream unit produces 0 17° C/W
Fourth upstream unit produces 0 145° C/W
Total temperature rise = 23 (0 285 + 0 21 + 0.17 + 0 145) = 18 63° C
Available temperature difference (heat sink to air)
123 - 9 2 - 55 - 18 63 = 40 17° C
° C/W (allowable) = $\frac{40.17}{46}$ = 0 873

∴ From figure 7 this performance is achieved by 25 WF - 0281

5. To calculate the individual case temperatures for each thyristor, we established, from figure 7 that the thermal resistance of a 25 WF - 0281 at an air flow of 15 CFM would be 0 56° C/W
At 46 Watts this gives 46 × 0 56 = 25 8° C
∴ The case temperatures would be

First thyristor	55 + 9 2 + 25 8	= 90° C
Second thyristor	55 + 9.2 + 25 8 + 11 4	= 101 4° C
Third thyristor	55 + 9 2 + 25 8 + 18 63	= 108 63° C

SPECIFICATION
The design has been checked above and the performance meets the physical restraints. Therefore to specify the assembly (see page 8) we have -

1. U1 end plates at both ends
U1, ; U1

2. All sectors are the same therefore they can be specified together
U1, Sectors (1 to 4) , U1

3. The length of all sectors are the same and each contain a thyristor hole pattern (In the case of non-standard hole patterns, a drawing is required)
U1, Sectors (1 to 4) 25 WF - 0281S_ ; U1
Note: If sector lengths are in inches use four digits (0281), for lengths in MM use five digits (00714)

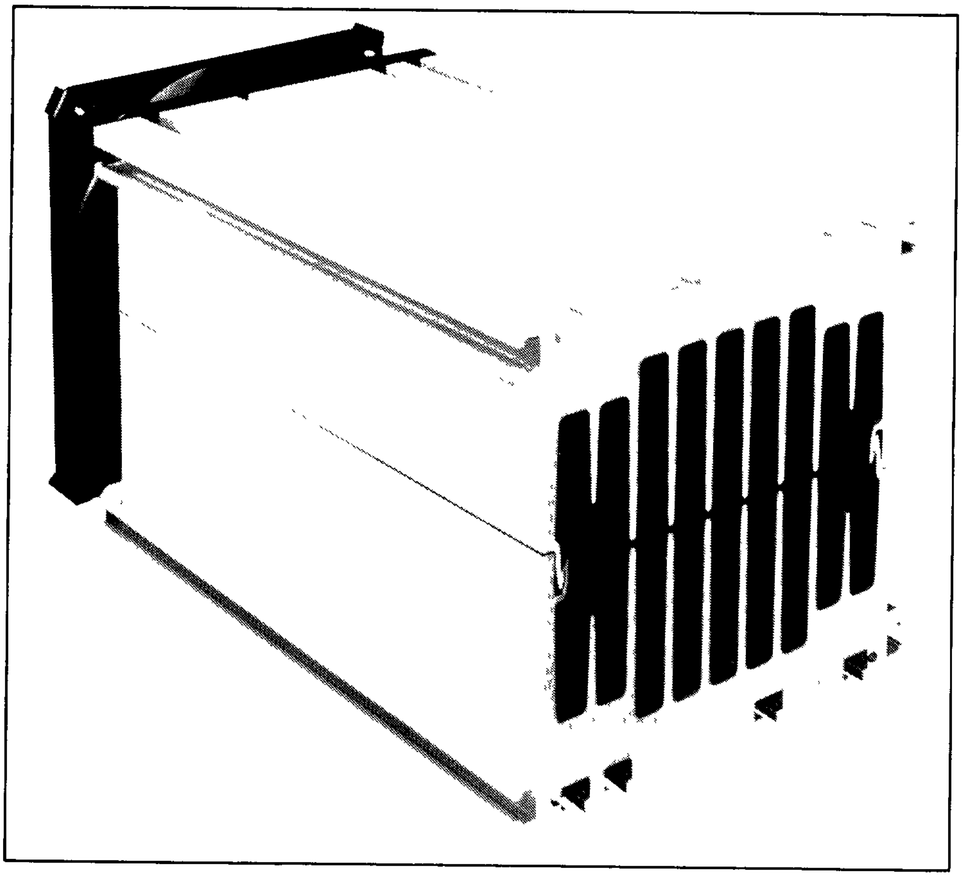
4. With a plain surface finish and three 'double' station lengths the complete specification becomes -
U1, Sectors (1 to 4) 25 WF - 0281S_1 × 3 ; U1

Other Heat Sinks for Force Cooling

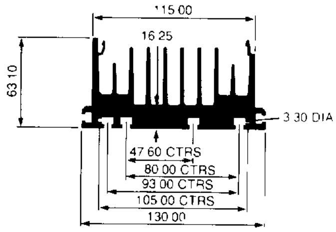
69DN

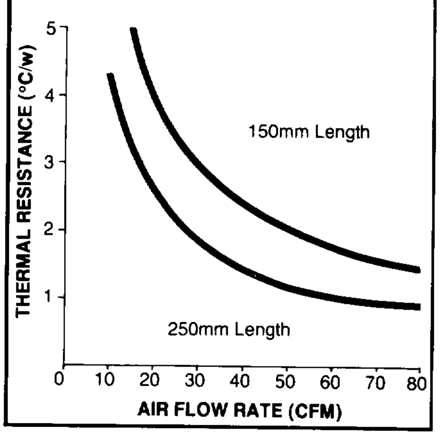
This heat sink is made up of two pieces of 69DN heat sink, clipped together to form a fully enclosed square shaped heat sink suitable for forced cooling with a standard 120mm Axial fan

It has tee slotted features which allow a variety of devices to be mounted easily and securely without drilling. Fan gaskets and end plates are available if required.



Profile

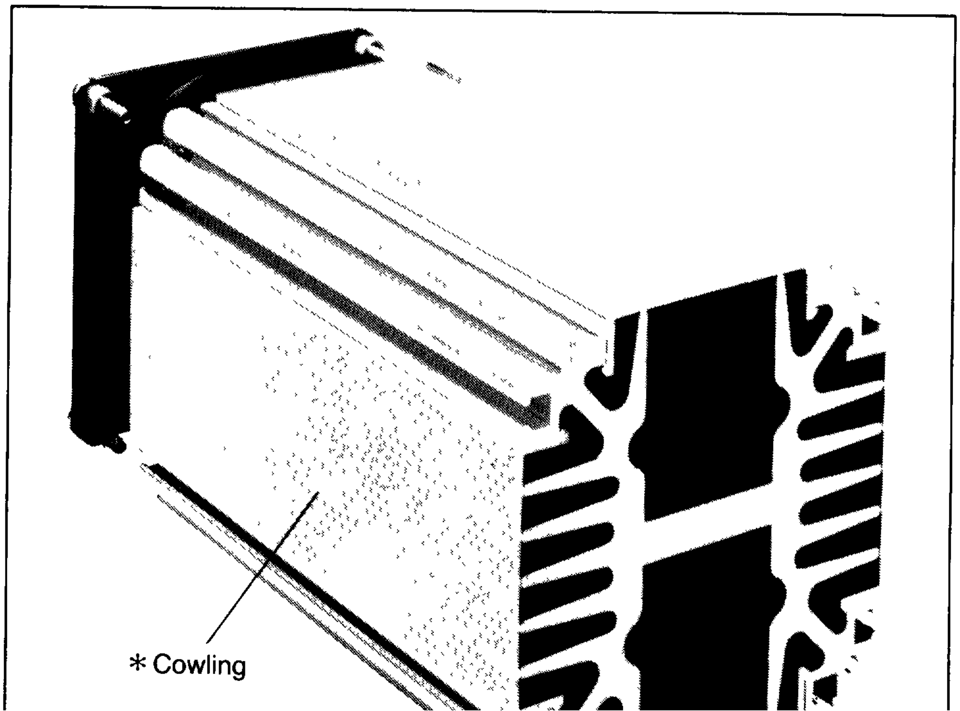




**GRAPH OF
THERMAL RESISTANCE vs AIR FLOW RATE
FOR 69DN HEAT SINK PAIR**

70DN

This heat sink has been designed to suit a standard 80mm Axial fan for force cooling a variety of metal and plastic devices, semi conductor packs, etc.



Profile