Stacked Fin Design Guide

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Thermal Cooling Solutions from **Smart** to **Finish**

Standard Stack-Fin™ Shapes

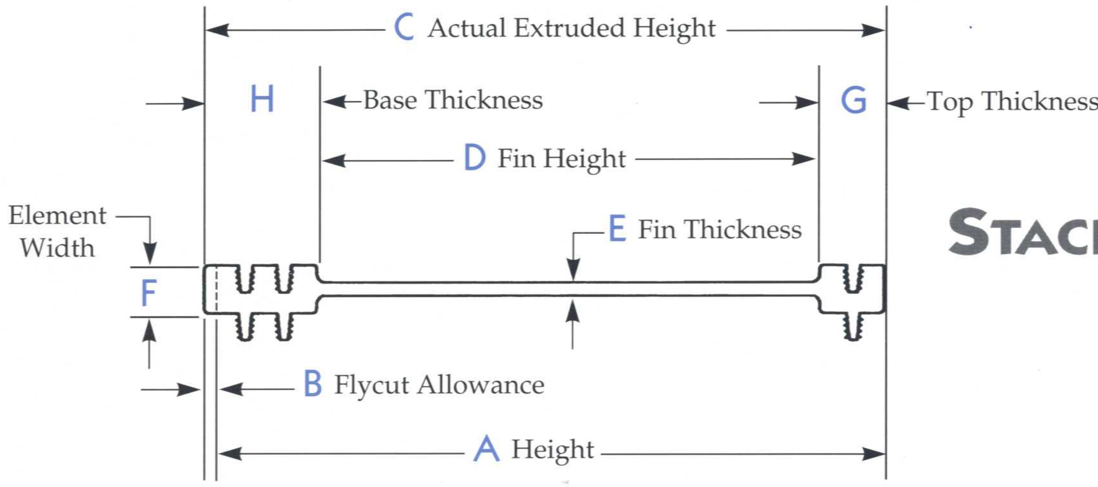
SUMMARY OF ENGINEERING DETAIL

	DIE #	13945	14275	14445	14775	14496	14704	14341	14766	14706	14804	15704
A	HEIGHT (nominal)	1.500	2.180	2.500	2.500	2.730	2.950	3.250	3.500	4.315	5.000	6.000
B	FLYCUT ALLOWANCE	0.040	0.070	0.070	0.070	0.070	0.080	0.070	0.080	0.080	0.000	0.090
C	ACTUAL EXTRUDED HEIGHT	1.540	2.250	2.570	2.570	2.800	3.030	3.320	3.580	4.395	5.000	6.095
	FIN STYLE	STRT	STRT	STRT	ACCORD	STRT	STRT	STRT	STRT	STRT	STRT	STRT
D	FIN HEIGHT	0.960	1.516	1.911	1.970	2.007	2.266	2.504	2.816	3.625	4.200	5.356
E	FIN THICKNESS	0.055	0.060	0.050	0.050	0.060	0.060	0.060	0.060	0.060	0.070	0.080
F	ELEMENT WIDTH (B distance)	0.150	0.188	0.180	0.180	0.182	0.181	0.184	0.230	0.230	0.182	0.215
G	TOP THICKNESS	0.140	0.234	0.234	0.175	0.273	0.249	0.234	0.23	0.250	0.400	0.234
H	BASE THICKNESS	0.440	0.500	0.425	0.425	0.520	0.515	0.582	0.530	0.520	0.400	0.500
	CLOSEST FAN SIZE (mm)	40	50	60	60	70	70	80	92	120	120	120
	SEA*/ELEMENT	2.110	3.288	4.082	4.952	4.258	4.834	5.396	6.132	7.630	8.624	10.806
	AIRFLOW (OPEN) in2	0.0192	0.194	0.248	0.646	0.245	0.278	0.319	0.492	0.620	0.470	0.537

TYPICAL THERMAL PERFORMANCES

FORCED CONVECTION GUIDELINES FOR REPRESENTATIVE STACK FIN™ ASSEMBLIES

# ELEMENTS	30	36	42	42	45	50	54	46	57	82	82
SIZE WIDTH	4.50	6.77	7.56	7.56	8.19	9.05	9.94	10.5	13.11	14.92	14.92
WIDTH	4.5	6.75	7.5	7.5	8.25	9.0	10.0	10.5	13.2	15.0	14.9200
LENGTH	4.5	6.75	7.5	7.5	8.25	9.0	10.0	10.5	13.2	15.0	14.9
θsa @ 200LFM	0.444	0.191	0.128	0.105	0.109	0.083	0.064	0.066	0.038	0.022	0.0174
θsa @ 400LFM	0.317	0.136	0.091	0.075	0.078	0.059	0.046	0.047	0.027	0.015	0.0124
WIDTH	4.5	6.75	7.50	7.50	8.25	9.00	10.00	10.5	13.20	15.00	15.0
LENGTH	9	13.50	15.00	15.00	16.50	18.00	20.00	21.00	26.40	20	20.0
θsa @ 200LFM	0.314	0.1374	0.0905	0.0746	0.0772	0.0584	0.0449	0.0471	0.0264	0.0185	0.0149
θsa @ 400LFM	0.224	0.0982	0.0647	0.0533	0.0552	0.0418	0.0325	0.0340	0.0191	0.0134	0.0108



STACK-FIN™

The electronics industries wide acceptance of modular packaging has given rise to the need for innovative thermal management solutions.

STACK-FIN™ is just such a solution. The high fin densities that can be achieved with STACK-FIN™ are ideal to meet the high power requirements of these modules such as:

- Isolated gate bipolar transistors, IGBTs
- Power MOSFETS
- Solid state relays
- R F transistors for transmitters
- Laser diodes
- Thermoelectric coolers.

The system mechanical designer can use the available STACK-FIN™ shapes to create custom, self shrouded, forced convection, high density heat transfer solutions for all of the above modules and more. The patented STACK-FIN™ element is a single base, fin and top shroud that can be stacked to achieve a high aspect ratio heat sink where the base and shroud are integral with the fin. There are no joints in the fin-to-base or fin-to-shroud transitions. The tongue and grooves in the base and top shroud provide an increase in the transition surface area thus compensating for the increased thermal resistance of the intimate joint. This increase in the interface area is more than 125% of the equivalent plane projected area. It has been proven to work in hundreds of applications where it has outperformed other joined systems such as bonded or staked fins.

Custom STACK-FIN™ heat sink assemblies can be provided;

- In overall heights from 1.50" to 6.00".
- In widths from 1.00" to 22.00"; milled to +/- .010".
- In lengths [air flow direction] from 3.00" to 24.00".
- Quick-turn and low cost new tooling when required
- Module mounting surfaces [.50" thick side] are flycut, .001"/.001" most sizes.
- In fin spacings from .182" up to .350" [fin centerline to centerline].
- In thermal resistances down to 0.0100 °C/W [see table].
- Mechanically exceptionally strong. No deformation even under 20,000 lb. clamping loads.
- With side rails [as standard option].
- With fan mounting interfaces for single or multiple fans; 60, 80 and 120 mm. stds.
- For in-line [along the length] as well as on some models impingement flow.
- With standard fans in these sizes; 60 X 20; 80 X 25/38.5; 120 X 25/32 mm.

Assemblies other than those described above can probably be supplied or closely approximated. Contact our Engineering Department with your specific requirements so that we may provide you with the advantages of a STACK-FIN™ heat sink solution. While most useful for forced convection applications, natural convection adaptations can be designed that utilize the full shrouding feature provided by the STACK-FIN™ elements.

STACK-FIN™ ASSEMBLIES

STACK-FIN™ heat sink assemblies are offered primarily for forced convection applications as is evident from the chosen element thickness [equivalent to the fin centerline spacing] . For natural convection offerings please consult our Engineering Department with your application details.

The design details and the thermal performance values for the available STACK-FIN™ shapes have been summarized on page 1 of this brochure.

The first step in heat sink design is to calculate the required Theta sa:

Assuming you have been given Tcmax., Thetacs, Tmax.amb. and Power;

Theta sa = Tmax.ambient - Tcmax. - Delta T interface / Power to be Dissipated

Assuming you have been given Tjmax.; Thetajc, Thetacs, Tmax.amb. and Power;

Theta sa = Tmax.ambient - Tjmax. - Delta Tjc - Delta T interface / Power

At this point it is appropriate to consider applying two factors that relate to the application. These are:

- Should a correction factor be applied to Theta sa for the maximum altitude to be encountered, our suggestion for world wide service, multiply by .862 for a compromise of 8,000'.
- Since fan flows decrease slowly over time should we pick an air flow reduction factor to compensate for this phenomenon over the planned life of the equipment under design. A common factor for this End-of-Life [EOL] prediction is a reduction in flow of 25% [therefore multiply the anticipated air flow by .75; this generally provides for fan life in the range of 50,000 hrs.

When the required real world Thermal Resistance [Theta sa] is known you can go to the summary chart of sizes and look for similar values. This will give you an idea of the range of element sizes and air flow rates that might be considered for this application.

Generally speaking several iterative trials will be required to match the heat sink size with the available space in the application. All heat sinks represent a problem in convective heat transfer. Convection is first a problem in packing enough fin surface area in the air flow stream and second controlling the boundary film thickness. The unique shrouded feature of the STACK-FIN™ construction assures a known air flow over the fins and maximizing this velocity minimizes the formation of insulating boundary films.

The velocity of the air flow in the air flow openings can be estimated from the fan manufacturers performance curves and the "air flow opening" line on the summary sheet. Remember that the fan manufacturer shows volumetric flow and our heat transfer is interested in linear flow rates, therefore:

For a 55 element STACK-FIN™ #14804 a 120mm fan capable of 70 cfm;

The internal air flow area is:

55 - 1 x .470 = 25.38 sq.in.

The air flow rate in linear feet/minute [lfm] is:

70 / 25.38 /144 = 397.2

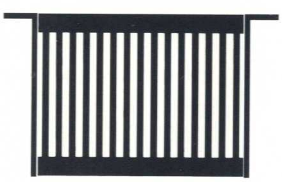
An indicator of the available surface is given with the line "SEA /element" line on the summary chart. The SEA for a STACK-FIN™ heat sink assembly is equal to the available surface with the air flow, the internal openings plus an allowance for the total external surfaces. SEA stands for the **S**pecific **E**ffective **A**rea, i.e. square inches of surface area per inch of length. This is the perimeter area listed in the shape catalogs of most of the heat sink suppliers not corrected for the part of the perimeter that is blocked by the power modules. The term "Effective" reflects this correction.

The standard offering for mounting legs on STACK-FIN™ heat sink assemblies are extruded angles that are attached to both the top [typically .234" thick] and bottom [typically .500" thick] solid sections. These are the most flexible options as they mount on the sides and can be extended out at the base [the thick side, about .50"] or they may be extended out at the top [the thin side, about .23"]. They can even be used on the base on one side and the top on the other side. The following sketch shows the various arrangements and typical hole spacings.

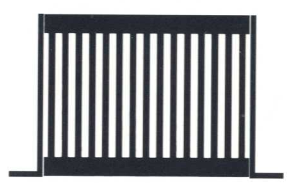
The following table shows the matching mounting angles for each of the standard STACK-FIN™ dies.

STACK-FIN Die #	Tall Leg [inches]	Short Leg [inches]	Angle Thickness [inches]
13945	1.50	.50	.125
14275	2.25	.50	.125
14445	2.50	.50	.125
14496	2.75	.63	.125
14704	3.03	.63	.125
14341	3.32	.63	.125
14766	3.58	.63	.125
14706	4.395	.75	.188
14804	5.00	.75	.188
15704	6.00	1.25	.125

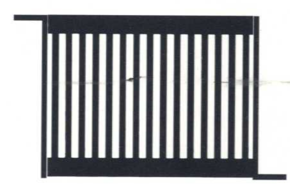
Custom side rails can be ordered to be machined from existing shapes or from a new die to meet unusual needs.



TOP MOUNT



BASE MOUNT



HYBRID MOUNT

Specify Air Flow Direction

MODULE MOUNTING SURFACES

The module mounting surfaces on a STACK-FIN™ heat sink are the .50" thick base. These surfaces are flycut on all STACK-FIN™ heat sinks to provide an optimum surface for the mounting of high power modules. The typical surface flatness will be .001" / .001" unless otherwise noted on the assembly drawing. Larger tolerances may be appropriate for the larger assemblies and in some special custom situations.

The top surface my be flycut to permit the high thermal performance mounting of a limited number of modules. In general, it would be preferable to design a custom STACK-FIN™ shape with a .500" thick top block in place of the more standard .234" thick block.

STACK-FIN™ ASSEMBLY WIDTH CONTROL

STACK-FIN™ heat sink assemblies have too many contributing tolerances to make the control of the assembly width possible without a quick milling operation. This straddle milling operation can produce a width within +/- .010" from the nominal or the defined with on the assembly drawing.

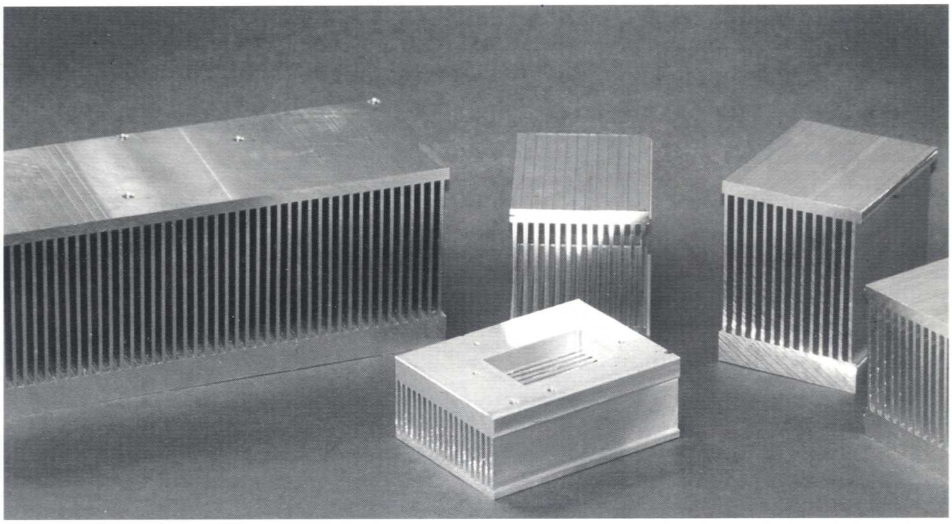
STACK-FIN™ ASSEMBLY HEIGHT CONTROL

All STACK-FIN™ heat sink assemblies are flycut. The tolerance on heights is: single flycut ± .070"; and double flycut ± .020 – considerably better than you could expect from commercial extrusion shape tolerances.

STACK-FIN™ ASSEMBLY STRENGTH

National Northeast has demonstrated the strength of the STACK-FIN™ assemblies to withstand the high compressive forces in high power "hockey puck" applications. The STACK-FIN™ assemblies have been subjected to forces of 20,000 pounds with no observable ill effects.

The STACK-FIN™ assemblies were compressed between a steel bar on one side and a steel disc the same diameter as a typical high power "hockey puck". measurements were taken at the top and the base of the STACK-FINS™ to allow detection of the slightest tendency to push apart [three locations across the top and three locations across the bottom]. No disassembly was detected, even after the application of the 20,000 pound load. Surface marking was observed but that was very minor.



VIBRATION TESTING OF STACK-FIN™ ASSEMBLIES

The vibration testing of Stack-Fin™ assemblies does not seem appropriate at the component stage because its response to vibration testing is entirely dependent upon how it is to be mounted in that assembly and the vibration level and spectrum to be imposed. For this reason no specific vibration testing has been done on any of the many available Stack-Fin™ shapes [and assemblies].

The Stack-Fin™ assembly is a fully contained extended fin assembly, i.e. the fins are fully contained by an upper structure that constrains all of the fins. There is very little opportunity for the fins to develop harmonics that could be potentially destructive to the assembly.

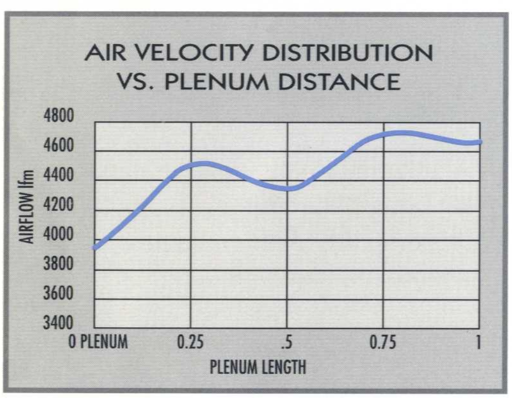
We have looked into the testing of these Stack-Fin™ assemblies on conventional vibration equipment. Because we could not describe any specific system their proposal was to solidly strap down to the test plate. This could not in any real sense be called similar to any of the possible mounting systems, each one an idiosyncratic approach and each one present its own results to the prescribed vibration testing routine.

International design standards suggest using frequency sweeps of 10 to 500 Hz, 5-10g's, with dwell times at any indicated harmonics for transportation and other land based equipment (Appendix B 68-2-6b IEC 1982). This type of testing should be done on each assembled system that incorporates the individual internal mechanical mounting of the heat sink.

There are some general guidelines to get the optimum performance from a heat sink fan. These are generally related to the clearances that surround the fan.

Fan suction clearance requires that there is a clear flow path equal in height to one half the fan venturi diameter. Where space does not allow this amount of clearance then it can be reduced by up to 50 % with a penalty in air flow rate and fan life. This is true for pushers, pullers and impingers. This is the clearance on the fan suction side whether it faces the heatsink or faces away (normal situation).

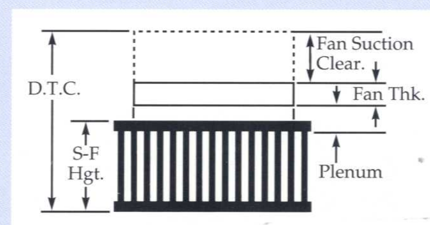
Fan plenum spaces are suggested to be assured that there is an even distribution of pressure upstream of the openings therefore an even distribution of air flow rates across the fin surface areas. We have run air velocity distribution curves versus the plenum distance and find that there is little advantage to a plenum distance more than .75". When this is cut in half there is a 10/15 % impact on the average flow velocity. The preceding curve (above) illustrates this point for a 60 X 20 mm fan and a 2.50" high STACK-FIN™ element.



The fan mounting is accomplished with a standard sheet metal plate for each fan and screwed to the top and bottom surface of the heat sink similar to that pictured below. These are secured with pan head self tapping screws top and bottom thus setting the plenum space at .75" as a standard for all fan sizes used as standards.

The heat sink size is a deceptive figure in understanding the full amount of space that is necessary for a full heat sink and fan with the appropriate air flow clearances. The Design Total Clearance [D.T.C.] for both impingement and in-line fan heat sink configurations are defined below in a manner that will permit detailed calculations for any combination of STACK-FIN™ heat sinks and fans chosen for a given application.

DESIGN TOTAL CLEARANCE FOR IMPINGEMENT FAN – HEAT SINKS

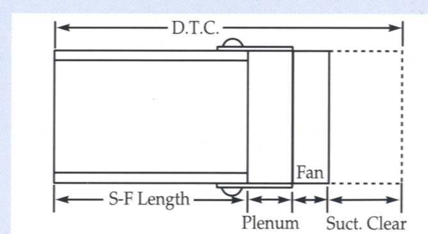


D.T.C. = S-F Height + Plenum Ring + Fan Thickness + Fan Suction Clearance
[Table] [Typ. .516"] [Mfgr. Catalog] [.5 Fan Venturi Diam.]

Minimum D.T.C. [With Some Loss of Thermal Performance]

D.T.C.min. = S-F Height + Fan Thickness + Fan Suction Clearance
[.25 Fan Venturi Diam.]

DESIGN TOTAL CLEARANCE FOR IN-LINE FAN – HEAT SINKS



D.T.C. = S-F Length + Plenum Ring + Fan Thickness + Fan Suction Clearance
[Thermal Design] [Typ. .75"] [Mfgr. Catalog] [.5 Fan Venturi Diam.]

Minimum D.T.C. [With Some Loss of Thermal Performance]

D.T.C.min. = S-F Length + Fan Thickness + Fan Suction Clearance
[.25 Fan Venturi Diam.]