An Assessment of Radiator Performance

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Table of contents

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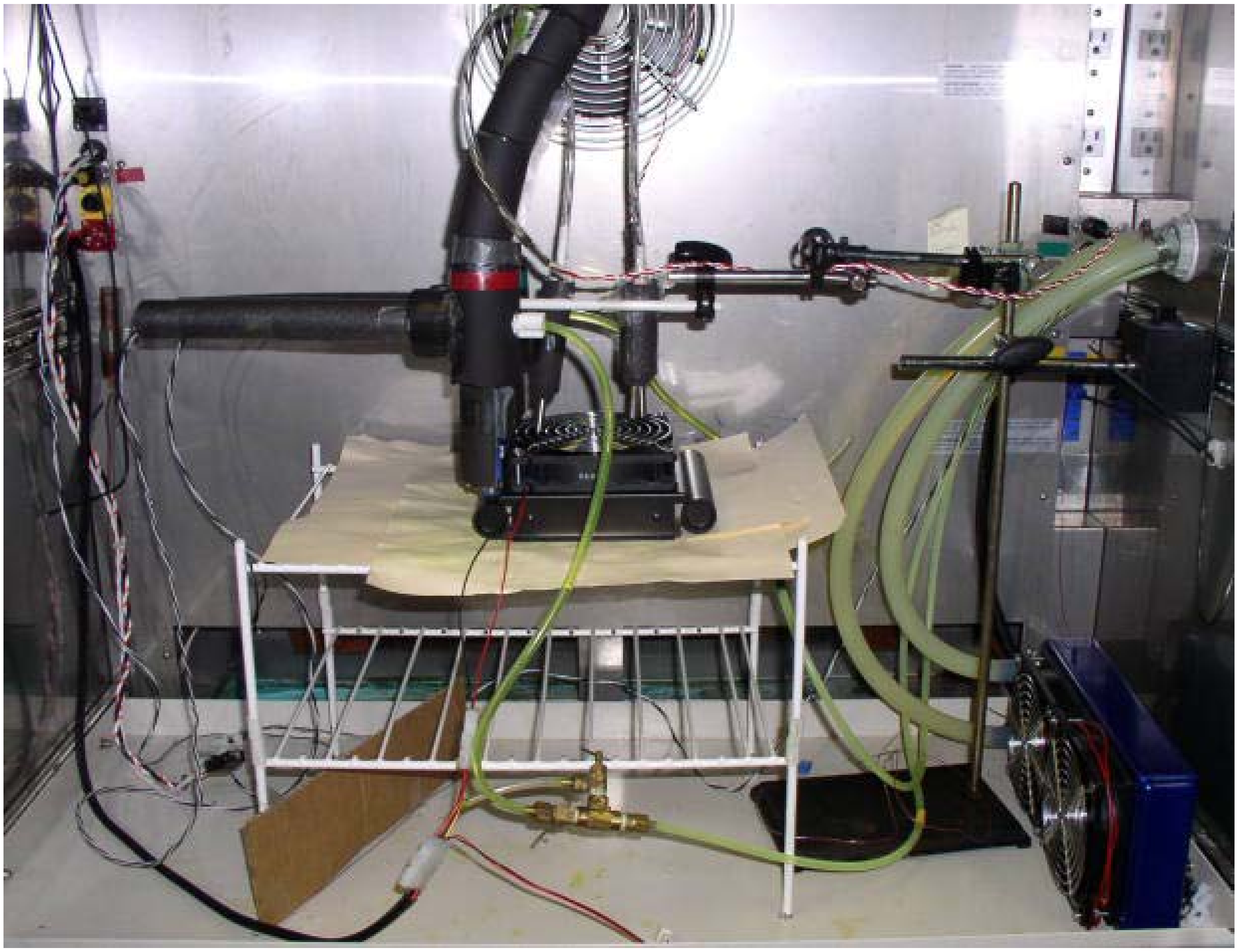
Introduction

This is a survey of radiator types in use in watercooling systems for personal computers. The focus of the survey is limited to the assessment of radiator performance with a single fan, selected on the basis of its noise to performance ratio. Limited also were the sizes, only radiators for a single120mm fan were compared, although two 80mm radiators were included to illustrate the difference between 1-pass and 2-pass configuration. Comparisons are made initially within a given type of radiator, and then between the different types.

Note that this testing was performed not to assess the ultimate performance capability of the radiators; for each this would occur at the maximum air and liquid side flow rates, together with the maximum temperature difference between the hot and cold sides. This test regime is 'noise limited' and is effected by using a single fan, the Delta WFB1212M for 120mm radiators @ 34db(A) and a Delta AFB0812H for 80mm radiators @ 31db(A).

1. <u>Test Equipment and Procedures</u>

Testing was performed in a Forma Scientific environmental chamber to control the ambient temperature; while the circulated coolant was held at 35°C with a Haake A82 recirculating chiller. Air and coolant temperatures were taken at equilibrium and measured to 2 decimal places with Fluke 2180A thermometers using an average where there were fluctuations. Flow was measured with a ½" Rosemount 8712C magnetic flow meter and pressures with a Foxboro 823DP differential pressure transducer, again measured to 2 decimal places using Philips PM2534 DMMs. The photo below shows a typical bench test setup.



All 120mm radiator testing was done with a single fan, a Delta WFB1212M turning at 2100 RPM producing 72.4 CFM (no restriction) with a noise SPL of 34 db(A). This fan was selected due to its moderate noise and relatively good performance compared to other fans with similar noise characteristics. For 80mm radiators a Delta AFB0812H is used having an SPL of 31 db(A). The coolant was distilled water and 5% HydrX. The temperature difference was 10°C for the 120mm radiators and 15°C for the 80s. These differentials were selected to reflect actual usage conditions; i.e. watercooling systems with single small radiators will run hotter than with larger or multiple radiators.

2. Radiator Descriptions

The following radiators were compared to each other in groups. Their attributes and dimensions are summarized in Table 1 below.

a. 120mm class

- **Group 1**
  - **MCR120-QP:** Swiftech's MCR120-QP is a single row, 2-pass configuration but utilizes a somewhat wider tube than others.
  - **Black Ice Pro (BIP):** Made by HW Labs, the BI Pro is a single row, 2-pass configuration.
  - **BI Cross** Also by HW Labs. The BI Cross (X-Flow ?) is the same radiator core as the BI Pro, but with different headers to convert it from a 2-pass to a single-pass, or cross flow configuration
  - **Corsair Hydrocool:** The radiator supplied in the Corsair Hydrocool was removed to test its performance. It is all aluminum and a 2-pass design.
- **Group 2**
  - **Black Ice Extreme (BIX):** Made by HW Labs, the BIX is a 2 row variant of the BI Pro, again a 2-pass configuration.
  - **ThermoChill 120.1:** Made by ThermoChill, the 120.1 is a 2 row, 2-pass radiator in its original version.
  - **CoolRad-12T:** Made for CoolingWorks, the CoolRad-12T is another 2 row, 2-pass radiator.
  - **CoolWave:** The CW120S2 is a generic OEM radiator having a 2 row, 2-pass configuration.
- **Group 3**
  - **Hayden:** Made by Hayden as a prototype for Swiftech, a stacked plate brazed all aluminum radiator in a 1-pass configuration.
  - **D-Tek Pro:** The D-Tek Pro is a 2-pass cut down corrugated plate heater core to a typical 120mm fan dimension.
  - **Lytron:** This Lytron model was the initial Swiftech radiator in 2000; it is similar to the current model M05-050 but has 2 more tubes. It is a continuous tube of copper, with soldered fittings on one side, and flat aluminum sheets are pierced and crimped around the tubes for fins.

b. 80mm class

- **MCR80-QP:** Swiftech's MCR80-QP is a single row, single pass radiator.
- **Black Ice (BI Micro):** Made by HW Labs, the BI Micro is a dual row 2-pass configuration.

Table 1

Model/Attributes	Material (tube/fin)	Frontal area, in²	Volume, in³	Number of tubes/rows	Fins per inch, FPI	Shroud depth, in.
MCR120-QP	Brass/cu	21.6	18.8	12/1	13.5	0.26
BI Pro, single 120 fan	" "	22.9	14.9	12/1	17	0.24
BI Cross, single	" "	22.9	14.9	12/1	17.3	0.24
Corsair (Hydrocool)	Alu/alu	22.6	18.1	15/1	18.5	0.32
BI Extreme, single	Brass/cu	22.9	32.1	12/2	17.5	0.21
ThermoChill 120.1	" "	23.3	29.1	12/2	22.5	0.36
CoolRad-12T	" "	23	29.2	12/2	16.5	0.24
CoolWave, single	" "	21.9	27.5	12/2	17.5	0.30
Hayden (prototype)	Alu/alu	23.3	29.1	10/1	12	0.58*
D-Tek Pro	Brass/cu	26.1	51.4	12/1	11	0.58*
Lytron (~=MO5-050)	Cu/alu	23.8	35.6	10/offset	22	0.60
MCR80-QP	Brass/cu	9.5	8.2	8/1	17	0.25
BI Micro	" "	8.8	12.3	8/2	17	0.23

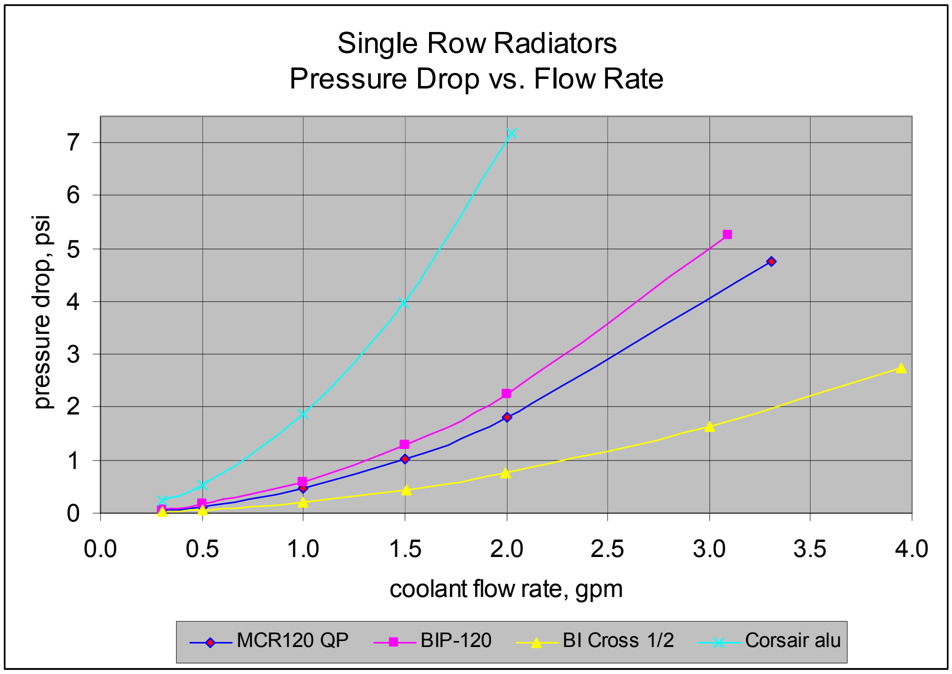
*External shroud added to flat faced radiators

3. Performance Testing

c. Group 1: Single Row Radiators

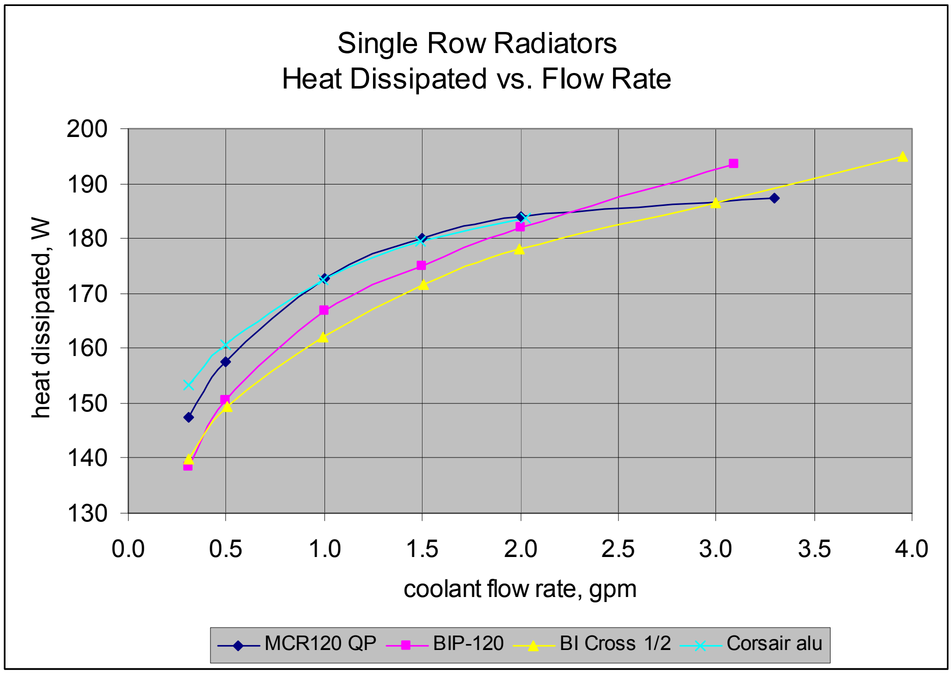
The first group of radiators tested was that having a single row of tubes. All of these radiators are a 2-pass configuration.

Graph 1



The large range of pressure drops reflects the difference in design and construction of these four radiators. The BI Cross (a cross flow configuration, corner to opposite corner) has the same core (tubes and fins) as the BI Pro; the greatly reduced flow resistance is due not only to that configuration (1 pass vs. 2 pass) but also to the 1/2" barbs – whereas all the other radiators tested had 3/8" barbs. The high flow resistance of the Corsair aluminum radiator is due to the structure of the tubes.

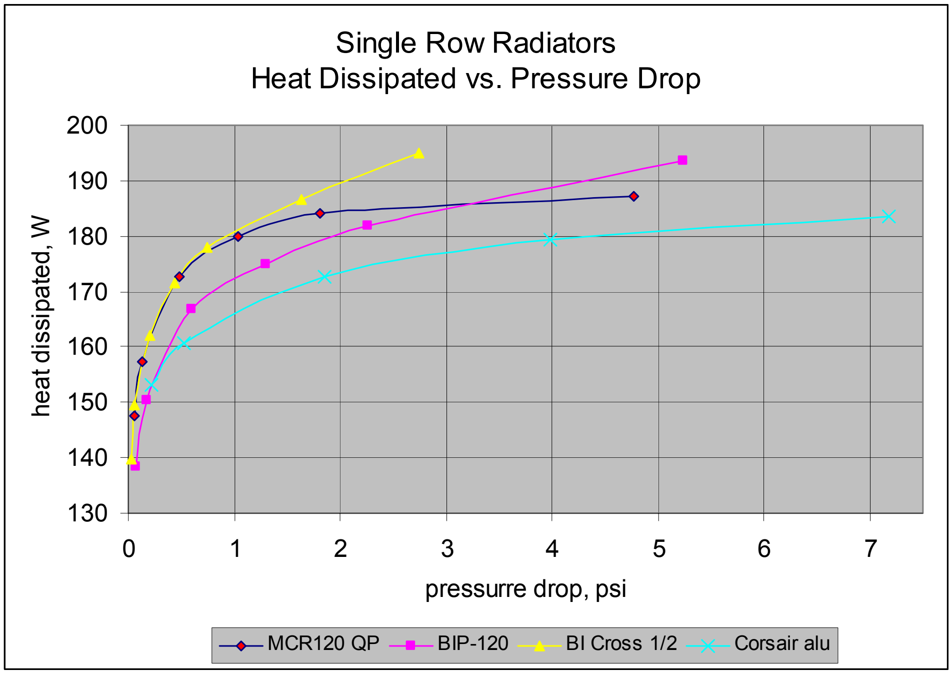
Graph 2



The above is the conventional plotting of heat dissipated vs. flow rate and the Swiftech MCR120-QP and the Corsair radiators have an advantage over both BI models. Note that the flow rate range of interest is between 1 and 1.5 gpm as most US designed systems will have flow rates in that range.

If graphs 1 and 2 are combined, one can see the resulting dissipation as a consequence of the pressure drop.

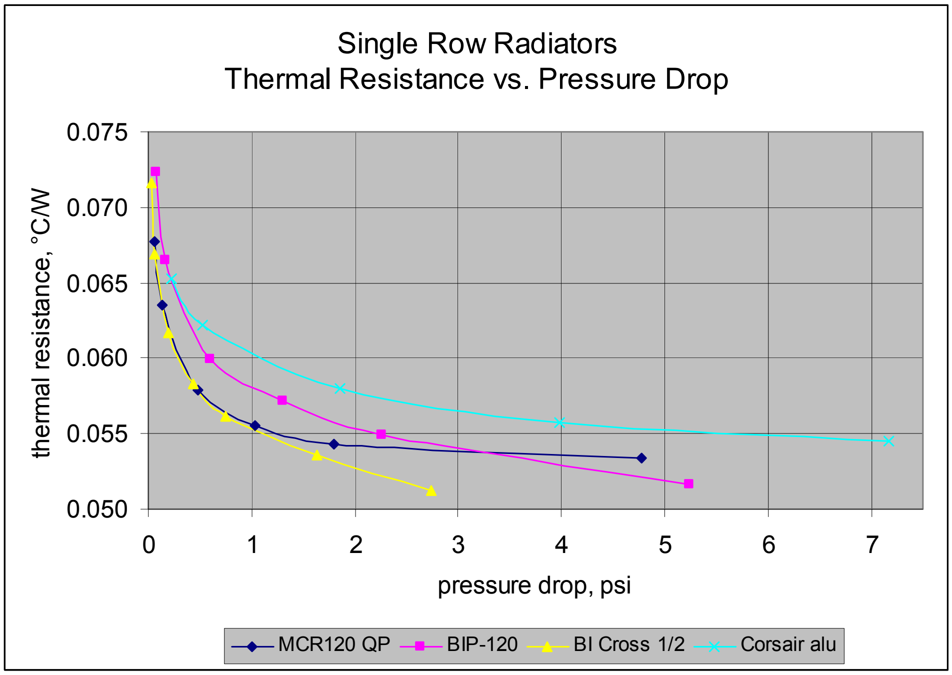
Graph 3



Now the MCR120-QP and the BI Cross have higher dissipation when the radiators' pressure drop is also considered. By counting the line symbols from left to right the flow rate is also known, the markers' flow rates being 0.3, 0.5, 1.0, 1.5, 2.0, and 3.0 GPM. It can be seen that the MCP120-QPs dissipation is exceeded by the BI Cross only when the flow rate is beyond 2 GPM, a situation most unlikely in a pc water cooling system. Under certain situations a single pass radiator may be useful, but generally their performance will always lag that of a 2-pass due to the lower tube fluid velocity. There are exceptions, one circumstance of which is described in the 80mm radiator tests below.

Another way to plot the above is substituting thermal resistance for the heat dissipated.

Graph 4

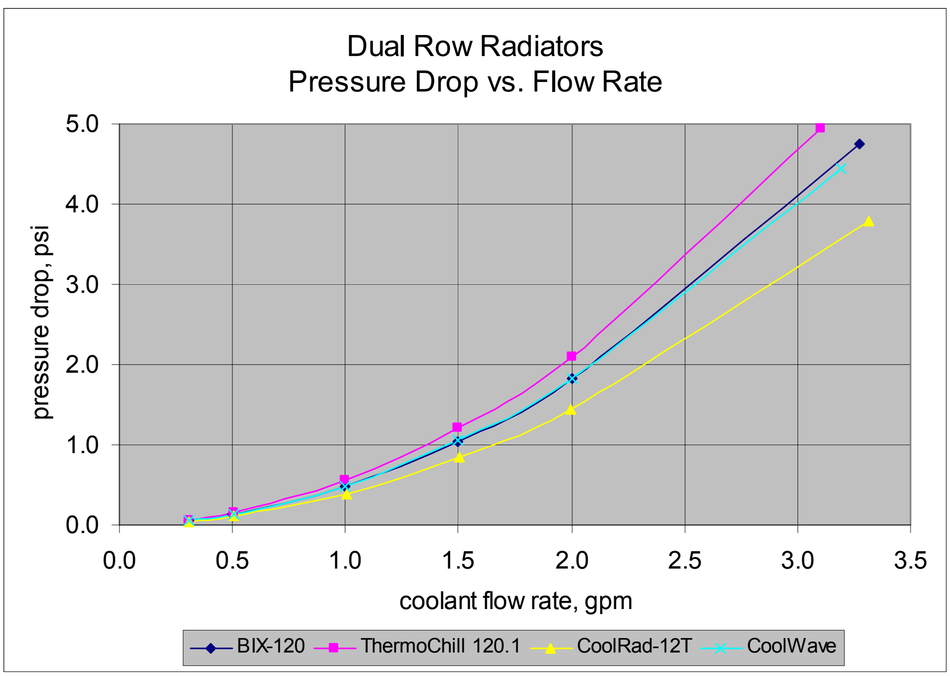


This presentation is more useful as if the system flow rate and the total heat load are known, then the coolant temperature can be estimated using the C/W.

Group 2: Dual Row Radiators

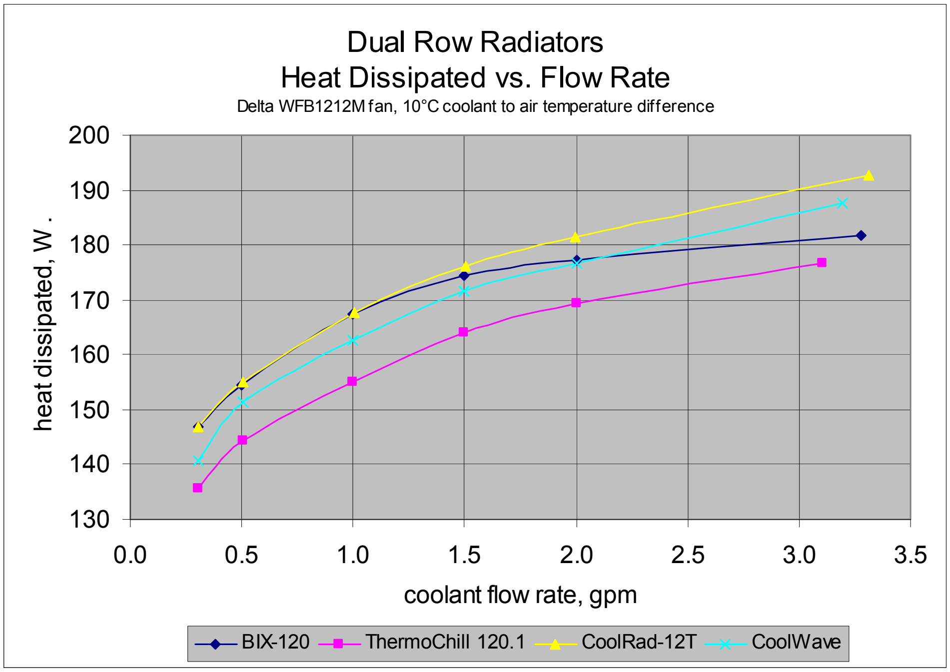
Dual row radiators exist to handle higher heat loads than single row versions, all shown have a 2-pass configuration.

Graph 5



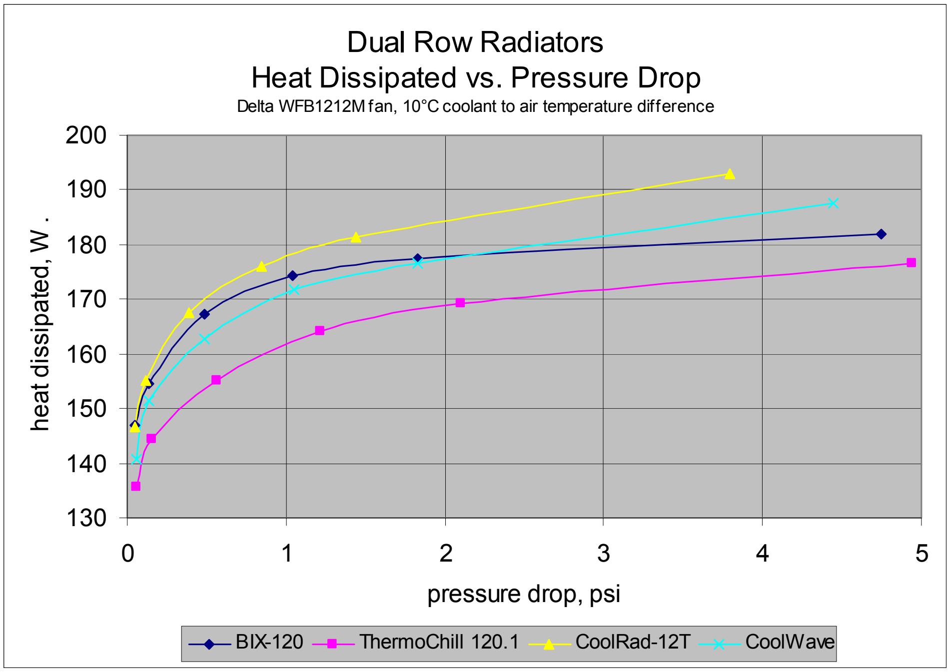
All four of the dual core radiators are similar in construction, even to the nominal tube dimensions; the lowest pressure drop being that of the CoolRad-12T.

Graph 6



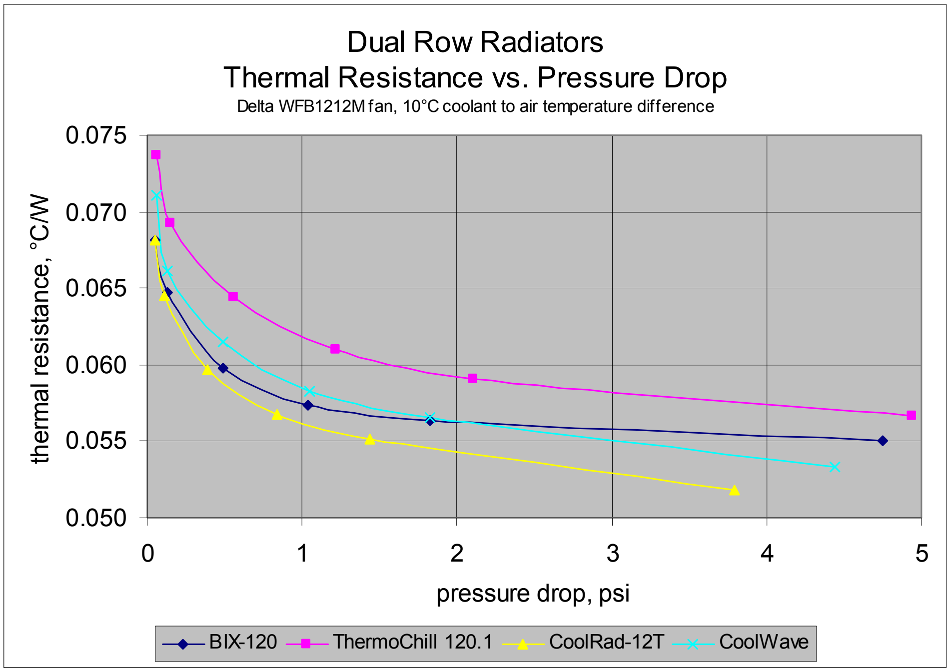
The BI Extreme and its clone, the CoolRad-12T, perform similarly with the edge to the CoolRad-12T at higher flow rates. The CoolWave was close, while the ThermoChill 120.1 indicates it needs more airflow to perform well.

Graph 7



Again, when plotting heat dissipated vs. the pressure drop; the edge, other things being equal, will go to the radiator having the lower flow resistance. The same relationship can be seen in graph 8 below by plotting the radiators' thermal resistance against the pressure drop.

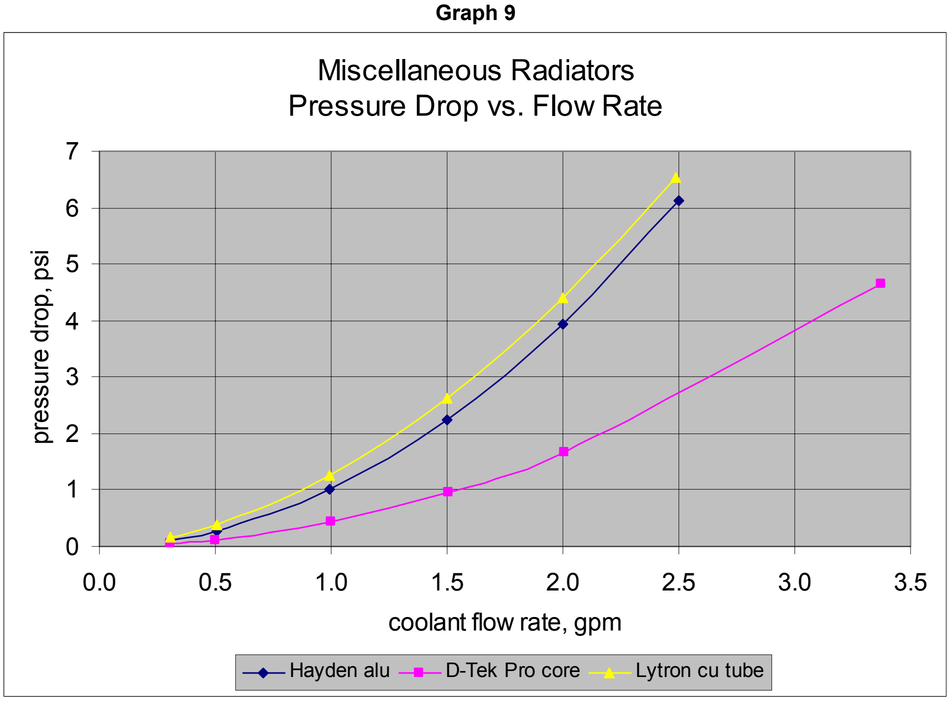
Graph 8



d. Group 3: Miscellaneous Radiators

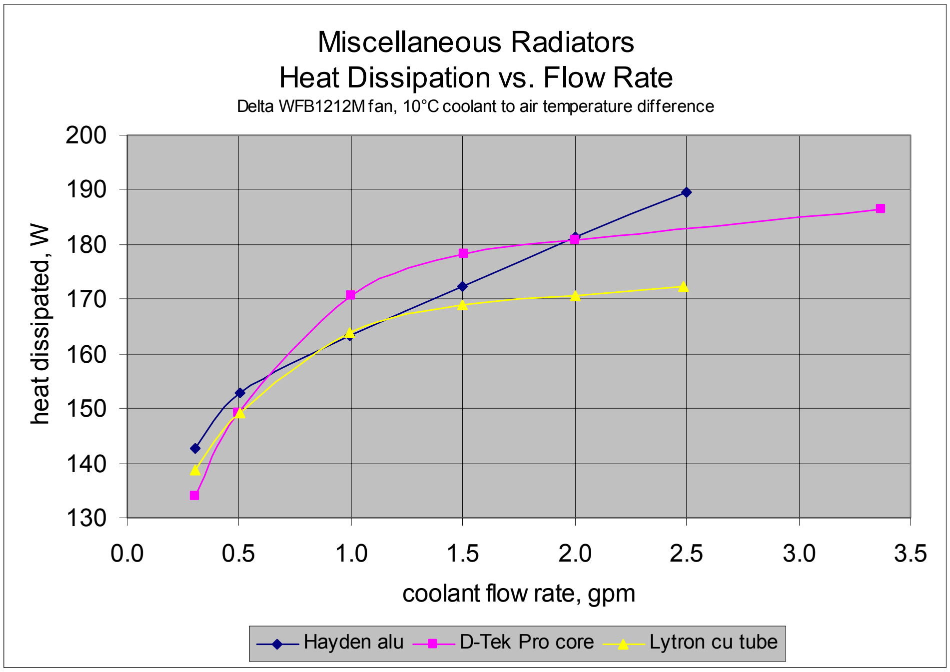
This assorted group includes corrugated plate (heater core), continuous tube, and aluminum stacked plate (oil cooler) configurations. Note that all 3 radiators are specifically made to the 120mm format thus eliminating the gross size differences that normally inhibit the comparison of these types.

Graph 9



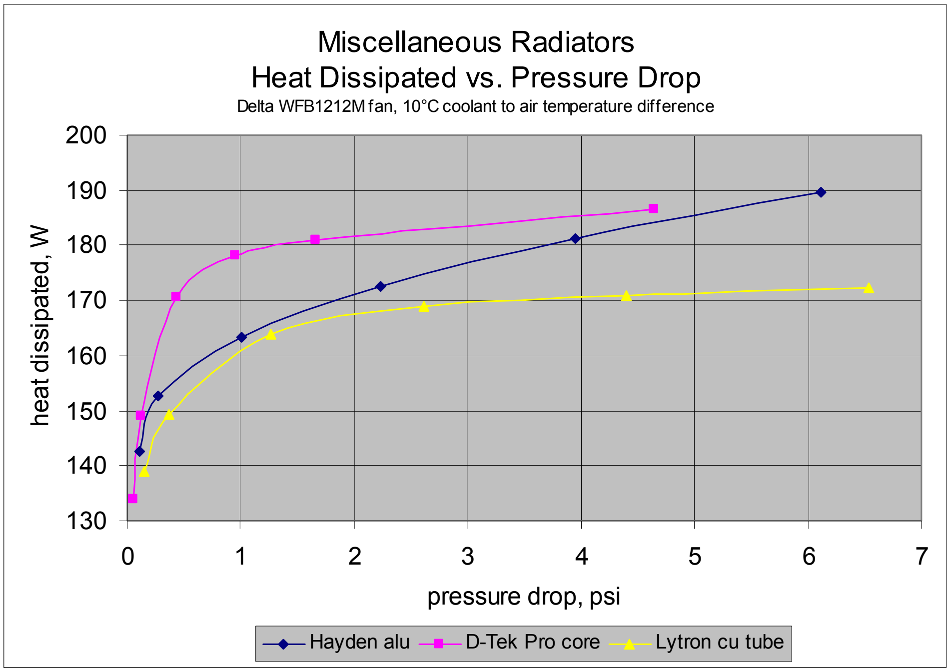
Expectedly the D-Tek Pro (cut down) heater core has low flow resistance while the copper continuous tube and the aluminum stacked plate designs have similarly high pressure drops.

Graph 10



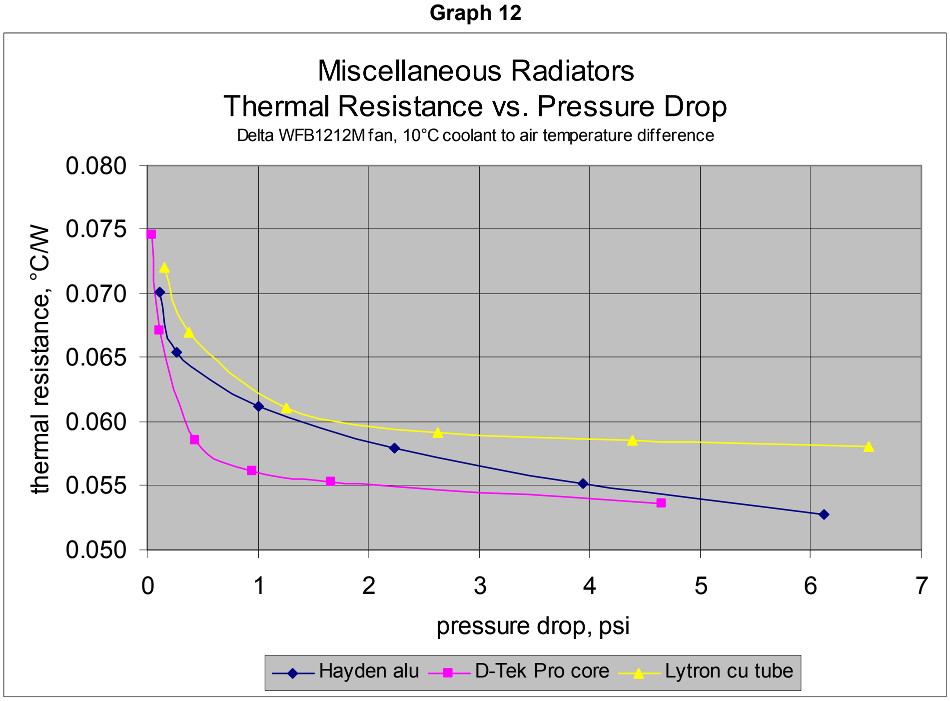
Bearing in mind that the flow rate range of interest is 1 to 1.5 gpm, it can be seen that the heater core is well optimized for this application.

Graph 11



From this graph it is clear that a heater core is a more effective design than either stacked aluminum plates or continuous tube, insofar as these models can be considered representative of their type/size. The continuous tube Lytron radiator is typical of the type, while the Hayden prototype is somewhat unique due to the greater plate width than their standard products.

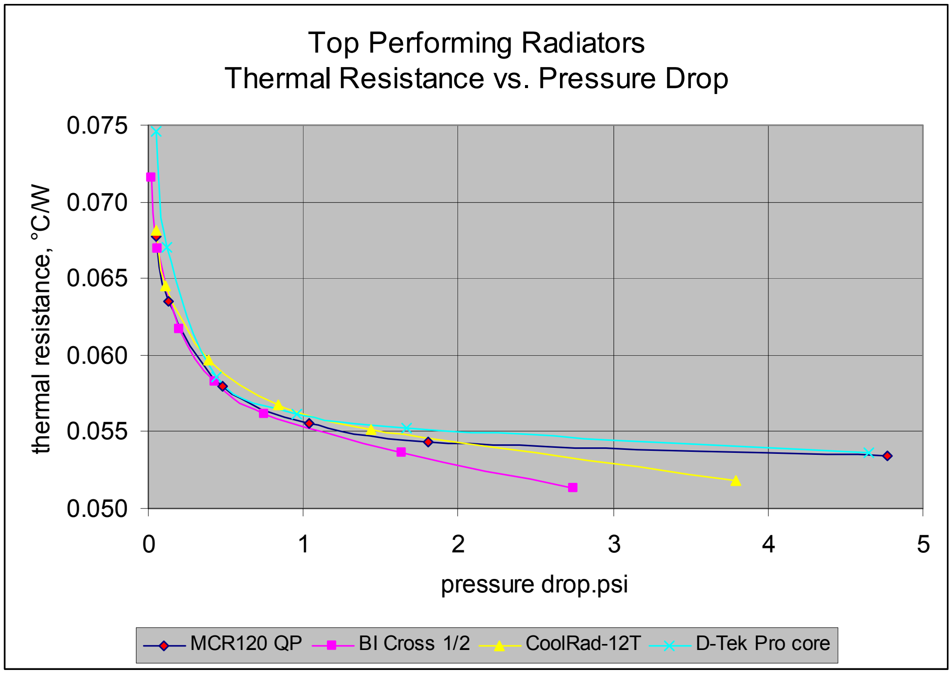
Graph 12



4. Summary: The Best 120mm Radiators Compared

How is 'best' defined for a radiator? Clearly it is the greatest cooling with the least pressure drop. On this basis the MCR120 QP and the BI Cross should be considered from the single row group, the CoolRad-12T from the dual row group, and the D-Tek Pro from the miscellaneous group. Note that the BI Cross is included although it is not directly comparable due to having 1/2" barbs while all the other radiators had 3/8". With the same size barbs it would not be close due to the higher pressure drop.

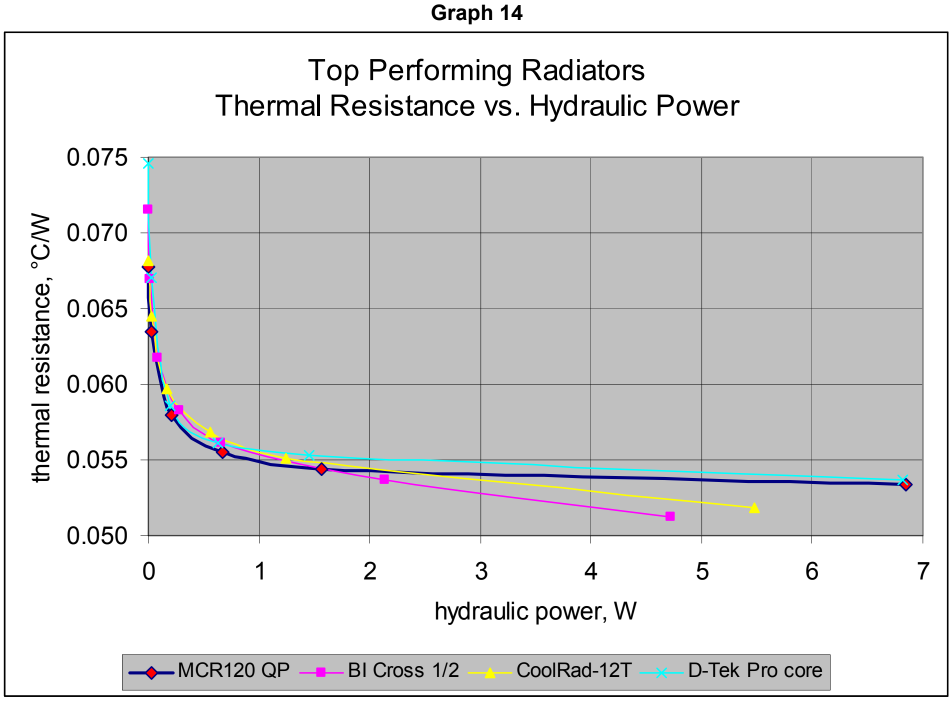
Graph 13



Here the MCR120 QP and the BI Crossflow are similar through 2 gpm, but this is due to the larger barbs on the crossflow.

Another way to consider the performance is to plot the thermal resistance vs. the hydraulic power. Hydraulic power represents the work expended pumping coolant through the radiator and is found by calculating the pressure drop by the flow rate by a constant (depending on the units used).

Graph 14



What is being illustrated here is the 'work' required to achieve a given thermal resistance. It can be seen that the MCR120 QP is a more effective solution until flow rates exceed 2 gpm.

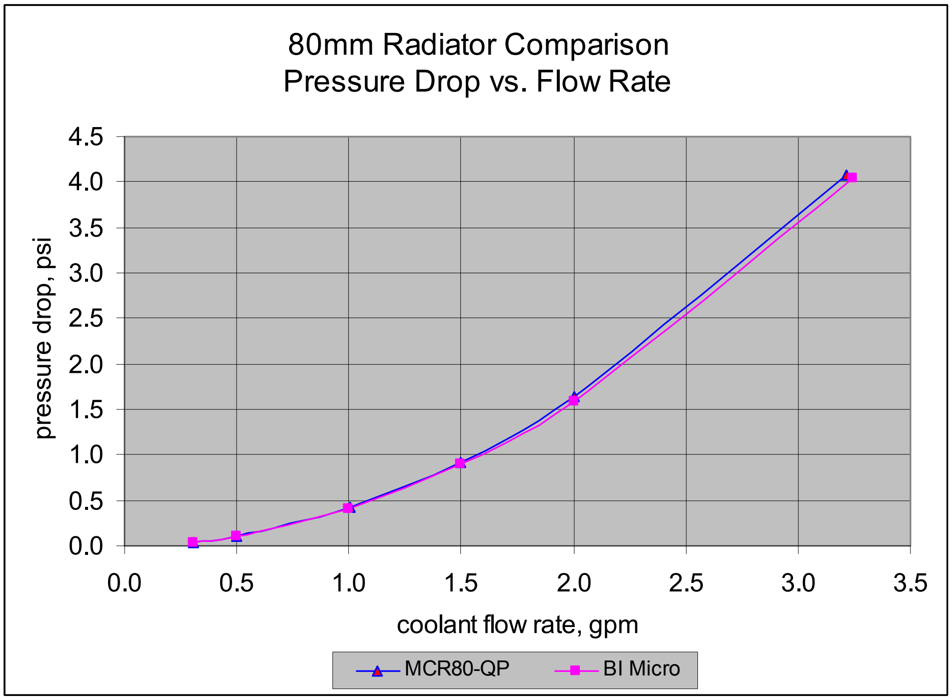
So what can be 'concluded' regarding 120mm radiator types, bearing in mind that the fan is pre-determined based on noise and the flow rate range of interest is 1 to 1.5 gpm ? The flat tube and folded fin radiators were slightly superior to corrugated plate heater cores, both of which were appreciably better than continuous tube or stacked plate aluminum oil coolers. Note that stacked plate aluminum oil coolers can be very effective, but not the size and configuration tested.

While all the brass/copper tube/fin radiators were superior to the aluminum, this difference is not related to the materials, rather to the specific tube design of the Corsair radiator resulting in high flow resistance (but contributing to the cooling as well – a tradeoff).

5. 80mm Radiators

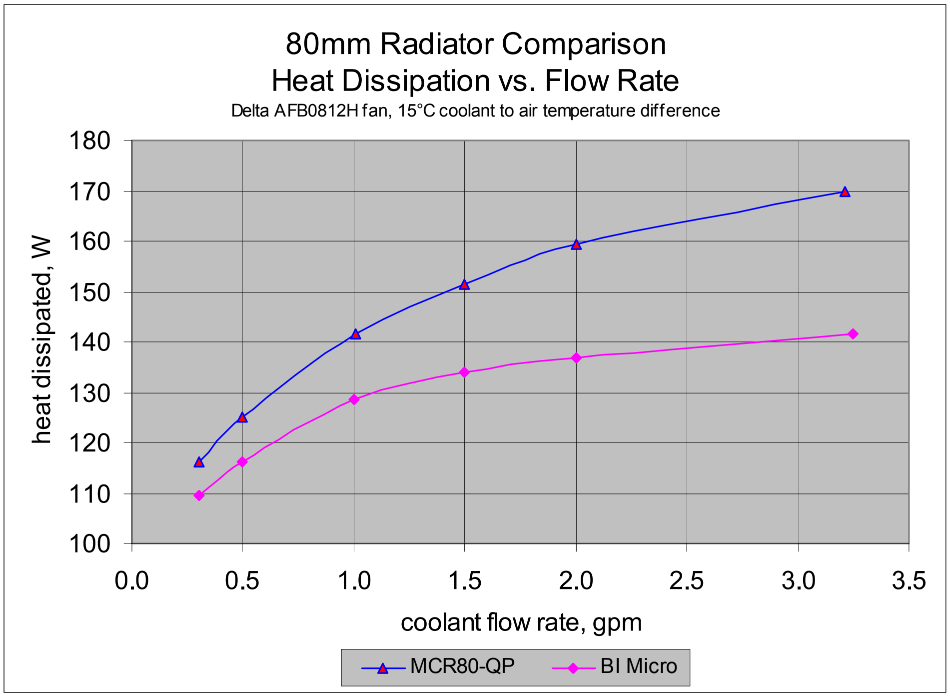
Two 80mm radiators were tested to illustrate the differences between a single row, 1-pass; and dual row, 2-pass configurations.

Graph 15



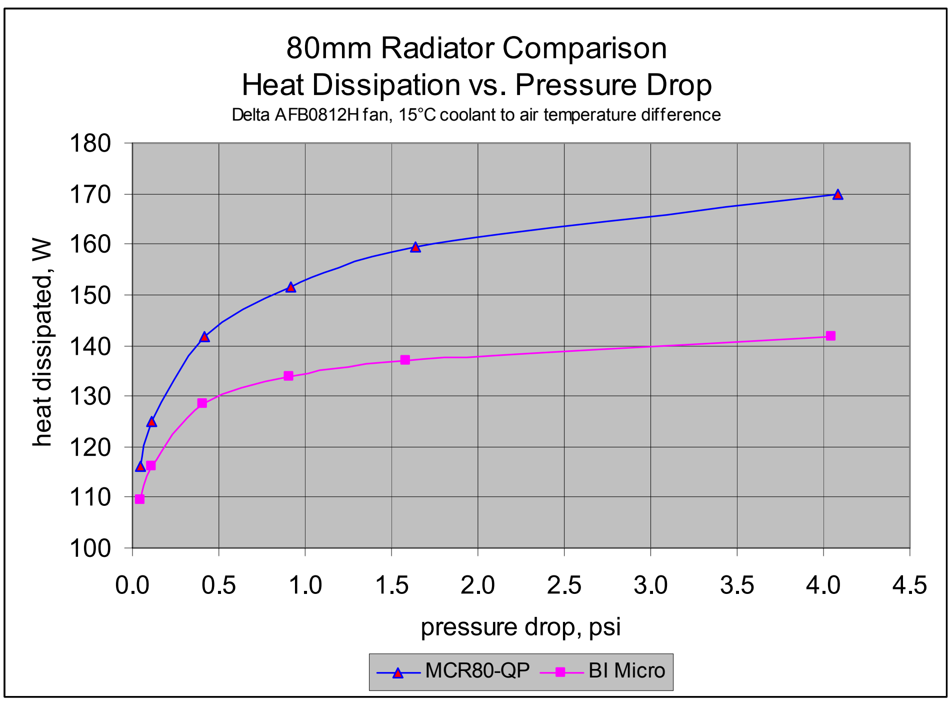
Notwithstanding the difference between having one and two rows of tubes and one and 2-pass configuration, the flow resistance of the two is quite similar due to the MCR80-QP's single row of tubes being larger, and having a single pass configuration.

Graph 16



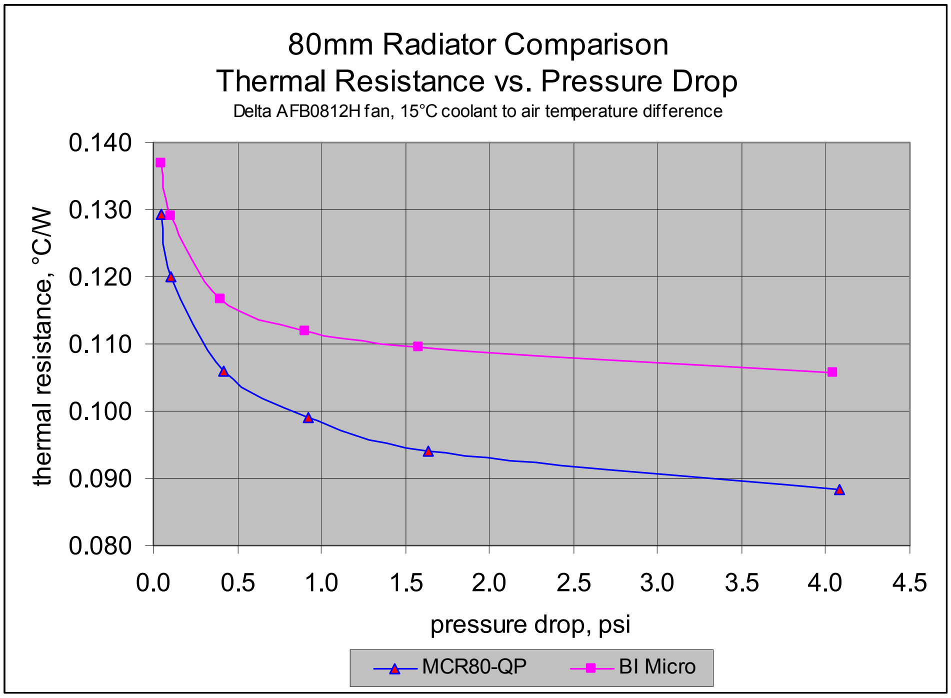
While the flow resistance of the two 80mm radiators is similar, the MCR80-QP provides ~10% better dissipation in the flow range of interest, 1 to 1.5 gpm.

Graph 17



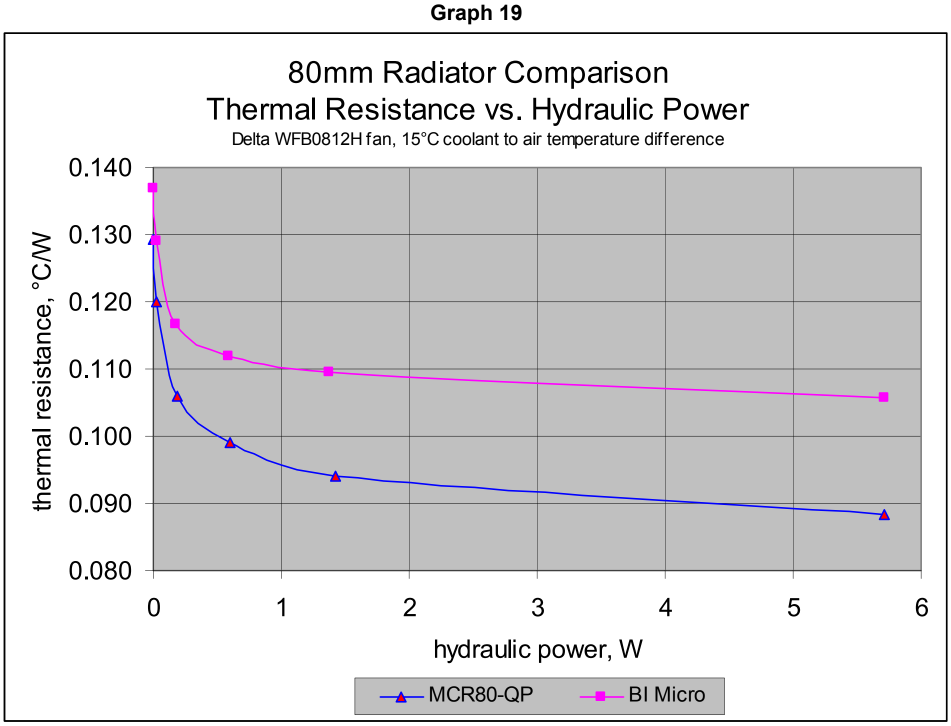
The same advantage of the MCR80-QP over the BI micro is apparent above.

Graph 18



The difference in the C/Ws indicates that with a 100W load, the MCR80-QP will drop the coolant temperature 1°C+ in the flow range of interest.

Graph 19



And the MCR80-QP's higher performance is apparent no matter how the data is presented.

This superiority of a single row over a dual row is due to the more efficient use of the fan's output. Single row cores have lower air flow resistance and with lower powered fans achieve greater throughput than the same fan with dual row cores. Notwithstanding the greater fin surface area in a dual row core, the lower air velocity reduces the convection more than the increased area increases it.

6. Conclusions

Dual row radiators and heater cores have a greater heat rejection capability than single row, but to utilize the higher capability stronger fans must be used to overcome the airflow resistance. Stronger fans make more noise and it was found that with an upper limit of 34 db(A) there is no way to achieve higher performance using a dual row core similar to those tested.

Some may ask: What is a radiator's 'rating'? The answer is 'it depends'. Specifically any 'rating' will, indeed must, define the flow rates on both the air and liquid sides and the temperature difference between the two sides. All of the thermal resistance and dissipation graphs above describe the 'ratings' of these radiators, but the air side flow rate is not known, only the air source (the fan) is held constant. Putting a more, or less, powerful fan on the radiator would necessitate new curves to define its 'rating. There is no single value that describes a radiator's 'rating' without also stating the flow and temperature conditions.