WHITE PAPER

Fan Array Systems

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BACKGROUND

Fan Array Systems (FAS) have been in use for many years as parallel fan systems. The three basic types of fans (centrifugal, axial and mixed flow fans) have all been applied as parallel fans in a variety of applications like wind tunnel designs, air pollution control and filtration, fume exhaust systems, Air Handling Unit (AHU) systems etc.

In recent years, small direct drive (DD) plenum centrifugal fans (16 inches to 22 inches diameter wheels) in an array (six fans or more) seem to be gaining popularity as supply air (SA) fan systems in AHU applications. Several claims are being made in the market place ranging from improved efficiency, low noise, savings in real estate space, redundancy/ less impact of a fan failure, ease of serviceability of a failed small motor, improved controllability at part load, low vibration levels etc., when compared to Conventional Air-handling Systems (CAS).

In any system design, engineers are faced with specific challenges and have to make choices by exercising good judgment. Each system has its own advantages and disadvantages and FAS is not a panacea for all applications.

OBJECTIVE

The objective of this white paper is to provide engineers with guidelines on the advantages and disadvantages of FAS when compared to CAS. Alternatives to small FAS with medium (18 inches to 27 inches wheel diameter) and large (30 inches and larger wheel diameter) fan array systems are also presented.

OVERALL ANALYSIS OF CURRENT FAS AND CAS SYSTEMS

The following table 1 summarizes the advantages and disadvantages of FAS over CAS currently available in the market. Positive (advantage FAS) and negative (advantage CAS) rating points are assigned. This rating system is subjective and is open to debate.

Table 1.

	Description	Rating	Advantage FAS(+)	Advantage CAS(-)
1	Efficiency	-1.0	Smaller air jets coming out of fans cause more uniform air distribution downstream. This is advantageous in blow-through AHU systems only.	Smaller fans and motors of FAS are less efficient. This is further exacerbated by tighter (~0.25D) wheel-wall spacing in the 'cells' that can cause high system effects.
2	Reliability	-0.5	Redundancy – if one little fan fails, others can makeup. However, with more moving parts the higher the probability of failure.	Larger fans are more reliable as much fewer parts. FAS needs back-draft damper when a fan fails. Low fan speeds are more reliable.
3	Total Cost	-1.0	Expensive lattice frame structure with acoustic lining. Additional costs of multiple motors, wiring conduits, and controller	Current conventional method involves insulating the main AHU casing only.
4	Serviceability	+1.0	1 serviceman with basic tools can perform service if a little fan fails. Less down time.	Special rigging may be required for CAS.
5	Real estate savings	+0.5	33% shorter axial length maybe true for floor space savings with FAS.	However, similar reductions in width and height are possible with CAS.
6	Sound	+1.0	Low frequency casing radiated noise may be reduced due to small lattice structure and end reflection	However, 'A' weighted sound may be the same. FAS useful in low frequency sound critical applications only.
7	Drive flexibility	-0.5	FAS can be applied only on higher cost direct drive applications with VFD.	CAS can be used both in lower cost belt drive and direct drive applications
8	AMCA license on base fan	-0.5	Not available. High claimed static efficiency of 75% questionable on small 18" fan	Available
	OVERALL RATING	-1.0		

Thus in the above subjective analysis, CAS (Overall Rating = -1.0) holds a slight edge. However, both FAS and CAS have their own applications in the marketplace. One will never replace the other. Both systems will grow depending on the specific requirements of the market.

A HYBRID APPROACH

This approach involved the design and testing of smaller arrays of larger fan modules. These single fan modules would be AMCA certified as a product-line (MPQN).

Following main features were incorporated in the design and testing of the MPQN product line:

1. Rate and AMCA certify11 module sizes (182 to 490).
2. Assess the efficiency and sound power levels of a 3 X 3 size 182 MPQN (Arr. 4) fan array. Compare results with a 2x2 size 245 MPQN array, 1x2 365 MPQN array and an optimum 490 EPQN single fan selections for a CAS.
3. Simultaneous fan operation with manual on/off and manual speed adjustment via variable frequency drive (VFD) was sought without provisions for a controller for selectively controlling individual fans of the fan array or independently controlling fans.

TEST PROCEDURE AND DATA ANALYSIS

1. All testing was performed per AMCA STD 210 for air performance and AMCA STD 300 for sound performance in TCFC's AMCA accredited laboratory.
2. A 3 x 3 182 MPQN and a 2 x 2 245 MPQN arrays were tested and the results were compared to a single module test. It was proven that fan laws for parallel fans hold true for both air and sound performance for each array.

RESULTS AND DISCUSSION

All comparisons (based on tests) were done at the following design point for consistency:

Airflow = 34000 cfm
SP = 4.2 iwc
Density = 0.075 lbm/cu ft

Table 2.

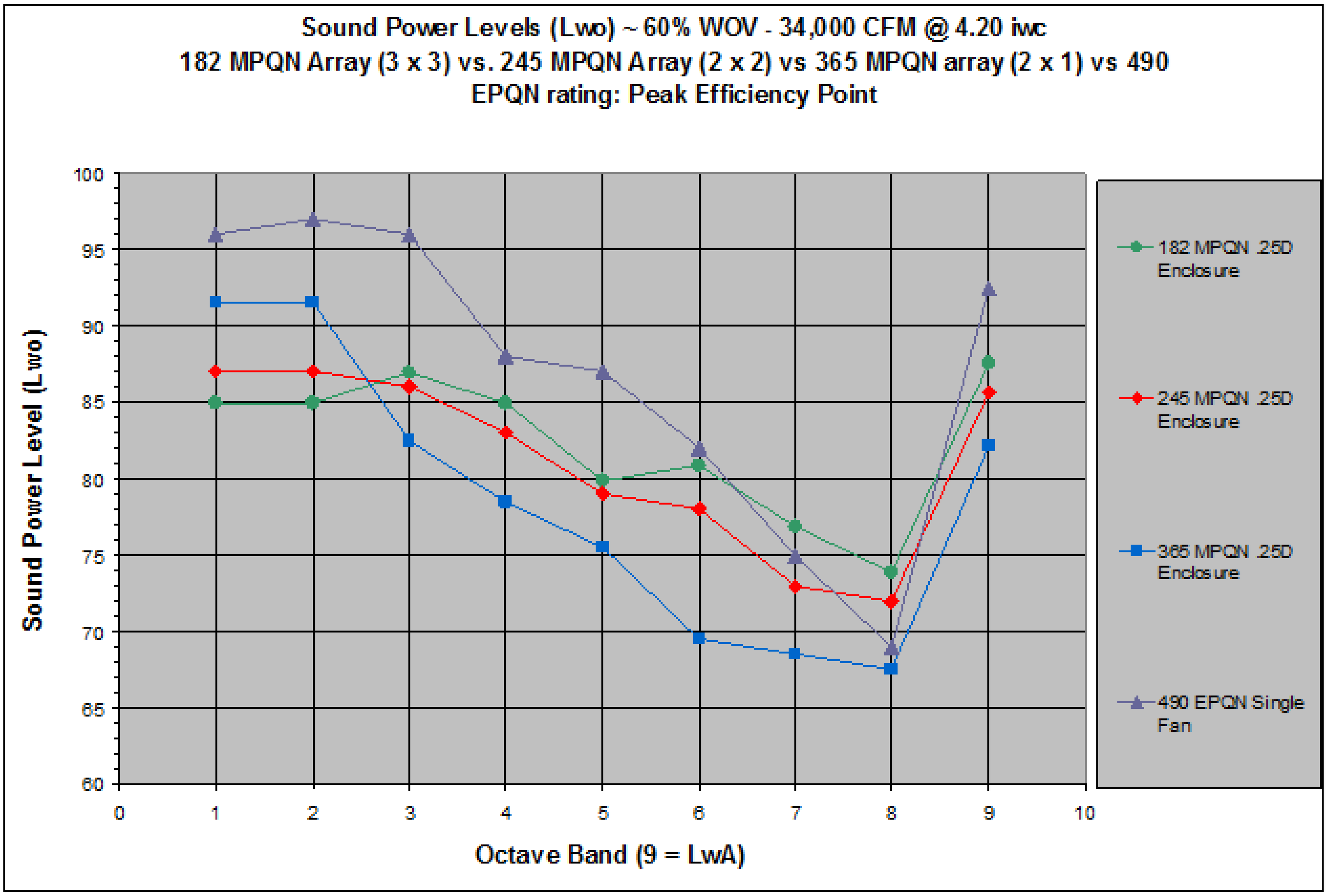
	Array (Qty) Type	Size (Dia) In.	Flow /fan CFM	Speed (RPM)	BHP /fan	Total BHP	Stat. Eff. (%)	LwoA/ Fan dBA	LwoA Tot dBA	Leng (L) In.	Wid (W) In.	Ht (H) In.
1	3x3 (9) MPQN	182 (18.25)	3778	2073	3.8	34.0	66.0	79	88.5	27.4	95.6	95.6
2	2x2 (4) MPQN	245 (24.5)	8500	1625	8.2	32.9	68.1	80	86.0	36.8	82.8	82.8
3	1x2 (2) MPQN	365 (36.5)	17000	1037	16.1	32.2	70.0	80	83.0	54.8	119.2	59.9
4	Single EPQN	490 (49.0)	34000	773	30.5	30.5	73.7	93	93.0	69.8	68.0	68.0

The following conclusions may be drawn from Table 2:

1. The 3x3 182 MPQN system (smallest 18.25 in dia wheel) is the least efficient with the smallest axial length.
2. The single 490 EPQN (49 in dia wheel) is the most efficient, but also has the loudest outlet Sound Power Level (LwoA).
3. The 1x2 365 MPQN (36.5 in dia wheel) is the most efficient MPQN system and has the lowest LwoA.
4. Motor selections for the arr 4 fans must be carefully done so that there is adequate torque (constant HP) beyond synchronous speed and adequate HP (constant torque) below synchronous speed.
5. Structural design and isolation of the array block must be given due consideration by AHU manufacturers.
6. All options must be considered before arriving at a decision.

The 8 octave sound spectra for the 4 configurations above are shown in Figure 1 below. Note that the LwoA for size 365 is 5.5 dBA lower than the size 182. However, it should also be noted that the size 182 (3x3 array) does have an advantage at the lower frequencies of 63 Hz and 125 Hz. The crossover appears to be between the 125 to 250 Hz. The above may be attributed to the small cell outlet area End Reflection Losses (ERL) that lowers the low frequency sound escaping the fan cell.

Figure 1.



Sound Power Levels (Lwo) ~ 60% WOV - 34,000 CFM @ 4.20 iwc
182 MPQN Array (3 x 3) vs. 245 MPQN Array (2 x 2) vs 365 MPQN array (2 x 1) vs 490
EPQN rating: Peak Efficiency Point
Sound Power Level (Lwo)
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
7
8
9
10
Octave Band (9 = LwA)
182 MPQN .25D Enclosure
245 MPQN .25D Enclosure
365 MPQN .25D Enclosure
490 EPQN Single Fan

CONTROL METHODS FOR FANS IN AN ARRAY

Figure 2.

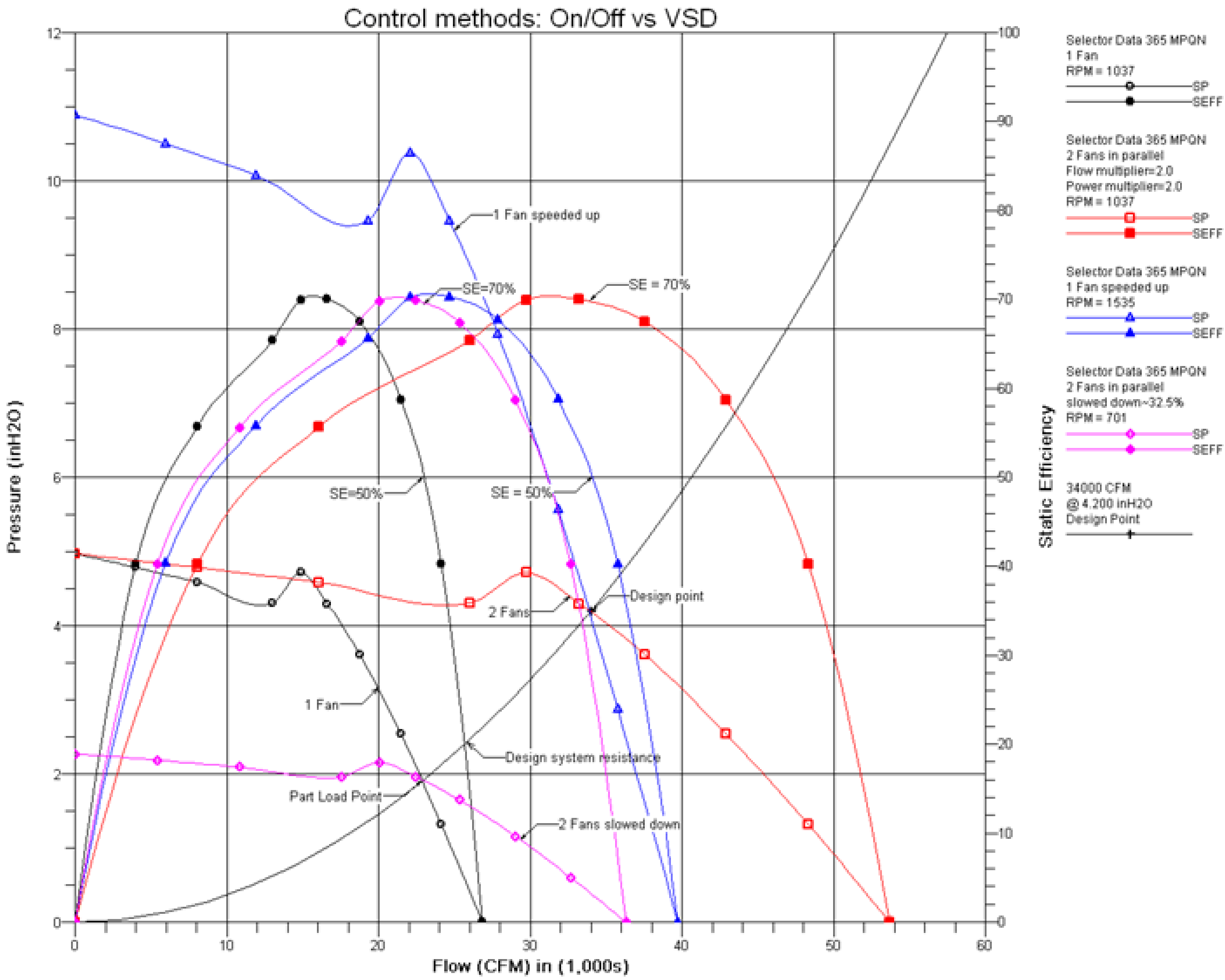
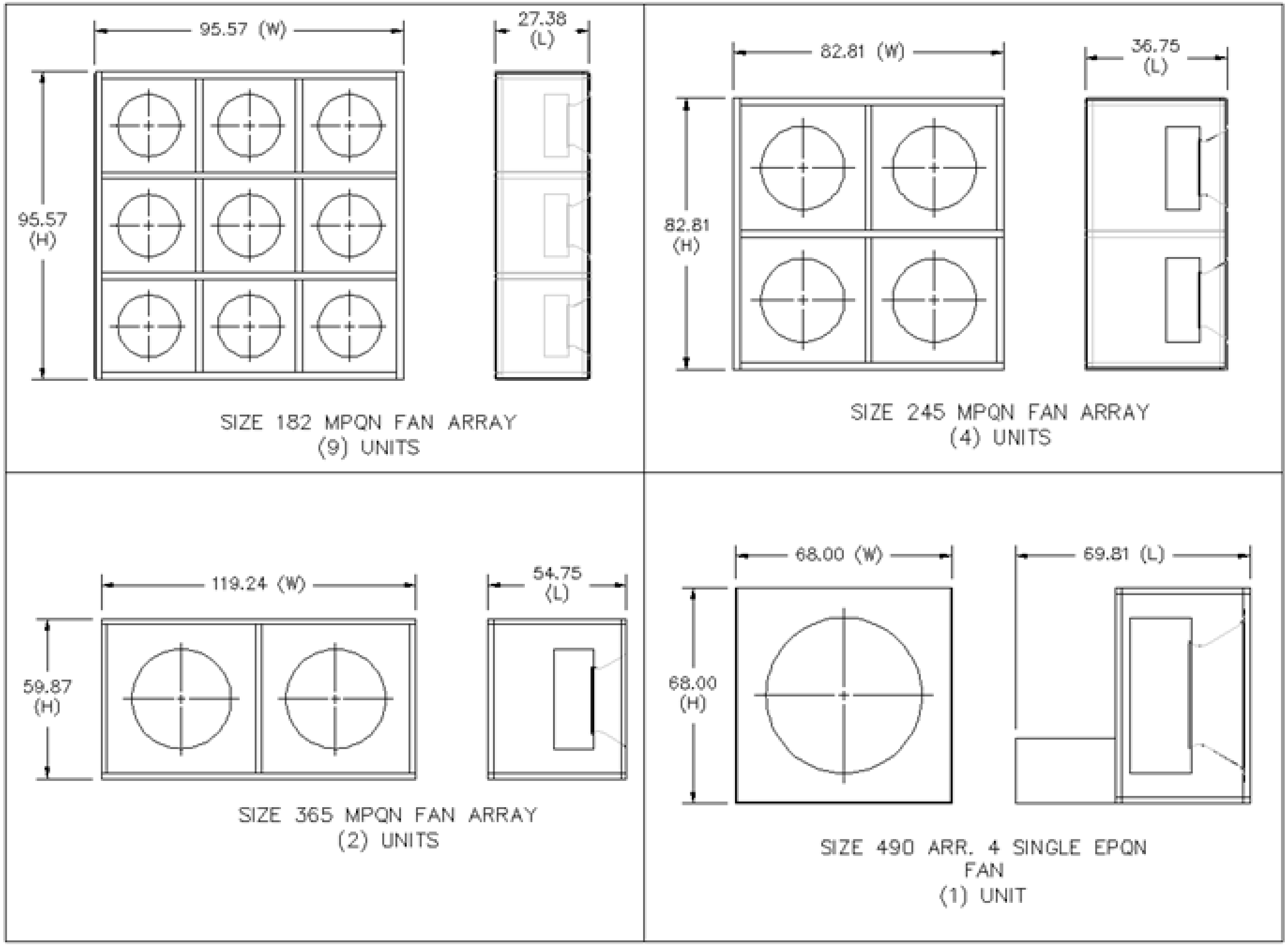


Figure 2 above shows the advantage of Variable Speed Drive (VSD) control over on/off control for fan arrays. For simplicity a single vs. dual (2 fans in parallel) 36.5 in diameter MPQN fan system is shown. For the same design system resistance corresponding to a design point of 34000 cfm at 4.2 iwc SP, single fan operates at a Static Efficiency (SE) ~ 50% while the dual fan operates at a SE ~ 70% both at design point and part load point (23000 cfm at 1.9 iwc SP). Speed turn down for the dual fans in the above example is 32% that results in a 69% power savings at part load [Power reduction ~ (speed reduction) ^3].

Thus, on / off control is not recommended, even for small fans. The same control VSD signal should be used to speed up and slow down fans together. Turning parallel fans off and on also has the potential of forcing a fan into stall, from which it may never be able to recover.

DIMENSIONAL COMPARISON



CONCLUSION

So, will the Overall Rating (Table 1) of Fan Array Systems (FAS) improve with medium and large arrays to 0.0 or positive? How much positive? These are difficult questions to answer. It should be evaluated on a case-by-case basis. FAS are not a panacea for all applications. Large fan array systems are attractive from efficiency and ‘A’ weight sound perspective while small fan arrays have attractive low frequency sound characteristics, but are poor in efficiency and ‘A’ weight sound. VSD control is always a better choice over on/off control for power savings regardless of fan size and array size.