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THE EFFECT OF A SPEED CONTROLLER ON FAN NOISE (PWM INVERTOR TYPE)

P Hunnaball and A G Tull

Woods of Colchester Ltd incorporating Keith Blackman, Colchester, Essex

INTRODUCTION

The requirement for energy conservation in the building environment comes at a time when the restrictions on the acoustic environment are also being tightened. In recent years, the control of the H & V systems in buildings has rapidly progressed, with one obvious area of energy conservation being the control of fan speed to regulate duty requirements. All current methods of fan control are shown in Figure 1 (1) with a generalised table of each method's range and cost effectiveness.

Woods of Colchester as a major fan manufacturer has a declared interest in all aspects of fan control and is committed to an ongoing investigation of all aspects of fan regulation techniques, enabling the utilisation of information, in both product design and customer applications.

This report summarises the investigation into the effect of a 'state of the art' PWM microcomputer controlled invertor used to control a belt-driven forward curve centrifugal fan, and a direct drive axial flow fan.

Types of Fans Tested

a) Aerofoil fan - Woods 30J, 4 Pole, Form B:
This unit is direct drive, with the motor held centrally in the duct by 8 tie rods. Impeller construction is of 10 cast aluminium blades held between clamp plates. To ensure minimum air noise a bellmouth was fitted to the inlet of the fan, to give smooth inlet flow.

b) Centrifugal fan - Keith Blackman Series 28 Forward Curve:
This fan is belt driven, the motor is foot mounted onto the fan base platform, no isolation exists between the motor and the fan substructure. Impeller construction is of plate steel, welded and pop riveted. (It should be noted that this fan is of somewhat sturdier construction than many standard H & V fans of the same type).

Invertor Details

The unit is a FUJI FVR G5 invertor (2) which incorporates a sinusoidal wave Pulse Width Modulating control system (PWM). The invertor allows for, as a standard feature, the direct digital programming of all facilities. Three major functions of the invertor are significant to noise generation, and are shown below in order of importance:

a) Variable Torque Settings; that allow programmable variations of voltage/frequency relationships, which vary between a linear ($V \propto Hz$) and an approximated square law relationship ($V^2 \propto Hz$), the latter being recommended for fan and pump applications where torque loads are variable.

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b) Operating Sound Selection; allows the carrier frequency pulse width to operate over a range of frequencies between 1.5kHz and 2kHz.

c) Jump Frequency Control; allows "jumping" of the output frequency which could be useful when resonances occur in the driven unit.

Figure 2 shows the output current waveforms, at a nominal 30Hz supply, of the invertor drive (on maximum starting torque setting) and the generated sinewave supply.

Method

Each fan was, in turn, mounted onto a test duct which conformed to BS848:Pt 2 Code 8 installation (3). This involves running the fan with a free inlet and a ducted outlet. The open inlet was situated centrally inside the anechoic chamber, with the anechoically terminated ducted outlet discharging through the chamber wall to an adjacent test space. Sound measurements were taken over a 2m hemispherical surface for the inlet, and 'in-duct' on the outlet (710mm diameter ductwork) using a single microphone position. A flexible connector was included in the test arrangement immediately after the fan to ensure no hard-coupled transmission occurred along the measuring ductwork.

After setting the fan to a nominal peak efficiency duty, it was controlled using the invertor and tested at 100, 80, 60 and 40% of full speed. The range of torque settings available from the unit (see Figure 3) are covered from the linear volts/frequency relationship to a square law approximation (the latter recommended by the manufacturer for fans and pumps). A narrow band analysis was performed at various duties to identify the generated pure tones. The aerofoil fan was also tested at the same speeds using a generated (sine wave) frequency supply. This gave a base reference to show the magnitude of any extraneous noise generated by the invertor.

Results of Tests

Figures 3 and 4 summarize the tests performed, and data is presented as a calculated dB'A' sound pressure level for both inlet and outlet tests on each fan. This method of presentation was chosen because it gave the clearest indication of the direct subjective effect of this type of control.

Figure 5 shows a narrow band and 1/3 octave spectra at one representative duty.

Comments

Results of the tests on the inlet side show consistency between the centrifugal and the axial fan. High torque settings on the invertor results in a high degree of noise caused by forced vibrations in the motor. The lower torque settings result in a decrease in sound level very close to the ideal fan law reduction. The optimum sound level for speed is successfully demonstrated by the axial flow fan on the sinusoidal generated supply.

Levels on the discharge side illustrate that the axial flow fan with the motor in the airstream and its directly coupled impeller, radiates considerably more noise into the airway than the centrifugal fan with its motor out of the airway, belt driven impeller arrangement. It is likely that a belt driven aerofoil would also give a much reduced level of radiated noise.

A series of static excitation "Bump" tests were made on both the axial flow, and centrifugal fan. Measurements were made at various positions all over the units on the casing, impeller and mounting frame. The results of these tests demonstrated that a series of minor resonances were apparent on both fans in the range 500 Hz to 4kHz, this means that both units will be very responsive to the type of vibration induced by the controller.

Conclusions

This design of controller with its programmable flexibility gives an acceptable acoustic performance when used with the low torque settings. The idea of being able to alter the fundamental frequency is attractive, but within the limited scope available does not really make any significant improvements.

Caution should still be used when controlling by invertor on lightweight fans, or where fans are mounted on flimsy structures and in any installation where the fan is run in an open environment. In these situations the torque characteristics suited to fans should always be utilized.

Fan type will also affect the amount of noise radiated into the system, and if possible indirect drive should be considered for critical applications.

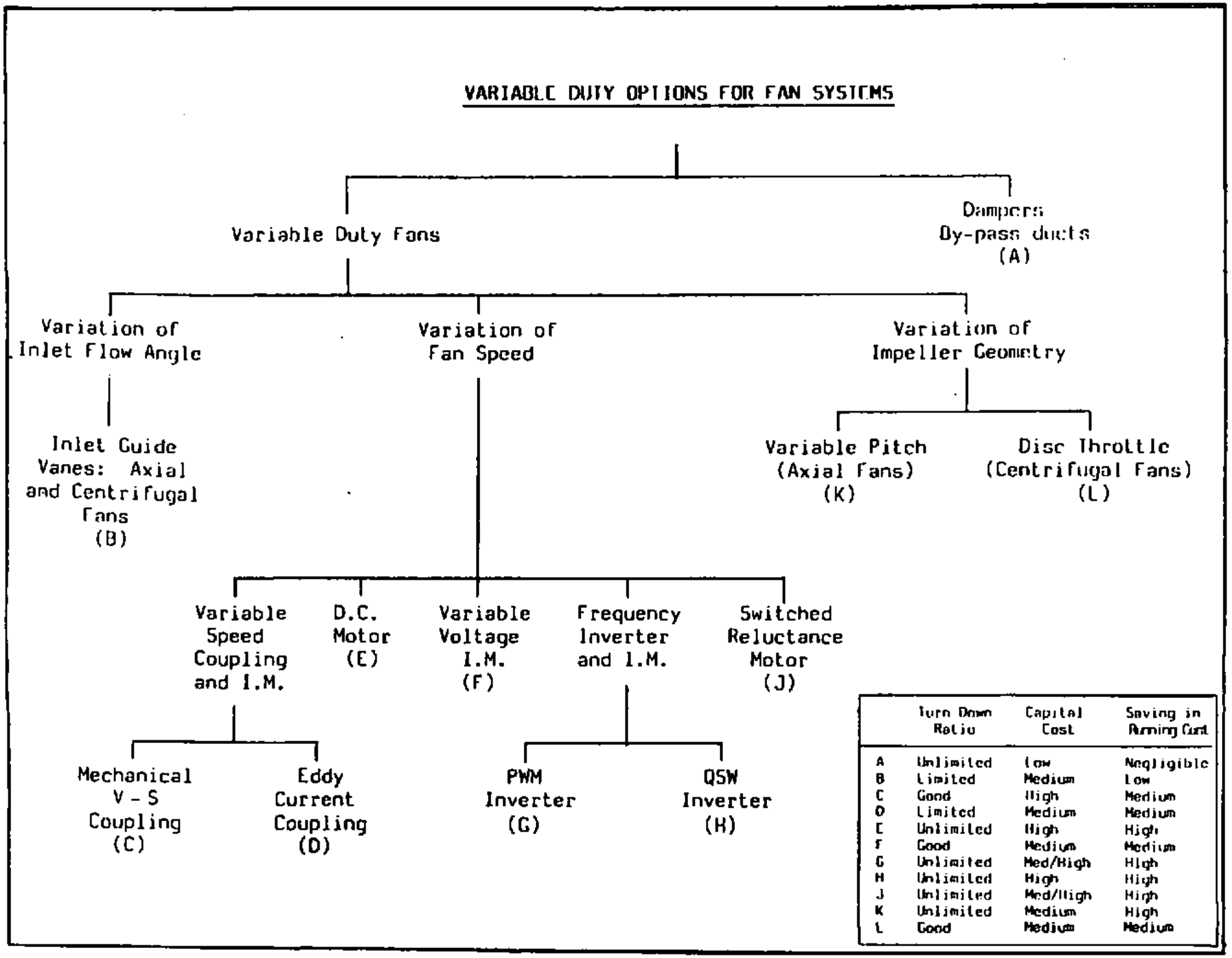
It is likely that with careful application of damping materials and the design of fan hardware to suit the problems of general invertor drives, a considerable reduction in the resultant noise level could be expected. However this would result in considerable increase in initial fan cost, and may make the option of invertor control less attractive. Some invertors are available that have a fundamental in the ultrasonic range, however, they are limited to very low powers. If this range can be extended with further technology advances, then noise problems from invertors may be eliminated.

References

(1) Woods internal report on variable duty fans
Author: G.A.C. Courtier, April 1987

(2) FUJI INVERTOR supplied by Bearing Services Limited

(3) BS848.Pt.2.1985 Methods of Noise Testing



	Turn Down Ratio	Capital Cost	Saving in Running Cost
A	Unlimited	Low	Negligible
B	Limited	Medium	Low
C	Good	High	Medium
D	Limited	Medium	Medium
E	Unlimited	High	High
F	Good	Medium	Medium
G	Unlimited	Med/High	High
H	Unlimited	High	High
J	Unlimited	Med/High	High
K	Unlimited	Medium	High
L	Good	Medium	Medium

FIGURE 1

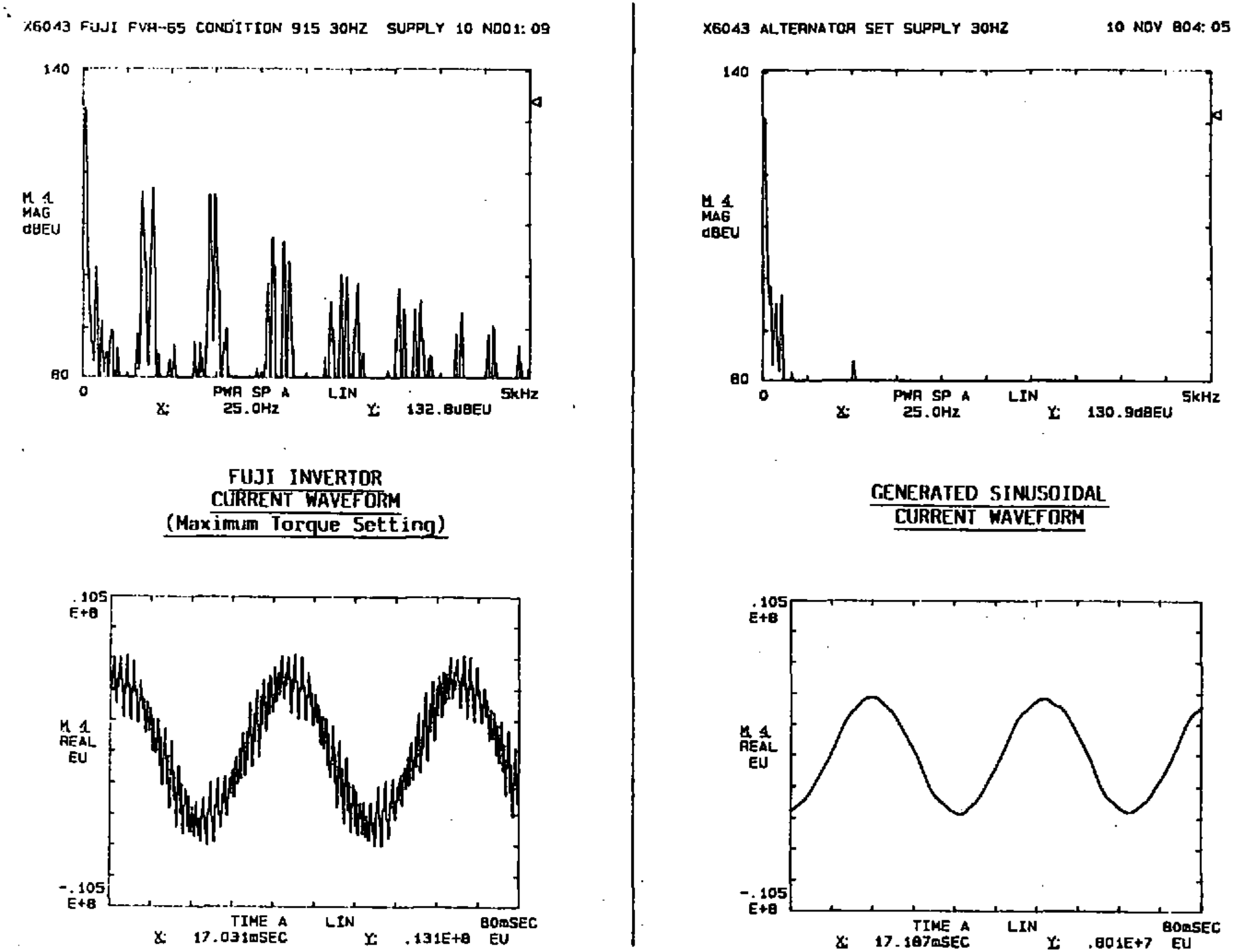


FIGURE 2 : COMPARISON OF 30Hz SUPPLY WAVEFORMS

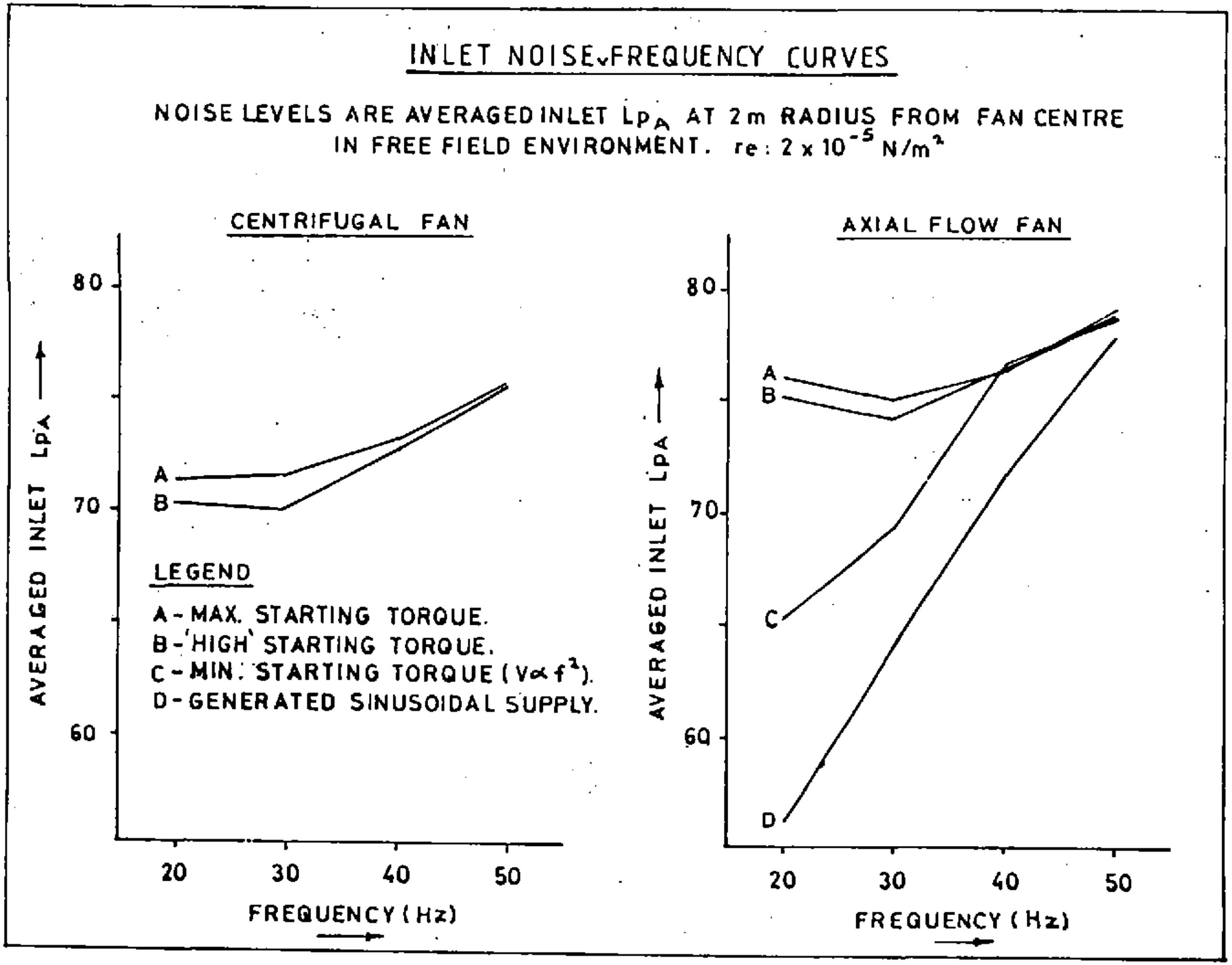
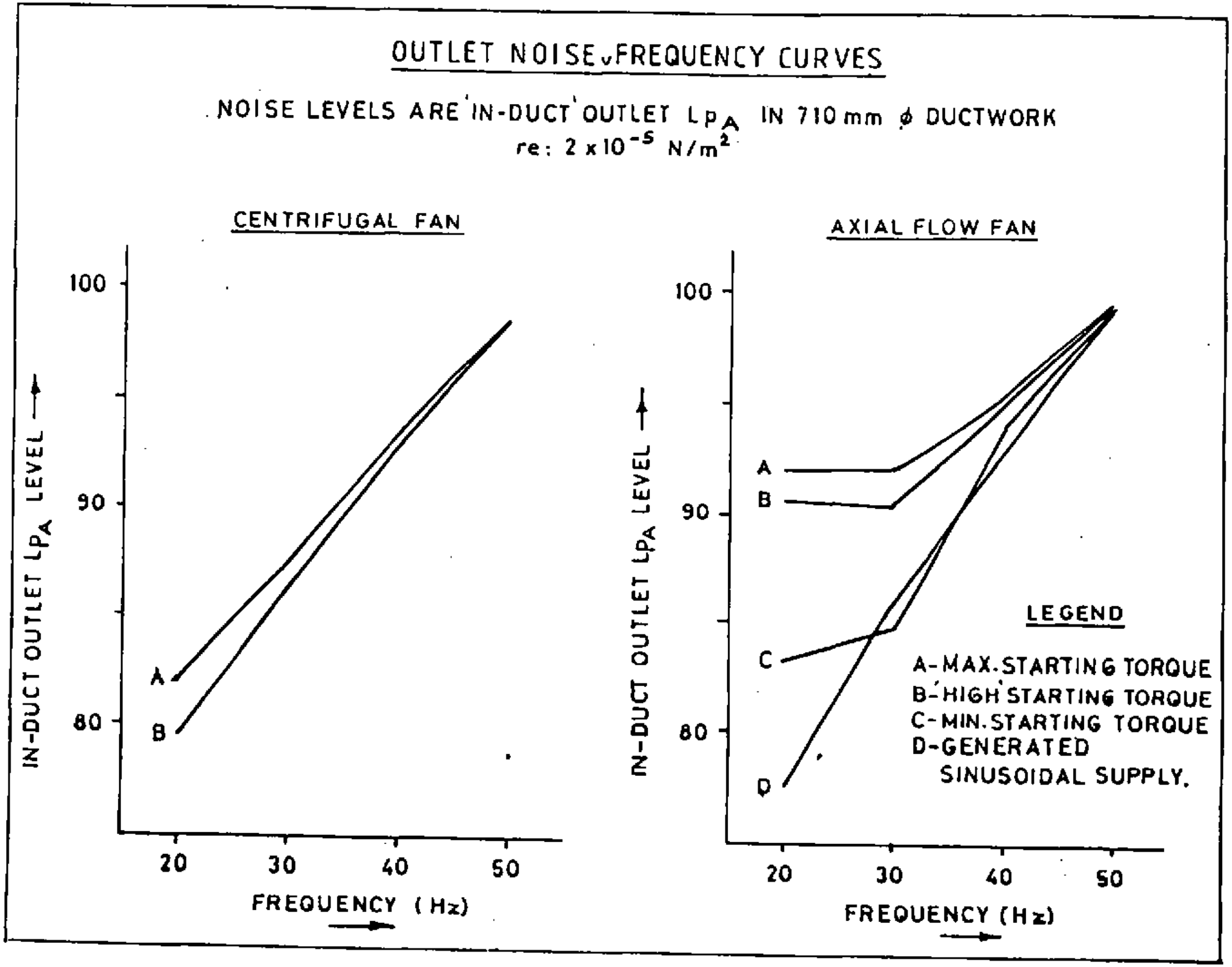

INLET NOISE v FREQUENCY CURVES
NOISE LEVELS ARE AVERAGED INLET LpA AT 2m RADIUS FROM FAN CENTRE
IN FREE FIELD ENVIRONMENT. re: 2 x 10-5 N/m2
CENTRIFUGAL FAN
AXIAL FLOW FAN
AVERAGED INLET LpA
FREQUENCY (Hz)
80
70
60
20
30
40
50
A
B
C
D
LEGEND
A - MAX. STARTING TORQUE.
B - 'HIGH' STARTING TORQUE.
C - MIN. STARTING TORQUE (V∝f2).
D - GENERATED SINUSOIDAL SUPPLY.

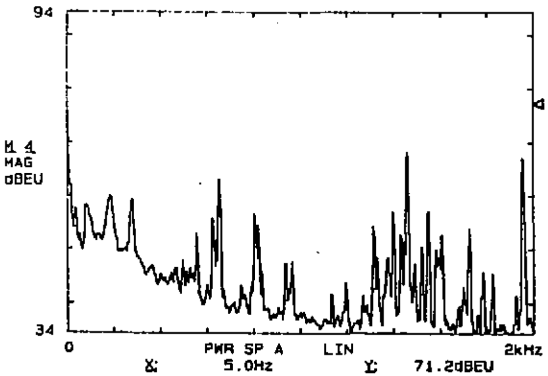
FIGURE 3



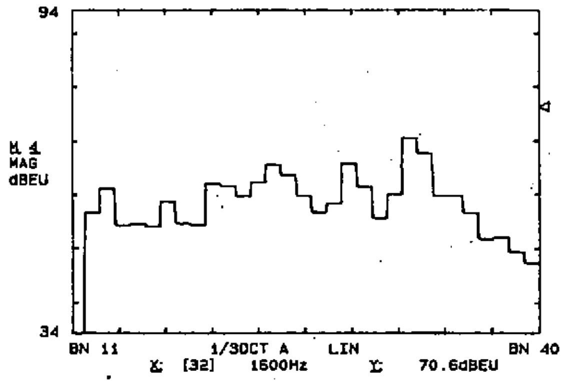
OUTLET NOISE v FREQUENCY CURVES
NOISE LEVELS ARE 'IN-DUCT' OUTLET Lp A IN 710 mm ϕ DUCTWORK
re: 2 x 10^-5 N/m^2
CENTRIFUGAL FAN
AXIAL FLOW FAN
IN-DUCT OUTLET LpA LEVEL
FREQUENCY (Hz)
100
90
80
20
30
40
50
A
B
C
D
LEGEND
A-MAX. STARTING TORQUE
B-HIGH STARTING TORQUE
C-MIN. STARTING TORQUE
D-GENERATED SINUSOIDAL SUPPLY.

FIGURE 4

X6043 FUJI FVR-65 CONDITION 915 30HZ INLET 9-11-801:36



X6043 FUJI FVR-65 CONDITION 915 30HZ INLET 9-11-801:11



	PWR SPECTRUM	ChA
1	80.0Hz	58.3dBEU
2	185.0	60.0
3	280.0	59.2
4	555.0	53.1
5	625.0	55.9
6	655.0	63.3
7	805.0	56.7
8	820.0	54.7
9	935.0	47.6
10	940.0	46.9
11	965.0	47.9
12	1195.0	43.9
13	1315.0	54.5
14	1400.0	57.0
15	1460.0	68.4
16	1520.0	50.5
17	1550.0	57.1
18	1725.0	54.0
19	1955.0	67.2
20		

1/3 OCTAVE Ch A			BAND 30	A WEIGHT OFF	
[11]	12.50Hz	56.7dBEU	[26]	400.0Hz	56.7dBEU
[12]	16.00	61.1	[27]	500.0	58.5
[13]	20.00	54.3	[28]	630.0	65.8
[14]	25.00	54.6	[29]	800.0	61.4
[15]	31.50	54.0	[30]	1000.0	55.5
[16]	40.00	58.8	[31]	1250	60.1
[17]	50.00	54.7	[32]	1600	70.6
[18]	63.00	54.3	[33]	2000	67.7
[19]	80.00	62.1	[34]	2500	59.7
[20]	100.00	61.6	[35]	3150	59.8
[21]	125.0	59.6	[36]	4000	56.5
[22]	160.0	62.3	[37]	5000	51.6
[23]	200.0	65.7	[38]	6300	52.1
[24]	250.0	63.6	[39]	8000	49.2
[25]	315.0	59.7	[40]	10000	47.2
			overall		76.4

FIGURE 5 : NARROW-BAND AND THIRD OCTAVE LEVELS AT 30Hz SUPPLY AT MAXIMUM STARTING TORQUE SETTING