APPENDIX A: LIST OF USED SYMBOLS

It was found necessary to use the same symbol to denote different quantities in order not to depart too drastically from the conventions normally employed in general papers. For example, α denotes the modified coefficient of kinetic energy and the diffuser's divergence angle.

The following is a list of symbols used in this paper.

A.1 General Symbols

a, b, n = King's law constants
A = sectional area of diffuser
AR = W_e / W_i = area ratio
E = output voltage of hot wire anemometer
C_p = pressure recovery coefficient
C_{pL} = local pressure recovery coefficient
C_{pth} = ideal pressure recovery coefficient
$H_{12} = \delta_1 / \delta_2$ = shape factor
p = pressure (force per unit area)
$\tilde{p}_l$ = pressure loss of diffuser
u, v = velocity components
V_{eff} = effective cooling velocity of hot wire
U_c = streamwise velocity near the center axis of diffuser
U_L = local streamwise velocity
$\bar{u}$ = mean streamwise velocity over the cross section
W_e, W_i = width of inlet or exit of diffuser
x, y, z = cartesian coordinates

α = modified coefficient of kinetic energy

δ = boundary layer thickness

δ_1 = displacement thickness

δ_2 = momentum thickness

η = diffuser effectiveness

ρ = density (mass per unit volume)

μ = viscosity

ν = μ / ρ = kinematic viscosity

ω_x = streamwise component of mean vorticity

A.2 Symbols in This Experiment

C_{pdf} = C_{pVR} - C_{puf} = pressure recovery from unforced case

D_j = jet hole diameter

D_t = tripping wire diameter

dif = state value of system

dp = differential pressure

dpv = output voltage of pressure transducer

Δp = differential pressure between inlet and outlet of diffuser

q = control variable (jet flow rate per control step)

f_p = pulse frequency

Q_j = jet flow rate

SV = control reference

U = mean velocity in X direction

U_0 = freestream velocity

V = mean velocity in Y direction

V_j = jet mean speed

VR = ratio, V_j / U_0

W = mean velocity in Z direction

X = streamwise coordinate (measure from jet hole)

Y = vertical coordinate (measure from lower wall)

Z = spanwise coordinate (measured from left wall viewed from upstream)

α = divergence angle of diffuser

ϕ = jet pitch angle

θ = jet skew angle

Subscript

e = diffuser outlet X=250 mm

i = diffuser inlet X=-10 mm

int = initial situation

uf = non-jet situation

VR = issuing jet situation

APPENDIX B: LIST OF EXPRIMENTAL INSTRUMENTS

Table B.1 Experimental instruments

Instruments	Model	Mfg. Co.
Blower	SFJ-304-IV-1	SWIDEN
Electric Valve	2AF5-10	CKD
Rotameter	J-2693	RIKASEIKI KOGYO
Personal Computer	SRV 4100-500	SORD
Interface Board (A/D, D/A Converter)	AD12-16(PC)E	CONTEC
X-Array Hot Wire Probe	0252R-T5	NIHON KAGAKU KOGYO
Hot Wire Anemometer (CTA System Anemometer)	MODEL 1010	NIHON KAGAKU KOGYO
Single-Wire Probe	9055P0141	DANTEC
Linearizer	MODEL 1013	NIHON KAGAKU KOGYO
Temperature Measurement Unit / Probe	MODEL 1020	NIHON KAGAKU KOGYO
Stepping Motor	KP6M2-005	JAPAN SERVO
Stepping Motor Driver	SMD-301	JAPAN SERVO
Interface Board (Stepping Motor Control Unit)	SMC-3(PC)	CONTEC
Electric Motor	M6100-201K	ORIENTAL MOTOR
Revolution Indicator	MODEL 00204	ONO SOKKI
Differential Pressure Transducer	3051CD1A52A1 AB4D9D3Q4	FISHER-ROSEMOUN T

APPENDIX C: JET SPEED MEASUREMENTS

Jet speed measurements were carried out by using an X-array hot wire probe. Each channel of the X-array hot wire probe was individually used for the measurements because the probe diameter was not sufficiently small in comparison with the jet orifice diameter. Figure C.1 shows a schematic diagram of the jet speed measurements. The hot wire probe was traversed at equal interval of 0.3 mm in the transverse direction of the jet orifice because the jet orifice became wider in the spanwise direction due to the jet pitch angle. Figure C.2 shows the distribution of the jet speed along the center axis of the jet orifice. Table C.1 gives the jet speed for Fig. C.2. The jet mean speed is calculated by integrating along the center axis of the jet orifice from traversing distance equals -1 mm to 1 mm (corresponding to the D_j=2 mm case). For the steady jet case (f_p=0 Hz) this result coincides with the result calculated from the continuity equation (conservation of mass). Figure C.3 shows the jet speed versus the jet flow rate. From Fig. C.3, for the pulsed jet case the relationship between the jet mean speed and the jet flow rate is given by

$$V_j = 0.95 \times Q_j , \tag{C.1}$$

or

$$V_j = 1.03 \times Q_j . \tag{C.2}$$

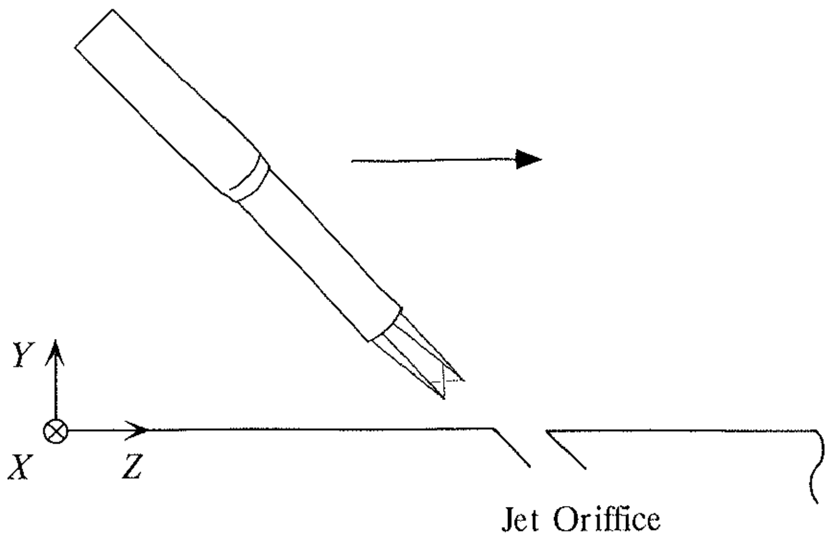
Equations (C.1) and (C.2) correspond to f_p=10 Hz and f_p=20 Hz, respectively. For the steady jet case the jet mean speed are calculated from the continuity equation, for D_j=2 mm and D_j=3 mm, as

$$Q_j = 0.565 \times V_j , \tag{C.3}$$

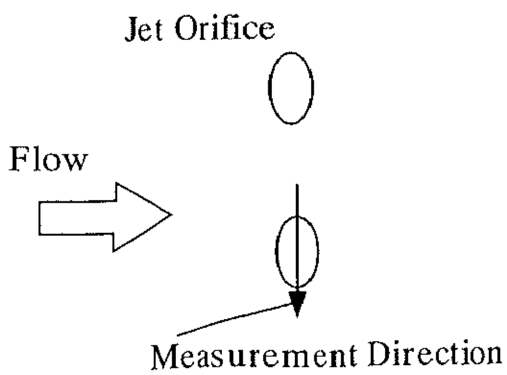
and

$$Q_j = 1.272 \times V_j , \tag{C.4}$$

respectively.

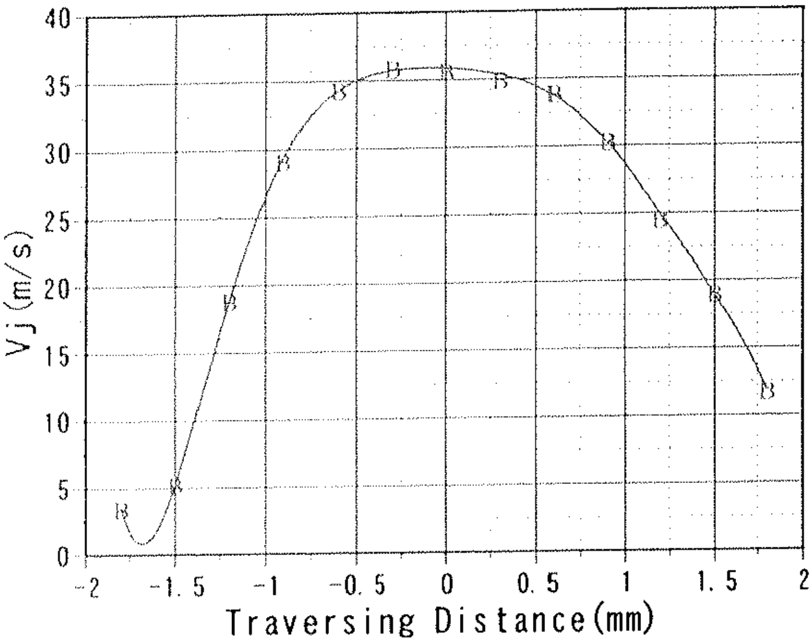


(a) Viewed from upstream

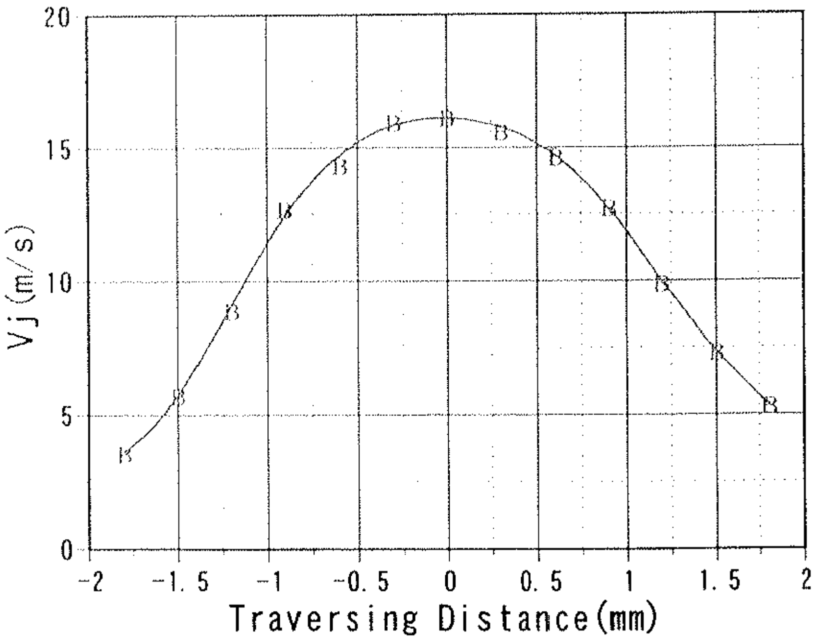


(b) Viewed from top

Figure C.1 Schematic diagram of jet speed measurements.



(a) f_p=0 Hz, Q_f=16 l/min



(b) f_p=10 Hz, Q_f=16 l/min

Figure C.2 Distribution of jet speed along the center axis of jet orifice.

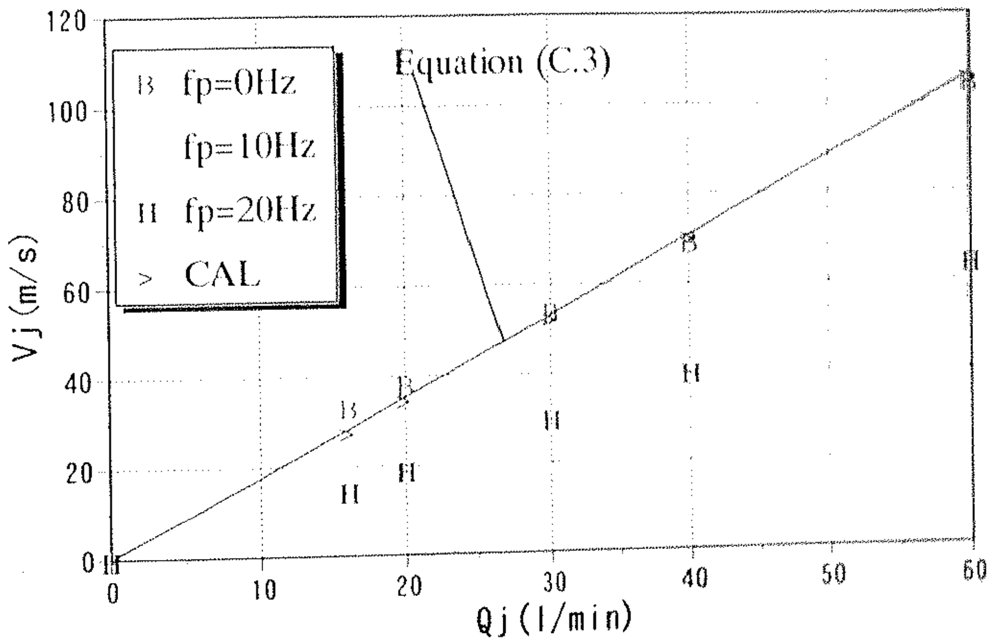


Figure C.3 Jet speed versus jet flow rate (D_j=2 mm); comparison with the values calculated from the continuity equation (CAL).

Table C.1 Values of jet speed along the center axis of jet orifice (ϕ=45 deg)

Pulse Frequency f_p (Hz)	Jet Flow Rate Q_j (l/mim)	Traversing Distance (mm)	Jet Speed (m/s)
0	16	-1.8	3.521
0	16	-1.5	5.292
0	16	-1.2	18.898
0	16	-0.9	29.181
0	16	-0.6	34.394
0	16	-0.3	35.954
0	16	0	35.710
0	16	0.3	35.048
0	16	0.6	33.997
0	16	0.9	30.401
0	16	1.2	24.623
0	16	1.5	19.112
0	16	1.8	11.884
0	20	-1.8	11.488
0	20	-1.5	18.805
0	20	-1.2	25.151
0	20	-0.9	32.351
0	20	-0.6	37.039
0	20	-0.3	39.594
0	20	0	41.516
0	20	0.3	41.418
0	20	0.6	38.977
0	20	0.9	35.389
0	20	1.2	30.655
0	20	1.5	25.378
0	20	1.8	20.892
0	30	-1.8	26.535
0	30	-1.5	35.001
0	30	-1.2	43.558
0	30	-0.9	49.546
0	30	-0.6	55.662
0	30	-0.3	58.478
0	30	0	58.877
0	30	0.3	56.342
0	30	0.6	51.375
0	30	0.9	44.517

Table C.1 Continued

Pulse Frequency f_p (Hz)	Jet Flow Rate Q_j (*l*/mim)	Traversing Distance (mm)	Jet Speed (m/s)
0	30	1.2	38.574
0	30	1.5	32.527
0	30	1.8	27.016
0	40	-1.8	29.090
0	40	-1.5	38.439
0	40	-1.2	49.570
0	40	-0.9	60.301
0	40	-0.6	68.968
0	40	-0.3	73.282
0	40	0	75.271
0	40	0.3	74.487
0	40	0.6	69.448
0	40	0.9	60.863
0	40	1.2	53.968
0	40	1.5	44.996
0	40	1.8	35.292
0	60	-1.8	52.739
0	60	-1.5	69.463
0	60	-1.2	83.897
0	60	-0.9	96.989
0	60	-0.6	107.457
0	60	-0.3	111.773
0	60	0	112.025
0	60	0.3	109.577
0	60	0.6	100.076
0	60	0.9	86.136
0	60	1.2	72.716
0	60	1.5	59.597
0	60	1.8	47.688
10	16	-1.8	3.616
10	16	-1.5	5.778
10	16	-1.2	8.960
10	16	-0.9	12.745
10	16	-0.6	14.384
10	16	-0.3	15.990
10	16	0	16.175

Table C.1 Continued

Pulse Frequency f_P (Hz)	Jet Flow Rate Q_j (l/mim)	Traversing Distance (mm)	Jet Speed (m/s)
10	16	0.3	15.653
10	16	0.6	14.697
10	16	0.9	12.795
10	16	1.2	9.951
10	16	1.5	7.374
10	16	1.8	5.367
10	20	-1.8	4.284
10	20	-1.5	7.313
10	20	-1.2	11.601
10	20	-0.9	16.428
10	20	-0.6	19.392
10	20	-0.3	19.953
10	20	0	20.499
10	20	0.3	21.923
10	20	0.6	19.648
10	20	0.9	17.980
10	20	1.2	12.892
10	20	1.5	10.659
10	20	1.8	7.330
10	30	-1.8	7.718
10	30	-1.5	13.176
10	30	-1.2	19.745
10	30	-0.9	25.548
10	30	-0.6	27.972
10	30	-0.3	31.694
10	30	0	31.791
10	30	0.3	30.733
10	30	0.6	28.442
10	30	0.9	25.672
10	30	1.2	20.510
10	30	1.5	15.128
10	30	1.8	13.776
10	40	-1.8	13.006
10	40	-1.5	20.179
10	40	-1.2	27.240
10	40	-0.9	33.462

Table C.1 Continued

Pulse Frequency f_p (Hz)	Jet Flow Rate Q_j (l/mim)	Traversing Distance (mm)	Jet Speed (m/s)
		-0.6	37.496
		-0.3	40.973
10	40	0	39.167
10	40	0.3	39.013
10	40	0.6	34.952
10	40	0.9	30.008
10	40	1.2	26.277
10	40	1.5	21.038
10	40	1.8	17.977
10	40	-1.8	5.605
10	40	-1.5	7.749
20	16	-1.2	11.980
20	16	-0.9	12.771
20	16	-0.6	16.122
20	16	-0.3	15.159
20	16	0	15.679
20	16	0.3	14.757
20	16	0.6	14.227
20	16	0.9	11.980
20	16	1.2	10.261
20	16	1.5	8.211
20	16	1.8	6.691
20	16	-1.8	7.349
20	16	-1.5	11.121
20	20	-1.2	14.270
20	20	-0.9	17.100
20	20	-0.6	18.253
20	20	-0.3	20.759
20	20	0	21.986
20	20	0.3	20.342
20	20	0.6	18.465
20	20	0.9	16.135
20	20	1.2	13.384
20	20	1.5	11.483
20	20	1.8	9.431
20	20	-1.8	13.885
20	20		
20	30		

Table C.1 Continued

Pulse Frequency f_p (Hz)	Jet Flow Rate Q_l (l/mim)	Traversing Distance (mm)	Jet Speed (m/s)
20	30	-1.5	19.071
20	30	-1.2	24.496
20	30	-0.9	28.804
20	30	-0.6	31.816
20	30	-0.3	33.846
20	30	0	33.642
20	30	0.3	28.858
20	30	0.6	26.516
20	30	0.9	23.076
20	30	1.2	20.647
20	30	1.5	16.548
20	30	1.8	13.569
20	40	-1.8	18.546
20	40	-1.5	24.344
20	40	-1.2	31.808
20	40	-0.9	36.863
20	40	-0.6	38.448
20	40	-0.3	43.924
20	40	0	43.692
20	40	0.3	42.804
20	40	0.6	38.251
20	40	0.9	33.585
20	40	1.2	28.212
20	40	1.5	24.197
20	40	1.8	18.480