Experiment – 5 Airflow System –Jet Investigation Experiment

Aim of this Experiment

Jet Investigation duct has been designed for operation with theAirflow System. The duct allows students to investigate the phenomenon of jet attachment toan adjacent wall and the so called Coanda effect.

Experimental Set – up

Experimental system has some essential items needed for the experimental use. It features a large capacity **airflow system, a plenum chamber, multi-tube monometer** and**Bernoulli investigation duct**.

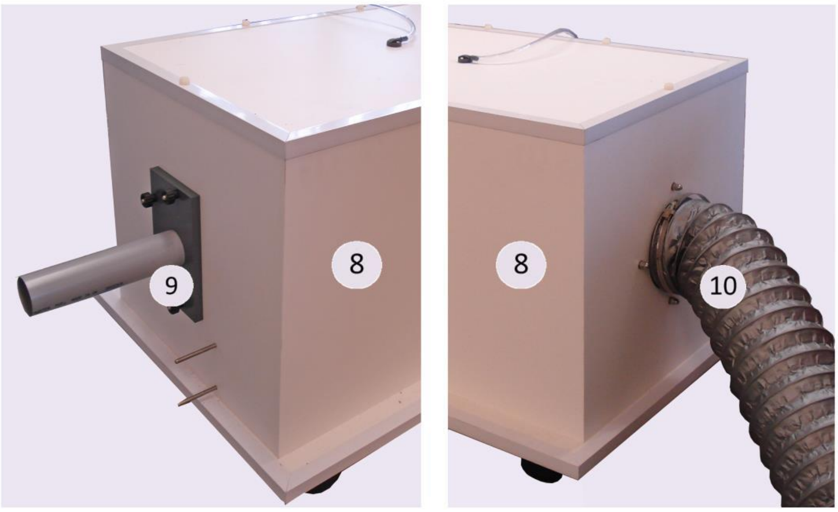
The **Airflow System** has been specifically designed to allow students to investigate a wide range of and low speed air flow phenomena and fundamental aerodynamics. Airflow System base unit consists of a large capacity variable speed centrifugal fan with a separate aerodynamically designed plenum chamber containing multiple screens, flow straightener and acceleration section. The fan and plenum chamber are connected by a length of flexible hose and this allows the two components to be arranged in a variety of convenient locations either at bench or floor level.

A large number of optional ducts may be attached to the **plenum discharge** that allow investigation of airflow on the positive side of the fan.

In addition there are additional optional items that attach to the suction or intake side of the fan.

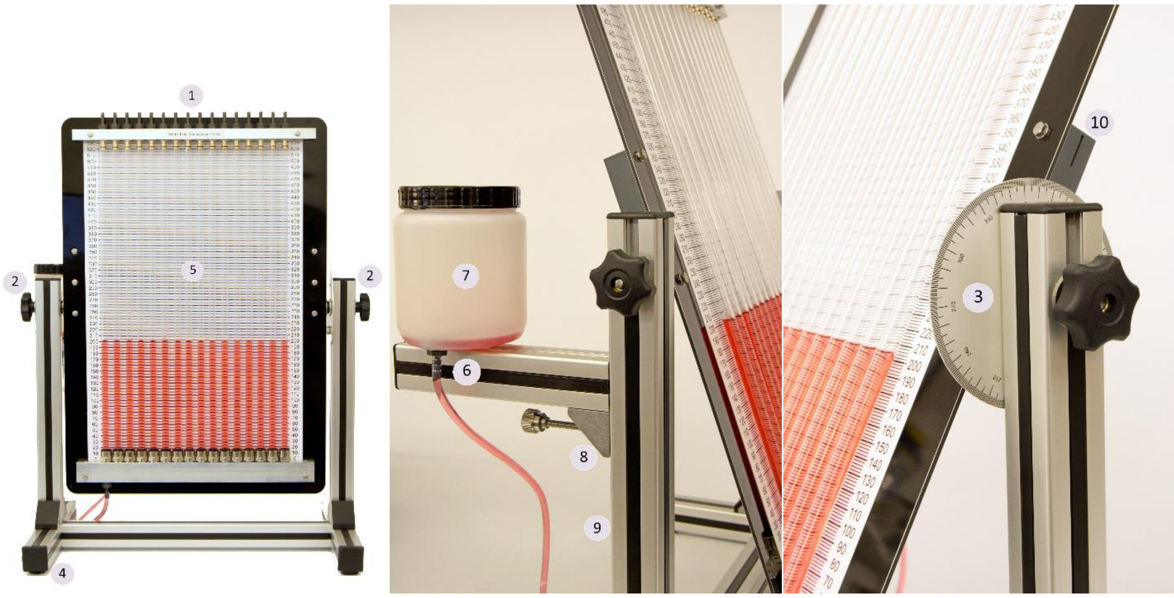
The ability to utilise both the intake and discharge sides of the fan, together with a continuously expanding range of optional accessories makes the **Airflow System** a very flexible and cost effective unit.

General experimental setup of Airflow System: 1. Fan; 2. Fan Speed Control; 3. RCCB & MCB Box; 4. Fan Outlet; 5. Fan Inlet; 6. RCCB; 7. MCB

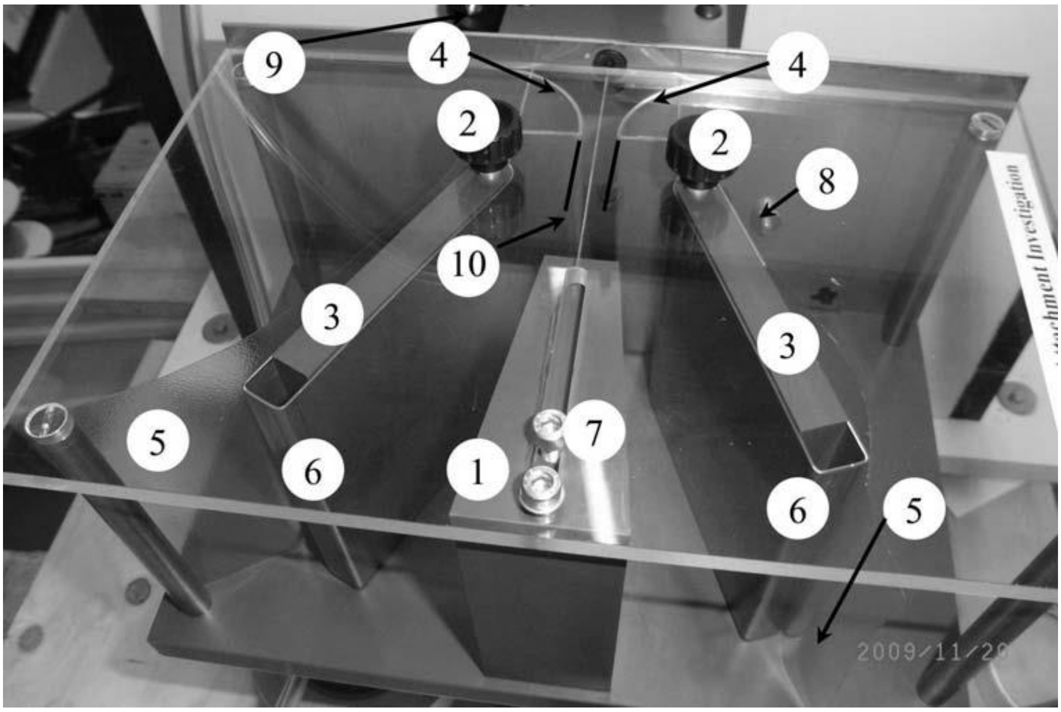


General experimental setup of Plenum Chamber: 8. Plenum Chamber; 9. Plenum Discharge; 10. Plenum Inlet

Multi-tube Manometer has been designed for operation with the Airflow System. However as a 16 tube manometer it may equally be used in any application that is within its pressure range. Last apparatus for the experimental setup is Bernoulli investigation duct.

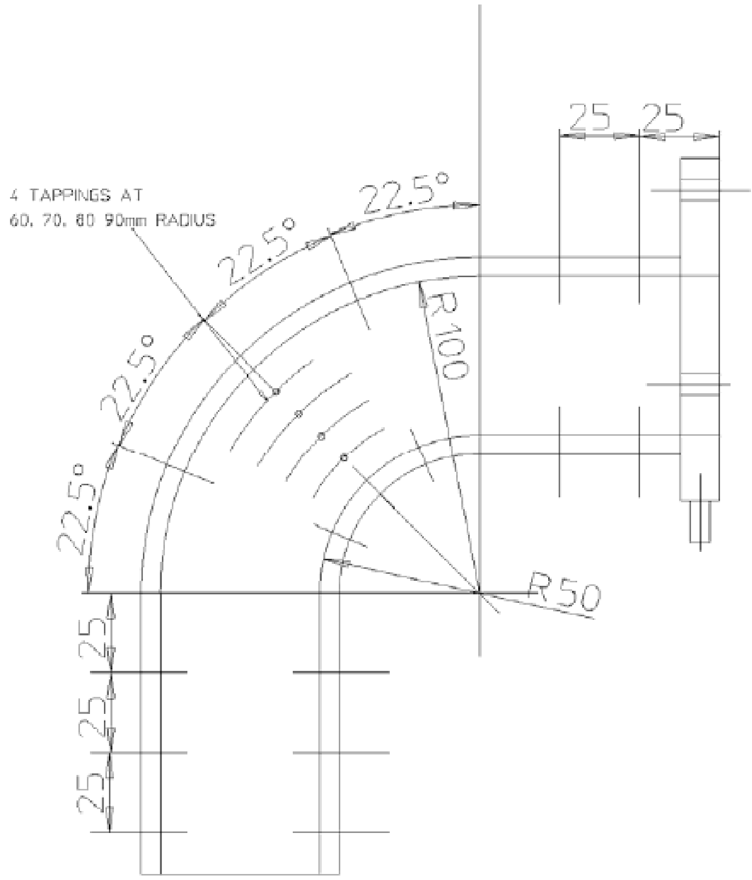


General experimental setup of Multi-Tube Manometer: 1. Manometer Tube Couplings; 2. Side Clamps; 3. Angle Indicator; 4. Rubber Feet; 5. Manometer Tubes; 6. Reservoir Tapping; 7. Reservoir; 8. Reservoir Clamp; 9. Reservoir Track; 10. Marker



General experimental setup of Jet Attachment: 1. Splitter Block; 2. Locking Nut; 3. Attachment wall; 4. Jet nozzle; 5. Flexible Seal; 6. Wall extension; 7. Splitter Lock Screw; 8. Jet nozzle lock screw; 9. Mounting nuts; 10. Jet effective width "w"; 11. Wall extension lock screw

Schematic Diagram of inner radius, outer radius and radial pressure tapping centre lines



Theory

In a variety of aerodynamic experiments, such as flow around a cylinder and the flow around a wingthe phenomena of separation of flow is commonly observed. The jet attachment experiment eals with a phenomenon, that is effectively, the reverse of separation, in that a jet, emerging close to awall will attached to the wall and follow the contour.

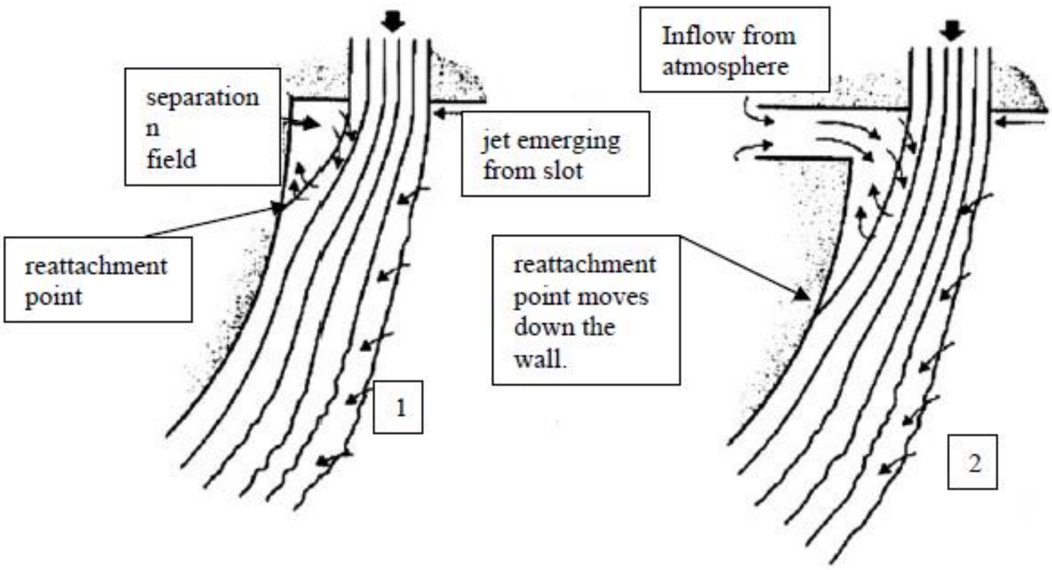


Figure Jet Flow: 1. strong recirculatingturbulent field; 2. effect of opening an aperture in the separation field

It is found that even if the wall curves appreciably the jet will still attach to its surface and follow thecurve. Use of this phenomena was proposed in the 1930s by Henry Coanda, who made several devicesthat use this form Jet deflection. For this reason, the phenomena are often referred to as the Coandaeffect.

It is known that a jet emerging into a field will entrain fluid adjacent to the point that it exits the orifice.In most cases, the jetty emerging is very turbulent and results in very strong mixing. In figure 6.1,the jet leaves the slot, and in an area adjacent the jet separates, and there is a strong recirculatingturbulent field. The presence of the wall restricts mixing on this side and entrainment. This, togetherwith the recirculation in the separated area and fluid being entrained to the right of the jet, both pullsand pushes the jet back towards the wall.

The pressure in the separation field is lower than the atmospheric pressure on the opposite side of thejet. Figure 6.2 shows the effect of opening an aperture in the separation field. Due to the low pressurearea is entrained from outside, and this has the effect of extending the reattachment point further downthe wall. If the entrainment rate is increased, the reattachment point will move further and further downthe wall.

Given sufficient entrainment the jet can effectively be detached permanently from the wall.
Once attached to the wall as in Figure the jet is unlikely to detach as to do so would require theaddition of fluid between the jet and the wall. Separation is unlikely then unless the curvature of thewall is large or there is an adverse (increasing) pressure gradient.

The description overleaf assumes two dimensional flow. If, however the jet is round for example thenair entrained around the ends of the jet will also be entrained and cause separation sooner.
Due to the importance of these effects, the ratio of jet width to jet thickness is important wheninvestigating this phenomenon.

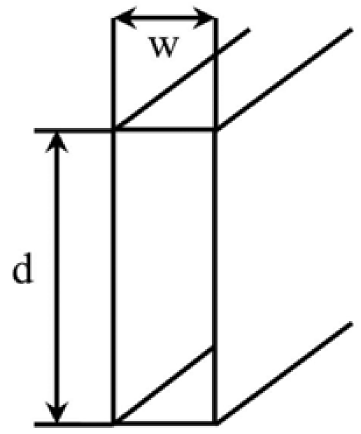


Figure Aspect Ratio; AR = (d/w)

The “Coanda effect” can be used in fluid logic controls to act as a “flip-flop” control. These are analogous to electronic flip-flop switches that effectively stay in a set state unless an external signalacts upon them, at which point they switch over to the opposite state.

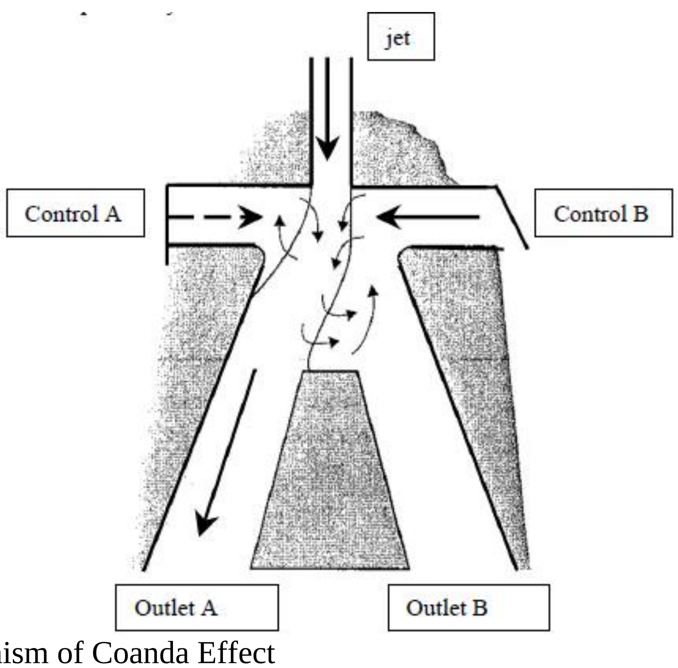


Figure The Mechanism of Coanda Effect

The jet emerging at the top of the diagram causes turbulent recirculation and entrainment on both sidesas it emerges. If both control flab A and B are closed, then there is no preferred route for the flow. Ifcontrol flap B is opened, then air will be entrained on this side and the jet will move towards the wall onOutlet A and will attach to the wall. Even if control flap B is closed the jet will remain attached to thewall if the jet and divider between outlet A and B have been designed correctly.

Only if control flap A is opened will the flow be diverted to outlet B. Again unless acted upon bycontrol B, the flow will remain attached to wall B and exit through outlet B.

By using this phenomena, fluid switches like these can be constructed and developed into and/or gates to build up logic circuits.

Jet Attachment Investigation experiment allows students to investigate the phenomenon indetail and operate a flip-flop in this manner.

Experiment -5.1

Investigation of Jet Attachment

Procedure

It is necessary to connect the manometer to the**Plenum chamber** for reference purposes. The**airflow fan**should be started and the **Multi-Tube Manometer** levels should be adjusted.

Connection to the Airflow System

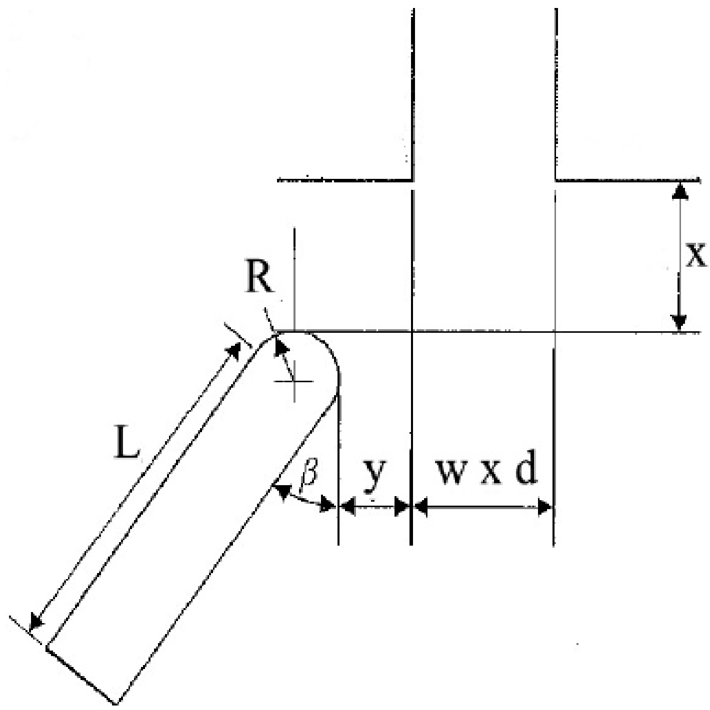
Care must be exercised when connecting the manometer to the airflow system. The following method is suggested to prevent the manometer liquid from being eitherdriven out of the manometer tubes or drawn into the tubes connected to the accessories.

Before starting the fan, connect the pressure hoses to the accessory in use and to the manometer.Notethat the two outer tubes(left and right) are not normally connected/used.

Set the manometer to the vertical or inclined condition as required and adjust the reservoir to aboutmid-height. Record the atmospheric datum or zero level. Then start the fan and slowly increase thespeed, at the same time monitoring the manometer levels. As the pressures in the various tubes moveup and/or down adjust the **reservoir** level also up or down, so that the liquid levels are kept withinthe range of the manometer.

Once the fan is running at the desired speed make any final adjustments to the reservoir level to set theatmospheric datum to a convenient value using the two outer tubes as a reference. Record this atmospheric datum as the reference value. It is this value that will be either taken from, oradded to the other levels recorded on the manometer tubes.

Adjustment Details for the Jet Attachment Investigation accessory: Please also refer to the figure.

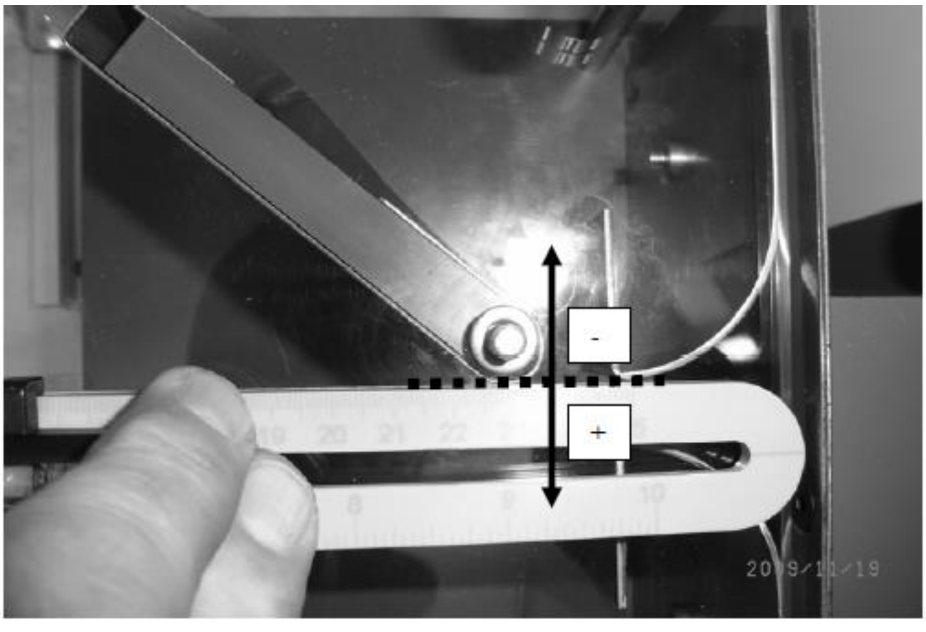


The width of the jet **w** and the offset of the jet **y** from the moveable wall can all be adjusted by movingthe two steel **jet nozzle** plates. The plates are secured in position by the **jet nozzle lock screws.**

In order to examine jet attachment without the complication of the splitter and second wall the **splitterblock** can be removed by taking out the **locking screws** and sliding the block out of the duct.

Next one of the **attachment walls** may be swung to the horizontal position(as in the picture belowon the right) to remove it from the flow.

In the above arrangement the jet has been located so that y, the distance between the edge of the jetand the left hand wall is 0mm. This can be checked with the angle gauge supplied as shown below.

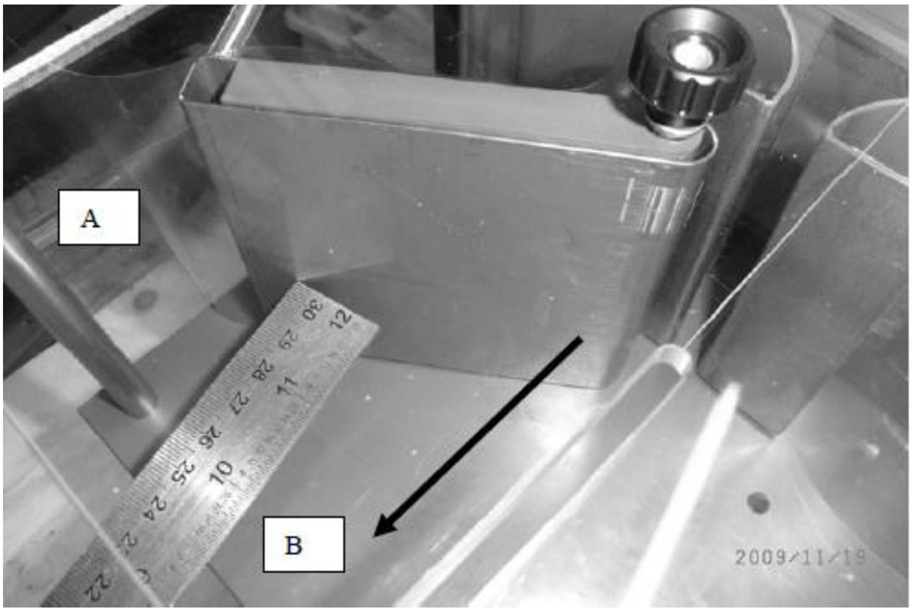


Using a combination of the angle gauge and a rule, the distance **y** may be measured and adjusted. Notethat the value of y may be set at positive or negative values. In the above diagram, a negative settingwould be regarded as the jet edge being closer to the centre line of the wall pivot(as indicated by thearrows).

The **flexible seal** may either be allowed to sit against the outside of the wall or held back so that thecap between the jet and the wall is open. Tests are carried out with and without the seal in position inorder to see how the induced flow referred to Figure 6 affects the turning angle of the air.

The procedure is to set the wall angle β to zero and bring the fan to a convenient speed close to maximum. This is then held constant through the tests by maintaining the plenum chamber pressure ata constant value.

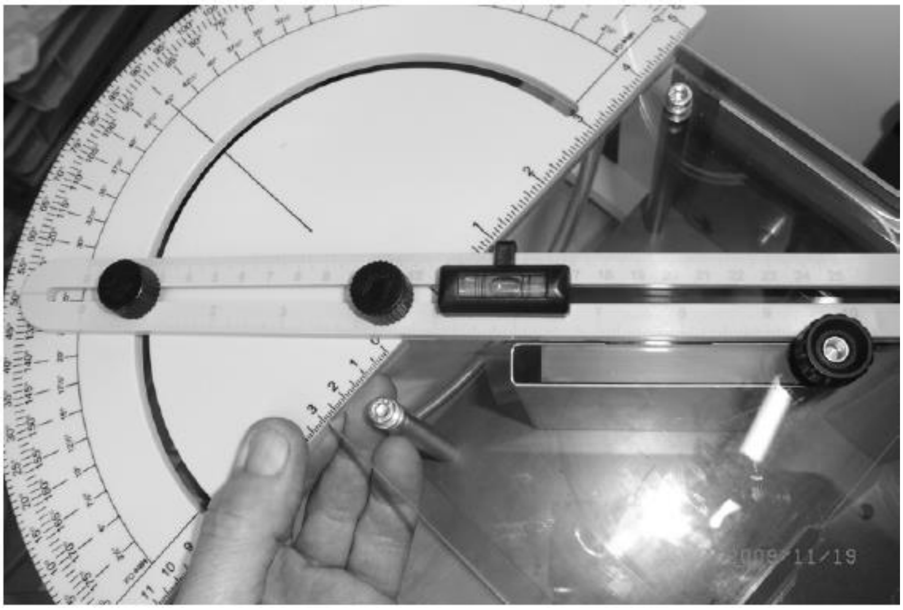
Using a flat surface aligned with the flow, now slowly move the wall to increase the wall angle β.



As shown a rule is a convenient tool. By holding a hand adjacent to the end of the wall (at A above) thejet will be felt as it turns and follows the wall. As the wall angle β is increased a point will be foundwhere the flow detaches and continues along arrow B. It may be necessary to repeat this processseveral times in order to determine the angle at which the flow “just breaks away” this angle is βs.

The point at which the flow detaches can often also be “heard” as a change in the sound of the flow.By using the angle gauge supplied, measure the wall angle βs at this condition.

Then slowly move the wall back to reduce the angle and determine the point at which the flow reattaches to the wall. This angle is βr. This procedure should be repeated several times until theangle is determined and repeatable, to within about 1°.



It is recommended that to save setting time, the procedure is repeated with the **flexible seal** inposition and not in position. It will be found that the results are very different in the two conditions.

The procedure is repeated at different valves of **y** offset and constant jet width **w**.

If time permits the whole procedure may be repeated at different jet width **w** values.

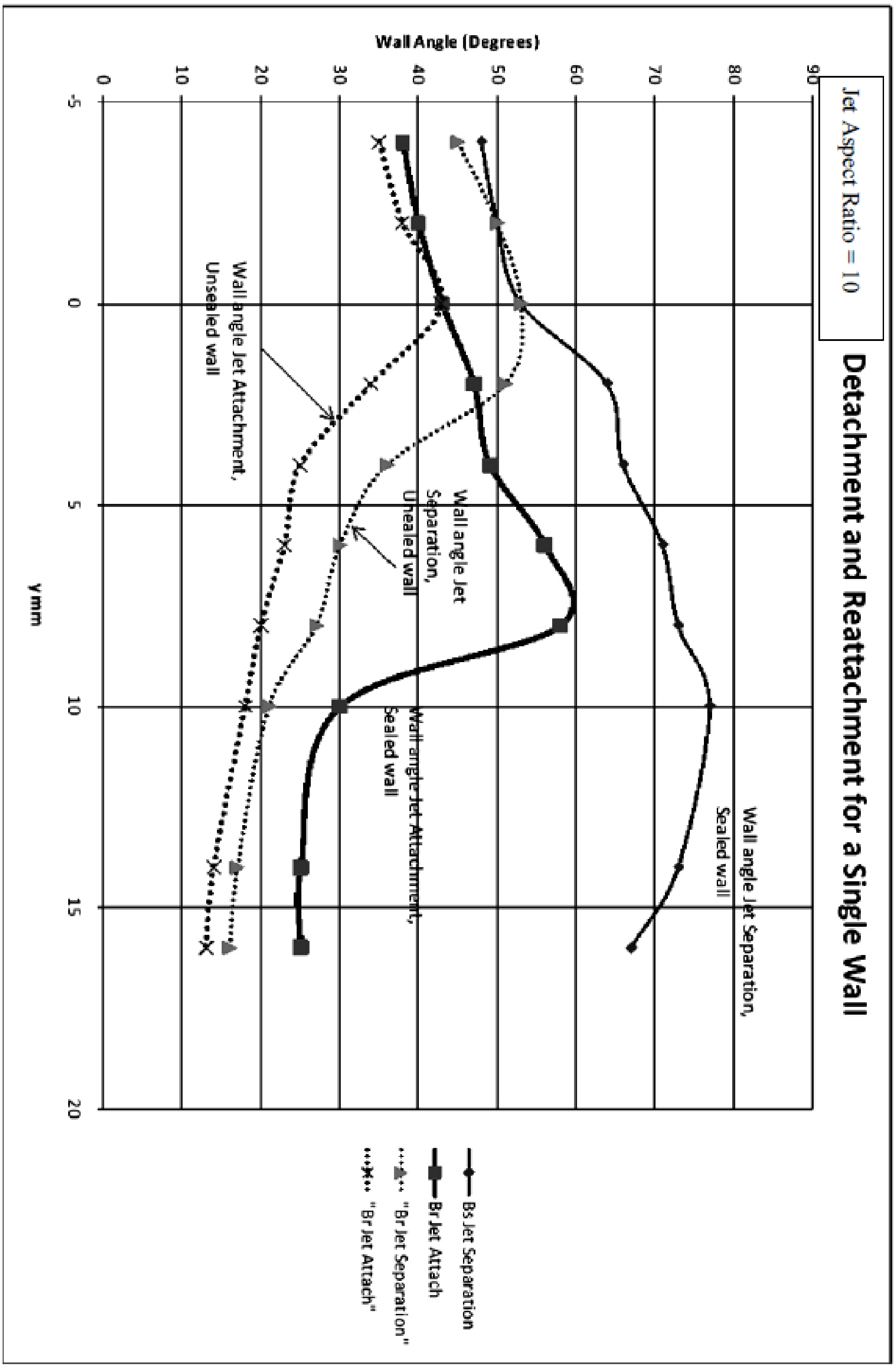
Typical Results

Jet Width w = 10mm
Aspect Ratio

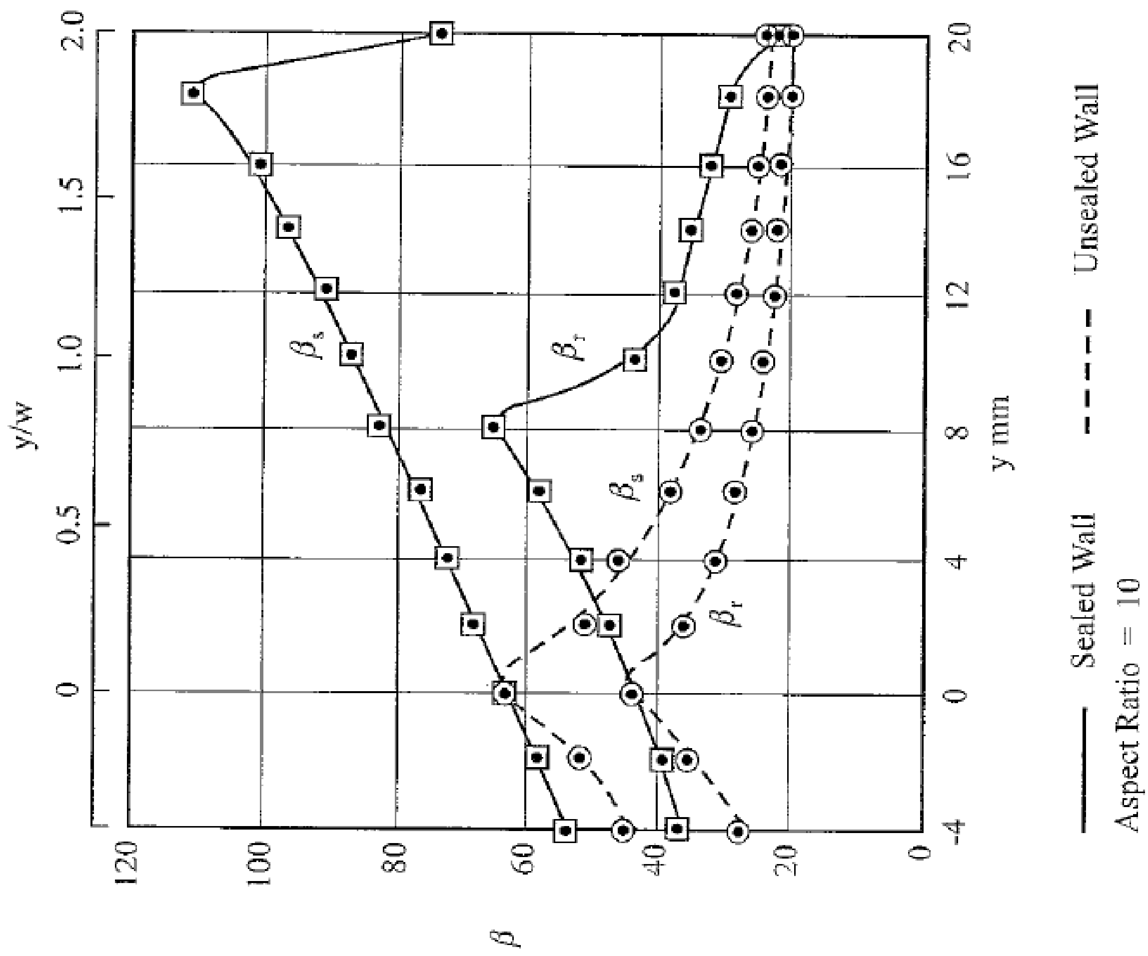
$$AR = \frac{d}{b}$$
$$= \frac{100}{10}$$
$$= 10$$

	Flexible seal Closed		Flexible Seal Open	
y mm	βs	βr	βs	βr
-4	48	38	45	35
-2	50	40	50	38
0	53	43	53	43
2	64	47	51	34
4	66	49	36	25
6	71	56	30	23
8	73	58	27	20
10	77	30	21	18
14	73	25	17	14
16	67	25	16	13

The data is presented graphically



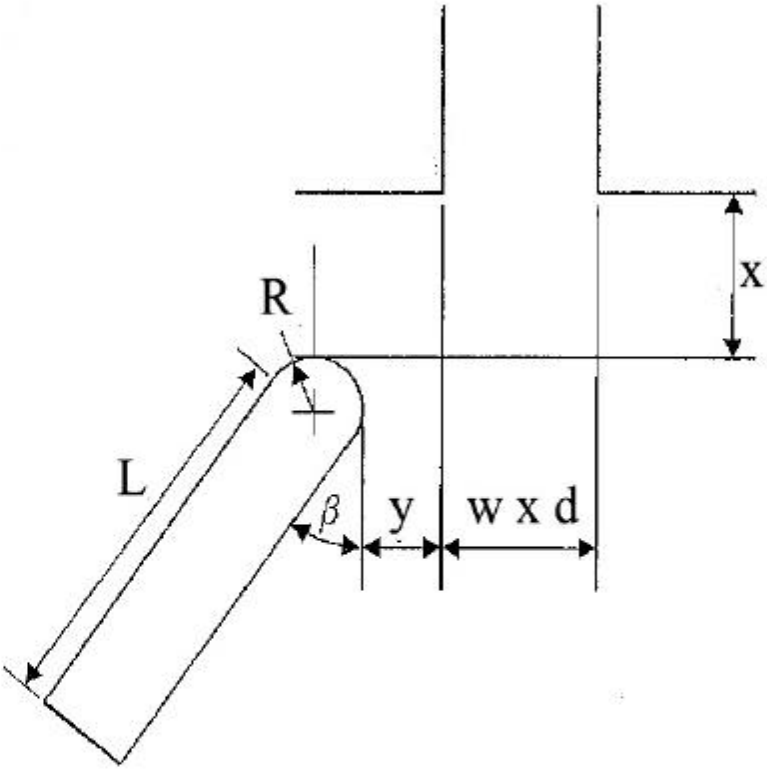
Data from more general test



Appendix – I Some Useful Data

Manometer Fluid Density 800 kg/m^3

Jet Depth	**d**	**100mm**
Jet width	**w**	**Adjustable**
Distance of jet from wall	**x**	**12.0mm**
Wall radius	**R**	**6.0mm**
Wall angle	β	**Adjustable**
Edge of Jet to Wall distance	**y**	**Adjustable**



Appendix –II Symbolas and Units

UNITS

Symbol	Designation	Unit
C	Constant	-
Cp	Non dimensional Pressure coefficient	-
g	Acceleration due to gravity	m/s^2
h	Manometer liquid height	mm
p	Static pressure	kN/m^2
P	Total pressure	kN/m^2
ρ	Density of manometer fluid	Kg/m^3
$\dot{Q}$	Flow Volume	m^3/s
r	radius dimension	m
v	Local velocity	m/s
V	Free Stream Velocity	m/s