AIR IN PIPELINE - GANGA JAL PROJECT, AGRA

CLIENT : UTTAR PRADESH JAL NIGAM

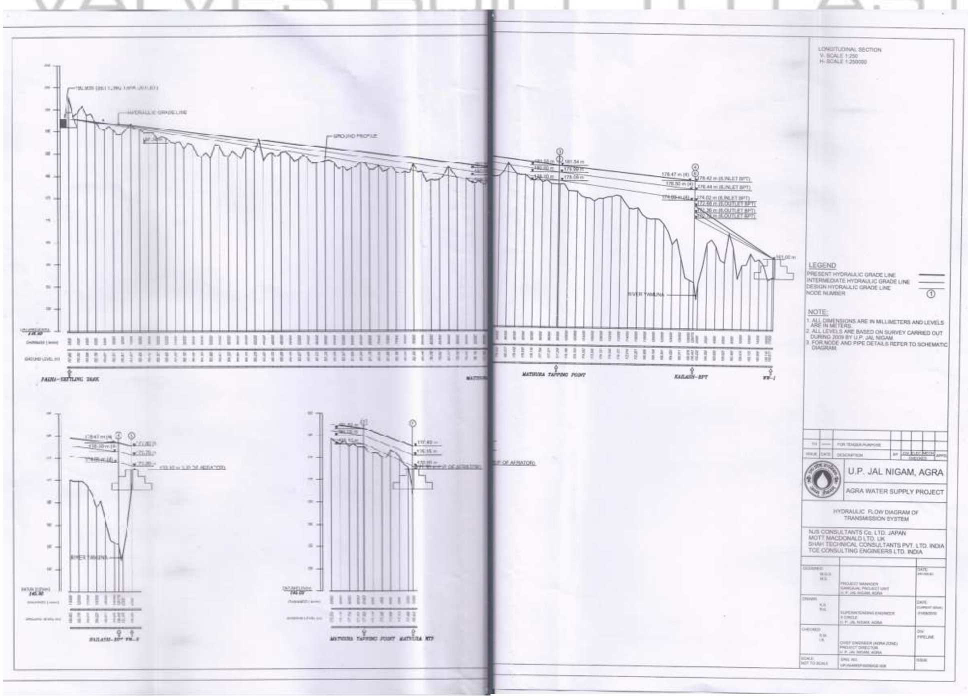
EQUIPMENT : AIR VACCUM VALVE

DATA

Pipe Size	V_c for Horizontal pipe	V_c for downward sloping pipe)	Proposed discharge (mld)	Corresponding velocity (m/s)
2100 Ø	2.20 m/s	2.90 m/s	183.5	0.61
2800 Ø	2.54 m/s	3.34 m/s	3423	0.64
1600 Ø	1.92 m/s	2.53 m/s	144	0.83
800 Ø	1.36 m/s	1.28 m/s	25	0.58

V_c = critical velocity when exceeded, air begins to move downstream with water flow

HYDRAULIC LINE DIAGRAM



WHY IS AIR A PROBLEM

1. Air pockets reduced the effective pipe cross section, which leads to reduction in pipe capacity.

2. Air bubbles introduce vertical momentum into the flow due to their buoyancy and may then have significant effects on the flow field.

3. Air accumulation in a system may lead to disruption of flow and such effect as blow-out or blow-back.
   For instance, air entrained at a hydraulic jump may not be able to move downstream with the flow and instead 'blow-back'. This can lead to vibration and structural damage.

4. In ferrous pipe lines, the presence of air enhances corrosion by making more oxygen available.

5. Air can cause difficulty in filter operation. Air bubbles can become trapped in sand filters reducing their efficiency.

6. Presence of air can reduce pump and turbine efficiency. Admission of air into a pump can cause loss of priming.

7. Air can produce false readings on measuring devices.

HOW DOES AIR ENTER A PIPELINE

1. At normal temperatures, the saturation level of dissolved air in water is 2% approx. which comes out of the solution usually as a result of a pressure drop.

2. Temperature increases can also promote air release as the vapour pressure of water increases with temperature (from say 1.70 KN/m^2 at $15^\circ c$ to 4.24 KN/m^2 at $30^\circ c$). In other words at $30^\circ c$ the potential volume of air to be released is 2.5 times greater than the volume that can be released at $15^\circ c$. So Thermal variation is an important aspect for consideration while designing pipe systems.

3. Entrainment at inflow locations such as drop chamber, inlet or intake.

4. Entrainment due to vortices at inlet or intake.

5. The flow within a pipe system man change from gravity to surcharged flow leading to the formation of a Hydraulic Jump whose violent action breaks up the large air bubbles into small bubbles capable of being carried by the flow.

6. Filling or emptying of lines. Particularly during filling, air moving along the pipeline can get trapped at high points in the system.

7. Negative pressure at the inlet of the pipe.

AIR / WATER FLOW PATTERNS

Vertical Flow Patterns are generally more axis symmetric compared with **horizontal flows. In inclined pipes** the pattern is nearly similar except at very high air volumes. The common ones are:

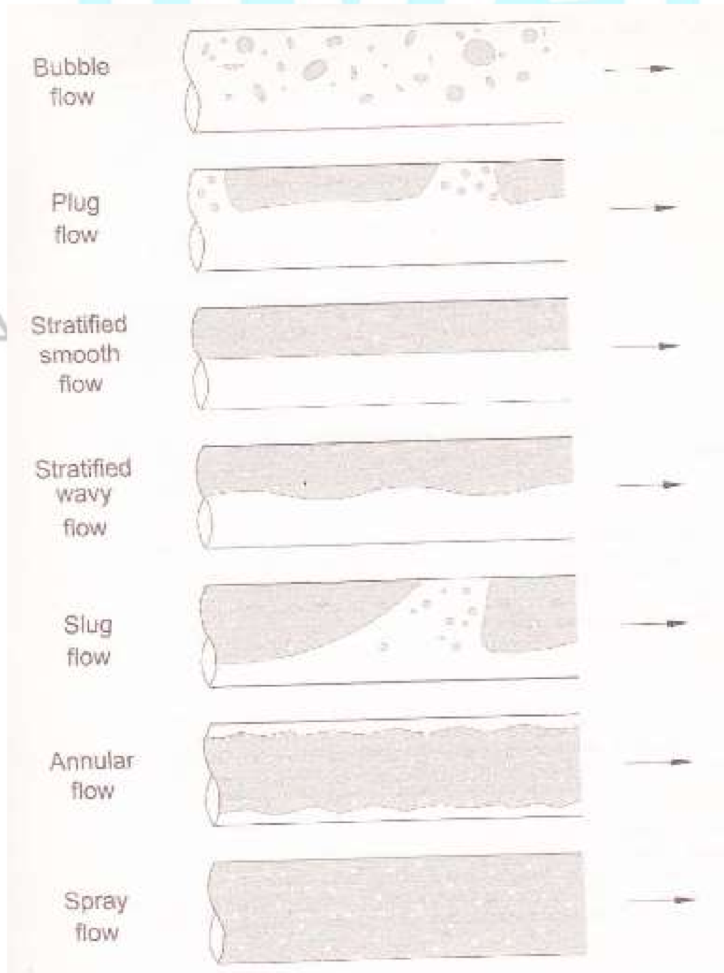
1. **Bubble flow**: Air is distributed in the water as spherical bubbles which are small compared to the pipe dia. This is the case when quantity of air is small, mixed with moderate quantity of water.

2. **Plug flow**: As air flow increases the bubbles coalesce forming an intermittent flow pattern in which air pockets develop. These pockets or plugs are entrapped in the main water flow and are transported with it along the top of the pipe.

3. **Stratified smooth flow**: a distinct horizontal interface separates the air and water flows. This flow pattern is observed at relatively low rates of air and water flows.

4. **Slug flow**: with increased air flow very large air bubbles at regular intervals, almost the size of pipe cross section, literally choke the pipe, except for a thin annulus of liquid along the pipe wall (in vertical pipe) or below the air pocket (in horizontal or inclined pipe)

5. **Other forms of flow** (Annular flow and spray flow) may not be relevant for these happen with increased air flow rates.



For Horizontal or near horizontal pipes the flow is more complex. Intermittent and dispersed bubble flows are the dominant flow regimes likely to be encountered in such alignment. The enclosed sketch depicts the generalized flow regimes for a) horizontal pipe line – **Figure 3** and b) upward sloping pipe line – **figure 4.**

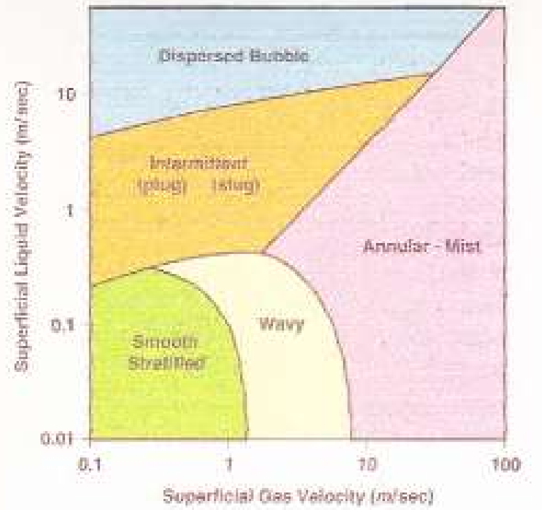


Figure 3 Generalised flow regime map for horizontal two-phase flow (based on Taitel and Dukler, 1976)

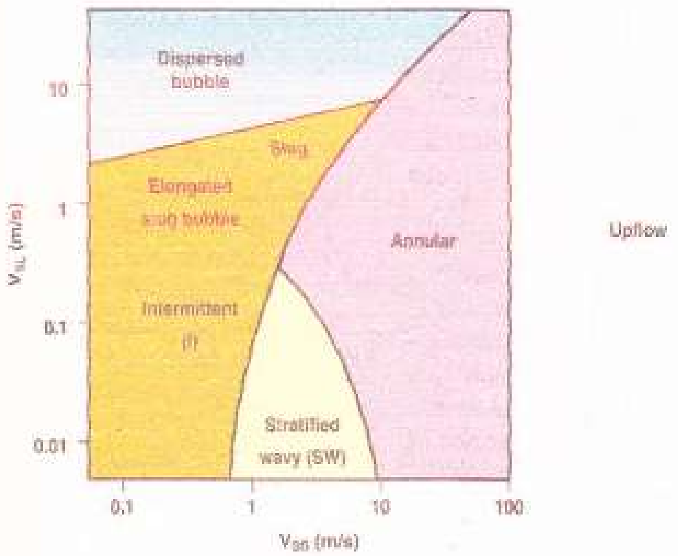


Figure 4 Generalised flow regime map for upward sloping two-phase flow (based on Barnea et al, 1980)

CRITERIA FOR AIR BUBBLES / POCKET MOVEMENT

LONG CONDUITS have a L/D ratio > 20. Air bubbles collect at the conduit roof in distant air pockets, and will only be transported downstream when the flow has the capacity to remove or clear large air pockets in a downward sloping conduit. If the flow does not have this capacity then air pockets build up in size and eventually blow back upstream. Also, larger air pockets scale with the conduit dimension.

Air starts to move in a pipe line if the critical velocity is exceeded. For downwards slope, θ, higher than 5% (2.9°):

$$\frac{V_c}{\sqrt{gD}} = 1.509 \sqrt{\tan \theta}$$

g= 9.81 m/s² gravitational acceleration
D= Pipe dia in m
θ= Pipe slope (to horizontal plane) in degrees

Thus for a pipe Ø of 2100, 2800, 1600 and 800 mm corresponding critical flow velocity in downward sloping (higher than 5%) pipe line will be:

2100 Ø - 1.54 m/s
2800 Ø - 2.34 m/s
1600 Ø - 1.77 m/s
800 Ø - 1.25 m/s

Another experimental result gives the following equation for air flow in gravity mains:

$$\frac{V_c}{\sqrt{gD}} = 0.484 \quad \text{(for horizontal stretches)}$$

and

$$\frac{V_c}{\sqrt{gD}} = 0.638 \quad \text{(for downward sloping pipe)}$$

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INFERENCE

1. **Greater the pipe size more is the critical velocity beyond which air bubbles / pockets begin to travel with the flow.**

2. **Greater the downward slope, more is the critical velocity**.

3. Increasing velocities in large trunk mains also imply greater friction losses. Consequently therefore, lower velocities of 1 to 1.5 m/s are chosen which inhibit movement of air bubbles / pockets along with the flow of water. And it is on account of this that spacing of air release, air intake valves on such mains are more dense.
4. For the proposed system in terms of pipe line size (dia) and the carrying capacity of water (mld) the corresponding water velocities are considerably lower than the critical or threshold velocities and therefore there is just no way for air bubbles / pockets to be purged out hydraulically i.e. along with water flow.

5. Arising out of 4) above the system needs careful scrutiny in terms of ventilation and possibly a fairly dense regime of valves for air discharge and suction.

AIR REMOVAL EQUIPMENT

The primary consideration in sizing air removal equipment is to provide enough capacity to maintain the line free of air during operation. A secondary consideration is the rate of initial priming of the system.

SELECTION AND SIZING AIR VALVES

The large orifice diameter of an air release valve should not be confused with the nominal inlet size of the valve. The nominal inlet size is the diameter of the inlet into the valve from the pipe whereas the large orifice diameter refers to the diameter of the opening where the air exits the vale into the atmosphere. These two dimensions are not necessarily similar. It is the large orifice area and the valve's dynamic characteristics that determine performance, not the nominal inlet diameter. It cannot be taken for granted that different valve designs of the same nominal diameter will perform equally.

Generally, the small orifice diameter remains the same irrespective of the nominal valve size but may change for different working pressures. The nominal valve size has no influence on the small orifice size.

Falvey (1980) states that if the desired capacity cannot be achieved with a single air valve, valves can be placed in clusters of up to four on a single vent pipe from a pipeline.

From manufacturers' information, it is generally considered that locating air valves for air intake will suffice for air discharge. However the sizes selected may not be large enough for air to discharge efficiently. In addition, the positioning of valves for air intake may not allow for the collection of air that is transported along the pipe while the pipe is in operation.

POSITIONING OF AIR VALVES

Most available guidance suggests that the analysis of the pipeline gradient with respect to the hydraulic grade line is the principle method of identifying suitable locations for air valves. All the positions along the pipe line profile where the pipe elevation is below the hydraulic grade line should be identified.

The following priority locations are identified for placement of air valves for air intake:

- High points (summits) which can fall below the hydraulic grade line (HGL)
- 3-4 m below the summit points formed by the intersection of the HGL and the pipe profile.
- Negative breaks, profile points where the upward slope decreases or the downward slope increases.
- 3-4 m below the negative break points formed by the intersection of the pipeline profile and the HGL.

It is suggested that the location of air release valves is the same as above but they are also required on descending sections of pipeline for filling.

It is difficult to size air valves on the descending section. In practice it is usual for air release valves in the descending section to be one or two standard sizes less than that at the apex.

The situation of air release valves on the descending, horizontal and shallow angled ascending sections of a pipeline is decided in terms of the relative distance between locations, taking into account the valves already positioned for intake purposes.
Other situations in which the use of air valves should be considered, including:

- The location of a double orifice air release just downstream from a non-return valve will help to dampen water hammer when discharge from a pump ceases.
- Where the end of a pipeline is terminated by a blank end or closed valve, a double orifice air release valve should be installed.
- A single small orifice air release valve should be installed immediately subsequent to abrupt increases or decreases in elevation of a pipe line and on the highest point of centrifugal pump casing.

The South African air valve manufacturer, Vent-O-Mat, recommends that on ascending sections of considerable length valves should be positioned every 600 m to ensure adequate discharge when filling and ample ventilation when the pipe is beign drained. For long descending sections and long horizontal sections, same recommendations are given.

<u>LARGE ORIFICE AIR VALVES</u>

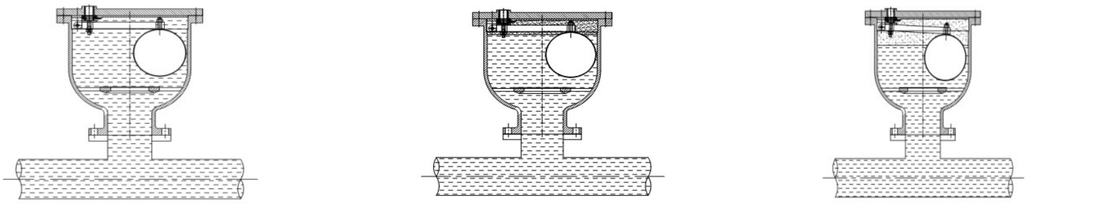
- “A large orifice air valve, when used as an alternative for a one-way surge tank (or discharge tank) should be placed as near as possible to and just downstream from the pump check valve?

- “Depending on the longitudinal profile and the positioning of the shut off valves or non-return valves in the line, a large orifice air valve should be provided to prevent sub-atmospheric pressures in the line when it is drained. **To ensure the flexible and effective operation of the pipe line, shut-off valves are normally provided at intervals of between 1500 and 3000 m (or more).** The result is that the spacing of large orifice air valves is more or less the same due to the requirement that one should be able to drain off any section between shut-off valves.”

- “The results of surge analyses indicate where sub-atmospheric pressures might occur and it is suggested that large orifice air valves should be provided wherever the pressure drops below 6.0 m absolute”.

SMALL ORIFICE AIR VALVES

Small orifice air valves release air while the pipeline is in operation and so the emphasis for the design of such valves is to provide a collection chamber underneath the valve from where the air can be captured temporarily and then released through the air valve.



1. PIPE LINE UNDER HYDRAULIC PRESSURE 2. AIR ACCUMULATING IN CHARGED PIPE LINE 3. HIGH PRESSURE AIR DISLODGES FLOAT AND ESCAPES

The following approach is suggested to determine the position of the small orifice air valve.

- Determine where the air in the pipe line will be transported hydraulically and by working through all sections of the pipe line identify those sections where air is not transported hydraulically.

- Those positions identified are potential locations where a small orifice air valve is required.

- Define the points where the small orifice air valve should be installed by evaluating all the locations identified previously, working downstream.

"If the distance between the small orifice air valves is short (say 250m), it is not necessary to provide a small orifice air valve at all the identified points, provided that the line is effectively filled and that the upstream small orifice air valve effectively releases all the air that reached it".
For effective operation of the small orifice air valve a collector chamber is required to capture the air. It is suggested that the small orifice air valve should be installed on a T-piece, the diameter of which should be at least 50% that of the pipe.

The AWWA MANUAL M51 suggests that air valves should be installed at the following locations:

- **High points.** Valves are needed at high points to provide venting while the pipe is being filled, during normal operation of the pipe line and for air inflow when draining. A high point is defined by the hydraulic gradient and is considered the upper end of any pipe segment that slopes up to the hydraulic gradient or runs parallel to it.

- **Increased down slope**. A double orifice air valve should be considered at abrupt increases in down slope.

- **Decreased upslope**. A large orifice valve (air intake and release) or double orifice air valve should be considered at abrupt decreases in upslope.

- **Long ascents**. A large orifice valve (air intake and release) or double orifice air valve should be considered at intervals of 400 m to 800 m along ascending sections of pipe line

- **Horizontal runs**. A combination air valve should be considered at the beginning and end of long horizontal sections, and a large orifice valve (air release) or double orifice air valve should be considered at 400 m intervals along horizontal sections of pipeline.

- **Venturi meters**. Air release valves should be installed upstream of venturi meters to eliminate measurement inaccuracy caused by trapped air.

- **Pumps**. Air intake/release valves should be installed on the discharge side of deep well and vertical turbine pumps to remove the air in the well column during pump startup and to allow air to re-enter the line after pump shutdown.

- **Siphons**. To maintain a siphon on a section of pipe line that extends above the hydraulic gradient and that constantly runs under negative pressure air release valves at the high point of the siphon to vent the air.

The following locations for air valves are suggested:

- At the top of each rise in gradient
- Where the pipeline rises steeply and then changes gradient so as to rise less steeply, a valve should be installed at the change in grade.
- Where long stretches of pipe exist with no definable high point, valves should be inserted at least every 800 m, especially when the pressure in the main is decreasing and thereby allowing air to come out of solution from the water.

BS 8010-2.5: 1989 CODE OF PRACTICE FOR PIPE LINE

Section 18.3 Air Valves

On long sections of pipeline of even gradient, air valves should be positioned at intervals of approximately 0.5 km, depending on the diameter of the main and the air valve chosen. Air valves may also be required where the gradient of the pipe line changes.

INFORMATION FROM PRACTICAL EXPERIENCE

GENERAL

Information from practical experience suggests that insufficient information was available for design of pipelines to prevent air problems and in some cases the guidance in "accepted" design sources was considered to be flawed. From a designer's view point **some of the most relevant questions are**:

- What are the minimum slopes at which pipes need to be laid to avoid accumulation or air?
- Are these slopes different for downward and for upward slopes?
- Is there a need for pipelines to be laid with an undulating profile?
- In gravity pipe lines is it necessary to ensure that the pipe downstream of a high point is steep enough to give a uniform depth of 2/3 (or less) of the pipe diameter? This is meant to facilitate priming and re-priming and allow air to pass up to an air valve
- Where do air valves need to be provided?

PIPELINE PROFILE

With regard to the pipeline profile, **current design practice manuals** such as Pont de Musson 1994 (from company St. Gobain) **suggest that pipes should be laid at minimum slopes of 1:250 (for downward slope) and 1:500 (for upward slope).** Minimum downward slopes of 1:300 are also used in practice. **The slope of 1:500 has been suggested as the shallowest gradient that can be constructed with no risk of a backfall,** which would otherwise prevent the pipe from draining. It is therefore more of a maintenance requirement than a hydraulic consideration.

HYDRAULIC CONSIDERATIONS

Minimum design flow velocities to ensure air movement are usually taken in the range of 1 to 2 m/s.

The requirement for a minimum downward slope is linked with the need to prevent pipes flowing more than 2/3 full during priming or re-priming to allow air to pass upstream to an open air valve. Some designers have quoted half full pipe as the condition to achieve the above.

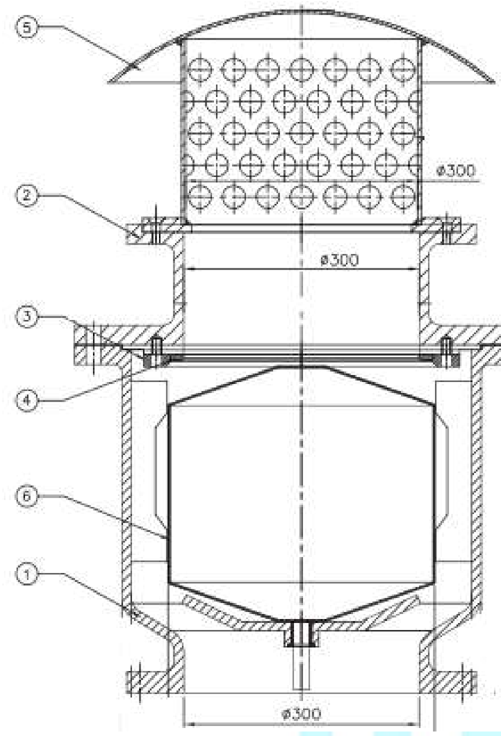
DISTANCE BETWEEN AIR VALVES

Minimum distance between 500 m and 800 m are generally used to site air valves. Different air valve manufacturers offer their own recommendations but they are generally within this range.

LOCATION OF AIR VALVES

Some practitioners locate air valves exactly at the high points but there is some awareness that the air can collect slightly downstream of this point, thus rendering the valve ineffective. Recommendations from some air valve manufacturers indicate that it **is advantageous to position air valves a few metres below apex points formed by the intersection of the pipeline with the hydraulic gradient line.**

OUR CONTRIBUTION TO THE SOLUTION



Sr.No.	COMPONENT	MATERIAL
1	BODY	CAST IRON IS 210 GR. FG 200
2	TOP COVER	CAST IRON IS 210 GR. FG 200
3	SEAL RETAINER	S.S. AISI 304
4	SEAL	BUNA N/EPDM
5	COWL	M.S.
6	FLOAT	STAINLESS STEEL ASTM A 240
7	FASTENERS (NOT SHOWN)	S.S. AISI 304

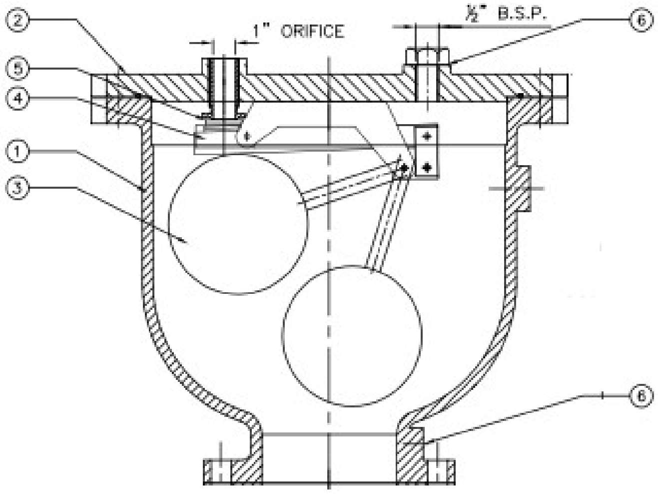
NOTE:

1) ALL DIMENSIONS ARE IN mm
2) VALVE FLANGES SHALL BE FACED & DRILLED AS PER IS:1538 TABLE 4 & 6

VALVE SIZE	FLANGE O.D.	P.C.D.	No. OF HOLES	HOLE DIA.
300ø	445	400	12	23

3) HYDROSTATIC TEST (CLOSED END METHOD)
BODY : 9 Kg/sq.cm. FOR 5 min.
SEAT : 6 Kg/sq.cm. FOR 2 min.
4) PAINTING : LIQUID EPOXY PRIMER FOLLOWED BY LIQUID EPOXY PAINT (SHADE : RAL 5005 BLUE)
Min. DFT 250 Micron m.
5) VALVE GENERALLY AS PER AWWA C 512
6) PRESSURE RATING : PN 0.6
7) QUANTITY : 18 Nos.

AIR VACUUM VALVES
(300 dia.)



Sr.No.	COMPONENT	MATERIAL
1	BODY	CAST IRON IS 210 GR. FG 200
2	TOP COVER	CAST IRON IS 210 GR. FG 200
3	FLOAT	STAINLESS STEEL ASTM A 240
4	INTERNAL LINKAGES ARRAGEMENT	STAINLESS STEEL
5	SEAL	BUNA N/EPDM
6	DRAIN PLUG	Std.

NOTE:

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VALVE SIZE	FLANGE O.D.	P.C.D.	No. OF HOLES	HOLE DIA.
150ø	285	240	08	23

3) HYDROSTATIC TEST (CLOSED END METHOD)
   BODY : 9 Kg/sq.cm. FOR 5 min.
   SEAT : 6 Kg/sq.cm. FOR 2 min.
   ISV SHALL BE HYDROSTATICALLY TESTED FOR
   BODY : 9 Kg/sq.cm. FOR 5 min
   SEAT : 6 Kg/sq.cm. FOR 2 min.
4) PAINTING : LIQUID EPOXY PRIMER FOLLOWED BY LIQUID EPOXY PAINT (SHADE : RAL 5005 BLUE) Min. DFT 250 Micron m.
5) AIR VALVE GENERALLY AS PER AWWA C 512

AIR RELEASE VALVE (150 dia.)