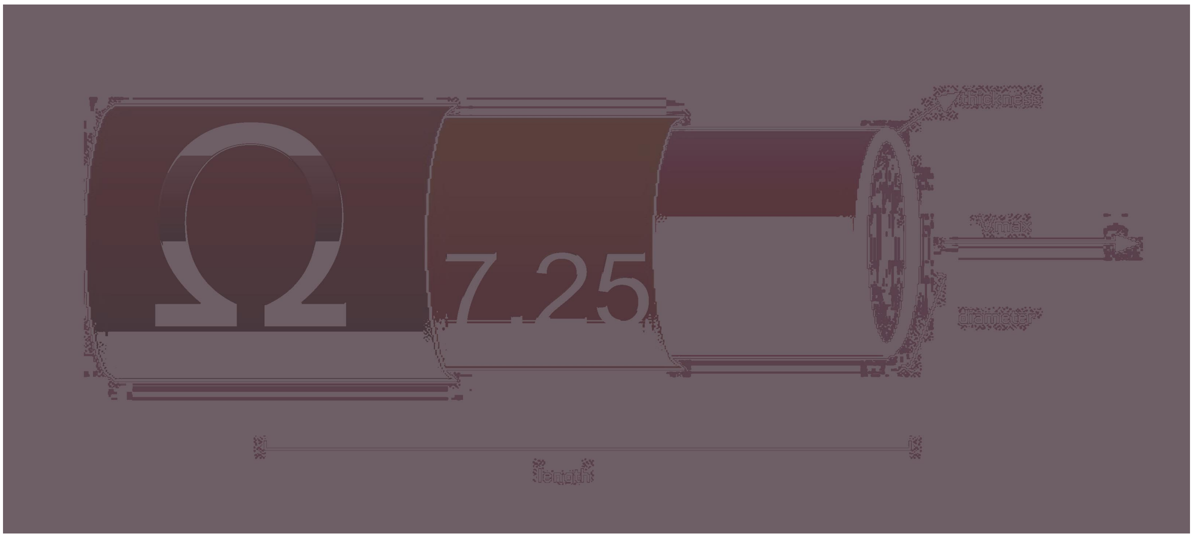

7.25

Composer / researcher

Dimitri Voudouris

Composed

[2012 – 2014]

Composition

Ω 725.3

Section	Sub-section	Day	length in [meters] [46mm] diameter	length in [meters] [30mm] diameter	length in [meters] [10mm] diameter	length in [meters] [7mm] diameter
1	1.1	1	0.6 – 0.82			
	1.2	2	7.5 – 8.9			
	1.3	2	30.45 – 36			
	1.4	4	28.05 – 31.04			
	1.5	1	46 – 50.85			
	1.6	10	48.42 – 56			
	1.7	2	56.74 – 59.10			
	1.8	5	58.8 – 65.06			
	1.9	11	62.03 – 63.87			
	1.1	10	66.17 – 72.32			
	1.11	3	68.76 – 74.55			
	1.12	10	76.4 – 77			
	1.13	6	74.56 – 77.8			
2	2.1	12			5.5 – 9.5	
	2.2	12			4.74 – 12.6	
	2.3	15			40.45 – 58.3	
	2.4	15			38.2 – 42.65	
	2.5	13			62.83 – 74.24	
	2.6	13			56.85 – 65.33	
	2.7	13			72.36 – 75.62	
3	3.1	5		98 – 134		
	3.2	7		274 – 296.36		
	3.3	7		389.4 – 414.25		
	3.4	4		65.3 – 77.01		
	3.5	4		145.03 – 266.67		
4	4.1	13			44.23 – 54.36	
	4.2	12			35.64 – 41.01	
	4.3	13			46.39 – 72.11	
5	5.1	12			13.33 - 17.54	
	5.2	12			16.44 – 19.09	
	5.3	13			22.01 – 22.46	
	5.4	12			38.72 – 47.60	
	5.5	13			56.94 – 57.33	
6	6.1	17				13.61 – 23.67
	6.2	17				45.23 – 72.33

Sound analysis: Pipe corrosion affecting liquid volumetric flow rate

Duration: **38 min 40 sec**

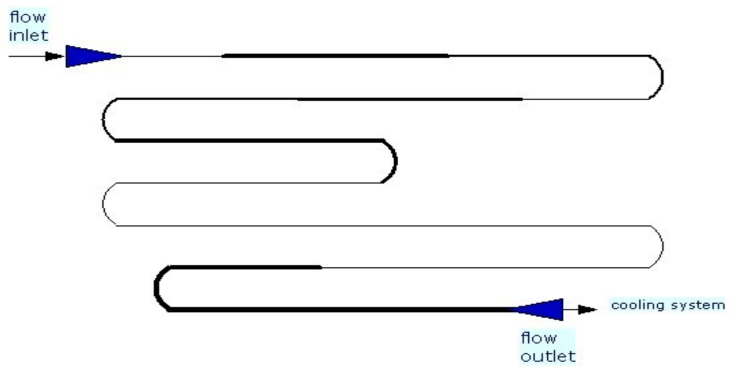
Index **Page**

Hydrophonics

Hydro – *Greek hydor* – meaning - liquid, Phonics – *Greek phon(e)-* meaning – sound, is a series of compositions that relate to conditions affecting liquid flow in an enclosed transport system. A series of sine waves are applied to each composition, through precise calculations of volumetric flow rate.

Kinematic behaviour of water in galvanized pipe system

Ageing acts to increase pipe surface roughness in most piping systems. This in turn increases flow resistance. Factors such as rust, rot, corrode, tuberculate, or support biological growth that adheres to deposits. Where low velocities are predominate sediment and deposits adhere to the walls of the piping.
An industrial water pipeline supplying a cooling system was inspected and tested prior to replacement of the aged [galvanized iron] piping to [Poly (vinyl chloride) referred to as PVC] piping. The volumetric flow of water in the existing [galvanized iron] piping was tested, a non-consistent flow rate through 725.3 meters of pipeline was present. Various other tests were conducted [every 0.5m of pipe line, r*epeating these tests on a daily bases* produced various results] namely pressure, velocity, and flow rate variations. To inspect these results a Sidemen's clamp [SITRANS FUP1010 Water Check Metering Kit] was used. A number of calculations were performed and the results were graphically plotted to determine these variations that offer resistance to the constant flow rate due to corrosion.



Pipes					
7mm		6m	30m	44m	
10mm		20m	35.2m	25m	
30mm		100m	300m	20m	15m
46mm		100m	10.1m	20m	

Pipe outlay covering area of 725.3 meters, water flowing at 15.6ºC

fig 1

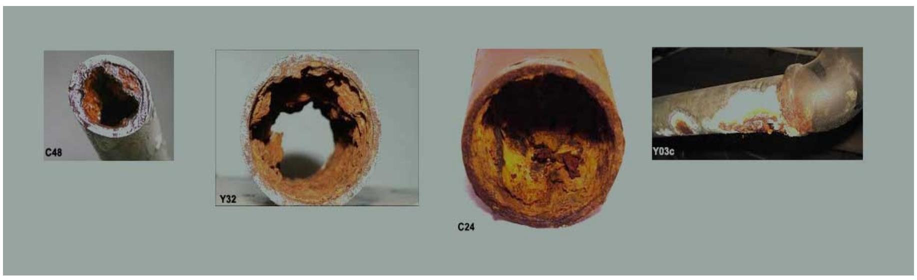


fig 2 : Images of corroded pipeline

Calculations used and mechanics of fluid flow (water)

Corrosion normally will limit pipe velocity. Corrosive lines should have lower velocity than the non-corrosive counterpart.

substance	density	volume expansivity	Kinematic viscosity	surface tension	bulk modulus
	ρ(kgm ^ -3)	*B(10^ -5 deg-1)*	*η(1.13 ^ -5kgm^ -1s^ -1)* @ 15.6°C	*S(10^ -3Nm^ -1)*	*K(Pa)*
Water	1000	20	100	73	0.22x10^10

properties of water near room temperature

fig 3

Density:

The density (kgm ^ -3) of fluid is described as a mass to volume ratio wereas pressure (mmHg) of a fluid is described as magnitude of normal forces on surface to the surface area. P=Fs/A, **P** - pressure, hydraulic models can be used to identify where, when and how negative pressures may occur. The composition from the experiment – **Ω** **725.3** focuses on situations where there are rough pipes (e.g. corroding iron pipes or pipes with a build-up of sediment). **A** - surface area. **Fs** - magnitude of normal forces on surface.

Viscocity:

The viscosity of a fluid is its resistance to shear or flow, and is a measure of the fluids adhesive/cohesive or frictional properties. The viscosity will arise due to internal molecular friction within a fluid producing the frictional drag effect. In pure liquids like water we can refer to Poiseuille equation **L** - length of tube , **p1-p2** - pressure difference, **a** - internal radius, **η** – viscosity

$$rate\ of\ flow = \frac{\pi a^4}{8\eta}\frac{p_1 - p_2}{L}$$

Surface Tention:

One of the most important properties of a liquid is the tendecy for its surface to contract. The tension in the surface of a liquid is dependent of the area thus called surface tensionand is defined as the force per unit length acting across any line drawn in the surface and tending to pull the surface apart across the line. The surface tension S of a liquid can be regarded as the potential energy per unit are of the surface (this tension arises because molecules are closer together near the surface than deeper in the liquid).

Volumetric / Weight / Mass flow rates:

The flow rate equals the cross sectional area of the pipe it flows in times the velocity of the fluid. If the pipe radius decreases velocity of the fluid increases similarly if the pipe radius increases velocity of the fluid decreases.

Volumetric flow rate Q *flow rate (m^3s)* ***D*** *is the pipe diameter, and* ***V*** *is the average velocity.*

$$Q = \frac{\Pi}{4} D^2 V$$

Weight flow rate (W) = *weight of fluid flowing past a section* per unit time

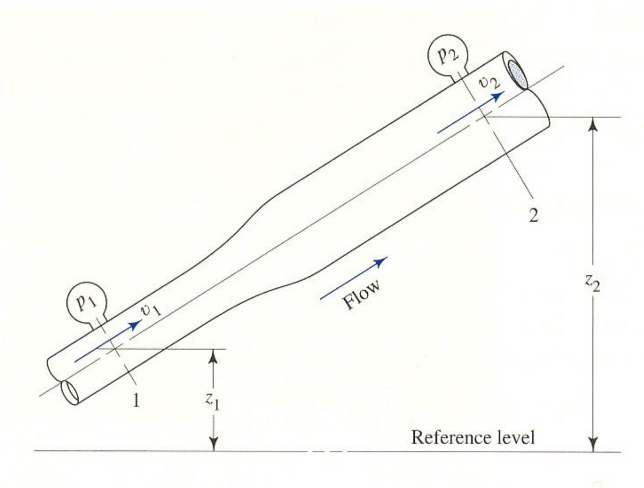
W = Q*γ

where Q is the flow rate and γ is the specific weight (m^3/s * N/ m^3 = N/s)

Mass of flow rate (M) = *mass of fluid flowing past a section per unit time*

M = Q*ρ

*where Q is the flow rate, and ρ is the density (= kg/ m^3 * m^3/s = kg/s),*



in ***fig 4*** *above M1 mass of fluid in section 1 = M2 mass of fluid in section 2*

Reynolds number:

Reynolds Number: where **ρ** is the density of the fluid, **μ** is its dynamic viscosity, and v=μρ is the kinematic viscosity

$$R_e = \frac{DV\rho}{\mu} = \frac{DV}{v} = \frac{4Q}{\pi D v} = \frac{4m}{\pi D \mu}$$

The pressure drop ***ΔP*** *is related to the loss in the Engineering Bernoulli Equation, or equivalently, the frictional head loss* ***hf ,*** *through*

$$\Delta P = \rho x loss = \gamma h_f$$

Here, the specific weight **γ=ρg**, where **g** is the magnitude of the acceleration due to gravity.

Power:

The power required to overcome friction is related to the pressure drop through

$$Power = \Delta P Q$$

or we can relate it to the head loss due to pipe friction via $Power = \gamma h_f Q$

Head Loss/Pressure Drop:

Head loss is the measure of the reduction in the total head of the liquid as it moves through a system. The total head is the sum of the elevation head, velocity head and pressure head. Head loss is unavoidable and is present because of the friction between the fluid and the walls of the pipe and is also present between adjacent fluid particles as they flow along the pipe. Head loss is a measure of the reduction in the total head (sum of elevation head, velocity head and pressure head) of the fluid as it moves through a fluid system.

The head loss ***hf*** *is related to the Fanning friction factor* ***f*** *through* $h_f = 2f\left[\frac{L}{D}\right]\left[\frac{V^2}{g}\right]$

or alternatively we can write the pressure drop as

$$\Delta P = 2f\left[\frac{L}{D}\right]\left[\rho V^2\right]$$

Hazen and Williams developed an empirical formula for the flow of water in pipes at (16ºC) The Hazen-Williams formula for water at (16ºC) can be applied to water and other liquids having the same kinematic viscosity of 1.130 centistokes which equals 0.00001211 ft 2/sec or 31.5 SSU (Saybolt Second Universal). The viscosity of water varies with temperature, so some error can occur at temperatures other than (16ºC).

Hazen-Williams - formula for friction (head) loss in ***psi***

$$p_f = \frac{0.0009015L}{D_I^{4.8655}}\left[\frac{100Q}{C}\right]^{1.85}$$

pf = friction (head) loss, psi, ***DI*** = pipe inside diameter, in ***C*** = Hazen-Williams coeffiscient [Friction Factor, dimensionless c = 150-155 for PE , (not related to Darcy-Weisbach friction factor, f)], ***Q*** = flow rate, gpm

Since the Hazen-Williams parameter HW C is the only parameter in the Hazen-Williams formula that relates the fluid and pipe in estimating the water frictional loss, the value varies with pipe roughness (pipe type plus the internal pipe conditions). Due to the corrosion or fouling in the water service over time, the parameter $_{HW}C$ for a given pipe is expected to vary (i. e., decrease) with age. Degradation of $_{HW}C$ can be of the following: Hazen-Williams C Conditions 60 to 75 moderately or severely corrosive water for 15-year old pipe.

Friction Factor:

In laminar flow,

$$f = \frac{16}{R_e}$$

In turbulent flow we can use either the Colebrook or the Zigrang-Sylvester Equation, depending on the problem. Both give equivalent results well within experimental uncertainty. In these equations **ε** , is the average roughness of the interior surface of the pipe.

Colebrook Equation

$$\frac{1}{\sqrt{f}} = -4.0\log_{10}[\frac{\varepsilon/D}{3.7} + \frac{1.26}{R_e\sqrt{f}}]$$

Zigrang-Sylvester Equation

$$\frac{1}{\sqrt{f}} = -4.0\log_{10}[\frac{\varepsilon/D}{3.7} - \frac{5.02}{R_e}\log_{10}\frac{\varepsilon/D}{3.7} + \frac{13}{R_e}]$$

Composition

In the hydrophonic work **Ω** *725.3,* I focused on the kinematic behaviour of water. All calculations and algorithms were generated through Matlab *software*. Inspections of complex waves were done through Fourier acoustic analysis. Modular synthesis was applied and precise translation of variants namely pressure, volumetric flow rate, head loss due to friction were processed into fixed modules with alternating values of pitch, time duration and intensity of the sound.

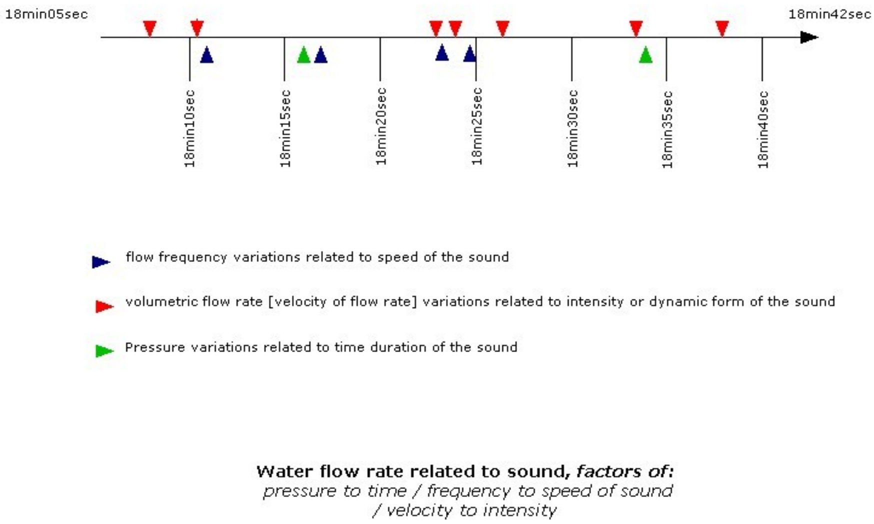
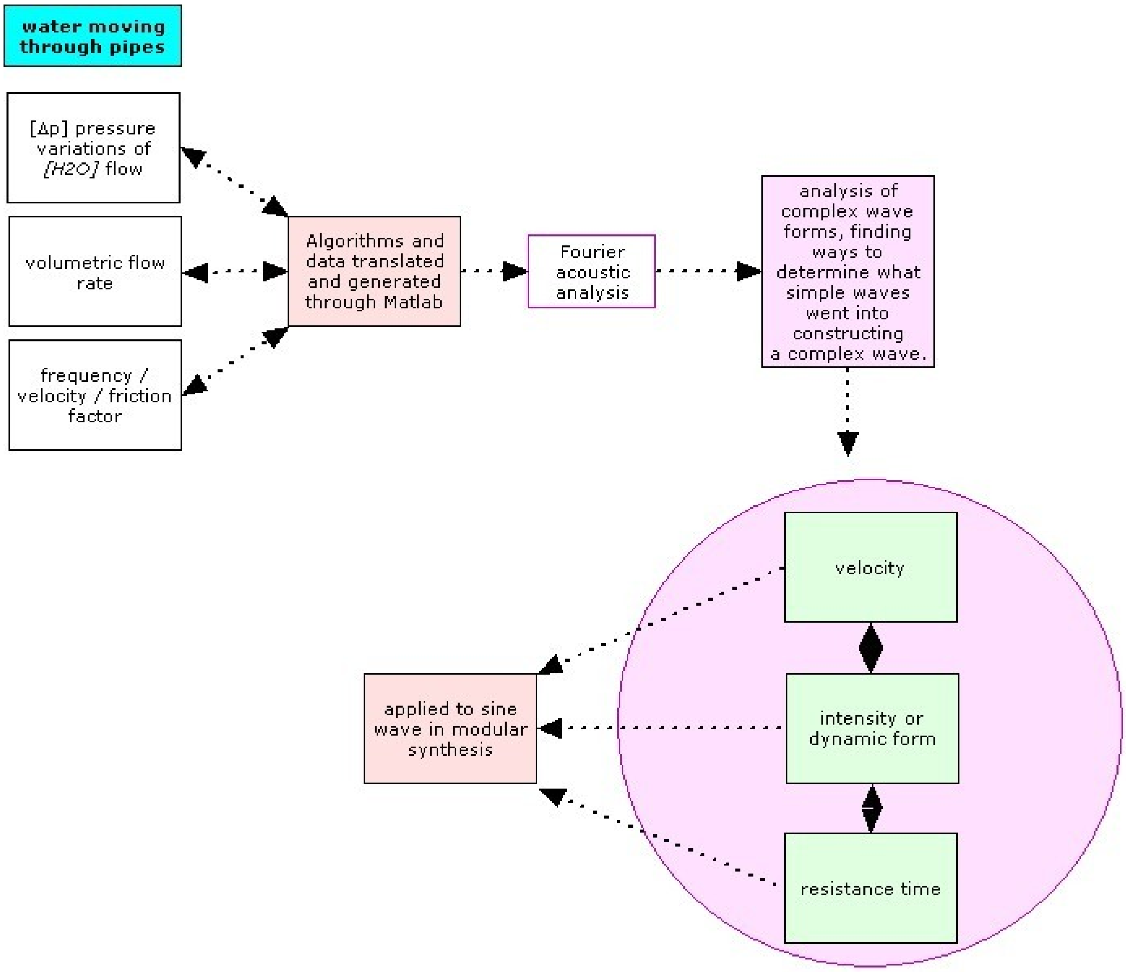


fig 5

- **Flow frequency rate:** In a sound wave, the complementary variable to sound pressure is the acoustic particle velocity . Together they determine the acoustic intensity of the wave. The local instantaneous sound intensity is the product of the sound pressure and the acoustic particle velocity.
- **Pressure variations:** Since a sound wave consists of a repeating pattern of high-pressure and low-pressure regions moving through a medium, it is sometimes referred to as a pressure wave. If a detector used to detect a sound wave, it would detect fluctuations in pressure as the sound wave impinges upon the detecting device. At one instant in time, the detector would detect a high pressure; this would correspond to the arrival of compression at the detector site. At the next instant in time, the detector might detect normal pressure. And then finally a low pressure would be detected, corresponding to the arrival of a rarefaction at the detector site. The fluctuations in pressure as detected by the detector occur at periodic and regular time intervals. In fact, a graph of pressure versus time would appear as a sine curve. The peak points of the sine curve correspond to compressions; the low points correspond to rarefactions; and the "zero points" correspond to the pressure that the air would have if there were no disturbance moving through it. The representation of sound by a sine wave is merely an attempt to illustrate the sinusoidal nature of the pressure-time fluctuations.
- **Flow velocity:** an ultrasonic flow meter is a type of flow meter that measures the velocity of a fluid with ultrasound to volume flow.



Composition of Ω725.3

fig 6

Examples: In relation to sound / pressure,volumetric flow rate, water head loss including friction and velocity variations.

Pressure to Time:

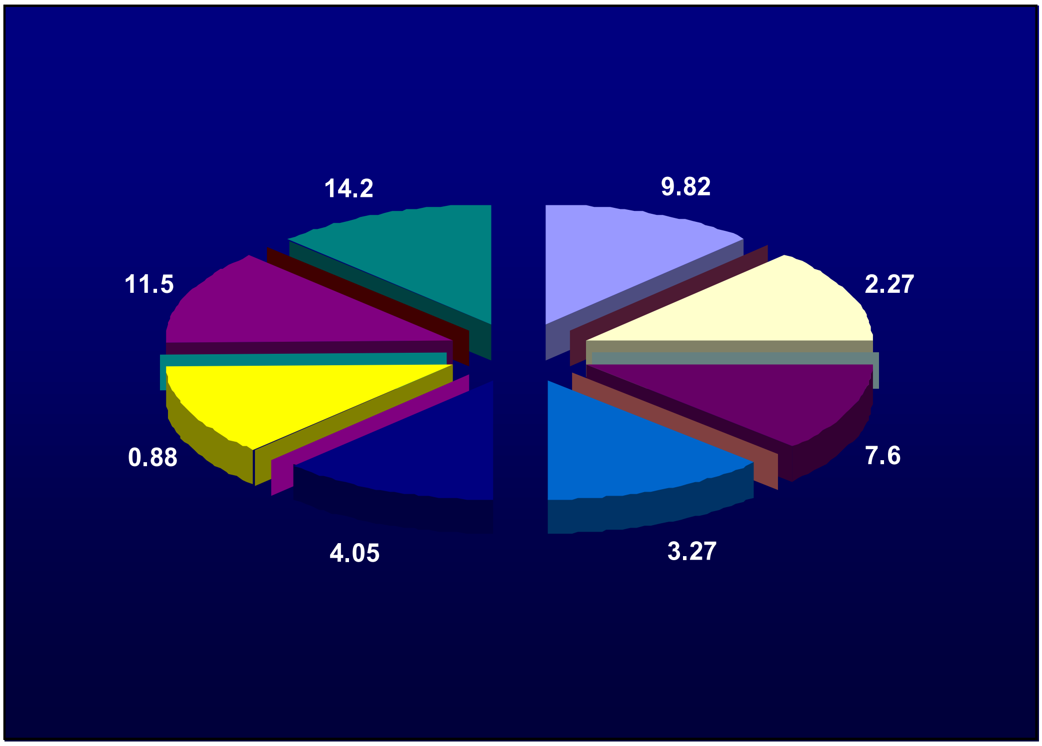


fig 7 - Pressure variations (psi) in a corroded pipe [6 metre length of (20mm diameter)]

Volumetric flow rate to intesity and dynamics of sound:

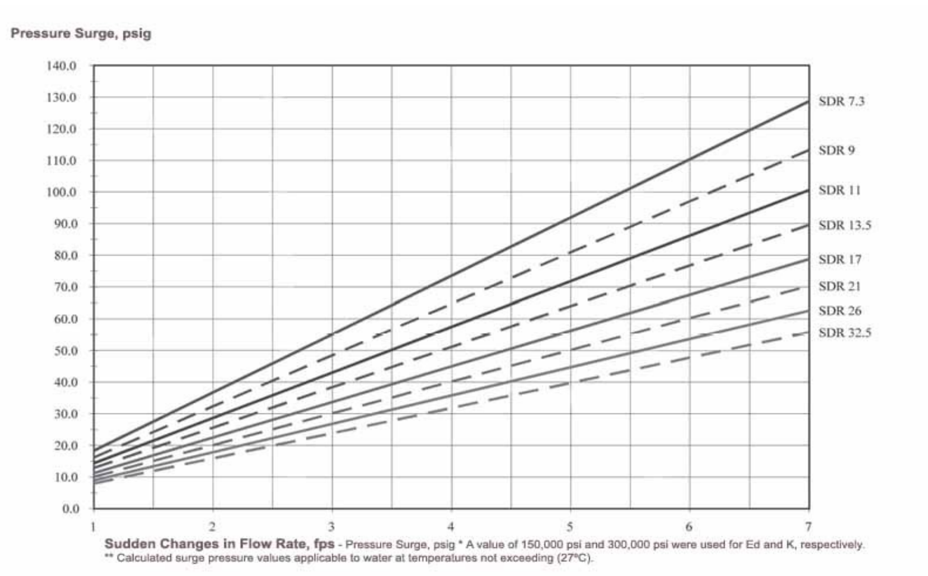


fig 8

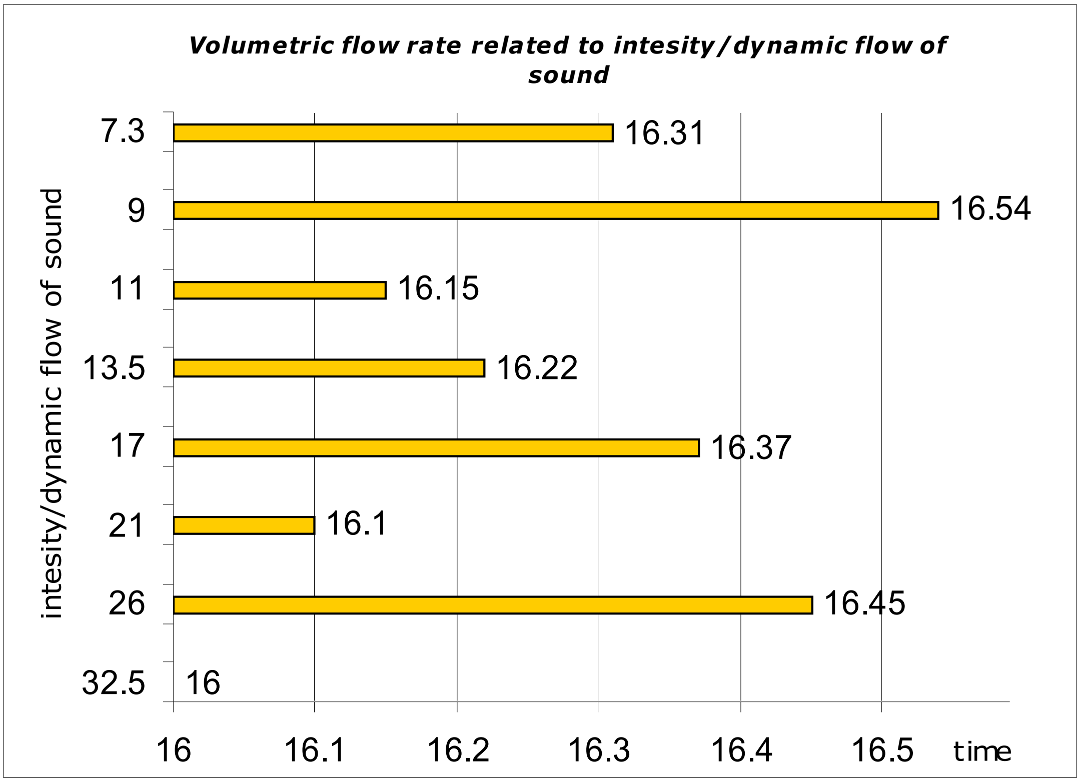


fig 9

The results obtained from volumetric flow rate (fig 8) are directly related to dynamic flow of sound / sound intensity (***I***) db is defined as the sound power P_{ac} (watt) per unit area *A* ***(m²).***

Water head loss, velocity, friction factor:

Diameter [mm]	Length [m]	Flow rate [l/s]	Velocity [m/s]	Design coeffiscient	AHL [kPa]
30	100	5.3	7.5	120	2375.8
	100	5.8	8.2	120	2807.5
	100	4.3	6.1	120	1613
	100	. 7	9.9	120	3977.1
	100	5.7	8.1	120	2718.5
	100	3.6	5.1	120	1160.7
	100	6.2	8.8	120	3176.6
	100	5.19	7.3	120	2285.3
	100	5.88	8.3	120	2879.6
	100	4.72	6.7	120	1916.9

fig 10 - ***AHL****: Actual Head Loss in [kPa] : 100m length and 30mm diameter pipe – Calculated using the Hazen-Williams equation [Kinematic behaviour of water in corroded galvanized iron pipe, showing water headloss ,an increase and reduction in flow rate and fluid velocity]*

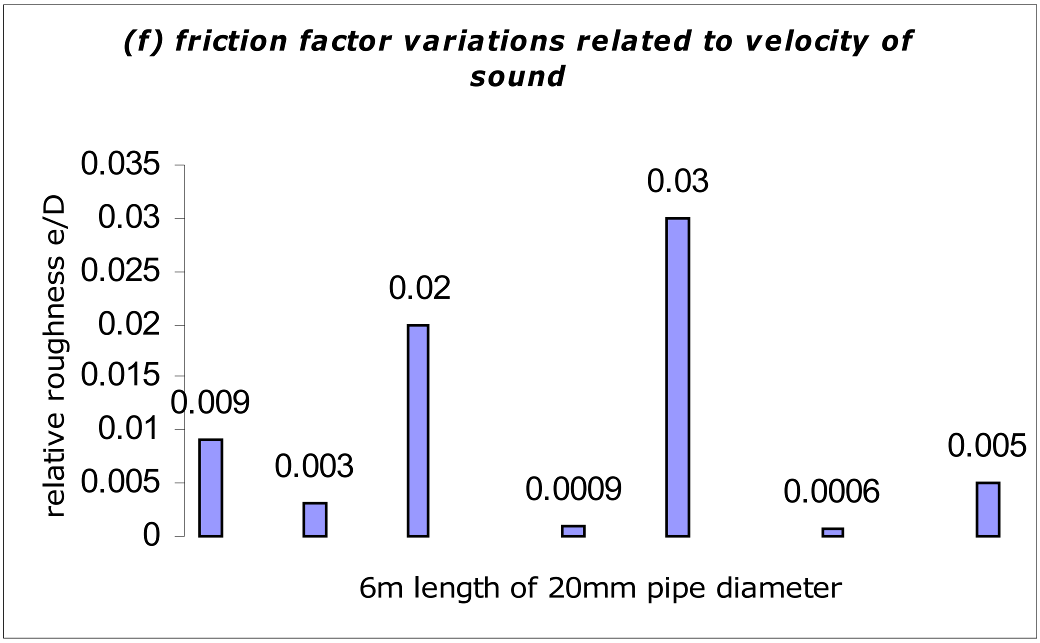


fig 11

Live Performance:

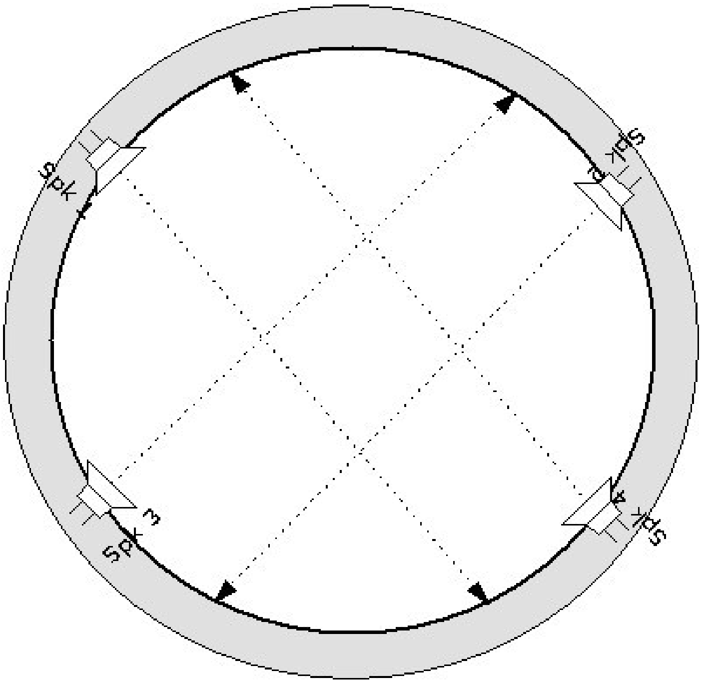


***fig 12 -** Speaker spatialisation in pipeline*

*in **fig 13** -*

- *4 Active audio speaker monitors.*
- *1 Sub-woofer*
- *1 Mixer*
- *1 Computer*
- *1 Sound projectionist*

****

- The sound is to be played at a high volume - [loud].
- The four speakers [Active audio Speaker Monitors] are to be positioned in this order:

[Spk 1 - left and Spk 2 - right channels] similarly [Spk 4 - left + Spk 3 - right channels].

****

- All the lights to be switched off during the performance [*total darkness*]

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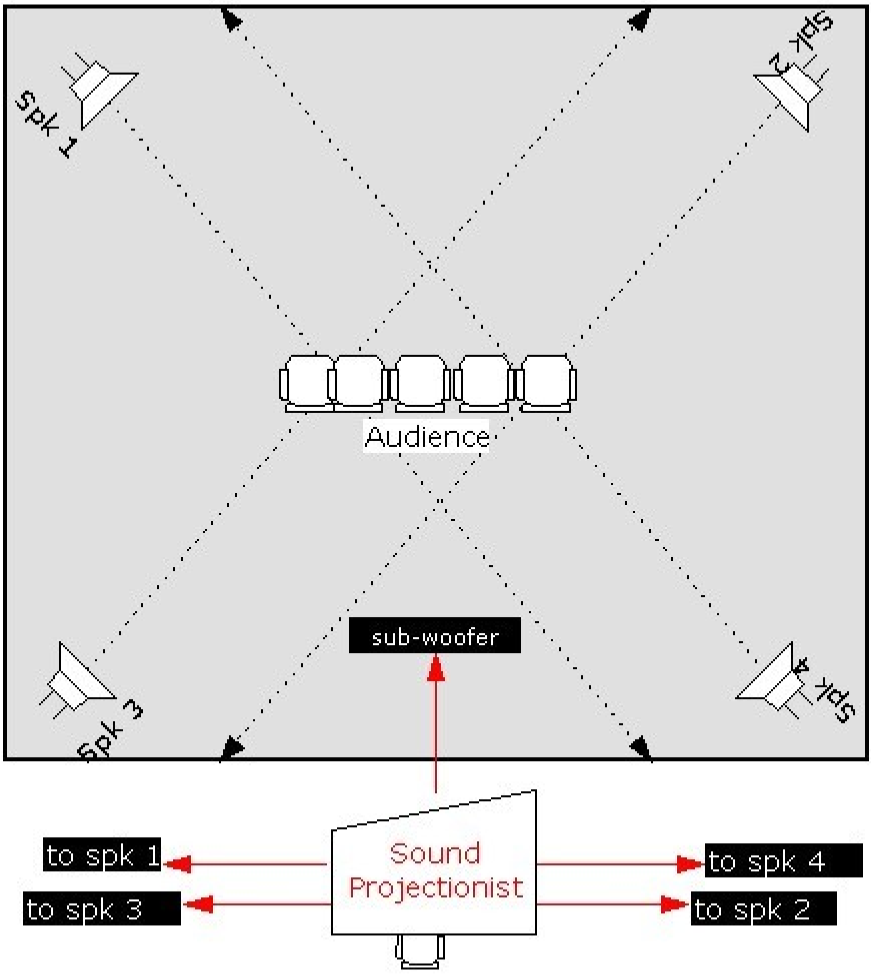

Speaker positioning in acoustic space

fig 13

References:

1. "Flow of Fluids through Valves, Fittings, and Pipes", Technical Paper No. 410, Crane Co.,New York, 1985
2. Hooper, W. B., "Two-K Method Predicts Head Losses in Pipe Fittings", *Chem. Engineering*, p.96, Aug. 24, 1981.
3. “Piping Handbook”, Nayyar, Mohinder L., Editor in Chief, Sixth Ed., McGraw-Hill, Inc., New *York 1982.*
4. F.M. White, Fluid Mechanics, 7th Edition, McGraw-Hill, New York, 2011.