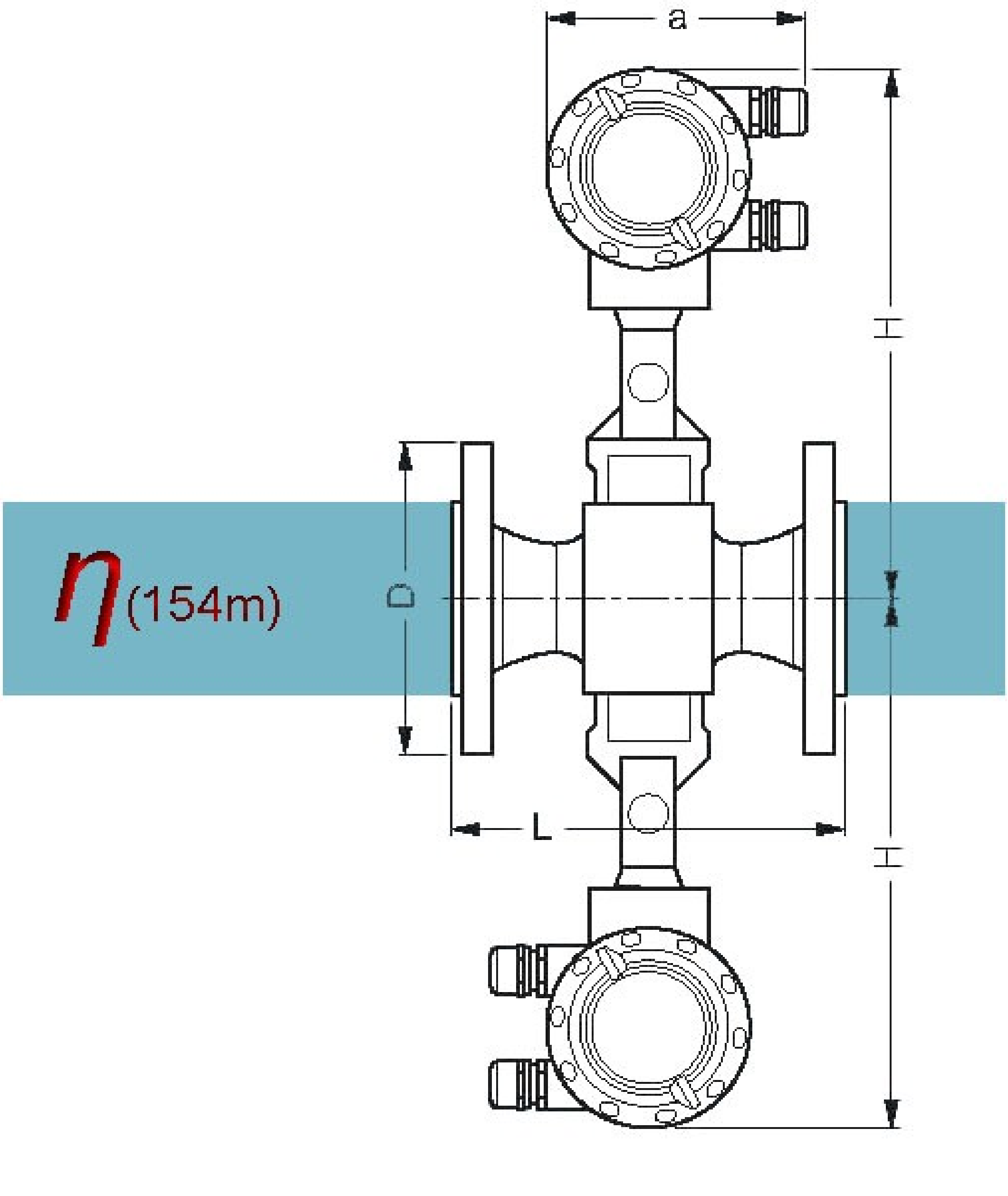

a
H
H
D
L
η(154m)

Composer / researcher

Dimitri Voudouris

Composed

2013 - 2016

Composition

η *(154m)*

Block: (1-13)

Duration

56 min 36 sec

Index	Page

Flow mechanics:

When fluids flow they have a certain amount of internal friction called viscosity. It is essentially a friction force between different layers of fluid as they move past one another. In liquids the viscosity is due to the cohesive forces between the molecules due to adhesive, cohesive and frictional forces a velocity gradient exists, the magnitude of this gradient (how fast the speed changes with distance) is characteristic of the fluid. In trying to find out what factors control how fast fluids can flow through pipes, the following factors are isolated: (a)The pressure difference between the ends of the pipe. The bigger the pressure difference, the faster will be the flow. (b)The length of the pipe more liquid will flow through a shorter than a longer pipe in the same time. (c) The radius of the pipe more liquid will flow through a wide than a narrow pipe in the same time.

Friction Coefficient - Calculates the pressure drop in a pipe. It is defined as follows. Cf = Wall shear stress / Dynamic Pressure (Dynamic Pressure - Consider a fluid flowing with mean velocity um. if the kinetic energy of the fluid is converted into flow or fluid energy, the pressure would increase. The pressure rise due to this conversion is called the dynamic pressure. Wall Shear Stress (τ) - The wall shear stress is the shear stress in the layer of fluid next to the wall of the pipe.
The friction head is some function of um such that hf = φumn. Clearly for laminar flow, n =1 but for turbulent flow n is between 1 and 2 and its precise value depends upon the roughness of the pipe surface. Surface roughness promotes turbulence. ***Relative surface roughness*** *is defined as ε = k/D where* *k* *is the mean surface roughness and* *D* *the bore diameter, turbulence occurs at a lower Reynolds number for rough pipes.*

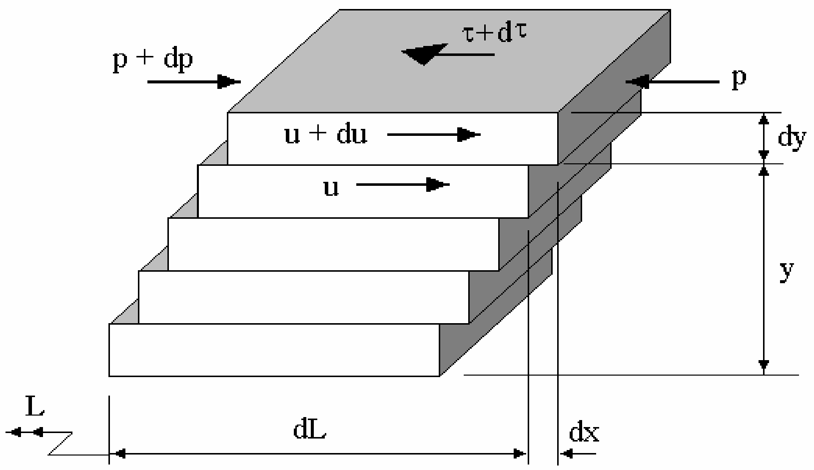


Fig:0.5 *Fluid flowing over a flat surface in laminated layers from left to right as shown*

y *is the distance above the solid surface,* ***L*** *is an arbitrary distance from a point upstream,* ***dy*** *is the thickness of each layer,* ***dL*** *is the length of the layer,* ***dx*** *is the distance moved by each layer relative to the one below in a corresponding time* ***dt***, ***u*** *is the velocity of any layer,* ***du*** *is the increase in velocity between two adjacent layers. Each layer moves a distance* ***dx*** *in time* ***dt*** *relative to the layer below it. The ratio* ***dx/dt*** *must be the change in velocity between layers so* ***du = dx/dt***.

Laminar flow (Newtonian fluids) **-** A *stream line* is an imaginary line with no flow normal to it, only along it. When the flow is laminar, the streamlines are parallel and for flow between two parallel surfaces we may consider the flow as made up of parallel laminar layers. In a pipe these laminar layers are cylindrical and may be called *stream tubes*. In laminar flow, no mixing occurs between adjacent layers and it occurs at low average velocities.

Turbulent flow (Non-Newtonian fluids) – They do not obey Poiseuille's law because their viscosities are velocity dependent . If turbulence does occur in the flow then the volume flow rate is dramatically reduced. A pipe with uneven or rough surface areas, promotes various degrees of turbulence because the wall shear stress is the shear stress in the layer of fluid next to the wall of the pipe.

Examining fluid flow through a circular pipe:

A water pipe is used to cool down certain pharmaceutical processes, variations of temperature and irregular volumetric flow rate in the cooling process. The pipe was inspected to determine whether there are signs of corrosion constraints leading to - head loss complications, variations in - (v) volumetric flow rate, ($\Delta\rho$) , (η) viscosity affecting kinematic viscosity and (τ) wall surface roughness. SiTRANS FX 300 sandwich pressure sensor with isolation valve was used to determine the variations in flow rate through the system.

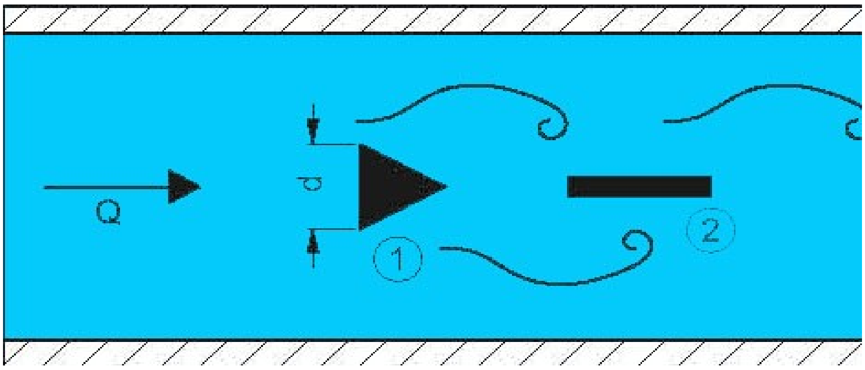


Fig : 1

The flow meter calculates the flow velocity using the following equation: Q = A.V = A.d / St.f = 101,93 . f / K [m³/h]

Q = flow rate [m³/h], **f** = vortex shedding frequency [Hz], **K** = calibration constant [pulses/m³], **d** = width of the bluff body [m], **St** = Strouhal Number, **A** = cross-section area [m²], **V** = flow velocity [m/s]

Requirements:

In order to generate the vortex streets, the medium must have a minimum velocity: For liquids the flow velocity must be 0.4 to 10 m/s (1.3 to 32.8 ft/s)

Design:

• **Vortex flow meter with pressure sensor and isolation valve** - Allowing the pressure sensor to be shut off for the purpose of pressure or leak testing of the pipeline or for being exchanged without interrupting the process. Using the built-in two-way valve, the pressure sensor can also be calibrated and tested at a later time.

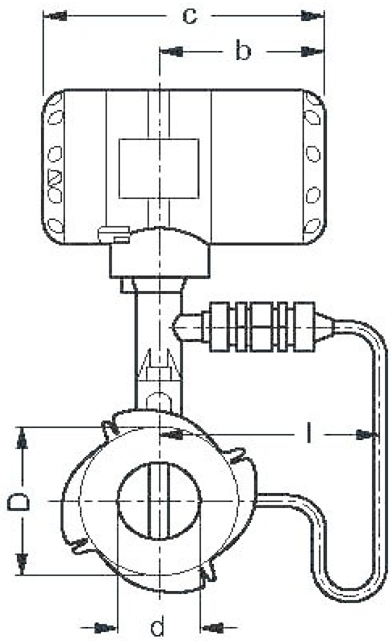


Fig : 2 *Sandwich version with pressure sensor, side view, b = 105 mm , c = 179 mm*

Operating Principle:

Flow tables

Measuring Range Limits

Water

Size DN to EN 1092-1	DN to ASME B16.5	Q_{min} EN 1092-1 [m³/h]	Q_{max} EN 1092-1 [m³/h]	Q_{min} ASME B16.5 [m³/h]	Q_{max} ASME B16.5 [m³/h]
15	½"	0.45	5.07	0.44	4.94
25	1"	0.81	11.40	0.81	11.40
40	1½"	2.04	28.58	2.04	28.58
50	2"	3.53	49.48	3.53	49.48
80	3"	7.74	108.37	7.74	108.37
100	4"	13.30	186.22	13.30	186.21
150	6"	30.13	421.86	30.13	421.86
200	8"	56.60	792.42	56.60	792.42
250	10"	90.48	1 266.8	90.48	1 266.8
300	12"	131.41	1 839.8	131.41	1 839.8

Values based on water at 20 °C (68 °F)

SITRANS F X vortex flow meters measure flow rate by detecting the frequency at which alternating vortices are shed from a bluff body inserted into the flow stream. This principle of measurement is known as Von Karman’s vortex street principle: alternating vortices form behind an object in a stream. The frequency of the alternating vortices is proportional to the flow rate. The passage of a vortex causes a slight stress on a pick-up placed downstream of the bluff body. The stress is picked up and counted as pressure surges by a dual Piezo crystal placed inside the wing.

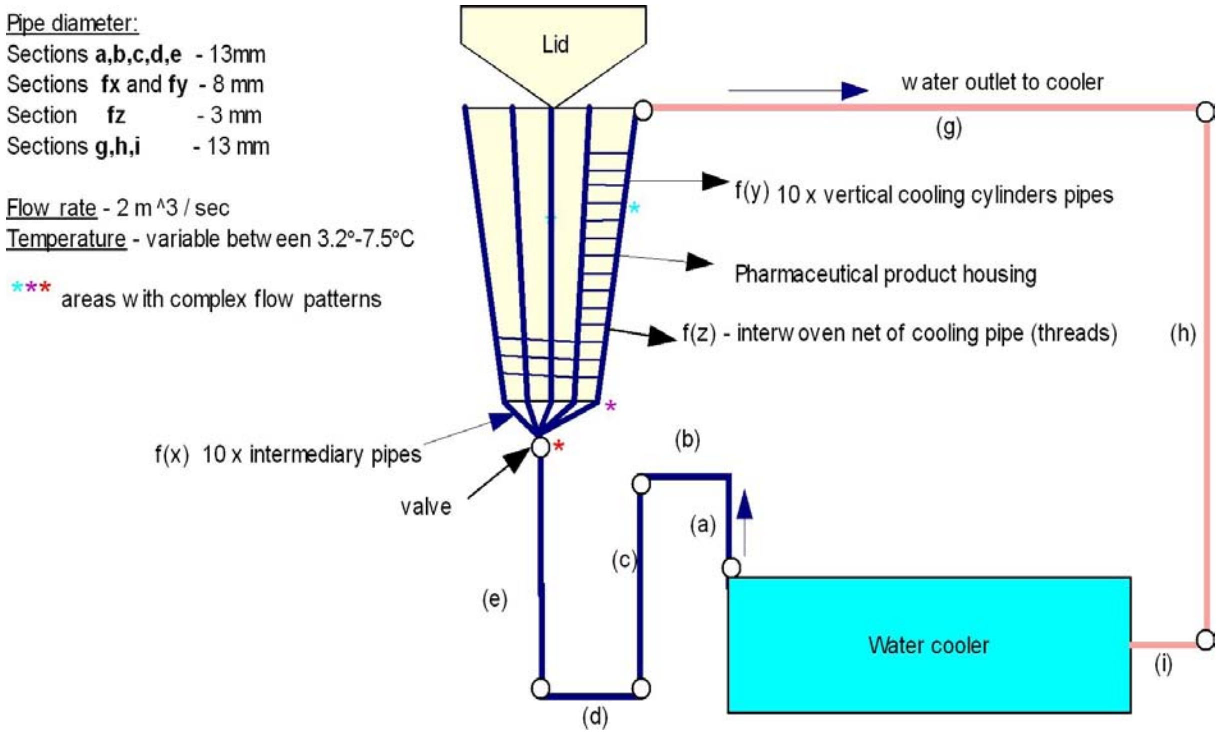


Fig : 3 **- Diagrammatic cross section outlay of cooling system**

Pipe layout diagnostics

Pipes number	Pipe length (m)	Total length	Angles <
Inlet			
f(x) – 10	1.5	15	20º
f(y) – 10	3	30	30º
f(z) threads(2035)	approximation	57	180º
a,b,c,d	1.5	6	90º
e	2.5	5	90º
Outlet			
g	13	13	110º
h	28	22	90º
I	6	6	90º

Fig : 4 - **Pipe diagnostics : Total length = 154m**

Minor losses is a term used to describe losses that occur in fittings, expansions, contractions, and the like. Fittings commonly used in the industry include bends, tees, elbows, unions, and of course, valves used to control flow [***Fig3*** *:*shows areas of complex flow patterns (***)]. Even though these losses are minor, they can be substantial compared to those for flow through short straight pipe segments. Losses are commonly reported in velocity heads. A velocity head is $(V^2)/2g$, $h_m = K_L V^2/2g$ were K_L is called the loss coefficient.

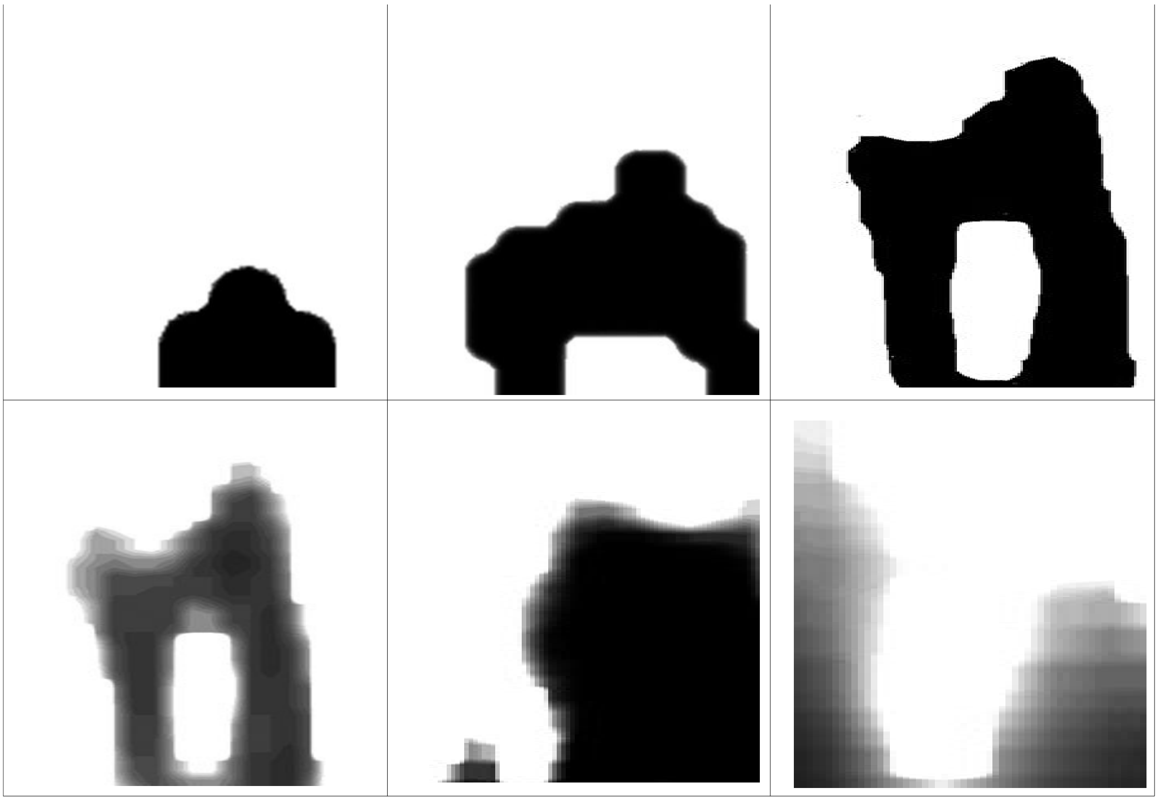
Fig 5 *:* **Pharmaceutical cooling system - Section:** 37C4

Frequency variations traveling through the system are directly dependent on [pressure, density, temperature, viscosity, surface roughness]. An increase in viscosity results in a decrease in pressure and vice-versa, similarly viscosity of a liquid decreases with increasing temperature. Similarly the speed with which a sound wave travels in a medium is determined by the strength of the forces among the molecules. At the macroscopic level these forces are characterized by the *bulk modulus K.* This quantity relates the pressure changes ΔP and the fractional density change $\Delta P/P{:}\Delta P = K(\Delta P/P)$.The velocity of sound (c) is found to depend only on the bulk modulus and the density *(ρ)* of the medium. Using dimensional analysis , one finds that (c) must be proportional to $\sqrt{K}/\rho$. , $c = \sqrt{K}/\rho$. In addition microscopic forces are determined, by calculating alternating - viscosities (η), temperature (t), degrees of corrosion *(surface roughness* (τ)).

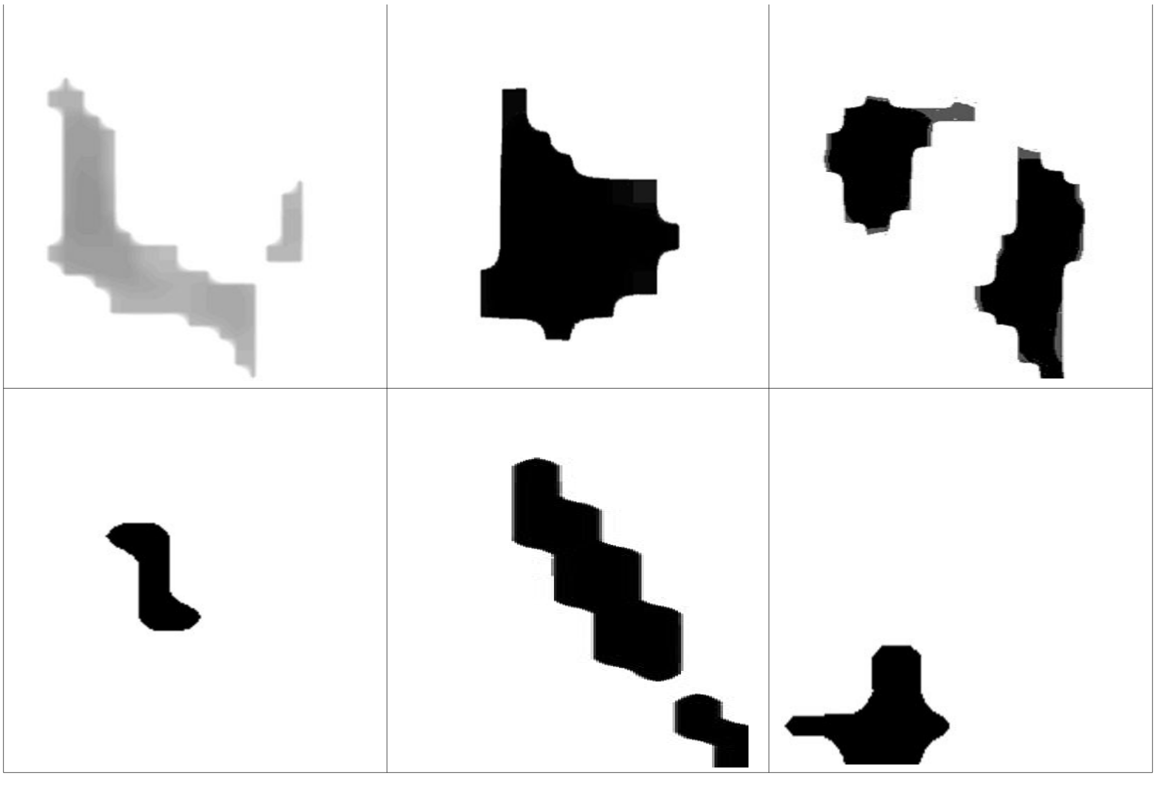
Material	Density (kgm^{-3})	Sound velocity(ms-1)
Water	1000	1480
Iron	7900	5130

Fig : 5 *- Densities and sound velocities (temperature is 20°C)*

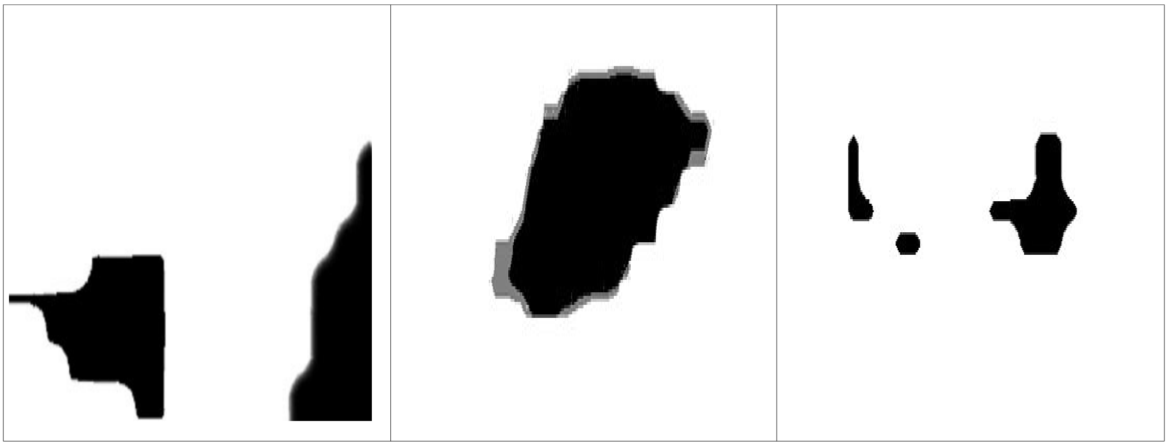
Optical micrograms representing the schematic morphology of corrosion prepared on transverse sections:



Fig;6a1: *Top left to right* **C94,C112,C93a,C80c,A12.1a, A24c -** (*100 x magnification of various shapes of corrosion)*



Fig;6a2: *Top left to right* **B73,A2,G74c,L170c,G74a, G33c -** *(45 x magnification of various shapes of corrosion)*



Fig;6a3: *Top left to right* **HC9,HC4a1,CI94g -** (5*5 x magnification of various shapes of corrosion)*

Surface roughness other than what is provided by the manufacturer on installation, are due to chemical changes induced on the walls of the system overtime causing the wall shear stress (τ) [the shear stress in the layer of fluid next to the wall of the pipe affecting all other layers] to rise . The magnitude of corrosion is directly proportional to escalating or de-escalating pitch of frequency with distinctive variations in turbulence. The Vortex flow meter gave precise calculations of structures and types of corrosion in specified areas e.g. a] Penetrable corrosion, b] Impenetrable corrosion, c] Suspended in fluid i.e. shifting or dislodged corroded particles, such as in ***fig 6a1-6a3.*** (21) out of (452) optical micrograms sketched (above) ranging from simplistic to more complex multi angular shapes producing various degrees of hindrance to flow.

Flow patterns:

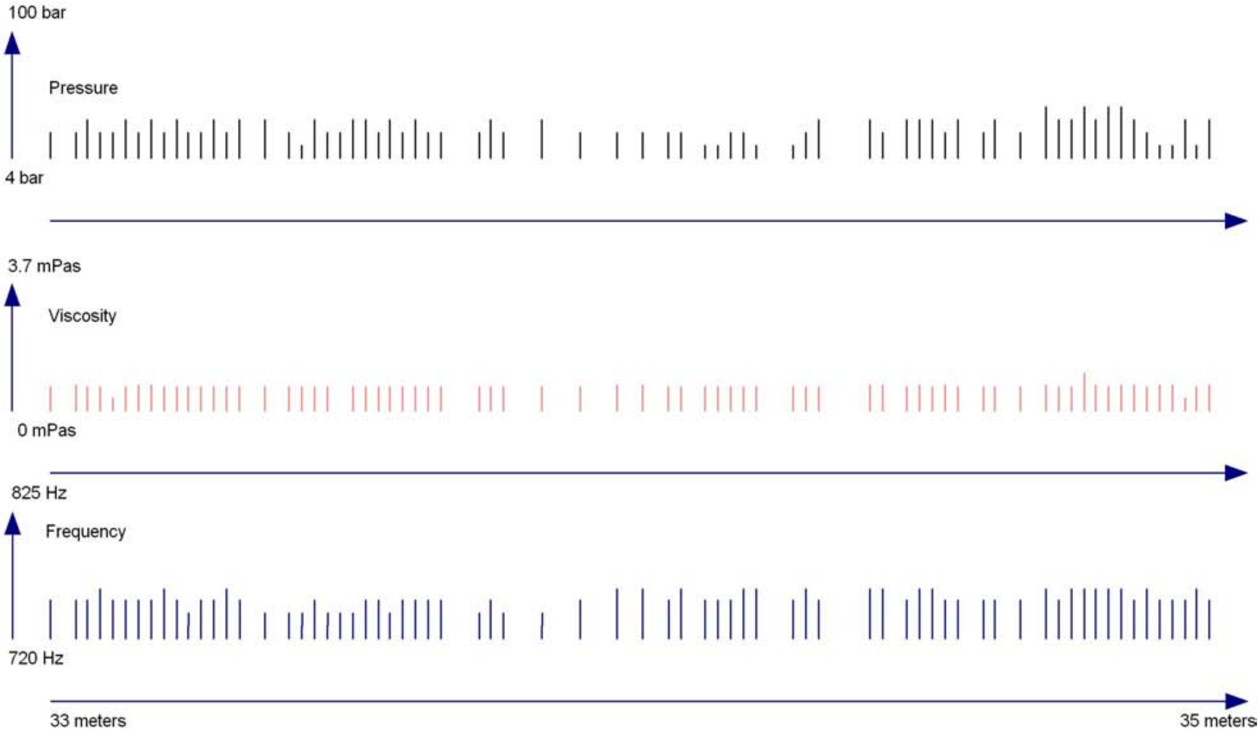


***Fig : 7 -* Graph 7.4: Laminar flow -** *pressure, viscosity, frequency* **graphs at 33.4 -33.42 meter of pipeline**

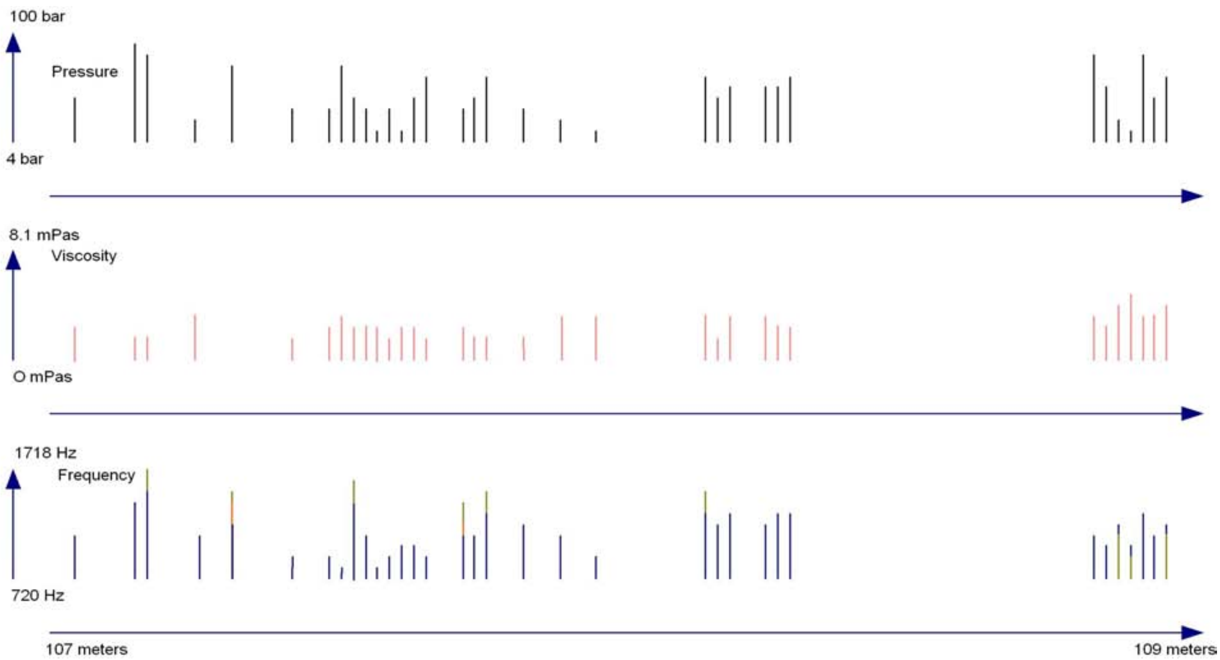


***Fig : 8 -* Graph 15.6: Turbulent flow -** *pressure, viscosity, frequency* **graphs at 107-107.15 meter of pipeline (section showing three overlapping frequencies)**

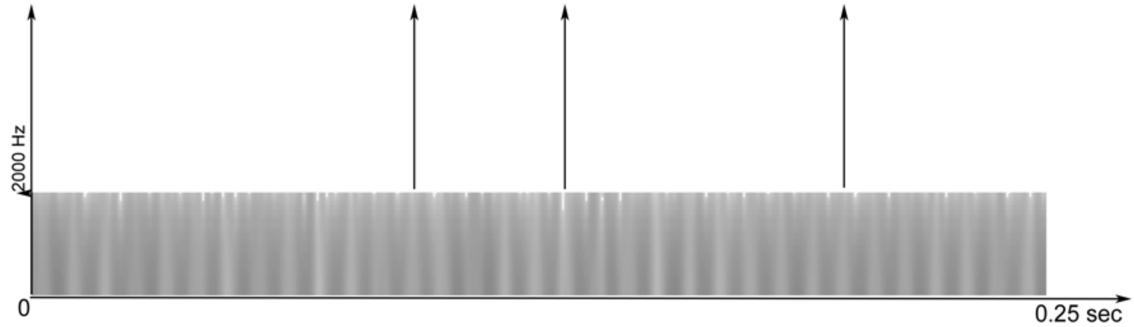


Fig :9 - *primary flow (frequency / time), analysed in - Fig 7,8*

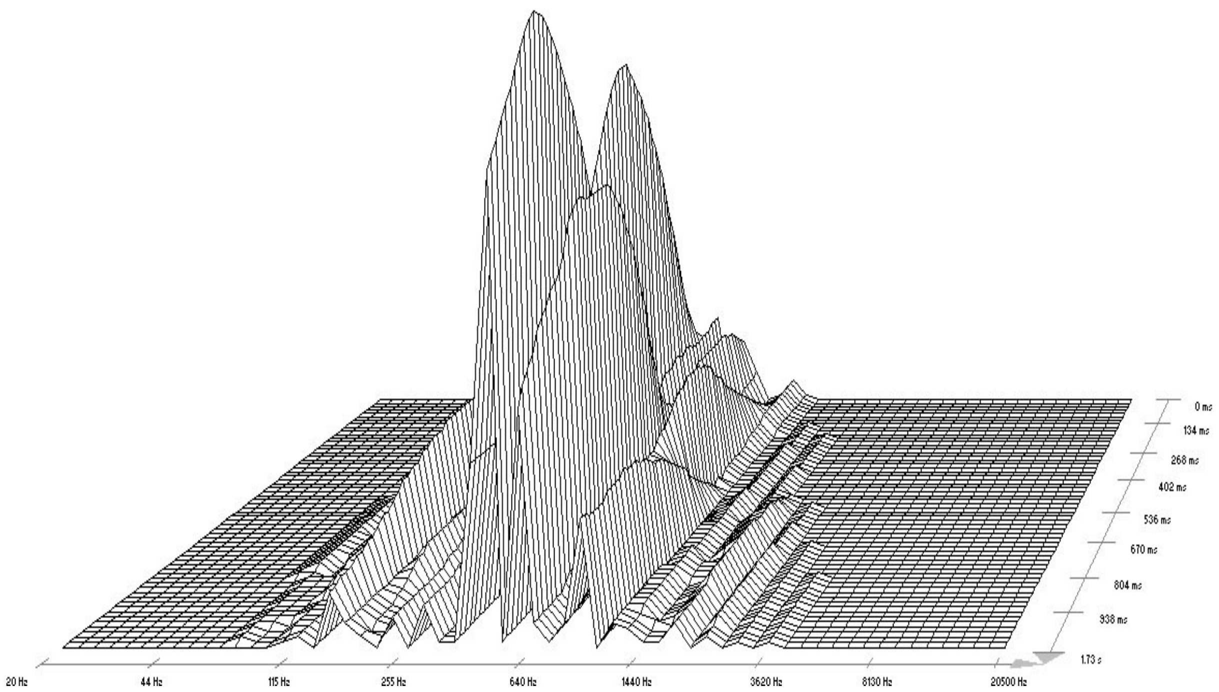


Fig : 10 - frequency graph *[area plane (c) 7.824 – 8.167 meters]* ***showing resistance to flow***

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 undergoing physiological changes in pitch,duration and dynamics through precise calculations of flow patterns are applied to each composition.

Composition:

η (154m) is the second hydrophonic work which focuses on the kinetic behaviour of water with particular reference to flow patterns in the presence of resistance. ***η*** is a Greek letter pronounced "ita" and is a scientific symbol of viscosity, **154** is the length of pipe in **(m)** meters. Changes in pressure ($\Delta\rho$) , fluid density (ρ_f), temperature (t), viscosity (η) , (τ) surface roughness in the investigation of corrosion are linked to the audible frequency spectrum.
Data was collected via 2-wire technology and HART communication method, the capturing of data was repeated to exclude errors. Transcription of the data was used in [plotting - comparative frequency, pressure, viscosity and flow graphs, detecting areas of surface roughness] the composition.
Audio frequencies selected were proportional to the flow rate. Head loss due to friction was processed into fixed modules with alternating values of pitch, dynamics and time duration. All calculations and algorithms were generated through *Matlab* software. Inspections of complex waves were done through Fourier acoustic analysis. The composition is broken down into 13 sound blocks and 3 *(sub)*-blocks, showing pitch variations revealing moments of laminar and turbulent flow in areas with surface roughness on a macro and micro-environmental scale. Each *(sub)*-block [block 2.1,8.1,9.1] suggests alternate data from repeated readings collected in a specific region of the pipe with alternate sound possibilities that could not be included in the main composition of [block 2,8,9]. In block 6 and 7 results may seem other than what was intended, variations in resistance portrayed by [ebass1] are too subtle to be noticed by the human ear thus flow is said to be laminar, however introducing [ebass2] the performer over emphasizes specific areas in the score [were resistance was detected] showing a possibility of turbulence.
High flow rates resulted in pitches outside the audible range, adjustments were made to include them within +/- 17.0000 Hz upper and +/- 19Hz lower range, yet not loosing the intensity of the composition.

References:

1. F.M. White, Fluid Mechanics, 7th Edition, McGraw-Hill, New York, 2011
2. D.J. Dunn, Tutorial 1 : Fluid flow theory D203, Engineering Council, United Kingdom, 2013