Flow Friction& Energy Determination In Pipe Flow Pressure (Influence Areas), Giving Stability Criteria On Working Hydraulics Pressures On The Flow

Mr. Prasanta Biswas[1^]

[1]Masters In Civil Engineering (with specialization in Environmental Engineering) From Jadavpur University, Kolkata, West Bengal; Attached With Academic Institution (as Assistant Professor) Affiliated by West Bengal University of Technology, WBUT, West Bengal, India (Approved by All India Council of Technical Education, AICTE, India), BF 142, BF Block, Sector 1, Bidhannagar, Kolkata, West Bengal. ^ Corresponding author, paport2018@gmail.com

ABSTRACT - Flow in pipeline is part of infrastructure projects. It has various other sectors of application like pipe-line liquid transportation, pipe-line water conveyance etc. In all types & kinds of the pipe-flow, the methodology & findings given & determined in this study should be applicable. This study includes the discussion of energy flow area offered by the pipe-flow which would further be having the stability challenging situations to its pipeline design. In doing this exploration, several methodologies have been devised & described to find out the resultant & its centroid of the energy engulfed areas of the pipe flow. Head-loss & its cause of the flow demand are in its new dimension of discussion to get them on finding into the stability criterion. Various research scopes are always in the evolving stages of the finding given in this study. Lots of flexibility in the evaluation, application &determination are also its another facet. On entirety, this study provides a broad new discovery of the subjective matter of the pipe flow, irrespective of any particular field of its application – it's independently diversified &having multi-dimensional areas of utility.

KEYWORDS: Pipe Flow Area, Energy, Pressure Friction, Liquid Demand, Hydraulic Pressure, Tank Location, Liquid Pressure Loss, Resultant, Centroid, Reaction Diagram, Pipe Design Stability, Wall Friction Gain, Loss Friction.

NOTATION:

Symbol	Description (with the subject of the flow)
D	Pipe Diameter
L	Total Pipe Length
L_{II}	Pipe Length (Section I to II)
L_n	Pipe Length (Section II to n)
V	Pipe-flow Velocity
T	Time of Flow
Q	Flow-rate (or Discharge) in Pipe
H	Pipe flow Pressure (Demand/Loss)
K	Co-efficient of Pipe Roughness
Q	Flow-volume in Pipe
i-th	Number of section, 0 to n-th section
0, I, II, III, . . . n	Pipe section of interest
*	Multiplication sign, unless mentioned otherwise
Δ or d	Derivative or Differential
dH	Differential of H
dT	Differential of T
dQ	Differential of Q
H.P.D	Hydraulic Pressure Diagram of Pipe Flow
P.L.D	Pressure Loss Diagram of Pipe Flow
A_d	Pressure Head Area or Area of H.P.D
$A_{eff.}$	Head-loss Area or Area of L.P.D
Π	Numerical constant equal to 3.14
u.d.l	Uniformly Distributed Load
M & C	Gradient & Intercept respectively

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I. INTRODUCTION

Sizing & its selection in pipe line construction is a matter of prudent knowledge of engineering application. Effectiveness in design & its implementation is the cause of the status of a pipe-line project towards sustainable longevity. It is for the sake of not only for a project's budget, is also on behalf of the entire human civilization it forwards to.

In most of the pipe-line projects, ineffectiveness development is the prime concern to the designers & engineers. Because, placing of pipes on ground with correctly designed gradient is 'ultimately' the utmost tedious work, to get on realized and/or to keep them on stable mobility. There are lots of decisive points come into the views which take & require experience hands to make the project sustainable & durably efficient. And, as a result 'selection' is the word to recognize on. To everywhere in a pipe-line supply project it is always searched on to which component is comfortably & effectively suited to make the entire project a sustainable & long-lasting project with the almost minimal maintenance requirements. From design topography to its pipe material, correct choose of everything is a field of expertise in fulfilling desired goals of the project itself.

A 'good' design provides smooth undergoing of its flow of each & every kinetics. Its dynamics must be in its 'desired' existence on all over the 'required' governance. In pipe-line projects such as liquid supply project, sewerage project, oil transmission project etc., of in-land and/or under sea, it always becomes a point of stage in the design to finalize the material of the conduit or pipe through which the carrying liquids would flow. This particular selective decision is a functional variable dependent on several of its attributes. These attributes include velocity of flow & bed slope of the pipe line.

Several projects come to failure like a devastating land-slide only because of this one variable of pipe-line project & that is the pipe material. Besides having all the other design kinetics as correct as scientifically effective, this only variable i.e., the pipe material or the material co-efficient of pipe line flow is the most important one which is required to be given maximum seriousness in its choosing & manufacturing & in implementing the other variables interlinked to it. The material chosen in preparing conduit/pipe could differ from the place to place in one single pipe line. This is also a thoughtful concern to the pipe-line design decision.

On a whole, the entire facility should be provided with good combination of the flow variables so as to cause the project's effectiveness & stability.

In this study, the flow kinetics of pipe-line project is discussed. This description is accomplished by sighting & applying the research course of its required engineering application. In subsequent discussions it has been shown that how pipe material (its types, co-efficient etc.) is having its various affecting & reactive collaborations with the flow mechanism in the pipe-line flow system. It should give the inherent idea of how the pipe material could be designed according to the characterization of the flow-kinetics it is responsible to carry with greater offset of stability against failure by pipe corrosion, erosion, decay, breakage, design standard etc. etc.

Pressure diagrams for the subject matter of pipe-line liquid transportation have been constructed, shown & analyzed in this study. This diagram does exist on the hydraulic gradient of the pipe line liquid requirement project. It is discussed that these diagrams get developed over the length span of pipe line & enact on the pressure head requirement at the outlets, wherever needed, in the distribution network along the pipe lines.

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It is well known that there'd always be the head-loss to transport the liquid over a span of its pipe length. This head-loss is the energy required to get the transportation accomplished. This indicates that there is always a simultaneous evolvement of the two pressures (& its diagrams) – one is the diagram of the *pressure head requirement* (i.e., the liquid demand) & another is for the *head-loss evolvement* due to the first one; it'd also be the vice-versa. The latter could be realized as a result of the causation or event of its earlier one, as discussed. These two diagrams have been explained in numerous ways of applications to find out several outcomes of them. These outcomes ultimately demarcate & need the facility of the knowledge in the civil engineering field to create a way of finding the reaction motives existing as the reactive force at the outlets/junctions along the pipe line against the two diagrams as said. Based on this, the efficiency as well as the longevity of pipe material should be thereby become possible to get to be described in a secured manner of the determination to chalk out & describe the pipe material's sustenance. This study at the last ends with lots of future scopes of it.

II. GOALS OF THE STUDY

Followings are the goals of this study –

- ❖ To attain at the knowledge of the (simultaneous) happening of pipe flow pressures.
- ❖ To determine & evaluate the areas of the pressure diagrams.
- ❖ To determine the resultant of liquid head-loss & liquid pressure head in the network of pipes.
- ❖ To initiate the happening of pipe flow pressure & head-loss by the several methodology, besides the moment-area method.
- ❖ To discriminate the pressure head diagrams linked with the head loss & vice-versa.
- ❖ To evaluate & locate the position of the pressure resultants.
- ❖ To apply the shear force-moment theory of mechanics.
- ❖ To have the extent of application of the knowledge into various future scopes.
- ❖ To make the pipe line into better stability of protection by giving the balanced liquid frictions.
- ❖ To giving the concept into similar like subjects, theory& application.

III. METHODOLOGY OF THE STUDY

In a pipeline flow, the general layout of the flow profile is a well known knowledge. Pipelines are generally constructed to make the liquids available to near to its distant places; somewhere in a network of pipes or somewhere at a straight reach of the supply line of pipes. With the passage of every length of the supply of liquids through the pipe-line, there is always a very common term found happening along the pipe-line called as *'head-loss'*. This is here denoted by H with the suffix of the *pipe flow-length section* it is meant to be of. This head-loss is nothing but the loss of energy. But it is very much a required fact behind making the head requirement or the supply happen at the locations of supply. This head requirement is here termed as the *'pressure head'* denoted by H with the suffix of the *specified point or location* where the head is required as a demand (of supply). This is shown in the Figure 1 considering the pipe-line of n-th segment/section of pipes.

For the discussion of this study only the section I to II is chosen & described subsequently till its last segment 'the n-th section', in the description of this study.

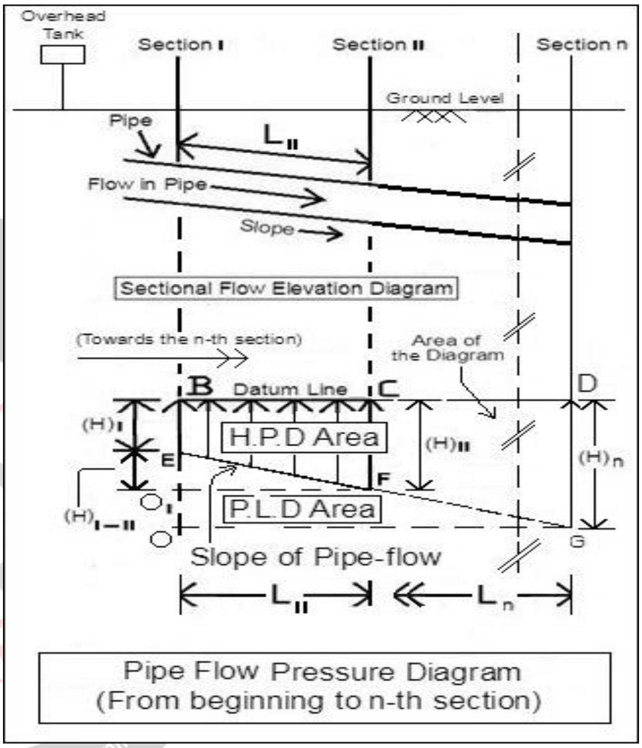

Figure 1: The Pressure Diagram (Tank Location Subjection)

In between the section I & n-th there could or not be the network of pipes, in parallel or series combination as it'd be, but the fundamental of the pipe-line flows would follow the description as described in this study's outcomes. However with this knowledge of the simultaneous happening of the two heads in the pipe-line's flowing liquids, this study has discussed its several findings applying various techniques & philosophy to get to the required destination of knowledge.

The entire study could be divided into following five(5) stages:

a) Head-loss & Pressure head requirement along with their differential dimensions.
b) Position & Resultant of the Pressure Head in pipe network.
c) Pressure reaction determination.
d) Energy identification & its equation development (flow energy to electrical energy).

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e) Facilitative study to the network design in the distribution system.

These stages are discussed as the following discussion follows of –

A sectional detailing is shown in the Figure 1 which is showing a schematic n-th section of pipe-flows, starting from 0^{th} section or else. In this, the hydraulic pressures experienced by the lengths of pipes of the flow are represented in diagrammatic form in the figure where sectional flow & its hydraulic pressure diagrams for network pipes of distribution system of liquid supply are shown. Figures given in this study are all inter-connected with each other in the meaning & all.

For the chosen sectional lengths (Figure 1), there is the formation of the two diagrams, simultaneously &also spontaneously. It is quite clear that the pressure heads (demands) on any sectional length of the pipe-flow create a diagram EBCFE & for an entire considered length (L) of segmental flow-lengths it is BCDGFEB within the flow dynamics by the pipe-flow. The area BCDGOEB is considered to be unity. These diagrams do always get formed whenever a pipe segment consisting of two junction points of withdrawal or of the kind alike is allowed to flow.

The entire diagram BCDGOEB is consisting of the two parts – one BCDGFEB, trapezoidal in shape & another one EGO, triangular by shape. The details characteristics of these diagrams are tabulated & given in the Table 5. The hydraulic pressure diagram (termed a H.P.D), shown by EBCFE, is subjected by the hydraulic pressure requirements (i.e., the withdrawal requirement or demand of liquids). Let this diagram (BCEFB) be called as the **Hydraulic Pressure Diagram** (H.P.D) which is for the entire length L is BCDGFEB (trapezoid). The diagram, EBCFE, has its two vertical sides (EB & FC) formed by the existing hydraulic heads which are the requirements of the withdrawal to be fulfilled, by the network design or else.

All the heads are shown acting in vertical upward direction by their capacity because of representing them to be under the need fulfillment, datum interface influence & other flow dynamics as well & also of design considerations of the liquid distribution network. Another diagram EFO or EGO is obvious & quite evident to be expressed as the diagram known to be as the head-loss diagram.

It is nothing but the effect of the BCEFB or BCDGFEB respectively to the section concerned.

It is a well known fact that in meeting every requirement of liquid head every time, there must be some head-loss & vice-versa. So in here, with the development of EBCFE, the formation of EFO happens. As it goes over up to the entire length 'L' it transforms to EGO as its head-loss diagram. It is thereby required to be said that this formation of EFO or EGO is simultaneous & vice-versa, as explained already. Let this head-loss diagram be termed as **Pressure Loss Diagram** (P.L.D).

The area EBCFE is the part of the entire H.P.D for the said section of consideration like the EFO of EGO. Two sides of the pressure-flow diagram, EBCFE, show & indicate the hydraulic pressure heads (required or to be required) by their respective magnitudes $(H)_I$, $(H)_{II}$, . . . ,$(H)_n$ etc. of the pipe-flow section. Top (horizontal) base of the pressure diagram is the 'datum line' (BC) with respect to which all the pressures of the pipe-flow are assumed showing themselves in the representative form of the estimation in the diagram by magnitudes & else. This datum might be the 'ground level' (Figure 1). This area is working in this study by the notation A_d which for all the intermediary pipe segments (except at the beginning) should be the trapezoidal (Figure 1). For the P.L.D's area, the area to be known as is $A_{eff.}$ or effective area or the area effective to the causation of the pipe flow.

<u>Tank Location Feature:</u>

The tank location defines the flow direction & the consideration of the fulfillments in the head requirements. In consequent to this, shape of the diagrams changes. Direction of the arrows shows & indicates the pressure lines so considered. It is also flexible & optional to choose like the tank location with respect to the distribution network. The direction of the pressure arrows can thereby be suitably changed to the better mode of the presentation philosophy.

All the hydraulic pressure heads (of liquids) are here deployed as to have been supplied from the nearby source/storage (liquid tank) location as shown in the Figure 1. This location of the source/storage is kept fixed for this entire study (on the left side of the figure). So far as the network design & the goals of this study are concerned, the incorporation of all the flows (& their characteristic features) at the points in the pipe network is required to be estimated always to be away from the tank so that the tank capacity is well utilized by its downstream demands. In fact, the tank capacity must be designed to meet the distribution network requirements.

With the formation of the pipe flow pressure areas in addition to the tank location preference, the two possible diagrams are possible to be determined for each preference of the tank location for each of the H.P.D & P.L.D of the several findings so determined in the subsequent. This means, if the tank location is chosen from the one as shown in the Figure 1, then there'd be the another possible location which is from the n-th section to the beginning for which the diagram (only H.P.D is shown & it'd be in the similar way to determine its P.L.D by the subjection) would be the one shown in the Figure 3.

The two possible cases, of the pressure diagrams, as described are completely different, but unique to the specific one single situation of itself, in its evaluation process of this study. Also, the connecting sloping line might be, as explained, in any optional gradient (elevation/depression) depending on the direction of the

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pressure head demands for the H.P.D and/or the head-loss for the P.L.D.

Though this study is meant & described taking the tank location as shown by the Figure 1, but there would be the possible determinations for the one of the Figure 3 in which case the pressure demands & its head-losses would be required to be determined from the selected tank location & thereby it'd be looking like the figure shown in the Figure 3.

Already explained & easily recognized to the fact of the optional determinations for each of these two possible cases to be of the tank location within them.

Table 1: The Pipe Flow (Differential) Energy

Section	Pressure Head		Pressure Head Loss Area, $[(\mathbf{A})_{\mathbf{eff.}}]^{?}$
	Symbol	Equation	
0 to I segment	$(\mathrm{H})_{0-\mathrm{I}}$	$+[(\mathrm{H})_{\mathrm{I}}-(\mathrm{H})_{0}]$	$[(\mathrm{A})_{\mathrm{eff.}}]_{0-\mathrm{I}}$
I to II segment	$(\mathrm{H})_{\mathrm{I}-\mathrm{II}}$	$+[(\mathrm{H})_{\mathrm{II}}-(\mathrm{H})_{\mathrm{I}}]$	$[(\mathrm{A})_{\mathrm{eff.}}]_{\mathrm{I}-\mathrm{II}}$
II to III segment	$(\mathrm{H})_{\mathrm{II}-\mathrm{III}}$	$+[(\mathrm{H})_{\mathrm{III}}-(\mathrm{H})_{\mathrm{II}}]$	$[(\mathrm{A})_{\mathrm{eff.}}]_{\mathrm{II}-\mathrm{III}}$
. . .	. . .	. . .	. . .
(n-1) to n-th segment	$(\mathrm{H})_{(n-1)-n}$	$+[(\mathrm{H})_{n}-(\mathrm{H})_{n-1}]$	$[\mathrm{A}_{\mathrm{eff.}}]_{(n-1)-n}$

?area of the triangular portion unless otherwise defined.

Load Feature: It is quite comprehended from evaluation & determination, there'd be the loads acting on entire pipe networks. Theses loads are coming as the *pipe flow pressure* for need fulfillment & its *pressure losses* required to transporting the flow along the pipe flow. These two pressures/loads shown in the Figure 1 as the respective H.P.D& P.L.D along with their directions of action are, by their existence in the pipe network, the nature of uniformly distributed load (u.d.l or U; unit load per unit length of pipe flow). In this study, the sectional points are considered as the support of the load diagram such as H.P.D and/or P.L.D. In the subsequent it is given how these support reactions could be having the implication using the structural analysis shear force & moment theorems, to determine the loads/pressures acting at their location of existence. It is thereby considered that the supports (i.e., the sectional points like of H_{I}, H_{II}, H_{III}, . . . , H_{n}) are to be of the fixed-end support type so far as the pipe flow is occurred to, serving the water demand needs; in the determination, each time one specific section needs required to be brought into the calculation, keeping other supports as non-importance and/or rather fixed support type, as well.

It'd be quite satisfactory to consider all the sectional points/supports as only the fixed support type on all through as the entire diagrams looking to be consisting of small, small sections having the fixed end supports. And, these fixed supports, bearing the u.d.l on its overhanging spans on either/both the sides, should comply with the reaction condition by the nature of itself.

In this study, moment & horizontal thrusts at the supports are neglected. With these, it takes to the field of finding of the pipe flow reaction/friction& the flow energy in the pipe as well, described afterwards in this study, along with the stability criteria. All these considerations of support condition, u.d.l., direction sign. & other features are applicable for this entire study on all along & on its all the determination & findings; equally & unalterably, although these could be suitably changed to utility.

In what way of this presentation could be brought to the limelight of description, it'd be found that they all shall be exposing into these so given by the discussion related to the subsequent resulting figures given afterwards. And, the lower inclined surface of the diagram (EBCFE) which is merely dependent on the bed slope of the pipe or pipe-flow does actually represent the profile variation of the hydraulic heads at the outlet/withdrawal/junction points. These are shown here by the one single inclined line EF or EG.

All the required detailing of the parameter or symbols used is given in the Notation, unless otherwise specified.

Table 2: On The Entirety (Of The Energy Formation)

Section	Pressure Head Loss		Pressure Head Loss Area, $[(\mathbf{A})_{\mathbf{eff.}}]^{??}$
	Symbol	Equation	
I to n-th segment	$(\mathrm{H})_{\mathrm{I}-n}$	$+[(\mathrm{H})_{n}-(\mathrm{H})_{\mathrm{I}}]$	$[(\mathrm{A})_{\mathrm{eff.}}]_{\mathrm{I}-n}$
II to n-th segment	$(\mathrm{H})_{\mathrm{II}-n}$	$+[(\mathrm{H})_{n}-(\mathrm{H})_{\mathrm{II}}]$	$[(\mathrm{A})_{\mathrm{eff.}}]_{\mathrm{II}-n}$

??area of the Triangular portion unless otherwise defined.

The introduction of the segmental determination of the energy could be best understood in a tabulation format. The areas & the head-losses are given in the Table 1 & 2 for the n-th section of the pipe-flow (Figure 1).

The energy equation given in the Table 5 is having its supportive knowledge gaining tabulation as given in the Table 3, in addition to the Table 1 & 2. In applying fundamental of the pressure diagrams, the Table 4 (including Table 4a & Table 4b) would essentially be a required of evaluation in this determination.

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Table 3: The Energy & Areal Energy

Section	The Diagram Area		Energy (H) in terms of	
			Pressure Head	Head-loss
	Pressure Head Area (Trapezoidal) = H.P.D Area (A_d)	Head-loss Area (Triangular) = Non-H.P.D Area, ($A_{eff.}$)	For Trapezoidal	For Triangular
0 to I segment	$(A_d)_{0-I}$	$(A_{eff.})_{0-I}$	given in the Table 5.	given in the Table 5.
I to II segment	$(A_d)_{I-II}$	$(A_{eff.})_{I-II}$		
II to III segment	$(A_d)_{II-III}$	$(A_{eff.})_{II-III}$		
…	…	…		
(n-1) to n-th segment	$(A_d)_{(n-1)-n}$	$(A_{eff.})_{(n-1)-n}$		

It is hereby mentioned that the notation H is applied both for the loss & its pressure heads over a sectional length (L) of the pipe flow (Figure 1), such as H_{I-II} be the head-loss for the section I to II wherein H_I& H_{II} be the pressure head requirement at the section I & section II respectively, where,$L = \cdots + L_{II} + L_n$.

It is required to mention here that there could be various sections in a pipe flow length that could be brought into under the discussion, whereas in this study it is considered to be in the way as it describes to in the given meaningful way corresponding to its related depictions.

3.1 DESCRIPTION OF PRESSURE ENERGY (In Terms Of Hydraulic Heads)

It is the section where the main theme of this study starts. It is regarding the hydraulic energy which does exist in the pipeline flows of the liquids. As explained there are the formation of the two areas, the energy here is described as the representative of the hydraulic heads so formed for each of the areas. However these two areas should be equal in magnitude to each other because of general variation in the fundamental of the flow & etc. The energy which is thereby corresponding to the hydraulic pressures, in the two areas, is given in the Table 2 & determined as followed –

The pressures are here in the distribution network kept in the vertical upwards direction as shown in the diagram EBCFE; this direction whether upwards or downwards is optional. The area of this diagram EBCFE is the pressure (hydraulic caused by the liquid 'demand' head) created onto or existing on the reach of the length 'L_{II}' of the pipe-flow. This means that areal contribution of each considered flow-length by its own subjected hydraulic heads gives the energy (in Newton. meter) or the work done by the flow over the pipe-length, once it (the pressure diagram area) is multiplied by the underlying pipe-flow area.

Of the trapezoidal pressure distribution, the diagram area (EBCFE) is,$A_d = \left[\frac{(H)_I + (H)_{II}}{2}\right](L_{II})$ ... (1)

where $(H)_I$ & $(H)_{II}$ be the pressure heads at the section I & section II respectively. Theses heads represent the liquid pressures available at their respective chosen sections. The suffix 'd' represents the 'demand' area of the diagram H.P.D.

The unit of the Eq.(1) is square meter which means that it can be as,$A_d = \left[\frac{(H)_I + (H)_{II}}{2}\right]\left(\frac{AL}{A}\right)_{I-II}$; where, A_d = H.P.D area for the deputed section I – II ; $(q)_{I-II} = A_{I-II}\,L_{II}$ = Time Flow-Volume = $(QT)_{I-II}$; A = flow area (cross-sectional); for the section I-II, it is A_{I-II}.

$$\text{Or, } A_d = \left[\frac{(H)_I + (H)_{II}}{2}\right]\left(\frac{q}{A}\right)_{I-II}$$

$$\text{Or,} A_d = \left[\frac{(H)_I + (H)_{II}}{2}\right]\left[\left(\frac{Q}{A}\right)T\right]_{I-II} \quad \dots (2)$$

where, T=Duration of the Flow; say, it is T_{I-II} for the section I-II.

Now, by applying the continuity equation on the section I-II, from the section I to the section II,

$$Q = VA$$

where, Q & V = Flow-rate & Flow-velocity (sectional) respectively.

$$\text{Or, } \left(\frac{q}{T}\right) = VA$$

Thereby for the section I – II, $(q)_{I-II} = (TVA)_{I-II}$ ... (3)

From Eq.(2) & Eq.(3),

$$A_d = \left(\frac{1}{2}\right)[(H)_I + (H)_{II}](TV)_{I-II} \quad \dots (4)$$

This equation is very important so far as its utility is involved in this study. As said, the unit of the pressure diagram area is the same i.e. sq. m or as N/m while the head (H) is to be treated in the unit of pressure (N/m^2) in the Eq.(1) or Eq.(4). The energy can be derived & estimated out from this as explained& given in the Table 2.

Applying the equation L = VT, into the Eq.(4),

$$A_d = [(H)_I + (H)_{II}](L_{II}/2)$$

It is the required Eq.(1). With this enunciation the general philosophy of the equation L=VT along with the equation of flow-continuity are held satisfied in the methodology of this derivation.

$$\text{Thereby, } [(H)_I + (H)_{II}] = 2\left(\frac{A_d}{L_{II}}\right) \quad \dots (5)$$

The Eq.(5) defines that the summation of the head-losses is equal to twice the areal diagram (EBCFE) divided by the flow-length of the pipe (Table 4a). Thereby, in finding the equation, Eq.(5), it would be useful suitably in their

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pertinent corresponding uses of its given determining equations & it's been given in its applicational discussion later in this study.

Further, here is an interesting extraction obtained in the Eq.(5) which when expressed as $[(A_{I-II})(A_d)] = [(H)_I + (H)_{II}](q/2)$ presents the areal features of the network's pipe-flow characteristic into more cognizable formation, making it to more easy way of the estimation suitably – this is on owing to the regardful consideration on the slope of the pipe-flow also.

Again, the net hydraulic liquid-pressure lost in a pipe length, say, over the section I – II should be presented in the similar way as like the A_d of H.P.D & is given in the following –

In every pipe flow, there must be the certain head-loss, over the pipe-length & it's at the point of the section chosen. As evident from the Figure 1, the datum line is all the time in the work of giving the shapes to the diagram area over the flow-length, on everywhere across as the networks design.

Table 4a: Distribution Network Pressure Diagrams

Pipe Section	H.P.D		
	Area	**Shape**	**Feature**
I to II	BCFEB	Trapezoidal	Liquid Pressure Requirement (Demand)
…	…	…	
I to n-th	BCDGFEB	Trapezoidal	

A typical of such happening in the general pipe-flow has shown the influencing diagram so caused & created by the pressure needs as shown in the Figure 1 wherein the head-loss in causing the flows in the network pipes of the city's distribution zones gets created by the triangle EFO (Figure 1& Table 4b).

And, it is the head lost to cause the liquid to flow in the subsequent pipes in pipeline project. Here, H.P.D is dependent on P.L.D & vice-versa; they form together simultaneously & Pressure direction is optional – this is to be valid & applicable for both the Table 4a & Table 4b, unless applied otherwise as some special or design cases to the subjective filed of the (pipe) flow energy.

For a sectional pipe-flow between the selected segments, section I to the section II, the head of liquid lost = $(H)_{I-II}$ whose diagram area is EFO & the length over which this triangle area is formed in the pressure diagram is = L_{II}. Thereby, the area of the triangle EFO = $A_{eff.}$ = Effective Area = Area of the EFO = $\frac{1}{2}[(H)_{I-II}](L_{II})$ which is equal to the (1 – A_d) of the hydraulic pressure by the property of simultaneity as said earlier, considering the entire area including H.P.D & P.L.D for a particular section as unity; where, $A_{eff.}$ = the (effective) area for the head-loss represented by the diagram area EFO.

Thereby, the head-lost area which is for the P.L.D would be

$$A_{eff.} = \frac{1}{2}[(H)_{I-II}](L_{II}) \quad \text{... (6)}$$

Thereby, Eq.(6) is the energy elapsed in transferring the liquid from section - I to section - II & it could be obtained by the value $A_{eff.}$ just as similar as explained by the A_d for the pressure head area. Yet, this study's objective is not to describe or give elaboration about energy creation in the network system, primarily; rather, it'd focus on the entire discussion of the various dimensions indeed.

The Eq.(6) is a very particular equation for its subsequent use in this study's foregoing design as it's ultimately causing the flows through pipes. This equation is, as earlier, to be obtained for a specified section of length (L) subjecting to its corresponding hydraulic gradients for the subjected head-loss of the pipe-flow.

Table 4b: Distribution Network Pressure Loss Diagrams

Pipe Section	P.L.D		
	Area	**Shape**	**Feature**
I to II	EFO	Triangular	Liquid Pressure Lost (Transmission Loss)
…	…	…	
I to n-th	EGO	Triangular	

Thereby the similar types of the equations as obtained earlier, from the Eq.(1) to the Eq.(5), can hereby also be possible to be determined by the Eq.(6) which is, as said, the equation of causing the mobility or motion of flows in pipes of the distribution network. The equations of the head-lost are hereby similarly obtained as –

Applying the Q = VA & Q = q/T into the Eq.(6),

$$(A_{eff.}) = \frac{1}{2}[(H)_{I-II}]\left(\frac{AL}{A}\right)_{I-II}$$

$$= \frac{1}{2}[(H)_{I-II}]\left(\frac{q}{A}\right)_{I-II}$$

$$= \frac{1}{2}[(H)_{I-II}](TV)_{I-II}$$

where, q = QT = TVA

$$\text{Or,}(H)_{I-II} = 2\left(\frac{A_{eff.}}{L}\right)_{I-II} = 2(A_{eff.})\left(\frac{A}{q}\right)_{I-II}$$

$$\text{Or, } (H)_{I-II} = 2(A_{eff.})\left(\frac{A}{TV}\right)_{I-II} \quad \text{... (7)}$$

The Eq.(7) is although having the similar significance as explained earlier of the Eq.(5) or Eq.(1) using the same Figure 1, but it is useful to the regards of the better compatibility of the application in the different way by the own characteristics in itself. In this way, there can be variety of equations representing their different features of the compatibility.

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The significance between the Eq.(5) & Eq.(7) is their simultaneous presence, not of separate happening as explained – the earlier ones represent the actual pressures existing at various nodes such as I, II, III while the latter expresses its background influencing dynamics or the energy used to materialize the flowing in segments of network pipes (Table 5). More precisely, the Eq.(5) & Eq.(7) are the equations of the nodal head & the head lost over the given section I – II respectively which could be the guiding equation in the foregoing discussion of distribution network design analysis.

Table 5: Consumptive Energy & Flows%

Boundary Condition	Areal & Hydraulic Pressure Distribution			
	Area of the Pressure Diagram		Hydraulic Heads^	
	Area of the Pressure Diagram (A_d)	Area of the Head-loss Diagram (A_{eff})	Hydraulic Pressure, $[(H_I) + (H_{II})]$	Hydraulic Pressure Loss, $(H)_{I-II}$
Col. 1	**Col.2**	**Col. 3**	**Col.4**	**Col. 5**
By the general physical formation in the diagram area	$\left(\frac{1}{2}\right)[(H_I) + (H_{II})](L_{II})$	$\frac{1}{2}(H)_{I-II} * (L_{II})$	To be found from Col.2.	To be found from Col.3.
By Flow (Volume/Area)	$\left(\frac{1}{2}\right)[(H_I) + (H_{II})]\left(\frac{q}{A}\right)$	$\frac{1}{2}(H)_{I-II} * (q/A)$	To be found from Col.2.	To be found from Col.3.
By Flow, Q	$\left(\frac{1}{2}\right)[(H_I) + (H_{II})]\left(\frac{Q}{A}\right)T$	$\frac{1}{2}(H)_{I-II} * (Q/A)$	To be found from Col.2.	To be found from Col.3.
Application of Q = VA & Q=(q/T)	$[(H_I) + (H_{II})]\left(\frac{TV}{2}\right)$	$\frac{1}{2}(H)_{I-II} * (TV)$	To be found from Col.2.	To be found from Col.3.
Joint Areal Effects	To be found from Col.(4)	To be found from Col.(5)	$2A_d * (A/q)$	$2A_{eff.} * (A/q)$

%it is indicative by terms of the energy heads used & remaining to be in use, causing motion to the flows, in turn.

^provided the H.P.D area is given or assumed; although there would be alternative ways of manual measurements of it.

Equations of the areal diagrams (A_d & $A_{eff.}$) are for the respective heads available & heads lost, required for the simultaneous checking also while the flows are dealt with by the nodal heads & it's vice-versa. All these formulations are presented in the Table 1 to 5 wherein for the understanding of the knowledge, the given energy & flows are for the section I - II. Likewise, like this, the other sections can be computed in the similar was & it's utmost nonetheless.

It's nonetheless that the equations so formulated are to be in designing the liquid supply distribution pipes. The Table 5 shows it to be applied on the areal determination in order to have the design estimation process as compatible as of flexible use & also of logical representation besides research interests – although these can also be a guide of checking in the design values related with heads & subsequently in its useful adjustments in the pipeline project & design.

The energy equations are hereby given in the representative head presence, be it the pressure or the loss. The background knowledge of this energy determinations given in their both the unitary fundamentals & physical existences has been followed, in preparing the fundamentals given in the tabulation, in the Table 5. Application of this table is very research based, prospering & needs further enhancement of practical realization using model, laboratory testing (mathematical & instrumental) etc. of experimentation & subsequent validation fields (of requirements).

3.2 DETERMINATION OF THE PRESSURE RESULTANT & ITS LOCATION

In this segment, the most interesting application is given. In the event of pressure change, the motion occurs. In static nature of body, there are the inter-particular movements of various related forces, moments etc. of the kinetics generally seen existing under their given state of the art. In dynamics of various physical forces the changing formations usually occur by their changing values. In the pipe-flow hydraulic, pressure head is the representative of the pressure loss. That is to create a particular head demand the loss becomes the one of the design considerations to have it visualized. It is also the kind of the concept in vice-versa.

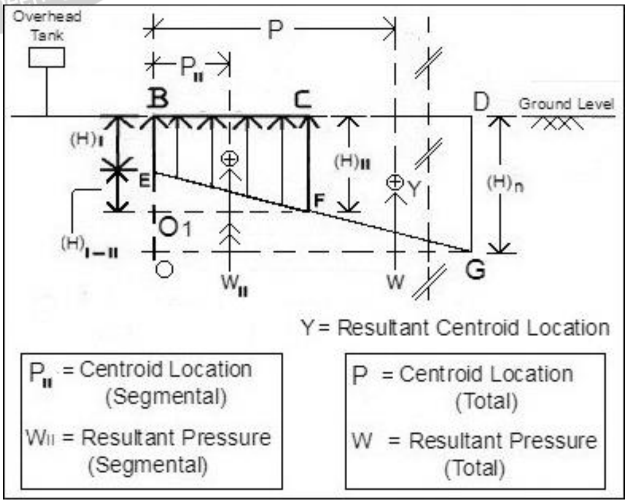

Figure 2: The Resultant & Centroid Location (H.P.D)

As given in the Figure 1, for a sectional length of flow the governing head demand H_I & H_{II} both creates a typical formation of pressure diagram (also shown in Figure 2). This development & formation of the diagram is on all

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through, everywhere, be it sectional or on a whole. This diagram is divided into two parts –

(i) **H.P.D - Hydraulic Pressure Diagram**
(ii) **P.L.D - Pressure Loss Diagram**

In determination of both these diagrams with several findings & features, the fundamental is given as,

Let, Head loss, Y = function of (X); where, X = pressure demand of the liquid flow. Now, the relationship of this functional attachment is thereby be,

$Y = f(X_I) + f(X_{II}) + f(X_{III}) + . . . + f(X_n)$

Or, $Y = f(X_I) + f(X_{II}) + f(X_{III}) + \ldots + f(X_n)$ ... (8)

where, X's be H_I, H_{II}, H_{III},…,H_n of the H.P.D (Figure 1).

This equation, Eq.(8) is true to its opposite sense also. There'd be several of variety degrees of the finding where this simple basic should be kept in mind to assess & determine the flow-kinetics.

3.2.1 HYDRAULIC PRESSURE DIAGRAM (H.P.D)

It is the diagram which shows & gets created every time the liquid is allowed to flow through pipe. The pressure demand of the liquid heads is its representation. As discussed earlier (Table 5) the area, which is trapezoidal by nature always, covered by this diagram is completely an energy indication. It provides the visualized knowledge of how the pressure development looks like under the sectional length of pipe-flow & what it actually defines. The trapezoidal area, formed due to the liquid head requirements is the multiplied value of the liquid head & the length of the liquid flow. It could be related with the work done as a particular given quantity of the head is given to go through a distance (L) to arrive & satisfy the sectional liquid head demands.

The functional variables of this work done could also be given the correlative comparison to make them understood by momentum. In that case, the mass should define liquid head quantity which needs to be travelled through & the velocity for the length of the flow. By this comparison of the momentum of the flow with the work done of it, various flow hydraulic situations should be possible to be found out & determined to make the subject more realistic, pragmatic & advancing.

Applying the general formula of finding out centroids, resultant & resultant's centroid, the trapezoidal area is given here its detail analysis to determine them for the covered area under the subjection. In this regard, the following notations are used –

P_i = the (i-th) resultant centroids such as P_0, P_I, P_{II} etc. of the sectional 'trapezoids', that may also be consisting of number of areas of different regular trigonometric figures or else in themselves. W_i = the (i-th) resultants acting through centroid locations P_i of the i-th section; where i = the section like . . . , I, II, III,. . . , n (as shown in the Figure 2).

P= the resultant centroid which is the unique one, specific to a sectional length (L) of flow under consideration. W = the resultant for the Figure 3 for the H.P.D shown in the Figure 2.

For information, P & W be the respective variables meant for the entire pipe section of the length 'L'. Y = the centroid location of the resultant W for the entire length 'L'.

For this study the Figure 2 is the figure wherein all the necessary dimensions are shown to find out the resultant & its location (centroid) in the H.P.D. The pipe-flow of the length 'L' is shown with the continuation line to give the sectional to entirety range of consideration in the pressure-line diagrams. The centroid distance is here considered always to be measured with respect to the section I & this determinations is given as –

For the section from I – II,

$$P_{II} = (P)_{I-II} = (2p_I + p_{II}) * \left(\frac{L_{II}}{5}\right)$$

And, for the entire pipe-length L of the section from II – n,

$$P_n = (P)_{II-n} = (2p_{II} + p_n) * \left(\frac{L_n}{5}\right) \quad \ldots (9)$$

where, $p_I, p_{II}, \ldots, p_n$ = pressure intensity equivalent or the representative conversion of the pressure demands (H_I, H_{II}, H_{III} , . . . H_n) of the H.P.D.

Eq.(9) is a typical form of the determined equation required to apply to all the positions of the variable in the H.P.D & P.L.D.

Thereby the equation of the centroid (P) of the entire pipe section of the length L is here considered to be equal to the Eq.(9), but it is not the equal to P_n or $(P)_{I-n}$ for the notation discrimination & dimensional difference. Let this centroid P be termed as the location of the resultant centroid where the resultant (W) of all the segments, sub-segments etc. exists. The magnitude of P is always greater on importance to the resultant centroid position 'Y' than the centroid locations of any sections or sub-sections such $P_{II}, P_{III}, \ldots, P_n$ etc.After finding the P, now its W is going to be determined. This is the resultant pressure of the H.P.D that acts through the point of resultant centroid 'P'. Already told that the resultant centroid & its resultant pressure is determined here with respect to the reference section I unless specified otherwise.

Determination of the W is hereby given in the following three methods:

3.2.1.1 METHOD OF MOMENT

In this method the simple moment is taken & the resultant W is determined. For instance, for the section I – II, considering moment about the point B of the diagram H.P.D & considering the +ve sign for clockwise moments

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&vertically upward forces shown by the directions in the Figure 2 or 3,

$$(-)H_{II} * (L_{II}) + (-)W_{II} * (P_{II}) + (-)W * P = 0$$

Or, $(-)H_{II} * L_{II} + (-)W_{II} * (P_{II}) = W * P$

Or, $W = (-)[H_{II} * L_{II} + W_{II} * P_{II}] * (1/P)$ ... (10)

It is the equation of the resultant W if only the section I to II is considered; where W = the resultant liquid head pressure acting through the P of the pipe-flow H.P.D.

Similarly, for the entire pipe section of length 'L' of the given pipeline,

$$\begin{bmatrix} \ldots + (-)(H_{II} * L_{II}) + (-)W_{II} * P_{II} \\ +(-)H_n * (L_{II} + L_n) \\ +(-)W_n * (P_n) + (-)W * P \end{bmatrix} = 0$$

$$\text{Or,} W = (-)\begin{bmatrix} \ldots + H_{II} * L_{II} + W_{II} * (P_{II}) \\ +H_n * (L_{II} + L_n) \\ +W_n * (P_n) \end{bmatrix} * (1/P) \quad \ldots (11)$$

The –ve sign. in the Eq. (10) &(11) indicates the correction to be made & it should be given into the direction of the required variable in its applied direction. The energy or work done is here clearly got be visualized in the Equations. Thereby it is the equation representing the energy per resultant centroid.

Similarly, the resultant centroid location, P, the Eq. (10) &.(11) gives as the energy per resultant liquid pressure W. Similar determination could though be determined taking the moment about the n-th section or else, instead of the chosen section I.

Also, it is a customary observation of the balancing equation, applying this method, on the view of the energy or work done. On the whole, everywhere, there shall be the various findings but are all of the energy representatives.

Thus, this presence of energy/work done as so discussed has become proved to be an essential & obedient guise in the subject of the pipe flow.

3.2.1.2 METHOD OF MOMENT-RESULTANT-MOMENT

It is as similar as the method to determine the P or W of a particular segmental area or the entire pipeline length. The related formula is given as,

W = (Moment of the resultant liquid pressure heads through the centroids of the sectional H.P.Ds about any reference) divided by the P of the entire segment of discussion under consideration.

That is,

$$W = \begin{bmatrix} + \ldots + (W)_{II}(P)_{II} + (W)_{III}(P)_{III} \\ +(W)_{IV}(P)_{IV} + \ \ldots + (W)_n(P)_n \end{bmatrix} * (1/P) \quad \ldots (12)$$

The sectional or sub-sectional Ws are either given or could be determined from the Eq.(11) or (12). This determination of the resultant pressure under a sectional pipe flow is also having the existence of the energy/work done in the form as it'd be observed from the Eq.(12).

The notation used in this study for the sectional centroid & the integrated is given in the Table 6.

Table 6: Determination of Centroid & Its Resultant (For H.P.D)

The Lineal Section	Centroid		Resultant Pressure Head Energy (Total), W = Moment of the Pressure Head Energy (selectively sectional)about the reference say H_I, H_{II} etc. (Figure 2), of the corresponding centroids divided by the col.3.#	Remarks
	P = The distance Of the pressure diagram (of H.P.Ds) centroids (trapezoidal) subjected to the "section" (with reference to the 'initial' head-loss point of the lineal section, say H_I for the head-loss over the section I to II, H_{I-II})^	Of the 'Entire' Resultant of the Pressure Energy Heads (entirely so selected) = Location of the Resultant = ∑(Moment of the H.P.D areas about the reference) divided by the total H.P.D area, (A_d).@		
col.1	col.2	col.3	col.4(to be guided by the col.2)	col.5
0 - I	(P_I)	P = Centroid (Total) of the entire H.P.D	W_I	The W value is of having the several fields of applicability. It is differential to integrated, as on suitability for desired purposes.
I – II	(P_{II})		W_{II}	
II – III	(P_{III})		W_{III}	
…	…		…	
(n-1) – n-th	$(P)_n$		W_n	

^apply necessary theorems if provided with irregular boundary also, over large length of consideration, subject to the reference selection.

@it could be determined by the evaluation given in this study as well.

#sign convention given here depends on the 'moment' rule of mechanics; it is simply the area of the H.P.D; this estimation is not only flexible to the volume of the diagram under selection from smaller to the integrated volume of interests in the suitable respective determination of interests consequently, but also in its determination applying the different methods discussed here in this study as well.

The sectional Ws might also be the average of the sectional (or sub-sectional) heads, i.e., for the section I-II, it would be the average of the H_I & H_{II} for the section I & II respectively – although it'd find suitable for small lengths of the pipe flow (Table 1, 2, 3 & 4). This would facilitate to

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take the measurement using manometer, venturimeter etc. for small scale or model based applications of requirements.

3.2.1.3 MOMENT-AREA METHOD

In this, each of the H.P.D's, be it for the sections shown or any sub-section chosen within the given ones, is determined in their areal formation by the geometric formation so formed. In doing this, the areas & theirs' resultant centroid locations are taken into the consideration of the moment-are method to determine the resultant.

Following is the relation as determined by this conventional & usual method of the "Moment-Area" method –

$$W = \left(\frac{1}{a}\right)\begin{bmatrix} \dots + W_{II}(A_d)_{II} + W_{III}(A_d)_{III} \\ +W_{IV}(A_d)_{IV} \\ + \dots + W_n(A_d)_n \end{bmatrix} \qquad \dots(13)$$

where, total H.P.D area for the pipeline length of L,

$$= a = \dots + (A_d)_{II} + (A_d)_{III} + (A_d)_{IV} + \dots + (A_d)_n$$

In this way, the diagram area, H.P.D for the segmental length of flow provides the under-covered features of it. This, unfolding the detail explanation of the hydraulic flow, gives all the possible dimensions of the knowledge from itself & it is given in tabulation in the Table 6. This determination thereby provides the central location of the centroid & the resultant pressure of the flowing liquid in the pipeline network of distribution projects, in addition to the sub-section availability.

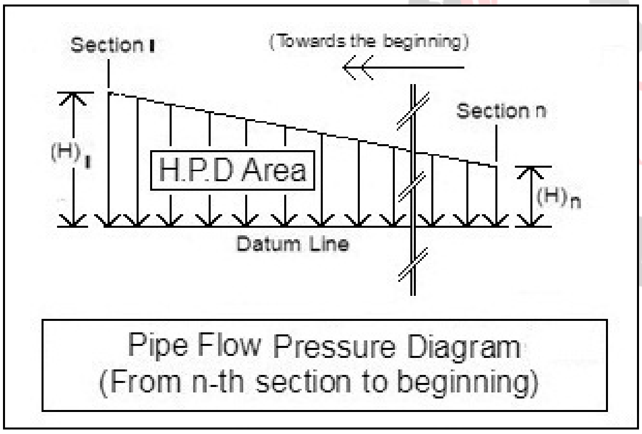

Figure 3: The H.P.D Area (Tank Location Subjection). (Ref. Figure 1)

3.2.2 PRESSURE LOSS DIAGRAM (P.L.D)

Given the fact that started from the discussion of the H.P.D, the following discussion should be the effect of it. In every meeting of the head requirement, there'd be the formation of some kinds of loss (of energy). This loss is called the head-loss which is due to the transport of the liquid flow from one section to another section as required to be in a distribution network. The lower portion of the pressure diagram (Figure 2 & 4) is the diagram meant to be defining this defining loss. It is 'triangular' in shape. Thereby the loss of the liquid flow caused in simultaneous to the formation of the H.P.D is represented by the diagram, called here as the Pressure Loss Diagram (P.L.D).

The energy or the work done in this case is the area covered under the P.L.D & its presentation is given in the Table 5 in terms of the area $A_{effective}$ or $A_{eff.}$ to define & indicate the simultaneous formation of the P.L.D with its H.P.D & vice-versa.

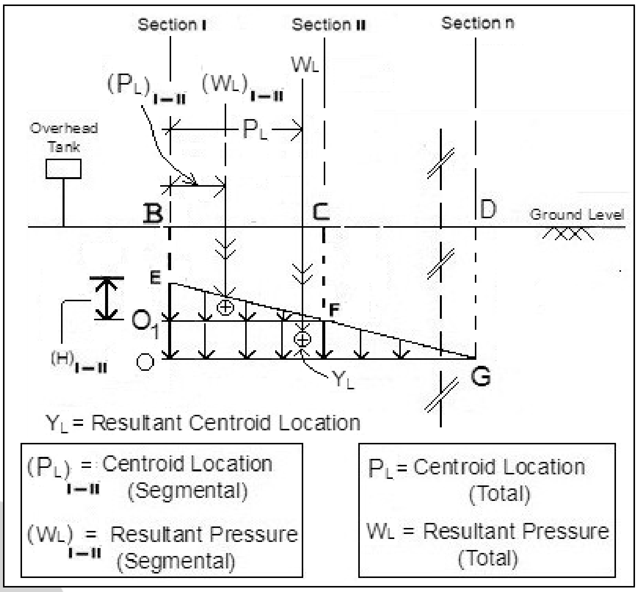

Figure 4: The Resultant & Centroid Location (P.L.D)

In a P.L.D there could be the presence of small to big P.L.Ds in multiple numbers, like H.P.D. For Each of these P.L.Ds there must be the position of centroid in each & its resultant pressure of the loss passing through the centroid. Like the H.P.D the resultant position is also entirely 'indicative only' in the P.L.D. All these are then required to be brought into the determination as explained earlier in the heading 'H.P.D' of the article 3.2.1.

Keeping the same sign convention (as given in the Figure 3, it is shown that the loss pressures, in the P.L.D, are acting in the vertically downward direction just as similar as the H.P.D& this direction is considered +ve), the resultant pressure (W_L) & its centroid (P_L) here in this case of P.L.D can be determined by the similar methods as given in the H.P.D evaluation as followed –

3.2.2.1 BY THE METHOD OF MOMENT

Treating the term W_L& P_L as the definition as given by the H.P.D for the resultant determination, but the terms are for the P.L.D here, taking moment about the section n (Figure 4) for the entire pipeline length of 'L' considering the +ve sign for the clockwise moments & direction of the pressure losses are vertically downwards, the moment $(W_L * P_L)$ should be equal to the

$$\begin{bmatrix} \dots + (-)(H_{I-II})(\dots + L - L_{II}) \\ +(-)(W_L)_{I-II}[\dots + L - (P_L)_{I-II}] \\ + \dots + (-)(H_L)_{n-1}[\dots + L - (L_L)_{n-1}] \\ +(-)(W_L)_n[\dots + L - (P_L)_n] \end{bmatrix} \qquad \dots(14)$$

where, the suffix 'L' denotes the variables defined for the P.L.D; Y_L = position of the resultant centroid of length 'L' for the P.L.D.

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In the Eq.(14), the direction of the head-loss should be opposite to the Pressure heads of the H.P.D (Table 8). For intermediate sections if considered the reference section should be taken into the estimation determination in accordance to the sign convention & general rule of moment theory of force mechanics.

This is the equation not only for the resultant value but also for the energy or work done as explained in earlier in the heading H.P.D & by the Table 5. Like the H.P.D, the given/considered direction needs to be changed or it can though be kept as the downward direction by mentioning the –ve sign in the application.

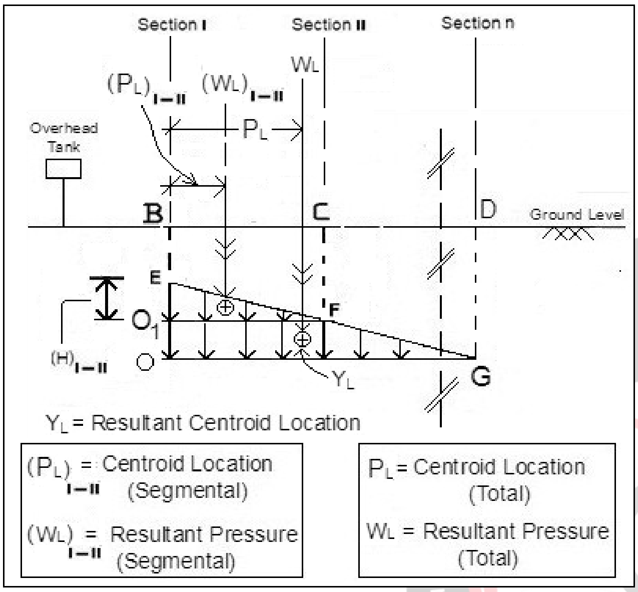

Figure 4: The Resultant & Centroid Location (P.L.D)

3.2.2.2 BY THE METHOD OF MOMENT-RESULTANT-MOMENT

As like earlier in the evaluation of the H.P.D, following is the determination –

W_L = (Moment of the resultant liquid pressure head through the sectional P.L.Ds about any reference) divided by the P_L of the entire segment of discussion under consideration.

That is, W_L is equal to,

$$(P_L)^{-1} * \begin{bmatrix} \dots + (W_L)_{II}(P_L)_{II} + (W_L)_{III}(P_L)_{III} + \\ (W_L)_{IV}(P_L)_{IV} \dots + (W_L)_n(P_L)_n \end{bmatrix} \quad \dots(15)$$

where, for the resultant centroids for the P.L.D, for the section I – II, $(P_L)_{I-II} = \left(\frac{1}{3}\right) * (L_{II})$; and, for the section II to n-th it is as, $(P_L)_{II-n} = \left(\frac{1}{3}\right) * (L_n)$.

The determination of the 'triangular' shaped P.L.D is thereby the similar methodology of the mathematics as applied in the Eq.(11) of the H.P.D evaluation (section 2.2.1.1).

In this way, the location & magnitude of the resultants are possible to be determined for the pressure diagram formed by the liquid transmission in distribution network of a town/city (Table 7 & Table 9).

And, like the Table 6, the features of the resultant in the case of P.L.D are tabulated in the Table 8 with the visionary outcome & evaluation in its determination – the Table 8 should be thereby read as the same meaning, definition & significance except the P.L.D's formation & fundamental.

Table 7: The Pressure Load (H.P.D)

The Lineal Section	Resultant Pressure Head Energy (Total), W; the reference is different at the different areal diagrams.[%]			
	Symbol	Method 1	Method 2	Method 3
0 - I	W_1	$\pm\frac{(H_0 P_I)}{P} \pm \frac{(H_I)(L_I - P_I)}{P} = \pm\frac{(H_I)(L_I - P_I)}{P}$	$\left[\frac{(H_0 + H_I)}{2} * \left(\frac{P_I}{P}\right)\right] = \left[\left(\frac{H_I}{2}\right)\left(\frac{P_I}{P}\right)\right]$	$\frac{(A_d)_I P_I}{P}$
I – II	W_2	$\left[\pm\frac{(H_I P_I)}{P} \pm \frac{H_{II}(L_{II} - P_{II})}{P}\right]$	$\left[\frac{(H_I + H_{II})}{2} * \left(\frac{P_{II}}{P}\right)\right]$	$\frac{(A_d)_{II} P_{II}}{P}$
II – III	W_3	$\left[\pm\frac{(H_{II} P_{II})}{P} \pm \frac{H_{III}(L_{III} - P_{III})}{P}\right]$	$\left[\frac{(H_{II} + H_{III})}{2} * \left(\frac{P_{III}}{P}\right)\right]$	$\frac{(A_d)_{III} P_{III}}{P}$
…	…	…	…	…
(n-1) – n-th	W_n	$\left[\pm\frac{(H_{n-1} P_{n-1})}{P} \pm \frac{H_n(L_n - P_n)}{P}\right]$	$\left[\frac{(H_{n-1} + H_n)}{2} * \left(\frac{P_n}{P}\right)\right]$	$\frac{(A_d)_n P_n}{P}$

[%] U_d= the u.d.l to be added with as its "total load"- moment into the determination of the Method 1 & Method 2; U_d = u.d.l of the H.P.D; i.e., the H.P.D area is the respective W; Note, A_d (for the section I-II) = $(H_I+H_{II})*L_{II}/2$; H_0 = 0. (Ref. Table 6).

These findings shall be helpful in guiding the design & making better control on entire evaluation & implementation.

3.2.2.3 BY THE MOMENT-AREA METHOD

In the similar way of the fundamental of the Moment-Area method as explained by the H.P.D evaluation, the following is the determination of the resultant for the P.L.D area–

The pressure loss resultant of the P.L.D for the entire pipe length 'L' is given as which is W_L equal to,

$$(a_L)^{-1} * \begin{bmatrix} \dots + (W_L)_{II}(A_{eff.})_{II} + (W_L)_{III}(A_{eff.})_{III} \\ +(W_L)_{IV}(A_{eff.})_{IV} + \dots + (W_L)_n(A_{eff.})_n \end{bmatrix} \quad \dots(16)$$

where, total P.L.D area for the pipeline length of L on its entire range of the consideration in the determination of this study $= a_L = \begin{bmatrix} \dots + (A_{eff.})_{II} + (A_{eff.})_{III} \\ +(A_{eff.})_{IV} + \dots + (A_{eff.})_n \end{bmatrix}$

Like the H.P.D, in this way of the determination of the P.L.D, the resultant pressure loss & its location is determined applying the methodology of this study& several applications of mathematics. The fundamentals of

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the findings of the P.L.D are given in tabulation in the Table 8.

It is hereby mentioned that the evaluation & determination given in the Table 6 & Table 8 should be not the only one way of the finding, rather to be as the alternative one (might be used in cross-checking in its either direction of the determination& vice-versa), of the resultant pressure of the H.P.D & P.L.D respectively.

3.3 DETERMINATION OF THE PIPE-FLOW FRICTION

This segment describes the effect of the earlier segments. There is the description of the simultaneity & spontaneity in the formation of the pressure diagrams. Also, it has been discussed of the equations related with the resultants & their locations. Prior to this resultant determination, the areal features & their actual implications over the subject matter of the liquid transmission pipeline have been discussed to explore the existence of the energy in the pipeline.

Pressure values of the H.P.D & L.P.D discussed & determined in the article 3.2 in terms of the resultants do signify the magnitude of the pressure head (both in demand & loss) to causing the load on the pipeline system of the liquid transportation. This load or pressure on the system of pipe and/or network is the given load which acting '*external*'.

This external pressure should create an internal pressure (for both the H.P.D & P.L.D) on all along the wall of the pipeline. This physical phenomenon is quite the kind of the Newton's third law. And because of this, there'd be the friction produced to be acting along the wall in the tendency to resist the given external pressure loads due to the flowing liquids. This resistive pressure (called here as '**pressure friction**') is thereby against the external pressure & it is presumably considered it to occur along the pipe wall creating an opposite & equal magnitude of the external pressure. This phenomenon might be called as '***wall friction gain***' & it is shown in the Figure 5 as the reaction diagram.

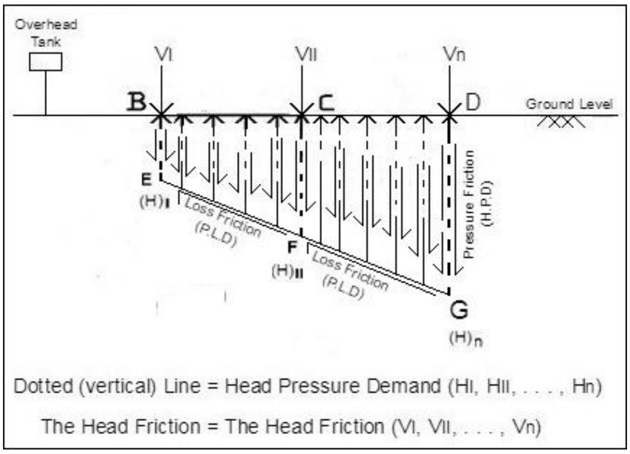

Figure 5: The Reaction Diagram

The vertically downward arrows at the section point I, II, III, . . . , n are the resistive pressure or friction so caused by the corresponding pressure heads of demand fulfillment. As these are the of frictional stress category, so their arrows are denoted accordingly like the shear stress acting on element of a soil particle. These frictions or the pipe-flow frictions are given the notation such as V_I, V_{II}, V_{III} . . . , V_n at meeting the pressure demands of H_I, H_{II}, H_{III}, . . . , H_n respectively. This is for the H.P.D.

For the P.L.D there'd also be the similar phenomenon of the wall friction gain in which the pipe friction would act along the pipe length as for the external pressure it is given to serve to. The direction & magnitude is also equal & same like the same principle of the friction pressure developed in the case of H.P.D.

3.3.1 DETERMINATION OF REACTIVE REACTION (FRICTIONAL) – H.P.D

In this, the pressure friction is determined applying the mathematics & the methodology.

Suppose,

V_I =the pressure friction along the wall to supply the liquid demand (at the section I).

V_{II} =the pressure friction along the wall to supply the liquid demand (at the section II).

Total pressure on the H.P.D (between the section I & II) $= (M)_{I-II} = \left(\frac{V_I+V_{II}}{2}\right) * (L_{II})$

Total pressure on the H.P.D (between the section II& n) $= (M)_{II-n} = \left(\frac{V_{II}+V_n}{2}\right) * (L_n)$

These pressures are given here irrespective of the unitary presentation which is not required at this stage of the methodological discussion.

Taking the moment of the reaction diagram of the reaction frictions about the section n considering the +ve sign for the clockwise moments & -ve sign for the anti-clockwise moments, W of H.P.D in vertically upward direction & the pressure frictions as reaction in the vertically downward direction (Figure 2 & 5),

$$\begin{bmatrix} \ldots + (-)V_I * (L_{II} + \cdots + L_n) \\ +(-)V_{II} * (\ldots + L_n) \\ +W_{P.F} * (L_{II} + \cdots + L_n - L_{P.F}) \end{bmatrix} = 0 \qquad \ldots(17)$$

$$\text{Or,} V_I = (-)\left(\frac{1}{L_{II}+\cdots+L_n}\right)\begin{bmatrix} \pm \cdots + V_{II}(\ldots + L_n) \\ -W_{P.F}(L_{II} + \cdots + L_n - L_{P.F}) \end{bmatrix}$$

And, the pressure friction at the section II,

$$V_{II} = (+)[W_{P.F} - V_I] \qquad \ldots(18)$$

where, $W_{P.F}$ =Total load or the total pressure friction on the reaction diagram $= \frac{(V_I+V_n)}{2} * (\ldots + \cdots + L_{II} + \cdots + L_n)$.

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In the equation, Eq.(17) & Eq.(18) would take the inclusion of the lineal loads, moments etc. of the pipe-flow span for which the sign '$\pm$' is given just for making it signified & featured. It is thereby obtained that the final sign of the equations would be on the basis of the sign '$\pm$'which could be though applied to other determinations of this study given earlier herein.

Table 8: Determination of Centroid & Its Resultant (For P.L.D)

The Lineal Section	Centroid Location		Resultant Pressure Loss Energy (Total), W_L = Moment of the Pressure Loss Energy (selectively sectional) about the reference say $H_{0\text{-}I}$, $H_{I\text{-}II}$ etc. (Figure 4), of the corresponding centroids divided by the col.3).#	Remarks
	P_L = The distance Of the pressure loss diagram (of P.L.Ds) centroids (triangular) subjected to the "section" (with reference to the initial head-loss point, & say at the head-loss $H_{I\text{-}II}$on the head-loss over the section I to II).^	Of the 'Entire' Resultant of the Pressure Energy Losses (entirely so selected) = Location of the Resultant = ∑(Moment of the P.L.D areas about the reference (so selected) divided by the total P.L.D area, ($A_{eff.}$).		
col.(1)	col.(2)	col.(3)	col.(4)	col.(5)
0 - I	$(P_L)_{0\text{-}I}$	P_L= Centroid (Total) of the entire P.L.D	$(W_L)_1$	The W_L value is of having the several fields of feasibility. It is differential to integrated, as on suitability for desired purposes.
I – II	$(P_L)_{I\text{-}II}$		$(W_L)_2$	
II – III	$(P_L)_{II\text{-}III}$		$(W_L)_3$	
. . .	. . .		. . .	
(n-1) – n-th	$(P_L)_{(n\text{-}1)\text{-}n}$		$(W_L)_n$	

^apply necessary theorems if provided with irregular boundary, over large length of consideration.

#sign convention given here depends on the 'moment' rule of mechanics.

It is thereby quite evident & determined that the pressure frictions are critically existing at the points of the withdrawal points or sections, provided $W_{H.P.D} = (M)_{I-II} + (M)_{II-n}$ or $\& W_{H.P.D} = W_{(\text{Reaction Diagram})}$ other methodological determinations as described in the article 3.2; where, $W_{H.P.D}$ = the total load on the H.P.D $\neq$ W; $W_{(\text{Reaction Diagram})}$ =Total load or the friction pressure on the reaction diagram.

3.3.2 DETERMINATION OF REACTIVE REACTION (FRICTIONAL) – P.L.D

Suppose, V_{I-II} , V_{II-n} be the friction (called here as 'loss friction') resistance offered by the transmission length $L_{I\text{-}II}$ & $L_{II\text{-}n}$ respectively. In the Figure 4 & 5, this loss friction could be recognized by the 'representative' actions of head-loss as they act towards the length of the flow along the pipe wall, though they are shown in the figure as the vertical ordinate of the head-loss presentation. This '**loss friction**' acts along the pipe length in opposite direction to & with the equal magnitude of the direction of the flow motion.

In the similar way like the article 3.3.1, considering the pipe is of the circular section of flow, the total pressure (as the loss friction) on the P.L.D (between the section I & II) is determined as,

$$(M_L)_{I-II} = \left(\frac{1}{2}\right)(V_{I-II}) * (\pi D) * L_{II}$$

&, on the P.L.D (between the section II& n) it is,

$$(M_L)_{II-n} = \left(\frac{1}{2}\right)(V_{II-n}) * (\pi D) * L_n$$

Taking the balance of the friction loss along the transmission length of the pipe for the section I – II with the prevalent 'external' head-loss, $(M_L)_{I-II} = (H)_{I-II}$

Or, $\left(\frac{1}{2}\right)(V_{I-II}) * (\pi D) * L_{II} = (H)_{I-II}$

$$\text{Or, } (V_{I-II}) = \left(\frac{2}{\pi D}\right)[(H)_{I-II}/L_{II}] \qquad \ldots(19)$$

$$\&, (V_{I-II}) = [W_L - (V_{II-n})] \qquad \ldots(20)$$

Thereby the determination of the loss friction of the sectional pipeline shows the linear variation of itself. Eq.(19) & (20) is the equations to determine the frictions along the pipe wall length.

It is here required to mention that in determining the equations of this study the unitary adjustments are given mere importance than on towards making the finding more realistic to the respective cases. If required so, the liquid property like density, viscosity, temperature of fluid etc. should be included into the required adjustments of the determination.

In this way the determinations of the 'wall friction gain' are required to be determined keeping the article 3.2 as its movement of determinable knowledge & the Table 5 as the pressure diagram on the wholesomeness.

3.3.3 STABILITY CRITERIA

Here, a discussion is given on how to make stability in the pipeline susceptible to the pressures caused by the H.P.D & P.L.D. And, the followings are the criterion –

For the H.P.D: For the section I-II, it is given as,

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- Critical Friction: $H_I = (V_I)$
- Sub-critical Friction: $H_I > (V_I)$
- Super critical Friction: $H_I < (V_I)$

For the P.L.D: For the section I-II it is given as,

- Critical Friction: $(H)_{I-II} = (M_L)_{I-II}$
- Sub-critical Friction: $(H)_{I-II} > (M_L)_{I-II}$
- Super critical Friction: $(H)_{I-II} < (M_L)_{I-II}$

It is from the range of the pressure demand & loss quite clear that H_I & its consequent H_{I-II} are the kind of the external type of the effect of V_I & $(M_L)_{I-II}$ respectively. At this point of discussion, it is recognizable that it's decisive point of fact whether there'd be the research interest in knowing the basis of this measurement of stability on behalf of the resultants or not.

Although there must be different & several criterion as well as measurements to describe the subjective discussion apart from the ways given in this study.

3.4 DETERMINATION OF PIPE FLOW ENERGY

In this discussion, the fluid energy existing in the pipeline in its fluid flow function as well as transportation is described in various angles of the research scope. In general, the subjective field of the fluid flow in a pipeline is occurred to be in association with the happening of the H.P.D & P.L.D. Within these two, the energy concept could be assessed (Figure 1 & others). The following is given with regard with this –

Let, y = H.P.D ordinate & x = P.L.D magnitude

If curve is drawn on the basis of this x & y, then the area under the curve= $A_{xy} = f(x, y)$

The nature of variation of this functional attachment in the twos is of the following two ratios abiding the mathematics involved,

$$\frac{dA}{dx} = \frac{d}{dx} f(x, y) = f'(x, y)$$

Also,

$$\frac{dA}{dy} = \frac{d}{dy} f(x, y) = f'(x, y)$$

Slope of the curve would be equal to $\theta = \left(\frac{dA}{dy} / \frac{dA}{dx}\right) = \left(\frac{dx}{dy}\right)$ = Slope of the Pipe Flowvariation by the demand, loss & etc. which is the inclined line joining the peak points (E, F, G of the Figure 1) in H.P.D & P.L.D.

For the section I-II, following three would be the determination,

$\theta = \frac{dx}{dy} = \frac{H_{I-II}}{(H_I + H_{II})/2} \ldots$ (on the basis of average).

In another way of the determination,

$\theta = \left(\frac{dx}{dy}\right) = (H_{I-II}/W) \ldots$ (on the basis of resultant centroid & pressure).

And, conversely to the consideration of the total area or load or the pressure, $\theta = \frac{dx}{dy} = \frac{H_{I-II}}{(H_I + H_{II})(L_{II}/2)} \ldots$ (on the basis of total liquid flow pressure with location).

Each of these findings should deliver the research interests which are beyond of this study. Yet, its introduction is quite given along with in the below –

For the resultant centroid & pressure, the slope equation would be as, $(dy) = \frac{W}{H_{I-II}}(dx)$

Integrating both sides,

$y = \left(\frac{W}{H_{I-II}}\right)(x) + I_1$ where, I_1 = Integration constant.

Table 9: The Pressure Loss Load (P.L.D)

The Lineal Section	Resultant Pressure Loss Energy (Total), W_L; the reference is different at the different areal diagrams		
	Symbol	Method 1	Method 3
0 - I	$(W_L)_1$	$\pm(H_{0-I}) * \left[\frac{(P_L)_{0-I}}{P_L}\right]$	$\pm(A_{eff.})_I * \left[\frac{(P_L)_{0-I}}{P_L}\right]$
I – II	$(W_L)_2$	$\pm(H_{I-II}) * \left[\frac{(P_L)_{I-II}}{P_L}\right]$	$\pm(A_{eff.})_{II} * \left[\frac{(P_L)_{I-II}}{P_L}\right]$
II – III	$(W_L)_3$	$\pm(H_{II-III}) * \left[\frac{(P_L)_{II-III}}{P_L}\right]$	$\pm(A_{eff.})_{III} * \left[\frac{(P_L)_{II-III}}{P_L}\right]$
…	…	…	…
(n-1) – n-th	$(W_L)_n$	$\pm(H_{(n-1)-n}) * \left[\frac{(P_L)_{(n-1)-n}}{P_L}\right]$	$\pm(A_{eff.})_n * \left[\frac{(P_L)_{(n-1)-n}}{P_L}\right]$

U_L= the u.d.l to be added with as its "total load"- moment in the determination of the Method 1, Method 2 is not applicable (Table 7); U_L = u.d.l of the P.L.D; i.e., the P.L.D area is the respective W_L; Note, $A_{eff.}$ (for I-II) = $(H_{I-II})*(L_{II}/2)$; $H_0 = 0$. (Ref. Table 8).

It is thereby found that the ordinate based or differential description & determination is also possible & this'd be helpful in the control over the entire flow dynamics of pipe flow & on the research of interests indeed.

IV. RESULT & DISCUSSION

1) It is a study after all which gives interesting inclusion of the fields of the application into the sector of distribution network.
2) The head-loss which is having the functional attachment with its simultaneous part is clearly understood & well explained by the formulation so determined.
3) The two areas, H.P.D & P.L.D, are described with their entire possibility of existence. These have got better dimension after applying the moment-area method. This includes & should widen the application field to

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several dimensions which are not of restrictive kind, rather evolving nature.

4) The reaction diagram is another &an responsive field of knowledge to be described. It provides more extensions of the knowledge which must include the usefulness of the point no. (2) & (3).
5) The terminology could be made with some better philosophy to have the knowledge broad & diverse.
6) Dissemination in the concerned field of the subjective discussion ha clearly described the notation-wise presence of the useful understanding, differential/sectional derivatives & its introduction..
7) The study has provided how the areas are having their meaningful implications in the mechanics/the operation of the head-loss phenomenon.
8) The critical conditions have been described which is related with stability of the entire system.
9) Applying mathematics it has also been shown how the areas act in themselves in the entire system & how the slope of their variation of existences could be.
10) It is mentioned here that there'd be the energy existing in the pipe network on due event of the liquid's flowing. How this energy which has been described in their respective equation could be so formed should be the future scope of this study.
11) Entirely, this study is the complete set of knowledge in the event of the head-loss & its H.P.D covering several mechanics in its discussion amongst its vastness of evolving attributes of the study itself.

V. CONCLUSION

(1) This study is entirely an analysis with prudent application by the property of itself.

(2) It is totally a different methodology applied in the description of the mechanics of the subject.

(3) The application of the conventional centroid & the resultant theory has opened the numerous possibilities of the hydraulic diagrams as a field of multi-various application.

(4) There must be the various future scopes of this study, described in across this study from place to places, of which that are not explained also, rather comprehensive & recognisable &of the diverse kind beyond the subject of application.

(5) Graphical analysis could be done to become understood of the knowledge of the profile of the findings of this study.

(6) There is also an interesting fact of concern about the energy evolvement. This is shortly described using mathematics. Thereby this energy could be collected, stored & produced to useful nature by maintaining the pipeline network with the necessary arrangements. The sectional outlets/junctions points like I, II, III. . . n-th (as shown in the Figure 1) might be the points of the source of the energy collection using electrical appurtenances.

(7) In addition to the energy production from the network of pipelines, there are the reactions found acting along the pipeline (both for the H.P.D & P.L.D). This extraction as described in this study should explore the application of how a good balancing & stable design could be done.

(8) Pipe material is also possible to be chosen & selective over the finding of the energy so produced to erode the pipe material on account of the reactive pipe friction.

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