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CNESTEN

DEVELOPMENT OF RADIOMETRIC METHODS FOR OPTIMIZATION OF PHOSPHATE TRANSPORT PROCESS BY "SLURRY PIPE"

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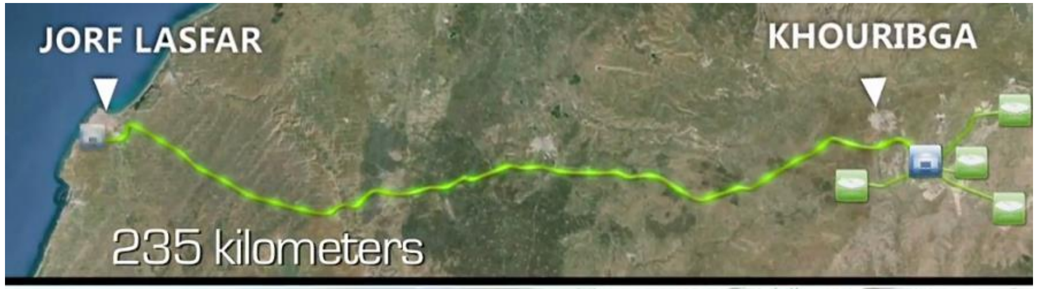
INTRODUCTION

- Morocco can now lay claim to the largest phosphate slurry pipeline system in the world.
- The system consists of several pipelines totaling 235 km in length. and transports 4400t/h of phosphate ore
- The main delivery pipeline is 187 km long
- The slurry pipeline represents an efficient transport system, competitive and ecologically profitable.
- With a total of 235 km of pipeline, Morocco will produce 38MT/Y of phosphate with a logistic cost reduction of 90%



WHY SLURRY PIPELINES ?

Slurry pipelines have following advantages:

- It can be able to move large amounts of coal over long distances.
- Efficient cost with minimum potential for en-route environmental disruption.
- Operating costs for labor is low.
- More environmentally friendly

Two major disadvantages of slurry pipelines are:

- Water requirements.
- Low degree of operational flexibility.

SLURRY TRANSPORTATION BY PIPELINE

Slurry Pipeline project needs its own specific study based on following

- Ore type
- Ore characteristics
- Water availability
- Terrain conditions

Pipelines can be built in a variety of terrains, but it is in mountainous regions that pipelines becomes particularly attractive

HISTORICAL DEVELOPMENT OF SLURRY PIPELINES

Product	Location	Length (km)	Diameter (mm)	MTA
Coal	Black Mesa, Arizona	439	450	4.8
Iron concentrate	Samarco, Brazil	395	500	12
Copper Concentrate	Alumbrera, Argentina	316	150	0.8
Copper Concentrate	Antamina	302	200 - 250	2.2
Coal	Belovo-Novosibirsk, USSR	262	525	3
Copper Concentrate	Collahuasi, Chile	203	175	1
Phosphate Concentrate	OCP, Morocco	187	900	38
Coal	Consolidation, Ohio	174	250	1.3
Copper Concentrate	Escondida, Chile	167	150 - 175	2.0
Copper Concentrate	OK Tedi, PNG	156	150	0.6
Phosphate Conc.	Vernal, Utah	153	250	2.9
Phosphate Conc.	Simplot, Idaho	138	225	1.9
Copper Concentrate	Los Pelambres	120	175	1.1
Ramu	Long distance - ore	120	600	3.4
Copper Concentrate	Freeport, Indonesia	119	100 - 125	1.3
Iron concentrate	Jian Shan, China	105	225	2

Tab. 1: Examples of Slurry Pipelines Built Since 1957

THE STUDY CONTEXT

The slurry pipelines platform is very complex by :

- Its different mechanical components,
- The particularity of the fluid
- And the variable conditions of flow.

The application of radiation techniques on the phosphate slurry pipe requires:

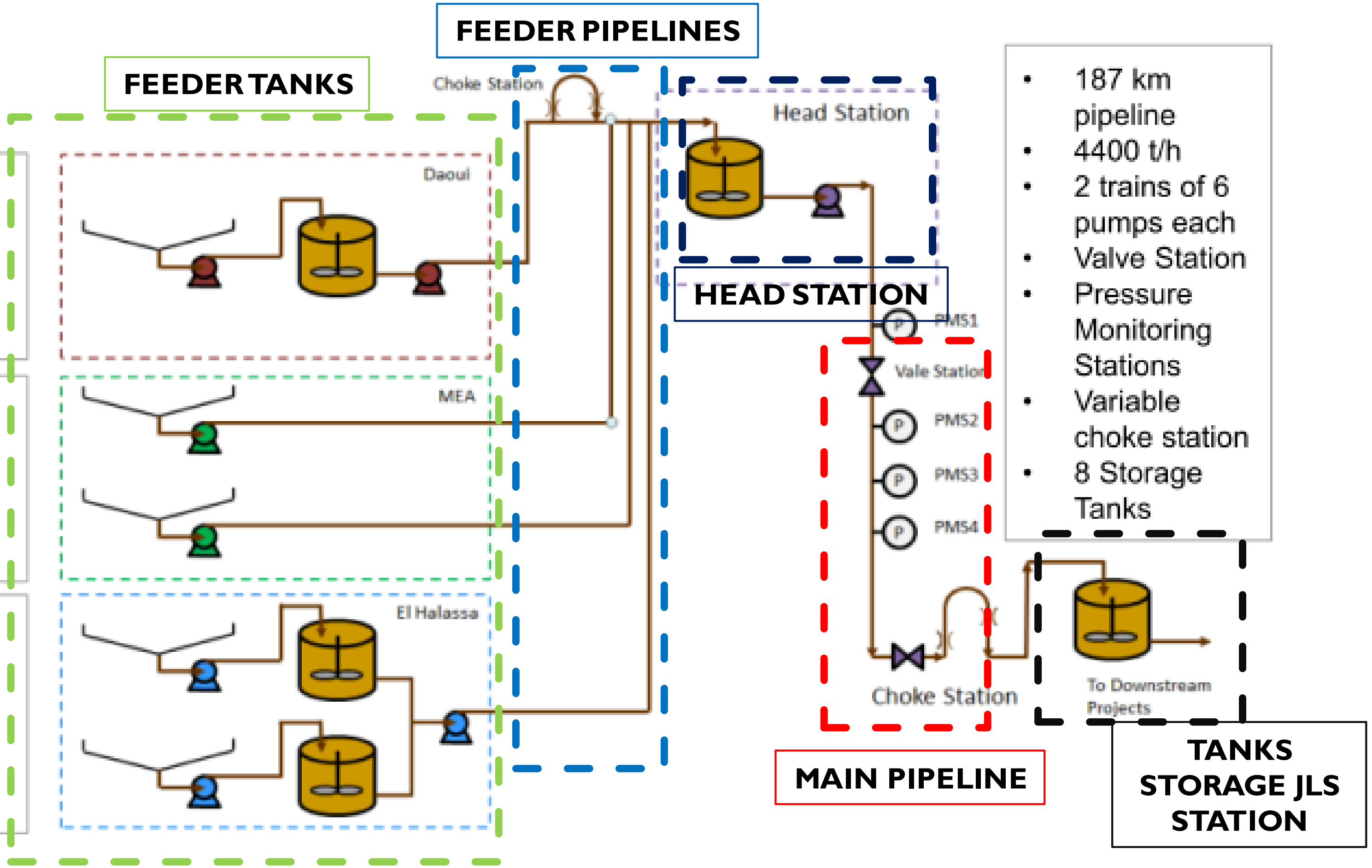
- first a well understanding of how the slurry pipe system is designed and a basic knowledge on slurry mixtures behavior inside such equipment.

SLURRY PIPE SYSTEM DESCRIPTION

- 22.2 km pipeline
- 1400 t/h
- 2 trains of 4 pumps each
- Variable choke station

- 1.8 km pipeline
- 700 & 1400 t/h
- Utilises thickener underflow pumps

- 14.9 km pipeline
- 1500 t/h
- 2 trains of 5 pumps each



- 187 km pipeline
- 4400 t/h
- 2 trains of 6 pumps each
- Valve Station
- Pressure Monitoring Stations
- Variable choke station
- 8 Storage Tanks

SLURRY PIPE SYSTEM DESCRIPTION

FEEDER TANKS

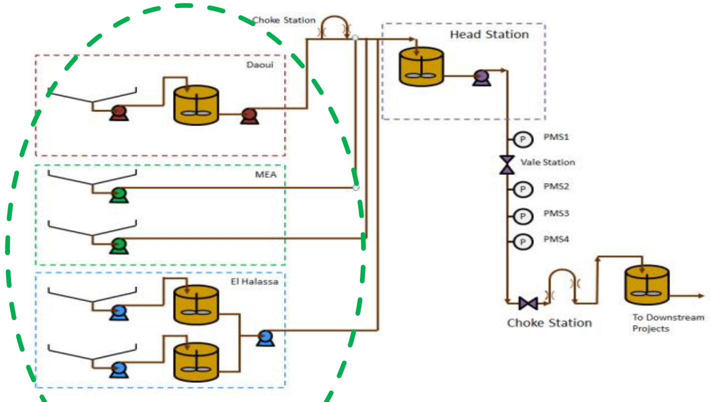


Figure 1. Main Pipeline Components

- The raw phosphate, from different mines in Khouribga, is routed to four processing units (leaching and flotation, 6,300 m3 each)

SLURRY PIPE SYSTEM DESCRIPTION

FEEDER TANKS

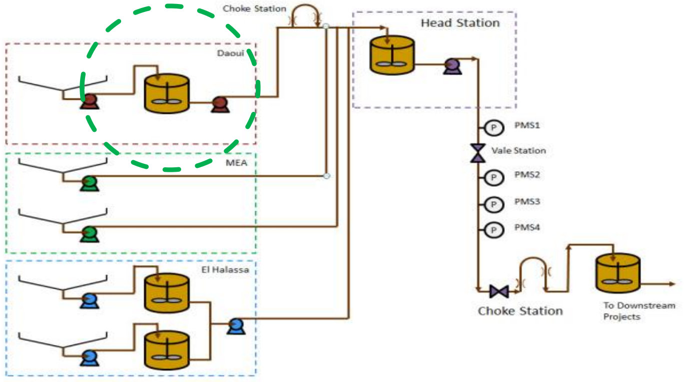


Figure 1: Main Pipeline Components

- Phosphate prepared for transport via (Slurry Pipeline). These units are equipped with milling systems and sludge settling (thickeners) to prepare phosphate pulp for hydraulic pipeline systems.

SLURRY PIPE SYSTEM DESCRIPTION

FEEDER PIPELINES

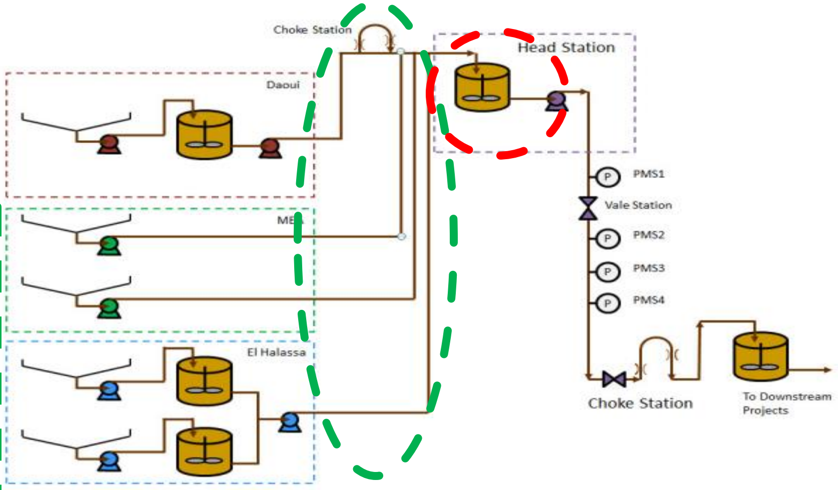


Figure 1: Main Pipeline Components

- The ground pulp is thickened and stored in tanks at the exit of the concentrating factories and pumped via pipelines to the secondary collection station called **"head station".**

SLURRY PIPE SYSTEM DESCRIPTION

HEAD STATION

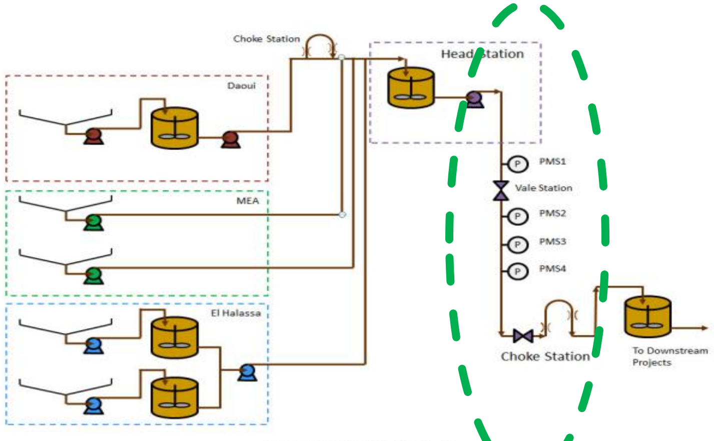


Figure 1: Main Pipeline Components

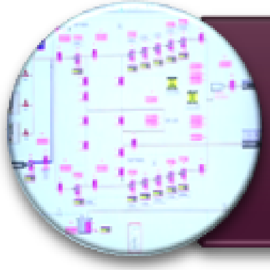
- Phosphate pulp supplies the main pipeline (900mm in diameter coated steel)
- 187 km length, which provides hydraulic transport from Khouribga to JorfLasfar chemical site.
- 4 secondary pipelines (350-500 mm diameter) of 48 km length are connecting concentrating factories to the head station
- The final station at JorfLasfar comprises ten storage tanks for the reception and distribution of phosphate pulp, with a control system.

SLURRY PIPE SYSTEM DESCRIPTION

MAIN PIPELINE

Khouribga-JorfLasfar pipeline is completely buried to a depth of two meters.

It is equipped with four intermediate pressure control stations, located every 40 kilometers, to provide direct pressure data required for the control system.



The pipeline is also equipped with a system of control and data acquisition (SCADA) to allow operators to manage, monitor and carry out all operations.

SLURRY AND SLURRY FLOWS

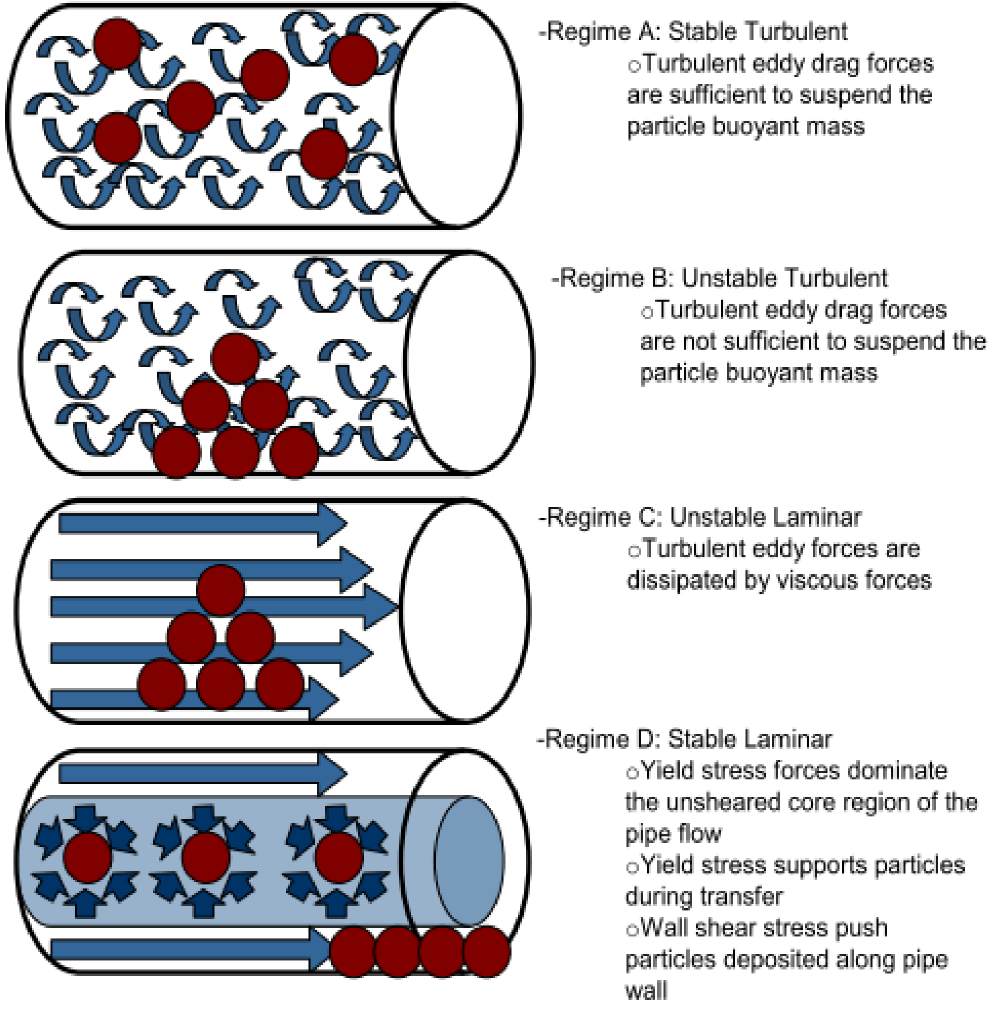
Slurry

- Slurry is essentially a mixture of solids and liquids; Its physical characteristics are dependent on many factors such as:
- size and distribution of particles, concentration of solids in the liquid phase, 25-65%
- size of the conduit (pipe diameter),
- Level of turbulence,
- temperature,
- and Viscosity of the slurry (absolute or dynamic viscosity of the carrier).

SLURRY AND SLURRY FLOWS

Slurry flows

- The flow of slurry in a pipeline is much different from the flow of a single phase liquid.
- A two phase mixture, such as slurry, must overcome a deposition critical velocity or a viscous transition critical velocity. If the slurry's speed of flow is not sufficiently high,
- The particles will not be maintained in suspension. On the other hand, in the case of highly viscous mixtures, if the shear rate in the pipeline is excessively low, the mixture will be too viscous and will resist flow



MIXTURE CLASSIFICATION

Homogeneous (d ≤ 40):

- Low solid concentration   Newtonian
- High solid concentration Non-Newtonian
- There is little change in concentration within the pipe cross section

- concentrate slurry after undergoing a process of grinding and thickening. Particles are then very fine and the mixture is at a high concentration (50–60% by weight).
- As the concentration of particles is increased . the mixture becomes more viscous and develops non-Newtonian properties.
- Typical particle sizes for homogeneous mixtures are smaller than 40μm to 70μm (325–200 mesh), depending on the density of the solids.

MIXTURE CLASSIFICATION

Pseudo-homogeneous (40 μm ≤ d ≤ 150 μm)

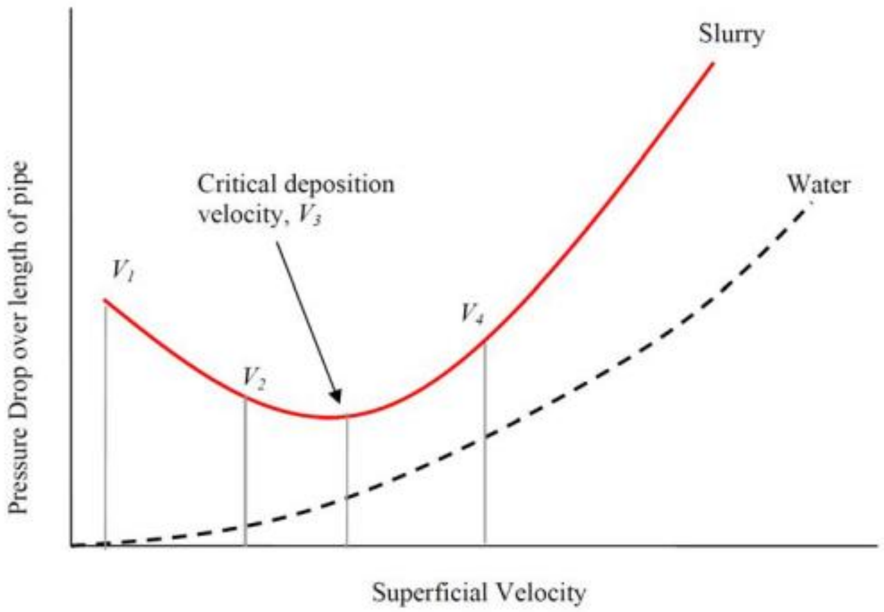
- Under turbulent condition, the mixture can be transported with a uniform solid concentration distribution across the pipeline .

Heterogeneous (0.15 mm ≤ d ≤ 1.5 mm)

- For acceptable transport velocities, a solid concentration gradient exists over the cross section of the pipe (vertical plane) .

SLURRIES CRITICAL VELOCITIES

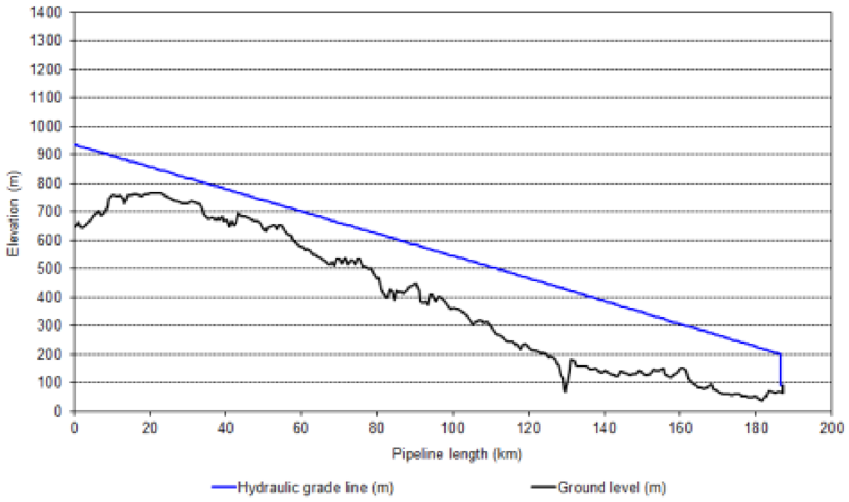
- V 1 : velocity at or above which the bed in the lower half of the pipe is stationary. In the upper half of the pipe, some solids may move by saltation or suspension.
- V 2 : velocity at or above which the mixture flows as an asymmetric mixture with the coarser particles forming a moving bed.
- **V 3 : velocity at or above which all particles move as an asymmetric suspension and below which the solids start to settle and form a moving bed. This velocity corresponds to the critical velocity**
- V 4 : velocity at or above which all solids move as a symmetric suspension.



CONTROL OF THE MAIN PIPELINE

Control of the pipeline must ensure:

- **No slack flow** on the predominantly downhill route profile
- **High enough velocity** to avoid solids deposition on pipe invert
- **Turbulent** rather than laminar flow
- **Flow rate and pressure** within the design limits



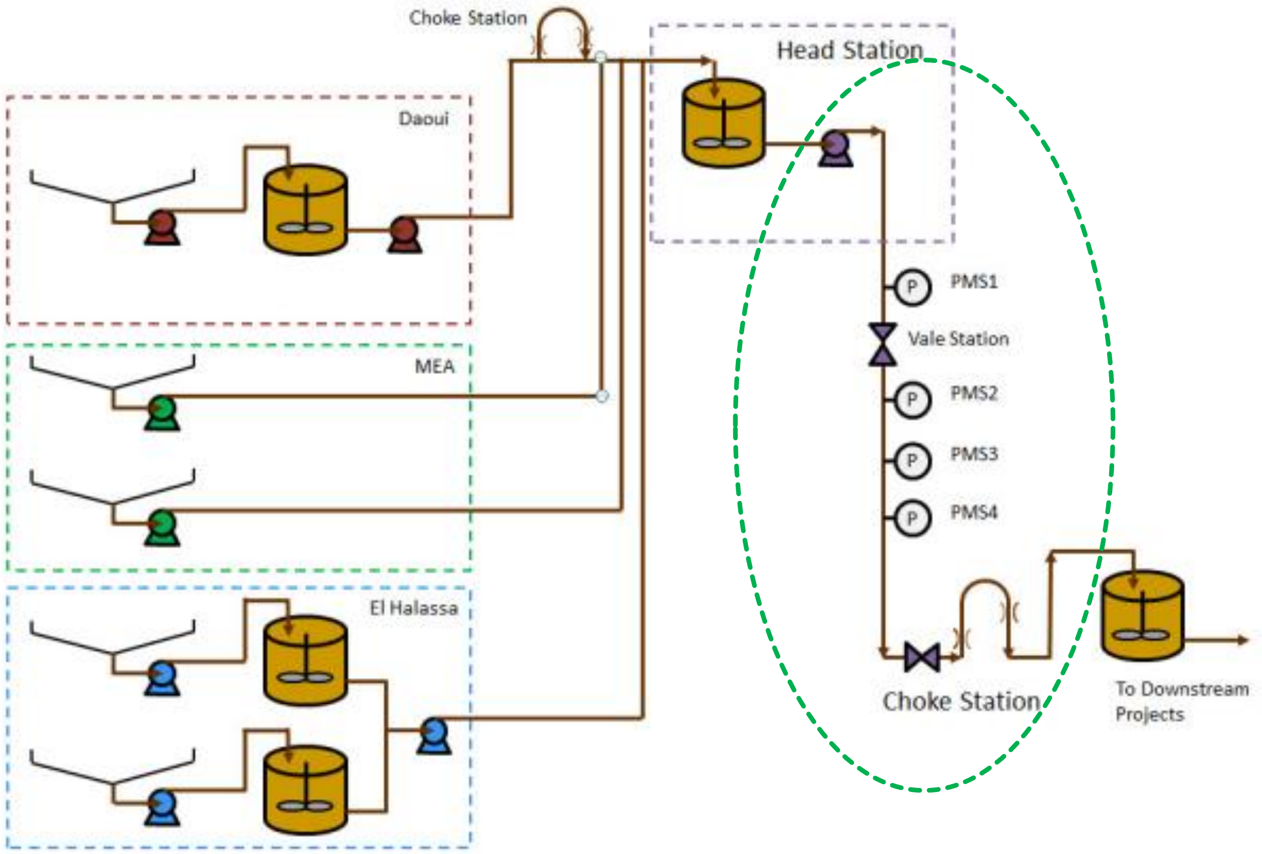


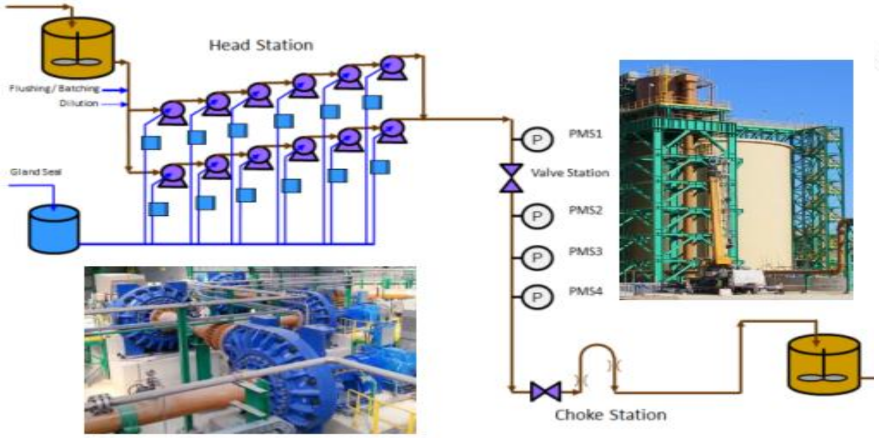
Fig 8: Main Pipeline composents

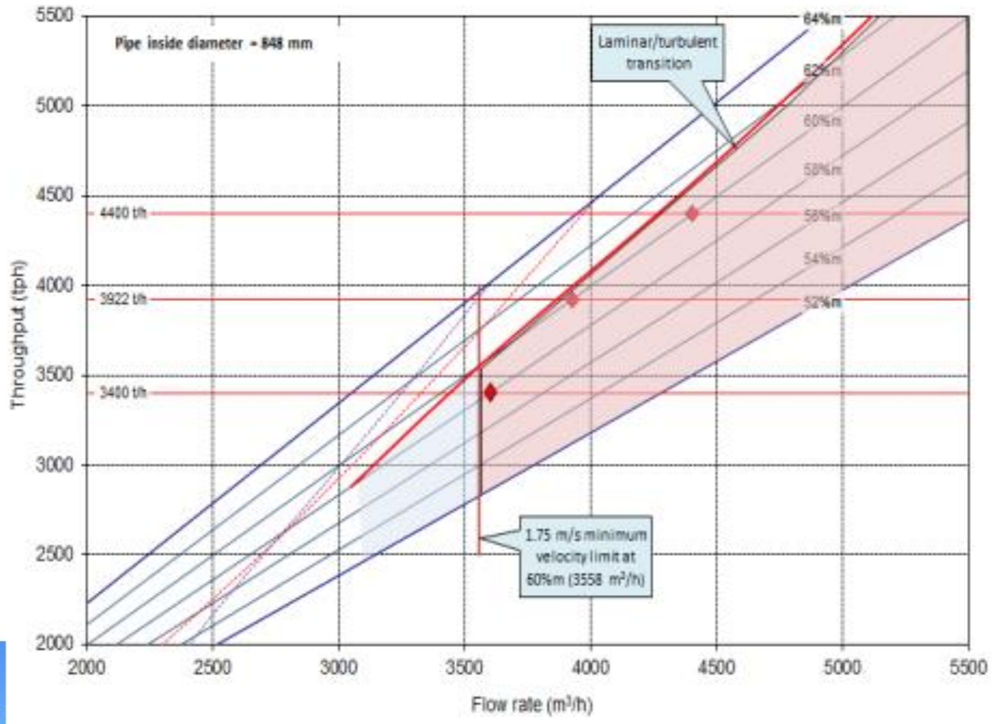
CONTROL OF MAIN PIPELINE

- The system must accommodate a wide range of operating conditions while satisfying the design criteria

Instruments used for control and monitoring of the overland pipeline:

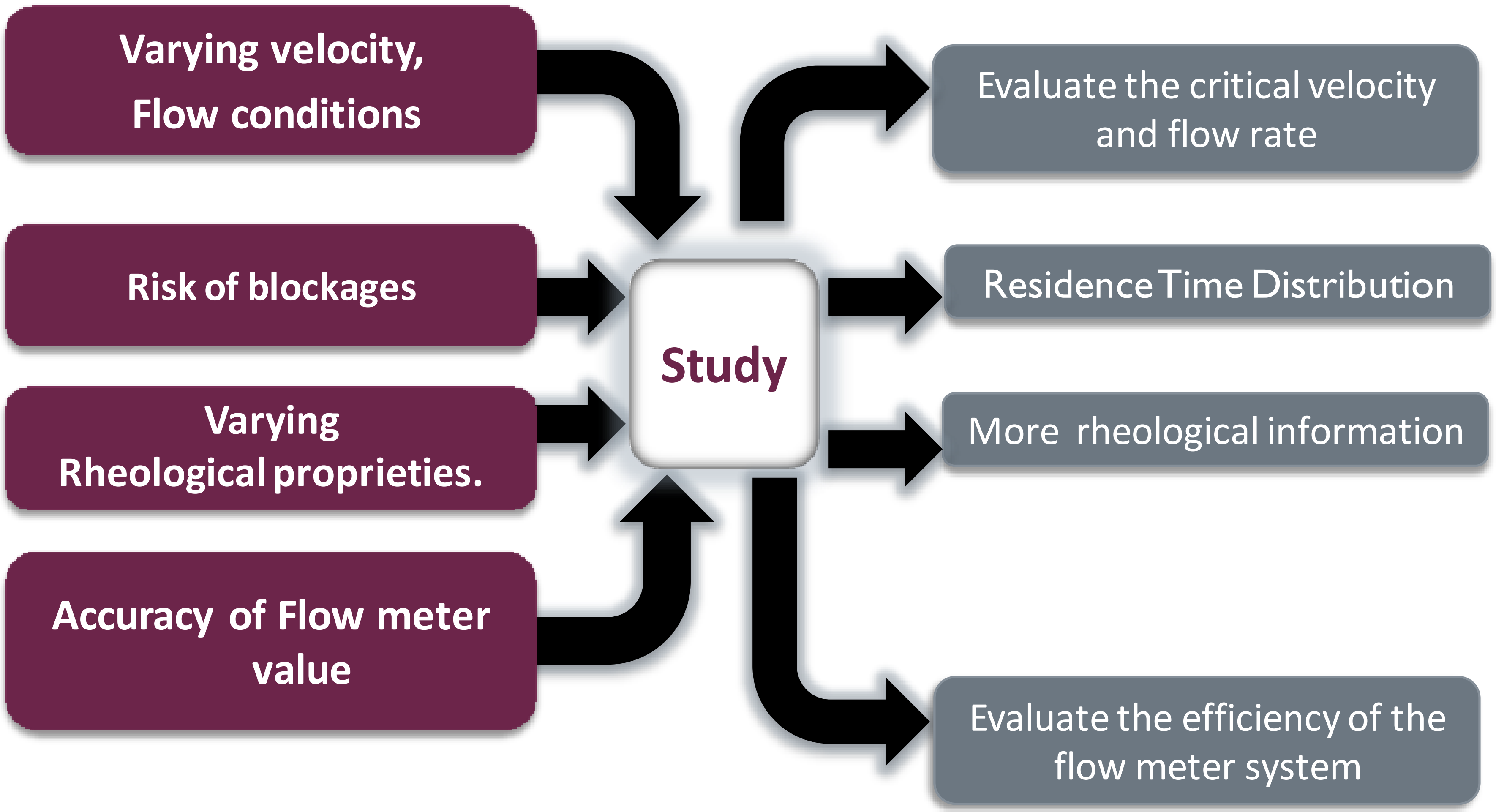
- Tank level transmitter and level switches
- Pressure transmitters
- Flow meters
- Density meters
- …





PROCESS ENGINEERING NEEDS AND PROPOSAL STUDIES

The new slurry pipe installed raises new challenges for radioisotope technology as applied to phosphate industry.
it is the first time such a material is transported by pipe over such long distances and the risk of blockages cannot be neglected.



PROCESS ENGINEERING NEEDS AND PROPOSAL STUDIES

The radiotracer study scheduled for the next three months will concern

1st

THE EVALUATION OF THE FLOW RATE OF THE SLURRY AT DIFFERENT POINTS AFTER THE HEADING STATION

2sd

SLURRY PIPE WILL BE STUDIED IN ORDER TO EVALUATE THE CRITICAL VELOCITY AND/OR TO MEASURE THE RTD OF THE FLUID ACCORDING TO THE NEEDS OF THE END USER

DEVELOPMENT OF TOMOGRAPHY SYSTEM FOR CORROSION INSPECTION

The pipeline is DN 450 steel piping with high density polyethylene (HDPE) internal lining.

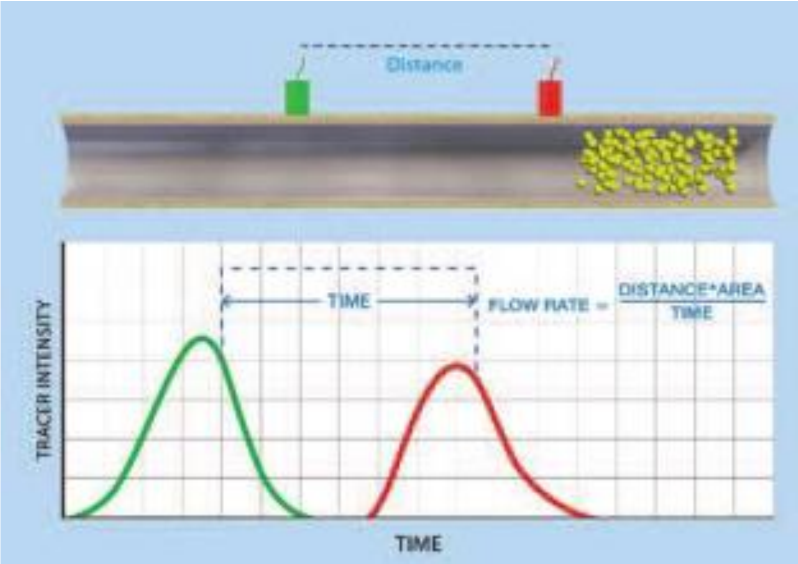
EXT DIAM 900mm)

The results compared to the measurements given by the flow meters in place. This will allow the process engineers to evaluate the efficiency of the installed equipment.

1st : RADIOTRACER APPLICATION (FLOW RATE)

A field radiotracer investigation consists, in brief, of the following main steps :

1. Design of tracer strategy together with processing engineers
2. Selection of tracers
3. Tracer mixture preparation, calibration
4. Selection/design of tracer injection and sampling procedures
5. Tracer injection
6. Data evaluation
7. Reporting of results.



Tracer principle

1st : RADIOTRACER APPLICATION (FLOW RATE)

- Radioactive tracer s are used for the precise determination of the flow rate
- Measuring the velocity or the flow rate of these components is difficult and frequently requires the use of non-invasive methods

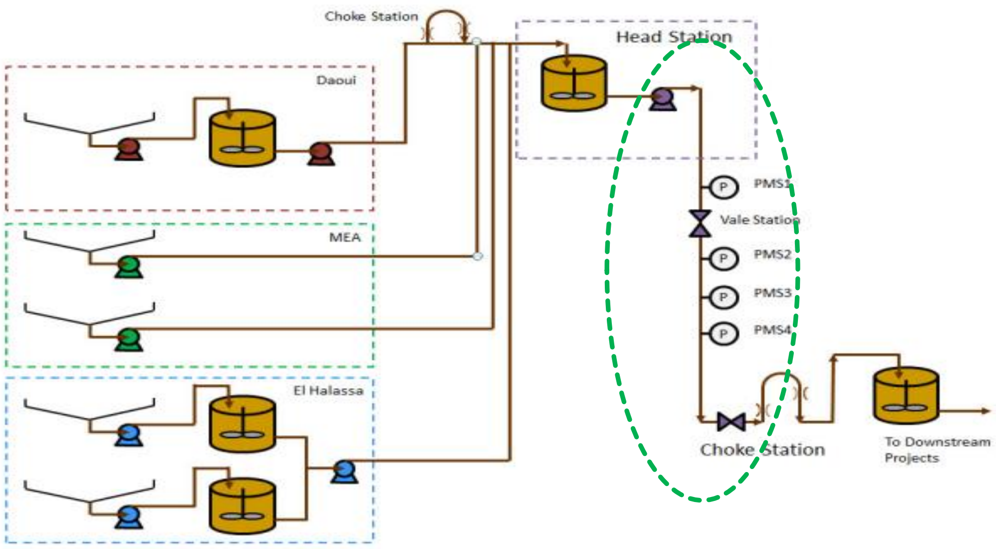
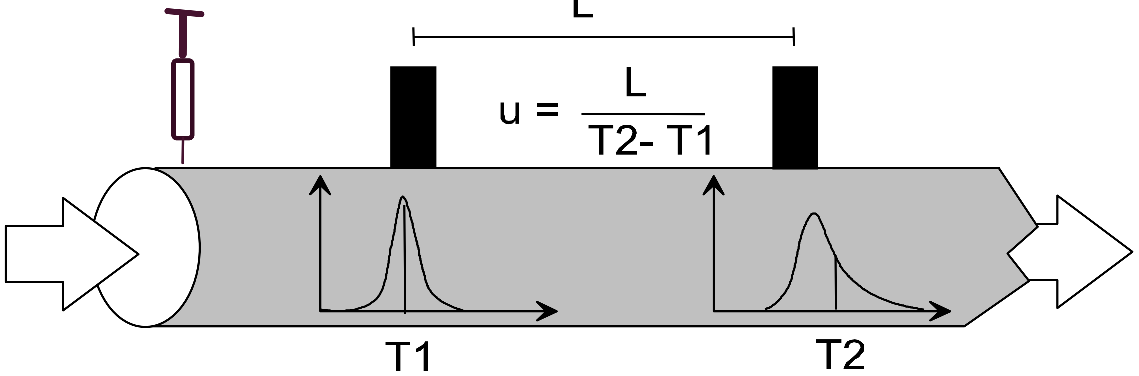
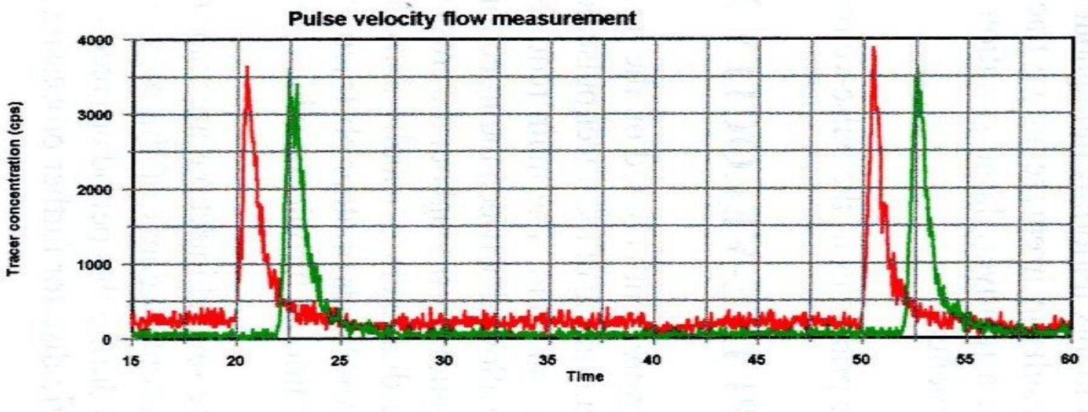


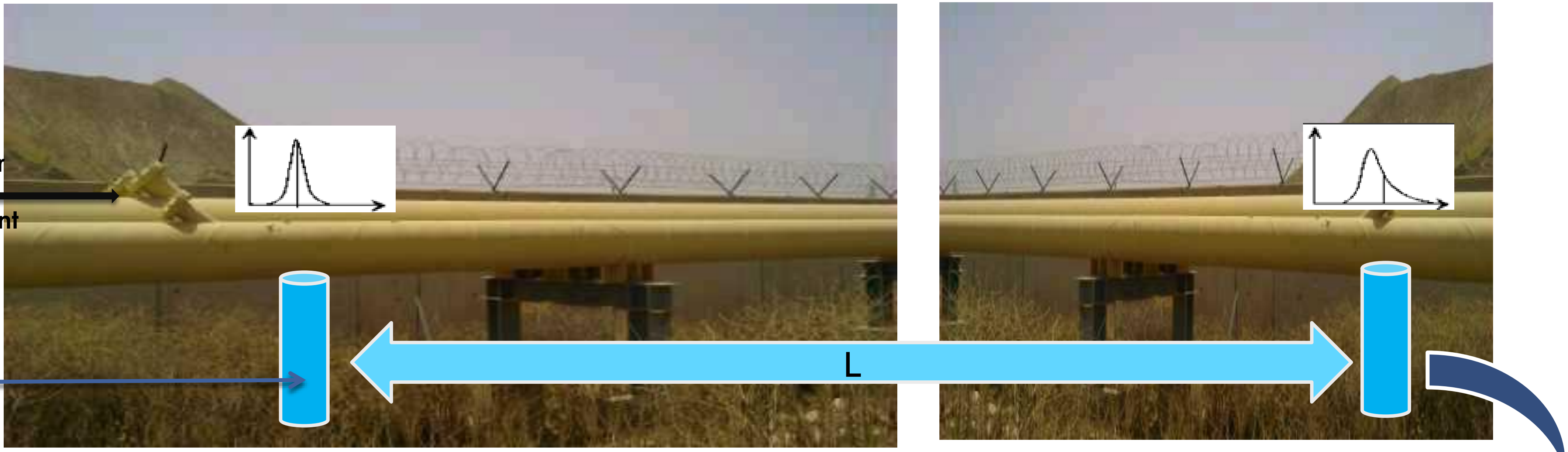
Figure 1: Main Pipeline Components





1st : RADIOTRACER APPLICATION (FLOW RATE)

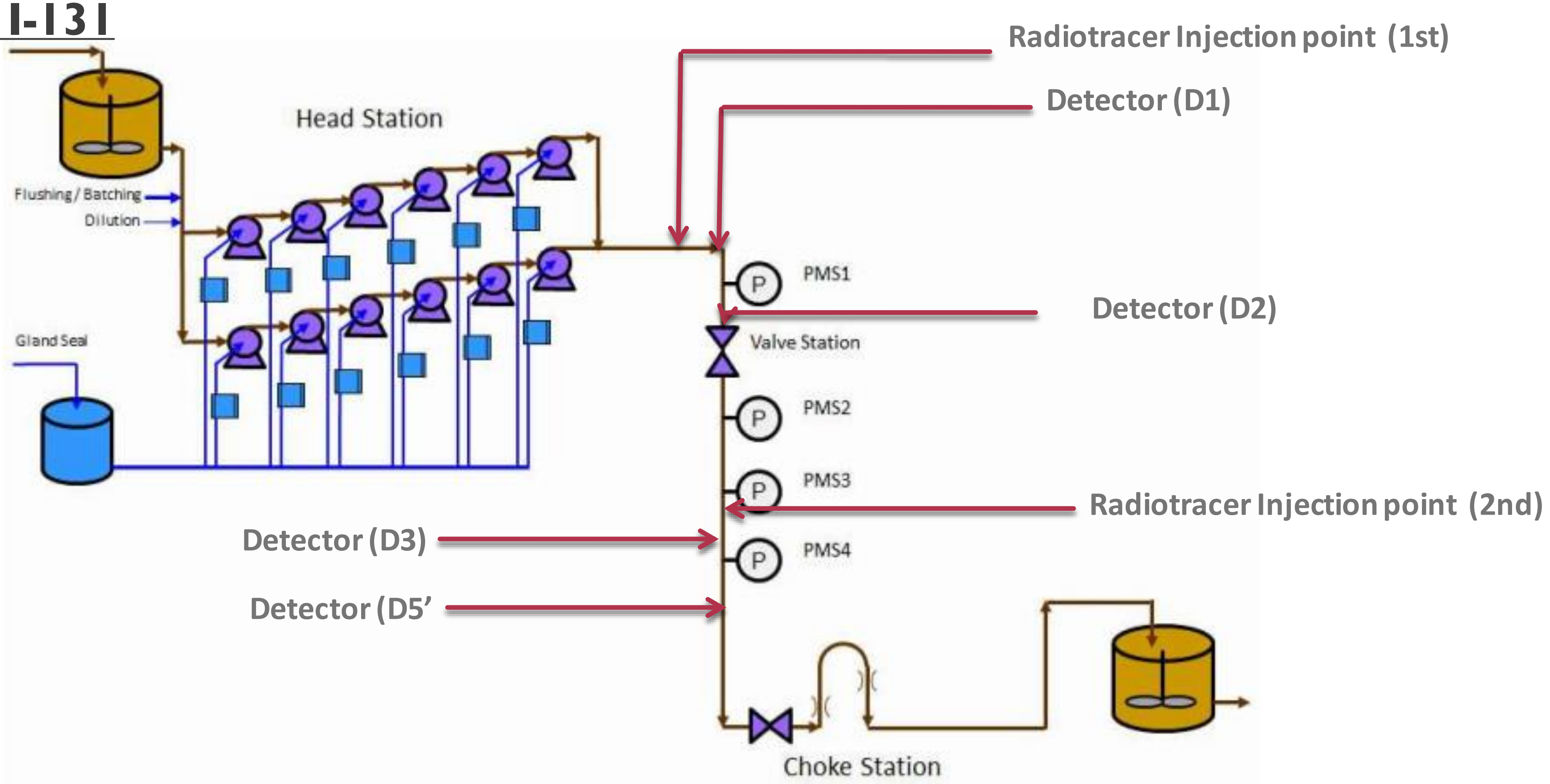
FLOW MEASUREMENT TECHNIQUE " ALLEN METHOD " OR PULSE VELOCITY



The ALLEN method generally allows for average flow measurements with accuracy better than ± 1%,

1st : RADIOTRACER APPLICATION (FLOW RATE)

- **Radioisotope I-131**

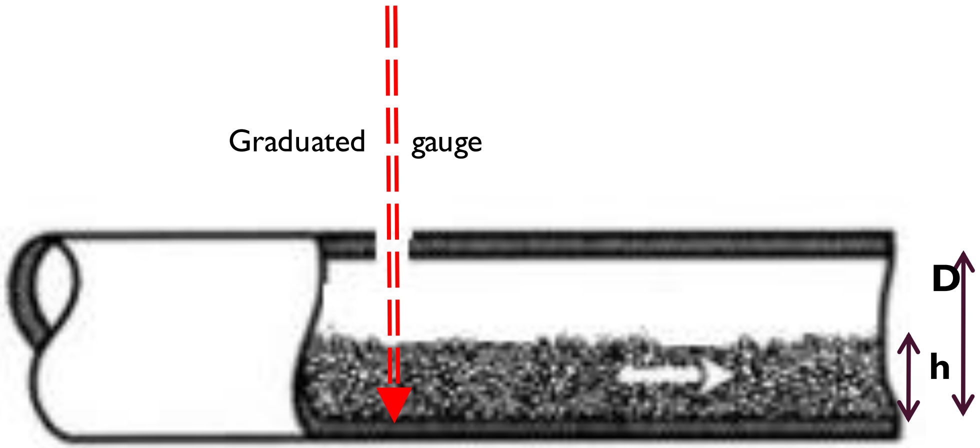


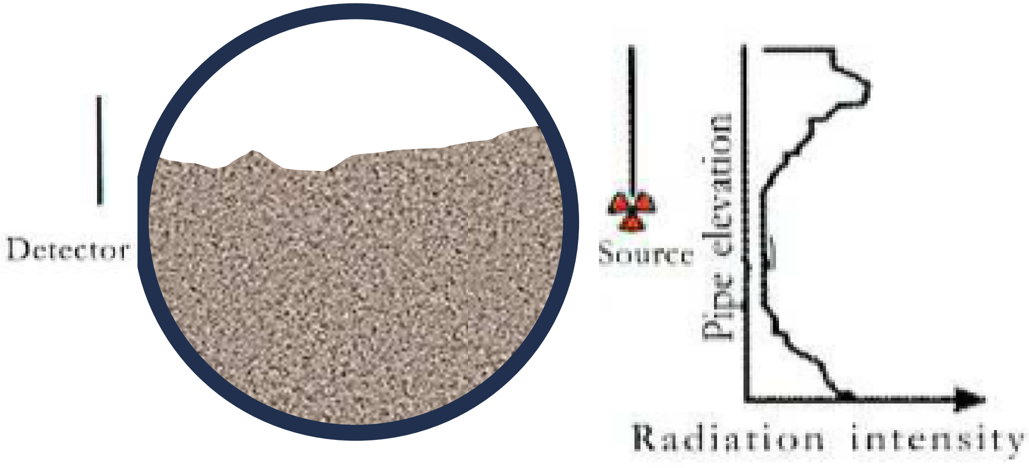
The injection of tracers can be realized by various manners: very fast injection, injection with constant flow, injection in a very high-pressure

1st : RADIOTRACER APPLICATION (FLOW RATE)

THE PROBLEM:

- The pipeline section not completely cover by the slurry phosphates
- To measure real volume we will determinate the real section:





Pipe scanning

$$Qr = L * Sr / T$$

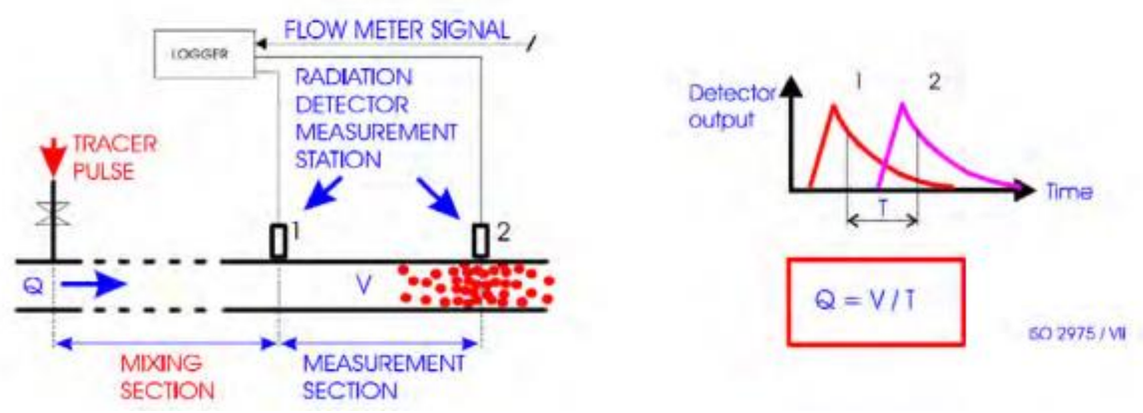
COMPARAISON WITH THE MEASUREMENTS GIVEN BY THE FLOW METERS IN PLACE

- **Calibration with the radiotracer transit time method :**

Transit time method is commonly used in calibrating flow meters in processing pipes in closed conduits.

Covers a very large range of flow speeds, and reaches a small uncertainty without disturbing the process.

The distance between injection and measuring sections should be great enough to achieve adequate mixing of the tracer with the water flowing in the conduit.



This technique is already accepted as standard for flow meter calibration in several countries. Better than 1% accuracy is achievable.

1st : RADIOTRACER APPLICATION (FLOW RATE

This experimental study will take place in the next three months

The results will be exchanged with the tracer community interested

Your collaboration and your recommendations kindly requested.

Thank you for your attention