LDS CONCEPT BASED ON REMOTE SENSING PETROLEUM PIPELINE SEEPS DETECTION IN DEEP

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Abstract

Pipeline is an efficient and economic transportation means for petroleum. However, risks associated with leakage of petroleum transportation are still high. In practice, slightly more than two million kilometers petroleum pipelines are feeding refineries and providing services to the need of business around the world. In each of the both technical and environmental issue, Leak Detection Systems in short LDSs are being part of essence of the pipeline network. From the case of technical issue LDSs specifically are going to develop to provide reliable process. In the same way the result of real-time monitoring of spillage is preventing the course of pollution and decreasing the time to fix pollution respectively. Nowadays, LDSs have been inset of detecting spillage by the systems of Software and Hardware, Remote sensing and Satellite imagery followed by Bio-mimicry method. Many pipeline companies operate with legacy LDSs and also many other new LDSs to keep environmental clean and operational safe. Comparative methods also provide the need of company beneficiary based on strength, weakness of each existing methods. In the following pages LDSs are well discussed. It has focused on important keys of Capabilities and limitations of current LDSs, Regulatory requirement as well as Department of Environment (DOE) and International Petroleum Industry Environmental Conservation Association (IPIECA), and advance leak detection technology. Furthermore, in real-world applications adaptability of detection systems are evaluated from the series of parameters according to the ISO and Standards. It helps decision maker with choosing one or the series of high-tech tools for a new pipeline projects and existing hotlines individually aim to detecting leak place accurately and inexpensively.

Keyword: LDS, Petroleum Pipeline Transportation, Thermal Remote sensing

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Introduction

It is generally accepted that pipelines to be much safer for transporting large volume of oil over large distance[1] rather than other variable alternatives such as truck trailer, railroads and shipping. In theory therefore, it is the best option from the environmental and safety perspective[3][2]. However, residual impacts and risks are inevitable from seeps of the petroleum pipeline transportation[3]. In practice, LDSs performance is pertained on geo-location of pipeline corridors, phase shift or single phase process and quality of application engineered. It is therefore a real-time and well designed LDS application is essence to the pipeline[4]. Figure 1 illustrates general point of schema of instrumentation in case of detecting small leaks location and existing leaks detection.

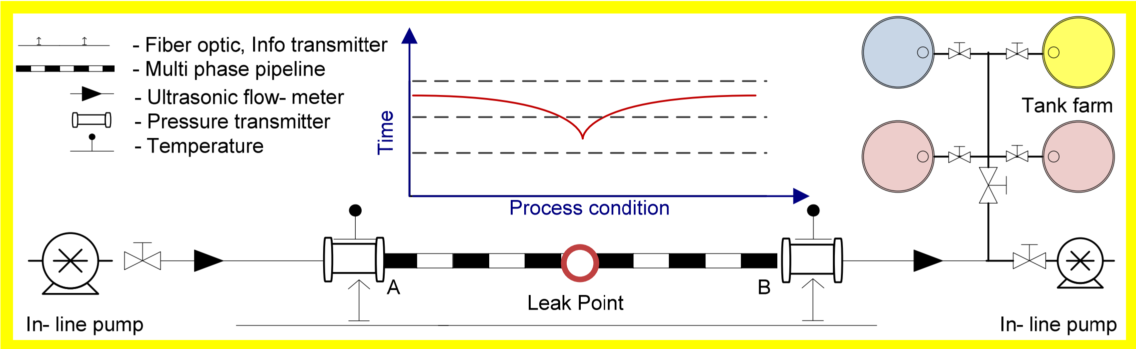

Figure 1 : Scheme of instrumentation available on pipeline stream

Basically, leak detection Methodology is based on the theory that if a leak happens in the pipeline, the pressure in the line drops. If the decreases are more than normal level, leak alarm generates accordingly. Advance technology offers statistical model of both flow and pressure measurement named statistical techniques. The performance of leak detection system varies significantly, but the best technology may not work properly if engineered poorly[5].

Two main types of systems are available for continuous pipeline monitoring. The first type is simple to deploy. It can only detect large leaks. If this system calibrates for small leak detection, false alarms will occur frequently. A typical example of this type of leak detection system is the Mass or Volume balance method. The second type can detect small leaks but they were complicated to build and extremely difficult to maintain. For

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[3] Statistics from the US Association of Oil Pipe Lines (AOPL) show an average spill amount of around one gallon per million barrel miles – equivalent to less than one teaspoon per thousand barrel miles. The European experience has been similar, with Conservation of Clean Air and Water in Europe – CONCAWE- reporting an average net spillage (the residual amount of oil left in the environment following clean-up) of two parts per million (or 0.0002%) of the oil transported through up to 30,800km of pipelines over a period of 25 years .
(www.caspiandevelopmentandexport.com)

instance Dynamic model-based systems are typical example. The result of removing those deficiencies from existing systems was statistical pipeline leak detection system software. According to the report from the mentioned system offered by ATMOS™, during all of the tests in pilot plant, the responses of the system are monitored closely[5]. The minimum leak created was 0.5% and the maximum leak 55%. All leaks created during the field tests were detected and leak size and location estimates were given.

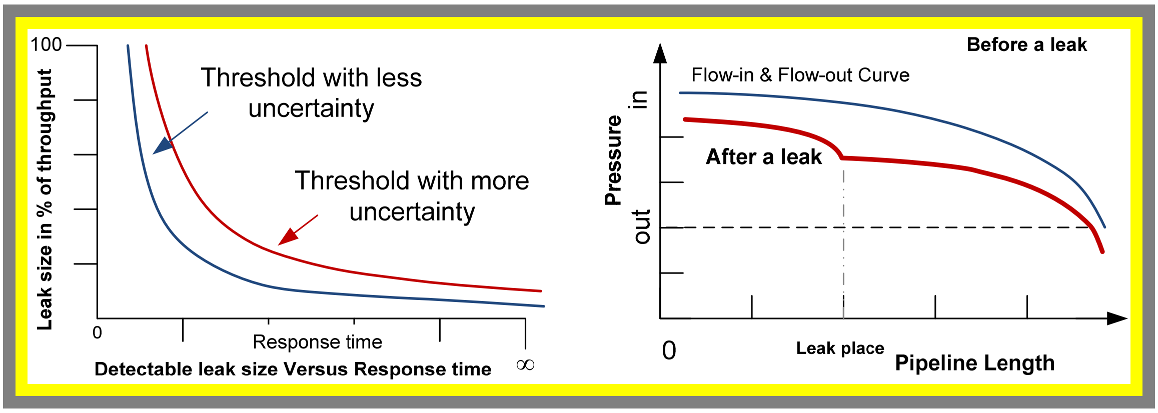


Figure 2: Detectable leak size Vs response time is shown on the left and leak place on the right

In December 2000, Esso Petroleum Company Limited tested ATMOS™ pipe on their West London Phase-shift product Pipeline Network by the generation of 18 controlled leaks. The pipeline network is used to transfer petroleum to Heathrow, Gatwick airports and two other customers. It consists of three main segments of varying diameters and has a total length of 218 Kilometres. The shortest detection time was 1 minute that was for shut-in leak of 24000 liter per hour. In contrast the longest detection time was 61 minutes during transient operation conditions for leak of almost 3000 liter per hour. Leak location accuracy will depend on following main factors for instance; number and locations of the pressure meters available, accuracy of pressure meters used, accuracy of flow meters used and Sample interval.

All in all, two major problems are defined with current situation. The first, according to the Figure 2 large leak can be detected quickly and have a short response time. In contrast, small leak not detectable and have a response time of infinity. The next is detecting existing leak during slack line conditions. It cannot be detectable.

Finally, the main objective is developing a model to pinpoint leak place accurately and inexpensively. It supposed to help decision maker with choosing one or the series of high-tech tools for the existing hotlines or a new pipeline projects.

Methodology

Structure is designed based on the characteristics of pipeline and corridor. In real world companies want to tackles a reliable and safe operation with existing infrastructure as well as good elective choice for new projects. Figure 3 illustrates short state of LDSs activities. Some traditional LDSs and the method of new technologies are classified in three categories according to the physical principles of the corridor.

For instance, the Statistics model, and Software/Hardware application may be purchased to new project, however existing pipelines may be start with novel of GIS/RS or Bio-application with suspecting leakage. In the following the robust techniques are discussed and classified as Visual and External leak detection from hardware, FPC and MVB from software, Spectral Scanner and thermal infra-red from GIS/RS including Bio-mimicry from "C" respectively.

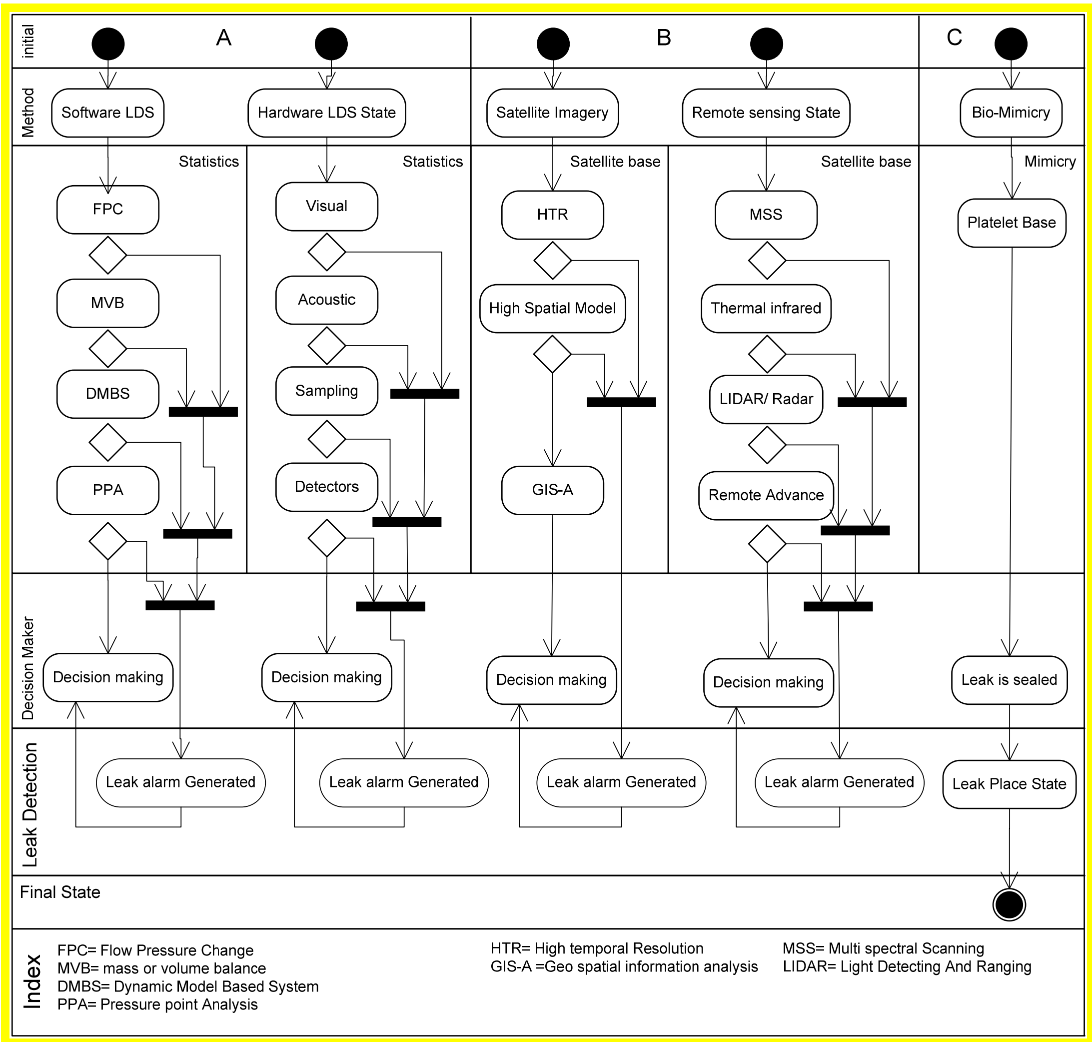


Figure 3: Activity of leak detection method

Hardware and Software classification

The Measuring devices basically are composed the control systems that transfer petroleum. The main process variables are available from transmitter, such as pressure, temperature, flow and density, in real time. So following items are measured again at destination; total flow, pressure and sometimes temperature.

Visual Leak Detection

Methods of inspection include walking, driving, flying or other appropriate means of pipeline corridor[6]. Visual leak detection is classified with vehicular access via improved roads can easily be driven. Long pipelines and obstructed view of Right of Way (ROW) are often inspected from small aircraft or helicopter, from the air.

External Leak Detection

External leak detection methods are another choice. Although this method is costly, it has proven results for short pipelines. There are several factors that affect the performance of external leak detection systems (other than visual inspection) and should be considered as part of the selection process. Its factors are Liquid Sensor Cables, Fiber Optic Cables, Vapor Sensing, and Acoustic Emissions.

Volume Balance

The method of MVB identifies an imbalance between the In-Out volumes of petroleum. The In –Out volumes of pipeline are measured over a specified time period. The Inlet is subtracted from the Outlet over the time period. A leak is suspected if the difference exceeds a threshold. This algorithm is simple and can be implemented manually by pipeline controllers. The threshold is dependent on the accuracy of the meter, time period, the pipeline volume, and the state of flow in pipeline.

Rate of Pressure-Flow Change

The first instance of software is working based on rate of pressure and flow change. Rapid increase in the difference between inflow and/or outflow are associated with the onset of a leak. This approach is effective for large leaks only. The capability of MVB is dependent on the size of the leak, the skill and experience of the pipeline controller, instrument reliability, the operating conditions, and the selection of alarm set points.

Statistical analysis Methods

In the simplest form of this method, statistical analysis is performed on a measured pressure to detect a decrease the value of either Pressure and/or Flow over a threshold. Leak alarm generation is based on a set of consistent patterns of relative changes of the mean data at different locations. For example, a leak alarm is generated only if the inlet flow exceeds the outlet flow. Statistical analysis also requires a long time to set up and establish the baseline parameter distribution. Existing leak itself is part of the statistical baseline and would never be detected, unless it grew to a significantly larger leak[6]. Based on the quality of hardware and software, this system cannot detect leaks lower than 1.5 kg/ s, this amount of spillage in compare with CONCAWE reporting shows how far we are to meet the need of the process quality. The demand of automation LDS needs to improve the performance of existing techniques. So developing the level of expertise for maintenance, monitoring system, and pinpoint is necessary.

Geo-spatial Information System and Remote Sensing

Another powerful tool has been introduced as GIS-RS method. Figure 4 shows the scheme and data flow of Remote sensing and earth observation which is running on Geo-spatial information system platform. Existing leakage or even-if less than one percent can obtain from satellite and airborne scanning, in contrast to the mater that it is not detected by the other methods. Gathering data enters from purposed region and remote observation resource such as radar data, ground measurements, statistics, vegetation, thermal IR and etc. Consumer can access to the necessary data through the internet. Preprocessing prepares data to thematic processing. Thematic map processing then will represent the outcomes through internet.

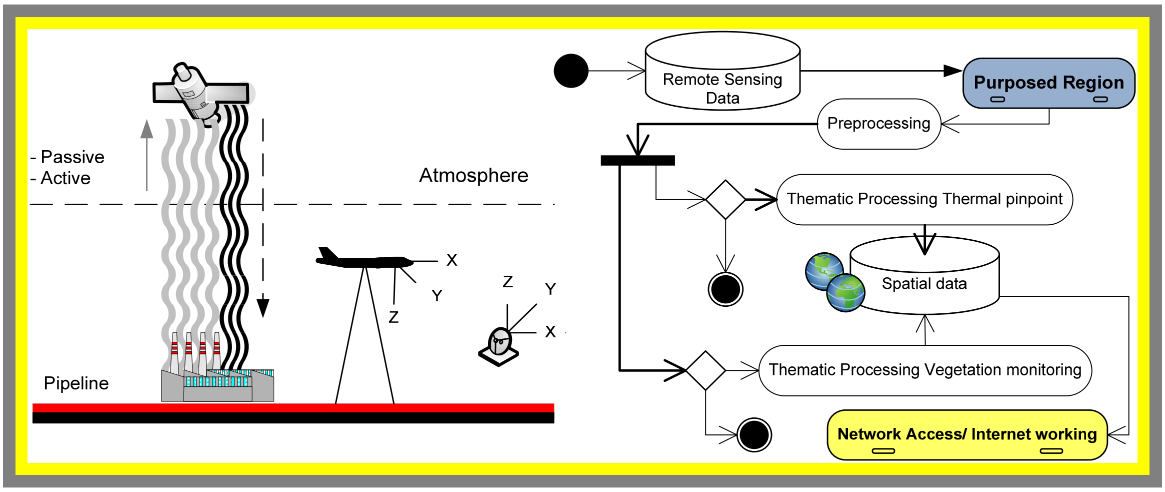


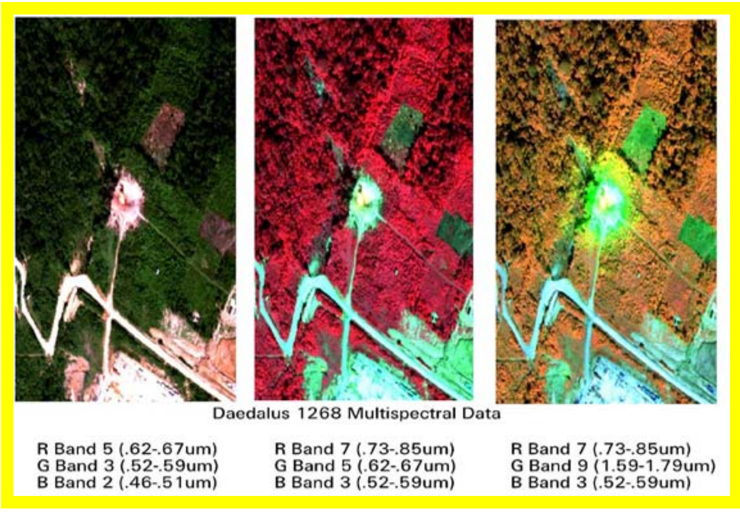
Figure 4: General scheme of satellite data and imagery storing and processing

The first problem of data preprocessing is data transformation to uniform formats of geo-information context, where will be carried out further data processing and analysis. Error will fixed from images with color correction process and ortho-rectification due to lens refraction and camera geometry, angle of observation and contour. All functions are supposed to be realized with the help of existing GIS software.

Figure 5: Containment and routing of underground pipeline in the purpose region "Daedalus Multispectral Scanner4"

Figure 5 shows Leak detection applications used for Short Wave Infra Red Namely SWIR bands[5] and the thermal IR. The SWIR again indicates distortion of vegetation as a result of either excessive water or contamination.

The thermal IR picks up the least temperature differences due to changes in soil moisture content in and around a leak location. Figure 5 shows leak that is not visible to the naked eyes[7]. Figure 6 (Extreme right picture) shows an example of vegetation distortion. Stress in the SWIR bands is much more visible than in the NIR [7]. This module has to adjust for specific monitoring with spill oil. Result of processing is stored in database. It can be used hereafter as prior information. It also fulfills in the distributed geo-informational aspect which is built on DBMS (e.g. Oracle or SQL) and network GIS interoperability.



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[4] The Daedalus 1268 scanner is a passive, electro-optical sensor designed to collect and record reflected or emitted electromagnetic radiation. The system separates the radiation into 12 distinct spectral bands from the visible region through the thermal infrared

[5] Pairs of SWIR bands (1.08, 1.46 μm), (1.08, 1.57 μm), (1.08, 1.66 μm), and (1,08, 2.18 μm).

Figure 6: Vegetation Stress realized from Thermal IR image analysis

Development of platelet solution

The last processing method is discussed as Bio-mimicry mechanism. It has been fine tuning artificial platelet technology for oil pipeline. Engineers do not even need to know the exact location of the leak. It can fix the spill out fluid from hairline crack and pinpoint. Figure 7 illustrates leak sealing process adapted from the human body's own leak sealing mechanism. This unique and innovative concept is based on the method the human body uses to heal wounds and can be optimized for a wide variety of fluid flow applications. Platelets® can be introduced into a pipeline in a number of ways such as via pig launchers. It has been possible to utilize existing infrastructure for injection and no modifications to the system have been required[8]. It utilizes the fluid flow inside a pipeline to deliver discrete particles, known as "Platelets®", to the leak site. On reaching the site, fluid forces entrain the Platelets® into the leak where they are held against the pipe wall, thus stemming the flow. The particular size, shape and material of the Platelets® depends upon the application in question; fluid properties, flow characteristics, pipe diameter and leak size are all amongst the considerations when selecting the type of Platelets® to use.

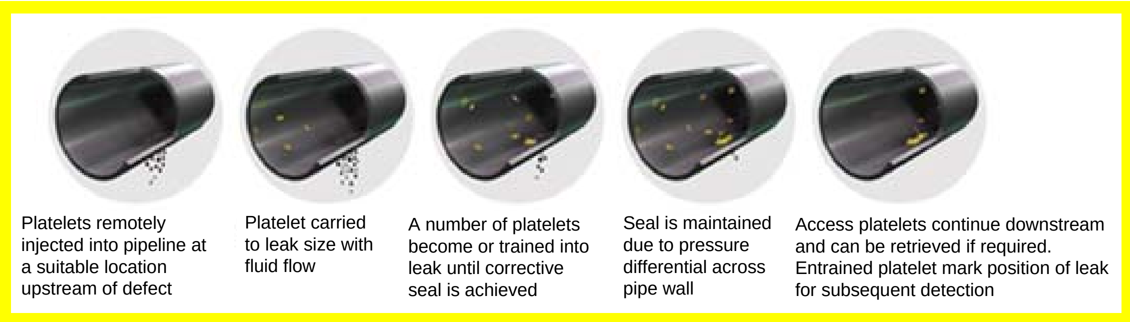

Figure 7 : a unique and innovative approach to leak sealing and location in pressurized pipelines

There is some fact [8], namely Platelets® - The Facts;

- Remote deployment mean there is no requirement for access to leak site.
- No requirement to shut-down intend to deploy whilst system operational.
- Adaptability for variety of leak scenarios applies for corrosion pitting, fitting failures, hairline cracks, 6 o'clock grooves.
- Emergency response of ongoing integrity management programme.
- Temperature ≤ 90°C, Pressure ≤ 3,000 psi
- Øleak/ ØPipeline = 1/20.

Result

Based on definitions with different methods, Table 1 illustrates the comparison of important keys. Each parameter is ranked from 1 to 5. Key point weight is given maximum rank of 5 as capability and minimum rank of 1 as limitation. Common problems arise from the fact that those methods lack behind definition of existing leak, and pinpoint seeps.

Capabilities and limitations of the latest methods have come by eight parameters from three categories in Table 3. Leak detecting, and leak location highlight to decision maker. However system will gain from those parameters, but their faced the fact of Operational cost Vs. Implementation cost. The table also shows the weight of capabilities devoted to important key of those methods. The most dramatic changes are evident in hardware, and statistics methods. From overall ranking of view Hardware method had the rank of 20. The minimum ranks were with Instrumentation cost, Maintenance and False alarm of 2 despite the fact that the Maximum rank were with Operation cost, Leak location and Learning of 4. Statistic method on the other hand had the rank of 23. The minimum ranks were with operation cost and leak location of 3, however the maximum ranks were just with low maintenance cost of 4. By leak location, leak detection, false alarm, and maintenance the rank had high considerably across the GIS/RS as well as Bio mimicry platelet. To sum up this probably indicates a table of content at applicant confidence for companies who are more willing to have investing on a system or the series mechanism aim to come over the leak solution. In case of use the series mechanism, classification of static state is done.

Table 1: Capability and Limitation of leak detection method with GIS /RS and Platelet technology

Capability and limitation of leak detection method	**Require Built-in Equipment**	**Implementation Cost**	**Learning**	**leak Detection**	**Maintenance needs**	**Frequent false alarm**	**Leak location**	**Operation Cost**	**Summery**

		No need	Needful	Low	Most High/ High	Easy	Hard	Existing	1% ≥ Seeps	Shut in	1% ≤ Seeps ≤ 5%	Easy	Hard	Less	high	Small leak	Large leak	No / Long time	Low	High	Most high	Overall Ranking
Key point weight		5	1	5	1	5	1	5	4	1	2	5	1	5	1	5	3	1	5	3	1	1 5
Hardware	Visual	5		5		2		1				1		1		3			1			[19] 2.37
	Ext. Leak Detection	1		1		3		4				2		2		4			3			[20] 2.50
Software	Volume balance	4		2		3		3				2		2		3			4			[23] 2.87
	Rate of Flow/ Pressure Change	4		2		3		3				4		3		3			4			[26] 3.25
Statistics Method		3		3		2		3				4		2		3			3			[23] 2.87
Satellite imagery GIS/RS		5		3		4		4				4		5		4			3			[32] 4
Biomimicry- Platelet		3		3		4		5				5		5		3			2			[29] 3.62

Classification of approach

Some keys attribute are defined and common features of LDSs have already been compared. According to the Figure 8 the challenge is having developed system of the combination of A, B, C techniques, to exploit advantage and take the edge off disadvantage of the feasible and reliable LDSs. Figure 8 gives an idea about how can use comparative method as a mixed mechanism in a network of pipelines array. Classification diagram shows static point of activities and field attribute relationship. So it doesn't matter which method run through the network. The mater is which method addresses you better quality during seeps detecting process. The performance of the system depends on leak detection equipped of pipeline. Obviously, Pipeline companies may be applied one or several types of techniques during its longevity.

Those applications have to follow the policy, standards and regulations[9]. For instance American Petroleum Institute (API) Publication, Computational Pipeline Monitoring (API 1130) recommends that a leak detection system be tested during commissioning and every five years. So validations of leak detection systems have to do by testing the installed system. This testing should follow the requirement of the API. It keeps ongoing process in right direction by proper elective choices.

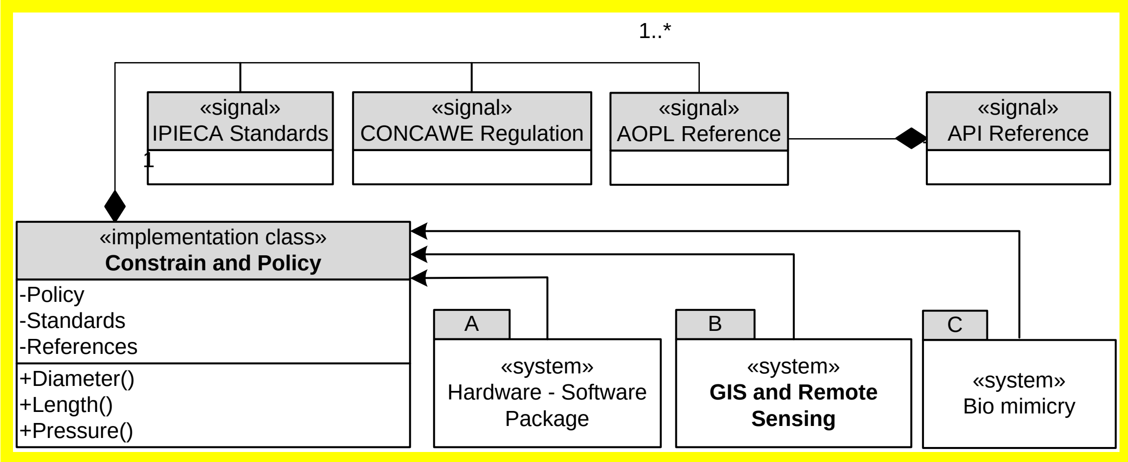

Figure 8: LDS generation from the models with constrain of ISO

The topmost compartment contains the name of class. The middle section contains a list of operations and the bottom compartment contains a list of functions. Figure 9 is shows classification in detail but they typically show not all attributes and operations. So compartments class come with functions and variables that are useful for particular diagram. Each instance of type "Constrain and Policy" seems to contain an instance of types "API", "IPIECA" and "CONCAWE" respectively.

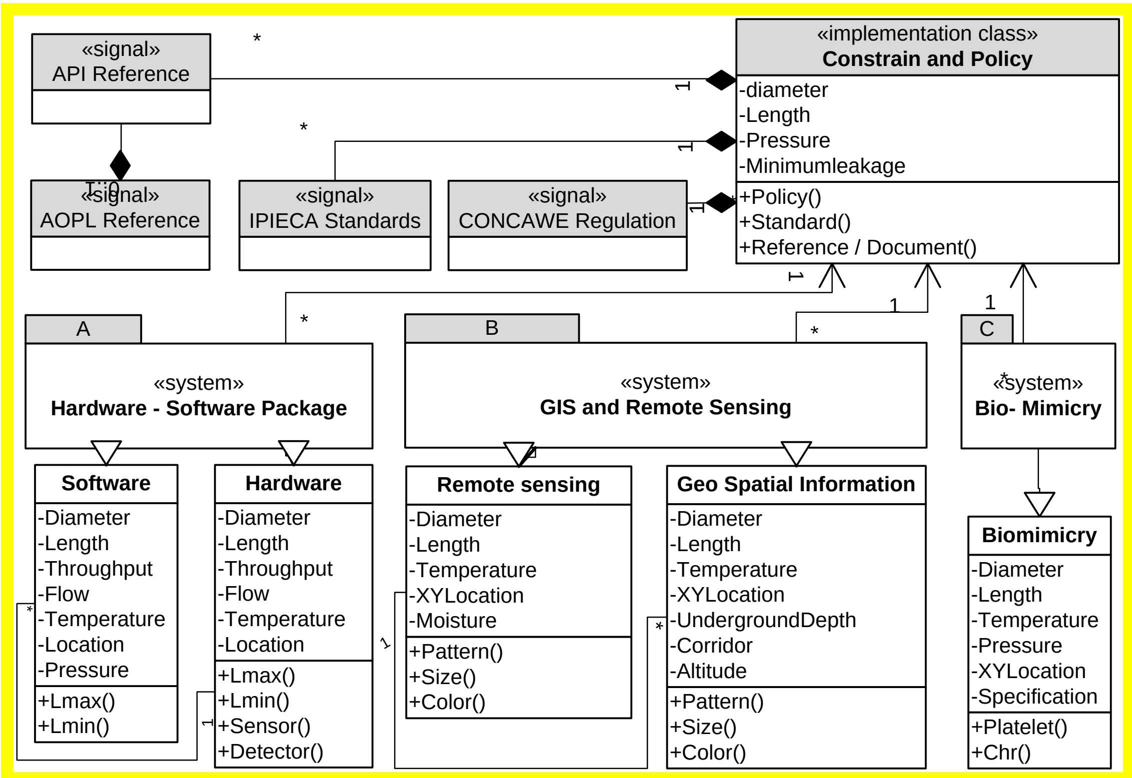

Figure 9: Classification of Static / Dynamic State

Those are relationships as known composition. There are other forms of relationship among of systems and policy. Those relations don't have whole or part of implications. For instance each function of types "Hardware-Software, GIS/RS, Biomimicry" refers back to its parent named "Constrain and Policy". Elaborates further on relationship that each function of type "Software or Hardware" technique will work under pipeline safety regulation [9-12].

In short while there is no single solution effectively detects all pipeline leaks, then multiple processes must be in place with trained personnel to achieve optimum pipeline system performance and safety. However, there is no guarantee that a pipeline system, equipped with an advance leak detection system, will detect every leak. The best way to detect a pipeline leak is adhere to regulatory requirements. So it seems safety regulations provide the methods used by operator to the remote leak detection capabilities. A discussion of the inadequacies of current leak detection systems as well as address existing technological inadequacies in U.S over a l0-year period (1997-2007), during which Hazardous Materials Safety Administration (PHMSA) implemented the integrity management program, the median volume lost from hazardous liquid pipeline accidents dropped by more than half, from 200 to less than 100 barrels. At the same time, the number of accidents declined by over a third[6].

Conclusion

The results of study help decision maker to find the best solution of developing over traditional monitoring system. Seeps detecting systems on the other hands need to apply with the most reliable equipments, and cost effective method. However, organization sometimes needs to run an experienced prospective like GIS/RS. The more study on experience of advance country as well as the result of scientific output is very helpful in guiding. Hardware, Software principle produces online codes of fluid behavior through the pipeline. Those codes are processed by the software. Leak point locations obtain from change detection of volume balance and pressure point analysis in compare with parameters value at the beginning, however existing leakage cannot realized.

Satellite information storing and processing system is developed with use of GIS technological possibilities. Geographic Resources Analysis Support System should be freely distributed multi-user system supporting own database for raster, vector, and site data and containing modules for realization of various data processing algorithms for space monitoring. Furthermore Geo spatial information system and remote sensing in short GIS /RS significantly detect leaks in pipeline regardless of hardware, tools and equipment mounted. When somewhere seeps happen, differentia in temperature and/or stress in pipeline corridor are recognized by thermal scanner and satellite imagery.

Finally about the platelet, since Platelets® are deployed remotely they are a cost effective alternative. So direct access to the leak site, is not required. In the case of hairline cracks and pinhole leaks the leak zone is very small therefore micro-platelets have been designed to respond to the more modest flow fluctuation induced by the very small aperture leaks typical of hairline cracks and pinholes. The radioactive micro-platelets were injected successfully located by the pig mounted detector.

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Glossary of Term

CONCAWE: Conservation of Clean Air and Water in Europe 2

IPIECA: International Petroleum Industry Environmental Conservation Association 1

IR: Infra Red 6

LDS: Leak Detection System 1

petroleum: Crude and oil derivatives 1
SWIR: Short Wave Infra Red (1-2.5 μm) is sensetive to the visible near IR 6