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# DEFINING INDICATORS TO MOTORIZE BLOCK VALVES AIMING TO REDUCE POTENCIAL LEAKAGE APPLIED TO OSBRA PIPELINE

Pires L. F. G. [1], Sousa A. G. [2], Castro N. C. [3], Spagnolo R.[4]



## Abstract

The discussion about motorizing block valves is a constant point being brought up when it is intended to control or reduce the amount of liquid leaking in the event of a pipe rupture. During the pipeline's project stage the installation of blocking valves along the pipeline must be taken into consideration to meet the operation and maintenance requirements as well as to reduce the potential amounts of volume being leaked. In existing pipelines, the main concern is the definition of which valves are candidates to be motorized. In both situations criteria should be established to define this choice. A math algorithm was developed to define the potential leakage due to gravity along the pipeline profile where the influence of a valve over another is verified, as well as the contribution of the check valves existing in the pipeline. The present work defines a parameter based on the extension protected by the valve and the reduction of the potential leakage. This parameter is then fed to a worksheet where the efficiency indicators are calculated to each valve eligible to be motorized. It also takes into consideration factors relative to the valve location, such as the environmental sensitivity, risk assessment, social diagnosis and device's proximity to contingency resources. Finally, after considering all the above aspects, it's possible to come up with a final classification, recommending specific valves to be priorized on an eventual process of motorization adequacies. This methodology was applied, experimentally on a pipe segment of TRANSPETRO's São Paulo-Brasilia pipeline – OSBRA , where it proved to be an important technological and management tool.

## 1. Introduction

The occurrence of leakage of crude oil and by products resulting from pipeline transportation has reduced significantly in the last thirty years. In the United States of America this annual reduction is about 40%. (Ref Association of Oil Pipelines) and the average volume of product leakage is around one third of former levels. These changes have occurred due to the introduction of accident prevention policies and techniques to reduce potential leakage. In this scenario, the motorizing of intermediary blocking valves to be used in the event of a pipe rupture represents an alternative for the reduction of potential volumes leaked.

The choice of valves to be motorized has to be based on criteria not usually defined by standards. The spacing of main line block valves in onshore pipelines is defined as 12 km for LPG by ASME ANSI B31.4 and the Canadian standard CSA Z662 specifies spacing of 15 km for transportation of liquids with high vapor pressure (HVP) in high consequence areas (HCA). Valve automation with the objective of reducing the potential volume of liquid leaked is not dealt with in these standards, even because its effectiveness can be questionable in function of design characteristics. As a consequence, companies have developed policies and the appropriate tools to allow them to respond to emergency situations in order to ensure the safety of the pipeline, the public and the environment. Specifically with regard to the automation of mainline block valves, studies developed at TRANSPETRO by Mohitpour et al (2004) and at ENBRIDGE by Wier e Li (2009), may be considered a point of reference.

This paper presents a procedure and the criteria for the definition of an order of priority to automation of intermediate main line block valves, in pipeline. The methodology has been applied to a real case: the OSBRA pipeline, the largest oil pipeline in length in Brazil.

[1] D.Sc., Mechanical Engineer - PUC-Rio
[2] Mechanical Engineer – Petrobras Transporte S.A. - TRANSPETRO
[3] M.Sc., Civil Engineer – Petrobras Transporte S.A. – TRANSPETRO
[4] M.Sc., Civil Engineer – Petrobras Transporte S.A. - TRANSPETRO

## 2. Description of the Pipeline

OSBRA is a pipeline composed of two segments: The first is 786.6 km long with 20” diameter, connecting the Planalto Refinery (REPLAN) in São Paulo to the Senador Canedo terminal (Goiânia). Besides REPLAN, there are five terminals and 46 intermediate main line block valves. The second segment is 178 km long with 12” diameter, connecting Senador Canedo to the Brasília terminal and has 9 intermediate main line blocking valves. The pipeline transports light products with a nominal flow capacity of 1200m³/h.

## 3. Criteria

The study of the problem has indicated the presence of several factors that may interfere in the choice of a main line block valve to be motorized (and remotely operated), such as the reduction of the potential spill in volume (the volume of liquid that it can be leaked in any point of the pipeline due a total bursting of the main line), the location of the valve, the area of the pipeline affected by the leaking, the presence of water course, population and difficulty of access. It must be observed that some of these factors are qualitative and so it has become necessary to establish ranges and weight values so that one numerical indicator may be achieved.

### 3.1. Potential Leakage in Volume

According to previous studies carried out by TRANSPETRO for the oil pipelines OSPAR and ORBEL II (Mohitpour et al, 2004) a volume leakage of 3180 $m^3$ is considered as a determinant value for a potential environmental impact on high consequence areas (HCA). Despite the values presented in standards such as the API 1130 , this volume has been adopted as the value used by the US Department of Energy (US DOE) established by the US Coast Guard ( US Coast Guard Rule 33). Studies regarding smaller values may be presented in terms of high effectiveness of the automation of certain valves or of some point of specific interest.

The worst case scenario, in which a total bursting of the main line is foreseen, is used for calculating the potential leakage in volume in the event of a line rupture. This scenario must take into account the following facts:

- Pipeline operating at its maximum capacity
- Operation of emergency flow restriction devices, such as valves operated from a distance and check valves
- Profile of pipeline elevation and variation of the internal diameter of the pipe
- Time to recognize a rupture and time to enact the measures adopted to minimize the event

Taking into consideration that the most of pipeline leak detection systems works in five-minute cycles, this value was chosen as the time used to recognize the rupture. From this moment on, the operator turns off the pumps and closes the motorized blocking valves . The time needed for complete closing of those valves is estimated at 3 minutes; 8 minutes can be considered as the time necessary for isolation of the leaking space.

This way, the total volume of liquid leaking will be obtained through the addition of the initial volume (8 minutes multiplied by the maximum flow) to the volume drained by gravity due to the pipeline profile between the leaking point and the spaces isolated upstream and downstream. The second term can be determined through the geometry and the profile, according to a routine developed in Excel worksheets called MAVAZ (Pires et al. 2005). In those worksheets, the profiles of maximum potential volume leaked are presented, along with two other profiles, where the effects of the check valves and the effects of those valves associated with the effects of the motorization of all the intermediary blocking valves are estimated. Through these profiles, it is possible to carry out an initial evaluation of the effectiveness of the motorization of the valves. Figure 1 presents these curves for the final part of the pipe, between the terminals of Uberlândia and Senador Canedo.

It can be observed that the check valves currently installed already allow a significant reduction in leaked volume and that there are several points of the pipeline with potential volumes above 3180 m³. The blocking valves with a high potential for motorization are presented in Table 1. The point of leakage selected is the one with the greatest leaked volume after the valve. Other valves can be selected with regard to some neighboring point of special interest.

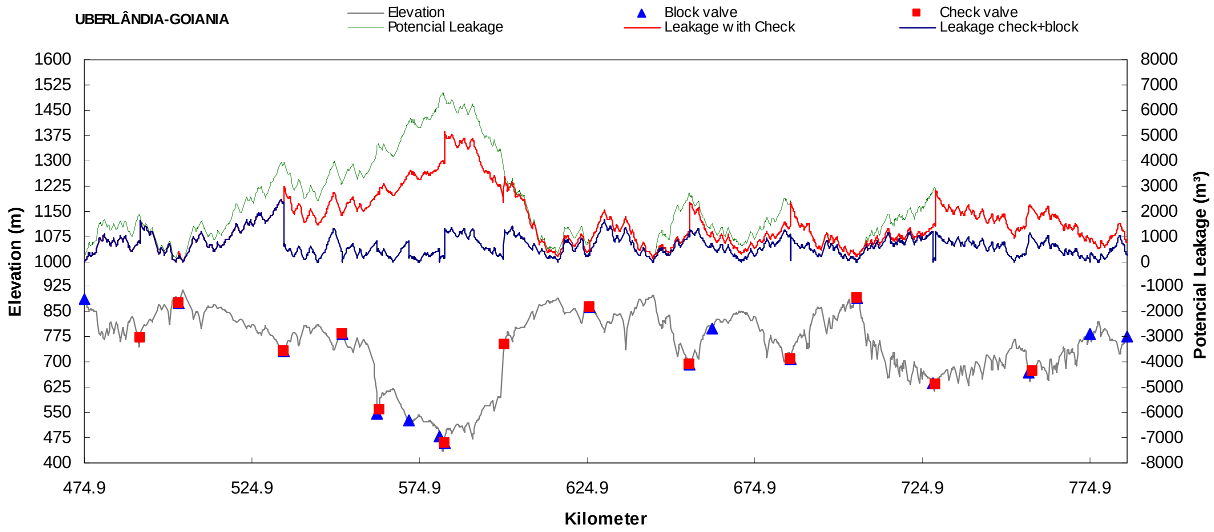


Figure 1: Profile of potential leakage on the Uberlândia-Senador Canedo pipeline section

Table 1 – Reduction of the potential leaked volume with regard to motorization. Uberlândia-Senador Canedo pipeline section

| Valve | Location km | Site of leak km | Vol. without motorization m³ | Vol. with motorization m³ | Reduction % |
|---|---|---|---|---|---|
| VES-20420 | 562.44 | 564.18 | 3108 | 506 | 83 |
| VES-20430 | 571.91 | 573.44 | 3501 | 158 | 95 |
| VES-20440 | 581.02 | 582.10 | 3993 | 222 | 94 |
| VES-20450 | 582.35 | 582.40 | 5136 | 1278 | 75 |

To define a motorization priority, it is necessary to establish a measurement for this criterion. Based on the limit of 3180 m³, five bands of potential leaked volume were established, equally distributed with values from 1 to 5 as shown in Table 2.

Table 2 – Table of bands for the Criterion of Maximum Potential Volume Leaked

| Volume (m³) | Value |
|---|---|
| 0 – 1000 | 1 |
| 1001 - 2000 | 2 |
| 2001 - 3180 | 3 |
| 3181 - 4000 | 4 |
| > 4001 | 5 |

Table 3 – Table of bands for the Criterion of Effectiveness of Protected Length

| Graphic Area | Value |
|---|---|
| 0 - 3000 | 1 |
| 3001 - 7000 | 2 |
| 7001 - 18000 | 3 |
| 18001 - 34000 | 4 |
| > 34001 | 5 |

### 3.2. Effectiveness of Protected Length

This indicator refers to the effectiveness of the reduction of potential volumes leaked along the pipeline. Figure 2 shows a hypothetical pipeline for the purpose of illustration. The bold black line represents the potential volume without the action of blocking valves. With the performance of the first blocking valve, the reduction of the potential volume is shown by the dotted line and with the performance of the second valve, the reduction is shown by the dot-and-dash line. We can see that the percentual reduction at any point of the pipeline after the second valve is bigger than that observed at the first one. Nevertheless, the pipe-length protected by the first valve is greater. In summary, a valve placed in the initial part of the pipeline protects a greater length, but results in a smaller reduction in the potential leakage volumes. The opposite occurs when the valve is positioned near the end of the pipeline. This way, the effectiveness of each one must be obtained not by means of relative reduction, measured for a certain point, but by the area between the line of volume without motorization and the line of reduced volume after motorization. The calculation of this indicator was performed on an electronic worksheet integrating the area between the two curves of potential volume leaked, limited between two consecutive valves.

To define a motorization priority it is necessary to establish a measure for this criterion. Based on the values of the area between the curves, we can establish the number of valves per band. For instance, there are three valves which cover an area between 0 and 500 $m^3$xkm. This way, five bands of reduced volume effectiveness were established as shown in Table 3.

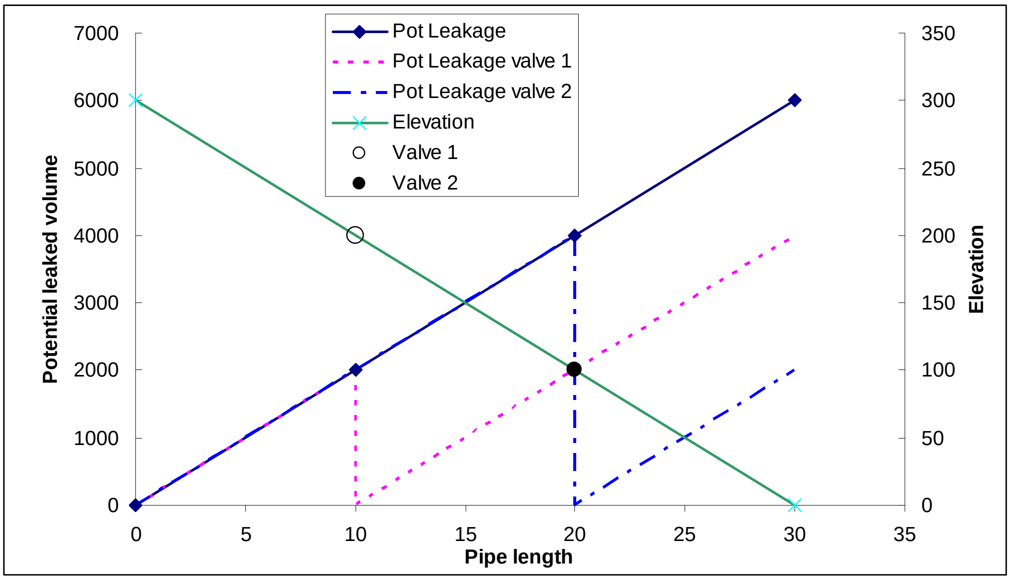


Figure 2 – Potential leaked volume with and without block valve motorization

### 3.3. Environmental Sensitivity

This parameter was taken from GIS Transpetro (Transpetro´s Geographical Information System), an information software geo-referenced to Transpetro´s pipelines right of way and the equipment located in them, as well as images taken from the air and engineering documents. The GIS classifies areas according to the following criteria of environmental sensitivity: Very High, High, Medium, Low and Very Low. For example, the image in Figure 3 was taken from the GIS and shows this classification via color differentiation.

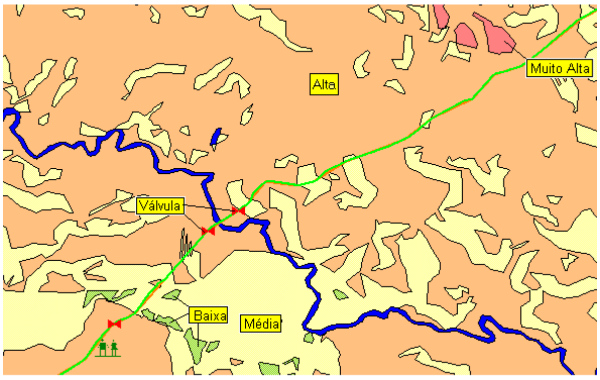


Figure 3 – Example of image obtained with GIS

Table 4 – Table of bands of Environmental Sensitivity Criteria

| Environmental Sensitivity | |
|---|---|
| Very Low | 1 |
| Low | 2 |
| Medium | 3 |
| High | 4 |
| Very High | 5 |

As the environmental aspect is covered by other criteria such as MARA and Risk Evaluation (PID), where such systems are well defined, less emphasis has been given to this criterion. The five bands of sensitivity have been classified as shown in Table 4.

### 3.4 Risk Assessment PID 2007

This parameter was analyzed based on a risk assessment, carried out in 2007, based on the indications of TRANSPETRO´S Pipeline Integrity Standards. These standards aim to detail all procedures relevant to the structural integrity of pipelines. As such, the evaluation classifies each kilometer of the band according to the following scale: Low, Medium and High. These classifications are determined following analysis of factors inherent to each pipeline failure problem: Internal Corrosion, External Corrosion, Geotechnical Factors and Acts by Third Parties. All factors are assessed and related to the population density and environmental conditions of the site. Values of 1, 3 and 5 were adopted for the bands Low, Medium and High respectively.

### 3.5 Study of Risk Analysis

SRA is the abbreviation for the study of risk analysis, a study carried out at OSBRA in 2004, where some areas of ALARP, defined as the combination of the initials for As Low As Reasonably Practicable (as low as possible), were detected, meaning a direction in the use of controls of risk reduction. These local areas, where communities exist are a focus of special attention by the Company. Based on this premise, this criterion is considered as one of the most important and it has been adopted with punctuation of 5 for the ALARP areas and of 0 for the other areas.

### 3.6 Social Diagnosis 2007

This criterion was achieved on the basis of assessed information at GIS TRANSPETRO (System of Geographic Information at TRANSPETRO ) Such data were estimated and consolidated through a social-environmental diagnosis initiated in the beginning of January 2007,when 54 communities, predominantly rural and urban, were found in the area of direct influence of the pipeline (200 m for each side of the direction). This way, when there is an indication for any of those areas near the valve being studied, it was viewed as a critical point. The image presented in Figure 4 shows the way the software presents the information. The criterion adopted for punctuation is 5 points for the areas where communities exist and 0 for the other areas.

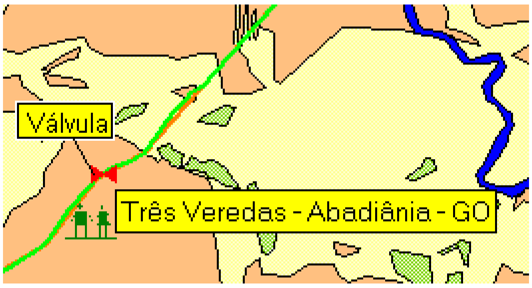


Figure 4 – Example of image obtained with the GIS

### 3.7 MARA

MARA is the abbreviation for Mapping of Evaluation of Environmental Risks. This mapping was made at OSBRA in 2004, having as objective to complement the Study of Risk Analysis emphasizing the environmental risks. This study pointed out the places of higher environmental risks. In its methodology the following activities were taken into consideration: survey of the existing data (such as air photography, satellite images along others), field study to improve the characterization of the crossing points of the pipeline with sensitive areas such as riparian vegetation and forest fragments; drawing of maps of the environmental elements subject to environmental impact due to pipeline leakage, for rural and urban areas; and finally identification of areas prone to oil spill . The criterion adopted for punctuation is 5 points and for the areas with the presence of important water courses of captivating and 0 for the others.

### 3.8 Proximity of Contingency Resources

The relevance of this parameter lies in the relative distance of the spill location to an operational unit with contingency resources (people, materials and equipment) of the closer PETROBRAS system – Terminals and Refineries. So it can be understood that the greater the distance between the valve and the contingency resources, the greater its priority to be motorized. The value refers to the kilometers of the pipelines´ right of way, with the criterion in Table 5 being adopted .

Table 5 – Table of bands for the Criterion of Resources Proximity

| **Proximity of contingency resources** | |
|---|---|
| 0 - 20 (km) | 1 |
| 21 - 40 (km) | 2 |
| 41- 60 (km) | 3 |
| 61 - 80 (km) | 4 |
| > 81 (km) | 5 |

## 4. Weights

For the final quantification of indicators, in order to create the priority of the blocking valve motorization, weights were established for each indicator, based on the sensitivity and experience of the areas involved in the pipeline operation. These values are presented in Table 6.

Table 6 – Table of weighs for the criteria

| **Indicator** | **Enviromental Sensitivity** | **PID** | **ALARP** | **Social Diagnosis** | **MARA** | **Proximity of contingency resources** | Effectiveness of Protected Length | **Potential Leakage in Volume** |
|---|---|---|---|---|---|---|---|---|
| **Weight** | 10 | 12 | 12 | 10 | 10 | 10 | 15 | 12 |

## 5. Definition of Priority of Valve Motorization

To define the motorization priority of the main block valves, all the indicators were placed in the columns of an electronic worksheet, where for each valve the value of the indicator band was inserted. A total value was estimated based on the addition of the value of the band of each indicator multiplied by the respective weight. This total value defines the order of priority and is presented in Table 7 for the first five valves.

Table 7 – Final priority table for the motorization of the block values

| | | **WEIGHTS** | **10** | **12** | **12** | **10** | **10** | **10** | **15** | **12** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Valve** | **Place (km)** | **Priority (ranking)** | **Enviromental Sensitivity** | **PID** | **ALARP** | **Social Diagnosis** | **MARA** | **Proximity of contingency resources** | **Effectivenes s of Protected Lengh** | **Potential Leakage in Volume** | **Addition** |
| VES-20080 | 105.817 | 1 | 40 | 36 | 60 | 50 | 50 | 50 | 15 | 12 | 313 |
| VES-20450 | 582.35 | 2 | 40 | 36 | 0 | 0 | 50 | 50 | 75 | 60 | 311 |
| VES-20430 | 571.91 | 3 | 40 | 12 | 0 | 50 | 50 | 50 | 60 | 48 | 310 |
| VES-20090 | 106.694 | 4 | 30 | 36 | 60 | 50 | 50 | 50 | 15 | 12 | 303 |
| VES-12080 | 128.6736 | 5 | 20 | 12 | 60 | 50 | 50 | 30 | 15 | 24 | 261 |

## 6. Analyses of Hydraulic Transients

The motorization of main block valves may create hydraulic transients in the pipeline as a result of an undue closing. These transients have not been foreseen in the project phase of the pipeline as the main block valves would not be motorized. Thus an analysis of these transients has to be performed to verify if the resulting maximum pressures do not affect the pipeline. For the safety of the pipeline, it is considered the perfect functioning of the safety valves (SDV) in the pump station entrance and the interlock causing the turning off of the pumps. The pipeline filled with diesel, with the complete configuration of the first phase, flows at 1290m³/h with an extraction flow in Uberaba of the 200m³/h. The hydraulic gradient of the initial condition is presented in Figure 5.

Typically, the closing of an intermediary valve causes the blocking of the pipeline and an elevation of the initial pressure due to the water hammer. The pressure continues to go up due to the pressurization caused by the pumps operation. When the pressure reaches the SDV setpoint, it closes the suction station and turns off the pumps. This effect occurs successively up to REPLAN where the pumps remain turned on. For example, the profile of maximum pressures created in the closing of the VES-20450, in kilometer 582,35, is presented in Figure 6.

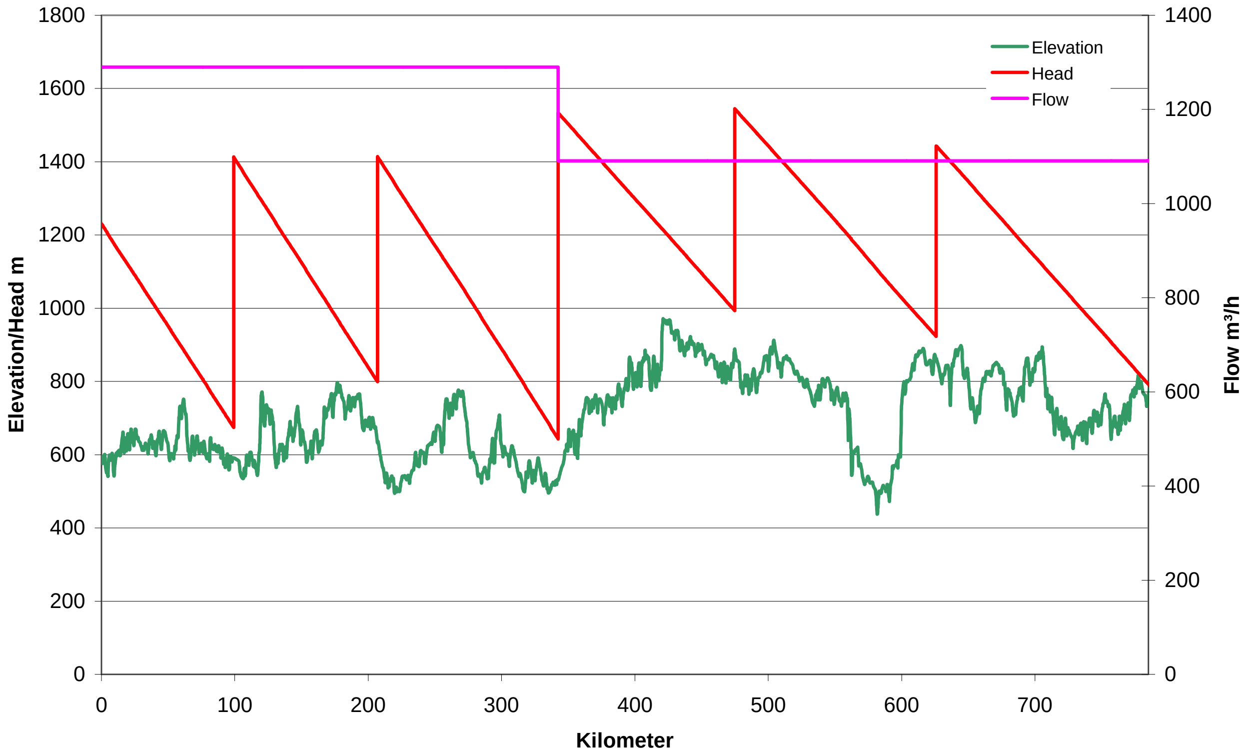


Figure 5 – Hydraulic gradient profile of OSBRA 20”

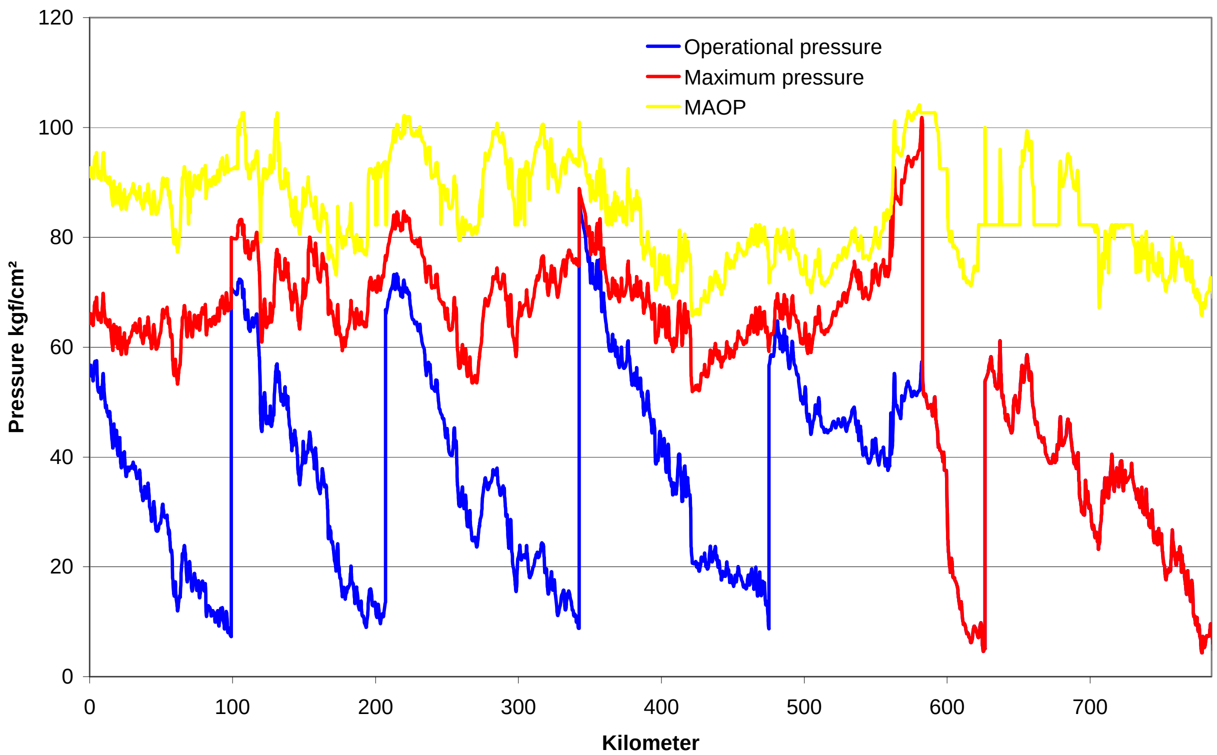


Figure 6 – Profile of maximum pressures for the closing of the VES-20450

## 7. Conclusion

Eight criteria that may be used to define the motorization priority of the main block valves already existing in a pipeline were established, bands and weights were defined in order to quantify each criterion and the procedure was inserted in an electronic worksheet for calculating the order of priority. This methodology was applied to the OSBRA pipeline which defined the first five valves candidate to motorization: VES-20080, 450,430, 090, e VES-12080. To ensure the safe operation of the pipeline after the motorization, the hydraulic transients resulting from the undue closing of these valves were simulated and it was noticed that the maximum pressures observed do not go beyond the maximum possible operational pressure (MAOP) of the pipe.

## 8. Acknowledgements

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