EVALUATION OF PREDICTIVE ASSESSMENT RELIABILITY ON CORRODED TRANSMISSION PIPELINES

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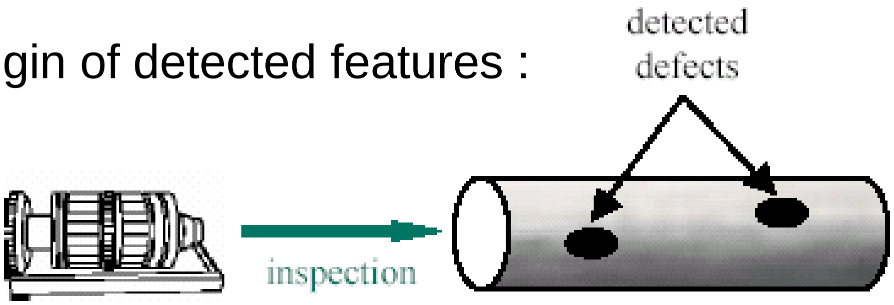
Presented by Maxime LECCHI

Agenda

1. **Context**
2. **Defining preventive repair programs using a probabilistic approach**
3. **Evaluation of the predictive assessment reliability : Case study**
    1. **ILI data matching**
    2. **Corrosion rate calculation/comparison**
    3. **Inspection/re-inspection interval**
4. **Conclusion**

In Line Inspection of transmission pipelines

➔ Origin of detected features :



» External interference

» Corrosion, …

Need for a methodology to:

✓ Assess the integrity of ageing pipelines

✓ Determine preventive repair programs and re-inspection intervals

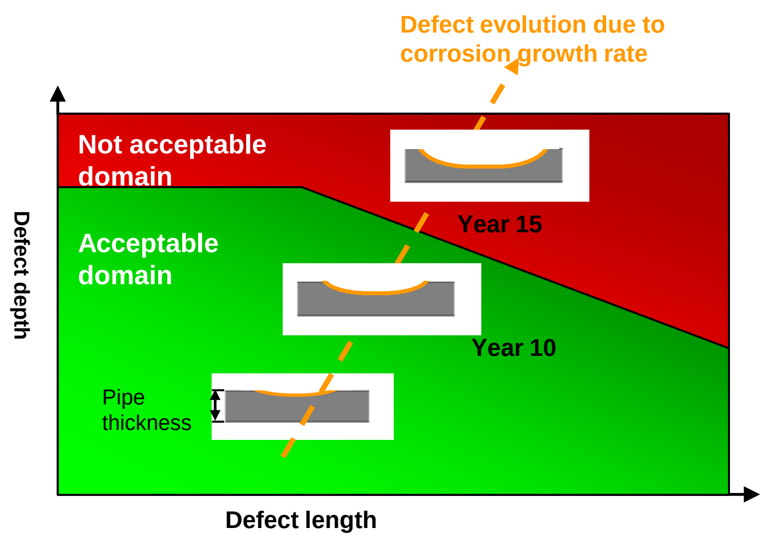
GADline® methodology and associated softwares

2. Defining preventive repair programs using a probabilistic approach (1/8)

At the date of inspection

Corrosion features are „Acceptable" (no need to repair)

but corrosion features size may grow



Preventive repair programs using a probabilistic approach based on:

- Remaining external corrosion features
- Corrosion growth rates distribution
- **Risk level** to prioritize the defects to repair

2. Defining preventive repair programs using a probabilistic approach (2/8)

- Limit-state functions

2 limit-state functions:

- failure due to internal pressure leading to burst
- a limit on the depth

LIMIT-STATES FUNCTIONS

Burst pressure

Feature depth

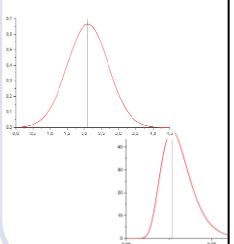
INPUT PARAMETERS

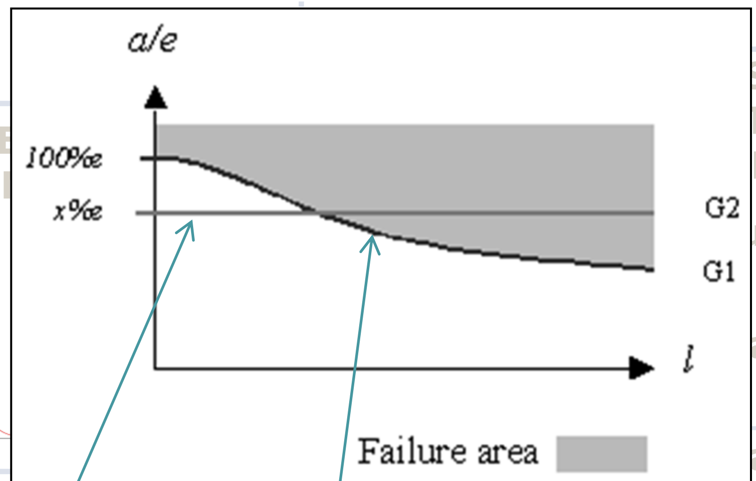
Defect size

Pipe characteristics

Corrosion rate

PARAMETE… MODELLI…





Limit on the depth (%)

i.e. BS 7910

INTERPRETATION OF THE RESULTS

Comparison with target safety levels

Preventive repair program

2. Defining preventive repair programs using a probabilistic approach (3/8)

- Modelling of input parameters
  - ILI features
  - Parameters modelling
    →Statistical distributions

LIMIT-STATES FUNCTIONS

Burst pressure

Feature depth

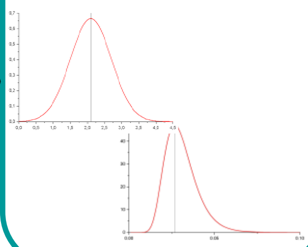
INPUT PARAMETERS

Defect size

Pipe characteristics

Corrosion rate

PARAMETERS MODELLING



CALCULATION

Monte Carlo random draws

3 OUTPUTS PROBABILITY OF FAILURE

POF : punctual per defect

POF : per year per defect

POF : per year per km

INTERPRETATION OF THE RESULTS

Comparison with target safety levels

Preventive intervention program

2. Defining preventive repair programs using a probabilistic approach (4/8)

- Corrosion rate calculation

$$Cr = \frac{\text{ILI feature depth at inspection time}}{\text{Age of the corrosion}}$$

Then

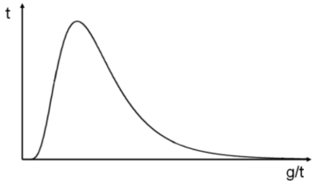
Or

1. The **log-normal paramaters** are calculated from local corrosion rate distribution :

   The user may divide the pipe into homogeneous sections depending on environmental conditions, pipe age, coating, cathodic protection efficiency, …

2. **Log-normal parameters** are directly filled in by the user :

   The user must be experimented in pipeline integrity (ground corrosivity, cathodic protection, …)



2. Defining preventive repair programs using a probabilistic approach (5/8)

- Failure probability calculation

  - Calculation of 3 types of POF using :
    - ✓ Monte Carlo methodology
    - ✓ various failure scenarii

LIMIT-STATES FUNCTIONS

Burst pressure

Feature depth

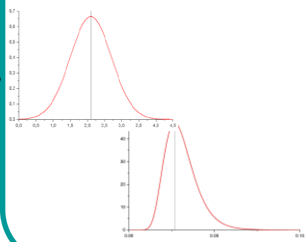
INPUT PARAMETERS

Defect size

Pipe characteristics

Corrosion rate

PARAMETERS MODELLING



CALCULATION

Monte Carlo random draws

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INTERPRETATION OF THE RESULTS

Comparison with target safety levels

Preventive repair program

2. Defining preventive repair programs using a probabilistic approach (6/8)

- Result Interpretation

• POF/km/year compared with target values

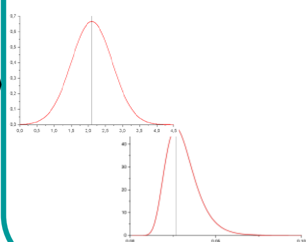
• Which year and defect(s) make a km of pipeline becomes critical?

→ Integration in a preventive intervention program

LIMIT-STATES FUNCTIONS
Burst pressure
Feature depth

INPUT PARAMETERS
Defect size
Pipe characteristics
Corrosion rate

PARAMETERS MODELLING



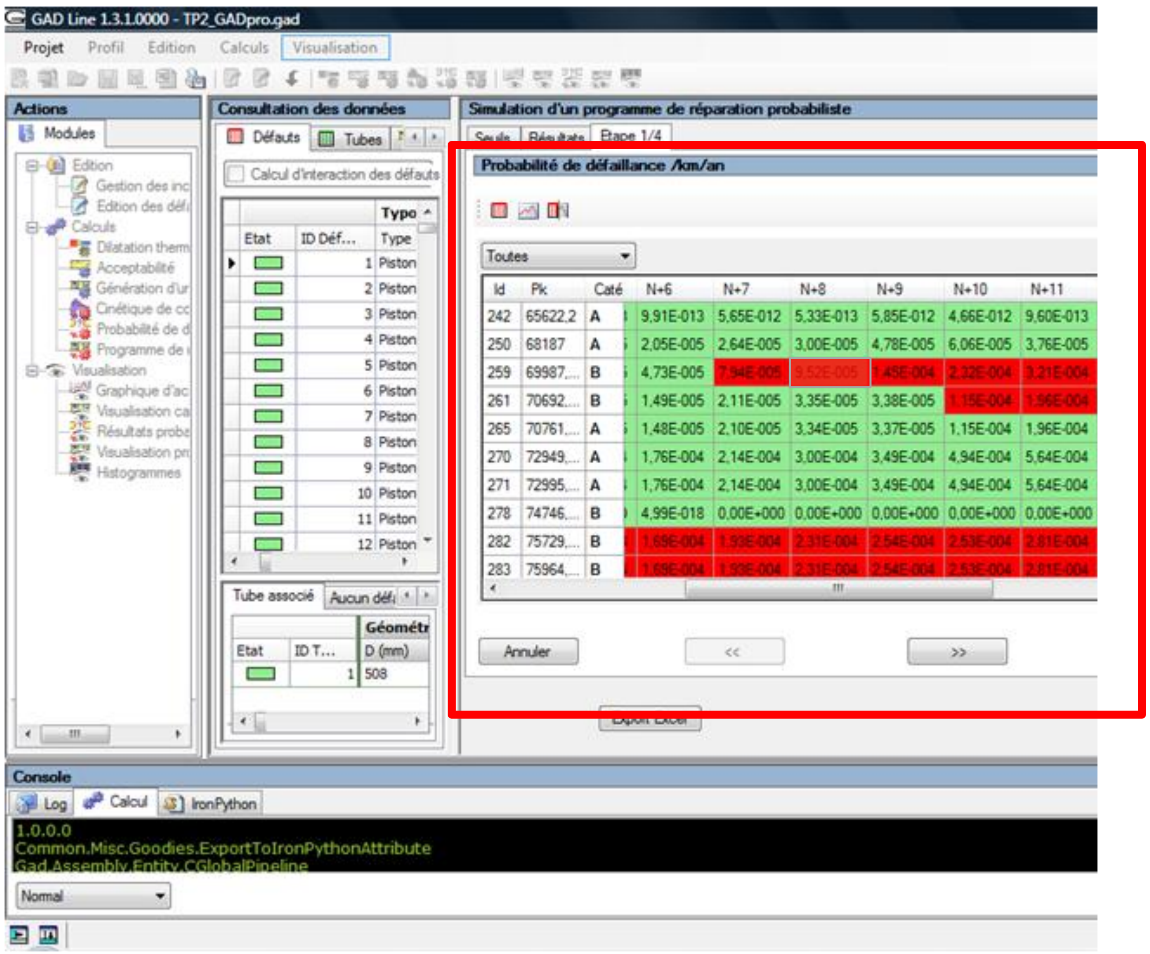
CALCULATION
Monte Carlo random draws

3 OUTPUTS PROBABILITY OF FAILURE
POF : punctual per defect
POF : per year per defect
POF : per year per km

INTERPRETATION OF THE RESULTS
Comparison with target safety levels
Preventive repair program

2. Defining preventive repair programs using a probabilistic approach (7/8)

- GADline ® software – GADpro module



The table shows when the failure probability of a feature exceeds the criteria

2. Defining preventive repair programs using a probabilistic approach (8/8)

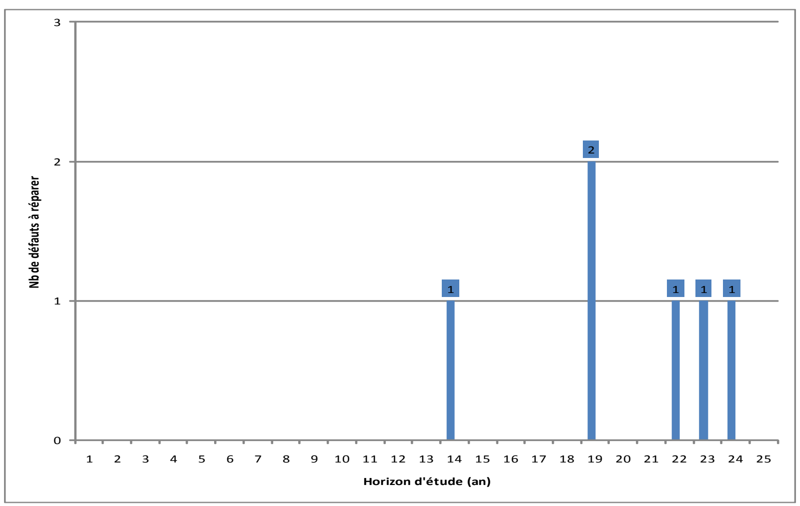
- GADline ® software – GADpro module

N°	ANALYSE PROBABILISTE	GADline 3.0
Projet :		
Date	Auteur et Visa	GRTgaz CENTRE TECHNIQUE ET D'EXPERTISE POLE NATIONAL D'EXPERTISE

Seuils (/an/km)		Cat. A	Cat. B	Cat. C
Petite brèche		1,00E-02	2,82E-04	1,41E-04
Moyenne brèche		1,00E-02	1,29E-04	6,47E-05
Grande brèche		1,48E-03	4,78E-06	2,39E-06

Période d'étude :	25
Profondeur maximale acceptable (%) :	80

Mode de calcul de la cinétique de corrosion :		Mode simple	
Forme	0,2213	Echelle	-3,1642



The diagram shows the number of defects for which the failure probability exceeds the criteria, for each year over a period of time

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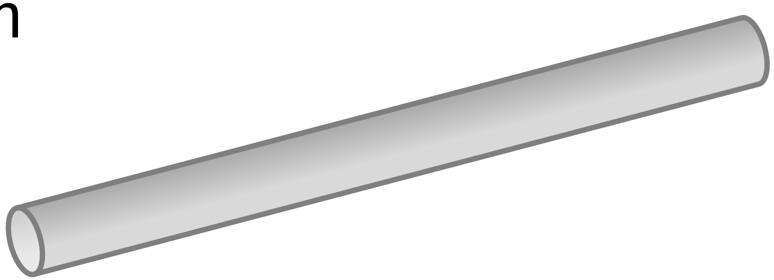
3. Evaluation of the predictive assessment reliability : Case study

A gas transmission coal tar enamel coated pipeline was inspected in <u>**1999** and in **2009**</u>

- Diameter: 24 inches
- Inspected Length : 125 km

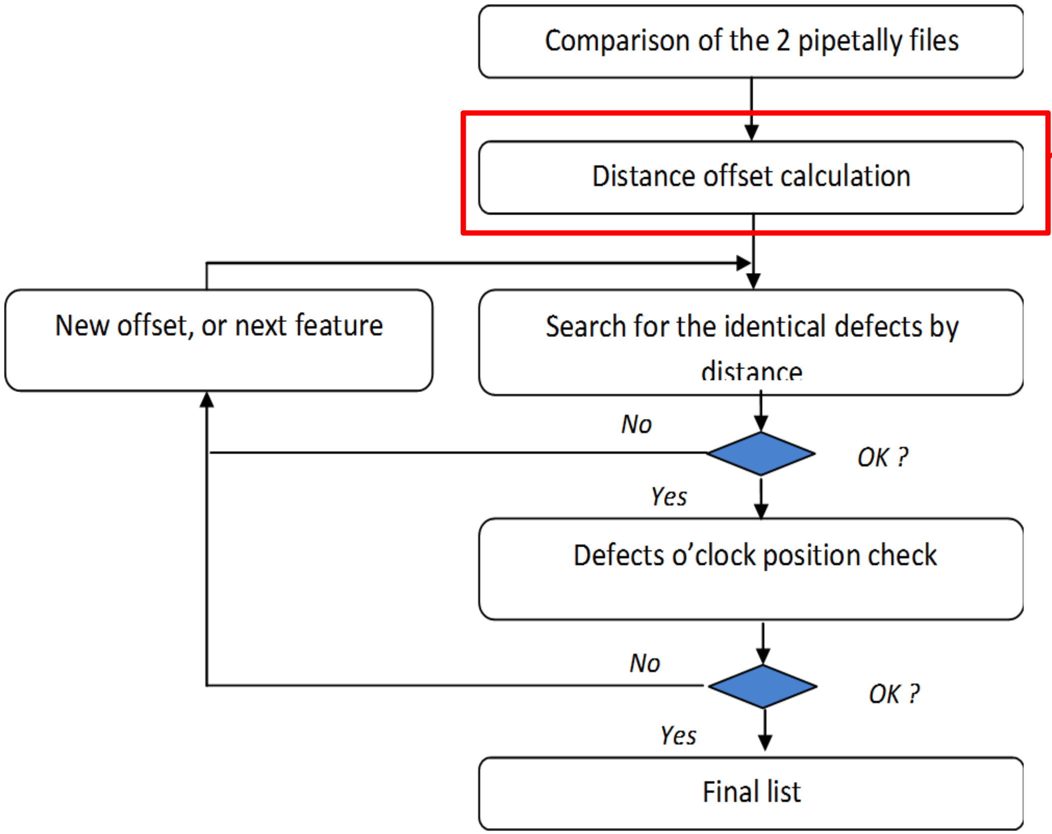


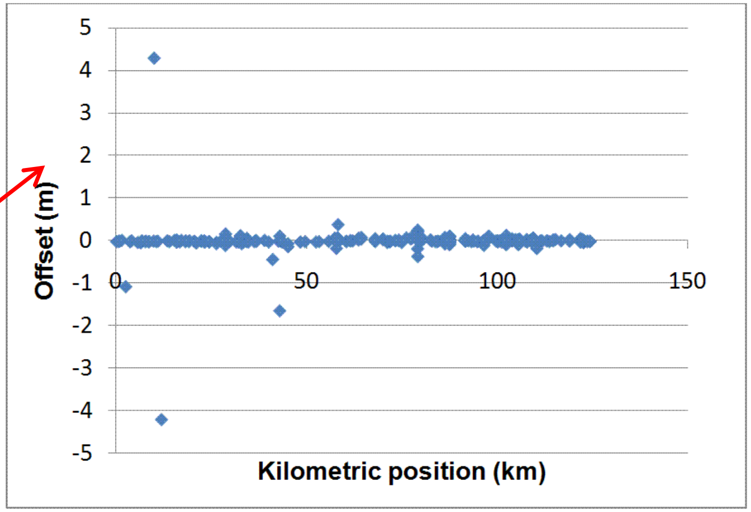
<u>**Matching** between 1999 features and 2009 features is the starting point to determine :</u>

- **Corrosion growth rates**
- **Preventive repair program**
- **Reinspection interval**

3.1. ILI data matching

- Matching Process





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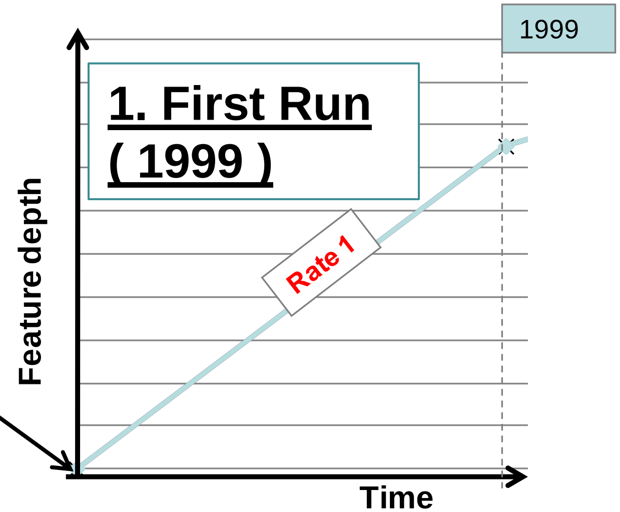
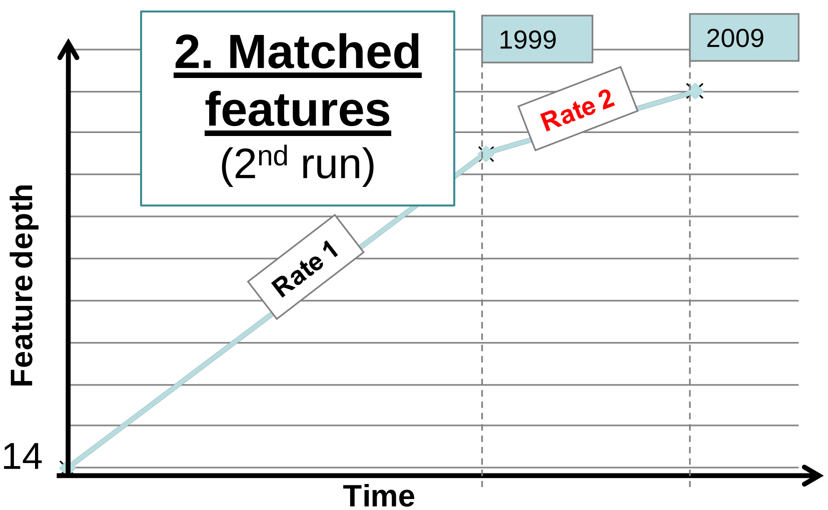
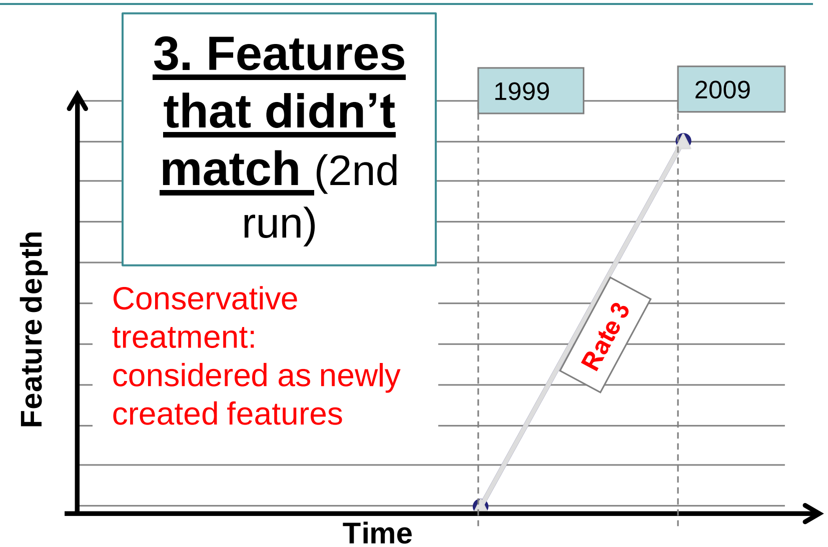
3.2. Corrosion rate calculation & comparison (1/2)

- 3 calculated average corrosion rates

Assumption for external corrosion defects initiation time:
To (building date) + 10 years

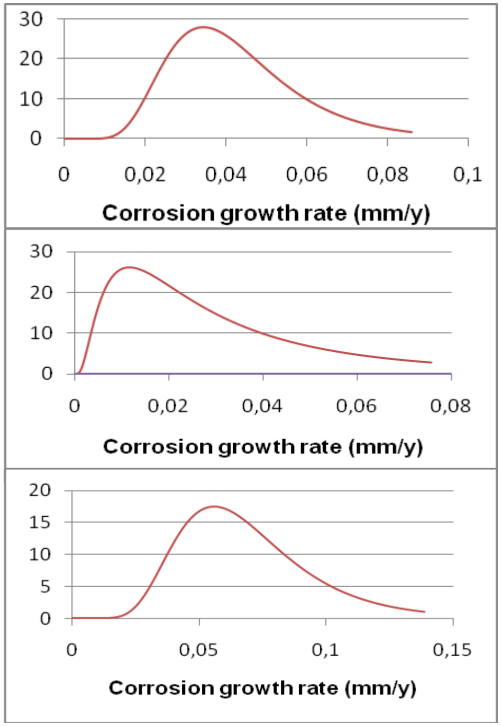






3.2. Corrosion rate calculation & comparison (2/2)

CORR. RATE CALCULATIONS RESULTS		
Rate	**Description**	**Mean Value**
1	Run «1999»	43 µm/y
2	Matched features	38 µm/y
3	Not matched features	69 µm/y

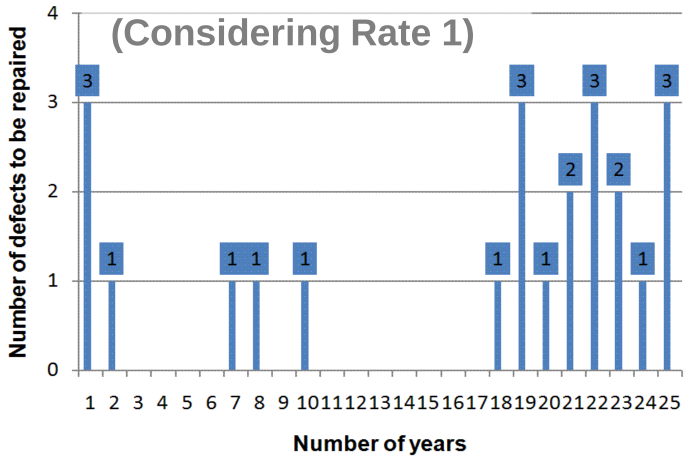


Conclusions

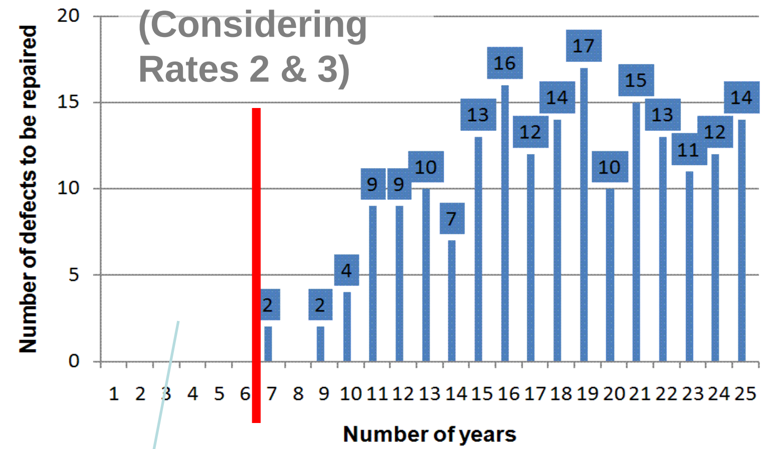
- **Similar average corrosion rate for the matched features between 2009 and 1999** – Delayed time to corrosion initiation assumption validation
- **Features that didn't match show the highest corrosion rate** (as expected according to assumptions)

3.3. Inspection/re-inspection interval (1/2)

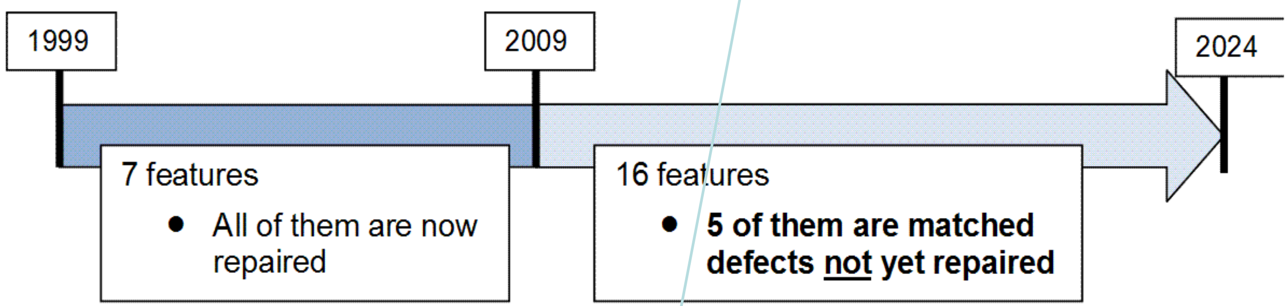
- If applied in 1999:



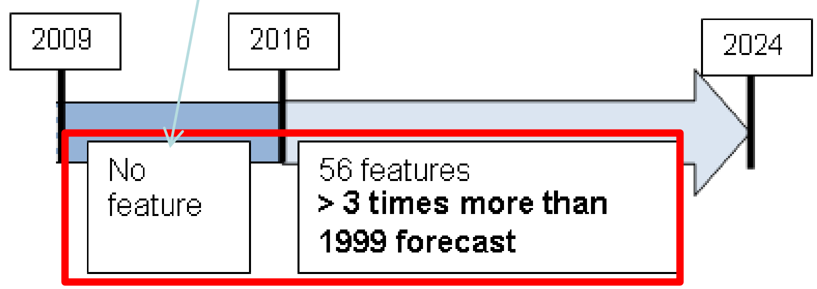
- In 2009:



•1999 program:



•2009 program:



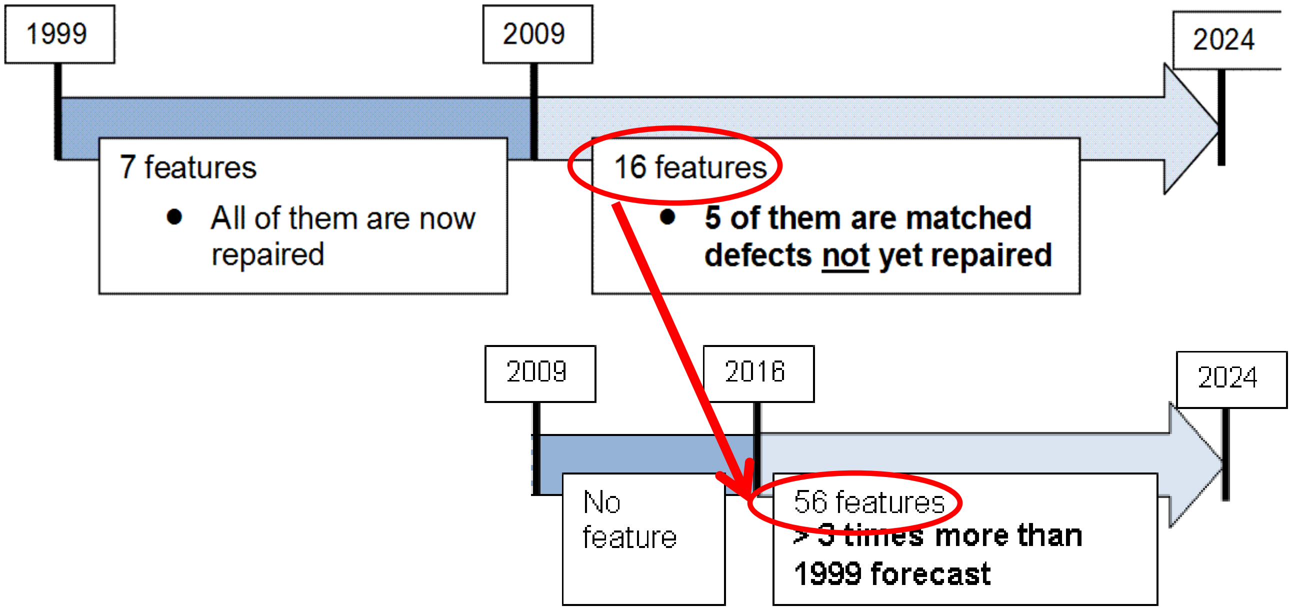
3.3. Inspection/re-inspection interval (2/2)

•Important increase of the number of defects

Mainly due to performance gap between the two inspections, (detection threshold decreased from 10% to 5%)

•Date of the first repair : 2016

7 years after the re-inspection



Consequently, we have set a 15 years limit for re-inspection interval

4. Conclusion

The study highlighted :

- The importance of **making the appropriated choice for the corrosion rate calculation**
- The importance of the **matching process**
- Re-inspection programs shall be limited in time (15 years after an ILI) to take into account uncertainty due to the creation of new corrosion features
- The 10 years delayed initiation time assumption seems to be valid

Further assessments on other pipelines are in progress …

Thank you for your attention.

Do you have any questions?

Appendix

- Calculation of failure probability:

The methodology can take into account different failure modes according to the surface covered by the corrosion defect

Defect diameter given by: $$\pi\left(\frac{d(T)}{2}\right)^2 = w(T)\times l(T)$$

Probability of failure using Montecarlo random shots:

$$Pj\,(Ti) = \frac{\sum_p \left(w_p * I\left[P_{burst} < Pop\right]\right)}{Total\ number\ of\ random\ shots}$$

We obtain:

- the punctual probability of failure by small leak ($P_j^1\ (T_i)$)
- the punctual probability of failure by medium leak ($P_j^2\ (T_i)$)
- the punctual probability of failure by large leak ($P_j^3\ (T_i)$)

Then, the punctual probability of failure is given by:

$$P_j^0\,(T_i) = P_j^1\,(T_i) + P_j^2\,(T_i) + P_j^3\,(T_i)$$

Appendix

- Calculation of failure probability:

Then the annual probability of failure for each defect is calculated :

$$pof_j[T_i;T_{i+1}] = \frac{p_j(T_{i+1}) - p_j(T_i)}{1 - p_j(T_i)}$$

The annual probability of failure of a defect (j) represents the probability that (j) reaches the failure area in the course of the [Ti ; Ti+1] period. This probability is calculated for each defect. It is calculated with the punctual probability of failure in each failure mode that is considered as well as with the total punctual probability of failure.

Finally, the annual probability of failure per kilometer of pipe is calculated :

$$POF[T_i;T_{i+1}] = 1 - \prod_{i} \left(1 - pof_j[T_i;T_{i+1}]\right)$$

This result corresponds to the probability that a failure occurs on one kilometer during the [Ti ; Ti+1] period. In this formula, (j) represents all the defects that belong to the considered kilometer.

Appendix

- Threshold values:

Those values are determined based on a french methodological guidebook related to safety studies.

The guidebook, recognized by the regulator, gives a risk matrix, in which different threshold probabilities of reaching points in the environment of the pipeline are given depending on the context.

For our need, these thresholds are converted to obtain probabilities of failure due to corrosion.

It finally leads us to a range of threshold probabilities of failure per kilometer and per year **between 10^{-2} and 10^{-7}, depending on the context and scenario (pressure, diameter, location, safety distance around the pipeline, leak size,...).**