REPLACEMENT STRATEGIES FOR AGEING PIPELINES AND THE CONSEQUENCES FOR FUTURE INVESTMENTS

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ABSTRACT

Investments in gas distribution networks are very high, exceeding worldwide hundreds of billions of euros. Some of the materials used are already in operation for tens of years and may be replaced/renovated in due time. Too early replacement results in loss of capital. However, by too late replacement safety and security of supply may be in serious danger. An adequate replacement strategy is therefore needed. In this paper a decision tool for strategic replacement decisions is described. This approach is based on academic knowledge as well as practical experience on the various pipeline materials (steel, cast iron, plastics) in operation. The methodology described is based on an approach used by life insurance companies. The effects of various (environmental) parameters are described by static and dynamic factors. For the methodology a software tool, called Qualital, has been developed. This software tool is based on all the expertise and experiences of the Dutch gas companies and is already used successfully now by a number of companies. By using the methodology decisions on priority replacements can be made as well as insight on future investments be obtained. The system also secures historical knowledge within the company.

INTRODUCTION

To distribute natural gas to various customers, very large gas networks are in use, extending worldwide to some millions of kilometres. Some parts of these gas networks are already in operation for more than 100 years. Various pipeline materials are used like grey cast iron, ductile iron, steel and polyethylene.
Pipeline systems for gas distribution have been designed for very long lifetimes, often exceeding 50 years. Nevertheless, all systems will age in time. In steel systems corrosion problems may eventually result in failure, and plastic pipeline systems may degrade by external effects, like mechanical stresses and environmental influences. These aging phenomena are affected by many factors and the combined influence of all these factors are not yet fully known.
Based on the long years experience of experts in field practice and many laboratory studies a methodology has been developed to support decisions with respect to replacement of pipelines in existing systems. In the paper this methodology will be described, and the use will be illustrated by some examples. Apart from a technical judgment of the pipelines, the methodology also comprises financial information. In this way the financial implications of chosen replacement strategies can be evaluated, e.g. the consequences for future investments.

In the specifications on various pipeline materials, requirements have been defined by which premature failure is almost prevented in field practice. However, all materials will age in time. External conditions (mechanical, physical and chemical loading) will affect these aging processes. In steel pipelines corrosion may take place, and in plastics pipes slow crack growth may eventually result in failure. A lot is already known about these aging and failure processes. However, still limited knowledge is available on the very long-term behaviour at rather low loading conditions which usually occur in field practice. Therefore, a lifetime assessment of existing pipeline materials cannot be based solely on scientific knowledge. Experience obtained in field practice should also be taken into account.

MODEL ANALOGY

An approach has been chosen based on the methodology used by life insurance companies. These companies have to assess the expected lifetime of the person involved. For that purpose they distinguish between static and dynamic factors affecting the lifetime. Static effects are already predetermined at the birth of a person, e.g. hereditary determined diseases. This usually leads to a fixed reduction of expected lifetime (e.g. a reduction of 10 years). A dynamic factor leads to a continuous reduction in lifetime, e.g. the lifetime of a smoking person continuously reduces. This approach, using static and dynamic factors, has also been used now in assessing the lifetime of pipeline materials.

REPLACEMENT MODEL FOR PIPELINE MATERIALS

In the analogy with life insurance the theoretical life time expectancy of a person is the lifetime of a just-borned child under ideal conditions and without any heriditary diseases and deviations. This lifetime expectancy will be reduced by static and dynamic factors. Projected on gas distribution pipelines, this means that just after production the pipeline material will have an ideal, unstressed lifetime. But this lifetime will be reduced by static factors, like the way of jointing and the installation technique used. This results in an expected lifetime for this particular pipeline. When environmental conditions do not affect this pipeline this expected lifetime is indeed the life span in field practice. Usually, however, the environment will affect the pipe life and by these dynamic factors the expected lifetime will be reduced. A dynamic factor normally will affect the lifetime during the complete time of this pipeline in operation, e.g. an acid soil condition will continuously affect the corrosion process of steel pipelines. Each dynamic factor has a typical time dependence. It indicates the acceleration of the aging process. Under ideal conditions the lifetime of a pipe will be reduced one year after being in use for one year. A dynamic influence will, however, increase this reduction, for instance to a reduction in lifetime of 2 years after 1 year use.
The end of lifespan of a particular pipeline is determined by a reduction caused by all static and dynamic factors from the ideal lifetime (unstressed lifetime). This procedure leads to a so-called year of reassessment of the pipeline material. At this time a careful evaluation of all data available and possibly completed with an extra inspection will result in a decision on replacement/renovation. In figure 1 this approach is schematically illustrated.

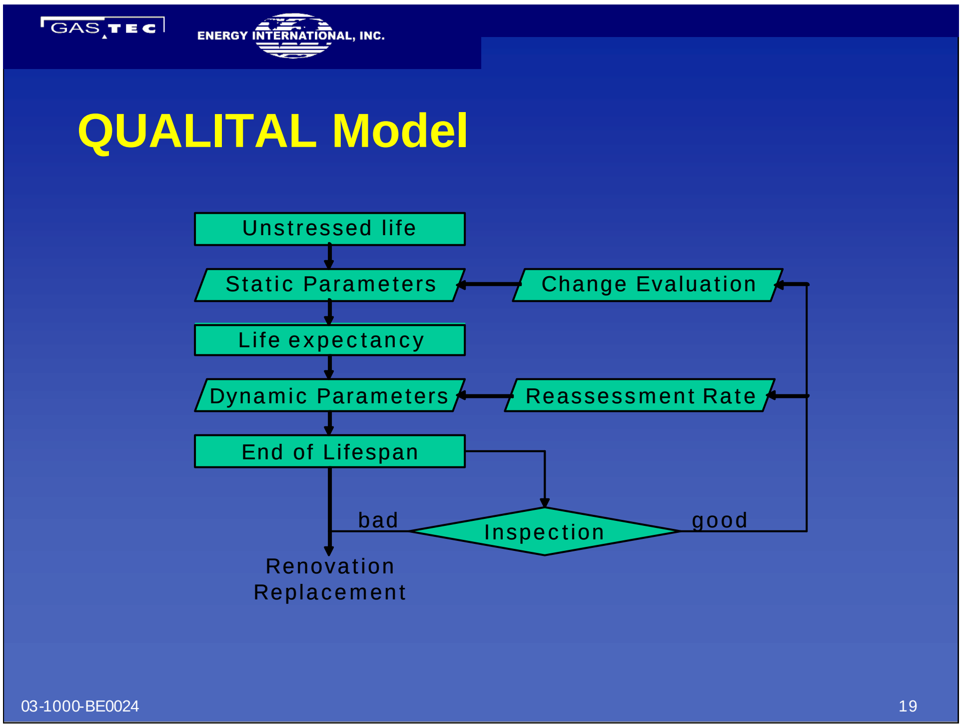
• 

Fig. 1 Schematic representation of the judgment process

This approach can be described by a number of equations :

TIO = Present Year – Year of Installation **(1)**

In which TIO is the time in operation, i.e. the number of years the pipeline is in operation.

EL = UL – Sum SF **(2)**

In which EL is the expected lifetime, UL is the unstressed lifetime and SF the reduction of lifetime caused by static factors.

RT = EL / (1 + Sum DF(t)) **(3)**

In which RT is the time to reassessment, and DF(t) the reduction of lifetime caused by the dynamic factors.

YR = Year of Installation + RT **(4)**

In which YR is the year of reassessment of the pipeline.

The quality of the particular pipeline can be described at a certain moment in time with a time-dependent quality-factor :

QF(t) = EL – TIO (1 + Sum DF(t)) **(5)**

In which QF is the time-dependent quality-factor expressed in years.

This quality-factor indicates how quickly the lifetime reduces in time. For an assessment of any pipe material it is not only important to know the residual lifetime, but it is also important to know how quickly the remaining lifetime will decrease in time., i.e. the quality-factor is an important parameter as well.

Based on a comparison of times to reassessment and the quality factors priorities with respect to replacement/renovation can be taken. To do this analysis a lot of data on the various pipeline segments should be known and the effects of each static and dynamic factor on the lifetime of the materials involved must be known. In the next paragraph some remarks on these static and dynamic factors will be made.

STATIC AND DYNAMIC FACTORS

Static influences only result in a time independent fixed lifetime reduction. When the environment does not affect the pipeline materials the final lifespan is known.
In this paper the static factors for steel and cast iron pipes will not be discussed. Only some remarks will be made on plastic pipeline materials.
For (impact-modified) PVC materials the jointing technique is an important static factor of influence. Rubberring joints, presently used in the Netherlands, perform much better in practice than solvent-cemented joints, which were used decades ago. This results in a different static factor for both types of joints.
For polyethylene the type is very important in determining the static factor. PE types of the first generation are vulnerable to point loading, whereas PE types of the second and third generation are hardly affected by point loading. This different behaviour can be expressed in the static factors used.

The reduction in lifetime caused by dynamic factors is dependent on the time in use. Longer times in operation then lead to a longer lifetime reduction. For instance a dynamic factor may result in a lifetime reduction of 3 years when the pipe has been in operation for only 1 year. In this situation the deterioration of the pipeline during 1 year in operation is as severe as 3 years under ideal conditions.
One of the dynamic factors for plastic pipelines is the presence of soil polluting components. PVC and PE lines in the neighbourhood of polluting petrol stations will degrade faster. This effect can be expressed in the dynamic factor.

FIELD OF APPLICATION

The methodology described above, is aimed to be a complete checklist of all the influencing factors. Unfortunately, however, a lot of data are usually not available. Some data can be obtained from a Distribution Information System (DIS). Other relevant data are based on practical experience, like results of field inspections. All the information should be carefully and systematically collected. The reliability of the methodology will be improved much if all the available data are used. In the Netherlands all energy companies have bundled their expertise and experience in this approach. Based on this common approach a software tool has been developed for the described methodology. This software tool is called Qualital. Within this common approach each energy company can still apply its own replacement policy, but decisions are based on all shared expertise.

An important aspect of the field of application is the size of the population (pipeline segment) used. Each segment should consist of the same pipeline batch, and the total length of the segment should be exposed to the same environment. The pipeline segment should also be installed at the same time. Apart from these conditions a number of criteria can be mentioned in selecting the optimal population size :

- A population should be as large as possible, because this makes the evaluation easier and cheaper
- A segment should preferably be a fully connected pipeline
- Ideally all segments should have the same, fixed length
- The size of the population should be large enough for a random test

It will be clear that it will be difficult to fulfil all these criteria, therefore usually a pragmatic choice will be made.

SOFTWARE TOOL

The described system has been developed for all pipeline materials used in gas distribution systems in the Netherlands, i.e. grey cast iron, ductile iron, steel, rigid PVC, impact-modified PVC, PE and asbestos cement.
The system has been evaluated by 11 companies by judging various pipeline networks differing in material type and age. Based on these evaluations the system was slightly adapted. This is a feature of the system as well; the system is a kind of self-learning system. By using the developed software programme many pipeline segments of a gas network can be judged at the same time. In this evaluation use is made of data stored in various databases. The software tool automatically calculates for each pipeline segment the following indicators :

- Time in operation (years)
- Expected lifetime (years)
- Quality-factor
- Time to reassessment (date)

The results of a large number of pipeline segments can also be graphically presented. An example is given in figure 2.

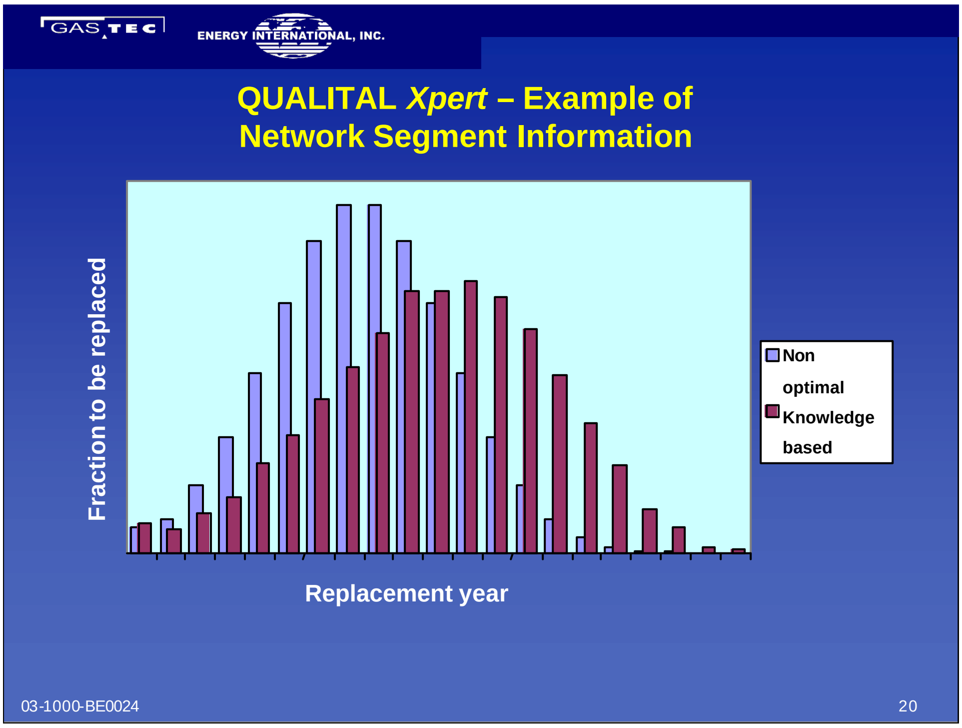


Figure 2 Graphical presentation of some results

CONCLUSIONS

Investments in gas distribution systems are very high. Safety and security of supply are very important and must be guaranteed by adequate management of these systems. A good renovation and replacement strategy for the present gas networks strongly supports keeping safety and security at a high level.

An adequate renovation and replacement strategy must be based on a systematic evaluation of the condition of the pipeline systems on a regular basis. In this evaluation the effects of various factors on the quality of the system should be determined. Such an evaluation supports decisions on short-term issues, like replacement priorities, as well as on long-term decisions on future investments. This decision support system has been developed in the Netherlands based on the knowledge and experience of all energy companies. A software tool has been built, which can be connected to any distribution information system (DIS) or geographic information system (GIS). This system is now implemented or being implemented at a number of Dutch energy companies.

By using this decision support system, replacement will be done at the right moment with minimized costs, it gives insight into future investments, and it secures historical knowledge.

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