# Attachment 8.11

Response to Draft Decision:
Mains Replacement Program
Review

A report by Jacobs

2016/17 to 2020/21 Access
Arrangement Information
Response to Draft Decision

Australian Gas Networks

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# Mains Replacement Program Review

Australian Gas Networks

RO033000_001| 0

06 January 2015

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# Mains Replacement Program Review

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| Project no: | RO033000 |
| Document title: | Mains Replacement Program Review |
| Document No.: | RO033000_001 |
| Revision: | 0 |
| Date: | 06 January 2015 |
| Client name: | Australian Gas Networks |
| Client no: | Client Reference |
| Project manager: | Charles Allen |
| Author: | Lindsay Robson |
| File name: | |

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# Executive summary

1) This review of Australian Gas Networks Limited's (AGN's) South Australian Main Replacement Program (MRP) provides:

   a) an industry context to the prudency of the MRP provided through the examination of similar replacement programs, particularly cast iron replacement, adopted in the United States (US) and the United Kingdom (UK)

   b) our opinion on whether AGN's recognition of the need for the MRP and its proposed timing is consistent with a service provider acting "in accordance with accepted good industry practice" based on our direct experience with those similar overseas programs for accelerated replacement

   c) comments on the risk assessment provided by AGN which is based on the guidance for risk assessment in *AS/NZS 4645.1:2008 – Gas distribution networks, Part 1: Network Management*.

   Item a) above includes discussion on why jurisdictions have required that all cast iron be removed from networks on an accelerated basis irrespective of pipe age or condition and similar considerations in US jurisdictions requiring action to be taken with vintage plastic. It also highlights those conditions existing on AGN's South Australian gas network, many of which are common, that have led to several fatal incidents in overseas jurisdictions and how these conditions create an unpredictable risk for networks.

2) The principal driver in both the US and the UK can be described as a societal concern over the risks of incidents leading to loss of life or significant property damage. Whereas risk is the relationship between the frequency or likelihood of an event and consequence of an event (e.g., the number of people affected), societal concern (together with risk) includes other aspects of society's reaction to that event. These may be less amenable to numerical representation and include such things as public outcry, political reaction and loss of confidence in the utility company and regulator. As such, risk may be seen as a subset of societal concern.

3) AS/NZS 4645 is focused on the risk to be managed in three categories; people, supply and the environment. While the standard focuses on people, one should not under-estimate the impact of property damage, which should also be taken into account as is the case in the US and the UK, as an incident in the Central Business District (CBD), for example, causing significant property damage may impact buildings around the primary property and may negatively impact public and business confidence, even if there is no loss of life. We have reviewed AGN's risk analysis conducted in accordance with AS/NZS 4645, and support the approach and outcomes, with the proviso that we believe it may underestimate the risk for some of the assets. However, the outcomes (risk treatment actions) are consistent with our expectation and experience in that those assets that pose an unacceptable risk should be replaced as soon as practicable.

4) Even though the amount of cast iron main in the US is declining, incidents caused by cast iron gas distribution main failures have continued, resurging attention to the risks associated with cast and wrought iron pipelines.

5) Incidents clearly have a societal impact, in deaths, injuries, property damage; burden on the community, utility, state and industry; and in a host of other ways. They must be addressed. However after more than two decades of various risk-based cast iron replacement schemes, the UK was still experiencing infrequent failures giving rise to about four serious fires and explosion incidents per annum. The Health Safety Executives (HSE) determined the risk associated with cast and ductile iron was no longer acceptable. The UK Iron Main Replacement Program (IMRP) was therefore introduced in 2002 to address societal concerns around this risk. The industry embarked on a 30 year plan to remove some 120,000 km of pipe at an estimated cost of GBP 30 billion. HSE's precautionary approach in the face of uncertainty attaches more weight to consequences in its decision making.

6) For cast iron pipe, pipe fractures are the primary mode of failure resulting in the risk of an uncontrolled release of gas. Cast iron pipes fracture circumferentially (around the pipe) or axially (along the pipe) depending on the pipe diameter, extent of corrosion, and external stresses. In the UK and US, utility companies also discovered that if a cast iron main has a break on it the chances of it breaking again increase.

7) The primary problem encountered with bare and unprotected steel pipe is corrosion and the development of leaks over time. Bare and unprotected steel removal programs in the US are both associated with the removal of cast iron and the elimination of low pressure systems.

8) In both the US and the UK, the driver for removal of cast iron is safety based on the recognition that cast iron is not a suitable material for gas distribution networks. The principal goal is to remove the risk as fast as possible via accelerated programs. The speed of removal is usually judged by what is feasibly possible. This is often based on rates of replacement or installation previously achieved, the availability of resources and the impact on customers both physically and economically. The discussion then shifts to orders of priority of removal which usually addresses the removal of pipes that have some risk associated characteristics such as location to buildings, soil types, or history of breaks in the area, as a priority over those that do not share these characteristics.

9) The primary problem encountered with vintage plastic pipe in the US is that some of the early products found in systems have an oxidized inner surface that predisposes the inner surface to experience cracks faster when certain stresses are applied. The resulting shortened crack initiation time leads to dramatically reduced overall pipeline longevity through a predominant failure mechanism known as slow crack growth. This failure mode can have catastrophic consequences. This situation has led to a direction by California State authorities that the vintage plastic pipe risk be addressed, leading to systematic replacement of such pipe by distribution companies in California. Other distribution companies in other states such as Georgia have initiated similar programs. We understand that AGN has similar issues with its vintage plastic pipe.

10) The UK detailed modelling approach is not necessarily something that should be imitated by AGN; for instance, the CEPA/AESL report for HSE/Ofgem identified several problems with the modelling approach applied in the UK. In any event, once high risk mains are excluded from the population (as a result of replacement), accurate risk-scoring is challenging because many of the factors that contribute to an incident and resulting fatalities, are by their nature, difficult to capture data-wise and to model.

    The AGN model is appropriate for use as a means of prioritisation for the SA network. This is particularly because, as we understand it, the inventory of mains seeking to be 'ranked' is not large when taking into consideration the time frame over which replacement of the high risk inventory is envisaged. In the UK, due to the volume of at risk pipe, the replacement program timeframe extends to 30 years, and therefore it is appropriate to invest resources in the collection and analysis of detailed data, and to attempt to distinguish at more granular level differences in risk between mains. In AGN's case however, we understand that the inventory at risk is such that the capability (and plan) exists to replace most such assets within a timeframe of 5-10 years. In that instance, given our comments above regarding the uncertainty level associated with even so-called sophisticated modelling, we would question the merit of investing resources to attempt to replicate UK modelling or to provide a more granular level of risk modelling.

11) For reasons we set out below, the reader will see that in the US the decisions to replace at risk piping materials have been taken by companies and regulators based on a qualitative assessment of risks associated with the failure mode of materials and on the economic value of elevating system pressures. Where quantitative analysis has been applied it is to determine the priority and therefore order of replacement and not whether to replace or not. The allocation of priorities is typically achieved by the company applying its mains hazard model weighted in favour of the failure mode of the material. Replacement is usually planned in a zonal or block replacement methodology where for example, UPS and other material pipe would be combined with higher risk cast iron to facilitate removal of the low pressure system concurrently. Risk modelling, unlike in the UK, is not used to determine the likelihood of an incident but simply what pipe to remove first, given that the risk of the material is nationally accepted. So prioritization factors will include proximity to high occupancy buildings, number of prior breaks, then highest level of leaks etc.

12) It is our opinion that AGN's recognition of the need for the MRP and its proposed timing is consistent with a prudent service provider acting "in accordance with accepted good industry practice" based on our direct experience with similar overseas programs (UK and US) for accelerated main replacement for Cast Iron, UPS and vintage plastic.

# 1. Practice Note compliance acknowledgement

Jacobs, Jacobs' project manager and the report's primary author hereby acknowledge that it/they have read, understood and complied with the Federal Court of Australia's Practice Note CM7 Expert Witnesses in proceedings in the Federal Court of Australia, issued 4 June 2013.

# 2. Jacobs' experience and expertise

Jacobs' primary report author, and consultants supporting this report have worked with gas operators in the US and the UK since the 1980s as both staff members and consultants on issues related with cast iron and bare steel networks. This includes the then British Gas through Transco to National Grid and, since the breakup and selloff of some of the networks, Jacobs consultants continue to work with one of largest Gas Distribution Network (GDN) operators on safety and system integrity, asset management related issues and regulatory support during price control processes. The current UK GDNs are National Grid Gas, Wales and West Utilities, SGN, and Northern Gas Networks.

In the US, Jacobs' consultants have a history of involvement as expert witness in regulatory proceedings on cast iron related issues and specifically on the prudence of accelerated mains replacement for cast iron networks. The acceptance in the UK of the Iron Main Replacement Program (IMRP) in 2002, as well as a series of positions on this issue taken in the US since 2011 by the Pipeline and Hazardous Materials Safety Administrations (PHMSA), the US Department of Transportation, and the Board of Directors of the US National Association of Regulatory Utility Commissioners, have increased the number of accelerated programs. The Jacobs consultants engaged in preparing this report have supported a number of regulatory applications for Accelerated Main Replacement Programs in the US have developed testimony for three separate cast iron and unprotected steel (UPS) accelerated replacement programs in the US in 2015 alone.

The primary author of this report is Lindsay D. Robson.

Mr. Robson is a law graduate of Victoria University of Wellington, Wellington, New Zealand. Following graduation he worked for 5 years at the law offices of Bell Gully in Wellington.

In 1989 Mr. Robson joined the legal department of the North Thames region of the then British Gas plc (BG). Shortly after Mr Robson started at BG an explosion occurred on a cast iron pipe in London resulting in significant property damage and litigation. In the course of preparing to defend the resulting claims, Mr. Robson delved deeply into the company's main replacement activities and the failure characteristics of cast iron pipe.

As BG transitioned from a fully integrated well to burner gas company to individual segment operators, Mr. Robson remained with the pipeline business which became BG Transco then Transco plc. Over the next 10 years and following several more incidents following cast iron pipe failures, Mr. Robson developed a deep knowledge and expertise on the subject of accelerated main replacement and the rationale for such programs and was a member of the company's Main Replacement Policy Committee. He was closely involved with the company's subsidiary Advantica in testing model development and individual program element design and was involved in the 30/30 Iron Main Replacement Program, which was developed through a tripartite arrangement with the Health and Safety Executive (HSE) and the Office of Gas and Electricity Markets (Ofgem) in the period 1999-2001. During his time with BG, Transco and National Grid, Mr. Robson represented the company and supported other company representatives in meetings and discussions with the HSE.

In 2003 Mr. Robson began working with Jacobs as a consultant engaged both in the UK and the US. Since acting as a consultant, Mr. Robson has had the opportunity to review a number of main replacement programs with major US utilities and has continued to work with one of the larger Gas Distribution utilities in the UK since National Grid disposed of half the Distribution system into three additional network operators. The UK ongoing work has included reviews of all aspects of the company's operational safety management systems and plastic pipe installation practices since the 1970's when the UK first started installing plastic pipe.

More recently in the US, Mr. Robson has assisted in the development of programs for accelerated main replacement for Peoples Gas of Chicago Illinois; has assisted the UK GDNs with proposals for new pipe replacement risk model criteria; served as a member of the team advising the panel established by the US State of California to investigate the San Bruno incident and recently has developed and is developing the safety case basis for testimony in support of funding for accelerated main replacement programs for three gas distribution utilities in the US State of New Jersey.

Mr. Robson also has significant experience with quality programs associated with pipeline construction and regularly carries out operations audits for pipeline operators and for distribution companies in the US and the UK and has advised Canadian operators on practices in processes for leak management and public and system safety. In the course of his career, Mr. Robson also reviewed utility main replacement programs when conducting merger due diligence reviews and company management audits.

Mr. Robson is a director of and regular committee participant with the Interstate Natural Gas Pipeline Association of America (INGAA). INGAA takes up issues of significance and develops guidelines through its committee structure. These guidelines address issues such as Construction Quality and Safety Management Programs, Inspector qualifications, pipeline integrity issues etc. Mr. Robson has had input to these guidelines and continues to be closely engaged with INGAA.

Appendix A provides a sample of relevant qualifications for Jacobs with which Mr. Robson and /or consultants assisting him in the preparation of this report were engaged.

# 3. Jacobs' scope of work

Jacobs was engaged by AGN to provide an international perspective of the approach taken to the management of certain piping materials commonly in use over the years within gas distribution systems in countries such as the UK and US. The materials reviewed, most of which are relevant to the AGN situation are cast iron, bare and unprotected steel, wrapped steel, bare and protected steel, ductile iron and vintage PE.

In addition to the provision of an international perspective by providing a discussion of the UK and US experiences, we were asked to comment on how the US and UK companies and regulators addressed the quantitative measure or prioritization of risk removal.

Our approach involved a review of AGN documents to familiarize ourselves with their approach, meetings, and reviews of the iterative process around developing AGN's approach to replace at risk mains.

The Terms of Reference for the engagement is provided in Appendix C.

# 4. Replacement justification - societal concerns

The principal driver in the US and the UK for accelerated cast iron replacement programs, broadly speaking, is the societal concern over the risk of incidents leading to loss of life or significant property damage. Whereas risk is the relationship between the frequency or likelihood of an event and consequence of an event (e.g. the number of people affected), societal concern includes (together with risk) the consideration of other aspects of society's reaction to that event.[1] These may be less amenable to numerical representation and include such things as public outcry, political reaction and loss of confidence in the utility company and regulator. As such, risk may be seen as a subset of societal concern.

Most societal concern to-date has been directed specifically at cast iron networks due to that material's disproportionate operational risk as shown below.

In the UK and the US "societal concern" which is sometimes called the "safety case" is the primary driver as the decision to replace cast iron follows a number of incidents causing, in some cases, multiple fatalities and significant property damage. Even though these incidents did not occur in a range of geographical areas within either country, the decision was taken to replace at risk pipes across the UK and in most US states[2].

We believe it is appropriate for the Australian Energy Regulator (AER) to consider UK and US experience as the piping materials are broadly the same as in the AGN South Australia system and, as was the case in the US where UK prior experience was considered, Australia has the opportunity to take international experience into account.

## 4.2 US experience

The U.S. Department of Transportation **Pipeline and Hazardous Materials Safety Administration (PHMSA)** regulations require gas distribution operators to submit incident reports when a leak causes an injury or fatality, property damage in excess of $50,000, or the unintentional release of more than three million standard cubic feet of gas. The resulting gas distribution incident reports[3] (excluding those caused by leaks beyond the customer meter) for 2005 through 2014 show the following[4]:

- **10.2 percent** of the incidents occurring on gas distribution mains involved cast iron mains. However, **only 2.3 percent** of distribution mains are cast iron.
- In proportion to overall cast iron main mileage, the frequency of incidents on mains made of cast iron is more than **four times that of** mains made of other materials.
- **40 percent** of the cast/wrought iron main incidents caused a fatality or injury, compared to only 18 percent of the incidents on other types of mains.
- **10 percent of all fatalities** and **7 percent of all injuries** on gas distribution facilities involved cast or wrought iron pipelines.

Even though the amount of cast iron main in the US has been declining and its replacement, in principle, uses a risk based priority, incidents caused by cast iron gas distribution main failures have continued. This has maintained the industry's interest in finding the best ways to manage the risks associated with cast and wrought iron pipelines.

- **In 1999**, the US experienced two significant incidents.
  - The first was a gasoline pipeline rupture in Bellingham, Washington, resulting in the loss of three lives (two 10-year old boys and an 18-year old man), eight additional injures, release of some 237,000 gallons of gasoline into a creek, and an estimated $45 million in property damage.

[1] It is our view that using the broader risk definition in AS/NZS ISO 31000:2009 – Risk management, Principles and guidelines, "effect of uncertainty on objectives" as applied by AGN will drive the same conclusions about the need to adopt an accelerated CI mains replacement program.

[2] Some US States have Gas Distribution Companies with no cast iron or UPS pipe.

4 http://opsweb.phmsa.dot.gov/pipeline_replacement/cast_iron_inventory.asp

- The second was a natural gas pipeline rupture in Carlsbad New Mexico, resulting in the death of twelve people camping on the pipeline right-of-way

- **In 2010,** a natural gas pipeline in San Bruno, California exploded causing the loss of eight lives, the destruction of 38 homes and damaged 70 other home
- **February 9, 2011** – A tragic explosion on North 13th Street in Allentown, Pa. Local emergency responders worked to limit the spread of the fire while the operator cut through reinforced concrete to access the gas main. A preliminary investigation found a crack in a 12-inch cast iron main that was installed in 1928 and was operating at less than 1 psig at the time of incident. As a result of the explosion and ensuing fire, five people lost their lives, three people required in-patient hospitalization, and eight homes were destroyed.
- **January 18, 2011** – An explosion and fire caused the death of one gas utility employee and injuries to several others while gas utility crews were responding to a natural gas leak in Philadelphia, Pa. A preliminary investigation found a circumferential break on a 12-inch cast iron distribution main that was installed in 1942 and was operating at 17 psig.
- **January 9, 2012** – A home exploded on Payne Ave in Austin, Texas, resulting in one fatality and one injury from a leak that originated at a break in a four-inch cast iron gas main installed in 1950. The cast iron main break occurred after rainfall that followed extended drought conditions.

Incidents clearly have a societal impact, in deaths, injuries, property damage; burden on the community, utility, state and industry; and in a host of other ways. Conclusions about how to address these impacts have come about, in summary, as follows:

- These two incidents triggered a series of reviews that led to the creation of the natural gas and hazardous liquid pipeline integrity management regulations.
- In 2002, the Office of Pipeline Safety estimated that the cost to comply with the proposed integrity management regulations was between US$4.7 and US$11 billion over 20 years and would result in savings of approximately $6.2 billion.
- The California Public Utilities Commission issued Pacific Gas & Electric a $1.6 billion penalty. The State of California passed legislation that required natural gas distribution companies in California to file Pipeline Safety Enhancement Plans. The estimated cost of these plans is estimated at approximately $8 - $10 billion over 11 years.
- The latest noted incident also resulted in the Department of Transportation creating new regulations. The now pending integrity validation process regulation is estimated to address 60,000 to 180,000 km of cast iron pipelines at a projected cost of more than US$35 to $US10 billion over 10 years.

As a result of the incidents above and the general national concern about the societal risks associated with aging and failing infrastructure, utilities across the US have been systematically removing cast and ductile iron materials from the distribution system and have removed unprotected steel at the same time. Subsequently, as a result of issues emerging with older plastic pipe, and in particular ALDYL A plastic, utilities are embarking on programs to address older plastic. It is important to note that cast iron and UPS pipe replacement programs are being delivered in the US as a result of concerns about societal risks (sometimes called the safety case) even where there is no recent or any experience with local incidents causing loss of life or property damage.

## 4.3 UK experience

In the UK, in 2002, the Health and Safety Executive (HSE) took the decision that, given the uncertainty around the risks posed by the remaining iron mains pipes in the UK system, it was necessary to replace them as fast as practicable to address what they expressly described as “societal concerns”. From our experience, this concern had long been the driver for UK cast iron main replacement given the large lengths of pipe of this material remaining.

In both the US and UK, there is a recognition that the disproportionate number of incidents experienced by cast iron pipe must be addressed. Formulating a set of strategies that reduces occurrences and mitigates impacts has required, and will continue to require, a broad partnership of stakeholders.

As stated above in the US section, incidents clearly have a societal impact, in deaths, injuries, property damage; burden on the community, utility, state and industry; and in a host of other ways. Conclusions about how to address these impacts have come about, in summary, as follows:

- Various risk-based cast iron replacement schemes have been adopted in the UK since the 1970s. However, over 30 years later the UK was still experiencing failures leading to about four serious fires and explosion incidents each year. Based on a number of studies into these incidents, the UK Health Safety Executive (HSE)[5] determined that the risk posed by cast and ductile iron, including the unpredictable nature of that risk and inability of well-intentioned risk management programs to effectively reduce that risk, could no longer be accepted. The UK Iron Main Replacement Program (IMRP) was introduced in 2002 to address societal concerns by dealing directly with the inherent risk posed by iron mains (both cast and ductile iron). This embarked the industry on a 30-year plan to remove some 120,000 km of pipe at an estimated cost of £30 billion.

Table 3 provides the UK experience of incidents (page 16).

While AGN's South Australia MRP is of course much smaller than many of the accelerated mains replacement programs adopted overseas, it addresses proportionately the same risk as these other jurisdictions given the conditions under which failures have occurred apply equally to the South Australian networks. These conditions are discussed in the following section.

# 5. Cast iron

## 5.1 Safety case

US regulators have justified accelerated cast iron replacement based on a safety case. In the UK, policy makers determined that cast iron mains posed a 'societal risk' meaning a hazard that impacts society at large, such as a risk of multiple fatalities from a gas explosion. In both the US and the UK, the qualitative case was built from a detailed review of a series of incidents that have occurred on iron mains and from a review of frequency and nature of breaks, leaks, and corrosion (failure modes) found on iron networks that can, under certain conditions, result in an incident. This was coupled in both cases with an unwillingness of policy makers and regulators to tolerate a known risk associated with obsolete materials.

In both the US and the UK the risk to be avoided is not limited to the risk of multiple fatalities but also the risk of significant property damage such as, if an incident occurs when a building is empty, had the building been occupied it would have potentially resulted in loss of life.

It is cast iron's failure mode that has caused regulators in the US and UK to support accelerated replacement. This failure mode has proven to be unpredictable and catastrophic. Ground movement is the primary trigger for failure.

In its Final Decision under Docket No. 09-0167, approving an accelerated main replacement program for Peoples Gas Light of Chicago IL, the Illinois Commerce Commission (ICC-Gas Regulator) the Commission said:

*"The Case for Acceleration*
*We are told by [Pipeline Safety] Staff that an accelerated modernization program for the Company is shown to be a necessity that neither the Commission nor PGL can ignore. Mr. Stoller points out that the Company's system is old, antiquated and approaching the point where further aging will become an emergency matter rather than one which can reasonably be planned and executed. It is important to Staff that the replacement program begins very soon in order to keep the system safe for the citizens of Chicago. This echoes the City's similar position of public safety in urging for our adoption of ICR.*

*On the other hand, we observe PGL and the AG to dispute Staffs assertions. They each point out that there is nothing to show that the Company's system is not being operated safely at the present time. We see*

5 The HSE is the UK's national independent watchdog for work-related health, safety and illness.

*nothing in these arguments to contradict or explain away the testimony of Mr. Stoller or PGL's expert Mr. Marano or to give confidence to the Commission for maintaining the status quo. While Mr. Marano did say that PGL has prudently managed its system and the risks it poses are well in line with acceptable industry measures, his testimony further tells us that there is a need to pursue a more accelerated approach of upgrading this system to prevent or mitigate foreseeable future risk of system and asset failure. The Commission recalls well his point that costs will only rise as matters get worse or if an emergency were to erupt. Immediate safety concerns are not what drive our concern.*

*We expect PGL to stay attentive to the prudent operation of its system. No company wants to come before the Commission and explain away service failures or worse events. What we glean from Mr. Marano's testimony is that PGL's performance is fine to this point but performance alone will not obliterate the risks. The Commission does not condone such a band-aid approach nor do we consider it safe for any length of time. In other words, a band-aid will not suffice in the situation where a cut is in serious need of stitching."*

And further said, echoing the "societal concern" discussion above:

*"With Staff's testimony, accelerated system improvement has become for the Commission a mailer of the public interest more so than just a Company proposal. Mr. Stoller's experience and perceptions of the instant situation inform us well, and his concerns are shared by the City, the Union and this Commission. On the other hand, the AG remains adamant in arguing against the 2030 date that Mr. Marano determined most reasonable in his analysis. We respect the AG's position of wanting to maintain the status quo.*

*In the end, however, safety and reliability are simply not negotiable. Together with all of the evidence at hand, the testimony of Mr. Stoller confirms for the Commission what it should do in terms of Rider ICR. Due to the many benefits that the accelerated plan provides to ratepayers, the Commission is of the opinion that time is of the essence and hereby requires completion of the acceleration plan project by 2030. Any variance from this completion date will require the Company to seek the Commission's approval".*

By way of context, the PGL pipe replacement program was an accelerated program with the 20 year time frame for removal based on an assessment of achievable rates of replacement. Also this was a system that had not experienced any significant or recent incidents at the time it applied for funding and was approaching the consideration of its system needs based on the standard of a prudent operator.

### 5.1.1 Breaks/fractures (primary safety issue and driver)

For cast iron pipe, pipe fracture is the primary mode of failure resulting in the risk of an uncontrolled release of gas. Cast iron pipes fracture circumferentially (around the pipe) or axially (along the pipe) depending on the pipe diameter, extent of corrosion, and external stresses.[6] These fractures are primarily caused by ground movement creating stress on the pipe that is in excess of the pipe's beam strength. The result is that the pipe breaks completely (into two pieces). While the integrity of cast iron, like all materials, declines over time, the cast iron failure mode can occur irrespective of the age or condition of the pipe. This makes it impossible to predict when and where a cast iron pipe will fail.

When breaks occur on low-pressure systems with cast iron distribution lines, the volume of gas escaping is much less than what might escape through the same size failure in a system operating at higher pressures. However, even a relatively small volume of natural gas leakage can have and has had catastrophic consequences in the US[7] and UK.

The primary problems encountered with cast iron systems are twofold:

[6] The operating pressure of cast iron pipes, which produces internal stress, is a limited factor in the failure mode because of the relatively low operating pressure of most of the cast iron distribution system including the AGN system in South Australia. Circumferential fractures tend to result in catastrophic failure.

[7] Explosion in Allentown PA, USA on February 9, 2011, caused by a crack in a 12" cast iron pipe, operating at low pressure (less than 6.9 kPa), resulting in the loss of five lives, injuring three requiring hospitalization, and destroying eight homes.

- First, cast iron pipe has little inherent flexibility. This makes it susceptible to breakage due to road condition and ground movement, which is most frequently caused by general ground conditions (as captured by background breakage zones), and ever increasing construction activity near the pipes. Ground movement creates an excessive bending stress in the pipe that may cause it to fail catastrophically in an unpredictable circumferential break resulting in a relatively large release of gas. Cast iron pipes with diameters of 12 inches or less are more susceptible to these unpredictable breaks, and we understand that over 98% of AGN's cast iron pipe is smaller than 12 inch. Further, surface pressures that exist today were most often not known, understood, or anticipated when the pipe was installed. The failure mode of these various pipe materials directly influences the principal risk associated with the integrity of the gas mains - the risk of injuries, fatalities and damage to property caused by gas releases and potential subsequent explosions.
- Second, when originally installed in rigid 12 or 18-foot lengths, pipe sections were joined with either bell and spigot type connections or mechanical joints. The annular space in bell and spigot connections was packed with jute fibre followed by lead or cement to form a gas tight joint, while mechanical joints were installed with bolted connections with a gasket seal. With time, ground movement and/or drying action of natural gas cause a joint to leak. Remedial action in the form of external clamps, encapsulation or internal seals then becomes necessary. The larger the diameter of a cast iron pipe, the less susceptible it is to breaks, with joint leaks being most likely. The risk of breaks progressively diminishes as the diameter, and thus the wall thickness of the pipe, increases to a point where the likelihood of a break is highly unlikely.

  As stated above and supported by data obtained during work with a confidential client, the fracture rate of cast iron pipe increases significantly as the diameter reduces. The table below illustrates the experience of this client.

**Table 1 - Cast iron pipe fracture rate by diameter**

| Main Diameter (Inches) | Fracture Rate (per 100km/year) |
|---|---|
| 3 | 11.1 |
| 4-5 | 18.1 |
| 6-7 | 11.6 |
| 8-11 | 6.7 |
| 12-17 | 3.0 |
| 18+ | 1.8 |

However, factors other than main diameter can influence the fracture rate of a main. A paper published by the Institution of Gas Engineers in London, and authored by D. Needham and M. Howe in 1979 stated that ground movement may occur in two ways. First, a main may be laid in unstable ground and this has been estimated in the UK to have accounted for 1/3 of fractures. This happens when a main is laid in a poorly compacted trench, where the ground deforms geologically, where the ground water level changes or where there are over steep embankments. Few detailed records were kept in South Australia when the cast iron system was first installed and it is reasonable to assume that unstable ground (such as clay soils), and the related risk of fracture, will be commonly present around the cast iron pipes in that network.

The second way is where the ground is forced or disturbed by an applied load. This condition was estimated to account for 2/3 of fractures. Examples are increased traffic loading or excavating or tunnelling in adjacent ground. Traffic loading has been considered in further detail in the paper. If a road surface is in bad repair the loading on the mains under the road increases. A well surfaced road spreads a load evenly whereas pot holes cause the load to be concentrated at one point. This loading also occurs when heavy vehicles mount sidewalks which are less capable of spreading loads. Vehicles also apply accentuated loading when they accelerate, break or corner; meaning that mains are more likely to fracture near road junctions, work entrances, traffic lights and bus stops. It has been estimated that the loading is increased by a factor of ten if a road surface is in bad repair. These factors would also apply for the majority of the South Australia cast iron pipes.

These considerations were influential in the early days of risk assessments for main replacement in the UK. In the UK, and US utility companies also discovered that if a main has a break on it, the chances of it breaking again increase.

A third known cause of fracture is the effect of weather conditions on clay soils such as found throughout the SA network. Cast iron networks in clay soils subjected to periods of prolonged drought will show a sharp increase in fracture rates when wet weather returns. This is a risk not found in sandy soil types. Both the type and location of failure due to this cause is again not predictable based on the age or condition of the pipe.

### 5.1.2 Leaks

Leaks generally, whether from joints, cracks, or breaks, represent a loss of system integrity. While leaks are less likely than breaks to cause major incidents, under the right conditions they also result in unacceptable consequences. Cast iron is an obsolete material requiring mechanical joints that are susceptible to leaks. Lawmakers and regulators in the US have prohibited the use of cast iron for pipeline installation in a gas distribution system[8] allowing only steel and plastic. This prohibition evidences the recognition that cast iron is an unsuitable material for gas distribution networks irrespective of its condition. As presented above there are active programs in the US and UK to remove cast iron and replace it with modern plastic or cathodically protected steel, which does not suffer from the same unpredictable and catastrophic failure mode that is a defining characteristic of cast iron.

### 5.1.3 Corrosion

As stated in the HSE OFGEM Review of the UK IMRP "Corrosion of buried cast iron pipe, often termed graphitic corrosion or graphitisation, results in much of the iron effectively dissolving into the groundwater (electrolyte) around the pipe, leaving a corrosion product based on the residual graphite structure of cast iron. In grey irons, the corrosion product, termed graphitised iron, is invariably a consistent cohesive mass that adheres to the pipe surface; its consistency has been likened to hard chocolate. Samples of small diameter grey iron water mains that were fully graphitised (through wall corrosion around entire pipe diameter) have been recovered, tested and found to be leak tight at internal pressures up to several bar. In the absence of ground movement or external loading, fully graphitised iron mains, well supported by surrounding soils, have continued to provide leak free service for long periods of time. All pipes below ground will also be subject to some degree of corrosion, from the oxidative action of adjacent soils, and the overall pipe strength will deteriorate with time as it corrodes in service. The overall rate of corrosion for well protected pipe within benign soils may be almost zero; for poorly protected pipe within highly corrosive soils, the overall rate of corrosion will be extremely rapid."

The UK report concluded that *"Inevitably, the combination of external loading and corrosion will result in a finite service life and eventual failure of the pipe".* While the major concern is the fracture failure mode, corrosion represents a concern that cannot be dismissed and supports the argument in favour of replacement and the recognition that case iron is not suitable material for a gas network.

### 5.1.4 Programs

#### 5.1.4.1 US examples and conclusions

The US Department of Transportation's Pipeline and Hazardous Materials Administration (PHMSA) currently reports that nineteen (19) US states and territories have completely eliminated cast and wrought iron natural gas distribution lines within their borders. These are Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, North Carolina, North Dakota, Oklahoma, Oregon, Puerto Rico, South Carolina, Utah, Vermont, Washington, Wisconsin, and Wyoming. Many of the remaining states have active programs of cast iron replacement including Illinois, New Jersey, Georgia, Massachusetts, Rhode Island, Alabama, Louisiana, Kentucky, Texas, Missouri, Pennsylvania, Ohio, Indiana, Nebraska, Delaware, Connecticut, Michigan, Arkansas, the District of Columbia and Utah.

[8] 49CFR192 Subpart B Materials

The move to accelerate replacement in the US is not driven only by specific conditions, or as a reaction to a rash of incidents, but as an 'in principle' objective to remove the inherent risks associated with cast iron from the nation's natural gas infrastructure. This is illustrated by the federal and state government responses and the introduction of replacement programs from coast to coast. These programs are agreed based on the need to remove cast iron on a schedule limited only by the available resources and program management risk. We note that this is the same basis used by AGN in developing its 5 year replacement program. Typically, programs that we have supported have annual implementation rates of 150-175 miles (240-280km) of main and associated services including Peoples Gas of Chicago IL, Public Service Electric and Gas of Newark NJ and Elizabethtown Gas of Elizabeth NJ.

In the United States, the preferred method of addressing the risk posed by cast iron is no longer to manage cast iron pipes, but rather to replace the material. The replacement of cast iron is accomplished by using a combination of three approaches: plan, condition, and enforced. This method provides for a discrete-term, proactive, systematic improvement of a company's distribution network.

The plan approach, involves systematic, accelerated, replacement of large contiguous areas of low pressure and medium-pressure cast iron main while reducing the system risk, creating the best economic efficiencies for construction and also certain operation and maintenance economies. This drives the overall schedule.

The condition approach for identification and removal of cast iron pipes is to evaluate individual segments of pipe against such factors as maintenance history, soil conditions, and risks inherent in the pipe segment's location. Also if a pipe has been subjected to a lot of repairs over its life to date, or as is called in the US a "Band-Aid" approach, it may be selected for replacement early based on its condition. The condition approach will usually be wrapped into the plan approach to the extent possible.

The enforced approach entails the removal or replacement of pipes to accommodate public work projects such as road improvements and water, storm sewer, and wastewater infrastructure projects. It is beneficial to all parties involved if the removal and replacement of pipes can be done in conjunction with other projects, especially to minimize public inconvenience and to avoid the duplication of efforts.

In conjunction with the replacement of low pressure cast iron and bare steel pipe, US local gas distribution companies (LDCs) are "modernizing" their systems by elevating pressures. This includes eliminating over the period of the program an entire class of asset, while facilitating enhanced customer benefits from the system upgrade, simplifying the operation and maintenance of the system by eliminating district regulators, and reducing greenhouse gas emission from leaks and lost gas.

Rates of replacement are influenced by factors such as:

- Previous removal performance
- Availability of resources
- Need for system reinforcement
- Activities by other organizations
- The ability to determine appropriate zonal arrangements for economic reasons around risk removal
- Seasonal influences such as festivals, holidays, weather, etc.

Once a rate of replacement has been resourced, the replacement rate is then sustained over the program to maintain or improve cost efficiency, unless externalities dictate otherwise.

In the US the regulatory standards that must be met are that the program and the costs incurred are a prudent investment, and the asset installed is both used and useful to current ratepayers.

The American Gas Association (AGA) conducted a survey of members in 2014 with the following results:

- Based on responses from 108 members, Local Distribution Companies (LDCs) plan to replace between 5,680 and 6,360 km per year of aging mains and services through 2017 and beyond.
- These numbers will continue to increase as a host of newly-authorized accelerated replacement programs ramp up.
- The purpose of this survey was to aggregate the expected replacement data in order to quantify the associated reduction in emissions.
- Specific member responses to this survey remain anonymous and the final summary only includes the aggregated responses.

*“Every natural gas utility is focused on upgrading and modernizing its infrastructure," Dave McCurdy, CEO of the American Gas Association, which represents local natural companies, said in a statement following the release of the Quadrennial Energy Review. "This is an ongoing priority for natural gas utilities."*[9]

**Table 2 - AGA Pipeline Replacement Survey (kms)**

| Type | 2014 | 2015 | 2016 | 2017 | Total Remaining |
|---|---|---|---|---|---|
| Cast Iron | 1900 | 2170 | 1850 | 1830 | 40390 |
| Bare Steel | 2960 | 2980 | 3050 | 3070 | 95090 |
| Vintage plastic | 830 | 1220 | 1300 | 1250 | 53270 |

#### 5.1.4.2 UK examples and conclusions[10]

The early 1970’s saw three significant developments that affected the British Gas Industry; the conversion of the entire distribution system from manufactured to natural gas; a series of explosion incidents in 1976 and 1977 that led to a government enquiry; and the development of polyethylene as a suitable material for gas transportation.

Following several severe gas explosions over the Christmas and New Year period of 1976/77, the Secretary of State for Energy commissioned an enquiry chaired by Dr P.J. King to examine the circumstances surrounding the incidents and to consider improvements to existing procedures or systems and new measures which might reasonably be implemented to lead to a reduction in such incidents. Dr King recommended that priority should be given to the replacement of higher-risk mains in those locations where a failure could cause a serious incident. The mains targeted were small diameter cast iron and steel mains in the most hazardous locations.

Between 1975 and 2000, approximately 60,000km of pipe, representing one-third of the 1975 iron gas main population in Britain, was replaced using polyethylene pipe. In accordance with Dr King’s recommendations, this programme replaced small-diameter mains in the most hazardous locations as a priority. Hazard was assessed by surveying the route of mains and identifying places of public assembly (schools, hospitals etc.) and properties with cellars, where hazard is increased; and measuring the amount of open ground between the line of the main and the property. Greater amounts of open ground provide opportunity for gas to vent to atmosphere, so reducing hazard.

Incidents continued to occur in the UK after those in the late 1970’s including an explosion in Putney London in January 1985 which resulted in 8 fatalities when gas escaped from a fractured cast iron gas main destroyed a block of flats. Other incidents occurred with some causing loss of life and others significant property damage such as the Greenly House explosion in the City of London. This happened on

9 http://www.usnews.com/news/articles/2015/04/27/ernest-moniz-gas-pipelines-a-very-obvious-vulnerability

10 Mostly taken from a paper entitled RISK-PRIORITISED DISTRIBUTION ASSET MAINTENANCE presented to the 23rd World Gas Conference in Amsterdam 2006

in the morning of Boxing Day, which meant the building and surrounding area was thankfully empty of people. The effect of these incidents was to reinforce the will of the HSE to accelerate the removal of Cast Iron from the UK distribution system. The illustration in the table below from the HSE/Ofgem 10 Year Review of the IMRP shows incidents resulting in fatalities in the UK in the 10 years leading up to the review.

**Table 3 - UK Incidents**

| Location/year | Pipe Type | Diameter | Year Laid | Building Distance | Soil Type | Cause | Results |
|---|---|---|---|---|---|---|---|
| Ilkeston<br>1995 | Medium pressure ductile iron pipe | 8" | 1971 | n/a | Silty clay | • Graphitic corrosion, potentially cause by the surrounding soil conditions.<br>• There had been recorded incidents of corrosion (86 and 91 and potentially a fracture in 91) prior to explosion | • 1 fatality<br>• 1 serious injury<br>• 4 minor injuries<br>• Property destroyed |
| Grangetown<br>1996 | Low pressure cast iron pipe | 4" | 1905 | 2.9m | Silty sand and gravel | • Fracture of pipe caused by severe corrosion, surrounding ground conditions | • 1 fatality<br>• 1 minor burns<br>• Internal walls of property damaged, and fire damage |
| Ecclestone<br>1999 | Low pressure spun iron main | 4" | 1962 | 15m | Reddish brown clay | • Fracture caused by ground movement and stress corrosion<br>• Gas likely to have been ignited by light switch<br>• There was no history of corrosion of fracture on the pipe | • 1 fatality<br>• 1 injury<br>• Extensive damage from explosion and fire to property |
| Larkhall<br>1999 | Medium pressure ductile iron | 250mm | 1974 | 10m | clay | • Cause of fracture recorded as unknown - court case suggested that the soil conditions may be been a factor<br>• Fracture history of pipe was unknown as Transco did not have appropriate records<br>• Court case ensued. Transco fined £15m, as Judge ruled that they should have been aware that iron mains could corrode in adverse soil conditions within ten years and the problem had been highlighted by fatal blasts at Warrington and Ilkeston | • 4 fatalities<br>• 1 house destroyed<br>• damage to nearby properties |

| Location/year | Pipe Type | Diameter | Year Laid | Building Distance | Soil Type | Cause | Results |
|---|---|---|---|---|---|---|---|
| Linfield St, Dundee<br>2000 | Cast iron low-pressure gas mains | 4" | 1967 | 0.8m | Clayey fine sandy to coarse gravel | Fracture of gas pipe caused by:<br>• stresses caused by uneven settlement of supporting soil over the sewer connections<br>• stresses associated with tapered service connection<br>• two previous fractures of 4" cast iron mains in local area<br>• drainage in the area had not been constructed to correct standards<br>Gas most likely ignited due to someone lighting a cigarette<br>Previous fractures had occurred in 1957 and 1996 - but the mains that fractured had not been scheduled for replacement | • 2 fatalities<br>• 1 serious injury<br>• 3 other injuries |
| Batley<br>2000 | Low pressure spun iron main | 4" | 1960 | 3.5m | made up ground, brick and clay | Uneven support to main and also ground movement due to the surrounding soils<br>Had a risk score of 84 prior to incident - the mains were not due for replacement under the 'at risk' replacement policies in place at the time | • 2 fatalities<br>• 1 property destroyed and 1 property damaged |
| Clitheroe<br>2002 | steel pipe | 2" | n/a | 0.2m | Brown clay | Corrosion of 1" siphon standpipe<br>Ignition due to use of cooker or washing machine | • 1 fatality<br>• 3 injuries<br>• fire damage |
| West Bridgeford<br>2002 | Low pressure spun iron pipe | 8" | 1960 | 26m | Clay | Uneven support due to concrete around the main<br>There was no history of fracture or corrosion | • 2 fatalities<br>• 1 injury<br>• 2 flats destroyed<br>• 2 flats partially destroyed |
| Buckstone Grove, Edinburgh<br>2006 | Low pressure cast iron | 4" | n/a | n/a | n/a | Fracture caused by:<br>• Ground instability caused by the nature of the local ground<br>• A concrete section water valve chamber positioned in close proximity to the gas main may also have contributed to the failure by acting as a pivot point<br>The fracture led to an explosion because of an unsealed service entry point following permeation through the soil. The main was targeted in the replacement programme, but had a low risk rating and was therefore not scheduled for removal for a number of years (primarily because no history of failure on that part of the mains) | • 1 serious injury<br>• serious damage to building |

By the year 2000, approximately 120,000km of iron main remained in use throughout Great Britain. This gave rise to about four serious fire and explosion incidents per year, with associated injuries to occupants. The dilemma facing the British gas industry and its regulators was either to tolerate this relatively low level of incident and its potentially fatal consequences or to maintain investment in replacement in a way that would further reduce the small residual risk.

**Table3 - Sources and causes of incidents on the UK gas network 1990-2001[11]**

| Source of incident | Number of incidents | Cause of failure |
|---|---|---|
| Cast iron<12" | 41 | Fracture all cases |
| Cast iron>12" | 4 | Fracture all cases |
| Ductile iron | 3 | Corrosion all cases |
| Steel mains | 0 | n/a |
| Steel services | 8 | Corrosion all cases |

In addition to a focus on iron mains, it was determined that under normal conditions it was unlikely that failure in a pipe located more than 30m away from a building posed a risk of causing an incident. Thus it was only the iron pipes situated within 30m of buildings that were classified as being 'at risk' of causing incidents. Based on the information received from the UK Gas Distribution Networks (GDNs) in response to a Questionnaire, over 90% of the mains population was located within 30m of buildings and over time the 'at risk' population might grow through encroachment as new buildings are constructed. This is also true of the US experience and, according to advice from AGN, virtually all of AGN's cast iron is within 30m of property.

In 2002 it was estimated that there was approximately 91,000km of these 'at risk' mains remaining on the network, which were scheduled for replacement or decommissioning over time. In introducing the IMRP the UK HSE took the decision that given the uncertainty around the risks posed by the remaining iron mains pipes it was necessary to replace them as fast as practicable to address societal concerns. The HSE said in its enforcement policy[12]:

*"There is a high level of societal concern about the potential consequences of gas mains failure. The Health and Safety Executive (HSE) is therefore requiring Transco to take further prudent and practicable steps to reduce this risk. The Office of Gas and Electricity Markets (Ofgem) have agreed that if HSE requires Transco to accelerate its current mains replacement programme it will adjust Transco's price control to allow for this."*

And that:

*"The principal risk associated with the integrity of the gas mains supply is the risk of injuries, fatalities, and damage to property caused by gas releases and subsequent explosions. An accelerating rate of pipe fracture could lead to widespread failure in the integrity of the network. The combination of widespread failure and a catastrophic incident could affect public confidence to the extent that risks are re-evaluated and deemed unacceptable."*

The justification for the implementation of the IMRP centred around the uncertainty that existed in 2002 about whether large parts of the iron mains network had reached, or were approaching the end of their reliable mechanical life. The concern was that this would increase the probability of an accelerating rate of failure in the future, which could then lead to an increased number of incidents. If this were to occur, it would lead to a loss of public confidence and create significant pressure for the operators to replace large

[11] HSE/Ofgem: 10 year review of the Iron Mains Replacement Programme
Prepared by Cambridge Economic Policy Associates Ltd for the Health and Safety Executive and Office of Gas and Electricity Markets 2011
[12] http://www.hse.gov.uk/gas/domestic/gasmain.pdf

parts of the network in a very short period of time; this was in itself deemed to be inherently risky, highly disruptive and costly.

As a result of these concerns a precautionary decision was taken by the HSE – to increase the replacement rate in 2002, in order to avoid the risk of having to replace significant parts of the network in a short time period, following widespread failure of the network and an increase in the number of incidents.

The HSE decision (HSE (2001)) at the time stated that:

*'This precautionary approach is in line with the principles of risk aversion under conditions of uncertainty and the duty to avoid unacceptable harm unless the costs of doing so can be shown to be grossly disproportionate.'*

## 5.2 Technical and capacity considerations

### 5.2.1 Water ingress

Water ingress can cause both a prolonged and a momentary loss of supply, both of which present a public safety concern. If this loss of supply resulted in a loss of flame then when the gas begins to flow again, it can easily fill a confined space. Prioritisation of mains replacement in Victoria rated water ingress highly because of risk of getting gas into a building. It is both a reliability and safety issue which can be overcome by elevating pressures when replacing cast iron and UPS. The option to replace is the most practical when elevating pressures as there is a constraint in the levels to which pressure can be raised with cast iron and UPS.

### 5.2.2 Pressure elevation – modern system with enhanced reliability and customer benefits

System modernization (pressure elevation) will provide many other benefits in addition to the removal of water ingress as a threat. The customers will benefit from having a greater selection of gas appliances to choose from, including more efficient and environmentally-friendly models, reduced gas costs associated with lost gas and more accurate gas volume metering. Operationally, AGN will benefit from the elimination of an entire class of gas pressure regulator stations, a potential reduction in third party excavation damage, an ability to isolate smaller portions of the system, the ability to trace the source of a leak more accurately, a reduction in leak repairs from aged mains, and increased safety for maintenance crews.

## 5.3 Timing

### 5.3.1 Overseas approaches to accelerate removal

In both the US and the UK, the driver for removal of cast iron is safety based on the recognition that cast iron is not a suitable material for gas distribution networks. The principal goal is to remove the risk as fast as possible via accelerated programs. The speed of removal is usually judged by what is feasibly possible and is often based on rates of replacement previously achieved, the availability of resources, and the impact on customers both physically and economically. The discussion then shifts to orders of priority of removal which usually addresses the removal of pipes that have some risk associated characteristics such as location to buildings, soil types, or history of breaks in the area, as a priority over those that do not share these characteristics.

It is common in the US to also replace other materials that are interspersed through the cast iron low pressure system at the same time as the CI. This includes UPS and plastic and we agree with AGN's program which does this as well. The rationale is that this additional pipe was likely not pressure tested to a higher level when installed and is so mixed in the low pressure system that it becomes economically unviable to leave it in place. To try and upgrade is cost prohibitive due to the complexities of upgrading isolated segments of other materials.

In the UK for cast iron main, a mains fracture factor is calculated by combining data on the diameter of the main, its individual breakage history and a factor developed from the breakage history of other cast iron mains within a 400m zone around the main being considered. The other factors in the UK model are a gas ingress factor measuring the capability for gas to get into a building following a fracture and then a consequence factor. These measures are designed to “predict” the chances of an incident and therefore as a tool to prioritize replacement.

### 5.3.2 UK removal of small diameter cast iron

In the UK the low pressure small diameter mains (less than 12 inches) accounted for 77% of the ‘at risk’ mains population in 2003, and this category was targeted specifically for replacement. Prior to 2002 the historic (1977 to 2002) rate of replacement of the iron mains averaged around 2,650km per annum, at which rate the remaining ‘at risk’ mains would have been removed in 35 years.

It was determined that the 35 year option was the minimum rate of replacement that would enable Transco (now National Grid) to comply with its legal requirements, however it was not the fastest rate practicable. The 25-year option was discounted on the grounds that a replacement rate of 4,300km per annum had never been achieved, and had the potential to lead to a level of disruption too high for the public to tolerate. The 30 year option would require a maximum replacement rate of 3,580km per annum; this was judged to represent an achievable level of replacement that would not cause excessive disruption for the public. The 30-year replacement option was determined to be consistent with As Low as Reasonably Practicable (ALARP) principles.  Thus, the objective of the IMRP in 2002 was for the GDNs to increase the rate of replacement to be in a position to replace the ‘at risk’ pipes within a total of 30 years. The number of years to remove was a direct function of the miles of main in the system and an achievable rate of acceleration. The intention was to remove at risk pipe as soon as reasonably practicable (ALARP), with acceleration as the driver.

The principle used to determine this schedule is the same as proposed by AGN. That is, AGN has determined the most prudent and efficient rate of replacement, given its resources and the cost of achieving a reduction in risk, in accordance with relevant standard to which it is subject (AS4645).

### 5.3.3 US embarking on accelerated replacement of CI/UPS based on failure mode

In the United States in 2011, under the direction of the then United States Secretary of Transportation, Ray LaHood, the US Department of Transportation (DOT) and the Pipeline and Hazardous Materials Safety Administration (PHMSA) called for stakeholders to address the fitness for service of the nation’s natural gas systems, including the replacement of aging facilities.  This is the DOT’s “Call to Action”[13] which sought more aggressive actions on the part of pipeline owners and operators to repair and replace infrastructure that is considered at-risk. PHMSA specifically targeted cast iron and unprotected steel pipe. The “call to action” followed the 2010 San Bruno pipeline explosion (suburb of San Francisco in California), which resulted in multiple fatalities and significant property damage and occurred on a welded steel transmission line in California, and two incidents (explosions) on cast iron in Pennsylvania in close succession, one of which resulted in the death of a gas company worker. In its decision D1212030 following the San Bruno incident, the California Public Utilities Commission (CPUC) said:

> *“Among all public utility facilities, natural gas transmission and distribution pipelines present the greatest public safety challenges. Unlike more common public utility facilities, gas pipelines carry flammable gas under pressure – in transmission lines, often at high pressure – and these pipelines are typically located in public right-of-way’s, at times in densely populated areas. The dimensions of the threat to public safety from natural gas pipeline systems, including the pace at which death and life-altering injuries can occur, are far more extreme than other public utility systems. This requires that natural gas system operators and this Commission assume a different perspective when considering natural gas system operations.*
>
> *In the context of an unending obligation to ensure safety, we must also realize that in practical terms safety is exacting, detailed, and repetitive. It is also expensive, so ensuring that high value safety improvements are prioritized and obtaining efficiencies wherever*

[13] http://opsweb.phmsa.dot.gov/pipeline_replacement/action.asp

*possible is also essential. And, in the end, if the goal of safe operations is met, the reward is that absolutely nothing bad happens. In short, safety is difficult, expensive and seemingly without reward."*

The "Call to Action" was followed by an advisory bulletin issued by PHMSA on March 23, 2012, to owners and operators of natural gas cast iron distribution pipelines and state pipeline safety representatives. The bulletin urged operators of natural gas distribution systems to accelerate the replacement of aging infrastructure to enhance safety, and requested state agencies to consider enhancements to cast iron replacement plans and programs

Secretary LaHood called for an evaluation of the fitness for service of the aging aspects of natural gas infrastructure and for actions to be taken to address safety risks. Such evaluations would involve operators such as LDCs, utility regulators, safety regulators and other interested stakeholders in the development of a strategy for addressing aging natural gas infrastructure. The "Call to Action" proposed that pipeline owners and operators take an aggressive approach to repairing and accelerating replacing pipeline facilities that are more hazardous. The "Call to Action" specifically identified the benefits of infrastructure investment to enhance public safety and to provide for the future integrity of the pipeline system. Secretary LaHood's call asked for "smart modernization" of the infrastructure resulting from a DOT action plan directed by Congress in Section 7 of the Pipeline Safety Regulatory Certainty, and Job Creation Act of 2011 to develop a report on the national cast iron inventory and under the same Act of Congress, PHMSA must conduct a state-by-state survey on the progress of cast iron pipeline replacement

In 2013 the Board of Directors of the US National Association of Regulatory Utility Commissioners resolved to "encourage regulators and industry to consider sensible programs aimed at replacing the most vulnerable pipelines as quickly as possible"; and further resolved that state commissions should:

*"explore, examine, and "consider adopting alternative rate recovery mechanisms as necessary to accelerate the modernization, replacement and expansion of the nation's natural gas pipeline systems".*[14]

In addition, on April 21, 2015, the White House released a New Agenda to Modernize Energy Infrastructure in the Quadrennial Energy Review (QER), specifically calling for programs to accelerate pipeline replacement in natural gas distribution systems. Since the release of this review, the current US Secretary of Energy has made a number of speeches and has written editorial pieces in newspapers in support of accelerated main replacement programs for distribution companies for vintage at-risk materials.

*"The natural gas system, the distribution pipes, are a big issue,"* The US Secretary of Energy said *"About half of the distribution pipes in the country are 50 years old or older, so that's a very obvious area."*[15] And further said "*If you look at aging infrastructure, the estimate just to replace all of the very old – like 50 years and older – natural gas distribution pipes, for both environmental methane leaks and safety reasons, is estimated at a quarter trillion dollars".*

And in an op-ed article written by the US Secretary of Energy:

*The QER also makes specific recommendations to accelerate the replacement of aging and leak-prone natural gas distribution system pipelines that pose safety, reliability and environmental concerns*[16]*.*

Jacobs has referred to the UK's precautionary approach described above when preparing and presenting testimony in the US in support of accelerated replacement programs, and it has been reflected in the approach taken by the US federal government and state regulators, as seen in the pipeline and distribution integrity management rules.

[14] http://www.naruc.org/Resolutions/Resolution%20Encouraging%20Natural%20Gas%20Line%20Investment%20and%20the%20Expedited%20Replacement%20of%20High%20GAS%20AND%20CI.docx.pdf

[15] http://www.usnews.com/news/articles/2015/04/27/ernest-moniz-gas-pipelines-a-very-obvious-vulnerability

[16] http://www.chron.com/opinion/outlook/article/Moniz-Energy-infrastructure-needs-attention-6244048.php

AGN has similarly considered the safety implications in developing its MRP and its conclusions are supported by both the UK and US approaches. We consider the AGN MRP complies with the obligation under NGR 79 (1)(a) that the service provider must be acting “in accordance with accepted good industry practice”, when incurring capital expenditure.

# 6. Unprotected steel

## 6.1 Corrosion

The primary problem encountered with unprotected steel pipe is corrosion and the development of leaks over time. Specifically, unprotected steel pipe deteriorates due to contact with moisture present in the soil. The rate of corrosion varies depending on a number of characteristics of the soil, including moisture and acidity ("pH"). Uncontrolled corrosion will ultimately result in numerous, relatively small gas leaks.

When the coating on a coated, but unprotected, steel pipe is breached, rapid metal loss will be experienced at the location where the coating defects occur, eventually allowing gas to escape.

## 6.2 Leaks

Initially, a leak from an unprotected steel pipe starts as a pinhole leak. Over-time metal loss will increase in size and location, allowing more gas to escape, eventually resulting in numerous relatively small gas leaks. Eventually, these small leaks multiply and can grow to the point where they threaten the integrity of the pipe. In general, the deterioration of bare and unprotected steel accelerates as it ages. Clay soils can make detection of the leaks difficult and can act as a conduit through which the gas migrates. We understand a considerable amount of AGN's UPS is in clay soil.

## 6.3 Overseas experience

Bare and unprotected steel removal programs in the US are both associated with the removal of cast iron and the elimination of low pressure systems, and standalone non-low pressure replacement programs. It is typical that the UPS assets will be replaced along with an accelerated cast iron mains replacement program as is planned by AGN under the MRP.

# 7. HDPE

## 7.1 Vintage Plastic (PE) Pipe

The primary problem encountered with vintage plastic pipe in the US is that some of the early products found in systems have an oxidized inner surface that predisposes the inner surface to experience cracks faster when certain stresses are applied. The resulting shortened crack initiation time leads to dramatically reduced overall pipeline longevity through a predominant failure mechanism known as slow crack growth.

This failure mode can have catastrophic consequences and was the cause of a large incident involving multiple fatalities in Puerto Rico in 1996, and incidents in California leading to the California Public Utilities Commission (CPUC) identifying Aldyl A PE pipes as a major potential hazard that will not be manageable by leak surveying. Additionally, the US Department of Transportation (DOT) has issued various Pipeline and Hazardous Materials Safety Administration (PHMSA) advisory bulletins about this early PE[17].

AGN has experienced similar incidents with its HDPE pipe material. We understand this pipe material was manufactured locally in Australia and is therefore not the identical material referenced here or used in the US. However, the US experience with equivalent materials has been the same. The CPUC, in 2014, published a study on Aldyl A Polyethylene pipe, a product manufactured in the US by DuPont called the *Hazard Analysis & Mitigation Report on Aldyl A Polyethylene Gas Pipelines in California*. This study examined potential hazards in California gas and electric utility operations, and sought to understand each utility's approach to mitigate the risks posed by the hazard.

The report found that "the danger associated with slow crack growth on Aldyl A is that, although the failures develop slowly, when they do fail, they fail much more abruptly and rapidly than underground leaks on steel distribution pipes Instead of small pin-hole leaks developing slowly over a number of years, as is typical of steel pipes, the leaks on Aldyl A are far more likely to be of a serious nature much more quickly. The 1996 San Juan incident and the two 2011 California incidents are good examples of this abrupt failure characteristic".

As a recommendation the report concluded:

*"This paper has highlighted the potential danger associated with early vintage Aldyl A pipes. It would be an undesirable outcome, however, for an operator to rely on this paper's determination of early vintage Aldyl A pipelines to be a potential major pipeline hazard as sole basis for wholesale removal of early vintage Aldyl A pipes from their systems. A properly executed comprehensive pipeline risk management program should take into account all identified threats affecting pipeline safety in combination, rather than to treat each threat in isolation, in order to arrive at the best allocation of utility resources needed to minimize the combined risks created by the threats in a cost effective manner. The potential hazards with early vintage Aldyl A pipes are operator specific, depending on the stress factors put on the pipes by the operators. Having highlighted the potential danger associated with early vintage Aldyl A pipes, we defer the mitigation of this potential hazard and the consideration on the scope and pace of any replacement program to the operators' judgment, since pipeline replacement programs are more suitably dealt with in the larger context of a general rate case or equivalent proceeding"*[18]

Due to the similarities in failure modes of vintage PE in the US and in the AGN SA network, and given the 3 serious incidents involving HDPE, we would submit that AGN has a clear basis for a decision to seek a replacement program for its Class 575 HDPE pipe and should have a robust risk mitigation plan, to include replacement, for its Class 250 HDPE based on its age and the US experience with Aldyl A pipe material.

[17] https://www.gpo.gov/fdsys/pkg/FR-2007-09-06/html/07-4309.htm
[18] Hazard Analysis & Mitigation Report on Aldyl A Polyethylene Gas Pipelines in California.

# 8. Review of AGN risk analysis

AGN has provided us with its risk-based approach based on the application of AS 4645 to develop its proposed accelerated main replacement program (Appendix A). We have had the opportunity to review this approach and have reservations as to the conservative application of AS 4645 to asset family main replacement as explained below (conservative to the extent that we would have assessed certain risks as being greater than the assessment AGN has given them). We understand that AGN will submit the risk matrix in support of the rationale for the program. However, we have advised that international practice does not require the use of a standard risk matrix approach to support a replacement program, noting however that the outcomes are consistent with overseas experience.

## 8.1 AS/NZS 4645

This standard is the base requirement for the management of a gas distribution network in Australia and as such is the source document for decisions on the health of the assets in the network. AS/NZS 4645 establishes requirements against which a network should assess risk. The guidance sets a basis to:

- Assess hazard severity
- Assess hazard frequency
- Rank risk based on severity and frequency analysis
- Treat risks, including specific guidance for gas distribution networks in operation

## 8.2 AGN's risk approach

While the results of the AS 4645 risk matrix analysis provide support for a mains replacement program that is consistent with international replacement programs, the UK program and programs since in the US were justified on a safety case[19]/assessment that did not rely on the use of a formal risk matrix. Jacobs believes, based on our experience, that the case for replacement already exists, and that the AS 4645 matrix can be used with the cautions set out below to aid in the prioritization of replacement on an accelerated basis.

AGN has grouped the network mains in to eleven categories based on asset material, location and pressure to facilitate a more granular assessment of risk than assessing mains as a single asset class.

The mains categories adopted by AGN are as follows:

1) **CI/UPS CBD program** – this category refers to all CI/UPS mains located within the Adelaide CBD;
2) **CI/UPS trunk mains** – this category refers to all medium pressure larger diameter CI/UPS trunk mains outside the CBD;
3) **CI/UPS higher risk areas** – this category refers to all low pressure CI/UPS mains in areas with a history of crack failure.[20] These mains are typically located in older suburbs that contain older-style residential buildings with underfloor spaces, where escaped gas has the potential to collect;
4) **CI/UPS remaining** – this category refers to the remaining CI/UPS mains in areas where there have been no recorded cracks to date;
5) **HDPE 250 higher risk areas** – this category refers to Class 250 polyethylene mains, which operate at medium pressure and are located in areas with a history of crack failure.[21] These mains were installed during the 1970s and 1980s and have become brittle and susceptible to cracking, and many are located in populated areas near buildings where escaped gas has the potential to collect;
6) **HDPE 250 remaining** – this category refers to the remaining Class 250 polyethylene mains, which operate at medium pressure, have become brittle and susceptible to cracking and are located in areas where there

[19] The term "safety case" is used as described in Section 5.1 accepting that the AGN risk matrix is also primarily an analysis of the mains safety risk.
[20] These mains have a crack frequency rate almost 2.5 times that of CI mains in the UK.
[21] These mains have a crack frequency rate almost three times higher than CI/UPS mains.

have been no recorded cracks to date. As with other HDPE mains, these mains may have also sustained squeeze off damage and as a result are considered likely to exhibit slow crack growth failures in the future.

7) **HDPE 575 (high risk areas)** – this category refers to Class 575 polyethylene mains that operate at high or medium pressure, and are located in areas with a history of cracking. Many of these mains are located in populated areas near buildings where escaped gas has the potential to collect;
8) **HDPE 575 remaining** – this refers to the remaining Class 575 polyethylene mains that operate at high or medium pressure, and are located in areas where there have been no recorded cracks to date. These mains may have sustained squeeze off damage and as a result are considered likely to exhibit slow crack growth failures in the future;
9) **Multi-user inlet services (CI/UPS)** – this category refers to 1,328 predominantly UPS services running through unit developments and commercial premises. These assets are located across the network;
10) **New PE** – this refers to the new polyethylene pipe that has recently been installed in the network and is not considered susceptible to cracking; and
11) **Protected steel –** this refers to steel pipe with a PE coating that is typically now used only in very high pressure applications (network trunk mains), and cathodically protected to maintain integrity and longevity. These mains are not susceptible to the cracking issues that affect PE pipes.

## 8.3 Severity rating

Based on the international experience with the asset classes defined above (cast iron, unprotected steel and vintage plastic), and the experience of AGN, we believe the severity class rankings set out in the severity rating assessment (below) are appropriate although some, should rightly be classified with a higher severity.

| | Catastrophic | Major | Severe | Minor | Trivial |
|---|---|---|---|---|---|
| **People** | Multiple fatalities result 1 2 | Few fatalities or several people with life-threatening injuries 3 4 5 6 7 8 9 10 11 | Injury or illness requiring hospital treatment | Injuries requiring first aid treatment | Minimal impact on health and safety |
| **Supply** | Long term interruption of the supply | Prolonged interruption or long-term restriction of supply | Short term interruption or prolonged restriction of supply 2 | Short term interruption or restriction of supply but shortfall met from other sources 1 3 4 5 6 7 8 9 10 11 | No impact; no restriction of gas distribution network supply |
| **Environment** | Effects widespread, viability of ecosystems or species affected, permanent major changes | Major off-site impact or long-term severe effects or rectification difficult | Localised (<1ha) and short-term (<2 yr) effects, easily rectified | Effect very localised (<0.1 ha) and very short term (weeks), minimal rectification | No effect, or minor on-site effects rectified rapidly with negligible residual effect 1 2 3 4 5 6 7 8 9 10 11 |

**Key:**
1. CI/UPS CBD program
2. CI/UPS trunk mains
3. CI/UPS higher risk areas
4. CI/UPS remaining
5. HDPE 250 higher risk areas
6. HDPE 250 remaining
7. HDPE 575 higher risk areas
8. HDPE 575 remaining
9. Multi-user inlet services (CI/UPS)
10. New PE
11. Protected steel

We are specifically focussed on the first ranking under the heading "People" as this is where the fundamental safety risk is. This should not in any way be taken as a diminution of the importance of reliability of supply or the environment, but is a direct acknowledgement that the risk of a gas escape leading to an explosion causing significant loss of life and/or property damage is, and should be, the principal concern. We believe the right class of materials has been correctly identified in the appropriate severity class with the caution expressed below.

One point we would make here in describing our view that the approach is conservative is to apply some caution to the allocation of “CI &UPS higher risk areas” and “CI & UPS remaining” family to the major and not catastrophic risk class. Within this class there are likely to be numerous cast iron and UPS assets in close proximity (30m) of high occupancy buildings within suburban areas such as schools, hospitals, shopping malls, aged care homes and office buildings. Any one of these buildings could fit within the AS 4645 category “Catastrophic” as a severity class as the consequence of an event may be multiple fatalities. In addition, we believe the HDPE high-risk areas family should be included in the catastrophic category as directly from AGN’s own experience these pipes can crack with catastrophic consequences.

We do have a concern that the approach does not consider the importance of property damage. In the US and the UK significant property damage is a key consideration as the incident could have led to loss of life if there had been people in the building. The authors of this Jacobs report were involved with the aftermath of two incidents in the UK that, but for the timing of the explosion, could have resulted in significant loss of life. One was in the central part of the City of London in a bank building that exploded during the morning of the day after Christmas when thankfully no one was at work.

The other appropriate and internationally consistent characteristic of this approach is that it is proactive in finding a way to prevent incidents from happening. In this context, it is comparable to the US regulation requiring that operators implement a Transmission and a Distribution Integrity Management program designed to require the operator to know their system and to take capital spending decisions based on the asset failure mode, life expectancy and other characteristics of the system. This proactive approach means you will take decisions to remove and replace entire asset families (such as low pressure cast iron) where experience locally, nationally and internationally so indicates. In other states of Australia, in the UK and in the US, CI, UPS and some vintage plastic assets are being removed in an asset family context.

## 8.4 Frequency rating

This classification caused us some initial concern as the gap between “frequent” and “occasional” in AS 4645 is substantial. Effectively it ranges from ‘once or more a year’ to ‘may occur in the pipe’s lifetime’. Here we draw attention again to the unpredictable nature of cast iron pipe failures and the potential for catastrophic results of a failure. In essence, the result of this classification is that all potentially bad pipes could fall in the “occasional” ranking. As a result, we can support the allocation presented by AGN in this classification. However, again we believe this is conservative, i.e. result in a lower risk rating. In other works, if there were a category between “occasional” and “frequent”, it would allow for some of the ratings to be in that category.

| Frequency Class | Frequency Description | AGN Asset Classification |
|---|---|---|
| Frequent | Expected to occur once per year or more | |
| Occasional | May occur occasionally in the life of the gas distribution network | 1 2 3 5 7 |
| Unlikely | Unlikely to occur within the life of the gas distribution network, but possible | 4 6 8 9 |
| Remote | Not anticipated for this gas distribution network at this location | |
| Hypothetical | Theoretically possible but has never occurred on a similar gas distribution network | 10 11 |

**Key:**

1. CI/UPS CBD program
2. CI/UPS trunk mains
3. CI/UPS higher risk areas
4. CI/UPS remaining

12. HDPE 250 higher risk areas
13. HDPE 250 remaining
14. HDPE 575 higher risk areas
15. HDPE 575 remaining

16. Multi-user inlet services (CI/UPS)
17. New PE
18. Protected steel

## 8.5 Risk matrix rating

The risk ratings that result from the application of the severity class and the frequency class are in our opinion overly conservative. We say they are conservative because of the concern expressed above that some pipes within the "CI &UPS higher risk" family, and HDPE higher risk families can reasonably be seen from the discussion above as falling within the "catastrophic" class.

| | Catastrophic | Major | Severe | Minor | Trivial |
|---|---|---|---|---|---|
| Frequent | | | | | |
| Occasional | 1 2 | 3 5 7 | | | |
| Unlikely | | 4 6 8 9 | | | |
| Remote | | | | | |
| Hypothetical | | 10 11 | | | |

Extreme    Intermediate    Negligible
High    Low

**Key:**

1. CI/UPS CBD program
2. CI/UPS trunk mains
3. CI/UPS higher risk areas
4. CI/UPS remaining

19. HDPE 250 higher risk areas
20. HDPE 250 remaining
21. HDPE 575 higher risk areas
22. HDPE 575 remaining

23. Multi-user inlet services (CI/UPS)
24. New PE
25. Protected steel

## 8.6 Risk treatment actions

Even though the required action in the extreme class is stated to be immediate reduction in risk, we believe that a planned removal program within the shortest feasible time is entirely consistent with the requirement. Again, with reservations around some of the pipe within the "CI &UPS higher risk" family, we believe the Risk Treatment Actions as allocated are appropriate.

As is consistent with implementation plans for programs introduced in the UK in the 1990's and more recently in the US, the emphasis shifts from a decision to replace to the priority of pipes for replacement. Pipes are prioritized with reference to removing the highest risk in as economic way as is reasonably possible.

As a result, most jurisdictions in the US and the UK have chosen to take a zonal or block approach to balance the need to remove cast iron and UPS pipe as quickly as reasonably possible while considering the economics and customer impacts. These customer impacts include the impact on rates and the disruption to daily lives. By adopting a block approach it is possible to go in and disrupt the neighbourhood once as opposed to moving in and out as a purely risk removal based approach would require.

## 8.7 Cost benefit analyses

Typically, Cost Benefit Analyses (CBAs) have not been used in the UK or the US to justify MRPs. The rational or justification for these programs is based on the safety case for the removal of the at risk materials. As was stated in a review of the UK IMRP conducted for the HSE and Ofgem[22]

*"Whilst it is recognized that a CBA was not used to provide the justification for the rationale or design of the IMRP, we note the note within the HSE's economic policy framework that CBA can be used to help make judgments about whether future risk reduction measures are reasonably practicable".*

## 8.8 Prioritization Model

AGN provided us with a model developed to assist in prioritizing mains for replacement, which uses the modeling undertaken for the UK HSE as a basis. That is, the AGN model uses historical crack frequency of mains and history of incidents on the network, to arrive at a fatality rate per kilometer of main. Jacobs has discussed data availability with AGN and understands that data limitations for the AGN network do not allow for the same granularity achieved in the UK modelling. Notwithstanding this, the model provides a suitable ranking prioritization for the SA network with the proposed timeframe and comparatively small inventory of mains providing some amelioration for the data limitations. The UK, due to the volume of at risk pipe, required an extended replacement program. It is therefore appropriate that they invest in the collection and analysis of more detailed data to help identify differences in risk between mains at a more granular level. Given its relatively limited inventory of at risk pipe, AGN has the capability, based on historical capital delivery, to complete its replacement program in approximately 5 years. Given the uncertainty level associated with even "sophisticated" modelling, we would not recommend that AGN invest additional resources in an attempt to replicate the UK modelling.

[22] HSE/Ofgem: 10 year review of the Iron Mains Replacement Programme
Prepared by Cambridge Economic Policy Associates Ltd for the Health and Safety Executive and Office of Gas and Electricity Markets 2011

# 9. Declaration

Jacobs, Jacobs' project manager and primary author of this report declare that, collectively, they have made all the enquiries that they believe are desirable and appropriate and that no matters of significance that Jacobs, Jacobs' project manager and report primary author regard as relevant have, to their combined knowledge, been withheld from this report.

# Appendix A. AGN Qualitative Risk Analysis

| | Catastrophic | Major | Severe | Minor | Trivial |
|---|---|---|---|---|---|
| **People** | Multiple fatalities result<br>1 2 | Few fatalities or several people with life-threatening injuries<br>3 4 5 6 7 8 9 10 11 | Injury or illness requiring hospital treatment | Injuries requiring first aid treatment | Minimal impact on health and safety |
| **Supply** | Long term interruption of the supply | Prolonged interruption or long-term restriction of supply | Short term interruption or prolonged restriction of supply<br>2 | Short term interruption or restriction of supply but shortfall met from other sources<br>1 3 4 5 6 7 8 9 10 11 | No impact; no restriction of gas distribution network supply |
| **Environment** | Effects widespread, viability of ecosystems or species affected, permanent major changes | Major off-site impact or long-term severe effects or rectification difficult | Localised (<1ha) and short-term (<2 yr) effects, easily rectified | Effect very localised (<0.1 ha) and very short term (weeks), minimal rectification | No effect, or minor on-site effects rectified rapidly with negligible residual effect<br>1 2 3 4 5 6 7 8 9 10 11 |

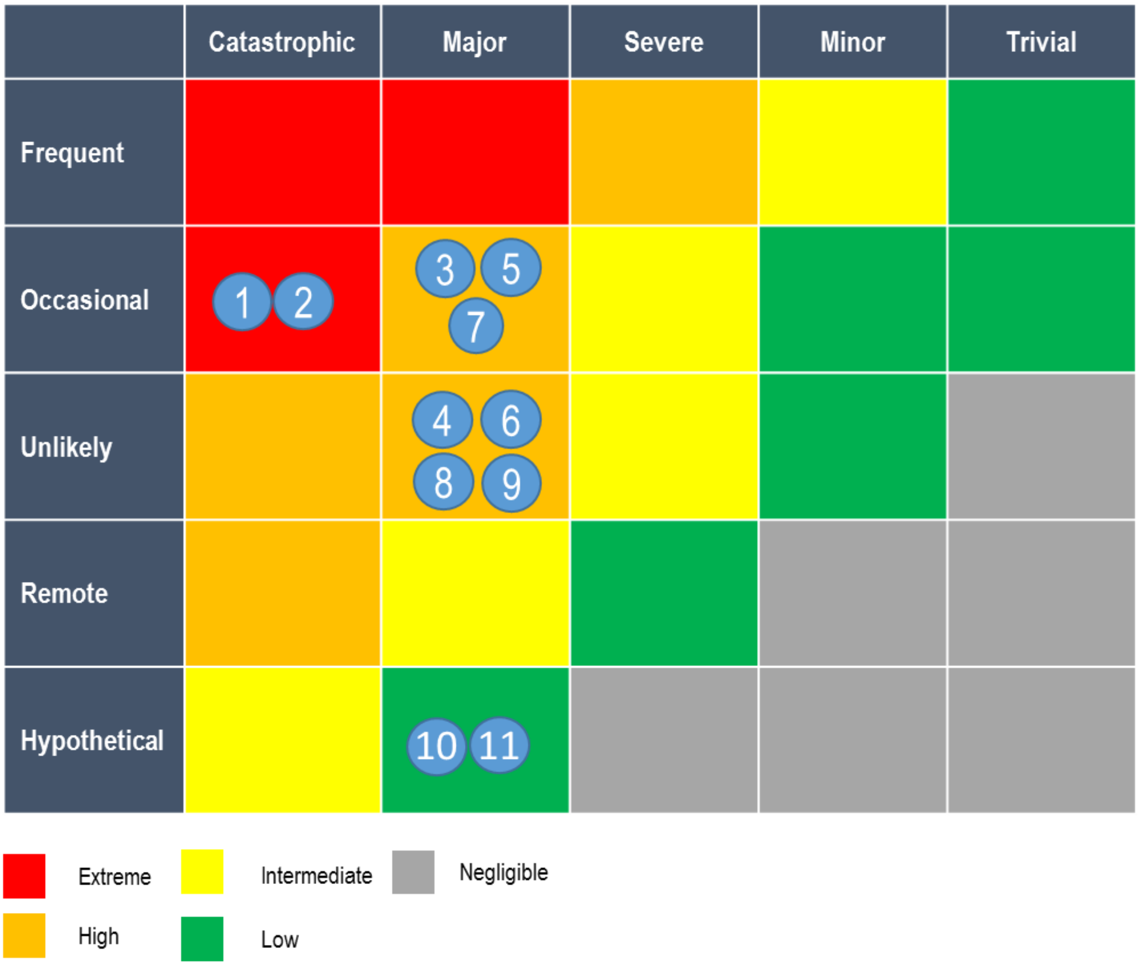
Key:

1. CI/UPS CBD program
2. CI/UPS trunk mains
3. CI/UPS higher risk areas
4. CI/UPS remaining
5. HDPE 250 higher risk areas
6. HDPE 250 remaining
7. HDPE 575 higher risk areas
8. HDPE 575 remaining
9. Multi-user inlet services (CI/UPS)
10. New PE
11. Protected steel

| Frequency Class | Frequency Description | AGN Asset Classification |
|---|---|---|
| **Frequent** | Expected to occur once per year or more | |
| **Occasional** | May occur occasionally in the life of the gas distribution network | 1 2 3 5 7 |
| **Unlikely** | Unlikely to occur within the life of the gas distribution network, but possible | 4 6 8 9 |
| **Remote** | Not anticipated for this gas distribution network at this location | |
| **Hypothetical** | Theoretically possible but has never occurred on a similar gas distribution network | 10 11 |

Key:

1. CI/UPS CBD program
2. CI/UPS trunk mains
3. CI/UPS higher risk areas
4. CI/UPS remaining
5. HDPE 250 higher risk areas
6. HDPE 250 remaining
7. HDPE 575 higher risk areas
8. HDPE 575 remaining
9. Multi-user inlet services (CI/UPS)
10. New PE
11. Protected steel




Key:

1. CI/UPS CBD program
2. CI/UPS trunk mains
3. CI/UPS higher risk areas
4. CI/UPS remaining
5. HDPE 250 higher risk areas
6. HDPE 250 remaining
7. HDPE 575 higher risk areas
8. HDPE 575 remaining
9. Multi-user inlet services (CI/UPS)
10. New PE
11. Protected steel

| Risk Rank | Required Action | AGN Asset Classification |
|---|---|---|
| Extreme | Modify the threat, the frequency or the consequences to ensure that the risk rank is reduced to Intermediate or lower.<br>For a gas distribution network in operation the risk must be reduced immediately. | 1 2 |
| High | Modify the threat, the frequency or the consequences to ensure that the risk rank is reduced to Intermediate or lower.<br>For a gas distribution network in operation the risk must be reduced as soon as possible, typically within a timescale of not more than a few weeks. | 3 4 5 9 6 7 8 |
| Intermediate | Repeat threat identification and risk evaluation process to verify and, where possible, quantify the risk estimation; determine the accuracy and uncertainty of the estimation. Where the risk rank is confirmed to be Intermediate, if possible modify the threat, the frequency or the consequence to reduce the risk rank to Low or Negligible.<br><br>Where the risk rank cannot be reduced to Low or Negligible action shall be taken to:<br>a) remove threats, reduce frequencies and/or reduce severity of consequences to the extent practicable; and<br>b) demonstrate ALARP.<br>For a gas distribution network that is in operation, the reduction to Low or Negligible or demonstration of ALARP must be completed as soon as possible, typically within a timescale of not more than a few months. | |
| Low | Determine the management plan for the threat to prevent occurrence and to monitor changes which could affect the classification. | 10 11 |
| Negligible | Review at the next review interval. | |

Key:
1. CI/UPS CBD program
2. CI/UPS trunk mains
3. CI/UPS higher risk areas
4. CI/UPS remaining
5. HDPE 250 higher risk areas
6. HDPE 250 remaining
7. HDPE 575 higher risk areas
8. HDPE 575 remaining
9. Multi-user inlet services (CI/UPS)
10. New PE
11. Protected steel

# Appendix B. Qualifications

Jacobs' Utilities Practice serves both the public and private sectors, providing management, engineering and operations related advisory services to clients globally. Engagements in the natural gas transmission and distribution industries include capital investment analysis, litigation support, asset integrity, merger and acquisition assistance, management audits, budget reviews, and policy and procedure reviews.

Below is a summary of several Regulatory Support and Asset Integrity Management assignments.

## *Regulatory Support*

### Safety, Modernization and Reliability Program – Elizabethtown Gas (2015-Present)

We provided evidence and analysis in support of Elizabethtown Gas' (ETG) vision for a Safety, Modernization and Reliability Program (SMART) that effectuate the retirement of vintage, at-risk pipe materials, and the replacement of those materials with a modern system. This included the removal of cast iron and unprotected steel and the removal of the low pressure system by elevating the pressures to medium. Our support centered on

- Establishing the System Vision
- Preparing a Safety Case
- Developing a Program Cost Projection (Business Case)
- Documenting Customer Benefits and Avoided Cost
- Creating a Program Implementation Plan

In the course of this project we carried out a bottom up cost analysis and model in support of the business case for the program and presented in testimony to the State regulatory Commission.

### Gas System Modernization Program – Public Service Electric & Gas (2014-2015)

PSE&G wanted to initiate a gas infrastructure filing to replace approximately 4,000 miles of cast iron and bare steel while recovering all associated costs promptly.

Jacobs provided evidence and analysis in support of the Gas System Modernization Program; the Program is the first five years of PSE&G's long-term (30 years) System Modernization Plan. We developed and provided written testimony that included the safety case and business case. The safety case consisted of understanding the current infrastructure replacement program, its effectiveness and safety; and contrasting those understandings to what would occur if the system was made of modern materials installed using top-quality construction techniques. The business case involved an examination of the program plan, construction cost, and development of customer benefits, avoided costs, and economic impact of program delays. Our efforts included:

- Identification and review of relevant documents from previous infrastructure cases for both PSE&G and other New Jersey gas distribution companies;
- Identification and review of PSE&G records and filings;

- Discussions with the appropriate subject matter experts from PSE&G, who have responsibility for gas operations, engineering, and accounting;
- Examination of PSE&G gas operations and engineering policies, procedures and practices regarding the conversion of the low-pressure portion of the system to an elevated pressure, and the replacement of higher-risk pipe materials (e.g., cast iron, unprotected steel);
- Review of PSE&G gas operations and engineering policy, procedures and practices regarding the Program and grid replacement plan.

## PE Pipe Condition and Quality Review – SGN UK (2014)

Recently we completed a review for the asset manager of SGN plc, the owner/operator of the gas distribution systems for Scotland and Southern England, of the PE system. This was designed to determine the construction methods and processes carried out when plastic pipe was first brought into service in the UK, and to identify if any issues might be apparent from leak data, past construction issues with failed fusion joints and a review of current construction methods. This review was both a desktop and field based review. In the UK they used a wide range of plastic pipe materials including AldylA and PVC, and now use PE80 and PE100.

## Accelerated Mains Replacement Program – Peoples Gas (2008-2015)

Wanting to accelerate the replacement of its higher-risk assets Peoples Gas first filing was unsuccessful. With Jacobs' regulatory support, which included a safety case, program implementation roadmap, program cost projection, an estimate of avoided costs, and examination of customer benefits, Peoples Gas's rate case filing was successful. The approved program would replace cast and ductile iron main and upgrade the system from low to medium pressure.

Due to the size of the program, Jacobs provided implementation advisory support that included:

- The creation of the Program Management Office (PMO)
- Assisting with the development of optimum staffing levels and roles and responsibilities for both field facing activities and project controls
- Assisting with the creation of a master plan to oversee prioritization and implementation process of the accelerated program
- Identifying and tracking regulatory deliverables
- Assisting in determining the vision for the distribution system into the future given that 60 percent will be replaced over the next 20 years
- Investigated innovations and new technologies
- Evaluated a range of possible contracting options and potential savings in accounting practice changes
- advised on the options for efficient materials procurement and handling to support the program
- Establishment a quality management system
- Reviewed the network planning Stoner model and planning manual
- Developed an integrated long-range capital planning model

## Review of Capital and Operating Plans and Programs – SourceGas (2013)

In light of an aggressive regulatory plan, and consequential capital investment and operating expenditure commitments, SourceGas' Board of Directors sought an independent review of its capital and operating plans to ensure they were replacing "the right asset classes in the right timeframe".

Jacobs undertook a study to corroborate the impact of SourceGas' existing and proposed safety enhancement programs and the potential impact of pending pipeline safety regulatory actions. Drawing on our broad pipe replacement project management experience of substantial, multi-year capital infrastructure programs this study involved:

- A pre-assessment to identify any gaps that may hinder executing the asset replacement programs effectively and efficiently, scrutinizing the program's scope, needs, and costs.
- A collaborative vertical review of completed replacement projects of various asset types to obtain a thorough review of policies, processes, information systems, and interdepartmental coordination from identification through closeout. The vertical assessment is process focused, assessing the soundness of the process and not the accuracy or quality of data, information, findings, conclusions, recommendation or decisions associated with the specific projects reviewed.
- An examination of the cost method, and drivers, used to estimate the total installed cost and project program cost, including direct and indirect costs of the asset replacement programs and the breakout of projected capital and operating expenditures, as well as forecast accuracy and cost contingency, as these are often misunderstood by regulators, as well as utilities.
- A review of the capability and capacity that SourceGas may need to manage and execute the capital programs effectively in the event of a large step change in spending.

## UK Gas Distribution Networks (GDNs) UK (2011-2012)

As part of the GDN price control process, the UK Regulator OfGem sought to introduce changes to the risk model criteria utilized by the GDNs as a legacy control following the sale by National Grid UK of four of the former Grid LDCs. We were engaged by all four GDN companies to assist in the development of the new criteria around threasholds for priorities and different approaches being encouraged to dealing with lower risk (large diameter) cast iron pipe.

## Pipe Replacement Strategies & Risk Prioritization Review National Grid – UK, (Formerly Transco), UK (1989-2003)

Following a number of significant incidents from unplanned releases of gas due to aging pipe infrastructure, our client sought a report on their pipe replacement strategies and risk prioritization models that would establish legal precedence that the company's pipe replacement policy was prudent. This review was comissioned by Lindsay Robson, then a senior counsel for the then Transco and now a Jacobs consultant, and was carried out by a number of Jacobs consultants, specifically including Christopher Pioli.

Each pipeline replacement strategy dating back to the early 1970's was methodically reviewed and documented, supported by a comparison of current practices in North America and Europe during the same periods. The pipe risk and replacement prioritization model at the time of the incident and current model were reviewed. Methodology, data, threats, hazards and algorithms used to develop the probability of failure, gas egress, and consequence of failure factors was examined. The policies, processes, and procedures supporting the implementation of the risk models were also reviewed.

Although the pending litigation was settled out of court, the company has used the report in preparing legal strategies in similar cases. We were also retained to conduct a similar extensive review of their post-2000 pipe replacement strategy.

# Asset Integrity Management

## Baseline Assessment of Gas Distribution Assets – City of Mesa (2008)

Concerned with the increasing capital and operating expenditures and associated regulatory uncertainty, the City of Mesa, sought an independent assessment of the gas distribution assets' health, providing additional insight for a strategic plan.

Jacobs conducted a baseline assessment and evaluation of the gas distribution assets owned and operated by the City of Mesa. The primary objective of the study was to provide a report to the City Council that:

- Characterized the present condition of the gas distribution assets
- Described the system's strengths and vulnerabilities
- Recommended and prioritized actions to prevent or remediate threats or risks to delivery of safe, reliable service
- Estimated the capital investment or O&M resources necessary to mitigate those threats or risks to delivery of safe, reliable service

## Pipe Replacement Strategies & Risk Prioritization – National Grid UK (1996-2006)

Over a number of decades Jacobs' consultants have carried out numerous capital investment related studies and activities in the UK both as consultants and as National Grid staff.

## Asset Management Practices Review – SGN UK (2010)

As part of its preparation for upcoming Price Control submissions, SGN, a UK Network operator with 5+million customers in Scotland and Southern England, wished to review its key strategies and primary asset delivery objectives, to provide evidence regarding the condition of its assets and its asset management systems.

Jacobs reviewed SGN's asset management practices with respect to low-pressure holders, high-pressure storage sites, offtake/entry points, transmission reducing stations and pressure reducing stations, assessing inspection measures and KPIs and SGN's compliance with these. This was to ensure that SGN was evaluating the correct information to monitor the quality of its assets and the effectiveness of its asset management program related to the construction, operation, and maintenance of the gas distribution and transmission systems.

Also, SGN wished to:

- Conduct a review of external practices to identify 'best practice' and other opportunities for learning with respect to standards, policies, practices, measures, and KPIs to provide assurance the company was compliant with regulatory requirements and its current standards and policies,
- Evaluate the measures and KPIs in use for effectiveness and consistency, and
- Compare the measures against external companies in North America to help identify best practices or leading industry practices.

In carrying out the assessment, several key themes emerged:

- Availability and accuracy of asset data limit a complete asset management approach to maintenance.

- Policies and standards represent a wealth of experience and present opportunities for reduced maintenance or associated capital design cost.
- Enhanced structured approach to asset upgrade, replacement, or disposal could provide long-term value.

## San Bruno Incident (2011)

In response to the San Bruno incident, the California Public Utilities Commission (CPUC) formed an Independent Review Panel (Panel) of experts. The Panel retained Jacobs as technical advisors.

Included in the Panel's scope of work was to gain an understanding of the underlying reasons for the incident, delve into the complexities of how pipeline integrity management and regulatory oversight operate and to offer recommendations for actions which the operator and regulators could consider, reducing the likelihood of future incidents.

In addition, our investigation addressed such items as worker safety versus system safety, data management, threat identification, the spirit of regulatory compliance, organizational effectiveness, resource allocation, quality assurance, enterprise risk management, the strategic integrity plan, and organization culture.

The resulting report was regarded by the senior leadership of both PGE and the CPUC as their roadmap to improvement.

# Appendix C. Terms of Reference

JOHNSON WINTER & SLATTERY

LAWYERS

Partner: Anthony Groom +61 8 8239 7124
Email: Anthony.groom@jws.com.au
Our Ref: B2385
Your Ref:
Doc ID: 67310602.1

5 January 2016

Lindsay Robson
Jacobs Group (Australia) Pty Limited
32 Cordelia Street
SOUTH BRISBANE QLD 4101

Dear Mr Robson

**Australian Gas Networks Limited – South Australian Access Arrangement review**

We act for Australian Gas Networks Limited (**AGN**) in relation to the Australian Energy Regulator's (**AER**) review of the Access Arrangement for AGN's South Australian gas distribution network under the National Gas Law and National Gas Rules for the period July 2016 to June 2021.

AGN wishes to engage you to prepare an expert report in connection with AGN's access arrangement revision proposal.

This letter sets out the matters which AGN wishes you to address in your report and the requirements with which the report must comply.

***Terms of Reference***

On 26 November 2015 the AER released its Draft Decision in respect of AGN's proposed access arrangement. In that Draft Decision the AER did not approve the scope of the mains replacement plan as proposed by AGN.

In response to the Draft Decision AGN has revised its mains replacement plan.

AGN wishes you to provide your expert opinion as to the following matters:

(a) the safety risks that have been shown to exist in respect of cast iron, unprotected steel and HDPE mains in international jurisdictions and the approach taken to addressing these risks;

(b) whether you consider the risk assessment undertaken by AGN in accordance with AS 4645 to be similar to approaches taken in other jurisdictions with cast iron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replacement programs and the appropriateness of the frequency and severity ratings made and consequent treatment actions identified by AGN in following AS 4645; and

(c) given your expertise, whether you consider the revised AGN mains replacement plan is consistent with the actions of a prudent service provider acting efficiently and in accordance with accepted good industry practice.

In terms of the efficiency limb of the test you are only required to comment as to whether the timeliness and order of priority of replacement of the mains proposed by AGN is consistent with appropriate risk mitigation strategies. Other elements of efficiency (including the unit costs of contractors and suppliers engaged by AGN) will be dealt with elsewhere in AGN's submission.

***Use of Report***

It is intended that your report will be submitted by AGN to the AER with its response to the Draft Decision.

If AGN was to challenge any decision ultimately made by the AER, that appeal will be made to the Australian Competition Tribunal and your report will be considered by the Tribunal. AGN may also seek review by a court and the report would be subject to consideration by such court. You should therefore be conscious that the report may be used in the resolution of a dispute between the AER and AGN. Due to this, the report will need to comply with the Federal Court requirements for expert reports, which are outlined below.

***Compliance with the Code of Conduct for Expert Witnesses***

Attached is a copy of the Federal Court's Practice Note CM 7, entitled "*Expert Witnesses in Proceedings in the Federal Court of Australia*", which comprises the guidelines for expert witnesses in the Federal Court of Australia (**Expert Witness Guidelines**).

Please read and familiarise yourself with the Expert Witness Guidelines and comply with them at all times in the course of your engagement by AGN.

In particular, your report should contain a statement at the beginning of the report to the effect that the author of the report has read, understood and complied with the Expert Witness Guidelines.

Your report must also:

1 contain particulars of the training, study or experience by which the expert has acquired specialised knowledge;

2 identify the questions that the expert has been asked to address;

3 set out separately each of the factual findings or assumptions on which the expert's opinion is based;

4 set out each of the expert's opinions separately from the factual findings or assumptions;

5 set out the reasons for each of the expert's opinions; and

6 otherwise comply with the Expert Witness Guidelines.

The expert is also required to state that each of the expert's opinions is wholly or substantially based on the expert's specialised knowledge.

It is also a requirement that the report be signed by the expert and include a declaration that "*[the expert] has made all the inquiries that [the expert] believes are desirable and appropriate and that no matters of significance that [the expert] regards as relevant have, to [the expert's] knowledge, been withheld from the report*".

Please also attach a copy of these terms of reference to the report.

***Terms of Engagement***

Your contract for the provision of the report will be directly with AGN. You should forward your account for the work performed directly to AGN.

Please sign a counterpart of this letter and return it to us to confirm your acceptance of the engagement.

Yours faithfully


**Enc:** **Federal Court of Australia Practice Note CM 7, "Expert Witnesses in Proceedings in the Federal Court of Australia"**

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Signed and acknowledged by Mr Lindsay Robson

Date January 5, 2016