- General Observations On the Myth of a -

Best International Pipeline Standard

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by
Richard B. Kuprewicz
President, Accufacts Inc.
kuprewicz@comcast.net
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Accufacts Inc.

"Clear Knowledge in the Over Information Age"

This report, developed from information clearly and readily in the public domain, represents the opinions of the author who is solely responsible for its content.

Executive Summary

> No one country's current requirements or standards adequately capture all the relevant factors that should prevent a pipeline failure, or ensure wise selection of pipeline routes in all countries.

This report provides a simple perspective on major pipeline standards or safety regulations often cited as references for new pipelines contemplated in various countries. Specifically, this paper refutes observations indicating that certain pipeline projects are following a mythical "Best International Standard, or Standards." Some countries have standards that address certain specific pipeline issues, many quite well, but are deficient or differential in other important areas that may make their application, especially in another country, problematic or risky. Several of the reasons preventing development of a "one size fits all" Best International Standard for pipelines include: ongoing pipeline regulation/standard/code evolution, misunderstandings or differences in dealing with threats across various stages of a pipeline's lifecycle, and diverse cultural and jurisprudence driving regulatory acceptance of varying risks among countries (e.g., wide variation in enforcement effectiveness)."

Pipeline project managers and industry public relations spokespersons would be well advised to avoid utilizing the term "Best International Standard, or Standards" in trying to sell their particular pipeline project or route. Credibility and confidence with the public is best served by clearly indicating the <u>specific</u> core pipeline standards or safety regulations that are employed to establish minimum safety approaches for a particular pipeline project in a given country. Given the obligation to be brief, this paper's observations will focus on natural gas and liquid land-based steel transmission pipelines. Such infrastructure serves as critical links in transporting natural gas, crude oil, natural gas liquids, hydrocarbon products such as gasoline, jet fuel, diesel, fuel oil, and their intermediate products, all of which can play a critical role in allowing a modern economy to function.

Two major topics driving pipeline regulatory, standard, and code development in many countries are also discussed in further detail: Risk Assessment ("RA") and Integrity Management ("IM"). Important cautions concerning a subset of RA, the application of numerical risk applications, often called Quantified or Quantitative Risk Analysis ("QRA") are briefly presented. At this time QRA for pipelines is defined or allowed in only a very few relatively low mileage pipeline countries, but its application is expected to grow. Pipeline IM is gaining new emphasis after serious "wake up calls" of major gas and liquid transmission pipeline ruptures, with loss of life, following a cycle of pipeline deregulation in the United States.[1]

Pipeline regulations and standards are periodically updated. This paper references pipeline standards this author has observed as often cited as key anchor references, and by no means am I suggesting that these are the only major pipeline standards. The author has utilized his best efforts to ensure that the most recent versions of references used in this paper have been evaluated. Given

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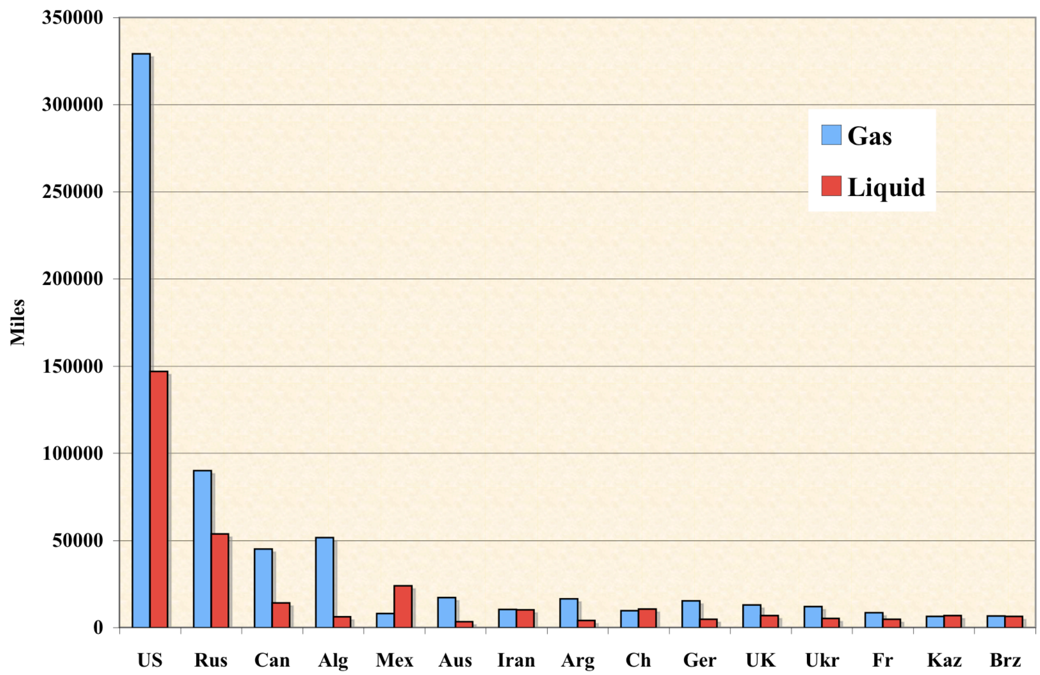
Cover page photo of Camisea pipeline failure –from Peruvian congressional investigation committee report – Camisea pipeline ruptures – June 2006 available at E-Tech International Projects web site http://www.etechinternational.org/projects.htm.

[1] See NTSB reports on the Bellingham liquid transmission pipeline failure of June 10, 1999 (NTSB PAR-02-02), and the Carlsbad natural gas transmission pipeline rupture of August 19, 2000 (NTSB PAR-03-01) at the web site: http://www.ntsb.gov/Publictn/P_Acc.htm.

the various strengths and weaknesses in all pipeline standards, the reader is advised to verify that the latest current editions of key references cited for any proposed pipeline project in their respective country are proper and appropriately utilized.[2]

Figure 1 - Countries with the Greatest Pipeline Mileage



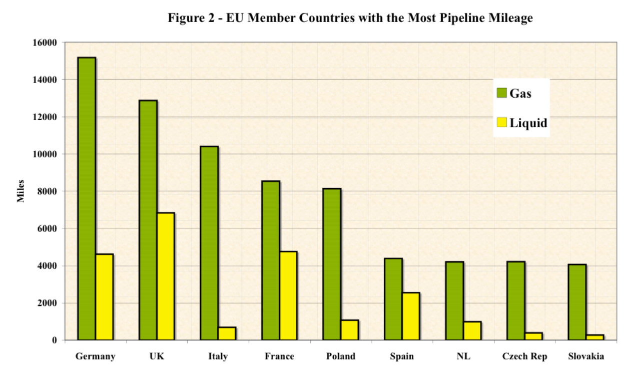
Data from CIA web site https://www.cia.gov/cia/publications/factbook/fields/2117.html

A Perspective on the World's Major Pipeline Mileage

The evolution of pipeline safety standards and regulations has historically followed U.S. code or regulatory efforts derived from numerous pipeline failures spanning many decades. While there are many basic similarities in dealing with pipeline safety, there are also various important differences throughout the world. This is especially true concerning pipeline routing issues, as more countries are faced with a need to install pipelines to meet demand. Most transmission pipeline systems utilize pipe operated at high pressures and high stress levels. What usually mandates different approaches in pipeline regulation/standards/guidance is: how a specific country addresses the various risks associated with the different stages of a pipeline's long lifecycle; the level of detail in specific code/standard/regulations governing application; whether these standards are evolving using newer, and sometimes developing techniques intended to push technical advances (such as newer grades of high stress steel that permit thinner pipe wall to contain pressure); the effectiveness of regulatory "oversight" agencies to enforce such regulations and standards; and the willingness or tolerance of a country's society/government to accept the risk of

[2] For example, the Australian Pipeline Standard, AS 2885.1 "Pipelines Gas and liquid Petroleum, Part 1: Design and construction" is undergoing considerable modification, but has not been issued. The 2001 amended version of the 1997 Standard currently in force is thus utilized for this paper.

major loss of life. Fortunately, the vast majority of pipeline is still located in sparsely populated areas or areas of lower population density and/or low environmental sensitivity. However, there are locales where population growth has encroached around originally sparsely populated pipeline routes or where a pipeline operator has chosen to route a new pipeline in higher density areas. Such route selection is usually based on saving costs that may or may not be real, or of benefit to the public. In all fairness, there are indeed some pipeline routes where the pipeline operator has little choice in avoiding sensitive or populated areas, though this limited option route is fairly rare.



Data from CIA web site https://www.cia.gov/cia/publications/factbook/fields/2117.html

Figure 1 represents a chart of the approximate liquid and gas transportation pipeline mileage for the fifteen countries containing most of the world's pipelines (roughly 80% of the total). Those countries with the most pipeline mileage have been placed in rank order with countries containing the greater total miles to the left side of the graph. The mileage indicated in Figure 1 is derived from data in the 2006 CIA's World FactBook and excludes gas distribution systems. Given several variables, including the timing of information provided to that database, the FactBook mileage should be considered "approximate" and not be taken as exact.[3] This database, however, is suitable for the purpose of demonstrating the relative proportion and division of high pressure, high stress land based steel transmission pipeline mileage across the world that is the focus of this paper. Discussion of low stress pipelines, such as gas distribution pipeline or low stress gathering pipeline, is not the focus of this paper as such low stress systems generally do not fail as very high-energy release ruptures. Transmission pipelines are those pipelines that transport "conditioned or treated" fluid, usually for long distances. As a point of reference, utilizing a more definitive reporting database, the U.S. has approximately 295,000 miles of onshore natural gas transmission pipeline, roughly 1.2 million miles of gas distribution main pipelines for the last reported year of 2005, and 167,000 miles of liquid transmission pipelines as of 2007.[4]

The development of most of the world's transmission pipeline mileage was associated with large oil or gas field discoveries, the land size of the country, and the need to get these discoveries (many in remote areas) to market, including to other consumer countries. Figure 1 clearly indicates that the U.S. transmission pipeline mileage exceeds the combined mileage for the remaining fourteen indicated counties. This observation should not come as a surprise given the U.S.'s earlier discovery history and severe appetite for fossil fuel energy, easily outstripping other consumer countries.

Because the European Union ("EU") might now be moving toward a more consistent pipeline code approach in that region of the world, Figure 2 provides a pipeline mileage summary (excluding gas

[3] With crude oil prices of over $60/bbl there has been a rush to get oil and natural gas pipelines to market which can cause a change in pipeline mileage, though not all these "pipe dreams" will be built.
[4] U.S. Pipeline and Hazardous Materials Safety Administration ("PHMSA") "Office of Pipeline Safety Pipeline Statistics" databases at http://ops.dot.gov/stats/stats.htm.

distribution systems) for the nine EU members containing the greatest mileage of pipelines (approximately 80 % of the total mileage of 116,939 miles in the twenty-seven current member countries). Two of the EU countries (the UK via PD 8010, and the Netherlands via NEN 3650) are often cited by industry as leading efforts in the application of numerical risk analysis, or QRA, to pipelines, even though they are relatively low pipeline mileage countries (see Figure 5).

Figure 1 also helps demonstrate why the U.S. has historically played a lead role in the development of pipeline safety standards. In the U.S., pipeline safety regulation came about in federal law in the late 1970's after several dramatic and tragic pipeline failures. Since then, this author would characterize the pipeline safety regulatory process in the U.S as having ebbed and flowed several times over the past 30 years, with the current cycle coming out of a period favoring pipeline deregulation (ebbing) through the 1990's. Since the previously mentioned 1999 Bellingham and 2000 Carlsbad pipeline tragedies, the regulatory process has moved toward more pipeline safety regulation in this country, based on the public's and Congress's perception that pipeline deregulation had swung a little to the extreme.

Despite the amount of pipeline mileage in the U.S., it would be inappropriate, unfair, and this author believes downright wrong, to characterize pipeline standards developed in the U.S. as presently leading the world. There are certain areas of the U.S. pipeline safety regulation and standard effort that do indeed still lead the world. Many other countries, however, have developed superior technical approaches in certain specific areas of pipeline regulation or standards surpassing U.S. efforts. For example, as will be discussed in the next section, some countries now permit pipelines to operate at higher Design Factors ("DF") while the U.S, an earlier developer of this concept in the research stage, is a latecomer in advancing this technical step in the field.[5, 6]

Various Design Factor Approaches

DF = hoop stress/SMYS

Most countries take similar safety approaches for transmission pipelines, applying some modified form of Barlow's Formula, when considering pressure, pipe grade (yield strength), pipe diameter, and thickness. There may be a small variation in comparing the Barlow Formula among countries as definitions of thickness, diameter, and yield stress may vary slightly. The critical controlling factor in applying this formula is the limitation on the maximum Design Factor value allowed in the regulations or standards. In simple terms the Design Factor is the ratio, or fraction, of the allowed hoop stress pressure, Maximum Operating Pressure ("MOP") or Maximum Allowable Operating Pressure ("MAOP"), to the pipe's specified minimum yield strength ("SMYS") also expressed in pressure.[7] Normally the maximum allowable DF is set depending on pipe location, type of fluid to

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[5] See Accufacts Inc., "Increasing MAOP on Gas Transmission Pipelines, March 31, 2006 at http://www.pstrust.org, and 3/9/07 comment letter to Docket Management System DOT Docket No. 26617-Increasing MOP on New Liquid Pipelines, at http://dms.dot.gov/search/searchFormSimple.cfm.

[6] Ironically much testing supporting higher Design Factors occurred at a U.S. research facility. There are approximately 5000 miles of U.S. gas transmission pipeline that has operated at a 80% DF limit for many decades, grandfathered prior to initial passage of U.S. pipeline safety regulations, that until recently limited the DF to a maximum of 0.72 in the U.S.

[7] Some countries designate their maximum operating pressure as MOP and some as MAOP. The U.S uses both terms, MOP for liquids and MAOP for gas. MOP or MAOP is not the pressure limit of the

be moved in a pipeline, and population density or other sensitive factors. The higher the Design Factor the greater the permitted pipeline maximum operating pressure for a given grade, thickness, and diameter of a pipe. Conversely, for a specified maximum operating pressure, pipe grade, and pipe diameter, the lower the Design Factor the thicker the pipe wall. Specifying a lower DF has historically been one approach to reduce the failure risks associated with segments of a pipeline. Figure 3 lists various maximum Design Factors for often-cited core pipeline regulation countries. For illustrative purposes for Canada, an "equivalent" Design Factor is given to reflect that the Canadian Design Factor is divided into a "design factor" and a "location factor" which must be multiplied together to yield a Design Factor comparable with the values shown for the other countries in Figure 3. There also may be more than one Design Factor within a Class based on other restrictions, such as road crossings, that will reduce the Design Factor at specific sites. Definitions for the various Classes may also be different, varying among countries. At Design Factors of 0.3 or less, most pipelines are not readily susceptible to pipeline rupture.[8]

Figure 3 - Typical Maximum Design Factors For Transmission Pipe

	Liquid	Natural Gas [2]	
USA			
No classification	0.72 [1]		Special permits to 0.8 under consideration. B31.4 limits DF to max 0.72.
Class 1 Location		0.72	Special permits to 0.8 now allowed. B31.8 subdivides Class 1 into Div 1 and Div 2 based on hydrotest pressure.
Class 2 Location		0.6	Special permits to increase DF now allowed.
Class 3 Location		0.5	Special permits to increase DF now allowed.
Class 4 Location		0.4	
Canada			
Class Location Assessment Area 1	0.8	0.8	Equivalent Design Factor Shown = Canadian design factor x Location Factor which also depends on fluid and other factors.
Class Location Assessment Area 2	0.8	0.72	
Class Location Assessment Area 3	0.8	0.56	
Class Location Assessment Area 4	0.8	0.44	
Australia			
Location Class R1	0.72	0.72	Specifies one Design Factor though Location Class is utilized in defining the minimum number of protection measures required in each Class.
Location Class R2	0.72	0.72	
Location Class T1	0.72	0.72	
Location Class T2	0.72	0.72	
U.K.			
No Class Location	0.72		> 0.72 allowed, but recommends a full Risk Assessment.[3, 4]
Location Class 1		0.72	> 0.72 allowed in Class 1 & minor incursions in Class 2, but recommends a full Risk Assessment.[3, 4]
Location Class 2		0.3	Can be raised to 0.72 if Risk Analysis justified to a statutory authority.
Location Class 3		0.3	
ISO 13623			
No Classification	0.77		
Location Class 1		0.83	Remote areas (desert, tundra)
Location Class 2		0.77	
Location Class 3		0.67	
Location Class 4		0.55	
Location Class 5		0.45	

Notes:
1 = the U.S. Design Factor for liquids does not distinguish between Low Vapor Pressure (LVP) and High Vapor Pressure (HVP) liquids. Design Factor for liquids for all other indicated standards are for LVP liquids
2 = for natural gas and HVP liquids.
3 = Risk Assessment is not a Risk Analysis though a Risk Analysis may be part of a Risk Assessment.
4 = demonstrated to regulatory authorities that increase failure probability and risk due to ultimate limit states is not significant. Demonstration is defined as "risk-based techniques and structural reliability analysis or other relevant advanced analysis methods."

> Prudent siting and other factors related to pipeline proximity to population or other sensitive areas must carefully consider and thoroughly evaluate rupture risks, especially for higher capacity larger diameter higher-pressure pipeline systems.

The lower Design Factors tend to drive pipelines in some countries to thick walled pipe (i.e., pipe where the D/t $\leq$ 20). Essentially all of the U.S. transmission

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pipeline as accumulation pressure over these defined operating limits (e.g., surge) is allowed under various operating conditions.

[8] In certain situations, or for pipelines that move reactive fluids, pipe can be made to rupture at design factors less than 0.3. Transportation of such reactive or highly corrosive fluids in U.S. transmission pipelines is not permitted unless certain precautions are undertaken. This does not mean that non-reactive fluids cannot corrode pipelines, as internal corrosion remains a significant cause of transmission pipeline repairs or failure in the U.S.

pipelines are considered thin walled as pipe is installed at much higher D/t's, though even this thin wall pipe will be thicker in the higher class locations requiring lower Design Factors. For a given pressure, thicker wall pipe tends to buy an operator time between the introduction of an anomaly to a pipeline and its possible time to failure. There are definitely benefits to having thicker walled pipe, but it is a myth that such pipe, even thick walled, is invincible to failure, especially if the pipe is not properly managed during its lifecycle stages or its long operating life. For major transmission pipelines, given the considerable investment (which can easily run into the many multimillions of dollars), the increasing price of steel, the drive to boost capacity to gain economies of scale, the improvement in higher stress capability grades of steel (e.g., X-100, X-120), and demands for greater pipeline efficiencies, many future large scale long distance transmission pipeline operators will want to move to larger diameter, higher yield stress thinner pipe, able to handle increasing pipeline pressures (well in excess of a historical cutoff level of 1440 psig). Such high capacity pipelines are capable of quickly releasing (within several minutes) many hundreds of tons of material in the event of rupture.

Observations on Different Standard Approaches Through a Pipeline's Lifecycle

Figure 4 - Observations on Major Pipeline Standard Approaches by Pipeline Lifecycle Stage

	Active Pipeline Lifecycle Stage				
Country	**Design***	**Material**	**Construction Initial Testing**	**Operation**	**Maintenance**
US 49CFR195(liq) 49CFR192(gas)	Different key regulations & references for liquid & gas (i.e., ASME B31.4-liq, B31.8/B31.8S-gas). Abnormal loading must be considered. No pipeline Design Life triggers. No pipeline Safety Evaluation process defined or required. No pipeline siting/routing guidelines. ASME B31.8S for gas defines "risk-based" approach. Acceptable risk thresholds not defined.	References industry standards. Fracture toughness & fatigue requirements in ASME B31.4 & ASME B31.8.	Procedures for high stress hydrotest <u>not</u> defined. 100% NDT of girth welds <u>not</u> required. Laydown guidelines provided.	Allows waiver of overpressure event reporting, though B31.4 and B31.8 code limit overppressure to 110% MOP/MAOP.** IM program requires MOC process.	Defines requirements in overall IM program, mininum inspection tools/methods & minimum reinspection intervals.
Canada CSAZ662	One key reference for liquid & gas pipelines. Incorporates pipeline Design Life qualifiers. Limit States approach permited if declared suitable by operator. Nonmandatory guidelines for Risk Assessment incorporated (QRA thresholds not defined).	More prescriptive material guidance. Incorporates greater clarity in fracture toughness & fatigue requirements.	Sets upper limit for maximum hydrotest pressure and incorporates more detailed hydrotest procedures. 100% NDT of girth welds <u>not</u> required. Requires pipe installation & project documentation (QA/QC).	Overpressure limited to 110% MOP MOC process <u>not</u> incorporated but suggested in nonmandatory IM guidelines.	Provides nonmandatory guidance for IM program.
Australia AS2885	One key reference for liquid & gas. Incorporates Design Life triggers. Provides pipeline route selection protocols. Mandates design against external interference threats. Risk Assessment study required for approval (benchmarks to ALARP). Utilizes qualitative approach to develop Risk Class along pipeline. Actions required along pipeline for each Risk Class defined, and must be documented and approved.	More detailed material conditions. Requires a fracture control plan and outlines toughness testing methods.	Hydrotest required before placement in service, but test pressure range <u>not</u> incorporated. Identifies minimum records to be retained for life of pipeline.	Overpressure limited to 110% MAOP. Provides guidance in external interference protection. Includes MOC process.	Requires design for smart pigging.
UK PD8010	One key reference for liquid & gas pipelines. Incorporates pipeline Design Life. Recommends proxity offsets for gas and HVP liquids. Incorporates pipeline route selection guidelines. Safety Evaluation in the form of Risk Assessment required for new pipeline. Allows QRA approach, but no clear societal risk level thresholds.	Includes more detail in material, fracture toughness, & fatigue requirements. Outlines QA/QC process.	Sets hydrotest pressure range and incorporates more detailed hydrotest procedures. Alternative to construction hydrotest (SRA) permitted. Recommends 100% girth weld NDT for <u>most</u> liquid (can be reduced if welding quality proves consistant), and 100% NDT for all natural gas pipelines. Provides pipe installation & project documentation guidelines.	Overpressure limited to 110% MAOP. More detailed internal corrosion program guidance. Incorporates a MOC process.	IM referenced to Design Life. Focus on smart pigging for IM. Insufficient details in IM guidance approach such as reinspection interval.
ISO 13623	One key reference for liquid & gas. Encompasses pipeline Design Life. Requires Safety Evaluation for pipelines containing cerrtain fluids in certain areas utilizing Risk Assessment (No QRA risk thresholds). Includes nonmandatory pipeline routing process.	Includes fracture toughness & fatigue requirements.	Require high stress hydrotest for <u>certain specific fluids in special areas</u>. Requires 100% girth weld NDT <u>on only</u> certain specific fluids operating above specified stress levels.	Overpressure limited to 110% MAOP Limited MOC guidance.	Focuses on smart pigging for intgerity monitoring.
Notes:	*** = See previous section on Design Factors**			**** = MOP/MAOP plus accumulation pressure**	

A previous paper has discussed in detail the five active lifecycle elements or stages of a pipeline.[9] A more detailed review of various key pipeline references or standards will indicate how various countries approach safety with regard to these pipeline stages. Figure 4 provides a simple summary from this author's perspective of major pipeline standard approaches in various "core" or anchor countries. Comments in the figure are referenced to the U.S. as the base. These observations are by no means meant to be all the major observations, nor all the major countries or standards, just some from the author's perspective, that are more significant that space will allow. The ISO 13623 pipeline standard has also been included in Figure 4. It should be noted that the ISO Standard does not preempt member countries that have legislated or established pipeline requirements for public safety and protection of the environment.

There are no internationally recognized acceptable risk criteria threshold levels for pipelines to be used in all countries.

Standards are only as good as the Quality Administration/Quality Control ("QA/QC"), and the regulatory enforcement of these utilized standards, to ensure that specific intended approaches are being applied appropriately or followed, especially in the field. A recent example involving a multi-billion dollar pipeline project emphasizing this point is the Camisea Project in the Peruvian Amazon. Despite superior requirements for testing, the QA/QC process appears to have broken down during the field construction/initial inspection phase. The new liquid pipeline has had five major pipeline failures in its first two years of operation. Further background and analysis of this project can be found on the Web.[10] The cover photo on this report provides an example of just one of the many pipeline failures that have occurred on the Camisea Project pipelines since their initial startup.

Two Recent Major Developments Driving Pipeline Safety Approaches

On the international front, two more recent major developments concerning pipeline safety standard/regulatory efforts merit special discussion: Risk Assessment including a possible offspring QRA, and a new approach getting particular emphasis in the U.S., pipeline Integrity Management.

Risk Assessment and QRA – New tools in the pipeline world, or an illusion/deception?

From this author's perspective, none of the countries shown in Figure 5 has yet to clearly legislate specific regulatory acceptable risk criteria thresholds adequate for pipelines, especially societal risks for rupture (frequency per year vs. number of fatalities per event usually known as F/N graphs).

Some countries are moving their pipeline regulatory efforts away from the traditional prescriptive approach that sets clearly defined minimum requirements which pipeline companies must follow, toward a more "performance" based methodology. Performance based usually indicates Risk Management of which Risk Assessment is a critical major component (the other component is Risk Control). RA is a defined process approach, either identified in regulation or in a clear standard, which involves the identification of pipeline

[9] Accufacts Inc., "Increasing MAOP on Gas Transmission Pipelines," March 31, 2006.
[10] At http://www.amazonwatch.org/amazon/PE/camisea/and at http://www.etechinternational.org/projects.htm.

risks, the evaluation of these identified risks, and subsequent management of these risks. Note that RA does not guarantee that a particular risk has been eliminated, just "managed." Some countries, such as the U.S., set no measured performance based risk threshold benchmarks (other than release is an RA failure). Other countries require RA efforts to meet more definitive measures such As Low As Reasonably Practical/Practicable ("ALARP"), for example. A very few countries have now proceeded to more specific RA approaches, requiring additional detailed or numerical methods, such as QRA, to meet regulatory defined specific risk benchmarks, or quantified risk acceptance criteria thresholds, for pipelines. This author believes that the establishment of particular QRA risk acceptance criteria threshold requirements is the responsibility of the legislature serving the populace within a specific country. Given the potential for high capacity (i.e., large diameter high-pressure) pipelines to quickly generate very large potential impact zones, if QRA is allowed, numerical risk threshold values should be established for both individual and especially important societal risks, which take on special significance in high population density areas.

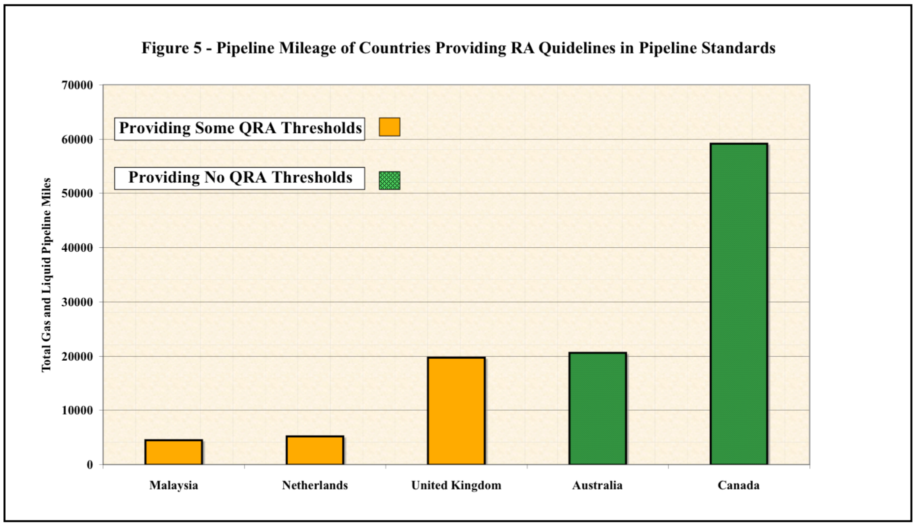

Figure 5 represents the pipeline mileage of those countries often referenced or cited as leading the QRA effort in their pipeline standards.[11] In Figure 5, I have taken the liberty of further identifying those countries that have provided <u>some</u> risk criteria thresholds, or QRA threshold targets for pipelines.[12] Note the absence of the U.S. in Figure 5. While QRA will be primarily utilized for new pipelines, the relative magnitude of existing pipeline mileage is one possible indicator of future pipeline growth and helps "reality check" or benchmark the confidence in a QRA document if too much emphasis is placed on a country's historical pipeline experience to determine future risk probabilities or frequencies. History can be a very poor predictor of future pipeline failures for many reasons.

In fairness to the UK, it should also be noted that the low maximum Design Factor for sensitive areas, such as high population, of 0.3 (see Figure 3) can substantially reduce rupture failure risk for <u>transmission pipelines</u> in these locations. Transmission pipelines typically do not transport reactive fluids that can seriously accelerate or increase the probability of failure from internal corrosion. Comparing Figure 5 to Figure 1 should clearly suggest that QRA is currently being applied to a very small number of pipeline miles. QRA applied to pipelines is still in its infancy stages, and its prudent application and acceptance is still under development before society in many countries accepts this tool.

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[11] Mileage from 2006 CIA's World Fact Book, other "reliability-based" or probability supported techniques include for example, limit states and structural reliability analysis.

[12] By no means is this author suggesting that these threshold values are complete or appropriate.

The potential for large capacity high-pressure pipelines to differentially release upon rupture many hundreds of tons of hazardous material in close proximity to civilian personnel, makes pipeline infrastructure a much different risk than that applied to fixed industrial or refinery/chemical plants. In many countries such nonlinear facilities have defined fence boundaries and require some form of Process Safety Management ("PSM") to manage risks for the protection of the workers and the public.[13] Frequently, this author observes pipeline projects trying to cite inappropriate acceptable risk thresholds used for such fixed fence boundary or secured plant facilities. While I absolutely respect the right of each country to develop its own pipeline standards and approaches, including the right to define and utilize QRA, such approaches should be: clear, defendable, represent sound engineering and management practices, in the public domain, and focused on pipelines. The inadequacies, or downright misapplication and misinformation utilized in several recent attempts to apply incomplete QRA approaches to justify high profile, poorly chosen pipeline routes in Ireland and Canada, raises serious questions as to the purpose of this numerical approach for some pipelines.[14]

In Risk Assessment, it is all too easy to create an illusion that more numbers mean more fact, somehow better data, or that the numbers or software models developing the numbers are real. Often, efforts to utilize incomplete QRA come across to the public as very unwise attempts to deceive, resulting in serious loss of credibility and confidence. Four major fatal areas in the misuse of QRA that this author repeatedly observes relate to: 1) application of QRA to fill in missing important information gaps in poor or incomplete technical approaches, especially the extrapolation of unproven models beyond their experience, 2) inappropriate utilization of poor historical databases to unwisely predict future failure probabilities of complex and very different pipeline systems, 3) linearization or simplification of historical data into probability values when system failure is anything but linear (the greater the complexity the more likely the failure from linkages that can drive to failure), and 4) misrepresentation of rupture dynamics that seriously understate or bias the consequences as low risks or "not credible" (e.g. betting on delayed ignition to reduce impact area).

> While this author supports Risk Management approaches including QRA, such techniques should never be utilized as tools to justify poor management or engineering practices, or to rationalize unwise judgment in pipeline route selection.

The U.S. has moved more toward a risk-based or "performance based" regulatory approach in the past decade. This approach should not be confused with QRA, as QRA is not currently defined in U.S. pipeline regulations or law for many very good reasons. Neither the individual nor the societal risks for pipelines have been defined or accepted in this country, and the U.S. has a long legal history of dealing with negligent approaches rather punitively. Given this country's jurisprudence, the great step allowing QRA in the U.S. is most unlikely, especially in the near term. There is considerable effort and

> Misapplication of QRA to create the illusion of pipeline safety raises serious questions as to whether this tool is really a device for public deception, to be utilized in forcing poor pipeline route selection on the public.

[13] Pipelines are exempted from the Seveso II Directive, and in the U.S., PSM regulation.
[14] Richard B. Kuprewicz, "The Proposed Corrib Onshore System – An Independent Analysis," October 24, 2005, and "Commentary on the Risk Analysis for the Proposed Emera Brunswick Pipeline Through Saint John, NB," October 18, 2006, at http://www.pstrust.org/.

legislation required before any specific country makes the leap from risk-based, Risk Assessment approaches in pipeline regulation to application of specific numerical QRA utilizing accepted risk threshold values. If QRA is being cited to justify a pipeline project route, readers are advised to verify that laws have been passed to permit such utilization for pipelines within a particular country and that the historical databases that are often citied as factual information are reasonable and, more appropriately, transferable to a new specific pipeline project.

Pipeline Integrity Management – One developing safety net

While leading the world at this specific time in this area, the author must caution that U.S. IM efforts are still in their early stages of development and application, and are still evolving.

As discussed previously, a series of tragic pipeline failures in the U.S during a pipeline cycle of deregulation, resulted in codifying into federal preemptive pipeline safety regulation one safety approach called Integrity Management. IM is not a new concept, but this author concludes its minimum requirements defined in the U.S. Code of Federal Regulation ("CFR") for pipeline safety are leading this important effort in the world. Note that IM is still in its early stages of application, and "tuning" can be expected in the future, especially as technology advances. The regulations (one for liquid and one for gas transmission pipelines) require a pipeline operator to maintain, integrate, and continuously evaluate and manage a database of information concerning their pipeline to ensure that the pipe integrity remains sound if a pipeline release could affect or occur in High Consequence Areas, or "HCAs." HCAs contain the potential to impact large numbers of people or buildings, or in the case of liquid pipelines, to also impact areas of navigable waterways or unusually sensitive areas, such as critical drinking water sources. U.S. IM regulations require a phased baseline inspection using methods defined from a prescribed list of possible inspection techniques in these HCA segments. These sensitive pipeline segments are subject to periodic re-inspection at minimum intervals, currently defined differently for liquid and gas.

Although Figure 1 indicates that U.S. transmission pipeline mileage is quite high, only a small percentage (less than 25 percent) of the total U.S. gas and liquid transmission pipeline miles are required to be inspected under the HCA definition. More mileage of liquid pipe than gas transmission pipeline (over two and a half times as much liquid pipeline mileage) is actually captured under the HCA definition sweep. It is worth noting that many pipeline operators inspect considerably more of their transmission pipeline than the minimum required under current federal IM regulations. Though the newly required inspections cover a relatively small portion of the total transmission pipeline miles, as a result of the new IM program "there have been 55,000 repairs of federally regulated pipelines in the last five years where problems were identified and fixed without incident."[15] This number reflects more than 50% of the phased baseline inspections required under the IM regulations. Efforts are presently underway to possibly relax the seven-year required re-inspection intervals initially defined by Congress for gas transmission pipelines following the required baseline assessments.[16] Liquid pipelines are required to re-inspect at a minimum of every five years.

[15] Observation by PHMSA Administrator Admiral Thomas J. Barrett, "PHMSA Chief Wants Review of Pipeline Inspection Intervals," Oil and Gas Journal Volume 105 Issue 9, March 05, 2007.
[16] Public Notice of THLPSSC and TPSSC Technical Pipeline Safety Standards Committee Meetings of 4/25-26/2007, in U.S. Federal Register, March 23, 2007.

From this author's perspective, the U.S. is leading the effort to advance IM for pipeline systems. A similar effort has now been recently codified into law via the U.S. Pipeline Inspection, Protection, Enforcement, and Safety ("PIPES") Act of 2006 requiring similiar focus on a Distribution Integrity Management Program ("DIMP") for the approximately 1.2 million miles of low stress natural gas distribution pipeline systems in this country. The U.S. federal regulations concerning IM and transmission pipelines are much more detailed than those evolving or required by other country standards discussed in this paper. Ironically, a great deal of the technology/tools prescribed in U.S. IM rulemaking are taking advantage of technical advances developed in other countries. For example, much of the research development on various smart pigging applications was actually initiated and advanced in other countries, with the U.S., pipeline operators taking advantage in the field application of these research efforts. High-pressure hydrotesting is another IM approach that may have started in the U.S many years ago, but the field application and advancement in detailed regulation or code has occurred in other countries, and not in U.S pipeline safety regulations.

Some countries' IM approaches appear to be placing much more emphasis on the capabilities of smart pigs to determine anomalies that can lead to pipeline release. While present smart pigging technology is exceptional at identifying many general and specific forms of corrosion for example, the current state of the art pig technology is very poor at determining anomalies associated with axial cuts, grooves, or dents with stress concentrators. The various IM inspection methods defined in U.S. IM regulations have different strengths and weaknesses to determine various threats. No one IM inspection approach is presently capable of identifying all risks of concern that can cause a pipeline to fail. It is incumbent on the pipeline operator and a country's regulatory agency to choose which IM approach and in what frequency best suits an operation for their particular risk threat profile. This risk profile can change often during a pipeline's long life, and can easily vary from country to country.

> IM should never be taken as an absolute safety against poor management or technical approaches that can substantially increase failure risks through the various stages in a pipeline's lifecycle.

> Special care should be taken to not oversell or overstate the technical capabilities of various IM inspection approaches, particularly smart pigs, especially if too much credit (reduced risk) is taken for IM in QRA.

As in QRA, there is a limitation to the use or value of IM in pipelines. It is critically important that IM not be utilized as the only safety net to avoid risks from poor practices that can result in a release. Prudent management will utilize good engineering and management practices and sound judgment to complement a pipeline project throughout all of the pipeline's various lifecycle stages with more than one level of safety to assure a pipeline is and remains sound. Risk Assessment, even QRA, can be utilized to assist management in determining which IM methods are best to help reduce the risk of pipeline failure. Overstatement of IM technology capabilities appears to be a recurring problem that is being uncovered in too many pipeline projects attempting to misuse RA, or worse, poor QRA to justify unwise pipeline siting.

Conclusions

It should be evident by now that no one country or standard has a monopoly on the best approaches to improve pipeline operation, safety, and route selection. While there are many similarities in pipeline code and pipeline safety regulation throughout the world, there are subtle and important differences in various approaches. It is a myth, if not a downright deception, to try and create the impression that there is a "Best International Standard" governing pipeline projects. While the U.S leads the world in transmission pipeline mileage, restructurings, corporate takeovers, and deregulation efforts in the U.S energy industry have caused this country to fall behind in many pipeline technical advancements more likely to be codified or promulgated in other countries. A prudent pipeline operator will take the best approaches from various countries and incorporate these concepts into the stages of a pipeline's long lifecycle, which will usually exceed any specific country's current requirements. Given its infancy stage, it should be clear that advances in QRA application for pipelines, especially high capacity pipelines, need further work.

In one very specific area, Integrity Management, the U.S clearly currently leads the world in regulatory development. The forces that triggered this leadership focus in IM were founded on several very high profile tragedies created by an era of over deregulation. Lastly, it is important to recognize that many pipeline operators exceed the minimum standards imposed by any country or its referenced required codes. One can usually spot these prudent pipeline operators by noting the consistency in their approaches, the clarity in showing how they comply with specific cited codes and regulations, their ability to readily communicate the unique risks for a specific pipeline route and how they are dealing with these risks, that QRA is not the major focus of the project nor misapplied, and lastly by their avoidance of the apparent public relations spin phrase "following a Best International Standard, or Standards."

Abbreviations - Countries

Alg – Algeria	Arg – Argentina	Aus – Australia
Brz – Brazil	Can – Canada	Ch – China
Czech Rep – Czech Republic	Fr – France	Ger – Germany
Kaz – Kazakhstan	Mex – Mexico	NL – Netherlands
Rus – Russia	UK – United Kingdom	Ukr – Ukraine
US – United States		

Other Abbreviations

ALARP - As Low as Reasonably Practical/Practicable	AS – Australian Standard	ASME – American Society of Mechanical Engineers
CFR – US Code of Federal Regulation	CIA – Central Intelligence Agency	CSA – Canadian Standards Association
D – Pipe outside diameter	DF – Design Factor	DIMP – Distribution Integrity Management Program
EU – European Union	F/N – Graph of frequency of event per year vs. number of casualties/fatalities per event	HCA – High Consequence Area
IM – Integrity Management	ISO – the International Organization for Standardization	HVP – High vapor pressure liquid
LVP – Low vapor pressure liquid	MAOP – Maximum Allowable Operating Pressure	MOC – Management of Change
MOP – Maximum Operating Pressure	NTD – Non Destructive Testing	NEN – Netherlands Standardization Institute
NTSB – National Transportation Safety Board	PD – Published Document	PHMSA – Pipeline and Hazardous Material Safety Administration
PIPES – Pipeline Inspection, Protection, Enforcement, and Safety Act of 2006	PSM – Process Safety Management	QA/QC – Quality Administration/Quality Control
QRA – Quantified or Quantitative Risk Analysis	RA – Risk Assessment	SMYS – Specified Minimum Yield Strength
SRA – Structural Reliability Analysis	t – pipe wall thickness	THLPSSC – Technical Hazardous Liquid Pipeline Safety Standards Committee
TPSSC – Technical Pipeline Safety Standards Committee		