

INEOS

Olefins & Polymers USA

ISO 9080 and the US Natural Gas Distribution Industry

Steve D. Sandstrum¹
INEOS Olefins & Polymers USA

Gene Palermo, PhD²
Plastics Pipe Institute
Washington DC

ABSTRACT:

This is a follow-up paper to a series of papers prepared at the request of the AGA-PMC to educate the US gas distribution industry on the history and benefits of PE 100 polyethylene resins for gas piping applications.

In this paper, we briefly explain the nature of ISO 9080, the preeminent ISO standard by which these new HDPE materials are stress rated and how they compare to the ASTM methodology currently utilized throughout the US natural gas distribution industry. Finally, an assessment is made of the benefits to be realized by the US gas distribution industry through the incorporation of the ISO protocol into the prevailing ASTM HDPE and PE gas pipe standards

INTRODUCTION:

The continuing expansion of applications for HDPE pipe has led to extensive research and development of higher performance polymers. Recognizing the needs of specific end uses such as natural gas distribution, resin companies in collaboration with pipe producers continue to develop materials which offer higher levels of performance as defined under internationally recognized standards.

An integral part of this development cycle is the evolution of product and performance standards and specifications which provide for the characterization of product improvements in accordance with industry recognized design .. criteria. In the United States, we define the long term hydrostatic strength of HDPE pipe resins in accordance with ASTM D2837.(1) These materials are then converted into pipe which must meet the requirements for PE gas pipe established in ASTM D2513.(2)

On a more global scale, ISO 9080 is used to determine the long term hydrostatic strength of PE materials.(3) These materials are then utilized to manufacture gas pipe produced in accordance with ISO 4437.(4)

Clearly, a fundamental understanding of these two standards systems is important as the gas distribution and HDPE pipe industries continue to globalize. In the paragraphs that follow, we shall take a closer look at the ISO 9080 protocol and investigate just how it relates to the ASTM D2837 methodology. Comparative examples of HDPE pipe resin hydrostatic data using both the ISO and ASTM protocol shall then be presented. This paper will conclude with a brief discussion on the impact of incorporating the ISO method

1. Now with ISCO Industries LLC
2. Now Principle of P-Cubed Consulting

into the relevant ASTM standards and the benefits to be realized by the US gas distribution industry.

SO, WHAT IS ISO 9080?

ISO 9080 is one of the most widely recognized standard methodologies for regression analysis of piping materials in the world. In essence it is the ISO equivalent of the ASTM D2837 protocol.

The method is similar to that proposed by ASTM D2837 in that PE pipe specimens are placed on hydrostatic test in a controlled environment under specific conditions of stress and temperature. The specimens are monitored and data is gathered as specimens fail over time. The data is then analyzed using the protocol set forth in ISO 9080.

A typical set of ISO 9080 curves is shown in Figure I. The reader will note the similarities to the ASTM D2837 regression curves and the metric nomenclature.

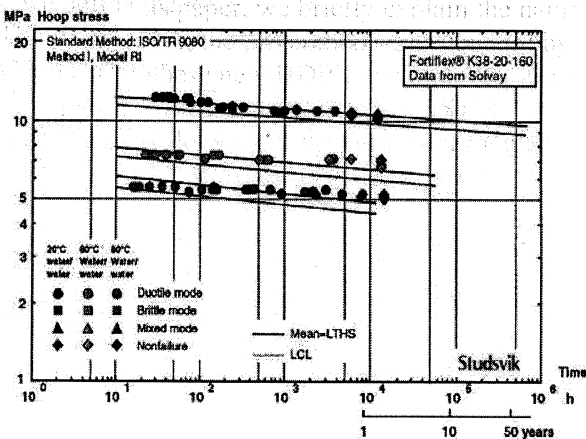


Figure I: Typical ISO TR9080 Regression Curves for a PE2406

Within ISO 9080, the stress regression curves are analyzed to determine the 50-year strength of the material. The lower confidence limit (LCL) of the 50-year intercept generated using this technique is then categorized into one of a series

of minimum recommended strength (MRS) categories in megaPascals, or MPa as defined within ISO 12162.(5)

A table of these LCL intercept values, their respective MRS classifications and subsequent PE designations is shown in Table I.

**Table I
MRS Classifications and PE Designations**

LCL Range (MPa)	MRS Classification (Mpa)	PE Material Designation
3.15 – 3.99	3.15	PE31.5
4.00 – 4.99	4.0	PE40
5.00 – 6.29	5.0	PE50
6.30 – 7.99	6.3	PE63
8.00 – 9.99	8.0	PE80
10.00 – 11.19	10.0	PE100
11.20 – 12.49	11.2	
12.50 – 13.99	12.5	
14.00 – 15.99	14.0	

The PE designations presented in Table I are then referenced in ISO 4437, the internationally recognized standard for HDPE gas distribution pipe. These designations are utilized in combination with other performance criteria to establish the pressure capability of a PE pipe for gas distribution applications under the ISO system of standards much like ASTM D2513 references the HDB established in ASTM 2837.

COMPARING ISO 9080 AND ASTM D2837:

The fundamental technique by which materials are analyzed in ISO 9080 is quite different from the procedure used in ASTM D2837 despite similarities in the methodology. Table II presents a summary of the fundamental differences between the two methodologies.

The two methods differ specifically in their treatment of the pipe failure data. Both methods utilize basic regression equations to project the service life of the material being analyzed. The

ASTM D2837 method establishes a long-term hydrostatic strength (LTHS) at 100,000 hours based on the collection and regression analysis of 10,000 hours of pipe failure data. ISO 9080 uses the same 10,000 hours of data to project a service life based on a 97.5% LCL at 50 years.

Table II
Comparison of ISO TR9080 and ASTM D2837

Property	ISO TR9080	ASTM D2837
Classification	MRS	HDB
Linearity	No assumption	Assumes linearity
Data Requirements	25 points at 10,000 hrs.	18 points at 10,000 hrs.
Regression	All points combined	Individual temperatures
Coefficients	3	2
Extrapolation	50-year	100,000 hour
Intercept	97.5% LCL	Mean LTHS
Units	MPa	Psi

The net effect of this difference in regression analysis and the subsequent categorization of the intercepts may be seen in Figure II. Here we see that the ISO regression extends well beyond the 100,000 hour intercept established by ASTM D2837.

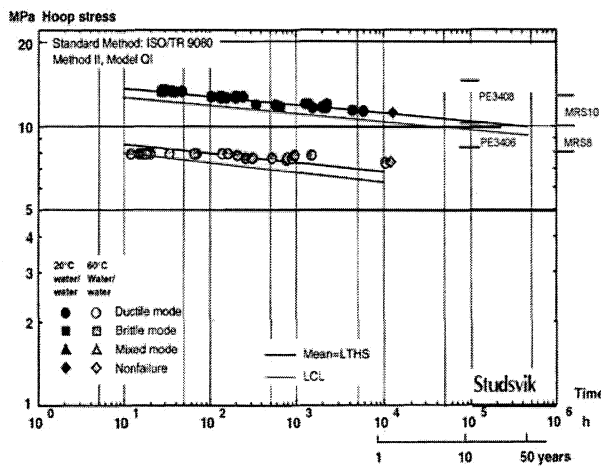


Figure II: ISO 9080 Regression Curve for a PE3408

The reader will note that Figure II depicts two data sets, the top one at 20 deg F and the lower one at 60 deg F. Also note that the LCL regression is shown as the lower "shadow" line below each data set.

From Figure II we see the relationship of the ASTM D2837 regression analysis to that of the ISO 9080 regression. Figure II depicts a set of hydrostatic data for a commercially recognized PE3408 which has been evaluated in accordance with the ISO 9080 protocol. The 100,000 hour intercept ranges for PE2406 and PE3408 characteristic of the ASTM D2837 methodology have been superimposed onto the graph as well as the MRS8 and MRS10 ranges found in the ISO 9080 standard.

Figure II clearly shows that a typical commercial PE3408 when analyzed using the ISO 9080 protocol falls well below the lower limit for the higher strength MRS10 quality of material recognized under the ISO 9080 methodology. As such, the PE3408 would be designated an MRS8 in accordance with ISO 9080 and 12162.

Similar analyses of commercial PE2406 HDPE resin show that these types of materials may be characterized as also meeting the MRS 8 classification. Such is the case with the regression curve shown in Figure I.

OKAY, AND SO?

Questions have arisen within the gas industry regarding incorporation of the ISO 9080 methodology into the ASTM system and the net impact of such a change. From the preceding discussion, we see that the two protocol utilize similar methods to establish the long term strength for HDPE pipe. However, differences do exist. Specifically:

- The long term strength of HDPE pipe resins is established using a 50 year intercept under the ISO system as opposed to the 100,000 hour intercept characteristic to the ASTM methodology.

- The ISO method establishes the long term strength of the material on the basis of the 97.5 % LCL as opposed to the mean value utilized in the ASTM D2837 protocol

Other differences also exist between the two methods. However, these two fundamental points appear to hold significant potential to users of HDPE gas pipe. The examples presented demonstrate these differences and clearly show how traditional PE3408 and PE2406 materials as established under the ASTM D2837 method would qualify as MRS 8 materials under the ISO technique. Similarly, the examples presented here would suggest that an HDPE resin meeting the MRS8 or MRS10 classification under the ISO 9080 protocol may be designated a PE2406 or PE3408 under the ASTM method.

BENEFITS TO THE US GAS DISTRIBUTION INDUSTRY:

The HDPE pipe industry continues to move toward coalescence of the long-term strength rating protocols of ASTM and ISO. At the same time, the US gas distribution industry is poised to realize significant benefits resulting from this next evolution in the standards surrounding this important application for HDPE pipe.

Improved Technical Performance-

Foremost among the benefits is the recognition and standardization of higher levels of technical performance for HDPE gas distribution pipe. Through incorporation of the ISO protocol, we see a higher level of gas pipe performance is possible in the PE100 HDPE products that have become the international standard for gas distribution pipe. These unique materials offer specific advantages such as:

- A higher pressure capability
- Resistance to Rapid Crack Propagation
- Improved Slow Crack Growth Resistance

Each of these properties have been discussed in detail in previous works presented before the

AGA.(6)(7)(8) A brief example relating to pressure capability is presented in Table III.

Table III: PE100 vs. PE80 vs PE3408 Pressure Rating

Design Aspect	PE100	PE80	PE3408
Prevailing Standard	ISO 4437	ISO 4437	ASTM D2513
MRS (Mpa)	10	8	
HDB (psi)	-	-	1600
Service Coefficient, C	2	2	-
Design Factor, F	-	-	0.32
Pipe SDR	11	11	11
MOP, bars	10	8	-
MAOP, psi	-	-	102
MAOP equivalent	145*	116*	-
MOP equivalent	-	-	7.0 *

Here we compare the pressure designations for an SDR 11 pipe produced from the three different classifications of material and placed into service under both of the prevailing gas distribution standards, ISO 4437 or ASTM D2513. From this, we see that the end results are quite interesting. Specifically:

- The PE100 material allows for a 25% increase in the MOP under the ISO protocol as compared to PE80.
- The ISO and ASTM pressure equations are essentially the same but the results are quite different as it relates to pressure rating.
- Differences exist in the application of the design factor and how it is stated, the units or measurement and the limitations placed on the application.

One should also bear in mind that in the United States, CFR Title 49, Part 192.121 limits the MAOP for polyethylene to 100 psi. This is currently under study for increase to 125 psi. Similarly, the service factor of 0.32 is being evaluated for increase to 0.40. These two factors would significantly affect the range of

application for any materials used in accordance with ASTM D2513 and certainly influence the comparison presented in Table III.

*Note: The MAOP and MOP equivalents shown in Table III are mathematical conversions of the MOP and MAOP values shown in the table, respectively. These are provided for purposes of reference and comparison only and their presentation in this table should not be considered as a qualification or approval for use in gas distribution under the opposing standard protocol.

From Table III we see how the two terms, HDB and MRS, are used to pressure rate an HDPE pipe system for gas distribution under their respective standards system. Applications standards within each system place additional requirements on the HDPE pipe. In the case of ASTM D2513, HDPE pipe must exhibit resistance to slow crack growth as evidenced by elevated temperature pipe testing and standard ESCR or PENT testing. Within ISO 4437, the standard requires substantiation of slow crack growth resistance via notched pipe testing and resistance to rapid crack propagation via S4 or full scale testing.(9)(10) These additional requirements combined with their respective stress rating protocols position the gas distribution industry for higher levels of technical performance.

Globalization of the Natural Gas Industry-

Another key benefit of a basic understanding of the two systems is a common format by which to support the global development of the gas distribution industry. Numerous articles have been written regarding the globalization of various industries including gas distribution. Figure III depicts a generalized representation of the global influence of the two principal standards systems. From this we see that a fundamental understanding of how the two standards systems work and how they relate to each other is paramount to global development of the gas distribution industry.

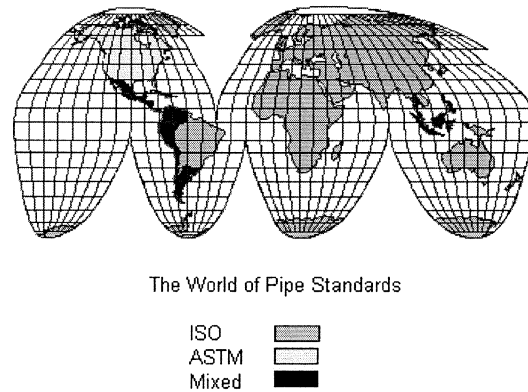


Figure III: The World of Pipe Standards

CONCLUSION:

From this discussion we see that the ISO 9080 protocol is similar in approach to the ASTM D2837 methodology. Both methods:

- Utilize accepted mathematical models to perform a regression analysis on pipe data to establish a long term strength.
- The long term strength under either system is categorized into one of a series of hydrostatic design bases (HDB) in the case of ASTM D2837 or minimum required strengths (MRS) in the case of ISO 9080.
- Additional applications standards exist within each system that provide for how these design strengths are used to pressure rate an HDPE pipe for gas distribution service. Within ISO, that standard is ISO 4437 and within ASTM it is D2513.

Additionally, we have discussed the basic differences that exist between the two systems.

- The ASTM methodology utilizes a 100,000 hour regression analysis while the ISO protocol uses a 50-year regression analysis
- The ASTM method also uses the mean LTHS to determine the 100,000 intercept while the ISO system relies on the 97.5% LCL intercept at 50 years.
- Fundamental differences do exist within the applications standards, ISO 4437 and ASTM

D2837, and local industry regulation which may significantly influence the MAOP or MOP.

Finally, this discussion has provided some comparative examples of both ISO and ASTM regression methods and how they relate to each other using commercially available HDPE gas pipe resins.

Clearly, as the gas distribution industry continues to globalize, the need to understand both the ISO and ASTM systems of stress rating and how they relate to each other will only expand. From this discussion, we see that incorporation of the ISO 9080 protocol into the ASTM system the potential will provide a common basis for evaluation and comparison of higher levels of HDPE gas pipe performance on an international scale. This will:

- Provide ease of comparison and technical operation across geographic borders as gas utilities continue to grow in the international arena.
- Allow for a standardized approach to the utilization of these high performance HDPE materials in demanding gas distribution applications.
- Position the gas distribution industry to utilize further advancements in resin and HDPE pipe technology on a worldwide scale.

REFERENCES:

- (1) ASTM D2837, "Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials", American Society for Testing and Materials.
- (2) ASTM D2513, "Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings", American Society for Testing and Materials.
- (3) ISO 9080, "Plastics Piping and Ducting Systems Determination of Long-Term Hydrostatic Strength of Thermoplastics Materials in Pipe Form by Extrapolation", International Organization for Standardization.
- (4) ISO TR4437, "Buried Polyethylene (PE) Pipes for Supply of Gaseous Fuels – Metric Series – Specifications", International Organization for Standardization.
- (5) ISO 12162, "Thermoplastics Materials for Pipes and Fittings for Pressure Applications – Classification and Designation – Overall Service (Design) Coefficient", International Organization for Standardization.
- (6) Sandstrum, S.D., "What is PE100?", AGA-PMC Winter Workshop, New Orleans,, 1999.
- (7) Sandstrum, S.D., "PE100 vs. PE3408: Can Someone Please Explain These?", AGA Operations Conference, Cleveland, 1999.
- (8) Sandstrum, S.D., "PE100: Performance Plus", 1999 International Plastic Fuel Gas Pipe Symposium, New Orleans.
- (9) ISO 13479, "Polyolefin Pipes for the Conveyance of Fluids – Determination of Resistance to Crack Propagation – Test Method for Slow Crack Growth on Notched Pipes (notch test)", International Organization for Standardization.
- (10) ISO 13479, "Polyolefin Pipe for the Conveyance of Fluids – Determination to Crack Propagation – Test Method for Slow Crack Growth on Notched Pipes (Notch Test)", International Organization for Standardization.