PHP Controlled Correspondence Sheet

PHMSA Control Number :

Action Office: PHP- 30

PHP Control Number: 09-0204 **Due Date: 10-18-2009**

Writer: Philip Bennett

Subject: Petition for Rulemaking Increase Design Factor for New Polyethylene Pipe

Action: Petition for Rulemaking

Date	Action	Action by

Date	Note	Note by

For more information please contact:
Glenda Marshall, Glenda.marshall@dot.gov

AGA
American Gas Association

August 12, 2009

AUG 17 2009

Mr. Jeffrey D. Wiese
Associate Administrator for Pipeline Safety
U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
East Building, 2nd Floor
1200 New Jersey Ave., SE
Washington, DC 20590

Re: Petition for Rulemaking
Increase Design Factor for New Polyethylene Pipe

Dear Mr. Wiese:

Pursuant to 49 CFR 192.133, I have enclosed an original and three copies of the American Gas Association's Petition for Rulemaking to increase the design factor for new polyethylene pipe (PE). AGA appreciates the support of the Pipeline and Hazardous Materials Safety Administration (PHMSA) and other stakeholders have provided for half a decade to demonstrate the efficacy of the 0.4 design factor for modern PE piping. AGA believes the work has shown the use of the increased design factor to be safe, reliable, cost effective and beneficial to the public. The adoption of the regulatory language presented in the petition will promote pipeline safety and benefit the environment.

Please file the petition to the docket in your normal manner.

Sincerely,

Philip Bennett

Philip Bennett

TECHNICAL SUBSTANTIATION SUMMARY FOR AN INCREASE IN THE DESIGN FACTOR FOR PE GAS DISTRIBUTION PIPING SYSTEMS

Prepared By:
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Joint Industry IDF Steering Committee

Revised: July 31, 2009

ACKNOWLEDGEMENTS

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Christina Sames – American Gas Association
Perry Sheth – KeySpan
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Michael Comstock – City of Mesa
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The authors of this report would like to thank the financial support of the Operation Technology Group and the contribution of its Technical Project Committee members.

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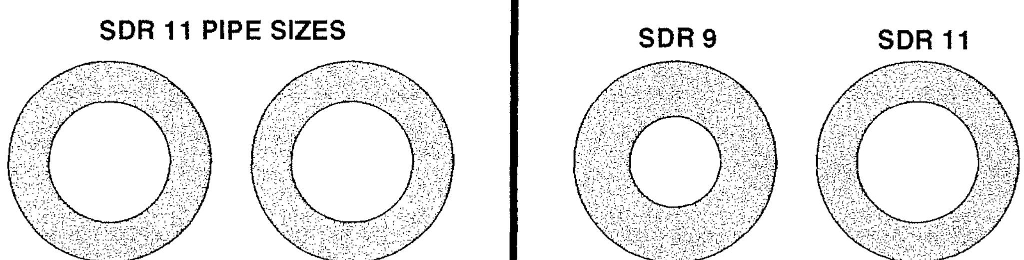
EXECUTIVE SUMMARY

Demographic changes and rapid urbanization impose additional demands for greater capacity and fuel efficiencies to meet our Nations ever growing energy requirements. As a result, there is an increasing need for gas distribution companies to operate their gas distribution network to its optimum capabilities. Recent rule changes by the Department of Transportation Pipeline Hazardous Materials and Safety Administration (DOT PHMSA) have aided gas companies in their efforts to meet this challenge. Specifically, based on the positive in-service field experience under previous wavier(s) in various parts of the U.S., Title 49 CFR Part 192 requirements has been recently amended to permit the use of modern PE materials at design pressures up to 124 psig for gas distribution applications. While this is a positive step forward, additional small-scale changes to the Federal regulations are still needed. Specifically, revising Part 192.121 to permit the use of a 0.40 design factor in calculating the design pressure for plastic piping systems subject to the design pressure limitations prescribed under Part 192.123.

The primary benefit of using a 0.40 design factor is the corresponding increase in the overall flow capacity which would aid gas utilities in enhancing the service reliability to their customers. Gas utilities can realize greater flow capacity for a given pipe diameter by increasing the pressures and/or use thinner wall pipe for a given pressure, as shown in Figure 1 below. In both situations, gas utilities can more effectively serve their customers without compromising safety and system integrity of the gas distribution network.



SDR 11 PIPE SIZES

DF = 0.32	DF = 0.40
$p = \frac{2*1600}{11-1}*0.32$	$p = \frac{2*1600}{11-1}*0.40$
$p = \frac{3200}{10}*0.32$	$p = \frac{3200}{10}*0.40$
$p = 102.4 psig$	$p = 128 psig$

SDR 9, DF = 0.32	SDR 11, DF = 0.40
$p = \frac{2*1600}{9-1}*0.32$	$p = \frac{2*1600}{11-1}*0.40$
$p = \frac{3200}{8}*0.32$	$p = \frac{3200}{10}*0.40$
$p = 128 psig$	$p = 128 psig$

- 11% increase in flow capacity for a given pipe diameter
- 17% reduction in pipe material

Figure 1: Design implications associated with increased design factor

Since the mid-1990's, the American Gas Association Plastics Materials Committee and other industry organizations have supported numerous efforts to increase the design factor; however, owing to the lack of technical data and information with respect to the safety implications associated with an increased design factor, these efforts were halted.

In 2004, industry and trade representatives met with the representatives of the Department of Transportation Pipeline Hazardous Materials and Safety Administration (PHMSA) to outline the necessary technical approach to establish the validity of increasing the design factor from 0.32 to 0.40 for PE piping systems, and to address the safety considerations using an increased design factor.

Following that meeting and with the financial support of Operation Technology Development (OTD) group, a comprehensive program (Increase in Design Factor – IDF) was established. The IDF program was divided into three distinct phases:

> Phase I: Development of minimum material performance based requirements for PE materials and review of additional design and engineering considerations to justify an increase in the design factor.
>
> Phase II: Perform comprehensive testing and evaluation to validate the impact of an increase design factor on key construction, maintenance, and operating practices to ensure the safety and integrity of the gas distribution systems.
>
> Phase III: Perform targeted field experiments under special permit[1] (waivers) to obtain actual in-service operating experience and establish the technical basis for continued efforts related to future rule-making initiatives by the Department of Transportation.

From the onset, in order to ensure an objective peer review of the technical data, a joint industry steering committee (IDF steering committee) was established consisting of representatives from each of the key stakeholder groups: gas utility companies, regulatory representatives, and pipe/resin/and fittings manufacturers. Throughout the course of the IDF program, the IDF steering committee has helped to effectively guide the overall technical approach and establish the technical recommendations to ensure that the overall safety and integrity of the gas distribution network is not adversely compromised.

The cumulative results of the IDF program clearly validate that the proposed increase in the design factor is justified for the following reasons:

1. The technical basis and approach for the transition to a 0.40 is identical and consistent with the approach utilized by the DOT when the last change in the design factor was instituted in 1978[2].

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[1] The use of the term "special permit" is based on recent revisions within DOT. It is used in place of the former term of waiver.

[2] Federal Register, Vol. 43 No.64, Monday April 3, 1978

2. Over the past few decades, there have been significant and notable improvements in the performance characteristics of PE materials. ASTM standards and specifications have been significantly strengthened to ensure that materials with excellent resistance to known failure modes are utilized for gas distribution applications. In addition, the cumulative results of comprehensive R&D efforts have led to the development of effective process improvements and technologies that help to ensure safe construction, maintenance, and continued operations of modern PE piping systems.
3. The recommendations of the IDF steering committee are more conservative than the current code requirements. Specifically, the adoption of increased performance based requirements and appropriate size limitations help to ensure that only suitable materials with excellent mechanical and physical properties in the most optimum sizes are utilized in conjunction with the proposed 0.40 design factor.
4. The range of maximum design pressures are within the range of operating experience at gas utility companies, i.e., the IDF steering committee recommends to keep the maximum design pressure limitation of 125 psig.
5. The proposed increase in the design factor will enable gas utilities to increasingly utilize safe and proven PE materials in order to extend their gas distribution infrastructure.
6. The proposed increase in the design factor will enable gas utility companies to implement more flexible and effective design methodologies to satisfy the need for increased capacity. The intent is consistent and analogous to the recent rulemaking permitting the increase in percent (%) specified minimum yield strength (SMYS) to 80% for steel systems, i.e. increased capacity.
7. The cumulative results of the comprehensive testing and evaluation and the inherent conservatism of the proposed recommendations help to ensure that the overall safety and system integrity will not be adversely compromised.
8. There are significant overall benefits to the general public and the environment associated with the proposed increase in the design factor.

The following sections outline the recommendations and provide the technical rationale and engineering justification to facilitate a change in the design factor for PE piping systems.

1.0 PROPOSED EXEMPTIONS TO CFR PART 192 REQUIREMENTS

Based on the cumulative results of the IDF program and the significant improvements in the performance characteristics of modern PE materials, the IDF steering committee unanimously supported three key recommendations as shown in Table 1 below.

Section	Proposed Change(s)	Implication(s)
§192.121	**F = 0.40**	• Permits for the implementation of more effective and flexible design methodologies to enhance/satisfy capacity considerations.
§192.123 (X)	**Min. Wall = 0.090" and a NEW Table which specifies minimum wall thickness values as a function of distribution pipe sizes**	• Increases the minimum wall thickness for service tubing from 0.062" to 0.090". • Specifies a limit on the minimum wall thickness for pipe sizes 2" though 12" based on the technical data developed within the IDF program taking into account various operating practices. Note, this recommendation is more conservative than the current requirements in the Federal Code.
§192.123 (X)	**Specify PE2708 and PE4710**	• Ensures that only those PE materials which conform to increased performance based requirements established by the IDF steering committee and supported by the PPI HSB are utilized in conjunction with the 0.40 design factor.

Table 1: Summary of proposed changes being requested within this special permit

The remaining sections of this document provide comprehensive discussions with respect to the technical rationale and engineering justification for each of the recommendations noted above. In a cumulative sense, the supporting documentation clearly demonstrates that the proposed increase in the design factor will permit for greater design flexibility and will not adversely compromise safety and/or overall system integrity.

2.0 DESIGN FACTOR FOR PLASTIC PIPING SYSTEMS

Historical Perspective and Technical Rationale for 0.40 Design Factor

Based on fundamental design principles, a safe and effective design is predicated on how well a system balances the in-service strength of the various components and the applied stress to which they may be subjected. The common practice is to express this balance through the use of a design factor taking into account various technical considerations. This is true for both steel piping systems and plastic piping systems. The major difference between the two is that for steel piping systems, a unique design factor is assigned for each major technical consideration (temperature, class locations, manufacture processing).

$$p_{steel} = \frac{2St}{D} xExFxT$$

In contrast, for plastic piping systems, a single design factor is utilized taking into account all the pertinent technical considerations.

$$p_{plastic} = \frac{2St}{D} xDF$$

In both situations, the primary objective based on fundamental engineering considerations is to effectively balance the material's durability and the anticipated loadings in order to ensure safe and long term service performance.

During 1967, the United States of America Standards Institute (USASI) – now known as the American National Standards Institute (ANSI) – issued a revision of the code of practice USAS B31.8, "Gas Transmission and Distribution Piping Systems", which for the first time officially recognized thermoplastics piping as suitable materials for gas distribution. Based on this revision, the long-term hydrostatic strength (LTHS) of a thermoplastics pipe material was to be established on the basis of empirical testing at the base temperature of 73°F.The hydrostatic design stress (HDS) by which pipe is pressure rated was then determined by multiplying the LTHS by a unique set of design factors which varied from 0.32 to 0.20 based on class location.

During that time, major standards, including ASTM and AWWA, had already established the practice of utilizing a design factor of 0.50 for water applications. The maximum value of 0.32 for natural gas applications was established by applying two additional strength reduction factors to the 0.50 DF utilized for water pipe applications: a 0.80 multiplier to cover for possible adverse effects by constituents of fuel gas; and, another 0.80 multiplier to compensate for use at increased temperatures greater than 73°F.

$$DF_{gas} = DF_{water} \times 0.8 \times 0.8$$
$$DF_{gas} = 0.5 \times 0.8 \times 0.8$$
$$DF_{gas} = 0.32$$

A year later, US Congress approved the Natural Gas Pipeline Safety Act which required the DOT to develop and enforce minimum safety regulations for the transport of gases by pipeline. Subsequently, during 1970 DOT issued a set of regulations for natural gas piping which were essentially the same as under USAS B31.8, with the exception of referencing the newly issued ASTM D2837 method for the determination of the long term hydrostatic strength of plastic piping materials.

During 1978, the DOT Office of Pipeline Safety issued an amendment that established a single DF of 0.32 for plastic piping regardless of class locations. This amendment also permitted the use of thermoplastics pipe up to 140°F, provided the piping material had an established LTHS – and thereby, an established HDB – for the maximum temperature of use. To facilitate design for any temperature within the range of 73° and 140°F, this amendment established standard design temperatures of 73°, 100°, 120° and 140°F. If a pipe, while in service, is subjected to a temperature intermediate between any of these temperatures then its pressure rating must be based on the HDB for at least the next higher standard temperature. It is important to emphasize that the adoption of this amendment at that time, particularly the adoption of the single DF of 0.32, was based on the positive in-service experience with the use of PE materials since their initial introduction and use, i.e. less than 10 years. Moreover, given the limited experience, there were several comments which were received that favored a higher design factor.

Inarguably, since 1978 to now, there have been significant improvements in the performance characteristics of modern PE materials, ASTM testing methods and standards have been effectively modified to eliminate the potential for relatively poor performing materials to be utilized, and finally, comprehensive R&D efforts have led to the development of effective process improvements and technologies to ensure the safe construction and operations of modern PE systems.

Based on the resulting benefits associated with each of the aforementioned technical considerations, the water industry has approved the increase in the design factor from 0.50 to 0.63 for PE pipe[3]. Based on this change and following the same technical approach which was utilized by the DOT during 1978, it stands to reason that the design factor for gas applications can be effectively be increased to 0.40 as shown below.

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[3] ANSI/AWWA C901-08, Polyethylene (PE) Pressure Pipe and Tubing, ½ in. (13mm) through 3 in. (76mm), for Water Service. October 1, 2008

$$DF_{gas} = DF_{water} \times 0.8 \times 0.8$$
$$DF_{gas} = 0.63 \times 0.8 \times 0.8$$
$$DF_{gas} = 0.40$$

Based on the preceding discussions, it stands to reason that the technical rationale for the proposed increase in the design factor to 0.40 is consistent with previous rulemaking efforts while retaining the same degree of safety (magnitude) for each of the technical considerations.

Implications of Proposed 0.40 Design Factor

The net effect of the proposed increase in the design factor is that it will enable gas utility companies to implement more effective design methodologies in order to satisfy the need for additional capacity in a safe and reliable manner. Table 2 presents the calculated maximum design pressures using both a 0.32 and 0.40 design factor in the formula contained within §192.121 for both MDPE[4] and HDPE[5] materials.

	MDPE (S = 1250 psi)		HDPE (S = 1600 psi)	
SDR	Pressure, psig (DF = 0.32)	Pressure, psig (DF = 0.40)	Pressure, psig (DF = 0.32)	Pressure, psig (DF = 0.40)
21	40	50	51.2	64
17	50	62.5	64	80
13.5	64	80	81.9	102.4
11.5	76.2	95.2	97.5	121.9
11	80	100	102.4	128
9.3	96.4	120.5	123.4	154.2
9	100	125	128	160

Table 2: Calculated design pressure as a function of SDR using a 0.32 and 0.40 design factor for both MDPE and HDPE pipe materials

[4] The use of the term MDPE is synonymous with PE2708 materials which satisfy the increased performance based requirements established by the IDF steering committee and PPI HSB. The two terms are used interchangeably throughout the remainder of the document.

[5] The use of the term HDPE is synonymous with PE4710 materials which satisfy the increased performance based requirements established by the IDF steering committee and PPI HSB. The two terms are used interchangeably throughout the remainder of the document.

3.0 PERFORMNACE CHARACTERISTICS OF MODERN PE MATERIALS

In addition to the proposed increase in the design factor contained within Section 192.121, a key recommendation of the IDF steering committee is to amend the material designation codes for PE materials which can be utilized in conjunction with an increased design factor.

Over the past few decades, the cumulative results of comprehensive testing and data development effectively demonstrates that there has been a considerable improvement in the performance characteristics of modern PE material and testing methodologies to ensure that materials with excellent resistance to known failure modes are utilized for gas distribution applications. The recognition that the performance characteristics of modern PE materials have improved is implicit in the current code language and reinforced by the recent amendments by the Department of Transportation to raise the maximum design pressure of PE piping systems up to 125 psig provided that only PE materials produced after the effective date of the rule change (July 14, 2004) are utilized.

This point notwithstanding, in order to provide additional assurances, the IDF steering committee in concert with the Plastics Pipe Institute (PPI) Hydrostatic Stress Board (HSB) adopted several additional performance based requirements for PE materials to enhance overall safety and integrity of the natural gas distribution network. These include:

1. 50-year substantiation of HDB within ASTM D2513 to ensure effective resistance to failures from increased internal pressure
2. Increase in the LCL/LTHS ratio to 90% as compared to 85%.
3. Increase in the PENT failure times to 500 hours as compared to the current 100 hour requirement
4. Additional design considerations to ensure ample resistance to the potential of failures from Rapid Crack Propagation during the planning phase

In the context of the overall IDF steering committee recommendations, it is important to emphasize the critical nature of these additional performance based requirements.

One significant implication of modern thermoplastic materials, such as polyethylene, is that the failure strength is dependent on the duration of the loading and temperature. For safe and efficient long term service, the pressure rating must be established on the basis of the material's long term strength, as represented by its hydrostatic design basis (HDB), under anticipated service conditions.

The primary assumption in §192.121 is that plastic piping materials will behave in the "ductile" manner throughout its service life, i.e. the primary mode of failure is that of "bursting" due to internal pressure. The effect of add-on or other stresses (localized stress intensifications) on the pipe while in service are considered to be negligible and can be effectively compensated through the use of a strength reduction factor or the *design factor.*

Over 40 years of safe operating experience has demonstrated the safety of using plastic pipe in gas distribution applications, and the design approach has been effective in the prevention of catastrophic pipeline failures. Field experience has demonstrated that from a material perspective, the long term performance of plastic piping systems is dependent on the materials' ability to effectively resist localized stress intensifications generated by a number of installation and operational variables in addition to the internal pressure. As a result, the magnitude of the design factor is primarily a function of the materials ability to resist localized stress intensifications leading to failures in the "brittle" manner due to slow crack growth (SCG) mechanism.

Today's polyethylene piping manufactured in accordance with ASTM D2513 requirements have improved significantly with respect to their SCG resistance characteristics. In addition, standards/specifications and test methods to effectively characterize the PE materials' long term hydrostatic strength and hydrostatic design basis have also been significantly improved through the inclusion of validation requirements which previously did not exist. Cumulatively, for materials conforming to the ASTM D2513 requirements, the design factor of 0.32 is overly conservative and can be increased without compromising safety and overall system integrity.

Not only are the IDF steering committee performance based requirements significantly more conservative than the current code requirements, they also help to effectively delineate the improved performance characteristics among modern PE materials via the use of different material designation codes.

The material designation codes reference the pipe materials by their standard terminology in accordance to ASTM D1600 entitled *"Standard Terminology Relating to Abbreviations, Acronyms, and Codes for Terms Relating to Plastics"*, followed by a four or five digit number. The first two digits reference the material's ASTM cell classification in accordance with the appropriate ASTM standard specification for that particular thermoplastic material. In the case of PE materials, the cell classifications are specified within ASTM D3350. The last two digits represent the PPI recommended Hydrostatic Design Stress (HDS) which is equal to the product of the materials HDB rating and the design factor for water applications divided by 100.

Therefore, for a PE3408 defined in accordance with ASTM D3350-02a:

- PE is the abbreviation in accordance with ASTM D1600
- 3 refers to the density cell classification in accordance with ASTM D3350
- 4 refers to the PENT values (slow crack growth cell class) in accordance with ASTM D3350 which requires 30 hours of PENT failure times (Note: ASTM D2513 requires a minimum of 100 hour PENT time to failure)

- It has an 800 psi HDS which is the product of its HDB rating and the design factor for water (1600 psi times 0.50) at 73°F. This product divided by 100 yields 8 or 08.

From the above example, taking into account the increased performance based requirements recommended by both the IDF steering committee and the PPI HSB and the recent increase in the design factor for water applications, it was clear that additional new naming conventions (material designation codes) would be required to clearly delineate the higher performance PE materials which can be utilized in conjunction with the increased design factor for gas applications.

Following extensive efforts by PPI and its member companies, new material designation codes have been established within various applicable ASTM standards and specifications which retain the same methodology but extend the numbering systems to take into account the raised bar requirements with respect to the increased PENT values and increased HDS.

Therefore, based on this new material designation codes, for a **PE4710**:

- PE is the abbreviation in accordance with ASTM D1600
- 4 refers to the **NEW** density cell classification in accordance with ASTM D3350-05
- 7 refers to the **NEW** PENT values (slow crack growth cell class) in accordance with ASTM D3350-05 which requires **500 hours of PENT failure times**
- It has a 1008 psi HDS which is the product of its HDB rating and the design factor for water (1600 psi times 0.63) at 73°F. This product divided by 100 yields 10.

In order to more effectively delineate these new material designation codes, PPI TR-4 has been recently amended and a special section has been added for those PE materials which satisfy these raised bar requirements. As a result, in order to more effectively reflect the raised bar requirements and ensure that only these respective materials are utilized in conjunction with the increased design factor, the IDF steering committee unanimously supported revising §192.123 and incorporating the new PE material designation codes, e.g. PE2708 and PE4710.

4.0 JUSTIFICATION OF MINIMUM WALL THICKNESS REQUIREMENTS

In addition to the increased design factor and citing the new material designation codes, the most important recommendation of the IDF steering committee relates to the "self-imposed" limitations on the permissible minimum wall thicknesses as a function of pipe diameter that can be used in conjunction with an increased design factor. The remainder of this section outlines the overall technical approach and data development used to develop the specific wall thickness size limitations as a function of pipe outside diameter.

While the steering committee recommendations and industry efforts to implement new material designation codes help to ensure that only those materials which sufficiently satisfy the increased performance based requirements are used for gas distribution applications, it was readily apparent that additional work was needed to validate the theoretical considerations and quantify the impact of increased pressures on the pipe, fittings, and various types of joints.

The primary objective of the IDF program Phase II efforts was to perform comprehensive testing to evaluate the impact of an increased design factor on pertinent construction, maintenance, and operating practices on polyethylene piping systems. Specifically, to validate the safe long term performance of PE piping systems (pipe, fittings, and joints) at stress levels corresponding to the use of a 0.40 design factor over the theoretical intended design life of 50-years

Noting that the proposed increase in the design factor will be applied to newly installed PE piping (both MDPE and HDPE) for both main and service tubing, the consensus input of the IDF steering committee was to establish the lower bound limits for suitable pipe sizes (outside diameter and wall thickness) to be used in conjunction with the 0.40 design factor.

Based on the results of the pressure calculations, it was noted that the lower boundary limits could not be effectively determined by exclusively taking into account the pressure limitations. For example, by only taking into account design pressure considerations, gas utility companies could potentially use 2-inch SDR21 HDPE materials for main sizes. While this potential reality is even permitted under the current code requirements, the use of 2" SDR 21 pipe sizes could potentially poses several technical challenges. Subsequently, the steering committee investigated all probable pipe sizes and wall thickness considerations taking into various factors including manufacturability, installation, and long term operations considerations.

Following a comprehensive review of the various probable design scenarios and taking into account all of the technical considerations, the unanimous decision of the IDF steering committee was to perform comprehensive testing and evaluations on both 2-SDR 13.5 and 4-inch SDR17 pipe sizes made from both MDPE and HDPE materials as these sizes represented a high probability of use by gas companies under a 0.40 design factor.

As previously noted, over 40 years of safe operating experience with the use of plastic piping materials have demonstrated that the long term performance is not predicated by the plastic piping materials ability to withstand failures due to internal pressure, but rather by their ability to effectively resist localized stresses produced by add-on stresses.

As a result, a comprehensive battery of tests were performed to evaluate the combined influence of increased internal pressures and other add-on stresses including effects of squeeze-off, rock impingement, surface scratches, earth loading, bending stresses, etc on the pipe wall. Both the 2-inch SDR13.5 and 4-inch SDR17 pipe sizes made from both MDPE and HDPE materials were subjected to long term sustained pressure testing at elevated temperatures (80°C) at test pressures corresponding to the use of a 0.80 design factor. In addition to increased stress levels, the unanimous decision of the IDF steering committee was to extend the testing duration for test times corresponding to projected in-service failure times greater than 50 years. Table 4 provides an overview of the test parameters. Taking into account the added degree of conservatism in the test methodology, for all of the pipe sizes made from both grades of PE materials, there were no failures that were observed. The results clearly demonstrated the increased performance characteristics of modern PE materials.

Material and Size	Corresponding Service Conditions at 23°C (73°F) based on Proposed Test Conditions at 80°C		Calculated Maximum Design Pressure using a 0.40 design factor and a LTHS value based on 73°F temperature rating, psig
MDPE	Pressure, psig	Time	
SDR 11	200	>100 years	102
SDR 13.5	160	>100 years	80
SDR 17	126	>100 years	64
HDPE	Pressure, psig	Time	Max. Design Pressure using a 0.40 design factor, psig
SDR 11	256	>100 years	128
SDR 13.5	204	>100 years	102
SDR 17	160	>100 years	80

Table 4: Comparison of the test conditions versus actual maximum design pressures obtained using the proposed 0.40 design factor

While the overall results of the testing on the pipe were positive, a comprehensive battery of tests was performed on various types of joints (butt heat fusion, saddle fusion, electrofusion, and mechanical joining). Numerous specimens for various types of joints were fabricated using existing procedures and existing product designs. The joints were then subjected to long term sustained pressure testing at elevated temperatures using the conditions outlined in Table 4. There were no failures for any of the joint specimens (butt heat fusion, saddle heat fusion, and electrofusion) that were observed confirming the ability to make strong joints which can perform at the increased stress levels over their intended design life.

However, during the fabrication of both saddle heat fusion specimens and electrofusion saddles on the 2-inch SDR 13.5 pipe size, it was noted that existing procedures and product design(s) may need to be modified to prevent through wall failures during the joining process for 2-inch SDR13.5 pipe sizes – both MDPE and HDPE.

Therefore, on the basis of the technical data and taking into account actual field experience by gas utility companies installing larger diameter pipe sizes, the IDF steering committee unanimously supported the following recommendations:

1. The minimum wall thickness should be increased from 0.0625" to 0.090" under §192.123(c).
2. For pipe sizes 2" through 12", additional limitations should be incorporated with respect to minimum wall thickness values (SDR values) as a function of pipe size. Specifically,
    a. 2-inch IPS pipe sizes should be limited to SDR11 or lower (thicker wall)
    b. 3-inch IPS pipe sizes should be limited to SDR 13.5 or lower (thicker wall)
    c. 4-inch IPS pipe should be limited to SDR17 or lower (thicker wall)
    d. 6-inch IPS through 12-inch IPS should be limited to SDR21 or lower (thicker wall)

5.0 IMPACT ON OPERATIONS

While the preceding technical discussion clearly establishes the efficacy of modern PE materials satisfying the increased performance based requirements to safely operate under the proposed 0.40 design factor, the IDF steering committee also investigated the impact to operations by taking into account potential high level key risks and threats associated with PE piping systems.

In general, the distribution infrastructure has been a safe and proven means of transporting natural gas service to meet the Nation's ever growing energy needs. There have been numerous studies which have validated this point, most recently a study by the American Gas Foundation (AGF)[6].

The AGF study provides a comprehensive review of the incident failure data, as reported to DOT, for both transmission and distribution systems. Based on the results of this study, from an overall perspective, the rate of incidents and failures overall are downward. This downward trend can be attributed to several factors including:

- improvements in the material performance characteristics for PE materials
- improved test methods and qualification requirements for materials used in gas distribution applications
- improved operating practices based on the cumulative results of R&D over the past three decades

The implicit recognition of these key improvements and proven safe operations of PE piping systems operating at 125 psig also potentially influenced the DOT to enact a rule change removing the 100 psig limitation for PE materials produced after 2005.

In order to better understand the impact to operations associated with an increased design factor, it was important to correlate the empirical data on the enhanced performance characteristics of modern PE materials with potential key risks and threats to which the piping systems may be subjected. The major threats to pipeline systems are organized in a hierarchy of various root causes as defined in DOT Research and Special Projects Administration (RSPA) Form 7100.1. The original classifications were intended for steel transmission pipelines and gathering lines. Subsequent research by Kiefner and Associates and the Allegro Study built upon the original classifications to take into account additional types of piping materials found in distribution systems. Table 5 below presents the major threats to the pipeline infrastructure as defined by RSPA along with the additional refinements based on previous research.

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[6] American Gas Foundation, "Safety Performance and Integrity of the Natural Gas Infrastructure", January 2005. www.gasfoundation.org

OPS Category	Sub-Categories by Kiefner List	Modified Subcategory List for Distribution Systems	Additional Subcategory List for PE Piping Systems Considered by IDF Committee

Outside Force Damage	• Third party excavation
	• Vandalism
	• Earth movement
	• Heavy rains/floods
	• Previously damaged pipe
	• Lightning
	• Cold weather
		• Third party excavation
		• Vandalism
		• Earth movement (e.g. frost heave, subsidence, landslide, seismic movement, etc)
		• Heavy rains/floods
		• Previously damaged pipe
		• Lightning
		• Cold Weather
			• Effects of Add-on Stresses
			  • Earth loading
			  • Rock impingement
			  • Surface scratches
			  • Excessive bending strain

Corrosion	• External Corrosion • Internal Corrosion • Stress corrosion cracking	• External Corrosion (steel pipe) • Internal Corrosion (steel pipe) • **Other degradation mechanisms (cast iron graphitization)**	• **Other degradation mechanism** (Outdoor storage requirements)
Construction Errors	• Defective fabrication weld • Defective girth weld • Construction damage	• Defective fabrication weld • Defective girth weld • Construction damage	• Joint integrity (butt heat fusion, saddle heat fusion, electrofusion, and mechanical joining)
Material Defects	• Defective Pipe • Defective Seams • Stripped Threads / broken couplings • Gasket / o-ring failures • Seal / packing failures	• Defective Pipe • Defective Seams (steel only) • Stripped Threads / broken couplings • Gasket / o-ring failures • Seal / packing failures	• Use of regrind (rework materials)
Operator Error	Incorrect operation	Incorrect operation	
Equipment Malfunction	Malfunction of control / relief equipment	Malfunction of control / relief equipment	
Miscellaneous / Other	Miscellaneous/Unknown	Miscellaneous/Unknown	

Table 5: Major threats to Pipeline Systems, Reference: AGF Study

In the context of the IDF program, two important observations were made by the steering committee:

- Given the various types of materials used for distribution applications, the relative importance of each major category of threat will be different since the IDF program is exclusive to PE materials.
- Based on 40-years of in-service experience, the failure mechanisms resulting from the respective threat(s) (outside of third party damage in some instances) will be via the slow crack growth mechanism which is a time-dependent threat.

Therefore, to ensure the overall safety and integrity of the gas distribution network using a 0.40 design factor, it was readily apparent that technical data must demonstrate that the modern PE materials can effectively withstand failures resulting via the slow crack growth mechanism regardless of the cause. Provided that this is true, then it can be effectively demonstrated that there is ample safeguards to ensure overall safety and system integrity.

Based on the comprehensive data developed within IDF program and taking into account the various respective threats, the cumulative technical data demonstrates that modern PE piping materials satisfying the increased performance characteristics have ample safeguards against know failure mechanisms such as slow crack growth. Table 6-9 illustrate that various types of threats and their subcategory, the resulting implications, and the relevance of current code requirements and technical data to ensure effective design of PE piping systems using a 0.40 design factor.

In a cumulative sense, based on the IDF steering committee performance based recommendations and the inherently conservative limitations on the possible sizes (minimum wall thickness values as a function of outside diameter) contained within the petition, it can be reasonably inferred that the proposed increase in the design factor will not adversely compromise system operations, safety, and overall system integrity.

Threat	Outcome	Management and mitigation under stress levels provided for under current regulations	Impact at higher operating stress	Foundation for Operations at higher stress levels	Additional measures and special technical considerations / studies
Outside Force Damage					
▪ Third Party Excavation	▪ Potential for thru wall failures	▪ Inspection protocols ▪ One-call systems ▪ New technologies for better locating and damage prevention	▪ No substantive impact	▪ Proposed design constraints within the range of experience of gas utility companies, e.g. several companies presently operate 125 psig systems	▪ Maintain current maximum pressure of 125 psig under code requirement
▪ Effects of Add-on Stresses ▪ Rock Impingement ▪ Surface Scratches ▪ Bending ▪ Earth Loading	▪ "Brittle-like" failures due to slow crack growth mechanism	▪ ASTM D2513-99 requirements - incorporated through reference in Appendix A of CFR Part 192	▪ No substantive impact	▪ Positive test results at stress levels comparable to using a 0.80 design factor ▪ 50-years substantiation requirements per ASTM D2513-99 ▪ Minimum PENT failure times of 500 hours	▪ GTI/PPI/AGA studies for IDF program ▪ NTSB Report: "Brittle-like Cracking of PE…" NTSB/SIR-98/01, PB98-917001, 1998

Table 6: Impact to operations for an increased design factor – Outside Force Damage Considerations

Threat	Outcome	Management and mitigation under stress levels provided for under current regulations	Impact at higher operating stress	Foundation for Operations at higher stress levels	Additional measures and special technical considerations / studies
Construction Errors – Joint Integrity Considerations					
• Butt fusion joint integrity	▪ Brittle-like failures due to slow crack growth mechanism	▪ ASTM D2513-99 provisions for 50-years substantiation requirements for ductile performance incorporated through reference in Appendix A of CFR Part 192 ▪ Joining procedures per Part 192.281 and 192.283 ▪ Qualification of joiners per Part 192.285 ▪ Inspection of joints per Part 192.287 ▪ ASTM D2657 ▪ Pre-service pressure testing	▪ No substantive impact	▪ Test results demonstrate safe performance at stress levels comparable to using a 0.80 design factor ▪ Effective resistance to SCG failures for modern PE materials	▪ GTI/PPI/AGA studies for IDF program ▪ PPI TR-33
• Saddle Heat Fusion	▪ Propensity for Blow-out ▪ Control/equipment malfunction	▪ Joining procedures per Part 192.281 and 192.283 ▪ Qualification of joiners per Part 192.285 ▪ Inspection of joints per Part 192.287 ▪ Controls and fitting design for appropriate pipe sizes ▪ ASTM F905 requirements	▪ Increased risk for blow-out at higher ambient temperatures ▪ LIMIT use to a minimum of SDR11 for 2-inch pipe sizes and above	▪ Test results demonstrate safe performance at stress levels comparable to using a 0.80 design factor ▪ Ample margin of safety using SDR11 for 2-inch pipe sizes and above over range of ambient temperature extremes	▪ GTI/PPI/AGA studies for IDF program ▪ PPI TR-41

Table 7: Impact to operations for an increased design factor – Construction Errors (Joining Considerations)

Threat	Outcome	Management and mitigation under stress levels provided for under current regulations	Impact at higher operating stress	Foundation for Operations at higher stress levels	Additional measures and special technical considerations / studies
Construction Errors – Joint Integrity Considerations					
• Electrofusion	▪ Propensity for Blow-out ▪ Control/equipment malfunction	▪ Joining procedures per Part 192.281 and 192.283 ▪ Qualification of joiners per Part 192.285 ▪ Inspection of joints per Part 192.287 ▪ Controls and fitting design for appropriate pipe sizes ▪ ASTM F1055 requirements	▪ Increased risk for blow-out at higher ambient temperatures ▪ LIMIT use to a minimum of SDR11 for 2-inch pipe sizes and above	▪ Test results demonstrate safe performance at stress levels comparable to using a 0.80 design factor ▪ Ample margin of safety using SDR11 for 2-inch pipe sizes and above over range of ambient temperature extremes	▪ GTI/PPI/AGA studies for IDF program ▪ ASTM F1055
• Mechanical Saddles	▪ Gasket / O-ring failures	▪ Joining procedures per Part 192.281 and 192.283 ▪ Qualification of joiners per Part 192.285 ▪ Inspection of joints per Part 192.287 ▪ Fitting design ▪ ASTM F1924 requirements	▪ No substantive impact	▪ Test results demonstrate safe performance at stress levels comparable to using a 0.80 design factor	▪ GTI/PPI/AGA studies for IDF program ▪ PPI TR-41

Table 8: Impact to operations for an increased design factor – Construction Errors (Joining Considerations)

Threat	Outcome	Management and mitigation under stress levels provided for under current regulations	Impact at higher operating stress	Foundation for Operations at higher stress levels	Additional measures and special technical considerations / studies
Material Defects					
• Defective Pipe • Use of regrind / rework in PE pipe	• Potential for failures	▪ Materials specification in procurement ▪ ASTM D2513 requirements ▪ PPI MS-2	▪ Marginal Impact	▪ QA/QC in manufacturing ▪ QA/QC for incoming materials inspection	▪ New ASTM D2513 requirements and PPI TN-30 which addresses effective process controls
Miscellaneous (Equipment and Fittings Related)					
▪ Equipment and Fittings related	▪ Gasket/O-Ring failures ▪ Incorrect pressure rating ▪ Manufacturing issues ▪ Pipe and fittings mismatch	▪ ASTM D2513 ▪ ASTM F1924 ▪ ASTM F1055 ▪ ASTM F1973	▪ No substantive impact	▪ QA/QC in manufacturing ▪ QA/QC for incoming materials inspection ▪ Increased training requirements and operator qualification	

Table 9: Impact to operations for an increased design factor – Material Defects and Miscellaneous Considerations

6.0 PROPOSED BENEFITS

Besides the technical considerations, the IDF steering committee performed comprehensive work to quantify the potential benefits associated with the proposed increase in the design factor. Based on the resulting analysis, it was readily concluded that the proposed increase in the design factor will permit gas utility companies to utilize proven PE materials with increased performance characteristics and implement more flexible and effective design scenarios to satisfy the need for additional capacity. In turn, these more flexible and effective design methodologies will provide a positive overall environmental impact.

Capacity Considerations

From a fundamental engineering perspective, the capacity, or volumetric flow rate, is dependent on several geometric characteristics of the pipe and operating conditions including:

- Length of pipe
- Pressure differential
- Internal diameter of pipe
- Temperature of gas
- Elevation difference between beginning and end of line section
- Gas gravity
- Compressibility of gas
- Internal pipe surface roughness
- Flow characteristics of gas

In general, the volumetric flow rate is linearly related to the internal cross-sectional area of the pipe, i.e., if the internal diameter of the pipe increases (increase in the cross-sectional area), then the flow rate will also increase.

To aid gas utility engineers in the overall system design and planning, the American Gas Association (AGA) has published a guideline to estimate the volumetric gas flow entitled "Steady Flow in Gas Pipelines". The document references several recommendations for determining the gas flow rate including: Panhandle A, Panhandle B, and Weymouth. For the purposes of this analysis, the following closed form solution was utilized:

General:

$$Q_b = 38.77(T_b/P_b)\left[\frac{P_1^2 - P_2^2 - \frac{0.0375G(h_2-h_1)P_{avg}^2}{z_{avg}\,T_{avg}}}{G\;T_{avg}\;L\;z_{avg}\;f}\right]^{0.500} D^{5/2} \qquad \text{A-3a}$$

A.G.A. Steady flow in gas pipelines (IGT), pp 16, Figure A-3

Where,

T_b (Base temperature)= 520°R=60°F,
P_b (Base pressure)= 14.73psia,
P_1 and P_2 (Pressure at beginning and end of line section respectively) [psia(lb/in^2-abs)],
G (Gas gravity) = 0.6459
h_1 and h_2 (Elevation at beginning and end of line section respectively),
P_{avg} (Average pressure) = 37.6 psia(lb/in^2-abs),
Z_{avg} (Compressibility factor) = 1 (Ref. 3),
T_{avg} (Average temperature) = 520 °R,
L (Line length) = 1000ft =0.189393939 miles,
f (Friction factor) = 0.00255, $\sqrt{1/f} = 4\log\frac{3.7D}{k_e}$,
where Ke is effective roughness of pipe interior = 0.0005in,
D (Internal diameter of pipe) [inch].

Using the AGA equation and neglecting the elevation change, the above equation can be simplified to the following:

$$Q_b = C\left[p_1^2 - p_2^2\right]^{0.5} D^{5/2} \quad \text{where C is constant.} \qquad (2)$$

Based on a review of the terms in Equation (2), it is apparent that the flow rate is a function of both the pressure differential and internal pipe diameter raised to an exponent. As a result, if there is either an increase in the pressure differential or internal pipe diameter, there is a corresponding increase in the volumetric flow rate. Based on Equation (2), a series of analyses were performed on various pipe sizes from 4-inch to 12-inch to determine the relative trends with respect to the flow rate as a function of varying SDR values, pressure differentials, and length of installed plastic piping. Typical results for 4-inch IPS pipe size(s) are presented in Table 10 and Figure 2.

Nom. O.D. (in.)	SDR	O.D.(in)	Wall Thickness (in.)	I.D.(in)	Inlet Press. (psi)	Outlet Press. (psi)	Pressure Diff.(psi)	Length(ft)	Q (MCFH)	% Difference
4	9	4.5	0.482	3.536	16	15	1	100	73	---
	11		0.409	3.682					81.1	11.10%
	13.5		0.333	3.834					90.09	23.41%
	17		0.264	3.972					98.75	35.27%
	21		0.214	4.072					105.34	44.30%
4	9	4.5	0.482	3.536	20	15	5	100	168.57	---
	11		0.409	3.682					187.26	11.09%
	13.5		0.333	3.834					208	23.39%
	17		0.264	3.972					228.01	35.26%
	21		0.214	4.072					243.22	44.28%
4	9	4.5	0.482	3.536	25	15	10	100	247.48	---
	11		0.409	3.682					274.9	11.08%
	13.5		0.333	3.834					305.37	23.39%
	17		0.264	3.972					334.75	35.26%
	21		0.214	4.072					357.07	44.28%
4	9	4.5	0.482	3.536	30	15	15	100	313.8	---
	11		0.409	3.682					348.6	11.09%
	13.5		0.333	3.834					387.24	23.40%
	17		0.264	3.972					424.49	35.27%
	21		0.214	4.072					452.8	44.30%

Comments Average internal roughness k= 0.0005in
Z_avg = 1 (Compressibility factor)
G=0.6459 (Gas gravity) (Average Natural Gas Composition)
Elevation change is neglected
Temperature is assumed to be 60F

Table 10: Calc. flow rates as a function of SDR and pressure differential – 4" pipe

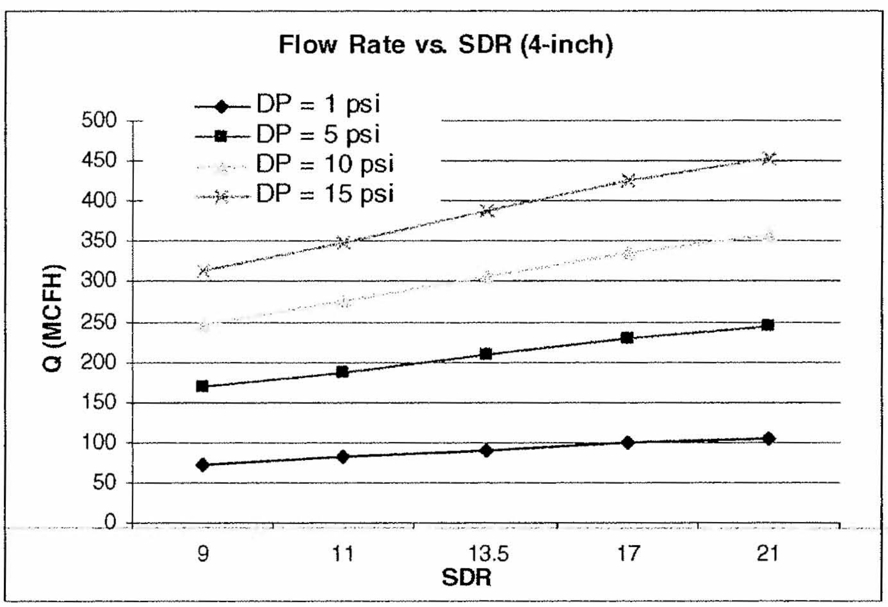

Figure 2: Graphical representation of calculated flow as a function of SDR – 4" pipe

The preceding analysis and data confirms the basic fundamental principles of physics - that for all things being the same, then the flow rate increases as either the internal diameter is increased and/or the pressure differential is increased. It is important to note that several simplifying assumptions were built into the analysis to develop the relative trends. Consequently, the actual values (magnitude) of the flow rates will change as one removes the simplifying assumptions and utilizes more robust flow calculation tools and software. However, the relative trends demonstrated in the preceding analysis will remain the same.

Take for example a 4-inch pipe SDR 9 with a pressure differential of 1 psi. The calculated flow rate is 73 MCFH over a 100 feet length – see Table 10. For a comparative standpoint, for a 4-inch SDR11 (increase in the internal diameter) and the same pressure differential of 1 psi, the calculated flow rate is then 81.1 MCFH, i.e., an 11% increase.

Alternatively, take for example a 4-inch pipe SDR 9 with a pressure differential of 1 psi. The calculated flow rate is 73 MCFH. For the same pipe geometry and length scales and a pressure differential of 5 psi, the calculated flow rate is then equal to 168 MCFH representing a 167% increase.

The trends noted above are significant in that the proposed increase in the design factor facilitates more flexible and effective design scenarios to address the need for additional capacity and in turn increasingly utilize PE materials which have been shown to be a safe and proven material for gas distribution applications.

In general, gas utility companies have long understood the benefits associated with PE piping systems. In addition to being lightweight, easy to handle and join, ability to be provided in coils, PE plastic piping eliminates the need for long term corrosion control measures. Based on industry reported statistics, the estimated savings using PE piping as compare to steel piping can be as high as 50% in some circumstances as shown in the Table 11 below. Given the increased capacity considerations, gas utilities can employ more effective design methodologies in the selection of suitable materials for their gas distribution networks – more PE!

	Non-Paved Areas	Paved Areas
Pipe Size	Est. Total Cost Savings for PE vs. Steel	Est. Total Cost Savings for PE vs. Steel
2"	43%	57%
4"	37%	40%
6"	34%	33%
8"	22%	18%
12"	20%	15%

Table 11: Estimated total cost savings for PE pipe versus Steel Pipe

Environmental Benefits

As previously noted above, the primary implication of the proposed increase in the design factor is to facilitate a more effective design of the gas distribution infrastructure by selecting the best suited materials in the most efficient sizes for the intended application. Under the current code requirements for using a 0.32 design factor, the maximum benefits or use of PE piping systems is not fully realized. While recent changes to the CFR Part 192 to allow PE piping systems to operate at pressures up to 125 psig represents a step in the positive direction, the resulting design scenarios often cannot effectively satisfy the necessary capacity considerations due to the reduced internal diameter of the PE pipe. Therefore, the proposed increase in the design factor is really centered on increasing the use of plastic piping materials, given their documented benefits, as compared to other materials in the most efficient sizes to increase the volumes of gas that can be transported in a safe and reliable manner. In order to quantify the environmental impact of the increased use of PE materials as compared to metallic piping over a range of possible sizes, a comprehensive analysis was performed to determine the net green house gas emissions.

It is generally understood that there are differences in the amount of energy that is required to produce various items. As a baseline frame of reference, a comprehensive analysis was performed to estimate the greenhouse gas (GHG) emission factors resulting from the upstream manufacture associated with steel and PE piping. The GHG emission factors for both the steel piping and PE[7] piping were developed using emission factors developed for the Environmental Protection Agency's (EPA) Waste Reduction Model (WARM) with certain conservative built in simplifications. The GHG emission for the steel piping was assumed to be mainly attributed to the material itself and the energy that is used in the upstream manufacturing process such as coal consumption, residual fuel consumption, electricity usage, etc.). The resulting set of GHG data for steel piping (recycled-content steel piping) did not take into account:

- Potential increase in the GHG emission with steel piping resulting from the pipe installation
- Potential increase in the GHG emissions from the transport of the steel piping from the manufacturing center (retailer) to the job site as a result of the increased weight of the pipe
- Potential increase in the GHG emission resulting from differences in the possible leakage rates between the steel pipe as compared to the PE pipes

In a similar manner, using the life-cycle process and transportation energy data, unique GHG emission factors for the production of PE resin using 100% virgin inputs were developed. The underlying life-cycle data which was utilized was submitted through the Plastic Division American Chemistry Council and synthesized by the National Renewable Energy Laboratory U.S. Life-Cycle Inventory Database[8]. The data is summarized in Table 14 below.

[7] For the purposes of these discussions, there is no differentiation being made with respect to the medium density PE and high density PE. For the purposes of the analysis, factors for the high density (PE4710 materials) were utilized.

[8] Database available at http://www.nrel.gov/lci/

	Process Energy	Transportation Energy	Process Non-Energy	Net Emissions
Steel – 72% recycled content	0.54	0.10	0.24	0.87
Steel – 100% recycled content	0.19	0.09	0.24	0.51
PE Resin (HDPE)	0.23	0.05	0.03	0.31

Table 14: GHG emission factors from upstream HDPE and steel manufacture (MTCE/Ton) developed by ICF International and PSE&G. NP = Not Published

Based on the data contained with Table 14, it is clearly evident that the upstream steel production process for either the 72% recycled content or 100% recycled content is significantly more energy and GHG intensive process as compared to the production of the PE resin. This is illustrated in Table 15 below.

Scenario	Description	% Increase in NET GHG Emissions
1	Use of 72% recycled content steel instead of 100% recycled content steel	+70%
2	Use of 72% recycled content steel instead of PE	+180%
3	Use of 100% recycled content steel instead of PE	+64%

Table 15: Comparison of the increase in the net GHG emission for using different materials

From the preceding, the data and analysis demonstrates that the proposed increase in the design factor which permits for greater design flexibility, and in turn, increased use of PE materials in the most efficient sizes provides a meaningful environmental benefit in terms of reduced net GHG emissions.

SUMMARY

There has been a continued interest on the part of gas distribution companies to design and construct their gas distribution network to its maximum potential. Since the mid-1990's, the American Gas Association Plastics Materials Committee and other industry organizations have supported numerous efforts to increase the overall capacity considerations without sacrificing overall safety and system integrity.

Recent rule changes by the DOT PHMSA have aided in this effort. Specifically, based on the positive in-service field experience under previous wavier(s) in various part of the U.S., Title 49 CFR Part 192 requirements has been recently amended and now permit the use of modern PE materials at design pressures up to 125 psig for gas distribution applications. However, additional small-scale changes to the regulations are still necessary. Specifically, revising Part 192.121 to permit the use of a 0.40 design factor in calculating the design pressure for plastic piping systems subject to the revised limitations prescribed under Part 192.123.

In order to ensure that all of the technical and safety considerations were effectively resolved, a comprehensive program has been in place to establish the technical validity of increasing the design factor. The overall program was divided into three distinct phases:

> Phase I: Development of minimum material performance based requirements for PE materials and investigation of additional design and engineering considerations to justify an increase in the design factor.
>
> Phase II: Perform comprehensive testing and evaluation to validate the impact of an increase design factor on key construction, maintenance, and operating practices to ensure the safety and integrity of the gas distribution network.
>
> Phase III: Perform targeted field experiments under special permits to develop actual in-service operating experience and establish the technical basis for continued efforts related to future rule-making initiatives by the Department of Transportation.

A joint industry steering committee was established consisting of representatives from each of the key stakeholder groups: gas utility companies, regulatory representatives, and pipe/resin/and fittings manufacturers in order to ensure an objective review of the technical data and promote consensus based recommendations.

The cumulative results of the IDF program and the recommendations of the steering committee clearly validate that the proposed increase in the design factor is justified for the following reasons:

1. The technical basis and approach for the transition to a 0.40 is identical and consistent with the approach utilized by the DOT when the last change in the design factor was instituted in 1978.

2. Over the past few decades, there have been significant and notable improvements in the performance characteristics of modern PE materials, ASTM standards and specifications have been significantly strengthened to ensure that materials with excellent resistance to SCG failure mode are utilized for gas distribution applications, and comprehensive R&D efforts have led to the development of effective process improvements and technologies to ensure the safe construction and operations of modern PE piping systems.
3. The cumulative results of the comprehensive testing at design pressures equivalent to the use of a 0.8 design factor demonstrated that pipe and fittings can safely perform at the proposed design pressures contained within this waiver.
4. The recommendations of the IDF steering committee are significantly more conservative than the current code requirements. Specifically, the adoption of increased performance based requirements and appropriate size limitations help to ensure that only suitable materials with excellent mechanical and physical properties in the most optimum sizes are utilized in conjunction with the proposed 0.40 design factor.
5. The range of maximum design pressures are within the range of operating experience at gas utility companies, i.e., the special permit continues to keep the maximum design pressure limitation of 125 psig.
6. The proposed exemptions will enable gas utility companies to increasingly utilize safe and proven PE materials to extend their gas distribution infrastructure.
7. The proposed exemptions will enable gas utility companies to implement more flexible and effective design methodologies to satisfy the much needed capacity considerations. The intent of the exemptions contained within this special permit is consistent with the recent rulemaking permitting the increase in percent (%) specified minimum yield strength (SMYS) to 80% for steel systems.
8. The cumulative results of the comprehensive testing and evaluation and the inherent conservatism of the proposed recommendations help to ensure that the overall safety and system integrity will not be adversely compromised.
9. There are significant overall benefits to the general public and the environment associated with the proposed increase in the design factor.

In summary, based on the cumulative results of the data and recommendations resulting from the increase in design factor program, it is evident that the proposed increase will provide gas utility companies greater design flexibility and the ability to increasingly utilize a safe and proven PE materials to safely and more effectively provide natural gas service to their customers.

PHMSA 18757

BEFORE THE
PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION
UNITED STATES DEPARTMENT OF TRANSPORTATION
WASHINGTON, D.C.

)
)
)
)

Petition for Rulemaking
From The American Gas Association

COMES NOW the American Gas Association, hereafter called AGA, and submits this petition for rulemaking. In support of said petition, AGA states:

1. AGA submits the petition to the Associate Administrator of the Pipeline and Hazardous Materials Safety Administration, PHMSA, pursuant to 49 CFR 190.133.

2. The petition seeks substantive changes to sections §192.121 - *Design limitations of plastic pipe* and §192.123 - *Design limitations for plastic pipe.*

3. The petition seeks to increase the design factor (DF) in section 192.121 from 0.32 to 0.40 for polyethylene pipe (PE) installed after the date of promulgation of a revised rule.

4. The petition seeks more comprehensive safety limitations for plastic pipe specifications in 192.123. There would be new limitations for minimum wall thickness and standard design ratio (SDR) for specific diameter plastic piping.

5. The requested regulatory changes would have the purpose and effect of allowing gas utilities to design, install, and operate new PE piping with operating capacities consistent with the capabilities of modern plastic materials.

6. The petition provides documentation of the comprehensive program, supported by the Operation Technology Development (OTD) group, to establish the technical evidence for the proposed changes. The program has included laboratory testing and evaluation to ensure that the safety and integrity of the gas distribution system is maintained at the increased design factor. Field experiments, authorized by special permits from state and federal pipeline safety agencies, have been initiated to confirm design and laboratory evaluations. This effort has been active since at least 2004.

7. The technical evaluation of the plastic pipeline design factor has been publicly discussed and supported in various regulatory initiatives through the AGA, Gas Piping

Technology Committee (GPTC), Plastics Pipe Institute (PPI), Gas Technology Institute (GTI), and others entities.

8. The public benefits from the increased use of PE piping, in lieu of steel, because the plastic piping systems have quantifiable lower emissions. Moreover, plastic is not susceptible to corrosion, which is responsible for some of the leakage in steel piping systems.

9. The regulatory language for the existing and proposed sections is provided herein for PHMSA's review.

10. AGA does not expect that the adoption of the proposed language would either increase costs to gas utilities or have any adverse consequences.

11. The adoption of the propose language will not create burdens on small businesses, small organizations and small governmental jurisdictions.

12. No changes are recommended to recordkeeping requirements.

I. Background

For over a decade, there has been tremendous interest on the part of gas distribution companies to increasingly utilize their PE piping infrastructure to its maximum capabilities. This has been supported through various regulatory initiatives through the AGA, GPTC, PPI, GTI, and others.

As of June 2004, the Department of Transportation Pipeline Hazardous Materials Safety Administration adopted several amendments to Title 49, Part 192 of the Code of Federal Regulations and its respective Subparts, which govern the minimum requirements for the safe use of plastic piping systems. Specifically, an amendment to Part 192.123 was adopted to increase the maximum allowable design pressure for PE piping systems from 100 psig to 125 psig. However, it was generally recognized that additional changes are required to maximize the benefits associated with the use of plastic piping systems by gas distribution companies - specifically, an increase in the design factor used to calculate the design pressure from 0.32 to 0.40 within Part 192.121 requirements.

The primary implication of the proposed increase in the design factor is that it permits gas utility companies to more effectively design their PE piping systems for the intended application in order to satisfy the necessary capacity considerations.

The remainder of the sections to follows presents both the current and proposed code language and a comprehensive justification for the proposed changes which clearly demonstrates that the increase in the design factor from 0.32 to 0.40 will not adversely compromise overall safety and system integrity.

II. Current Requirements

CHAPTER I--RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION, DEPARTMENT OF TRANSPORTATION

PART 192--TRANSPORTATION OF NATURAL AND OTHER GAS BY PIPELINE: MINIMUM FEDERAL SAFETY STANDARDS

Subpart C--Pipe Design

§192.121 - Design limitations of plastic pipe[1]

Subject to the limitation of §192.123, the design pressure for plastic pipe is determined by either of the following formulas:

$$P = 2S\frac{t}{(D-t)}(DF)$$

$$P = \frac{2S}{(SDR-1)}(DF)$$

[where] P = Design pressure, gauge, psig (kPa)

S = For thermoplastic pipe, the HDB is determined in accordance with the listed specification at a temperature equal to 23°C (73°F), 38°C (100°F), 49°C (120°F), or 60°C (140°F); for reinforced thermosetting plastic pipe, 75,800 kPa (11,000 psi).

t = Specified wall thickness, mm (in.)

D = Specified outside diameter, mm (in.)

DF = 0.32 or

= 0.40 for nominal pipe size (IPS or CTS) 4-inch or less, SDR-11 or greater (i.e. thicker pipe wall), PA-11 pipe produced after January 23, 2009

§192.123 - Design limitations for plastic pipe

[1] The following language reflects the recent rulemaking to include new language related to the introduction of the PA11 piping systems. Federal Register/Vol. 73, No 248/Wednesday, December 24, 2008/Rules and Regulations 790005

(a) Except as provided for in paragraph (e) and (f) of this section, the design pressure may not exceed a gauge pressure of 100 psig (689kPa) for plastic pipe used in:

(1) Distribution systems; or

(2) Classes 3 and 4 locations.

(b) Plastic pipe may not be used where operating temperatures of the pipe will be:

(1) Below –20°F (-20°C), or –40°F (-40°C) if all pipe and pipeline components whose operating temperature will be below –29°C (-20°F) have a temperature rating by the manufacturer consistent with the operating temperature; or

(2) Above the following applicable temperatures:

(i) For thermoplastic pipe, the temperature at which the HDB used in the design formula under 192.121 is determined

(ii) For reinforced thermosetting plastic pipe, 150°F (66°C)

(c) The wall thickness for thermoplastic pipe may not be less than 0.062 inches (1.57 millimeters)

(d) The wall thickness for thermosetting plastic pipe may not be less than that listed in the following table

....

(e) The design pressure for thermoplastic pipe produced after July 2004 may exceed a gauge pressure of 100 psig (689kPa) provided that:

(1) The design pressure does not exceed 125 psig (864kPa)

(2) The material is a PE2406 or a PE3408 as specified within ASTM D2513 (ibf, see 192.7)

(3) The pipe size is nominal pipe size (IPS) 12 or less; and

(4) The design pressure is determined in accordance with the design equation defined in 192.121

(f) The design pressure for polyamide-11 (PA-11) pipe produced after January 23, 2009 may exceed a gauge pressure of 100 psig (689 kPa) provided that:

(1) The design pressure does not exceed 200 psig (1279 kPa)

(2) The pipe size is nominal pipe size (IPS or CTS) 4-inch or less; and

(3) The pipe has a standard dimension ratio of SDR-11 or greater (i.e. thicker pipe wall)

III. Proposed Changes (Changes in *Bold/Italics*)

§192.121 - Design limitations of plastic pipe[2]

Subject to the limitation of §192.123, the design pressure for plastic pipe is determined by either of the following formulas:

[2] The following language reflects the recent rulemaking to include new language following the introduction of the PA11 piping systems. Federal Register/Vol. 73, No 248/Wednesday, December 24, 2008/Rules and Regulations 790005

$$P = 2S \frac{t}{(D-t)}(DF)$$

$$P = \frac{2S}{(SDR-1)}(DF)$$

[where] P = Design pressure, gauge, psig (kPa)

S = For thermoplastic pipe, the HDB is determined in accordance with the listed specification at a temperature equal to 23°C (73°F), 38°C (100°F), 49°C (120°F), or 60°C (140°F); for reinforced thermosetting plastic pipe, 75,800 kPa (11,000 psi).

t = Specified wall thickness, mm (in.)

D = Specified outside diameter, mm (in.)

DF = 0.32 or

= 0.40 for nominal pipe size (IPS or CTS) 4-inch or less, SDR-11 or ~~greater~~ *less* (i.e. thicker pipe wall), PA-11 pipe produced after January 23, 2009

= *0.40 for PE2708 or PE4710 pipe produced after [insert effective date]*

§192.123 - Design limitations for plastic pipe

(a) Except as provided for in paragraph (e) and (f) and (x) of this section, the design pressure may not exceed a gauge pressure of 100 psig (689kPa) for plastic pipe used in:

(1) Distribution systems; or

(2) Classes 3 and 4 locations.

(b) Plastic pipe may not be used where operating temperatures of the pipe will be:
(1) Below –20°F (-20°C), or –40°F (-40°C) if all pipe and pipeline components whose operating temperature will be below –29°C (-20°F) have a temperature rating by the manufacturer consistent with the operating temperature; or
(2) Above the following applicable temperatures:
(i) For thermoplastic pipe, the temperature at which the HDB used in the design formula under 192.121 is determined
(ii) For reinforced thermosetting plastic pipe, 150°F (66°C)

(c) The wall thickness for thermoplastic pipe may not be less than 0.062 inches (1.57 millimeters)

(d) The wall thickness for thermosetting plastic pipe may not be less than that listed in the following table

....

(e) The design pressure for thermoplastic pipe produced after July 2004 may exceed a gauge pressure of 100 psig (689kPa) provided that:

(1) The design pressure does not exceed 125 psig (864kPa)
(2) The material is a PE2406 or a PE3408 as specified within ASTM D2513 (ibf, see 192.7)
(3) The pipe size is nominal pipe size (IPS) 12 or less; and
(4) The design pressure is determined in accordance with the design equation defined in 192.121

(f) The design pressure for polyamide-11 (PA-11) pipe produced after January 23, 2009 may exceed a gauge pressure of 100 psig (689 kPa) provided that:
(1) The design pressure does not exceed 200 psig (1279 kPa)
(2) The pipe size is nominal pipe size (IPS or CTS) 4-inch or less; and
(3) The pipe has a standard dimension ratio of SDR-11 or ~~greater~~ less (i.e. thicker pipe wall)

(X) The design pressure for polyethylene (PE) pipe produced after [insert effective date] for use in distribution systems or class 3 and 4 locations provided that:

(1) The design pressure is determined in accordance with the equation defined in 192.121using a 0.40 design factor

(2) The material is a PE2708 or a PE4710 as specified within PPI TR4

(3) The design pressure does not exceed 125 psig (864 kPa)

(4)For PE piping systems operating at gauge pressure of less than 100 psig (689 kPa), the wall thickness may not be less than that listed in the table below

Nominal Pipe Size in inches	Minimum Wall Thickness in inches	Corresponding SDR values
½" – 1-1/2"	0.090 in.	Variable
2-inch	0.216 in.	11
3-inch	0.259 in.	13.5
4-inch	0.265 in.	17
6-inch	0.315 in.	21
8-inch	0.411 in.	21
10 inch	0.512 in.	21
12-inch	0.607 in.	21

(5)For PE piping systems operating at gauge pressure of greater than 100 psig (689 kPa), the wall thickness may not be less than that listed in the table below

Nominal Pipe Size in inches	Minimum Wall Thickness in inches	Corresponding SDR values
½" – 1-1/2"	0.090 in.	Variable
2-inch	0.216 in.	11
3-inch	0.259 in.	13.5
4-inch	0.333 in.	13.5
6-inch	0.491 in.	13.5
8-inch	0.639 in.	13.5
10-inch	0.796 in.	13.5
12-inch	0.944 in.	13.5

IV. Justification

Since 2004, a comprehensive program has been in place, with the financial support of Operation Technology Development (OTD) group, to establish the technical substantiation for the proposed changes. The Increase in Design Factor (IDF) program was divided into three distinct phases:

Phase I: Development of minimum material performance based requirements for PE materials and investigation of additional design and engineering considerations to justify an increase in the design factor.

Phase II: Perform comprehensive testing and evaluation to validate the impact of an increase design factor on key construction, maintenance, and operating practices to ensure the safety and integrity of the gas distribution systems.

Phase III: Perform targeted field experiments under special permit[3] (waivers) to obtain actual in-service operating experience and establish the technical basis for continued efforts related to future rule-making initiatives by the Department of Transportation.

From the inception of the program, objective peer review of the technical data was assured by establishing a joint industry steering committee consisting of representatives from each of the key stakeholder groups: gas utility companies, regulatory representatives, and pipe, resin, and fittings manufacturers. The joint industry steering committee efforts were critical in terms of effectively guiding the overall technical approach and establishing the technical recommendations to ensure that the overall safety and integrity of the gas distribution network is not adversely compromised.

Significant progress has been made relative to each of the aforementioned phases resulting in the approvals of several special permits in various states to allow the use of a 0.40 design factor for new PE piping systems.

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[3] The use of the term "special permit" is based on recent revisions to the definitions within DOT – formerly referred to as "waiver". These terms may be used interchangeably throughout the document.

From Phase I, a comprehensive set of raised bar performance based requirements were established by the IDF steering committee that are significantly more conservative than the current requirements contained within ASTM D2513-98. These additional performance based requirements help to ensure that only those materials which can satisfy the recommended raised bar performance requirements are utilized in conjunction with the proposed increased design factor.

From Phase II, the cumulative results of comprehensive testing and evaluation demonstrated that there are no deleterious effects for the proposed increase in the design factor. Specifically, the result of comprehensive testing on pipe, fittings, and various types of joints at pressures corresponding to the use of 0.80 design factor effectively demonstrated that there were no failures at test times significantly greater than the theoretical intended design life of 50-years. This underscores the improvements in the performance characteristics of modern PE piping materials which conform to the raised bar requirements developed by the IDF steering committee.

Based on the positive results of both Phases I and II, a series of special permits were filed in various states to allow the use of a 0.40 design factor subject to strengthened limitations within CFR Part 192 requirements as part of the Phase III efforts. To date, five (5) special permits have been granted in various parts of the United States. This includes the states of Arizona, Indiana, Maryland, New Jersey, and Tennessee. These special permits have been formally reviewed and commented on by the PHMSA and the appropriate state regulatory agencies.

The technical considerations notwithstanding, there are significant overall benefits associated with the proposed changes. As previously noted, the primary implication associated with the increase in the design factor is that it permits gas utility companies to increasingly utilize safe and proven PE materials to satisfy the necessary capacity considerations in the most optimum design scenarios. As part of the Phase III efforts, a series of analyses were performed to quantify the key benefits associated with the proposed increase in the design factor. The results demonstrate that there is approximately an 11% (or greater) increase in capacity by designing the PE piping systems in their optimum size configuration for the intended application.

Additionally, using the PE life cycle data synthesized by the National Renewable Energy Laboratory U.S. Life-Cycle Inventory Database as the basis for assessing the greenhouse gas

(GHG) emissions equivalency[4], and taking into account the environmental impact associated with only the upstream production perspective, the results demonstrated that the proposed increase in the design factor would result in a significant reduction in emissions. Specifically, the results demonstrated that the proposed change in the design factor would facilitate the increased use of PE materials which have lower net natural gas emissions as compared to steel piping systems. It is important to emphasize that these results are significantly conservative in that only one portion of the overall life-cycle analysis was considered. By taking other factors into account, these savings undoubtedly will increase the overall positive environmental impact for the proposed change being solicited.

Cumulatively, the results of the IDF program clearly demonstrate the reliability of the proposed increase in the design factor subject to the revised limitations. The results show that the overall safety and system integrity will not be adversely compromised, and there are additional benefits for the gas utility companies and the public.

V. Conclusion

AGA appreciates the effort that PHMSA, state regulators, OTD and other stakeholder have provided in supporting the effort to analyze and test the performance of polyethylene material at the 0.4 design factor. AGA believes the work has shown that the use of the increased design factor to be safe, reliable, cost effective and beneficial to the public. The adoption of the regulatory language presented in the petition will promote pipeline safety and benefit the environment.

The American Gas Association, founded in 1918, represents 202 local energy companies that deliver clean natural gas throughout the United States. There are more than 70 million residential, commercial and industrial natural gas customers in the U.S., of which almost 93 percent — more than 65 million customers — receive their gas from AGA members. AGA is an advocate for natural gas utility companies and their customers and provides a broad range of programs and services for member natural gas pipelines, marketers, gatherers, international natural gas companies and industry associates. Today, natural gas meets almost one-fourth of the United States' energy needs.

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[4] Database is available at: http://www.nrel.gov/lci/

Respectfully submitted,

Date:

By: [signature]
Philip Bennett

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CERTIFICATE OF SERVICE

I hereby certify that I have caused a copy of the Petition of the American Gas Association to be served upon the Administrator, Pipeline and Hazardous Materials Safety Administration by depositing the same in United States mail, to the addresses shown, with proper postage, on the 12 day of August, 2009.

Pipeline and Hazardous Materials Safety Administration
U.S. Department of Transportation- East Building
1200 New Jersey Ave, SE
Washington, DC 20590

[signature]
Philip Bennett

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