NEAL & HARWELL, PLC
LAW OFFICES
150 FOURTH AVENUE, NORTH
SUITE 2000
NASHVILLE, TENNESSEE 37219-2498

TELEPHONE
(615) 244-1713

FACSIMILE
(615) 726-0573

March 25, 2008

Sharla Dillon, Docket Manager
Tennessee Regulatory Authority
460 James Robertson Parkway
Nashville, TN 37238

VIA HAND DELIVERY

filed electronically in docket office on 03/25/08

RE: Petition of Atmos Energy Corporation for a Waiver to Permit the Limited Use of Polyethylene Piping, TRA Docket No. 07-00251

Dear Ms. Dillon:

We are filing an Amended (Renumbered) Petition of Atmos Energy Corporation in the above-referenced matter. The original and four copies are enclosed. An electric version is being provided via e-mail.

Best regards.

Sincerely,

A. Scott Ross

ASR:prd

Enclosures

BEFORE THE TENNESSEE REGULATORY AUTHORITY
NASHVILLE, TENNESSEE

IN RE:

PETITION OF ATMOS ENERGY CORPORATION FOR A WAIVER TO PERMIT THE LIMITED USE OF POLYETHYLENE PIPING	))))	**DOCKET NO. 07-00251**

AMENDED (RENUMBERED) PETITION OF ATMOS ENERGY CORPORATION

Atmos Energy Corporation respectfully submits this Amended Petition in order to correct non-consecutive paragraph numbering in its initial Petition in this matter. This Amended Petition makes no substantive change to the initial Petition. Atmos, therefore, will rely upon the Verification submitted with the original Petition.

RENUMBERED PETITION

Pursuant to Tennessee Code Annotated § 65-28-104, et seq., 49 U.S.C. § 60118, and Tennessee Regulatory Authority Rule 1220-4-5-.48, Atmos Energy Corporation, a Texas and Virginia corporation, ("Atmos" or the "Company") respectfully requests that the TRA approve its Petition for a waiver to permit the limited use of polyethylene ("PE") piping in natural gas distribution systems in accordance with the design formula prescribed under 49 C.F.R. § 192.121 and subject to the limitations of Section 192.123 therein.

In support of this Petition, Atmos submits the following:

1. Full name and address of the principal place of business of the Company are:

   Atmos Energy Corporation
   5430 LBJ Freeway, Suite 1800
   Dallas, TX 75240

2. All correspondence and communications with respect to this Petition should be sent to the following:

Mr. Ernie Napier
Vice President – Technical Services
Kentucky/Mid-States Division
Atmos Energy Corporation
810 Crescent Centre, Suite 600
Franklin, TN. 37067-6226

William T. Ramsey
A. Scott Ross
Neal & Harwell, PLC
One Nashville Place, Suite 2000
150 Fourth Avenue North
Nashville, Tennessee 37219

3. Atmos is incorporated under the laws of the States of Texas and Virginia and is engaged in the business of transporting, distributing and selling natural gas in twelve states. Atmos' Kentucky/Mid-States Division provides natural gas distribution service in Tennessee, Kentucky, Missouri, Virginia, Georgia, Illinois and Iowa. Atmos is a public utility pursuant to the laws of the State of Tennessee, and its public utility operations are subject to the jurisdiction of this Authority.

4. Demographic changes and rapid urbanization impose increasing demands for capacity and fuel efficiencies to meet growing natural gas supply requirements. As a result, there is a need for gas distribution companies to operate their gas distribution network to its optimum capabilities.

5. A comprehensive Increase in Design Factor ("IDF") program was established in order to help natural gas distribution utilities meet new demands in the safest and most reliable way possible by studying the use of PE materials in piping systems. The 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[1] (waivers) to obtain actual in-service operating experience and establish the technical basis for

[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.

continued efforts related to future rule-making initiatives by the Department of Transportation.

In order to ensure an objective peer review of the technical data, 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. This joint industry steering committee has effectively guided the technical approach and established the technical recommendations to ensure that the overall safety and integrity of the gas distribution network is not adversely compromised by the use of PE materials. The Joint Industry IDF Steering Committee's report, *Technical Substantiation Summary for an Increase in the Design Factor for PE Gas Distribution Piping Systems,* was released on July 16, 2007 and a copy is attached hereto as Exhibit A.

6. Over the past few decades, there have been significant and notable improvements in the performance characteristics of PE materials. American Society for Testing and 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 research and development efforts have led to the development of effective process improvements and technologies that help to ensure the safe construction and operations of modern PE piping systems.

7. 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. Based on the positive in-service field experience under previous waiver(s) in various parts of the country, Title 49 CFR Part 192 requirements have been recently amended and now permit the use of modern PE materials at design pressures up to 125 psig for gas distribution applications. Additional small-scale changes to the regulations are still necessary, however. 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.

8. The above-referenced federal safety standards have been adopted by the Tennessee Regulatory Authority. See Tenn. Code Ann. § 65-28-104, et seq. Under the provisions of applicable law, including 49 U.S.C. § 60118, and 49 C.F.R. §§ 192.121 and

192.123(a), the Authority may waive compliance with any part of an applicable standard on terms it considers appropriate if the waiver is not inconsistent with pipeline safety. See In re: Application of Nashville Gas Company, Inc. for a Waiver of Sections 192.121 and 192.123(a) of Part 192 of U.S.C. Title 49, Docket No. 01-01133 (June 17, 2002).

9. Atmos respectfully requests that the Authority grant a waiver from Title 49 Code of Federal Regulations Part 192, Sections 192.121 (Design of Plastic Pipe), and 192.123 (Limitations for Plastic Pipe) to allow the use of PE piping systems within its gas distribution systems as agreed to by the Authority in order to provide gas service in a safe and more reliable manner. Atmos requests that the Authority grant a waiver to allow the use of a 0.40 design factor used in determining the maximum design pressure subject to the revised limitation(s) within §192.123 up to a maximum design pressure no greater than 125 psig as currently permitted under Part 192. Attached Exhibit A sets forth the specific changes and the technical justification for why Sections 192.121 and 192.123 should be waived by the Authority and approved by the DOT – PHMSA.

10. Atmos proposes to utilize a 0.40 design factor for PE piping systems installed after effective date of this waiver to occur within its service territory, subject to the approval by the Authority. Atmos proposes to install no more than 5 miles of such pipe on a trial basis in various class locations. Atmos further requests that the Authority permit the continued satisfactory operations of these systems at the installed pressures until such time, if any, that PHMSA adopts an increased design factor. Upon the effective date of PHMSA regulation to increase design factor, this waiver will be superceded by the provisions within the final rule.

11. Atmos would utilize PE2708, PE3710, and PE4710, which have higher performance characteristics and meet the requirements of ASTM D3350-05 and are listed in the Plastic Pipe Institute's ("PPI") Technical Report PPI TR-4/2007. The design factor contained within the formula under Section 192.121 is used to account for nominal variations in material and manufacturing quality, as well as to compensate for other stresses in the pipe, which are unrelated to internal pressure, such as earth loading, subsidence, compression fittings, and temperature changes. Results of comprehensive testing and evaluation in the context of the joint industry IDF program, at test pressures two times greater than the maximum operating pressures determined using a 0.40 design

factor, have amply demonstrated that the pipe, fittings, and joints will perform safely over their intended design life.

12. Atmos would incorporate additional limitations within Section 192.123 for plastic piping systems in order to effectively bound the design criteria and ensure safe long-term performance in conjunction with the use of a 0.40 design factor. At present, 192.123 permits that use of any pipe size and wall thickness at the operating pressures determined using the design formula contained within 192.121 provided that the minimum wall thickness is greater than 0.063". In order to provide additional assurances of safe operations, the Atmos proposes to increase the minimum wall thickness requirements under §192.123 (c) to 0.090". Furthermore, the Atmos proposes to amend §192.123 (c) by incorporating a table with minimum wall thickness values for distribution piping sizes up to 125 psig operating pressures as determined by the use of the design formula contained within §192.121 using a 0.40 design factor.

Nominal Pipe Size	Minimum Wall Thickness	Corresponding SDR Values
2-inch	0.216 in.	11
3-inch	0.259 in.	13.5
4-inch	0.264 in.	17
6-inch	0.390 in.	17
8-inch	0.410 in.	21
10-inch	0.511 in.	21
12-inch	0. 608 in.	21

For the case of 2-inch IPS SDR13.5 pipe size, the Atmos proposes to limit the use of only qualified mechanical fittings for extending lateral connections. Moreover, for 2-inch SDR 13.5 pipe sizes, the installation of saddle heat fusion and electrofusion fittings may only be permitted on non-pressurized ("dead") pipe sections. Finally, the Atmos proposes to limit the maximum operating pressure for pipe sizes 8-inch through 12-inch SDR 21 to less than or equal to 30 psig.

13. Atmos would to design, construct, maintain, and operate the PE systems in accordance with Atmos Energy's approved construction standards. The following records

will be maintained to monitor the performance of the installed gas pipelines systems subject to Part 192.613 and 192.617 requirements including: type of material, location, length, pressure, pipe size, wall thickness, and class location.

14. The technical basis for both these waivers has been studied for several years and comprehensive series of tests have been conducted to verify that these waivers are justified. International experience using a 0.40 design factor has been positive. Specifically, since 1996, Canadian regulations (CSA Z-662) have permitted the use of a 0.40 design factor without any maximum pressure limitation. Moreover, the use of the International Organization for Standardization ("ISO") design methodology would result in similar operating pressures for the installed PE piping system under consideration as proposed using a 0.40 design factor. Exhibit A shows the adequacy of these proposed changes in ensuring both safety and integrity of the overall gas distribution network. The proposed changes set forth herein will assure that the regulations are kept current with advancement in pipe performance characteristics, test methodologies, and process control improvements without sacrificing overall safety and integrity of the gas distribution network.

15. Pursuant to Tenn. Code Ann. § 65-4-117, the TRA has the authority to grant the waiver that Atmos requests. Further, it is the understanding of Atmos from communications with TRA staff that safety officials are not opposed to such a waiver.

WHEREFORE, Atmos Prays:

1. That the Authority find that proposals contained in this Petition will promote the safe optimization of Atmos' gas distribution systems;

2. That the Authority approve Atmos' Petition for waiver pursuant to its requests contained herein; and

3. That Atmos be granted such other and/or further relief as may be warranted.

Respectfully submitted,

NEAL & HARWELL, PLC

By:______________________________

William T. Ramsey, #9245
A. Scott Ross, #15634
2000 One Nashville Place
150 Fourth Avenue, North
Nashville, TN 37219-2498
(615) 244-1713 – Telephone
(615) 726-0573 – Facsimile

Counsel for Atmos Energy Corporation

EXHIBIT A

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

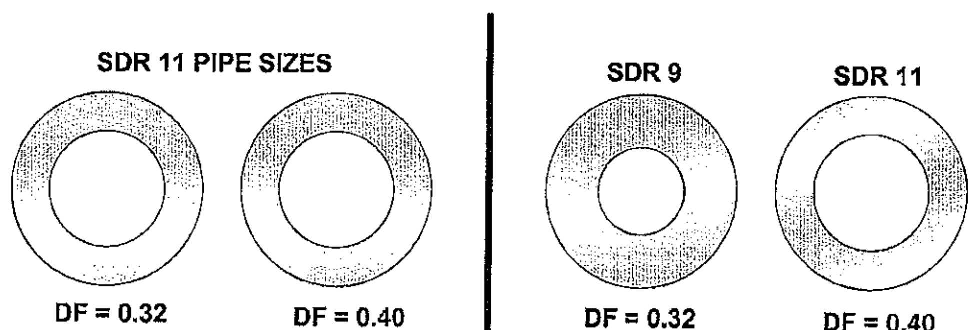
Prepared By:
Hitesh Patadia
Joint Industry IDF Steering Committee

July 16, 2007

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 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 124 psig for gas distribution applications. While this is a positive step forward, 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.

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, DF = 0.32:

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

SDR 11, DF = 0.40:

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

SDR 9, DF = 0.32:

$$p = \frac{2*1600}{9-1}*0.32$$
$$p = \frac{3200}{8}*0.32$$
$$p = 128 psig$$

SDR 11, DF = 0.40:

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

- 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 key representatives at DOT 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 as shown below.

> 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[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.

At the onset, in order to ensure an objective peer review of the technical data, 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. This joint industry steering committee has effectively guided the technical approach and established the technical recommendations contained within the proposed special permit 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 exemptions contained within the respective special permit are 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.

[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. 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 the safe construction and operations of modern PE piping systems.
3. The recommendations that are contained within the respective special permit are significantly more conservative than the current code requirements. Specifically, the special permit seeks to increase the minimum wall thickness requirements from 0.0625" to 0.090".
4. 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.
5. The proposed exemptions will enable gas utilities to increasingly utilize safe and proven PE materials to extend their gas distribution infrastructure.
6. The proposed exemptions will enable gas utility companies to implement more flexible and effective design methodologies to satisfy the need for increased 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.
7. The proposed increase in the design factor is consistent with positive international experience using higher design factors. In Canada, CSA Z-662 has permitted the use of a 0.40 design factor for PE systems without any maximum pressure limitation since 1996. Moreover, the International Organization for Standardization (ISO) permits the use of an equivalent minimum design factor up to 0.50 based on the respective design considerations .
8. Finally, and most importantly, the cumulative results of the comprehensive testing and evaluation and the inherent conservatism of the proposed exemptions contained within this special permit ensure and advance shared safety and system integrity goals between the gas utility companies and the regulatory agencies.

The following sections outline the proposed changes contained within this special permit and provide the technical rationale and engineering justification for each of the proposed exemptions that are being requested. From a cumulative sense, the supporting documentation amply demonstrates that the overall safety and system integrity will not be compromised and that there is a significant benefit to the general public associated with increasing the design factor as proposed.

1.0 PROPOSED EXEMPTIONS TO CFR PART 192 REQUIREMENTS

Two sections in the Federal Pipeline Safety Regulations, Title 49 Code of Federal Regulations Part 192, prescribe the procedure for determining the design pressure of thermoplastic pipe and its design limitations. Section 192.121, *Design of Plastic Pipe,* sets forth the formula for determining the design pressure. Section 192.123, *Design Limitations for Plastic Pipe,* limits the maximum design pressure of plastic pipe to 124 psig.

Existing Rules:
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 for plastic pipe
The design pressure for plastic pipe is determined in accordance with the following formula, subject to the limitation of §192.123:

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

[where]

P = Design pressure, gage, kPa (psi)
S = For thermoplastic pipe the long-term hydrostatic strength 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.)
F = Design Factor (0.32)

§192.123 - Design limitations for plastic pipe
(a) Except as provided for in paragraph (e) 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.
(a) Plastic pipe may not be used where operating temperatures of the pipe will be:
(1) Below –20F (-20C), or –40F (-40C) if all pipe and pipeline components whose operating temperature will be below –29C (-20F) 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, 150F (66C)

(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

Proposed Revisions:

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 for plastic pipe

The design pressure for plastic pipe is determined in accordance with the following formula, subject to the limitation of §192.123:

$$P = 2S\frac{t}{(D-t)} \times \underline{F}$$

[where]

P =	Design pressure, gage, kPa (psi)
S =	For thermoplastic pipe the long-term hydrostatic strength 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.)
F =	Design Factor (0.40)

§192.123 - Design limitations for plastic pipe

(a) Except as provided for in paragraph (e) 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 –20F (-20C), or –40F (-40C) if all pipe and pipeline components whose operating temperature will be below –29C (-20F) 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, 150F (66C)

(b) The wall thickness for thermoplastic pipe may not be less than ~~0.062~~ 0.090".

(c) (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 2006 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~~ PE2708, PE3710, or PE4710 which meets all of the requirements as specified within Plastics Pipe Institute (PPI) TR-3 (ibf, see 192.7)

(3) The pipe size is nominal pipe size (IPS) 12 or less; and the wall thickness may not be less than that listed in the following table

Nominal Pipe Size in inches	Minimum Wall Thickness in inches	Corresponding SDR Values
2-inch	0.216 in.	11
3-inch	0.259 in.	13.5
4-inch	0.264 in.	17
6-inch	0.390 in.	17
8-inch	0.410 in.	21
10-inch	0.511 in.	21
12-inch	0. 608 in.	21

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

This special permit seeks to revise both sections §192.121 and §192.123. Specifically, this special permit seeks to change the design factor within in section 192.121 from 0.32 to 0.40 subject to revised limitations per 192.123 which provides for an added degree of conservatism to enhance overall safety considerations as compared to existing requirements. This specific proposal attempts to build upon the recent rule changes enacted by DOT PHMSA which permits the use of PE piping systems to operate at pressures up to 125 psig.

There are three key exemptions which are being requested, as shown in Table 1 below.

Section	Proposed Change(s)	Implication(s)
§192.121	**F = 0.40**	• Permits increased operating pressures and allows for more effective and flexible design methodologies to enhance/satisfy capacity considerations
§192.121(b)(2)(b) and §192.123 (e)(3)	**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, at present there is no limitation on the minimum wall thickness values.
§192.123 (e)(2)	**Specify PE2708 and PE4710**	• Ensures that only those PE materials which conform to the IDF steering committee recommendations 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 proposed exemption noted above. In a cumulative sense, the supporting documentation clearly demonstrates that the proposed increase in the design factor subject to the revised limitations within 192.123 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 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 for water from 0.50 to 0.63. 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 increased to 0.40 as shown below.

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

Based on the preceding discussions, it stands to reason that there is ample technical justification for an increased design factor by following the same technical approach which was utilized during the last change in the design factor. However, there are additional technical arguments to support an increase in the design factor. There has been safe positive experience associated the use of a 0.40 throughout the international community. Specifically, since 1996, the Canadian Standards Association (CSA Z-662) have permitted the use of a 0.40 design factor for gas applications without any limitation on the maximum design pressure. The International Organization for Standardization (ISO) also permits the use of an equivalent minimum design factor up to a 0.50 design factor based on the respective design considerations for a given location. The United States remains the only remaining country which is still utilizing a "blanket" 0.32 design factor for all plastic piping systems in gas distribution applications.

Implications of Proposed 0.40 Design Factor

As previously discussed, the primary benefit associated with an increased design factor is the corresponding increase in the overall flow capacity considerations. There are two key implications associated with the aforementioned proposed changes to increase the design factor.

1. Gas utilities can operate their PE systems at higher pressures for a given wall thickness
2. Gas utilities can utilize thinner wall pipe for a given pressure

Each of these respective implications will enable gas utility companies to implement more flexible and effective design methodologies to increase the overall capacity of the gas delivery infrastructure in a safe and economic manner.

To illustrate each of these respective points, consider the following examples, the design pressure for a 2-inch SDR 11 high density polyethylene (HDPE) pipe with a long term hydrostatic strength of 1600 psi at 73F using both a design factor of 0.32 and 0.40 is calculated as follows:

a.) 2-inch, SDR 11 HDPE pipe, LTHS = 1600 psi, SDR = 11, **DF = 0.32**

$$p = \frac{2St}{(D-t)} \times 0.32 \quad \text{or} \quad p = \frac{2S}{(SDR-1)} \times 0.32$$

$$p = \frac{2*1600}{11-1} \times 0.32$$

$$p = \frac{3200}{10} \times 0.32$$

$$p = 102.4 psig$$

b.) 2-inch, SDR 11 HDPE pipe, LTHS = 1600 psi, SDR = 11, **DF = 0.40**

$$p = \frac{2*1600}{11-1} \times 0.40$$

$$p = \frac{3200}{10} \times 0.40$$

$$p = 128 psig$$

Alternatively, with the proposed change in the design factor, utilities could choose to still operate their systems at the current operating pressure but with a thinner wall pipe (increasing value of SDR), as shown below:

a.) 2-inch, SDR 11 HDPE pipe, LTHS = 1600 psi, **SDR = 9**

$$p = \frac{2*1600}{9-1} \times 0.32$$

$$p = \frac{3200}{8} \times 0.32$$

$$p = 128 psig$$

b.) 2-inch, SDR 13.5, HDPE pipe, LTHS = 1600 psi, **SDR = 11**

$$p = \frac{2*1600}{11-1} \times 0.40$$

$$p = \frac{3200}{10} \times 0.40$$

$$p = 128 psig$$

Using this same approach for various SDR values for both medium density [2](PE2406/PE2708) and high density (PE3408/3710 and 4710)[3], Table 2 presents the calculated maximum design pressures using both a 0.32 and 0.40 design factor.

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[2] The use of the term MDPE refers to PE2708 materials which satisfy the more stringent requirements established by the joint industry steering committee

	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)
32.5	25.4	31.7	32.5	40.6
26	32	40	41	51.2
23.7	35.2	44.1	45.1	56.4
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

From an engineering perspective, it is clear that the proposed increase in the design factor will permit greater flexibility in the overall design methodology of their respective delivery infrastructure. However, it is unknown at this time which alternative will be more probable; however, the net effect of either scenario is an increase in the overall capacity, as discussed in the sections to follow.

[3] The use of the term HDPE refers to PE 3710 and PE4710 materials which satisfy the more stringent requirements established by the joint industry steering committee

3.0 PERFORMNACE CHARACTERISTICS OF MODERN PE MATERIALS

In addition to the proposed increase in the design factor contained within Section 192.121, the special permits seeks 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 (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. Design procedures and considerations to ensure ample resistance to the potential of failures from Rapid Crack Propagation

In the context of the proposed exemptions within this special permit, it is important to emphasize the critical nature of these additional performance based requirements. Not only are these requirements significantly more conservative than the current code requirements, they also have an impact on the ability to effectively delineate the improved performance characteristics of 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 was recently amended and a special section has been added for those PE materials which satisfy these raised bar requirements. As a result, this special permit seeks to revise 192.123(e)(2) to effectively reflect that only these respective materials will be used in conjunction with the increased design factor.

4.0 MINIMUM WALL THICKNESS REQUIREMENTS

In addition to seeking an increased design factor and the use of the new material designation codes, the most important provision contained within the proposed special permit relates to the "self-imposed" limitations on the permissible minimum wall thickness values as a function of pipe diameter used in conjunction with an increased design factor.

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 raised bar performance 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 as a function of pipe geometry.

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 safe long term performance over the theoretical intended design life of 50-years operating at stress levels corresponding to a 0.40 design factor taking into account various failure modes to which the plastic piping system (pipe, fittings, and joints) may be subjected.

As previously discussed, it was readily apparent from the onset that the increase in design factor will be applied to new PE piping systems using either a medium density polyethylene pipe (MDPE) or high density polyethylene pipe (HDPE) for both main and service piping. Based on company specific design and installation practices, some gas utility companies operate their service tubing at the same pressure as the mains. These companies then regulate the pressure at the house meter set. Therefore, the consensus based opinion of the joint industry IDF steering committee was to use a conservative approach and evaluate the lower bound limits for possible main and service pipe sizes. Subsequently, the selection of appropriate pipe sizes was critical for evaluation purposes taking into account both pressure limitation and wall thickness considerations.

Based on the results of the pressure calculations, it was readily apparent that the lower boundary limits could not be effectively determined by taking into account the pressure limitations exclusively. For example, based on the results of the pressure calculations, gas utility companies could potentially use 2-inch SDR21 high density PE materials for main sizes. While this potential reality is permitted under the current code requirements, the use of 2" SDR 21 pipe sizes, for example, poses several technical and economic challenges that are not mutually exclusive. Specifically, it is very difficult to manufacture 2-inch SDR21 pipe sizes in coils. Gas utility companies routinely utilize coiled pipe technologies for 2-inch and 4-inch applications. As a result, the inability to utilize coiled pipe potentially increases the installation costs and eliminates any potential savings from reduced material costs.

Subsequently, the steering committee investigated all probable pipe sizes and wall thickness considerations taking into account both manufacturability considerations and installation requirements. Table 3 presents a summary of the pipe sizes and wall thickness for PE materials per ASTM D2513 [3].

	Pipe Size						
SDR	2	3	4	6	8	10	12
21	----			0.316	0.410	0.511	0.608
17	----		0.264	0.390	0.508	0.633	0.750
13.5	0.176	0.259	0.333	0.491	0.639	0.797	0.945
11.5	----	0.305	0.392	0.576	0.750	0.935	1.109
11	0.216	0.318	0.409	0.603	0.785	0.978	1.160
9.33	0.256	0.377	0.484	0.713	0.928	1.156	1.371

Table 3: Wall thickness values for various pipe sizes per ASTM D2513 requirements

Based on the wall thickness values presented in Table 2 and taking into account installation practices, manufacturing considerations, and pressure limitations, the steering committee unanimously agreed to evaluate 2-inch SDR 13.5 and 4-inch SDR 17 pipe sizes as they effectively represent the lower boundary limit for potential use with an increased design factor.

The 2-inch SDR13.5 value was chosen for two main reasons. First, this particular size is the smallest that can be coiled thereby allowing gas utility companies to take advantage of the resulting installation savings. Second, this size can also be readily used for 60 psig applications with ample safeguards against over pressurization issues. While 2-inch SDR17 could also be utilized for 60 psig applications, it would pose many other installation challenges as previously discussed. Moreover, it is important to note, for pipe sizes less than 2-inch (service tubing), the corresponding wall thickness values are greater than SDR11. As a result, the 2-inch SDR13.5 effectively represents the lower boundary limit based on both pressure and wall thickness considerations.

For pipe sizes greater than 2-inch, the steering committee chose to evaluate 4-inch SDR 17 taking into account similar considerations. First, while some gas utility companies could potentially utilize 4-inch SDR21 high density PE for 60 psig applications, this would again impose additional installation and manufacturability challenges – coiling and re-rounding. However, 4-inch SDR17 medium density PE would potentially be an effective alternative, especially for 60 psig applications. Second, the jump from 2-inch to 4-inch pipe sizes was due to the fact that there is very limited use of 3-inch pipe size in the industry. More importantly, based on the results of pressure and wall thickness considerations, it was noted that realistically, only 3-inch SDR13.5 pipe size would be feasible. However, from Table 2, it is evident that wall thickness for 3-inch SDR13.5 (0.259 in.) closely correlates (within manufacturing tolerances) to the 4-inch SDR17 pipe (0.264 in.).

Therefore, taking into account manufacturing considerations (ability to coil), installation considerations (re-rounding, planting/plowing techniques, etc), and pressure limitations, the steering committee determined that the 2-inch SDR 13.5 and 4-inch SDR17 effectively represents the lower bound limits for use in conjunction with an increased design factor. That is, assuming the results of the testing are positive, then for 2-inch SDR13.5 (wall thickness of 0.176 in.) would be the lower bound limit and all wall thickness greater than (alternatively, all SDR values lower than) this limit would also work safely. For pipe sizes 4-inch and greater, the minimum wall thickness corresponding to 4-inch SDR17 (wall thickness of 0.264 in.) would be the lower bound limit and all wall thickness values greater than this minimum wall thickness for larger diameter pipe would also be suitable for use at the increased design factor. As an example, 6-inch SDR 21, which has a wall thickness of 0.316 in. (SDR21), will also be suitable.

Based on the results of previous GRI sponsored research, it has been demonstrated that the majority of field failures occur at points of localized stress intensifications on either the pipe or fittings. As a result, the IDF steering committee agreed to perform comprehensive testing using 2-inch SDR13.5 and 4-inch SDR17 pipe sizes to validate the safe long term performance of modern PE piping systems to withstand the combined influence of increased internal pressures and other add-on stresses including points of squeeze-off, rock impingement, surface scratches, earth loading, bending stresses, etc. Moreover, additional comprehensive tests were performed to validate the impact of an increased design factor critical operating practices including various methods of joining.

To ensure an added degree of conservatism, the IDF steering committee proposed to evaluate the combined effects of add-on stresses including squeeze-off, rock impingement, bending strain, and earthloading in conjunction with the increased pressures on pipe specimens (2" SDR13.5 and 4" SDR17). The steering committee agreed to perform comprehensive long term sustained pressure testing at elevated temperatures (80°C) at test pressures <u>corresponding to the use of a 0.80 design factor</u>. Moreover, the committee agreed to extend the testing duration for test times corresponding to projected in-service failure times greater than 50 years. In doing so, this testing criterion effectively bounded the worst case principles, as shown in Table 4 below.

Material and Size	Corresponding Service Conditions at 23°C (73°F) based on Proposed Test Conditions at 90°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

From Table 4, it is clear the added degree of conservatism inherent within the testing protocols. That is, for all of the testing on both the pipe specimens and secondary stress states, the effective corresponding test pressure was two times greater than the resulting maximum design pressure using a 0.40 design factor. The results of the comprehensive long term sustained pressure testing at elevated temperatures were consistent with expectations. The results demonstrated that the PE materials which satisfy the raised bar performance based requirements have ample degree of resistance to known failure mechanisms over their intended design life.

While the overall results for the pipe material were positive, it was also recognized that the additional tests were necessary to evaluate the various means of joining the pipe segments to develop an overall PE piping system. To that end, the steering committee agreed to evaluate conventional butt heat fusion, saddle heat fusion, electrofusion, and mechanical joining.

In general, to promote the safe joining of plastic piping materials, Title 49CFR Part 192 prescribes certain requirements for developing and qualifying approved joining procedures that must be in place at each utility for use with their plastic piping materials. Specifically,

- Each joint must be made in accordance with written procedures that have been proven by test or experience to produce strong leak tight joints – CFR Part 192, §192.273
- Written procedures for various types of joints must be qualified by subjecting them to various required tests – CFR Part 192, §192.283
- All persons making joints must be qualified under the operators written procedures - CFR Part 192, §192.285

- Gas system operators must ensure that all persons who make or inspect joints are qualified - CFR Part 192, §192.285 and §192.287

Subsequently, in the context of the IDF program, comprehensive tests were performed to validate the safe long term performance of various types of joints consistent with CFR Part 192 requirements. Like the case of various types of secondary stress states, the testing criterion used to evaluate the various types of joints were again more conservative as compared to existing standards.

Numerous specimens for various types of joints (butt heat fusion, saddle heat fusion, electrofusion, and mechanical) were subjected to long term sustained pressure testing at elevated temperatures using the conditions outlined in Table 4. For all cases, the results were consistent with expectations. All of the joints were prepared using existing joining procedures and existing product designs. There were no failures for any of the joint specimens that were observed which confirms the ability to make strong joints which can perform at the increased stress levels over their intended design life.

Subsequently, the joint industry steering committee proposed additional limitations on the minimum permissible wall thickness values (SDR values) over the range of distribution piping sizes while still being able utilize existing saddle and electrofusion practices under "live" conditions.

Therefore, in the context of this special permit, additional conservative limitations were adopted.

1. The minimum wall thickness values for ½" through 1-1/2" is being increased from 0.0625" to 0.090".
2. For pipe sizes 2" through 12", additional limitations are placed with respect to minimum wall thickness values (SDR values) which can be utilized. For 2" pipe sizes and SDR values below SDR11, existing operating practices and joining procedures can be readily utilized which the gas utilities have a long history of use. In addition, it is important to emphasize that the PPI TR-41 was developed using test conditions in anticipation of a 0.40 design factor.

5.0 IMPACT ON OPERATIONS

While the preceding technical discussion clearly establish the ability to safely operate PE piping system using an increased design factor subject to the revised limitations under Part 192.123, it is important to illustrate the relevant impact to operations taking into account high level key risks and threats for PE piping systems.

From a high level perspective, 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).

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 124 psig led the DOT to enact a rule change removing the 100 psig limitation for materials produced after 2005.

The aforementioned recommendations contained within the respective special permit were based on comprehensive data which was developed as part of the overall Increase in Design Factor Program. From the onset, the joint industry steering committee established the necessary testing protocols and recommendations to ensure that all relevant safety implications associated with an increased design factor were taken into account and ample supporting technical data would be developed.

In order to better understand the impact to operations associated with an increased design factor, it was important to correlate the data development with respect to 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.

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, in order 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 be developed to 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 with increased performance characteristics have ample safeguards against know failure mechanisms. 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 joint industry steering committee recommendations and the inherently conservative provisions contained within this special permit, it can be reasonably inferred that the proposed increase in the design 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 124 psig systems	▪ Maintain current maximum pressure of 124 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 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 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
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

There are significant tangible benefits associated with permitting the use of an increased design factor including increased capacity considerations and potential cost savings. Together, these advantages will enable gas companies to increasingly utilize safe and proven PE materials in order to safely and cost effectively extend their respective companies gas delivery infrastructure.

The most significant benefit associated with an increased design factor is the increase in flow capacity considerations. From a fundamental 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"(Ref.1). The document referenced 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:

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

A.G.A. Steady flow in gas pipelines (IGT), pp 16, Figure A-3 (Ref.1)

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:

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

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 small scale analysis was performed for a 4-inch IPS pipe size 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. The results of the analysis 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

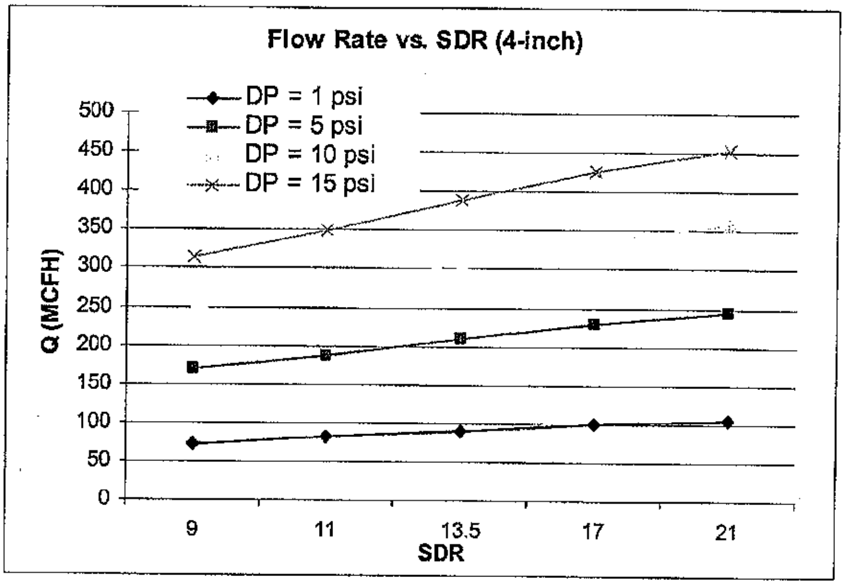

Figure 2: Graphical representation of calculated flow as a function of SDR – 4" pipe

Based on the preceding analysis and data, it confirms the basic fundamental principles of physics - that for all things being the same, then the flow rate will increase 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 2. With an increase in the SDR value (increase in the internal diameter) to 11 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.

In order to take maximum advantage of increased capacity considerations, higher pressure differentials will be required as predicated by system design considerations and need. This may or may not cause an increase in operation costs depending on the source of the inlet pressure. If regulators control the inlet pressure, then there may not be any corresponding increase to operating costs. If compressors are utilized as the source of the inlet pressure, then there may be a potential cost increase depending on the frequency of operation.

The most significant potential implication associated with the increased capacity is the corresponding increase in the use of PE materials for replacement and rehabilitation purposes. 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

8.0 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, the Gas Technology Institute (GTI) performed extensive research 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 clearly validate that the proposed exemptions contained within the respective special permit are justified:

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 known failure modes 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 which are contained within the respective special permit are significantly more conservative than the current code requirements. Specifically, the special permit seeks to increase the minimum wall thickness requirements from 0.062" to 0.090".
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 proposed increase in the design factor is consistent with positive international experience using higher design factors. In Canada, CSA Z-662 has permitted the use of a 0.40 design factor without any maximum pressure limitation since 1996. Moreover, the International Organization for Standardization (ISO) permits the use of an equivalent minimum design factor up to 0.50 based on the respective design considerations.
9. and evaluation and the inherent conservatism of the proposed exemptions contained within this special permit ensure and advance shared safety and system integrity goals between the gas utility companies and the regulatory agencies.

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 cost effectively provide natural gas service to its customers.