KyPSC Case No. 2025-00125
TABLE OF CONTENTS

VERIFICATION

STATE OF OHIO)
) **SS:**
COUNTY OF HAMILTON)

The undersigned, Bruce L. Sailers, Director Jurisdictional Rate Administration, being duly sworn, deposes and says that he has personal knowledge of the matters set forth in the foregoing data requests and that the answers contained therein are true and correct to the best of his knowledge, information and belief.

Bruce L. Sailers Affiant

Subscribed and sworn to before me by Bruce L. Sailers on this 14th day of July, 2025.

NOTARY PUBLIC

My Commission Expires: July 8, 2027

EMILIE SUNDERMAN
Notary Public
State of Ohio
My Comm. Expires
July 8, 2027

VERIFICATION

STATE OF NORTH CAROLINA)
) **SS:**
COUNTY OF MECKLENBURG)

The undersigned, Adam Long, VP, Chief Operations Officer, Natural Gas Business, being duly sworn, deposes and says that he has personal knowledge of the matters set forth in the foregoing data requests and that the answers contained therein are true and correct to the best of his knowledge, information and belief.

Adam Long Affiant

Subscribed and sworn to before me by Adam Long on this 14 day of July, 2025.

SHANNON L. WALL
Notary Public, North Carolina
Mecklenburg County
My Commission Expires
June 28, 2027

NOTARY PUBLIC

My Commission Expires: 6/28/2027

VERIFICATION

STATE OF NORTH CAROLINA)
)
COUNTY OF MECKLENBURG)

SS:

The undersigned, Lindsay B. Philemon, Manager, Customer Governance & Compliance, being duly sworn, deposes and says that she has personal knowledge of the matters set forth in the foregoing data requests and that the answers contained therein are true and correct to the best of her knowledge, information and belief.

Lindsay B. Philemon Affiant

Subscribed and sworn to before me by Lindsay B. Philemon on this 14th day of July, 2025.

CHRISTINE PURSER
NOTARY PUBLIC
Mecklenburg County, North Carolina
My Commission Expires July 20, 2025

NOTARY PUBLIC

My Commission Expires: 7-20-25

VERIFICATION

COMMONWEALTH OF MASSACHUSETTS	)	
	)	
	)	**SS:**
COUNTY OF MIDDLESEX	)	

The undersigned, Joshua C. Nowak, Vice President, being duly sworn, deposes and says that he has personal knowledge of the matters set forth in the foregoing data requests and that it is true and correct to the best of his knowledge, information and belief.

Joshua C. Nowak Affiant

Subscribed and sworn to before me by Joshua C. Nowak on this 15 day of July, 2025.

NOTARY PUBLIC

My Commission Expires:

REGINA A. KOLB
Notary Public
COMMONWEALTH OF MASSACHUSETTS
My Commission Expires On
November 27, 2026

VERIFICATION

COMMONWEALTH OF PENNSYLVANIA)
) **SS:**
COUNTY OF CUMBERLAND)

The undersigned, John J. Spanos, President, being duly sworn, deposes and says that he has personal knowledge of the matters set forth in the foregoing data requests and that the answers contained there are true and correct to the best of his knowledge, information and belief.

John J. Spanos

John J. Spanos Affiant

Subscribed and sworn to before me by John J. Spanos on this 13th day of July, 2025.

Commonwealth of Pennsylvania - Notarial Seal
MEGAN LYNN ECKRICH - Notary Public
Cumberland County
My Commission Expires September 16, 2027
Commission Number 1264513

Megan Lynn Eckrich

NOTARY PUBLIC

My Commission Expires: September 16, 202

VERIFICATION

STATE OF OHIO)
) **SS:**
COUNTY OF HAMILTON)

The undersigned, Jefferson "Jay" P. Brown, Director Rates & Regulatory Planning, being duly sworn, deposes and says that he has personal knowledge of the matters set forth in the foregoing data requests and that the answers contained there are true and correct to the best of his knowledge, information and belief.

Jefferson "Jay" P. Brown Affiant

Subscribed and sworn to before me by Jefferson "Jay" P. Brown on this 16th day of July, 2025.

NOTARY PUBLIC

My Commission Expires: July 8, 2027

EMILIE SUNDERMAN
Notary Public
State of Ohio
My Comm. Expires
July 8, 2027

VERIFICATION

STATE OF MASSACHUSETTS)
)
COUNTY OF MIDDLESEX)

SS:

The undersigned, Daniel S. Dane, President, being duly sworn, deposes and says that he has personal knowledge of the matters set forth in the foregoing data requests and that the answers contained are true and correct to the best of his knowledge, information and belief.

Daniel S. Dane Affiant

Subscribed and sworn to before me by Daniel S. Dane on this 15th day of July, 2025.

NOTARY PUBLIC

My Commission Expires:

REGINA A. KOLB
Notary Public
COMMONWEALTH OF MASSACHUSETTS
My Commission Expires On
November 27, 2026

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-001

REQUEST:

Refer to the Application, Schedule L, page 6 of 6. Explain why installation staff is not available after normal business hours for Meter Pulse Service customers.

RESPONSE:

Meter Pulse Service (MPS) is an information service and does not require emergency response such as a natural gas leak. This service has consistent but low incremental enrollment of approximately one installation each year. The MPS installation is scheduled with a Duke Energy Kentucky employee during normal business hours.

PERSON RESPONSIBLE: Bruce L. Sailers

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-002

REQUEST:

Refer to the Application, Schedule L-1, page 81 of 90. Explain what would necessitate Duke Kentucky elevating the curtailment of gas from Stage 1 to Stage 2 and from Stage 2 to Stage 3.

RESPONSE:

During a natural gas system emergency, the Company's Gas Control team closely monitors the system's pressure. The need for additional curtailment is based on a loss of pressure in the system that results in the expectation that firm customers will lose service if additional curtailment is not implemented. The different stages represent the Company's plan to minimize the impact of curtailments on customers.

PERSON RESPONSIBLE: Bruce L. Sailers

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-003

REQUEST:

Refer to the Application, Schedule L-1, page 82 of 90. Explain how Duke Kentucky will determine the authorized daily volumetric limitation for Non-Priority Use Customers during a curtailment event.

RESPONSE:

Large volume customers are assigned an account representative. The daily volumetric limitation is based on an agreement between customers and the Company on the volume of natural gas required to maintain the customer's facility at a minimum level. The volumetric limitation is a basic needs level that eliminates the need for the customer to re-light their facility.

PERSON RESPONSIBLE: Bruce L. Sailers

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-004

REQUEST:

Refer to the Application, Schedule L-1, pages 89–90 of 90. Explain why this bill format example only has two pages.

RESPONSE:

The bill format example represents the condensed bill format.

PERSON RESPONSIBLE: Bruce L. Sailers

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-005

REQUEST:

Refer to the Direct Testimony of Bruce L. Sailers (Sailers Direct Testimony), page 13, lines 16–18, regarding the seasonal soft close option. Also refer to Schedule L, page 5 of 6.

a. For calendar year 2023, 2024, and 2025 to date, provide the number of customers that used the seasonal soft close option.

b. For calendar year 2023, 2024, and 2025 to date, provide the monthly usage for each customer that used the seasonal soft close option from when the account went into soft close status to when the soft close status ended.

c. Explain any concerns or confusion customers have expressed regarding the seasonal soft close option.

d. Explain how eliminating the seasonal soft close option will improve the customer experience.

RESPONSE:

a. The following table contains the number of customers that used seasonal soft close (SSC) by calendar year.

Year	Customers
2023	208
2024	218
2025	191

b. The Company provides the amount of CCF consumed by each customer between the time they started and ended seasonal soft close. Please see STAFF-DR-02-005 Attachment.

c. In order to be eligible for the SSC program, customers must be combination electric and natural gas customers that utilize natural gas service solely for space heating purposes; not hot water heating or other uses. When a customer continues natural gas usage despite being enrolled in SSC, usually due to the presence of natural gas appliances (i.e., water heaters, stove tops, ovens), they are removed from the SSC program due to ineligibility. Once removed from the program, natural gas billing is resumed. This reinstatement of billing in the summer months is often a point of customer confusion.

In addition, if a natural gas only customer is placed on SSC mistakenly, their account may be closed causing additional issues when the Company attempts to reopen the account in the fall.

d. The Company proposes to terminate the SSC program and therefore improve the customer experience by eliminating confusion regarding the program's administration. Refer to the response to part (c), which details confusion expressed by customers regarding the program.

PERSON RESPONSIBLE: Bruce L. Sailers

Reference Number	Usage/CCF
1	4
2	41
3	0
4	10
5	4
6	1
7	0
8	0
9	6
10	0
11	0
12	48
13	0
14	30
15	3
16	1
17	7
18	1
19	4
20	0
21	17
22	0
23	0
24	0
25	0
26	0
27	32
28	3
29	0
30	1
31	0
32	0
33	0
34	0
35	0
36	7
37	0
38	0
39	4
40	9
41	4
42	0
43	0

Reference Number	Usage/CCF
44	0
45	10
46	0
47	2
48	0
49	0
50	6
51	0
52	0
53	0
54	0
55	8
56	10
57	0
58	0
59	9
60	4
61	0
62	4
63	1
64	0
65	0
66	0
67	1
68	3
69	0
70	13
71	0
72	0
73	0
74	0
75	0
76	0
77	15
78	0
79	0
80	0
81	27
82	0
83	0
84	0
85	0
86	1

Reference Number	Usage/CCF
87	44
88	0
89	20
90	0
91	0
92	9
93	8
94	0
95	0
96	2
97	1
98	0
99	1
100	2
101	0
102	5
103	0
104	1
105	0
106	0
107	0
108	40
109	0
110	0
111	0
112	0
113	0
114	0
115	2
116	2
117	41
118	1
119	5
120	109
121	1
122	0
123	0
124	44
125	0
126	3
127	0
128	8
129	0

Reference Number	Usage/CCF
130	1
131	86
132	1
133	0
134	22
135	0
136	4
137	0
138	0
139	0
140	15
141	44
142	0
143	0
144	1
145	8
146	10
147	0
148	0
150	2
151	3
152	30
153	0
154	0
155	0
156	0
157	0
158	2
159	40
160	7
161	5
162	9
163	15
164	2
165	0
166	44
167	40
168	0
169	0
170	5
171	30
172	0
173	9

Reference Number	Usage/CCF
174	7
175	8
176	40
177	0
178	0
179	0
180	30
181	4
182	109
183	0
184	0
185	7
186	0
187	0
188	15
189	1
190	2
191	20
192	0
193	44
194	3
195	15
196	0
197	1
198	0
199	4
200	2
201	7
202	10
203	0
204	0
205	0
206	3
207	0
208	0
209	4

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-006

REQUEST:

Refer to Sailers Direct Testimony, page 15, lines 14–22 and page 16, lines 10–14.

a. Explain whether the revision to define the source of the highest incremental gas cost paid by Duke Kentucky is a departure from Duke Kentucky's current practice or just a clarification of the current practice.

b. Provide support for the $15/dekatherms (DTH) flat fee.

c. For calendar years 2023, 2024, and 2025 to date, provide the number of times suppliers have failed to comply with an Operational Flow Order (OFO) and indicate how many resulted in under-deliveries and how many resulted in over-deliveries.

(1) For any non-compliance with an OFO that resulted in under-deliveries, provide the fees paid by the supplier under the current tariff and the fees the supplier would have paid if the proposed tariff were in effect.

(2) For any non-compliance with an OFO that resulted in over-deliveries, provide the fees paid by the supplier under the current tariff and the fees the supplier would have paid if the proposed tariff were in effect.

d. Provide an estimate for 2023 through the current date of the dollar amount by which Duke Kentucky or its system supply customers have been disadvantaged by the current provisions of the tariff.

e. Explain why it is reasonable to confiscate suppliers' gas in the event of an over-delivery as opposed to paying the lowest cost of gas in its system supply as the current tariff specifies.

RESPONSE:

a. The Company clarifies that the highest price of gas will be determined from the sources referenced. It is possible, although unlikely, that the Company may not be purchasing from one of the referenced sources on a particular OFO day. Under such a scenario, this would be a departure from current practice. However, in that scenario where a supplier decides not to fulfill their requirements because they assess that the Company may have a lower price, the supplier's non-action would potentially force the Company to purchase from the market at the price the supplier would have otherwise purchased.

b. The Company supports the $15/dekatherms (DTH) charge as a deterrent against potential incentive for a supplier to profit from not complying with OFO directives. For example, see the response to (a) above. To ensure compliance on an OFO day and reduce the risk of pipeline penalties, the Company proposes this standard as used by other major natural gas utilities in Kentucky.

c. For calendar years 2023 - 2025, there were a total of 16 days that suppliers failed to comply with an OFO. Eleven of those days were for Under Deliveries and five were for Over Deliveries. For additional information, see STAFF-DR-02-006 Attachment.

(1) See STAFF-DR-02-006 Attachment.

(2) See STAFF-DR-02-006 Attachment.

d. For period of 2023 to present, the Company has paid $1,284.68 for when suppliers over delivered on OFO days and the Company bought those volumes and

absorbed the excess gas into storage. In addition, there were unrealized disadvantaged values when Duke Energy Kentucky was able to absorb the excess gas, on over deliveries, or provide the needed volumes, on under deliveries, without incurring pipeline or storage penalties.

e. It is reasonable to prevent suppliers from potentially having financial incentive to over deliver on an OFO day. If the supplier has a source of supply at a cost less than the Company's lowest cost on the OFO day, the supplier may receive an incentive from ignoring the OFO directive and over supplying. The Company, in such a situation, would be paying a supplier to over deliver which may result in financial benefit for the supplier while potentially harming the Company through pipeline penalties due to a failure to comply.

PERSON RESPONSIBLE: Bruce L. Sailers

Duke Energy Kentucky
Case No. 2025-00125
STAFF-DR-02-006 Attachment
Part 6.c Page 1 of 1

KY OFOs

Non-Compliance Dates	Under/Over Deliveries
1/13/2024	Under
1/15/2024	Under
1/16/2024	Under
1/17/2024	Under
1/20/2024	Under
1/21/2024	Under
1/22/2024	Under
10/3/2024	Over
10/4/2024	Over
10/5/2024	Over
10/6/2024	Over
10/12/2024	Over
1/13/2025	Under
1/14/2025	Under
1/20/2025	Under
1/21/2025	Under

Number of Days

	Under Deliveries	Over Deliveries	Total
January-24	7	0	7
October-24	0	5	5
January-25	4	0	4
	11	5	16

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

CONFIDENTIAL STAFF-DR-02-007
(As to Attachment only)

REQUEST:

Refer to Sailers Direct Testimony, Confidential Attachment BLS-3. Provide support for the contracted reconnection rate.

RESPONSE:

CONFIDENTIAL PROPRIETARY TRADE SECRET (As to Attachment only)

Please see STAFF-DR-02-007 Confidential Attachment, for a copy of the contract with the selected vendor.

PERSON RESPONSIBLE: Bruce L. Sailers

CONFIDENTIAL PROPRIETARY TRADE SECRET

STAFF-DR-02-007 CONFIDENTIAL ATTACHMENT

FILED UNDER SEAL

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-008

REQUEST:

Refer to Sailers Direct Testimony, page 13, lines 21-22 and Confidential Attachment BLS-3. Reconcile the explanation for the increased reconnection charge provided at the informal conference held on June 20, 2025 and testimony.

RESPONSE:

Mr. Sailers is unaware of a reconnection charge proposal stated at the June 20, 2025 informal conference that conflicts with the proposed $110 reconnection charge in his testimony and proposed tariff sheets in this proceeding. If a different value was used as an example at the informal conference, Mr. Sailers confirms that the value used at the informal conference was only an example and not a proposal.

If this question refers to how the Company arrives at a $110 proposal as shown in Confidential Attachment BLS-3, the following steps are followed:

1. First, the Company calculates an internal based charge excluding all labor related components following the Commission's order in Case No. 2021-00190.
2. Next, the Company uses the full contractor rate as directed by the Commission in Case No. 2021-00190.
3. Next, the Company calculates a percentage of natural gas reconnections that are expected to be performed by contractors and the percentage performed by employees.

4. Next, using the values described above, the Company calculates a weighted average value. The value is $112.14.
5. Finally, only for convenience, the Company rounds down to the nearest $5 increment which results in the proposed value of $110.00.

PERSON RESPONSIBLE: Bruce L. Sailers

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

CONFIDENTIAL STAFF-DR-02-009
(As to Attachment only)

REQUEST:

Provide a copy of Duke Kentucky's Transmission Integrity Management Program (TIMP).

RESPONSE:

CONFIDENTIAL PROPRIETARY TRADE SECRET (As to Attachment only)

Please see STAFF-DR-02-009 Confidential Attachment.

PERSON RESPONSIBLE: Adam Long

CONFIDENTIAL PROPRIETARY TRADE SECRET

STAFF-DR-02-009 CONFIDENTIAL ATTACHMENT

FILED UNDER SEAL

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

CONFIDENTIAL STAFF-DR-02-010
(As to Attachment only)

REQUEST:

Provide a copy of Duke Kentucky's Distribution Integrity Management Program (DIMP).

RESPONSE:

CONFIDENTIAL PROPRIETARY TRADE SECRET (As to Attachment only)

Please see STAFF-DR-02-010 Confidential Attachment.

PERSON RESPONSIBLE: Adam Long

CONFIDENTIAL PROPRIETARY TRADE SECRET

STAFF-DR-02-010 CONFIDENTIAL ATTACHMENT

FILED UNDER SEAL

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-011

REQUEST:

Provide the lost and unaccounted for natural gas as reported on the most recent PHMSA Annual 7100 filing.

RESPONSE:

The Annual Report for Calendar Year 2024 Gas Distribution System submitted for Kentucky on 3/12/2025 reported the following:

Part G, Percent of Unaccounted for Gas: 1.86%

PERSON RESPONSIBLE: Adam Long

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-012

REQUEST:

Provide the location of any master meters owned by Duke Kentucky.

RESPONSE:

The Company has one master meter located in Covington, KY.

PERSON RESPONSIBLE: Lindsay B. Philemon

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

CONFIDENTIAL STAFF-DR-02-013
(As to Marked Attachments only)

REQUEST:

Refer to the Direct Testimony of Joshua Nowak (Nowak Direct Testimony), generally.

a. Provide an electronic copy of the return on equity (ROE) workpapers in Excel spreadsheet format with all formulas, columns, and rows intact and fully accessible.

b. Provide each of the Value Line Investment Survey company profile sheets supporting the ROE analyses.

c. Confirm that Duke Kentucky did not exclude any outliers in the ROE evaluation. If Duke Kentucky did exclude outliers, identify all excluded outliers, and explain why they were excluded.

RESPONSE:

CONFIDENTIAL PROPRIETARY TRADE SECRET
(As to Marked Attachments only)

a. Please see the following index of attachments containing workpapers relied upon by Mr. Nowak in the preparation of his Direct Testimony and exhibits.

Attachment	Support For	Document
STAFF-DR-02-013 Attachment 1	Attachments JCN-2 to JCN-10	Attachments JCN-2 to JCN-10
STAFF-DR-02-013 Attachment 2	Figure 2	FOMC Federal Funds Rate
STAFF-DR-02-013 Confidential Attachment 3	Figure 3	S&P 500 and S&P 500 Utilities Indices Performance (6/1/2022 to 4/30/2025)

STAFF-DR-02-013 Attachment 4	Figure 4	Current and Projected Interest Rates
STAFF-DR-02-013 Attachment 5	Figure 5	CBOE VIX – January 1, 2010 – April 30, 2025
STAFF-DR-02-013 Attachment 6	Figure 6	Percent Change in Real GDP (From Previous Quarter)
STAFF-DR-02-013 Confidential Attachment 7	Attachment JCN-7	Bond Yield Plus Risk Premium Analysis Data and Workpaper
STAFF-DR-02-013 Confidential Attachment 8	Attachment JCN-10	Proxy Group Capital Structure Analysis Data and Workpaper

b. Please see STAFF-DR-02-013 Confidential Attachment 9.

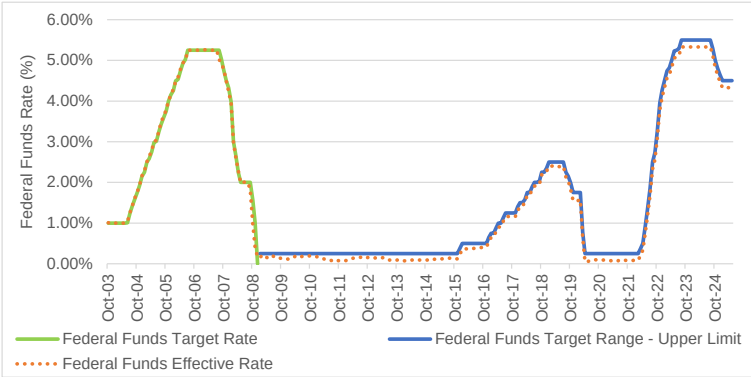
c. In one of two estimates of the of the Market Risk Premium Mr. Nowak's considered in his CAPM analysis, Mr. Nowak excluded S&P 500 companies with growth rates less than 0 percent and greater than 20 percent. However, Mr. Nowak did not exclude any proxy company values from his cost of equity analyses as outliers. Rather, Mr. Nowak applied his informed judgment of the analytical results, as well as economic and capital market conditions, in developing his recommended ROE.

PERSON RESPONSIBLE: Joshua C. Nowak

SUMMARY OF RESULTS

Company	Ticker	*Primary Analyses*															*Benchmark Analysis*		**Average of DCF, CAPM, and Risk Premium**
		CONSTANT GROWTH DCF				**CAPM**							**Risk Premium (Average)**						
						Value Line Beta			Bloomberg Beta										
		30-Day Average	90-Day Average	180-Day Average	***Average***	Current Yield	Near-Term Projected Yield	Long-Term Projected Yield	Current Yield	Near-Term Projected Yield	Long-Term Projected Yield	***Average***	Current Yield	Near-Term Projected Yield	Long-Term Projected Yield	***Average***	**Expected Earnings**		
Atmos Energy Corporation	ATO	9.20%	9.28%	9.38%	**9.29%**	12.49%	12.48%	12.46%	11.12%	11.10%	11.04%	**11.78%**	10.41%	10.37%	10.28%	**10.36%**	9.35%		**10.47%**
New Jersey Resources Corporation	NJR	10.26%	10.29%	10.35%	**10.30%**	13.36%	13.36%	13.36%	11.49%	11.47%	11.43%	**12.41%**	10.41%	10.37%	10.28%	**10.36%**	14.87%		**11.02%**
NiSource Inc.	NI	11.60%	11.56%	11.75%	**11.64%**	12.92%	12.92%	12.91%	11.48%	11.46%	11.41%	**12.18%**	10.41%	10.37%	10.28%	**10.36%**	10.25%		**11.39%**
Northwest Natural Gas Company	NWN	11.36%	11.43%	11.51%	**11.44%**	12.49%	12.48%	12.46%	10.67%	10.64%	10.58%	**11.55%**	10.41%	10.37%	10.28%	**10.36%**	8.36%		**11.11%**
ONE Gas Inc.	OGS	7.59%	7.62%	7.66%	**7.62%**	12.05%	12.04%	12.00%	11.24%	11.22%	11.17%	**11.62%**	10.41%	10.37%	10.28%	**10.36%**	7.73%		**9.87%**
Southwest Gas Holdings, Inc.	SWX	11.76%	11.78%	11.81%	**11.78%**	12.92%	12.92%	12.91%	11.86%	11.84%	11.80%	**12.38%**	10.41%	10.37%	10.28%	**10.36%**	8.65%		**11.51%**
Spire, Inc.	SR	10.61%	10.87%	11.08%	**10.85%**	12.49%	12.48%	12.46%	11.29%	11.27%	11.21%	**11.86%**	10.41%	10.37%	10.28%	**10.36%**	9.30%		**11.02%**
Low		7.59%	7.62%	7.66%	**7.62%**	12.05%	12.04%	12.00%	10.67%	10.64%	10.58%	**11.55%**					7.73%		**9.87%**
Median		10.61%	10.87%	11.08%	**10.85%**	12.49%	12.48%	12.46%	11.29%	11.27%	11.21%	**11.86%**	10.41%	10.37%	10.28%	**10.36%**	9.30%		**11.02%**
Mean		10.34%	10.41%	10.51%	**10.42%**	12.67%	12.67%	12.65%	11.31%	11.29%	11.23%	**11.97%**	10.41%	10.37%	10.28%	**10.36%**	9.79%		**10.91%**
High		11.76%	11.78%	11.81%	**11.78%**	13.36%	13.36%	13.36%	11.86%	11.84%	11.80%	**12.41%**					14.87%		**11.51%**

FRED Graph Observations



Federal Reserve Economic Data
Link: https://fred.stlouisfed.org
Help: https://fredhelp.stlouisfed.org
Economic Research Division
Federal Reserve Bank of St. Louis

FEDFUNDS Federal Fun Federal Funds Federal Funds Effective Rate, Percent, Monthly, Not Seasonally Adjusted

Frequency: Monthly

observation_date	DFEDTAR	DFEDTARU	FEDFUNDS
2003-10-01	1.00		1.01
2003-11-01	1.00		1.00
2003-12-01	1.00		0.98
2004-01-01	1.00		1.00
2004-02-01	1.00		1.01
2004-03-01	1.00		1.00
2004-04-01	1.00		1.00
2004-05-01	1.00		1.00
2004-06-01	1.01		1.03
2004-07-01	1.25		1.26
2004-08-01	1.43		1.43
2004-09-01	1.58		1.61
2004-10-01	1.75		1.76
2004-11-01	1.93		1.93
2004-12-01	2.15		2.16
2005-01-01	2.25		2.28
2005-02-01	2.49		2.50
2005-03-01	2.58		2.63
2005-04-01	2.75		2.79
2005-05-01	2.98		3.00
2005-06-01	3.01		3.04
2005-07-01	3.25		3.26
2005-08-01	3.44		3.50
2005-09-01	3.59		3.62
2005-10-01	3.75		3.78
2005-11-01	4.00		4.00
2005-12-01	4.15		4.16
2006-01-01	4.26		4.29
2006-02-01	4.50		4.49
2006-03-01	4.53		4.59
2006-04-01	4.75		4.79
2006-05-01	4.93		4.94
2006-06-01	5.02		4.99
2006-07-01	5.25		5.24
2006-08-01	5.25		5.25
2006-09-01	5.25		5.25
2006-10-01	5.25		5.25
2006-11-01	5.25		5.25
2006-12-01	5.25		5.24
2007-01-01	5.25		5.25
2007-02-01	5.25		5.26
2007-03-01	5.25		5.26
2007-04-01	5.25		5.25
2007-05-01	5.25		5.25
2007-06-01	5.25		5.25
2007-07-01	5.25		5.26
2007-08-01	5.25		5.02
2007-09-01	5.03		4.94

	Federal Funds Target Rate	**Federal Funds Target Range - Upper Limit**	**Federal Funds Effective Rate**
Oct-03	1.00%		1.01%
Nov-03	1.00%		1.00%
Dec-03	1.00%		0.98%
Jan-04	1.00%		1.00%
Feb-04	1.00%		1.01%
Mar-04	1.00%		1.00%
Apr-04	1.00%		1.00%
May-04	1.00%		1.00%
Jun-04	1.01%		1.03%
Jul-04	1.25%		1.26%
Aug-04	1.43%		1.43%
Sep-04	1.58%		1.61%
Oct-04	1.75%		1.76%
Nov-04	1.93%		1.93%
Dec-04	2.15%		2.16%
Jan-05	2.25%		2.28%
Feb-05	2.49%		2.50%
Mar-05	2.58%		2.63%
Apr-05	2.75%		2.79%
May-05	2.98%		3.00%
Jun-05	3.01%		3.04%
Jul-05	3.25%		3.26%
Aug-05	3.44%		3.50%
Sep-05	3.59%		3.62%
Oct-05	3.75%		3.78%
Nov-05	4.00%		4.00%
Dec-05	4.15%		4.16%
Jan-06	4.26%		4.29%
Feb-06	4.50%		4.49%
Mar-06	4.53%		4.59%
Apr-06	4.75%		4.79%
May-06	4.93%		4.94%
Jun-06	5.02%		4.99%
Jul-06	5.25%		5.24%
Aug-06	5.25%		5.25%
Sep-06	5.25%		5.25%
Oct-06	5.25%		5.25%
Nov-06	5.25%		5.25%
Dec-06	5.25%		5.24%
Jan-07	5.25%		5.25%
Feb-07	5.25%		5.26%
Mar-07	5.25%		5.26%
Apr-07	5.25%		5.25%
May-07	5.25%		5.25%
Jun-07	5.25%		5.25%
Jul-07	5.25%		5.26%
Aug-07	5.25%		5.02%
Sep-07	5.03%		4.94%

2007-10-01	4.74		4.76	Oct-07	4.74%		4.76%
2007-11-01	4.50		4.49	Nov-07	4.50%		4.49%
2007-12-01	4.33		4.24	Dec-07	4.33%		4.24%
2008-01-01	3.98		3.94	Jan-08	3.98%		3.94%
2008-02-01	3.00		2.98	Feb-08	3.00%		2.98%
2008-03-01	2.66		2.61	Mar-08	2.66%		2.61%
2008-04-01	2.24		2.28	Apr-08	2.24%		2.28%
2008-05-01	2.00		1.98	May-08	2.00%		1.98%
2008-06-01	2.00		2.00	Jun-08	2.00%		2.00%
2008-07-01	2.00		2.01	Jul-08	2.00%		2.01%
2008-08-01	2.00		2.00	Aug-08	2.00%		2.00%
2008-09-01	2.00		1.81	Sep-08	2.00%		1.81%
2008-10-01	1.56		0.97	Oct-08	1.56%		0.97%
2008-11-01	1.00		0.39	Nov-08	1.00%		0.39%
2008-12-01			0.16	Dec-08	0.00%		0.16%
2009-01-01		0.25	0.15	Jan-09		0.25%	0.15%
2009-02-01		0.25	0.22	Feb-09		0.25%	0.22%
2009-03-01		0.25	0.18	Mar-09		0.25%	0.18%
2009-04-01		0.25	0.15	Apr-09		0.25%	0.15%
2009-05-01		0.25	0.18	May-09		0.25%	0.18%
2009-06-01		0.25	0.21	Jun-09		0.25%	0.21%
2009-07-01		0.25	0.16	Jul-09		0.25%	0.16%
2009-08-01		0.25	0.16	Aug-09		0.25%	0.16%
2009-09-01		0.25	0.15	Sep-09		0.25%	0.15%
2009-10-01		0.25	0.12	Oct-09		0.25%	0.12%
2009-11-01		0.25	0.12	Nov-09		0.25%	0.12%
2009-12-01		0.25	0.12	Dec-09		0.25%	0.12%
2010-01-01		0.25	0.11	Jan-10		0.25%	0.11%
2010-02-01		0.25	0.13	Feb-10		0.25%	0.13%
2010-03-01		0.25	0.16	Mar-10		0.25%	0.16%
2010-04-01		0.25	0.20	Apr-10		0.25%	0.20%
2010-05-01		0.25	0.20	May-10		0.25%	0.20%
2010-06-01		0.25	0.18	Jun-10		0.25%	0.18%
2010-07-01		0.25	0.18	Jul-10		0.25%	0.18%
2010-08-01		0.25	0.19	Aug-10		0.25%	0.19%
2010-09-01		0.25	0.19	Sep-10		0.25%	0.19%
2010-10-01		0.25	0.19	Oct-10		0.25%	0.19%
2010-11-01		0.25	0.19	Nov-10		0.25%	0.19%
2010-12-01		0.25	0.18	Dec-10		0.25%	0.18%
2011-01-01		0.25	0.17	Jan-11		0.25%	0.17%
2011-02-01		0.25	0.16	Feb-11		0.25%	0.16%
2011-03-01		0.25	0.14	Mar-11		0.25%	0.14%
2011-04-01		0.25	0.10	Apr-11		0.25%	0.10%
2011-05-01		0.25	0.09	May-11		0.25%	0.09%
2011-06-01		0.25	0.09	Jun-11		0.25%	0.09%
2011-07-01		0.25	0.07	Jul-11		0.25%	0.07%
2011-08-01		0.25	0.10	Aug-11		0.25%	0.10%
2011-09-01		0.25	0.08	Sep-11		0.25%	0.08%
2011-10-01		0.25	0.07	Oct-11		0.25%	0.07%
2011-11-01		0.25	0.08	Nov-11		0.25%	0.08%
2011-12-01		0.25	0.07	Dec-11		0.25%	0.07%
2012-01-01		0.25	0.08	Jan-12		0.25%	0.08%
2012-02-01		0.25	0.10	Feb-12		0.25%	0.10%
2012-03-01		0.25	0.13	Mar-12		0.25%	0.13%
2012-04-01		0.25	0.14	Apr-12		0.25%	0.14%
2012-05-01		0.25	0.16	May-12		0.25%	0.16%
2012-06-01		0.25	0.16	Jun-12		0.25%	0.16%
2012-07-01		0.25	0.16	Jul-12		0.25%	0.16%
2012-08-01		0.25	0.13	Aug-12		0.25%	0.13%
2012-09-01		0.25	0.14	Sep-12		0.25%	0.14%
2012-10-01		0.25	0.16	Oct-12		0.25%	0.16%
2012-11-01		0.25	0.16	Nov-12		0.25%	0.16%
2012-12-01		0.25	0.16	Dec-12		0.25%	0.16%
2013-01-01		0.25	0.14	Jan-13		0.25%	0.14%
2013-02-01		0.25	0.15	Feb-13		0.25%	0.15%
2013-03-01		0.25	0.14	Mar-13		0.25%	0.14%
2013-04-01		0.25	0.15	Apr-13		0.25%	0.15%
2013-05-01		0.25	0.11	May-13		0.25%	0.11%
2013-06-01		0.25	0.09	Jun-13		0.25%	0.09%
2013-07-01		0.25	0.09	Jul-13		0.25%	0.09%
2013-08-01		0.25	0.08	Aug-13		0.25%	0.08%
2013-09-01		0.25	0.08	Sep-13		0.25%	0.08%
2013-10-01		0.25	0.09	Oct-13		0.25%	0.09%
2013-11-01		0.25	0.08	Nov-13		0.25%	0.08%
2013-12-01		0.25	0.09	Dec-13		0.25%	0.09%
2014-01-01		0.25	0.07	Jan-14		0.25%	0.07%
2014-02-01		0.25	0.07	Feb-14		0.25%	0.07%
2014-03-01		0.25	0.08	Mar-14		0.25%	0.08%
2014-04-01		0.25	0.09	Apr-14		0.25%	0.09%
2014-05-01		0.25	0.09	May-14		0.25%	0.09%
2014-06-01		0.25	0.10	Jun-14		0.25%	0.10%
2014-07-01		0.25	0.09	Jul-14		0.25%	0.09%
2014-08-01		0.25	0.09	Aug-14		0.25%	0.09%
2014-09-01		0.25	0.09	Sep-14		0.25%	0.09%
2014-10-01		0.25	0.09	Oct-14		0.25%	0.09%

2014-11-01	0.25	0.09	Nov-14	0.25%	0.09%
2014-12-01	0.25	0.12	Dec-14	0.25%	0.12%
2015-01-01	0.25	0.11	Jan-15	0.25%	0.11%
2015-02-01	0.25	0.11	Feb-15	0.25%	0.11%
2015-03-01	0.25	0.11	Mar-15	0.25%	0.11%
2015-04-01	0.25	0.12	Apr-15	0.25%	0.12%
2015-05-01	0.25	0.12	May-15	0.25%	0.12%
2015-06-01	0.25	0.13	Jun-15	0.25%	0.13%
2015-07-01	0.25	0.13	Jul-15	0.25%	0.13%
2015-08-01	0.25	0.14	Aug-15	0.25%	0.14%
2015-09-01	0.25	0.14	Sep-15	0.25%	0.14%
2015-10-01	0.25	0.12	Oct-15	0.25%	0.12%
2015-11-01	0.25	0.12	Nov-15	0.25%	0.12%
2015-12-01	0.38	0.24	Dec-15	0.38%	0.24%
2016-01-01	0.50	0.34	Jan-16	0.50%	0.34%
2016-02-01	0.50	0.38	Feb-16	0.50%	0.38%
2016-03-01	0.50	0.36	Mar-16	0.50%	0.36%
2016-04-01	0.50	0.37	Apr-16	0.50%	0.37%
2016-05-01	0.50	0.37	May-16	0.50%	0.37%
2016-06-01	0.50	0.38	Jun-16	0.50%	0.38%
2016-07-01	0.50	0.39	Jul-16	0.50%	0.39%
2016-08-01	0.50	0.40	Aug-16	0.50%	0.40%
2016-09-01	0.50	0.40	Sep-16	0.50%	0.40%
2016-10-01	0.50	0.40	Oct-16	0.50%	0.40%
2016-11-01	0.50	0.41	Nov-16	0.50%	0.41%
2016-12-01	0.65	0.54	Dec-16	0.65%	0.54%
2017-01-01	0.75	0.65	Jan-17	0.75%	0.65%
2017-02-01	0.75	0.66	Feb-17	0.75%	0.66%
2017-03-01	0.88	0.79	Mar-17	0.88%	0.79%
2017-04-01	1.00	0.90	Apr-17	1.00%	0.90%
2017-05-01	1.00	0.91	May-17	1.00%	0.91%
2017-06-01	1.13	1.04	Jun-17	1.13%	1.04%
2017-07-01	1.25	1.15	Jul-17	1.25%	1.15%
2017-08-01	1.25	1.16	Aug-17	1.25%	1.16%
2017-09-01	1.25	1.15	Sep-17	1.25%	1.15%
2017-10-01	1.25	1.15	Oct-17	1.25%	1.15%
2017-11-01	1.25	1.16	Nov-17	1.25%	1.16%
2017-12-01	1.40	1.30	Dec-17	1.40%	1.30%
2018-01-01	1.50	1.41	Jan-18	1.50%	1.41%
2018-02-01	1.50	1.42	Feb-18	1.50%	1.42%
2018-03-01	1.58	1.51	Mar-18	1.58%	1.51%
2018-04-01	1.75	1.69	Apr-18	1.75%	1.69%
2018-05-01	1.75	1.70	May-18	1.75%	1.70%
2018-06-01	1.89	1.82	Jun-18	1.89%	1.82%
2018-07-01	2.00	1.91	Jul-18	2.00%	1.91%
2018-08-01	2.00	1.91	Aug-18	2.00%	1.91%
2018-09-01	2.03	1.95	Sep-18	2.03%	1.95%
2018-10-01	2.25	2.19	Oct-18	2.25%	2.19%
2018-11-01	2.25	2.20	Nov-18	2.25%	2.20%
2018-12-01	2.35	2.27	Dec-18	2.35%	2.27%
2019-01-01	2.50	2.40	Jan-19	2.50%	2.40%
2019-02-01	2.50	2.40	Feb-19	2.50%	2.40%
2019-03-01	2.50	2.41	Mar-19	2.50%	2.41%
2019-04-01	2.50	2.42	Apr-19	2.50%	2.42%
2019-05-01	2.50	2.39	May-19	2.50%	2.39%
2019-06-01	2.50	2.38	Jun-19	2.50%	2.38%
2019-07-01	2.50	2.40	Jul-19	2.50%	2.40%
2019-08-01	2.25	2.13	Aug-19	2.25%	2.13%
2019-09-01	2.15	2.04	Sep-19	2.15%	2.04%
2019-10-01	1.99	1.83	Oct-19	1.99%	1.83%
2019-11-01	1.75	1.55	Nov-19	1.75%	1.55%
2019-12-01	1.75	1.55	Dec-19	1.75%	1.55%
2020-01-01	1.75	1.55	Jan-20	1.75%	1.55%
2020-02-01	1.75	1.58	Feb-20	1.75%	1.58%
2020-03-01	0.78	0.65	Mar-20	0.78%	0.65%
2020-04-01	0.25	0.05	Apr-20	0.25%	0.05%
2020-05-01	0.25	0.05	May-20	0.25%	0.05%
2020-06-01	0.25	0.08	Jun-20	0.25%	0.08%
2020-07-01	0.25	0.09	Jul-20	0.25%	0.09%
2020-08-01	0.25	0.10	Aug-20	0.25%	0.10%
2020-09-01	0.25	0.09	Sep-20	0.25%	0.09%
2020-10-01	0.25	0.09	Oct-20	0.25%	0.09%
2020-11-01	0.25	0.09	Nov-20	0.25%	0.09%
2020-12-01	0.25	0.09	Dec-20	0.25%	0.09%
2021-01-01	0.25	0.09	Jan-21	0.25%	0.09%
2021-02-01	0.25	0.08	Feb-21	0.25%	0.08%
2021-03-01	0.25	0.07	Mar-21	0.25%	0.07%
2021-04-01	0.25	0.07	Apr-21	0.25%	0.07%
2021-05-01	0.25	0.06	May-21	0.25%	0.06%
2021-06-01	0.25	0.08	Jun-21	0.25%	0.08%
2021-07-01	0.25	0.10	Jul-21	0.25%	0.10%
2021-08-01	0.25	0.09	Aug-21	0.25%	0.09%
2021-09-01	0.25	0.08	Sep-21	0.25%	0.08%
2021-10-01	0.25	0.08	Oct-21	0.25%	0.08%
2021-11-01	0.25	0.08	Nov-21	0.25%	0.08%

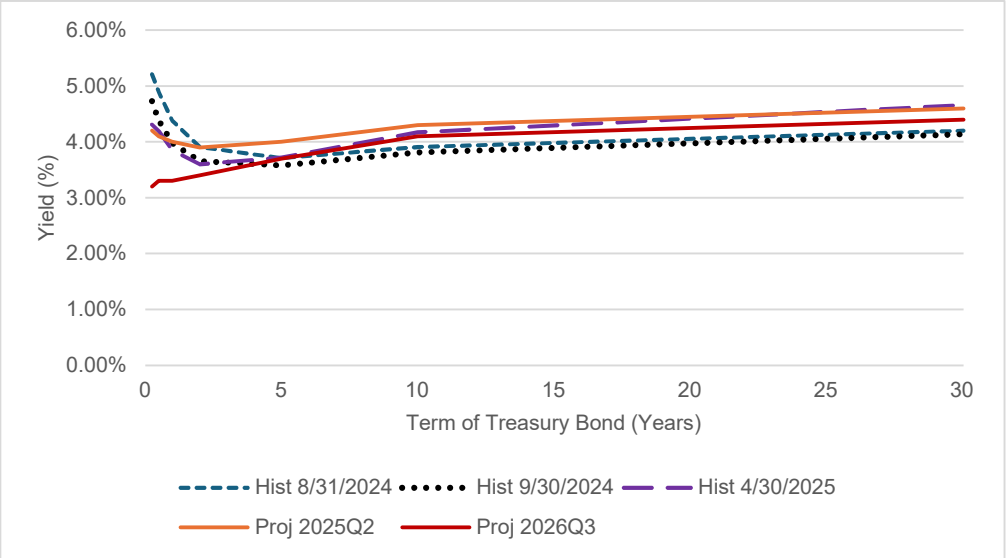
2021-12-01	0.25	0.08	Dec-21	0.25%	0.08%
2022-01-01	0.25	0.08	Jan-22	0.25%	0.08%
2022-02-01	0.25	0.08	Feb-22	0.25%	0.08%
2022-03-01	0.37	0.20	Mar-22	0.37%	0.20%
2022-04-01	0.50	0.33	Apr-22	0.50%	0.33%
2022-05-01	0.94	0.77	May-22	0.94%	0.77%
2022-06-01	1.38	1.21	Jun-22	1.38%	1.21%
2022-07-01	1.85	1.68	Jul-22	1.85%	1.68%
2022-08-01	2.50	2.33	Aug-22	2.50%	2.33%
2022-09-01	2.73	2.56	Sep-22	2.73%	2.56%
2022-10-01	3.25	3.08	Oct-22	3.25%	3.08%
2022-11-01	3.95	3.78	Nov-22	3.95%	3.78%
2022-12-01	4.27	4.10	Dec-22	4.27%	4.10%
2023-01-01	4.50	4.33	Jan-23	4.50%	4.33%
2023-02-01	4.74	4.57	Feb-23	4.74%	4.57%
2023-03-01	4.82	4.65	Mar-23	4.82%	4.65%
2023-04-01	5.00	4.83	Apr-23	5.00%	4.83%
2023-05-01	5.23	5.06	May-23	5.23%	5.06%
2023-06-01	5.25	5.08	Jun-23	5.25%	5.08%
2023-07-01	5.29	5.12	Jul-23	5.29%	5.12%
2023-08-01	5.50	5.33	Aug-23	5.50%	5.33%
2023-09-01	5.50	5.33	Sep-23	5.50%	5.33%
2023-10-01	5.50	5.33	Oct-23	5.50%	5.33%
2023-11-01	5.50	5.33	Nov-23	5.50%	5.33%
2023-12-01	5.50	5.33	Dec-23	5.50%	5.33%
2024-01-01	5.50	5.33	Jan-24	5.50%	5.33%
2024-02-01	5.50	5.33	Feb-24	5.50%	5.33%
2024-03-01	5.50	5.33	Mar-24	5.50%	5.33%
2024-04-01	5.50	5.33	Apr-24	5.50%	5.33%
2024-05-01	5.50	5.33	May-24	5.50%	5.33%
2024-06-01	5.50	5.33	Jun-24	5.50%	5.33%
2024-07-01	5.50	5.33	Jul-24	5.50%	5.33%
2024-08-01	5.50	5.33	Aug-24	5.50%	5.33%
2024-09-01	5.30	5.13	Sep-24	5.30%	5.13%
2024-10-01	5.00	4.83	Oct-24	5.00%	4.83%
2024-11-01	4.81	4.64	Nov-24	4.81%	4.64%
2024-12-01	4.65	4.48	Dec-24	4.65%	4.48%
2025-01-01	4.50	4.33	Jan-25	4.50%	4.33%
2025-02-01	4.50	4.33	Feb-25	4.50%	4.33%
2025-03-01	4.50	4.33	Mar-25	4.50%	4.33%
2025-04-01	4.50	4.33	Apr-25	4.50%	4.33%
2025-05-01	4.50	4.33	May-25	4.50%	4.33%

CONFIDENTIAL PROPRIETARY TRADE SECRET

STAFF-DR-02-013 CONFIDENTIAL ATTACHMENT 3

FILED UNDER SEAL

Tenor	Treeasury.gov Hist 8/31/2024	Treeasury.gov Hist 9/30/2024	Treeasury.gov Hist 4/30/2025	Blue Chip May 2025 Proj 2025Q2	Blue Chip May 2025 Proj 2026Q3
0.25	5.21%	4.73%	4.31%	4.20%	3.20%
0.5	4.89%	4.38%	4.19%	4.10%	3.30%
1	4.38%	3.98%	3.85%	4.00%	3.30%
2	3.91%	3.66%	3.60%	3.90%	3.40%
5	3.71%	3.58%	3.72%	4.00%	3.70%
10	3.91%	3.81%	4.17%	4.30%	4.10%
30	4.20%	4.14%	4.66%	4.60%	4.40%



https://home.treasury.gov/resource-center/data-chart-center/interest-rates/TextView?type=daily_treasury_yield_curve&field_tdr_date_value=2024

Date	1 Mo	1.5 Mo	2 Mo	3 Mo	4 Mo	6 Mo	1 Yr	2 Yr	3 Yr	5 Yr	7 Yr	10 Yr	20 Yr	30 Yr
8/1/2024	5.55	N/A	5.46	5.37	5.28	5.08	4.62	4.16	3.96	3.84	3.89	3.99	4.35	4.27
8/2/2024	5.54	N/A	5.43	5.29	5.14	4.88	4.33	3.88	3.7	3.62	3.68	3.8	4.19	4.11
8/5/2024	5.52	N/A	5.43	5.35	5.14	4.91	4.34	3.89	3.71	3.62	3.66	3.78	4.16	4.06
8/6/2024	5.5	N/A	5.43	5.34	5.18	5	4.46	3.99	3.76	3.73	3.79	3.9	4.28	4.18
8/7/2024	5.5	N/A	5.43	5.34	5.21	4.99	4.45	4	3.81	3.79	3.85	3.96	4.35	4.26
8/8/2024	5.55	N/A	5.42	5.34	5.21	5.01	4.48	4.04	3.86	3.83	3.89	3.99	4.38	4.28
8/9/2024	5.54	N/A	5.4	5.33	5.22	5.02	4.5	4.05	3.86	3.8	3.85	3.94	4.33	4.23
8/12/2024	5.53	N/A	5.4	5.33	5.2	5.02	4.47	4.01	3.82	3.75	3.8	3.9	4.3	4.19
8/13/2024	5.48	N/A	5.39	5.32	5.18	4.97	4.4	3.93	3.75	3.68	3.74	3.85	4.25	4.16
8/14/2024	5.49	N/A	5.39	5.32	5.21	5	4.42	3.94	3.76	3.67	3.72	3.83	4.22	4.12
8/15/2024	5.53	N/A	5.4	5.34	5.22	5.04	4.52	4.08	3.9	3.79	3.83	3.92	4.28	4.18
8/16/2024	5.53	N/A	5.4	5.33	5.21	5.02	4.49	4.06	3.87	3.77	3.81	3.89	4.26	4.15
8/19/2024	5.51	N/A	5.39	5.31	5.19	5	4.48	4.06	3.86	3.75	3.78	3.86	4.23	4.11
8/20/2024	5.48	N/A	5.36	5.29	5.17	4.97	4.43	3.99	3.8	3.7	3.73	3.82	4.19	4.07
8/21/2024	5.45	N/A	5.33	5.26	5.13	4.92	4.36	3.92	3.74	3.64	3.69	3.79	4.15	4.06
8/22/2024	5.51	N/A	5.35	5.28	5.15	4.96	4.43	3.99	3.82	3.72	3.77	3.86	4.21	4.13
8/23/2024	5.51	N/A	5.35	5.25	5.13	4.92	4.36	3.9	3.73	3.65	3.71	3.81	4.18	4.1
8/26/2024	5.49	N/A	5.34	5.24	5.13	4.91	4.38	3.91	3.74	3.66	3.72	3.82	4.19	4.11
8/27/2024	5.49	N/A	5.33	5.23	5.12	4.89	4.34	3.83	3.72	3.66	3.73	3.83	4.21	4.13
8/28/2024	5.47	N/A	5.33	5.21	5.12	4.87	4.36	3.83	3.72	3.63	3.74	3.84	4.22	4.13
8/29/2024	5.4	N/A	5.33	5.22	5.12	4.89	4.38	3.87	3.76	3.66	3.76	3.87	4.24	4.15
8/30/2024	5.41	N/A	5.32	5.21	5.12	4.89	4.38	3.91	3.79	3.71	3.8	3.91	4.28	4.2
9/3/2024	5.38	N/A	5.31	5.19	5.1	4.8	4.35	3.88	3.73	3.65	3.73	3.84	4.21	4.13
9/4/2024	5.33	N/A	5.28	5.18	5.05	4.74	4.23	3.76	3.63	3.56	3.65	3.77	4.14	4.06
9/5/2024	5.3	N/A	5.29	5.15	5.04	4.73	4.21	3.75	3.61	3.54	3.63	3.73	4.11	4.02
9/6/2024	5.28	N/A	5.28	5.13	5.02	4.69	4.1	3.66	3.54	3.5	3.6	3.72	4.1	4.03
9/9/2024	5.25	N/A	5.25	5.11	4.99	4.68	4.12	3.68	3.54	3.49	3.58	3.7	4.08	4
9/10/2024	5.18	N/A	5.18	5.06	4.92	4.65	4.07	3.59	3.42	3.43	3.53	3.65	4.04	3.97
9/11/2024	5.21	N/A	5.19	5.1	4.99	4.72	4.12	3.62	3.45	3.45	3.54	3.65	4.03	3.96
9/12/2024	5.18	N/A	5.22	5.06	4.97	4.68	4.09	3.64	3.47	3.47	3.57	3.68	4.07	4
9/13/2024	5.15	N/A	5.17	4.97	4.92	4.6	4	3.57	3.42	3.43	3.53	3.66	4.05	3.98
9/16/2024	5.11	N/A	5.1	4.96	4.88	4.55	3.96	3.56	3.42	3.41	3.51	3.63	4.01	3.94
9/17/2024	5.05	N/A	5.05	4.95	4.87	4.55	3.99	3.59	3.45	3.44	3.53	3.65	4.02	3.96
9/18/2024	4.91	N/A	4.91	4.84	4.76	4.5	3.95	3.61	3.49	3.47	3.58	3.7	4.08	4.03
9/19/2024	4.89	N/A	4.91	4.8	4.73	4.46	3.93	3.59	3.47	3.49	3.6	3.73	4.11	4.06
9/20/2024	4.87	N/A	4.88	4.75	4.7	4.43	3.92	3.55	3.46	3.48	3.59	3.73	4.1	4.07
9/23/2024	4.85	N/A	4.84	4.72	4.65	4.4	3.91	3.57	3.47	3.51	3.62	3.75	4.12	4.09
9/24/2024	4.78	N/A	4.78	4.69	4.63	4.36	3.88	3.49	3.44	3.47	3.6	3.74	4.13	4.09
9/25/2024	4.79	N/A	4.78	4.69	4.64	4.36	3.89	3.53	3.49	3.52	3.65	3.79	4.18	4.14
9/26/2024	4.9	N/A	4.87	4.68	4.65	4.38	3.96	3.6	3.54	3.55	3.65	3.79	4.17	4.12
9/27/2024	4.9	N/A	4.87	4.68	4.64	4.35	3.9	3.55	3.49	3.5	3.6	3.75	4.15	4.1
9/30/2024	4.93	N/A	4.87	4.73	4.65	4.38	3.98	3.66	3.58	3.58	3.67	3.81	4.19	4.14
10/1/2024	4.96	N/A	4.87	4.71	4.63	4.36	3.96	3.61	3.52	3.51	3.6	3.74	4.14	4.08
10/2/2024	4.92	N/A	4.83	4.69	4.61	4.36	3.97	3.63	3.54	3.55	3.65	3.79	4.19	4.14
10/3/2024	4.99	N/A	4.85	4.68	4.61	4.37	4.02	3.7	3.62	3.62	3.71	3.85	4.24	4.18
10/4/2024	5.01	N/A	4.88	4.73	4.68	4.45	4.2	3.93	3.84	3.81	3.88	3.98	4.33	4.26
10/7/2024	5	N/A	4.87	4.77	4.67	4.45	4.24	3.99	3.89	3.86	3.92	4.03	4.37	4.3
10/8/2024	4.96	N/A	4.85	4.75	4.65	4.44	4.21	3.98	3.86	3.86	3.94	4.04	4.38	4.32
10/9/2024	4.93	N/A	4.84	4.75	4.65	4.46	4.24	3.99	3.89	3.91	3.97	4.06	4.41	4.34
10/10/2024	4.98	N/A	4.84	4.75	4.65	4.45	4.22	3.98	3.88	3.91	3.99	4.09	4.44	4.38
10/11/2024	4.97	N/A	4.82	4.73	4.65	4.44	4.18	3.95	3.85	3.88	3.97	4.08	4.44	4.39
10/15/2024	4.93	N/A	4.82	4.73	4.65	4.42	4.18	3.95	3.86	3.86	3.93	4.03	4.37	4.32
10/16/2024	4.91	N/A	4.8	4.72	4.63	4.42	4.17	3.93	3.84	3.84	3.92	4.02	4.36	4.3
10/17/2024	4.93	N/A	4.83	4.74	4.65	4.45	4.21	3.96	3.89	3.9	3.99	4.09	4.44	4.39
10/18/2024	4.92	N/A	4.82	4.73	4.65	4.45	4.19	3.95	3.86	3.88	3.97	4.08	4.44	4.38
10/21/2024	4.92	N/A	4.82	4.73	4.66	4.47	4.24	4.02	3.95	3.98	4.07	4.19	4.54	4.49
10/22/2024	4.89	N/A	4.81	4.72	4.66	4.47	4.24	4.03	3.98	4	4.1	4.2	4.55	4.49
10/23/2024	4.88	N/A	4.8	4.73	4.66	4.48	4.27	4.07	4.03	4.05	4.14	4.24	4.58	4.51
10/24/2024	4.87	N/A	4.78	4.7	4.65	4.48	4.25	4.07	4.02	4.03	4.12	4.21	4.54	4.47
10/25/2024	4.89	N/A	4.79	4.73	4.68	4.51	4.29	4.11	4.05	4.07	4.15	4.25	4.58	4.51
10/28/2024	4.88	N/A	4.77	4.7	4.65	4.46	4.28	4.12	4.09	4.11	4.19	4.28	4.61	4.53
10/29/2024	4.88	N/A	4.77	4.7	4.64	4.45	4.29	4.11	4.08	4.11	4.18	4.28	4.61	4.52
10/30/2024	4.87	N/A	4.77	4.67	4.57	4.44	4.28	4.15	4.14	4.14	4.2	4.29	4.6	4.49
10/31/2024	4.76	N/A	4.76	4.64	4.56	4.43	4.27	4.16	4.12	4.15	4.21	4.28	4.58	4.47
11/1/2024	4.75	N/A	4.74	4.61	4.53	4.42	4.28	4.21	4.18	4.22	4.3	4.37	4.68	4.57
11/4/2024	4.75	N/A	4.74	4.65	4.51	4.39	4.25	4.17	4.1	4.17	4.24	4.31	4.6	4.5
11/5/2024	4.72	N/A	4.72	4.64	4.49	4.39	4.27	4.19	4.11	4.16	4.22	4.26	4.55	4.44
11/6/2024	4.68	N/A	4.71	4.64	4.54	4.41	4.31	4.27	4.2	4.27	4.37	4.42	4.71	4.6
11/7/2024	4.69	N/A	4.69	4.63	4.52	4.4	4.28	4.21	4.13	4.17	4.25	4.31	4.62	4.52

11/8/2024	4.7	N/A	4.69	4.63	4.53	4.42	4.32	4.26	4.18	4.2	4.25	4.3	4.58	4.47
11/12/2024	4.7	N/A	4.7	4.63	4.54	4.45	4.38	4.34	4.29	4.32	4.38	4.43	4.7	4.58
11/13/2024	4.69	N/A	4.67	4.6	4.5	4.4	4.31	4.27	4.25	4.3	4.38	4.44	4.73	4.63
11/14/2024	4.7	N/A	4.68	4.61	4.53	4.43	4.36	4.34	4.3	4.32	4.38	4.43	4.69	4.58
11/15/2024	4.7	N/A	4.67	4.6	4.52	4.44	4.34	4.31	4.27	4.3	4.36	4.43	4.7	4.6
11/18/2024	4.7	N/A	4.65	4.63	4.52	4.44	4.33	4.29	4.25	4.28	4.35	4.42	4.7	4.61
11/19/2024	4.67	N/A	4.63	4.62	4.51	4.44	4.34	4.27	4.24	4.25	4.32	4.39	4.66	4.57
11/20/2024	4.68	N/A	4.63	4.62	4.52	4.44	4.37	4.31	4.26	4.28	4.34	4.41	4.66	4.59
11/21/2024	4.72	N/A	4.67	4.63	4.52	4.45	4.39	4.34	4.3	4.3	4.36	4.43	4.68	4.61
11/22/2024	4.72	N/A	4.67	4.63	4.53	4.46	4.42	4.37	4.32	4.3	4.35	4.41	4.67	4.6
11/25/2024	4.74	N/A	4.67	4.62	4.52	4.46	4.37	4.21	4.21	4.17	4.21	4.27	4.53	4.45
11/26/2024	4.74	N/A	4.67	4.61	4.52	4.45	4.37	4.21	4.21	4.17	4.24	4.3	4.56	4.48
11/27/2024	4.76	N/A	4.7	4.6	4.54	4.43	4.34	4.19	4.17	4.11	4.17	4.25	4.52	4.44
11/29/2024	4.76	N/A	4.69	4.58	4.52	4.42	4.3	4.13	4.1	4.05	4.1	4.18	4.45	4.36
12/2/2024	4.75	N/A	4.63	4.51	4.51	4.43	4.3	4.17	4.11	4.08	4.13	4.19	4.46	4.36
12/3/2024	4.66	N/A	4.56	4.49	4.48	4.4	4.27	4.17	4.13	4.11	4.17	4.23	4.5	4.4
12/4/2024	4.65	N/A	4.54	4.47	4.46	4.38	4.23	4.13	4.09	4.07	4.13	4.19	4.45	4.35
12/5/2024	4.59	N/A	4.53	4.46	4.46	4.38	4.23	4.15	4.1	4.07	4.12	4.17	4.43	4.33
12/6/2024	4.57	N/A	4.5	4.42	4.42	4.34	4.19	4.1	4.05	4.03	4.09	4.15	4.42	4.34
12/9/2024	4.56	N/A	4.5	4.42	4.43	4.34	4.2	4.13	4.09	4.07	4.13	4.2	4.47	4.39
12/10/2024	4.53	N/A	4.48	4.41	4.42	4.35	4.22	4.15	4.08	4.09	4.15	4.22	4.49	4.41
12/11/2024	4.49	N/A	4.45	4.38	4.38	4.32	4.21	4.15	4.09	4.13	4.2	4.26	4.55	4.48
12/12/2024	4.43	N/A	4.44	4.35	4.36	4.31	4.22	4.18	4.14	4.18	4.25	4.32	4.62	4.55
12/13/2024	4.43	N/A	4.43	4.34	4.36	4.32	4.24	4.25	4.21	4.25	4.33	4.4	4.69	4.61
12/16/2024	4.43	N/A	4.44	4.37	4.36	4.3	4.24	4.25	4.22	4.25	4.32	4.39	4.68	4.6
12/17/2024	4.46	N/A	4.44	4.38	4.36	4.3	4.25	4.25	4.22	4.26	4.33	4.4	4.68	4.59
12/18/2024	4.44	N/A	4.43	4.36	4.36	4.3	4.3	4.35	4.35	4.4	4.45	4.5	4.74	4.65
12/19/2024	4.42	N/A	4.42	4.35	4.35	4.29	4.28	4.32	4.35	4.43	4.51	4.57	4.82	4.74
12/20/2024	4.43	N/A	4.42	4.34	4.35	4.29	4.27	4.3	4.32	4.37	4.45	4.52	4.79	4.72
12/23/2024	4.44	N/A	4.44	4.36	4.37	4.3	4.26	4.3	4.36	4.44	4.52	4.59	4.85	4.78
12/24/2024	4.44	N/A	4.44	4.4	4.38	4.3	4.24	4.29	4.36	4.43	4.52	4.59	4.84	4.76
12/26/2024	4.45	N/A	4.45	4.35	4.37	4.31	4.23	4.3	4.35	4.42	4.49	4.58	4.83	4.76
12/27/2024	4.44	N/A	4.43	4.31	4.35	4.29	4.2	4.31	4.36	4.45	4.53	4.62	4.89	4.82
12/30/2024	4.43	N/A	4.42	4.37	4.33	4.25	4.17	4.24	4.29	4.37	4.46	4.55	4.84	4.77
12/31/2024	4.4	N/A	4.39	4.37	4.32	4.24	4.16	4.25	4.27	4.38	4.48	4.58	4.86	4.78
1/2/2025	4.45	N/A	4.36	4.36	4.31	4.25	4.17	4.25	4.29	4.38	4.47	4.57	4.86	4.79
1/3/2025	4.44	N/A	4.35	4.34	4.31	4.25	4.18	4.28	4.32	4.41	4.51	4.6	4.88	4.82
1/6/2025	4.43	N/A	4.36	4.35	4.31	4.24	4.17	4.28	4.3	4.42	4.52	4.62	4.91	4.85
1/7/2025	4.42	N/A	4.35	4.35	4.31	4.24	4.19	4.3	4.33	4.46	4.57	4.67	4.97	4.91
1/8/2025	4.41	N/A	4.34	4.35	4.31	4.25	4.19	4.28	4.31	4.45	4.56	4.67	4.97	4.91
1/9/2025	4.44	N/A	4.36	4.35	4.31	4.24	4.16	4.27	4.31	4.46	4.57	4.68	4.98	4.92
1/10/2025	4.42	N/A	4.35	4.36	4.33	4.27	4.25	4.4	4.46	4.59	4.7	4.77	5.04	4.96
1/13/2025	4.42	N/A	4.36	4.37	4.34	4.3	4.24	4.4	4.49	4.61	4.71	4.79	5.05	4.97
1/14/2025	4.42	N/A	4.35	4.36	4.33	4.29	4.22	4.37	4.46	4.59	4.7	4.78	5.06	4.98
1/15/2025	4.4	N/A	4.34	4.35	4.32	4.26	4.19	4.27	4.34	4.45	4.55	4.66	4.95	4.88
1/16/2025	4.43	N/A	4.36	4.34	4.32	4.26	4.18	4.23	4.29	4.39	4.5	4.61	4.91	4.84
1/17/2025	4.43	N/A	4.35	4.34	4.32	4.28	4.21	4.27	4.33	4.42	4.52	4.61	4.91	4.84
1/21/2025	4.42	N/A	4.35	4.36	4.33	4.28	4.21	4.29	4.33	4.4	4.49	4.57	4.87	4.8
1/22/2025	4.42	N/A	4.35	4.36	4.32	4.28	4.2	4.29	4.34	4.43	4.51	4.6	4.89	4.82
1/23/2025	4.45	N/A	4.36	4.36	4.32	4.27	4.18	4.29	4.35	4.45	4.55	4.65	4.92	4.87
1/24/2025	4.45	N/A	4.36	4.35	4.32	4.25	4.17	4.27	4.33	4.43	4.53	4.63	4.91	4.85
1/27/2025	4.44	N/A	4.36	4.32	4.3	4.25	4.13	4.17	4.24	4.32	4.43	4.53	4.82	4.76
1/28/2025	4.44	N/A	4.35	4.31	4.3	4.26	4.14	4.19	4.25	4.33	4.43	4.55	4.84	4.78
1/29/2025	4.43	N/A	4.34	4.31	4.34	4.27	4.17	4.21	4.27	4.35	4.44	4.55	4.85	4.79
1/30/2025	4.37	N/A	4.38	4.3	4.33	4.27	4.16	4.18	4.24	4.31	4.41	4.52	4.81	4.76
1/31/2025	4.37	N/A	4.37	4.31	4.33	4.28	4.17	4.22	4.27	4.36	4.47	4.58	4.88	4.83
2/3/2025	4.37	N/A	4.38	4.34	4.35	4.28	4.2	4.26	4.28	4.35	4.45	4.54	4.82	4.77
2/4/2025	4.36	N/A	4.38	4.33	4.35	4.27	4.18	4.21	4.25	4.31	4.42	4.52	4.81	4.75
2/5/2025	4.35	N/A	4.37	4.33	4.35	4.27	4.17	4.17	4.19	4.24	4.33	4.43	4.69	4.64
2/6/2025	4.37	N/A	4.38	4.34	4.36	4.28	4.19	4.21	4.23	4.28	4.36	4.45	4.7	4.65
2/7/2025	4.37	N/A	4.38	4.35	4.37	4.3	4.25	4.29	4.31	4.34	4.42	4.49	4.75	4.69
2/10/2025	4.38	N/A	4.4	4.35	4.37	4.31	4.24	4.28	4.3	4.34	4.42	4.51	4.76	4.71
2/11/2025	4.38	N/A	4.4	4.35	4.37	4.31	4.25	4.29	4.28	4.37	4.45	4.54	4.8	4.75
2/12/2025	4.38	N/A	4.39	4.35	4.36	4.33	4.3	4.36	4.37	4.48	4.56	4.62	4.9	4.83
2/13/2025	4.37	N/A	4.39	4.34	4.35	4.33	4.27	4.31	4.31	4.39	4.46	4.52	4.79	4.72
2/14/2025	4.37	N/A	4.38	4.34	4.35	4.32	4.23	4.26	4.26	4.33	4.41	4.47	4.75	4.69
2/18/2025	4.38	4.41	4.38	4.34	4.37	4.34	4.24	4.29	4.33	4.4	4.48	4.55	4.83	4.77
2/19/2025	4.38	4.42	4.38	4.34	4.35	4.34	4.22	4.28	4.3	4.37	4.46	4.53	4.79	4.76
2/20/2025	4.37	4.4	4.38	4.33	4.35	4.33	4.2	4.28	4.27	4.34	4.43	4.5	4.77	4.74
2/21/2025	4.36	4.39	4.38	4.32	4.34	4.3	4.15	4.19	4.19	4.26	4.35	4.42	4.69	4.67
2/24/2025	4.36	4.38	4.37	4.31	4.34	4.3	4.15	4.13	4.17	4.23	4.32	4.4	4.69	4.66
2/25/2025	4.34	4.37	4.37	4.3	4.33	4.28	4.12	4.07	4.08	4.12	4.21	4.3	4.59	4.55
2/26/2025	4.35	4.38	4.37	4.31	4.32	4.28	4.12	4.05	4.04	4.06	4.16	4.25	4.55	4.51
2/27/2025	4.38	4.38	4.38	4.32	4.32	4.28	4.13	4.07	4.05	4.09	4.19	4.29	4.59	4.56
2/28/2025	4.38	4.37	4.38	4.32	4.32	4.25	4.08	3.99	3.99	4.03	4.14	4.24	4.55	4.51
3/3/2025	4.38	4.38	4.37	4.35	4.31	4.31	4.06	3.96	3.93	3.97	4.06	4.16	4.49	4.45
3/4/2025	4.39	4.38	4.37	4.34	4.31	4.28	4.04	3.96	3.94	4.01	4.11	4.22	4.56	4.53
3/5/2025	4.38	4.38	4.36	4.35	4.3	4.3	4.06	3.99	4.01	4.08	4.18	4.28	4.61	4.57

3/6/2025	4.38	4.37	4.34	4.34	4.28	4.27	4.02	3.96	3.98	4.06	4.18	4.29	4.63	4.58
3/7/2025	4.38	4.36	4.33	4.34	4.29	4.29	4.05	3.99	4.01	4.09	4.21	4.32	4.66	4.62
3/10/2025	4.37	4.35	4.34	4.33	4.28	4.25	3.98	3.89	3.91	3.98	4.1	4.22	4.58	4.54
3/11/2025	4.37	4.37	4.33	4.34	4.28	4.26	4.03	3.94	3.92	4.03	4.16	4.28	4.63	4.59
3/12/2025	4.36	4.36	4.34	4.35	4.3	4.27	4.07	4.01	3.98	4.09	4.2	4.32	4.67	4.63
3/13/2025	4.37	4.37	4.34	4.34	4.28	4.27	4.03	3.94	3.93	4.02	4.15	4.27	4.63	4.59
3/14/2025	4.37	4.36	4.33	4.33	4.3	4.29	4.09	4.02	4	4.09	4.2	4.31	4.65	4.62
3/17/2025	4.37	4.35	4.33	4.34	4.3	4.29	4.11	4.06	4.03	4.11	4.21	4.31	4.64	4.6
3/18/2025	4.37	4.35	4.33	4.34	4.29	4.29	4.13	4.04	4.01	4.07	4.18	4.29	4.61	4.58
3/19/2025	4.37	4.34	4.32	4.33	4.3	4.29	4.1	3.99	3.95	4.03	4.14	4.25	4.58	4.56
3/20/2025	4.36	4.34	4.34	4.33	4.29	4.27	4.06	3.95	3.93	4.01	4.12	4.24	4.57	4.55
3/21/2025	4.36	4.33	4.33	4.33	4.29	4.26	4.04	3.94	3.92	4	4.12	4.25	4.6	4.59
3/24/2025	4.35	4.34	4.34	4.33	4.3	4.27	4.11	4.04	4.01	4.09	4.22	4.34	4.68	4.66
3/25/2025	4.36	4.34	4.33	4.33	4.3	4.26	4.09	3.96	3.98	4.07	4.19	4.31	4.67	4.65
3/26/2025	4.36	4.34	4.33	4.33	4.31	4.26	4.1	3.98	4.01	4.08	4.22	4.35	4.71	4.69
3/27/2025	4.37	4.35	4.36	4.33	4.31	4.27	4.1	3.97	4	4.09	4.23	4.38	4.75	4.73
3/28/2025	4.38	4.35	4.35	4.33	4.3	4.26	4.04	3.89	3.91	3.98	4.11	4.27	4.65	4.64
3/31/2025	4.38	4.36	4.35	4.32	4.31	4.23	4.03	3.89	3.89	3.96	4.09	4.23	4.62	4.59
4/1/2025	4.38	4.36	4.35	4.32	4.3	4.23	4.01	3.87	3.85	3.91	4.03	4.17	4.56	4.52
4/2/2025	4.38	4.36	4.34	4.32	4.32	4.24	4.04	3.91	3.89	3.95	4.07	4.2	4.58	4.54
4/3/2025	4.36	4.37	4.38	4.31	4.29	4.2	3.92	3.71	3.68	3.75	3.88	4.06	4.51	4.49
4/4/2025	4.36	4.35	4.36	4.28	4.25	4.14	3.86	3.68	3.66	3.72	3.84	4.01	4.44	4.41
4/7/2025	4.36	4.36	4.36	4.29	4.28	4.14	3.86	3.73	3.72	3.82	3.97	4.15	4.61	4.58
4/8/2025	4.36	4.39	4.37	4.31	4.3	4.14	3.83	3.71	3.71	3.88	4.05	4.26	4.76	4.71
4/9/2025	4.36	4.38	4.37	4.35	4.36	4.23	4.03	3.91	3.91	4.06	4.2	4.34	4.78	4.72
4/10/2025	4.36	4.36	4.39	4.34	4.33	4.17	3.97	3.84	3.85	4.04	4.21	4.4	4.9	4.86
4/11/2025	4.37	4.35	4.38	4.34	4.35	4.21	4.04	3.96	3.98	4.15	4.32	4.48	4.91	4.85
4/14/2025	4.34	4.36	4.37	4.33	4.34	4.21	3.99	3.84	3.87	4.02	4.2	4.38	4.84	4.8
4/15/2025	4.35	4.36	4.36	4.33	4.32	4.21	3.99	3.84	3.85	3.98	4.15	4.35	4.82	4.79
4/16/2025	4.35	4.35	4.35	4.33	4.34	4.2	3.96	3.77	3.77	3.91	4.08	4.29	4.77	4.74
4/17/2025	4.36	4.35	4.38	4.34	4.35	4.22	3.99	3.81	3.82	3.95	4.13	4.34	4.82	4.8
4/21/2025	4.35	4.35	4.37	4.34	4.33	4.21	3.95	3.75	3.77	3.97	4.19	4.42	4.94	4.91
4/22/2025	4.33	4.37	4.35	4.33	4.33	4.21	3.98	3.76	3.82	3.98	4.19	4.41	4.9	4.88
4/23/2025	4.33	4.36	4.34	4.33	4.33	4.22	4.01	3.81	3.87	4	4.2	4.4	4.86	4.83
4/24/2025	4.34	4.36	4.37	4.32	4.32	4.22	3.97	3.77	3.8	3.91	4.11	4.32	4.79	4.77
4/25/2025	4.34	4.37	4.36	4.32	4.32	4.22	3.95	3.74	3.76	3.88	4.06	4.29	4.75	4.74
4/28/2025	4.35	4.37	4.37	4.32	4.32	4.22	3.92	3.67	3.67	3.81	4.01	4.23	4.71	4.69
4/29/2025	4.35	4.38	4.36	4.31	4.3	4.2	3.89	3.65	3.65	3.77	3.96	4.19	4.66	4.64
4/30/2025	4.35	4.37	4.36	4.31	4.37	4.19	3.85	3.6	3.58	3.72	3.93	4.17	4.68	4.66

	1 Mo	2 Mo	0.25 3 Mo	4 Mo	0.5 6 Mo	1 1 Yr	2 2 Yr	3 Yr	5 5 Yr	7 Yr	10 10 Yr	20 Yr	30 30 Yr
8/30/2024	5.41%	5.32%	5.21%	5.12%	4.89%	4.38%	3.91%	3.79%	3.71%	3.80%	3.91%	4.28%	4.20%
9/30/2024	4.93%	4.87%	4.73%	4.65%	4.38%	3.98%	3.66%	3.58%	3.58%	3.67%	3.81%	4.19%	4.14%
4/30/2025	4.35%	4.36%	4.31%	4.37%	4.19%	3.85%	3.60%	3.58%	3.72%	3.93%	4.17%	4.68%	4.66%
30-day avg	4.36%	4.36%	4.32%	4.32%	4.22%	3.99%	3.83%	3.84%	3.95%	4.11%	4.28%	4.71%	4.69%

DATE	OPEN	HIGH	LOW	CLOSE
1/4/2010	21.68	21.68	20.03	20.04
1/5/2010	20.05	20.13	19.34	19.35
1/6/2010	19.59	19.68	18.77	19.16
1/7/2010	19.68	19.71	18.7	19.06
1/8/2010	19.27	19.27	18.11	18.13
1/11/2010	16.93	17.74	16.86	17.55
1/12/2010	17.95	19.46	17.95	18.25
1/13/2010	17.94	18.72	17.56	17.85
1/14/2010	18.16	18.27	17.38	17.63
1/15/2010	17.63	19.02	17.63	17.91
1/19/2010	18.63	18.85	17.33	17.58
1/20/2010	18.51	19.69	18.44	18.68
1/21/2010	18.59	22.3	18.27	22.27
1/22/2010	22.27	28.01	22.27	27.31
1/25/2010	27.32	27.32	24.61	25.41
1/26/2010	26.03	26.22	22.77	24.55
1/27/2010	24.81	25.69	23.14	23.14
1/28/2010	22.79	25.3	22.69	23.73
1/29/2010	23.73	25.03	22.11	24.62
2/1/2010	24.33	24.33	22.58	22.59
2/2/2010	22.59	22.99	21.08	21.48
2/3/2010	22.11	22.11	21.33	21.6
2/4/2010	22.63	26.32	22.63	26.08
2/5/2010	25.69	29.22	25.37	26.11
2/8/2010	26.11	27.11	25.48	26.51
2/9/2010	26.51	26.56	24.78	26
2/10/2010	26.36	26.77	24.8	25.4
2/11/2010	25.82	26.11	23.87	23.96
2/12/2010	23.96	25.54	22.73	22.73
2/16/2010	23.51	23.57	22.13	22.25
2/17/2010	22.25	22.6	21.7	21.72
2/18/2010	21.72	22.21	20.6	20.63
2/19/2010	21.07	21.14	19.71	20.02
2/22/2010	20.16	21	19.59	19.94
2/23/2010	20.39	21.94	20.06	21.37
2/24/2010	21.23	21.58	20.22	20.27
2/25/2010	22.03	22.68	20.06	20.1
2/26/2010	19.88	20.53	19.32	19.5
3/1/2010	19.93	19.94	19.18	19.26
3/2/2010	18.83	19.36	18.6	19.06
3/3/2010	18.95	19.3	18.42	18.83
3/4/2010	18.86	19.27	18.58	18.72
3/5/2010	18.06	18.15	17.23	17.42
3/8/2010	17.95	17.96	17.56	17.79
3/9/2010	18.18	18.19	17.51	17.92
3/10/2010	18	18.6	17.43	18.57
3/11/2010	18.9	19.34	18.06	18.06
3/12/2010	17.97	18.53	17.58	17.58
3/15/2010	18.28	18.78	17.96	18
3/16/2010	17.78	18.01	17.42	17.69
3/17/2010	16.97	17.17	16.52	16.91
3/18/2010	16.96	16.99	16.31	16.62
3/19/2010	16.17	17.57	16.17	16.97
3/22/2010	18.3	18.34	16.77	16.87
3/23/2010	16.84	17.09	16.21	16.35
3/24/2010	16.85	17.92	16.83	17.55
3/25/2010	17.07	18.54	16.62	18.4
3/26/2010	18.27	18.69	17.35	17.77
3/29/2010	18.17	18.28	17.57	17.59
3/30/2010	17.64	18.08	17.13	17.13
3/31/2010	17.66	17.92	17.29	17.59
4/1/2010	17.01	18.09	16.79	17.47
4/5/2010	17.96	18.16	17.02	17.02
4/6/2010	17.39	17.54	16.08	16.23
4/7/2010	16.72	17.21	16.16	16.62
4/8/2010	17.21	17.8	16.3	16.48
4/9/2010	16.32	16.65	16.06	16.14
4/12/2010	15.67	16	15.23	15.58
4/13/2010	15.98	16.77	15.81	16.2
4/14/2010	15.8	16.38	15.55	15.59
4/15/2010	15.87	16.5	15.68	15.89
4/16/2010	16.19	19.7	16.11	18.36
4/19/2010	19.14	19.55	17.34	17.34
4/20/2010	16.84	16.89	15.73	15.73
4/21/2010	15.94	16.85	15.5	16.32
4/22/2010	17.48	18.19	16.2	16.47
4/23/2010	16.62	16.71	16.12	16.62
4/26/2010	17.52	17.53	17.07	17.47
4/27/2010	18.13	23.2	17.94	22.81
4/28/2010	22.08	23.03	20.86	21.08
4/29/2010	20.37	20.37	18.44	18.44
4/30/2010	18.75	22.39	18.41	22.05
5/3/2010	22.41	22.41	19.61	20.19
5/4/2010	22.46	25.7	22.46	23.84
5/5/2010	25.96	27.23	23.75	24.91
5/6/2010	25.88	40.71	24.43	32.8
5/7/2010	32.76	42.15	31.71	40.95
5/10/2010	28.65	30.89	25.68	28.84
5/11/2010	31.04	31.04	25.86	28.32
5/12/2010	26.56	26.67	24.98	25.52
5/13/2010	26.17	26.85	24.3	26.68
5/14/2010	28.4	33.24	28.4	31.24
5/17/2010	31.33	35.25	30.76	30.84
5/18/2010	28.67	34.17	28.09	33.55
5/19/2010	34.65	38.42	33.07	35.32
5/20/2010	41.79	46.37	40.3	45.79
5/21/2010	47.66	48.2	38.95	40.1
5/24/2010	41.74	41.74	35.57	38.32
5/25/2010	43.15	43.74	34.59	34.61
5/26/2010	32.54	35.02	24.1	35.02
5/27/2010	30.24	31.03	29.54	29.68
5/28/2010	30.23	33.3	29.53	32.07
6/1/2010	34.87	35.68	31.82	35.54
6/2/2010	34.39	34.57	29.94	30.17
6/3/2010	29.65	31.2	29.12	29.46
6/4/2010	32.93	36.12	31.81	35.48
6/7/2010	35.66	36.8	34.43	36.57

6/8/2010	36.53	37.38	33.36	33.7
6/9/2010	32.33	34.12	30.23	33.73
6/10/2010	31	31.77	29.69	30.57
6/11/2010	31.79	31.79	28.6	28.79
6/14/2010	27.94	28.72	26.98	28.58
6/15/2010	27.68	27.84	25.68	25.87
6/16/2010	26.72	26.72	25.34	25.92
6/17/2010	25.59	26.64	25.05	25.05
6/18/2010	24.87	24.88	23.3	23.95
6/21/2010	22.9	25.64	22.87	24.88
6/22/2010	25.14	27.05	24.41	27.05
6/23/2010	26.93	28.55	26.54	26.91
6/24/2010	27.61	30.27	27.53	29.74
6/25/2010	29.64	30.41	28.07	28.53
6/28/2010	29.2	29.9	28.47	29
6/29/2010	31.22	35.39	31.22	34.13
6/30/2010	33.95	34.63	31.74	34.54
7/1/2010	34.41	37.58	32.72	32.86
7/2/2010	31.71	31.88	29.35	30.12
7/6/2010	28.82	31.15	27.96	29.65
7/7/2010	29.56	29.56	26.84	26.84
7/8/2010	26.5	27.42	24.22	25.71
7/9/2010	25.35	25.67	24.37	24.98
7/12/2010	24.66	25.14	23.53	24.43
7/13/2010	23.29	24.57	23.12	24.56
7/14/2010	24.61	25.8	24.18	24.89
7/15/2010	25.08	27.24	24.74	25.14
7/16/2010	25.77	28.16	25.71	26.25
7/19/2010	27.02	27.3	25.12	25.97
7/20/2010	27.35	27.4	23.79	23.93
7/21/2010	23.61	26.63	23.59	25.64
7/22/2010	24.37	24.85	23.72	24.63
7/23/2010	24.79	25.17	23.32	23.47
7/26/2010	24.37	24.61	22.7	22.73
7/27/2010	21.89	23.57	21.86	23.19
7/28/2010	23.93	24.54	22.24	24.25
7/29/2010	23.4	25.54	23.04	24.13
7/30/2010	25.47	27.32	23.35	23.5
8/2/2010	23.07	23.24	21.74	22.01
8/3/2010	22.44	23.06	21.98	22.63
8/4/2010	22.69	23.69	22.16	22.21
8/5/2010	23.04	23.13	22.07	22.1
8/6/2010	23.34	23.89	21.72	21.74
8/9/2010	21.85	22.87	21.36	22.14
8/10/2010	23.3	24.24	22.17	22.37
8/11/2010	24.96	26.1	24.96	25.39
8/12/2010	27.21	27.21	25.18	25.73
8/13/2010	26.08	26.26	25.45	26.24
8/16/2010	27.41	28.1	25.38	26.1
8/17/2010	24.72	24.89	23.71	24.33
8/18/2010	24.3	25.23	23.4	24.59
8/19/2010	24.48	26.78	24.26	26.44
8/20/2010	26.73	27	25.49	25.49
8/23/2010	25.97	25.97	24.62	25.66
8/24/2010	27.91	28.77	26.32	27.46
8/25/2010	28.3	28.92	26.46	26.7
8/26/2010	26.45	27.55	25.86	27.37
8/27/2010	26.5	28.11	24.41	24.45
8/30/2010	25.88	27.21	25.41	27.21
8/31/2010	27.58	27.83	25.93	26.05
9/1/2010	25.13	25.13	23.86	23.89
9/2/2010	24.23	24.31	23.15	23.19
9/3/2010	21.99	22.78	21.24	21.31
9/7/2010	22.77	23.94	22.77	23.8
9/8/2010	23.51	23.56	22.92	23.25
9/9/2010	22.22	23.24	22.14	22.81
9/10/2010	22.64	22.87	21.76	21.99
9/13/2010	21.06	22.05	20.93	21.21
9/14/2010	21.69	21.97	20.85	21.56
9/15/2010	22.55	22.8	22.1	22.1
9/16/2010	22.65	22.83	21.71	21.72
9/17/2010	21.65	22.56	21.63	22.01
9/20/2010	22.47	22.58	21.25	21.5
9/21/2010	21.54	22.59	21.42	22.35
9/22/2010	22.56	23.19	21.91	22.51
9/23/2010	23.91	24.06	22.56	23.87
9/24/2010	22.61	22.61	21.71	21.71
9/27/2010	22.58	22.75	21.97	22.54
9/28/2010	22.92	24.28	22.4	22.6
9/29/2010	23.14	23.45	22.72	23.25
9/30/2010	22.85	24.52	22.39	23.7
10/1/2010	22.9	23.67	22.46	22.5
10/4/2010	23.63	24.34	23.3	23.53
10/5/2010	22.52	23.08	21.71	21.76
10/6/2010	21.82	22.13	21.46	21.49
10/7/2010	21.31	22.16	21.28	21.56
10/8/2010	21.58	21.64	20.29	20.71
10/11/2010	19.33	19.51	18.8	18.96
10/12/2010	20	20.1	18.55	18.93
10/13/2010	17.92	19.16	17.9	19.07
10/14/2010	19.59	21.02	19.4	19.88
10/15/2010	20.2	21.59	19.02	19.03
10/18/2010	20.43	20.71	18.88	19.09
10/19/2010	20.7	21.35	19.33	20.63
10/20/2010	21.2	21.2	19.67	19.79
10/21/2010	19.7	20.53	18.93	19.27
10/22/2010	19.36	19.36	18.76	18.78
10/25/2010	19.22	19.88	18.86	19.85
10/26/2010	20.52	21.01	20.22	20.22
10/27/2010	21.11	22.37	20.69	20.71
10/28/2010	20.28	21.41	20.18	20.88
10/29/2010	21.2	21.4	20.86	21.2
11/1/2010	21.65	22.54	20.92	21.83
11/2/2010	21.34	21.82	21.22	21.57
11/3/2010	21.66	22.02	19.54	19.56
11/4/2010	18.03	18.8	17.97	18.52
11/5/2010	18.07	18.44	17.92	18.26
11/8/2010	19.33	19.35	18.21	18.29

11/9/2010	18.51	19.39	17.83	19.08
11/10/2010	18.94	19.96	18.41	18.47
11/11/2010	19.44	19.75	18.48	18.64
11/12/2010	19.59	21.23	19.29	20.61
11/15/2010	20.33	20.37	19.14	20.2
11/16/2010	21.26	23.07	20.95	22.58
11/17/2010	22.19	22.21	21.22	21.76
11/18/2010	20.31	20.31	18.75	18.75
11/19/2010	19.15	19.72	17.76	18.04
11/22/2010	19.45	20.14	18.35	18.37
11/23/2010	20.25	21.45	20.24	20.63
11/24/2010	19.42	19.61	18.73	19.56
11/26/2010	21.17	22.22	20.28	22.22
11/29/2010	23.15	23.84	21.38	21.53
11/30/2010	23.27	23.79	22.42	23.54
12/1/2010	21.19	21.43	20.4	21.36
12/2/2010	21.13	21.13	19.1	19.39
12/3/2010	19.26	19.28	17.71	18.01
12/6/2010	18.8	18.85	17.95	18.02
12/7/2010	17.13	18.15	17.13	17.99
12/8/2010	17.97	18.32	17.69	17.74
12/9/2010	17.32	17.84	17.24	17.25
12/10/2010	17.06	17.63	17.06	17.61
12/13/2010	16.82	17.67	16.68	17.55
12/14/2010	17.6	17.95	17.22	17.61
12/15/2010	17.99	18.14	17.37	17.94
12/16/2010	18.03	18.27	16.88	17.39
12/17/2010	17.62	17.64	15.46	16.11
12/20/2010	16.22	16.86	15.78	16.41
12/21/2010	16.2	16.62	16.08	16.49
12/22/2010	16.52	16.56	15.45	15.45
12/23/2010	15.44	16.86	15.4	16.47
12/27/2010	18.26	18.32	17.66	17.67
12/28/2010	17.3	17.99	17.3	17.52
12/29/2010	17.49	17.49	17.02	17.28
12/30/2010	17.65	17.89	17.46	17.52
12/31/2010	17.91	18.13	17.75	17.75
1/3/2011	17.94	17.95	16.91	17.61
1/4/2011	17.34	18.24	17.33	17.38
1/5/2011	17.81	17.95	16.86	17.02
1/6/2011	16.8	17.56	16.79	17.4
1/7/2011	17.31	18.07	16.57	17.14
1/10/2011	18.35	18.63	17.54	17.54
1/11/2011	16.61	17.35	16.6	16.89
1/12/2011	16.26	16.5	16.17	16.24
1/13/2011	16.51	16.78	16.14	16.39
1/14/2011	16.67	16.71	15.37	15.46
1/18/2011	16.19	16.2	15.71	15.87
1/19/2011	15.89	17.67	15.86	17.31
1/20/2011	17.81	18.85	17.65	17.99
1/21/2011	17.03	18.61	16.6	18.47
1/24/2011	18.78	18.93	17.56	17.65
1/25/2011	18.22	18.55	17.59	17.59
1/26/2011	17	17.42	16.59	16.64
1/27/2011	16.84	16.89	15.81	16.15
1/28/2011	15.94	20.08	15.92	20.04
1/31/2011	19.61	19.96	17.1	19.53
2/1/2011	18.59	18.63	17.4	17.63
2/2/2011	17.82	17.84	17.28	17.3
2/3/2011	17.53	17.8	16.61	16.69
2/4/2011	16.64	16.74	15.89	15.93
2/7/2011	16.14	16.54	15.84	16.28
2/8/2011	16.29	16.6	14.86	15.81
2/9/2011	16.27	16.52	15.86	15.87
2/10/2011	16.74	17.07	16	16.09
2/11/2011	16.53	16.53	15.55	15.69
2/14/2011	16.07	16.26	15.22	15.95
2/15/2011	16.3	16.75	16.27	16.37
2/16/2011	16.31	16.74	15.84	16.72
2/17/2011	17.01	17.3	15.88	16.59
2/18/2011	16.59	16.91	15.54	16.43
2/22/2011	19.46	21.45	18.38	20.8
2/23/2011	20.84	23.22	20.3	22.13
2/24/2011	22.28	22.71	20.81	21.32
2/25/2011	20.41	20.44	18.88	19.22
2/28/2011	19.12	19.27	18.14	18.35
3/1/2011	17.63	21.01	17.63	21.01
3/2/2011	20.73	21.14	19.62	20.7
3/3/2011	19.27	19.27	18.25	18.6
3/4/2011	18.56	20.33	18.31	19.06
3/7/2011	19.37	21.77	18.95	20.66
3/8/2011	20.58	21.06	19.15	19.82
3/9/2011	20.05	20.96	19.41	20.22
3/10/2011	21.37	22.25	20.34	21.88
3/11/2011	21.72	21.75	19.97	20.08
3/14/2011	21.79	22.74	20.92	21.13
3/15/2011	25.66	25.72	23.31	24.32
3/16/2011	24.65	31.28	24.04	29.4
3/17/2011	26.94	27.54	25.44	26.37
3/18/2011	23.9	24.85	23.09	24.44
3/21/2011	22.1	22.16	20.22	20.61
3/22/2011	20.53	20.59	19.97	20.21
3/23/2011	20.59	21.05	18.19	19.17
3/24/2011	18.45	18.99	17.87	18
3/25/2011	17.87	18.08	17.07	17.91
3/28/2011	18.31	19.44	17.96	19.44
3/29/2011	19.17	19.78	18	18.16
3/30/2011	17.82	17.89	17.25	17.71
3/31/2011	17.9	17.95	17.41	17.74
4/1/2011	16.68	17.62	16.44	17.4
4/4/2011	17.63	17.85	17.39	17.5
4/5/2011	17.87	17.87	16.5	17.25
4/6/2011	16.75	17.15	16.5	16.9
4/7/2011	16.92	17.77	16.49	17.11
4/8/2011	16.51	18.33	16.51	17.87
4/11/2011	16.74	17.05	16.22	16.59
4/12/2011	17.58	18.46	16.88	17.09
4/13/2011	16.33	17.38	16.2	16.92

4/14/2011	17.77	18.08	16.08	16.27
4/15/2011	15.97	15.98	14.92	15.32
4/18/2011	18.3	19.07	16.81	16.96
4/19/2011	16.62	16.72	15.69	15.83
4/20/2011	14.31	15.39	14.3	15.07
4/21/2011	14.71	15.23	14.4	14.69
4/25/2011	15.64	16.06	15.5	15.77
4/26/2011	15.36	15.66	15.07	15.62
4/27/2011	15.37	16.42	15.13	15.35
4/28/2011	15.54	15.54	14.27	14.62
4/29/2011	14.56	14.99	14.49	14.75
5/2/2011	15.07	16.13	15.07	15.99
5/3/2011	16.35	17.29	16.13	16.7
5/4/2011	16.84	17.72	16.83	17.08
5/5/2011	17.68	19.11	16.74	18.2
5/6/2011	17.17	19.29	16.12	18.4
5/9/2011	18.59	18.59	17.04	17.16
5/10/2011	16.84	16.9	15.79	15.91
5/11/2011	16.27	17.49	16.23	16.95
5/12/2011	17.27	17.89	16.03	16.03
5/13/2011	16.02	17.56	15.98	17.07
5/16/2011	17.86	18.25	16.61	18.24
5/17/2011	18.54	19.09	17.47	17.55
5/18/2011	17.56	17.68	16.03	16.23
5/19/2011	15.9	16.56	15.5	15.52
5/20/2011	15.88	17.43	15.7	17.43
5/23/2011	20.03	20.03	17.47	18.27
5/24/2011	18.07	18.19	17	17.82
5/25/2011	18.26	18.26	16.7	17.07
5/26/2011	17.17	17.46	15.9	16.09
5/27/2011	16.11	16.27	15.36	15.98
5/31/2011	15.85	16.5	15.15	15.45
6/1/2011	15.95	18.48	15.95	18.3
6/2/2011	17.92	18.72	17.39	18.09
6/3/2011	18.23	19.87	17.12	17.95
6/6/2011	18.42	18.65	17.65	18.49
6/7/2011	18.13	18.48	17.39	18.07
6/8/2011	18.15	18.83	17.72	18.79
6/9/2011	18.2	18.31	17.26	17.77
6/10/2011	17.93	19.16	17.93	18.86
6/13/2011	19.1	20.02	18.41	19.61
6/14/2011	18.56	18.56	17.8	18.26
6/15/2011	19.31	21.66	19.03	21.32
6/16/2011	21.37	24.65	20.81	22.73
6/17/2011	21.56	22.39	20.35	21.85
6/20/2011	22.99	23.08	19.99	19.99
6/21/2011	19.46	19.46	17.72	18.86
6/22/2011	18.86	18.9	17.72	18.52
6/23/2011	20.23	21.5	19.22	19.29
6/24/2011	19.2	21.28	19.1	21.1
6/27/2011	21.6	21.82	20.27	20.56
6/28/2011	20.3	20.45	19.17	19.17
6/29/2011	18.62	18.83	16.32	17.27
6/30/2011	16.67	16.77	15.88	16.52
7/1/2011	16.06	16.29	15.12	15.87
7/5/2011	16.32	16.5	15.89	16.06
7/6/2011	16.46	17.08	16.32	16.34
7/7/2011	15.3	16.13	15.3	15.95
7/8/2011	17.14	17.14	15.95	15.95
7/11/2011	17.44	19.06	17.16	18.39
7/12/2011	19.55	20.13	18.25	19.87
7/13/2011	19.08	20.16	18.09	19.91
7/14/2011	20.08	21.58	19.35	20.8
7/15/2011	20.25	21.68	19.52	19.53
7/18/2011	21.25	21.93	20.9	20.95
7/19/2011	20.14	20.43	19.12	19.21
7/20/2011	18.81	19.65	18.61	19.09
7/21/2011	18.61	18.63	17.15	17.56
7/22/2011	17.22	17.95	17.14	17.52
7/25/2011	19.26	19.5	18.73	19.35
7/26/2011	19.75	20.5	19.56	20.23
7/27/2011	20.87	23.2	20.87	22.98
7/28/2011	22.83	23.99	21.2	23.74
7/29/2011	25.28	25.94	23.65	25.25
8/1/2011	22.63	25.63	22.46	23.66
8/2/2011	24.22	24.79	22.65	24.79
8/3/2011	23.58	25.23	22.76	23.38
8/4/2011	24.57	32.07	24.31	31.66
8/5/2011	28.48	39.25	27.54	32
8/8/2011	36.9	48	35.29	48
8/9/2011	42.12	47.56	34.28	35.06
8/10/2011	39.33	44.41	37.34	42.99
8/11/2011	41.94	42.88	37.5	39
8/12/2011	37.08	37.85	34.01	36.36
8/15/2011	34.73	34.83	31.47	31.87
8/16/2011	33.36	34.49	31.68	32.85
8/17/2011	32.09	33.32	30.81	31.58
8/18/2011	36.77	45.28	36.69	42.67
8/19/2011	45.34	45.4	39.99	43.05
8/22/2011	38.8	43.58	38.78	42.44
8/23/2011	41.89	42.54	35.83	36.27
8/24/2011	37.12	37.38	34.55	35.9
8/25/2011	34.43	40.14	34.05	39.76
8/26/2011	41.18	43.84	34.33	35.59
8/29/2011	33.81	33.81	32.21	32.28
8/30/2011	32.97	33.55	31.55	32.89
8/31/2011	31.2	32.53	30.16	31.62
9/1/2011	31.91	32.38	30.76	31.82
9/2/2011	34.29	34.74	32.7	33.92
9/6/2011	39.84	39.86	37	37
9/7/2011	34.24	34.7	33.38	33.38
9/8/2011	34.41	34.71	32.79	34.32
9/9/2011	35.53	40.74	35.53	38.52
9/12/2011	42.56	43.18	38.58	38.59
9/13/2011	38.68	39.43	36.69	36.91
9/14/2011	36.59	37.76	33.4	34.6
9/15/2011	33.43	33.98	31.75	31.97
9/16/2011	31.81	32.48	30.43	30.98

9/19/2011	34.8	35.33	32.35	32.73
9/20/2011	32.42	33.14	31.45	32.86
9/21/2011	33	37.32	32.45	37.32
9/22/2011	41	43.87	39.33	41.35
9/23/2011	42.17	42.82	40.42	41.25
9/26/2011	40.99	43.34	39.02	39.02
9/27/2011	36.59	38.57	35.32	37.71
9/28/2011	37.7	41.24	36.65	41.08
9/29/2011	38.62	42	38.03	38.84
9/30/2011	40.93	42.99	39.88	42.96
10/3/2011	44.25	45.55	41.51	45.45
10/4/2011	46.18	46.88	40.02	40.82
10/5/2011	40.73	41.2	37.51	37.81
10/6/2011	38.24	38.74	36.15	36.27
10/7/2011	35.67	37.82	35.19	36.2
10/10/2011	35.45	35.45	32.96	33.02
10/11/2011	33.95	34.24	32.62	32.86
10/12/2011	31.57	31.93	29.79	31.26
10/13/2011	31.99	32.76	30.48	30.7
10/14/2011	29.07	29.96	28.08	28.24
10/17/2011	30.35	33.39	30.12	33.39
10/18/2011	33.37	34.71	29.69	31.56
10/19/2011	32.92	35.47	31.91	34.44
10/20/2011	34.44	36.87	34.16	34.78
10/21/2011	32.76	32.98	31.32	31.32
10/24/2011	31.67	31.7	28.84	29.26
10/25/2011	30.68	32.46	30.32	32.22
10/26/2011	30.44	33.3	29.63	29.86
10/27/2011	24.72	26.46	24.7	25.46
10/28/2011	26.02	26.02	24.44	24.53
10/31/2011	27.09	29.97	27.01	29.96
11/1/2011	36.03	37.53	33.87	34.77
11/2/2011	33.53	34.27	32.55	32.74
11/3/2011	31.38	34.65	30.21	30.5
11/4/2011	31.46	32.56	30.14	30.16
11/7/2011	31.4	32.15	29.85	29.85
11/8/2011	29.34	30.49	27.47	27.48
11/9/2011	31.32	36.43	30.98	36.16
11/10/2011	33.09	35.5	32.12	32.81
11/11/2011	29.91	30.42	29.45	30.04
11/14/2011	31.42	32.85	31.13	31.13
11/15/2011	31.74	32.55	30.4	31.22
11/16/2011	32.66	33.51	30.54	33.51
11/17/2011	33.15	36.46	32.89	34.51
11/18/2011	33.16	33.99	31.92	32
11/21/2011	34.59	35.29	32.53	32.91
11/22/2011	33.12	33.39	31.28	31.97
11/23/2011	32.91	34.57	32.68	33.98
11/25/2011	34.61	34.77	33.12	34.47
11/28/2011	31.93	33.11	31.57	32.13
11/29/2011	31.76	32.02	30.56	30.64
11/30/2011	27.72	28.5	27.03	27.8
12/1/2011	27.63	27.89	26.64	27.41
12/2/2011	26.26	27.62	25.29	27.52
12/5/2011	26.74	28.31	26	27.84
12/6/2011	27.91	28.13	27.41	28.13
12/7/2011	28.61	29.58	28.44	28.67
12/8/2011	29.63	30.91	29.02	30.59
12/9/2011	29.61	29.61	26.29	26.38
12/12/2011	26.78	27.73	25.64	25.67
12/13/2011	24.72	26.28	23.27	25.41
12/14/2011	26.16	27.55	25.76	26.04
12/15/2011	24.38	25.28	24.14	25.11
12/16/2011	24.16	25.02	23.51	24.29
12/19/2011	25.14	25.38	24.38	24.92
12/20/2011	23.56	23.58	22.54	23.22
12/21/2011	22.52	23.94	21.12	21.43
12/22/2011	21.08	21.33	20.34	21.16
12/23/2011	21.1	21.21	20.72	20.73
12/27/2011	22.58	22.66	21.68	21.91
12/28/2011	22.12	23.56	22.11	23.52
12/29/2011	23.52	23.52	22.65	22.65
12/30/2011	22.86	23.46	22.65	23.4
1/3/2012	22.95	23.1	22.54	22.97
1/4/2012	23.44	23.73	22.22	22.22
1/5/2012	22.75	23.09	21.34	21.48
1/6/2012	21.24	21.72	20.58	20.63
1/9/2012	21.67	21.78	21	21.07
1/10/2012	20.14	20.69	20.05	20.69
1/11/2012	21.18	21.22	20.98	21.05
1/12/2012	21.01	22.03	20.46	20.47
1/13/2012	21.41	22.43	20.91	20.91
1/17/2012	20.9	22.25	20.69	22.2
1/18/2012	23.2	23.44	20.78	20.89
1/19/2012	20.49	20.87	19.45	19.87
1/20/2012	19.91	19.94	18.16	18.28
1/23/2012	19.22	19.31	18.55	18.67
1/24/2012	19.76	20	18.63	18.91
1/25/2012	19.35	19.55	17.15	18.31
1/26/2012	17.96	19.17	16.8	18.57
1/27/2012	19.16	19.16	18.26	18.53
1/30/2012	20.33	20.33	19.38	19.4
1/31/2012	19.07	19.84	18.13	19.44
2/1/2012	18.68	18.82	17.99	18.55
2/2/2012	18.38	18.5	17.98	17.98
2/3/2012	16.84	17.32	16.1	17.1
2/6/2012	17.98	18.02	16.11	17.76
2/7/2012	17.93	18.1	17.5	17.65
2/8/2012	17.79	18.46	17.53	18.16
2/9/2012	18.12	18.72	18.07	18.63
2/10/2012	20.1	21.98	19.02	20.79
2/13/2012	19.64	19.68	17.92	19.04
2/14/2012	19.45	20.76	18.95	19.54
2/15/2012	19.74	21.77	19.44	21.14
2/16/2012	21.59	21.76	19.22	19.22
2/17/2012	18.73	18.79	17.54	17.78
2/21/2012	18.41	18.94	17.65	18.19
2/22/2012	18.85	18.94	17.74	18.19

2/23/2012	18.73	18.97	16.64	16.8
2/24/2012	16.68	17.62	16.42	17.31
2/27/2012	19.1	19.25	17.58	18.19
2/28/2012	18.67	18.67	17.88	17.96
2/29/2012	17.8	18.75	17.53	18.43
3/1/2012	18.02	18.03	17.26	17.26
3/2/2012	17.65	17.65	17.14	17.29
3/5/2012	18.27	18.9	18.02	18.05
3/6/2012	20.57	21.24	20.3	20.87
3/7/2012	20.43	20.44	19.07	19.07
3/8/2012	18.08	18.46	17.76	17.95
3/9/2012	17.16	17.54	16.63	17.11
3/12/2012	15.79	16.67	15.23	15.64
3/13/2012	14	16.08	13.99	14.8
3/14/2012	14.42	16.19	14.39	15.31
3/15/2012	15.32	16.06	14.58	15.42
3/16/2012	14.43	15.24	13.66	14.47
3/19/2012	15.42	15.43	14.54	15.04
3/20/2012	15.82	15.95	15.11	15.58
3/21/2012	14.72	15.31	14.19	15.13
3/22/2012	16.04	16.58	15.56	15.57
3/23/2012	15.65	16.39	14.69	14.82
3/26/2012	14.51	15.03	14.26	14.26
3/27/2012	14.52	15.59	14.14	15.59
3/28/2012	15.58	17.27	15.4	15.47
3/29/2012	16.84	17.2	15.39	15.48
3/30/2012	14.88	15.98	14.67	15.5
4/2/2012	16.35	16.58	15.02	15.64
4/3/2012	15.61	16.65	15.56	15.66
4/4/2012	17.07	17.74	16.31	16.44
4/5/2012	17.02	17.13	16.29	16.7
4/9/2012	18.94	18.94	17.93	18.81
4/10/2012	19.1	21.06	18.62	20.39
4/11/2012	19.22	20.12	18.73	20.02
4/12/2012	19.63	19.74	17.2	17.2
4/13/2012	17.95	19.62	17.85	19.55
4/16/2012	18.87	20.42	18.6	19.55
4/17/2012	18.66	18.66	17.58	18.46
4/18/2012	19.02	19.17	17.7	18.64
4/19/2012	18.51	19.69	17.69	18.36
4/20/2012	17.92	18.05	16.97	17.44
4/23/2012	20.22	20.27	18.95	18.97
4/24/2012	19.22	19.22	18.09	18.1
4/25/2012	17.05	17.38	16.82	16.82
4/26/2012	16.97	17.04	15.75	16.24
4/27/2012	15.83	16.47	15.83	16.32
4/30/2012	17.04	17.41	16.92	17.15
5/1/2012	17.27	17.49	16.01	16.6
5/2/2012	17.25	17.63	16.78	16.88
5/3/2012	16.9	17.92	16.73	17.56
5/4/2012	18.03	19.28	17.81	19.16
5/7/2012	19.8	19.87	18.41	18.94
5/8/2012	19.44	20.91	17.95	19.05
5/9/2012	20.65	21.59	19.38	20.08
5/10/2012	19.25	19.88	18.77	18.83
5/11/2012	19.93	19.94	18.62	19.89
5/14/2012	21.47	21.87	20.94	21.87
5/15/2012	21.43	22.7	20.76	21.97
5/16/2012	21.54	22.69	20.83	22.27
5/17/2012	21.99	24.51	21.87	24.49
5/18/2012	23.27	25.14	23.07	25.1
5/21/2012	24.88	24.88	22.01	22.01
5/22/2012	21.76	23.19	19.98	22.48
5/23/2012	23.32	24.62	21.99	22.33
5/24/2012	22	23.22	21.48	21.54
5/25/2012	22.05	22.29	21.3	21.76
5/29/2012	21.7	22.47	20.99	21.03
5/30/2012	22.68	24.14	22.66	24.14
5/31/2012	23.83	25.46	22.78	24.06
6/1/2012	25.87	26.71	23.94	26.66
6/4/2012	26.35	27.73	25.72	26.12
6/5/2012	25.9	25.9	24.5	24.68
6/6/2012	23.76	23.89	21.8	22.16
6/7/2012	21	22.48	20.74	21.72
6/8/2012	22.54	23.1	20.29	21.23
6/11/2012	19.87	23.56	19.63	23.56
6/12/2012	23.15	23.9	22.09	22.09
6/13/2012	22.93	24.93	22.66	24.27
6/14/2012	24.19	24.81	21.55	21.68
6/15/2012	22.47	23.09	20.61	21.11
6/18/2012	21.76	21.98	18.24	18.32
6/19/2012	17.66	18.62	17.36	18.38
6/20/2012	17.96	20.05	17.09	17.24
6/21/2012	16.89	20.48	16.77	20.08
6/22/2012	18.65	19.37	17.9	18.11
6/25/2012	20.47	21.36	19.89	20.38
6/26/2012	20.01	20.57	19.42	19.72
6/27/2012	19.55	20.12	19.38	19.45
6/28/2012	20.33	21.19	19.6	19.71
6/29/2012	17.52	19.71	16.87	17.08
7/2/2012	17.62	18.19	16.66	16.8
7/3/2012	16.67	16.92	16.27	16.66
7/5/2012	17.61	18.22	17.18	17.5
7/6/2012	18.2	18.25	16.95	17.1
7/9/2012	18.17	18.32	17.73	17.98
7/10/2012	17.51	19.19	17.29	18.72
7/11/2012	17.98	19.17	17.84	17.95
7/12/2012	18.82	19.51	17.75	18.33
7/13/2012	17.78	17.82	16.36	16.74
7/16/2012	17.31	17.32	16.46	17.11
7/17/2012	16.72	17.46	16.09	16.48
7/18/2012	16.81	16.81	15.69	16.16
7/19/2012	16.06	16.7	15.45	15.45
7/20/2012	16.65	17.05	15.97	16.27
7/23/2012	20.41	20.49	18.34	18.62
7/24/2012	18.38	21	18.37	20.47
7/25/2012	19.79	20.67	18.99	19.34
7/26/2012	17.68	18.47	17.07	17.53

7/27/2012	17.11	17.3	16.52	16.7
7/30/2012	17.55	18.08	17.23	18.03
7/31/2012	18.4	19.09	18.26	18.93
8/1/2012	18.8	19.18	18.2	18.96
8/2/2012	19.05	19.25	17.56	17.57
8/3/2012	16.05	16.45	15.64	15.64
8/6/2012	15.85	16.27	15.82	15.95
8/7/2012	15.55	16.03	15.48	15.99
8/8/2012	16.46	16.47	15.27	15.32
8/9/2012	15.39	15.67	15.28	15.28
8/10/2012	15.34	15.5	14.73	14.74
8/13/2012	14.09	14.67	13.67	13.7
8/14/2012	13.91	15.06	13.91	14.85
8/15/2012	14.82	14.98	14.36	14.63
8/16/2012	14.88	15.15	14.28	14.29
8/17/2012	14.23	14.3	13.3	13.45
8/20/2012	14.11	14.78	13.99	14.02
8/21/2012	14.1	15.44	14.04	15.02
8/22/2012	15.32	15.52	14.75	15.11
8/23/2012	15	16.45	15	15.96
8/24/2012	15.99	16	15.18	15.18
8/27/2012	16.15	16.38	15.75	16.35
8/28/2012	16.32	16.92	16.01	16.49
8/29/2012	16.61	17.06	16.5	17.06
8/30/2012	17.48	18.05	17.44	17.83
8/31/2012	17.25	18.04	16.92	17.47
9/4/2012	18.65	18.96	17.85	17.98
9/5/2012	17.38	17.84	16.99	17.74
9/6/2012	17.3	17.3	15.6	15.6
9/7/2012	15.6	15.6	14.33	14.38
9/10/2012	14.27	16.28	13.97	16.28
9/11/2012	16.11	16.41	15.78	16.41
9/12/2012	15.59	16.31	15.43	15.8
9/13/2012	15.6	16.54	13.91	14.05
9/14/2012	13.82	14.71	13.51	14.51
9/17/2012	14.67	14.92	14.38	14.59
9/18/2012	14.51	14.88	14.17	14.18
9/19/2012	13.95	14.08	13.61	13.88
9/20/2012	14.63	14.67	14.07	14.07
9/21/2012	13.94	14.18	13.69	13.98
9/24/2012	15.06	15.06	13.87	14.15
9/25/2012	14.19	15.72	14.03	15.43
9/26/2012	15.83	17.08	15.83	16.81
9/27/2012	16.38	16.5	14.83	14.84
9/28/2012	15.23	15.77	14.95	15.73
10/1/2012	16.03	16.53	15.13	16.32
10/2/2012	15.85	16.5	15.7	15.71
10/3/2012	15.63	16.02	15.13	15.43
10/4/2012	15.23	15.33	14.53	14.55
10/5/2012	13.68	14.78	13.67	14.33
10/8/2012	15.19	15.46	15.04	15.11
10/9/2012	15.28	16.4	15.18	16.37
10/10/2012	16.52	16.79	16.13	16.29
10/11/2012	15.33	15.8	15.31	15.59
10/12/2012	15.41	16.18	14.96	16.14
10/15/2012	16.05	16.21	15.23	15.27
10/16/2012	14.84	15.23	14.5	15.22
10/17/2012	15.43	15.63	14.9	15.07
10/18/2012	15.25	15.5	14.68	15.03
10/19/2012	14.91	17.6	14.9	17.06
10/22/2012	17.44	17.98	16.62	16.62
10/23/2012	18.23	19.65	18.17	18.83
10/24/2012	18.22	18.67	17.93	18.33
10/25/2012	17.56	18.64	17.3	18.12
10/26/2012	18.03	18.64	17.52	17.81
10/31/2012	17.68	18.84	17.56	18.6
11/1/2012	17.77	17.79	16.45	16.69
11/2/2012	16.06	17.6	16.05	17.59
11/5/2012	18.33	18.7	18.13	18.42
11/6/2012	18.16	18.17	17.19	17.58
11/7/2012	17.72	19.4	17.62	19.08
11/8/2012	18.69	18.69	17.96	18.49
11/9/2012	18.8	18.81	17.67	18.61
11/12/2012	18.15	18.15	16.45	16.68
11/13/2012	17.36	17.38	16.12	16.65
11/14/2012	16.32	18.05	15.93	17.92
11/15/2012	17.74	18.64	17.62	17.99
11/16/2012	17.65	18.5	16.41	16.41
11/19/2012	15.88	15.98	15.1	15.24
11/20/2012	15.11	15.65	15.06	15.08
11/21/2012	14.96	15.43	14.77	15.31
11/23/2012	15	15.26	15	15.14
11/26/2012	15.63	15.84	15.47	15.5
11/27/2012	15.3	15.93	15.01	15.92
11/28/2012	16.43	16.98	15.47	15.51
11/29/2012	15.21	15.51	15.02	15.06
11/30/2012	15.26	16.17	14.89	15.87
12/3/2012	15.81	16.69	15.76	16.64
12/4/2012	16.66	17.37	16.38	17.12
12/5/2012	16.95	17.53	16.27	16.46
12/6/2012	16.59	16.85	16.31	16.58
12/7/2012	16.12	16.65	15.73	15.9
12/10/2012	16.47	16.47	15.96	16.05
12/11/2012	15.94	16.01	15.42	15.57
12/12/2012	15.6	16.09	15.41	15.95
12/13/2012	15.87	16.67	15.71	16.56
12/14/2012	16.68	17.15	16.61	17
12/17/2012	17.2	17.2	16.21	16.34
12/18/2012	16.39	16.43	15.46	15.57
12/19/2012	16.05	17.46	16.04	17.36
12/20/2012	17.26	17.96	17.11	17.67
12/21/2012	19.85	19.93	17.76	17.84
12/24/2012	18.46	18.66	17.84	17.84
12/26/2012	18.71	19.63	18.61	19.48
12/27/2012	19.39	20.9	19.11	19.47
12/28/2012	20.32	23.23	19.94	22.72
12/31/2012	22.14	22.72	17.88	18.02
1/2/2013	15.24	15.93	14.6	14.68

1/3/2013	14.77	14.92	14.24	14.56
1/4/2013	14.23	14.31	13.64	13.83
1/7/2013	14.53	14.53	13.71	13.79
1/8/2013	13.88	14.29	13.62	13.62
1/9/2013	13.32	13.93	13.22	13.81
1/10/2013	13.33	13.88	13.33	13.49
1/11/2013	13.55	13.79	13.22	13.36
1/14/2013	13.66	13.85	13.41	13.52
1/15/2013	13.97	13.99	13.33	13.55
1/16/2013	13.7	13.76	13.2	13.42
1/17/2013	13.45	13.7	13.16	13.57
1/18/2013	13.52	13.53	12.29	12.46
1/22/2013	13.28	13.32	12.43	12.43
1/23/2013	12.67	12.67	12.3	12.46
1/24/2013	12.73	13.5	12.4	12.69
1/25/2013	12.63	12.99	12.5	12.89
1/28/2013	13.29	13.91	13.29	13.57
1/29/2013	13.87	13.88	13.04	13.31
1/30/2013	13.64	14.33	13.6	14.32
1/31/2013	14.43	14.43	14.04	14.28
2/1/2013	13.37	13.38	12.72	12.9
2/4/2013	14	14.75	13.8	14.67
2/5/2013	14.21	14.21	13.39	13.72
2/6/2013	14.06	14.08	13.34	13.41
2/7/2013	13.47	14.41	13.43	13.5
2/8/2013	13.2	13.2	12.89	13.02
2/11/2013	13.37	13.42	12.91	12.94
2/12/2013	12.82	13.13	12.63	12.64
2/13/2013	12.88	13.19	12.67	12.98
2/14/2013	13.3	13.32	12.64	12.66
2/15/2013	12.47	12.89	12.24	12.46
2/19/2013	12.81	12.85	12.08	12.31
2/20/2013	12.32	14.68	12.32	14.68
2/21/2013	14.68	16.21	14.67	15.22
2/22/2013	14.6	15.02	14.16	14.17
2/25/2013	13.69	19.28	13.57	18.99
2/26/2013	17.5	18.23	16.75	16.87
2/27/2013	16.57	16.6	14.42	14.73
2/28/2013	15	15.6	14.16	15.51
3/1/2013	16.1	16.82	15.14	15.36
3/4/2013	16.16	16.16	14.01	14.01
3/5/2013	13.44	13.66	13.24	13.48
3/6/2013	13.18	13.77	13.17	13.53
3/7/2013	13.45	13.56	13.03	13.06
3/8/2013	12.67	13.3	12.49	12.59
3/11/2013	12.31	12.34	11.5	11.56
3/12/2013	11.79	12.93	11.74	12.27
3/13/2013	12.18	12.55	11.79	11.83
3/14/2013	11.7	11.75	11.05	11.3
3/15/2013	11.52	11.99	11.21	11.3
3/18/2013	13.47	13.64	12.57	13.36
3/19/2013	13.03	15.4	12.92	14.39
3/20/2013	13.18	13.18	12.3	12.67
3/21/2013	13.07	14.21	12.62	13.99
3/22/2013	13.34	13.85	13.19	13.57
3/25/2013	12.85	14.61	12.39	13.74
3/26/2013	12.95	13.21	12.69	12.77
3/27/2013	13.72	13.97	12.97	13.15
3/28/2013	12.91	13.07	12.54	12.7
4/1/2013	13.46	14.05	13.26	13.58
4/2/2013	13.11	13.18	12.76	12.78
4/3/2013	12.65	14.66	12.62	14.21
4/4/2013	14.1	14.79	13.89	13.89
4/5/2013	15.64	15.65	13.86	13.92
4/8/2013	14.04	14.5	13.19	13.19
4/9/2013	13.11	13.68	12.75	12.84
4/10/2013	12.66	12.88	12.32	12.36
4/11/2013	12.55	12.62	12.15	12.24
4/12/2013	12.61	13.12	11.99	12.06
4/15/2013	13.12	17.27	12.66	17.27
4/16/2013	14.72	14.87	13.91	13.96
4/17/2013	15.35	17.9	14.98	16.51
4/18/2013	16.34	18.2	16.32	17.56
4/19/2013	16.67	16.98	14.87	14.97
4/22/2013	15.08	16	14.04	14.39
4/23/2013	13.81	14.87	13.46	13.48
4/24/2013	13.57	13.75	13.36	13.61
4/25/2013	13.61	13.87	13.13	13.62
4/26/2013	13.94	14.18	13.49	13.61
4/29/2013	13.72	13.94	13.36	13.71
4/30/2013	13.71	14.28	13.51	13.52
5/1/2013	13.88	14.67	13.87	14.49
5/2/2013	14.48	14.48	13.58	13.59
5/3/2013	12.92	13.15	12.77	12.85
5/6/2013	13.06	13.19	12.66	12.66
5/7/2013	12.63	12.96	12.49	12.83
5/8/2013	12.87	13.04	12.62	12.66
5/9/2013	12.91	13.53	12.78	13.13
5/10/2013	13.08	13.45	12.54	12.59
5/13/2013	12.57	12.87	12.49	12.55
5/14/2013	12.61	13.21	12.54	12.77
5/15/2013	12.98	13.43	12.78	12.81
5/16/2013	13.07	13.46	12.79	13.07
5/17/2013	12.73	12.94	12.26	12.45
5/20/2013	13.28	13.28	12.84	13.02
5/21/2013	13.08	13.44	12.89	13.37
5/22/2013	13.45	14.45	13.05	13.82
5/23/2013	14.94	15.11	13.87	14.07
5/24/2013	14.59	14.79	13.99	13.99
5/28/2013	13.67	14.56	13.56	14.48
5/29/2013	15.3	15.65	14.59	14.83
5/30/2013	14.9	14.98	14.27	14.53
5/31/2013	15.02	16.35	14.36	16.3
6/3/2013	16.4	17.58	16.15	16.28
6/4/2013	16.16	17.25	15.82	16.27
6/5/2013	16.86	17.84	16.57	17.5
6/6/2013	17.7	18.51	16.6	16.63
6/7/2013	15.9	16.21	14.96	15.14

6/10/2013	15.16	15.6	15.1	15.44
6/11/2013	16.91	17.14	16	17.07
6/12/2013	16.51	18.6	16.43	18.59
6/13/2013	18.38	18.58	16.37	16.41
6/14/2013	16.63	17.26	16.03	17.15
6/17/2013	16.53	17.62	16.33	16.8
6/18/2013	16.81	16.95	16.46	16.61
6/19/2013	16.89	17.18	15.36	16.64
6/20/2013	18.4	21.32	18.01	20.49
6/21/2013	18.97	20.93	18.25	18.9
6/24/2013	20.87	21.91	18.58	20.11
6/25/2013	18.65	19.22	17.82	18.47
6/26/2013	17.23	18.06	17.08	17.21
6/27/2013	16.6	16.97	16.34	16.86
6/28/2013	17.25	17.69	16.19	16.86
7/1/2013	16.9	16.9	16	16.37
7/2/2013	16.49	16.93	15.88	16.44
7/3/2013	17.22	17.32	16.2	16.2
7/5/2013	15.59	16.28	14.89	14.89
7/8/2013	14.66	15.27	14.66	14.78
7/9/2013	14.33	14.65	14.26	14.35
7/10/2013	14.46	14.62	14.06	14.21
7/11/2013	13.57	14.2	13.57	14.01
7/12/2013	13.9	14.04	13.74	13.84
7/15/2013	13.98	14.11	13.5	13.79
7/16/2013	13.78	14.56	13.78	14.42
7/17/2013	14.2	14.44	13.76	13.78
7/18/2013	13.63	13.8	13.2	13.77
7/19/2013	13.89	13.97	12.54	12.54
7/22/2013	13.23	13.37	12.29	12.29
7/23/2013	12.15	13.06	12.07	12.66
7/24/2013	12.69	13.49	12.69	13.18
7/25/2013	13.47	13.54	12.91	12.97
7/26/2013	13.41	13.73	12.71	12.72
7/29/2013	13.54	13.86	13.38	13.39
7/30/2013	13.45	14.14	13.35	13.39
7/31/2013	13.55	13.83	12.94	13.45
8/1/2013	12.89	13.25	12.82	12.94
8/2/2013	12.66	12.74	11.98	11.98
8/5/2013	12.29	12.42	11.83	11.84
8/6/2013	12.19	12.93	12.06	12.72
8/7/2013	13.17	13.91	12.96	12.98
8/8/2013	12.5	13.13	12.37	12.73
8/9/2013	12.88	13.66	12.71	13.41
8/12/2013	13.52	13.57	12.8	12.81
8/13/2013	12.86	13.37	12.29	12.31
8/14/2013	12.48	13.09	12.35	13.04
8/15/2013	14.14	14.85	13.91	14.73
8/16/2013	14.56	14.88	13.62	14.37
8/19/2013	14.94	15.2	14.35	15.1
8/20/2013	15.22	15.25	14.29	14.91
8/21/2013	16	16.56	14.67	15.94
8/22/2013	15.26	15.26	14.66	14.76
8/23/2013	14.29	14.82	13.98	13.98
8/26/2013	14.37	15.01	13.9	14.99
8/27/2013	16.56	17.13	15.82	16.77
8/28/2013	16.96	17.11	16.1	16.49
8/29/2013	16.79	16.98	15.99	16.81
8/30/2013	16.75	17.81	16.7	17.01
9/3/2013	16.47	17.37	16.11	16.61
9/4/2013	16.88	17.01	15.77	15.88
9/5/2013	16.12	16.12	15.63	15.77
9/6/2013	15.35	16.81	15.17	15.85
9/9/2013	15.86	16.02	15.22	15.63
9/10/2013	14.89	15.09	14.5	14.53
9/11/2013	14.74	14.74	13.82	13.82
9/12/2013	13.93	14.39	13.73	14.29
9/13/2013	14.27	14.55	14.11	14.16
9/16/2013	14.1	14.49	13.87	14.38
9/17/2013	14.44	14.61	14.28	14.53
9/18/2013	14.68	14.68	13.23	13.59
9/19/2013	13.02	13.39	13.02	13.16
9/20/2013	13.3	13.47	12.52	13.12
9/23/2013	14.04	14.71	14.02	14.31
9/24/2013	14.17	14.37	13.75	14.08
9/25/2013	14.24	14.62	13.89	14.01
9/26/2013	13.8	14.4	13.58	14.06
9/27/2013	14.62	15.79	14.62	15.46
9/30/2013	17.49	17.49	16.16	16.6
10/1/2013	16.31	16.46	15.47	15.54
10/2/2013	16.4	16.81	16.13	16.6
10/3/2013	16.63	18.71	16.63	17.67
10/4/2013	17.72	17.87	16.66	16.74
10/7/2013	18.76	19.41	18.08	19.41
10/8/2013	19.01	21.01	18.98	20.34
10/9/2013	20.19	21.34	19.04	19.6
10/10/2013	17.66	17.92	16.29	16.48
10/11/2013	16.31	16.38	15.46	15.72
10/14/2013	17.08	17.74	15.8	16.07
10/15/2013	16.41	18.67	16.16	18.66
10/16/2013	17.14	17.15	14.67	14.71
10/17/2013	14.52	14.59	12.89	13.48
10/18/2013	12.86	13.53	12.34	13.04
10/21/2013	13.34	13.63	13.07	13.16
10/22/2013	12.99	13.92	12.93	13.33
10/23/2013	13.71	14.21	13.42	13.42
10/24/2013	13.5	13.62	13.15	13.2
10/25/2013	13.16	13.44	13.08	13.09
10/28/2013	13.62	13.72	13.22	13.31
10/29/2013	13.25	13.63	13.06	13.41
10/30/2013	13.72	21.26	13.64	13.65
10/31/2013	13.83	14.02	13.28	13.75
11/1/2013	13.46	13.92	13.22	13.28
11/4/2013	13.35	13.67	12.91	12.93
11/5/2013	13.22	13.64	12.86	13.27
11/6/2013	13.01	13.33	12.67	12.67
11/7/2013	12.99	14.14	12.93	13.91
11/8/2013	13.76	13.8	12.84	12.9

11/11/2013	12.85	12.93	12.4	12.53
11/12/2013	12.8	13.06	12.63	12.82
11/13/2013	13.35	13.35	12.46	12.52
11/14/2013	12.8	12.94	12.28	12.37
11/15/2013	12.12	12.45	11.99	12.19
11/18/2013	12.41	13.22	12.41	13.1
11/19/2013	13.03	13.68	12.88	13.39
11/20/2013	13.56	13.94	12.97	13.4
11/21/2013	13.09	13.09	12.44	12.66
11/22/2013	12.69	12.91	12.24	12.26
11/25/2013	12.55	12.92	12.49	12.79
11/26/2013	12.84	12.99	12.49	12.81
11/27/2013	12.81	12.98	12.44	12.98
11/29/2013	13.06	13.78	12.93	13.7
12/2/2013	13.91	14.31	13.78	14.23
12/3/2013	14.74	15.04	14.43	14.55
12/4/2013	15.03	15.71	14.22	14.7
12/5/2013	14.82	15.38	14.7	15.08
12/6/2013	13.97	14.09	13.62	13.79
12/9/2013	13.97	14.07	13.49	13.49
12/10/2013	14.14	14.22	13.69	13.91
12/11/2013	13.98	15.43	13.98	15.42
12/12/2013	15.44	16.09	15.21	15.54
12/13/2013	15.17	15.8	15.06	15.76
12/16/2013	15.64	16.08	15.3	16.03
12/17/2013	16.04	16.67	15.81	16.21
12/18/2013	15.95	16.75	13.74	13.8
12/19/2013	13.59	14.21	12.89	14.15
12/20/2013	13.61	13.87	13.12	13.79
12/23/2013	13.37	13.53	13.02	13.04
12/24/2013	12.85	12.89	12.48	12.48
12/26/2013	12.48	12.5	11.69	12.33
12/27/2013	12.21	12.59	12.2	12.46
12/30/2013	12.87	13.58	12.83	13.56
12/31/2013	13.43	14.35	13.38	13.72
1/2/2014	14.32	14.59	14	14.23
1/3/2014	14.06	14.22	13.57	13.76
1/6/2014	13.41	14	13.22	13.55
1/7/2014	12.38	13.28	12.16	12.92
1/8/2014	13.04	13.24	12.86	12.87
1/9/2014	12.83	13.26	12.83	12.89
1/10/2014	12.6	12.9	12.14	12.14
1/13/2014	12.18	13.65	11.82	13.28
1/14/2014	12.89	12.9	11.96	12.28
1/15/2014	12.15	12.4	11.81	12.28
1/16/2014	12.32	12.66	12.28	12.53
1/17/2014	12.34	12.93	12.04	12.44
1/21/2014	12.63	13.42	12.61	12.87
1/22/2014	12.57	13.12	12.55	12.84
1/23/2014	13.67	14.66	13.67	13.77
1/24/2014	14.95	18.14	14.92	18.14
1/27/2014	17.29	18.99	16.85	17.42
1/28/2014	17.27	17.28	15.8	15.8
1/29/2014	17.95	18.04	16.71	17.35
1/30/2014	16.37	17.39	15.96	17.29
1/31/2014	18.71	18.99	17.27	18.41
2/3/2014	18.57	21.48	18.34	21.44
2/4/2014	19.99	20.07	18.44	19.11
2/5/2014	19.59	20.72	19.13	19.95
2/6/2014	19.09	19.09	17.09	17.23
2/7/2014	16.15	16.31	15.09	15.29
2/10/2014	15.63	15.76	15.1	15.26
2/11/2014	15.29	15.29	14.08	14.51
2/12/2014	14.31	14.64	14.02	14.3
2/13/2014	15.24	15.24	13.98	14.14
2/14/2014	14.21	14.22	13.44	13.57
2/18/2014	13.95	14.51	13.77	13.87
2/19/2014	14.85	15.73	14.12	15.5
2/20/2014	15.28	15.8	14.59	14.79
2/21/2014	14.74	14.79	14.19	14.68
2/24/2014	14.83	14.83	13.97	14.23
2/25/2014	14.17	14.83	13.66	13.67
2/26/2014	13.83	14.54	13.73	14.35
2/27/2014	14.56	14.69	13.92	14.04
2/28/2014	14.22	14.79	13.49	14
3/3/2014	16.47	16.78	15.38	16
3/4/2014	14.53	14.54	14	14.1
3/5/2014	14.13	14.32	13.81	13.89
3/6/2014	13.82	14.42	13.73	14.21
3/7/2014	13.51	14.43	13.51	14.11
3/10/2014	14.76	15.28	14.2	14.2
3/11/2014	14.22	14.93	13.84	14.8
3/12/2014	15.37	15.64	14.43	14.47
3/13/2014	14.28	16.66	14.24	16.22
3/14/2014	16.74	18.22	16.09	17.82
3/17/2014	16.39	16.4	15.37	15.64
3/18/2014	15.42	15.47	14.16	14.52
3/19/2014	14.56	15.95	13.89	15.12
3/20/2014	15.58	15.62	14.5	14.52
3/21/2014	13.96	15.17	13.77	15
3/24/2014	14.7	16.07	14.56	15.09
3/25/2014	14.16	15.05	13.96	14.02
3/26/2014	13.64	15.28	13.46	14.93
3/27/2014	15	15.63	14.49	14.62
3/28/2014	14.15	14.86	13.73	14.41
3/31/2014	13.88	14.16	13.57	13.88
4/1/2014	13.43	13.56	13.06	13.1
4/2/2014	13.17	13.35	12.92	13.09
4/3/2014	13.02	13.7	13.02	13.37
4/4/2014	12.88	14.55	12.6	13.96
4/7/2014	14.96	16.01	14.57	15.57
4/8/2014	15.59	16.2	14.81	14.89
4/9/2014	14.58	14.94	13.7	13.82
4/10/2014	13.98	16.38	13.81	15.89
4/11/2014	16.66	17.85	15.89	17.03
4/14/2014	16.14	17.4	16.1	16.11
4/15/2014	16.14	17.5	15.47	15.61
4/16/2014	14.89	15.27	14.05	14.18

4/17/2014	14.09	14.17	13.07	13.36
4/21/2014	14.1	14.11	13.17	13.25
4/22/2014	13.13	13.26	12.9	13.19
4/23/2014	13.35	13.75	13.27	13.27
4/24/2014	13.36	14.08	13.09	13.32
4/25/2014	13.93	14.67	13.91	14.06
4/28/2014	14.27	15.28	13.82	13.97
4/29/2014	13.88	14.24	13.61	13.71
4/30/2014	14.05	14.18	13.34	13.41
5/1/2014	13.64	13.75	13.1	13.25
5/2/2014	13.15	13.5	12.83	12.91
5/5/2014	13.95	14.2	13.08	13.29
5/6/2014	13.65	13.9	13.28	13.8
5/7/2014	13.64	14.49	13.39	13.4
5/8/2014	13.69	13.88	12.92	13.43
5/9/2014	13.55	14.03	12.87	12.92
5/12/2014	12.46	12.58	11.88	12.23
5/13/2014	12.36	12.74	12.05	12.13
5/14/2014	12.42	12.51	12.03	12.17
5/15/2014	12.73	13.77	12.72	13.17
5/16/2014	13.31	13.66	12.26	12.44
5/19/2014	13.17	13.21	12.28	12.42
5/20/2014	12.69	13.3	12.32	12.96
5/21/2014	12.38	12.46	11.8	11.91
5/22/2014	11.93	12.09	11.68	12.03
5/23/2014	11.96	11.97	11.36	11.36
5/27/2014	11.69	11.84	11.5	11.51
5/28/2014	11.6	11.86	11.5	11.68
5/29/2014	11.58	11.82	11.41	11.57
5/30/2014	11.66	11.7	11.32	11.4
6/2/2014	11.69	12.17	11.29	11.58
6/3/2014	12.03	12.13	11.72	11.87
6/4/2014	12.15	12.33	11.91	12.08
6/5/2014	12.09	12.34	11.44	11.68
6/6/2014	11.32	11.39	10.73	10.73
6/9/2014	11.23	11.51	10.99	11.15
6/10/2014	11.3	11.66	10.93	10.99
6/11/2014	11.42	11.87	11.19	11.6
6/12/2014	11.81	12.81	11.71	12.56
6/13/2014	12.45	12.69	11.89	12.18
6/16/2014	12.65	12.87	12.28	12.65
6/17/2014	12.81	12.89	12.06	12.06
6/18/2014	11.8	11.91	10.57	10.61
6/19/2014	10.53	10.82	10.42	10.62
6/20/2014	10.4	11.02	10.34	10.85
6/23/2014	11.26	11.35	10.92	10.98
6/24/2014	11.02	12.27	10.87	12.13
6/25/2014	12.31	12.33	11.37	11.59
6/26/2014	11.51	12.51	11.5	11.63
6/27/2014	11.72	12.04	11.19	11.26
6/30/2014	11.75	11.81	11.3	11.57
7/1/2014	11.28	11.42	10.92	11.15
7/2/2014	11.18	11.18	10.56	10.82
7/3/2014	10.47	10.76	10.28	10.32
7/7/2014	11.15	11.54	11.01	11.33
7/8/2014	11.72	12.51	11.72	11.98
7/9/2014	11.74	12.05	11.5	11.65
7/10/2014	13.22	13.23	12.05	12.59
7/11/2014	12.5	12.68	12.07	12.08
7/14/2014	11.6	11.83	11.4	11.82
7/15/2014	11.53	12.47	11.46	11.96
7/16/2014	10.81	11.45	10.59	11
7/17/2014	11.35	15.38	10.85	14.54
7/18/2014	13.34	13.55	12.04	12.06
7/21/2014	12.85	13.62	12.46	12.81
7/22/2014	11.97	12.24	11.69	12.24
7/23/2014	11.54	12.16	11.41	11.52
7/24/2014	11.43	12.06	11.43	11.84
7/25/2014	12.03	12.75	12.03	12.69
7/28/2014	12.93	13.64	12.54	12.56
7/29/2014	12.35	13.35	12.12	13.28
7/30/2014	12.63	14.07	12.53	13.33
7/31/2014	14.35	17.11	14.26	16.95
8/1/2014	16.67	17.57	15.52	17.03
8/4/2014	16.64	16.8	14.69	15.12
8/5/2014	15.54	17.14	15.1	16.87
8/6/2014	17.22	17.3	15.7	16.37
8/7/2014	15.5	17.25	15.44	16.66
8/8/2014	16.43	17.09	15.53	15.77
8/11/2014	15.16	15.16	13.72	14.23
8/12/2014	14.42	14.74	13.76	14.13
8/13/2014	13.57	13.93	12.84	12.9
8/14/2014	13.05	13.13	12.42	12.42
8/15/2014	11.91	14.94	11.89	13.15
8/18/2014	12.85	12.85	12.26	12.32
8/19/2014	12.14	12.46	11.91	12.21
8/20/2014	12.23	12.24	11.6	11.78
8/21/2014	11.93	13.51	11.52	11.76
8/22/2014	11.88	12.48	11.47	11.47
8/25/2014	11.58	11.77	11.24	11.7
8/26/2014	11.33	11.93	11.33	11.63
8/27/2014	11.69	11.93	11.54	11.78
8/28/2014	12.38	12.73	12.05	12.05
8/29/2014	11.86	12.44	11.78	11.98
9/2/2014	12.32	13.41	12.23	12.25
9/3/2014	12.03	12.55	11.91	12.36
9/4/2014	12.4	12.99	11.7	12.64
9/5/2014	12.37	13.18	11.96	12.09
9/8/2014	12.64	13.09	12.4	12.66
9/9/2014	12.7	13.91	12.7	13.5
9/10/2014	13.36	14.06	12.86	12.88
9/11/2014	13.53	13.67	12.66	12.8
9/12/2014	12.85	14.27	12.85	13.31
9/15/2014	13.54	14.19	13.54	14.12
9/16/2014	14.48	14.53	12.72	12.73
9/17/2014	13.06	14.53	11.73	12.65
9/18/2014	12.55	12.58	11.98	12.03
9/19/2014	11.73	12.61	11.52	12.11

9/22/2014	13.14	13.98	13.13	13.69
9/23/2014	14.82	14.94	13.83	14.93
9/24/2014	14.62	14.93	13.24	13.27
9/25/2014	14.11	16.69	14.03	15.64
9/26/2014	15.77	15.98	14.31	14.85
9/29/2014	16.96	17.08	15.45	15.98
9/30/2014	15.49	16.43	15.18	16.31
10/1/2014	16.44	17.56	16.08	16.71
10/2/2014	16.7	17.98	15.9	16.16
10/3/2014	15.16	15.43	14.44	14.55
10/6/2014	14.46	15.77	14.05	15.46
10/7/2014	16.18	17.46	15.97	17.2
10/8/2014	17.35	18.03	14.97	15.11
10/9/2014	15.64	19.38	15.34	18.76
10/10/2014	19.11	22.06	18.14	21.24
10/13/2014	21.16	24.64	20.52	24.64
10/14/2014	23.77	24.55	21.48	22.79
10/15/2014	26.36	31.06	24.64	26.25
10/16/2014	29.26	29.41	24.61	25.2
10/17/2014	21.68	23.08	20.23	21.99
10/20/2014	22.11	22.16	18.51	18.57
10/21/2014	17.72	17.75	16.03	16.08
10/22/2014	16.06	18.43	15.56	17.87
10/23/2014	16.07	17.06	15.68	16.53
10/24/2014	16.43	18.06	16.09	16.11
10/27/2014	17.24	17.87	16	16.04
10/28/2014	15.69	15.78	14.39	14.39
10/29/2014	14.61	16.28	14.19	15.15
10/30/2014	15.31	15.75	14.07	14.52
10/31/2014	13.84	14.83	13.72	14.03
11/3/2014	14.41	14.99	14.23	14.73
11/4/2014	15.05	15.93	14.83	14.89
11/5/2014	14.15	14.99	14.15	14.17
11/6/2014	14.46	15.08	13.67	13.67
11/7/2014	13.71	14.16	13.01	13.12
11/10/2014	13.16	13.25	12.38	12.67
11/11/2014	12.71	13.18	12.6	12.92
11/12/2014	13.76	13.76	12.99	13.02
11/13/2014	13.33	14.31	12.87	13.79
11/14/2014	13.79	14.15	13.31	13.31
11/17/2014	14.7	14.73	13.84	13.99
11/18/2014	13.86	13.99	13.13	13.86
11/19/2014	14.01	14.78	13.83	13.96
11/20/2014	14.66	15.74	13.58	13.58
11/21/2014	13.16	13.8	12.9	12.9
11/24/2014	12.92	13.02	12.43	12.62
11/25/2014	12.55	13.02	12.23	12.25
11/26/2014	12.27	12.4	11.91	12.07
11/28/2014	12.64	13.49	12.36	13.33
12/1/2014	14.16	14.75	13.94	14.29
12/2/2014	14.1	14.17	12.85	12.85
12/3/2014	12.75	12.88	12.21	12.47
12/4/2014	12.7	13.23	12.09	12.38
12/5/2014	12.08	12.28	11.53	11.82
12/8/2014	13.05	14.67	12.55	14.21
12/9/2014	16.23	16.68	14.84	14.89
12/10/2014	15.56	18.92	15.4	18.53
12/11/2014	17.68	20.13	15.94	20.08
12/12/2014	20.51	23.06	18.34	21.08
12/15/2014	19.59	24.83	17.77	20.42
12/16/2014	23.55	25.2	19.6	23.57
12/17/2014	23.9	24.61	19.26	19.44
12/18/2014	17.14	18.51	16.07	16.81
12/19/2014	16.57	17.2	16.11	16.49
12/22/2014	16.32	16.88	15.03	15.25
12/23/2014	14.47	15.21	14.32	14.8
12/24/2014	14.52	14.54	14.01	14.37
12/26/2014	14.6	14.84	14.13	14.5
12/29/2014	16.04	16.14	15.06	15.06
12/30/2014	15.9	16.2	15.48	15.92
12/31/2014	15.91	19.91	15.86	19.2
1/2/2015	17.76	20.14	17.05	17.79
1/5/2015	19.19	21.29	19.19	19.92
1/6/2015	20.33	22.9	19.52	21.12
1/7/2015	20.15	20.72	19.04	19.31
1/8/2015	17.93	18.09	16.99	17.01
1/9/2015	16.44	18.42	16.44	17.55
1/12/2015	18.02	20.44	18.02	19.6
1/13/2015	18.21	21.58	17.65	20.56
1/14/2015	22.87	23.34	21.32	21.48
1/15/2015	21.23	23.31	20.86	22.39
1/16/2015	22.8	23.43	20.95	20.95
1/20/2015	20.07	21.37	19.58	19.89
1/21/2015	20.92	21.28	18.64	18.85
1/22/2015	17.98	19.23	16.07	16.4
1/23/2015	16.79	17.09	15.81	16.66
1/26/2015	16.96	17.43	15.52	15.52
1/27/2015	17.6	18.41	16.67	17.22
1/28/2015	16.97	20.44	16.92	20.44
1/29/2015	20.46	21.56	18.66	18.76
1/30/2015	20.23	22.18	19.24	20.97
2/2/2015	20.89	22.81	19.35	19.43
2/3/2015	18.41	18.89	17.2	17.33
2/4/2015	17.82	18.38	16.82	18.33
2/5/2015	17.29	17.43	16.67	16.85
2/6/2015	16.29	18.74	16.06	17.29
2/9/2015	19.16	19.28	18.21	18.55
2/10/2015	17.72	18.36	16.97	17.23
2/11/2015	17.43	17.81	16.82	16.96
2/12/2015	16.39	16.47	15.28	15.34
2/13/2015	15.11	15.64	14.69	14.69
2/17/2015	15.86	16.33	15.53	15.8
2/18/2015	16.74	16.74	15.44	15.45
2/19/2015	16.11	16.22	15.1	15.29
2/20/2015	15.73	16.29	14.27	14.3
2/23/2015	15.05	15.48	14.49	14.56
2/24/2015	14.5	14.63	13.53	13.69
2/25/2015	13.64	14.06	12.86	13.84

2/26/2015	13.55	14.57	13.55	13.91
2/27/2015	14.07	14.17	13.29	13.34
3/2/2015	13.9	13.9	12.87	13.04
3/3/2015	13.35	14.69	13.25	13.86
3/4/2015	14.31	15.33	14.13	14.23
3/5/2015	14.01	14.58	13.88	14.04
3/6/2015	14.61	15.83	14.18	15.2
3/9/2015	15.72	15.76	14.71	15.06
3/10/2015	16.47	16.91	16.03	16.69
3/11/2015	16.44	17.19	16.29	16.87
3/12/2015	16.45	16.45	15.3	15.42
3/13/2015	15.47	16.74	15.32	16
3/16/2015	15.78	15.89	15.36	15.61
3/17/2015	16.31	16.37	15.66	15.66
3/18/2015	14.6	16.29	13.38	13.97
3/19/2015	14.68	14.97	13.84	14.07
3/20/2015	13.52	13.53	12.54	13.02
3/23/2015	13.52	13.53	12.89	13.41
3/24/2015	13.36	13.68	12.59	13.62
3/25/2015	13.26	15.55	13.2	15.44
3/26/2015	16.64	17.19	15.23	15.8
3/27/2015	15.73	15.83	14.19	15.07
3/30/2015	14.76	14.76	14.08	14.51
3/31/2015	14.97	15.74	14.33	15.29
4/1/2015	15.32	16.66	15.08	15.11
4/2/2015	15.3	15.51	14.27	14.67
4/6/2015	15.75	15.76	14.04	14.74
4/7/2015	14.57	14.81	14.01	14.78
4/8/2015	14.59	14.77	13.75	13.98
4/9/2015	14.14	14.59	13.09	13.09
4/10/2015	13.2	13.26	12.51	12.58
4/13/2015	13.17	14.31	12.71	13.94
4/14/2015	14.34	14.74	13.64	13.67
4/15/2015	13.58	13.58	12.83	12.84
4/16/2015	13.27	13.35	12.5	12.6
4/17/2015	13.97	15.02	13.73	13.89
4/20/2015	13.67	13.67	12.83	13.3
4/21/2015	12.75	13.51	12.66	13.25
4/22/2015	12.97	13.8	12.57	12.71
4/23/2015	12.96	12.96	12.12	12.48
4/24/2015	12.21	13.02	12.16	12.29
4/27/2015	12.34	13.4	12.33	13.12
4/28/2015	13.26	14.23	12.41	12.41
4/29/2015	13.44	14.34	12.61	13.39
4/30/2015	13.89	15.29	12.49	14.55
5/1/2015	13.98	13.98	12.68	12.7
5/4/2015	13.12	13.18	12.1	12.85
5/5/2015	13.21	14.41	12.97	14.31
5/6/2015	13.93	16.36	13.89	15.15
5/7/2015	15.48	15.97	14.81	15.13
5/8/2015	13.36	13.42	12.7	12.86
5/11/2015	13.35	13.85	13	13.85
5/12/2015	14.73	15.13	13.73	13.86
5/13/2015	13.63	14.04	13.06	13.76
5/14/2015	13.14	13.29	12.72	12.74
5/15/2015	12.46	13.09	12.35	12.38
5/18/2015	13.08	13.22	12.55	12.73
5/19/2015	12.95	13.13	12.55	12.85
5/20/2015	12.9	13.27	12.62	12.88
5/21/2015	13.03	13.09	12.09	12.11
5/22/2015	12.37	12.37	11.82	12.13
5/26/2015	13.45	14.63	13.34	14.06
5/27/2015	14.16	14.41	13.05	13.27
5/28/2015	13.49	13.99	13.31	13.31
5/29/2015	13.59	14.43	13.4	13.84
6/1/2015	13.92	14.86	13.47	13.97
6/2/2015	14.72	15.05	13.59	14.24
6/3/2015	13.73	14.2	13.4	13.66
6/4/2015	14.57	15.49	13.99	14.71
6/5/2015	15.01	15.65	14.21	14.21
6/8/2015	14.84	15.5	14.67	15.29
6/9/2015	15.18	15.74	14.47	14.47
6/10/2015	14.24	14.37	12.96	13.22
6/11/2015	13.04	13.22	12.56	12.85
6/12/2015	13.31	14.02	13.3	13.78
6/15/2015	15.48	15.57	14.91	15.39
6/16/2015	15.62	15.62	14.81	14.81
6/17/2015	14.66	15.49	14.07	14.5
6/18/2015	14.03	14.03	12.54	13.19
6/19/2015	13.35	14	12.96	13.96
6/22/2015	13.42	13.46	12.43	12.74
6/23/2015	12.5	12.68	11.93	12.11
6/24/2015	12.57	13.33	12.01	13.26
6/25/2015	12.96	14.16	12.92	14.01
6/26/2015	14.13	14.91	13.64	14.02
6/29/2015	16.7	19.5	15.82	18.85
6/30/2015	17.6	19.8	17.49	18.23
7/1/2015	16.63	17.26	15.65	16.09
7/2/2015	15.43	17.48	15.39	16.79
7/6/2015	18.65	18.95	16.57	17.01
7/7/2015	17.22	19.2	15.93	16.09
7/8/2015	17.38	19.76	16.94	19.66
7/9/2015	17.46	20.05	17.2	19.97
7/10/2015	17.45	18.17	16.6	16.83
7/13/2015	15.29	15.36	13.82	13.9
7/14/2015	13.91	13.95	12.9	13.37
7/15/2015	13.35	13.97	12.81	13.23
7/16/2015	12.59	12.61	11.87	12.11
7/17/2015	11.77	12.22	11.77	11.95
7/20/2015	12.25	12.37	11.71	12.25
7/21/2015	12.42	12.79	12.21	12.22
7/22/2015	12.77	12.83	12.05	12.12
7/23/2015	12.06	13.08	11.73	12.64
7/24/2015	12.87	14.73	12.86	13.74
7/27/2015	15.6	16.27	15.03	15.6
7/28/2015	14.87	15.62	13.32	13.44
7/29/2015	13.57	13.59	11.85	12.5
7/30/2015	12.72	13.42	12.09	12.13

7/31/2015	12.03	12.63	11.82	12.12
8/3/2015	12.85	13.55	12.32	12.56
8/4/2015	12.66	13.22	12.29	13
8/5/2015	12.02	12.72	10.88	12.51
8/6/2015	12.2	14.25	12.16	13.77
8/7/2015	13.57	14.58	13.29	13.39
8/10/2015	12.73	12.78	12.18	12.23
8/11/2015	13.24	14.33	13.02	13.71
8/12/2015	15.19	16.28	13.45	13.61
8/13/2015	13.87	14.33	13.06	13.49
8/14/2015	13.69	13.87	12.8	12.83
8/17/2015	14.32	14.52	13.01	13.02
8/18/2015	13.41	13.94	13.17	13.79
8/19/2015	14.84	15.96	13.73	15.25
8/20/2015	16.55	19.24	16.13	19.14
8/21/2015	22.55	28.38	20.8	28.03
8/24/2015	28.03	53.29	28.03	40.74
8/25/2015	31.13	38.06	28.08	36.02
8/26/2015	31.13	35.62	28.67	30.32
8/27/2015	27.11	29.9	24.49	26.1
8/28/2015	26.69	29.2	25.77	26.05
8/31/2015	27.03	29.37	26.63	28.43
9/1/2015	31.91	33.82	29.91	31.4
9/2/2015	29.14	30.45	24.77	26.09
9/3/2015	25.21	26.31	23.45	25.61
9/4/2015	27.43	29.47	25.68	27.8
9/8/2015	25.05	26.25	24.13	24.9
9/9/2015	22.39	26.82	21.51	26.23
9/10/2015	26.87	27.22	23.53	24.37
9/11/2015	25.38	25.81	23.15	23.2
9/14/2015	24.03	25.32	23.64	24.25
9/15/2015	23.28	23.77	22.13	22.54
9/16/2015	22.57	22.94	21.09	21.35
9/17/2015	21.54	23.33	17.87	21.14
9/18/2015	23.07	23.99	20.98	22.28
9/21/2015	21.97	22.48	20.05	20.14
9/22/2015	22.97	26.29	22.25	22.44
9/23/2015	22.09	23.2	21.14	22.13
9/24/2015	23.53	25.3	21.81	23.47
9/25/2015	21.12	24.29	20.81	23.62
9/28/2015	25.02	28.33	24.94	27.63
9/29/2015	26.57	28.2	25.76	26.83
9/30/2015	24.64	25.88	23.25	24.5
10/1/2015	23.14	25.23	22.55	22.55
10/2/2015	23.99	24.47	20.35	20.94
10/5/2015	20.31	20.42	19.14	19.54
10/6/2015	19.54	20.32	18.82	19.4
10/7/2015	18.96	19.73	18.33	18.4
10/8/2015	18.62	19.02	16.34	17.42
10/9/2015	17.15	18.2	16.89	17.08
10/12/2015	17.68	17.81	16.15	16.17
10/13/2015	17.08	17.7	16.14	17.67
10/14/2015	17.67	18.78	17.3	18.03
10/15/2015	17.62	17.85	16.04	16.05
10/16/2015	15.64	16.86	15.05	15.05
10/19/2015	15.68	16.23	14.82	14.98
10/20/2015	15.17	16.34	14.72	15.75
10/21/2015	14.98	16.7	14.41	16.7
10/22/2015	15.02	15.92	14.45	14.45
10/23/2015	13.46	15.12	13.24	14.46
10/26/2015	14.76	15.43	14.68	15.29
10/27/2015	15.75	15.99	14.78	15.43
10/28/2015	15.14	15.73	12.8	14.33
10/29/2015	14.8	15.46	14.33	14.61
10/30/2015	14.6	15.39	14	15.07
11/2/2015	15.41	15.51	13.67	14.15
11/3/2015	14.33	14.73	13.81	14.54
11/4/2015	14.04	15.88	13.96	15.51
11/5/2015	15.39	16.39	15	15.05
11/6/2015	14.91	16	14.32	14.33
11/9/2015	15.34	17.09	15.14	16.52
11/10/2015	16.69	16.96	15.24	15.29
11/11/2015	15.07	16.15	15.02	16.06
11/12/2015	17.06	18.5	16.65	18.37
11/13/2015	18.68	20.67	18.2	20.08
11/16/2015	20.51	20.55	17.25	18.16
11/17/2015	17.82	19.59	16.86	18.84
11/18/2015	19.01	19.45	16.8	16.85
11/19/2015	16.25	18.26	16	16.99
11/20/2015	16.13	16.38	15.47	15.47
11/23/2015	16.15	16.74	15.38	15.62
11/24/2015	16.53	17.21	15.48	15.93
11/25/2015	15.55	15.89	15.05	15.19
11/27/2015	15.31	16.09	15.12	15.12
11/30/2015	15.55	16.57	15.52	16.13
12/1/2015	15.61	16.34	14.63	14.67
12/2/2015	15.04	16.49	14.71	15.91
12/3/2015	15.87	19.35	15.86	18.11
12/4/2015	17.43	17.65	14.69	14.81
12/7/2015	15.65	17.18	15.58	15.84
12/8/2015	17.69	18.33	16.52	17.6
12/9/2015	18.05	20.13	15.72	19.61
12/10/2015	19.25	19.72	18.13	19.34
12/11/2015	21.36	25.27	20.88	24.39
12/14/2015	24.7	26.81	21.47	22.73
12/15/2015	20.76	21.62	20.02	20.95
12/16/2015	19.25	20.24	17.12	17.86
12/17/2015	16.18	19.05	16.13	18.94
12/18/2015	19.34	23.3	18.75	20.7
12/21/2015	19.64	20.21	18.7	18.7
12/22/2015	17.61	18.22	16.6	16.6
12/23/2015	15.86	16.25	15.33	15.57
12/24/2015	15.44	15.88	14.45	15.74
12/28/2015	17.65	18.13	16.88	16.91
12/29/2015	15.91	16.48	15.63	16.08
12/30/2015	16.5	17.42	16.5	17.29
12/31/2015	17.97	20.39	17.51	18.21
1/4/2016	22.48	23.36	20.67	20.7

1/5/2016	20.75	21.06	19.25	19.34
1/6/2016	21.67	21.86	19.8	20.59
1/7/2016	23.22	25.86	22.4	24.99
1/8/2016	22.96	27.08	22.48	27.01
1/11/2016	25.58	27.39	23.83	24.3
1/12/2016	22.97	23.93	21.91	22.47
1/13/2016	21.72	26.11	21.44	25.22
1/14/2016	24.75	26.28	23.07	23.95
1/15/2016	28.96	30.95	26.67	27.02
1/19/2016	25.4	27.59	25.21	26.05
1/20/2016	27.78	32.09	26.59	27.59
1/21/2016	27.79	28.43	25.01	26.69
1/22/2016	24.21	24.55	22.22	22.34
1/25/2016	23.3	24.31	22.38	24.15
1/26/2016	23.75	24.02	22.33	22.5
1/27/2016	22.88	27.22	20.42	23.11
1/28/2016	22.15	23.81	21.9	22.42
1/29/2016	21.59	21.74	19.5	20.2
2/1/2016	21.32	23.66	19.61	19.98
2/2/2016	21.34	22.42	21.06	21.98
2/3/2016	21.49	27.7	21.42	21.65
2/4/2016	22.29	23.14	21.24	21.84
2/5/2016	22.09	24.11	21.91	23.38
2/8/2016	25.89	27.72	25.56	26
2/9/2016	28.3	28.31	25.99	26.54
2/10/2016	25.75	26.6	24.47	26.29
2/11/2016	29.01	30.9	26.67	28.14
2/12/2016	27.16	27.57	24.92	25.4
2/16/2016	24.96	25.52	23.32	24.11
2/17/2016	23.4	24.16	21.83	22.31
2/18/2016	22.16	22.53	21.29	21.64
2/19/2016	22.39	23.44	20.52	20.53
2/22/2016	20.14	20.35	19.02	19.38
2/23/2016	19.75	21.16	19.54	20.98
2/24/2016	22.28	22.87	20.26	20.72
2/25/2016	20.54	21.26	19.1	19.11
2/26/2016	18.89	20.13	18.46	19.81
2/29/2016	20.49	20.81	18.38	20.55
3/1/2016	19.84	20.17	17.66	17.7
3/2/2016	17.98	18.41	16.78	17.09
3/3/2016	17.25	17.56	16.32	16.7
3/4/2016	16.48	17.35	16.05	16.86
3/7/2016	17.98	18.04	16.87	17.35
3/8/2016	18.38	18.89	17.82	18.67
3/9/2016	18.56	19.11	18.31	18.34
3/10/2016	18.17	19.59	17.06	18.05
3/11/2016	17.09	17.27	16.28	16.5
3/14/2016	17.01	17.67	16.69	16.92
3/15/2016	17.6	17.85	16.84	16.84
3/16/2016	15.96	16.33	14.89	14.99
3/17/2016	15.34	15.38	13.82	14.44
3/18/2016	14.05	14.36	13.75	14.02
3/21/2016	14.57	14.73	13.79	13.79
3/22/2016	14.57	14.76	13.75	14.17
3/23/2016	14.57	15.03	14.33	14.94
3/24/2016	16.3	16.44	14.71	14.74
3/28/2016	15.65	16.04	14.89	15.24
3/29/2016	15.74	15.89	13.79	13.82
3/30/2016	13.69	13.89	13.06	13.56
3/31/2016	13.73	14.28	13.49	13.95
4/1/2016	15.23	15.28	13	13.1
4/4/2016	13.88	14.24	13.66	14.12
4/5/2016	15.39	15.72	14.93	15.42
4/6/2016	15.61	15.98	14	14.09
4/7/2016	15.14	16.77	14.68	16.16
4/8/2016	15.34	15.93	14.84	15.36
4/11/2016	15.34	16.26	14.83	16.26
4/12/2016	15.98	16.57	14.84	14.85
4/13/2016	14.49	14.53	13.6	13.84
4/14/2016	13.9	14.12	13.38	13.72
4/15/2016	13.77	14.19	13.58	13.62
4/18/2016	14.87	14.94	13.23	13.35
4/19/2016	13.18	13.88	12.98	13.24
4/20/2016	13.39	13.5	12.5	13.28
4/21/2016	13.2	14.14	13.16	13.95
4/22/2016	13.7	14.19	13.15	13.22
4/25/2016	14.07	14.76	13.86	14.08
4/26/2016	14.01	14.43	13.66	13.96
4/27/2016	14.15	14.95	13.5	13.77
4/28/2016	14.53	15.61	13.3	15.22
4/29/2016	15.21	17.09	14.91	15.7
5/2/2016	16.33	16.5	14.48	14.68
5/3/2016	14.92	16.42	14.91	15.6
5/4/2016	15.47	16.85	15.39	16.05
5/5/2016	15.54	16.45	15.22	15.91
5/6/2016	16.2	16.58	14.71	14.72
5/9/2016	15.2	15.39	14.17	14.57
5/10/2016	13.98	14.35	13.55	13.63
5/11/2016	13.92	14.69	13.29	14.69
5/12/2016	14.55	15.42	13.95	14.41
5/13/2016	15.15	15.47	13.97	15.04
5/16/2016	15.72	15.98	14.28	14.68
5/17/2016	14.57	16.12	14.48	15.57
5/18/2016	15.72	16.47	14.86	15.95
5/19/2016	16.37	17.65	16.28	16.33
5/20/2016	16.13	16.3	15.11	15.2
5/23/2016	16.33	16.47	15.4	15.82
5/24/2016	16.03	16.06	14.36	14.42
5/25/2016	14.19	14.33	13.64	13.9
5/26/2016	13.8	14.11	13.43	13.43
5/27/2016	13.49	13.76	13.04	13.12
5/31/2016	13.94	15	13.45	14.19
6/1/2016	14.45	15.25	14.18	14.2
6/2/2016	14.42	14.92	13.62	13.63
6/3/2016	13.78	14.66	12.9	13.47
6/6/2016	13.84	14.27	13.42	13.65
6/7/2016	12.77	14.05	12.72	14.05
6/8/2016	13.84	14.27	13.7	14.08

6/9/2016	14.01	14.85	13.99	14.64
6/10/2016	14.89	17.33	14.85	17.03
6/13/2016	18.24	21.01	17.89	20.97
6/14/2016	21.28	22.16	20.27	20.5
6/15/2016	20.25	20.45	18.63	20.14
6/16/2016	20.8	22.89	19.24	19.37
6/17/2016	19.42	20.03	18.71	19.41
6/20/2016	17.42	18.55	16.59	18.37
6/21/2016	17.67	18.96	16.91	18.48
6/22/2016	18.26	21.22	17.83	21.17
6/23/2016	19.54	19.79	17.25	17.25
6/24/2016	26.06	26.24	19.48	25.76
6/27/2016	24.38	26.72	22.93	23.85
6/28/2016	21.76	22.07	18.75	18.75
6/29/2016	18.12	18.27	16.48	16.64
6/30/2016	16.91	16.99	15.29	15.63
7/1/2016	15.59	15.86	14.61	14.77
7/5/2016	16.05	16.62	15.49	15.58
7/6/2016	15.87	17.04	14.96	14.96
7/7/2016	14.8	15.98	14.33	14.76
7/8/2016	14.64	14.75	13.19	13.2
7/11/2016	13.25	13.67	13	13.54
7/12/2016	12.93	13.93	12.75	13.55
7/13/2016	13.32	13.79	12.92	13.04
7/14/2016	12.5	13.37	12.14	12.82
7/15/2016	13.12	13.22	12.27	12.67
7/18/2016	12.75	13.12	12.33	12.44
7/19/2016	12.53	12.83	11.94	11.97
7/20/2016	11.94	11.97	11.4	11.77
7/21/2016	11.8	13.06	11.69	12.74
7/22/2016	12.8	12.88	11.97	12.02
7/25/2016	12.64	13.72	12.39	12.87
7/26/2016	12.88	13.5	12.8	13.05
7/27/2016	12.61	13.74	12.5	12.83
7/28/2016	12.51	13.52	12.36	12.72
7/29/2016	12.85	12.9	11.77	11.87
8/1/2016	11.89	12.98	11.86	12.44
8/2/2016	12.39	14.24	12.35	13.37
8/3/2016	13.53	13.91	12.73	12.86
8/4/2016	12.73	12.98	11.79	12.42
8/5/2016	12.08	12.26	11.18	11.39
8/8/2016	11.66	11.78	11.41	11.5
8/9/2016	11.4	11.92	11.02	11.66
8/10/2016	11.55	12.5	11.37	12.05
8/11/2016	11.93	12.11	11.38	11.68
8/12/2016	11.61	12	11.28	11.55
8/15/2016	11.81	12.17	11.58	11.81
8/16/2016	12.04	12.78	11.87	12.64
8/17/2016	12.57	13.71	12.14	12.19
8/18/2016	12.2	12.53	11.42	11.43
8/19/2016	11.67	12.28	11.33	11.34
8/22/2016	12.53	13.02	11.94	12.27
8/23/2016	12.15	12.44	11.72	12.38
8/24/2016	12.7	14.01	12.3	13.45
8/25/2016	13.62	14.09	13.29	13.63
8/26/2016	13.54	14.93	12.13	13.65
8/29/2016	14.09	14.43	12.9	12.94
8/30/2016	12.94	13.6	12.7	13.12
8/31/2016	13.14	14.34	12.97	13.42
9/1/2016	13.07	14.61	12.99	13.48
9/2/2016	13.47	13.9	11.9	11.98
9/6/2016	12.42	12.93	11.85	12.02
9/7/2016	11.89	12.45	11.77	11.94
9/8/2016	11.74	12.6	11.65	12.51
9/9/2016	12.52	17.54	12.52	17.5
9/12/2016	20.13	20.51	14.76	15.16
9/13/2016	15.98	18.97	15.83	17.85
9/14/2016	17.63	18.14	16.34	18.14
9/15/2016	17.97	18.07	15.74	16.3
9/16/2016	16.41	17.1	15.28	15.37
9/19/2016	15.14	15.96	14.6	15.53
9/20/2016	14.98	16.09	14.69	15.92
9/21/2016	15.07	15.65	12.98	13.3
9/22/2016	13.39	13.39	11.76	12.02
9/23/2016	12	12.58	11.93	12.29
9/26/2016	13.26	14.63	13.26	14.5
9/27/2016	13.36	14.76	12.97	13.1
9/28/2016	12.9	13.57	12.24	12.39
9/29/2016	12.53	15.69	12.14	14.02
9/30/2016	14.91	15.2	12.53	13.29
10/3/2016	13.75	14.42	13.42	13.57
10/4/2016	13.4	14.57	12.92	13.63
10/5/2016	13.56	13.68	12.7	12.99
10/6/2016	13.11	13.84	12.8	12.84
10/7/2016	13.52	14.15	12.21	13.48
10/10/2016	14.19	14.36	13.29	13.38
10/11/2016	13.71	16.47	13.69	15.36
10/12/2016	15.53	16.34	15.26	15.91
10/13/2016	16.88	17.95	16.14	16.69
10/14/2016	16.49	16.5	15.25	16.12
10/17/2016	17.01	17.11	16.13	16.21
10/18/2016	15.82	15.85	15.03	15.28
10/19/2016	15.45	15.68	13.87	14.41
10/20/2016	14.43	14.72	13.74	13.75
10/21/2016	14.04	14.53	13.27	13.34
10/24/2016	13.19	13.26	12.83	13.02
10/25/2016	12.91	13.86	12.73	13.46
10/26/2016	13.66	14.8	13.66	14.24
10/27/2016	14.37	15.43	13.6	15.36
10/28/2016	15.67	17.35	14.65	16.19
10/31/2016	16.31	17.63	16.25	17.06
11/1/2016	16.54	20.43	16.51	18.56
11/2/2016	19.09	19.82	18.56	19.32
11/3/2016	19.85	22.57	18.84	22.08
11/4/2016	21.86	23.01	19.2	22.51
11/7/2016	19.78	19.86	18.39	18.71
11/8/2016	18.92	19.91	17.7	18.74
11/9/2016	20.7	21.48	14.33	14.38

11/10/2016	14.01	16.3	13.26	14.74
11/11/2016	14.83	16	14.15	14.17
11/14/2016	14.69	15.56	14.39	14.48
11/15/2016	14.16	14.65	13.3	13.37
11/16/2016	13.51	14.49	13.51	13.72
11/17/2016	13.37	13.55	12.97	13.35
11/18/2016	13.56	13.74	12.85	12.85
11/21/2016	13.27	13.44	12.16	12.42
11/22/2016	12.26	12.83	12.2	12.41
11/23/2016	12.34	13.01	12.19	12.43
11/25/2016	12.52	12.74	12.31	12.34
11/28/2016	13.4	13.5	12.74	13.15
11/29/2016	13.07	13.55	12.62	12.9
11/30/2016	12.6	13.42	12.23	13.33
12/1/2016	13.4	14.72	13.05	14.07
12/2/2016	14.16	14.48	12.39	14.12
12/5/2016	13.75	13.77	12.14	12.14
12/6/2016	12.19	12.3	11.54	11.79
12/7/2016	11.59	12.24	11.33	12.22
12/8/2016	12.1	13.4	11.3	12.64
12/9/2016	12.59	12.72	11.67	11.75
12/12/2016	12.23	12.78	12.07	12.64
12/13/2016	12.46	13.42	12.34	12.72
12/14/2016	12.88	13.39	12.48	13.19
12/15/2016	13.07	13.24	12.46	12.79
12/16/2016	12.88	12.95	12.15	12.2
12/19/2016	12.5	12.52	11.67	11.71
12/20/2016	11.65	11.75	11.38	11.45
12/21/2016	11.44	11.49	10.93	11.27
12/22/2016	11.32	11.67	11.14	11.43
12/23/2016	11.38	11.81	11.35	11.44
12/27/2016	12.26	12.33	11.84	11.99
12/28/2016	11.89	13.04	11.85	12.95
12/29/2016	13.15	13.71	12.95	13.37
12/30/2016	13.2	14.68	13.05	14.04
1/3/2017	14.07	14.07	12.85	12.85
1/4/2017	12.78	12.8	11.63	11.85
1/5/2017	11.96	12.09	11.4	11.67
1/6/2017	11.7	11.74	10.98	11.32
1/9/2017	11.71	12.08	11.46	11.56
1/10/2017	11.59	11.79	11.31	11.49
1/11/2017	11.56	12.23	11.21	11.26
1/12/2017	11.48	12.6	11.32	11.54
1/13/2017	11.45	11.62	10.94	11.23
1/17/2017	12.2	12.75	11.79	11.87
1/18/2017	11.79	12.81	11.69	12.48
1/19/2017	12.58	13.28	12.17	12.78
1/20/2017	12.58	12.59	11.53	11.54
1/23/2017	12.3	12.62	11.59	11.77
1/24/2017	11.82	11.89	11.04	11.07
1/25/2017	10.79	11.05	10.51	10.81
1/26/2017	10.61	11.01	10.6	10.63
1/27/2017	10.57	10.82	10.3	10.58
1/30/2017	11.1	12.9	11.1	11.88
1/31/2017	12.29	12.99	11.79	11.99
2/1/2017	11.79	12.05	9.97	11.81
2/2/2017	12.37	12.47	11.62	11.93
2/3/2017	11.84	11.84	10.72	10.97
2/6/2017	11.37	11.84	11.09	11.37
2/7/2017	11.39	11.67	11.06	11.29
2/8/2017	11.19	11.82	11.15	11.45
2/9/2017	11.44	11.53	10.74	10.88
2/10/2017	10.85	10.95	10.55	10.85
2/13/2017	11.36	11.4	11.07	11.07
2/14/2017	11.17	11.34	10.73	10.74
2/15/2017	10.84	12.01	10.8	11.97
2/16/2017	12.02	12.86	11.69	11.76
2/17/2017	11.84	12.26	11.37	11.49
2/21/2017	12.05	12.09	11.5	11.57
2/22/2017	11.48	12.07	11.44	11.74
2/23/2017	11.66	12.46	11.54	11.71
2/24/2017	11.81	12.59	11.34	11.47
2/27/2017	11.78	12.14	11.53	12.09
2/28/2017	12.19	12.96	12.13	12.92
3/1/2017	12.31	12.58	11.78	12.54
3/2/2017	12.43	12.71	11.32	11.81
3/3/2017	11.96	11.97	10.94	10.96
3/6/2017	11.59	11.72	11.06	11.24
3/7/2017	11.27	11.58	11.04	11.45
3/8/2017	11.49	11.86	11.09	11.86
3/9/2017	11.75	12.43	11.62	12.3
3/10/2017	11.97	12.09	11.46	11.66
3/13/2017	12.16	12.23	11.29	11.35
3/14/2017	11.39	12.54	11.28	12.3
3/15/2017	12.12	12.25	10.6	11.63
3/16/2017	11.29	11.55	11.16	11.21
3/17/2017	11.38	11.38	10.78	11.28
3/20/2017	11.71	11.72	11.03	11.34
3/21/2017	11.15	12.85	10.92	12.47
3/22/2017	12.95	13.16	11.99	12.81
3/23/2017	12.65	13.17	12.18	13.12
3/24/2017	12.86	14.16	12.27	12.96
3/27/2017	14.78	15.11	12.48	12.5
3/28/2017	12.44	12.67	11.34	11.53
3/29/2017	11.54	11.7	11.03	11.42
3/30/2017	11.37	11.64	11.12	11.54
3/31/2017	11.61	12.54	11.5	12.37
4/3/2017	12.59	13.59	12.27	12.38
4/4/2017	12.71	13.07	11.7	11.79
4/5/2017	11.89	12.89	10.9	12.89
4/6/2017	13.11	13.22	11.7	12.39
4/7/2017	13.17	13.43	12.23	12.87
4/10/2017	13.24	14.11	12.94	14.05
4/11/2017	14.32	15.88	14.17	15.07
4/12/2017	15.16	16.16	14.84	15.77
4/13/2017	15.89	16.22	14.97	15.96
4/17/2017	16.19	16.28	14.6	14.66
4/18/2017	14.5	15.5	14.29	14.42

4/19/2017	14	15.15	13.46	14.93
4/20/2017	14.59	14.81	13.83	14.15
4/21/2017	13.85	15.33	13.85	14.63
4/24/2017	11.56	12.01	10.82	10.84
4/25/2017	10.81	11.15	10.22	10.76
4/26/2017	10.61	10.89	10.39	10.85
4/27/2017	10.72	11.08	10.33	10.36
4/28/2017	10.39	11.16	10.29	10.82
5/1/2017	10.92	11.04	9.9	10.11
5/2/2017	10.15	10.59	10.04	10.59
5/3/2017	10.56	11.15	10.4	10.68
5/4/2017	10.71	11.24	10.27	10.46
5/5/2017	10.51	10.98	9.99	10.57
5/8/2017	10.53	10.55	9.67	9.77
5/9/2017	9.87	10.14	9.56	9.96
5/10/2017	9.75	10.24	9.62	10.21
5/11/2017	10.34	11.23	10.32	10.6
5/12/2017	10.72	10.87	10.28	10.4
5/15/2017	10.54	10.88	10.25	10.42
5/16/2017	10.46	10.67	10.18	10.65
5/17/2017	11.89	15.59	11.53	15.59
5/18/2017	14.06	16.3	14.03	14.66
5/19/2017	14.23	14.23	11.72	12.04
5/22/2017	12.29	12.52	10.89	10.93
5/23/2017	11	11	10.56	10.72
5/24/2017	10.61	10.9	9.88	10.02
5/25/2017	9.82	10.29	9.72	9.99
5/26/2017	9.93	10.48	9.65	9.81
5/30/2017	10.61	10.84	10.14	10.38
5/31/2017	10.1	11.3	9.93	10.41
6/1/2017	10.42	10.54	9.69	9.89
6/2/2017	10.08	10.3	9.58	9.75
6/5/2017	10.08	10.28	9.6	10.07
6/6/2017	10.19	10.77	9.86	10.45
6/7/2017	10.48	10.93	10.12	10.39
6/8/2017	10.27	10.53	9.73	10.16
6/9/2017	9.93	12.11	9.37	10.7
6/12/2017	11.19	12.37	11.19	11.46
6/13/2017	11.12	11.14	10.26	10.42
6/14/2017	10.33	11.26	10.01	10.64
6/15/2017	11.06	12.01	10.74	10.9
6/16/2017	10.63	11.35	10.26	10.38
6/19/2017	10.57	10.6	10.01	10.37
6/20/2017	10.28	11.15	10.24	10.86
6/21/2017	11.03	11.4	10.4	10.75
6/22/2017	10.81	11.01	10.24	10.48
6/23/2017	10.25	10.69	9.85	10.02
6/26/2017	10.13	10.44	9.68	9.9
6/27/2017	10.04	11.31	9.8	11.06
6/28/2017	11.17	11.49	9.76	10.03
6/29/2017	9.79	15.16	9.73	11.44
6/30/2017	11.74	11.85	10.4	11.18
7/3/2017	11.07	11.45	10.28	11.22
7/5/2017	11.2	12.03	10.79	11.07
7/6/2017	11.2	13.05	11.18	12.54
7/7/2017	12.48	12.57	10.98	11.19
7/10/2017	11.26	11.73	10.61	11.11
7/11/2017	10.79	12.14	10.68	10.89
7/12/2017	10.85	10.85	10.08	10.3
7/13/2017	10.07	10.4	9.9	9.9
7/14/2017	10.09	10.14	9.5	9.51
7/17/2017	9.77	10.03	9.71	9.82
7/18/2017	9.86	10.35	9.66	9.89
7/19/2017	9.69	9.94	9.58	9.79
7/20/2017	9.66	10.28	9.5	9.58
7/21/2017	9.52	9.98	9.3	9.36
7/24/2017	9.94	9.97	9.26	9.43
7/25/2017	9.4	9.52	9.04	9.43
7/26/2017	9.25	9.66	8.84	9.6
7/27/2017	9.33	11.5	9.16	10.11
7/28/2017	10.62	11.3	10.26	10.29
7/31/2017	10.53	10.84	10.23	10.26
8/1/2017	10.19	10.56	9.95	10.09
8/2/2017	10.08	10.81	9.8	10.28
8/3/2017	10.47	10.6	9.9	10.44
8/4/2017	10.48	10.5	9.68	10.03
8/7/2017	10.19	10.32	9.76	9.93
8/8/2017	10.04	11.52	9.52	10.96
8/9/2017	11.49	12.63	11.11	11.11
8/10/2017	11.57	16.17	11.56	16.04
8/11/2017	16.17	17.28	14.5	15.51
8/14/2017	14.05	14.05	12.06	12.33
8/15/2017	11.78	12.37	11.45	12.04
8/16/2017	11.59	12.54	11.25	11.74
8/17/2017	11.81	15.77	11.54	15.55
8/18/2017	15.38	16.04	13.32	14.26
8/21/2017	14.59	14.74	13.07	13.19
8/22/2017	12.6	12.94	11.35	11.35
8/23/2017	11.51	12.59	11.39	12.25
8/24/2017	12.06	12.83	11.55	12.23
8/25/2017	12.2	12.45	11.1	11.28
8/28/2017	12.09	12.11	11.23	11.32
8/29/2017	13.33	14.34	11.48	11.7
8/30/2017	11.4	11.98	10.96	11.22
8/31/2017	11.07	11.22	10.34	10.59
9/1/2017	10.33	10.46	10.02	10.13
9/5/2017	11.75	14.06	11.41	12.23
9/6/2017	12.27	12.59	11.35	11.63
9/7/2017	11.93	12.07	11.32	11.55
9/8/2017	11.87	12.6	11.84	12.12
9/11/2017	11.38	11.39	10.51	10.73
9/12/2017	10.66	10.95	10.29	10.58
9/13/2017	10.72	10.86	10.33	10.5
9/14/2017	10.57	11.04	10.28	10.44
9/15/2017	10.51	10.74	10	10.17
9/18/2017	10.18	10.42	9.88	10.15
9/19/2017	10.16	10.3	9.85	10.18
9/20/2017	10.04	10.67	9.67	9.78

9/21/2017	9.74	10.21	9.54	9.67
9/22/2017	9.9	10.2	9.5	9.59
9/25/2017	10.08	11.21	9.79	10.21
9/26/2017	10.42	10.68	9.94	10.17
9/27/2017	9.9	10.42	9.63	9.87
9/28/2017	9.74	10.13	9.55	9.55
9/29/2017	9.59	9.83	9.36	9.51
10/2/2017	9.59	10.04	9.37	9.45
10/3/2017	9.3	9.75	9.3	9.51
10/4/2017	9.53	9.88	9.53	9.63
10/5/2017	9.48	9.62	9.13	9.19
10/6/2017	9.23	10.27	9.11	9.65
10/9/2017	9.92	10.53	9.88	10.33
10/10/2017	10.15	10.66	9.94	10.08
10/11/2017	9.95	10.38	9.72	9.85
10/12/2017	9.94	10.33	9.65	9.91
10/13/2017	9.95	9.98	9.44	9.61
10/16/2017	9.95	10.02	9.75	9.91
10/17/2017	9.85	10.46	9.78	10.31
10/18/2017	10.34	10.41	9.87	10.07
10/19/2017	10.22	11.77	9.99	10.05
10/20/2017	9.92	10.04	9.29	9.97
10/23/2017	10.25	11.08	9.94	11.07
10/24/2017	10.89	11.16	10.39	11.16
10/25/2017	11.34	13.2	10.99	11.23
10/26/2017	11.17	11.81	10.6	11.3
10/27/2017	11.12	11.12	9.74	9.8
10/30/2017	10.28	10.89	10.1	10.5
10/31/2017	10.34	10.37	9.9	10.18
11/1/2017	9.79	10.49	9.74	10.2
11/2/2017	10.44	10.89	9.67	9.93
11/3/2017	9.83	9.91	8.99	9.14
11/6/2017	9.63	9.74	9.38	9.4
11/7/2017	9.31	10.31	9.29	9.89
11/8/2017	9.79	10.27	9.5	9.78
11/9/2017	9.94	12.19	9.79	10.5
11/10/2017	10.78	11.58	10.5	11.29
11/13/2017	11.43	12.18	11	11.5
11/14/2017	11.53	12.61	11.45	11.59
11/15/2017	12.52	14.51	12.33	13.13
11/16/2017	12.47	12.52	11.38	11.76
11/17/2017	11.75	12.01	11.16	11.43
11/20/2017	11.96	12.08	10.44	10.65
11/21/2017	10.74	10.78	9.67	9.73
11/22/2017	9.6	9.88	9.32	9.88
11/24/2017	9.82	9.96	8.56	9.67
11/27/2017	10.07	10.26	9.79	9.87
11/28/2017	9.72	10.31	9.53	10.03
11/29/2017	9.91	10.93	9.81	10.7
11/30/2017	10.49	12.05	10.25	11.28
12/1/2017	11.19	14.58	10.54	11.43
12/4/2017	11.05	11.86	10.26	11.68
12/5/2017	11.38	11.67	10.65	11.33
12/6/2017	11.63	11.68	10.86	11.02
12/7/2017	10.9	11.32	10.12	10.16
12/8/2017	10	10.06	9.43	9.58
12/11/2017	9.74	10.08	9.28	9.34
12/12/2017	9.36	9.92	9.21	9.92
12/13/2017	9.78	10.21	9.65	10.18
12/14/2017	9.98	10.54	9.78	10.49
12/15/2017	10.12	10.2	9.22	9.42
12/18/2017	9.46	9.89	9.24	9.53
12/19/2017	9.4	10.15	9.18	10.03
12/20/2017	9.69	9.85	8.9	9.72
12/21/2017	9.59	9.86	9.2	9.62
12/22/2017	9.37	10.18	9.35	9.9
12/26/2017	10.19	10.46	10.13	10.25
12/27/2017	10.04	10.79	9.71	10.47
12/28/2017	10.29	10.44	10.07	10.18
12/29/2017	10.03	11.06	9.95	11.04
1/2/2018	10.95	11.07	9.52	9.77
1/3/2018	9.56	9.65	8.94	9.15
1/4/2018	9.01	9.31	8.92	9.22
1/5/2018	9.1	9.54	9	9.22
1/8/2018	9.61	9.89	9.32	9.52
1/9/2018	9.41	10.09	9.37	10.08
1/10/2018	10.11	10.85	9.82	9.82
1/11/2018	9.69	10.02	9.62	9.88
1/12/2018	9.74	10.31	9.54	10.16
1/16/2018	10.42	12.41	10.4	11.66
1/17/2018	11.35	12.81	11.18	11.91
1/18/2018	12.01	12.4	11.62	12.22
1/19/2018	12.3	12.33	11.18	11.27
1/22/2018	11.59	11.62	10.84	11.03
1/23/2018	10.77	11.57	10.76	11.1
1/24/2018	11	12.19	10.89	11.47
1/25/2018	11.27	12.01	11.2	11.58
1/26/2018	11.4	11.6	11.08	11.08
1/29/2018	11.71	13.84	11.68	13.84
1/30/2018	13.93	15.42	13.88	14.79
1/31/2018	14.23	14.44	13.41	13.54
2/1/2018	13.05	14.3	12.5	13.47
2/2/2018	13.64	17.86	13.64	17.31
2/5/2018	18.44	38.8	16.8	37.32
2/6/2018	37.32	50.3	22.42	29.98
2/7/2018	31.38	31.64	21.17	27.73
2/8/2018	27.29	36.17	24.41	33.46
2/9/2018	32.18	41.06	27.73	29.06
2/12/2018	27.25	29.7	24.42	25.61
2/13/2018	26.94	27.82	24.47	24.97
2/14/2018	23.48	25.72	18.99	19.26
2/15/2018	18.39	20.66	17.6	19.13
2/16/2018	18.74	20.99	17.44	19.46
2/20/2018	20.53	21.61	19.75	20.6
2/21/2018	20.76	21.04	16.97	20.02
2/22/2018	20.57	20.61	18.07	18.72
2/23/2018	17.96	18.8	16.47	16.49
2/26/2018	16.53	16.94	15.8	15.8

2/27/2018	15.83	18.98	15.29	18.59
2/28/2018	18.08	20.44	15.65	19.85
3/1/2018	19.96	25.3	19.57	22.47
3/2/2018	22.47	26.22	19.36	19.59
3/5/2018	21.55	21.57	17.94	18.73
3/6/2018	18.25	19.64	17.68	18.36
3/7/2018	20.11	20.49	17.52	17.76
3/8/2018	17.56	17.68	14.91	16.54
3/9/2018	16.41	16.75	13.31	14.64
3/12/2018	15.28	16.35	15.18	15.78
3/13/2018	15.7	16.98	15.03	16.35
3/14/2018	16.59	17.59	14.94	17.23
3/15/2018	16.99	17.41	15.96	16.59
3/16/2018	16.6	16.72	15.23	15.8
3/19/2018	16.63	21.87	16.56	19.02
3/20/2018	18.38	19.31	18.09	18.2
3/21/2018	17.76	18.37	16.26	17.86
3/22/2018	18.13	23.81	18.12	23.34
3/23/2018	24.02	26.01	21.63	24.87
3/26/2018	23.41	24.54	20.71	21.03
3/27/2018	20.33	24.06	19.84	22.5
3/28/2018	22.52	24.94	21.71	22.87
3/29/2018	22.87	23.05	19.6	19.97
4/2/2018	21.07	25.72	20.44	23.62
4/3/2018	23.03	23.38	20.92	21.1
4/4/2018	21.68	24.51	19.86	20.06
4/5/2018	19.76	20.21	18.57	18.94
4/6/2018	20.33	23.12	18.6	21.49
4/9/2018	21.27	22.02	20.34	21.77
4/10/2018	20.51	21.68	20.24	20.47
4/11/2018	20.95	21.66	19.64	20.24
4/12/2018	19.83	19.92	18.16	18.49
4/13/2018	18.27	18.45	17.26	17.41
4/16/2018	17.59	17.66	16.38	16.56
4/17/2018	16.16	16.27	14.57	15.25
4/18/2018	15.3	16.9	14.95	15.6
4/19/2018	15.55	16.92	15.16	15.96
4/20/2018	16.16	17.5	15.19	16.88
4/23/2018	17.29	17.56	15.79	16.34
4/24/2018	16.16	19.66	15.37	18.02
4/25/2018	18.14	19.84	17.75	17.84
4/26/2018	18.07	18.12	16.24	16.24
4/27/2018	16.22	16.77	15.25	15.41
4/30/2018	15.39	16.35	15.13	15.93
5/1/2018	15.78	16.82	15.42	15.49
5/2/2018	15.48	15.97	14.75	15.97
5/3/2018	15.78	18.66	15.43	15.9
5/4/2018	15.94	16.92	10.91	14.77
5/7/2018	15.32	15.52	14.51	14.75
5/8/2018	14.53	15.56	14.52	14.71
5/9/2018	14.54	14.63	13.38	13.42
5/10/2018	13.36	13.63	12.92	13.23
5/11/2018	13.22	13.44	12.65	12.65
5/14/2018	12.95	13.28	12.81	12.93
5/15/2018	13.13	15.01	12.5	14.63
5/16/2018	14.38	14.91	13.21	13.42
5/17/2018	13.54	13.86	12.65	13.43
5/18/2018	13.18	13.87	13.06	13.42
5/21/2018	13.44	13.59	12.78	13.08
5/22/2018	13.03	13.42	12.77	13.22
5/23/2018	13.5	14.6	12.49	12.58
5/24/2018	12.73	14.24	12.53	12.53
5/25/2018	12.44	13.52	12.29	13.22
5/29/2018	14.39	18.78	14.39	17.02
5/30/2018	16.6	16.64	14.65	14.94
5/31/2018	14.93	16.29	14.2	15.43
6/1/2018	14.92	14.93	13.37	13.46
6/4/2018	13.91	13.91	12.69	12.74
6/5/2018	12.91	13.34	12.3	12.4
6/6/2018	12.1	12.56	11.62	11.64
6/7/2018	11.66	13.28	11.22	12.13
6/8/2018	12.54	13.31	12.09	12.18
6/11/2018	12.52	12.69	12.14	12.35
6/12/2018	12.29	12.6	11.88	12.34
6/13/2018	12.13	12.95	11.98	12.94
6/14/2018	12.98	13.07	11.88	12.12
6/15/2018	12.19	13.16	11.93	11.98
6/18/2018	12.79	13.74	12.28	12.31
6/19/2018	14.61	14.68	13.21	13.35
6/20/2018	12.9	13.02	12.25	12.79
6/21/2018	12.54	15.18	12.18	14.64
6/22/2018	14.6	14.6	13.11	13.77
6/25/2018	15.07	19.61	14.56	17.33
6/26/2018	16.71	17.54	15.1	15.92
6/27/2018	16.52	18.19	14.76	17.91
6/28/2018	17.54	18.99	16.4	16.85
6/29/2018	15.73	16.51	14.66	16.09
7/2/2018	17.7	18.08	15.54	15.6
7/3/2018	15.37	16.45	14.68	16.14
7/5/2018	15.62	16.22	14.47	14.97
7/6/2018	14.99	15.45	13.34	13.37
7/9/2018	13.42	13.45	12.6	12.69
7/10/2018	12.52	13.21	11.93	12.64
7/11/2018	14.05	14.15	13.09	13.63
7/12/2018	13.07	13.33	12.42	12.58
7/13/2018	12.39	12.97	11.62	12.18
7/16/2018	12.46	12.97	12.13	12.83
7/17/2018	12.91	13.18	11.85	12.06
7/18/2018	11.87	12.47	11.44	12.1
7/19/2018	12.2	13.09	11.79	12.87
7/20/2018	13	13.58	12.49	12.86
7/23/2018	13.47	13.55	12.58	12.62
7/24/2018	12.61	13.21	11.66	12.41
7/25/2018	12.37	12.82	11.8	12.29
7/26/2018	12.45	12.53	11.78	12.14
7/27/2018	12.17	14.26	11.6	13.03
7/30/2018	13.63	14.46	12.98	14.26
7/31/2018	13.98	14.12	12.81	12.83

8/1/2018	13.09	13.63	12.45	13.15
8/2/2018	13.57	14.53	12.17	12.19
8/3/2018	12.43	12.46	11.07	11.64
8/6/2018	11.91	12.15	11.17	11.27
8/7/2018	11.12	11.24	10.52	10.93
8/8/2018	10.93	11.18	10.52	10.85
8/9/2018	10.94	11.31	10.17	11.27
8/10/2018	11.82	13.82	11.59	13.16
8/13/2018	14.5	15.02	12.95	14.78
8/14/2018	13.93	14.22	13.11	13.31
8/15/2018	13.52	16.86	13.44	14.64
8/16/2018	14.18	14.36	12.82	13.45
8/17/2018	13.18	13.96	12.4	12.64
8/20/2018	12.57	12.79	12.26	12.49
8/21/2018	12.47	12.89	12.09	12.86
8/22/2018	13.09	13.29	11.97	12.25
8/23/2018	12.03	12.68	11.65	12.41
8/24/2018	12.13	12.17	11.83	11.99
8/27/2018	12.37	12.48	12.02	12.16
8/28/2018	12.01	12.5	11.87	12.5
8/29/2018	12.34	12.55	12.09	12.25
8/30/2018	12.25	13.95	12.24	13.53
8/31/2018	13.54	14.03	12.82	12.86
9/4/2018	13.13	14.35	13.12	13.16
9/5/2018	13.69	14.3	13.23	13.91
9/6/2018	14.21	15.41	13.72	14.65
9/7/2018	14.72	15.63	14.31	14.88
9/10/2018	15.09	15.2	13.93	14.16
9/11/2018	13.96	14.92	13.21	13.22
9/12/2018	13.07	13.86	12.91	13.14
9/13/2018	12.91	12.91	12.3	12.37
9/14/2018	12.13	13.15	11.93	12.07
9/17/2018	12.72	13.75	12.32	13.68
9/18/2018	13.48	13.48	12.56	12.79
9/19/2018	12.61	12.77	11.66	11.75
9/20/2018	11.82	11.96	11.31	11.8
9/21/2018	11.76	12.03	11.1	11.68
9/24/2018	12.46	12.92	12.18	12.2
9/25/2018	12.28	12.6	11.8	12.42
9/26/2018	12.21	13.13	11.55	12.89
9/27/2018	12.77	13	11.94	12.41
9/28/2018	12.59	13.22	12.09	12.12
10/1/2018	11.99	12.4	11.57	12
10/2/2018	12.47	12.69	11.61	12.05
10/3/2018	11.66	12.14	11.34	11.61
10/4/2018	12.84	15.84	12.42	14.22
10/5/2018	14.29	17.36	11.72	14.82
10/8/2018	16.05	18.38	15.69	15.69
10/9/2018	16.12	17.49	15.27	15.95
10/10/2018	16.03	22.96	15.83	22.96
10/11/2018	23.07	28.84	20.65	24.98
10/12/2018	21.63	26.8	20.88	21.31
10/15/2018	21.97	22.89	19.47	21.3
10/16/2018	20.28	20.56	17.55	17.62
10/17/2018	17.06	19.55	17.06	17.4
10/18/2018	18.02	21.57	17.51	20.06
10/19/2018	19.24	21.08	18.39	19.89
10/22/2018	19.38	20.89	18.82	19.64
10/23/2018	22.18	24.66	20.18	20.71
10/24/2018	21.6	26.38	20.4	25.23
10/25/2018	24.78	24.78	22.06	24.22
10/26/2018	24.51	27.52	23.33	24.16
10/29/2018	24.48	27.86	22.01	24.7
10/30/2018	23.94	25.55	23.11	23.35
10/31/2018	22.72	22.8	20.39	21.23
11/1/2018	20.96	21.21	19.03	19.34
11/2/2018	18.52	21.61	18.05	19.51
11/5/2018	20.58	20.87	19.64	19.96
11/6/2018	19.84	20.6	19.69	19.91
11/7/2018	18.03	18.05	16.33	16.36
11/8/2018	16.18	17.2	16.09	16.72
11/9/2018	16.87	18.41	16.84	17.36
11/12/2018	17.26	20.71	17.25	20.45
11/13/2018	19.45	21.25	19.11	20.02
11/14/2018	20.52	22.36	19.3	21.25
11/15/2018	20.41	22.97	19.94	19.98
11/16/2018	20.04	21.36	18.1	18.14
11/19/2018	18.78	20.99	18.52	20.1
11/20/2018	20.76	23.81	20.37	22.48
11/21/2018	21.66	22.31	20.11	20.8
11/23/2018	21.23	22.65	20.65	21.52
11/26/2018	20.78	20.8	18.67	18.9
11/27/2018	19.41	19.93	18.7	19.02
11/28/2018	18.87	19.38	18.18	18.49
11/29/2018	18.65	20.48	18.59	18.79
11/30/2018	19.18	19.91	18.03	18.07
12/3/2018	16.04	17.28	15.94	16.44
12/4/2018	16.84	21.94	16.26	20.74
12/6/2018	23.53	25.94	20.94	21.19
12/7/2018	22.42	24.71	19.9	23.23
12/10/2018	23.95	25.94	22.5	22.64
12/11/2018	22.96	23.6	21.39	21.76
12/12/2018	21.91	21.91	20.5	21.46
12/13/2018	21	21.57	20.34	20.65
12/14/2018	21.57	22.47	20.95	21.63
12/17/2018	22.36	25.88	21.97	24.52
12/18/2018	24.68	26.14	23.64	25.58
12/19/2018	25.15	26.64	22.5	25.58
12/20/2018	26.09	30.3	24.68	28.38
12/21/2018	28.24	31.35	25.71	30.11
12/24/2018	29.29	36.1	29.16	36.07
12/26/2018	35.5	36.2	29.59	30.41
12/27/2018	31.2	33.8	29.66	29.96
12/28/2018	29.97	31.05	27.43	28.34
12/31/2018	27.59	27.64	25.33	25.42
1/2/2019	27.54	28.53	23.05	23.22
1/3/2019	25.68	26.6	24.05	25.45
1/4/2019	24.36	24.48	21.19	21.38

1/7/2019	22.06	22.71	20.91	21.4
1/8/2019	20.96	22.03	20.09	20.47
1/9/2019	20.44	22.8	19.48	19.98
1/10/2019	20.98	21.32	19.29	19.5
1/11/2019	19.68	20.16	18.12	18.19
1/14/2019	19.84	20.27	18.7	19.07
1/15/2019	18.53	19.2	17.98	18.6
1/16/2019	18.08	19.04	17.76	19.04
1/17/2019	19.51	19.72	17.85	18.06
1/18/2019	17.8	18.18	17.17	17.8
1/22/2019	18.53	21.15	18.2	20.8
1/23/2019	20.85	22.02	19.47	19.52
1/24/2019	19.69	20.25	18.63	18.89
1/25/2019	18.43	18.46	17.31	17.42
1/28/2019	18.56	20.42	18.42	18.87
1/29/2019	19.45	19.93	18.42	19.13
1/30/2019	19.15	19.31	17.54	17.66
1/31/2019	17.39	17.72	16.54	16.57
2/1/2019	16.63	16.83	16.08	16.14
2/4/2019	16.72	16.73	15.6	15.73
2/5/2019	15.79	15.94	15.04	15.57
2/6/2019	15.44	15.87	15.09	15.38
2/7/2019	15.66	17.89	15.51	16.37
2/8/2019	16.81	17.63	15.62	15.72
2/11/2019	16.17	16.5	15.34	15.97
2/12/2019	15.23	15.65	14.95	15.43
2/13/2019	15.46	15.91	15	15.65
2/14/2019	15.61	17.27	15.3	16.22
2/15/2019	16.82	16.82	14.79	14.91
2/19/2019	15.65	16.16	14.64	14.88
2/20/2019	14.92	15.19	13.99	14.02
2/21/2019	14	15.17	13.85	14.46
2/22/2019	14.46	14.47	13.51	13.51
2/25/2019	13.91	14.9	13.44	14.85
2/26/2019	15.16	15.28	14.52	15.17
2/27/2019	15.53	16.17	14.7	14.7
2/28/2019	15.17	15.24	14.39	14.78
3/1/2019	14.57	14.84	13.41	13.57
3/4/2019	13.77	16.98	13.38	14.63
3/5/2019	14.52	15.39	14.26	14.74
3/6/2019	14.91	16.11	14.74	15.74
3/7/2019	16.33	17.81	15.54	16.59
3/8/2019	17.38	18.33	16.02	16.05
3/11/2019	16.28	16.43	14.33	14.33
3/12/2019	13.97	14.7	13.61	13.77
3/13/2019	14	14.05	13.25	13.41
3/14/2019	13.35	13.84	13.16	13.5
3/15/2019	13.21	13.28	12.5	12.88
3/18/2019	13.13	13.8	13	13.1
3/19/2019	12.89	13.77	12.37	13.56
3/20/2019	13.54	14.3	13.05	13.91
3/21/2019	14.11	14.56	13.26	13.63
3/22/2019	13.77	17.52	13.62	16.48
3/25/2019	17.76	17.85	16.26	16.33
3/26/2019	16.22	16.3	14.67	14.68
3/27/2019	14.52	16.71	14.51	15.15
3/28/2019	15.38	15.62	14.41	14.43
3/29/2019	14.19	14.43	13.64	13.71
4/1/2019	13.9	14.01	13.32	13.4
4/2/2019	13.62	13.68	13.13	13.36
4/3/2019	13.06	14.27	12.85	13.74
4/4/2019	13.84	14.03	13.4	13.58
4/5/2019	13.46	13.47	12.17	12.82
4/8/2019	13.55	13.77	13.1	13.18
4/9/2019	13.46	14.39	13.31	14.28
4/10/2019	14.09	14.29	13.27	13.3
4/11/2019	13.37	13.58	12.91	13.02
4/12/2019	12.96	12.96	11.95	12.01
4/15/2019	12.46	13.14	12.24	12.32
4/16/2019	12.26	12.47	11.85	12.18
4/17/2019	12.12	13.02	11.03	12.6
4/18/2019	12.8	13.12	12.02	12.09
4/22/2019	13.21	13.36	12.38	12.42
4/23/2019	12.66	12.69	12.08	12.28
4/24/2019	12.53	13.23	12.26	13.14
4/25/2019	13.29	14.3	12.81	13.25
4/26/2019	13.44	13.62	12.49	12.73
4/29/2019	13.04	13.27	12.65	13.11
4/30/2019	13.11	14.05	12.88	13.12
5/1/2019	12.86	14.83	12.74	14.8
5/2/2019	14.35	15.92	13.8	14.42
5/3/2019	14.11	14.15	12.8	12.87
5/6/2019	12.89	18.8	12.89	15.44
5/7/2019	15.9	21.84	15.8	19.32
5/8/2019	18.95	21.74	18.29	19.4
5/9/2019	21.4	23.38	18.87	19.1
5/10/2019	18.79	20.19	15.57	16.04
5/13/2019	18.62	21.32	18.35	20.55
5/14/2019	19.4	19.65	17.45	18.06
5/15/2019	17.57	19.15	16.41	16.44
5/16/2019	16.69	17.13	15.16	15.29
5/17/2019	15.89	16.81	14.86	15.96
5/20/2019	15.88	17.63	15.46	16.31
5/21/2019	15.86	16.22	14.79	14.95
5/22/2019	15.06	15.44	14.42	14.75
5/23/2019	15.93	18.05	15.28	16.92
5/24/2019	16.34	16.52	15.52	15.85
5/28/2019	16.55	17.7	15.9	17.5
5/29/2019	18.55	19.04	17.62	17.9
5/30/2019	17.47	18.11	16.72	17.3
5/31/2019	19.05	19.72	18.01	18.71
6/3/2019	19.41	19.75	18.16	18.86
6/4/2019	18.74	18.74	16.97	16.97
6/5/2019	17.06	17.49	16.04	16.09
6/6/2019	16.25	16.54	15.36	15.93
6/7/2019	15.65	16.44	15.33	16.3
6/10/2019	16.3	16.47	15.84	15.94
6/11/2019	15.84	16.7	15.5	15.99

6/12/2019	16.26	16.43	15.78	15.91
6/13/2019	16.16	16.21	15.61	15.82
6/14/2019	16	16.4	15.21	15.28
6/17/2019	15.65	15.76	15.24	15.35
6/18/2019	14.89	15.54	14.62	15.15
6/19/2019	15.05	15.71	14.15	14.33
6/20/2019	14.04	16.03	13.19	14.75
6/21/2019	14.74	15.48	14.42	15.4
6/24/2019	15.46	15.56	15.23	15.26
6/25/2019	15.43	16.68	15.1	16.28
6/26/2019	16.1	16.6	15.47	16.21
6/27/2019	15.66	16.4	15.66	15.82
6/28/2019	15.7	16.13	15.08	15.08
7/1/2019	13.85	14.64	13.8	14.06
7/2/2019	14.16	14.3	12.9	12.93
7/3/2019	13.18	13.19	12.56	12.57
7/5/2019	13	14.47	12.04	13.28
7/8/2019	13.73	14.44	13.64	13.96
7/9/2019	14.47	14.71	13.99	14.09
7/10/2019	14.38	14.69	12.98	13.03
7/11/2019	13.01	13.33	12.39	12.93
7/12/2019	12.76	12.82	12.28	12.39
7/15/2019	12.58	13.02	12.49	12.68
7/16/2019	12.61	13.14	12.28	12.86
7/17/2019	12.62	13.97	12.24	13.97
7/18/2019	14.45	14.5	13.19	13.53
7/19/2019	13.31	14.45	13.09	14.45
7/22/2019	14.55	14.7	13.42	13.53
7/23/2019	13.42	13.52	12.55	12.61
7/24/2019	12.8	13.1	11.98	12.07
7/25/2019	12.24	13.54	11.69	12.74
7/26/2019	12.58	12.72	12.01	12.16
7/29/2019	12.15	13.17	12.15	12.83
7/30/2019	12.87	14.18	12.87	13.94
7/31/2019	13.83	16.55	13.46	16.12
8/1/2019	15.41	19.46	13.73	17.87
8/2/2019	17.69	20.11	17.04	17.61
8/5/2019	19.96	24.81	19.91	24.59
8/6/2019	22.29	22.87	19.77	20.17
8/7/2019	20.7	23.67	18.94	19.49
8/8/2019	19.36	19.89	16.82	16.91
8/9/2019	18.14	19.44	17.31	17.97
8/12/2019	17.87	21.26	17.77	21.09
8/13/2019	21.28	21.64	17.52	17.52
8/14/2019	17.81	22.71	17.75	22.1
8/15/2019	21.58	24.1	20.78	21.18
8/16/2019	20.48	20.5	18.41	18.47
8/19/2019	17.93	18.22	16.52	16.88
8/20/2019	16.78	17.7	16.45	17.5
8/21/2019	17.01	17.04	15.51	15.8
8/22/2019	16.12	17.68	15.63	16.68
8/23/2019	16.15	21.07	16.04	19.87
8/26/2019	20.34	21.33	19.06	19.32
8/27/2019	20.18	21.04	18.49	20.31
8/28/2019	20.55	21.64	19.1	19.35
8/29/2019	19.02	19.2	17.6	17.88
8/30/2019	17.94	19.18	17.09	18.98
9/3/2019	20.96	21.15	19.41	19.66
9/4/2019	18.23	18.83	17.26	17.33
9/5/2019	16.92	17.05	15.45	16.27
9/6/2019	15.92	16.06	14.91	15
9/9/2019	15.26	16.13	14.95	15.27
9/10/2019	15.53	16.52	15.11	15.2
9/11/2019	15.33	15.52	14.55	14.61
9/12/2019	14.69	14.94	13.85	14.22
9/13/2019	14.16	14.31	13.51	13.74
9/16/2019	14.89	15.29	14.5	14.67
9/17/2019	14.92	15.03	14.4	14.44
9/18/2019	14.61	15.8	13.8	13.95
9/19/2019	14.66	14.66	13.31	14.05
9/20/2019	13.94	15.84	13.35	15.32
9/23/2019	15.35	16	14.71	14.91
9/24/2019	14.77	17.62	14.33	17.05
9/25/2019	17.05	18.45	15.69	15.96
9/26/2019	16.23	17.09	15.35	16.07
9/27/2019	15.77	18.69	15.15	17.22
9/30/2019	17.23	17.35	16.2	16.24
10/1/2019	16.02	18.62	15.79	18.56
10/2/2019	18.75	21.46	18.75	20.56
10/3/2019	20.11	21.44	19.03	19.12
10/4/2019	19.42	19.97	16.97	17.04
10/7/2019	18.27	18.52	16.44	17.86
10/8/2019	17.61	20.38	17.42	20.28
10/9/2019	19.94	20	17.77	18.64
10/10/2019	19.28	19.8	17.56	17.57
10/11/2019	17.35	17.44	15.11	15.58
10/14/2019	15.66	16.5	14.51	14.57
10/15/2019	13.94	14.43	13.39	13.54
10/16/2019	13.94	14.26	13.6	13.68
10/17/2019	13.79	14.18	13.31	13.79
10/18/2019	14.2	15.16	13.78	14.25
10/21/2019	14.24	14.63	14	14
10/22/2019	13.99	14.61	13.7	14.46
10/23/2019	14.83	15.12	14.01	14.01
10/24/2019	13.98	14.34	13.4	13.71
10/25/2019	13.53	13.79	12.62	12.65
10/28/2019	13.01	13.14	12.66	13.11
10/29/2019	13.16	13.52	13.07	13.2
10/30/2019	13.23	13.77	12.27	12.33
10/31/2019	12.21	13.95	12.19	13.22
11/1/2019	12.99	13.12	12.25	12.3
11/4/2019	12.68	13.13	12.44	12.83
11/5/2019	12.85	13.28	12.25	13.1
11/6/2019	13.18	13.39	12.6	12.62
11/7/2019	12.59	12.89	12.26	12.73
11/8/2019	12.98	13.05	12	12.07
11/11/2019	13.15	13.49	12.66	12.69
11/12/2019	12.64	13.1	12.36	12.68

11/13/2019	12.91	13.9	12.88	13
11/14/2019	13.16	13.81	12.93	13.05
11/15/2019	12.95	12.97	11.92	12.05
11/18/2019	12.39	13.1	12.32	12.46
11/19/2019	12.33	13.01	12.16	12.86
11/20/2019	13.42	14.17	12.61	12.78
11/21/2019	13.35	13.86	12.49	13.13
11/22/2019	12.82	13.25	12.33	12.34
11/25/2019	12.51	12.59	11.73	11.87
11/26/2019	11.88	12.04	11.42	11.54
11/27/2019	11.55	11.79	11.44	11.75
11/29/2019	12.5	12.83	12.12	12.62
12/2/2019	12.69	15.27	12.55	14.91
12/3/2019	14.68	17.99	14.61	15.96
12/4/2019	16.38	16.4	14.12	14.8
12/5/2019	14.46	15.37	14.17	14.52
12/6/2019	14.37	14.47	13.19	13.62
12/9/2019	14.25	16.07	12.25	15.86
12/10/2019	15.8	16.9	14.93	15.68
12/11/2019	15.57	15.97	14.98	14.99
12/12/2019	14.94	15.55	13.6	13.94
12/13/2019	13.18	14.35	12.54	12.63
12/16/2019	12.47	12.53	11.71	12.14
12/17/2019	12.23	12.47	11.9	12.29
12/18/2019	12.24	12.7	11.93	12.58
12/19/2019	12.55	12.78	12.43	12.5
12/20/2019	12.55	12.61	12.04	12.51
12/23/2019	12.81	12.9	12.41	12.61
12/24/2019	12.65	12.84	12.56	12.67
12/26/2019	12.74	12.75	11.72	12.65
12/27/2019	12.61	13.72	11.89	13.43
12/30/2019	13.74	15.14	13.44	14.82
12/31/2019	14.84	15.39	13.75	13.78
1/2/2020	13.46	13.72	12.42	12.47
1/3/2020	15.01	16.2	13.13	14.02
1/6/2020	15.45	16.39	13.54	13.85
1/7/2020	13.84	14.46	13.39	13.79
1/8/2020	15.16	15.24	12.83	13.45
1/9/2020	12.95	13.24	12.53	12.54
1/10/2020	12.42	12.87	12.09	12.56
1/13/2020	12.84	13.09	12.32	12.32
1/14/2020	12.72	13.82	12.05	12.39
1/15/2020	12.79	12.83	11.95	12.42
1/16/2020	12.2	12.42	11.78	12.32
1/17/2020	12.21	12.48	11.75	12.1
1/21/2020	13.23	13.33	12.32	12.85
1/22/2020	12.45	13.01	12.31	12.91
1/23/2020	13.26	14.15	12.94	12.98
1/24/2020	12.75	15.98	12.62	14.56
1/27/2020	17.42	19.02	16.82	18.23
1/28/2020	16.94	18.03	15.69	16.28
1/29/2020	15.68	16.65	14.94	16.39
1/30/2020	17.82	18.39	15.3	15.49
1/31/2020	16.25	19.99	16.18	18.84
2/3/2020	18.64	18.88	17.1	17.97
2/4/2020	16.45	16.46	15.63	16.05
2/5/2020	16.29	16.32	15.02	15.15
2/6/2020	15.13	15.66	14.7	14.96
2/7/2020	15.07	16.16	14.81	15.47
2/10/2020	15.88	16.43	15.01	15.04
2/11/2020	14.91	15.27	14.38	15.18
2/12/2020	14.86	14.88	13.73	13.74
2/13/2020	14.43	15.44	14	14.15
2/14/2020	14.12	14.54	13.38	13.68
2/18/2020	14.98	15.49	14.53	14.83
2/19/2020	14.66	14.74	14.21	14.38
2/20/2020	14.54	17.21	14.49	15.56
2/21/2020	17.33	18.21	16.19	17.08
2/24/2020	22.25	26.35	22	25.03
2/25/2020	22.19	30.25	22.19	27.85
2/26/2020	26.63	29.57	24.76	27.56
2/27/2020	28.95	39.31	27.79	39.16
2/28/2020	42.02	49.48	39.37	40.11
3/2/2020	34.86	43.77	31.5	33.42
3/3/2020	33.64	41.06	24.93	36.82
3/4/2020	34.44	35.58	30.3	31.99
3/5/2020	33.61	42.84	33.54	39.62
3/6/2020	41.46	54.39	40.84	41.94
3/9/2020	41.94	62.12	41.94	54.46
3/10/2020	49.68	55.66	43.56	47.3
3/11/2020	52.24	55.82	49.98	53.9
3/12/2020	61.46	76.83	59.91	75.47
3/13/2020	71.31	77.57	55.17	57.83
3/16/2020	57.83	83.56	57.83	82.69
3/17/2020	82.69	84.83	70.37	75.91
3/18/2020	69.37	85.47	69.37	76.45
3/19/2020	80.62	84.26	68.57	72
3/20/2020	67.86	69.51	57.42	66.04
3/23/2020	74.08	76.74	60.46	61.59
3/24/2020	58.76	61.88	36.24	61.67
3/25/2020	61.44	68.86	58.03	63.95
3/26/2020	65.67	67.06	57.66	61
3/27/2020	64.95	69.1	61.8	65.54
3/30/2020	66.3	67.69	56.6	57.08
3/31/2020	56.69	58.75	50.88	53.54
4/1/2020	57.38	60.59	52.76	57.06
4/2/2020	54.46	57.24	50.45	50.91
4/3/2020	51.11	52.29	46.74	46.8
4/6/2020	44.17	45.73	43.45	45.24
4/7/2020	44.83	47.51	43.51	46.7
4/8/2020	45.9	47.28	42.53	43.35
4/9/2020	43	45.73	41.39	41.67
4/13/2020	44.6	45.04	41.17	41.17
4/14/2020	40.24	40.57	37.31	37.76
4/15/2020	39.4	43.23	39.34	40.84
4/16/2020	41.92	43.02	39.87	40.11
4/17/2020	39.5	40.26	37.63	38.15
4/20/2020	40.68	43.83	39.88	43.83

4/21/2020	44.28	47.77	43.77	45.41
4/22/2020	44.91	45.07	41.41	41.98
4/23/2020	41.3	42.47	39.06	41.38
4/24/2020	41.91	42.08	35.6	35.93
4/27/2020	36.29	36.44	32.51	33.29
4/28/2020	33.21	35.39	30.54	33.57
4/29/2020	32.48	33.19	30.71	31.23
4/30/2020	30.99	35.94	30.93	34.15
5/1/2020	38.17	39.57	36.59	37.19
5/4/2020	39.13	40.32	35.53	35.97
5/5/2020	34.82	36.22	31.95	33.61
5/6/2020	32.69	35.69	31.68	34.12
5/7/2020	32.12	32.28	30.37	31.44
5/8/2020	30.14	30.39	27.89	27.98
5/11/2020	28.46	31.46	26.97	27.57
5/12/2020	28.47	33.04	26	33.04
5/13/2020	32.74	37.42	30.77	35.28
5/14/2020	35.16	39.28	32.33	32.61
5/15/2020	32.5	35.13	31.04	31.89
5/18/2020	30.71	31.08	28.35	29.3
5/19/2020	28.73	30.74	28.37	30.53
5/20/2020	29.52	29.83	27.83	27.99
5/21/2020	28.97	30.2	27.67	29.53
5/22/2020	31.36	31.55	28.03	28.16
5/26/2020	27.72	28.58	27.18	28.01
5/27/2020	27.62	30.53	25.92	27.62
5/28/2020	27.82	29.89	27.43	28.59
5/29/2020	29.3	30.16	27.29	27.51
6/1/2020	28.94	30.6	28.11	28.23
6/2/2020	28.4	28.52	26.66	26.84
6/3/2020	26.75	26.98	25.04	25.66
6/4/2020	26.23	26.43	24.38	25.81
6/5/2020	24.79	25.09	23.54	24.52
6/8/2020	25.56	25.98	24.65	25.81
6/9/2020	25.93	27.7	25.71	27.57
6/10/2020	26.73	29.01	26.06	27.57
6/11/2020	30.45	42.58	29.49	40.79
6/12/2020	37.68	44.16	34.97	36.09
6/15/2020	44.09	44.44	34.28	34.4
6/16/2020	34.28	37.45	31.73	33.67
6/17/2020	33.28	35.17	32.25	33.47
6/18/2020	33.83	36.25	32.24	32.94
6/19/2020	32.07	35.12	30.4	35.12
6/22/2020	35.22	35.39	31.64	31.77
6/23/2020	31.71	31.71	29.26	31.37
6/24/2020	31.05	37.12	30.95	33.84
6/25/2020	36.59	36.93	31.59	32.22
6/26/2020	33.01	36.25	31.04	34.73
6/29/2020	35.05	36.31	31.78	31.78
6/30/2020	32.54	32.94	29.56	30.43
7/1/2020	30.96	31.76	28.2	28.62
7/2/2020	28.33	28.44	25.9	27.68
7/6/2020	27.76	28.33	24.92	27.94
7/7/2020	28.77	29.63	27.25	29.43
7/8/2020	28.95	30.2	27.24	28.08
7/9/2020	28.18	31.48	26.11	29.26
7/10/2020	30.86	30.91	27.13	27.29
7/13/2020	27.85	32.45	26.87	32.19
7/14/2020	31.14	33.67	29.21	29.52
7/15/2020	29.15	30.09	27.17	27.76
7/16/2020	28.41	29.29	26.98	28
7/17/2020	27.15	27.54	25.41	25.68
7/20/2020	26.94	27.08	24.35	24.46
7/21/2020	24.08	25.65	23.61	24.84
7/22/2020	24.56	26.26	24.13	24.32
7/23/2020	23.97	26.95	23.6	26.08
7/24/2020	27.96	28.58	25.53	25.84
7/27/2020	26.6	26.94	24.55	24.74
7/28/2020	24.86	25.85	24.05	25.44
7/29/2020	25.16	25.42	23.73	24.1
7/30/2020	25.04	28.29	24.64	24.76
7/31/2020	24.79	26.41	23.55	24.46
8/3/2020	25.75	26.01	22.17	24.28
8/4/2020	24.01	24.76	22.92	23.76
8/5/2020	23.44	23.61	22.86	22.99
8/6/2020	23.03	24.11	20.97	22.65
8/7/2020	23.45	24.02	22.02	22.21
8/10/2020	22.88	23.52	21.46	22.13
8/11/2020	21.85	24.93	20.28	24.03
8/12/2020	22.82	22.88	21.54	22.28
8/13/2020	22.2	22.92	21.45	22.13
8/14/2020	22.27	23.55	21.79	22.05
8/17/2020	22.52	22.82	21.34	21.35
8/18/2020	21.69	22.55	21.18	21.51
8/19/2020	21.6	22.98	20.99	22.54
8/20/2020	24.1	24.6	22.37	22.72
8/21/2020	22.58	24.47	22.06	22.54
8/24/2020	22.87	23.18	21.25	22.37
8/25/2020	22.16	23.43	21.53	22.03
8/26/2020	22.14	23.27	20.92	23.27
8/27/2020	23.42	27.09	21.44	24.47
8/28/2020	24.59	26.3	22.64	22.96
8/31/2020	23.91	26.5	21.77	26.41
9/1/2020	25.86	26.59	25.02	26.12
9/2/2020	26.01	27.07	25.53	26.57
9/3/2020	26.28	35.94	25.66	33.6
9/4/2020	34.62	38.28	29.5	30.75
9/8/2020	30.61	35.93	30.52	31.46
9/9/2020	31.68	31.78	28.12	28.81
9/10/2020	28.67	30.56	27.59	29.71
9/11/2020	28.63	29.73	26.51	26.87
9/14/2020	25.86	26.79	25.38	25.85
9/15/2020	25.92	26	24.92	25.59
9/16/2020	25.31	26.59	24.84	26.04
9/17/2020	28.22	28.92	26.26	26.46
9/18/2020	26.65	28.1	25.28	25.83
9/21/2020	28.04	31.18	27.39	27.78
9/22/2020	28.61	28.78	26.48	26.86

9/23/2020	27.02	29.73	25.19	28.58
9/24/2020	29.54	30.49	27.94	28.51
9/25/2020	28.17	30.43	26.02	26.38
9/28/2020	27.15	27.19	24.9	26.19
9/29/2020	26.81	27.43	25.98	26.27
9/30/2020	26.69	27.12	25.06	26.37
10/1/2020	25.78	27.11	25.33	26.7
10/2/2020	28.87	29.9	26.93	27.63
10/5/2020	29.52	29.69	27.27	27.96
10/6/2020	28.05	30	26.01	29.48
10/7/2020	29.26	29.76	27.94	28.06
10/8/2020	27.65	27.99	24.88	26.36
10/9/2020	26.2	26.22	24.03	25
10/12/2020	25.65	25.65	24.14	25.07
10/13/2020	25.67	26.93	25.16	26.07
10/14/2020	25.72	27.23	25.53	26.4
10/15/2020	27.1	29.06	26.82	26.97
10/16/2020	27.16	27.46	26.19	27.41
10/19/2020	27.36	29.69	27.04	29.18
10/20/2020	28.81	29.6	28.29	29.35
10/21/2020	29.12	30.55	28.37	28.65
10/22/2020	30.1	30.12	27.68	28.11
10/23/2020	28.47	28.67	27.26	27.55
10/26/2020	29.38	33.68	29.22	32.46
10/27/2020	32.04	33.77	31.85	33.35
10/28/2020	34.69	40.77	34.68	40.28
10/29/2020	38.8	41.16	35.63	37.59
10/30/2020	40.81	41.09	36.5	38.02
11/2/2020	38.57	38.78	36.13	37.13
11/3/2020	36.44	36.44	34.19	35.55
11/4/2020	36.79	36.85	28.03	29.57
11/5/2020	27.56	28.14	26.04	27.58
11/6/2020	27.87	29.44	24.56	24.86
11/9/2020	24.8	25.82	22.41	25.75
11/10/2020	25.36	26.77	24.35	24.8
11/11/2020	25.01	25.12	22.57	23.45
11/12/2020	24.39	27.27	23.53	25.35
11/13/2020	24.94	25.03	22.74	23.1
11/16/2020	23.66	24.08	22.43	22.45
11/17/2020	22.84	24.09	22.34	22.71
11/18/2020	22.86	23.92	21.66	23.84
11/19/2020	23.62	24.52	22.56	23.11
11/20/2020	23.43	23.73	22.13	23.7
11/23/2020	23.66	23.96	22.45	22.66
11/24/2020	22.04	22.48	20.8	21.64
11/25/2020	21.65	22.5	21.13	21.25
11/27/2020	21.52	21.6	19.51	20.84
11/30/2020	22.64	22.89	20.48	20.57
12/1/2020	20.21	20.92	20	20.77
12/2/2020	21	21.25	20.04	21.17
12/3/2020	21.24	21.88	20.72	21.28
12/4/2020	21.05	21.15	19.97	20.79
12/7/2020	22.04	22.62	21.17	21.3
12/8/2020	21.65	22.25	20.52	20.68
12/9/2020	20.66	22.93	20.1	22.27
12/10/2020	22.12	23.46	21.53	22.52
12/11/2020	22.49	25.14	22.48	23.31
12/14/2020	22.67	24.82	21.95	24.72
12/15/2020	24	24.07	22.73	22.89
12/16/2020	22.51	23.67	22.29	22.5
12/17/2020	21.98	22.27	21.52	21.93
12/18/2020	22.15	23.77	21.57	21.57
12/21/2020	24.25	31.46	24.23	25.16
12/22/2020	25.24	25.56	23.53	24.23
12/23/2020	23.49	23.68	22.13	23.31
12/24/2020	22.47	22.83	21.39	21.53
12/28/2020	22.11	22.12	21.15	21.7
12/29/2020	21.61	23.72	20.99	23.08
12/30/2020	22.58	23.15	22.41	22.77
12/31/2020	22.99	23.25	21.24	22.75
1/4/2021	23.04	29.19	22.56	26.97
1/5/2021	26.94	28.6	24.8	25.34
1/6/2021	25.48	26.77	22.14	25.07
1/7/2021	23.67	23.91	22.25	22.37
1/8/2021	22.43	23.34	21.42	21.56
1/11/2021	23.31	24.81	23.23	24.08
1/12/2021	23.49	25.15	22.83	23.33
1/13/2021	23.07	24.18	21.92	22.21
1/14/2021	22.22	23.47	21.66	23.25
1/15/2021	23.52	25.8	23.08	24.34
1/19/2021	23.03	23.56	22.53	23.24
1/20/2021	22.82	22.86	21.37	21.58
1/21/2021	21.34	22.22	21.09	21.32
1/22/2021	22.24	23.73	21.27	21.91
1/25/2021	22.31	26.63	22.2	23.19
1/26/2021	23.91	23.94	22.55	23.02
1/27/2021	23.82	37.21	23.71	37.21
1/28/2021	33.25	36.29	27.39	30.21
1/29/2021	35.16	37.51	29.24	33.09
2/1/2021	31.45	33.96	29.03	30.24
2/2/2021	28.01	28.08	25.31	25.56
2/3/2021	24.59	25.43	22.91	22.91
2/4/2021	23.44	23.44	21.68	21.77
2/5/2021	21.99	22.16	20.86	20.87
2/8/2021	21.89	22.07	21.23	21.24
2/9/2021	21.57	22.26	20.65	21.63
2/10/2021	21.64	23.85	19.69	21.99
2/11/2021	22.09	23.25	21.11	21.25
2/12/2021	21.6	22.45	19.95	19.97
2/16/2021	21.13	22.46	20.88	21.46
2/17/2021	22.02	23.44	21.09	21.5
2/18/2021	21.98	24.23	21.8	22.49
2/19/2021	23.1	23.19	20.84	22.05
2/22/2021	24.46	25.09	21.96	23.45
2/23/2021	22.82	27.01	22.5	23.11
2/24/2021	23.76	25.04	21.31	21.34
2/25/2021	21.73	31.16	21.52	28.89
2/26/2021	28.73	30.82	25.23	27.95

3/1/2021	25.2	25.39	23.17	23.35
3/2/2021	23.58	24.6	22.8	24.1
3/3/2021	22.8	26.79	22.45	26.67
3/4/2021	26.52	31.9	24.93	28.57
3/5/2021	29.48	30.03	24.33	24.66
3/8/2021	27.61	28.39	24.07	25.47
3/9/2021	25.11	25.25	22.9	24.03
3/10/2021	23.76	23.87	22.38	22.56
3/11/2021	22.5	22.5	21.45	21.91
3/12/2021	22.57	22.99	20.63	20.69
3/15/2021	21.84	21.86	19.87	20.03
3/16/2021	20.14	20.31	19.33	19.79
3/17/2021	20.1	20.95	19.18	19.23
3/18/2021	18.95	22.6	18.95	21.58
3/19/2021	21.43	23.17	19.9	20.95
3/22/2021	21.91	22.29	18.87	18.88
3/23/2021	19.46	21.58	18.8	20.3
3/24/2021	20.64	21.49	19.3	21.2
3/25/2021	20.8	23.55	19.81	19.81
3/26/2021	19.32	21.49	18.68	18.86
3/29/2021	20.4	21.6	19.42	20.74
3/30/2021	20.76	21.75	19.47	19.61
3/31/2021	19.8	20.11	18.85	19.4
4/1/2021	18.6	18.64	17.29	17.33
4/5/2021	18.16	18.4	17.35	17.91
4/6/2021	18.07	18.3	17.37	18.12
4/7/2021	17.99	18.17	16.87	17.16
4/8/2021	16.92	17.36	16.55	16.95
4/9/2021	17.05	17.34	16.2	16.69
4/12/2021	17.43	17.91	16.81	16.91
4/13/2021	16.99	17.86	16.43	16.65
4/14/2021	16.71	17.69	15.38	16.99
4/15/2021	16.78	16.92	15.94	16.57
4/16/2021	16.65	16.88	16.05	16.25
4/19/2021	17.04	18.61	16.78	17.29
4/20/2021	17.36	19.7	17.24	18.68
4/21/2021	18.48	19.29	16.91	17.5
4/22/2021	17.28	19.9	16.99	18.71
4/23/2021	18.56	18.78	16.8	17.33
4/26/2021	17.94	18.17	16.87	17.64
4/27/2021	17.62	18.16	16.97	17.56
4/28/2021	17.47	17.84	16.67	17.28
4/29/2021	16.88	18.87	16.77	17.61
4/30/2021	17.67	19.25	17.64	18.61
5/3/2021	18.65	19.12	17.8	18.31
5/4/2021	18.16	21.85	18.11	19.48
5/5/2021	18.84	19.58	17.89	19.15
5/6/2021	18.41	20.6	18.21	18.39
5/7/2021	18.45	18.57	16.68	16.69
5/10/2021	17.34	19.75	17.07	19.66
5/11/2021	21.17	23.73	20.71	21.84
5/12/2021	22.42	28.38	21.66	27.59
5/13/2021	26.03	28.93	22.23	23.13
5/14/2021	21.77	22.1	18.66	18.81
5/17/2021	19.89	21.58	19.67	19.72
5/18/2021	18.89	21.45	18.81	21.34
5/19/2021	22.46	25.96	21.88	22.18
5/20/2021	22.33	23.5	20.19	20.67
5/21/2021	20.42	20.89	19.53	20.15
5/24/2021	20.5	20.51	18.38	18.4
5/25/2021	18.35	19.29	16.87	18.84
5/26/2021	18.37	18.92	17.35	17.36
5/27/2021	18.03	18.17	16.52	16.74
5/28/2021	16.8	16.86	15.9	16.76
6/1/2021	17.24	18.53	15.68	17.9
6/2/2021	17.86	18.31	16.74	17.48
6/3/2021	17.73	19.27	17.45	18.04
6/4/2021	18.09	18.42	16.18	16.42
6/7/2021	17.34	17.35	15.78	16.42
6/8/2021	16.58	17.75	15.15	17.07
6/9/2021	17.18	17.96	15.55	17.89
6/10/2021	18.18	18.29	16.01	16.1
6/11/2021	16.18	16.2	15.15	15.65
6/14/2021	16.04	17.04	15.04	16.39
6/15/2021	16.27	17.35	16.14	17.02
6/16/2021	16.99	19.11	16.42	18.15
6/17/2021	18.49	19.22	16.71	17.75
6/18/2021	16.96	21.04	16.92	20.7
6/21/2021	21.74	21.82	17.81	17.89
6/22/2021	17.91	18.32	15.76	16.66
6/23/2021	16.25	16.84	14.86	16.32
6/24/2021	15.99	16.05	14.19	15.97
6/25/2021	16.04	16.17	15.21	15.62
6/28/2021	16.07	16.46	15.39	15.76
6/29/2021	15.69	16.31	14.1	16.02
6/30/2021	16.18	17.31	15.58	15.83
7/1/2021	15.62	16.01	15.31	15.48
7/2/2021	15.53	15.54	14.25	15.07
7/6/2021	15.77	17.94	15.73	16.44
7/7/2021	16.43	17.64	16.08	16.2
7/8/2021	17.74	21.29	17.74	19
7/9/2021	17.88	18.13	16.08	16.18
7/12/2021	16.85	17.52	16.14	16.17
7/13/2021	16.39	17.23	15.94	17.12
7/14/2021	17.34	17.51	15.95	16.33
7/15/2021	16.7	18.09	16.56	17.01
7/16/2021	16.8	18.7	16.03	18.45
7/19/2021	19.61	25.09	19.27	22.5
7/20/2021	20.89	22.97	19.37	19.73
7/21/2021	19.73	19.82	17.81	17.91
7/22/2021	17.59	18.45	17.4	17.69
7/23/2021	16.98	17.48	16.33	17.2
7/26/2021	18.67	19.39	17.53	17.58
7/27/2021	18.62	20.44	18.25	19.36
7/28/2021	19.41	19.62	17.52	18.31
7/29/2021	17.91	18.01	17.19	17.7
7/30/2021	19.69	19.72	17.53	18.24
8/2/2021	18.16	19.87	17.99	19.46

8/3/2021	19.17	20.44	17.7	18.04
8/4/2021	18.23	18.9	17.67	17.97
8/5/2021	17.73	17.84	17.23	17.28
8/6/2021	17.46	17.5	16.14	16.15
8/9/2021	17.12	17.39	16.59	16.72
8/10/2021	16.82	17.05	16.34	16.79
8/11/2021	16.81	17.09	15.87	16.06
8/12/2021	16.33	16.42	15.49	15.59
8/13/2021	15.68	15.72	15.19	15.45
8/16/2021	17.05	17.71	16.02	16.12
8/17/2021	17.31	19.56	16.71	17.91
8/18/2021	17.56	21.64	17.31	21.57
8/19/2021	23.12	24.74	20.37	21.67
8/20/2021	22.74	23.9	18.18	18.56
8/23/2021	18.83	18.95	16.95	17.15
8/24/2021	16.96	17.51	16.94	17.22
8/25/2021	17.42	17.5	16.46	16.79
8/26/2021	17.46	19.27	17.16	18.84
8/27/2021	17.95	18.22	16.11	16.39
8/30/2021	16.77	16.8	15.98	16.19
8/31/2021	15.98	17.07	15.91	16.48
9/1/2021	16.06	16.71	15.68	16.11
9/2/2021	16.27	16.98	15.73	16.41
9/3/2021	16.27	17.06	16.08	16.41
9/7/2021	16.94	18.39	16.89	18.14
9/8/2021	18.97	19.64	17.78	17.96
9/9/2021	19.44	19.54	17.17	18.8
9/10/2021	17.94	21.13	16.99	20.95
9/13/2021	19.64	21.18	18.76	19.37
9/14/2021	19.58	20.47	18.39	19.46
9/15/2021	19.3	20.27	18.01	18.18
9/16/2021	18.41	19.76	17.65	18.69
9/17/2021	18.37	21.51	18.35	20.81
9/20/2021	24.25	28.79	23.9	25.71
9/21/2021	23.41	25.6	21.71	24.36
9/22/2021	22.72	23.4	20.75	20.87
9/23/2021	19.91	20.21	18.42	18.63
9/24/2021	19.33	20.41	17.63	17.75
9/27/2021	17.78	19.32	17.74	18.76
9/28/2021	19.74	24.82	19.71	23.25
9/29/2021	22.07	23.79	21.45	22.56
9/30/2021	21.48	24.71	20.6	23.14
10/1/2021	24.78	24.89	20.64	21.15
10/4/2021	22.9	24.58	21.88	22.96
10/5/2021	22.92	23.17	20.62	21.3
10/6/2021	22.95	24.4	20.99	21
10/7/2021	20.54	20.76	19.07	19.54
10/8/2021	19.46	19.94	18.2	18.77
10/11/2021	19.93	20.45	18.11	20
10/12/2021	20.62	20.81	18.97	19.85
10/13/2021	20.14	20.23	18.44	18.64
10/14/2021	18.01	18.08	16.8	16.86
10/15/2021	16.64	16.85	15.72	16.3
10/18/2021	17.29	17.93	16.27	16.31
10/19/2021	16.09	16.31	15.57	15.7
10/20/2021	15.82	15.89	15.29	15.49
10/21/2021	16.06	16.11	14.92	15.01
10/22/2021	15.35	16.39	14.84	15.43
10/25/2021	16.14	16.33	15.1	15.24
10/26/2021	15.02	16.71	14.9	15.98
10/27/2021	15.79	17.29	15.54	16.98
10/28/2021	17.06	17.16	16.23	16.53
10/29/2021	17.4	18.06	16.13	16.26
11/1/2021	16.85	17.7	16.32	16.41
11/2/2021	16.54	16.65	15.89	16.03
11/3/2021	16.11	16.39	14.9	15.1
11/4/2021	15.06	16.14	14.73	15.44
11/5/2021	15.59	17.02	14.95	16.48
11/8/2021	17.23	17.69	16.44	17.22
11/9/2021	17.43	18.57	17.21	17.78
11/10/2021	17.74	19.9	17.22	18.73
11/11/2021	18.34	18.39	17.27	17.66
11/12/2021	17.49	17.69	16.15	16.29
11/15/2021	17.03	17.46	16.49	16.49
11/16/2021	16.86	17.08	16.03	16.37
11/17/2021	16.36	17.19	16.28	17.11
11/18/2021	16.81	18.15	16.38	17.59
11/19/2021	17.36	19.01	17.23	17.91
11/22/2021	18.2	19.59	17.35	19.17
11/23/2021	20.24	20.91	19.03	19.38
11/24/2021	19.17	20.96	18.52	18.58
11/26/2021	26.62	28.99	23.88	28.62
11/29/2021	25.31	25.69	21.71	22.96
11/30/2021	26.23	28.56	23.71	27.19
12/1/2021	24.92	32.61	22.38	31.12
12/2/2021	29.44	30.68	27.15	27.95
12/3/2021	26.95	35.32	25.89	30.67
12/6/2021	28.99	30.82	26.75	27.18
12/7/2021	24.58	24.69	21.58	21.89
12/8/2021	21.74	23.11	19.85	19.9
12/9/2021	20.31	22.12	19.94	21.58
12/10/2021	21.27	21.3	18.69	18.69
12/13/2021	19.29	21.18	18.96	20.31
12/14/2021	19.67	23	19.67	21.89
12/15/2021	21.6	23.47	19.02	19.29
12/16/2021	18.56	22.13	18.19	20.57
12/17/2021	20.7	23.26	20.49	21.57
12/20/2021	25.89	27.39	22.85	22.87
12/21/2021	22.28	22.68	20.9	21.01
12/22/2021	21.04	21.36	18.59	18.63
12/23/2021	18.81	18.93	17.62	17.96
12/27/2021	19.37	19.41	17.55	17.68
12/28/2021	17.78	18.47	17.51	17.54
12/29/2021	17.63	18	16.71	16.95
12/30/2021	17.3	17.79	16.62	17.33
12/31/2021	17.63	18.27	16.99	17.22
1/3/2022	17.6	18.54	16.56	16.6
1/4/2022	16.57	17.81	16.34	16.91

1/5/2022	17.07	20.17	16.58	19.73
1/6/2022	20.29	21.06	19.08	19.61
1/7/2022	19.85	20.8	18.57	18.76
1/10/2022	19.58	23.33	19.29	19.4
1/11/2022	19.62	21	18.2	18.41
1/12/2022	18.17	18.69	17.36	17.62
1/13/2022	18.06	20.61	17.45	20.31
1/14/2022	20.11	22.07	19.05	19.19
1/18/2022	21.18	23.2	21.18	22.79
1/19/2022	23.12	23.99	21.85	23.85
1/20/2022	23.46	25.89	21.68	25.59
1/21/2022	25.38	29.79	25.31	28.85
1/24/2022	28.2	38.94	28.02	29.9
1/25/2022	32.29	35.85	29.13	31.16
1/26/2022	29.35	33.04	26.9	31.96
1/27/2022	32.19	33	28.42	30.49
1/28/2022	30.27	32.82	27.28	27.66
1/31/2022	28.36	29.41	24.71	24.83
2/1/2022	24.57	25.33	21.96	21.96
2/2/2022	21.56	22.73	20.46	22.09
2/3/2022	22.63	25.81	22.3	24.35
2/4/2022	23.77	26.26	22.07	23.22
2/7/2022	24.09	24.82	22.02	22.86
2/8/2022	23.09	23.48	21.32	21.44
2/9/2022	21.27	21.3	19.93	19.96
2/10/2022	20.37	24.77	20.18	23.91
2/11/2022	24.39	30.99	23.33	27.36
2/14/2022	29.17	32.04	28.33	28.33
2/15/2022	28.09	28.09	25.33	25.7
2/16/2022	25.19	27.09	23.88	24.29
2/17/2022	24.83	28.37	24.76	28.11
2/18/2022	26.66	29.71	26.38	27.75
2/22/2022	31.8	32.04	28.4	28.81
2/23/2022	28.04	31.07	27.2	31.02
2/24/2022	37.5	37.79	29.45	30.32
2/25/2022	31.68	32	26.93	27.59
2/28/2022	32.44	33.51	28.43	30.15
3/1/2022	29.45	35.19	29.44	33.32
3/2/2022	34.2	34.41	30.12	30.74
3/3/2022	30.52	32.01	29.31	30.48
3/4/2022	31.9	34.65	31.47	31.98
3/7/2022	35.88	36.55	32.59	36.45
3/8/2022	36.19	37.52	32.78	35.13
3/9/2022	33.74	34.12	31.39	32.45
3/10/2022	33.03	34.03	30.23	30.23
3/11/2022	30.43	31.04	28.84	30.75
3/14/2022	31.03	33.18	30.06	31.77
3/15/2022	33.13	33.83	29.57	29.83
3/16/2022	29.02	29.8	26.29	26.67
3/17/2022	26.51	27.47	25.25	25.67
3/18/2022	26.36	26.82	23.85	23.87
3/21/2022	25.14	25.36	22.99	23.53
3/22/2022	24.02	24.02	22.7	22.94
3/23/2022	23.04	24.03	22.64	23.57
3/24/2022	23.61	23.79	21.49	21.67
3/25/2022	21.87	22.86	20.8	20.81
3/28/2022	22.14	23.33	19.54	19.63
3/29/2022	19.7	19.73	18.67	18.9
3/30/2022	19.38	20.51	18.72	19.33
3/31/2022	19.68	21.48	19.54	20.56
4/1/2022	20.62	20.86	19.41	19.63
4/4/2022	20.75	20.78	18.45	18.57
4/5/2022	18.79	21.57	18.55	21.03
4/6/2022	21.27	24.78	21.24	22.1
4/7/2022	21.97	23.82	21.12	21.55
4/8/2022	21.25	22.34	20.28	21.16
4/11/2022	23.09	24.42	22.09	24.37
4/12/2022	24.94	25.38	22.27	24.26
4/13/2022	23.52	24.45	21.37	21.82
4/14/2022	21.72	22.7	20.85	22.7
4/18/2022	24.52	24.6	21.98	22.17
4/19/2022	22.55	22.92	20.36	21.37
4/20/2022	21.13	21.32	19.75	20.32
4/21/2022	20.24	23.28	19.81	22.68
4/22/2022	22.71	28.27	22.62	28.21
4/25/2022	30.04	31.6	26.8	27.02
4/26/2022	27.38	33.81	27.06	33.52
4/27/2022	31.11	32.77	29.82	31.6
4/28/2022	29.91	32	28	29.99
4/29/2022	28.97	34.34	28.54	33.4
5/2/2022	33.35	36.64	31.74	32.34
5/3/2022	31.76	32.82	29.06	29.25
5/4/2022	29.12	29.42	24.94	25.42
5/5/2022	25.97	33.2	25.78	31.2
5/6/2022	32.23	35.34	29.83	30.19
5/9/2022	31.9	35.48	31.9	34.75
5/10/2022	33.66	34.84	32.24	32.99
5/11/2022	32.87	34.39	30.69	32.56
5/12/2022	33.74	34.76	31.7	31.77
5/13/2022	31.09	31.2	28.78	28.87
5/16/2022	30.01	30.23	27.36	27.47
5/17/2022	27.07	27.17	25.51	26.1
5/18/2022	26.74	31.49	26.21	30.96
5/19/2022	31.24	33.11	29.06	29.35
5/20/2022	28.78	32.91	28.06	29.43
5/23/2022	28.98	30.39	28.29	28.48
5/24/2022	29.43	31.07	29.04	29.45
5/25/2022	29.33	30.23	28.16	28.37
5/26/2022	28.42	28.46	27.11	27.5
5/27/2022	27.5	27.54	25.57	25.72
5/30/2022	26.16	26.81	26.08	26.54
5/31/2022	27.47	28.35	25.94	26.19
6/1/2022	26.05	27.73	25.38	25.69
6/2/2022	25.73	26.5	24.33	24.72
6/3/2022	24.91	25.96	24.76	24.79
6/6/2022	25.37	25.81	24.82	25.07
6/7/2022	25.54	26.24	23.88	24.02
6/8/2022	24.37	24.78	23.74	23.96

6/9/2022	24.29	26.24	23.82	26.09
6/10/2022	26.26	29.63	26.05	27.75
6/13/2022	31.37	35.05	31.29	34.02
6/14/2022	33.01	34	32.06	32.69
6/15/2022	32.39	32.77	27.76	29.62
6/16/2022	30.35	34.82	30.35	32.95
6/17/2022	32.84	33.31	30.47	31.13
6/20/2022	32.06	32.16	30.98	31.03
6/21/2022	30.63	30.65	29.33	30.19
6/22/2022	31.45	31.57	28.78	28.95
6/23/2022	29.29	29.77	28.74	29.05
6/24/2022	29.07	29.72	26.83	27.23
6/27/2022	28.3	28.66	26.93	26.95
6/28/2022	26.9	28.68	26.47	28.36
6/29/2022	28.8	29.36	27.85	28.16
6/30/2022	29.42	30.22	28.28	28.71
7/1/2022	29.53	29.59	26.69	26.7
7/4/2022	27.96	28.1	27.46	27.53
7/5/2022	27.37	29.82	27.3	27.54
7/6/2022	27.84	28.07	26.43	26.73
7/7/2022	26.73	26.79	25.66	26.08
7/8/2022	26.41	26.61	24.43	24.64
7/11/2022	26.42	26.74	25.79	26.17
7/12/2022	27.14	27.75	25.82	27.29
7/13/2022	27.35	29.06	26.23	26.82
7/14/2022	27.47	28.45	26.2	26.4
7/15/2022	26.72	26.72	24.13	24.23
7/18/2022	24.83	25.91	24.38	25.3
7/19/2022	25.12	25.41	24.23	24.5
7/20/2022	24.23	24.73	23.4	23.88
7/21/2022	24.07	24.67	22.92	23.11
7/22/2022	23.3	23.81	22.41	23.03
7/25/2022	24.33	24.57	23.19	23.36
7/26/2022	23.95	25.31	23.82	24.69
7/27/2022	24.27	24.41	23.02	23.24
7/28/2022	23.33	23.54	22.22	22.33
7/29/2022	22.13	22.16	21.21	21.33
8/1/2022	22.41	23.27	22.26	22.84
8/2/2022	24.08	24.68	22.67	23.93
8/3/2022	23.86	23.92	21.68	21.95
8/4/2022	22.06	22.66	21.44	21.44
8/5/2022	21.5	22.58	20.76	21.15
8/8/2022	21.74	22.01	20.83	21.29
8/9/2022	21.41	22.23	21.41	21.77
8/10/2022	22.28	22.34	19.54	19.74
8/11/2022	19.84	20.85	19.71	20.2
8/12/2022	20.34	20.35	19.12	19.53
8/15/2022	20.74	21.16	19.81	19.95
8/16/2022	20.23	20.39	19.5	19.69
8/17/2022	19.74	20.63	19.41	19.9
8/18/2022	20.51	20.61	19.43	19.56
8/19/2022	20.16	21.27	20.08	20.6
8/22/2022	22.41	24.62	22.39	23.8
8/23/2022	24.13	24.21	23.07	24.11
8/24/2022	24.37	24.86	22.73	22.82
8/25/2022	22.41	23.13	21.77	21.78
8/26/2022	22.07	25.9	21.67	25.56
8/29/2022	26.86	27.67	25.47	26.21
8/30/2022	25.75	27.69	25.13	26.21
8/31/2022	25.86	26.62	25.31	25.87
9/1/2022	26.88	27.45	25.25	25.56
9/2/2022	25.51	26.28	23.19	25.47
9/5/2022	26.51	26.85	25.84	25.99
9/6/2022	25.46	27.8	25.33	26.91
9/7/2022	26.93	27.15	24.54	24.64
9/8/2022	24.7	25.9	23.56	23.61
9/9/2022	23.49	23.57	22.64	22.79
9/12/2022	23.58	24.23	23.16	23.87
9/13/2022	23.67	28.15	23.53	27.27
9/14/2022	26.73	27.56	26.16	26.16
9/15/2022	26.1	26.93	25.42	26.27
9/16/2022	27.47	28.45	26.14	26.3
9/19/2022	27.69	27.95	25.56	25.76
9/20/2022	25.65	27.81	25.61	27.16
9/21/2022	28.03	30.18	25.55	27.99
9/22/2022	28.16	28.38	26.71	27.35
9/23/2022	27.68	32.31	27.58	29.92
9/26/2022	31.74	32.88	29.83	32.26
9/27/2022	31.2	34.14	30.3	32.6
9/28/2022	34.5	34.88	30.03	30.18
9/29/2022	31.67	33.46	31.16	31.84
9/30/2022	31.61	33.25	29.39	31.62
10/3/2022	33	33.06	29.63	30.1
10/4/2022	29.52	29.62	28.56	29.07
10/5/2022	29.36	30.11	28.5	28.55
10/6/2022	28.6	30.74	28.56	30.52
10/7/2022	30.37	32.02	29.88	31.36
10/10/2022	32.93	33.99	32.05	32.45
10/11/2022	33.56	34.43	32.45	33.63
10/12/2022	33.54	34.53	33.11	33.57
10/13/2022	33.6	33.87	31.63	31.94
10/14/2022	31.89	32.98	31.14	32.02
10/17/2022	32.27	32.59	30.7	31.37
10/18/2022	31.1	31.93	30.42	30.5
10/19/2022	30.94	31.9	30.76	30.76
10/20/2022	31.3	31.32	29.76	29.98
10/21/2022	30.21	30.44	29.24	29.69
10/24/2022	30.65	30.95	29.78	29.85
10/25/2022	29.8	30	28.22	28.46
10/26/2022	28.44	28.52	27.27	27.28
10/27/2022	27.51	27.67	26.94	27.39
10/28/2022	27.43	27.59	25.75	25.75
10/31/2022	26.91	27.07	25.84	25.88
11/1/2022	25.96	26.35	25.66	25.81
11/2/2022	26.04	26.62	25.39	25.86
11/3/2022	25.98	26.87	25.1	25.3
11/4/2022	25.63	25.71	24	24.55
11/7/2022	25.67	25.67	24.34	24.35

11/8/2022	24.71	26.16	24.24	25.54
11/9/2022	25.34	26.35	25.02	26.09
11/10/2022	26.51	26.59	22.84	23.53
11/11/2022	23.89	23.91	22.37	22.52
11/14/2022	23.99	24.33	22.86	23.73
11/15/2022	23.77	26.22	23.18	24.54
11/16/2022	24.29	24.72	23.99	24.11
11/17/2022	24.05	25.18	23.81	23.93
11/18/2022	24.03	24.12	22.98	23.12
11/21/2022	24.05	24.12	22.3	22.36
11/22/2022	22.59	22.71	21.28	21.29
11/23/2022	21.49	21.78	20.32	20.35
11/24/2022	20.5	20.54	20.31	20.42
11/25/2022	20.61	21.11	20.46	20.5
11/28/2022	22.09	22.5	21.65	22.21
11/29/2022	22.09	22.57	21.83	21.89
11/30/2022	21.7	22.63	20.31	20.58
12/1/2022	20.83	21.06	19.8	19.84
12/2/2022	20.42	20.96	18.95	19.06
12/5/2022	20.3	21.29	19.78	20.75
12/6/2022	20.69	22.6	20.38	22.17
12/7/2022	22.32	23.01	22.18	22.68
12/8/2022	22.81	23.28	22.06	22.29
12/9/2022	22.55	23.21	22.18	22.83
12/12/2022	24.4	25.05	24.18	25
12/13/2022	25.24	25.84	21.46	22.55
12/14/2022	22.83	23.47	21.07	21.14
12/15/2022	21.52	23.67	21.25	22.83
12/16/2022	23.26	23.83	22.09	22.62
12/19/2022	22.63	22.86	21.61	22.42
12/20/2022	23.17	23.39	21.35	21.48
12/21/2022	21.25	21.29	19.94	20.07
12/22/2022	20.08	24.3	20.01	21.97
12/23/2022	22.17	22.64	20.78	20.87
12/27/2022	21.67	22.8	21.59	21.65
12/28/2022	21.47	22.26	20.96	22.14
12/29/2022	22.25	22.31	21.36	21.44
12/30/2022	21.83	22.4	21.59	21.67
1/3/2023	23.09	23.76	22.73	22.9
1/4/2023	22.93	23.27	21.94	22.01
1/5/2023	22.2	22.92	21.97	22.46
1/6/2023	22.69	22.9	21	21.13
1/9/2023	21.75	21.98	21.27	21.97
1/10/2023	22.22	22.46	20.58	20.58
1/11/2023	20.8	21.25	20.62	21.09
1/12/2023	21.56	21.8	18.83	18.83
1/13/2023	19	19.41	18.01	18.35
1/16/2023	19.44	19.63	19.41	19.49
1/17/2023	19.89	20.22	19.21	19.36
1/18/2023	19.28	20.58	18.71	20.34
1/19/2023	20.43	21.71	20.17	20.52
1/20/2023	20.28	20.7	19.41	19.85
1/23/2023	20.21	20.33	19.55	19.81
1/24/2023	19.89	20.47	18.91	19.2
1/25/2023	19.56	20.9	18.99	19.08
1/26/2023	19.05	19.48	18.67	18.73
1/27/2023	18.9	19	17.97	18.51
1/30/2023	19.76	20.25	19.54	19.94
1/31/2023	20.12	20.7	19.13	19.4
2/1/2023	19.62	20.04	17.7	17.87
2/2/2023	17.74	19.25	17.06	18.73
2/3/2023	18.57	19.3	17.93	18.33
2/6/2023	19.23	19.81	19.21	19.43
2/7/2023	19.54	19.99	18.43	18.66
2/8/2023	18.88	20.12	18.55	19.63
2/9/2023	19.24	21.08	19.02	20.71
2/10/2023	20.74	21.94	20.44	20.53
2/13/2023	21.66	21.69	20.33	20.34
2/14/2023	20.72	20.75	18.48	18.91
2/15/2023	19.37	19.41	18.11	18.23
2/16/2023	18.26	20.27	18.23	20.17
2/17/2023	20.94	21.3	19.82	20.02
2/20/2023	21.06	21.28	20.96	21.23
2/21/2023	21.8	23.34	21.8	22.87
2/22/2023	23.03	23.63	22.02	22.29
2/23/2023	21.96	22.43	20.89	21.14
2/24/2023	21.35	22.9	21.32	21.67
2/27/2023	21.99	22.02	20.68	20.95
2/28/2023	21.3	21.37	20.1	20.7
3/1/2023	20.39	21.32	20.22	20.58
3/2/2023	21.41	21.42	19.55	19.59
3/3/2023	19.76	19.76	18.16	18.49
3/6/2023	19.05	19.19	18.49	18.61
3/7/2023	18.64	19.74	18.51	19.59
3/8/2023	19.71	20.01	19	19.11
3/9/2023	19.33	23.14	18.88	22.61
3/10/2023	23.34	28.97	21.79	24.8
3/13/2023	24.05	30.81	23.85	26.52
3/14/2023	26.85	27.24	22.27	23.73
3/15/2023	23.21	29.91	23.19	26.14
3/16/2023	26.19	27.49	22.97	22.99
3/17/2023	22.92	26.14	22.58	25.51
3/20/2023	27.77	28.91	24	24.15
3/21/2023	24.16	24.16	21.29	21.38
3/22/2023	21.8	22.38	19.94	22.26
3/23/2023	21.54	24.91	20.16	22.61
3/24/2023	22.11	25.21	21.6	21.74
3/27/2023	22.05	22.93	20.57	20.6
3/28/2023	20.53	21.4	19.91	19.97
3/29/2023	19.39	19.45	19.09	19.12
3/30/2023	19.12	20.08	18.85	19.02
3/31/2023	19.21	19.43	18.52	18.7
4/3/2023	19.79	19.83	18.54	18.55
4/4/2023	18.79	20.03	18.58	19
4/5/2023	19.42	20.08	19	19.08
4/6/2023	19.3	19.88	18.35	18.4
4/10/2023	19.39	20.05	18.93	18.97
4/11/2023	19.08	19.28	18.56	19.1

4/12/2023	19.38	19.98	18.25	19.09
4/13/2023	18.83	19.06	17.77	17.8
4/14/2023	17.94	18.12	17.07	17.07
4/17/2023	17.58	17.79	16.9	16.95
4/18/2023	16.94	17.34	16.58	16.83
4/19/2023	17.3	17.72	16.17	16.46
4/20/2023	16.85	17.69	16.33	17.17
4/21/2023	17.51	17.71	16.58	16.77
4/24/2023	18.22	18.24	16.74	16.89
4/25/2023	17.62	19.86	17.33	18.76
4/26/2023	18.66	19.61	17.87	18.84
4/27/2023	18.43	18.43	16.72	17.03
4/28/2023	17.21	17.65	15.72	15.78
5/1/2023	16.41	16.62	15.53	16.08
5/2/2023	16.27	19.81	16.26	17.78
5/3/2023	17.82	18.83	17.19	18.34
5/4/2023	19.17	21.33	18.67	20.09
5/5/2023	19.5	19.63	16.69	17.19
5/8/2023	17.73	17.88	16.83	16.98
5/9/2023	17.29	17.86	17.22	17.71
5/10/2023	17.58	18.31	16.36	16.94
5/11/2023	16.8	18.19	16.63	16.93
5/12/2023	16.83	17.92	16.38	17.03
5/15/2023	17.44	18.16	17.08	17.12
5/16/2023	17.54	18.3	17.26	17.99
5/17/2023	17.96	18.26	16.68	16.87
5/18/2023	16.92	17.15	16.05	16.05
5/19/2023	16.13	17.36	15.85	16.81
5/22/2023	17.45	18.13	16.82	17.21
5/23/2023	17.35	19.31	17.3	18.53
5/24/2023	18.8	20.81	18.8	20.03
5/25/2023	19.54	19.95	18.7	19.14
5/26/2023	19.07	19.56	17.27	17.95
5/29/2023	17.53	17.6	17.34	17.46
5/30/2023	17.56	18.34	16.98	17.46
5/31/2023	18.04	18.4	17.12	17.94
6/1/2023	17.24	17.59	15.58	15.65
6/2/2023	15.65	15.65	14.42	14.6
6/5/2023	15.28	15.29	14.66	14.73
6/6/2023	14.91	14.97	13.95	13.96
6/7/2023	14.14	14.29	13.77	13.94
6/8/2023	14.14	14.21	13.53	13.65
6/9/2023	13.78	14.14	13.5	13.83
6/12/2023	14.44	15.02	14.32	15.01
6/13/2023	14.99	15.06	14.47	14.61
6/14/2023	14.48	14.73	13.83	13.88
6/15/2023	14.09	14.52	13.79	14.5
6/16/2023	14.49	14.54	13.48	13.54
6/19/2023	14.09	14.19	14.01	14.19
6/20/2023	14.36	14.67	13.86	13.88
6/21/2023	13.88	13.89	13.1	13.2
6/22/2023	13.88	13.98	12.73	12.91
6/23/2023	13.24	13.8	12.88	13.44
6/26/2023	14.43	14.71	13.78	14.25
6/27/2023	14.11	14.34	13.59	13.74
6/28/2023	13.9	13.96	13.36	13.43
6/29/2023	13.64	13.85	13.41	13.54
6/30/2023	13.51	13.59	12.96	13.59
7/3/2023	13.85	13.85	13.47	13.57
7/4/2023	13.54	13.71	13.52	13.7
7/5/2023	14.19	14.74	14.05	14.18
7/6/2023	14.85	17.08	14.79	15.44
7/7/2023	15.97	16.06	14.33	14.83
7/10/2023	16.08	16.21	15.04	15.07
7/11/2023	15.02	15.25	14.63	14.84
7/12/2023	14.82	14.82	13.51	13.54
7/13/2023	13.44	13.61	13.12	13.61
7/14/2023	13.72	13.76	13.22	13.34
7/17/2023	13.78	14	13.43	13.48
7/18/2023	13.61	13.67	13.29	13.3
7/19/2023	13.32	13.84	13.12	13.76
7/20/2023	13.96	14.23	13.58	13.99
7/21/2023	13.87	13.89	13.37	13.6
7/24/2023	14.29	14.3	13.73	13.91
7/25/2023	14.02	14.09	13.82	13.86
7/26/2023	13.86	14.16	13.15	13.19
7/27/2023	13.14	15.02	12.74	14.41
7/28/2023	14.03	14.18	13.27	13.33
7/31/2023	13.98	14.09	13.57	13.63
8/1/2023	13.75	14.3	13.75	13.93
8/2/2023	15.7	16.48	14.95	16.09
8/3/2023	16.77	17.42	15.72	15.92
8/4/2023	16.01	17.39	14.57	17.1
8/7/2023	16.9	17.36	15.77	15.77
8/8/2023	16.28	18.14	15.96	15.99
8/9/2023	15.81	16.87	15.38	15.96
8/10/2023	15.58	16.86	14.6	15.85
8/11/2023	15.53	16.51	14.84	14.84
8/14/2023	15.88	16.06	14.77	14.82
8/15/2023	14.95	16.57	14.91	16.46
8/16/2023	16.54	16.93	15.8	16.78
8/17/2023	16.96	18.13	16.4	17.89
8/18/2023	17.8	18.88	17.14	17.3
8/21/2023	18.03	18.11	16.88	17.13
8/22/2023	16.96	17.58	16.61	16.97
8/23/2023	16.64	17.1	15.91	15.98
8/24/2023	15.57	17.32	15.48	17.2
8/25/2023	17.21	17.36	15.45	15.68
8/28/2023	16.24	16.28	15	15.08
8/29/2023	15.08	15.3	14.34	14.45
8/30/2023	14.53	14.7	13.83	13.88
8/31/2023	13.98	14	13.44	13.57
9/1/2023	13.56	13.56	13.02	13.09
9/4/2023	13.62	13.82	13.51	13.82
9/5/2023	14.15	14.47	13.7	14.01
9/6/2023	14.27	15.3	14.13	14.45
9/7/2023	14.81	15.69	14.4	14.4
9/8/2023	14.22	14.87	13.58	13.84

9/11/2023	14.17	14.33	13.74	13.8
9/12/2023	14.02	14.42	13.71	14.23
9/13/2023	14.42	14.68	13.41	13.48
9/14/2023	13.39	13.46	12.79	12.82
9/15/2023	12.7	14.17	12.68	13.79
9/18/2023	14.4	14.75	13.86	14
9/19/2023	14.11	14.88	13.86	14.11
9/20/2023	14.18	15.15	13.57	15.14
9/21/2023	15.49	17.54	15.1	17.54
9/22/2023	17.31	17.41	15.93	17.2
9/25/2023	17.25	18.41	16.79	16.9
9/26/2023	18.03	19.5	17.17	18.94
9/27/2023	18.29	19.71	18.03	18.22
9/28/2023	18.22	18.77	17.06	17.34
9/29/2023	16.87	17.74	15.83	17.52
10/2/2023	17.31	18.55	16.93	17.61
10/3/2023	17.81	20.48	17.52	19.78
10/4/2023	20.72	20.88	18.3	18.58
10/5/2023	18.67	19.58	18.26	18.49
10/6/2023	18.73	19.93	17.19	17.45
10/9/2023	19.54	19.6	17.56	17.7
10/10/2023	17.7	17.86	16.51	17.03
10/11/2023	16.95	17.78	16.09	16.09
10/12/2023	16.08	18.08	15.44	16.69
10/13/2023	16.53	20.78	16.5	19.32
10/16/2023	19.1	19.57	17.14	17.21
10/17/2023	17.41	18.54	16.97	17.88
10/18/2023	18.36	20.15	17.88	19.22
10/19/2023	19.73	21.4	18.55	21.4
10/20/2023	21.59	21.83	20.42	21.71
10/23/2023	21.83	23.08	19.48	20.37
10/24/2023	20.03	20.24	18.65	18.97
10/25/2023	19.39	21.24	18.86	20.19
10/26/2023	21.78	21.96	20.22	20.68
10/27/2023	20.39	22.07	19.72	21.27
10/30/2023	21.13	21.16	19.55	19.75
10/31/2023	19.86	19.86	17.97	18.14
11/1/2023	18.02	18.42	16.63	16.87
11/2/2023	16.59	16.62	15.58	15.66
11/3/2023	15.7	15.83	14.91	14.91
11/6/2023	15.39	15.58	14.84	14.89
11/7/2023	15.1	15.17	14.71	14.81
11/8/2023	14.91	15.09	14.3	14.45
11/9/2023	14.61	15.57	14.13	15.29
11/10/2023	15.09	15.45	14.16	14.17
11/13/2023	15.16	15.19	14.58	14.76
11/14/2023	14.83	14.86	13.91	14.16
11/15/2023	14.21	14.35	13.97	14.18
11/16/2023	14.12	14.42	13.68	14.32
11/17/2023	14.18	14.19	13.67	13.8
11/20/2023	14.26	14.31	13.39	13.41
11/21/2023	13.45	14.31	13.13	13.35
11/22/2023	13.08	13.25	12.82	12.85
11/23/2023	12.84	12.87	12.75	12.8
11/24/2023	13.03	13.17	12.45	12.46
11/27/2023	13.14	13.28	12.64	12.69
11/28/2023	12.78	14.3	12.56	12.69
11/29/2023	12.71	13.1	12.48	12.98
11/30/2023	13.07	13.39	12.82	12.92
12/1/2023	12.94	12.96	12.48	12.63
12/4/2023	13.28	13.7	12.98	13.08
12/5/2023	13.26	13.76	12.81	12.85
12/6/2023	12.78	13.03	12.64	12.97
12/7/2023	13.17	13.28	12.95	13.06
12/8/2023	13.14	13.24	12.35	12.35
12/11/2023	13.05	13.14	12.61	12.63
12/12/2023	12.69	12.74	11.81	12.07
12/13/2023	12.2	12.46	11.82	12.19
12/14/2023	11.96	12.74	11.84	12.48
12/15/2023	12.12	12.54	12.01	12.28
12/18/2023	12.62	12.64	12.4	12.56
12/19/2023	12.6	12.6	12.33	12.53
12/20/2023	12.63	13.93	12.29	13.67
12/21/2023	13.4	14.49	13.34	13.65
12/22/2023	13.72	13.96	13	13.03
12/26/2023	13.77	13.8	12.96	12.99
12/27/2023	13.02	13.04	12.37	12.43
12/28/2023	12.44	12.65	12.38	12.47
12/29/2023	12.55	13.19	12.36	12.45
1/2/2024	13.22	14.23	13.1	13.2
1/3/2024	13.35	14.22	13.33	14.04
1/4/2024	13.93	14.2	13.64	14.13
1/5/2024	14.24	14.58	13.29	13.35
1/8/2024	14	14.18	13.02	13.08
1/9/2024	13.2	13.45	12.74	12.76
1/10/2024	12.86	12.95	12.67	12.69
1/11/2024	12.64	13.31	12.35	12.44
1/12/2024	12.66	13.08	12.47	12.7
1/15/2024	13.23	13.34	13.2	13.25
1/16/2024	14.12	14.35	13.52	13.84
1/17/2024	14.59	15.4	14.38	14.79
1/18/2024	14.85	14.89	13.89	14.13
1/19/2024	13.8	14.58	13.28	13.3
1/22/2024	13.77	13.84	13.17	13.19
1/23/2024	13.2	13.29	12.53	12.55
1/24/2024	12.66	13.18	12.41	13.14
1/25/2024	13.18	13.58	13.06	13.45
1/26/2024	13.73	14.1	13.2	13.26
1/29/2024	13.98	15.35	13.59	13.6
1/30/2024	13.69	13.74	13.23	13.31
1/31/2024	13.42	14.61	13.18	14.35
2/1/2024	14.21	14.63	13.87	13.88
2/2/2024	13.95	14.23	13.39	13.85
2/5/2024	14.37	14.53	13.58	13.67
2/6/2024	13.57	13.78	12.98	13.06
2/7/2024	13.06	13.13	12.81	12.83
2/8/2024	12.95	13.17	12.74	12.79
2/9/2024	12.79	13.01	12.69	12.93

2/12/2024	13.48	13.94	13.34	13.93
2/13/2024	13.96	17.94	13.43	15.85
2/14/2024	15.38	15.47	14.22	14.38
2/15/2024	14.27	14.64	13.94	14.01
2/16/2024	13.94	14.71	13.75	14.24
2/19/2024	14.72	14.78	14.65	14.71
2/20/2024	15.09	15.91	15.07	15.42
2/21/2024	15.54	16.12	15.22	15.34
2/22/2024	14.28	14.64	14.12	14.54
2/23/2024	14.31	14.31	13.64	13.75
2/26/2024	14.17	14.2	13.66	13.74
2/27/2024	13.63	13.75	13.41	13.43
2/28/2024	13.52	13.9	13.44	13.84
2/29/2024	14.14	14.15	13.3	13.4
3/1/2024	13.34	13.66	13.08	13.11
3/4/2024	13.49	13.58	13.32	13.49
3/5/2024	13.75	15.1	13.75	14.46
3/6/2024	14.27	14.93	13.89	14.5
3/7/2024	14.98	14.98	14.25	14.44
3/8/2024	14.22	15.53	13.97	14.74
3/11/2024	15.51	16.04	15.13	15.22
3/12/2024	14.97	15.2	13.81	13.84
3/13/2024	13.89	14.04	13.67	13.75
3/14/2024	13.62	15.33	13.42	14.4
3/15/2024	14.33	15.53	14.14	14.41
3/18/2024	14.75	14.85	14.26	14.33
3/19/2024	14.5	14.86	13.8	13.82
3/20/2024	13.83	14.17	13.01	13.04
3/21/2024	12.98	13.08	12.4	12.92
3/22/2024	12.92	13.15	12.58	13.06
3/25/2024	13.67	13.67	13.11	13.19
3/26/2024	13.12	13.43	12.84	13.24
3/27/2024	13.13	13.34	12.66	12.78
3/28/2024	12.93	13.1	12.84	13.01
4/1/2024	13.61	14.15	13.55	13.65
4/2/2024	13.74	15.43	13.68	14.61
4/3/2024	15	15.18	14.25	14.33
4/4/2024	14.29	16.92	13.74	16.35
4/5/2024	16.45	16.75	15.53	16.03
4/8/2024	16.24	16.5	15.11	15.19
4/9/2024	15.34	16.63	14.94	14.98
4/10/2024	15.24	16.62	14.59	15.8
4/11/2024	16.02	17.61	14.91	14.91
4/12/2024	14.91	19.2	14.91	17.31
4/15/2024	16.94	19.46	16.26	19.23
4/16/2024	19.49	19.56	17.64	18.4
4/17/2024	18.24	19.11	17.54	18.21
4/18/2024	17.91	18.37	17.21	18
4/19/2024	21.33	21.36	18.17	18.71
4/22/2024	18.59	18.72	16.69	16.94
4/23/2024	16.72	16.76	15.69	15.69
4/24/2024	15.76	16.38	15.58	15.97
4/25/2024	16.25	17.55	15.27	15.37
4/26/2024	15.49	16.06	14.92	15.03
4/29/2024	15.37	15.42	14.63	14.67
4/30/2024	14.82	15.9	14.67	15.65
5/1/2024	15.75	16.22	14.35	15.39
5/2/2024	15.14	16.09	14.6	14.68
5/3/2024	14.51	14.58	13.48	13.49
5/6/2024	13.98	14.02	13.44	13.49
5/7/2024	13.52	13.64	13.16	13.23
5/8/2024	13.24	13.51	12.94	13
5/9/2024	13.08	13.29	12.68	12.69
5/10/2024	12.77	12.96	12.5	12.55
5/13/2024	13.26	13.66	13.25	13.6
5/14/2024	13.71	14.03	13.27	13.42
5/15/2024	13.73	13.94	12.38	12.45
5/16/2024	12.52	12.67	12.33	12.42
5/17/2024	12.28	12.48	11.91	11.99
5/20/2024	12.27	12.59	12.07	12.15
5/21/2024	12.3	12.56	11.84	11.86
5/22/2024	12.05	12.81	11.78	12.29
5/23/2024	11.53	13.37	11.52	12.77
5/24/2024	12.86	12.89	11.89	11.93
5/27/2024	12.41	12.49	12.35	12.36
5/28/2024	12.51	13.44	12.36	12.92
5/29/2024	13.75	14.32	13.69	14.28
5/30/2024	14.82	14.88	13.67	14.47
5/31/2024	14.5	14.87	12.84	12.92
6/3/2024	13.08	14.31	13	13.11
6/4/2024	13.51	14.08	13.11	13.16
6/5/2024	13.14	13.25	12.6	12.63
6/6/2024	12.75	12.98	12.54	12.58
6/7/2024	12.69	13.08	12.11	12.22
6/10/2024	13.09	13.28	12.62	12.74
6/11/2024	12.85	13.47	12.78	12.85
6/12/2024	13.1	13.15	11.94	12.04
6/13/2024	12.05	12.68	11.88	11.94
6/14/2024	12.22	13.45	12.12	12.66
6/17/2024	13.07	13.29	12.5	12.75
6/18/2024	12.7	12.74	12.24	12.3
6/19/2024	12.32	12.55	12.32	12.48
6/20/2024	12.5	13.55	12.18	13.28
6/21/2024	13.22	13.78	12.99	13.2
6/24/2024	13.85	13.88	13.15	13.33
6/25/2024	13.48	13.52	12.84	12.84
6/26/2024	12.81	13.24	12.37	12.55
6/27/2024	12.69	12.77	12.21	12.24
6/28/2024	12.24	12.76	11.87	12.44
7/1/2024	12.98	13.26	12.1	12.22
7/2/2024	12.67	12.88	11.85	12.03
7/3/2024	12.13	12.23	11.95	12.09
7/4/2024	12.1	12.35	12.09	12.26
7/5/2024	12.37	12.61	11.84	12.48
7/8/2024	12.91	12.91	12.31	12.37
7/9/2024	12.48	12.61	12.35	12.51
7/10/2024	12.51	12.92	12.39	12.85
7/11/2024	12.88	13.33	12.23	12.92

7/12/2024	12.87	12.89	12.11	12.46
7/15/2024	12.78	13.26	12.75	13.12
7/16/2024	13.38	13.47	12.95	13.19
7/17/2024	13.6	14.88	13.54	14.48
7/18/2024	14.27	16.43	14.08	15.93
7/19/2024	16.44	17.19	10.62	16.52
7/22/2024	16.79	16.89	14.75	14.91
7/23/2024	15.21	15.35	13.9	14.72
7/24/2024	15.35	18.46	15.18	18.04
7/25/2024	18.41	19.36	16.42	18.46
7/26/2024	17.97	18.05	16.37	16.39
7/29/2024	16.59	17.21	16.23	16.6
7/30/2024	16.64	18.32	16.26	17.69
7/31/2024	16.66	16.77	15.71	16.36
8/1/2024	16.2	19.48	15.95	18.59
8/2/2024	20.52	29.66	20.01	23.39
8/5/2024	23.39	65.73	23.39	38.57
8/6/2024	33.71	34.77	24.02	27.71
8/7/2024	24.77	29.76	21.97	27.85
8/8/2024	28.34	29.47	23.36	23.79
8/9/2024	23.78	24.52	20.26	20.37
8/12/2024	20.79	21.19	18.89	20.71
8/13/2024	20.06	20.79	17.95	18.12
8/14/2024	18.41	18.49	16.12	16.19
8/15/2024	16.27	16.68	14.77	15.23
8/16/2024	15.29	15.76	14.65	14.8
8/19/2024	15.94	16.07	14.46	14.65
8/20/2024	14.89	15.93	14.78	15.88
8/21/2024	16.25	17.17	15.92	16.27
8/22/2024	16.27	18.06	15.76	17.55
8/23/2024	17.12	17.21	15.61	15.86
8/26/2024	16.27	16.67	15.81	16.15
8/27/2024	16.21	16.81	15.37	15.43
8/28/2024	15.51	17.89	15.46	17.11
8/29/2024	16.54	16.57	15.19	15.65
8/30/2024	15.67	16.04	14.78	15
9/2/2024	15.87	15.99	15.48	15.55
9/3/2024	15.76	21.99	15.71	20.72
9/4/2024	23.2	23.31	19.34	21.32
9/5/2024	20.75	21.53	19.21	19.9
9/6/2024	21.98	23.76	18.83	22.38
9/9/2024	21.32	21.41	19.29	19.45
9/10/2024	19.86	20.74	18.9	19.08
9/11/2024	19.41	21.41	17.55	17.69
9/12/2024	17.62	18.59	16.89	17.07
9/13/2024	17.03	17.18	16.23	16.56
9/16/2024	17.16	17.69	16.91	17.14
9/17/2024	17.16	18.08	16.67	17.61
9/18/2024	17.58	19.39	17.11	18.23
9/19/2024	17.21	17.27	16.21	16.33
9/20/2024	16.35	16.68	15.81	16.15
9/23/2024	16.71	16.95	15.75	15.89
9/24/2024	15.87	16.67	15.27	15.39
9/25/2024	15.82	15.82	15.17	15.41
9/26/2024	15.06	15.83	14.9	15.37
9/27/2024	15.64	16.97	15.2	16.96
9/30/2024	17.01	17.79	16.47	16.73
10/1/2024	16.96	20.73	16.61	19.26
10/2/2024	19.65	20.36	18.58	18.9
10/3/2024	19.63	20.75	19.16	20.49
10/4/2024	20.48	20.48	18.48	19.21
10/7/2024	20.76	23.03	20.65	22.64
10/8/2024	22.92	23.14	21.14	21.42
10/9/2024	21.98	22.01	20.71	20.86
10/10/2024	20.91	21.39	20.64	20.93
10/11/2024	20.87	21.16	20.14	20.46
10/14/2024	20.86	20.86	19.69	19.7
10/15/2024	19.61	20.89	19.44	20.64
10/16/2024	20.77	21.01	19.45	19.58
10/17/2024	19.55	19.65	18.88	19.11
10/18/2024	19.3	19.32	17.99	18.03
10/21/2024	18.78	19.34	18.36	18.37
10/22/2024	18.79	19.44	18.05	18.2
10/23/2024	18.21	20.47	18.18	19.24
10/24/2024	18.87	20.24	18.63	19.08
10/25/2024	19.22	20.51	18.23	20.33
10/28/2024	19.11	19.88	18.91	19.8
10/29/2024	19.75	20.53	19.06	19.34
10/30/2024	19.33	20.44	19.3	20.35
10/31/2024	21.44	23.42	21.12	23.16
11/1/2024	22.96	23.09	21.16	21.88
11/4/2024	22.5	23.07	21.73	21.98
11/5/2024	21.98	22.06	20.2	20.49
11/6/2024	16.06	16.82	15.44	16.27
11/7/2024	15.86	15.86	15.13	15.2
11/8/2024	15.13	15.33	14.66	14.94
11/11/2024	15.33	15.56	14.89	14.97
11/12/2024	15.09	15.37	14.69	14.71
11/13/2024	15.09	15.26	13.77	14.02
11/14/2024	14.17	14.32	13.59	14.31
11/15/2024	15.02	17.55	14.56	16.14
11/18/2024	16.6	17	15.35	15.58
11/19/2024	15.44	17.93	15.37	16.35
11/20/2024	16.19	18.79	16.04	17.16
11/21/2024	17.1	17.99	15.73	16.87
11/22/2024	16.67	17.56	15.24	15.24
11/25/2024	15.23	15.72	14.54	14.6
11/26/2024	14.95	15.03	13.88	14.1
11/27/2024	14.28	15.13	13.96	14.1
11/28/2024	14.07	14.07	13.87	13.9
11/29/2024	14	14.15	13.49	13.51
12/2/2024	14.08	14.1	13.3	13.34
12/3/2024	13.38	13.77	13.19	13.3
12/4/2024	13.16	13.61	12.89	13.45
12/5/2024	13.46	13.7	13.26	13.54
12/6/2024	13.62	13.74	12.7	12.77
12/9/2024	13.36	14.23	13.35	14.19
12/10/2024	14.3	14.54	13.86	14.18

12/11/2024	14.42	14.43	13.52	13.58
12/12/2024	13.73	13.95	13.39	13.92
12/13/2024	13.57	14.25	13.24	13.81
12/16/2024	14.37	14.69	13.99	14.69
12/17/2024	14.98	15.94	14.78	15.87
12/18/2024	15.57	28.32	14.82	27.62
12/19/2024	21.61	24.12	20.16	24.09
12/20/2024	24.14	26.51	17.82	18.36
12/23/2024	18.09	20.02	16.74	16.78
12/24/2024	16.97	17.04	14.27	14.27
12/26/2024	14.99	15.93	14.55	14.73
12/27/2024	15.38	18.45	15.29	15.95
12/30/2024	17.21	19.22	16.44	17.4
12/31/2024	17.39	17.81	16.68	17.35
1/2/2025	17.21	19.5	16.96	17.93
1/3/2025	17.66	17.94	16.11	16.13
1/6/2025	16.77	16.87	15.71	16.04
1/7/2025	16.48	18.9	15.79	17.82
1/8/2025	17.91	19.5	17.37	17.7
1/9/2025	18.51	18.52	17.95	18.07
1/10/2025	18.29	20.31	18.05	19.54
1/13/2025	21.18	22.04	19.15	19.19
1/14/2025	18.79	19.66	18.24	18.71
1/15/2025	19.08	19.14	15.96	16.12
1/16/2025	15.87	16.6	15.64	16.6
1/17/2025	16.19	16.23	15.53	15.97
1/20/2025	16.46	16.59	15.8	15.81
1/21/2025	16.29	16.29	14.93	15.06
1/22/2025	14.89	15.29	14.59	15.1
1/23/2025	15.28	15.39	14.59	15.02
1/24/2025	15.02	15.16	14.58	14.85
1/27/2025	18.83	22.51	17.57	17.9
1/28/2025	18.29	18.39	16.25	16.41
1/29/2025	16.42	18.08	16.17	16.56
1/30/2025	15.93	16.42	15.32	15.84
1/31/2025	15.45	17.09	14.9	16.43
2/3/2025	20.36	20.42	17.66	18.62
2/4/2025	18.78	19.11	16.78	17.21
2/5/2025	17.54	17.75	15.77	15.77
2/6/2025	15.88	16.15	14.99	15.5
2/7/2025	15.38	16.66	14.79	16.54
2/10/2025	16.58	16.61	15.7	15.81
2/11/2025	16.13	16.42	15.75	16.02
2/12/2025	15.91	17.18	15.64	15.89
2/13/2025	15.97	16.33	14.98	15.1
2/14/2025	15.08	15.42	14.74	14.77
2/17/2025	15.38	15.57	15.34	15.37
2/18/2025	15.57	16.03	15.35	15.35
2/19/2025	15.14	15.96	15.05	15.27
2/20/2025	15.61	16.63	15.12	15.66
2/21/2025	15.63	19.03	15.28	18.21
2/24/2025	18.08	20.24	17.31	18.98
2/25/2025	19.09	21.48	18.85	19.43
2/26/2025	18.96	20.06	17.83	19.1
2/27/2025	18.25	21.47	17.67	21.13
2/28/2025	21.21	22.4	19.05	19.63
3/3/2025	19.83	24.31	19.25	22.78
3/4/2025	22.96	26.35	21.71	23.51
3/5/2025	23.03	24.84	21.37	21.93
3/6/2025	22.6	25.92	22.39	24.87
3/7/2025	24.85	26.56	23.09	23.37
3/10/2025	24.7	29.56	24.68	27.86
3/11/2025	27.94	29.57	26.18	26.92
3/12/2025	26.88	26.91	23.89	24.23
3/13/2025	24.92	26.13	23.46	24.66
3/14/2025	24.35	24.36	21.48	21.77
3/17/2025	22.89	22.95	20.32	20.51
3/18/2025	20.83	22.57	20.41	21.7
3/19/2025	21.84	22.1	19.42	19.9
3/20/2025	19.52	21.17	19.3	19.8
3/21/2025	20.02	21.14	19.15	19.28
3/24/2025	19.13	19.14	17.46	17.48
3/25/2025	17.58	17.77	17.02	17.15
3/26/2025	17.23	19.07	16.97	18.33
3/27/2025	18.36	19.28	17.95	18.69
3/28/2025	19.08	22.18	18.92	21.65
3/31/2025	24.11	24.8	21.67	22.28
4/1/2025	22.06	23.52	21.58	21.77
4/2/2025	22.3	23.66	20.68	21.51
4/3/2025	26.38	30.02	24.93	30.02
4/4/2025	30.12	45.61	29.99	45.31
4/7/2025	60.13	60.13	38.58	46.98
4/8/2025	44.04	57.52	36.48	52.33
4/9/2025	50.98	57.96	31.9	33.62
4/10/2025	34.44	54.87	34.44	40.72
4/11/2025	40.8	46.12	36.85	37.56
4/14/2025	34.76	35.17	29.75	30.89
4/15/2025	30.01	31.45	28.29	30.12
4/16/2025	33.24	34.96	29.48	32.64
4/17/2025	30.79	32.55	29.57	29.65
4/21/2025	32.75	35.75	31.79	33.82
4/22/2025	32.61	32.68	30.08	30.57
4/23/2025	28.75	30.29	27.11	28.45
4/24/2025	28.69	29.66	26.36	26.47
4/25/2025	26.22	27.2	24.84	24.84
4/28/2025	25.75	26.93	24.7	25.15
4/29/2025	24.76	25.99	23.76	24.17
4/30/2025	24.35	28.17	24.23	24.7

2010-2019	16.86
2020-2021	24.46
2022-2025	19.58

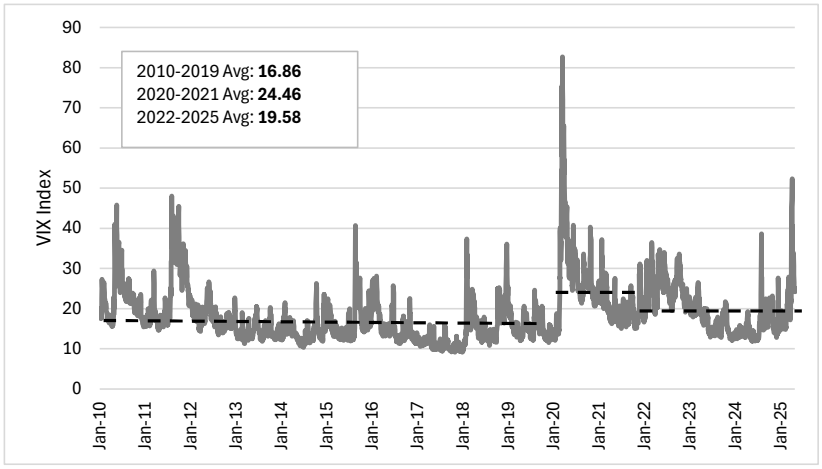


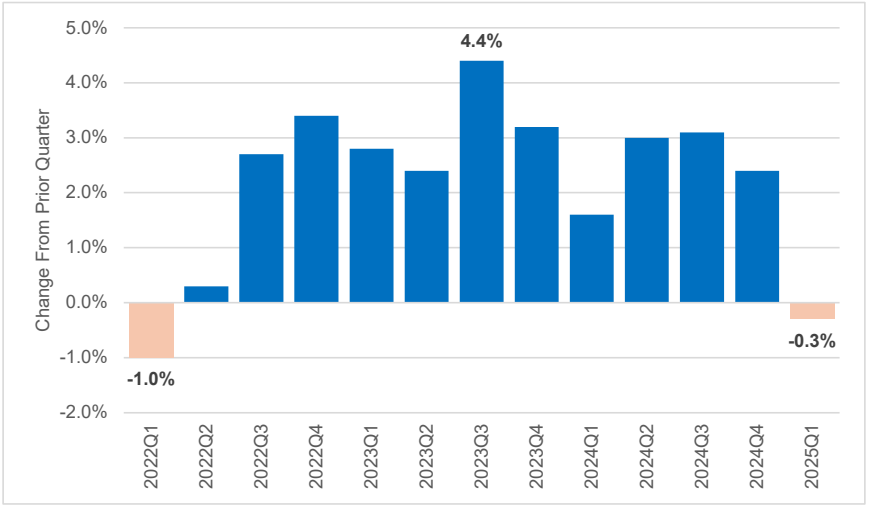
Table 1. Real Gross Domestic Product and Related Measures: Percent Change from Preceding Period

Line		2021	2022	2023	Seasonally adjusted at annual rates															
					2020	2021				2022				2023				2024		
					Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3 [r]
1	**Gross domestic product (GDP)**	**6.1**	**2.5**	**2.9**	**4.4**	**5.6**	**6.4**	**3.5**	**7.4**	**-1.0**	**0.3**	**2.7**	**3.4**	**2.8**	**2.4**	**4.4**	**3.2**	**1.6**	**3.0**	**3.1**
2	**Personal consumption expenditures**	**8.8**	**3.0**	**2.5**	**5.8**	**9.5**	**14.1**	**3.1**	**4.4**	**1.0**	**2.6**	**1.5**	**1.2**	**4.9**	**1.0**	**2.5**	**3.5**	**1.9**	**2.8**	**3.7**
3	Goods	11.3	-0.6	1.9	3.1	17.9	14.4	-9.6	4.6	-1.7	-1.5	-2.3	-0.7	7.4	-0.3	3.5	3.4	-1.2	3.0	5.6
4	Durable goods	16.6	-1.9	3.9	4.5	31.0	14.7	-24.8	8.6	0.1	-2.2	-1.9	-2.0	17.1	-0.3	4.2	2.9	-1.8	5.5	7.6
5	Nondurable goods	8.6	0.1	0.8	2.3	10.9	14.2	0.4	2.5	-2.7	-1.2	-2.5	0.1	2.5	-0.4	3.1	3.6	-0.8	1.7	4.6
6	Services	7.5	5.0	2.9	7.1	5.4	13.9	10.4	4.3	2.4	4.7	3.5	2.2	3.8	1.6	2.1	3.5	3.4	2.7	2.8
7	**Gross private domestic investment**	**8.8**	**6.0**	**0.1**	**13.0**	**-2.4**	**-6.4**	**16.3**	**28.3**	**7.4**	**-8.5**	**-5.7**	**5.8**	**-8.9**	**8.0**	**10.1**	**0.7**	**3.6**	**8.3**	**0.8**
8	Fixed investment	7.3	2.7	2.4	16.0	9.4	5.5	-2.1	2.9	8.5	2.0	-1.8	-1.9	3.1	8.6	2.6	3.5	6.5	2.3	2.1
9	Nonresidential	6.0	7.0	6.0	11.1	9.6	8.9	-1.8	3.4	13.6	7.3	7.7	5.7	5.3	9.9	1.1	3.8	4.5	3.9	4.0
10	Structures	-2.6	3.6	10.8	1.8	8.8	0.6	-3.8	-9.5	10.9	8.8	9.2	9.8	14.9	16.4	1.7	6.5	6.3	0.2	-5.0
11	Equipment	6.7	4.4	3.5	17.3	5.3	8.7	-10.6	1.5	16.4	1.1	6.6	1.1	0.9	12.5	-1.1	0.7	0.3	9.8	10.8
12	Intellectual property products	10.2	11.2	5.8	10.3	14.3	13.8	8.6	12.4	12.6	12.7	8.0	7.9	4.5	3.9	2.8	5.2	7.5	0.7	3.1
13	Residential	10.9	-8.6	-8.3	31.0	8.7	-3.7	-3.4	1.2	-4.5	-11.6	-25.2	-22.8	-4.3	4.5	7.7	2.5	13.7	-2.8	-4.3
14	Change in private inventories	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	**Net exports of goods and services**	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16	Exports	6.5	7.5	2.8	26.8	0.3	3.2	0.9	25.5	-4.6	12.7	14.5	-1.1	2.0	-4.8	4.9	6.2	1.9	1.0	9.6
17	Goods	7.7	5.9	2.3	28.5	-1.2	1.2	-2.7	27.6	-9.4	10.9	20.3	-5.4	5.3	-10.9	7.5	5.3	-0.2	0.9	10.3
18	Services	4.0	11.1	3.8	22.8	3.3	7.4	8.9	21.1	6.9	16.8	2.6	8.7	-4.5	8.8	0.0	8.0	6.1	1.2	8.4
19	Imports	14.7	8.6	-1.2	32.3	8.3	8.3	8.6	20.8	13.4	5.9	-5.4	-4.5	-0.8	-3.1	4.7	4.2	6.1	7.6	10.7
20	Goods	14.5	6.7	-1.8	31.3	8.0	5.3	0.9	21.7	13.6	3.1	-8.2	-4.0	0.1	-5.0	5.1	1.8	6.5	8.4	10.7
21	Services	15.7	17.8	1.6	37.6	9.9	25.5	55.3	16.6	12.4	20.4	8.1	-6.9	-4.8	5.0	2.6	14.8	4.8	4.3	11.0
22	**Government consumption expenditures and gross investment**	**-0.3**	**-1.1**	**3.9**	**-1.5**	**5.2**	**-4.2**	**-1.5**	**-0.3**	**-3.4**	**-1.5**	**1.6**	**5.4**	**5.1**	**2.9**	**5.7**	**3.6**	**1.8**	**3.1**	**5.1**
23	Federal	1.8	-3.2	2.9	0.1	17.2	-8.0	-7.5	3.1	-8.5	-3.3	-0.4	9.0	4.6	-1.1	5.3	-0.3	-0.4	4.3	8.9
24	National defense	-1.0	-3.9	3.2	12.9	-7.9	-2.8	-4.6	-3.7	-11.2	2.0	-2.9	7.6	4.9	0.8	6.7	-1.3	-2.5	6.4	13.9
25	Nondefense	5.8	-2.3	2.5	-15.4	63.0	-14.3	-11.3	13.0	-5.0	-9.7	2.9	10.8	4.3	-3.5	3.4	0.9	2.6	1.5	2.6
26	State and local	-1.6	0.2	4.4	-2.5	-1.6	-1.8	2.3	-2.3	-0.1	-0.4	2.7	3.4	5.3	5.4	5.9	6.1	3.1	2.3	2.9
	Addenda:																			
27	Gross domestic income (GDI) [1]	6.6	2.8	1.7	15.1	4.2	5.3	4.4	6.4	1.7	-0.3	3.9	-1.4	1.7	2.1	2.7	5.1	3.0	2.0	2.1
28	Average of GDP and GDI	6.3	2.7	2.3	9.6	4.9	5.9	3.9	6.9	0.3	0.0	3.3	1.0	2.3	2.3	3.5	4.1	2.3	2.5	2.6
29	Final sales of domestic product	5.8	1.9	3.3	4.9	7.8	8.7	0.4	3.2	-0.9	2.3	3.5	1.9	5.1	2.6	3.0	3.7	2.1	1.9	3.3
30	Gross domestic purchases	7.1	2.8	2.3	5.7	6.5	7.0	4.4	7.4	1.4	-0.2	0.2	2.7	2.4	2.5	4.4	3.0	2.2	3.8	3.4
31	Final sales to domestic purchasers	6.9	2.3	2.7	6.1	8.7	9.2	1.4	3.4	1.5	1.8	0.9	1.3	4.6	2.6	3.1	3.5	2.7	2.8	3.7
32	Final sales to private domestic purchasers	8.5	3.0	2.5	7.8	9.5	12.3	2.0	4.1	2.5	2.4	0.8	0.6	4.6	2.5	2.6	3.5	2.9	2.7	3.4
33	Gross national product (GNP)	5.7	2.4	2.7	3.9	5.5	5.4	3.5	7.8	-1.8	0.9	2.9	2.8	2.1	2.5	4.3	3.1	1.4	2.7	2.4
34	Disposable personal income	3.4	-5.5	5.1	-8.0	57.6	-27.7	-4.5	-4.5	-10.9	-1.8	6.6	3.8	10.9	3.4	1.4	3.2	5.6	1.0	1.1
	Current-dollar measures:																			
35	GDP	10.9	9.8	6.6	7.3	11.1	13.2	9.8	15.1	7.3	9.7	7.4	7.2	6.6	4.3	7.7	4.8	4.7	5.6	5.0
36	GDI	11.5	10.1	5.3	18.3	9.6	12.0	10.8	14.0	10.2	9.1	8.6	2.3	5.5	4.0	6.0	6.7	6.1	4.6	4.1
37	Average of GDP and GDI	11.2	10.0	6.0	12.6	10.3	12.6	10.3	14.5	8.7	9.4	8.0	4.7	6.0	4.2	6.8	5.8	5.4	5.1	4.6
38	Final sales of domestic product	10.7	9.2	7.0	7.7	13.5	15.6	6.7	10.5	7.5	12.0	8.2	5.8	8.9	4.7	6.3	5.3	5.2	4.5	5.3
39	Gross domestic purchases	11.7	9.9	5.8	8.2	11.4	13.4	10.4	15.1	9.6	8.4	5.0	6.4	5.8	4.1	7.1	4.8	5.3	6.4	5.4
40	Final sales to domestic purchasers	11.4	9.3	6.2	8.7	13.8	15.7	7.4	10.7	9.8	10.6	5.7	5.1	8.0	4.4	5.8	5.3	5.8	5.3	5.7
41	Final sales to private domestic purchasers	12.8	10.0	6.3	10.0	14.0	18.8	8.1	11.5	10.9	10.7	6.1	4.6	8.6	4.9	5.0	5.3	5.9	5.3	5.3
42	GNP	10.5	9.7	6.4	6.8	10.9	12.0	9.9	15.5	6.5	10.4	7.6	6.6	5.9	4.4	7.6	4.7	4.5	5.3	4.4
43	Disposable personal income	7.7	0.7	9.0	-6.2	64.8	-23.1	0.9	2.0	-4.0	5.6	11.7	7.9	15.3	6.4	4.1	4.9	9.2	3.6	2.7

r Revised

1. Gross domestic income deflated by the implicit price deflator for gross domestic product.

2020 Q4	4.4	2020Q4	4.4%
2021 Q1	5.6	2021Q1	5.6%
2021 Q2	6.4	2021Q2	6.4%
2021 Q3	3.5	2021Q3	3.5%
2021 Q4	7.4	2021Q4	7.4%
2022 Q1	-1	2022Q1	-1.0%
2022 Q2	0.3	2022Q2	0.3%
2022 Q3	2.7	2022Q3	2.7%
2022 Q4	3.4	2022Q4	3.4%
2023 Q1	2.8	2023Q1	2.8%
2023 Q2	2.4	2023Q2	2.4%
2023 Q3	4.4	2023Q3	4.4%
2023 Q4	3.2	2023Q4	3.2%
2024 Q1	1.6	2024Q1	1.6%
2024 Q2	3	2024Q2	3.0%
2024 Q3	3.1	2024Q3	3.1%
2024 Q4	2.4	2024Q4	2.4%
2025 Q1	-0.3	2025Q1	-0.3%



CONFIDENTIAL PROPRIETARY TRADE SECRET

STAFF-DR-02-013 CONFIDENTIAL ATTACHMENT 7

FILED UNDER SEAL

CONFIDENTIAL PROPRIETARY TRADE SECRET

STAFF-DR-02-013 CONFIDENTIAL ATTACHMENT 8

FILED UNDER SEAL

CONFIDENTIAL PROPRIETARY TRADE SECRET

STAFF-DR-02-013 CONFIDENTIAL ATTACHMENT 9

FILED UNDER SEAL

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-014

REQUEST:

Refer to the Nowak Direct Testimony, page 31, lines 14-16.

a. Provide support for the use of S&P Capital IQ consensus analysts' forecasts of earnings growth in the discounted cash flow (DCF) analyses.

b. Provide a comparison of Yahoo! Finance and S&P Capital IQ as sources of analysts' forecasts for growth.

RESPONSE:

a. As described on pages 31 and 32 of Nowak Direct Testimony, academic research demonstrates that investors' decisions are informed by expectations of growth in earnings and growth in dividends occurs primarily as a result of earnings per share. Consistent with those findings, S&P Capital IQ is a source of long-term earnings growth rates and therefore appropriate to apply as an estimate in the DCF model. Further, S&P Capital IQ is a source of consensus estimates reflecting the views of multiple analysts and demonstrating that it is a meaningful measure of growth among the investment community.

b. As a preliminary matter, the question is unclear as to what comparison is being requested. Mr. Nowak had previously relied on Yahoo! Finance as a source of growth rates in his Discounted Cash Flow (DCF), analysis. However, Yahoo! Finance ceased publication of long-term earnings growth estimates in 2024. Nonetheless, both Yahoo! Finance and S&P Capital IQ are consensus estimates of earnings growth and therefore represent credible sources of measures of long-term growth. I have consistently relied on

S&P Capital IQ in my DCF analysis since Yahoo! Finance ceased publication of long-term earnings growth estimates.

PERSON RESPONSIBLE: Joshua C. Nowak

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-015

REQUEST:

Refer to the Nowak Direct Testimony, page 31, lines 12-22, page 32, and Attachment JCN-4. Provide an update to the DCF analyses including Value Line dividend per share growth rates.

RESPONSE:

As demonstrated on pages 31 and 32 of Mr. Nowak's Direct Testimony, research indicates that "Growth in dividends occurs primarily as a result of growth in earnings per share (EPS)." The "Discounted Cash Flow" model refers to the cash flows investors can expect to receive during the time they own the stock. Those cash flows include both quarterly dividend payments and any capital appreciation that occurs between when the stock is purchased and when it is sold. Dividend payments and capital appreciation are both a function of earnings per share, which is ultimately what determines the return to the investor. Dividends are based on management decisions related to cash management and other factors, and therefore earnings growth rates are more likely to accurately reflect investors' growth expectations than are dividend growth rates. As such, and as discussed on pages 31 and 32 of Nowak Direct Testimony, "investors base their investment decisions on analysts' expectations of growth in earnings." In fact, in a survey completed by 297 members of the Association for Investment Management and Research, the majority of respondents ranked earnings as the most important variable in valuing a security - more important than cash flow, dividends, or book value (*see* Block, Stanley B., "A Study of

Financial Analysts: Practice and Theory," Association for Investment Management and Research). Further, as addressed on page 32 of Nowak Direct Testimony, "the only forward-looking growth rates that are available on a consensus basis are analysts' EPS growth rates."

As such, Mr. Nowak's analysis relies on estimates of earnings per share growth estimates and does not apply Value Line dividend per share (DPS) growth rates. Despite the limited analytical relevance of DPS as compared to EPS growth rates in the DCF analysis, please see STAFF-DR-02-015 Attachment 1 for the requested analysis. However, the analytical results contained in STAFF-DR-02-015 Attachment 1 call into question the reasonableness of Value Line DPS growth rates in the DCF model. STAFF-DR-02-015 Attachment 2 contains the same DCF analysis as provided in STAFF-DR-02-015 Attachment 1, but relying exclusively on Value Line DPS growth rates and excluding all EPS growth rates. The results produce mean ROE estimates (7.73 percent to 7.90 percent) that are below any ROE authorized by any Commission for natural gas utility since at least 1980. Further, individual proxy companies are unreasonably low. For example, the 30-day Constant Growth DCF result for Northwest Natural Gas Company is 5.22 percent. By comparison, the average yield on the Moody's Baa Utility Bond Index was 5.90 percent over that same 30-day period. It is highly unlikely that an investor would accept the incremental risk associated with equity ownership over a debt investment for a lower return. As such, DCF results based on Value Line DPS growth rates fail basic tests of economic logic.

PERSON RESPONSIBLE: Joshua C. Nowak

30-DAY CONSTANT GROWTH DCF

Company	Ticker	[1] Annualized Dividend	[2] Stock Price	[3] Dividend Yield	[4] Expected Dividend Yield	[5] Value Line Dividend Growth	[6] Value Line Earnings Growth	[7] S&P Cap. IQ Earnings Growth	[8] Zacks Earnings Growth	[9] Average Growth Rate	[10] Low ROE	[11] Mean ROE	[12] High ROE
Atmos Energy Corporation	ATO	$3.48	$149.80	2.32%	2.40%	7.00%	6.00%	7.30%	7.10%	6.85%	8.39%	9.25%	9.71%
New Jersey Resources Corporation	NJR	$1.80	$48.16	3.74%	3.85%	5.00%	5.00%	7.80%	n/a	5.93%	8.83%	9.78%	11.68%
NiSource Inc.	NI	$1.12	$39.62	2.83%	2.93%	4.50%	9.50%	8.26%	8.20%	7.61%	7.39%	10.55%	12.46%
Northwest Natural Gas Company	NWN	$1.96	$41.60	4.71%	4.82%	0.50%	6.50%	6.50%	n/a	4.50%	5.22%	9.32%	11.36%
ONE Gas Inc.	OGS	$2.68	$73.97	3.62%	3.69%	2.50%	4.00%	3.00%	4.70%	3.55%	6.17%	7.24%	8.41%
Southwest Gas Holdings, Inc.	SWX	$2.48	$74.65	3.32%	3.44%	5.50%	10.00%	n/a	6.60%	7.37%	8.91%	10.81%	13.49%
Spire, Inc.	SR	$3.14	$76.28	4.12%	4.24%	4.00%	4.50%	8.08%	6.50%	5.77%	8.20%	10.01%	12.36%
Median				3.62%	3.69%	4.50%	6.00%	7.55%	6.60%	5.93%	8.20%	9.78%	11.68%
Mean				3.52%	3.62%	4.14%	6.50%	6.82%	6.62%	5.94%	7.59%	9.56%	11.35%

Notes:
[1] Source: Bloomberg Professional
[2] Source: Bloomberg Professional, equals 30-day average as of March 31, 2025
[3] Equals [1] / [2]
[4] Equals [3] x (1 + 0.50 x [9])
[5] Source: Value Line
[6] Source: Value Line
[7] Source: S&P Capital IQ
[8] Source: Zacks
[9] Equals Average ([5], [6], [7], [8])
[10] Equals [3] x (1 + 0.50 x Minimum ([5], [6], [7], [8]) + Minimum ([5], [6], [7], [8])
[11] Equals [4] + [9]
[12] Equals [3] x (1 + 0.50 x Maximum ([5], [6], [7], [8]) + Maximum ([5], [6], [7], [8])

90-DAY CONSTANT GROWTH DCF

Company	Ticker	[1] Annualized Dividend	[2] Stock Price	[3] Dividend Yield	[4] Expected Dividend Yield	[5] Value Line Dividend Growth	[6] Value Line Earnings Growth	[7] S&P Cap. IQ Earnings Growth	[8] Zacks Earnings Growth	[9] Average Growth Rate	[10] Low ROE	[11] Mean ROE	[12] High ROE
Atmos Energy Corporation	ATO	$3.48	$145.07	2.40%	2.48%	7.00%	6.00%	7.30%	7.10%	6.85%	8.47%	9.33%	9.79%
New Jersey Resources Corporation	NJR	$1.80	$47.78	3.77%	3.88%	5.00%	5.00%	7.80%	n/a	5.93%	8.86%	9.81%	11.71%
NiSource Inc.	NI	$1.06	$38.00	2.79%	2.90%	4.50%	9.50%	8.26%	8.20%	7.61%	7.35%	10.51%	12.42%
Northwest Natural Gas Company	NWN	$1.96	$41.04	4.78%	4.88%	0.50%	6.50%	6.50%	n/a	4.50%	5.29%	9.38%	11.43%
ONE Gas Inc.	OGS	$2.64	$72.36	3.65%	3.71%	2.50%	4.00%	3.00%	4.70%	3.55%	6.19%	7.26%	8.43%
Southwest Gas Holdings, Inc.	SWX	$2.48	$74.14	3.34%	3.47%	5.50%	10.00%	n/a	6.60%	7.37%	8.94%	10.83%	13.51%
Spire, Inc.	SR	$3.14	$71.84	4.37%	4.50%	4.00%	4.50%	8.08%	6.50%	5.77%	8.46%	10.27%	12.63%
Median				3.65%	3.71%	4.50%	6.00%	7.55%	6.60%	5.93%	8.46%	9.81%	11.71%
Mean				3.59%	3.69%	4.14%	6.50%	6.82%	6.62%	5.94%	7.65%	9.63%	11.42%

Notes:
[1] Source: Bloomberg Professional
[2] Source: Bloomberg Professional, equals 90-day average as of March 31, 2025
[3] Equals [1] / [2]
[4] Equals [3] x (1 + 0.50 x [9])
[5] Source: Value Line
[6] Source: Value Line
[7] Source: S&P Capital IQ
[8] Source: Zacks
[9] Equals Average ([5], [6], [7], [8])
[10] Equals [3] x (1 + 0.50 x Minimum ([5], [6], [7], [8]) + Minimum ([5], [6], [7], [8])
[11] Equals [4] + [9]
[12] Equals [3] x (1 + 0.50 x Maximum ([5], [6], [7], [8]) + Maximum ([5], [6], [7], [8])

180-DAY CONSTANT GROWTH DCF

Company	Ticker	[1] Annualized Dividend	[2] Stock Price	[3] Dividend Yield	[4] Expected Dividend Yield	[5] Value Line Dividend Growth	[6] Value Line Earnings Growth	[7] S&P Cap. IQ Earnings Growth	[8] Zacks Earnings Growth	[9] Average Growth Rate	[10] Low ROE	[11] Mean ROE	[12] High ROE
Atmos Energy Corporation	ATO	$3.48	$139.73	2.49%	2.58%	7.00%	6.00%	7.30%	7.10%	6.85%	8.57%	9.43%	9.88%
New Jersey Resources Corporation	NJR	$1.80	$47.00	3.83%	3.94%	5.00%	5.00%	7.80%	n/a	5.93%	8.93%	9.88%	11.78%
NiSource Inc.	NI	$1.06	$35.67	2.97%	3.08%	4.50%	9.50%	8.26%	8.20%	7.61%	7.54%	10.70%	12.61%
Northwest Natural Gas Company	NWN	$1.96	$40.39	4.85%	4.96%	0.50%	6.50%	6.50%	n/a	4.50%	5.37%	9.46%	11.51%
ONE Gas Inc.	OGS	$2.64	$71.61	3.69%	3.75%	2.50%	4.00%	3.00%	4.70%	3.55%	6.23%	7.30%	8.47%
Southwest Gas Holdings, Inc.	SWX	$2.48	$73.65	3.37%	3.49%	5.50%	10.00%	n/a	6.60%	7.37%	8.96%	10.86%	13.54%
Spire, Inc.	SR	$3.14	$68.62	4.58%	4.71%	4.00%	4.50%	8.08%	6.50%	5.77%	8.67%	10.48%	12.84%
Median				3.69%	3.75%	4.50%	6.00%	7.55%	6.60%	5.93%	8.57%	9.88%	11.78%
Mean				3.68%	3.79%	4.14%	6.50%	6.82%	6.62%	5.94%	7.75%	9.73%	11.52%

Notes:
[1] Source: Bloomberg Professional
[2] Source: Bloomberg Professional, equals 180-day average as of March 31, 2025
[3] Equals [1] / [2]
[4] Equals [3] x (1 + 0.50 x [9])
[5] Source: Value Line
[6] Source: Value Line
[7] Source: S&P Capital IQ
[8] Source: Zacks
[9] Equals Average ([5], [6], [7], [8])
[10] Equals [3] x (1 + 0.50 x Minimum ([5], [6], [7], [8]) + Minimum ([5], [6], [7], [8])
[11] Equals [4] + [9]
[12] Equals [3] x (1 + 0.50 x Maximum ([5], [6], [7], [8]) + Maximum ([5], [6], [7], [8])

30-DAY CONSTANT GROWTH DCF

Company	Ticker	[1] Annualized Dividend	[2] Stock Price	[3] Dividend Yield	[4] Expected Dividend Yield	[5] Value Line Dividend Growth	[6] ROE
Atmos Energy Corporation	ATO	$3.48	$149.80	2.32%	2.40%	7.00%	9.40%
New Jersey Resources Corporation	NJR	$1.80	$48.16	3.74%	3.83%	5.00%	8.83%
NiSource Inc.	NI	$1.12	$39.62	2.83%	2.89%	4.50%	7.39%
Northwest Natural Gas Company	NWN	$1.96	$41.60	4.71%	4.72%	0.50%	5.22%
ONE Gas Inc.	OGS	$2.68	$73.97	3.62%	3.67%	2.50%	6.17%
Southwest Gas Holdings, Inc.	SWX	$2.48	$74.65	3.32%	3.41%	5.50%	8.91%
Spire, Inc.	SR	$3.14	$76.28	4.12%	4.20%	4.00%	8.20%
Median				3.62%	3.67%	4.50%	8.20%
Mean				3.52%	3.59%	4.14%	7.73%

Notes:
[1] Source: Bloomberg Professional
[2] Source: Bloomberg Professional, equals 30-day average as of March 31, 2025
[3] Equals [1] / [2]
[4] Equals [3] x (1 + 0.50 x [5])
[5] Source: Value Line
[6] Equals [4] + [5]

90-DAY CONSTANT GROWTH DCF

Company	Ticker	[1] Annualized Dividend	[2] Stock Price	[3] Dividend Yield	[4] Expected Dividend Yield	[5] Average Growth Rate	[6] Mean ROE
Atmos Energy Corporation	ATO	$3.48	$145.07	2.40%	2.48%	7.00%	9.48%
New Jersey Resources Corporation	NJR	$1.80	$47.78	3.77%	3.86%	5.00%	8.86%
NiSource Inc.	NI	$1.06	$38.00	2.79%	2.85%	4.50%	7.35%
Northwest Natural Gas Company	NWN	$1.96	$41.04	4.78%	4.79%	0.50%	5.29%
ONE Gas Inc.	OGS	$2.64	$72.36	3.65%	3.69%	2.50%	6.19%
Southwest Gas Holdings, Inc.	SWX	$2.48	$74.14	3.34%	3.44%	5.50%	8.94%
Spire, Inc.	SR	$3.14	$71.84	4.37%	4.46%	4.00%	8.46%
Median				3.65%	3.69%	4.50%	8.46%
Mean				3.59%	3.65%	4.14%	7.80%

Notes:
[1] Source: Bloomberg Professional
[2] Source: Bloomberg Professional, equals 90-day average as of March 31, 2025
[3] Equals [1] / [2]
[4] Equals [3] x (1 + 0.50 x [5])
[5] Source: Value Line
[6] Equals [4] + [5]

180-DAY CONSTANT GROWTH DCF

Company	Ticker	[1] Annualized Dividend	[2] Stock Price	[3] Dividend Yield	[4] Expected Dividend Yield	[5] Average Growth Rate	[6] Mean ROE
Atmos Energy Corporation	ATO	$3.48	$139.73	2.49%	2.58%	7.00%	9.58%
New Jersey Resources Corporation	NJR	$1.80	$47.00	3.83%	3.93%	5.00%	8.93%
NiSource Inc.	NI	$1.06	$35.67	2.97%	3.04%	4.50%	7.54%
Northwest Natural Gas Company	NWN	$1.96	$40.39	4.85%	4.87%	0.50%	5.37%
ONE Gas Inc.	OGS	$2.64	$71.61	3.69%	3.73%	2.50%	6.23%
Southwest Gas Holdings, Inc.	SWX	$2.48	$73.65	3.37%	3.46%	5.50%	8.96%
Spire, Inc.	SR	$3.14	$68.62	4.58%	4.67%	4.00%	8.67%
Median				3.69%	3.73%	4.50%	8.67%
Mean				3.68%	3.75%	4.14%	7.90%

Notes:
[1] Source: Bloomberg Professional
[2] Source: Bloomberg Professional, equals 180-day average as of March 31, 2025
[3] Equals [1] / [2]
[4] Equals [3] x (1 + 0.50 x [5])
[5] Source: Value Line
[6] Equals [4] + [5]

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-016

REQUEST:

Refer to the Nowak Direct Testimony, page 35, line 20 and page 36, lines 1-4. Refer also to Attachment JCN-6.

a. Explain why Yahoo! Finance Beta values, once adjusted, should not be included in the analyses in addition to Value Line and Bloomberg Beta values.

b. Provide the adjusted Yahoo! Finance Beta Values for the proxy group companies.

RESPONSE:

a. Mr. Nowak is not aware of Yahoo! Finance's methodology for calculating Beta, including the reference index used and any adjustments made to its Beta estimates. However, Mr. Nowak understands that Yahoo! Finance Beta estimates are based on five years of monthly returns. Five years of monthly returns, or 60 total observations, may not produce a statistically robust relationship for estimating Beta so they should not be included in the CAPM analysis.

b. Mr. Nowak does not have the requested Yahoo! Finance Beta estimates consistent with the date of his cost of equity analyses and therefore has not performed the requested calculations.

PERSON RESPONSIBLE: Joshua C. Nowak

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-017

REQUEST:

Refer to the Nowak Direct Testimony, Attachment JCN-4. The Earnings Growth rate values from Zacks and S&P Cap. IQ show 'n/a' for proxy group companies. Confirm that these unavailable values were not supplemented in the Average Projected EPS Growth Rate calculation, and rather this calculation relied only on the available EPS data from the two other sources for these companies. If not confirmed, explain.

RESPONSE:

Confirmed. "Average Growth Rates" in Column [8] of Attachment JCN-4 were not supplemented and the average only relies on available data presented in the exhibit.

PERSON RESPONSIBLE: Joshua C. Nowak

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-018

REQUEST:

Refer to the Nowak Direct Testimony, pages 36, and Attachments JCM-5 and JCM-6.

a. Explain why it is not inconsistent to use a Value Line Beta value, which is based on the broader New York Stock Exchange Composite Index, and a market risk premium based on the much narrower S&P 500 Index, in the CAPM analyses.

b. Provide the expected market return using the broader New York Stock Exchange Composite Index as the market proxy and provide an update to the CAPM analyses using this market return.

c. For rate making purposes for state regulated electric utilities, explain why the Federal Energy Regulatory Commission (FERC) methodology of only considering growth rates between 0 percent and 20 percent is reasonable.

RESPONSE:

a. As shown on pages 33 and 34 of Nowak Direct Testimony, both equation [3] (the CAPM formula) and equation [4] (the Beta coefficient formula) require an estimate of the required market return as a whole. The return on market indices (i.e., the S&P 500 and the New York Stock Exchange Composite Index) are used as a proxy for "the return on the market as whole." To the extent that the Market Risk Premium and Beta coefficient apply different market indices in their respective estimates of the overall market return, as long as the individual estimates are both measures of the overall market and there is no bias between the two estimates, there is no fundamental inconsistency. Further, over the

five-year analytical period incorporated in Value Line's Beta estimates on which Mr. Nowak relies, weekly returns on the S&P 500 and the New York Stock Exchange Composite Index were highly correlated. Therefore, it is unlikely for any significant difference in Beta coefficients estimated based on the S&P 500 versus the New York Stock Exchange Composite Index.

b. Mr. Nowak does not have the data required to estimate the market risk premium for broader New York Stock Exchange Composite Index consistent with the date of his cost of equity analyses and therefore has not performed the requested calculations.

c. The FERC method of calculating the market return is intended to estimate the same input to the CAPM that Mr. Nowak is estimating in his CAPM approach – the required return for the market as a whole. As such, there is no basis for a distinction for applicability to state regulated electric utilities versus FERC-regulated electric utilities. Regardless of the jurisdiction, the same analytical principles apply. Therefore, the FERC methodology, while conservative, is reasonable.

PERSON RESPONSIBLE: Joshua C. Nowak

Duke Energy Kentucky
Case No. 2025-00125
STAFF's Second Request for Information
Date Received: July 1, 2025

STAFF-DR-02-019

REQUEST:

Provide any Pipeline and Hazardous Materials Safety Administration (PHMSA) bulletins for the past 60 days related to Aldyl-A pipe.

RESPONSE:

PHMSA has not issued an advisory bulletin in the past 60 days related to Aldyl-A pipe, however, there have several reports and/or bulletins issued related to Aldyl-A pipe. Documents uploaded for review include:

- PHMSA advisory bulletin concerning the susceptibility of certain older plastic pipes to premature brittle-like cracking, ADB-2007-01. See attachment STAFF-DR-02-019 Attachment 1.
- NTSB report dated April 23, 1998, regarding Brittle-Like Cracking in Plastic Pipe for Gas Service, NTSB/SIR–98/01. See attachment STAFF-DR-02-019 Attachment 2.
- On June 11, 2014, the Staff of the California Public Utilities Commission issued a Hazard Analysis and Mitigation Report specific to ALDYL-A Polyethylene Gas Pipelines. The report provides hazard-specific background knowledge and technical analysis and includes recommendations to decision makers for policy improvements and best practices with respect to ALDYL-A Polyethylene. See attachment STAFF-DR-02-019 Attachment 3.

- In 2021, PHMSA issued a NPRM for the Safety of Gas Distribution Pipelines that specifically calls out for ALDYL-A pipe to be tracked as a separate material in DIMP Plans. See attachment STAFF-DR-02-019 Attachment 4.
- NTSB Pipeline Investigation Report, PIR-25-01, related to the West Reading, PA event March 24, 2023. See attachment STAFF-DR-02-019 Attachment 5.
- Lastly, NTSB is in the process of finalizing a report regarding a November 6, 2024, event in South Jordan, Utah related to a house explosion linked to ALDYL-A pipe.

PERSON RESPONSIBLE: Adam Long

safety procedures used for filling, operating, and discharging MATs to determine whether additional safety procedures should be implemented. To this end, we request that persons who use such transportation systems to provide us with information on the effectiveness of the current DOT regulations, consensus standards, and industry best practices. We are also interested in any other procedures utilized to ensure that operations related to the transportation of acetylene on MATs are performed safely.

We would also like to work with shippers, carriers, and facilities that receive shipments of acetylene in MATs to develop and implement a pilot program to test the effectiveness of current or alternative procedures or methods designed to enhance the safety of transportation operations involving acetylene on MATs. As part of this program, we will assist individual companies or facilities to evaluate the effectiveness of their current procedures and to identify additional measures that should be implemented. We welcome suggestions concerning how such a program should be structured and the entities that should participate.

To ensure that our message reaches all stakeholders affected by these risks, we plan to communicate this advisory through our public affairs notification and outreach processes. For additional visibility, we have made this advisory available on the PHMSA homepage at *http://www.phmsa.dot.gov* and the DOT electronic docket site at *http://dms.dot.gov*. In addition, if you are aware of other companies that are involved in the charging, operating, and discharging MATs, please share this advisory notice with them and, if possible, identify them in your correspondence with this agency. We believe a collaborative effort involving an integrated and cooperative approach will help us to address safety risks, reduce incidents, enhance safety, and protect the public.

Issued in Washington, DC on August 30, 2007.

Theodore L. Willke,

Associate Administrator for Hazardous Materials Safety.

[FR Doc. 07–4355 Filed 9–5–07; 8:45 am]

BILLING CODE 4910–60–P

DEPARTMENT OF TRANSPORTATION

Pipeline and Hazardous Materials Safety Administration

[Docket No. PHMSA–2004–19856]

Pipeline Safety: Updated Notification of the Susceptibility to Premature Brittle-Like Cracking of Older Plastic Pipe

AGENCY: Pipeline and Hazardous Materials Safety Administration (PHMSA); DOT.

ACTION: Notice; Issuance of Advisory Bulletin.

SUMMARY: PHMSA is issuing this updated advisory bulletin to owners and operators of natural gas pipeline distribution systems concerning the susceptibility of older plastic pipe to premature brittle-like cracking. PHMSA previously issued three advisory bulletins on this subject: Two on March 11, 1999 and one on November 26, 2002. This advisory bulletin expands on the information provided in the three prior bulletins by listing two additional pipe materials with poor performance histories relative to brittle-like cracking and by updating pipeline owners and operators on the ongoing voluntary efforts to collect and analyze data on plastic pipe performance. Owners and operators of natural gas pipeline distribution systems are encouraged to review the three previous advisory bulletins in their entirety.

FOR FURTHER INFORMATION CONTACT: Richard Sanders at (405) 954–7214, or by e-mail at *richard.sanders@dot.gov*.

SUPPLEMENTARY INFORMATION:

I. National Transportation Safety Board (NTSB) Investigation

On April 23, 1998, the National Transportation Safety Board (NTSB) issued its Special Investigation Report, *Brittle-Like Cracking in Plastic Pipe for Gas Service,* NTSB/SIR–98/01. The report described the results of the NTSB's special investigation of polyethylene gas service pipe, which addressed three major safety issues: (1) Vulnerability of plastic piping to premature failures due to brittle-like cracking; (2) adequacy of available guidance relating to the installation and protection of plastic piping connections to steel mains; and, (3) effectiveness of performance monitoring of plastic pipeline systems to detect unacceptable performance in piping systems.

(1) *Vulnerability of plastic piping to premature failures due to brittle-like cracking:* The NTSB found that failures in polyethylene pipe in actual service are frequently brittle-like, slit failures, not ductile failures. It concluded the number and similarity of plastic pipe accident and non-accident failures indicate past standards used to rate the long-term strength of plastic pipe may have overrated the strength and resistance to brittle-like cracking for much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s. The NTSB also concluded any potential public safety hazards from these failures are likely to be limited to locations where stress intensification exists. The NTSB went on to state that more durable modern plastic piping materials and better strength testing have made the strength ratings of modern plastic piping more reliable.

(2) *Adequacy of available guidance relating to the installation and protection of plastic piping connections to steel mains:* The NTSB concluded that gas pipeline operators had insufficient notification of the brittle-like failure potential for plastic pipe manufactured and used for gas service from the 1960s to the early 1980s. The NTSB also concluded this may not have allowed companies to implement adequate surveillance and replacement programs for older plastic piping. The NTSB explained the Gas Research Institute (GRI) developed a significant amount of data on older plastic pipe but the data was published in codified terms making it insufficient for use by pipeline system operators. The NTSB recommended that manufacturers of resin and pipe, industry trade groups and the Federal government do more to alert pipeline operators to the role played by stress intensification from external forces in the premature failure of plastic pipe due to brittle-like cracking.

(3) *Effectiveness of performance monitoring of plastic pipeline systems as a way of detecting unacceptable performance in piping systems:* The NTSB's analysis noted that Federal regulations require pipeline operators to have an ongoing program to monitor the performance of their pipeline systems. However, the NTSB investigation revealed some gas pipeline operators' performance monitoring programs did not effectively collect and analyze data to determine the extent of possible hazards associated with plastic pipeline systems. The NTSB pointed out, ''such a program must be adequate to detect trends as well as to identify localized problem areas, and it must be able to relate poor performance to specific factors such as plastic piping brands, dates of manufacture (or installation dates), and failure conditions.''

Copies of this report may be obtained by searching the NTSB Web site at *www.ntsb.gov.*

II. Advisory Bulletins Previously Issued by PHMSA

The NTSB made several recommendations to PHMSA and to trade organizations in its 1998 special investigation report. In response, PHMSA issued three advisory bulletins. The first advisory bulletin, ADB–99–01, *Potential Failure Due to Brittle-Like Cracking of Certain Polyethylene Plastic Pipe Manufactured by Century Utility Products Inc,* was published in the **Federal Register** (FR) on March 11, 1999 (64 FR 12211) to advise natural gas pipeline distribution system operators that brittle-like cracking may occur on certain polyethylene pipe manufactured by Century Utility Products, Inc.

The second advisory bulletin, ADB–99–02, *Potential Failures Due to Brittle-Like Cracking of Older Plastic Pipe in Natural Gas Distribution Systems,* was also published in the **Federal Register** on March 11, 1999 (64 FR 12212) to advise natural gas pipeline distribution system operators of the potential for brittle-like cracking of plastic pipes installed between the 1960s and early 1980s.

The third advisory bulletin, ADB–02–07, *Notification of the Susceptibility To Premature Brittle-Like Cracking of Older Plastic Pipe,* was published in the **Federal Register** on November 26, 2002 (67 FR 70806) to reiterate to natural gas pipeline distribution system operators the susceptibility of older plastic pipe to premature brittle-like cracking. The older polyethylene pipe materials specifically identified in ADB–02–07 included, but were not limited to:

- Century Utility Products, Inc. products;
- Low-ductile inner wall ''Aldyl A'' piping manufactured by DuPont Company before 1973; and
- Polyethylene gas pipe designated PE 3306.

This third advisory bulletin also listed several environmental, installation and service conditions in which plastic piping is used that could lead to premature brittle-like cracking failure. PHMSA also described six recommended practices for polyethylene gas pipeline system operators to aid them with identifying and managing brittle-like cracking problems.

III. Plastic Pipe Studies

Beginning January 25, 2001, the American Gas Association (AGA) began to collect data on in-service plastic piping material failures with the objective of identifying trends in the performance of these materials. The resulting leak survey data, collected from 2001 to present, on the county's natural gas distribution systems includes both actual failure information and negative reports (reports of no leads) submitted voluntarily by participating pipeline operating companies.

The AGA, PHMSA, and other industry and state organizations continue to collect and analyze the data. Unfortunately, the data cannot be correlated with the quantities of each plastic pipe material that may be in service across the United States. Therefore, the data does not assess the failure rates of individual plastic pipe materials on a linear basis (i.e. per foot, per mile, etc.). However, the failure data reinforces what is historically known about certain older plastic piping and components. The data also indicates the susceptibility of additional specific materials to brittle-like cracking.

IV. Advisory Bulletin ADB–07–01

To: Owners and Operators of Natural Gas Pipeline Distribution Systems.

Subject: Updated Notification of the Susceptibility of Older Plastic Pipes to Premature Brittle-Like Cracking.

Advisory: All owners and operators of natural gas distribution systems who have installed and operate plastic piping are reminded of the phenomenon of brittle-like cracking. Brittle-like cracking refers to crack initiation in the pipe wall not immediately resulting in a full break followed by stable crack growth at stress levels much lower than the stress required for yielding. This results in very tight, slit-like, openings and gas leaks. Although significant cracking may occur at points of stress concentration and near improperly designed or installed fittings, small brittle-like cracks may be difficult to detect until a significant amount of gas leaks out of the pipe, and potentially migrates into an enclosed space such as a basement. Premature brittle-like cracking requires relatively high localized stress intensification that may result from geometrical discontinuities, excessive bending, improper installation of fittings, dents and/or gouges. Because this failure mode exhibits no evidence of gross yielding at the failure location, the term brittle-like cracking is used. This phenomenon is different from brittle fracture, in which the pipe failure causes fragmentation of the pipe.

All owners and operators of natural gas distribution systems are future advised to review the three earlier advisory bulletins on this issue. In addition to being available in the **Federal Register**, these advisory bulletins are available in the docket, and on PHMSA's Web site at *http://phmsa.dot.gov/* under Pipeline Safety Regulations.

In the first advisory bulletin, ADB–99–01, published on March 11, 1999 (64 FR 12211), PHMSA advises natural gas distribution system operators of the potential for poor resistance to brittle-like cracking of certain polyethylene pipe manufactured by Century Utility Products, Inc. In the second advisory bulletin, ADB–99–02, published on March 11, 1999 (64 FR 12212), PHMSA advises natural gas distribution system operators of the potential for brittle-like cracking of plastic pipes installed between the 1960s and early 1980s.

In the third advisory bulletin, ADB–02–07, published on November 26, 2002 (67 FR 70806), PHMSA reiterates to pipeline operators the susceptibility of some older plastic pipe to premature brittle-like cracking which could substantially reduce the service life of natural gas distribution systems and to explain the mission of the Plastic Pipe Database Committee (PPDC) ''to develop and maintain a voluntary data collection process that supports the analysis of the frequency and causes of in-service plastic piping material failures.'' The advisory bulletin also lists several environmental, installation and service conditions under which plastic piping is used which is used which could lead to premature brittle-like cracking failure. PHMSA also describes six recommended practices for polyethylene gas pipeline system operators to aid them with identifying and managing brittle-like cracking problems.

Lastly, the susceptibility of some polyethylene pipes to brittle-like cracking is dependent on the resin, pipe processing, and service conditions. As noted in ADB–02–07, these older polyethylene pipe materials include, but are not limited to:

- Century Utility Products, Inc. products;
- Low-ductile inner wall ''Aldyl A'' piping manufactured by DuPont Company before 1973; and
- Polyethylene gas pipe designated PE 3306.

The data now supports adding the following pipe materials to this list:

- Delrin insert tap tees; and,
- Plexco service tee Celcon (polyacetal) caps.

Authority: 49 U.S.C. chapter 601 and 49 CFR 1.53.

Issued in Washington, DC, on August 28, 2007.

Jeffrey D. Wiese,

Associate Administrator for Pipeline Safety.

[FR Doc. 07–4309 Filed 9–5–07; 8:45 am]

BILLING CODE 4910–60–M

DEPARTMENT OF TRANSPORTATION

Pipeline and Hazardous Materials Safety Administration

[Docket No. PHMSA–2007–28993]

Pipeline Safety: Adequacy of Internal Corrosion Regulations for Hazardous Liquid Pipelines

AGENCY: Pipeline and Hazardous Materials Safety Administration (PHMSA), U.S. Department of Transportation (DOT).

ACTION: Notice of availability of materials; request for comments.

SUMMARY: This notice announces the availability of materials, including a briefing paper prepared for PHMSA's Technical Hazardous Liquid Pipeline Safety Standards Committee (THLPSSC) and data on risks posed by internal corrosion on hazardous liquid pipelines. PHMSA is preparing a report to Congress on the adequacy of the internal corrosion regulations for hazardous liquid pipelines. Participants at a meeting of the THLPSSC discussed issues involved in examining the adequacy of the regulations and requested additional data. PHMSA requests public comment on these matters.

DATES: Submit comments by October 9, 2007.

ADDRESSES: Comments should reference Docket No. PHMSA–2007–28993 and may be submitted in the following ways:

- *E-Gov Web site: http://www.regulations.gov.* This Web site allows the public to enter comments on any **Federal Register** notice issued by any agency. Follow the instructions for submitting comments.
- *Fax:* 1–202–493–2251.
- *Mail:* Docket Management System: U.S. Department of Transportation, Docket Operations, M–30, Room W12–140, 1200 New Jersey Avenue, SE., Washington, DC 20590–0001.
- *Hand Delivery:* DOT Docket Management System, West Building Ground Floor, Room W12–140, 1200 New Jersey Avenue, SE., Washington, DC 20590–0001 between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

Instructions: Identify the docket number, PHMSA–2007–28993, at the beginning of your comments. If you submit your comments by mail, submit two copies. To receive confirmation that PHMSA received your comments, include a self-addressed stamped postcard. Internet users may submit comments at *http://www.regulations.gov.*

Note: Comments are posted without changes or edits to *http://www.regulations.gov*, including any personal information provided. There is a privacy statement published on *http://www.regulations.gov.*

FOR FURTHER INFORMATION CONTACT: Barbara Betsock at (202) 366–4361, or by e-mail at *barbara.betsock@dot.gov.*

SUPPLEMENTARY INFORMATION: The Pipeline Inspection, Protection, Enforcement, and Safety Act of 2006 directs PHMSA to review the internal corrosion regulations in subpart H of 49 CFR part 195 to determine if they are adequate to ensure adequate protection of the public and environment and to report to Congress on the results of the review. As an initial step in the review, PHMSA consulted the THLPSSC at its meeting on July 24, 2007. The briefing paper prepared for the committee members contains preliminary data on risk history as well as questions relating to the internal corrosion regulations. This briefing paper is posted on PHMSA's pipeline Web site (*http://ops.dot.gov*) and has been placed in the docket.

At the meeting, PHMSA officials committed to gathering additional data responding to questions posed by the committee members. PHMSA has updated the data and included data responsive to the committee members. This data is also posted on the pipeline Web site and contained in the docket.

PHMSA requests comments on the adequacy of the internal corrosion regulations and answers to the questions posed in the briefing paper. PHMSA will use these comments in its review of the internal corrosion regulations.

Authority: 49 U.S.C. 60102, 60115, 60117: Sec. 22, Pub. L. 109–468, 120 Stat. 3499.

Issued in Washington, DC on August 27, 2007.

Jeffrey D. Wiese,

Associate Administrator for Pipeline Safety.

[FR Doc. E7–17538 Filed 9–5–07; 8:45 am]

BILLING CODE 4910–60–P

DEPARTMENT OF VETERANS AFFAIRS

[OMB Control No. 2900–0675]

Proposed Information Collection Activity: Proposed Collection; Comment Request

AGENCY: Center for Veterans Enterprise, Department of Veterans Affairs.

ACTION: Notice.

SUMMARY: The Center for Veterans Enterprise (CVE), Department of Veterans Affairs (VA), is announcing an opportunity for public comment on the proposed collection of certain information by the agency. Under the Paperwork Reduction Act (PRA) of 1995, Federal agencies are required to publish notice in the **Federal Register** concerning each proposed collection of information, including each proposed extension of a currently approved collection, and allow 60 days for public comment in response to the notice. This notice solicits comments for information needed to identify veteran-owned businesses.

DATES: Written comments and recommendations on the proposed collection of information should be received on or before November 5, 2007.

ADDRESSES: Submit written comments on the collection of information through *http://www.Regulations.gov;* or Gail Wegner (00VE), Department of Veterans Affairs, 810 Vermont Avenue, NW., Washington, DC 20420 or e-mail: *gail.wegner@va.gov.* Please refer to ''OMB Control No. 2900–0675'' in any correspondence. During the comment period, comments may be viewed online through the Federal Docket Management System (FDMS) at *http://www.Regulations.gov.*

FOR FURTHER INFORMATION CONTACT: Gail Wegner at (202) 303–3296 or FAX (202) 254–0238.

SUPPLEMENTARY INFORMATION: Under the PRA of 1995 (Pub. L. 104–13; 44 U.S.C. 3501–3521), Federal agencies must obtain approval from the Office of Management and Budget (OMB) for each collection of information they conduct or sponsor. This request for comment is being made pursuant to section 3506(c)(2)(A) of the PRA.

With respect to the following collection of information, CVE invites comments on: (1) Whether the proposed collection of information is necessary for the proper performance of CVE's functions, including whether the information will have practical utility; (2) the accuracy of CVE's estimate of the burden of the proposed collection of

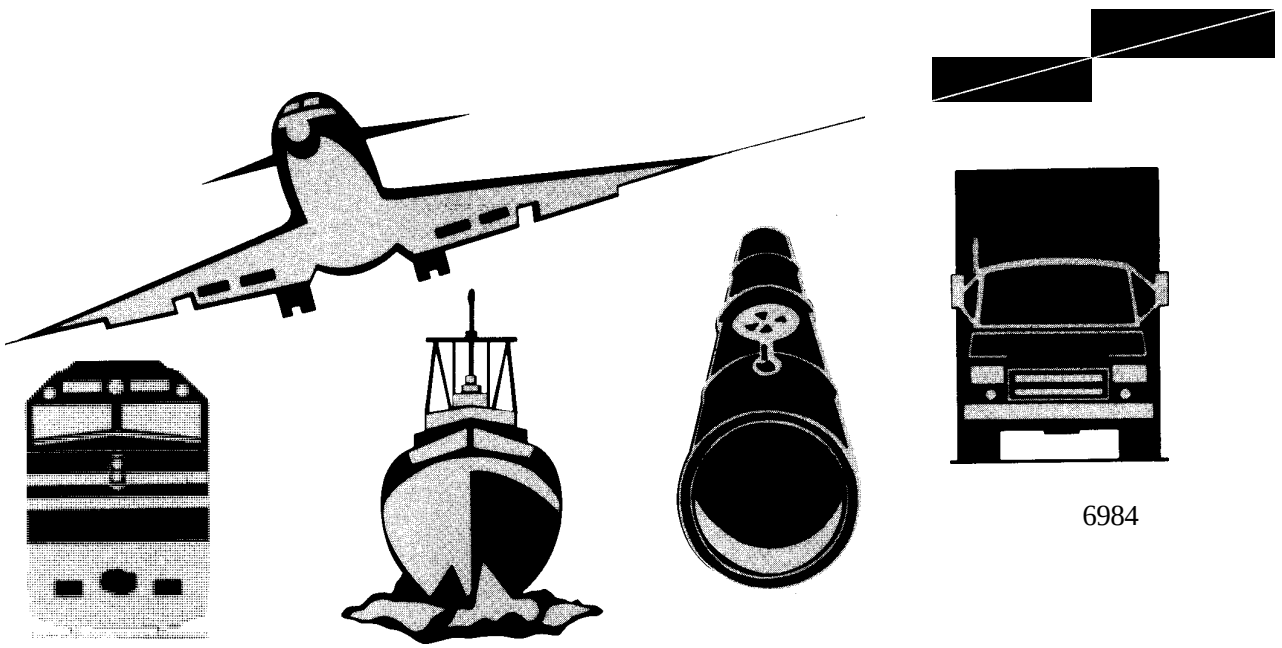
PB98-917001
NTSB/SIR-98/01

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SPECIAL INVESTIGATION REPORT

BRITTLE-LIKE CRACKING IN PLASTIC PIPE FOR GAS SERVICE



6984

Abstract: Despite the general acceptance of plastic piping as a safe and economical alternative to piping made of steel or other materials, the National Transportation Safety Board notes that a number of pipeline accidents it has investigated have involved plastic piping that cracked in a brittle-like manner. This special investigation report concludes that the procedure used in the United States to rate the strength of plastic pipe may have overrated the strength and resistance to brittle-like cracking of much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s. As a result, much of this piping may be susceptible to premature brittle-like failures when subjected to stress intensification, and these failures represent a potential public safety hazard.

The safety issues discussed in this report are the vulnerability of plastic piping to premature failures due to brittle-like cracking; the adequacy of available guidance relating to the installation and protection of plastic piping connections to steel mains; and performance monitoring of plastic pipeline systems as a way of detecting unacceptable performance in piping systems.

As a result of this special investigation, the National Transportation Safety Board issued recommendations to the Research and Special Programs Administration, the Gas Research Institute, the Plastics Pipe Institute, the Gas Piping Technology Committee, the American Society for Testing and Materials, the American Gas Association, MidAmerican Energy Corporation, Continental Industries, Inc., Dresser Industries, Inc., Inner-Tite Corporation, and Mueller Company.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

Information about available publications may be obtained by contacting:

National Transportation Safety Board
Public Inquiries Section, RE-51
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594
(202) 314-6551

Safety Board publications may be purchased, by individual copy or by subscription, from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
(703) 605-6000

BRITTLE-LIKE CRACKING IN PLASTIC PIPE FOR GAS SERVICE

SPECIAL INVESTIGATION REPORT

Adopted: April 23, 1998
Notation 6984

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C. 20594

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CONTENTS

APPENDIXES

INTRODUCTION

The use of plastic piping to transport natural gas has grown steadily over the years because of the material's economy, outstanding corrosion resistance, light weight, and ease of installing and joining. According to the American Gas Association (A.G.A.),[1] the total miles of plastic piping in use in natural gas distribution systems in the United States grew from about 9,200 miles in 1965 to more than 45,800 miles in 1970. By 1982, this figure had grown to about 215,000 miles, of which more than 85 percent was polyethylene.[2] Data maintained by Office of Pipeline Safety (OPS), an office of the Research and Special Programs Administration (RSPA) within the U.S. Department of Transportation (DOT), indicate that, by the end of 1996, more than 500,000 miles of plastic piping had been installed. Plastic piping as a percentage of all gas distribution piping installed each year has also grown steadily, as illustrated in figure 1.

Despite the general acceptance of plastic piping as a safe and economical alternative to piping made of steel or other materials, the Safety Board notes that a number of pipeline accidents it has investigated have involved plastic piping that cracked in a brittle-like manner.[3] (See table 1 for information on three recent accidents.) For example, on October 17, 1994, an explosion and fire in Waterloo, Iowa, destroyed a building and damaged other property. Six persons died and seven were injured in the accident. The Safety Board investigation determined that natural gas had been released from a plastic service pipe that had failed in a brittle-like manner at a connection to a steel main.

The Safety Board also investigated a gas explosion that resulted in 33 deaths and 69 injuries in San Juan, Puerto Rico, in November 1996.[4] The Safety Board's investigation determined that the explosion resulted from ignition of propane gas that had migrated under pressure from a failed plastic pipe. Stress intensification at a connection to a plastic fitting led to the formation of brittle-like cracks.

The Railroad Commission of Texas investigated a natural gas explosion and fire that resulted in one fatality in Lake Dallas, Texas, in August 1997.[5] A metal pipe pressing against a plastic pipe generated stress intensification that led to a brittle-like crack in the plastic pipe.

A Safety Board survey of the accident history of plastic piping suggested that the material may be susceptible to brittle-like cracking under conditions of stress intensification. No statistics exist that detail how much and from what years any plastic piping may already have been replaced; however, as noted above, hundreds of thousands of miles of plastic piping have been installed, with a significant amount of it having been installed prior to the mid-1980s. Any vulnerability of this material to premature failure could represent a serious potential hazard to public safety.

In an attempt to gauge the extent of brittle-like failures in plastic piping and to assess trends and causes, the Safety Board examined pipeline accident data compiled by RSPA. The examination revealed that the RSPA data are insufficient to serve as a basis for assessing the long-term performance of plastic pipe.

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[1]See appendix B for brief descriptions of the organizations, associations, and agencies referenced in this report.

[2]Watts, J., "Plastic Pipe Maintains Lion's Share of Market," *Pipeline and Gas Journal*, December 1982, p. 19, and National Transportation Safety Board Special Study--*An Analysis of Accident Data from Plastic Pipe Natural Gas Distribution Systems* (NTSB/PSS-80/1).

[3]The body of the report will make clear the distinction between brittle-like and ductile fractures.

[4]National Transportation Safety Board Pipeline Accident Report--*San Juan Gas Company, Inc./Enron Corp., Propane Gas Explosion in San Juan, Puerto Rico, on November 21, 1996* (NTSB/PAR-97/01).

[5]Railroad Commission of Texas Accident Investigation No. 97-AI-055, October 31, 1997.

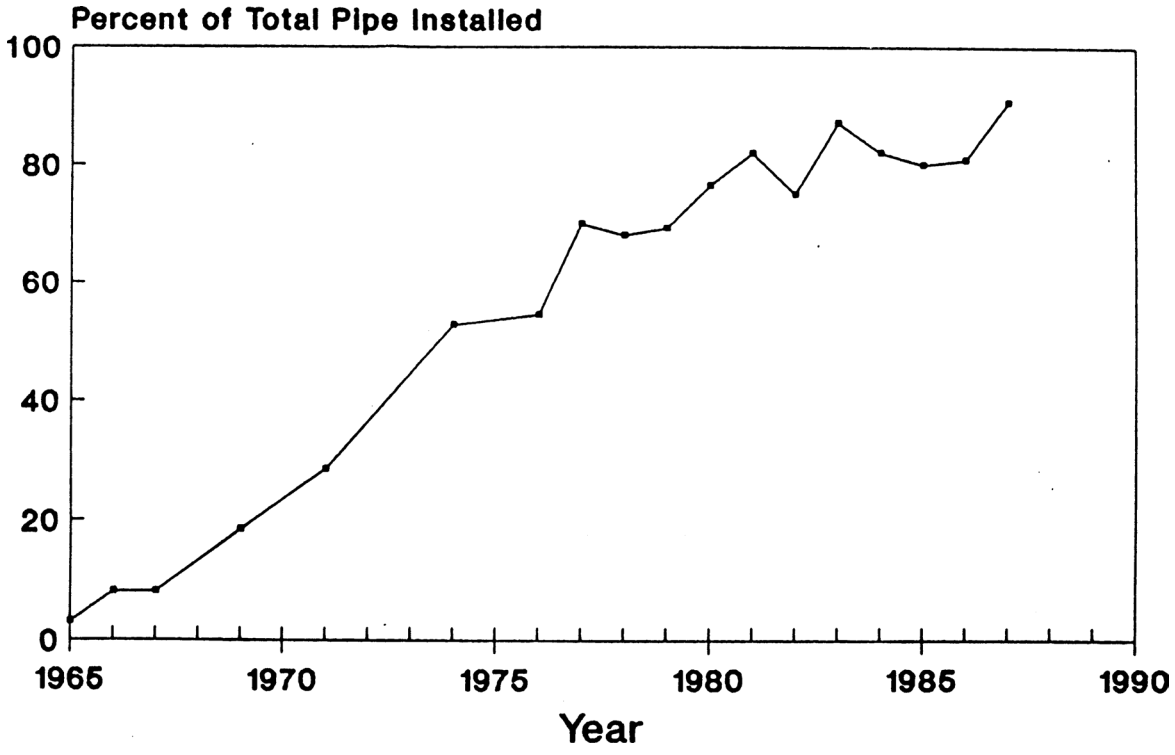

Figure 1 -- Plastic pipe as a percentage of all piping used in gas distribution. (*Source:* Duvall, D.E., "Polyethylene Pipe for Natural Gas Distribution," presented at the Transportation Safety Institute's Pipeline Failure Investigation course, 1997. Data from *Pipeline & Gas Journal* surveys.)

Lacking adequate data from RSPA, the Safety Board reviewed published technical literature and contacted more than 20 experts in gas distribution plastic piping to determine the estimated frequency of brittle-like cracks in plastic piping. The majority of the published literature and experts indicated that failure statistics would be expected to vary from one gas system operator to another based on factors such as brands and dates of manufacture of plastic piping in service, installation practices, and ground temperatures, but they indicated that brittle-like failures, as a nationwide average, may represent the second most frequent failure mode for older plastic piping, exceeded only by excavation damage.

The Safety Board asked several gas system operators about their direct experience with brittle-like cracks. Four major gas system operators reported that they had compiled failure statistics sufficient to estimate the extent of brittle-like failures. Three of those four said that brittle-like failures are the second most frequent failure mode in their plastic pipeline systems. One of these operators supplied data showing that it experienced at least 77 brittle-like failures in plastic piping in 1996 alone.

As an outgrowth of the Safety Board's investigations into the Waterloo, Iowa, San Juan, Puerto Rico, and other accidents, and in view of indications that some plastic piping, particularly older piping, may be subject to premature failure attributable to brittle-like cracking, the Safety Board undertook a special investigation of polyethylene gas service pipe. The investigation addressed the following safety issues:

- The vulnerability of plastic piping to premature failures due to brittle-like cracking;

- The adequacy of available guidance relating to the installation and protection of plastic piping connections to steel mains; and

Table 1 -- Recent pipeline accidents involving brittle-like cracking

Accident Location	Pipe Manufacturer	Year Pipe Manufactured	Year of Accident
Waterloo, Iowa	Amdevco/Century	1970	1994
San Juan, Puerto Rico	DuPont	1982	1996
Lake Dallas, Texas	Nipak	1970	1997

- Performance monitoring of plastic pipeline systems as a way of detecting unacceptable performance in piping systems.

As a result of its investigation, the Safety Board makes three safety recommendations to the Research and Special Programs Administration, one safety recommendation to the Gas Research Institute, three safety recommendations to the Plastics Pipe Institute, one safety recommendation to the Gas Piping Technology Committee, two safety recommendations to the American Society for Testing and Materials, one safety recommendation to the American Gas Association, two safety recommendations to MidAmerican Energy Corporation, two safety recommendations to Continental Industries, Inc., and one safety recommendation each to Dresser Industries, Inc., Inner-Tite Corporation, and Mueller Company.

INVESTIGATION

Accident History

On October 17, 1994, a natural gas explosion and fire in Waterloo, Iowa, destroyed a building and damaged other property. Six persons died and seven were injured in the accident. The Safety Board investigation determined that the source of the gas was a 1/2-inch-diameter plastic service pipe that had failed in a brittle-like manner at a connection to a steel main.[6]

Excavations following the accident uncovered, at a depth of about 3 feet, a 4-inch steel main. Welded to the top of the main was a steel tapping tee manufactured by Continental Industries, Inc. (Continental). Connected to the steel tee was a 1/2-inch plastic service pipe. (See figure 2.) Markings on the plastic pipe indicated that it was a medium-density polyethylene material manufactured on June 11, 1970, in accordance with American Society for Testing and Materials (ASTM) standard D2513. The pipe had been marketed by Century Utility Products, Inc. (Century). The plastic pipe was found cracked at the end of the tee's internal stiffener and beyond the coupling nut.

The investigation determined that much of the top portion of the circumference of the pipe immediately outside the tee's internal stiffener displayed several brittle-like slow crack initiation and growth fracture sites. These slow crack fractures propagated on almost parallel planes slightly offset from each other through the wall of the pipe. As the slow cracks from different planes continued to grow and began to overlap one another, ductile tearing occurred between the planes. Substantial deformation was observed in part of the fracture; however, the initiating cracks were still classified as brittle-like.

Samples recovered from the plastic service line underwent several laboratory tests under the supervision of the Safety Board. Two of these tests were meant to roughly gauge the pipe's susceptibility to brittle-like cracking. These tests were a compressed ring environmental stress crack resistance (ESCR) test in accordance with ASTM F1248 and a notch tensile test known as a PENT test that is now ASTM F1473. Lower failure times in these tests indicate greater susceptibility to brittle-like cracking under test conditions. The ESCR testing of 10 samples from the pipe yielded a mean failure time of 1.5 hours, and the PENT testing of 2 samples yielded failure times of 0.6 and 0.7 hours. Test values this low have been associated with materials having poor performance histories[7]

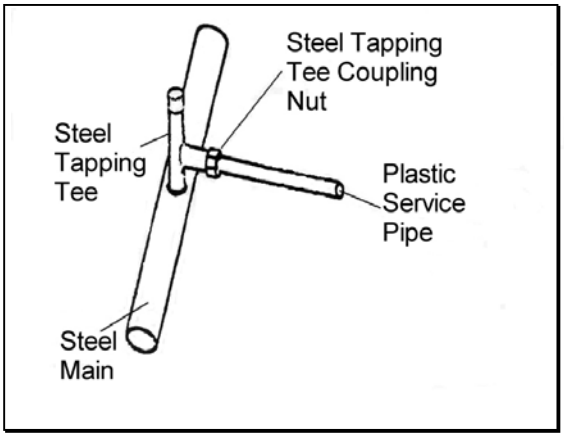

Figure 2 -- Typical plastic service pipe connection to steel gas main. Many connections are protected against shear and bending forces by a plastic sleeve that encloses the service pipe-to-tee connection on either side of the coupling nut.

[6]For more detailed information, see Pipeline Accident Brief in appendix A to this report.

[7]Uralil, F. S., et al., *The Development of Improved Plastic Piping Materials and Systems for Fuel Gas Distribution—Effects of Loads on the Structural and Fracture Behavior of Polyolefin Gas Piping*, Gas Research Institute Topical Report, 1/75 - 6/80, NTIS No. PB82-180654, GRI Report No. 80/0045, 1981, and Hulbert, L. E., Cassady, M. J., Leis, B. N., Skidmore, A., *Field Failure Reference Catalog for Polyethylene Gas Piping, Addendum No. 1*, Gas Research Institute Report No. 84/0235.2, 1989, and Brown, N. and Lu, X., "Controlling the Quality of PE Gas Piping Systems by Controlling the Quality of the Resin," *Proceedings Thirteenth International Plastic Fuel Gas Pipe Symposium*, pp. 327-338, American Gas

characterized by high leakage rates at points of stress intensification[8] due to crack initiation and slow crack growth typical of brittle-like cracking.

In late 1996, the Safety Board began an investigation of a November 1996 gas explosion that resulted in 33 deaths and 69 injuries in San Juan, Puerto Rico. The investigation determined that the explosion resulted from ignition of propane gas that, after migrating under pressure from a failed plastic pipe at a connection to a plastic fitting, had accumulated in the basement of a commercial building. The Safety Board concluded that apparent inadequate support under the piping and the resulting differential settlement generated long-term stress intensification that led to the formation of brittle-like circumferential cracks on the pipe.

The Railroad Commission of Texas investigation of a fatal natural gas explosion and fire in Lake Dallas, Texas, in August 1997 determined that a metal pipe pressing against a plastic pipe generated stress intensification that led to a brittle-like crack in the plastic pipe.

The Waterloo, San Juan, and Lake Dallas accidents were only three of the most recent in a series of accidents in which brittle-like cracks in plastic piping have been implicated. In Texas in 1971, natural gas migrated into a house from a brittle-like crack at the connection of a plastic service line to a plastic main.[9] The gas ignited and exploded, destroying the house and burning one person. The investigation determined that vertical loading over the connection generated long-term stress that led to the crack.

A 1973 natural gas explosion and fire in Maryland severely damaged a house, killed three occupants, and injured a fourth.[10] The Safety Board's investigation revealed that a brittle-like crack occurred in a plastic pipe as a result of an occluded particle that created a stress point.

The Safety Board's investigation of a natural gas explosion and fire that resulted in three fatalities in North Carolina in 1975[11] determined that the gas had accumulated because a concrete drain pipe resting on a plastic service pipe had precipitated two cracks in the plastic pipe. Available documentation suggests that these cracks were brittle-like.

A 1978 natural gas accident in Arizona destroyed 1 house, extensively damaged 2 others, partially damaged 11 other homes, and resulted in 1 fatality and 5 injuries.[12] Available documentation indicates that the gas line crack that caused the accident was brittle-like.

A 1978 accident in Nebraska involved the same brand of plastic piping as that involved in the Waterloo accident. A crack in a plastic piping fitting resulted in an explosion that injured one person, destroyed one house, and damaged three other houses.[13] The Safety Board determined that inadequate support under the plastic fitting resulted in long-term stress intensification that led to the formation of a circumferential crack in the fitting. Available documentation indicates that the crack was brittle-like.

A December 1981 natural gas explosion and fire in Arizona destroyed an apartment, damaged five other apartments in the same building, damaged nearby buildings, and injured three occupants.[14] The Safety Board's

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Association, Gas Research Institute, Battelle Columbus Laboratories, 1993.

[8]Stress intensification occurs when stress is higher in one area of a pipe than in those areas adjacent to it. Stress intensification can be generated by external forces or a change in the geometry of the pipe (such as at a connection to a fitting).

[9]National Transportation Safety Board Pipeline Accident Report--*Lone Star Gas Company, Fort Worth, Texas, October 4, 1971* (NTSB/PAR-72/5).

[10]National Transportation Safety Board Pipeline Accident Report--*Washington Gas Light Company, Bowie, Maryland, June 23, 1973* (NTSB/PAR-74/5).

[11]National Transportation Safety Board Pipeline Accident Brief--"Natural Gas Corporation, Kinston, North Carolina, September 29, 1975."

[12]National Transportation Safety Board Pipeline Accident Brief--"Arizona Public Service Company, Phoenix, Arizona, June 30, 1978."

[13]National Transportation Safety Board Pipeline Accident Brief--"Northwestern Public Service, Grand Island, Nebraska, August 28, 1978."

[14]National Transportation Safety Board Pipeline Accident Brief--"Southwest Gas Corporation, Tucson, Arizona, December 3, 1981."

investigation determined that assorted debris, rocks, and chunks of concrete in the excavation backfill generated stress intensification that resulted in a circumferential crack in a plastic pipe at a connection to a plastic fitting. Available documentation indicates that the crack was brittle-like.

A July 1982 natural gas explosion and fire in California destroyed a store and two residences, severely damaged nearby commercial and residential structures, and damaged automobiles.[15] The Safety Board's investigation identified a longitudinal crack in a plastic pipe as the source of the gas leak that led to the explosion. Available documentation indicates that the crack was brittle-like.

A September 1983 natural gas explosion in Minnesota involved the same brand of plastic piping as that involved in the Waterloo and Nebraska accidents.[16] The explosion destroyed one house and damaged several others, and injured five persons. The Safety Board's investigation determined that rock impingement generated stress intensification that resulted in a crack in a plastic pipe. Available documentation indicates that the crack was brittle-like.

One woman was killed and her 9-month-old daughter injured in a December 1983 natural gas explosion and fire in Texas.[17] The Safety Board's investigation determined that the source of the gas leak was a brittle-like crack that had resulted from damage to the plastic pipe during an earlier squeezing operation to control gas flow.[18]

A September 1984 natural gas explosion in Arizona resulted in five fatalities, seven injuries, and two destroyed apartments.[19] The Safety Board's investigation determined that a reaction between a segment of plastic pipe and some liquid trapped in the pipe weakened the pipe and led to a brittle-like crack.

During the course of the investigation of the accident at Waterloo, Iowa, the Safety Board learned of several other accidents, not investigated by the Safety Board, that involved cracks in the same brand of plastic piping as that involved in the Waterloo accident. Three of these accidents, which occurred in Illinois (1978 and 1979) and in Iowa (1983), resulted in five injuries and damage to buildings.[20] A 1995 accident in Michigan also involved a crack in this same brand of pipe.[21] Available documentation indicates that the cracks were brittle-like.

Strength Ratings, Ductility, and Material Standards for Plastic Piping

During the 1950s and early 1960s, when plastic piping was beginning to gain acceptance as an alternative to steel piping for the transport of water and gas, no established procedures existed for rating the strength of materials intended for use in plastic pressure piping.

In November 1958, the Thermoplastic Pipe Division of the Society of the Plastics Industry organized a group called the Working Stress Subcommittee.[22] The subcommittee, in January 1963, issued a procedure (hereinafter referred to as the PPI procedure) that specified a uniform protocol for rating the strength of materials used

[15]National Transportation Safety Board Pipeline Accident Brief--"Pacific Gas and Electric Company, San Andreas, California, July 8, 1982."

[16]National Transportation Safety Board Pipeline Accident Brief--"Northern States Power Company, Newport, Minnesota, September 19, 1983."

[17]National Transportation Safety Board Pipeline Accident Brief--"Lone Star Gas Company, Terell, Texas, December 9, 1983."

[18]Plastic pipe is sometimes squeezed to control the flow of gas. In some cases, squeezing plastic pipe can damage it and make it more susceptible to brittle-like cracking.

[19]National Transportation Safety Board Pipeline Accident Report--*Arizona Public Service Company Natural Gas Explosion and Fire, Phoenix, Arizona, September 25, 1984* (NTSB/PAR-85/01).

[20]Illinois Commerce Commission accident reports dated September 14, 1978, and December 4, 1979. Iowa State Commerce Commission accident report dated August 29, 1983.

[21]Research and Special Programs Administration Incident Report—"Gas Distribution System," Report No. 318063, January 8, 1996.

[22]This subcommittee was subsequently made into a permanent unit and was renamed the Hydrostatic Stress Board.

in the manufacture of thermoplastic pipe in the United States. In March 1963, the Thermoplastic Pipe Division adopted its current name, the Plastics Pipe Institute (PPI).

On July 1, 1963, the PPI established a voluntary program of listing the material strengths of plastic piping materials, specifically, those materials designed for water applications. To apply for a PPI listing, applicants sent strength test data to the PPI, often accompanied by the manufacturer's analysis of the data and a proposed material strength rating. The PPI would analyze the data and, if warranted, list the material for the calculated strength. The PPI did not certify or approve the material received or validate the data submitted, nor did it audit or inspect those submitting data.[23]

In simplified terms, the PPI procedure, which is performed by the materials manufacturers themselves, involves recording how much time it takes stressed pipe samples to rupture at a standardized temperature of 73 °F. The stresses used in the tests are recorded as "hoop stress," which is tensile stress in the wall of the pipe in a circumferential orientation (hence the term "hoop") due to internal pressure. Although hoop stress is expressed in pounds per square inch, it is a value quite different from the pipe's internal pressure.

The testing process involves subjecting pipe samples to various hoop stress levels, and then recording the time to rupture. For some samples at some pressures, rupture will occur in as little as 10 hours. As hoop stress is reduced, the time-to-failure increases. At some hoop stress level, at least one of the tested specimens will not rupture until at least 10,000 hours (slightly more than 1 year). After the rupture data points (hoop stresses and times-to-failure) for this material have been recorded, the data points are plotted on log-log coordinates as the relationship between hoop stress and time-to-failure. (See figure 3.) A mathematically developed "best-fit" straight line is correlated with the data points to represent the material's resistance to rupturing at various hoop stress levels.

Once the best-fit straight line is calculated to 10,000 hours, it is extrapolated to 100,000 hours (about 11 years). The hoop stress level that coincides with the point at which the line intersects the 100,000-hour time line represents the calculated long-term hydrostatic strength of that particular material.

To simplify the ratings and facilitate standardization, the PPI procedure grouped materials with similar long-term hydrostatic strength ranges into "hydrostatic design basis" categories. For example, those materials having long-term hydrostatic strengths between 1200 and 1520 psi were grouped together and assigned a hydrostatic design basis of 1250 psi. Those materials having long-term hydrostatic strengths between 1530 and 1910 psi were grouped together and assigned a hydrostatic design basis of 1600 psi.

To help ensure the validity of the mathematically derived line, the PPI procedure required the submission of all rupture data points. It further specified the minimum number of data points and minimum number of tested lots. The procedure employed statistical tests to verify the quality of data and quality of fit to the mathematically derived line. These measures excluded materials when the data demonstrated excessive data scatter due to either inadequate quality of data or deviation from straight line behavior through 10,000 hours.[24]

The PPI procedure, after some refinement, was issued as an ASTM method in 1969 (ASTM D2837). The PPI adopted a policy document[25] for PPI's listing service in 1968, which remained under PPI jurisdiction.

[23]As a result of Safety Board inquiries to the PPI about its inability to verify the actual data submitted, the institute, in 1997, revised its policy document for its listing service to require a signed statement from applicants that data accompanying applications for a PPI listing are complete, accurate, and reliable.

[24]The PPI procedure also had restrictions on the degree of slope of the straight line so that the material's strength would not excessively diminish beyond 100,000 hours.

[25]Plastics Pipe Institute, *Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermostatic Pipe*, PPI-TR3-July 1968.

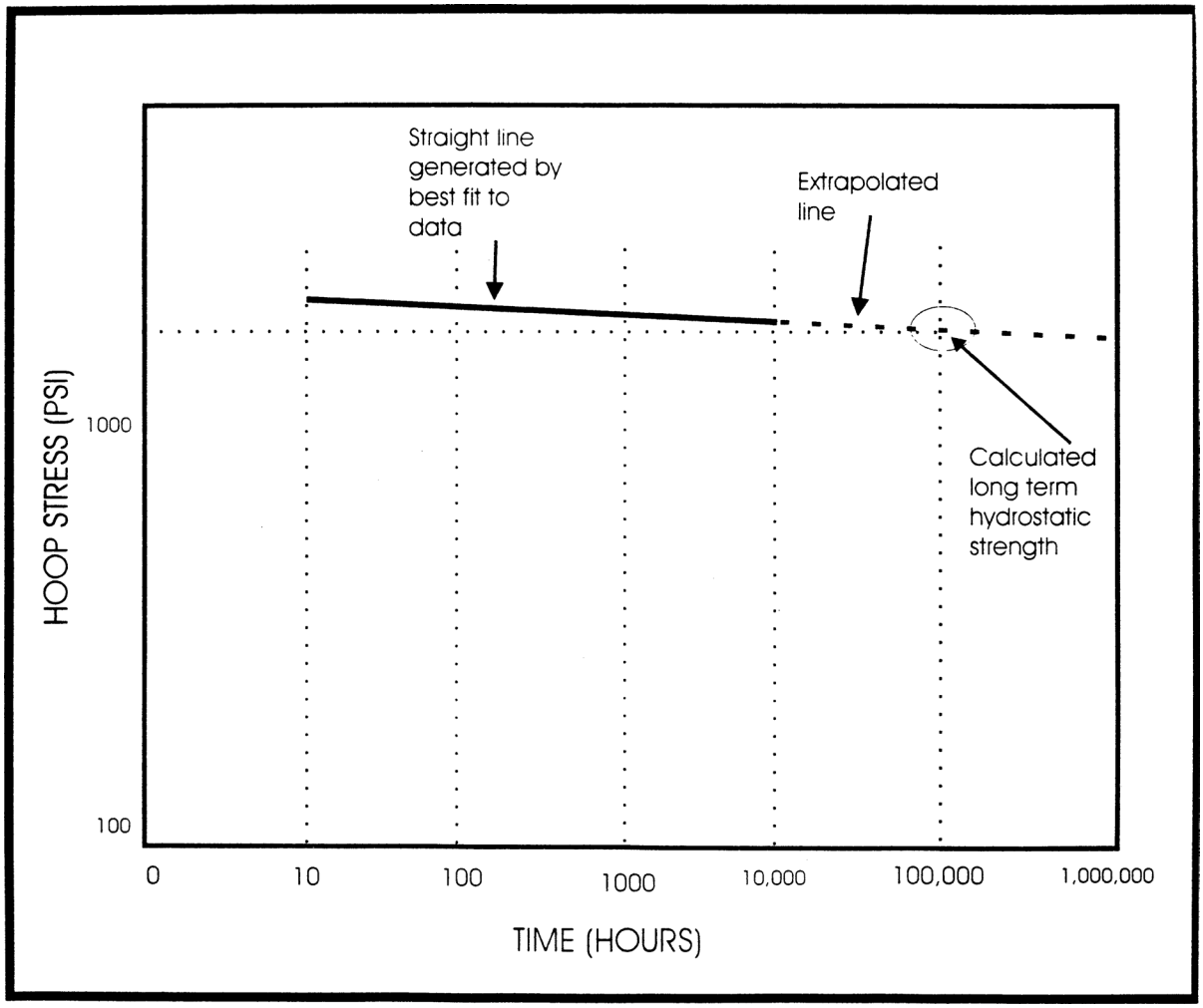

Figure 3 -- Stress rupture data plotted as best-fit straight line and extrapolated to determine long-term hydrostatic strength. (Derived from *A.G.A. Plastic Pipe Manual for Gas Service.)*

When polyethylene pipe fails during laboratory stress rupture testing at 73 °F, it fails primarily by means of ductile fractures, which are characterized by substantial visible deformation (see figure 4). During stress rupture tests, if hoop stress on the test piping is decreased, the time-to-failure increases, and the amount of deformation apparent in the failure decreases.[26] In pipe subjected to prolonged stress rupture testing, slit fractures[27] may begin to appear at some point (depending on the specific polyethylene resin material). Figure 5 shows a slit fracture that resulted from a stress rupture test. The PPI procedure did not differentiate between ductile and slit failure types, and, based on most available laboratory test data (at 73 °F),[28] assumed that both types of

[26]Mruk, S. A., "The Ductile Failure of Polyethylene Pipe," *SPE Journal*, Vol. 19, No. 1, January 1963.

[27]Because of the frequent lack of visible deformation associated with them, slit fractures are also referred to as brittle-like fractures.

[28]Kulhman, H. W., Wolter, F., Sowell, S., Smith, R. B., *Second Summary Report, The Development of Improved Plastic Pipe for Gas Service, Prepared for the American Gas Association*, Battelle Memorial Institute, covering the work from mid-1968 through 1969. Stress rupture tests were performed using methane and nitrogen as the internal pressure medium and air as the outside environment. Some experts have advised the Safety Board that stress rupture testing showing time-to-failure in the slit mode may vary with different pressure media and

Figure 4 -- Ductile fracture resulting from stress rupture test. Note substantial deformation (ballooning) at the failure.

failures would be described by the same extrapolated (straight) line.

In 1963-64, the National Sanitation Foundation[29] amended its standard for plastic piping used for potable water service to require that manufacturers furnish evidence of having an appropriate strength rating in accordance with the PPI procedure. Manufacturers then decided to utilize the PPI listing service, having determined that this was the most convenient way to furnish the required evidence.

In 1966, the ASTM issued ASTM D2513, the society's first standard specification covering polyethylene plastic piping for gas service.[30] ASTM D2513 made reference to long-term hydrostatic strength and hydrostatic design stress and included an appendix defining these terms in accordance with the PPI procedure.[31] It also required that polyethylene pipe meet certain requirements of ASTM D2239 (a polyethylene pipe specification for water service), which also included references to the PPI procedure. ASTM D2513 did not explicitly require materials to have a PPI listing.

environments and that Battelle Memorial Institute's choices for these fluids may have contributed to the slow recognition in the United States of a downturn in the stress rupture line.

[29]Now known as NSF International.

[30]This standard also included plastic piping materials other than polyethylene.

[31]Although adherence to ASTM appendixes is not mandatory, the PPI procedure was the only industry-accepted mechanism to determine long-term hydrostatic strength and hydrostatic design stress.

Figure 5 -- Slit fracture resulting from a stress rupture test conducted at 100 °F. Note lack of deformation visible in the fracture. This pipe was manufactured by DuPont in 1977. After failing Minnegasco's incoming inspection tests, the pipe was subjected to stress rupture testing. (*Source:* Henrich, R.C., and Funck, D.L., "Effects of ESCR Variation on Some Other Properties of Plastic Pipe." *Proceedings, Eighth Annual Plastic Fuel Gas Pipe Symposium, 1983.)*

Even without an explicit requirement, some manufacturers voluntarily obtained PPI listings for their resin materials[32] intended for gas use, and some others,[33] as noted above, obtained PPI listings for their resins that were intended for water use (but were similar to their resins intended for gas service) as a way of meeting National Sanitation Foundation requirements.

In 1967, the United States of America Standards Institute B31.8 code,[34] *Gas Transmission and Distribution Piping Systems*, for the first time recognized the suitability of plastic piping for gas distribution service and included requirements for the pipings' use. The 1966 issuance of ASTM D2513 and the 1967 inclusion of plastic piping within B31.8 cleared the way for the general use of plastic piping for gas distribution.[35] B31.8 included a design equation (see discussion below), and although the code, like the ASTM standard, did not explicitly require a PPI listing, it did require that material used to manufacture plastic pipe establish its long-term hydrostatic strength in accordance with the PPI procedure.

[32]Resins are polymer materials used for the manufacture of plastics.

[33]For example, E. I. du Pont de Nemours & Company, Inc., and Union Carbide Corporation.

[34]Now known as ASME B31.8.

[35]*A.G.A. Plastic Pipe Handbook for Gas Service*, American Gas Association, Catalog No. X50967, April 1971.

On August 12, 1968, the Natural Gas Pipeline Safety Act was enacted, requiring the DOT to adopt minimum Federal regulations for gas pipelines. In December 1968, the DOT instituted interim Federal regulations by federalizing the State pipeline safety regulations that were in place at the time. The DOT, having concluded that the majority of the States required compliance with the 1968 version of B31.8, adopted that version of the code for the Federal regulations covering those States not yet having their own natural gas pipeline safety regulations.

Most of these Federal interim standards were replaced in November 1970 by 49 *Code of Federal Regulations* (CFR) 192; however, the interim provisions concerning the design, installation, construction, initial inspection, and initial testing of new pipelines remained in effect until March 1971. At that time, 49 CFR 192 incorporated the design equation for plastic pipe from B31.8 and also required that plastic piping conform to ASTM D2513.[36]

The 1967 version of B31.8 introduced fixed design factors[37] (subsequently incorporated into 49 CFR 192) as a catch-all mechanism to account for various influences on pipe performance and durability. These influences included external loadings, limitations of and imprecision in the PPI procedure, variations in pipe manufacturing, handling and storage effects, temperature fluctuations, and harsh environments.[38] A design equation was used to determine the allowable gas service pipe pressure rating based on the hydrostatic design basis category, pipe dimensions, and design factor.[39] The design basis for plastic pipe thus used internal pressures as a design criterion but did not directly take into account additional stresses that could be generated by external loadings, despite the fact that field failures in plastic piping systems were frequently associated with external loads but were rarely attributable to internal pressure effects alone.[40]

Kulmann and Mruk have reported that no direct basis was established to design for external loads because:

- The industry had no easy means of quantifying external loads and their effects on plastic piping systems;[41] and

- Many in the industry believed that plastic piping, like steel and copper piping, behaved as a ductile material that would withstand considerable deformation before undergoing damage, thus alleviating and redistributing local stress concentrations that would crack brittle materials such as cast iron. This belief resulted from short-term laboratory tests showing that plastic piping had enormous capacity to deform before rupturing.[42]

Because of plastic piping's expected ductile behavior, many manufacturers believed it safe to base their designs on average distributed stress concentrations generated primarily by internal pressure and, within reason, to neglect localized stress concentrations. They believed such stress would be reduced by localized yielding, or deformation. Mruk and Palermo have pointed out that design protocols were predicated on the assumption of such ductile behavior.[43]

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[36]RSPA reviews revised editions of ASTM D2513 for acceptability before referencing them in 49 CFR 192.

[37]A design factor is similar to a safety factor, except that a design factor attempts to account for other factors not directly included within the design equation that significantly affect the durability of the pipe.

[38]Reinhart, F. W., "Whence Cometh the 2.0 Design Factor," Plastics Pipe Institute, undated, and Mruk, S. A., "Validating the Hydrostatic Design Basis of PE Piping Materials."

[39]The design equation (with the current design factor, 0.32) can be found in 49 CFR 192.121, although 192.121 erroneously references the long-term hydrostatic strength instead of the hydrostatic design basis category. RSPA is currently conducting rulemaking activities to correct this error.

[40]Kulmann, H. W., Wolter, F., Sowell, S., "Investigation of Joint Performance of Plastic Pipe for Gas Service," *1970 Operating Section Proceedings*, American Gas Association, pp. D-191 to D-198.

[41]Kulmann, Wolter, and Sowell.

[42]Mruk, S. A., "Validating the Hydrostatic Design Basis of PE Piping Materials."

[43]Mruk, S. and Palermo, E., "The Notched Constant

Figure 6 -- Slit fracture on a polyethylene pipe manufactured by DuPont that was found leaking and removed from a gas piping system.

In contrast, cast iron piping has recognized brittle characteristics. The design basis for cast iron therefore does not assume that localized yielding or deformation will reduce stress intensification. As a result, the design protocol for cast iron includes the quantification and direct input of external loading factors that can generate localized stress intensification.[44]

Failures in polyethylene piping that occur under actual service conditions are frequently slit failures; ductile failures are rare.[45] Figure 6 shows a slit (brittle-like) fracture in a pipe that was found leaking and had to be replaced. A rock pressing against the plastic pipe generated long-term stress intensification that led to the formation of the brittle-like crack. Slit failures in polyethylene, whether occurring during stress rupture testing or under actual service conditions, result from crack initiation and slow crack growth and are similar to brittle cracks in other materials in that they can occur with little or no visible deformation.[46]

Tensile Load Test: A New Index of the Long Term Ductility of Polyethylene Piping Materials," summary of presentation given in the Technical Information Session hosted by ASTM Committee F17's task group on Project 62-95-02, held in conjunction with ASTM Committee F17's November 1996 meetings, New Orleans, LA.

[44]Mruk and Palermo and Hunt, W. J., "The Design of Grey and Ductile Cast Iron Pipe," *Cast Iron Pipe News*, March/April 1970.

[45]Mruk, S. A., "Validating the Hydrostatic Design Basis of PE Piping Materials," and Bragaw, C. G., "Fracture Modes in Medium-Density Polyethylene Gas Piping Systems," *Plastics and Rubber: Materials and Applications*, pp. 145-148, November 1979.

[46]Mruk and Palermo have quantified and discussed the deformation in brittle-like failures in: Mruk, S. and Palermo, E., "The Notched Constant Tensile Load Test: A New Index of the Long Term Ductility of Polyethylene

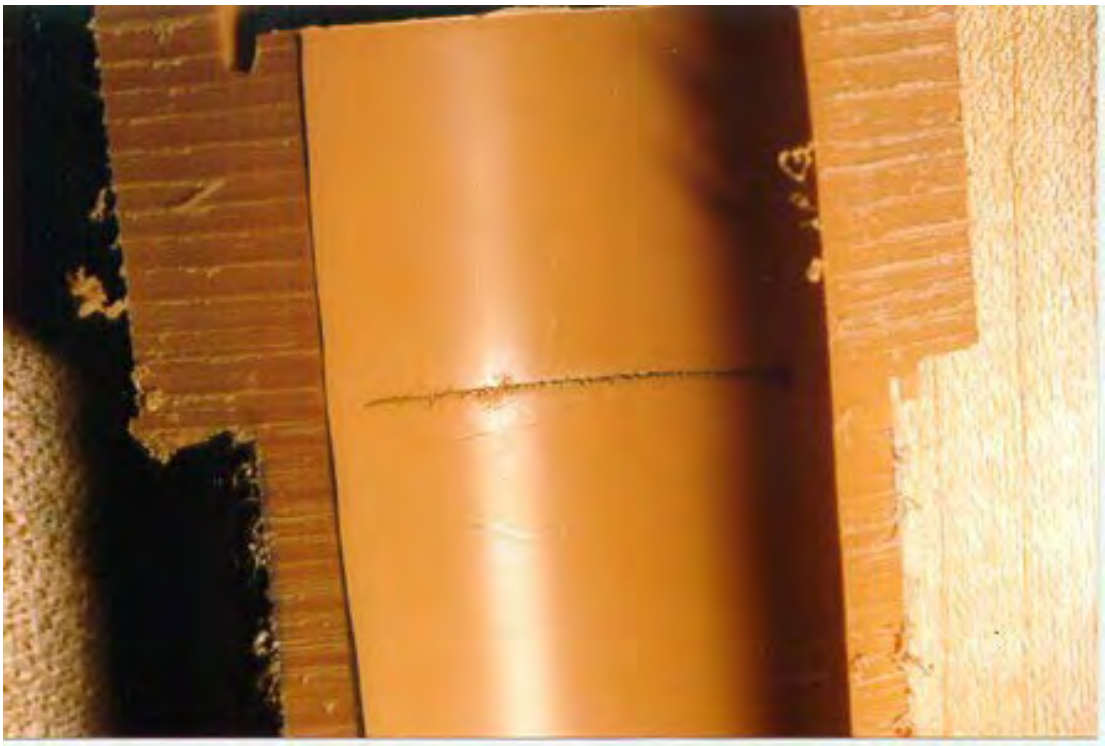

Figure 7 -- Interior of polyethylene pipe from San Juan pipeline accident showing brittle-like crack with no visible deformation.

Figure 7 illustrates brittle-like cracking that was found in a plastic pipe involved in the fatal propane gas explosion in San Juan, Puerto Rico, in November 1996. That pipe was manufactured in 1982 by E. I. du Pont de Nemours & Company, Inc., (DuPont) at its Pencador, Delaware, plant. Apparently, differential settlement resulting from inadequate support under the piping generated long-term stress intensification that led to the formation of brittle-like cracks in the pipe.

Figure 8 shows a brittle-like crack that was found in a plastic pipe involved in the fatal natural gas explosion and fire in Lake Dallas, Texas, in August 1997. That pipe was manufactured in 1970 by Nipak, Inc. A metal pipeline pressing against the plastic pipe generated long-term stress intensification that led to the crack.

During the 1960s and 1970s, some experts began to question the validity of the PPI procedure's assumption of a continuing, gradual straight-line decline in strength (figure 3). [47] By the late 1970s and early 1980s, the plastic piping industry in the United States realized that

Piping Materials," summary of presentation given in the Technical Information Session hosted by ASTM Committee F17's task group on Project 62-95-02, held in conjunction with ASTM Committee F17's November 1996 meetings, New Orleans, LA, and Mruk, S. A., "Validating the Hydrostatic Design Basis of PE Piping Materials," pp. 202-214, 1985.

[47]The 1971 *A.G.A. Plastic Handbook for Gas Service* noted that the cause and mechanisms of brittle fractures sometimes found with long-term stress rupture testing was not yet well established. Two of the pioneering papers in the United States to suggest a downturn in long-term hydrostatic strength with brittle-like failures or in elevated temperature testing were: Mruk, S. A., "The Ductile Failure of Polyethylene Pipe," *SPE Journal*, Vol. 19, No. 1, January 1963, and Davis, G. W., "What are Long Term Criteria for Evaluating Plastic Gas Pipe?" *Proceedings Third A.G.A. Plastic Pipe Symposium*, American Gas Association, pp. 28-35, 1971.

Figure 8 -- Brittle-like crack in pipe involved in August 1997 accident in Lake Dallas, Texas. The crack extends from the left to upper right of the area defined by the ellipse.

testing piping materials at elevated temperatures was a way to accelerate failure behavior that would occur much later at lower temperatures (such as 73 °F). Based on data derived from elevated-temperature testing, the industry concluded that the gradual straight-line decline in strength assumed by the PPI procedure was not valid. Instead, two distinct failure zones were indicated for polyethylene piping in stress rupture testing. (See figure 9.) The first zone is characterized by the gradual straight-line decline in strength accompanied primarily by ductile fractures. The first zone gradually transitions to the second zone, which is characterized by a more rapid decline in strength accompanied by brittle-like fractures only. The time and magnitude of this more rapid decline in strength varies by type and brand of polyethylene. Piping manufacturers have worked to improve their products' resistance to slit-type failures and thus to push this downturn further out in time. The PPI procedure did not account for this downturn, and the difference between the actual falloff shown in figure 9 and the projected straight-line strengths shown in figure 3 for listed materials became more pronounced as the lines were extrapolated beyond 100,000 hours.

As manufacturers steadily improved their formulations to delay the onset of the downturn in long-term strength and associated brittle-like behavior, PPI and ASTM industry standards were upgraded to reflect what the major manufacturers were able and willing to accomplish.[48] Accordingly, and because a consensus of manufacturers recognized the relationship between

[48]Both the PPI and the ASTM work on a consensus principle, meaning that requirements are put into place only when a consensus of voting members is reached. The PPI is a manufacturers' organization. With respect to the ASTM technical committee that generates requirements for plastic piping, the major piping manufacturers participate actively in the committee and are in a position to influence ASTM strength rating requirements.

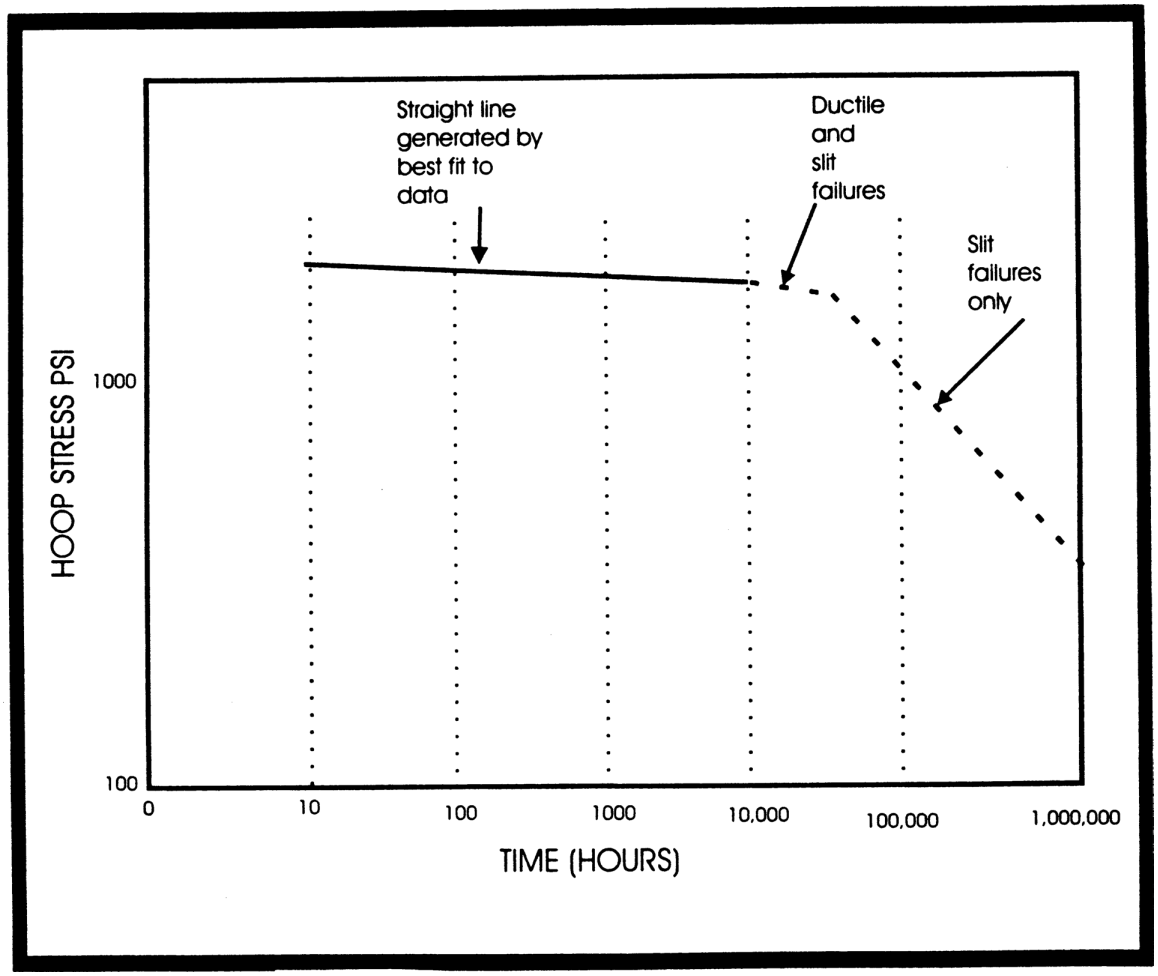

Figure 9 -- Stress rupture data plotted as best-fit straight line transitioning to downturn in strength. (Derived from *A.G.A. Plastic Pipe Manual for Gas Service*.)

improved elevated-temperature properties and improved longer term pipe performance, the PPI in 1982 recommended that ASTM D2513 specify a minimum acceptable hydrostatic strength at 140 °F. In 1984, ASTM D2513 included a statement in its non-mandatory appendix that gas pipe materials should have a specified long-term hydrostatic strength at 140 °F. In the 1988 edition, this requirement was moved to the mandatory section of the standard. This strength at 140 °F was calculated the same way that the 73 °F strength was calculated—data demonstrating a straight line to 10,000 hours was assumed to extrapolate to 100,000 hours without a downturn.

Gradually, more manufacturers obtained PPI listings for their resins intended for gas service, and by the early to mid-1980s, virtually all resins used for gas service had PPI listings. At that time, a consensus of manufacturers supported a change within ASTM D2513 to require PPI listings. In 1985, ASTM D2513 was revised to require that materials for gas service have a PPI listing.

By 1985, manufacturers reached a consensus to exclude materials that deviated from the 73 °F extrapolation before 100,000 hours. The PPI adopted this restriction and advised the industry that, effective January 1986, all materials not demonstrating straight-line performance to 100,000 hours would be dropped

from its listing.[49] In 1988, ASTM D2837 also included the restriction.[50] The new PPI and ASTM requirements had no effect on pipe installed prior to the effective date of the requirements.

On August 20, 1997, after manufacturers reached a consensus, the PPI issued notice that, effective January 1999, in order for materials to retain their PPI listings for long-term hydrostatic strength at temperatures above 73 °F (for example, at 140 °F), these materials will have to demonstrate (mathematically, via elevated-temperature testing) that a downturn does not exist prior to 100,000 hours or, alternatively, if a downturn does exist before 100,000 hours, the strength rating will be reduced to reflect the point at which the calculated downturn in strength intercepts 100,000 hours. An ASTM project has been initiated to incorporate this requirement within ASTM D2837. The Safety Board also notes that the PPI has endorsed a proposal to have ASTM D2513 require polyethylene piping to have no downturn in stress rupture testing at 73 °F before 50 years, as mathematically determined in elevated-temperature tests.

All available evidence indicates that polyethylene piping's resistance to brittle-like cracking has improved significantly through the years. Several experts in gas distribution plastic piping have told the Safety Board that a majority of the polyethylene piping manufactured in the 1960s and early 1970s had poor resistance to brittle-like cracking, while only a minority of that manufactured by the early 1980s could be so characterized.[51] Several gas system operators have told the Safety Board that they are aware of no instances of brittle-like cracking with their own modern polyethylene piping installations.

Century Pipe Evaluation and History

The Safety Board's investigation of the Waterloo, Iowa, accident determined that the pipe involved in the accident had been manufactured by Amdevco Products Corporation (Amdevco) in Mankato, Minnesota. Amdevco's Mankato plant first began producing plastic pipe in 1970, with plastic piping for gas service as its only piping product. Amdevco made the pipe from Union Carbide's Bakelite DHDA 2077 Tan 3955 (hereinafter referred to as DHDA 2077 Tan) resin material. Century Utility Products, Inc., marketed the pipe to Iowa Public Service Company,[52] and Century's name was marked on the pipe. Century and Amdevco formally merged in 1973. The combined corporation went out of business in 1979.

Because Amdevco/Century no longer exists, Safety Board investigators could locate no records to indicate the qualification steps Amdevco may have performed before Century marketed its pipe to Iowa Public Service Company. A plastic pipe manufacturer would normally have obtained documentation from its resin supplier indicating that the resin material had a sufficient long-term hydrostatic strength. Code B31.8 required and ASTM D2513 recommended that polyethylene pipe manufacturers perform certain quality control tests on production samples, including twice-per-year sustained pressure tests.

Like many gas operators of that time, Iowa Public Service Company (now MidAmerican Energy Corporation), which had installed the Waterloo piping in 1971, had no formal program for testing or evaluating products. According to MidAmerican Energy, the company accepted representations from a principal of Century, a former DuPont employee, who portrayed himself as being intimately involved with the development and marketing of DuPont's polyethylene piping. MidAmerican Energy has reported that these representations included assertions that Century

[49]Mruk, S. A., "Validating the Hydrostatic Design Basis of PE Piping Materials."

[50]*A.G.A. Plastic Pipe Manual for Gas Service*, American Gas Association, Catalog No. XR 9401, 1994.

[51]A number of these experts considered material to have poor resistance to brittle-like cracking if the material was shown to have a downturn in strength associated with brittle-like fractures in stress rupture testing (at 73 °F) before 100,000 hours.

[52]Because of a series of organizational changes and mergers, the name of the owner/operator of the gas system at Waterloo, Iowa, has changed over the years. In 1971, Iowa Public Service Company installed the gas service that ultimately failed. At the time of the accident, the gas system operator was Midwest Gas Company. The current operator is MidAmerican Energy Corporation.

plastic pipe met industry standards and had the same formulation as DuPont's plastic pipe. In 1970, according to MidAmerican Energy officials, Century offered Iowa Public Service Company attractive commercial terms for its product, with the result that, in 1970, when Amdevco first started to manufacture pipe, Iowa Public Service Company began purchasing all of its plastic pipe from Century.[53]

Before the Waterloo accident, a previous accident involving Century pipe had been reported in the Midwest Gas (the operator at the time of the accident) system. That accident occurred in August 1983 in Hudson, Iowa, and resulted in multiple injuries. Midwest Gas, attributing this accident to a rock pressing into the pipe, considered it an isolated incident. During 1992-94, the company had two significant failures with pipe fittings involving brittle-like cracks in Century pipe. Sections of the failed pipe were sent to the two affected pipe fitting manufacturers, and one responded that nothing was wrong with the fitting, suggesting instead that the problem might rest with the piping material.

MidAmerican Energy reported that, as a result of these two failures, Midwest Gas directed inquiries to other utilities operating in the Midwest and, in May 1994, learned of one other accident involving Century pipe. In June 1994, Midwest Gas decided to send samples of Century polyethylene piping to an independent laboratory for test and evaluation. The sample collection was in process at the time of the Waterloo accident. In August 1995, Midwest Gas issued a report, based on the laboratory testing, concluding that the Century samples had poor resistance to slow crack growth.

Subsequent to the accident, Midwest Gas worked to determine if its installations with Century plastic piping had had higher rates of failure than those with piping from other manufacturers. After analyzing the data, Midwest Gas concluded that the piping installations with Century piping had failure rates that were significantly higher than those installations with plastic piping from other manufacturers. Based on this analysis, as well as on other factors—including the severity and consequences of leaks involving Century piping, the laboratory test results, recommendations from two manufacturers of pipe fittings cautioning against use of their fittings with Century pipe because of the pipe's poor resistance to brittle-like cracking, and interviews with field personnel—MidAmerican Energy (the current operator) has replaced all its known Century piping with new piping, completing the replacement program in 1997.

Safety Board investigators found little additional documentation regarding qualification tests of Century plastic pipe by other gas system operators having Century pipe in service. A reference was found to a 1971 Northern States Power Company Testing Department progress report stating that Century pipe complied with ASTM D2513, and that the pipe was acceptable for use with DuPont polyethylene fittings. The actual progress report and records of any tests that may have been performed were not located.[54]

Union Carbide DHDA 2077 Tan Resin -- The resin used to manufacture the pipe involved in the Waterloo accident was DHDA 2077 Tan. To examine how Union Carbide qualified this material requires some background.

During the late 1960s, several companies manufactured plastic resin and plastic pipe for the gas distribution plastic piping market. At that time, Union Carbide began a process of modifying its DHDA 2077 Black resin (for water distribution) in order to create a DHDA 2077 Tan resin for the gas distribution industry.

Before Union Carbide could market its DHDA 2077 Tan resin material for natural gas service, it needed to generate stress rupture data, in accordance with the PPI procedure, that would support the long-term hydrostatic

[53]Iowa Public Service Company continued to purchase DuPont plastic piping fittings until fittings were available from Century. MidAmerican Energy made technical procurement decisions via a Gas Standards Committee. According to company officials, the company has implemented a process to ensure that it continues to receive quality products once the products have passed an initial qualification process.

[54]Northern States Power is based in St. Paul, Minnesota.

strength rating it was assigning to the material (a requirement of the interim Federal regulations effective at that time).[55] The company had three resources to draw upon to support the hydrostatic design basis category: (1) internal stress rupture data on its DHDA 2077 Tan resin, (2) a PPI listing already obtained on its similar black resin, and (3) additional internal stress rupture data on its black resin.

On June 11, 1968, Union Carbide began stress rupture testing on specimens of pipe made from a pilot-plant batch of its newly developed DHDA 2077 Tan resin. The results of this testing supported Union Carbide's declared hydrostatic design basis category for DHDA 2077 Tan. The number of data points generated by these stress rupture tests for the DHDA 2077 Tan was less than that required by PPI procedure; however, Union Carbide began to market the product for use in gas systems based on these tests and on additional testing performed on the company's black resin material.

Because Union Carbide had not developed the PPI-prescribed number of data points on its DHDA 2077 Tan resin before marketing the product, Safety Board investigators reviewed the data the company developed on its black resin. A review of Union Carbide's laboratory notebooks revealed that a number of adverse data points Union Carbide developed for its black resin were not submitted to the PPI when the company applied for a PPI listing for the black material.[56]

Union Carbide first made a commercial version of its DHDA 2077 Tan resin during the spring of 1969, and in April 1970, a first shipment of 80,000 pounds of DHDA 2077 Tan resin was shipped to Amdevco's Mankato plant. The next shipment of the material to Amdevco was not until 1971. Based on Amdevco's June 11, 1970, manufacturing date for the Waterloo pipe, Union Carbide manufactured, sold, and delivered the resin used to make the Waterloo pipe between the spring of 1969 and June 11, 1970, and the resin used to make the pipe involved in the Waterloo accident probably was included in the April 1970 shipment.

Union Carbide began, on December 3, 1970, additional stress rupture tests on its commercial DHDA 2077 Tan resin. These tests generated the results to further support its claimed long-term hydrostatic strength and also provided the number of data points required by the PPI procedure. Additional stress rupture tests on the commercial DHDA 2077 Tan resin beginning on December 28, 1970, and again on January 6, 1972, further supported the material's long-term hydrostatic strength.

During the late 1960s and 1970s, Minnegasco, a gas system operator based in Minneapolis, Minnesota, routinely employed a 1,000-hour sustained pressure test at 100 °F detailed in ASTM D2239 and a 1,000-hour sustained pressure test at 73 °F detailed in ASTM D2513 to qualify plastic piping for use in its system. Minnegasco went beyond the requirements of ASTM standards by continuing both versions of the testing beyond 1,000 hours until eventual failure occurred. The company used this information to evaluate the relative strengths of different brands of piping.

In 1969-70, Minnegasco began a series of tests on samples from five different suppliers of plastic piping made from DHDA 2077 Tan resin. On March 3, 1972, Minnegasco's laboratory issued an internal report that contained the results of its latest tests on piping made from the resin and referenced earlier tests on several brands of piping (including Amdevco/Century) that were also made from it. Based on this report, Minnegasco rejected for use in its gas system the DHDA 2077 Tan resin. According to the report, the company rejected the material because (1) none of the pipe samples made from this resin could consistently pass the 1,000-hour sustained pressure test at

[55]The company was required to follow the PPI procedure in developing the necessary stress rupture data, but no requirement existed for those data to be submitted to the PPI or for the PPI to assign a listing before the tested material could be marketed.

[56]Although the PPI procedure required the submission of all valid data points for statistical analysis, the Union Carbide employee who managed the data indicated that he believed he could discard data that, in his judgment, did not adequately characterize the material's performance. Union Carbide has contended that the non-submitted data may have been invalid because of experimental error, uncompleted tests, or other reasons.

100 °F, and (2) the pipe samples had lower performance in 73 °F sustained pressure tests than similar plastic piping materials already in use in the company's gas system.

In 1971, Union Carbide acknowledged to a pipe manufacturer that piping material manufactured by DuPont had a higher pressure rating at 100 °F than did its own DHDA 2077 Tan. Union Carbide laboratory notebooks examined by the Safety Board showed test results for the DHDA 2077 Tan material that generally met the 1,000-hour sustained pressure test value at both 100 °F and 73 °F, although, in the case of the 100 °F test, not by a wide margin. The notebooks also showed that the material had an early ductile-to-brittle transition point in stress rupture tests.[57]

Information Dissemination Within the Gas Industry

The OPS reports that more than 1,200 gas distribution or master meter system[58] pipeline operators submit reports to the OPS. Additionally, more than 9,000 gas distribution or master meter system pipeline operators are subject to oversight by the States.

As noted earlier, a frequent failure mechanism with polyethylene piping involves crack initiation and slow crack growth. These brittle-like fractures occur at points of stress intensification generated by external loading acting in concert with internal pressure and residual stresses.[59]

A 1985 paper[60] analyzed, for linear (straight line) behavior up to 100,000 hours, the stress rupture test performance (by elevated-temperature testing) of six polyethylene piping materials. The results were then correlated with field performance. This paper found that those materials that did not maintain linearity through 100,000 hours had what the author characterized as "known poor" or "questionable" field performance. On the other hand, those materials that maintained linearity through 100,000 hours had what the author characterized as "known good" field performance through their 20-year history logged as of 1985.

By the early to mid-1980s, the industry had developed a method to mathematically relate failure times to temperatures and stresses during stress rupture testing.[61] In the early 1990s, the industry developed "shift functions," another mathematical method to relate failure times to temperatures and stresses.[62]

One study[63] pointed out that using mathematical methods to calculate the remaining service life of pipe under the assumption that the pipe would only be exposed

[57]The data from the laboratory notebooks suggest that this material's early ductile-to-brittle transition would not have met today's standards.

[58]*Master meter system* refers to a pipeline system that distributes gas to a definable area, such as a mobile home park, a housing project, or an apartment complex, where the master meter operator purchases gas for resale to the ultimate consumer.

[59]Kanninen, M. F., O'Donoghue, P. E., Popelar, C. F., Popelar, C. H., Kenner, V. H., *Brief Guide for the Use of the Slow Crack Growth Test for Modeling and Predicting the Long-Term Performance of Polyethylene Gas Pipes*, Gas Research Institute Report 93/0105, February 1993. Because, after extrusion, the outside of the pipe cools before the inside, residual stresses are usually developed in the wall of the pipe.

[60]Mruk, S. A., "Validating the Hydrostatic Design Basis of PE Piping Materials."

[61]Bragaw, C. G., "Prediction of Service Life of Polyethylene Gas Piping System," *Proceedings Seventh Plastic Fuel Gas Pipe Symposium*, pp. 20-24, 1980, and Bragaw, C. G., "Service Rating of Polyethylene Piping Systems by the Rate Process Method," *Proceedings Eighth Plastic Fuel Gas Pipe Symposium*, pp. 40-47, 1983, and Palermo, E. F., "Rate Process Method as a Practical Approach to a Quality Control Method for Polyethylene Pipe," *Proceedings Eighth Plastic Fuel Gas Pipe Symposium*, pp. 96-101, 1983, and Mruk, S. A., "Validating the Hydrostatic Design Basis of PE Piping Materials," and Palermo, E. F., "Rate Process Method Concepts Applied to Hydrostatically Rating Polyethylene Pipe," *Proceedings Ninth Plastic Fuel Gas Pipe Symposium*, pp. 215-240, 1985.

[62]Popelar, C. H., "A Comparison of the Rate Process Method and the Bidirectional Shifting Method," *Proceedings of the Thirteenth International Plastic Fuel Gas Pipe Symposium*, pp. 151-161, and Henrich, R. C., "Shift Functions," *1992 Operating Section Proceedings*, American Gas Association.

[63]Broutman, L. J., Bartelt, L. A., Duvall, D. E., Edwards, D. B., Nylander, L. R., Stellmack-Yonan, M., *Aging of Plastic Pipe Used for Gas Distribution, Final Report*, Gas Research Institute report number GRI-88/0285, December 1988.

to stresses of internal operating pressures would result in unrealistically long service-life predictions. As noted earlier, polyethylene piping systems have failed at points of long-term stress intensification caused by external loading acting in concert with internal pressure and residual stresses; thus, to obtain a realistic prediction of useful service life, stresses from external loadings need to be acknowledged.

Over a number of years, the Gas Research Institute (GRI) sponsored research projects investigating various tests and performance characteristics of polyethylene piping materials. Among these projects was a series of research investigations directed at exploring the fracture mechanics principles behind crack initiation and slow crack growth. These investigations led to the development of slow crack growth tests. The research studies frequently identified the piping and resins studied by codes rather than by specific materials, manufacturers, or dates of manufacture.

In 1984, the GRI published a study[64] that compared and ranked several commercially extruded polyethylene piping materials produced after 1971. Again, the materials tested were identified by codes. Stress rupture tests were performed using methane and nitrogen as the internal pressure medium and air as the outside environment. Several stress rupture curves showed early transitioning from ductile to brittle failure modes.

The A.G.A.'s Plastic Materials Committee periodically updates the *A.G.A Plastic Pipe Manual for Gas Service*, which addresses a number of issues covered by this Safety Board special investigation. In 1991, the committee formed a task group to gather and then disseminate to the industry information regarding the performance of older plastic piping systems. The task group disbanded in 1994 without issuing a report.

In 1982 and 1986, DuPont formally notified its customers about brittle-like cracking concerns with the company's pre-1973 pipe. Safety Board investigators could find no record of either Century/Amdevco, Union Carbide, or any other piping or resin manufacturer formally notifying the gas industry of the susceptibility to premature brittle-like failures of their products. Nor does any mechanism exist to ensure that the OPS receives safety-related information from manufacturers.

Regarding Federal actions on this issue, the OPS has not informed the Safety Board of any substantive action it has taken to advise gas system operators of the susceptibility to premature brittle-like failures of any older polyethylene piping.[65]

Installation Standards and Practices

The discussion in this section is intended to present a "snapshot" of the regulations and some of the primary standards, practices, and guidance to prevent stress intensification at plastic service connections to steel tapping tees. The appendix to this report includes a description of the connection in the Waterloo accident, and figure 10 provides a close-up view of the failed fitting.

Federal Regulations -- The OPS establishes, in 49 CFR 192.361, minimum pipeline safety standards for the installation of gas service piping.

Paragraph 192.361(b) reads as follows:

> *Support and backfill.* Each service line must be properly supported on undisturbed or well-compacted soil….

Paragraph 192.361(d) reads:

> *Protection against piping strain and external loading.* Each service line must be installed so as to minimize anticipated piping strain and external loading.

[64]Cassady, M. J., Uralil, F. S., Lustiger, A., Hulbert, L. E., *Properties of Polyethylene Gas Piping Materials Topical Report (January 1973 - December 1983)*, GRI Report 84/0169, Gas Research Institute, Chicago, IL, 1984.

[65]The Safety Board asked the OPS for information about its actions in regard to older piping, after which, in 1997, the OPS notified State pipeline safety program managers of several issues regarding Century pipe and solicited input on their experiences with this particular piping.

Figure 10 -- Close-up view of failed plastic pipe connection to steel tapping tee from site of Waterloo, Iowa, accident. A portion of the fractured plastic service line (light-colored material) remains attached to the tee.

Subsequent to the Waterloo accident, personnel from the Iowa Department of Commerce, after discussions with OPS personnel, stated that the Waterloo installation was not in violation of the Federal regulation. They further stated that, while they agree that the installation of protective sleeves[66] at pipeline connections is prudent, a specific requirement to install protective sleeves is beyond the scope of Part 192 and is inconsistent with the regulation's performance orientation.

The Transportation Safety Institute (TSI), part of RSPA, conducts training classes for Federal and State pipeline inspectors. TSI instructors advise class participants that many of the performance-oriented regulations within Part 192 can only be found to be violated if the gas system fails in a way that demonstrates that the regulation was not followed. The TSI acknowledges the difficulty of identifying violations under paragraph 192.361(d). A TSI instructor told the Safety Board that, in the case of the failed pipe at Waterloo, an enforcement action faulting the installation would be unlikely to prevail because of the poor brittle-like crack resistance of the failed pipe and the length of time (23 years) between the installation and failure dates.

GPTC Guide for Gas Transmission and Distribution Piping Systems -- After the adoption of the Natural Gas Pipeline Safety Act in August 1968, the American Society of Mechanical Engineers, after discussions with

[66]Protective sleeves are intended to help shield the pipe at the connection point from bearing loads and shear forces and to limit the maximum pipe bending.

the Secretary of Transportation, formed the Gas Piping Standards Committee (later renamed the Gas Piping Technology Committee) to develop and publish "how-to" specifications for complying with Federal gas pipeline safety regulations. The result was the *GPTC Guide for Gas Transmission and Distribution Piping Systems* (GPTC Guide). The GPTC Guide lists the regulations by section number and provides guidance, as appropriate, for each section of the regulation.

In its investigation of the previously referenced 1971 accident in Texas, the Safety Board determined that protective sleeves were too short to fully protect a series of service connections to a main. The Safety Board noted that a protective sleeve must have the correct inner diameter and length if it is to protect the connection from excessive shear forces. As a result, and in response to a Safety Board safety recommendation,[67] the 1974 and later editions of the GPTC Guide included guidance that "a protective sleeve designed for the specific type of connection should be used to reduce stress concentrations." No guidance was included as to the importance of a protective sleeve's length, diameter, or placement.[68]

The GPTC Guide does not include recommendations to limit bending in plastic piping during the installation of service lines under 49 CFR 192.361. Although the guide references the *A.G.A. Plastic Pipe Manual for Gas Service*, and this manual does provide recommendations on bending limits, the GPTC Guide does not reference this manual in its guidance material under 49 CFR 192.361.

A.G.A. Plastic Pipe Manual for Gas Service -- The most recent edition of the *A.G.A. Plastic Pipe Manual for Gas Service*[69] identifies the connection of plastic pipe to service tees as "a critical junction" needing installation measures "to avoid the potentially high…stresses on the plastic at this point." The manual recommends proper support and the use of protective sleeves. Although the manual recommends following manufacturers' recommendations, no guidance is included on the importance of a protective sleeve's proper length, diameter, or placement. The manual includes, without elaboration, the following sentence:

> Installation of the tee outlet at angles up to 45° from the vertical or along the axis of the main as a 'side saddle' or 'swing joint' may be considered to further minimize…stresses.

The 1994 edition adds that manufacturers' recommended limits on bending at fittings may be more restrictive than for a run of piping alone.

A.G.A. Gas Engineering and Operating Practices (GEOP) Series -- The preface to the current *Distribution Book D-2* of the GEOP series states that the intent of the books is to offer broad general treatment of their subjects, and that listed references provide additional detailed information.

Figure 11 reproduces an illustration from *Book D-2*. This figure shows a steel tapping tee with a compression coupling joint connected to a plastic service. The illustration shows a protective sleeve and includes a note to extend the protective sleeve to undisturbed or compacted soil or to blocking. But the figure also shows the blocking positioned so that either the edge of the blocking or the edge of the protective sleeve might provide a fixed contact point on the plastic service pipe if the weight of backfill were to cause the pipe to bend down. Additional illustrations within this GEOP series book show this same positioning of the blocking with respect to the plastic pipe.

ASTM -- The most recent ASTM standard covering the installation of polyethylene piping was revised in 1994.[70] This standard addresses

[67]Safety Recommendation P-72-64 from National Transportation Safety Board Pipeline Accident Report-- *Lone Star Gas Company, Fort Worth, Texas, October 4, 1971.*

[68]The correct positioning of the protective sleeve has a bearing on its effective length.

[69]*A.G.A. Plastic Pipe Manual for Gas Service*, American Gas Association, Catalog No. XR 9401, 1994.

[70]ASTM D2774-94, *Standard Practice for Underground Installation of Thermoplastic Pressure Piping*, American Society for Testing and Materials, 1994.

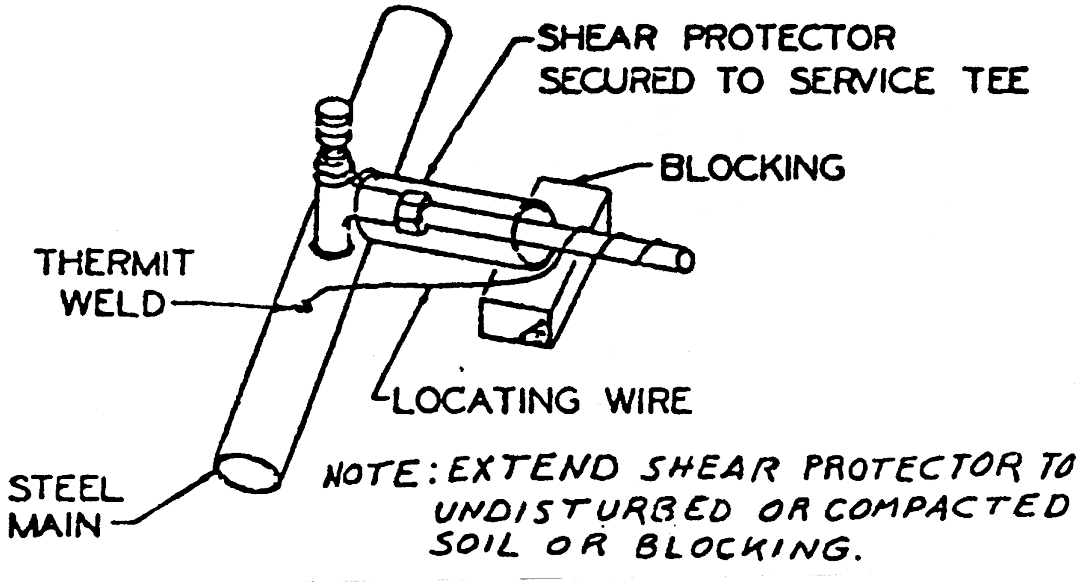

Figure 11 -- Reproduction from A.G.A. GEOP series illustrating application of protective sleeve. (Hand-scribed notation from the original.)

the vulnerability of the point-of-service connection to the main.

This standard, advising consultation with manufacturers, recommends taking extra care during bedding and backfilling to provide for firm and uniform support at the point of connection. In addition, the document recommends minimizing bends near tap connections, generally recommending that bends occur no closer than 10 pipe diameters from any fitting and that manufacturers' bend limits be followed. Similar recommendations for avoiding bends close to a fitting can be found in the forward to a water industry standard.[71]

This ASTM standard further recommends the use of a protective sleeve if needed to protect against possible differential settlement. Currently, manufacturers that provide protective sleeves have their own criteria for designing sleeve lengths and diameters for their fittings. Some manufacturers' criteria are based on limiting stress to a maximum safe value,[72] while one manufacturer has advised the Safety Board that its sleeve is not designed to limit bending, but only to guard against shear forces at the connection point.

Guidance Manual for Operators of Small Natural Gas Systems -- The OPS/RSPA *Guidance Manual for Operators of Small Natural Gas Systems* notes that plastic pipe failures have been found at transitions between plastic and metal pipes at mechanical fittings. The manual states the need to firmly compact soil under plastic pipe, advises following manufacturers' instructions for proper coupling procedures, and shows protective sleeves on connections of plastic services to steel tapping tees. The manual indicates that a properly designed protective sleeve should be used. The manual does not caution against bending the piping in proximity to a connection.

[71]Forward to American Water Works Association Standard C901-96, *AWWA Standard for Polyethylene (PE) and Tubing, ½ In. (13 mm) Through 3 In. (76 mm) for Water Service*, effective March 1, 1997.

[72]Allman, W. B., "Determination of Stresses and Structural Performance in Polyethylene Gas Pipe and Socket Fittings Due to Internal Pressure and External Soil Loads," *1975 Operating Section Proceedings*, American Gas Association, 1975.

Manufacturers' Recommendations -- As noted earlier, both the *A.G.A. Plastic Pipe Manual for Gas Service* and ASTM D2774 specifically refer the reader to manufacturers for further guidance on limiting shear and bending forces at plastic service connections made to steel mains via steel tapping tees.

Bending and Shear Forces -- Safety Board investigators contacted representatives of the four principal companies that marketed plastic piping for gas service to determine to what extent plastic piping manufacturers were providing recommendations for limiting shear and bending forces at plastic service connections to steel mains via steel tapping tees. The four manufacturers contacted were CSR PolyPipe, Phillips Driscopipe, Plexco, and Uponor Aldyl Company (Uponor).

Three out of four of these manufacturers had published recommendations addressing these issues. These three manufacturers have historically emphasized heat fusion fitting systems[73] instead of field-assembled mechanical fitting systems. Representatives of these manufacturers indicated that mechanical fittings manufacturers should provide installation instructions covering their systems. Accordingly, one of the manufacturers' published literature referred the reader to the manufacturers of mechanical fittings for installation instructions. Nonetheless, these three major polyethylene pipe manufacturers did, in fact, provide recommendations to limit shear and bending forces, and these recommendations can apply to plastic service connections to steel mains via steel tapping tees.

With respect to the specific issue of limiting bends, DuPont, in January 1970, issued recommendations to limit bends for polyethylene pipe. DuPont/Uponor[74] later published bend radius recommendations that differentiated between pipe segments consisting of pipe alone and those with fusion fittings. The recommendations specified much less bending for pipe segments with fusion fittings; however, DuPont/Uponor did not provide bend limits for mechanical fittings. Two of the other major manufacturers (Phillips Driscopipe and Plexco) provide bend limits and differentiate between pipe alone and pipe with fittings, without specifying the type of fittings. None of the manufacturers' literature discusses bending with or against any residual bend remaining in the pipe after it is uncoiled. (See "Pipe Residual Bending" below.)

Of these four major polyethylene gas pipe manufacturers, only CSR PolyPipe had no published recommendations for limiting shear and bending forces at plastic service connections to steel mains via steel tapping tees. Although the company does not manufacture steel tapping tees with compression ends for attachment to plastic services, it does manufacture pipe that will be attached to steel tapping tees via mechanical compression couplings. The company has been supplying polyethylene pipe to the gas industry since the 1980s[75] and is thus relatively new to that business compared to the other three major manufacturers. When CSR PolyPipe entered the market, plastic materials were vastly improved compared to earlier versions with respect to resistance to crack initiation and slow crack growth. For this reason, according to CSR PolyPipe personnel, the company saw less need to publish installation recommendations.

The Safety Board attempted to identify every U.S. steel tee manufacturer that currently manufactures steel tees with a compression end for plastic gas service connections.[76] The Safety Board identified and contacted representatives of Continental Industries (Continental), Dresser Industries, Inc. (Dresser), Inner-Tite Corp. (Inner-Tite),[77] and Mueller Company (Mueller).

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[73]Heat fusion fittings are used to make piping joints by heating the mating surfaces and pressing them together so that they become essentially one piece.

[74]Uponor purchased DuPont's plastic pipe business in 1991.

[75]CSR Hydro Conduit Company purchased PolyPipe in 1995. PolyPipe began supplying polyethylene pipe to the gas industry in the 1980s.

[76]J. B. Rombach, Inc., which manufactures M. B. Skinner Pipeline products, told the Safety Board that it no longer manufactures or markets its "Punch-It-Tee" line of steel tapping tees. Chicago Fittings Corporation told the Safety Board it no longer manufactures or markets its line of steel tapping tees. The Safety Board therefore made no further inquiry with these companies.

[77]Inner-Tite did not manufacture steel tees; it purchased them, affixed its own compression connections,

Only Continental and Inner-Tite offered protective sleeves to their customers as an option. None of these manufacturers has published installation recommendations to limit shear and bending forces on the plastic pipe that connects to their steel tapping tees.

On another issue related to protective sleeves, Safety Board examination of a protective sleeve offered by Continental to its customers revealed that the sleeve that did not have sufficient clearance to allow the application of field wrap (intended to protect the steel tee from corrosion after it is in the ground) to that portion of the steel tee under the sleeve. This observation was confirmed by a Continental representative.

Pipe Residual Bending -- The service involved in the Waterloo accident was installed with a bend at the connection point to the main. (See illustration in appendix A.) The plastic service pipe leaving the tee immediately curved horizontally. The pipe was cut out and brought into the laboratory, at which time the bend had a measured horizontal radius of approximately 34 inches. Based on field conditions and photos, MidAmerican Energy estimated the original installed horizontal bend radius to have been about 32 inches. This bend is sharper than that allowed by current industry installation recommendations for modern piping adjacent to fittings.

An issue related to recommended bend radius is residual pipe bending. Plastic pipe often arrives at a job site in banded coils. After the bands are released, the coiled pipe will partially straighten, but some residual bending will remain. The water industry already recognizes that bends *in* the direction of the residual coil bend should be treated differently than bends *against* the direction of the bend;[78] however, gas industry field bend radius recommendations do not address residual coil bending.

A former Iowa Public Service Company employee stated that Iowa Public Service Company, in an effort to reduce stress at connection points, generally attempted to install polyethylene services at an angle to the main to match the residual bend left after uncoiling the pipe. This former employee stated that no set time was specified to allow for complete relaxing of the pipe, but that the pipe would be placed in the ditch, and the crews would weld the tee at what they judged to be the appropriate angle.

MidAmerican Energy Installation Standards -- As a result of the Waterloo accident, Safety Board investigators examined some of MidAmerican Energy's construction standards for minimizing shear and bending forces at plastic service connection points to steel mains. Specifically, Safety Board investigators examined MidAmerican Energy's standards pertaining to providing firm support, using protective sleeves, and limiting bends at plastic service connections to steel mains.

According to the company, MidAmerican Energy no longer installed steel tapping tees with mechanical compression ends to connect to plastic service pipe. Instead, it employed steel tapping tees welded at the factory to factory-made steel-to-plastic transition fittings. It then field-fused the plastic ends from the transition fittings to the plastic service pipe.

MidAmerican Energy advised the Safety Board that it had no standard calling for firm compacted support under plastic service connection points to steel mains.

MidAmerican Energy designed, constructed, and installed its own protective sleeves for installation on its purchased steel tapping tee/transition fitting assemblies. MidAmerican Energy required its protective sleeves to be a minimum of 12 inches long; however, MidAmerican Energy could provide no design criteria for this length. MidAmerican Energy has reported that the company's unwritten field practice was to install the smallest diameter sleeve that will clear the field wrapped fitting, but MidAmerican Energy had no written re-quirements or design criteria for the diameter of its protective sleeves. The company's standard showed the sleeve as approximately centered over the steel-to-plastic transition, and no

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and marketed the complete assembly.

[78]Forward to American Water Works Association Standard C901-96.

criteria or instructions were provided for the correct positioning of the sleeves.

The Safety Board notes that manufacturers that provide factory-made steel-to-plastic transition fittings will also provide protective sleeves along with the transition fittings and will provide positioning guidance for their use.

Effective January 27, 1997, MidAmerican Energy instituted minimum bend radii requirements that differentiated between pipe segments consisting of pipe alone and pipe with fittings.

Gas System Performance Monitoring

This section examines gas system performance monitoring largely in the context of the Waterloo accident.

Federal regulations (49 CFR 192.613 and 192.617) require that gas pipeline system operators have procedures in place for monitoring the performance of their gas systems. These procedures must cover surveillance of gas system failures and leakage history, analysis of failures, submission of failed samples for laboratory examination (to determine the causes of failure), and minimizing the possibility of failure recurrences.

Prior to the Waterloo accident, Midwest Gas had two systems for tracking, identifying, and statistically characterizing failures. The first system was the leak data base, which tracked the status of leak reports, documented actions taken, and recorded almost all gas system leaks. The data base received input from two primary sources: leak reports from customers and leak survey results. The data base parameters classified the general type of piping material that leaked (such as "plastic," "cast iron," "bare steel"), and indicated whether the leak occurred in pipe or certain fittings. The parameters did not include manufacturers, manufacturing or installation dates, sizes,[79] or failure conditions commonly found with plastic piping (for example, poor fusions, bending force failures, insufficient soil compaction, rock impingement failures, and lack or improper use of protective sleeves). The data base indicated that the performance of plastic piping overall was comparable to other piping materials. MidAmerican Energy stated that the parameters chosen for this data base were those required for reporting to the DOT. The company said the parameters were also chosen on the premise that pipe meeting industry specifications would perform similarly.

The second system used by Midwest Gas for tracking failures was the company's material failure report data base, which was intended for use in evaluating the quality and performance histories of products installed in the company's gas system. Input to the data base was by way of a form (or, in some cases, a tag) filled out by field personnel. The form included categories such as the manufacturer, size, and an internal material identification number of the affected pipe or component. It also included areas for a narrative description of the failure. The form did not include dates of manufacture or installation dates or failure conditions commonly found on plastic piping. Field personnel sent the failed item, along with the completed form or tag, to engineering personnel, who examined the item and accompanying information to determine the need for corrections. Midwest Gas personnel then transcribed the narrative description of the failure word-for-word into the data base without attempting to determine and categorize causes of failure. Engineering personnel compiled the available data into periodically issued material summary reports. The company said engineering personnel from time to time sorted available data fields to determine trends.

The material failure report data base included only a portion of the leaks in the Midwest Gas system. For example, if Midwest Gas field personnel corrected a leak by replacing an entire line segment without digging up the leaking component (which the company said was a frequent occurrence with bare steel, cast iron, and certain plastic piping that was difficult to join), the material failure report data base system was not used. Also, field personnel were not required to use the reporting system if they determined that the failed item was related to an operating problem, such as excavation damage, rather than to a material problem.

[79] While sizes of the piping, along with a drawing of the piping assembly, were normally written or drawn on the forms, piping size was not captured in the data base generated by these forms.

Additionally, the company indicated that the system did not enjoy full participation from field personnel.

When, after the Waterloo accident, Midwest Gas attempted to determine if installations with Century plastic piping had higher rates of failure than those with piping from other manufacturers, it found that its material failure report data base's incomplete coverage of gas leaks made that data base unsuitable for the purpose. The company decided instead to use the leak data base, which the company believed included almost all leaks. But because the leak data base did not list the manufacturers of plastic piping, Midwest Gas took several months to correlate entries in the leak data base with records showing the manufacturers of plastic piping. Midwest Gas, in 1995, concluded that piping installations with Century piping had failure incidence rates that were significantly higher than the balance of its plastic piping system. The company did not correlate entries with the years of installation.

Since the Waterloo accident, the current Waterloo gas system operator, MidAmerican Energy, in addition to replacing all its Century pipe, has added parameters such as piping size, installation date, and pressure to the forms used for input into its leak data base. Also since the accident, MidAmerican Energy has added parameters such as installation date, pressure, and component location and position to its form for input into its material failure report data base. The company has also worked to determine if any other plastic piping manufacturers can be linked to piping with unacceptable performance.

The current (1994) edition of the *A.G.A. Plastic Pipe Manual for Gas Service* recommends the use and provides a sample of a form for recording information on plastic piping failures. The manual recommends collecting this information and then performing a visual examination or, in some cases, a laboratory analysis, to determine the type and cause of failure.

ANALYSIS

General

The common thread in a series of plastic pipeline accidents investigated by the Safety Board and others since the early 1970s—as well as in a number of reports of other, non-accident, plastic pipeline leaks—is the indicated presence of brittle-like cracking leading to eventual pipe failure. The number and similarity of these brittle-like failures seem to indicate that the long-term durability of plastic piping, which was premised on the pipe's ductility, may have been overstated by the method used to rate the long-term strength of plastic piping materials.

Based on the available evidence, any public safety threat posed by possible premature failure of plastic piping appears to be limited to locations where stress intensification exists. This special investigation examines in detail one installation configuration—plastic pipe mechanical connections to steel mains via steel tapping tees—where great potential exists for the generation of stress intensification. At these connections, certain poor installation practices have been known to create stress that is greater than the pipe can withstand. Thus, inadequate or improper installation of piping connections, in combination with brittle piping, represents one identifiable public safety hazard associated with the thousands of miles of older plastic piping now in service nationwide.

Gas system operators need to have an effective surveillance and data analysis (performance monitoring) program to determine the extent of the possible hazard associated with their pipeline systems, including plastic piping. Such a program must be adequate to detect trends as well as to identify localized problem areas, and it must be able to relate poor performance to specific factors such as plastic piping brands, dates of manufacture (or installation dates), and failure conditions.

The major safety issues developed during this special investigation are as follows:

- The vulnerability of plastic piping to premature failures due to brittle-like cracking;
- The adequacy of available guidance relating to the installation and protection of plastic piping connections to steel mains; and
- Performance monitoring of plastic pipeline systems as a way of detecting unacceptable performance in piping systems.

The remainder of this analysis addresses each of these major safety issues, as well as a number of other issues affecting the safety of plastic piping for gas service.

Durability of Century Utility Products Piping

Iowa Public Service Company, the company that installed the Century pipe involved in the 1994 Waterloo, Iowa, pipeline accident, began purchasing all of its plastic pipe from Century in 1970, when Amdevco/Century had just started to manufacture plastic pipe. These purchases were made without Iowa Public Service Company's having a testing or technical evaluation program and without Century/Amdevco having a successful track record. Iowa Public Service Company decided on the Century product because Century offered favorable commercial terms for a product it claimed was virtually identical to the DuPont plastic piping that had previously been used.

The Safety Board has investigated two other pipeline accidents, one in Nebraska in 1978 and one in Minnesota in 1983, that involved Century piping. The Safety Board is also aware of four other accidents that it did not investigate that involved the same brand of piping. Moreover, laboratory testing of Century product samples from the Waterloo accident determined that the material had the same brittle-like crack properties that have been associated with materials having poor performance histories.

Laboratory examination also revealed evidence of slow crack growth typical of brittle-like cracking.

The Century pipe involved in the Waterloo accident was made from Union Carbide's DHDA 2077 Tan resin. Although Union Carbide's laboratory data indicated that the material had the strength required by existing government and industry requirements, the Safety Board's review of the same data showed that the material had an early ductile-to-brittle transition, indicating poor resistance to brittle-like fractures.

In the early 1970s, a Minnesota gas system operator tested a number of piping products made from DHDA 2077 Tan resin, including those marketed by Century, as part of its comprehensive specification, testing, and evaluation program. The company rejected piping made from the Union Carbide product for use in its system based on the results of sustained pressure tests. Union Carbide, in 1971, acknowledged that its DHDA 2077 Tan resin material had a lower pressure rating at 100 °F than did DuPont's polyethylene pipe material.

Midwest Gas, the Waterloo, Iowa, gas operator at the time of the explosion and fire, had experienced at least three other significant failures involving Century pipe. The most recent failures, occurring between 1992 and 1994, prompted the company to collect samples of the Century material for independent laboratory testing. Samples were being gathered for testing at the time of the Waterloo accident. The subsequent laboratory report indicated that the Century piping had poor resistance to slow crack growth.

Midwest Gas's subsequent analysis of the company's leakage history concluded that its installations with Century piping had failure rates significantly higher than those with piping from other manufacturers. Midwest Gas had received warnings from two pipe fitting manufacturers against use of their products with Century pipe because of Century pipe's susceptibility to brittle-like cracking. The current operating company in the Waterloo, Iowa, area, MidAmerican Energy, has, since the accident, replaced all the identified Century piping in its gas pipeline system.

The Safety Board concludes that plastic pipe extruded by Century Utility Products, Inc., and made from Union Carbide's DHDA 2077 Tan resin has poor resistance to brittle-like cracking under stress intensification, and this characteristic contributed to the Waterloo, Iowa, accident.

The Safety Board believes that RSPA should notify pipeline system operators who have installed polyethylene gas piping extruded by Century Utility Products, Inc., from Union Carbide Corporation DHDA 2077 Tan resin of the piping's poor brittle-crack resistance. The Safety Board further believes that RSPA should require these operators to develop a plan to closely monitor the performance of this piping and to identify and replace, in a timely manner, any of the piping that indicates poor performance based on such evaluation factors as installation, operating, and environmental conditions; piping failure characteristics; and leak history.

Strength Downturn and Brittle Characteristics

While Century piping has been identified specifically as being subject to brittle-like cracking (slow crack growth), evidence suggests that much of the early polyethylene piping, depending on the brands, may be more susceptible to such cracking than originally thought and thus may also be subject to premature failure.

The principal process used in the United States to rate the strength of plastic piping materials has been, and remains, the procedure this report has referred to as the PPI procedure. The PPI procedure, which was developed in the early 1960s, involved subjecting test piping to different stress values and recording how much time elapsed before the piping ruptured. The resulting data were then plotted, and a best-fit straight line was derived to represent the material's decline in rupture resistance as its time under stress increased.

To meet the requirements of the PPI procedure, at least one tested sample had to be

able to withstand some level of hoop stress without rupturing for at least 10,000 hours, or slightly more than 1 year. The straight line plotted describing the data for this material was extrapolated out by a factor of 10, to 100,000 hours (about 11 years). The point at which the sloping straight line intersected the 100,000-hour point indicated the appropriate hydrostatic design basis for this material.

A key assumption characterized the assignment of a hydrostatic design basis under the PPI procedure: The procedure assumed that the gradual decline in the strength of plastic piping material as it was subjected to stress over time would always be described by a straight line. In the early 1960s, the industry had had little long-term experience with plastic piping, and a straight line seemed to represent the response of the material to laboratory stress testing. With little other information on which to base strength estimations, the straight-line assumption appeared valid.

As experience grew with plastic piping materials and as better testing methods were developed, however, the straight-line assumptions of the PPI procedure came to be challenged. Elevated-temperature testing indicated that polyethylene piping can exhibit a decline in strength that does not follow a straight line path but instead describes a downturn, as shown in figure 9. The difference between the actual (falloff) and projected (straight line) strengths became even more pronounced as the lines were extrapolated beyond 100,000 hours. The timing and slope of the downturn varied by pipe formulation and manufacturer.

Piping manufacturers addressed this issue by improving their formulations to delay onset of the downturn in strength. At the same time, the PPI procedure was improved to reflect the fact that elevated-temperature testing, by accelerating the fracture process, provided a good representation of the true long-term strength of the tested material at 73 °F. By 1986, the PPI adopted a requirement to exclude any materials that deviated from the straight-line path to at least 100,000 hours at 73 °F.

The combination of more durable modern plastic piping materials and more realistic strength testing has rendered the strength ratings of modern plastic piping much more reliable. Unfortunately, much of the early plastic piping was sold and installed with expectations of strength and long-term performance that, because they were based on questionable assumptions about long-term performance, may not have been valid. This is borne out by data from a variety of sources. The history of strength rating requirements, a review of the piping properties and literature, and observations of several experts with extensive experience in plastic piping, all suggest that much of the polyethylene pipe, depending upon the brands, manufactured from the 1960s through the early 1980s fails at lower stresses and after less time than originally projected. The Safety Board therefore concludes that the procedure used in the United States to rate the strength of plastic pipe may have overrated the strength and resistance to brittle-like cracking of much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s.

Another important assumption of the design protocol for plastic pipe involved the ductility of the materials. It was assumed, based on short-term tests, that plastic piping had long-term ductile properties. Ductile material, by bending, expanding, or flexing, can redistribute stress concentrations better than can brittle material, such as cast iron. Notable from results of tests performed under the PPI procedure was that those short-term stress ruptures in the testing process tended to be characterized by substantial material deformation in the area of the rupture. This deformation described a material with obvious ductile properties. Under prolonged testing, however, as time-to-failure increased, some stress ruptures in some materials occurred as slit failures that, because they were not accompanied by substantial deformation, were more typical of brittle-like failures. These slit or brittle-like failures were characterized by crack initiation and slow crack growth. The PPI procedure did not distinguish between ductile fractures and slit fractures and assumed that both failures would be described by the same straight line.

The assumption of ductility of plastic piping had important safety ramifications. For example, a number of experts believed it was safe to

design plastic piping installations based on stresses primarily generated by internal pressure and to give less consideration to stress intensification generated by external loading. Ductile material reduces stress intensification by localized yielding, or deformation.

As noted previously, laboratory data supported the strength rating assigned to DHDA 2077 Tan resin by the process used at the time to rate strength; nevertheless, the material showed evidence of early ductile-to-brittle transition. The fact that the process used to measure the long-term durability of piping materials did not reveal the premature susceptibility to brittle-like cracking of the DHDA 2077 Tan material highlights the weaknesses of the process in use at the time. More significantly, it calls into question the durability of other early materials that were rated using the same process and that remain in service today. This concern is heightened by the fact that, in addition to the Waterloo accident involving Century pipe and DHDA 2077 Tan resin, numerous other accidents investigated or documented by the Safety Board have suggested that brittle-like cracking occurs in older plastic piping at significant rates.

Stress intensification has been an element common to many plastic gas pipeline accidents investigated by the Safety Board. The premature transition of plastic piping from ductile failures to brittle failures appears to have little observable adverse impact on the serviceability of plastic piping except in those instances in which the piping is subjected to external stresses. Rock impingement, soil settlement, and excess pipe bending are among the potential sources of stress intensification, and the combination of brittle piping and external stresses can lead to significant rates of failures. These failures can, in turn, lead to serious accidents. The Safety Board therefore concludes that much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s may be susceptible to premature brittle-like failures when subjected to stress intensification, and these failures represent a potential public safety hazard.

The Safety Board believes that RSPA should determine the extent of the susceptibility to premature brittle-like cracking of older plastic piping (beyond that piping marketed by Century Utility Products, Inc.) that remains in use for gas service nationwide. RSPA should then inform gas system operators of the findings and require them to closely monitor the performance of the older plastic piping and to identify and replace, in a timely manner, any of the piping that indicates poor performance based on such evaluation factors as installation, operating, and environmental conditions; piping failure characteristics; and leak history. Because materials other than polyethylene have been used in plastic pipe for gas service, and even though the Safety Board has not examined those materials in depth, RSPA would do well to address those other plastic piping materials still in gas service.

The Safety Board further believes that RSPA should immediately notify those States and territories with gas pipeline safety programs of the susceptibility to premature brittle-like cracking of much of the plastic piping manufactured from the1960s through the early 1980s and of the actions that RSPA will require of gas system operators to monitor and replace piping that indicates unacceptable performance.

Information Dissemination Within the Gas Industry

As noted earlier, much of the polyethylene pipe, depending upon the brands, from the 1960s through the early 1980s may be susceptible to premature brittle-like failures when subjected to stress intensification. Poor resistance to crack initiation and slow crack growth in the face of stress intensification can translate into a higher incidence of leaks and a decrease in public safety.

Premature brittle-like cracking in plastic piping is a complex phenomenon. Those pipelines operators who wish to study the phenomenon can gain a basic understanding of brittle-like cracking by researching the technical literature, but without direct and straightforward communication to pipeline operators about brands of piping and conditions that increase the likelihood of brittle cracking, many pipeline operators may not have the knowledge to make good decisions affecting public safety. Some of these key decisions include how often to

conduct leak surveys and whether to repair or replace portions of pipeline systems.

Frequently, piping manufacturers, because they can receive feedback from a number of customers, are the first to learn of systemic problems with their products. For small operators, contact with a manufacturer may be the major source of outside communication about poorly performing products. Unfortunately, while manufacturers have a high degree of technical expertise regarding their products, they may also tend to aggressively publicize the best performance characteristics of their products while only reluctantly acknowledging weaknesses. The Safety Board is aware of only a very few cases in which manufacturers of resin or pipe have formally notified the gas industry of materials having poor resistance to brittle cracking.

Thus, although reputable manufacturers commonly provide essential technical assistance and serve as partners to pipeline operators, operators are still responsible for evaluating and determining which products are most likely to maintain the integrity of their pipeline systems. Furthermore, perhaps because the possibility of premature failure of plastic piping due to brittle-like cracking has not been fully appreciated within the industry and the scope of the potential problem has not been fully measured, the Federal Government has not provided information on this issue to gas system operators. The Safety Board concludes that gas pipeline operators have had insufficient notification that much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s may be susceptible to brittle-like cracking and therefore may not have implemented adequate pipeline surveillance and replacement programs for their older piping.

In the view of the Safety Board, manufacturers of resin and pipe should do more to notify pipeline operators about the poor brittle-crack resistance of some of their past products. The PPI is the manufacturers' organization that covers most of the major resin and pipe producers, many of whom have manufactured resin and pipe for several years. Although manufacturers of some of the worst performing materials and piping products may not have survived and therefore may not be current members of the PPI, the current members of the PPI have produced much, if not most, of the plastic piping and materials used in the manufacture of plastic piping over many years. The Safety Board therefore believes that the PPI should advise its members to notify pipeline system operators if any of their piping products, or materials used in the manufacture of piping products, currently in service for natural gas or other hazardous materials indicate poor resistance to brittle-like failure.

In the interest of public safety and in order for the Federal Government to fully exercise its oversight responsibilities, the Safety Board believes that RSPA should, in cooperation with the manufacturers of products used in the transportation of gases or liquids regulated by the OPS, develop a mechanism by which the OPS will receive copies of all safety-related notices, bulletins, and other communications regarding any defect, unintended deviation from design specification, or failure to meet expected performance of any piping or piping product that is now in use or that may be expected to be in use for the transport of hazardous materials.

Over a number of years, the GRI has developed a significant amount of data on older plastic piping, but it has published the data in codified terms. Without a way to associate codes with specific products, the average gas pipeline operator could not make effective use of the data. The Safety Board concludes that, even though the GRI has developed a significant amount of data about older plastic piping used for gas service, because the data have been published in codified terms, the information is not sufficiently useful to gas pipeline system operators. The Safety Board believes that the GRI should publish the codes used to identify plastic piping products in previous GRI studies to make the information contained in these studies more useful to pipeline system operators.

Installation Standards and Practices

Because of the large safety factor[80] used in the design equation, even many of the materials

[80]Technically, this term should be "design factor."

having early downturns in strength appear, absent stress intensification, to have the capacity to provide good service. Unfortunately, stress intensification, which can take many forms, has been found in a number of gas piping systems.

Almost all of the plastic pipeline accidents the Safety Board has investigated involving brittle-like cracking have been linked to stress intensification generated by external forces acting on the pipe. Examples of conditions that can generate stress intensification include differential earth settlement, particularly at connections with more rigidly anchored fittings; excessive bending as a result of installation configurations, especially at fittings; and point contact with rocks or other objects.

As discussed below, much of the guidance available to gas system operators for limiting stress intensification at plastic pipeline connections to steel mains is inadequate or ambiguous. It is particularly significant that none of the steel tapping tee manufacturers had published recommendations to safely limit shear and bending forces at connections where their products are used. Based on its review of this guidance and on the history of the plastic pipeline accidents it has investigated, the Safety Board concludes that, because guidance covering the installation of plastic piping is inadequate for limiting stress intensification at plastic service connections to steel mains, many of these connections may have been installed without adequate protection from shear and bending forces. The specific limitations of existing guidance are addressed in the sections that follow.

Federal Regulations -- RSPA acknowledges that the regulation that requires gas service lines to be installed so as to minimize anticipated piping strain and external loading lacks performance measurement criteria. The Safety Board pointed out in a previous accident investigation report[81] that, although the OPS considers many of its pipeline safety regulations to be performance-oriented requirements, many are no more than general statements of required actions that do not establish any criteria against which the adequacy of the actions taken can be evaluated. The Safety Board has further stated that regulations that do not contain measurable standards for performance make it difficult to determine compliance with the requirements. The Safety Board therefore previously recommended that RSPA:

> P-90-15
> Evaluate each of its pipeline safety regulations to identify those that do not contain explicit objectives and criteria against which accomplishment of the objective can be measured; to the extent practical, revise those that are so identified.

As a result of this safety recommendation, the OPS asked the National Association of Pipeline Safety Representatives liaison committee to review the 20 regulations deemed to be the least enforceable due to lack of clarity. The Safety Board has encouraged RSPA to make such a review a periodic effort so that all of the regulations, not just the specified 20, are continually clarified. The last correspondence to the Safety Board from the OPS regarding this recommendation was on March 8, 1993, and the recommendation has remained classified "Open--Acceptable Response." In an October 31, 1997, letter to the OPS, the Safety Board inquired as to the status of 28 open safety recommendations to RSPA, including P-90-15. The OPS has not yet provided a written response to the request for the status of P-90-15. The Safety Board will continue to follow the progress and urge completion of this recommendation. In the meantime, other elements of the gas pipeline industry can take steps to enhance the protection of vulnerable piping at connections, as outlined below.

A.G.A. Plastic Pipe Manual for Gas Service -- A protective sleeve helps to shield the pipe at the connection point from bearing loads and shear forces, and controls the maximum bending. The *A.G.A. Plastic Pipe Manual for Gas Service* recommends installing protective sleeves at connections of plastic pipe, but it does not directly address designing the sleeve to have the correct inner diameter and length, or the need to position the sleeve

[81]National Transportation Safety Board Pipeline Accident Report--*Kansas Power and Light Company Natural Gas Pipeline Accidents, September 16, 1988, to March 29, 1989 (*NTSB/PAR-90/03).

properly. Instead, it includes a sentence recommending that manufacturers' instructions be followed carefully. Such advice presumes that the manufacturers' instructions address designing the sleeve to have the correct inner diameter and length, as well as positioning the sleeve properly, in order to limit the shear and bending forces at the connection. Unfortunately, since none of the steel tapping tee manufacturers recommend any precautions to limit shear and bending forces at the connection point, gas pipeline operators may not realize the importance of determining these parameters.

The *A.G.A. Plastic Pipe Manual for Gas Service* does not provide an explanation for the following sentence:

> Installation of the tee outlet at angles up to 45° from the vertical or along the axis of the main as a 'side saddle' or 'swing joint' may be considered to further minimize…stresses.

This sentence is subject to different interpretations and does not explain how stresses might be reduced. Moreover, many gas system pipeline operators recognize that installing services 90° from the main helps with future locating of the pipe and reduces the likelihood of excessive bending, which could generate excessive stress. In the view of the Safety Board, this sentence does not provide useful guidance as it is written, and the A.G.A. Plastic Materials Committee would be well advised to either expand on or delete this sentence.

A.G.A. Gas Engineering and Operating Practices Series -- Illustrations from the GEOP series show protective sleeves extending to undisturbed or compacted soil or to blocking. But these figures show the blocking positioned so that, under some conditions, either the edge of the blocking or the edge of the protective sleeve might provide a fixed contact point on the service pipe. The Safety Board notes that B31.8 and ASTM D2774 discourage supporting plastic pipe by the use of blocking. In the view of the Safety Board, these illustrations would provide better guidance if they were revised to eliminate showing the possibility of blocking or other fixed contact point supporting plastic pipe.

The Safety Board believes that the A.G.A. should revise its *Plastic Pipe Manual for Gas Service* and the *Gas Engineering and Operating Practices* series to provide complete and unambiguous guidance for limiting stress at plastic pipe service connections to steel mains.

GPTC Guide for Gas Transmission and Distribution Piping Systems -- The Safety Board has previously noted that a protective sleeve's correct inner diameter and length are important to protect the piping from excessive forces. The Safety Board even issued a safety recommendation that the GPTC Guide be modified accordingly. As a result of this safety recommendation, the GPTC Guide now includes guidance under 49 CFR 192.361 to install protective sleeves "designed for the specific connection…to reduce stress concentrations." Designing protective sleeves for the specific connection is presumed to include designing the sleeve for the correct inner diameter and length, and may also include positioning the sleeve correctly, since positioning the sleeve affects its effective length. However, if steel tapping tee manufacturers do not address the parameters for sleeve design and positioning, gas pipeline operators may not realize the importance of determining these parameters. The guidance would be much more useful to gas pipeline operators if the GPTC included in the guide a specific statement of the need to design protective sleeves so that they will have the correct inner diameter and length, as well as the need to properly position the sleeves.

Although the guide references the *A.G.A. Plastic Pipe Manual for Gas Service* in various locations, and this manual provides recommendations on bending limits, the guide does not reference this manual under the guide material under 49 CFR 192.361. Therefore, the Safety Board believes that the GPTC should revise the guide to include complete guidance for the proper installation of plastic service pipe connections to steel mains. The guidance should emphasize the need to limit pipe bending and should include a discussion of the proper design and positioning of a protective sleeve to limit stress at the connection.

ASTM -- ASTM D2774 recommends the use of a protective sleeve, if needed to protect against possible differential settlement. The

standard practice additionally advises consultation with manufacturers, which would presumably address designing the sleeve with a proper diameter and length, as well as positioning the sleeve correctly. However, as noted previously, none of the steel tapping tee manufacturers has recommended precautions to limit stresses at the service to main connection; therefore, gas pipeline operators may not realize the importance of determining these parameters. Consequently, the Safety Board believes that the ASTM should revise ASTM D2774 to emphasize that a protective sleeve, in order to be effective, must be of the proper length and inner diameter for the particular connection and must be positioned properly.

Currently, manufacturers that provide protective sleeves have their own criteria for sleeve lengths and diameters. Some manufacturers' criteria are based on limiting stress to a maximum safe value,[82] while one manufacturer has advised the Safety Board that its sleeve is not designed to limit bending but only to guard against shear forces at the connection point. A published common criteria would better motivate a wider spectrum of manufacturers and gas operators to apply scientific reasoning to their decisions on protective sleeve use. A published common criteria would additionally provide guidance to gas operators who provide their own sleeves rather than using manufacturer-supplied sleeves. The Safety Board therefore believes that the ASTM should develop and publish standard criteria for the design of protective sleeves to limit stress intensification at plastic pipeline connections.

Guidance Manual for Operators of Small Natural Gas Systems -- The expressed purpose of RSPA's *Guidance Manual for Operators of Small Natural Gas Systems* is to assist nontechnically trained persons who operate small gas systems. However, the manual provides no caution against bending close to a plastic service connection to a steel main. The manual recommends following manufacturers' instructions and indicates that a properly designed sleeve should be used at this connection, which would address designing the sleeve with the proper diameter and length. However, as noted previously, none of the steel tapping tee manufacturers has recommended precautions to limit stresses at the service to main connection; therefore, nontechnically trained persons may not realize the importance of determining these parameters.

Because manufacturers' recommendations in the above areas are also currently inadequate, the Safety Board believes that RSPA should revise its *Guidance Manual for Operators of Small Natural Gas Systems* to include more complete guidance for the proper installation of plastic service pipe connections to steel mains. The guidance should address pipe bending limits and should emphasize that a protective sleeve, in order to be effective, must be of the proper length and inner diameter for the particular connection and must be positioned properly.

Manufacturers' Recommendations -- Reliance on manufacturers' recommendations is a common theme running through many of the primary published sources of industry guidance for limiting stress intensification on plastic piping. CSR PolyPipe was relatively new to providing polyethylene pipe to the gas market. When CSR PolyPipe entered the market, the three other major polyethylene piping manufacturers had already published installation recommendations to limit stress intensification, and plastic materials were vastly improved compared to earlier versions with respect to resistance to crack initiation and slow crack growth. CSR PolyPipe therefore saw less need to develop extensive recommendations. And although CSR PolyPipe does not manufacture steel tapping tees with compression ends for attachment to plastic services, it does manufacture the pipe that will be attached to steel tapping tees via mechanical compression couplings. To facilitate the safe use of plastic piping, the Safety Board believes that the PPI, of which all four of the major piping producers are members, should advise its plastic pipe manufacturing members to develop and publish recommendations for limiting shear and bending forces at plastic service pipe connections to steel mains.

[82]Allman, W. B., "Determination of Stresses and Structural Performance in Polyethylene Gas Pipe and Socket Fittings Due to Internal Pressure and External Soil Loads," *1975 Operating Section Proceedings*, American Gas Association, 1975.

Compared to plastic piping manufacturers, steel tapping tee manufacturers may have much less technical expertise regarding the strength and failure modes of plastic pipe; however, steel tapping tee manufacturers, who have designed their rigid steel tees to connect to flexible plastic gas pipe, have a responsibility to provide recommendations for the safe use of their products. If a steel tee manufacturer believes that installation options are dependent on the type of plastic to be connected and that these options can be addressed only by the pipe manufacturer, the tee manufacturer has a responsibility to state that in its literature and to provide the gas system operator with direction for best using its product safely.

The Safety Board therefore believes that Continental, Dresser, Inner-Tite, and Mueller should develop and publish detailed recommendations and instructions for limiting shear and bending forces at locations where their steel tapping tees are used to connect service pipe to steel mains. While gas system operators have the option of not accepting manufacturers' recommendations, many gas system operators rely on manufacturers to provide installation recommendations for the safe use of their products. With published recommendations, gas system operators may be far less likely to overlook prudent construction practices, such as providing proper compaction and support, limiting bends, and using protective sleeves. Tee manufacturers may wish to make these published recommendations even more effective by packaging them with each tee shipped, thus ensuring that the gas operator or the tee installer, or both, will have ready access to them.

A Continental representative told the Safety Board that the protective sleeve it provides to customers as an option does not provide sufficient clearance to allow field wrap to be applied to the metallic portion under the sleeve as a way to prevent corrosion. The Safety Board concludes that the use of Continental tapping tees with Continental protective sleeves may leave the tapping tees susceptible to corrosion because the sleeves do not provide sufficient clearance for the application of field wrap to the metallic steel tapping tee. The Safety Board therefore believes that Continental should provide a means to ensure that use of Continental-designed protective sleeves with the company's steel tapping tees at plastic pipe connections to steel mains does not compromise corrosion protection for the connection.

Installation Issues at Site of Waterloo Accident -- Safety Board examination of the fracture surface and the failed pipe from the Waterloo accident revealed evidence of stress intensification. For example, the upper portion of the inside of the pipe showed the impression of the edge of the tee stiffener, indicating that the top of the pipe had been pressed down. The failure of the pipe can be directly associated with this stressed area, which was characterized by several brittle-like slow crack growth fractures that originated on or near the pipe inner wall just outside the depression associated with the tip of the tee stiffener. These slow crack fractures propagated through the wall of the pipe.

The stress intensification noted in the Waterloo pipe was consistent with the pipe's having been subjected to shear and bending forces generated primarily by soil settlement.[83] Soil settlement is a common source of stress intensification for buried plastic pipelines, and it can occur and contribute to a piping failure even though no observable voids are noted during a subsequent excavation. Ultimate settlement of backfill can take many years, and sometimes it only occurs after periods of heavy rains (such as the area experienced the previous year) or under additional external loading (such as that represented by truck traffic over the connection).

The accident investigation could not determine whether the ground settlement at Waterloo occurred because of inadequate compaction and support under the connection at the time it was installed, or whether it occurred despite initial adequate compaction and support. Nor could it be conclusively determined whether the amount of soil settlement was slight and generated relatively low stresses over a long

[83]The failed pipe also showed signs that the installed horizontal curve may have generated horizontal bending forces. Other factors contributing to stress at the connection included the pipe's internal pressure and may have included residual stresses inside the wall of the pipe resulting from the manufacturing process.

period of time, or whether the soil settlement was substantial and generated relatively high stresses over a relatively short period of time. Because of these uncertainties, investigators could not determine how much more resistance to crack initiation and slow crack growth the pipe would have needed to have successfully resisted the stresses to which it was subjected.

MidAmerican Energy, at the time of this accident investigation, had no installation standard that called for firm compacted support under plastic service connection points to steel mains. MidAmerican Energy connected plastic service pipe to mains via factory-joined plastic-to-steel transition fittings. As noted previously, the manufacturers for these specialty fittings, unlike steel tapping tee manufacturers, have protective sleeves available. Although MidAmerican Energy designed its own protective sleeves for this application, it did so without a design criteria for length or inner diameter, or for positioning the protective sleeves. Without such criteria, MidAmerican Energy may reduce the sleeve's effectiveness in limiting stress intensification. The Safety Board concludes that, because MidAmerican Energy's gas construction standards do not establish well-defined criteria for supporting plastic pipe connections to steel mains or for designing or installing its protective sleeves at these connections, these standards do not ensure that connections will be adequately protected from stress intensification. The Safety Board believes that MidAmerican Energy should modify its gas construction standards to require (1) firm compacted support under plastic service connections to steel mains, and (2) the proper design and positioning of protective sleeves at these connections.

The service involved in the Waterloo accident was installed with a horizontal bend that was sharper than that recommended by current gas industry guidance recommendations; however, the bend may have been installed in the direction of the residual coil bend. Gas industry recommendations do not address residual bending in the pipe, even though plastic piping is often delivered to job sites in banded coils, which leaves some residual bending in the piping even after the bands are removed. Installing coiled pipe with any necessary bending in the direction of the residual bend may be a good practice to limit stresses. Conversely, bending pipe against the direction of the residual coil bend, even if the resulting bend is in accordance with gas industry recommendations, will induce greater stresses.

Plastic piping manufacturers continue to have the best combination of technical expertise and practical knowledge for determining bend radius recommendations. Therefore, the Safety Board believes that the PPI should advise its plastic pipe manufacturing members to revise their pipeline bend radius recommendations as necessary to take into account the effects of residual coil bends in plastic piping.

Gas System Performance Monitoring

Federal regulations require that gas pipeline system operators have in place an ongoing program to monitor the performance of their piping systems. Before the Waterloo accident, Midwest Gas developed only a limited capability for monitoring and analyzing the condition of its gas system. For example, the company did not statistically correlate failure rates to the amounts of installed pipe provided by specific manufacturers. The design of the program meant that the relatively few areas with high failure rates (for example, those with Century pipe) were aggregated with and therefore masked by the large number of plastic piping installations that had low failure rates. Thus, the Midwest Gas surveillance program did not reveal the high failure rates associated with Century pipe. Only after the accident did Midwest Gas identify the Century pipe within its pipeline system as having high failure rates, even though the company could have collected and processed the same type of data and reached the same determination before the accident. If Midwest Gas had further correlated its data to years of installation, it may have also been able to examine the effects of its changing installation methods or changes in performance with different manufacturers through the years.

The Safety Board concludes that, before the Waterloo accident, the systems used by Midwest Gas Company for tracking, identifying, and statistically characterizing plastic piping failures did not permit an effective analysis of system failures and leakage history. The Safety Board further concludes that if, before the Waterloo

accident, Midwest Gas had had an effective surveillance program that tracked and identified the high leakage rates associated with Century piping when subjected to stress intensification, the company could have implemented a replacement program for the pipe and may have replaced the failed service connection before the accident.

Since the accident, MidAmerican Energy has revised its systems, adding parameters to provide the company with added capability to sort failures. However, MidAmerican Energy has not chosen parameters that will allow an adequate analysis of its plastic piping system failures and leakage history. For example, the generic "improper installation" is a parameter to be linked to leaks; however, no parameters have been added for the presence, lack, improper design, or improper placement of a protective sleeve. And no parameters have been added to link leaks to squeeze locations, improper joining, or items to differentiate between insufficient support and excessive installed bending. The Safety Board therefore concludes that MidAmerican Energy's current systems for tracking, identifying, and statistically characterizing plastic piping failures do not enable an effective analysis of system failures and leakage history.

The Safety Board believes that MidAmerican Energy should, as a basis for the timely replacement of its plastic piping systems that indicate unacceptable performance, review its existing plastic piping surveillance and analysis program and make the changes necessary to ensure that the program is based on sufficiently precise factors such as piping manufacturer, installation date, pipe diameter, geographical location, and conditions and locations of failures.

An effective surveillance program would include the data base inputs that would allow the company to adequately monitor and characterize the types and causes of plastic piping field failures. The *A.G.A. Plastic Pipe Manual for Gas Service* recommends the use of a form for recording necessary information on plastic piping failures; this form may be helpful to MidAmerican Energy as it decides which data fields would be necessary to provide for an adequate analysis of its plastic piping system failures and leakage history. The *A.G.A. Plastic Pipe Manual for Gas Service* further recommends collecting this information, then performing visual examinations of the type and cause of failure and, in some instances, a laboratory analysis. The above steps may help MidAmerican Energy comprehensively monitor and address parts of its plastic pipeline system—other than those installations with Century pipe—that may also indicate unacceptable performance.

In a previous accident investigation report,[84] the Safety Board pointed out that many operators had not established procedures to comply with Federal regulations requiring surveillance and investigation of failures. The Safety Board recommended that RSPA:

> P-90-14
> Emphasize, as a part of OPS inspections and during training and State monitoring programs, the actions expected of gas operators to comply with the continuing surveillance and failure investigation, including laboratory examination requirements.

In a letter to the Safety Board, RSPA responded that the TSI had increased emphasis on gas surveillance and failure investigation in the operations block of its industry seminars held across the country. The letter stated that the TSI would incorporate a discussion of accident analysis into a new hazardous liquids seminar that was to be presented for the first time in FY 1992. Additionally, RSPA noted that it planned to place additional emphasis on continuing surveillance and failure investigation requirements in its new inspection forms at the time of the next revision. Based on this response, the Safety Board classified Safety Recommendation P-90-14 "Closed—Acceptable Action."

Despite the RSPA response to this safety recommendation, for a variety of reasons—including the inadequate performance monitoring

[84]National Transportation Safety Board Pipeline Accident Report--*Kansas Power and Light Company Natural Gas Pipeline Accidents, September 16, 1988, to March 29, 1989* (NTSB/PAR-90/03).

programs found at Midwest Gas/MidAmerican Energy, the susceptibility to brittle cracking of much of the polyethylene piping installed through the early 1980s, deficiencies noted in gas industry communications regarding poorly performing brands of polyethylene piping, and differences noted in the performance of different types and brands of polyethylene piping—RSPA may need to do more. Gas system operators may need to be advised once again of the importance of complying with Federal requirements for piping system surveillance and analyses. As is the case with older piping, an effective general pipeline surveillance program would be based on factors such as piping manufacturer, installation date, pipe diameter, operating pressure, leak history, geographical location, modes of failure (such as bending, inadequate support, rock impingement, or improper joining), location of failure (such as at the main to service or at pipe squeeze locations), and other factors such as the presence, absence, or misapplication of a sleeve. An effective program would also evaluate past piping and components installed, as well as past installation practices, to provide a basis for the replacement, in a planned, timely manner, of plastic piping systems that indicate unacceptable performance.

CONCLUSIONS

1. Plastic pipe extruded by Century Utility Products, Inc., and made from Union Carbide's DHDA 2077 Tan resin has poor resistance to brittle-like cracking under stress intensification, and this characteristic contributed to the Waterloo, Iowa, accident.

2. The procedure used in the United States to rate the strength of plastic pipe may have overrated the strength and resistance to brittle-like cracking of much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s.

3. Much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s may be susceptible to premature brittle-like failures when subjected to stress intensification, and these failures represent a potential public safety hazard.

4. Gas pipeline operators have had insufficient notification that much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s may be susceptible to brittle-like cracking and therefore may not have implemented adequate pipeline surveillance and replacement programs for their older piping.

5. Even though the Gas Research Institute has developed a significant amount of data about older plastic piping used for gas service, because the data have been published in codified terms, the information is not sufficiently useful to gas pipeline system operators.

6. Because guidance covering the installation of plastic piping is inadequate for limiting stress intensification at plastic service connections to steel mains, many of these connections may have been installed without adequate protection from shear and bending forces.

7. Because MidAmerican Energy Corporation's gas construction standards do not establish well-defined criteria for supporting plastic pipe connections to steel mains or for designing or installing its protective sleeves at these connections, these standards do not ensure that connections will be adequately protected from stress intensification.

8. Before the Waterloo, Iowa, accident, the systems used by Midwest Gas Company for tracking, identifying, and statistically characterizing plastic piping failures did not permit an effective analysis of system failures and leakage history.

9. If, before the Waterloo accident, Midwest Gas Company had had an effective surveillance program that tracked and identified the high leakage rates associated with Century Utility Products, Inc., piping when subjected to stress intensification, the company could have implemented a replacement program for the pipe and may have replaced the failed service connection before the accident.

10. MidAmerican Energy Corporation's current systems for tracking, identifying, and statistically characterizing plastic piping failures do not enable an effective analysis of system failures and leakage history.

11. The use of Continental Industries, Inc., tapping tees with the company's protective sleeves may leave the tapping tees susceptible to corrosion because the sleeves do not provide sufficient clearance for the application of field wrap to the metallic steel tapping tee.

RECOMMENDATIONS

As a result of this special investigation, the National Transportation Safety Board makes the following safety recommendations:

--to the Research and Special Programs Administration:

Notify pipeline system operators who have installed polyethylene gas piping extruded by Century Utility Products, Inc., from Union Carbide Corporation DHDA 2077 Tan resin of the piping's poor brittle-crack resistance. Require these operators to develop a plan to closely monitor the performance of this piping and to identify and replace, in a timely manner, any of the piping that indicates poor performance based on such evaluation factors as installation, operating, and environmental conditions; piping failure characteristics; and leak history. (P-98-1)

Determine the extent of the susceptibility to premature brittle-like cracking of older plastic piping (beyond that piping marketed by Century Utility Products, Inc.) that remains in use for gas service nationwide. Inform gas system operators of the findings and require them to closely monitor the performance of the older plastic piping and to identify and replace, in a timely manner, any of the piping that indicates poor performance based on such evaluation factors as installation, operating, and environmental conditions; piping failure characteristics; and leak history. (P-98-2)

Immediately notify those States and territories with gas pipeline safety programs of the susceptibility to premature brittle-like cracking of much of the plastic piping manufactured from the 1960s through the early 1980s and of the actions that the Research and Special Programs Administration will require of gas system operators to monitor and replace piping that indicates unacceptable performance. (P-98-3)

In cooperation with the manufacturers of products used in the transportation of gases or liquids regulated by the Office of Pipeline Safety, develop a mechanism by which the Office of Pipeline Safety will receive copies of all safety-related notices, bulletins, and other communications regarding any defect, unintended deviation from design specification, or failure to meet expected performance of any piping or piping product that is now in use or that may be expected to be in use for the transport of hazardous materials. (P-98-4)

Revise the *Guidance Manual for Operators of Small Natural Gas Systems* to include more complete guidance for the proper installation of plastic service pipe connections to steel mains. The guidance should address pipe bending limits and should emphasize that a protective sleeve, in order to be effective, must be of the proper length and inner diameter for the particular connection and must be positioned properly. (P-98-5)

--to the Gas Research Institute:

Publish the codes used to identify plastic piping products in previous Gas Research Institute studies to make the information contained in these studies more useful to pipeline system operators. (P-98-6)

--to the Plastics Pipe Institute:

Advise your members to notify pipeline system operators if any of their piping products, or materials used in the manufacture of piping products, currently in service for natural gas or

other hazardous materials indicate poor resistance to brittle-like failure. (P-98-7)

Advise your plastic pipe manufacturing members to develop and publish recommendations for limiting shear and bending forces at plastic service pipe connections to steel mains. (P-98-8)

Advise your plastic pipe manufacturing members to revise their pipeline bend radius recommendations as necessary to take into account the effects of residual coil bends in plastic piping. (P-98-9)

--to the Gas Piping Technology Committee:

Revise the *Guide for Gas Transmission and Distribution Piping Systems* to include complete guidance for the proper installation of plastic service pipe connections to steel mains. The guidance should emphasize the need to limit pipe bending and should include a discussion of the proper design and positioning of a protective sleeve to limit stress at the connection. (P-98-10)

--to the American Society for Testing and Materials:

Revise ASTM D2774 to emphasize that a protective sleeve, in order to be effective, must be of the proper length and inner diameter for the particular connection and must be positioned properly. (P-98-11)

Develop and publish standard criteria for the design of protective sleeves to limit stress intensification at plastic pipeline connections. (P-98-12)

--to the American Gas Association:

Revise your *Plastic Pipe Manual for Gas Service* and your *Gas Engineering and Operating Practices* series to provide complete and unambiguous guidance for limiting stress at plastic pipe service connections to steel mains. (P-98-13)

--to MidAmerican Energy Corporation:

Modify your gas construction standards to require (1) firm compacted support under plastic service connections to steel mains, and (2) the proper design and positioning of protective sleeves at these connections. (P-98-14)

As a basis for the timely replacement of your plastic piping systems that indicate unacceptable performance, review your existing plastic piping surveillance and analysis program and make the changes necessary to ensure that the program is based on sufficiently precise factors such as piping manufacturer, installation date, pipe diameter, geographical location, and conditions and locations of failures. (P-98-15)

--to Continental Industries, Inc.:

Provide a means to ensure that the use of your protective sleeves with your tapping tees at plastic pipe connections to steel mains does not compromise corrosion protection for the connection. (P-98-16)

--to Continental Industries, Inc. (P-98-17):

--to Dresser Industries, Inc. (P-98-18):

--to Inner-Tite Corporation (P-98-19):

--to Mueller Company (P-98-20):

Develop and publish recommendations and instructions for limiting shear and bending forces at locations where your steel tapping tees are used to connect plastic service pipe to steel mains.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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April 23, 1998

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National Transportation Safety Board
Washington, D.C. 20594

Pipeline Accident Briet

Pipeline Accident Number:	DCA-95-MP-001
Type of System:	Gas distribution
Accident Type:	Explosion and Fire
Location:	Waterloo, Iowa
Date and Time:	October 17, 1994; 10:07 a.m. local
Owner/Operator:	Midwest Gas Company[1]
Fatalities/Injuries:	Six fatalities and seven non-fatal injuries
Damage:	$250,000
Material Released:	Natural Gas
Pipeline Pressure:	25 pounds per square inch, gauge (psig)
Component Affected:	1/2-inch plastic pipe at steel tapping tee mechanical compression connection to steel main

The Accident

At 10:07 a.m. central daylight savings time on Monday, October 17, 1994, a natural gas explosion and fire destroyed a one-story, wood frame building in Waterloo, Iowa. The force of the explosion scattered debris over a 200-foot radius.

Six persons inside the building died, and one person sustained serious injuries. Three persons working in an adjacent building sustained minor injuries when a wall of the building collapsed inward from the force of the explosion. The explosion also damaged nine parked cars. A person in a vehicle who had just exited the adjacent building suffered minor injuries. Additionally, two firefighters sustained minor injuries during the emergency response. Two other nearby buildings also sustained structural damage and broken windows.

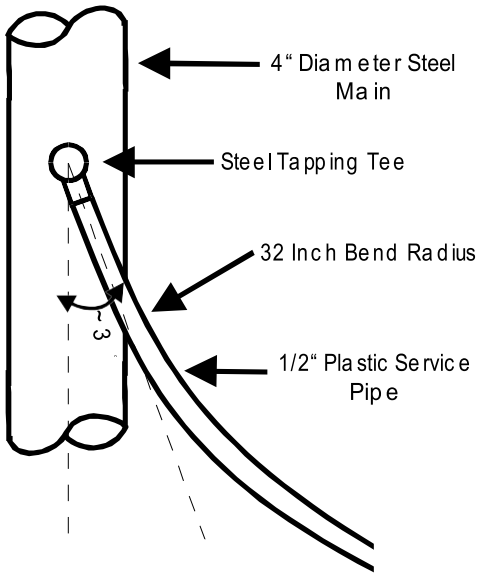
Site Information

The destroyed building was a neighborhood tavern known as Buzz's Bar. Adjacent to and east of the bar was Woodland Pattern Company, which was provided gas service by a 1/2-inch-diameter plastic polyethylene service pipeline. The service pipeline was installed by Iowa Public Service Company on September 3, 1971, and was operated at a maximum pressure of 25 psig.

[1]Because of a series of organizational changes and mergers, the name of the owner/operator of the gas system at Waterloo, Iowa, has changed over the years. In 1971, Iowa Public Service Company installed the gas service that ultimately failed. At the time of the accident, the gas system operator was known as Midwest Gas Company, while the current operator's name is MidAmerican Energy Corporation.

The underground pipeline connected with the steel gas main and entered the Woodland Pattern Company building between Buzz's Bar and the Woodland Pattern Company.

The area between Buzz's Bar and Woodland Pattern Company was unpaved and, according to those familiar with the location, was regularly used by beer trucks making deliveries to Buzz's Bar and by semitrailers delivering materials to Woodland Pattern Company. These trucks had been seen to drive over the area of the piping assembly that cracked. At various times, beer trucks servicing Buzz's Bar had been observed to park directly over the location of the pipe break. One witness stated that a beer delivery truck had been parked over the area of the pipe break at approximately 7:00 a.m. on the day of the accident.



Service-to-main connection at site of Waterloo accident.

Excavations following the accident uncovered a 4-inch-diameter steel main at a depth of about 3 feet. Welded to the top of the main was a steel tapping tee with markings indicating that the tee had been manufactured by Continental Industries, Inc. (Continental). Connected to the steel tee was a 1/2-inch-diameter plastic service pipe leading to Woodland Pattern Company. Markings on the plastic pipe indicated that it was a medium-density polyethylene material manufactured on June 11, 1970, in accordance with American Society for Testing and Materials (ASTM) standard D2513, and marketed by Century Utility Products, Inc. (Century). A circumferential crack through the plastic pipe was found at the tip of the tee's internal stiffener that protruded beyond the tee's coupling nut. A 1- to 2-foot-diameter "hard ball" surrounded the cracked pipe.[2]

Because Safety Board investigators did not arrive at the accident site until after excavation of the failed pipe, investigators had to consult several sources to determine the condition of the piping at the time of excavation. Photographs of the excavation, a Waterloo Fire Department video tape, and several witnesses all indicated that the downstream portion of the plastic pipe was found broken off and vertically displaced below the plastic pipe portion still attached to the steel tee. However, an Iowa State Fire Marshall's Office investigator, who directed and participated in the excavation, reported that the pipe was displaced by the excavation activities. That investigator also reported no observed voids in the soil under the failed assembly.

Service-to-main connection at site of Waterloo accident.

MidAmerican Energy estimated that the steel tee on the steel main was installed so that the polyethylene pipe exited the tee at an approximate 30° angle to the steel main. (See figure.)

[2]A "hard ball" is a term used in the gas industry for a soil condition where leaking natural gas over a period of time dries and hardens the soil adjacent to the leak.

The plastic service pipe leaving the tee immediately curved horizontally. After a portion of the pipe was taken to the laboratory for testing, the bend radius was measured at about 34 inches. Based on field conditions and photos, MidAmerican Energy has estimated the original installed horizontal bend radius to be approximately 32 inches.[3] This bend is sharper than currently recommended by industry guidelines for modern piping adjacent to fittings. However, a former Iowa Public Service Company employee stated that Iowa Public Service Company, in an effort to reduce the stress at the connection point, often attempted to install polyethylene services at an angle to the main to match the residual bend left after uncoiling the pipe.[4] This former employee stated that no set time was prescribed to allow for complete relaxing of the pipe, but that the pipe would be placed in the ditch, and the crews would weld the tee at what they judged to be the appropriate angle, in consideration of the natural bend of the pipe.

Also immediately from the tee outlet, the polyethylene bent downward. The tee outlet did not have a protective sleeve to reduce shear and bending forces at the connection.

Tests and Examination

Samples recovered from the plastic service line underwent several laboratory tests under the supervision of the Safety Board. Two of these tests were meant to roughly gauge the pipe's susceptibility to brittle-like cracking. These tests were a compressed ring environmental stress crack resistance (ESCR) test in accordance with ASTM F1248 and a notch tensile test known as a PENT test that is now ASTM F1473. Lower failure times in these tests indicate greater susceptibility to brittle-like cracking under test conditions. The ESCR testing of 10 samples from the pipe yielded a mean failure time of 1.5 hours, and the PENT testing of 2 samples yielded failure times of 0.6 and 0.7 hours. Test values this low have been associated with materials having poor performance histories[5] characterized by high leakage rates at points of stress intensification due to crack initiation and slow crack growth typical of brittle-like cracking.

To facilitate identification, the fracture surfaces were divided into two regions, A and B, around the circumference of the failed pipe. If a cross section of the pipe, looking toward the tee, were superimposed on a clock face, region A would extend from approximately the 9:00 position up across the top and down to about 1:30, with the center of the region at about 11:15. Region B took up the remainder of the pipe surface, extending from about the 1:30 position down across the bottom and up to 9:00.

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[3]Polyethylene pipe installed with a bend often, over time, permanently deforms in the direction of the bend. This permanent deformation partially reduces the stresses generated by the bending forces. When the pipe is released from its installation configuration, the pipe can straighten to some extent.

[4]MidAmerican Energy has indicated that Iowa Public Service's plastic service pipe was received in coils from Century. After uncoiling the pipe, some residual bending remains. The amount of residual bending depends on the factory coiling conditions.

[5]Uralil, F. S., et al., *The Development of Improved Plastic Piping Materials and Systems for Fuel Gas Distribution—Effects of Loads on the Structural and Fracture Behavior of Polyolefin Gas Piping*, Gas Research Institute Topical Report, 1/75 - 6/80, NTIS No. PB82-180654, GRI Report No. 80/0045, 1981, and Hulbert, L. E., Cassady, M. J., Leis, B. N., Skidmore, A., *Field Failure Reference Catalog for Polyethylene Gas Piping, Addendum No. 1*, Gas Research Institute Report No. 84/0235.2, 1989, and Brown, N. and Lu, X., "Controlling the Quality of PE Gas Piping Systems by Controlling the Quality of the Resin," *Proceedings Thirteenth International Plastic Fuel Gas Pipe Symposium*, pp 327-338, American Gas Association, Gas Research Institute, Battelle Columbus Laboratories, 1993.

The fracture in region A was located immediately outside the tee's internal stiffener. The crack was perpendicular to the pipe wall and directly in line with the end of the tee's internal stiffener. The inside surface of the pipe throughout region A was characterized by a circumferential impression from the tip of the tee's stiffener. A similar impression was not found in region B. This impression was only found on the pipe segment that was still attached to the steel tee, and was not evident on any part of the pipe segment that was detached from the steel tee. Region A was characterized by several brittle-like slow crack growth fractures, each of which initiated on or near the pipe inner wall just outside the depression associated with the tip of the tapping tee's stiffener. These slow crack fractures propagated on almost parallel planes slightly offset from each other through the wall of the pipe. As the cracks from different planes continued to grow and began to overlap one another, ductile tearing occurred between the planes, which produced a jagged appearance in parts of the overall circumferential crack in region A Thus, even though substantial deformation was observed in part of the fracture, the initiating cracks were still classified as brittle-like.

Region B contained two brittle-like crack growth sections that initiated from each end of region A. Cracks from each end of region A propagated through region B on approximate 45° planes towards the tee (partially exposing the tee's stiffener) and met at the bottom (the 6:00 position). The remaining ligament tore with visible deformation at the bottom.

Laboratory comparisons showed that the fractures that initiated and grew in region A were consistent with fractures generated by long-term shear and bending forces at the end of the stiffener. The fractures in region B were consistent with a continuation of the same loading system described for region A but occurred subsequent to those in region A. The last ligament that fractured at the 6:00 position in region B was consistent with ductile tearing. Examination could not determine whether the last remaining ligament tore because of concentrated stresses prior to the excavation or because of excavation activities after the accident.

Other Information

Flooding was reported in the area during the summer of 1993. Midwest Gas's most recent leak surveys, performed in March 1994, did not detect a leak in this area. Records of odorant tests performed in September 1994 and on October 17, 1994 (two and a half hours after the accident), show odorant levels that met the level required by Federal standards.[6]

Probable Cause

The National Transportation Safety Board determines that the probable cause of the natural gas explosion and fire in Waterloo, Iowa, was stress intensification, primarily generated by soil settlement at a connection to a steel main, on a 1/2-inch polyethylene pipe that had poor resistance to brittle-like cracking.

[6]Federal standards require the odorant in natural gas systems to be detectable at one-fifth of the lower explosive limit, which is typically at gas/air concentrations of 0.9 to 1.0 percent and above.

APPENDIX B

Organizations, Agencies, and Associations Referenced in this Report

American Gas Association (A.G.A.)
An organization dedicated to promoting and protecting the interests of its member natural gas local distribution companies. The A.G.A. has approximately 300 members, of which about 250 are natural gas local distribution companies.

American Society for Testing and Materials (ASTM)
An organization that provides a forum for producers, users, consumers, and others with a common interest, including representatives of government and academia, who come together to write standards for materials, products, systems, and services.

Gas Piping Technology Committee (GPTC)
An organization dedicated to the development of the *GPTC Guide for Gas Transmission and Distribution Piping Systems* (*GPTC Guide*). The purpose of the *GPTC Guide* is to provide assistance to gas pipeline system operators in complying with Federal regulations addressing the transportation of natural and other gases by pipeline.

Gas Research Institute (GRI)
A research, development, and commercialization organization dedicated to the interests of the natural gas industry. The organization's mission is to discover, develop, and deploy technologies and information that benefit gas customers and the industry.

Plastics Pipe Institute (PPI)
A manufacturers organization, the PPI is an operating unit of the Society of the Plastics Industry. Members of the PPI share a common interest in broadening market opportunities through the effective use of plastic piping in water and gas distribution, sewage and wastewater transport, oil and gas production, and in industrial, mining, power, communications, and irrigation applications.

Office of Pipeline Safety (OPS)
The Research and Special Programs Administration (see below) acts through the OPS to administer the U.S. Department of Transportation's national regulatory program to ensure the safe transportation of natural gas, petroleum, and other hazardous materials by pipeline. The OPS develops regulations and other mechanisms to ensure safety in design, construction, testing, operation, maintenance, and emergency response of pipeline facilities.

Research and Special Programs Administration (RSPA)
A part of the U.S. Department of Transportation, RSPA has responsibility for emergency preparedness, research and technology, and transportation safety. The agency's safety mandate is to protect the Nation from the risks inherent in the transportation of hazardous materials by all transportation modes, including pipelines. RSPA carries out its pipeline safety and training programs through the Office of Pipeline Safety (see above).

Hazard Analysis and Mitigation Report

Aldyl A Polyethylene Gas Pipelines

June 11, 2014

Hazard Analysis & Mitigation Report On Aldyl A Polyethylene Gas Pipelines in California

By

Steven Haine, P.E.
California Public Utilities Commission

With Technical Assistance Provided By

Dr. Gene Palermo
Palermo Plastics Pipe (P^3) Consulting

June 11, 2014

CONTENTS

About Hazard Analysis and Mitigation Reports

This paper is the first in a series of Hazard Analysis and Mitigation Reports. Prepared by the staff of the California Public Utilities Commission, the purpose of the Hazard Analysis and Mitigation Reports is to examine potential hazards in California gas and electric utility operations. The report seeks to understand each utility's approach to mitigate the risks posed by the hazard. The reports provide hazard-specific background knowledge and technical analysis.

A Hazard Analysis and Mitigation Report is premised on the theory that an inadequate risk assessment and management response to an otherwise moderately hazardous situation may well be more dangerous than an adequate response to an inherently more hazardous situation. Therefore, Hazard Analysis and Mitigation Reports will include recommendations to decision-makers for policy improvements and to the utility operators as to different types of best practices with respect to the particular hazard. The Commission's staff intends to have these reports serve as an important forward-looking tool to help prevent incidents from occurring.

INTRODUCTION

With heightened public awareness on gas pipeline safety in California, one topic that has received much public attention of late is the potential hazard associated with a type of polyethylene (PE) gas pipeline called Aldyl A. This is understandable, considering that one of the most devastating gas pipeline incidents, occurring on November 21, 1996 in San Juan, Puerto Rico, where thirty-three people were killed and at least sixty-nine were injured, was caused by a small slit fracture (Figure 1) on a small section of Aldyl A plastic gas service line.[1] This heightened awareness was further stoked by two gas incidents in Cupertino (Aug. 31, 2011) and Roseville (Sept. 27, 2011) that happened in quick succession involving Aldyl A pipes.[2,3] On March 14, 2012, early vintage Aldyl A pipes were identified as a major potential hazard affecting gas pipeline safety in a report prepared by the staff of the California Public Utilities Commission (CPUC).[4]

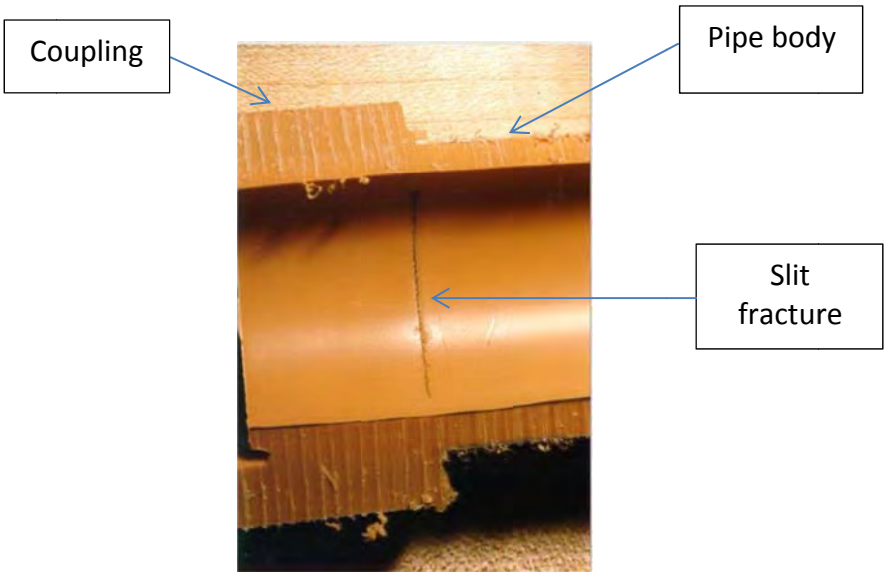

Figure 1: Enlarged view showing slit fracture on the interior of 1¼ Inch Aldyl A service pipe involved in the San Juan incident

[1] NTSB report on San Juan incident: http://www.ntsb.gov/doclib/reports/1997/PAR9701.pdf
[2] http://www.sfgate.com/news/article/Plastic-natural-gas-pipe-failure-data-kept-secret-2308629.php
[3] http://www.sfgate.com/bayarea/article/New-PG-E-blast-involved-problematic-plastic-2298864.php
[4] Risk Assessment Section Hazard Database Project, Report on Status and Initial Recommendations, March 14, 2012: http://www.cpuc.ca.gov/NR/rdonlyres/381B6603-37A4-48C0-A1B7-D4A56928F6CC/0/RiskAssessmentMarch2012ReportFINAL.pdf

As continuation of the effort initiated in the March 14, 2012 report, this paper examines the current status of the danger of potential failure due to slow crack growth associated with early generation Aldyl A PE pipes among major gas distribution operators under the CPUC's jurisdiction. This study encompasses the gas distribution operations of the Pacific Gas & Electric Company (PG&E), Southern California Gas Company (SoCalGas), San Diego Gas & Electric (SDG&E), Southwest Gas (SWG), and the propane system on Catalina Island owned and operated by Southern California Edison (SCE). The West Coast Gas Company and gas storage field operators are excluded from this study due to the absence of Aldyl A pipes from their systems. Municipalities, mobile home park gas systems, and small propane distribution systems are also excluded from this study.

The intent of this study is to examine the current inventory of Aldyl A pipes among the major California gas operators and the different strategies that these gas operators use to identify and mitigate the risks associated with older vintage Aldyl A pipes in order to see whether any common observations of deficiencies and recommendations for improvement can be made in order to enhance public safety. As part of the process, we examine the gas pipeline operators' knowledge of the extent of the problems posed by early vintage Aldyl A pipes and the adequacy of the operators' response.

HISTORY OF ALDYL A PIPES

This section describes the history and different vintages of Aldyl A pipes.[5]

Origin of the Aldyl A name

Aldyl® "A" is a trademarked name referring to a finished polyethylene pipeline product manufactured by the DuPont chemical company using DuPont's own proprietary Alathon®

[5] Information in this section was derived in large part from "Managing Aldyl 'A' PE Pipe in the Avista Natural Gas Distribution System" by Kristen Busko, Avista Utilities and Dr. Gene Palermo, Palermo Plastics Pipe Consulting.

polymer resin. (We will refer to it simply as Aldyl A throughout the rest of this paper.) Until the Aldyl A product line was acquired from DuPont by the Uponor company in 1991, no other manufacturers used this resin to produce pipelines under this or other trade names. The term pipeline in this context can refer to either the pipes or the fittings attached to the pipes made of an Alathon resin. This paper will deal with only Aldyl A products sold under the DuPont label.

The name "Aldyl" also has an interesting etymology. Prior to the introduction of Aldyl A pipes, the DuPont chemical company was manufacturing a bi-layer polyethylene/polyacetal pipeline product using Alathon polyethylene resin and Delrin® polyacetal resin. DuPont initially called this product "Aldel" as a portmanteau of **Al**athon and **Del**rin, in deference to the heritage of these two components in DuPont's product lines. To prevent confusion of "Aldel" with an existing trade name, "del" was changed to "dyl" and the trademark Aldyl® was born. In 1965, DuPont began to make gas pipes using PE only and called this pipe Aldyl® "A".

Vintage: 1965-1970

Aldyl A pipeline products were first introduced to the market in 1965. The initial PE resin from which Aldyl A was manufactured between 1965 and 1970 was Alathon 5040.

Vintage: 1970-1983

In 1970, DuPont discontinued the use of Alathon 5040 and began to manufacture Aldyl A pipes using an improved resin, Alathon 5043, due to the latter's higher density and resulting improved resistance to rupture. Alathon 5043 became the primary PE resin DuPont used to manufacture Aldyl A pipes from 1970 to 1983. It was also during this period that DuPont discovered during elevated temperature stress rupture testing that some Aldyl A pipe samples made of Alathon 5043 resin between 1970 and 1972 had what is now known as Low Ductile Inner Wall (LDIW) characteristics that resulted from excessive temperature settings during the extrusion process. This manufacturing issue affected only Aldyl A pipes made of Alathon 5043 resin during the 1970 to 1972 period and approximately 30% to 40% of pipes in this group were

affected. Samples with LDIW characteristics have an oxidized inner surface that predisposes the inner surface to initiate cracks faster. The resulting shortened crack initiation time leads to dramatically reduced overall pipeline longevity through a failure mechanism known as slow crack growth. There are no simple non-destructive tests that may be employed in the field to distinguish LDIW Aldyl A pipes from non-LDIW Aldyl A pipes. However, LDIW samples can be easily identified by a simple destructive testing procedure called a reverse bend test, in which a short cutout strip of pipe sample is bent sharply backwards. Samples with LDIW characteristics would show an immediate crazing pattern on the inner surface during the reverse bend test. When reviewing Aldyl A pipes of this vintage, visual inspection will not distinguish between LDIW and non-LDIW pipes due to their identical external appearance.

Another term often used in conjunction with the slow crack growth mechanism is "brittle-like cracking," which describes the relatively smooth fracture surfaces on a slowly growing crack as having the appearance characteristic of brittle fracture propagation. Compounding the problem of LDIW is the fact that Alathon 5043 resin has moderately low resistance to slow crack growth compared to later generation, improved Alathon resins.

Aldyl A PE pipes made by DuPont with LDIW characteristics are not the only plastic pipes with low resistance to slow crack growth. What sets the LDIW Aldyl A pipes apart from other types of plastic pipes with similarly low resistance to slow crack growth is that the brittle inner surface of LDIW pipes expedites crack initiation when external stresses are applied to the pipe. In polyethylene pipes, the crack initiation time typically accounts for 70% to 90% of the total time to failure upon application of a stress. Since the overall time to failure of a pipeline segment by slow crack growth is the sum of the crack initiation time and the crack propagation time, pipes with lower initiation time to crack formation, such as LDIW Aldyl A, would experience much higher rates of failure from slow crack growth. Aldyl A pipes made of Alathon 5043 with LDIW characteristics have a median projected time to failure only 1/10th that of Aldyl A pipes made of Alathon 5043 resin that have no LDIW characteristics.

Vintage: 1983-1988

In 1983, DuPont again changed the resin formulation, this time from Alathon 5043 to Alathon 5046-C. This new resin formulation offered an order of magnitude improvement in resistance to slow crack growth and long term performance over Alathon 5043. In accelerated stress testing in laboratory conditions, Alathon 5046-C offers a ten-fold increase in median time to failure over non-LDIW Alathon 5043. DuPont marketed Aldyl A pipes made of 5046-C as "Improved Aldyl A."

Vintage: 1988-1992

In 1988, DuPont offered yet another improvement in the Alathon series of resins, changing from Alathon 5046-C to Alathon 5046-U. This improved resin offered yet another ten-fold increase in median time to failure over its predecessor under accelerated stress testing conditions. Alathon 5046-U was also sold as "Improved Aldyl A." Aldyl A pipes made of Alathon 5046-U continued from 1988 to 1992.

Vintage: 1992-1999

The last improvement in the Alathon resin series occurred in 1992, when DuPont switched from Alathon 5046-U to Alathon 5046-O. Alathon 5046-O offered at least a three-fold improvement in median time to failure over its predecessor.

Table 1: Different Vintages and Resins of Aldyl A

Approximate Years of Manufacture	Alathon Resin	Relative Resistance to Slow Crack Growth
1965-1970	5040	Low
1970-1972	5043, LDIW	Low
1970-1983	5043, non-LDIW	Medium
1983-1988	5046-C	Medium High
1988-1992	5046-U	High
1992-1999	5046-O	Very High

TYPICAL FAILURE MODES

As is true with most plastic pipes, Aldyl A pipes can fail by one of three failure modes:[6]

1. Rapid Crack Propagation;
2. Ductile Rupture;
3. Slow Crack Growth.

Rapid crack propagation is a rare phenomenon, which usually occurs when a pipe is subjected to a rapid external stress, such as from a sharp blow on the pipe. There are on average only a handful of rapid crack propagation failures a year in the entire country. Once a failure occurred, the event would be immediately known by reports of loss of service and there would be little opportunity for the leaking gas to evade detection and to migrate into structures over a prolonged period of time. Ductile rupture is also somewhat rare as it occurs when a pipeline is significantly over-pressurized above its maximum allowable operating pressure due to the malfunction of a pressure regulating device or incorrect operating procedures. The root cause of such overpressure events would be the failure of a pressure regulating device and not a failure of the pipe material itself. Slow crack growth failure is characterized by crack initiation and propagation that occur over many years at relatively low loads below the yield point of the material. Slow crack growth failures are characterized by brittle (slit) fracture surfaces that exhibit very little ductile deformation.

While Aldyl A pipes can also fail due to improper joinings, this would be a problem associated with improper installation rather than a material defect. Likewise, third-party damage would have nothing to do with material failure. For all these reasons, this report elects to focus on the danger associated with slow crack growth, since it disproportionally affects early vintage Aldyl A

[6] Gas Technology Institute, "Plastic Pipe Failure, Risk, and Threat Analysis", Final Report, April 29, 2009.

pipes over other polyethylene gas pipeline materials and this is the mode of failure that has the most potential to cause significant property damage, injuries, or fatalities.

FACTORS CONTRIBUTING TO SLOW CRACK GROWTH ON ALDYL A PIPES

Slow crack growth begins when a microscopic defect in the pipe behaves as a stress concentrator when a force is exerted against the defect and enables this defect to grow in response to the stress. Internal pressure is the primary internal stress and field applied loads are sources of external stresses. Typical external stress on plastic pipelines can arise from impingement points due to rocky soil fill; bending or contraction forces arising from differential earth settlement or seismic activity, frost heave, or pipe bending beyond manufacturer's recommended maximum allowable curvature; different expansion/contraction rates of dissimilar materials between a fitting and a pipe body; stress exerted on the pipeline by tree roots; and stresses created when a fitting is fused by heat to a pipe body, where the joining interface may act as a stress intensifier due to geometric discontinuities. Likewise, dents and gouges on the pipe wall caused by installation or excavation damage can also act as external stress intensifiers.

SEVERAL EARLY WARNINGS

Letters from DuPont

Letter 1, December 17, 1982: Based on several instances of slit fracture on pre-1973 LDIW Aldyl A pipes subjected to rock impingement, DuPont issued the first letter to its Aldyl A customers warning of this danger. The letter urges operators to consider performing more frequent leak surveys on Aldyl A purchased before 1973. The letter also warns against installation procedures which would result in rock impingement on the pipes.

Letter 2, August 25, 1986: Data derived from the Rate Process Method indicating a shortened expected pipe life due to proper squeeze-offs in LDIW Aldyl A pipes prompted DuPont to issue another warning letter in 1986. The letter suggests the use of reinforcement clamps (now

commonly referred to as "collars") to mitigate this hazard. The letter further suggests that collars are effective in preventing slow crack growth at squeeze-off points.

NTSB investigative report

Prompted by the Century Utility Products pipe tragedy in Iowa and other incidents across the country involving plastic pipes that failed by brittle-like cracking through slow crack growth, the National Transportation Safety Board (NTSB) in April, 1998 released a special investigative report on the danger of "**BRITTLE-LIKE CRACKING IN PLASTIC PIPE FOR GAS SERVICE."** [7,8] Two major conclusions in the report are: 1) much of plastic pipelines manufactured from the 1960s through the early 1980s may be susceptible to brittle-like cracking (by slow crack growth) and 2) manufacturers may have over-rated the strength and resistance to brittle-like cracking of their plastic pipeline products.

PHMSA safety advisories

In response to findings in the NTSB investigative report, the Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a series of safety advisories on the danger of brittle-like cracking on 1960s to 1983 vintage plastic pipes. The first advisory was ADB-99-01, which specifically targeted pipes made by Century Utility Products from a Union Carbide resin. This was followed by ADB-99-02 that more generally applied the advisory to all 1960s to 1983 vintage plastic pipes (DuPont changed from Aldyl A to Improved Aldyl A in 1983). This in turn was followed by ADB-02-07a in 2002 that for the first time specifically identified "Low-ductile inner wall 'Aldyl A' piping manufactured by DuPont Company before 1973", along with PE 3306 pipes and Century pipes, as being susceptible to brittle-like cracking. In 2007, PHMSA released safety advisory ADB-07-01, which added Delrin® polyacetal inserts in DuPont service tees and Celcon® polyacetal caps in Plexco service tees as components susceptible to brittle-like cracking.

[7] NTSB Iowa incident report: DCA-95-MP-001, http://www.ntsb.gov/doclib/reports/1998/PAB9802.pdf
[8] NTSB Special Investigative Report: PB98-917001, NTSB/SIR-98/01, http://www.ntsb.gov/news/events/1998/SIR-98-01/index.html

DESCRIPTION OF UTILITY SYSTEMS

Commission Staff inquired of each natural gas utility in California about how many miles of Aldyl A pipes it has operating in its service territory. When records were available, that information is presented by installation year. While not a perfect overlay, this is the best proxy for vintage of pipeline to diagnose slow crack growth concerns.

Table 2: Current Miles of Aldyl A Mains by Installation Year

Installation Year	PG&E	SoCalGas	SDG&E	SWG (California)	SCE
1965-1972	700	655	188	0	0
1973-1985	3,708	38	6	32	0.3
Unknown manufacturer or installation year	180	7,913	1,435	N/A	N/A

Notes:
1. The year ranges in the table are intended to segregate the early vintage Aldyl A pipes with low resistance to slow crack growth from those that have medium resistance to slow crack growth. The cutoff year of 1985 is slightly arbitrary but is intended to capture most of the Alathon 5043, non-LDIW pipes taking into account the time lag between manufacturing year and installation year.
2. PG&E's mileage of Aldyl A pipes in the table includes both Aldyl A and TR-418 pipes.
3. SoCalGas' mileage of Aldyl A pipes with unknown manufacturer or installation year includes both Aldyl A and other types of PE pipes.

Pacific Gas & Electric (PG&E)

Records from PG&E indicate that between 1965 and 1991, PG&E installed plastic pipes manufactured by DuPont, Nipak, Phillips Driscopipe, Plexco and CSR/PolyPipe. It was only in the 2011 to 2012 timeframe that PG&E began in earnest to determine the extent of its inventory of Aldyl A pipes. It was, and remains so to this day, the practice of PG&E to include installation date and the type of pipe, such as polyethylene vs. steel, but not resin type or pipe manufacturer. This makes precise determination of resin type, manufacturing date, and manufacturer by location and by mileage practically impossible. In the miles of Aldyl A mains table above, the figures are in fact not only for Aldyl A pipes but combined miles of both Aldyl A and TR-418 pipes. In PG&E's case, the unknown number of miles (180 miles in the table) refers

to the number of miles of plastic mains that have no recorded entry for installation year. The state of the records is such that it is no longer possible to pinpoint precisely for each location whether a certain underground main is of Aldyl A, TR-418 pipes, or perhaps some other types of PE pipes. This means the actual number of unknown pipes could be much bigger than the 180 miles shown in the table. In an effort to be conservative to capture all Aldyl A pipes, PG&E labeled all PE installations in this period as Aldyl A. Likewise, in order to capture all LDIW Aldyl A pipes, PG&E labelled all installation jobs from 1970 to 1974 as potentially LDIW Aldyl A.

PG&E was also unable to provide records for the number of Aldyl A services connected to steel mains or the number of squeeze-off points without collars. PG&E does not routinely document Aldyl A or LDIW when excavation is performed on an existing pipe. It is also not standard practice to send cutouts to a laboratory for analysis.

PG&E has a dedicated Aldyl A pipeline replacement program that is discussed in detail in its general rate case filing. PG&E uses a pipe segmentation risk ranking methodology where each pipe segment is ranked and prioritized for replacement. With the help of a consultant, PG&E developed a risk ranking program specifically to target its Aldyl A pipeline segments.

Sempra Utilities (SoCalGas and SDG&E)

Due to common ownership by Sempra Utilities, SoCalGas and SDG&E share the same gas operation and maintenance procedures. Sempra's uncertainty with its inventory of Aldyl A pipes mirrors the problem facing PG&E. Sempra has a category of "unknowns" that is far larger than its inventory of known Aldyl A pipes. The unknowns could be Aldyl A, TR-418, or some other types of PE pipes. In other words, the actual inventory of Sempra's earlier vintage Aldyl A pipes could be substantially different from the numbers reported. Sempra has no knowledge of any LDIW pipes because no efforts were made to document LDIW pipes until the 2011 to 2012 timeframe. It is also not customary for Sempra to send cutout sections to laboratories to determine whether a failed segment has LDIW characteristics, nor are reverse bend tests performed in the field. Hence Sempra has no knowledge of any LDIW pipes still within its vast

system. Sempra does not have a dedicated program to replace Aldyl A pipes. Sempra also uses a pipe segmentation risk ranking methodology where each pipe segment is ranked and prioritized for replacement. Sempra further uses a normalization methodology to combine the risk ranking for plastic segments with the risk ranking for steel pipes segments to arrive at a combined ranking. Sempra does not have a pipeline replacement program dedicated to Aldyl A pipes.

Southwest Gas (SWG)

Of all SWG's California service territories, Aldyl A exists only in the South Lake Tahoe system that was acquired from Avista Utilities in 2005. According to SWG, it has only a small portion of Aldyl A pipes. In its latest general rate case application (A.12-12-024), SWG proposes to replace all its known Aldyl A pipes by 2018. This paper takes no position on the proposed accelerated Aldyl A replacement plan.

SWG further states that many of the records pertaining to its South Lake Tahoe assets were not transferred to SWG when it acquired the system. Within the category of pipes that SWG considers to be Aldyl A, SWG has been unable to determine the pipe classifications, such as ASTM 2306.[9] It is therefore entirely likely that its actual inventory of Aldyl A pipes could be substantially different from that reported.

SWG does not habitually track resin type, manufacturing date, lot number, or manufacturer. SWG does not use a pipeline segmentation process as do PG&E and Sempra. Instead, SWG manages each potential threat affecting a pipeline separately by using a program called SHRIMP, which stands for Simple, Handy, Risk-based Integrity Management Plan, developed by the American Public Gas Association to rank threats. Aldyl A is included as a threat category in the SHRIMP program.

[9] ASTM stands for American Society for Testing and Materials.

Southern California Edison (SCE)

Although primarily an electric-only company, SCE operates a low pressure propane system on Catalina Island running at less than 6 psig. SCE reports that there have been no failures associated with Aldyl A pipes on Catalina Island. The fact that it is low pressure significantly reduces the occurrence of some of the failure modes where slow crack growth originates from the inside of the pipe. Due to the small size of SCE's Catalina Island system, the problem of uncertainty of the inventory of Aldyl A pipes is much less severe. SCE does not track resin type, manufacturing date, and manufacturer. However, sufficient records exist for SCE to determine that Aldyl A pipes were installed at only one development between 1974 and 1976. Similar to SWG, SCE also uses SHRIMP to aid in its gas distribution integrity management.

Table 3: PHMSA Advisories Warning of Brittle-like Cracking

Year	Advisory	Pipeline Products Targeted in Advisory	Warnings	Key Recommendations
1999	ADB-99-01	Pre-1973 pipes sold by Century Utility Products made from a Union Carbide DHDA 2077 Tan resin	Warns of brittle-like cracking	Recommends identification of all such Century pipes subject to brittle-like cracking. Advisory further advises against repair procedures that rely on pinching (squeeze-off) for isolating sections of Century pipes.
1999	ADB-99-02	Plastic pipes installed between 1960 and the early 1980s	Warns of potential susceptibility to brittle-like cracking. Advisory further warns that rupture testing standards may have overrated the long-term resistance to brittle-like cracking.	Recommends operators to identify all pre-1982 plastic pipe installations, analyze leak histories, and evaluate any conditions that may impose high stresses on the pipe.
2002	ADB-02-07 ADB-02-07a	1. Century products 2. pre-1973 LDIW Aldyl A 3. pipes with PE 3306 designation	Warns of premature brittle-like cracking caused by rock impingement, shear/bending stresses, and squeeze-off	1. Use records to help identify locations of pipelines susceptible to brittle-like cracking. 2. Establish process to identify brittle-like cracking failures, 3. Use consistent format to collect data on system failures. 4. Collect samples of failed polyethylene piping exhibiting brittle-like cracking for possible lab analysis. 5. Record print line information from failed pipes. 6. For systems with no record of the piping material, consider recording print line data when piping is excavated for other reasons.
2007	ADB-07-01	Advisory adds Delrin insert tap tees; and Plexco service tee Celcon (polyacetal) caps to list of products identified in ADB-02-07/ADB-02-07	Not applicable	Not applicable

MEAN-TIME-TO-FAILURE FOR DIFFERENT VINTAGES UNDER DIFFERENT STRESSES

An effective way to measure the resistance of a piece of pipe against failure due to any type of applied stress is to measure its Mean-Time-to-Failure (MTTF) when subjected to such stress. MTTF is a measure of the average time before the first failure under constant application of this stress. MTTF projections due to slow crack growth for the different vintages and formulations of Aldyl A pipes can be obtained from accelerated testing methods. One of the most well-known accelerated testing methods for plastic pipes is the Rate Process Method, which relies on using elevated temperatures and pressures on a population of sufficiently large samples to predict the MTTF of PE pipes in the ground operating at normal temperatures and pressures under various stress factors, such as rock impingement, squeeze-off, bending, and deflection.[10,11,12] For each type of stress under consideration, the Rate Process Method fits the experimental failure points of time, temperature, and pressure to a linear function of the form:

$$\text{Log } t = A + B/T + C \text{ Log } (P)/T$$

Where:

t = slit failure time in hours due to a particular type of stress under consideration

T = temperature of pipe wall in degrees, Kelvin

P = hoop stress, or pressure, psig

A, B, and C are curve fitting constants

The results obtained from the Rate Process Method will be applied to this study. MTTF data for different vintages of Aldyl A pipe and TR-418 pipes obtained from the Rate Process Method

[10] E. F. Palermo, "Rate Process Method as a Practical Approach to a Quality Control Method for Polyethylene Pipe", Eighth Plastic Fuel Gas Pipe Symposium, New Orleans, November, 1983.

[11] E. F. Palermo, "Rate Process Concepts Applied to Hydrostatically Rating Polyethylene Pipe", Ninth Plastic Fuel Gas Pipe Symposium, New Orleans, November, 1985.

[12] E. F. Palermo, "Correlating Aldyl 'A' and Century PE Pipe Rate Process Method Projections With Actual Field Performance", AGA Operations Conference, 2004.

have been furnished by Dr. Gene Palermo of Palermo Plastics Pipe (P^3) Consulting and are summarized below for an illustrative scenario of a 2" O.D. main, operating at 60 psig and 70 ˚F:

Table 4: Projected Mean-Time-To-Failure (years) by Rate Projection Method

Pipe size: 2" O.D.									
Pressure: 60 psig									
Temperature: 70 ˚F									
		Confidence Levels							
		50%		70%		90%		98%	
Stress Type	**MTTF**	**Low End**	**High End**	**Low End**	**High End**	**Low End**	**High End**	**Low End**	**High End**
LDIW 5043, indented (rock impingement)	**12**	11	14	10	15	**9**	**16**	8	18
LDIW 5043, squeezed	**21**	16	27	14	31	**11**	**40**	8	53
LDIW 5043, control	144	117	178	104	200	86	243	69	304
non-LDIW 5043, multi saddle	2,291	1,414	3,711	1,087	4,827	691	7,601	404	13,005
non-LDIW 5043, indented (rock impingement)	**71**	44	115	34	149	**22**	**235**	13	404
non-LDIW 5043, control	1,318	1,082	1,604	973	1,784	813	2,135	663	2,618
5046, multi saddle	5,292	3,863	7,250	3,248	8,622	2,395	11,696	1,647	17,005
5046, control	8,094	3,974	16,487	2,701	24,251	1,394	46,990	645	101,506
TR-418 pipe, control	7,474	3,291	16,973	2,106	26,532	973	57,411	391	143,047
TR-418 socket tee, control	250	104	603	64	978	27	2,299	10	6,600

In Table 4, "control" refers to pipe samples that were not subjected to any external stresses such as rock impingement or squeeze-off. The only stress factors acting on the "control" population were the elevated temperature and pressure.

Precise MTTF data obtained from the Rate Process for the earliest vintage of Aldyl A pipes using Alathon 5040 resin are unavailable, but leak rate data from this vintage show comparable failure rates for Alathon 5040 and LDIW Aldyl A pipes.

The primary conclusion from the RPM data as shown in Table 4 is that there are three main waves of failures within the population of all Aldyl A pipes that should be of more immediate concern to an operator. Other waves are expected to occur far enough into the future that they will not be discussed in this paper, on the assumption that all such Aldyl A pipes will have been replaced far in advance of the expected mean times to failure.

Table 5 below shows the pronounced effect of lower operating pressures on the MTTF projections. As the operating pressure is decreased, the MTTF is increased and the confidence interval also widens.

Table 5: Effects of Different Operating Pressures on Projected MTTF (in years)

Pipe size: 2" O.D.								
Temperature: 70 ˚F								
			Confidence Levels					
			50%		70%		90%	
Stress Type	**Pressure**	**MTTF**	**Low End**	**High End**	**Low End**	**High End**	**Low End**	**High End**
LDIW 5043, indented (rock impingement)	40 psig	**20**	18	23	17	25	**15**	**28**
	50 psig	**15**	14	17	13	19	**12**	**21**
	60 psig	**12**	11	14	10	15	**9**	**16**
LDIW 5043, squeezed	40 psig	**50**	37	69	31	82	**23**	**110**
	50 psig	**31**	23	41	20	48	**15**	**63**
	60 psig	**21**	16	27	14	31	**11**	**40**
non-LDIW 5043, indented (rock impingement)	40 psig	**115**	67	195	50	261	**30**	**432**
	50 psig	**88**	54	146	41	192	**25**	**308**
	60 psig	**71**	44	115	34	149	**22**	**235**

With the exception of SCE's low-pressure system on Catalina Island, all operators have a significant percentage of polyethylene pipelines operating at different pressures according to the approximate profile below:

Table 6: Approximate Operating Pressure Profiles of Polyethylene Pipelines

Operating Pressure	PG&E	Sempra	SWG (California)	SCE
<7	n/a	n/a	0%	100%
<40	6%	7%	3%	0%
40 to 49	15%	22%	63%	0%
50 to 54	36%	30%	0%	0%
55 to 60	43%	41%	34%	0%
Total	100%	100%	100%	100%

Note: Pressure profiles for PG&E and Sempra were derived from historical gas incidents reported to the CPUC and are only representative of their current actual pressure profiles. The actual pressure profiles will differ slightly from these figures.

Table 7 below is obtained by combining Tables 1, 4, and 5 and by recognizing the maximum 3-year difference between manufacturing date and installation date:

Table 7: Projected Year in which Failure Would Occur for Different Pressures

Pipe size: 2" O.D.								
Temperature: 70 ˚F			Confidence Levels					
			50%		70%		90%	
Stress Type	**Pressure**	**Peak Year**	**Beginning Year**	**End Year**	**Beginning Year**	**End Year**	**Beginning Year**	**End Year**
LDIW 5043, indented (rock impingement)	40 psig	1993	1988	1998	1987	2000	1985	2003
	50 psig	1988	1984	1992	1983	1994	1982	1996
	60 psig	1985	1981	1989	1980	1990	1979	1991
LDIW 5043, squeezed	40 psig	2023	2007	2055	2001	2068	1993	2096
	50 psig	2003	1993	2027	1990	2034	1985	2049
	60 psig	1993	1986	2013	1984	2017	1981	2026
non-LDIW 5043, indented (rock impingement)	40 psig	2093	2037	2181	2020	2247	2000	2418
	50 psig	2067	2024	2132	2011	2178	1995	2294
	60 psig	2050	2014	2101	2004	2135	1992	2221

For the illustrative case of 2” O.D. pipe, operating at 60 psig and 70 ˚F, the first wave of pipe failure arises from rock impingement on LDIW Aldyl A pipes made of Alathon 5043 resin. Recall that LDIW Aldyl A pipes were manufactured from 1970 to 1972 and installed from 1970 to 1975. The installation date range differs from the manufacture date range due to time lag introduced by product delivery and storage of inventory at an operator’s yard before the product was installed in the ground. There was typically up to a one year time lag due to delivery and up to two years between receipt of delivery and installation in the ground. Since the operators in this study only tracked installation dates and did not record the manufacture dates of their batches of pipelines, it is logical to add three years to the vintages in order to arrive at some conservative interval to bracket the at-risk pipelines. The MTTF of this first wave is 12 years at 60 psig and 70 ˚F with a 90^{th} percentile range for a failure event to occur between of 9 years to 16 years. In other words, for pipelines that would eventually fail due to rock

impingement, there is a 90% probability that the failure would occur between 9 years and 16 years after initiation of the stress due to rock impingement, with average time to failure of 12 years. We caution that the previous statement should not be misinterpreted to imply that 90% of all LDIW Aldyl A pipe made of Alathon 5043 resin that are subjected to rock impingement will fail between 9 years and 16 years. The correct interpretation should be that of the very small sub-population of all LDIW Aldyl A pipes made of Alathon 5043 resin that would eventually fail due to rock impingement, 90% of the failures would occur between 9 years and 16 years at 60 psig and 70 ˚F. This distinction is important because not all Aldyl A pipes are subjected to rock impingement and, more importantly, a rock impingement has to be severe enough and be fortuitous enough to apply stress on a microscopic defect on the brittle inner wall to lead to initiation of slow crack growth in order for a failure to eventually occur. Since the last of this vintage of LDIW Aldyl A pipes was installed in around 1975 (1972 manufacturing date + three years due to depletion of inventory), the 90th percentile to affect this wave occurred between 1979 and 1991, with a peak at around 1985. Except for some short isolated sections of the population where the soil might have been disturbed again due to leak repairs, the wave of leaks should be substantially behind us. Even in cases where the soil might have been freshly re-disturbed, due to new excavation activity, the type of fill used would be expected to conform to new specifications to minimize stress due to rock impingement. To put it differently, if a LDIW Aldyl A pipe were subjected to rock impingement, initiation of a microscopic defect leading to slow crack growth and ultimate pipe failure would either not occur at all or, if it did, it would have likely occurred years ago, with the vast majority of such cases occurring before 1991. From a modeling standpoint for this illustrative scenario of a 2” O.D. main, operating at 60 psig and 70 ˚F, there should be few new cases of leaks due to slow crack growth caused by rock impingement in LDIW Aldyl A pipe. However, as Table 4 and Table 6 show, lower operating pressure can delay the onset of this wave as well as other waves.

Likewise, the second wave of failures peaking at 21 years for the illustrative scenario arises from stress concentration due to squeeze-off operations on the LDIW subpopulation of Aldyl A made of Alathon 5043 resin. Squeeze-off operations are typically employed to perform leak

repairs. Of the three waves, this wave is potentially the most long-lived because the clock starts not from the time the pipe is laid in the ground, but at any time a squeeze-off is applied after installation. Each time a leak is repaired, squeeze-off points are introduced and the clock starts counting down to the 90% confidence level of time to failure between 11 years and 40 years after the squeeze-off operation. An important moderating factor affecting this wave is that slow crack growth arising from squeeze-off applies only to the very tiny fraction of LDIW Aldyl A pipelines that were ever subjected to a squeeze-off operation and not to all LDIW Aldyl A pipes in general, as is the case with rock impingement.

As a result of the 1986 letter from DuPont, operators began to install reinforcement clamps, termed a "collar," over squeeze-off points in an attempt to restore the sections to a more circular shape in order to lessen the concentration of stresses at the squeezed points. Collars were also effective in lessening the chances of a squeeze-off point from failing due to slow crack growth. Since collars were not generally used on squeeze-off points at least prior to 1987, perhaps even later, it is reasonable to conclude that all the pre-1987 squeeze-off points are at risk of potential failure. At the 70% confidence level of 14 to 31 years, the upper range will end in 2017. At the 90% confidence interval of 11 years to 40 years, this wave will not end until 2026.

This second wave could potentially be even longer depending on when an operator began to adopt the use of collars as a mandatory procedure after a squeeze-off operation. The only certain inference one can reasonably draw is that there is a large legacy of pre-1987 leak repairs where squeeze-offs were performed without the use of collars that are now at risk of failure, although these are now at the tail end of this wave. Again, a lower operating pressure could significantly delay the onset of this second wave.

It should be noted that stress due to rock impingement occurs far more frequently than from squeeze-offs. Each contact point with a sharp rock is a potential initiation point, whereas a pipe segment has to have been squeezed to face the risk of failure due to squeeze-off.

Lastly, the third wave of failures at a MTTF of 71 years for the illustrative scenario arises from rock impingement on Aldyl A pipes made of Alathon 5043 resin that are free of LDIW characteristics. These were pipes that were manufactured from 1970 to 1983 and were generally installed from 1970 to 1986. The 90% confidence interval of failure times ranges from 22 years to 235 years. This wave began to rise slowly in 1992, steadily climbing to a plateau around 2012. This plateau is the extended weak peak for this wave and it will remain sustained close to this weak peak for close to the next hundred years due to the very large standard deviation of this wave.

In this section we only highlighted pipe failures due to rock impingement and squeeze-off, but earth settlement can also lead to slow crack growth. In fact excessive earth loading has resulted in almost 13% of all Aldyl A pipe and fittings failures according to anonymous data collected by the Plastic Pipe Data Collection Committee of the American Gas Association (AGA). [13] The AGA data further show that failures due to fittings account for almost 50% of all leaks on Aldyl A pipelines. Aldyl A fittings susceptible to failure include Delrin® polyacetal inserts in DuPont service Tees, Aldyl A Tees, Aldyl A saddles, and Aldyl A couplings.

With accurate knowledge of Aldyl A pipeline assets, including information on the amount of pipes installed by year and by manufacturing vintage, it is possible to construct mathematical models to predict the number of future failures by year due to each mechanism for each respective vintage of Aldyl A pipe by using the relevant MTTF data. Doing so would require making many simplifying assumptions and the need to blend these assumptions with actual operator-specific experience. This is a level of complexity we will not get into in this paper, particularly in light of the great uncertainties surrounding the quality of data provided by the operators. Instead, we will put the onus on the operators on how to prudently deal with data uncertainties caused by poor material traceability and poor asset knowledge in formulating a credible and cost effective risk management strategy.

[13] Plastic Piping Data Collection Initiative Status Report, March 27, 2013, Appendix D.

EXTRA SCRUTINY ON EARLY VINTAGE ALDYL A IS WARRANTED

We are mindful that proper risk management should examine all identified hazards in concert and deal with the hazards in relation to one another. Given the unique combination of factors facing the challenge of managing the risk presented by Aldyl A pipes, the extra scrutiny accorded older Aldyl A pipes is warranted.

First, slow crack growth on Aldyl A pipes fundamentally poses a high level of risk due to the abrupt nature of leaks created by this mode of failure. Unfortunately, more frequent leak surveys do not sufficiently mitigate the risk posed by slow crack growth on early vintage Aldyl A pipes to the point where this risk will become manageable.

When a PE pipe fails by slow crack growth, the crack can propagate either from the inside of a pipe to the outside or from the outside of the pipe and propagate to the inside, depending on the source of stress and the failure mechanism. In the 1996 San Juan incident, the crack propagated from the external side to the internal side. This crack was caused by bending stress acting on a stress intensification area created by the notched area between the coupling and the pipe body (Figure 1 on Page 4). The NTSB investigation revealed that the slit on the external side of this crack (entry side) measured only 1/4" in length, but by the time the crack propagated to the internal side (exit side), the crack had fanned out to create an exit measuring approximately 1" in length. This fanning characteristic of a small crack entry broadening significantly to a long exit crack is typical of slow crack growth propagation on PE pipes and explains much of the potential danger associated with all PE pipes with a weak resistance to slow crack growth and not just early vintage Aldyl A pipes.

Until a crack breaches the opposite side of a pipe wall, there will be no indication of a slowly developing crack. The crack might have taken many years to propagate from the initiation side to the exit side, but when this crack finally breaches the exit surface it will develop into a long exit crack in a very short time. A sufficiently long crack will have a large enough cross-section

area to allow gas to escape with a sufficient flow rate to migrate into structures and accumulate dangerously, but the flow rate will not be so high, as in a complete pipe rupture, for residents and bystanders to reliably detect the leaking gas by their sense of smell. The smaller entry crack limits the throughput of gas escaping through a breached crack, but even a small ¼" long entry crack, as that found on the pipe in the San Juan incident, was sufficient to produce a leak rate of 102 cubic feet an hour.[14] This leak rate was sufficiently small so as to evade timely and reliable notice by residents and bystanders, but sufficiently large to migrate underground and accumulate in the structure and cause the explosion. The abruptness of the failure from no flow to sufficient flow to cause undetected danger simply cannot be reliably caught in a timely manner by even annual leak surveys. This is what makes PE pipes with low resistance to slow crack growth so potentially dangerous and early vintage Aldyl A pipes fall in this category.

Second, California Gas operators have poor historical documentation of resin type, manufacturing date, and manufacturer, and other relevant pipeline asset information to aid in material traceability. It was common practice, and in fact remaining so to this day, for operators to document only installation dates and types of pipe material (i.e. polyethylene vs. steel, etc.), without specifying the manufacturer, trade name, resin type, and other relevant information to aid in material traceability and enhanced asset knowledge. For example, records of California operators in this study would only indicate an installation is of polyethylene pipes, but not whether it is Aldyl A PE pipes. In some cases operators rely on "tribal knowledge" to keep information alive, but this method is short-term since key personnel routinely retire.

A risk management program is only as effective as the accuracy and specificity of the input data into the program. From 1965 to the mid-1980s, California gas operators installed both Aldyl A PE pipes and other types of PE pipes. With poor asset knowledge of whether a particular installation during this period was of Aldyl A or some other PE pipes, a conservative approach is to assume all PE pipe installations during certain years are the more leak-prone Aldyl A pipes.

[14] Per NTSB report.

This conservative approach, while sound from a risk assessment point of view, has tremendous cost implications since it could unnecessarily force early retirement of the less leak-prone non-Aldyl A PE pipes.

Additionally, mathematical models based on Aldyl A leak rate data would yield unreliable results due to commingling of the mileage and leak data between Aldyl A and non-Aldyl A pipes.

DISCUSSION

The danger associated with older vintage Aldyl A pipes highlights the need for better records for material traceability and asset knowledge. Asset knowledge and material traceability were issues dating from the days of paper-based records and will remain so when these paper records are transferred into computerized format. All the operators examined by us have a sizable quantity of pipes with unknown manufacturing dates, unknown resin types, unknown lot numbers, or even unknown manufacturer sources. Without more robust material traceability to know with a great degree of certainty what assets are in the ground, risk assessment and risk mitigation strategies will be at best enormously expensive and at worst ineffective. Even going forward, some of these operators still have no plans to collect these types of information as they are not required to do so by pipeline regulations.

Operators should adopt opportunistic identification as a standard practice to determine whether an exposed pipe segment is of Aldyl A or some other PE pipes. If the pipe is Aldyl A efforts should be made to determine whether it is of LDIW type by a simple reverse bend test in the field whenever sections are cut out. On Aldyl A pipes, operators should also use opportunistic identification to record stress intensifiers, including squeeze-off points without collars and rocky soil fills that may cause rock impingent failures, as well as others. At present, California gas operators do not rely on opportunistic identification as a standard practice to help verify their inventory of Aldyl A pipes, nor do they identify the type of fill that might point to potential rock impingement issues.

Provided operators have good knowledge of their inventory of Aldyl A pipes, the hazard associated with Aldyl A is not necessarily unmanageable, but where operators have poor knowledge of their physical assets, then all the mitigation strategies become an unpredictable venture. Even in the best of circumstances when the operators have good knowledge of their Aldyl A assets, they are still beset by uncertainty arising from the difference between manufacturing date and installation date. This is a form of material traceability and asset knowledge problem. It is incredibly shortsighted for a gas operator to ignore the potential costs and consequences of poor asset knowledge and poor material traceability.

Operators did not always act on PHMSA's safety advisories in a timely manner. Operators had certain knowledge of the danger of premature failure associated with pre-1973 LDIW Aldyl A no later than 2002, when PHMSA released safety advisory ADB-02-07 and specifically mentioned pre-1973 Aldyl A. In fact, this knowledge occurred even earlier, when warning letters about pre-1973 LDIW Aldyl A were sent out by DuPont to the operators in 1982 and 1986, but the PHMSA advisory contained the strongest and clearest warning yet and so we will use 2002 as the base year when operators had explicit knowledge of the elevated danger and should have acted accordingly. Yet, the California operators in this study did not make a serious effort to document the location of Aldyl A pipes, in particular pre-1973 Aldyl A with LDIW, until being essentially compelled to do so by the implementation of PHMSA's gas Distribution Integrity Management Program (DIMP) in 2012. Sempra Utilities, for example, has no knowledge of the existence of any pre-1973 Aldyl A pipes with LDIW characteristics in its entire system even to this day because it was only in 2011/2012 that this operator began to collect information on LDIW pipes in its system. PG&E also has no standard procedures in place to routinely collect such information.

It is confounding that operators did not collect such information even if they were not required by law, when PHMSA safety advisories clearly demonstrated a need for prudent action a full decade prior. Granted that these were but advisories and the adoption of the recommended actions contained therein were voluntary, the potential danger associated with early vintage

Aldyl A pipes, as highlighted by the 1996 San Juan tragedy, made a compelling case for prompt action.

Due to low resistance to slow crack growth of earlier vintage Aldyl A pipes and the abrupt failure nature of slow crack growth, planned replacement rates may not be sufficient to mitigate risk nor can more frequent leak surveys. As shown in the MTTF section in this paper and Table 7, failure rates on non-LDIW pre-1983 Aldyl A will begin to rise in the coming decades, depending on actual operating pressure, temperature, and other pipeline specific variables, based on data obtained from the Rate Projection Method.

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

Pipeline safety regulations only require pipelines in distribution systems to be leak surveyed at annual intervals in business districts and at 5 years intervals in non-business districts. The abrupt failure nature of Aldyl A by slow crack growth means that leaks can develop undetected quickly between even annual leak survey intervals and migrate underground into structures and cause explosions.

SUMMARY OF FINDINGS

1. All early vintage Aldyl A pipes have low resistance to slow crack growth.

2. Aldyl A pipes with LDIW characteristics have both a significantly shortened crack initiation time and a low resistance to slow crack growth.

3. There is no non-destructive test in the field that can distinguish LDIW Aldyl A pipes from standard Aldyl A pipes.

4. California operators typically did not record the resin type and manufacturer of PE pipeline installation.

5. California gas operators typically recorded only the installation date and not the manufacturing date of the PE pipes.

6. Since historical installation records did not capture the relevant information, the mileage and location of Aldyl A pipes and LDIW Aldyl A pipes cannot be reliably determined after installation without performing excavation and possibly destructive testing.

7. California gas operators do not have a standard practice to use opportunistic identification when pipelines are exposed to capture relevant information that would aid in the identification of Aldyl A pipes and any stress intensifiers acting on the Aldyl A pipes.

8. Lack of specific and accurate record keeping distinguishing Aldyl A pipes from other assets highlights the need for better records for material traceability and asset knowledge. California gas operators have a sizable quantity of pipes with unknown manufacturing dates, unknown resin types, unknown lot numbers and even unknown manufacturer sources.

9. Without more robust material traceability to know with a great degree of certainty what assets are in the ground, risk assessment and risk mitigation strategies will be ineffective and expensive.

10. DuPont provided warning letters in 1982 and 1986 regarding pre-1973 LDIW Aldyl A pipes.

11. Initial PHMSA advisories were issued as early as 2002, providing certain knowledge of the risks of premature failure on pre-1973 LDIW Aldyl A pipes.

12. California gas operators have not acted on PHMSA safety warnings in a timely fashion. No meaningful action to identify inventory of Aldyl A pipes was undertaken until 2011/2012 when PHMSA's gas Distribution Integrity Management rules went into effect.

13. Depending on the different stress factors created by an operator's unique operating conditions, there could be different waves of failures unique to the operator in the oncoming decades. It is highly probable that the waves will occur sooner and with more intensity if the pipe is early vintage Aldyl A.

14. Some important pipeline data were not transferred by Avista Utilities to Southwest Gas when the South Lake Tahoe system was purchased from Avista Utilities.

RECOMMENDATIONS

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

Whereas gas safety regulations are generally viewed as minimum compliance standards, our efforts in this study to recognize potential safety concerns are unencumbered by existing or prior requirements in federal and state gas safety regulations. When strong recommendations are called for, our recommendations may exceed these minimum requirements and, in this spirit, we make the following safety recommendations:

1. **Operators should develop a more robust asset knowledge and material traceability program on their gas distribution assets**. This is consistent with the requirements and intent of PHMSA's DIMP regulations. Not knowing the system directly contradicts the spirit, if not the letter, of the DIMP regulations. Following the San Bruno tragedy, PG&E has made great strides

in this area on the gas transmission side, but all operators are still deficient on material traceability and asset knowledge on the gas distribution side.

2. **Operators should develop a strategy for better integrating supply chain information (e.g. resin type, manufacturing date, lot number, and other manufacturing data that are typically available during the purchase of materials).**

3. **Where feasible, operators should make use of opportunistic identification to determine whether an exposed pipe segment is of Aldyl A or some other materials and, if it is Aldyl A, whether the pipe has LDIW characteristics whenever sections are cut out.**

4. **Operators should react expeditiously to manufacturer warnings and PHMSA safety advisories.**

5. **Operators should re-examine their risk assessment and mitigation strategies to ensure they will be replacing the at-risk pipes at a sufficient rate to mitigate the risk associated with LDIW Aldyl A pipes dues to squeeze-offs and to pre-1983 non-LDIW pipes due to rock impingement.**

6. **Operators should, if not already doing so, explicitly consider the impacts of at-risk Aldyl A pipes in their next risk assessment and mitigation strategies provided to the Commission.**

7. **When acquiring systems, operators should ensure relevant pipeline records are transferred as a condition for final acquisition of a system.**

Within 60 calendar days of this report, Commission staff is requesting that the gas operators identified in this study submit a proposal to the director of the Safety and Enforcement Division and the Executive Director on how to address these safety recommendations. The proposal should also describe what actions the operator will take to address the following questions:

1. What actions will the operator take to remedy the historical deficiencies in asset knowledge with respect to Aldyl A pipes highlighted in this paper?

2. What actions will the operator take to address the different waves of expected failures on Aldyl A pipes due to the different stress intensifiers acting on the different vintages of pipes given the historical deficiencies in asset knowledge? The operators should not limit themselves to only the intensifiers we highlighted in this report.

3. In what forum (e.g. a general rate case or a separate application) will each operator intend to address the mitigation of the potential hazards posed by early vintage Aldyl A pipes?

Commission staff also requests that the operators concurrently serve their proposals to all parties in their respective outstanding general rate case proceedings and the gas safety rulemaking proceeding, R.11-02-019.

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61746 Federal Register / Vol. 88, No. 172 / Thursday, September 7, 2023 / Proposed Rules

DEPARTMENT OF TRANSPORTATION

Pipeline and Hazardous Materials Safety Administration

49 CFR Parts 191, 192, and 198

[Docket No. PHMSA–2021–0046]

RIN 2137–AF53

Pipeline Safety: Safety of Gas Distribution Pipelines and Other Pipeline Safety Initiatives

AGENCY: Pipeline and Hazardous Materials Safety Administration (PHMSA), Department of Transportation (DOT).

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: PHMSA proposes revisions to the pipeline safety regulations to require operators of gas distribution pipelines to update their distribution integrity management programs (DIMP), emergency response plans, operations and maintenance manuals, and other safety practices. These proposals implement provisions of the Leonel Rondon Pipeline Safety Act—part of the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2020—and a National Transportation Safety Board (NTSB) recommendation directed toward preventing catastrophic incidents resulting from overpressurization of low-pressure gas distribution systems similar to that which occurred on a gas distribution pipeline system in Merrimack Valley on September 13, 2018. PHMSA also proposes to codify use of its State Inspection Calculation Tool, which is used to help states determine the base-level amount of time needed for inspections to maintain an adequate pipeline safety program. Further, PHMSA proposes other pipeline safety initiatives for all part 192-regulated pipelines, including gas transmission and gathering pipelines, such as updating emergency response plans and inspection requirements. Finally, PHMSA proposes to apply annual reporting requirements to small, liquefied petroleum gas (LPG) operators in lieu of DIMP requirements.

DATES: Individuals interested in submitting written comments on this NPRM must do so by November 6, 2023.

ADDRESSES: Comments should reference Docket No. PHMSA–2021–0046 and may be submitted in any of the following ways:

E-Gov Web: https://www.regulations.gov. This site allows the public to enter comments on any Federal Register notice issued by any agency. Follow the online instructions for submitting comments.

Mail: Docket Management System: U.S. Department of Transportation, 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, Washington, DC 20590–0001.

Hand Delivery: DOT Docket Management System: West Building Ground Floor, Room W12–140, 1200 New Jersey Avenue SE, between 9:00 a.m. and 5:00 p.m. ET, Monday–Friday, except Federal holidays.

Fax: 202–493–2251

Instructions: Include the agency name and identify Docket No. PHMSA–2021–0046 at the beginning of your comments. Note that all comments received will be posted without change to *https://www.regulations.gov* including any personal information provided. If you submit your comments by mail, submit two copies. If you wish to receive confirmation that PHMSA received your comments, include a self-addressed stamped postcard.

Confidential Business Information: Confidential Business Information (CBI) is commercial or financial information that is both customarily and actually treated as private by its owner. Under the Freedom of Information Act (5 U.S.C. 552), CBI is exempt from public disclosure. If your comments in response to this NPRM contain commercial or financial information that is customarily treated as private, that you actually treat as private, and that is relevant or responsive to this NPRM, it is important that you clearly designate the submitted comments as CBI. Pursuant to 49 Code of Federal Regulations (CFR) 190.343, you may ask PHMSA to provide confidential treatment to the information you give to the agency by taking the following steps: (1) mark each page of the original document submission containing CBI as ''Confidential;'' (2) send PHMSA a copy of the original document with the CBI deleted along with the original, unaltered document; and (3) explain why the information you are submitting is CBI. Submissions containing CBI should be sent to Ashlin Bollacker, 1200 New Jersey Avenue SE, DOT: PHMSA–PHP–30, Washington, DC 20590–0001. Any comment PHMSA receives that is not explicitly designated as CBI will be placed in the public docket.

Docket: To access the docket, which contains background documents and any comments that PHMSA has received, go to *https://www.regulations.gov.* Follow the online instructions for accessing the docket. Alternatively, you may review the documents in person at DOT's Docket Management Office at the address listed above.

FOR FURTHER INFORMATION CONTACT: Ashlin Bollacker by phone at 202–680–8303 or by email at *ashlin.bollacker@dot.gov.*

SUPPLEMENTARY INFORMATION:

I. Executive Summary

A. Purpose of the Regulatory Action

PHMSA proposes a series of revisions to the pipeline safety regulations (49 CFR parts 190–199) in response to congressional mandates and an NTSB recommendation, and to implement lessons learned from a September 13, 2018, incident resulting from the overpressurization of a low-pressure gas distribution pipeline operated by Columbia Gas of Massachusetts (CMA) in the Merrimack Valley. That incident resulted in one fatality, more than 20 people (including three first responders) being hospitalized, damage to approximately 130 structures, and an evacuation request for more than 50,000

residents. PHMSA expects the proposals of this NPRM will address the root causes and aggravating factors contributing to the severity of that incident and help reduce the frequency and consequence of other failure mechanisms on gas distribution pipeline systems. The proposals include improved design standards for low-pressure gas distribution systems; enhanced distribution integrity management program requirements; strengthened recordkeeping, planning, and monitoring practices for maintenance and construction activities on gas distribution systems; and improved emergency response communication and coordination protocols during emergency events for all 49 CFR part 192-regulated gas pipelines.[1] PHMSA also proposes codifying within the pipeline safety regulations its State Inspection Calculation Tool (SICT). The SICT is one of many factors used to help States determine the base-level amount of time needed for administering adequate pipeline safety programs, which PHMSA considers when awarding grants to States supporting those programs. PHMSA anticipates these proposed regulatory amendments will improve public safety, while also reducing threats to the environment (including, but not limited to, reduction of greenhouse gas emissions during incidents on gas pipelines), and promoting environmental justice for minority populations, low-income populations, or other underserved and disadvantaged communities, or others who are particularly likely to live and work near higher-risk gas distribution pipeline systems.

A catalyst for this rulemaking is the 2018 Merrimack Valley incident. The NTSB investigated the cause of this incident and issued a full report on its findings and safety recommendations.[2] The NTSB found the cause to be CMA's weak engineering management that failed to adequately plan and oversee a cast iron main replacement project. Contributing to the incident was CMA's low-pressure gas distribution system that was designed and operated without adequate overpressure protection. The NTSB reviewed other incidents from the past 50 years and found several previous incidents that involved high-pressure gas entering low-pressure gas systems. The NTSB found that a common cause of failure was an overpressure protection design scheme, common on older low-pressure distribution systems, that can be defeated by a single failure mode (*e.g.,* operator error or equipment failure). Currently, low-pressure gas systems are not required to have a device at the service location that would prevent the overpressurization of a customer's piping, fittings, and appliances, a required design feature on high-pressure distribution systems. Instead, overpressure protection on low-pressure distribution systems often is provided by a redundant design scheme (*i.e.,* worker and monitor regulators at the regulator stations). While overpressurizations on distribution pipelines are infrequent, they have the potential to be catastrophic given their location within population centers. As a result of its investigation, the NTSB recommended that PHMSA revise the pipeline safety regulations to address overpressure protection failures like that which occurred on CMA's low-pressure system.

In 2020, the Leonel Rondon Pipeline Safety Act was enacted as sections 202–206 of the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2020 (PIPES Act of 2020, Pub. L. N 116–260). The law requires PHMSA to amend its regulations to ensure operators evaluate the risks associated with the presence of cast iron piping and the possibility of overpressurization on gas distribution systems through updates to their distribution integrity management program (DIMP). (49 U.S.C. 60109(e)(7)). The law further requires PHMSA to amend its regulations to ensure operators' emergency response plans include timely communications with first responders, public officials, customers, and the general public. (49 U.S.C. 60102(r)). PHMSA was also directed to amend its regulations to ensure operators' operations and maintenance (O&M) manuals include procedures for responding to overpressurization and a management of change (MOC) process with review and certification by relevant qualified personnel. (49 U.S.C. 60102(s)). PHMSA must also amend its regulations to ensure operators (1) keep ''traceable, reliable, and complete records;'' (2) monitor the gas pressure at district regulator stations during construction; and (3) assess and upgrade their district regulator stations to minimize the risk of overpressurization. (49 U.S.C. 60102(t)).

Pursuant to its statutory authority and in furtherance of its mission to protect people and the environment by advancing the safe transportation of energy and other hazardous materials essential to our daily lives, PHMSA proposes in this NPRM a number of regulatory amendments to implement those statutory mandates and NTSB recommendations arising from the 2018 CMA overpressure incident. PHMSA expects the proposed regulatory amendments to reduce the likelihood of another overpressure incident on low-pressure gas distribution systems similar to that which occurred in Merrimack Valley. PHMSA also expects the proposed amendments to reduce the frequency of, as well as public and environmental consequences from, failure mechanisms on gas distribution pipeline systems and other pipeline facilities. Additionally, this rulemaking aligns with the Administration's efforts to improve environmental justice and combat the climate crisis.[3] Older cast-iron or bare-steel gas distribution pipelines—a type of gas distribution pipeline particularly vulnerable to failure and overpressurization—are disproportionately concentrated in older, residential (often urban) areas with large minority, low- income, and other historically underserved and disadvantaged populations.[4] In addition, the reduced frequency and severity of incidents on gas pipelines anticipated from this rulemaking would have the benefit of minimizing the release of greenhouse gases from pipeline incidents—in particular methane—to the atmosphere.

The proposed rule is consistent with the goals of a new grant program established by the Bipartisan Infrastructure Law (BIL, enacted as the Infrastructure Investment and Jobs Act, Pub. L. 117–58). The new grant program, PHMSA's first ever Natural Gas Distribution Infrastructure Safety

[1] Part 192—regulated pipelines refers to gas distribution, transmission, and gathering pipelines, as applicable.

[2] NTSB, Accident Report PAR–19/02, ''Overpressurization of Natural Gas Distribution System, Explosions, and Fires in Merrimack Valley, Massachusetts, September 13, 2018'' (Sept. 24, 2019), *https://www.ntsb.gov/investigations/AccidentReports/Reports/PAR1902.pdf.*

[3] The White House Office of Domestic Climate Policy, ''U.S. Methane Emissions Reduction Action Plan,'' (Nov. 2021), *https://www.whitehouse.gov/wp-content/uploads/2021/11/US-Methane-Emissions-Reduction-Action-Plan-1.pdf.* This and other PHMSA rulemakings are identified in the U.S. Methane Emissions Reduction Action Plan as critical elements in the Federal government's efforts to address the climate crisis. *Id.* at 7–8 (listing PHMSA's Leak Detection and Repair rulemaking (proposed in 88 FR 31890 (May 18, 2023) (Leak Detection NPRM)), its Gas Gathering Final Rule (86 FR 63266 (Nov. 15, 2021)), its Valve Installation and Minimum Rupture Detection Standards Final Rule (87 FR 20940 (Apr. 8, 2022) (Valve Rule)), and its Gas Transmission Pipeline Safety Final Rule (87 FR 52224 (Aug. 24, 2022)).

[4] *See, e.g.,* Luna & Nicholas, ''An Environmental Justice Analysis of Distribution-Level Natural Gas Leaks in Massachusetts, USA,'' 162 Energy Policy 112778 (Mar. 2022); Weller et al., ''Environmental Injustices of Leaks from Urban Natural Gas Distribution Systems: Patterns Among and Within 13 U.S. Metro Areas,'' Environ. Sci & Tech. (May 11, 2022).

and Modernization grant program, authorizes $200 million a year in grant funding with a total of $1 billion in grant funding over the next five years. The grant funding is to be made available to a municipality or community owned utility (not including for-profit entities) to repair, rehabilitate, or replace its natural gas distribution pipeline systems or portions thereof or to acquire equipment to (1) reduce incidents and fatalities and (2) to avoid economic losses. The new grant program authorized by BIL can, however, address only part of the universe of at-risk distribution pipeline systems. While the grant program would assist eligible entities who receive funding in making needed repairs to their pipeline systems, PHMSA's proposal would go further in ensuring that all gas distribution and other part-192 regulated operators improve and maintain the safety of their systems and reduce the risk of public safety impacts and environmental damage from incidents on their pipeline systems.

B. Summary of the Proposed Regulatory Action

In this rulemaking, PHMSA proposes amendments to 49 CFR parts 191, 192, and 198. PHMSA also proposes compliance deadlines for each of the NPRM's regulatory amendments.

1. Clarifications and Updates to DIMP Plans—Part 192, Subpart P. Pursuant to 49 U.S.C. 60109(e)(7), PHMSA proposes several revisions to its DIMP regulations at 49 CFR part 192, subpart P. PHMSA further proposes that, subject to certain exceptions at § 192.1003, all gas distribution pipeline operators—including service lines—would need to update their DIMP plans in conformity with the amended requirements no later than one year after the publication of any final rule in this proceeding.

First, PHMSA proposes to require all operators of gas distribution pipeline systems identify and minimize the risks to their systems from specific threats in their DIMP. These specific threats, where applicable, include: (1) the presence of certain materials, such as cast iron and other piping with known issues; (2) overpressurization of low-pressure systems; and (3) extreme weather and other geohazards. Operators must also consider the effect of age on those specific threats faced by a distribution pipeline.

For operators of low-pressure gas distribution systems, PHMSA proposes that, when evaluating and ranking the above and other threats identified in their DIMP plans, operators must evaluate risks from: (1) abnormal operating conditions; and (2) potential consequences associated with low-probability events. If an operator can demonstrate through a documented engineering analysis, or an equivalent analysis incorporating operational knowledge, that no potential consequences are associated with a particular low-probability event, and therefore no potential risk exists, then the operator must notify PHMSA and state regulatory authorities of that determination within 30 days. Additionally, as part of the proposal to implement measures to minimize the risk of overpressurization, PHMSA would require operators of low-pressure distribution systems to identify, maintain, and obtain pressure control records. PHMSA would also require operators to identify and implement preventive and mitigative measures based on the unique characteristics of their system. If operators choose to implement measures to minimize the risk of an overpressurization on a low-pressure system, then they must notify PHMSA and state regulatory authorities no later than 90 days in advance of implementing any alternative measures. As an alternative to implementing such preventive and mitigative measures, operators could choose to upgrade their systems to meet new proposed design requirements applicable to new systems.

PHMSA is also proposing to omit operators of a liquefied petroleum gas (LPG) distribution pipeline system that serves fewer than 100 customers (small LPG operators) from the DIMP requirements. Based on recommendations from the National Association of Pipeline Safety Representatives (NAPSR), a National Academies of Science (NAS) study, and PHMSA's incident data, current DIMP requirements do not provide a safety benefit warranting the compliance burdens those requirements impose on small LPG operators and the administrative burdens placed on PHMSA and state regulatory authorities. Instead, PHMSA proposes to add a requirement for small LPG operators to complete an annual report providing data that would support PHMSA's regulatory oversight of the safety of those facilities.

2. Codifying in Regulation the Use of the State Inspection Calculation Tool—§§ 198.3 and 198.13. Consistent with 49 U.S.C. 60105(b) and 60105 note, PHMSA will update the SICT and proposes to revise its regulations to require that states use the SICT when ensuring an adequate number of safety inspectors are employed in their pipeline safety programs.[5] States would have to comply with these proposed changes no later than the next SICT update immediately following the effective date of any final rule in this proceeding. PHMSA proposes amendments to 49 CFR part 198 that would codify in regulation the SICT's use and define the terms ''State Inspection Calculation Tool'' and ''inspection person-days'' for the purposes of 49 CFR part 198.

3. Updates to Emergency Response Communications—§ 192.615. Pursuant to 49 U.S.C. 60102(a), PHMSA proposes a series of updates to its emergency response plan requirements that will be applicable to all operators of part 192-regulated gas pipelines. PHMSA also proposes certain emergency response plan requirements specific to gas distribution pipeline operators pursuant to 49 U.S.C. 60102(r). Unless a different compliance timeline is specified below, operators would need to update their emergency response plans in conformity with those amended requirements no later than one year after the publication of any final rule in this proceeding.

For all gas pipeline operators, PHMSA proposes to expand the existing list of pipeline emergencies in its regulations at § 192.615 for which operators must have procedures ensuring prompt and effective response by adding emergencies involving a release of gas that results in a fatality, as well as any other emergency deemed significant by the operator. In the event of a release of gas resulting in one or more fatalities, all operators must also immediately and directly notify emergency response officials upon receiving notice of the same. For distribution pipeline operators only, PHMSA's proposed expansion of the list of emergencies discussed above will also include the unintentional release of gas and shutdown of gas service to 50 or more customers (or 50 percent of its customers if it has fewer than 100 total customers); operators would need to immediately and directly notify emergency response officials on receiving notice of the same.

PHMSA also proposes regulatory amendments requiring gas distribution operators to update their emergency response plans to improve communications with the public during an emergency. First, PHMSA proposes to require gas distribution operators to establish and maintain communications with the general public as soon as practicable during an emergency. Second, PHMSA proposes to require gas

[5] The SICT can be accessed on the PHMSA Portal by authorized users.

distribution pipeline operators to develop and implement, no later than 18 months after the publication of any final rule in this proceeding, an opt-in system to keep their customers informed of the safety status of pipelines in their communities should an emergency occur.

PHMSA also seeks comment on whether it should require gas distribution operators to develop and implement emergency response procedures in accordance with incident command system (ICS) tools and practices. PHMSA also invites comment on the technical feasibility, practicability, and cost of immediate emergency notifications to customers via electronic text message or via a cellular phone application (''app'')—including both opt-in and opt-out notification approaches.

4. Updates to Operations and Maintenance Procedural Manuals—§ 192.605. Pursuant to 49 U.S.C. 60102(s), PHMSA also proposes a series of amendments to operations and maintenance (O&M) procedure manuals in § 192.605 that would require all gas distribution operators to implement within one year of the publication of any final rule issued in this proceeding. First, PHMSA proposes to require that operators of all gas distribution pipelines update their O&M procedures to account for the risk of overpressurization. PHMSA would require operators to have procedures for identifying and responding to overpressurization indications, including the specific actions and sequence of actions an operator would carry out to immediately reduce pressure or shut down portions of the gas distribution system, if necessary. PHMSA proposes that these O&M procedures would also describe investigating, responding to, and correcting the cause(s) of overpressurization indications.

Second, and again pursuant to 49 U.S.C. 60102(s), PHMSA proposes to require that operators of gas distribution pipelines develop and follow an MOC process when (1) installing, modifying, replacing, or upgrading regulators, pressure monitoring locations, or overpressure protection devices; (2) modifying alarm setpoints or upper or lower trigger limits on monitoring equipment; (3) introducing new technologies for overpressure protection into the system; (4) revising, changing, or introducing new standard operating procedures for design, construction, installation, maintenance, and emergency response; and (5) making any other changes that could impact the integrity or safety of a gas distribution system. Should any of these changes that an operator makes introduce a public safety hazard into the operator's gas distribution system, PHMSA proposes that the operator must identify, analyze, and control these hazards before resuming operations.

As part of the MOC process, PHMSA also proposes to require that gas distribution operators ensure qualified personnel review and certify construction plans associated with installations, modifications, replacements, or upgrades for accuracy and completeness, before the work begins. This amendment would ensure that qualified personnel—who are competently trained and experienced to identify system design and process deficiencies on gas distribution pipeline systems—provide oversight during the planning of those activities.

5. New Recordkeeping Requirements—§ 192.638. Pursuant to 49 U.S.C. 60102(t)(1), PHMSA proposes that all gas distribution pipeline operators identify and maintain traceable, verifiable, and complete maps and records documenting the characteristics of their systems that are critical to ensuring proper pressure controls for their gas distribution pipeline systems and to ensure that those records are accessible to anyone performing or supervising design, construction, and maintenance activities on their systems. PHMSA proposes to specify that these required records include (1) the maps, location, and schematics related to underground piping, regulators, valves, and control lines; (2) regulator set points, design capacity, and valve-failure mode (open/closed); (3) the system's overpressure protection configuration; and (4) any other records deemed critical by the operator. PHMSA proposes to require that the operator maintain these integrity-critical records for the life of the pipeline because these records are critical to the safe operation and pressure control of a gas distribution system. Operators would need to comply with this new requirement within one year of the publication of any final rule in this proceeding. If an operator does not have traceable, verifiable, and complete records as contemplated by this new requirement, then the operator must (1) identify and document which records they need, and (2) develop and implement procedures for generating or collecting those records, to include procedures for ensuring the generation or collection of those records. PHMSA also proposes that operators update these records on an opportunistic basis (*i.e.,* through normal operations, maintenance, and emergency response activities).

PHMSA expects that many gas distribution pipeline operators already have these records. Where they do not, these amendments would help to ensure that gas distribution pipeline operators improve the completeness and accuracy of their records. This amendment will also help to improve pipeline safety by ensuring operators provide appropriate personnel—such as qualified employees responsible for planning construction activities—with better, more complete, and more accurate records.

6. Monitoring of Gas Systems by Qualified Personnel—§ 192.640. Pursuant to 49 U.S.C. 60102(t)(2), PHMSA proposes that, where operators of gas distribution pipelines do not have the capability to remotely monitor pressure and either remotely or automatically shut off the gas flow at district regulator stations, operators must have qualified personnel on site to monitor certain construction projects so that they can prevent or respond to an overpressurization at a district regulatory station during those construction activities that have been determined to involve potential for such an event. Accordingly, PHMSA proposes requirements for all gas distribution operators to evaluate their construction projects to identify activities that could result in an overpressurization event at a district regulator station. If the operator identifies a potential for overpressurization due to a construction project, then the operator must ensure that at least one qualified employee or contractor is present during those activities that could result in a potential threat of overpressurization of the system. That qualified personnel would be responsible for monitoring the gas pressure in the affected portion of a gas distribution system and for promptly shutting off the gas flow to control an overpressurization event on the system. PHMSA is also proposing that operators must provide those qualified personnel with the location of all critical shutoff valves, pressure control records, and stop-work authority (unless prohibited by operator procedures) as well as the emergency response procedures, including the contact information of appropriate emergency response personnel. PHMSA proposes that gas distribution pipeline operators would need to comply with these requirements beginning one year after the publication of any final rule in this proceeding.

7. Requirements for New Regulator Stations—§§ 192.195 and 192.741. Pursuant to 49 U.S.C. 60102(t)(3), PHMSA proposes to require that

operators design new regulator stations on low-pressure distribution systems so there are redundant technologies installed to avoid or mitigate overpressurizations. Specifically, PHMSA proposes that all gas distribution operators, beginning one year after the publication of any final rule in this proceeding, equip all new, replaced, relocated, or otherwise changed district regulator stations serving low-pressure gas distribution systems with at least two methods of overpressure protection (such as a relief valve, monitoring regulator, automatic shutoff valve, or some combination thereof) that is appropriate for the configuration and siting of the station. Additionally, PHMSA proposes that operators minimize the risks from an overpressurization of a low-pressure system caused by a single event (such as excavation damage, natural forces, equipment failure, or incorrect operations) that either immediately or over time affects the safe operation of more than one overpressure protection device.

PHMSA also proposes to require that operators of low-pressure gas distribution systems monitor the outlet gas pressure at or near the district regulator station on such systems using a device capable of real-time notification to the operator of overpressurization. Low-pressure gas distribution operators are already required to have devices such as telemetering or recording gauges that record the gas pressure on their systems. However, some of these devices are not designed with the ability to provide real-time notification, and there is no explicit requirement that those devices be located near the district regulator station.

8. Construction Inspections for Gas Transmission Pipelines and Distribution Mains—§ 192.305. PHMSA proposes to amend § 192.305 to lift the indefinite stay of a regulatory amendment to that provision that had been introduced within a final rule issued on March 11, 2015.[6]

PHMSA also proposes an exception from this provision's inspection requirements for small gas distribution pipeline operators who would not be able to comply with the construction inspection requirement without using a third-party inspector. These regulatory amendments would, beginning one year after the publication of any final rule issued in this proceeding, apply to all other gas distribution pipelines operators; all gas transmission, all offshore gas gathering, and Type A gas gathering pipelines, and certain Types B and C gathering pipelines (specifically, those that are new, replaced, relocated, or otherwise changed).

9. Test Records—Clarification for Tests on Gas Distribution Systems—§§ 192.517 and 192.725. PHMSA proposes to amend § 192.517 to specifically identify the information that operators must record for tests performed on new, replaced, or relocated gas distribution pipelines and to ensure such records are available to operator personnel throughout the life of the pipeline. PHMSA proposes to amend § 192.725 to clarify that each disconnected service line must be tested in the same manner as a new, replaced, or relocated service line—that is, tested in accordance with 49 CFR part 192, subpart J—before being reinstated. PHMSA proposes to require that gas distribution operators comply with these amended testing recordkeeping requirements in connection with gas distribution pipelines that are new, replaced, or relocated beginning one year after the publication of any final rule in this proceeding.

10. Annual Reporting—§ 191.11. PHMSA proposes to add or expand annual reporting requirements for operators of gas distribution pipeline systems, including small LPG operators. For gas distribution pipelines, PHMSA proposes to collect additional information, such as the number and miles of low-pressure service lines, including their overpressure protection methods. For small LPG operators, these annual reports will collect information on the number and miles of service lines, and the disposition of any leaks. These proposed amendments will not apply to master meter systems, petroleum gas systems excepted from 49 CFR part 192 in accordance with § 192.1(b)(5), or individual service lines directly connected to production pipelines or gathering pipelines, other than a regulated gathering pipeline, as determined in § 192.8. PHMSA proposes that operators would need to comply with the above changes to annual reporting requirements beginning with the first annual reporting cycle after the effective date of any final rule issued in this proceeding.

11. Miscellaneous Amendments Pertaining to Part 192—Regulated Gas Gathering Pipelines—§§ 192.3 and 192.9. Following a decision by the U.S. Court of Appeals for the District of Columbia Circuit in litigation challenging application of requirements of PHMSA's April 2022 Valve Rule to gas and hazardous liquid gathering pipelines,[7] PHMSA issued a technical correction to the April 2022 Valve Rule codifying that decision.[8] PHMSA now proposes removal of certain exceptions introduced in the Technical Correction to restore, with respect to certain part 192-regulated gas gathering pipelines, application of specific regulatory amendments from the Valve Rule pertaining certain definitions (§ 192.3) as well as—by way of removal of exceptions within the regulatory cross-references at § 192.9—emergency planning and response (§ 192.615) and protocols for notifications of potential ruptures (§ 192.635).

C. Costs and Benefits

Consistent with 49 U.S.C. 60102(b) and Executive Order 12866 ''Regulatory Planning and Review,'' as amended by Executive Order 14094 ''Modernizing Regulatory Review'', PHMSA has prepared an assessment of the benefits and costs of the proposed rule as well as reasonable alternatives.[9] PHMSA expects that the rulemaking will yield significant public safety benefits associated with reduced frequency and severity of incidents similar to that which occurred in 2018 in Merrimack Valley, which resulted in a number of adverse consequences described in Section I.A. of this NPRM, as well as approximately $1.7 billion in property damage, lost gas, claims, other mitigation costs, and the social cost of methane emissions. PHMSA also expects that the proposed rule will yield other, unquantified benefits, which include improvements in risk reduction for pipeline leaks and incidents; reduced consequences from all incidents and emergencies; improved enforcement and oversight procedures; advanced safety measures and communications; avoided emissions; improved public confidence in the safety of gas pipeline systems; and associated environmental enhancements for populations, including those in historically disadvantaged areas. Cost savings reflect the removal of some requirements for small LPG operators. The costs of the proposed rule are attributed to new requirements and

[6] ''Pipeline Safety: Miscellaneous Changes to Pipeline Safety Regulations,'' 80 FR 12762, 12779 (Mar. 11, 2015). PHMSA indefinitely stayed § 192.305 in response to a petition for reconsideration. *See* ''Pipeline Safety: Miscellaneous Changes to Pipeline Safety Regulations: Response to Petitions for Reconsideration,'' 80 FR 58633, 58634 (Sept. 30, 2015).

[7] *GPA Midstream Ass'n* v. *Dep't of Transp.,* 67 F.4th 1188 (D.C. Cir. 2023).

[8] ''Pipeline Safety: Requirement of Valve Installation and Minimum Rupture Detection Standards: Technical Corrections,'' 88 FR 50056 (Aug. 1, 2023).

[9] 88 FR 21879 (Apr. 6, 2023); 58 FR 51735 (Oct. 4, 1993).

updates to operators' DIMPs, emergency response plans, operations and maintenance procedures, monitoring and inspection protocols, and other reporting and record-keeping proposals. The provisions include a range of proposals for primarily gas distribution operators, along with some proposals for other gathering and transmission operators.

PHMSA estimates the annualized costs of the proposed rule to be approximately $110 million per year at a 3 percent discount rate. In Table ES–1, below, PHMSA provides a summary of the estimated costs for the major provisions in this rulemaking and the total cost. For the full cost/benefit analysis and additional details on the summaries, please see the preliminary regulatory impact analysis (PRIA) in Docket No. PHMSA–2021–0046.

TABLE ES–1—TOTAL ANNUALIZED COSTS

[Millions, 2020$]

Proposed rule requirement	3% discount rate	7% discount rate
DIMP	$3.2	$4.3
Small LPG DIMP	−0.3	−0.3
SICT	0.0	0.0
Emergency response	1.0	1.2
O&M	42.8	44.7
Recordkeeping	24.3	27.8
Qualified personnel	34.8	34.8
District regulator stations	1.2	1.6
Inspections	0.04	0.05
Records: Tests	0.6	0.6
Annual Reporting	2.3	2.3
Total	110.0	117.1

Note: Costs annualized over 20 years.
Source: PHMSA analysis of gas distribution, transmission, and gathering operators, 2022.

PHMSA expects that each of the elements of the rulemaking, as proposed in this NPRM, will be technically feasible, reasonable, cost-effective, and practicable for the reasons stated in this NPRM and its supporting documents (including the PRIA and draft Environmental Assessment, each available in the docket for this rulemaking), and because the commercial, public safety and environmental benefits of those proposed regulatory amendments as described therein (reduced frequency and severity of incidents similar to the 2018 Merrimack Valley incident which bore an approximate cost of $1.7 billion in 2020$), would outweigh any associated costs and support PHMSA's proposed rule compared to alternatives.

II. Background

A. Gas Distribution Systems Overview

More than 2.3 million miles of gas distribution pipelines deliver gas to communities and businesses across the United States.[10] Gas distribution systems are made up of pipelines called ''mains,'' which distribute the gas within the system, and much smaller lines called ''service lines,'' which distribute gas to individual customers. Because the purpose of distribution pipelines is to deliver gas to customers, distribution pipeline systems are located predominantly in urban and suburban areas. Distribution pipelines are generally smaller in diameter than transmission pipelines and operate at lower pressures.

Risk to the public from gas distribution pipelines result from the potential for unintentional releases of the gas transported through the pipelines. Due to their proximity to populations, releases from distribution pipelines bear a particular risk to surrounding populations, communities, property, and the environment, and may result in death, injuries, and property damage.[11] Even small releases of natural gas can result in environmental harm, as methane (the primary constituent of natural gas) is a significant contributor to the climate crisis, with more than 25 times the impact on an equivalent basis as carbon dioxide.[12] While the overall trend in pipeline safety has steadily improved over the past two decades, gas distribution pipelines are still involved in a majority of serious gas pipeline incidents.[13] According to PHMSA's data, between 2003 and 2022, excavation damage was the leading cause of serious incidents along gas distribution pipelines (28 percent), followed by other outside force damage (23 percent) and incorrect operation (14 percent).[14]

Much of the Nation's gas distribution piping has been in the ground for a long time. Per PHMSA's gas distribution operator database, more than 50 percent of the nation's pipelines were constructed before 1970 during the creation of the interstate pipeline network built in response to the demand for energy in the post-World War II economy.[15] Historically, gas distribution pipelines were constructed from many different materials, including cast iron, steel, and copper. However, material fabrication and installation practices have improved since much of the Nation's gas distribution pipeline systems were installed, in acknowledgment that iron alloys like cast iron and steel degrade or corrode over time. Consequently, the age of a gas distribution system pipeline is an important factor in evaluating the risk it poses to public safety and the environment.

On April 4, 2011, following a string of major gas pipeline incidents, the Secretary of Transportation announced a Pipeline Safety Action Plan (Action Plan) that was a vehicle for Federal and State cooperation to accelerate the repair, rehabilitation, and replacement of the highest-risk pipeline infrastructure.[16] Efforts implementing the Action Plan focused on pipeline age and material as significant risk indicators. Pipelines constructed of cast- and wrought iron and bare steel were among those materials identified as posing the highest risk. In fact, operators of cast-iron and bare-steel distribution pipelines perform the vast majority of all leak repairs, despite these lines only making up about 21 percent of all distribution pipelines according to

[10] PHMSA, ''Annual Report Mileage for Gas Distribution Systems'' (June 1, 2022), *https://www.phmsa.dot.gov/data-and-statistics/pipeline/annual-report-mileage-gas-distribution-systems.*

[11] This gas, regulated under 49 CFR parts 191 and 192, can be natural gas and any ''flammable gas, or gas which is toxic or corrosive.'' *See* §§ 191.3 and 192.3 (definitions of ''gas''). By way of example, in addition to natural gas, PHMSA regulates as a ''flammable gas'' over 1,500 miles of hydrogen gas pipelines. *See* PHMSA Interpretation Response Letter No. PI–92–030 (July 14, 1992) (noting PHMSA regulates hydrogen pipelines under 49 CFR part 192); PHMSA, ''Presentation of Vincent Holohan for Workgroup#4: Hydrogen Network Components at December 2021 Meeting'' at slide 11 (Dec. 1, 2021), *https://primis.phmsa.dot.gov/meetings/FilGet.mtg?fil=1227.* PHMSA consequently understands the proposed revisions to 49 CFR parts 191 and 192 within this NPRM would apply not only to natural gas pipelines but also to other gas pipeline governed by 49 CFR parts 191 and 192.

[12] U.S. Envtl. Prot. Agency, Global Methane Initiative: Importance of Methane (last updated June 9, 2022), *https://www.epa.gov/gmi/importance-methane#:~:text=Methane%20is%20more%20than%2025,due%20to%20human%2Drelated%20activities.*

[13] Serious incidents are those including a fatality or injury requiring in-patient hospitalization, excluding incidents when secondary ignition is involved, sometimes called ''fire first'' incidents. Between 2001 and 2020, gas distribution incidents comprised 81 percent of all the serious incidents reported to PHMSA. The three-year average incident count between 2018 and 2020 is 25, down from an average of 28 serious incidents between 2001 and 2020. ''Pipeline Incident 20 Year Trends'' (Nov. 15, 2022), *https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends.*

[14] ''Pipeline Incident 20 Year Trends'' (Nov. 15, 2022), *https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends.*

[15] PHMSA, ''By-Decade Inventory: Reports'' (Mar. 16, 2020), *https://www.phmsa.dot.gov/data-and-statistics/pipeline-replacement/decade-inventory.*

[16] PHMSA, ''U.S. Transportation Secretary Ray LaHood Announces Pipeline Safety Action Plan'' (Apr. 4, 2011), *https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/dot4111.pdf.*

PHMSA's distribution operators' annual report data.[17]

Though the amount of cast and wrought iron pipe in use within gas distribution systems has declined significantly in recent years thanks to State and Federal safety initiatives and pipeline operators' replacement efforts, there are still approximately 20,000 miles of mains and 7,000 miles of service lines in the United States.[18] According to the U.S. Department of Energy, the total cost of replacing all cast iron and bare steel distribution pipelines in the United States would be approximately $270 billion.[19] PHMSA understands that both cost and practical barriers, such as urban excavation and disruption of gas supplies, can also limit replacement efforts. However, PHMSA finds that proactive management of the integrity of aging pipe infrastructure enhances safety and reliability, contributes to cost savings over the longer term, and can be less disruptive to customers and communities than a reactive approach. Accelerating leak detection, repair, rehabilitation, or replacement efforts also delivers the desired integrity and safety benefits more expeditiously, lowering maintenance requirements associated with the aging pipe that is being replaced.

There is no simple formula for determining which parts of the Nation's pipeline infrastructure should be of greatest concern. Factors often associated with higher risk include pipeline age, materials of construction, exposure to elements or outside forces, and an operator's practices in managing the integrity of its pipeline system. Each of these factors can contribute to a pipeline's risk, but effective integrity management can counterbalance the impact of aging and types of construction materials.

B. Gas Distribution Configurations

In a distribution system, gas is sourced from a transmission pipeline operating at a high pressure and must be safely delivered to the customer at lower pressures that are safe for customer piping and appliances. There are multiple points along the system where operators can reduce the pressure to be more suitable for the needs of the customer. City gate stations are the first such reduction point, and district regulator stations are pressure-reducing facilities downstream of city gate stations that further reduce the pressure from the pipeline coming from the city gate.[20] This lower pressure downstream of a district regulator station is more suitable for providing service to customers.

Each gas distribution system must be designed to operate safely at or below a certain pressure, also known as its maximum allowable operating pressure (MAOP), as determined in accordance with § 192.619. Exceeding this pressure can cause the gas to build up in the pipeline and potentially cause the failure of piping, joints, fittings, or customer appliances. As gas flows through a distribution system, devices called regulators control the flow of gas to maintain a constant pressure. If a regulator senses a drop or rise in pressure above or below a set point, it will open or close accordingly to adjust the pressure of gas. As an additional safety precaution against overpressurization, some distribution pipelines are also designed with a relief valve to vent the gas into the atmosphere. While modern gas regulators are highly reliable devices, they can fail due to physical damage, equipment failure (*e.g.,* degradation of materials such as seals and gaskets, defects or maintenance issues, or inability to control pressure as set), or the presence of foreign material in the gas stream.[21] Because there is the possibility of a regulator failing, distribution systems are typically designed with multiple means of protection and redundancies to reduce the likelihood of a catastrophic failure.

Many regulators require external control lines, which sense the outlet pressure of the regulator. Based on the pressure sensed through the control lines, the regulator valve will open or close to control the downstream pressure of the regulator. In some older installations, control lines are located farther downstream of the regulator station on the buried outlet piping based on either the manufacturer's recommendations or previous control-line standards and practices at the time of installation. However, a break in the control line (*e.g.,* if it is damaged during an excavation) will make the regulator sense a lower downstream pressure and will cause the regulator valve to open wider automatically. This could result in overpressurization of the downstream piping, which could lead to a catastrophic event. The same result occurs if the flow through the control line is otherwise disrupted, for example if the control line valve is shut off or if the control line is isolated from the regulator it is controlling.

In general, gas distribution pipeline systems can be classified as either low pressure or high pressure. In a high-pressure gas distribution system, the gas pressure in the main is substantially higher than what the customer requires, and a pressure regulator installed at each meter reduces the pressure from the main to a pressure that can be used by the customer's equipment and appliances. These regulators incorporate an overpressure-protection device to prevent overpressurization of the customer's piping and appliances should the regulator fail. Additionally, all new or replaced service lines connected to a high-pressure distribution system must have excess flow valves (see § 192.383). Excess flow valves can reduce the flow of gas through the service line by minimizing unplanned, excessive gas flows.[22]

In a low-pressure distribution system, the gas pressure in the main is substantially the same as the pressure provided to the customer (see § 192.3). Since a district regulator station located upstream of service lines acts as the primary means of pressure control in low-pressure distribution systems, an overpressurization in the system served by the district regulator could affect all the customers served by the system.

[17] Cast iron or bare steel pipelines account for 95 percent of corrosion leaks on mains, 92 percent of natural-force leaks on mains, 91 percent of pipe/weld/joint failure leaks; 97 percent ''other cause'' leaks on mains; and 76 percent of all known leaks. PHMSA, ''Cast and Wrought Iron Inventory'' (Apr. 26, 2021), *https://www.phmsa.dot.gov/data-and-statistics/pipeline-replacement/cast-and-wrought-iron-inventory* (''Cast and Wrought Iron Inventory'').

[18] *See* Cast and Wrought Iron Inventory.

[19] U.S. Dep't of Energy, ''Transforming U.S. Energy Infrastructures in a Time of Rapid Change: The First Installment of the Quadrennial Energy Review'' at S–5 (Apr. 2015) *https://www.energy.gov/sites/prod/files/2015/08/f25/QER%20Summary%20for%20Policymakers%20April%202015.pdf.*

[20] ''At the city gate the pressure of the gas is reduced, and [this] is normally the location where odorant (typically mercaptan) is added to the gas, giving it the characteristic smell of rotten eggs so leaks can be detected.'' Pipeline Safety Trust, ''Pipeline Basics & Specifics About Natural Gas Pipelines'' at 4 (Feb. 2019), *https://pstrust.org/wp-content/uploads/2019/03/2019-PST-Briefing-Paper-02-NatGasBasics.pdf.*

[21] Gas may contain moisture, dirt, sand, welding slag, metal cuttings from tapping procedures, or other debris. Problems caused by such foreign material in the gas stream are most prevalent following construction on the pipeline supplying gas to the district regulator station. American Gas Association, ''Leading Practices to Reduce the Possibility of a Natural Gas Over-Pressurization Event'' at 447 (Nov. 26, 2018).

[22] An excess-flow valve is a mechanical safety device installed on a gas service line to a residence or small commercial gas customer. In the event of damage to the gas service line between the street and the meter, the excess-flow valve will minimize the flow of gas through the service line. The pipeline safety regulations require a gas distribution company to install such a device on new or replacement service lines for single-family residences and certain multifamily and commercial buildings where the service line pressure is above 10 pounds per square inch gauge (psig). See 49 CFR 192.383 for specific requirements.

This is what occurred during the Merrimack Valley incident and is an inherent weakness of low-pressure gas distribution systems.

C. Merrimack Valley

On September 13, 2018, fires and explosions occurred after high-pressure natural gas entered a low-pressure natural gas distribution system operated by CMA, a subsidiary of NiSource, Inc.[23] One person, 18-year-old Leonel Rondon, was killed, and 22 people, including 3 firefighters, were transported to hospitals for treatment of their injuries. At least five homes were destroyed in the city of Lawrence and the towns of Andover and North Andover, MA, by the fires and explosions. More than 130 structures were damaged in total. Most of the damage occurred from fires ignited by natural gas-fueled appliances. More than 50,000 residents were asked to evacuate.

In response, fire departments from three municipalities were dispatched to the fires and explosions. First responders initiated the Massachusetts fire mobilization plan and received mutual aid from neighboring districts in Massachusetts, New Hampshire, and Maine. Emergency management officials had the electric utility shut off electrical power in the area. Additionally, CMA shut down its low-pressure natural gas distribution system, affecting 10,894 customers, including some outside of the affected area who had their service shut off as a precaution.

The NTSB on September 24, 2019, issued a final report of its investigation into the Merrimack Valley incident.[24] The NTSB found the cause of the incident was CMA's weak engineering management that failed to adequately plan, review, sequence, and oversee the construction project that led to the abandonment of a cast iron main without first relocating the regulator control lines to the new plastic main. The NTSB also found that contributing to the accident was CMA's low-pressure natural gas distribution system that was designed and operated without adequate overpressure protection.

D. Low-Pressure Gas Distribution System in South Lawrence

At the time of the incident, CMA owned and operated a network of gas pipeline systems for the transportation and delivery of natural gas that included approximately 25 different low-pressure gas distribution systems in Massachusetts. Among these systems, CMA owned and operated a low-pressure system in the area of South Lawrence, Massachusetts that served Lawrence, Andover, and North Andover, among other communities (South Lawrence system). The South Lawrence system was installed in the early 1900s and was constructed with cast iron and bare steel mains and used several regulator stations to control downstream pressure. The regulator stations were located below ground and contained regulators that monitored and controlled downstream pressure. Natural gas came into the South Lawrence system at a pressure of about 75 pounds per square inch, gauge (psig). The regulators reduced the pressure to about 0.5 psig for delivery to customers.

The South Lawrence system consisted of 14 regulator stations, wherein the regulator valves opened or closed based on the pressure the regulator sensed downstream to maintain the downstream pressure at a pre-set limit called a ''set point.'' This was to ensure the pressure in the system did not exceed the MAOP and become unsafe. Each regulator station in the South Lawrence system had at least two regulators in series—a ''worker regulator'' and a ''monitor regulator''—each with a control line that sensed downstream pressure and connected back to its regulator, thereby enabling the regulator station to regulate system pressure. The worker regulator was the primary regulator that maintained system pressure. The monitor regulator was the redundant backup in case the worker regulator was damaged or malfunctioned. If both control lines experienced a decrease in pressure, such as when the cast iron main was disconnected, the worker regulator and monitor regulator would automatically and continually increase the pressure, resulting in an overpressurization of the low-pressure system. That is precisely what occurred in CMA's gas main replacement project.

E. Gas Main Replacement Project

Beginning in 2016, CMA began a pipe replacement project in the South Lawrence system called the South Union Street project. CMA's field engineering department initiated the project in part due to the pending City of Lawrence water main project that would encroach on two aging cast iron mains on South Union Street. The construction project was also part of CMA's Gas System Enhancement Plan that called for replacing existing low-pressure cast iron pipelines (both mains and the accompanying service lines) with higher-pressure modern plastic piping.

The South Union Street project proposed replacing two low-pressure cast iron mains with one plastic high-pressure main. Once installed, the new plastic main would be ''tied-in'' to the distribution system and service lines supplying gas to customers. As is typical in pipe replacement projects, the two cast iron mains would be completely disconnected from the low-pressure system and abandoned in the ground upon completion.

The scope of the South Union Street project included the replacement of the cast iron mains near a belowground regulator station located at the intersection of Winthrop Avenue and South Union Street (the Winthrop regulator station), one of the 14 regulator stations that monitored and controlled downstream pressure in the South Lawrence system. Up until the time of the incident, two control lines connected the Winthrop regulator station and the two cast iron and bare steel mains on South Union Street.

CMA contracted with a pipeline services firm to complete the replacement project. CMA prepared a work package, which included materials such as isometric drawings and procedural details for disconnecting and connecting pipes, for each of the planned construction activities. However, CMA did not prepare a package for the relocation of the control lines serving the regulator station. The absence of a complete work package led to the contractor completing the installation of the plastic main with the regulator control lines at the regulator station still connected to the cast iron main that was being replaced.

In 2016, the construction crew installed the new plastic main on South Union Street and began feeding the new plastic main with gas from the Winthrop regulator station. However, CMA put the work on hold due to a city-wide moratorium on all gas, water, and sewer projects in Lawrence. Consequently, the construction crew was unable to begin any of the tie-in and abandonment procedures to tie-in or connect the mains or services to the new plastic main and thus was also unable to abandon the cast iron mains on South Union Street. The regulator control lines at the Winthrop regulator station remained connected to the cast iron mains that would ultimately be decommissioned.

The final stage of the South Union Street project involved the installation of tie-ins to the new plastic main, after which the legacy cast iron mains would be decommissioned and abandoned in

[23] CMA transferred from NiSource, Inc. to Eversource Energy in November 2020.

[24] NTSB/PAR–19/02 at 49.

their existing location. CMA then connected the plastic pipe to the gas distribution system, which allowed it to be monitored for pressure changes.

On September 13, 2018, at 4:00 p.m., the construction crew completed the final ''tie-in'' and abandonment procedure following the procedures CMA provided to the crew at South Union Street. Unbeknownst to the construction crew, the control lines were still connected to the abandoned cast iron main despite the gas now flowing through the new plastic main. At the Winthrop regulator station, about 0.5 miles south of the work area, the control lines that were still connected to the cast-iron mains on South Union Street sensed a sharp decline in pressure, causing the Winthrop regulator station to add more pressure into the South Lawrence low-pressure system. Feeding high-pressure gas into the low-pressure system resulted in a catastrophic overpressurization of the system. The overpressurization of the low-pressure system in the city of Lawrence and the towns of Andover and North Andover sent gas into home appliances at a rate that they were not designed to handle. This created explosions and fires in those homes and businesses. Local fire departments were the first to receive notification of the start of the incident via 9–1–1 calls. Shortly after 4:00 p.m., the local fire departments were inundated with calls from the public.

F. Emergency Response to the Merrimack Valley Incident

On September 13, 2018, the monitoring center in Columbus, OH, which was overseeing the CMA system, received pressure alarms on its supervisory control and data acquisition (SCADA) system.[25] The system recorded a sudden increase in pressure in the Merrimack Valley low-pressure system at 3:57 p.m. The SCADA's high-pressure alarms activated at 4:04 p.m. and 4:05 p.m. for the South Lawrence district regulator station and Andover, respectively. The SCADA system was only able to monitor system pressures; it could not remotely control the pressure of this system.

Following company protocol, at 4:06 p.m., the SCADA controller called the on-call technician in Lawrence, MA, and reported the high-pressure event. The on-call technician dispatched 3 field technicians to perform field checks on the 14 regulators within the South Lawrence system. Not until about 4:30 p.m. did a CMA field technician at the Winthrop regulator station (the location of the control lines still connected to the cast iron main) hear a loud sound and recognize that a large quantity of natural gas was flowing through the Winthrop regulator station. The CMA field technician adjusted the set point on the two regulators to reduce flow and isolated them. The CMA field technician then noticed that the sound of the flowing natural gas began to decrease.

Meanwhile, at 4:18 p.m., a CMA field engineer and a CMA field operations leader (FOL) were at another construction site when they received notice to respond to fire coming out of house chimneys. Due to traffic congestion, a police officer escorted the FOL to the construction site at Salem and South Union streets (location of the September 13 tie-in). When the FOL arrived at 5:08 p.m., crew members stated that they had confirmed the pressure in the entire low-pressure system was in the normal range before removing the bypass (*i.e.,* disconnecting the cast iron main from the Winthrop regulator station and connecting the new plastic main). At 5:19 p.m. the FOL took pressure readings at a nearby house and found the pressure was elevated. The FOL then recommended to a supervisor that CMA shut down the low-pressure system.

After being designated as the CMA Incident Commander by the Lawrence Operations Center manager, the FOL then called CMA's engineering department for the list of valves that needed closing to isolate and shut down the system. While waiting for this information, the FOL assigned crews to regulator stations and directed them to verify, with CMA's engineering department, the correct valve to close once they arrived at the regulator station. Once confirmed, they closed the valves. The FOL confirmed the closure of all valves at 7:24 p.m.

At 7:43 p.m., almost 4 hours after the CMA SCADA system detected the overpressurization, the president of CMA declared a ''Level 1'' emergency, in accordance with CMA's emergency response plan. According to the NTSB's report, the operator's Emergency Response Manual defines a ''Level 1'' emergency as a ''catastrophic event'' that includes the loss of a major natural gas facility or the loss of critical natural gas infrastructure.

Working through the night, CMA's engineering department worked under the FOL's direction to confirm that no gas was flowing into the regulator stations on the low-pressure system. On September 14, 2018, at 6:27 a.m., CMA confirmed the low-pressure distribution system was shut down for the 8,447 customers in the Lawrence, Andover, and North Andover areas. CMA shut down the natural gas to an additional 2,447 customers outside the immediate area as a precaution.

The following days required an unprecedented response effort. More than 50,000 residents were asked to evacuate from their homes following the overpressurization.[26] Thousands of homes needed to be entered, rendered safe, and secured to ensure that dangerous gas levels no longer existed. As the emergency response concluded, it was clear that the recovery effort would span months. CMA's work in the aftermath of the incident focused on repairing infrastructure damage, providing shelter, and finding longer-term housing solutions as recovery efforts extended into the fall and winter months.

The 2018 incident impacted three communities in the Merrimack Valley that, while geographically near one another, are different demographically. Lawrence is a densely populated city with many Spanish-speaking residents and a higher poverty rate than Andover and North Andover. Andover and North Andover are middle-class suburban communities, and although each has half the population size of Lawrence, their geographic size is four to five times that of Lawrence.

III. Recommendations, Advisory Bulletins, and Mandates

A. National Transportation Safety Board

The NTSB investigates serious pipeline accidents, including those that occur on gas distribution pipeline systems. The NTSB investigated CMA's overpressurization incident and issued its final report,[27] which included several findings and safety recommendations to NiSource, Inc., the Commonwealth of Massachusetts (Massachusetts), several other States,[28] and PHMSA.

[25] Operators use SCADA systems to monitor and control critical assets remotely. *See* § 192.631. Here, the South Lawrence system was monitored by CMA's corporate owner at the time, NiSource.

[26] Mass. Dep't of Pub. Utilities, ''Independent Assessment of Columbia Gas of Massachusetts' Merrimack Valley Restoration Program: Final Report,'' at A–2 (June 22, 2020), *https://www.mass.gov/doc/independent-assessment-of-columbia-gas-of-massachusetts-merrimack-valley-restoration-program/download.*

[27] *See* NTSB, PAR–19/02. The full report is available at *https://www.ntsb.gov/investigations/AccidentReports/Reports/PAR1902.pdf.*

[28] These states were Alabama, Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Idaho, Illinois, Kentucky, Louisiana, Maine, Maryland, Mississippi, Missouri, Montana, Nebraska, Nevada, New York, North Carolina, Pennsylvania, South Carolina, South

In its accident report, the NTSB issued two safety recommendations to PHMSA. The first, P–19–14, recommended that PHMSA require overpressure protection for low-pressure natural gas distribution systems that cannot be defeated by a single operator error or equipment failure. The NTSB further clarified that to satisfy this recommendation, PHMSA would not have to require that existing low-pressure gas distribution systems be completely redesigned; rather, PHMSA may satisfy this recommendation by requiring operators to add additional protections, such as slam-shut or relief valves, to existing district regulator stations or other appropriate locations in the system.[29] The second, P–19–15, recommended that PHMSA issue an advisory bulletin to all low-pressure natural gas distribution system operators of the possibility of a failure of overpressure protection. Further, P–19–15 stated that the advisory bulletin should recommend that operators use a failure modes and effects analysis or an equivalent structured and systematic method to identify potential failures and take action to mitigate those identified failures. In developing this NPRM, PHMSA also reviewed additional recommendations relating to the Merrimack Valley incident that NTSB made to states and operators.

B. Advisory Bulletins

1. Possibility of Overpressurization of Low-Pressure Distribution Systems Advisory Bulletin

On September 29, 2020, PHMSA issued an advisory bulletin (ADB–2020–02) to urge owners and operators of gas distribution systems to conduct a comprehensive review of their systems for the possibility of a failure of overpressure protection on low-pressure distribution systems.[30] The advisory bulletin addressed NTSB safety recommendation P–19–15, which underscored the elevated possibility of a common mode of failure on low-pressure distribution systems. Specifically, PHMSA requested owners and operators of low-pressure distribution systems to review the NTSB's report concerning the 2018 Merrimack Valley overpressurization event. PHMSA also recommended that operators review their current systems for a similar overpressure-protection configuration to that on the CMA pipeline involved in the incident. In the review of their systems, PHMSA urged operators to consider the possibility of a failure of overpressure-protection devices as a threat to their system's integrity. Additionally, PHMSA reminded owners and operators of their responsibilities under 49 CFR part 192, subpart P, to follow their DIMP and to revise their DIMP based on the new information provided in the NTSB's report and PHMSA's advisory bulletin. Finally, PHMSA recommended several ways that an operator can protect low-pressure distribution systems from an overpressurization event. Some examples include:

1. Installing a full-capacity relief valve downstream of the regulator station, including in applications where there is only worker-monitor pressure control;
2. Installing a ''slam-shut'' device;
3. Using telemetered pressure recordings at district regulator stations to signal failures immediately to operators at control centers; and
4. Completely and accurately documenting the location for all control lines on the system.

2. Cast-Iron Pipe Advisory Bulletin

On March 23, 2012, PHMSA issued advisory bulletin ADB–2012–05 to owners and operators of cast-iron distribution pipelines and State pipeline safety representatives.[31] PHMSA issued this advisory bulletin partly in response to the 2011 deadly explosions in Philadelphia and Allentown, PA, involving cast-iron pipelines installed in 1942 and 1928, respectively.[32] These incidents gained national attention and highlighted the need for continued safety improvements to aging gas pipeline systems. This advisory bulletin updated two prior advisory bulletins (ALN–91–02, issued on October 11, 1991, and ALN–92–02, issued on June 26, 1992 [33]) covering the continued use of cast-iron pipe in gas distribution pipeline systems. The ADB–2012–05 reiterated the two prior advisory bulletins, urging owners and operators to conduct a comprehensive review of their cast-iron gas distribution pipelines and replacement programs and to accelerate repair and replacement of high-risk pipelines. ADB–2012–05 also requested that State agencies consider enhancements to cast-iron replacement plans and programs. Specifically, in ADB–2012–05, PHMSA asked owners and operators of cast-iron distribution pipelines and State safety representatives to consider the following where improvements in safety are necessary:

1. Review current cast-iron replacement programs and consider establishing mandated replacement programs;
2. Establish accelerated leakage survey frequencies or leak testing;
3. Focus pipeline safety efforts on identifying the highest-risk pipe;
4. Use rate adjustments to incentivize pipeline rehabilitation, repair, and replacement programs;
5. Strengthen pipeline safety inspections, accident investigations, and enforcement actions; and
6. Install interior/home methane gas alarms.

PHMSA reminded owners and operators of their responsibilities under § 192.617 to establish procedures for analyzing incidents and failures to determine the causes of the failures and to minimize the possibility of a reoccurrence.

Finally, the advisory bulletin notes that the DOT, in accordance with the Pipeline Safety, Regulatory Certainty, and Job Creation Act of 2011 (Pub. L. 112–90), will continue to monitor the progress made by operators to implement plans of safe management and replacement of cast-iron gas pipelines and identify the total miles of cast iron pipelines in the United States.

C. Statutory Authority

Title II of the PIPES Act of 2020, the ''Leonel Rondon Pipeline Safety Act,'' included several mandates for PHMSA to update the regulations governing operators of gas distribution systems. This NPRM addresses mandates codified at 49 U.S.C. 60102(r)–(t), 60105(b), and 60109(e)(7). (*See* sections 202, 203, 204, and 206 of the PIPES Act of 2020). Additionally, PHMSA has general statutory authority to regulate the safety of gas pipeline facilities subject to this rulemaking as discussed in section V.A of this NPRM.

Dakota, Texas, Utah, Virginia, and Wyoming. NTSB/PAR–19/02 at 50.

[29] NTSB clarified this in an official correspondence to PHMSA on July 31, 2020. NTSB, ''Safety Recommendation P–19–014'' (July 31, 2020), *https://data.ntsb.gov/carol-main-public/sr-details/P-19-014*.

[30] ''Pipeline Safety: Overpressure Protection on Low-Pressure Natural Gas Distribution Systems,'' ADB–2020–02, 85 FR 61097 (Sept. 29, 2020).

[31] ''Pipeline Safety: Cast Iron Pipe (Supplementary Advisory Bulletin),'' ADB–2012–05, 77 FR 17119 (Mar. 23, 2012).

[32] On January 18, 2011, an explosion and fire caused the death of one gas utility employee and injuries to several other people while gas utility crews were responding to a natural gas leak in Philadelphia, Pennsylvania. On February 9, 2011, five people lost their lives, several homes were destroyed, and other properties were impacted by an explosion and subsequent fire in Allentown, Pennsylvania.

[33] Research and Special Programs Administration (RSPA), ALN–91–02 (Oct. 11, 1991), *https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/RSPA%20Alert%20Notice%2091-02.pdf;* RSPA, ALN–92–02 (June 26, 1992), *https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/RSPA%20Alert%20Notice%2092-02.pdf* (supplementing ALN–91–02).

1. Distribution Integrity Management Program Plans and State Inspection Calculation Tool (49 U.S.C. 60109(e)(7) and 49 U.S.C. 60105(b) and 60105 Note; PIPES Act of 2020 Section 202)

PHMSA is required to issue regulations ensuring that DIMP plans for gas distribution operators include an evaluation of certain risks, such as those posed by cast iron pipes and mains and low-pressure distribution systems, as well as the possibility of future accidents to better account for high-consequence but low-probability events. (49 U.S.C. 60109(e)(7)). Gas distribution operators were required make their DIMP plans, emergency response plans, and O&M manuals available to PHMSA or the relevant State regulatory agency no later than December 27, 2022. Gas distribution operators must also make these documents, in updated form, available to PHMSA or the relevant State regulatory agency: (1) two years after the promulgation of regulations as required; and (2) every 5 years thereafter, as well as following any significant change to the document. PHMSA must also update and codify the use of the SICT, a tool used to help states determine the minimum amount of time it must dedicate to inspections. (*See* 49 U.S.C. 60105(b) and 60105 note).

2. Emergency Response Plans (49 U.S.C. 60102(r); PIPES Act of 2020 Section 203)

PHMSA is required to update its emergency response plan regulations to ensure that each emergency response plan developed by a gas distribution system operator includes written procedures for how to handle communications with first responders, other relevant public officials, and the general public after certain significant pipeline emergencies (49 U.S.C. 60102(r)). Specifically, the updated regulations would ensure that pipeline operators contact first responders and public officials as soon as practicable after they know a release of gas has occurred that resulted in a fire related to an unintended release of gas, an explosion, one or more fatalities, or the unscheduled release of gas and shutdown of gas service to a significant number of customers. Similarly, the updated regulations would provide for general public communication of pertinent emergencies as soon as practicable and leverage communications methods facilitating rapid notice to the general public.

3. Operation and Maintenance Manuals (49 U.S.C. 60102(s); PIPES Act of 2020 Section 204)

PHMSA is required to update the regulations for O&M manuals to require distribution system operators to have a specific action plan to respond to overpressurization events (49 U.S.C. 60102(s)). Additionally, operators must develop written procedures for management of change processes for significant technology, equipment, procedural, and organizational changes to their distribution system and ensure that relevant qualified personnel, such as an engineer with a professional engineer (PE) license, reviews and certifies such changes (49 U.S.C. 60102(s)).

4. Pipeline Safety Practices (49 U.S.C. 60102(t); PIPES Act of 2020 Section 206)

PHMSA is required to issue regulations that require distribution pipeline operators to identify and manage ''traceable, reliable, and complete'' maps and records of critical pressure-control infrastructure and update these records as appropriate. The records must be submitted or made available to the relevant regulatory agency (*i.e.,* PHMSA or the State). These regulations must require records to be gathered on an opportunistic basis. (49 U.S.C. 60102(t)(1)).

PHMSA must also issue regulations requiring a qualified employee of a distribution system operator to monitor gas pressure at district regulator stations and be able to shut off flow or limit gas pressure during construction projects that have the potential to cause a hazardous overpressurization. An exception to this requirement would be made for a district regulator station that has a monitoring system and capability for a remote or automatic shutoff (49 U.S.C. 60102(t)(2)). PHMSA is further required to issue regulations on district regulator stations to ensure that gas distribution system operators minimize the risk of a common mode of failure at low-pressure district regulator stations, monitor the gas pressure of low-pressure distribution systems, and install overpressure protection safety technology at low-pressure district regulator stations. If it is not operationally possible to install such technology, this section would require the operator to identify plans that would minimize the risk of overpressurization (49 U.S.C. 60102(t)(3)).

IV. Proposed Amendments

A. Distribution Integrity Management Programs (Subpart P)

In 2009, PHMSA issued a final rule titled ''Pipeline Safety: Integrity Management Program for Gas Distribution Pipelines,'' creating 49 CFR part 192, subpart P.[34] As specified in § 192.1003, subpart P applies to operators of all gas distribution pipelines covered under part 192, subject to certain exceptions, and prescribes minimum requirements for integrity management programs for any such pipelines (referred to in this rulemaking as DIMPs). Adherence to a DIMP is an overall approach by operators to ensure the integrity of their distribution systems. The purpose of DIMP is to enhance safety by identifying and reducing pipeline integrity risks. DIMP regulations require that operators develop an integrity management plan that they must re-evaluate periodically; that integrity management plan complements operator efforts in complying with prescriptive operating and maintenance requirements elsewhere in part 192.

Pursuant to § 192.1007, DIMP regulations require operators implement the following steps in developing their DIMP plans:

(1) *Knowledge* (§ 192.1007(a))—Requires operators to understand their pipeline system's design and material characteristics, operating conditions and environment, and maintenance and operating history;

(2) *Identify Threats* (§ 192.1007(b))—Requires operators to identify existing and potential threats to their pipeline systems;

(3) *Evaluate and Rank Risk* (§ 192.1007(c))—Requires operators to evaluate and identify threats to determine their relative importance and rank the risks associated with their pipeline systems;

(4) *Identify and Implement Measures to Address Risks* (§ 192.1007(d))—Requires operators to determine and implement measures designed to reduce the risks from failure of their pipeline systems;

(5) *Measure Performance, Monitor Results, and Evaluate Effectiveness* (§ 192.1007(e))—Requires operators to measure the performance of their DIMPs and reevaluate threats and risks to their pipeline systems;

(6) *Periodic Evaluation and Improvement* (§ 192.1007(f))—Requires operators to periodically reevaluate threats and risks across the entire pipeline system; and

[34] 74 FR 63906 (Dec. 4, 2009).