

**INVESTIGATION OF MAXIMUM
TEMPERATURES ATTAINED BY
PLASTIC FUEL GAS PIPE INSIDE
SERVICE RISERS**

TR-30

2010



Foreword

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The purpose of this technical report is to provide essential information on a particular aspect of thermoplastic piping to engineers, users, contractors, code officials and other interested parties.

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1.0 INTRODUCTION

- 1.1 The maximum allowable temperatures for plastic piping systems used for fuel gas distribution are defined by Part 192, *Transportation of Natural Gas and Other Gas by Pipeline: Minimum Safety Standards*, Subchapter I), *Pipeline Safety*, of Title 49, *Transportation*, of the U. S. Code of Federal Regulations. By an act of Congress, the U. S. Department of Transportation regulates pipeline safety.
- 1.2 Section 375, *Service Lines: Plastic*, of Part 192 of the U. S. Pipeline Safety Regulations allows the use of properly designed metal-sleeved plastic riser pipe. A point that must be considered in proper design is the maximum temperature that can develop in the above-ground portion of the metal riser and its effect on the strength properties of the plastics gas carrier pipe. Section 121, *Design of Plastic Pipe*, of Part 192 limits the allowable operating temperature of a thermoplastic pipe to the highest value for which the pipes long-term hydrostatic strength has been established, except that it may not exceed 140°F.
- 1.3 There has been some concern that the portion of a plastic riser pipe that is brought up out of the ground inside a protective metal sleeve for connection to a gas meter located outdoors may experience considerably higher temperatures than buried pipe, possibly even above the 140°F limit. Since metal-sleeved risers may be exposed to direct sunlight, they could become heated to higher than ambient temperatures. This report presents test data showing the maximum temperatures that may be obtained by thermoplastics pipe installed inside a metal protective sleeve and the conditions under which the maximum temperatures occur. The report includes:
 - 1.3.1 A description of the test equipment, the environment, and the results obtained when evaluating for the effects of:
 - a. wall contact;
 - b. venting;
 - c. shading;
 - d. various insulating materials;
 - e. geographical location.
 - 1.3.2 A correlation of actual and estimated service riser temperatures across the U.S.A.

- 1.3.3 An evaluation of the influence of temperature cycling on the hydrostatic strength of polyethylene pipe.
- 1.3.4 A description of a plastic-pipe/metal-sleeve riser assembly design that minimizes temperatures in the plastic pipe.
- 1.3.5 A list of plastic pipe materials that can be operated safely at the temperatures encountered in a properly-designed service riser.

2.0 CONCLUSIONS

- 2.1 The results of this study, in which a separation of at least 1/6 inch was maintained between plastic and metal, point to the following conclusions regarding proper design and installation of thermoplastic pipe gas service risers:
 - 2.1.1 The plastic pipe must not touch the wall of the metal sleeve. Provisions must be included to assure that an annular space of at least 1/6-inch is maintained.
 - 2.1.2 In all areas of the U.S. except the desert southwest, 120°F is an appropriate temperature to use as the hydrostatic design basis for the plastic pipe.
 - 2.1.3 In the desert areas of southwestern U.S., 140°F should be used as the appropriate temperature for this purpose.
 - 2.1.4 Thermoplastic pipe may be utilized safely and effectively in metal-sleeved risers when the above provisions are observed and when pipe selection and design are based upon appropriately established hydrostatic design ratings and the applicable design factors identified in DOT Document 192.

Note

If an installation has less than the 1/6-inch separation used in this study, check the plastic pipe temperature to insure that it does not exceed either the pipe material limitations or the applicable code requirements.

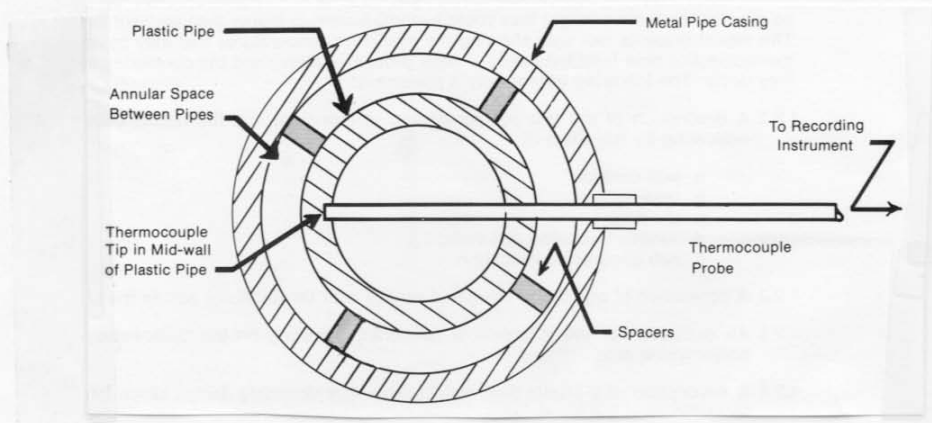


Figure 1. Top Cross-Sectional View of Plastic Pipe in Metal Casing Showing Thermocouple Arrangement

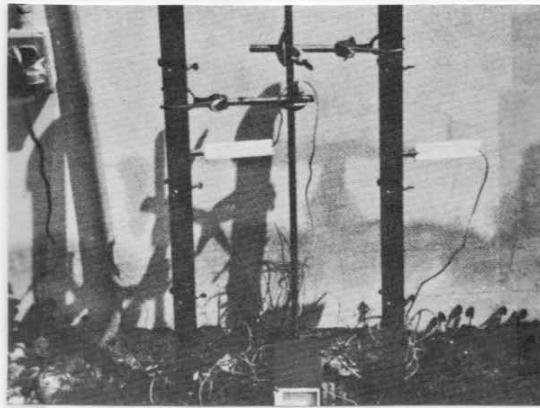


Figure 2. Photograph of Testing Arrangement with Two Test Riser Assemblies and a Temperature Recorder

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3.0 TEST ASSEMBLIES

- 3.1 The assemblies used for these tests consisted of 3-foot pipe lengths of 3/4-inch IPS polyethylene pipe installed in a 1-1/4-inch metal pipe. The two ends of the plastic pipe were stoppered and the ends of the metal pipe were capped. The plastic pipe was secured in the metal pipe by thumbscrews, so the annular space could be maintained at about 1/6 inch at all points and the plastic did not touch the metal pipe. By adjusting the thumbscrews, the plastic pipe could be brought into contact with the metal pipe when desired.
- 3.2 The assembly included a thermocouple with the sensing element at the mid-wall of the plastic pipe. A continuous strip-chart recorder measured the temperature. Figure 1 shows a cross section of the assembly, in which the thumbscrews are identified as spacers. Two of these complete test assemblies were used for tests that were carried out at various locations throughout the United States. Figure 2 is a photograph of a typical test arrangement, showing both test assemblies and the recorder.

4.0 SUMMARY OF TEST RESULTS AND OBSERVATIONS

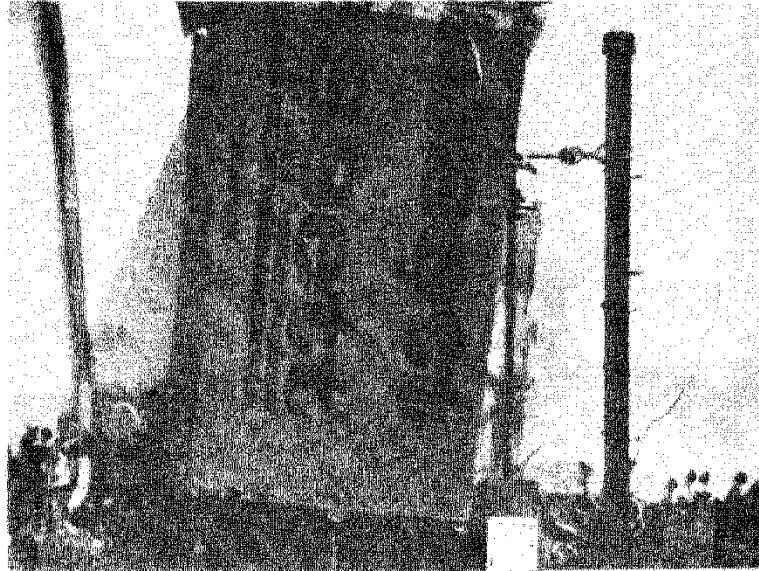
- 4.1 **The effect of wall contact** - In assemblies where the plastic pipe touches the metal pipe, temperatures in excess of 140°F are possible. Examples of several measured temperatures are shown in Table 1.

Table 1 Effect of Wall Contact

Location	Plastic Pipe Touching Metal Wall Temp. °F	Plastic Pipe Controlled (Not Touching) Temp. °F	Ambient Air Temp. °F Unshaded
Wilmington, DE	143	110	94
Orange, TX	149	116	96
Phoenix, AZ	156	122	107
San Francisco, CA	144; 140	-	95

- 4.2 The effect of shading** - A definite temperature reduction of the plastic pipe was obtained by shading the assembly. With one assembly shaded, its temperature was approximately 10°F lower than that of the unshaded assembly. Figure 3 is a photograph showing the arrangement in which one assembly is shaded and the other is exposed to the sun.

Figure 3. Arrangement of Test Assemblies and Recorder with One Test Assembly Shaded and One Unshaded



- 4.3 The effect of venting** - The metal sleeve was vented to determine whether this would have an effect on the temperature of the enclosed plastic pipe. This experiment was carried out because a hypothesis had been advanced that holes in the metal casing would allow air circulation and thus reduce the temperature. To determine the effects of venting, the caps were removed from both ends of one assembly only and both assemblies were then exposed to exactly the same environment. The plastic pipe temperatures in the vented and unvented assemblies differed by no more than 2°F, so the results indicate that there is no significant advantage to be obtained by venting.

4.4 The effects of insulating materials - Various types of insulation were placed between the plastic and metal pipes to study their possible effects. The materials evaluated were polystyrene foam, rubber, urethane foam, and asbestos. None of these insulators proved to be any more effective than air in the annular space.

4.5 The effects of geographic location - A series of tests were performed in several areas of the United States, representing significantly different climatic conditions. The basic test assemblies were used, with stoppered plastic pipes, capped metal casings, and a 1/6-inch insulating air space between the pipe and casing. Table 2 lists temperatures recorded at these sites during the summers of 1973 through 1975 and Table 3 lists the values obtained during the winter of 1975-76. From these data, it is obvious that the air temperature completely controls the plastic pipe minimum temperature under winter conditions.

Table 2. Temperatures Attained by Plastic Pipe in Test Assemblies During Summer Seasons

Test Location	Test Dates	Days Operated	Maximum Pipe Temp. (°F)	Total Hours* Pipe Above 100°F	Total Hours* Pipe Above 120°F
Wilmington, DE	July, 1973	10	115	3	0
Tulsa, OK	August, 1973	3	120	4	0
Keene, NH	July, 1973	6	112	2	0
Hialeah, FL	Sept., 1973	9	120	4.5	0
Orange, TX	July, 1974	4	118	5.5	0
Phoenix, AZ	August, 1974	4	124	8	3
San Ramon, CA	July, 1975	3	100	0	0
Pico Rivera, CA	August, 1975	4	112	4.5	0
Borrego Spring, CA	August, 1975	4	125	6.5	2.5

*On hottest day

Table 3. Temperatures Attained by Plastic Pipe in Test Assemblies During Winter Season

Test Locations	Test Dates	Days Operated	Minimum Air Temp., °F	Minimum Pipe Temp., °F
Wilmington, DE	December, 1975	3	15	15
Fitzwilliam, NH	January, 1976	3	16	16
Soda Springs, ID	February, 1976	7	2	2

5.0 ESTIMATED SERVICE RISER PIPE TEMPERATURES ACROSS THE U.S.

5.1 A correlation has been established between the ambient air temperature and the plastic pipe temperature in the simulated meter riser device, placed in stringent summertime environments. The value of this correlation is that it permits estimation of the number of hours the pipe will be above 120°F or above 100°F from a knowledge of the air temperature vs. time plot. Following are several such relationships:

- 5.1.1 When the air temperature is between 100°F and 105° F for 7-1/2hours, the temperature of the plastic pipe will be above 120° F for 2-1/2hours.
- 5.1.2 When the air temperature is between 100°F and 102°F for 3 hours, the temperature of the plastic pipe will be above 120°F for 1 hour.
- 5.1.3 If the air temperature is less than 100°F, the plastic pipe temperature will not reach 120°F.
- 5.1.4 If the air temperature is below 80°F, the plastic pipe temperature will not reach 100°F.
- 5.1.5 Air temperatures between 80°F and 99°F will probably cause the plastic pipe temperature to exceed 100°F. The pipe temperature will likely be above 100°F for about one-third of the daylight hours that the air temperature is between 80°F and 99°F.

- 5.2 A typical air temperature vs. plastic pipe temperature relationship is shown in Figure 4. A number of such relationships were used to arrive at the observations listed in 5.1 above.
- 5.3 The United States Weather Bureau issues specific climatic data from key U.S. cities on a monthly basis. Such data allowed use of the relationships described in the preceding section of this report to estimate how many hours per year the plastic pipe in the metal casing would exceed 120°F. The appended Table 4, consisting of five pages, shows data from the U.S. Summer Weather Record for 21 cities during the period from 1971 to 1974. For each of these cities, listed data include the highest temperature attained during the months of June through September, the highest temperature during the year, and number of days during the year when the temperature exceeded 90°F. The last column lists the estimated percentage of time during the year that the plastic pipe in a metal sleeve would have reached 120°F or higher in an unshaded stringent environment. Note that, in most cases, this column shows 0%. Phoenix is the only notable exception, and here the 120°F temperature is attained less than 2% of the time.

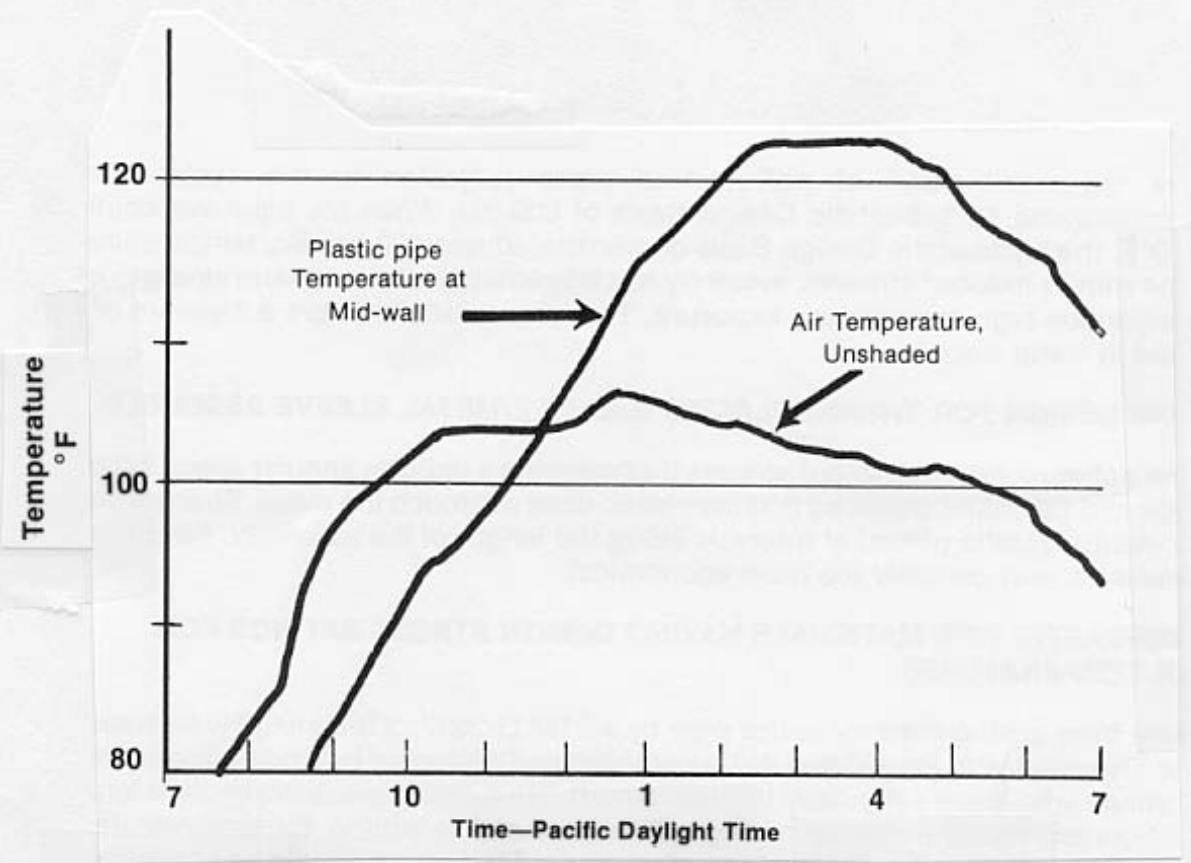


Figure 4. Air Temperature in Sun, and Temperature of Plastic Pipe in Standard Test Assemblies when Unshaded and Located on South Side of White Building in Southern California in July

6.0 INFLUENCE OF TEMPERATURE CYCLING ON HYDROSTATIC DESIGN PROPERTIES OF POLYETHYLENE PIPE

- 6.1 In plastic pipe design, the practice is to employ the highest temperature of the application as the basis for selecting the Recommended Hydrostatic Design Stress (RHDS). Such practice insures a conservative stance to follow when the environment of the application is not fully defined or the influences of variable temperatures on the pipe are not known.
- 6.2 The temperature ranges experienced by the plastic pipe in a metal casing have been well established by the series of experiments described in this report. An evaluation of the effect on polyethylene pipe under temperature cycling conditions has shown that the pressure -bearing capability of the pipe is better when cycled than when held continuously at the highest temperature. In this temperature cycling evaluation, the Hydrostatic Design Basis of the pipe was determined using the method defined in ASTM D-2837, "Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials". Water was used as the pressure-imposing fluid and its temperature was subjected to the following program:
- Hold at 73°F for three hours.
 - Raise to 140°F in a one-hour period.
 - Hold at 140°F for three hours.
 - Reduce to 73°F in one hour.
 - Repeat.

The regression curve of polyethylene pipes subjected to this cycle for 10,000 hours demonstrated a Hydrostatic Design Basis of 800 psi. When the pipe was held continuously at 140°F, the Hydrostatic Design Basis was 630 psi. So, evidently, temperature cycling of PE pipe with its induced stresses has less effect on the long-term strength of the pipe than continuous high temperature exposure. This characteristic offers a measure of safety to pipe used in a meter riser.

7.0 OPTIMUM DESIGN FOR THERMOPLASTIC GAS PIPE WITH METAL SLEEVE ASSEMBLY

- 7.1 For an optimum design, use spacers that maintain a uniform annular space between the plastic pipe and the metal sleeve so that the plastic does not touch the metal. Spacers may be rubber or flexible plastic, placed at intervals along the length of the assembly. Air is the most effective insulation and certainly the most economical. Products incorporating these design features are available commercially.

8.0 THERMOPLASTIC PIPE MATERIALS HAVING DESIGN STRESS RATINGS FOR HIGHER TEMPERATURES

A committee of the Plastics Pipe Institute regularly compiles and evaluates data obtained from testing thermoplastics pipe. The procedure is defined in ASTM D 2837, "Obtaining Hydrostatic Design Bases for Thermoplastic Pipe Materials". The committee issues a regularly updated report, TR-4, listing materials by their long-term strength categories. Consult the most recent TR-4 report, available from The Plastics Pipe Institute, for current listings.

Table 4. Highest Temperature Data from Weather Stations Around the U.S.

Source: U.S. Weather Bureau Publications

Note

The last column in this table is an estimate of the percent of hours per year when a plastic pipe encased in a metal pipe, with an annular air space of 1/6 inch, would have a temperature above 120°F.

Location and Year	Highest Temperature, °F				Year High, °F	No. Days over 90°F	% hours over 120°F
	June	July	Aug.	Sept.			
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Birmingham, AL							
1971	98	97	92	92	98	31	0
1972	92	94	97	94	97	45	0
1973	89	94	91	95	95	30	0
1974	93	95	91	90	95	34	0
Total, 4 years						140	0
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Phoenix, AZ							
1971	111	114	106	110	114	154	1.0
1972	112	115	116	105	116	160	1.1
1973	115	115	111	115	108	172	1.1
1974	116	113	110	110	116	180	1.1
Total, 4 years						666	1.1
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Location and Year	Highest Temperature, °F				Year High, °F	No. Days over 90°F	% hours over 120°F
	June	July	Aug.	Sept.			
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Los Angeles, CA							
1971	77	82	90	91	101	9	0
1972	77	87	90	89	90	2	0
1973	90	92	85	98	98	6	0
1974	80	84	78	86	100	4	0
Total, 4 years						21	0
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San Diego, CA							
1971	79	83	88	94	101	7	0
1972	77	92	90	85	92	4	0
1973	90	80	83	93	93	5	0
1974	82	86	77	84	94	2	0
Total, 4 years						18	0
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San Francisco, CA							
1971	83	79	87	103	103	5	0
1972	89	98	91	90	98	3	0
1973	98	79	83	85	98	6	0
1974	103	83	92	89	103	1	0
Total, 4 years						15	0
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Denver, CO							
1971	98	101	94	94	101	38	0
1972	89	100	98	85	100	75	0
1973	95	103	94	87	103	33	0.022
1974	96	95	94	93	96	46	0
Total, 4 years						192	0.005
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Wilmington, DE							
1971	92	95	90	88	95	14	0
1972	90	95	94	91	95	10	0
1973	95	94	100	95	100	24	0
1974	92	95	90	88	95	17	0
Total, 4 years						65	0
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Location and Year	Highest Temperature, °F				Year High, °F	No. Days over 90°F	% hours over 120°F
	June	July	Aug.	Sept.			
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Jacksonville, FL							
1971	98	96	94	92	98	71	0
1972	95	97	96	96	97	76	0
1973	95	96	95	94	96	81	0
1974	93	93	93	92	93	53	0
Total, 4 years						281	0
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Miami, FL							
1971	91	91	90	87	96	28	0
1972	91	89	89	89	91	20	0
1973	90	90	90	90	91	13	0
1974	92	93	92	92	93	51	0
Total, 4 years						112	0
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Atlanta, GA							
1971	93	91	89	87	93	11	0
1972	90	94	92	92	94	18	0
1973	89	94	91	94	94	16	0
1974	91	92	91	88	92	14	0
Total, 4 years						59	0
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Chicago, IL							
1971	97	90	94	94	94	35	0
1972	94	93	93	87	93	12	0
1973	91	95	95	94	95	29	0
1974	90	97	89	88	97	9	0
Total, 4 years						85	0
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Boston, MA							
1971	94	94	93	92	94	15	0
1972	86	94	88	88	94	9	0
1973	97	96	99	95	99	19	0
1974	93	95	91	87	95	7	0
Total, 4 years						50	0

Location and Year	Highest Temperature, °F				Year High, °F	No. Days over 90°F	% hours over 120°F
	June	July	Aug.	Sept.			
Minneapolis, MN							
1971	96	90	97	94	97	10	0
1972	92	91	97	83	97	9	0
1973	98	95	93	85	98	13	0
1974	88	101	90	85	101	15	0
Total, 4 years						47	0
Concord, NH							
1971	95	92	85	88	95	5	0
1972	87	92	88	85	92	3	0
1973	96	95	95	93	96	16	0
1974	92	93	92	88	93	11	0
Total, 4 years						35	0
New York, NY							
1971	93	96	92	91	96	18	0
1972	86	95	95	92	95	14	0
1973	95	94	98	96	98	18	0
1974	95	95	92	88	95	17	0
Total, 4 years						67	0
Charlotte, NC							
1971	94	91	90	89	94	12	0
1972	90	94	92	93	94	28	0
1973	90	97	94	93	97	25	0
1974	93	91	92	89	93	14	0
Total, 4 years						79	0
Bismarck, ND							
1971	84	93	102	100	102	18	0
1972	90	95	100	94	100	19	0
1973	92	108	107	84	108	23	0
1974	96	100	94	91	100	26	0
Total, 4 years						86	0
Columbus, OH							
1971	94	89	88	87	94	7	0
1972	86	92	91	86	92	3	0
1973	91	91	94	93	94	17	0
1974	88	93	91	85	93	11	0
Total, 4 years						38	0
Location and	Highest Temperature, °F				Year	No.	% hours

Year					High, °F	Days over 90°F	over 120°F
	June	July	Aug.	Sept.			
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Philadelphia, PA							
1971	92	96	89	92	96	20	0
1972	86	95	96	90	96	18	0
1973	93	93	99	97	99	28	0
1974	95	95	93	90	95	22	0
Total, 4 years						88	0
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Spokane, WA							
1971	90	99	101	86	101	31	0
1972	90	96	103	88	103	17	0
1973	100	95	95	93	100	29	0
1974	94	97	94	84	97	18	0
Total, 4 years						95	0
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Cheyenne, WY							
1971	92	95	91	86	95	9	0
1972	82	93	91	81	93	3	0
1973	91	98	89	79	98	9	0
1974	89	89	87	86	89	0	0
Total, 4 years						21	0
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