

Technical Report on Performance of API and ANSI End Connections in a Fire Test According to API Specification 6FA

API TECHNICAL REPORT 6F1
THIRD EDITION, APRIL 1999



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Upstream Segment

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FOREWORD

An analytical procedure to predict the performance of API Spec 6A and API Spec 6D standard end connections in the API Fire Test was developed in several research projects. In this Report these procedures are applied to API Spec 6A connections from $2\frac{1}{16}$ in. to $7\frac{1}{16}$ in., and API Spec 6D (ANSI) connections from 2 in. to 6 in.

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0 Introduction

The Production Department of API first published in 1978 a procedure for fire testing valves. The current procedure is API Spec 6FA, *API Specification for Fire Test for Valves* (1)¹. Basically, the Specification calls for a fire with an average temperature of 1400°F–1800°F to be applied for 30 minutes to a valve pressurized with water to detect leakage. Since end connections usually are included in these tests, they become potential failure points for a fire-tested valve assembly.

Since end connections are standard products, API has sponsored several research projects to define the ability of end connections to pass the fire test. Ten standard end connections of various sizes, types, and pressure ratings were tested in 1979 (2). (PRAC-79-21)

Two subsequent research projects (3, 4) in 1980–81 (PRAC 80-33) and 1981–82 (PRAC 81-33) resulted in procedures to analytically predict the performance of flanged and clamped connections to the fire environment.

This procedure basically is composed of four parts: (a) predicting the temperature distribution in the flange, (b) predicting the preload loss, (c) predicting the performance of the various seals with the reduced preloads which occur in a fire, and (d) predicting whether or not yielding of bolts is likely to occur. Significant yielding will lead to leakage either during the fire or shortly afterward.

A fourth project (PRAC-83-33) (5) evaluated the standard end connections in API Specifications 6A (6) and 6D (7) using these analytical procedures.

This report summarizes the results of all the projects. In addition, the appendixes present the analytical procedures used to generate the performance prediction of section 3.

1 Scope and Applicability

The sizes of interest are shown in Table 1. The ANSI (8) sizes are adopted by API Spec 6D. The API sizes refer to those in API Spec 6A.

Table 2 shows the materials and gasket types which have been studied. As can be seen, there are a large number of sizes and combinations of materials and gaskets.

One very important point is that this Technical Report, and the research projects which preceded it, are based on the fire test procedure in API Spec 6FA. Whether or not API Spec 6FA adequately defines a “true” fire is totally outside the scope of this bulletin. The test simulates a closed condition with no flow through the connection. If there were flow through the connector, the heat transfer response would likely

¹Numbers in parentheses refer to corresponding items in section 2, References.

be different. Also, the external loads from dead weight, piping system thermal expansion, wind, etc., could significantly affect a joint’s performance in a fire. These effects could be included in the design procedures reported herein, but they are not in the scope of this report.

1.1 EFFECTS OF FIRE ENVIRONMENT

Exposure to a fire environment around a flanged or clamped joint will tend to reduce the joint preload required for many seals to function. In a flanged joint, the flange exterior and bolts will heat up quicker than the seal and interior flange portion. This thermal gradient across the joint will cause preload to be lost. If enough preload is lost, the seal may unseat and leak; lose the contact pressure necessary to maintain a seal; fail if the seal is not strong enough to carry pressure load without the restraint from the adjacent contact surfaces, or fail if the temperature capacity of the seal material is exceeded.

1.1.1 In addition to preload loss from the thermal gradient, there is a preload loss due to the reduction of joint stiffness resulting from increasing temperature. Another factor which can cause preload loss is yielding of the gaskets, studs, or flanges. Bolt yielding results in permanent stretching which means permanent preload loss and likely leakage, either hot or cold.

Table 1—Sizes of Interest

ANSI Flanges Analyzed							
Nominal Pipe Size, in.	Class						
	150	300	400	600	900		
2	X	X		X		C1 1500	
2 ¹ / ₂	X	X		X		C1 1500	
3	X	X		X		X	
3 ¹ / ₂	X	X		X			
4	X	X	X	X		X	
5	X	X	X	X		X	
6	X	X	X	X		X	
Clamps and API Flanges Analyzed							
Size (Bore)	6B 2000	6B 3000	6B 5000	6BX 10000	6BX 15000	Clamp 5000	Clamp 10000
2 ¹ / ₁₆	X	X	X	X	X	X	X
2 ⁹ / ₁₆	X	X	X	X	X	X	X
3 ¹ / ₁₆				X	X		X
3 ¹ / ₈	X	X	X			X	
4 ¹ / ₁₆	X	X	X	X	X	X	X
5 ¹ / ₈	X	X	X	X		X	
7 ¹ / ₁₆	X	X	X	X		X	X

Table 2—Materials and Gaskets of Interest

Materials and Gaskets ANSI Flanges		
	Combinations	
	1	2
Flange Material	SA 105	316 SS
Bolt Material	SA 193 B7	SA 193 B8
Gasket Type	1. Spiral Wound 2. RTJ Type R	RTJ Type R
Gasket Material	1. Stainless 2. Soft Iron	Stainless

Materials and Gaskets ANSI Flanges		
	Combinations	
	1	2
Flange Material	4130	410 SS
Bolt Material	SA 193 B7	SA 453 Gr 660
Gasket Type	RTJ	RTJ
Gasket Material	Carbon Steel	Stainless Steel

1.2 SIGNIFICANT VARIABLES

Variables which are significant to this problem are as follows:

1.2.1 Size and Geometry of the Joint

The size will greatly affect the thermal gradient through the joint, with larger joints having much larger thermal gradient than smaller joints for a thermal event such as the standard API Fire Test. However, the larger joints do not get nearly as hot as the smaller joints for the fire test conditions of this Technical Report. Figures 1 and 2 illustrate this.

1.2.2 Type of Seal

Of particular importance for the seals is the seating load, the retaining load; amount of pressure energization; whether the seal is used in joints that make up face-to-face, or with standoff; and the gasket material.

1.2.3 Material of Construction

Carbon steel has a thermal conductivity approximately three times as large as that of austenitic stainless steel, and a lower thermal expansion coefficient. Thus, the thermal response and preload change of the joints are a very strong function of the material.

In addition, a critical variable is the yield strength of the bolts and flange at the high temperature of the test. If a large amount of yielding occurs, the remaining preload will be very small.

1.2.4 Joint Preloads and Internal Pressures

Flanged and clamped joints are normally designed with preloads based on two considerations: (a) the amount of preload required to seat the seal, and (b) the amount of preload required for the gasket retaining load, pressure end loads, and any external forces or moments. Joints in which the seating load is controlling (highest) will tend to have more preload margin for the pressure and retaining load case and, thus, may tend to be more leak resistant in the fire test. Further, the API Fire Test is at about 75% of the rated pressure. For high pressure connections, this 75% of rated pressure is a very large number compared to the retaining load. Thus, it might be expected that higher pressure joints are more resistant to the fire.

Another consideration is the variability of preload in actual field joints.

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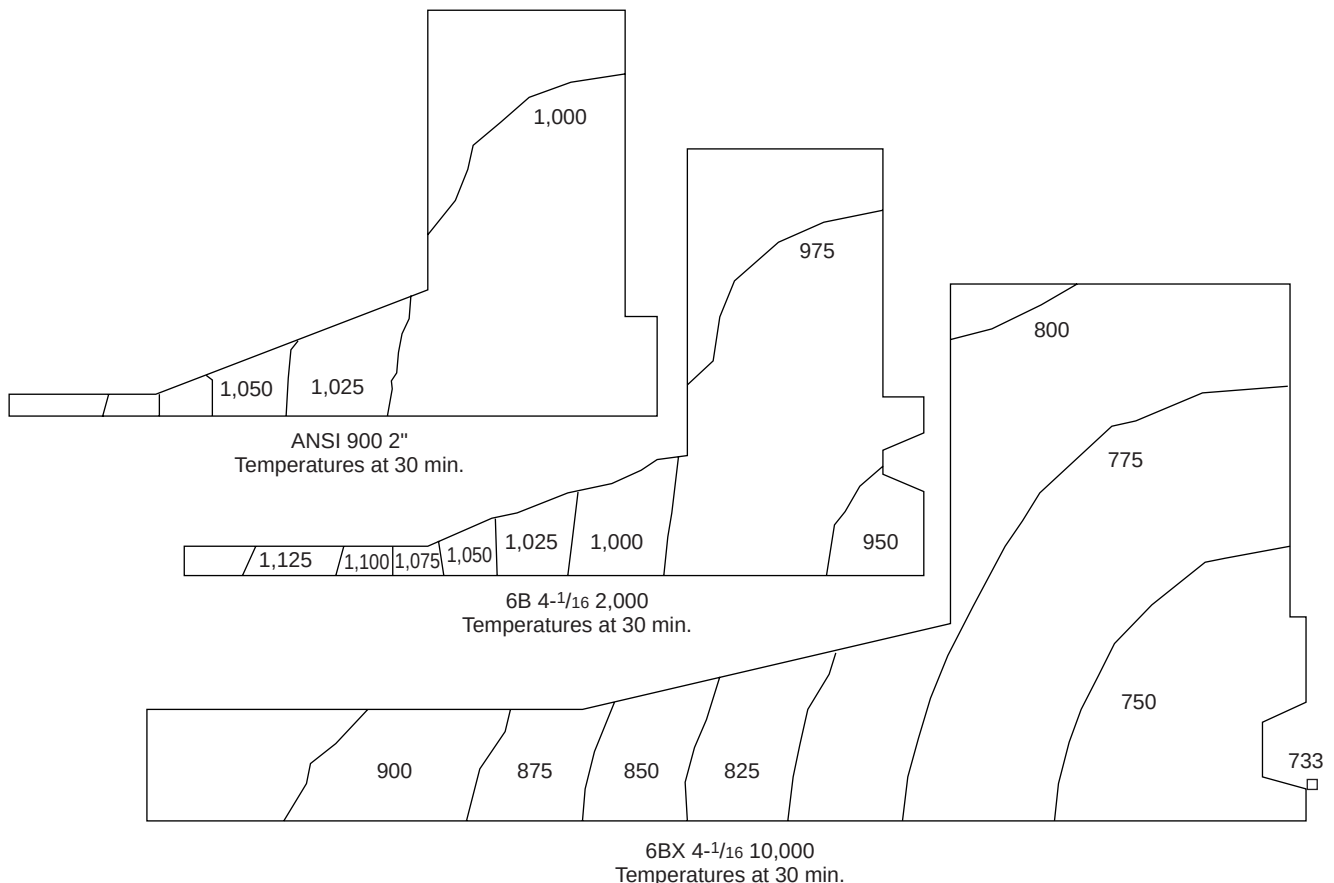


Figure 1—Typical Calculated Temperatures of Joints

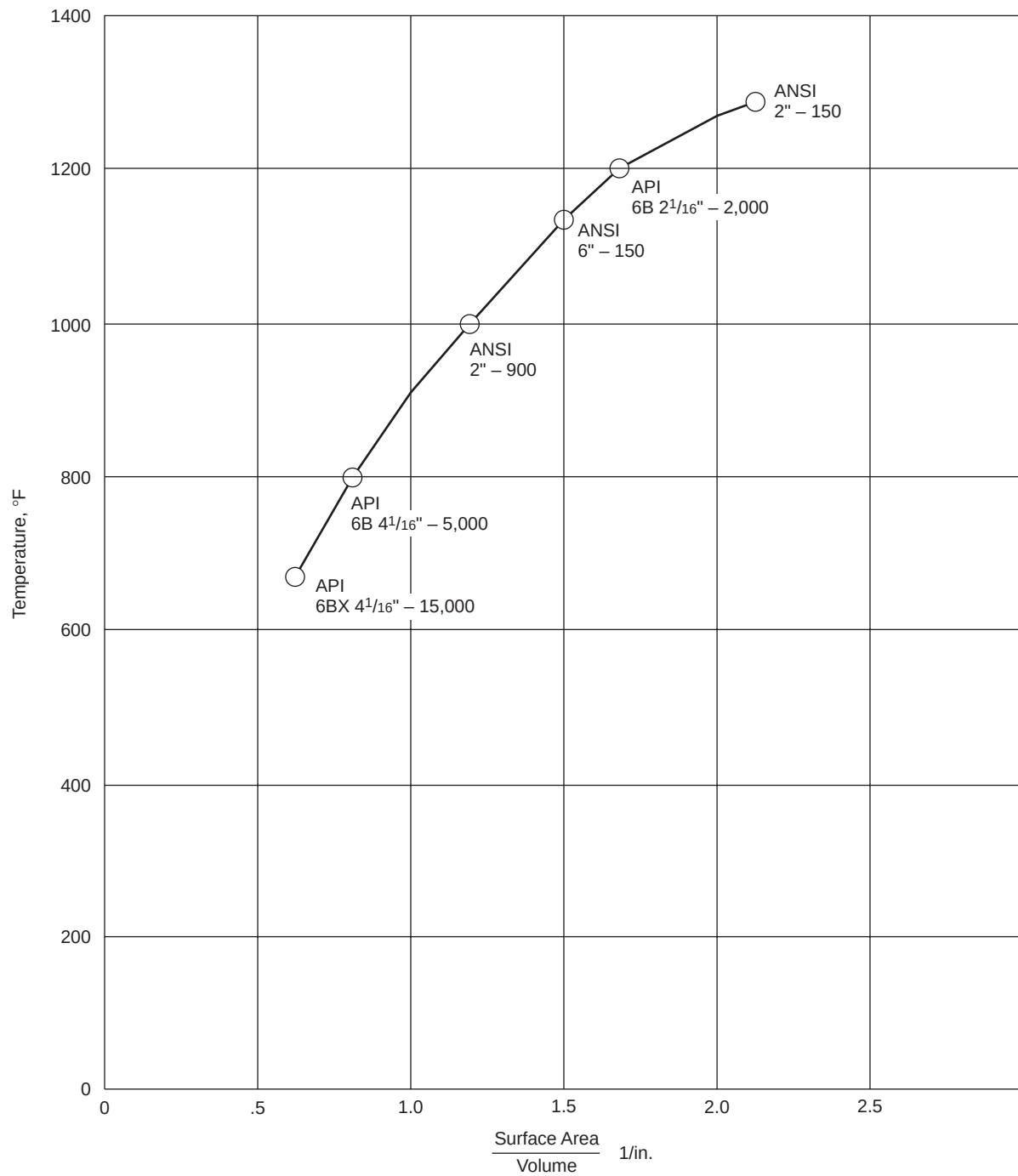


Figure 2—Average Calculated Temperatures of Various Joints Carbon Steel at 30 Minutes

3 Performance of API and ANSI End Connections in the Standard Fire Test of Specification 6FA

3.1 INTRODUCTION

The prediction of whether or not a particular joint will fail in the fire test is based on the three following considerations:

- Does the joint lose so much preload that it does not have enough left for the required seal retaining load?
- Does the joint get so hot that the bolts or the connection yield?
- Do the BX gaskets have enough elastic “springback” to keep from unseating?

Table 3 shows the classification adopted in reporting possible leakage.

3.2 MAKEUP ASSUMPTIONS

3.2.1 For the ANSI flanges, the assumptions contained in the *ASME Boiler and Pressure Vessel Code* (9) regarding flange makeup were used. The makeup assumption is that the joint is made up to a bolt load corresponding to the average of the required and actual bolt area, times the bolt allowable at room temperature.

3.2.2 For the API flanges, the bolts were assumed to be made up to one-half the yield strength.

3.2.3 The required makeup clamping load for clamp type connections is the greater of the gasket seating load and the gasket retaining load, plus design pressure end load. A positive angle of friction of 5.7 degrees is used for the makeup condition. Seating loads and retaining loads for RX gaskets are shown in Table A-1 of Appendix A.

3.2.4 Tables 4 through 6 summarize the findings.

Table 3—Classifications

A =	When made up to normal specifications the joint has adequate retaining load and the BX gaskets will not unseat. No leakage is predicted.
B =	When made up to normal specifications, the retaining load is between 50% and 100% of the recommendation of the <i>ASME Boiler and Pressure Vessel Code</i> (BPV). Leakage is possible.
C =	Retaining load is less than 50% of the recommendation of the BPV. Leakage is likely.
D =	BX gaskets will unseat. Leakage is likely.
E =	The yield strain of the bolt at temperature is between 75% and 100% of the makeup bolt strain. Therefore, leakage is likely.
F =	The yield strain of the bolt at temperature is less than 75% of the makeup bolt strain. Leakage is almost certain.

3.3 GENERAL PREDICTIONS

3.3.1 The spiral wound stainless steel gaskets have very high retaining and seating loads. Even though they easily stand the temperature, it is more difficult to maintain a seal with them. The RTJ gaskets are better from a retaining-load standpoint.

3.3.2 The low pressure and small size carbon steel and 4130 joints are the most susceptible to leakage under the no-flow conditions of the test.

3.3.3 Actual required retaining loads to maintain a seal are not well known. The *ASME Boiler and Pressure Vessel Code* requirements are guidelines, but they are likely to be conservative. Most joints that are classification B (50% to 100% of required retaining load) probably won't leak.

Table 4—Classification Summary of ANSI Carbon Steel Flanges Performance Prediction in Standard Fire Test

Nominal Pipe Class Size in.	Class				
	150	300	400	600	900
2	F	F, B	—	E, C	A
2½	F	F	—	B	A
3	F	E, B	—	C	C
3½	F	E, B	—	C	—
4	E	B	B	C	B
5	F	B	B	C	B
6	F	B	B	C	B

Spiral Wound Stainless Steel Gaskets

Nominal Pipe Class Size in.	Class				
	150	300	400	600	900
2	F	F	—	C, E	A
2½	E	E	—	B	A
3	E	A	—	C	C
3½	A	A	—	B	—
4	A	B	A	C	A
5	A	C	B	C	A
6	A	C	A	C	B

RTJ Soft Iron Gasket

Notes:

A = No leakage.

B = Retaining load 50% to 100% of required—probably won't leak.

C = Retaining load less than 50% of required—leakage likely.

D = BX gasket unseats—leakage likely.

E = Bolts yield small amount—leakage possible.

F = Bolts yield large amount—leakage likely.